WELCOME TO AWTEC 2018

On behalf of the local organizing committee, I would like to welcome all delegates to Taiwan to participate in the 4th Asian Wave and Tidal Energy Conference (AWTEC 2018). It is our privilege and honor to host the event at Taipei.

The conference is a platform for engineers, researchers, experts to keep abreast of the current state-of-the-art advancements in ocean energy in a broad sense, ranging from wave energy, tidal energy, ocean thermal energy, ocean current energy, to offshore wind energy.

The AWTEC conference was first held in Jejiu, Korea in 2012. Then it was held in Tokyo and Singapore in subsequent every two years. With the efforts of all delegates and the Organizing Committee members, the AWTEC conference series quickly become the most important event in ocean energy in Asia. These Conferences provide a forum to promote scientific advancement, technological progress, information exchange, and cooperation among engineers and researchers in ocean energy in an interdisciplinary spectrum.

In addition to technical sharing, we would also like to invite you to enjoy the rich traditional culture and international hospitality in metropolitan Taipei. It is a dynamic city perfectly mixed with oriental tradition and western modernity.

I believe AWTEC 2018 will be a fruitful event for you to share and to enjoy. We look forward to welcoming you in the golden season of 2018. I do wish you a rewarding experience in participating in AWTEC 2018. Enjoy your stay in Taiwan.

Jiahn-Horng Chen
Conference Chair

2018 awtec

Table of Contents

ORGANIZATIONS

AWTEC Executive Board

President Takeshi Kinoshita, Nagasaki Institute of Applied Science (Japan)

Prof. Chul H. Jo, Inha University (Korea)

Dr. Narasimalu Srikanth, Nanyang Technological University (Singapore)

AWTEC Organizing Committee

Irene Penesis, University of Tasmania, Australian Maritime College (Australia)

Mark Hemer, The Centre for Australian Weather and Climate Research (Australia)

Chee Ming Lim, Universiti Brunei Darussalam (Brunei)

Hongda Shi, Ocean University China (China)

Weimin Liu, The First Institute of Oceanography (China)

Dengwen Xia, National Ocean Technology Center (China)

Rafiuddin Ahmed, University of South Pacific (Fiji)

Johnny C.L. Chan, City University of Hong Kong (Hong Kong)

Abdus Samad, Indian Institute of Technology Madras (India)

Mukhtasor, Indonesian Ocean Energy Association (Indonesia)

Kyozuka Yusaku, Nagasaki University (Japan)

Shuichi Nagata, Saga University (Japan)

Changhong Hu, Kyushu University (Japan)

Young-Ho Lee, Korea Maritime and Ocean University (Korea)

Jin-Hak Yi, Korea Institute of Ocean and Technology (Korea)

Young-Do Choi, Mokpo National University (Korea)

Omar Yaakob, Universiti Teknologi Malaysia (Malaysia)

Lim Yun Seng, Universiti Tunku Abdul Rahman (Malaysia)

Mohd Zamri, University Malaysia Terengganu (Malaysia)

Myat Lwin, Myanmar Maritime University (Myanmar)

Htun Naing Aung, Union of Myanmar of Federation of Chambers of Commerce and Industries, Energy and Environment Cluster Group (Myanmar)

Ross Vennell, University of Otago (New Zealand)

Rajnish Sharma, University of Auckland (New Zealand)

Laura David, University of the Philippines (Philippines)

Michael Lochinvar Abundo, Nanyang Technology University (Singapore)

Prasanna Gunawardane, University of Peradeniya (Sri Lanka)

Cheng-Han Tsai, National Taiwan Ocean University (Taiwan)

Jiahn-Horng Chen, Research Center for Ocean Energy and Strategies (Taiwan)

Bang-Fuh Chen, National Sun Yat-San University (Taiwan)

Chaiwat Ekkawatpanit, King Mongkut University of Technology Thonburi (Thailand)

Pham Hoang Luong, Hanoi University of Science and Technology (Vietnam)

Nguyen Binh Khanh, Institute of Energy Science, Vietnam Academy of Science and Technology (Vietnam)

EWTEC Advisory Committee

AbuBakr Bahaj, University of Southampton (UK)

Cameron Johnstone, University of Strathclyde (UK)

Mats Leijon, Uppsala University (Sweden)

Local organizing committee

Jiahn-Horng Chen (Chair), National Taiwan Ocean University

Chia-Ming Fan (Program Chair), National Taiwan Ocean University

Pai-Chen Guan (Technical Chair), National Taiwan Ocean University

Yaw-Huei Lee (Program Co-Chair), National Taiwan Ocean University

Wei-Chu Weng (Program Co-Chair), National Taiwan Ocean University

Da-Wei Chen (Technical Co-Chair), National Taiwan Ocean University

Li-Shiou Yu (Secretary), National Taiwan Ocean University

Forng-Chen Chiu, National Taiwan University

Yi-Chih Chow, National Taiwan Ocean University

Ming-Chung Fang, National Cheng-Kung University

Ching-Yeh Hsin, National Taiwan Ocean University

Cheng Lin, National Chung-Hsing University

Cheng-Han Tsai, National Taiwan Ocean University

Robert Kuo-Cheng Tseng, CSBC Corporation

Ray-Yeng Yang, National Cheng-Kung University

Chih-Wei Yen, Industrial Technology Research Institute

Organizers

National Taiwan Ocean University

Co-organizers

Ministry of Science and Technology

Taiwan Society of Naval Architects and Marine Engineers

Sponsors

Ministry of Science and Technology

ONR Global

Industrial Technology Research Institute

Minesto AB

Ropers

Journal of Marine Science and Engineering

Aquanet Power

CSBC Corporation, Taiwan

Ship and Ocean Industries R&D Center

Contact us

contact email: awtec2018@gmail.com

PREVIOUS AWTEC

1st AWTEC	Jeju, South Korea, 2012
2nd AWTEC	Tokyo, Japan, 2014
3rd AWTEC	Singapore, 2016

GENERAL INFORMATION

Registration Package

Each registered delegate will receive a conference bag, a name badge, a Conference Program and Book of Abstracts, an EasyCard (good for MRT and metropolitan public transportation), four tickets for three lunches and reception dinner, a pen, a notebook, an USB flash drive, and some tourist maps. All participants are requested to wear their conference badges throughout the conference. Refreshments will be served only to identifiable conference participants during the morning and afternoon breaks.

Oral Presentations

The time allotted to each speaker for presentation and discussion is as follows:

Keynote speeches – 40 minutes

Invited speeches – 30 minutes

Contributed speeches – 20 minutes

Please respect each speaker's rights and adhere strictly to the time scheduled in the program. Before the start of their session, presenters are requested to contact their session chair and load their presentation files onto the computer. Standard presentation applications (Word, PowerPoint, Acrobat, RealPlayer, Media Player, etc) are installed on these computers.

Poster Presentations

Please complete your poster setup before 10:30 AM, September 10. The location of the poster session is next to the Conference Room A. Please stand by your poster during the coffee breaks on the first day (September 10) for discussion.

Internet

Participants have free access to Wi-Fi for wireless connection to the internet at the conference venue. Please limit your usage to one device. The passwords will be announced every day.

Messages

Participants may post messages on a notice board located near the registration desk. The organizer may also post updated information on the board. Please check the board frequently.

Reception

Reception is held at the Mayor's Residence Art Salon on the afternoon of September 9 (14:30-17:00). All registered delegates are welcome. All participants are requested to pick up the registration package at the entrance to the Art Salon and wear their conference badges before attending the reception.

Address: No.46, Xuzhou Rd., Taipei.

Reception Dinner

The reception dinner is held at Brasserie of Regent Taipei Hotel on the evening of September 10 after the afternoon technical sessions are closed (18:30-21:00). Shuttle buses are available at the venue. The departure time will be 17:30. Please wear the conference badge when attending the reception dinner.

Address: No. 3, Lane 39, Sec. 2, Zhongshan N. Rd., Taipei.

Banquet

The banquet is held at the International Reception Hall of the Grand Hotel on the evening of September 12 after the afternoon technical sessions are closed (18:30-21:30). Shuttle buses are available at the venue. The departure time will be 17:30. Please wear the conference badge when attending the banquet. The next AWTEC and the winners of best paper will be announced in the banquet.

Address: No.1, Sec. 4, Zhongshan N. Rd., Taipei.

Lunches

Lunches for registered participants and accompanying persons are served on September 10, 11, and 12.

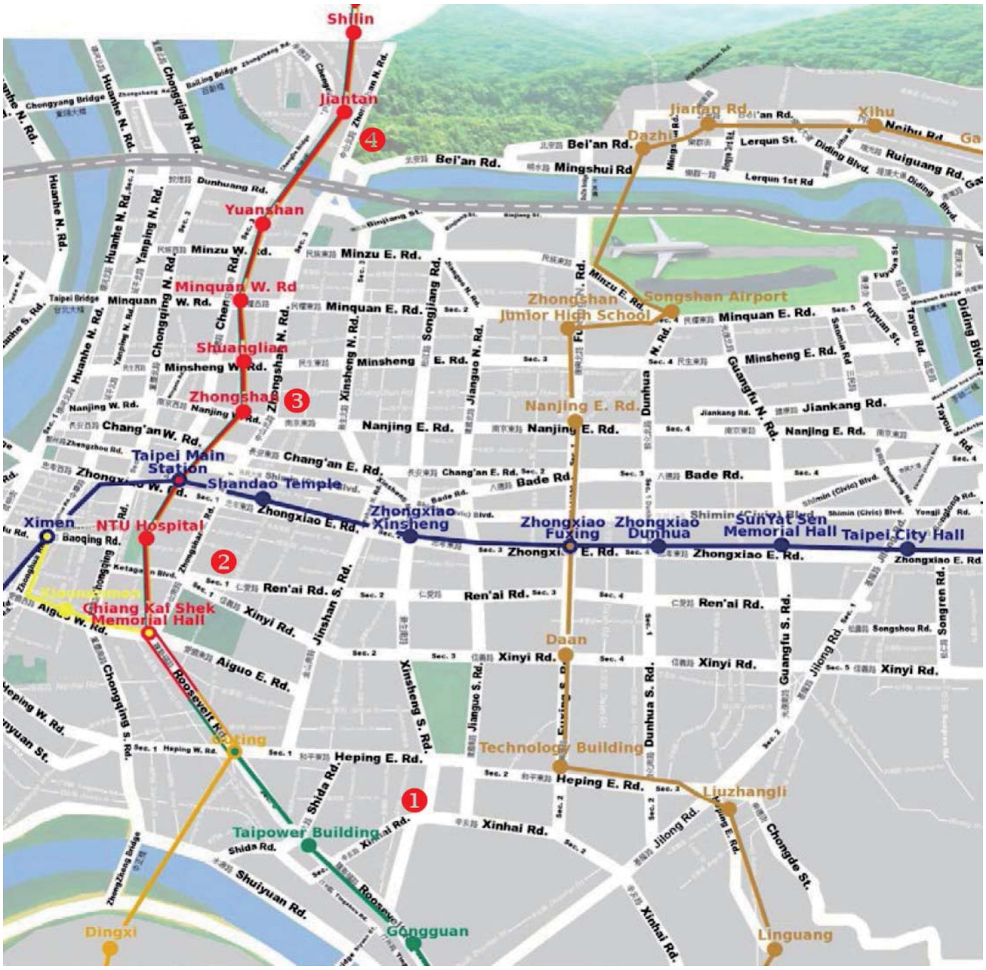
CONFERENCE MAP

❶ Venue: Howard Civil Service International House (No. 30, Sec. 3, Xinsheng S. Rd., Taipei) Technical program, September 10-12
http://www.howard-hotels.com.tw/en/civil-service/home/

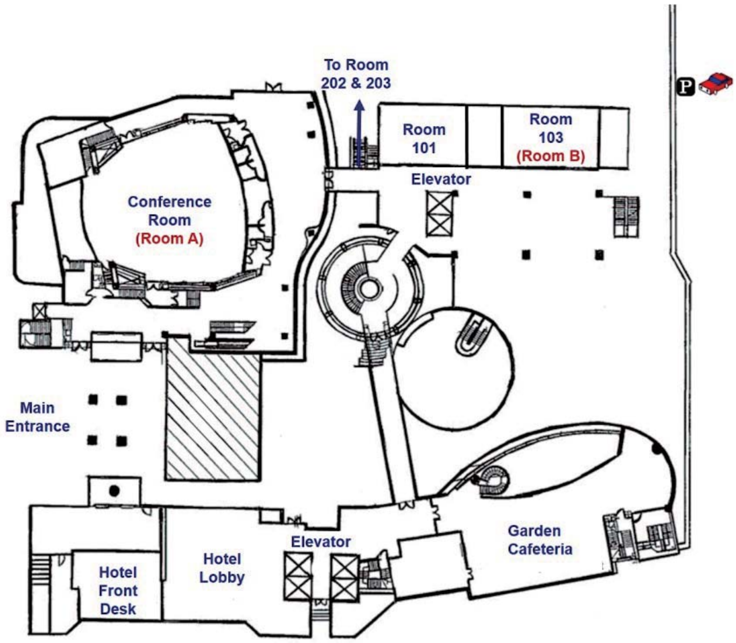
❷ Reception: Mayor's Residence Art Salon (No. 46, Xuzhou Rd., Taipei) 14:30-17:00, September 9 (Sunday)
http://www.mayorsalon.tw/Carousels/EnglishPage

❸ Reception dinner: Brasserie, Regent Taipei Hotel (No. 3, Lane 39, Sec. 2, Zhongshan N. Rd., Taipei) 18:30-21:00, September 10 (Monday)
https://www.regenthotels.com/regent-taipei/dining/brasserie

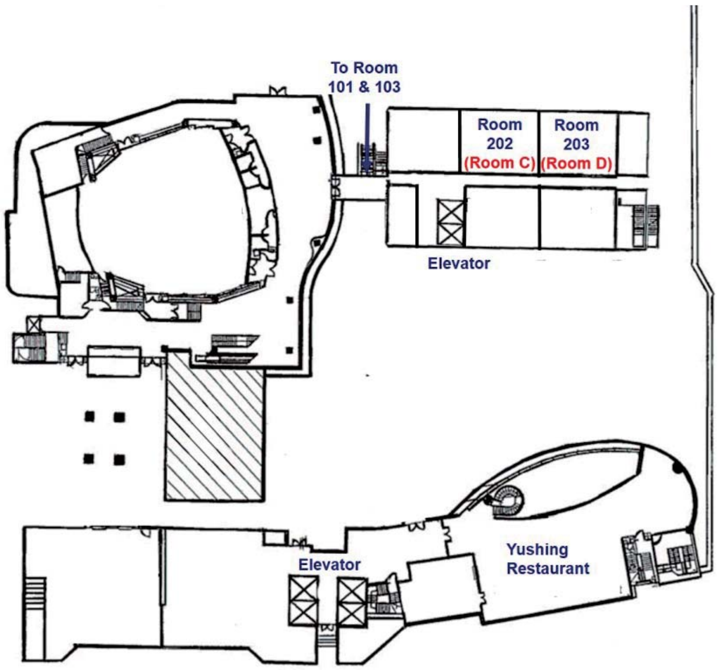
❹ Banquet: Grand Hotel (No.1, Sec. 4, Zhongshan N. Rd., Taipei)
18:30-21:00, September 12 (Wednesday)
http://www.grand-hotel.org/taipei/en/



First Floor of the Venue



Second Floor of the Venue



SPECIAL SESSIONS

Market Supports for Marine Renewables (13:00-15:00, September 11)

The session will cover various aspects of Market Supports that exist for the Marine Renewable Energy industry. Specifically, the panel will discuss the current status, effectiveness, and learnings that can be shared from experiences of representative stakeholders in different regions. The session will also touch in more detail on the more established market opportunities and the reasons that those countries have put supportive policies in place.

Panel Members:

Bruce Cameron (Principal Consultant, Envigour - Canada) - Moderator/Chair

Bruce has more than 40 years' experience in public policy critique, analysis and development. Close to 20 years of that experience was with the Nova Scotia Government in the Departments of Finance and Energy. Based upon significance experience in public consultation, policy and strategy development, Bruce can advise on policy options, alternatives and implementation strategies for public and private sector interests.

Bruce Cameron is the former Executive Director of Electricity, Renewables, and Efficiency with the Nova Scotia Department of Energy. He has developed policy leadership in the areas of electricity, renewable energy – particularly in the area of in-stream tidal energy – energy regulatory development – particularly in offshore oil and gas as well as marine renewables. In the development of strategic energy policies for – Nova Scotia, he also has extensive experience in stakeholder and public engagement. He has an MBA from Dalhousie University (1985) and undergraduate degree from Carleton University in the arts and social sciences (BA 1973) BJ Hon. (1974).

Mark Leybourne (Associate Director, ITPEnergised - UK)

Dr. Mark Leybourne is an Associate Director in ITPEnergised's offshore renewable energy group, based in Bristol, UK. He studied at the University of Southampton, completing an undergraduate degree in Aerospace Engineering and an Engineering Doctorate in the modelling, testing and development of a wave energy converter.

Mark works across a range of offshore wind, wave and tidal energy projects, providing technical, engineering, policy and strategic advice to both public and private clients. After joining the consultancy 10 years ago, he now leads the company's international offshore renewable energy work, with a strong focus on Asian markets such as those in China, India, Taiwan, Singapore, Philippines and Korea.

Mark is currently leading a tidal energy project in China that will provide the design of a 500kW turbine to ITPE's Chinese partners who will manufacture and supply the turbine to China Three Gorges. In addition to his activities in Asia, Mark has recently worked on European tidal energy projects for Morlais, PTEC and Minesto and he is currently leading the third-party engineering advisory work for Wave Energy Scotland's novel wave energy converter programme.

Michael Abundo (Managing Director, OceanPixel Pte Ltd - Singapore)

Dr. Michael Lochinvar Sim Abundo is the Managing Director of OceanPixel – based in Singapore with presence in the Philippines and activities throughout the South East Asian region. He is a green techno-preneur who specializes in ocean/marine renewable energy sector. Michael is actively helping increase the uptake of marine renewable energy in South East Asia and he has been involved in pilot projects in the region for both wave and tidal energy 'localized' for tropical conditions. Michael hopes to contribute to the development of the ocean renewable energy sector from R&D, networking, and commercialization.

Michael studied at the University of the Philippines and completed a PhD in Electrical and Electronics Engineering (EEE) focusing on Tidal In-Stream Energy (2012), and he also holds a Master's degree in Electrical Engineering on Instrumentation and Control (2006). He has served as a faculty member and research laboratory head for the Instrumentation, Robotics, and Controls Laboratory at the EEE Institute, University of the Philippines from 2004 to 2008 and was a Research Fellow for the Wind and Marine Renewables Group in the Energy Research Institute @ Nanyang Technological University (ERI@N) from 2011 to 2016. In parallel with OceanPixel, he is also currently handling duties in Nanyang Technological University - specifically, Programme Integration Management for the Rolls-Royce@NTU Coporate Lab.

Ralf Starzmann (Director, SCHOTTEL HYDRO - Germany)

Ralf Starzmann graduated as a mechanical engineer of the University. of Stuttgart, Germany, in 2007. Until 2008 he worked with Voith Hydro in their ocean energy department on wave and tidal energy devices. In 2008 he started as a Ph.D. student at the University of Siegen, Germany, specializing on the aero-acoustic analysis of the Wells turbine for ocean wave energy conversion. After completing his Ph.D. in 2012, he joined SCHOTTEL and is working on tidal energy related issues. This involves the hydraulic design of the SITturbine ans site assessment activities. Since 2015 Ralf is the Sales Director and Head of Hydrodynamics of SCHOTTEL Hydro. Ralf is also a member of the German mirror committee for IEC TC 114.

Chul H. Jo (Inha University - South Korea)

Professor Jo, Chul Hee has finished his Mater degree at Stevens Institute of Technology, USA in 1985 and Ph.D in Ocean Engineering at Texas A&M University in 1991. After working for Intec Engineering, Houston USA and Hyundai Heavy Industries, Korea from 1992 to 1997, he has joined to Inha University in Korea. His main research area is tidal current energy and he has been involved in many government advisory bodies and committees in ocean energy policy, development planning and research since 1998. Being the first author in ocean energy text book written in Korea, he has published more than 2000 journal and conference papers with more than 80 patents registered and pending in tidal current energy field. Prof. Jo has been conducted numerous government and industry projects developing tidal current generation system. He is currently the director of the Ocean Energy and Environmental Research Center and the vice president for KSNRE (Korean Society for New and Renewable Energy) and the Executive committee member for AWTEC (Asian Wave and Tidal Energy Conference).

Henry Han Lei (Managing Director, Hann-Ocean Group - Singapore)

Mr. Henry Han Lei is the Founder and Managing Director of the Hann-Ocean group. Mr. Han is also the inventor of the internationally patented Drakoo wave technology. He holds a Bachelor's degree in Naval Architecture from South China University of Technology and a Master's degree in Smart Product Design from Nan yang Technological University Singapore (NTU), obtained in 2005. Mr. Han possesses 8 years of naval architecture and ocean engineering design experience in marine design consultancy firms including MARIC; 11 years in defense project management at Defence Science and Technology Agency (DSTA) Singapore and 12 years of innovation development and business management experience at Hann-Ocean. More than 15 innovation prizes have been awarded to him including the Singapore Defence Technology Prize and the Innovation Excellence Award. Under Mr. Han's leadership, at the beginning of 2015, Hann-Ocean Energy successfully registered the business license for its subsidiary in Nantong, China to further expand production and business operations.

Blandine Battaglia (Project Engineer, SABELLA - France)

Blandine Battaglia joined SABELLA as project engineer in 2016, after finishing her studies at ENSTA ParisTech, with a specialization in Offshore Energies and Naval Architecture. She works on the development of the pilot tidal power plant in the Philippines, in collaboration with H&WB Asia Pacific.

Daniel Coles (Project Resource Analyst, SIMEC Atlantis - UK)

Since joining SIMEC Atlantis in July 2017, Daniel has worked on the power curve testing of the Meygen Phase 1A turbines and future phased array build out. Daniel also works on a wide range of development projects around the world to provide techno-economic feasibility assessments at specific sites. He holds a Masters degree in Mechanical Engineering from the University of Manchester (2011) and a PhD in tidal turbine array modelling from the University of Southampton (2016). After completing his doctorate he worked as a postdoctoral researcher at Imperial College London, implementing turbine micro-siting optimisation methods.

Cordage Technology for Renewable Energy Applications (15:30-17:10, September 11)

This section will cover the connection between alternative energies and the state of the art cordage technologies and knowledge. Specific subjects include the evolution of technologies in marine industry using cordage, significance and importance of industry standards, and proposed collaboration among suppliers, designers, industry regulations bodies, operators and research institutes. With the dialogue and discussion, we would like to provide a platform to reveal and address issues in advancing alternative energy and establish a mechanism for continuous collaboration among the various parties.

Section Lead

Rafael (Chiate) Chou, Ph.D. – Moderator/Chair

Dr. Chou had been active in the rope industry for almost two decades. At Samson Rope

Technologies, Dr. Chou and his technical team members had presented at many technical conferences on a broad range of subjects of rope technologies and application knowledges – including offshore, mining, crane, lifting, mooring, tug, etc. to promote safety and awareness for these fields.

After finishing his college study at National Taiwan University, Dr. Chou went to United State to study at New York University Tandon School of Engineering in 1986, receiving his Ph.D. degree in Chemical Engineering in 1990. After 30 years of successful career in textiles, fibers, composites and adhesives, Dr. Chou will be moving back Far East soon to continue his contribution to the fiber and marine industries.

Dr. Chou served as the Technical Committee Chair for Cordage Institute between 2004 and 2006. His research team was awarded Industry Compass Award in 2008 presented by Marine Technology Society for making the marine industry safer with technologies, and the Pilmsoll Award in 2011 presented by Professional Mariner for the best R&D team introducing science to the rope industry.

Agenda

- Opening – 5 min
- Introduction – Sponsors and Hosts – 15 min
- Alternative Energy – 10 min
- Go Deeper – Evolution of Critical Technologies in Marine Industry Using Cordage–40 min
    - Technology and Science
    - Engineering Design
    - Application Knowledge
- Best Practices and Industry Standards in the Energy Industry with Cordage – 30 min
    - Need for Best Practice – from beginning to the end
    - Operation Considerations
    - Industry Regulators and Standards
- Future Needs and Reality Check – 10 min
    - Technology Gaps
    - To Advance Effectively from Cordage Relevant Technology Viewpoint
- Bridging Technologies – 10 min
    - Resolutions and Vision
- Closing Remarks and Q&A

TECHNICAL AND CULTURAL TOURS

Tour to NTOU Marine Energy Test Site at Keelung (Morning of September 13)

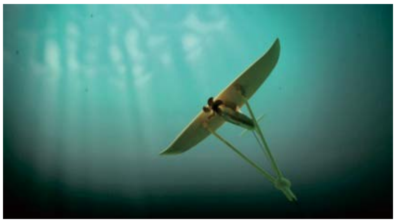
We are going to visit the Marine Energy Test Site of National Taiwan Ocean University on the morning of September 13 (Thursday). The site is at Keelung, about 35 km from the venue. In addition to the overview of the site, two wave energy converters and one tidal current turbine system, which are going to tested at the site, will be presented. The departure time is 09:00 at the venue. Please wear the conference badge when visiting the site.

● *MINESTO*

Minesto is marine energy developer with operations in Sweden, Taiwan and the UK. The company's awarded product, called Deep Green, is the only known, verified technology that can operate cost effectively in areas with low-flow tidal streams and ocean current.

The Deep Green technology converts kinetic energy in marine currents to renewable, predictable electricity with a unique, patented method similar to flying a kite in the wind. Control system functionality and power production performance have been verified in ocean trials with scale model prototypes since 2011. Minesto is currently commissioning its first utility-scale 0.5MW demonstrator in North West Wales.

In 2016, Minesto signeda collaboration agreement together with the Research Center for Ocean Energy and Strategies (RCOES) at National Taiwan Ocean University. The collaboration will include installation and ocean testing of a scale model prototype and research on Minesto's unique Deep Green technology. Within the scope of the collaboration agreement, Minesto and RCOES will explore the potential for Minesto's Deep Green technology in Taiwan.


● *ITRI*

The wave power generators of ITRI

The potential amount of Wave energy around Taiwan has been estimated at about 2.4 GW. It is very difficult to develop wave power plants in the short-term, a number of key issues have to be overcome, especially the typhoon and earthquake threats in Taiwan. In addition, the availability and safety of wave energy generators, reduce the wave power costs and the domestic maritime engineering energy shortage still needs to be solved soon. The Taiwan government devotes resources to research and development of wave energy generation systems applicable to domestic seas, through long-term sea testing and verification, and then gradually enlarge the scale to improve the performance of the wave power generators.

ITRI is funded by the BOE of MOEA of Taiwan government to develop the technology of wave energy generators for several years. The latest generation anti-typhoon bottom-mounted WEC of ITRI will be installed in the test site of NTOU for a short-term site testing in Sep. 2018.

10kW Bottom-mounted WEC

WEC deployment at the Test Site of NTOU

Tour to Aquanet's PTO site

Location: Full scale 1MW air turbine power take-off system test facility of Aquanet Power in Taoyuan, Taiwan.

Aquanet Power has successfully built a first of its kind unique full-scale wind tunnel test facility in Taoyuan, Taiwan. The test facility, equipped with simulation capabilities to simulate a variety of wave heights and wave periods has been built to fully test, validate and optimise the full scale 1MW rated capacity air turbine power take-off (PTO) system to work in any sea condition in the world. The fully automated facility has been designed and built to replicate various sea characteristics for both regular and irregular wave conditions. It is currently being used to showcase the performance and capability of the proprietary air turbine, the full PTO and control system in a variety of sea conditions.

To ensure the cost-effectiveness of the WEC system, a control strategy is carefully designed for the PTO system to respond to the irregularity of each incoming wave by adjusting the latching and the damping of the PTO system. With a simplified design and highly efficient air turbine, the efficiency of the system is thereby increased and hence its cost-effectiveness. The standardised PTO system is used for all product variants of the technology, for shallow water and deep-water applications, with small adjustments to suit any given project location.

The PTO system is now ready to be deployed not only with its dedicated Aquanet Oscillating Water Column but also with any other suitable OWC as a plug-and-play solution for any sea condition in the world.

The technical tour/site visit will bring delegates to Guanyin Industrial Park in Taoyuan, to see the first of its kind unique full-scale wind tunnel test facility. A tour and a short presentation of a full working PTO system will be shown.

If interested, please register at the Aquanet booth. First come, first serve.

Tour 1: Afternoon of Wednesday, September 12.
Departure at 14:30 from the venue.
Limited to 30 delegates.

Tour 2: Afternoon of Thursday, September 13.
Departure at 12:00 from the NTOU test site.
Limited to 60 delegates.

Tour to Jiufen Old Street (Afternoon of September 13)

Founded during the Qing Dynasty, this small town was a relatively isolated village until the discovery of gold during the Japanese occupation in 1893, quickly developing the town due to a gold rush. Many buildings in the town remain unchanged to this day, reflecting the Japanese influence on both architecture and culture on the island. During World War II, the town housed a Japanese prisoner of war camp where captured Allied Force soldiers (mainly British) were forced to work in the gold mines. After the war, gold mining activities declined, and the town today exists mainly as a tourist destination remembering and celebrating Taiwanese history and culture.

Feel spirited away in this decommissioned gold mining mountain town, originally built by the Japanese and now a maze of lanes and alleyways with rich history and culture.



AWTEC 2018 PROGRAM AT A GLANCE

September 09 (Sunday)

14:00-17:00	Registration desk open at the Mayor's Residence Art Salon
14:30-17:00	Reception at the Mayor's Residence Art Salon
17:00-18:30	Organizing Committee meeting

September 10 (Monday)

08:00-17:00	Registration desk open at the venue
08:50-09:10	Opening ceremony
09:10-10:30	Opening keynote speeches
10:30-11:00	Coffee break and group photograph
10:30-17:00	Poster sessions during the breaks
11:00-12:00	Invited speeches
12:00-13:00	Lunch
13:00-15:00	Parallel sessions I
15:00-15:30	Coffee break
15:30-17:10	Parallel sessions II
18:00-20:00	Reception dinner (buses depart from the venue at 17:30)

September 11 (Tuesday)

08:30-17:00	Registration desk open at the venue
09:00-10:20	Keynote speeches
10:20-17:00	Poster sessions during the breaks
10:20-10:40	Coffee break
10:40-12:00	Parallel sessions III
12:00-13:00	Lunch
13:00-15:00	Parallel sessions IV
15:00-15:30	Coffee break
15:30-17:10	Parallel sessions V
17:30-20:30	INORE workshop

September 12 (Wednesday)

08:30-17:00	Registration desk open at the venue
09:00-10:20	Keynote speeches
10:20-10:40	Coffee break
10:40-12:00	Parallel sessions VI
12:00-13:00	Lunch
13:00-15:00	Parallel sessions VII
15:00-15:30	Coffee break
15:30-17:10	Parallel sessions VIII
18:30-21:30	Conference banquet and closing ceremony (buses depart from the venue at 17:30)

September 13 (Thursday)

09:00-12:00	Technical tour to NTOU Marine Energy Test Site (buses depart from the venue at 09:00)
12:00-15:00	Culture tour to Jioufeng Old Streets (buses depart from NTOU Test Site at 12:00) or Technical tour to Aquanet's PTO site in Taoyuan (buses depart from NTOU Test Site at 12:00)

AWTEC 2018 PROGRAM

September 9 (Sunday) ***The Mayor's Residence Art Salon, Taipei***

14:00-17:00	Registration desk open
14:30-17:00	Welcome reception
17:00-18:30	AWTEC Organizing Committee Meeting

September 10 (Monday) ***Howard Civil Service International House, Taipei***

08:00-17:00	Registration desk open
08:50-09:10	Opening ceremony (Conference Room – Room A) Welcome Address 1: **Dr. J.H. Chen (Conference Chair)** Welcome Address 2: **Ms. Man-Li Chen (Legislator, Legislative Yuan)** Welcome Address 3: **Dr. Chu H. Jo (Professor of Inha University, Founder of AWTEC)** Welcome Address 4: **Dr. AbuBakr Bahaj (Professor of Southampton University)**
09:10-10:30	**Keynote Speech** (Conference Room – Room A) ***Chair: Prof. Irene Penesis (University of Tasmania, Australia)*** An Overview of Current Development, Vision and Challenge of Global Offshore Wind and Marine Energy Power (KS04) ***Prof. Kuang-Chong Wu (National Taiwan University, Taiwan)*** Hybrid Floating Renewables Towards Coastal Energy Resilience (KS02) ***Prof. Narasimalu Srikanth (Nanyang Technological Institute, Singapore)***
10:30-11:00	Coffee break and Group Photograph

10:30-17:00	Poster session during the coffee breaks ***(Details on Page 60)***
11:00-12:00	**Invited Speech** (Conference Room – Room A) ***Chair: Prof. Shiaw-Yih Tzang (National Taiwan Ocean University, Taiwan)*** Enabling Renewable Baseload Generation by Flying Subsea Kites (IS01) ***Dr. Martin Edlund (CEO of Minesto, Sweden)*** Aquanet Power: Designing and Optimising a Full Scale PTO for Commercialisation (IS02) ***Mr. Ali Baghaei (CEO of Aquanet Power Limited, Taiwan)***
12:00-13:00	**Lunch at Garden Cafeteria of Howard Civil Service International House (1st Floor)**

Parallel Sessions I

13:00-15:00	**Session 1-A (Room A)** **Floating Kuroshio Turbine** ***Details on Page 23***	**Session 1-B (Room B)** **Wave device development and testing (I)** ***Details on Page 24***	**Session 1-C (Room C)** **Tidal current energy resource characterization (I)** ***Details on Page 25***	**Session 1-D (Room D)** **Wave device hydrodynamics and structural mechanics** ***Details on Page 26***
15:00-15:30	Coffee break			

Parallel Sessions II

15:30-17:10	**Session 2-A (Room A)** **Tidal current device and environmental modeling** ***Details on Page 27***	**Session 2-B (Room B)** **Wave device and environmental modeling** ***Details on Page 28***	**Session 2-C (Room C)** **Tidal current device development and testing (I)** ***Details on Page 29***	**Session 2-D (Room D)** **Wave energy resource characterization (I)** ***Details on Page 30***
18:00-20:00	Reception Dinner at Brasserie of **Regent Hotel Taipei** (Buses depart from the venue at 17:30)			

September 11 (Tuesday) *Howard Civil Service International House, Taipei*

08:00-17:00	Registration desk open
09:00-10:20	**Keynote Speech** (Conference Room – Room A) ***Chair: Prof. Shuichi Nagata (Saga University, Japan)*** The Research Challenges in Delivering a Robust, Cost Effective International Tidal Energy Industry (KS01) ***Prof. C.M. Johnstone (University of Strathclyde, UK)*** Progress of Wave Energy Technology (KS05) ***Prof. Yage You (Guangzhou Institute of Energy Conversion (GIEC), Chinese Academy of Sciences, China)***
10:20-10:40	Coffee break
10:20-17:00	Poster session during the coffee breaks (***Details on Page 60***)

Parallel Sessions III

10:40-12:00	**Session 3-A (Room A)** **Tidal current device development and testing (II)** ***Details on Page 31***	**Session 3-B (Room B)** **Wave power take-off and device control (I)** ***Details on Page 32***	**Session 3-C (Room C)** **Policy development and legislation & Tidal current device environment modeling** ***Details on Page 33***	**Session 3-D (Room D)** **offshore wind** ***Details on Page 34***
12:00-13:00	**Lunch at Garden Cafeteria of Howard Civil Service International House (1st Floor)**			

Parallel Sessions IV

13:00-15:00	**Session 4-A (Room A)** **Special session: Market supports for marine renewables** ***Details on Page 35***	**Session 4-B (Room B)** **Future markets and financing & Wave device development and testing (II)** ***Details on Page 36***	**Session 4-C (Room C)** **Tidal current device hydrodynamics and structural mechanics (I)** ***Details on Page 37***	**Session 4-D (Room D)** **Environmental impact and appraisal (I)** ***Details on Page 38***
15:00-15:30	Coffee break			

Parallel Sessions V

15:30-17:10	**Session 5-A (Room A)** **Tidal current device development, test, and its environment impact and appraisal** ***Details on Page 39***	**Session 5-B (Room B)** **Special session: Cordage technology for renewable energy applications** ***Details on Page 40***	**Session 5-C (Room C)** **Tidal current device hydrodynamics and structural mechanics (II)** ***Details on Page 41***	**Session 5-D (Room D)** **Ocean energy system integration** ***Details on Page 42***
17:30-20:30	INORE Workshop, Yushing Restaurant of Howard Civil Service International House (2nd Floor)			

September 12 (Wednesday) ***Howard Civil Service International House, Taipei***

08:00-17:00	Registration desk open
09:00-10:20	**Keynote Speech** (Conference Room – Room A) ***Chair: Prof. Forng-Chen Chiu (National Taiwan University, Taiwan)*** Floating Type Ocean Current Turbine (KS03) ***Prof. Ken Takagi (University of Tokyo, Japan)*** Mechanical Motion Rectifier: A High Efficiency and Reliable WEC Power Takeoff (KS06) ***Prof. Lei Zuo (Virginia Tech., USA)***
10:20-10:40	Coffee break

Parallel Sessions VI

10:40-12:00	**Session 6-A (Room A)** **OTEC systems and wave devices** ***Details on Page 43***	**Session 6-B (Room B)** **Grid connection and system aspects & Offshore wind-wave/wind-current energy** ***Details on Page 44***	**Session 6-C (Room C)** **Tidal current device hydrodynamics and structural mechanics (III)** ***Details on Page 45***	**Session 6-D (Room D)** **Wave energy resource characterization (II)** ***Details on Page 46***
12:00-13:00	**Lunch at Garden Cafeteria of Howard Civil Service International House (1st Floor)**			

Parallel Sessions VII

13:00-15:00	**Session 7-A (Room A)** **Wave device development and testing (III)** *Details on Page 47*	**Session 7-B (Room B)** **Science supporting the success of the marine energy industry** *Details on Page 48*	**Session 7-C (Room C)** **Tidal current energy resource characterization (II)** *Details on Page 49*	**Session 7-D (Room D)** **Wave power take-off and device control (II)** *Details on Page 50*
15:00-15:30	Coffee break			

Parallel Sessions VIII

15:30-17:10	**Session 8-A (Room A)** **Test site** *Details on Page 51*	**Session 8-B (Room B)** **Tidal current energy resource characterization (III)** *Details on Page 52*	**Session 8-C (Room C)** **Environmental impact and appraisal (II)** *Details on Page 53*	**Session 8-D (Room D)** **Tidal current power take-off and device modeling** *Details on Page 54*
18:30-21:30	Conference Banquet & Best Paper and Best Student Presentation Awards announcement at International Reception Hall of Grand Hotel Taipei, Taipei (Buses depart from the venue at 17:30)			

September 13 (Thursday) *National Taiwan Ocean University, Keelung Jiufen, New Taipei City or Guanyin, Taoyuan*

09:00-12:00	Technical tour at NTOU Marine Energy Test Site ● Site visit ● ITRI ● Minesto ● Aquanet Power Buses depart from the venue at 9:00
12:00-15:00	Cultural tour to Jiufen Old Street. or Technical tour to Aquanet Power at Taoyuan (Maximum 60 delegates. Please sign at Aquanet exhibition booth). For either tour, buses depart from NTOU Test Site at 12:00. Simple lunch boxes will be prepared for all delegates.

September 10 (Monday)

Session 1-A (Room A)
Floating Kuroshio Turbine

Session Chair: ***Prof. Tsumoru Shintake (Okinawa Institute of Science and Technology, Japan)***

13:00-13:20 **Hydrodynamic effects of waves on a floating Kuroshio turbine (493)**

Forng-Chen Chiu*, Jun-Yen Shieh, Yu-Sheng Peng

13:20-13:40 **Design and analysis of the floating Kuroshio turbine blades (491)**

Fang-Ling Chiu, Sin-An Lai, Chi-Fang Lee, Yu-An Tzeng, Ching-Yeh Hsin*

13:40-14:00 **Hydrodynamic performance of a towed floating Kuroshio current turbine (386)**

Jing-Fa Tsai*, Yi-Hsiang Liao, Forng-Chen Chiu

14:00-14:20 **Dynamic simulation of the mooring system with a shock-absorbing mechanism for floating Kuroshio turbine (500)**

Chau-Chang Chou*, Ping-Yang Huang, Jian-Horng Chen, Ching-Yeh Hsin, Forng-Chen Chiu

14:20-14:40 **Development of passive oil compensated shaft seal module for Kuroshio Turbine (464)**

Jenhwa Guo*, Ling-Ji Mu, Sheng-Wei Huang

14:40-15:00 **Effect of mooring line materials on FKT system dynamics (382)**

Jo-Ti Wu*, Jiahn-Horng Chen, Ching-Yeh Hsin, Forng-Chen Chiu

September 10 (Monday)

Session 1-B (Room B)

Wave device development and testing (I)

Session Chair: *Prof. Chen-Chou Lin (National Taiwan Ocean University, Taiwan)*

13:00-13:20 **Array optimisation for wave damping and wave absorption (317)**

Clotilde Nové-Josserand*, Ramiro Godoy-Diana, Benjamin Thiria

13:20-13:40 **Uncertainty analysis for a wave energy converter: the Monte Carlo method (444)**

Jarrah Orphin*, Irene Penesis, Jean-Roch Nader

13:40-14:00 **Study of the effects of opening ratio of airflow control valve on the dual duct OWC chamber system (309)**

Kilwon Kim*, Jeongki Lee, Jongsu Choi

14:00-14:20 **Experimental investigation of a novel direct mechanical drive wave energy converter (335)**

Vishnu Vijayasankar, Gundi Amarnath, S. A. Sannasiraj, Abdus Samad*

14:20-14:40 **Initial design of OWC WEC applicable to breakwater in remote islands (380)**

Kyong-Hwan Kim*, Bowoo Nam, Sewan Park, Jeong-Seok Kim, Gilwon Kim, Chang-Hyuck Lim, Keyyong Hong

14:40-15:00 **Analysis of development status of wave energy development and utilization technology (415)**

Ting Yu*, Zhichuan Li, Yonghu Wu

September 10 (Monday)

Session 1-C (Room C)

Tidal current resource energy characterization (I)

Session Chair: ***Prof. Koju Hiraki (Kyushu Institute of Technology, Japan)***

13:00-13:20 **Experimental study of the wake past cubic wall-mounted elements to predict flow variations for tidal turbines (305)**

Maria Ikhennicheu*, Grégory Germain, Benoît Gaurier, Philippe Druault

13:20-13:40 **Numerically modelling the spatial distribution of weather windows: improving the site selection methodology for floating tidal platforms (348)**

John McDowell*, Penny Jeffcoate, Tom Bruce, Lars Johanning

13:40-14:00 **Impact of tidal stream site interconnectivity on resource assessments (302)**

Alice J. Goward Brown*, Peter E. Robins, Matt J. Lewis, Sophie Ward, Simon P. Neill

14:00-14:20 **Waves reduce the tidal-stream energy resource (277)**

Lewis M, Neill S, Robins P, Goward-Brown A, Reza Hashemi*

14:20-14:40 **Development of a wave-current numerical model using Stokes 2nd order theory (293)**

Catherine Lloyd*, Tim O'Doherty, Allan Mason-Jones

14:40-15:00 **Design process for a scale horizontal axis tidal turbine blade (292)**

Robert Ellis*, Matthew Allmark, Tim O'Doherty, Allan Mason-Jones, Stephanie Ordonez-Sanchez, Kate Johannesen, Cameron Johnstone

September 10 (Monday)

Session 1-D (Room D)

Wave device hydrodynamics and structural mechanics

Session Chair: ***Prof. Changhong Hu (Kyushu University, Japan)***

13:00-13:20 **Motion instabilities in tethered buoy WECs (498)**

J. Orszaghova*, H. Wolgamot, S. Draper, A. Rafiee

13:20-13:40 **Sloshing and violent in-chamber water column movement in an OWC wave energy converter (408)**

Krisna Adi Pawitan*, William Allsop, Tom Bruce

13:40-14:00 **Application of vortex method to performance analysis of wave energy converter: vorticity creation method from the boundary (434)**

Shuichi Nagata*, Yasutaka Imai, Tengen Murakami, Shigeki Okubo, Yutaka Okamoto

14:00-14:20 **Pseudo-nonlinear hydrodynamic coefficients for modelling point absorber wave energy converters (442)**

Benjamin W. Schubert*, Fantai Meng, Nataliia Y. Sergiienko, Will Robertson, Benjamin S. Cazzolato, Mergen H. Ghayesh, Ashkan Rafiee, Boyin Ding, Maziar Arjomandi

14:20-14:40 **A numerical calculation for hydrodynamic response analysis of a multi-buoy WEC platform (418)**

Sanghwan Heo*, Weoncheol Koo, Min-Su Park

14:40-15:00 **Bottom-hinged flap-type wave energy converter with efficient mechanical motion rectifier (424)**

Jia Mi, Lin Xu*, Beibei Liu, Liang Sun, Lei Zuo

September 10 (Monday)

Session 2-A (Room A)

Tidal current device and environmental modeling

Session Chair: ***Prof. Tim O' Doherty (Cardiff University, U.K.)***

15:30-15:50 **Characterising the effect of turbine operating point on momentum extraction of tidal turbine arrays (452)**

Christoph Hachmann*, Tim Stallard, Binliang Lin, Peter Stansby

15:50-16:10 **A sea-state based investigation for performance of submerged tensioned mooring supported tidal turbines (325)**

Song Fu*, Cameron Johnstone

16:10-16:30 **Numerical simulation research on output characteristics of tidal turbine in time-varying flow (405)**

Junzhe Tan*, Zhishuang Zheng, Peng Yuan, Shujie Wang, Xiancai Si, Xiaodong Liu

16:30-16:50 **Arrangement optimization of three tidal turbines considering efficiency and productivity (393)**

Chul-hee Jo, Hong-jae Park, Johnny C. L. Chan, Su-jin Hwang*

16:50-17:10 **Structural Safety Evaluation for the Driving part of 15kW-Class HATCT Model by FSI Analysis (384)**

Ming Guo*, Seung-Jun Kim, Young-Do Choi

September 10 (Monday)

Session 2-B (Room B)

Wave device and environmental modeling

Session Chair: ***Prof. Prasanna Gunawardane (University of Peradeniya, Sri Lanka)***

15:30-15:50 **On the modelling of arrays of wave energy converters (285)**

Ossama Abdelkhalik*, Shangyan Zou, Sameh Darwish

15:50-16:10 **Control-oriented modelling for wave energy converter M4 (425)**

Zhijing Liao, Nian Gai*, Peter Stansby, Guang Li

16:10-16:30 **Shallow and intermediate water wave energy converter (396)**

Ramuel T. Maramara, Masoud Masoumi*

16:30-16:50 **A seesaw shaped floating wave energy converter (438)**

Jiangbin Zhao*, Xin Wei, Jianlin Zhou, Yong Jin, Chenxing Sheng

16:50-17:10 **Equivalent circuit for mechanical-motion-rectifier based power take-off in wave energy harvesting (392)**

Chien-An Chen*, Xiaofan Li, Lei Zuo, Khai Ngo

September 10 (Monday)

Session 2-C (Room C)
Tidal current device development and testing (I)

Session Chair: Prof. Bang-Fuh Chen (National Sun Yat-sen University, Taiwan)

15:30-15:50 **Effect of chord-wise flexibility to the power extracting efficiency of tidal current energy (390)**

Xu Jianan*, Guan Daitao, Zhu Haiyang

15:50-16:10 **Protocols for testing marine current energy converters in controlled conditions. Where are we in 2018? (306)**

Grégory Germain*, B. Gaurier, M. Harrold, M. Ikhennicheu, P. Scheijgrond, A. Southall, M. Trasch

16:10-16:30 **The development and testing of a lab-scale tidal stream turbine for the study of dynamic device loading (321)**

Matthew Allmark*, Robert Ellis, Kate Porter, Tim O'Doherty, Cameron Johnstone

16:30-16:50 **Field performance testing of a floating tidal energy platform - Part 1: power performance (320)**

Ralf Starzmann, Inga Goebel, Penny Jeffcoate*

16:50-17:10 **Field performance testing of a floating tidal energy platform - Part 2: load performance (336)**

Penny Jeffcoate, Nick Cresswell*

September 10 (Monday)

Session 2-D (Room D)

Wave energy resource characterization (I)

Session Chair: *Prof. Yasutaka Imai (Saga University, Japan)*

15:30-15:50 **Experimental study on the efficiency of an OWC under different incident wave conditions (461)**

Yaw-Huei Lee*, Duy-Tong Nguyen, Yi-Chih Chow

15:50-16:10 **Alternative methods for offshore wind-wave resources and power assessments over the Gulf of Thailand and Andaman Sea (528)**

Woraluck Hongto, Worachat Wannawong, Donlaporn Saetae, Chaiwat Ekkawatpanit*, Peera Sakornmaneerat

16:10-16:30 **A cost-efficient seabed survey for bottom-mounted OWC on King Island, Tasmania, Australia (411)**

Remo Cossu*, Craig Heatherington, Alistair Grinham, Irene Penesis, Scott Hunter

16:30-16:50 **Numerical simulation for hydrodynamic response of wave energy converter in extreme waves (407)**

Di Wang, Decheng Wan*

16:50-17:10 **A meshless method for the two-dimensional extended Boussinesq equations (481)**

Wan-Rong Chou*, Chia-Cheng Tsai, Tai-Wen Hsu, Shih-Chun Hsiao

September 11 (Tuesday)

Session 3-A (Room A)

Tidal current device development and testing (II)

Session Chair: Mr. Peter Scheijgrond (Dutch Marine Energy Centre, Netherlands)

10:40-11:00 **River turbines controlled by mechanical three variable speed converters (525)**

Kyung Soo Han*

11:00-11:20 **Tidal energy in Australia - Assessing resource and feasibility to Australia's future energy mix (507)**

Irene Penesis, Mark Hemer, Remo Cossu, Jenny Hayward, Jean-Roch Nader*, Uwe Rosebrock, Alistair Grinham, Saad Sayeef, Peter Osman, Philip Marsh, Camille Couzi

11:20-11:40 **Robustness testing of techno-economic assessment tool for tidal energy converters (294)**

Steven Pyke*, Cameron Johnstone, Elaine Buck

11:40-12:00 **Case study presentation: Design study on different drive train concepts and rotor bearing arrangements used in a 1MW tidal stream turbine (300)**

M. Hofmann*, M. Baumann

September 11 (Tuesday)

Session 3-B (Room B)

Wave power take-off and device control (I)

Session Chair: ***Prof. Christophe Gaudin (The University of Western Australia, Australia)***

10:40-11:00	**Project Neptune: Critical component tests for a fully flooded direct-drive linear generator for wave energy convertors (340)** Joseph Burchell*, Nisaar Ahmed, Jose Ignacio Barajas-Solano, Markus Mueller, Mike Galbraith
11:00-11:20	**Numerical study on the behavior of an oscillating wave surge converter (375)** Huifeng Yu*, Yongliang Zhang
11:20-11:40	**Numerical analysis of two different hydraulic power take-off configurations for renewable energy applications (417)** Daniele Chiccoli, Mauro Bonfanti*, Giovanni Bracco, Panagiotis Dafnakis, Sergej Antonello Sirigu, Giuliana Mattiazzo
11:40-12:00	**Conversion characteristics of permanent magnet synchronous generator on wave energy converter (469)** Yasutaka Imai*, Shuichi Nagata, Tengen Murakami

September 11 (Tuesday)

Session 3-C (Room C)

Policy development and legislation &Tidal current device environment modeling

Session Chair: ***Prof. Philippe Druault (Sorbonne Université, France)***

10:40-11:00 **Creating regulatory certainty: A pathway to success in Nova Scotia, Canada (385)**

Sandra Farwell*

11:00-11:20 **Turbulence characteristics in tidal flows using LES and ALM to model the tidal power plant Deep Green (512)**

Sam T. Fredriksson*, Göran Broström, Björn Bergqvist, Johan Lennblad, Håkan Nilsson

11:20-11:40 **Numerical modelling of the Laminaria concept with coupled mooring and PTO system (395)**

Rémy CR Pascal*, Benjamin Gendron, Adrien Combourieu

11:40-12:00 **High performance synthetic ropes for wave and tidal PTO applications (526)**

Gabrielle Maassen*, Rafael Chou, Paul Chong

September 11 (Tuesday)

Session 3-D (Room D)
Offshore wind

Session Chair: ***Prof. Yoshikazu Tanaka (Hiroshima University, Japan)***

10:40-11:00 **Study on structural response of a floating structure for offshore wind power generation using a small-scale model experiment (330)**

Jumpei Oda*, Yoshikazu Tanaka, Hidetsugu Iwashita, Yukitaka Yasuzawa, Makoto Sueyoshi

11:00-11:20 **Release of a reliable open-source package for performance evaluation of ocean renewable energy devices (422)**

Yingyi Liu*, Shigeo Yoshida, Hiroshi Yamamoto, Akinori Toyofuku, Changhong Hu, Makoto Sueyoshi, Hongzhong Zhu

11:20-11:40 **Aerodynamic analysis of a large wind farm with actuator line model (406)**

Ping Cheng, Xinze Duan, Yang Huang, Decheng Wan*

11:40-12:00

September 11 (Tuesday)

Session 4-A (Room A)

Special session: Market supports for marine renewables

Session Chair: *Bruce Cameron (Principal Consultant, Envigour - Canada)*

13:00-15:00 The session will cover various aspects of Market Supports that exist for the Marine Renewable Energy industry. Specifically, the panel will discuss the current status, effectiveness, and learnings that can be shared from experiences of representative stakeholders in different regions. The session will also touch in more detail on the more established market opportunities and the reasons that those countries have put supportive policies in place.

Panel Members:

Bruce Cameron (Principal Consultant, Envigour - Canada)
-Moderator/Chair

Mark Leybourne (Associate Director, ITPEnergised - UK)

Michael Abundo (Managing Director, OceanPixel Pte Ltd - Singapore)

Ralf Starzmann (Director, SCHOTTEL HYDRO - Germany)

Prof. Chul H. Jo (Inha University - South Korea)

Blandine Battaglia (Project Engineer, SABELLA - France)

Henry Han Lei (Managing Director, Hann-Ocean Group - Singapore)

Daniel Coles (Project Resource Analyst, SIMEC Atlantis - UK)

September 11 (Tuesday)

Session 4-B (Room B)

Future markets and financing & Wave device development and testing (II)

Session Chair: ***Prof. Ossama Abdelkhalik (Michigan Tech University, U.S.)***

13:00-13:20 **Future prospects of marine energy technologies – Status and readiness? (497)**

A S Bahaj*

13:20-13:40 **Methods for identifying attractive wave energy scenarios (307)**

Owain Roberts*, Pablo Ruiz-Minguela, Henry Jeffrey

13:40-14:00 **Drakoo - Energizing the future with ocean waves (344)**

Henry L. Han*, Lex L. de Rijk

14:00-14:20 **Performance analysis of an OWC device integrated within a porous breakwater (451)**

Rebecca Grennell, Damon Howe*, Jean-Roch Nader, Gregor Macfarlane

14:20-14:40 **Experimental investigation of a five WECs array hydrodynamics (409)**

Sergej Antonello Sirigu*, Mauro Bonfanti, Panagiotis Dafnakis, Giovanni Bracco, Giuliana Mattiazzo

14:40-15:00 **Using structured innovation techniques to assess and develop potential technology for wave energy power conversion (374)**

Anna Stegman*, Henry Jeffrey, Lars Johanning, Stuart Bradley

Parallel Sessions IV

September 11 (Tuesday)

Session 4-C (Room C)
Tidal current device hydrodynamics and structural mechanics (I)

Session Chair: ***Prof. Liang Zhang (Harbin Engineering University, China)***

13:00-13:20 **Laboratory study of tidal turbine performance in irregular waves (457)**

Kate Porter*, Stephanie Ordonez-Sanchez, Matthew Allmark, Robert Ellis, Catherine Lloyd, Tim O' Doherty, Cameron Johnstone

13:20-13:40 **Tidal turbine interaction effect of upstream turbine wake on downstream turbine (281)**

Vincent Podeur*, Dominic Groulx, Christian Jochum

13:40-14:00 **Wake measurement metrics and the dependence of tidal turbine wakes on turbine operating condition (313)**

T. Ebdon*, D.M. O'Doherty, T. O'Doherty, A. Mason-Jones

14:00-14:20 **Prediction of the stability of a floating tidal turbine platform under towing conditions (399)**

Martin Koh*, Alex Ng

14:20-14:40 **Improvement of self-starting of Darrieus turbine by pitch variation (509)**

Koju Hiraki, Katsuhiro Henzan

14:40-15:00 **Global optimization of a horizontal axis tidal current turbine with shroud (410)**

Daisaku Sakaguchi, Yusaku Kyozuka

September 11 (Tuesday)

Session 4-D (Room D)

Environmental impact and appraisal (I)

Session Chair: ***Dr. Joseph Burchell (The University of Edinburgh, U.K.)***

13:00-13:20 **Observation of biofouling by using test plates in Hirado Strait of Nagasaki, Japan (372)**

Yusaku Kyozuka*, Seiji Kobayashi

13:20-13:40 **Proposed guidelines for preliminary assessments of the physical impacts of wave energy deployments (505)**

Mark Hemer*, Kathleen McInnes, Julian O' Grady, Ron Hoeke, Stephanie Contardo

13:40-14:00 **Effects of wave energy generators on Nephrops norwegicus (283)**

Anke Bender*, Jan Sundberg

14:00-14:20 **Monitoring different type of fish around tidal and oceanic current turbines in water tank (310)**

Takero Yoshida*, Jinxin Zhou, Sanggyu Park, Daisuke Kitazawa

14:20-14:40 **Simulation of composite suction foundation to topography change (467)**

San-Shan Lin*, Hsing-Yu Wang, Yun-Chih Chiang, Hui-Ming Fang, Sung-Shan Hsiao

14:40-15:00 **Lessons learned from practical asset management (429)**

Jamie Ian MacDonald, Mike Allan

September 11 (Tuesday)

Session 5-A (Room A)

Tidal current device development, test, and its environment impact and appraisal

Session Chair: ***Dr. Mark Hemer (CSIRO, Australian)***

15:30-15:50 **Blade element momentum theory to predict the effect of wave-current interactions on the performance of tidal stream turbines (381)**

Stephanie Ordonez-Sanchez*, Kate Porter, Matthew Allmark, Cameron Johnstone, Tim O'Doherty

15:50-16:10 **Effectively performing marine operations in strong current areas (352)**

D. Dhomé*, J.-C. Allo, M. Morandeau, C. Ramauge

16:10-16:30 **Recommend ultra low-head mini-hydro turbinegenerator system for coastal river application (436)**

Joe Martin, Jacek Swiderski, Liuchen Chang, Tony T Tung*, Wagner A. Barbosa, G Lucio Tiago Fiho, Antonio Carlos B Botan

16:30-16:50 **Sealing of tidal stream turbine rotor shafts (279)**

M. Hofmann, Michael Baumann*

16:50-17:10 **Dynamic sandbanks in close proximity to sites of interest for tidal current power extraction (502)**

Luke S. Blunden*, Stephen G. Haynes, AbuBakr S. Bahaj

September 11 (Tuesday)

Session 5-B (Room B)

Special session: Cordage technology for renewable energy applications

Session Chair: *Dr. Rafael (Chiate) Chou*

15:30-17:10

This section will cover the connection between alternative energies and the state of the art cordage technologies and knowledge. Specific subjects include the evolution of technologies in marine industry using cordage, significance and importance of industry standards, and proposed collaboration among suppliers, designers, industry regulations bodies, operators and research institutes. With the dialogue and discussion, we would like to provide a platform to reveal and address issues in advancing alternative energy and establish a mechanism for continuous collaboration among the various parties.

The Motivation and Purpose of the 100 min section is to have a dialogue between cordage suppliers and relevant industry and academic partners to enable and ensure success development and operation of the field operation for alternative energies.

Section Lead

Rafael (Chiate) Chou, Ph.D. – Moderator/Chair

Agenda

- Opening – 5 min
- Introduction – sponsors and hosts – 15 min
- Alternative energy – 10 min
- Go deeper – evolution of critical technologies in marine industry using cordage – 40 min
- Best practices and industry standards in the energy industry with cordage – 30 min
- Future needs and reality check – 10 min
- Bridging Technologies – 10 min
- Closing Remarks and Q&A

Parallel Sessions V

September 11 (Tuesday)

Session 5-C (Room C)
Tidal current device hydrodynamics and structural mechanics (II)

Session Chair: *Prof. Xu Wang (RMIT University, Australia)*

15:30-15:50 **Mooring system design for an underwater floating tidal current power device (400)**

Chul-Hee Jo, Su-Jin Hwang, Hong-Jae Park*

15:50-16:10 **Turbulent wake flow feature and torque performance of a drag-type hydraulic rotor (278)**

Wisdom Opare, Can Kang*, Yongchao Zhang, Chen Pan

16:10-16:30 **Numerical simulation on hydrodynamic performance of parallel twin vertical axis tidal turbines (314)**

Sun Ke*, Zhou Xue-han, Zhang Liang, Li Yan, Jiang Jin

16:30-16:50 **Dynamic analysis of jack-up platform structure in environment loads (463)**

Hung Chien Do*, Jianh-Horng Chen, Phan Van Quan

16:50-17:10 **Optimization study on the downstream section of a radial inflow turbine (311)**

Nazanin Ansarifard*, Alan Fleming, Alan Henderson, S.S Kianejad, Shuhong Chai

September 11 (Tuesday)

Session 5-D (Room D)
Ocean energy system integration

Session Chair: *Prof. Yukitaka Yasuzawa (Kyushu University, Japan)*

15:30-15:50 **Development of two-way type tidal power optimization program (K-TOP3.0) (460)**

Song-yi Lee, Tae-hyeon Jang, Hee-gon Kim, Yong-ho Lee, Jae-baek Choi, Hyo-keun Kwon

15:50-16:10 **Combined ocean renewable energy system (Cores) for islandic area on Malaysian Seas (443)**

Omar bin Yaakob*, Md. Afendi bin M. Yusuf, Jasrul Jamani bin Jamian, Muhammad Ariff bin Baharudin, Kang Hooi Siang, Nik Mohd Ridzuan bin Shaharuddin, Farah Ellyza binti Hashim, Zulfakar bin Aspar, Muhammad Adli bin Mustapa, Mohd Arif bin Ismail, Ahmad Mustaqim bin Abd Rahim, Muhammad Syazwan bin Bazli, Nurhaslinda binti Khaliddin, Siti Sarah binti Jupri

16:10-16:30 **Cross-stream active mooring for tidal stream power systems (350)**

Che-Chih Tsao*, Jia-Shi Lee, Yen-Yu Chen, Yu-Sheng Chen, Yi-Feng Hsu

16:30-16:50 **Tidal stream power development in San Bernardino Strait, Philippines (360)**

Blandine Battaglia*

16:50-17:10 **A study on integration of wave energy converter and semi-submersible floating wind turbine: A water Tank test (301)**

Hongzhong Zhu*, Changhong Hu, Makoto Sueyoshi, Shigeo Yoshida

September 12 (Wednesday)

Session 6-A (Room A)
OTEC systems and wave devices

Session Chair: ***Prof. Jiangbin Zhao (Wuhan University of Technology, China)***

10:40-11:00 **Optimization study on floating structure and risers design for a 100 MW-net ocean thermal energy conversion (OTEC) power plant (304)**

Ristiyanto Adiputra*, Tomoaki Utsunomiya

11:00-11:20 **Effect of air compressibility on primary energy conversion performance of OWC device (328)**

Yukitaka Yasuzawa*, Takatomo Setoguchi

11:20-11:40 **Parameter study of a low frequency two body wave energy converter (370)**

Xueyu Ji*, Elie Al Shami, Xu Wang, Lei Zuo

11:40-12:00 **Numerical study on performance analysis for OWC WEC applicable to breakwater (466)**

Sewan Park*, Kyong-Hwan Kim, Bo-Woo Nam, Jeong-Seok Kim, Keyyong Hong

September 12 (Wednesday)

Session 6-B (Room B)

Grid connection and system aspects & Offshore wind-wave/wind-current energy

Session Chair: ***Prof. Ei-ichi Kobayashi (Nagasaki Marine Cluster Association, Japan)***

10:40-11:00 **First experimental results of a grid connected vertical axis marine current turbine using a multilevel power converter (339)**

Johan Forslund*, Karin Thomas

11:00-11:20 **Structural integrity monitoring of hybrid offshore-wind and tidal-current turbines (470)**

Wonsul Kim, Jin-Hak Yi*, Jin-Soon Park

11:20-11:40 **Stabilized offshore floating wind platform using a dual-function wave energy converter (506)**

Dillon Martin*, Wei Che Tai, Lei Zuo

11:40-12:00 **The design of semi-submersible wind-tidal combined power generation device (366)**

Chao Hu*, Yuhan He, Yong Ma, Binghao Zhou

September 12 (Wednesday)

Session 6-C (Room C)

Tidal current device hydrodynamics and structural mechanics (III)

Session Chair: ***Dr. Sam Fredriksson (University of Gothenburg, Sweden)***

10:40-11:00 **The effect of bathymetry interaction with waves and sea currents on the loading and thrust of a tidal turbine (341)**

Jose Manuel Rivera Camacho*, Cameron M. Johnstone, Stephanie E. Ordonez Sanchez

11:00-11:20 **Preliminary design of a horizontal axis tidal turbine for low-speed tidal flow (357)**

Job Immanuel Encarnacion*, Cameron Johnstone

11:20-11:40 **PLAT-O #2 at FloWave: A tank-scale validation of ProteusDS at modelling the response of a tidal device to currents (Part 2) (359)**

Ilie Bivol*, Penny Jeffcoate, Lars Johanning, Ryan Nicoll, Jeffrey Steynor, Vengatesan Venugopal

11:40-12:00 **Hydrodynamic performance analysis of the turbine of 2×100kW tidal current energy generation device based on tidal bladed software (379)**

Zhichuan Li*, Ting Yu, Yonghu Wu, Juan Yue

September 12 (Wednesday)

Session 6-D (Room D)

Wave energy resource characterization (II)

Session Chair: ***Prof. Abdus Samad (IIT Madras, India)***

10:40-11:00 **Wave energy converter with wave direction tracking function (524)**

Ming-Yu Tsai*

11:00-11:20 **A modified reactive control method for direct-drive linear wave energy converters using excitation force identification (511)**

Xuanrui Huang*, Xi Xiao

11:20-11:40 **Simulation of typhoon Soudelor (2015) induced typhoon waves using multiple-resolution method (480)**

Tien-Hung Hou*, Shih-Chun Hsiao, Tai-Wen Hsu, Chia-Cheng Tsai, Meng-Ling Chiao

11:40-12:00 **Wave powered desalination systems for developing countries and islands (536)**

P. William Staby*

September 12 (Wednesday)

Session 7-A (Room A)

Wave device development and testing (III)

Session Chair: ***Dr. Remo Cossu (The University of Queensland, Australia)***

13:00-13:20 **Wave energy experiment in the Maldives (414)**

Tsumoru Shintake, Katsutoshi Shirasawa, Jun Fujita*, Shuji Misumi, Tamotsu Nagahama, Toshio Shindou, Hamish Taggart, Hideki Takebe

13:20-13:40 **Experimental analysis into the effects of air compressibility in OWC model testing (449)**

Damon Howe*, Jean-Roch Nader, Gregor Macfarlane

13:40-14:00 **Numerical analysis and validation of a pressure-differential wave energy converter (427)**

Fabian Wendt*, Yi-Hsiang Yu, Aurelien Babarit, Mike Delos-Reyes

14:00-14:20 **The viscous effect in power capture of bottom-hinged oscillating wave surge converters (423)**

Chen-Chou Lin*, Yi-Chih Chow, Shiaw-Yih Tzang

14:20-14:40 **Bayesian Reliability Modelling of a Tidal Turbine Pitch System (289)**

Fraser J. Ewing, Philipp R. Thies*, Iraklis Lazaki, Jonathan Shek

14:40-15:00 **Design of a 100 kW pilot wave energy system based on a ballscrew Electro-Mechanical Generator (EMG) (401)**

L. Castellini, M. Martini*, G. Alessandri, R. Maccaglia

September 12 (Wednesday)

Session 7-B (Room B)

Science supporting the success of the marine energy industry

Session Chair: ***Prof. Chaiwat Ekkawatpanit (King Mongkut University of Technology Thonburi, Thailand)***

13:00-13:20 **PRIMRE: A vision for a portal and repository for information on marine renewable energy (363)**

Frederick Driscoll*, Andrea Copping, Kelley Ruehl, Jon Weers, Ann Dallman

13:20-13:40 **Numerical modelling and field measurements for wave resource characterization (308)**

Zhaoqing Yang*, Wei-Cheng Wu, Taiping Wang, Gabriel García-Medina, Levi Kilcher

13:40-14:00 **A wave energy research centre in Albany, Australia (371)**

Christophe Gaudin*, Ryan Lowe, Scott Draper, Jeff Hansen, Hugh Wolgamot, Conleth O'Loughlin, Jonathan Fievez, Daniel Taylor, Alexandre Pichard

14:00-14:20 **The role of georisk management in marine renewable energy projects (501)**

John M. Reynolds*, Ana B. Fernandes, Lucy M.L. Catt

14:20-14:40 **Learning curves for marine operations in the offshore renewable energy sector (462)**

Ben Hudson*, Edward Kay, Mark Lawless, Tom Bruce

14:40-15:00 **Coastal erosion and measures at Ketzeliau Coast, Taiwan (472)**

Jen-Yi Chang, Tai-Wen Hsu*, Li-Chang Hsu, Yi-Shing Chang, Shin-Jye Liang

September 12 (Wednesday)

Session 7-C (Room C)

Tidal current energy resource characterization (II)

Session Chair: ***Prof. Xu Jianan (Harbin Engineering University, China)***

13:00-13:20	**Effect of turbulence intensity on the performance characteristics of large-scale Wells turbine (324)** P. Madhan Kumar, Abdus Samad*
13:20-13:40	**The numerical analysis of a vertical axis turbine for current energy conversion (391)** Min-Hsiung Yang*, Zih-Duan Ciou, Syue-Sinn Leu, Jun-Lum Cai, Wei-Ren Chau
13:40-14:00	**Study on high-frequency fluctuations in tidal current direction (431)** Patxi Garcia Novo*, Yusaku Kyozuka
14:00-14:20	**Assessment of the turbulent flow upstream of the Meygen Phase 1A tidal stream turbines (367)** Daniel Coles*, Charles Greenwood, Arne Vogler, Tom Walsh, David Taaffe
14:20-14:40	**Tidal turbine array design and energy yield assessment for Naru Strait, Japan (535)** Daniel Coles*, Tom Walsh, Yusaku Kyozuka, Yoichi Oda
14:40-15:00	**Current & tidal energy converters farm levelized cost of energy optimisation based on reliability assessment (538)** Nicolas Larivière-Gillet*, Loïc Klein, Raoul Cabon, Gautier Maigret, Théo Laraignou

September 12 (Wednesday)

Session 7-D (Room D)

Wave power take-off and device control (II)

Session Chair: ***Prof. Weoncheol Koo (Inha University, Korea)***

13:00-13:20 **Dynamic model testing of a combined C-Gen magnetic gear system for an oscillating wave surge converter (373)**

Richard Crozier, Ben McGilton*, Markus Mueller

13:20-13:40 **New hybrid HST pump development for wave energy applications-study on the slipper bearing of an axial piston pump (508)**

S.D.G.S.P. Gunawardane*, Sudesh Ratnayake, Tomiji Watabe

13:40-14:00 **Performance prediction of impulse turbine for wave energy conversion - effect of simple cascade on the performance (331)**

Manabu Takao*, Seisuke Fukuma, Miah Md. Ashraful Alam, Yoichi Kinoue, Shuichi Nagata, Toshiaki Setoguchi

14:00-14:20 **Optimization of resistive load for a wave energy converter with linear generator power take off (353)**

Tatiana Potapenko*, Irina Temiz, Mats Leijon

14:20-14:40 **Enhancing the relative capture width of submerged point absorbing wave energy converters (441)**

Boyin Ding*, Nataliia Sergiienko, Fantai Meng, Benjamin Cazzolato, Peter Hardy, Maziar Arjomandi

14:40-15:00 **Design of hydraulic power take-off for wave energy converter on artificial breakwater (389)**

Xu Jianan*, Xu Tao

September 12 (Wednesday)

Session 8-A (Room A)
Test site

Session Chair: ***Dr. Jin-Hak Yi (Korea Institute of Ocean Science and Technology, Korea)***

15:30-15:50 **Managing environmental effects to facilitate marine renewable energy development (323)**

Andrea Copping*, Mikaela Freeman, Alicia Gorton, Stacia Dreyer

15:50-16:10 **No evidence of long-term displacement of key wildlife species from wave and tidal energy testing (354)**

Caitlin Long*

16:10-16:30 **Status for development of open sea test site for wave energy converters in Korea (446)**

Jong-Su Choi*, JeongKi Lee, Chang Hyuck Lim, Tae Kyeoung Ko, Ji Yong Park, Kilwon Kim, Keyyong Hong, Seungho Shin, Jeong Seok Kim, Jeong-Hwan Oh, Kyong-Hwan Kim, Young-Duck Kim, Il-Hyoung Cho

16:30-16:50 **Planning on establishment of sea test-bed for tidal current energy converters in Jindo, Korea (459)**

Jin-Soon Park, Dong Hui Ko*, Jin-Hak Yi

16:50-17:10 **Wave energy resources at the test site in Keelung, Taiwan (515)**

Shiaw-Yih Tzang*, Chun-Che Chen, Yung-Lung Chen, Huan-Ru Chen, Jiahn-Horng Chen

September 12 (Wednesday)

Session 8-B (Room B)

Tidal current energy resource characterization (III)

Session Chair: ***Prof. Cheng-Han Tsai (National Taiwan Ocean University, Taiwan)***

15:30-15:50 **The field study of current estimation for Kuroshio Power-Generating Pilot facilities (516)**

Chang-Wei Lee*, Po-Feng Chen, Wan-Ting Chang, Yih Yang, Wen-Chang Yang

15:50-16:10 **Dynamic stability of a surfaced current turbine system (517)**

Shueei-Muh Lin, Yang-Yih Chien, Hung-Chu Hsu, Meng-Syue Li

16:10-16:30 **Study of vortex characteristics of a VATT wake based on CFD simu-lation (369)**

Zheng Yuan, Wei Qi Liu, Liang Zhang*

16:30-16:50 **Tidal & river energy converters power curve assessment: A standard protocol derived from IEC 62600 - 200 (537)**

Nicolas LARIVIERE-GILLET*, Karim BARROU, Frédéric PREVOST, Julien DALMAS, Cyril GIRY

16:50-17:10 **Multi-year assessment of Reynolds stress and turbulent kinetic energy at the European Marine Energy Centre in the absence of waves (541)**

Gareth Wakelam*, Brian G. Sellar, Vengatesan Venugopal

September 12 (Wednesday)

Session 8-C (Room C)

Environmental impact and appraisal (II)

Session Chair: ***Prof. Yusaku Kyozuka (Nagasaki University, Japan)***

15:30-16:00 (30 mins)

Annex IV State of the Science - sharing what we know about environmental effects of marine renewable energy development internationally (542)

Andrea Copping*

16:00-16:20

Automated system for marine environmental and technical monitoring (543)

Francis James Corpuz, Charles Ng, Marianne Eleanor Catanyag*, Ajay Vignesh Usha Sekar

16:20-16:40

Environmental effects monitoring of tidal in-stream energy converters in the Bay of Fundy, Canada: Challenges and research needs (504)

Craig Chandler*

16:40-17:10

September 12 (Wednesday)

Session 8-D (Room D)

Tidal current power take-off and device modeling

Session Chair: *Prof. Can Kang (Jiangsu University, China)*

15:30-15:50 **Defining a marine turbine condition-based maintenance and management strategy for low velocities in Mexico (299)**

Edith Rojo-Zazueta*, Ismael Mariño-Tapia, Rodolfo Silva, Matthew Allmark, Paul Prickett, Roger Grosvenor

15:50-16:10 **An energy harvester for Kuroshio power (388)**

Shang-Yu Tsai*, Bang-Fuh Chen

16:10-16:30 **Performance enhancement effort for vertical-axis tidal-current turbine in low water velocity (318)**

Dendy Satrio*, I Ketut Aria Pria Utama, Mukhtasor

16:30-16:50 **Tidal currents characterization with large eddy simulation (394)**

Adrien Bourgoin*, Sylvain Guillou, Riadh Ata

16:50-17:10 **Floating Tidal Energy Site Assessment Techniques for Coastal and Island Communities (345)**

Penny Jeffcoate*, John McDowell, Michael Hook

Poster Session

Time: Coffee breaks on September 10-11.

1 **Validation and update of the hybrid tidal system (282)**

Sheng Deng, Carl Byrne, Allan Mason-Jones

2 **Tidal wave energy large scale conversion technology (527)**

Md. Moniruzzaman

3 **Numerical simulation of wave-induced oscillation in a circular open caisson by OpenFOAM (533)**

Yan-Xiang Lin, Da-Wei Chen, Jiahn-Horng Chen*

4 **OIST wave energy converter monitoring system for Maldives island experiment (402)**

Hideki Takebe, Katsutoshi Shirasawa, Jun Fujita, Shuji Misumi, Tsumoru Shintake

5 **Wave energy prize testing at Carderock's Maneuvering and Seakeeping (MASK) Basin (440)**

Budi Gunawan, Ann Dallman, Vincent S. Neary, Frederick Driscoll, Dale Scott Jenne, Robert Thresher

6 **CFD analysis of a 5kW marine current turbine and diffuser system (483)**

In Cheol Kim, Young Ho Lee

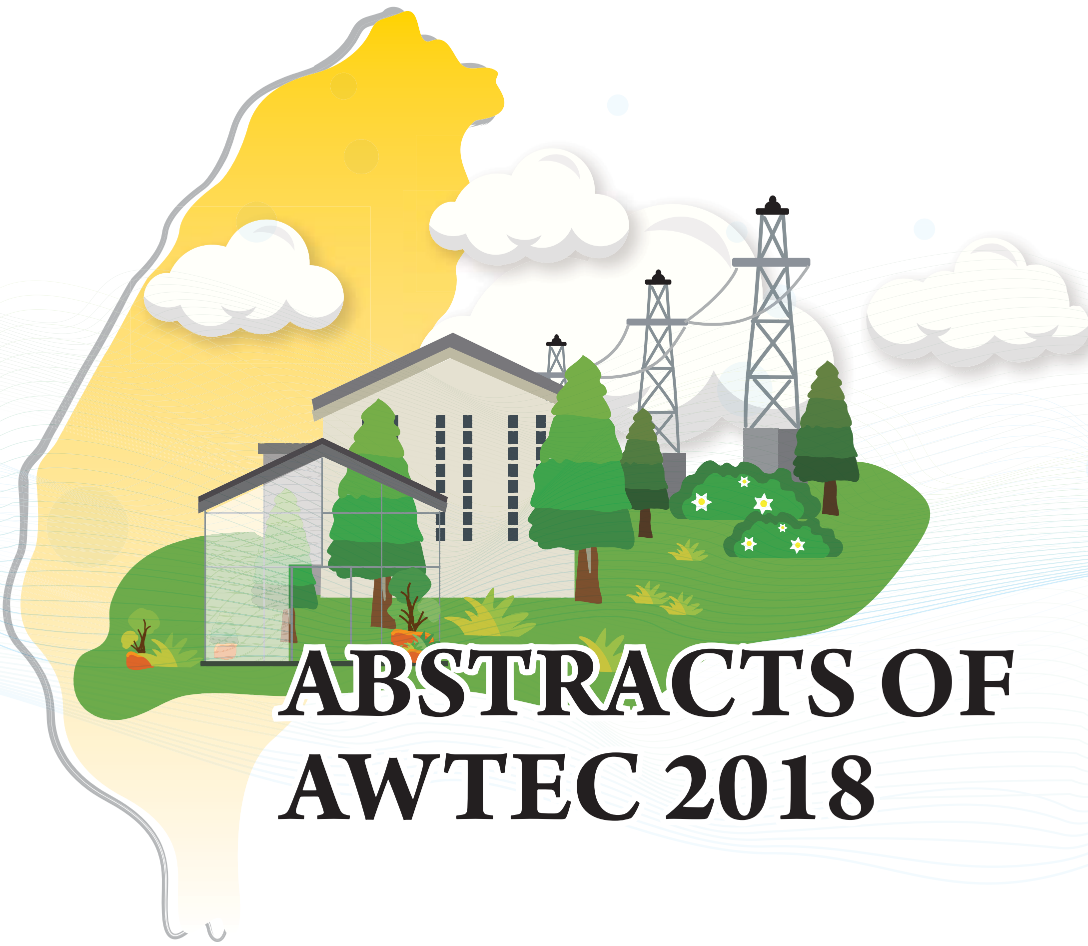
7 **The development of interactive ocean energy education modules (532)**

Pai-Chen Guan, Wei-Lun Lin, Wen-Kai Shih, Wen-Hsuan Chang, Yan-Ling Lu, Jia-Syuan Li

Poster Session

Time: Coffee breaks on September 10-11.

8	**Methodology of mooring analysis for the U-tube type FWEC (494)** Byung Ha Kim, Mohammed Asid Zullah, Young Ho Lee
9	**Applications of the generalized finite difference method to three-dimensional numerical wave (534)** Chia-Ming Fan, Chi-Nan Chu
10	**Design and analysis of segmented permanent-magnet transverse-flux tube linear synchronous generator (327)** Qiu Shuheng, Wang Haifeng
11	**Optimal design of vertical axis turbine using direct-forcing immersed boundary method (420)** Jason Chao-Ching Kao, Ming-Jyh Chern, Nima Vaziri
12	**Analysis of surface current variation observed with HF-radar in the coastal water off the Sihwa Tidal Power Plant (453)** Hyo-Keun KWON, Heegon KIM, Yongho LEE, SongYi LEE
13	**Simulation and experiment of the low-speed direct drive generator for Kuroshio current energy (471)** Po-Yu Chen, Kung-Yen Lee, Yi-Wen Juan, Jia-Han Li, Forng-Chen Chiu
14	**Submerged heaving and pitching flat plate - combined wave attenuation and WEC (403)** Andrea Mueller, Emre N. Otay
15	**International standards and certification for marine energy converters (545)** Bill Staby



ABSTRACTS OF AWTEC 2018

ABSTRACTS OF KEYNOTE SPEECHES

AWTEC 2018-KS01

The Research Challenges in Delivering a Robust, Cost Effective International Tidal Energy Industry

Cameron M. Johnstone

University of Strathclyde, UK

The extraction of energy from tidal flows has been identified as having potential to deliver highly valued and predictable renewable energy based electricity. In an effort to utilize this potential, considerable research and technology development programs have been undertaken in Europe, Asia and North America. This has also seen considerable investments being made by numerous Governments in an attempt to stimulate the development of an international tidal energy industry.

Within the last 10 years, a plethora of engineering technologies has been developed to harness energy from tidal flows. Some of these have progressed through progressive technology development programs which have seen technology prototyped, scaled tested then scaled up and deployed within pre- commercial technology demonstration projects. These have demonstrated technology robustness and shown energy can be successfully extracted from real sea conditions. This has resulted in more than 10 different engineering concepts being demonstrated at a utility scale > 0.5 MW.

In recent times, the first tidal arrays have been commissioned, with initial operational statistics showing to be highly positive in the context of operational hours and energy exported to the electrical network.

The important factor associated with these developments is the learning journey undertaken and the experiences gained from the design, manufacture, installations and commissioning processes. The next stages of tidal energy developments require the feeding of this information into the technology and project evolution process to inform the next generation of technology development and installation and intervention procedures. This is the stage where new, additional research challenges are identified and the need to expedite the addressing of these in an economic manner in order to evolve the sector towards commercial acceptability.

Achievement of commercial acceptability requires research focused on engineering product development and optimization for performance enhancement. Additionally, cost engineering is an important aspect identifying where costs can be reduced and taken out of specific technology, the installation and intervention processes. The levels of cost reductions to be attained are likely to be beyond those of cost reductions associated with volume production. Therefore, greater emphasis on product development with a focus on reduced weight, greater use of more durable and lower cost materials and ease of manufacture will be a significant influence on the research and development focus.

Tidal technology deployments to date have successfully demonstrated the harnessing of energy from tidal flows over a range of operating environments. The experiences and lessons learned from these are now feeding back into research and development programs to inform the next stages of technology development and commercial evolution. In undertaking the engineering development and testing, the information provided is also being used to investigate the economics of these technologies; and attainable cost reductions to be achieved.

To date, a substantive percentage of overall project costs is associated with installing and commissioning a tidal project, as identified in Fig. 1.

The use of large dynamic positioning vessels in undertaking installations results in: high upfront capital costs associated with vessel charter, together with; additional costly engineering challenges associated with 'heavy' handling and the installation of such devices at sea. In undertaking the installation and deployment of these pre-commercial systems, the use of large marine vessels with dynamic positioning capabilities developed for the offshore engineering and oil and gas sectors. An example of which is shown in Fig. 2.

Fig. 1 Example of a pre-commercial tidal turbine installation.

Utilising such vessels for installing and recovering tidal turbines results in high installation and operational and maintenance costs being encountered which can be detrimental to the viability of these deploy and test programs.

In the deployment of initial arrays, building a dependency on such installation methods result in these arrays becoming financially challenging. New engineering development is being undertaken on the development of new installation practices and methods. This enables the use of smaller, lighter and lower costs vessels which substantively reduce installation and intervention costs.

Fig. 2 Larger DP vessel being used for a tidal turbine installation.

From the experiences of deploying and operating a 0.5 MW tidal device, this paper will report on the technical and engineering approaches being adopted in developing both the tidal energy converter technologies and the manner in which they are being inter-connected within these initial arrays. It will identify the challenges being faced in developing tidal current technology, site installation practices, while remaining cost effective. The paper will conclude by drawing on the conclusions of the lessons learned to date when deploying and operating utility scale tidal technology and identify the areas and opportunities where technology breakthroughs may be made in order to deliver a more cost effective, utility scale multi MW tidal array.

AWTEC 2018-KS02

Hybrid Floating Renewables Towards Coastal Energy Resilience

Narasimalu Srikanth

Nanyang Technological Institute, Singapore

High density population resides in coastal regions of different countries. Remote islandic region such as in Southeast Asia and Caribbean region have poor energy per capita. Their regional economy greatly depends on the industrial activities such as fisheries and tourism and presently supported solely on diesel energy systems for its essential needs such as energy and water. This costs up to twenty percent of their GDP towards fossil fuel imports and it greatly hampers the ecology and further challenges the fuel transport logistics during natural disasters such as hurricanes and earthquake period.

Today land based solar energy systems have become prominent as a credible energy source and are adopted into regular energy mix of these region. However, in coastal settings due to limited land area for deployment, the present paper proposes the concept of floating renewable energy systems that can wisely utilize the shallow water region and the available tidal energy resources in the site. Tidal instream flow currents are predictable in ocean conditions and can work well with other energy forms such as solar photovoltaic systems. Today, with proper hydrodynamic modeling large floating structure scan be developed to support the concept of floating renewable energy platform. This paper shows how the seabed and coastal bathymetry surveys could be used with tidal current & wave measurements to perform hydrodynamics, fluid structure interaction studies, power predictions, etc. of these floating energy systems. In addition, through detailed resource mapping and device performance studies the best site locations can be identified for the ocean device deployment to achieve optimum levelized cost of energy, maximum availability and maximum capacity factor. Thus this paper aims to elucidate the hybrid floating energy system as a viable power plant towards tropical coastal and island regions.

AWTEC 2018-KS03

Floating Type Ocean Current Turbine

Ken Takagi

University of Tokyo, Japan

The Kuroshio is one of biggest ocean current. We have studied a floating type ocean current turbine system to utilize this energy and established elemental technologies for the system under the support of the New Energy and Industrial Technology Development Organization (NEDO). Based on this study NEDO and IHI corp. developed a 100 kW class (11m Turbine diameter) ocean current turbine system named “Kairyu” and successfully conducted a sea trial near Kuchinoshima Island last year.

The full scale floating type twin turbine system will have two turbines of about 40m diameter for the 1MW generator at a rated speed of 1.5m/s. The floating body is moored by a single mooring system with synthetic fiber lope to have a weather bane function. The turbine will be operated 50m under the sea surface. The motion simulator is one of important technologies which were developed in the project and validated with a tank test and a sea trial. Using the simulator, we have tested the system in several situations such as at a sudden change of flow direction, at starting-up the generator and in case of an accident on the turbine. Based on these elemental technologies, Kairyu was designed and constructed at the Yokohama works of IHI corp. A towing test of Kairyu was conducted off Kushikino and it successfully generated 100kW. After the towing test Kairyu was deployed near Kuchinoshima Island and a power generation test was conducted for one week. A brief history of the development and the sea trial will be presented at the conference.

AWTEC 2018-KS04

An Overview of Current Development, Vision and Challenge of Global Offshore Wind and Marine Energy Power

Kuang-Chong Wu

National Taiwan University, Taiwan

Energy is becoming an increasingly important priority for every country around the world. In order to reduce CO2 emissions and meet the 2°C Scenario (2DS) set by IEA, governments around the world have proposed various energy policies and development roadmaps in addition to developing suitable energy foresight technology. Currently, PV, Wind Power, Electric Vehicles, and Energy Storage are the 4 main pillars of development and deployment in most countries. The targets of these next stage efforts include building demonstration pilot sites, improving systems integration & efficiency, and reducing the costs from manufacturing & maintenance for commercialization.

To achieve the vision of a nuclear-free nation by 2025, the Taiwan government in 2016 initiated new energy policies. These policies include establishing energy transformation and an amendment of its Electricity Act. The power generated from renewable energy is expected to reach 20% by 2025 from exploring clean energy source and by adjusting current development strategies. In addition, most coal-fired power plants will be gradually replaced by natural gas-fired power plants to reduce air pollution and carbon emissions.

In 2016, the Taiwan government launched an Intelligent Green Energy Technology Park Construction in Shalun, Tainan for the purpose of promoting energy technologies and applications. The Park aims to boost research innovation, increase industrial applications, develop innovative products, increase smart systems & services, and initiate technology commercialization. These tasks will be performed through a green energy technology test platform as well as regional energy storage demonstration sites and test programs. Also in 2016, the Taiwan government launched a two-year Photovoltaic Project and a four-year Wind Power Project to accelerate renewable energy development. Under the two-year Photovoltaic Project, the performance and competitiveness of domestic PV farms will be raised through customized PV module development and improved reliability with increased security. The goal of the four-year Wind Power Project is to work with global wind power companies and increase the Asia-Pacific wind power market by using demonstration sites.

In addition to PV and Wind Power, Marine Energy is one new renewable energy focus which is not limited by land area. The estimated electricity potential from global marine energy is about 93,100 TWh, which is 5 times the electricity generated per year in Taiwan. Taiwan is an isolated island with about 10 GW of potential marine energy. The related marine technologies include marine wave power, marine current power, and ocean thermal energy. These technologies have the potential to raise the capacity of future total renewable. With this foresight, the Taiwan government has already initiated development strategies with this focus and has set-up demonstration sites with 10 kW generators. The next step will be developing larger generators and typhoon resistant designs for increased commercialization.

For the offshore wind energy development, Taiwan aims to reach 5.5GW of offshore wind energy by 2025, of which 738MW will be completed before 2020. Also, after 2025 the plan is to add another 5-6GW installed capacity, making Taiwan a major offshore wind farm in the world.

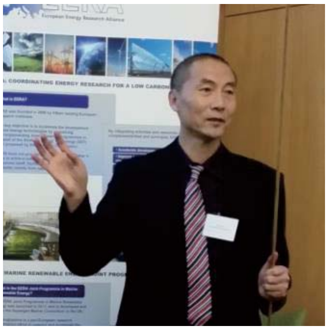
Wave energy and marine current energy have great development potential in Taiwan. CSBC, a major ship building company in Taiwan, in conjunction with Industrial Technology Research Institute, has developed a wave energy conversion system. A 20kW prototype has been tested in National Taiwan Ocean University test site in 2015. Research projects on current (Kuroshio) power system have been sponsored by Ministry of Science and Technology. Wanchi company has carried out the towing test of a 50kW prototype ocean current (Kuroshio) energy conversion system in March 2015 and deep-water mooring test in July 2016 for a week. CSBC Corporation Taiwan has also cooperated with National Taiwan University to develop a horizontal-axis ocean current (Kuroshio) power system, which is under small scale tank test. The goal is to build a 6MW demonstration power plant by 2025.

AWTEC 2018-KS05

Progress of Wave Energy Technology

Yage You

Guangzhou Institute of Energy Conversion (GIEC), Chinese Academy of Sciences, China



The presentation introduced the research of GIEC in wave energy utilization since 1980. Before 2002, all the researches were focused on development of Oscillating Water Column (OWC) wave energy converter (WEC). After having developed 3kW, 20kW, and 100kW OWCs and fulfilled a series of sea-tests, the study, however, encountered a setback. The conversion system consumed electrical energy of a constant power about 400W in operation, which was even greater than the output of the WEC in calm sea. While in rough sea, the output of the WEC usually exceeded its capacity. In these two cases, the WEC must be switched off. During the rest time, the WEC was normal in operation, but the efficiency of its conversion system was disappointingly low. The main reason of the low efficiency was caused by the much quicker variation of the air flow rate than that of rotation rate of the air turbine, which makes the turbine work in improper attack angle. Researchers realized that it is difficult to change the characteristic and to improve the performance of OWC in short period waves in China Sea. The easier way is to develop a new WEC, which has small oscillating period matching the short period of waves, has a power take-off (PTO) to be a pure generating system without consuming electricity in operation, and outputting smoothly in irregular waves. According to this idea, GIEC spent 5 years to develop an onshore Oscillating Body (OB) WEC in the first step, and spent another 10 years in the design of a floating OB WEC in the second step. The research followed 3 aims: improving the performance of wave-to-wire, decreasing the cost of the system and increasing the reliability. After the 15 years of hard work, GIEC has successfully developed a novel wave energy technology and the corresponding WEC - Eagle. The wave-to-wire efficiency in a 10-day average is 24%. The WEC is unmanned - all the necessary controls for energy conversion are driven by the hydraulic pressure in an autonomic way. The output of power can be AC or DC depending on the demand of the user. Fault-free time exceeds one year. After the development of half-scale (10kW) and full-scale (100kW) equipment, GIEC is now developing a commercial WEC - 1 MW Eagle.

AWTEC 2018-KS06

Mechanical Motion Rectifier: A High Efficiency and Reliable WEC Power Takeoff

Lei Zuo

Virginia Tech., USA

The power takeoff (PTO), the machinery to convert the mechanical energy into electricity, is widely considered as the single most important element in wave energy technology, and underlies many of the failures to date (A. Falcao 2010). The state-of-the-art ocean wave energy technology either uses direct-drive power takeoffs with linear electromagnetic generator or indirect-drive power takeoffs using intermediate fluid. The direct drives are simple and reliable but require heavy and bulk permanent magnets; the indirect drives are more compact but suffer from serious shortcomings on the complexity, reliability, and efficiency. Revolutionary power takeoff is urgently needed in order to realize the vast electricity potential from the ocean waves. This talk will present the design, modelling, lab test, wave tank test, and ocean trial of a “mechanical motion rectifier” based power takeoff, which converts the irregular oscillatory wave motion into regular unidirectional rotation of the generator. Lab tests show that up to 80% mechanical energy conversion efficiency was achieved with reduced force in the PTO motion system. The rotation inertia and two-body system design can further increase the power output in a large frequency range. Wave tank test and ocean trail also validated the high efficiency and reliability. The mechanical motion rectifier based power takeoff can be integrated into the point absorbers, wave attenuators, wave terminators, or other type of wave energy converter whenever oscillatory wave motion is involved. New extension has been made to simultaneously convert both ocean wave and marine current energy using a single power takeoff device.

ABSTRACTS OF INVITED SPEECHES

AWTEC 2018-IS01

Enabling Renewable Baseload Generation by Flying Subsea Kites

Martin Edlund

CEO, Minesto AB, Sweden

Ocean energy has the potential to play a crucial part in taking the next step of expansion of renewable energy. Minesto's awarded technology for converting energy from marine currents to clean electricity, Deep Green, can substantially increase that potential. With the same principle as flying a kite in the wind, Minesto's patented product streamlines the energy production and unlocks the vast resource of low-flow tidal streams and ocean currents.

Building on more than five years of scale model sea trials and recent experiences from commissioning of Minesto's utility-scale DG500 device in the UK, Dr. Martin Edlund will share his thoughts on how Asia's low-flow marine current resource – including the Kuroshio Current – can be exploited to enable renewable, sustainable baseload electricity generation from the ocean.

AWTEC 2018-IS02

Aquanet Power: Designing and Optimising a Full Scale PTO for Commercialisation

Ali Baghaei

CEO, Aquanet Power Limited, Taiwan

Aquanet Power has built and successfully commissioned, tested and validated its full-scale 1MW rated capacity air turbine power take-off (PTO) system of its wave energy conversion technology. The test and validation has fully de-risked the PTO equipment integration and control system enabling the full scale PTO System to achieve TRL8 level.

We will present the state-of-the-art bi-directional wind tunnel test facility built in early 2017 and its capability of simulating any sea conditions in the world. The test facility enabled Aquanet to test and validate its full-scale 1MW rated capacity air turbine PTO system of its wave energy conversion technology, thereby fully de-risking the PTO equipment integration and control system, onshore.

We will share some of the challenges and how we overcame those challenges as well as the process taken to test and fine tune the air turbine and PTO through sophisticated manipulation of the flow rate, pressure drop and control algorithms.

With a simplified design and highly efficient air turbine, the efficiency of the system is thereby increased and hence its cost-effectiveness.

Aquanet Power is developing a demonstration platform of its floating deep water application, ogWAVE, in the wave energy test basin under joint collaboration with its partners, National Taiwan Ocean University. A brief outline of the demonstration project will also be shared with the AWTEC delegates.

ABSTRACTS OF CONTRIBUTED PAPERS

AWTEC 2018-277

Waves reduce the tidal-stream energy resource

Lewis M*[1], Neill S, Robins P, Goward-Brown A, Reza Hashemi[2]

[1]Bangor University School of Ocean Sciences Menai Bridge, UK LL59 5AB.

[2]Department of Ocean Engineering University of Rhode Island, USA.

Corresponding author, m.j.lewis@bangor.ac.uk

If tidal-stream energy is to make a significant contribution to global renewable energy targets, understanding the influence of waves is essential as the majority of potential sites are exposed to waves. Wind waves add additional mass and momentum to the tidal flow, influencing the available resource as well as device performance and resilience. Here, the effect of waves to the resource and likely oceanographic conditions is presented. Oceanographic data from UK tidal-stream energy sites (directional wave-rider buoys, 4 and 5-beam ADCPs) were combined with dynamically coupled wave-tide regional model data (COAWST, which couples the SWAN wave model with the ROMS ocean model). The presence of waves altered the 15-minute averaged velocity profile and typically increased velocity shear. Averaged throughout a tidal cycle, the available tidal resource was also found to be reduced by ~ 10% per metre wave height increase. Further, waves were observed to be frequently aligned at an oblique angle to the tidal current. Therefore, realistic oceanographic conditions, such as the interaction of waves and tides, are needed to better understand the resource and improve device design criteria; for example, wave-current misalignment should be considered in device-scale studies of performance and resilience (e.g. CFD models).

AWTEC 2018-278

Turbulent wake flow feature and torque performance of a drag-type hydraulic rotor

Wisdom Opare*, Can Kang, Yongchao Zhang, Chen Pan

School of Energy and Power Engineering, Jiangsu University 301, Xuefu Rd., Zhenjiang, China.

Corresponding author, kangcan@mail.ujs.edu.cn

A drag-type rotor operating in the medium of water is investigated. The water tunnel is used to furnish flow environment for the rotor. Flow patterns near the rotor are measured with particle image velocimetry (PIV) technique and the wake flow is emphasized. At various rotor setting angles and upstream velocity magnitudes, velocity and vorticity distributions in the wake flows are depicted and compared. The torque coefficient of the rotor is calculated based on the result of computational fluid dynamics (CFD). As the rotor setting angle varies, the rotor wake profile is transformed. Inside the rotor wake, lowvelocity bands are separated by a region with fairly high velocity situated near the wake center. Large-scale flow structures are generated due to the interaction between outer stream and the wake flow. Small vortices are produced at the interface between the large-scale vortices, which is distinct as the rotor wake width is reduced. As upstream velocity increases, the profile of the vortex trapped by the concave side of the rotor blade changes considerably. Overall torque coefficient of the rotor is high and torque coefficient distribution over the rotor rotation cycle is uneven. High torque coefficient is agglomerated in the first and third quadrants. The medium property is a critical factor facilitating the torque performance. The relationship between flow feature and torque performance is substantiated.

AWTEC 2018-279

Sealing of tidal stream turbine rotor shafts

M. Hofmann, Michael Baumann*

SKF GmbH Germany, 11th floor, Gunnar-Wester Str. 12, 97421 Schweinfurt, Germany.

Corresponding author, Michael.Baumann@skf.com

The presentation covers typical customer requirements of rotor shaft seal applications, informs about key selection parameters and what the appropriate rotor shaft seal technology will be for shallow and deep water tidal turbine rotor shaft applications.

AWTEC 2018-281

Tidal turbine interaction effect of upstream turbine wake on downstream turbine

Vincent Podeur*[1], Dominic Groulx[1], Christian Jochum[2]

[1]Department of Mechanical Engineering, Dalhousie University Halifax, Nova Scotia, B3H 4R2, Canada.

[2]Institut de Recherche Dupuy de Lôme (IRDL), ENSTA Bretagne, Brest, FRE CNRS 3744, F-29200 Brest, France

Corresponding author, dominic.groulx@dal.ca

Flow perturbations carried in the wake of an upstream turbine can have a significant impact on the downstream one. To get a better understanding of the effect of unsteady asymmetric flow on a downstream turbine, fully transient simulations designed to study the effect of the wake of an upstream turbine on a downstream one were performed with a RANS k-ω SST turbulence model using ANSYS-CFX. Three different configurations were considered: the downstream turbine aligned with the upstream one, offset by 0.5D, and offset by 1D. A 10D clearance between both turbines was used. A horizontal axis tidal turbine (HATT) was used for the study. Results show that when fully in-line, the downstream turbine sees reduction in power coefficient by more than 69%, and temporal variation of this coefficient having a relative amplitude of more than 30%; and the blades see localized loading varying by a factor of up to 2 during their rotation and changes in the amplitude of loads applied at the same location varying by more than 13%.

AWTEC 2018-283

Effects of wave energy generators on Nephrops norwegicus

Anke Bender*, Jan Sundberg

Department of Engineering Science, Division for Electricity, Uppsala University Box 534, SE-75121 Uppsala, Sweden

Corresponding author, anke.bender@angstrom.uu.se

Wave energy research is primarily focused on the technical developments of energy conversion but the parallel evaluation of environmental effects related to wave energy is also essential and reflects sustainable development of renewable energy. At the west coast of Sweden, 120 km north of Gothenburg, the Wave Energy Park “Sotenäs Project” is located. This area has been the location of environmental impact studies from wave energy generators on the macro crustacean species Nephrops norvegicus (Linnaeus,1758), the Norway lobster. The Norway lobster is an ecologically as well as economically important species in Sweden and across Europe. The aim of this preliminary study was to detect possible positive or negative effects on numbers of individuals by the presence of the wave energy generators and the created “no take” zone. For that purpose, ROV aided seabed recordings of the characteristic Norway lobster burrow entrances were conducted inside the Wave Energy Park and respective control areas in 2016 and 2017. Preliminary results do not show a clear distinct result between the different transects and years. Long-term observations and complementary studies are necessary to draw conclusions and outweigh extreme and rare events of annual onetime samplings.

AWTEC 2018-285

On the modelling of arrays of wave energy converters

Ossama Abdelkhalik*, Shangyan Zou, Sameh Darwish

Mechanical Engineering -Engineering Mechanics Department, Michigan Technological University 1400 Townsend Dr, Houghton, MI 49931, USA

Corresponding author, ooabdelk@mtu.edu

This paper presents the concept of developing a surrogate model for the hydrodynamic interactions between heaving bodies including radiation wave effects. The surrogate model for an array of n heaving bodies is developed by creating an equivalent mechanical system that consists of n bodies in addition to other smaller intermediate bodies, springs, and dampers connected to each pair of the main n bodies. This equivalent mechanical system is designed such that the motions of its main bodies are the same as the motions of the actual array heaving bodies. The purpose is to develop dynamic models for wave energy converters (WECs) arrays that are more convenient to use for control design and optimization. The small moving mass that is connected between each two bodies in the surrogate mechanical system enables the modelling of the hydrodynamic interaction forces between the actual two buoys. A simulation tool is developed to simulate the motions of all bodies in the surrogate model. Also the motions of the actual WECs in the array are simulated using AQWA software. An optimization problem is then solved to minimize the error between the simulated motions of the WECs array in ocean, and the surrogate mechanical system. In this case study, the system design parameters to be optimized are: springs coefficients, dampers coefficients, and the additional body masses. Slack mooring dynamics are included in the derived equations of the motion of floating bodies. The proposed surrogate model is a time domain model that can be used for time-domain control design. The main advantage in the proposed technique is the ability to use a simple dynamic model for control design of arrays of wave energy converters. Simulations are presented that highlight the utility of the proposed model in control design.

AWTEC 2018-289

Bayesian Reliability Modelling of a Tidal Turbine Pitch System

Fraser J. Ewing*[1], Philipp R. Thies[2], Iraklis Lazakis[1], Jonathan Shek[1]

[1]Industrial Doctoral Centre for Offshore Renewable Energy, University of Edinburgh Sanderson Building, The Kings Buildings, Edinburgh, UK.

[2]College of Engineering, Mathematics and Physical Sciences, Penryn Campus, Penryn, UK.

Corresponding author, f.ewing@ed.ac.uk, jshek@exseed.ed.ac.uk

To date there has been no published reliability data for Tidal Stream Turbines (TST's). Thus, reliability assessments of failure critical components are highly uncertain. To reduce the Levelised cost of energy (LCoE) of TST technology it is critical to be able to perform accurate reliability assessments of devices at the design stage.

Based on experience from the wind industry, the power take off (PTO) is a failure critical assembly representing a high proportion of total turbine failures and downtimes. Many studies have found that the pitch system (PS) contributes to the majority of turbine failures [1], [2].

Bayesian reliability methods are of interest in industries where data is scarce or commercially sensitive as they allow for the use of surrogate data sources along with domain knowledge; they also allow for this knowledge to be updated as new data becomes available[3].

This research develops a Bayesian reliability model of a Horizontal axis TST PS using state of the art surrogate failure data and domain knowledge. The paper discusses the rationale behind Bayesian modelling and provides a framework for TST developers, researchers, consultants and the like to use their own device failure data when it becomes available to make accurate PS reliability assessments. The components of the PS focussed on in this research are the Dynamic Seal, Roller Bearing and Electric Motor. These are seen to be failure critical areas. Empirical

Physics of Failure (PoF) equations are used to determine individual failure rates for these components and then Monte Carlo methods are used to combine them. This combined part failure rate distribution is then updated using representative 'real' PS failure data (from the wind industry) to highlight the Bayesian updating process.

AWTEC 2018-292

Design process for a scale horizontal axis tidal turbine blade

Robert Ellis*[1], Matthew Allmark[1], Tim O'Doherty[1], Allan Mason-Jones[1], Stephanie Ordonez-Sanchez[2], Kate Johannesen[2], Cameron Johnstone[2]

[1]School of Engineering, Cardiff University Cardiff, CF24 3AA United Kingdom.

[2]Energy Systems Research Unit, University of Strathclyde Glasgow, G1 1XJ, United Kingdom.

Corresponding author, EllisR10@cardiff.ac.uk

If tidal energy extraction is to be maximised then emphasis needs to be placed on the design of the rotor geometry to optimise performance. The work documented in this paper describes the process used in the design and validation of a new blade based on the Wortmann FX63-137 aerofoil. BEMT was used as an initial tool to redesign the blade due to speed in which calculations can be completed. CFD models were produced after to incorporate the hydrodynamics and provide a 3D solution. The performance coefficients for CP and CT were calculated by each of the two computational methods for comparison with the experimental testing. The experimental testing was conducted at the INSEAN tow tank to provide validation for the computational models. The CFD model was found to closely predict the performance coefficients of the turbine at low TSR at and peak power. The BEMT model over predicted both the CP and the CT when compared to the experimental work, however was found to be good as an initial method for redesigning the blade.

AWTEC 2018-293

Development of a wave-current numerical model using Stokes 2nd order theory

Catherine Lloyd*, Tim O'Doherty, Allan Mason-Jones

School of Engineering, Cardiff University Queen's Buildings, 14-17 The Parade, Cardiff, CF24 3AA, UK.

Corresponding author, Lloydc11@cardiff.ac.uk

The optimisation of a Numerical Wave Tank is proposed to accurately model regular waves superimposed on a uniform current velocity. ANSYS CFX 18.0 was used to develop a homogenous multiphase model with volume fractions to define the different phase regions. By applying CFX Expression Language at the inlet of the model, stokes 2nd Order Theory was used to define the upstream wave characteristics. Horizontal and vertical velocity components, as well as surface elevation of the numerical model were compared against theoretical and experimental wave data for 3 different wave characteristics in 2 different depth tanks. The comparison highlighted the numerical homogeneity between the theoretical and experimental data. Therefore, this study has shown that the modelling procedure used can accurately replicate ocean wave-current conditions providing a potential substitute to experimental flume or tank testing.

AWTEC 2018-294

Robustness testing of techno-economic assessment tool for tidal energy converters

Steven Pyke*[1], Cameron Johnstone[1], Elaine Buck[2]

[1]Department of Mechanical and Aerospace Engineering, Strathclyde University James Weir Building, Glasgow, G1 1XJ, UK.

[2]EMEC, Old Academy Building Centre, Stromness, Orkney, KW16 3AW

Corresponding author, steven.pyke@emec.org.uk

This paper looks at the development of a TechnoEconomic Assessment (TEA) for tidal energy converters. The TEA has been established to help developers by providing a highlevel assessment of their tidal energy conversion device which gives an estimate of the affordability offered by the technology for a given resource. The affordability of the device is ultimately what will determine its commercial success and therefore being a decisive metric in supporting the development of a technology. To estimate the affordability of the device the TEA considers the fundamentals that impact on the costs and revenue thus evaluating the core design. Using different inputs to the TEA that represent different design approaches allows the developer to make design choices based on the outputs of the tool. This allows multiple design options to be analysed at an early stage of the design process, to establish the most promising configuration that could result in a commercial solution. The TEA aims to help developers at low TRLs as this is where the largest benefit can be realised. However, the assessment can still be used at higher TRLs to evaluate different approaches and to confirm progress. By carrying out this TEA at early TRLs it supports developers throughout the development of their technology, helping to find the optimal solution at the earliest development stage. This approach identifies areas of high risk early in the development program, a stage where costs and the impacts of change are lower.

AWTEC 2018-299

Defining a marine turbine condition-based maintenance and management strategy for low velocities in Mexico

Edith Rojo-Zazueta*[1], Ismael Mariño-Tapia[2], Rodolfo Silva[3], Matthew Allmark[1], Paul Prickett[1], Roger Grosvenor[1]

[1]Cardiff Marine Energy Research Group (CMERG) School of Engineering, Cardiff University Cardiff, South Glamorgan, CF24 3AA, Wales, UK.

[2]Departamento de Recursos del Mar, CINVESTAV-Mérida Km 6 Antigua Carretera a Progreso, Mérida, Yucatán, México.

[3]Instituto de Ingeniería, UNAM Circuito Escolar s/n, Ciudad Universitaria, Delegación Coyoacán, México City.

Corresponding author, RojoZazuetaEG@cardiff.ac.uk

The potential deployment of Tidal Stream Turbines in identified sites around Mexico is considered. An initial assessment of suitable locations is made based upon the nature and level of available resources. The characterisation of these resources is part of ongoing national research activities, summarised herein. One aspect of the specific nature of the available resources can be characterised as low velocity. This will require adaptations to existing turbine designs and to their management and operation. To aid this process the development and potential application of a drive train test rig is presented. Using inputs generated by simulation, laboratory tests and site-specific surveys this rig will be deployed to support the engineering and testing of turbine condition monitoring and management strategies.

AWTEC 2018-300

Case study presentation: Design study on different drive train concepts and rotor bearing arrangements used in a 1MW tidal stream turbine

M. Hofmann*, M. Baumann

SKF GmbH Germany, Gunnar-Wester-Str. 12, 97421 Schweinfurt, Germany.

Corresponding author, matthias.hofmann@skf.com

A correct drive train design is the foundation for a later reliable and robust horizontal tidal stream turbine. Bearings, sea water seal, gearbox, generator, etc. are key products and its prober selection and design is of extremely high importance. Engineering & application knowledge from similar ship propeller shaft and wind turbine applications is very helpful to re-use learning and reduce technical risks.

AWTEC 2018-301

A study on integration of wave energy converter and semi-submersible floating wind turbine: A water Tank test

Hongzhong Zhu*[1], Changhong Hu[2], Makoto Sueyoshi[2], Shigeo Yoshida[2]

[1]Research and Education Center for Green Technology, Kyushu University 6-1 Kasugakouen, Kasuga, Fukuoka 816-8580, JAPAN

[2]Research Institute for Applied Mechanics, Kyushu University 6-1 Kasugakouen, Kasuga, Fukuoka 816-8580, JAPAN

Corresponding author, zhuhongzhong@riam.kyushu-u.ac.jp

Economic efficiency and structural reliability are strongly required for ocean energy exploration. The integration of wave energy converter and floating offshore wind turbine has the potential to reduce the cost of energy since they can share the mooring system and the infrastructure of power grid. In this study, oscillating-water-column-type wave energy converters mounted on a semisubmersible-type floating wind turbine are considered. The wave energy converter is designed not only to capture wave energy but also to work as a damper of the semisubmersible for helping on enhancing the fatigue life of the wind turbine. Controllers for the wave energy converter and wind turbine for reducing the pitch motion of the semisubmersible are also presented in the study. The experimental results illustrate that the pitch of semisubmersible can be reduced by the controllers in most of the cases. However, the effectiveness of the controllers could be limited by the capacity of the wave energy converter especially when the motion of the floating turbine is large.

AWTEC 2018-302

Impact of tidal stream site interconnectivity on resource assessments

A.J. Goward Brown*, M.J. Lewis, P. Robins, S.Ward, S. P. Neill

Centre for Applied Marine Sciences / School of Ocean Sciences, Bangor University Menai Bridge, LL59 5AB, UK.

Corresponding author, a.j.gowardbrown@bangor.ac.uk

To reduce the uncertainty in resource assessments, the physical presence of the turbine arrays must be accounted for. Using a 3-D Regional Ocean Model with tidal stream energy extraction, we show that in regions where tidal stream energy sites have been leased in close proximity to each other there is some degree of inter-connectivity. In this paper a methodology is presented to identify the levels of connectivity between adjacent tidal energy developments to aid resource assessments and marine spatial planning.

AWTEC 2018-304

Optimization study on floating structure and risers design for a 100 MW-net ocean thermal energy conversion (OTEC) power plant

Ristiyanto Adiputra*, Tomoaki Utsunomiya

Marine System Engineering, Kyushu University Fukuoka 819-0395, Japan

Corresponding author, 3TE17262M@s.kyushu-u.ac.jp

This paper presents a design procedure based on optimization to contrive a floating structure for a commercial scale of OTEC power plant. In the aim to get a safe yet economical floating structure, a commercial oil tanker ship was converted as the plantship. The process was started by defining independent variables, constraints and fix parameters. The independent variables included the velocity of seawater transport and type of oil tanker ship. The next step was breaking down the fix parameters which were kept constant during the iteration process. These parameters were about the general requirements and the necessary equipment to produce 100 MW-net power output. Some constraints were also introduced as permissible borders to determine whether the

particular case was acceptable or not. The constraints included the constraint due to provided space, allowed weight, net power output and fluid phenomena on the riser. During the iteration process, a spiral model was developed as analysis guideline. Based on the result of the optimization, it could be concluded that the typical Suez-max oil tanker ship was the best option and the most optimum seawater transport velocity was 3 m/s. Finally, the general arrangements and the base layout design were also conceptualized in this paper.

AWTEC 2018-305

Experimental study of the wake past cubic wall-mounted elements to predict flow variations for tidal turbines

Maria Ikhennicheu*[1], Gregory Germain[1], Benoît Gaurier[1], Philippe Druault[2]

[1]Marine Structure Laboratory, IFREMER, 150 Quai Gambetta, 62200 Boulogne sur Mer. France.

[2]Sorbonne Universites, UPMC Univ Paris 06, CNRS, UMR 7190, Institut Jean Le Rond d'Alembert, F-75005 Paris, France.

**Corresponding author, gregory.germain@ifremer.fr*

There is a strong tidal energy potential in France, especially in the Alderney Race. In the area of study, where turbines will be installed, bathymetry variations are causing velocity fluctuations with a high turbulence rate in the water column: large coherent turbulent structures can be observed at the sea surface. Such events can have a major impact on the marine tidal turbines behaviour and structural fatigue. To reproduce and analyse these turbulent events, tests are carried out in the wave and current circulating flume tank of IFREMER in Boulogne-sur-Mer. Before trying to reproduce a complex bathymetry, we chose to introduce the topic by studying elementary obstacles representative of real seabed elements (with an aspect ratio of the magnitude of the mean bathymetry variations): a wide square cylinder and an inclined floor. Experiments are carried out with Reynolds number as high as achievable in Froude similitude: Re $= 2.5 \times 10^5$ and Fr = 0.23. The impact of the aspect ratio is studied by comparing results obtained with PIV and LDV measurements on the cube and cylinder cases. The addition of an inclined floor is also investigated. Results show a significant increase of the wake with the aspect ratio. The inclined floor induces a reduction of the shear layer created by the obstacle and modifications on the shedding frequency

AWTEC 2018-306

Protocols for testing marine current energy converters in controlled conditions. Where are we in 2018?

G. Germain*[1], B. Gaurier[1], M. Harrold[2], M. Ikhennicheu[1], P. Scheijgrond[3], A. Southall[4], M. Trasch[1]

[1]Marine Structure Laboratory, IFREMER, 150 Quai Gambetta, 62200 Boulogne s/ Mer. France.

[2]TOCARDO Tidal Power, Netherlands, NL.

[3]Dutch Marine Energy Centre, DMEC, The Netherlands.

[4]European Marine Energy Centre, EMEC, Orkney, UK.

**Corresponding author, ggermain@ifremer.fr*

Certification can help to reduce perceived risks of marine energy technologies in terms of performance and structural integrity, and thus helps to attract commercial financing and make export easier. At present, a certification scheme for marine energy convertor is under development by the International Electrotechnical Commission (IEC) involving all stakeholders in a consistent way based on international consensus. The implementation of international standards and certification schemes are needed to accelerate marine energy technologies development. In order to improve the work already achieved and to propose adaptations and enhancement, four experimental trials are undertaken on different kind of tidal energy devices (fixed and floating horizontal axis turbine as well as undulating membrane) under the Interreg 2 Seas Met-Certified project. The first results obtained under this project in the wave and current flume tank of Ifremer

are presented. The experimental set-up and protocol trials, taking into account the actual best practices and guidelines, are presented.

AWTEC 2018-307

Methods for identifying attractive wave energy scenarios

Owain Roberts*[1], Pablo Ruiz-Minguela[2], Henry Jeffrey[1]

[1]The University of Edinburgh 1.04 Alrick Building, King's Buildings, Edinburgh (UK) EH9 3JL

[2]Tecnalia Research and Innovation Parque Tecnológico, C/ Geldo, Edificio 700, E-48160 Derio, Bizkaia (Spain)

Corresponding author, owain.roberts@ed.ac.uk

The wave energy sector is currently in a prototyping stage. During this conceptual phase method are needed for identifying promising concepts which warrant further investigation. This paper focuses on the development of a model for assessing wave energy scenarios, combination of site, WEC and project specifications, on their commercial attractiveness. Quantitative evaluation is challenging due to the high degree of uncertainty at such an early development stage and the lack of design consensus within the sector. The methods presented here highlight some of the ways this uncertainty can be reduced even with high-level input parameters to the model.

AWTEC 2018-308

Numerical modelling and field measurements for wave resource characterization

Zhaoqing Yang*[1], Wei-Cheng Wu[1], Taiping Wang[1], Gabriel García-Medina[1], Levi Kilcher[2]

[1]Pacific Northwest National Laboratory 1100 Dexter Ave N, Ste 500, Seattle, WA 98006 USA

[2]National Renewable Energy Laboratory 15013 Denver West Parkway, Golden, CO 80401, USA

Corresponding author, zhaoqing.yang@pnnl.gov

Wave resource characterization is an essential step for Wave Energy Converter (WEC) development. The West Coast is one of the top regions in the U.S. with an energetic wave energy resource and great potential for early market development. This paper presents a study using a multi-scale modelling approach combined with shallow water wave measurements to improve the accuracy of wave resource characterization. The multi-scale wave modelling was conducted with a nested-grid WaveWatchIII (WW3) model from global to regional scales. The Unstructuredgrid Simulating Waves Nearshore (UnSWAN) model was used to provide accurate wave hindcast with a resolution of approximately 300 m, which meets the requirement recommended by IEC for wave resource assessment and characterization for the feasibility class. Extensive model validation for a period of 32 years was conducted using measured data from wave buoys maintained by National Data Buoy Center, as well as from three recently deployed nearshore buoys along the Oregon and California coasts. Inter-annual and seasonal variations of wave characteristics along the entire West Coast was analyzed. In addition, a sensitivity analysis was carried out to evaluate the quality of wind forcing on the accuracy of model prediction for large waves.

AWTEC 2018-309

Study of the effects of opening ratio of airflow control valve on the dual duct OWC chamber system

Kilwon Kim*, Jeongki Lee, Jongsu Choi

Korea Research Institute of Ships and Oceans Engineering, 32 Yuseong-daero 1312beon-gil yuseong-gu Daejeon, Korea.

Corresponding author, kimkilwon@kriso.re.kr

This paper deal with the investigation of the effects of opening ratio of airflow control valve for dual duct OWC chamber system. The system contains OWC chamber and dual duct. One duct is

used for installing the energy-converting device and other one is for control the flow rate using flow control valve. The performance of energy converting device can represented by the free surface elevation inside the chamber and bi-directional air velocity in the duct. The airflow control valve is use to control the air velocity against the difference proposed site incident wave conditions. The effects of opening ratio of control valve at the flow control duct have investigated using experimental methods. The wave elevation inside the chamber, the pressure difference and air velocities in the both of duct have measured to predict the pneumatic power of OWC system. A relationship between opening ratio of flow control valve and airflow rate has investigated in the dual duct OWC system.

AWTEC 2018-310

Monitoring different type of fish around tidal and oceanic current turbines in water tank

Takero Yoshida*[1], Jinxin Zhou[2], Sanggyu Park[2], Daisuke Kitazawa[1]

[1]Institute of Industrial Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8574, Japan

[2]Graduate School of Engineering, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8574, Japan

**Corresponding author, tyoshida@iis.u-tokyo.ac.jp*

Tidal and oceanic currents are promising marine renewable energy. However, there is a concern about potential effects on marine environment and organisms to install such kind of device in the ocean. In particular, collision with marine species and turbines is still unknown and this collision risk is a great concern among regulators and developers. If we attempt to install the device at a site where fishery is major industry, regulators and developers need to negotiate with local fishermen in advance, moreover they need to cautious it during operation. Therefore, several experiments were conducted in terms of collision risk. Taya [1] and Zhang et al. [6] carried out for an experiment with just one type of fish. Based on their research, another type of fish is examined in this research to show different behaviour around turbines.

AWTEC 2018-311

Optimization study on the downstream section of a radial inflow turbine

Nazanin Ansarifard*[1], Alan Fleming[1], Alan Henderson[2], S.S Kianejad[1], Shuhong Chai[1]

[1]Australian Maritime College, University of Tasmania, Maritime way, Newnham, TAS 7248, Australia.

[2]School of Engineering and ICT, University of Tasmania

**Corresponding author, nazanin.ansarifard@utas.edu.au*

The Oscillating Water Column (OWC) is a form of Wave Energy Converter (WEC) plant that is employed to harness the power of ocean waves. UniWave is a vented OWC type that extracts the pneumatic power solely from negative pressure drops in the chamber. Having a different flow profile compared to the conventional OWCs, there is a need for customizing a turbine design for the typical UniWave operation. The design modification of the downstream section in a radial inflow turbine has been considered for efficiency improvements. Being the linking element between the turbine and the chamber, this section has potential for significant impact on the turbine-chamber flow interaction. Four parameters are selected which mainly affect the shapes of the downstream guide vanes and the duct, and optimization methods are employed for efficiency maximization. Guide vane curvature, radius of the duct and use of a diffuser were shown to affect the efficiency and the downstream losses. An improved downstream section in a turbine-duct geometry can improve the turbine's peak efficiency by up to 14%, due to decreasing the pressure losses at the rotor downstream.

AWTEC 2018-313

Wake measurement metrics and the dependence of tidal turbine wakes on turbine operating condition

T. Ebdon*, D.M. O'Doherty , T. O'Doherty, A. Mason-Jones

School of Engineering, Cardiff University, Cardiff, United Kingdom

Corresponding author, ebdont@cardiff.ac.uk

Metrics are introduced for measuring the length and width of a turbine wake. These metrics are closely examined, and their relative advantages and disadvantages are discussed. Following this, a CFD study is carried out for a model-scale tidal turbine over a wide range of tip-speed ratios, and the performance and wake of the turbine is analysed. The study indicates that wake length is relatively unaffected by the turbine operating condition beyond the near wake, but that wake widths appear to be closely related to the turbine operating condition.

AWTEC 2018-314

Numerical simulation on hydrodynamic performance of parallel twin vertical axis tidal turbines

SUN Ke*[1], ZHOU Xue-han[1], ZHANG Liang[1], LI Yan[1], JIANG Jin[2]

[1]College of Shipbuilding Engineering, Harbin Engineering University, Harbin, China.

[2]School of Mechanical and Electrical Engineering, Jinling Institute of Technology, Nanjing, China.

Corresponding author, zhouxuehan@hrbeu.edu.cn

The single and parallel twin vertical axis hydro turbines were numerical simulated by open code-OpenFOAM, emphatically studied on the interference effect such as torque and load of turbine as well as hydrodynamic performance influenced by the distance and rotation forms between twin turbines and analyzed the wake flow field to show the velocity profile distribution. Results show that average power of parallel twin turbines is always higher than the power of a single turbine, the closer the lateral distance between turbines, the higher the power. At the same time, opposite outward rotation is the best arrangement form for twin turbines to get more power and counteract the lateral force.

AWTEC 2018-317

Array optimisation for wave damping and wave absorption

Clotilde Nové-Josserand, Ramiro Godoy-Diana, Benjamin Thiria

Laboratoire de Physique et Mécanique des Milieux Hétérogènes (PMMH), CNRS UMR 7636, ESPCI Paris, PSL Research University, Sorbonne Universités, 7 Quai Saint Bernard, 75005 Paris, France

Corresponding author, clotilde.nove-josserand@espci.fr

Considerable work has been undertaken for the improvement of Wave Energy Converters (WEC) and array design. The present work focuses on the local effects of wavestructure interactions within an array of oscillating absorbers in order to optimise energy absorption. We use a model system of flexible blades, subject to monochromatic waves and develop a simplified one-dimensional model in order to predict optimal configurations, depending on various parameters, which include the number of blades and spacing. Optimal configurations are found to converge towards both regular and irregular arrays, depending on array size and on the choice of local parameters. These optimal arrays are found to increase global forcing by up to 5% compared to regular arrays.

AWTEC 2018-318

Performance enhancement effort for vertical-axis tidal-current turbine in low water velocity

Dendy Satrio*, I Ketut Aria Pria Utama, Mukhtasor

Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Kampus ITS Sukolilo, Surabaya, Indonesia

**Corresponding author, dendy.satrio15@mhs.na.its.ac.id*

Tidal-current turbine which is vertical-axis type has been proposed by many researchers as a power generation with renewable energy resources. The main disadvantage of verticalaxis type is low performance compared with horizontal-type. This study focuses on how to enhance the performance by maintained lift capability with modified an original foil profile of NACA 63(4)021 to be a tubercle profile. The foil is simulated with Computational Fluid Dynamics software with some variations on angle of attack. Tubercle in leading-edge foil section can delay static stall angle and increase lift performance in high angle of attack. Since the vertical-axis turbine is rotated in 360^o that mean its angle of attack change continuously in each position of rotation then it will experience a dynamic stall. Therefore, vertical-axis turbine which the foil profile modified with tubercle become a good chance to increase the range operation of extracting energy in dynamic stall condition by maintain the lift performance in high angle of attack.

AWTEC 2018-320

Field performance testing of a floating tidal energy platform - Part 1: power performance

Ralf Starzmann, Inga Goebel, Penny Jeffcoate

SCHOTTEL Hydro GmbH, Spay, Germany.

**Corresponding author, rstarzmann@schottel.de*

SCHOTTEL HYDRO has developed the SCHOTTEL Instream Turbine (SIT). Four SITs had been mounted on Sustainable Marine Energy's floating surface platform PLAT-I, with a combined platform rated power of 280kW. The PLAT-I platform has been undergoing field performance testing in Scotland to determine the power performance of the individual turbines according to IEC62600- 200. Time series as well as processed performance data shows a high spatial variation of the inflow across the platform and hence a high dependency on the flow speed measurement location. The turbines power performance is found to be in line with design predictions, whereas the thrust loads measured are lower than the predictions.

AWTEC 2018-321

The development and testing of a lab-scale tidal stream turbine for the study of dynamic device loading

Matthew Allmark*[1], Robert Ellis[1], Kate Porte[2], Tim O'Doherty[1], Cameron Johnstone[2]

[1]School of Engineering, Cardiff University,The Parade Cardiff, Wales. CF24 3AA

[2]Department of Mechanical and Aerospace Engineering, University of Strathclyde, James Weir Building, Level 8, 75 Montrose Street, Glasgow, G1 1XJ.

**Corresponding author, allmarkmj1@cf.ac.uk*

The paper outlines the development and testing of a 0.9 m diameter lab-scale Horizontal Axis Tidal Turbine. The turbine was developed based on design experience acquired at Cardiff University during the development and testing of a number of legacy lab-scale Horizontal Axis Tidal Turbines. The development process was also considerate of design activities undertaken elsewhere within research. The development of the aforementioned Horizontal Axis Tidal Turbines was undertaken specifically to test under dynamic lab-scale conditions including both wave, turbulence and, ultimately, dynamic loadings caused by array interaction effects.

AWTEC 2018-323

Managing environmental effects to facilitate marine renewable energy development

Andrea Copping*[1], Mikaela Freeman[2], Alicia Gorton[3], Stacia Dreyer[4]

[1]Pacific Northwest National Laboratory 1100 Dexter Ave N, Suite 500, Seattle, WA USA School of Marine and Environmental Affairs, University of Washington, Seattle WA, USA

[2]Pacific Northwest National Laboratory 1100 Dexter Ave N, Suite 500, Seattle, WA USA

[3]Pacific Northwest National Laboratory Richland WA, USA

[4]School for the Future of Innovation in Society, Arizona State University, Tempe, AZ, USA

Corresponding author, andrea.copping@pnnl.gov

The marine renewable energy (MRE) industry is in the early stages of commercial development. In addition to the challenges of deploying and maintaining devices under harsh ocean conditions and transporting electricity to shore, concerns around potential environmental effects continue to slow permitting (consenting) processes. Regulators and stakeholders perceive a wide array of potential environmental interactions as risky and highly uncertain, and request that considerable baseline assessments and post-installation monitoring be carried out in order to permit or license a project. The MRE industry is struggling with the high cost of baseline assessments and post-installation monitoring, as well as extended timelines for obtaining permits, leading to uncertainty and risk for financing projects. As a means to mitigate this uncertainty and risk, regulators in the US have been engaged to ensure that they understand the underlying science that drives these challenges and to explore the feasibility of transferring learning and information from early MRE projects and analogous industry interactions to inform potential environmental effects and permitting for new MRE projects. The ability to use data and information from one project or location to another can aid the industry by reducing the high costs of environmental monitoring and accelerating permitting processes for future projects. This paper presents findings of a regulator survey and other engagements with regulators, provides insight into the process of data transferability, suggests a framework for data transferability and collection consistency, and details efforts to engage the research community in furthering this process.

AWTEC 2018-324

Effect of turbulence intensity on the performance characteristics of large-scale Wells turbine

P. Madhan Kumar*, Abdus Samad

Wave Energy and Fluids Engineering Laboratory, Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai 600036, India.

Corresponding author, madyypts@gmail.com

Wells turbine is a self-rectifying axial air turbine, which consists of symmetrical aerofoil at 90° stagger. It is used to extract power from the bidirectional airflow inside an oscillating water column. Generally, the performance of the turbomachines is affected by the turbulence intensity. In this numerical study, the effect of turbulence intensity on the performance of large-scale Wells turbine is investigated. Different values of turbulent intensities were applied at the inlet and their influence on the aerodynamic characteristics is analysed. A single blade with periodic boundary condition is taken as the computational domain for numerical analyses. The simulation results of the reference geometry were compared with existing experiment and numerical results. The performances of the Wells turbine with different turbulent intensities were computed by solving Reynolds-averaged Navier-Stokes (RANS) equations. Finally, the results were compared and analysed. It is found that the large-scale Wells turbine (LSWT) performance is unaffected by the varying inlet turbulence intensity. Furthermore, a marginal improvement in the performance was observed with an increase in turbulence intensity.

AWTEC 2018-325

A sea-state based investigation for performance of submerged tensioned mooring supported tidal turbines

Song Fu*, Cameron Johnstone

Energy Systems Research Unit, Department of Mechanical and Aerospace Engineering, University of Strathclyde, Glasgow, UK, G1 1XJ.

Corresponding author, song.fu@strath.ac.uk

This paper reports the performance of a tidal turbine station keeping system based on the adoption of a tensioned mooring system in different sea states. The capabilities of introducing damp are being investigated to reduce the peak loads that tidal turbine experienced during their operational life in high energy wave-current environments and extreme sea states. The loading on the turbine rotor blades and buoy are calculated using a wave and current coupled BEMT. The modeling algorithm developed is based on an inverted triple pendulum, responding to different sea state conditions to understand the system response behavior and the blades loading in different sea states, including the extreme conditions. The results show that the tensioned mooring system reduces peak thrust loading on the turbine, but it was found that there are certain limitation when using this design in extreme waves conditions.

AWTEC 2018-328

Effect of air compressibility on primary energy conversion performance of OWC device

Yukitaka Yasuzawa*[1], Takatomo Setoguchi[2]

[1]Department of Marine Systems Engineering, Kyushu University 744 Motooka, Nishi-ku, Fukuoka City, Fukuoka, Japan

[2]Department of Maritime Engineering, Graduate School, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka City, Fukuoka, Japan.

Corresponding author,yasuzawa@nams.kyushu-u.ac.jp

The authors have been developing a floating WEC (wave energy conversion) system with multiple cylindrical OWC columns. This structure has multiple OWC devices for electric power generation and buoyancy columns under the deck structure. In the present study, we have examined the scale effect of OWC device, focusing on the air compressibility of air chamber in OWC device, and have constructed mechanical modelling for the air chamber mechanics based on the theory of air damper with a nozzle. The relation between the water elevation motion and dynamic pressure in the air chamber is derived. We have applied it to our numerical program to estimate the primary energy conversion efficiency of OWC devices for various sizes. It is shown that the air compressibility has to be considered in case of realistic large size OWC device.

AWTEC 2018-330

Study on structural response of a floating structure for offshore wind power generation using a small-scale model experiment

Jumpei Oda*[1], Yoshikazu Tanaka[1], Hidetsugu Iwashita[1], Yukitaka Yasuzawa[2], Makoto Sueyoshi[3]

[1]Graduate School of Engineering, Hiroshima University 1-4-1 Kagamiyama, Higashi-Hiroshima City, Hiroshima, Japan

[2]Faculty of Engineering, Kyushu University 744 Motooka, Nishi-ku, Fukuoka, Japan

[3]Research Institute for Applied Mechanics, Kyushu University 6-1 Kasuga-koen, Kasuga, Fukuoka, Japan

Corresponding author, m175706@hiroshima-u.ac.jp

Increased use of renewable energy globally is required to decrease the use of fossil fuels and mitigate global warming. Japan has a vast exclusive economic zone and this area could be an energy source. Therefore, an offshore wind power generation has been attracting attention.

However, the water around Japan is deeper than it is around Europe, and the sea areas where a bottom-mounted offshore wind power facility can be installed are limited. Therefore, various floating offshore wind power facilities have been proposed. To realize a floating structure, it is necessary to evaluate its structural response to the external forces expected in the actual sea area and confirm its structural strength. Therefore, study of fluid force and structural response by analysis and experiment under actual size and condition is required. However, it is impractical to conduct experiments with a full-size structure at sea. Thus, a study using a small-scale model was used to study the fluid force and structural response. In this paper, we report the results of the structural response of a floating structure for offshore wind power generation based on the results of a small-scale model experiment.

AWTEC 2018-331

Performance prediction of impulse turbine for wave energy conversion - effect of simple cascade on the performance

Manabu Takao*[1], Seisuke Fukuma[1], Miah Md. Ashraful Alam[1], Yoichi Kinoue[2], Shuichi Nagata[2], Toshiaki Setoguchi[2]

[1]National Institute of Technology, Matsue College 14-4 Nishiikuma-cho, Matsue-shi, Shimane 690-8518, Japan

[2]Saga University 1 Honjo-machi, Saga-shi, Saga 840-8502, Japan

Corresponding author, takao@matsue-ct.jp

Wave energy can be converted into electrical energy by using a wave energy converter. The oscillating water column (OWC) based wave energy converter is one of the most useful device because of its simple structure and easy handling features. The water column in an air chamber oscillates in accordance with the surrounding ocean wave, and results in an alternating airflow inside the chamber. The airflow then rotates an air turbine connected to a generator. The authors have developed an impulse turbine that rotates to the perpendicular direction of alternating airflow. The turbine has two rows of guide vanes, and one rotor between them. The blade profile is formed by the combination of a circle and an ellipse. In the present study, a simple turbine cascade was employed as a purpose of reducing the manufacturing cost, and the performance of turbine with simple cascade was investigated using the computational fluid dynamics (CFD) analysis. Results are compared with the experimental data.

AWTEC 2018-335

Experimental investigation of a novel direct mechanical drive wave energy converter

Vishnu Vijayasankar*, Gundi Amarnath, S. A. Sannasiraj, Abdus Samad

Department of Ocean Engineering, Indian Institute of Technology Madras, Chennai 600036, India.

**Corresponding author, vishnuvijayasankar@gmail.com*

In the present work, a unique design using a direct mechanical drive based power takeoff system is proposed, designed, fabricated and tested for a point absorber. The power take-off mechanism in the design consists of rack and pinion arrangement, which converts the bidirectional reciprocating motion to unidirectional rotation. This mechanism is fixed on top of an oscillating buoy. The model is tested in a 4m wave flume to measure various parameters like Response Amplitude Operator of the buoy, capture width, electric power output and absorption efficiency for different wave height and periods. The model is also tested for friction outside the flume. The experiments revealed some promising results that can be taken forward for further investigations.

AWTEC 2018-336

Field performance testing of a floating tidal energy platform - Part 2: load performance

Penny Jeffcoate, Nick Cresswell*

Sustainable Marine Energy Ltd, Edinburgh, U.K.

*Corresponding author, nick.cresswell@sustainablemarine.com

Sustainable Marine Energy have developed a floating surface platform that hosts four SCHOTTEL Hydro Instream Turbines, with a combined platform rated power of 280kW. The PLAT-I platform has been undergoing Sea Acceptance Tests (SATs) in Scotland to determine performance across the range of operational modes. A numerical method for the evaluation of platform position limits and simulation results for mooring line loads are found to match well with SAT results, providing confidence for future platform deployments. The platform's loads and motions are found to be directly related to velocity and thus drag. Loads are strongly affected by mode of operation, with the platforms peak loadings and axial motion in the thrust-dominated operating regime. Maximum lateral motion occurs when in maintenance mode due to reduced side-damping. The platform performed well, and as expected, during the SATs and is due to be redeployed for the second phase of testing in 2018.

AWTEC 2018-339

First experimental results of a grid connected vertical axis marine current turbine using a multilevel power converter

Johan Forslund* and Karin Thomas

Division of Electricity, Department of Engineering Sciences, Uppsala University The Angstr ˚ om Laboratory, Uppsala, Sweden

*Corresponding author, johan.forslund@angstrom.uu.se

An experimental marine current power station has been deployed in Soderfors, Sweden. It comprises a vertical axis - turbine directly connected to a permanent magnet synchronous generator rated at 7.5 kW. The generator is controlled by a Back-To-Back 2L-3L Cascaded H-Bridge full scale bi-directional Power Converter located on shore. This paper presents the first test results of the power converter, including grid connection. The startup of the turbine, power extraction and initial active power injection to the grid, at 50% of rated power, operated as predicted by laboratory experiments and simulations. After 40 seconds of grid connection the safety system disconnect the grid converter due to high currents injected to the grid. The problem is mostly likely associated with the current controller in the dq0 frame. Further tuning of the PI regulators and the potential addition of an anti-windup could mitigate the control issue.

AWTEC 2018-340

Project Neptune: Critical component tests for a fully flooded direct-drive linear generator for wave energy convertors

Joseph Burchell*[1], Nisaar Ahmed[1], Jose Ignacio Barajas-Solano[1], Markus Mueller[1], Mike Galbraith[2]

[1]School of Engineering, Institute for Energy Systems, University of Edinburgh, Kings Buildings, Edinburgh, UK

[2]Fountain Design Limited Shildon, County Durham, UK

*Corresponding author, j.burchell@ed.ac.uk

A significant challenge for Wave Energy Convertor (WEC) designers and manufacturers is the efficient conversion of differing wave types into useful motion to produce electricity. The height, period and orientation of waves vary greatly as do their respective power levels [1]. In order to efficiently and cost effectively convert the kinetic energy of wave motion into electrical energy, a Power Take Off (PTO) system must be able to withstand the harsh environment of the offshore marine environment, provide efficient energy extraction over various wave load states whilst maintaining low O&M costs over a long life span [2].

AWTEC 2018-341

The effect of bathymetry interaction with waves and sea currents on the loading and thrust of a tidal turbine

Jose Manuel Rivera Camacho[1] , Cameron M. Johnstone[2], Stephanie E. Ordonez Sanchez[3]

ESRU, University of Strathclyde, 16 Richmond St. Glasgow G1 1XQ, Scotland. U.K.

**Corresponding author, jose.rivera-camacho@strath.ac.uk*

This paper reports work undertaken to advance analytical methods used to evaluate the influence of bathymetry on wave- current interactions with tidal turbines. The model takes in to account the wave transformation due to a sudden depth change in the sea level. The functions developed provide solutions for wave transformation by changes in bathymetry to find how this change effects the torque and thrust exerted over a tidal turbine. Costal site data for the west coast of the US, from the US DoE, has been used to access the robustness of these analytical methods. The high resolution data sets used have monitored wave, sea and climatic conditions over a period of 8 years.

AWTEC 2018-344

Drakoo - Energizing the future with ocean waves

Henry L. Han, Lex L. de Rijk*

Hann-Ocean Energy Pte. Ltd., 60 Paya Lebar Road, #04-36, Paya Lebar Square, Singapore 409051.

**Corresponding author, lex@hann-ocean.com*

The ocean provides an abundant source of renewable energy, including wave energy. Established in Singapore Hann-Ocean Energy has been developing its proprietary wave energy conversion technology “Drakoo” (“Dragon King of Ocean” or “Coolest” in Chinese) since 2008. The Drakoo has been tested successfully in full-scale in the Singaporean sea, in the National Renewable Energy Centre (UK) and Hann-Ocean’s large-scale wave flumes. The device allows for cost-effective electricity generation from all scales of waves. Having had its first commercial pilot project (16kWp) for Sembcorp Marine in August 2013 and followed by four more years further data collection and product development, the latest 15kWp Drakoo WEC module has been developed and tested extensively to produce affordable and clean electricity from as low as 0.3m sea waves, with a peak efficiency of 46% from waves to electricity. In this paper, the Drakoo development milestones are presented and the test results of the 15kWp Drakoo WEC module are discussed. Finally, the potential applications of Drakoo are illustrated.

AWTEC 2018-345

Floating tidal energy site assessment techniques for coastal and is-land communities

Penny Jeffcoate*[1], John McDowell[2], Michael Hook[1]

[1]Sustainable Marine Energy Ltd, Edinburgh, U.K.

[2]Industrial Doctorate Centre of Renewable Energy

**Corresponding author, penny.jeffcoate@sustainablemarine.com*

Sustainable Marine Energy and SCHOTTEL Hydro have developed a taut-moored mid-water column tidal energy platform, PLAT-O, and a semi-catenary moored floating surface platform, PLAT-I, that each host between two and four turbines. The combined platform rated power is up to 280kW. Each platform is suitable for different environmental conditions, with PLAT-I intended for low wave climates and PLAT-O for more extreme offshore conditions. This provides the basis for site selection criteria for each system. Site criteria include flow velocity, wave conditions, water depth and bathymetry, power requirements, and station keeping requirements. These have been designated into a Site Classification System for identifying sites suitable for each of SME’s platforms. Site assessment must be conducted to find these sites. Whilst in developed and more

easily accessible locations the equipment, vessels, and expertise used are readily available, in more remote areas and off-grid communities the traditional assessment techniques must be modified for the equipment available and for the cost associated with different survey methods. SME have developed a site assessment technique for their platform systems which is divided into four stages: Desktop Study, Visual Survey, Initial Survey, and Detailed Survey. Each stage increases complexity and cost. This allows sites to be discounted at early stages if unsuitable for further development before unnecessary money is spent. This system leads to a cost saving of up to 47% when assessing two sites using SME's method rather than two ADP surveys, and discounting one for inadequate velocity, as an example. The assessment technique, relevance to SME's tidal energy platforms, cost implications, and suggested modifications for applicability to other systems is presented.

AWTEC 2018-348

Numerically modelling the spatial distribution of weather windows: improving the site selection methodology for floating tidal platforms

John McDowell*[1,2], Penny Jeffcoate[2], Tom Bruce[1], Lars Johanning[1]

[1]Industrial Doctoral Centre for Offshore Renewable Energy

[2]Sustainable Marine Energy Ltd. La Belle Esperance, The Shore, Leith, Edinburgh, EH6 6QW.

**Corresponding author, john.mcdowell@sustainablemarine.com*

This paper examines the impact of MetOcean conditions on weather window availability and duration for tidal energy operations and maintenance. Understanding these impacts at the initial planning stage will give a better estimation of project lifetime costs, and ensure that these costs are factored into the site selection methodology. Several sources of freely available data were input into the Delft3D modelling suite to produce spatially and temporally varying estimates of MetOcean data for the Surigao area in the Philippines. This data was validated where possible, with the generated tidal heights and flow speeds seeing a good fit to adjacent tide gauge and acoustic data. A Dijkstra's Algorithm was applied to generate an optimum route to shore that accounted for depth restrictions. Weibull persistence statistics were successfully applied to the MetOcean characteristics at each point along this route, to calculate the probability of vessel limitations being exceeded. The number of probable access and waiting hours within a month, given a required weather window length and MetOcean threshold, was calculated. Flow is seen to be the most constraining, but also the most predictable MetOcean parameter and thus can be accounted for in operational planning. Wind is seen to impact little on transit but can be constraining for longer operations. Wave conditions are seen to constrain both transit and operations weather windows significantly under the limitations examined.

AWTEC 2018-350

Cross-stream active mooring for tidal stream power systems

Che-Chih Tsao*, Jia-Shi Lee, Yen-Yu Chen, Yu-Sheng Chen, Yi-Feng Hsu

Department of Power Mechanical Engineering, National Tsing Hua University 101 Kuang-fu Rd. Sec. 2, Hsinchu, Taiwan, Republic of China

**Corresponding author, cctsao@pme.nthu.edu.tw*

A new design for mooring tidal stream turbines is proposed and its feasibility is studied by analysis and scaled model tests. The design features mooring multiple turbines on a common tether with anchoring only at two ends. The whole array of turbines is in submerged floating with only two major lifting buoys partially above water surface. A new method to moor a single turbine on the common tether was devised and tested using models. The mooring system can prevent the single turbine from rolling and also allow bi-directional operation by a vertical flipping motion. An end clump system was also designed to work with the new turbine mooring method and the lifting buoys to maintain the turbines within desired depth range in varying operating flow speeds. Analysis in mechanics provided example designs and corresponding parameters. Scaled model

tests demonstrated the feasibility of the single turbine mooring method and the end clump depth maintaining approach.

AWTEC 2018-352

Effectively performing marine operations in strong current areas

D. Dhomé*, J.-C. Allo, M. Morandeau, C. Ramauge

[1]SABELLA SAS, 7 rue Félix Le Dantec, 29000 Quimper, France.

[2]Mojo Maritime France, 1 rue Du Guesclin, BP61905, 44019 Nantes Cedex 1, France.

**Corresponding author, d.dhome@sabella.bzh*

SABELLA's D10 marine current turbine was immersed in the Fromveur Passage in June 2015, becoming the first, and at present only, full scale marine current turbine to inject electricity into the grid in France. The initial installation was performed by lowering the whole tidal turbine at once, including the gravity-based foundation and its ballasts. This operation was carried out using a standard heavy lift vessel, without dynamic positioning, kept in position by her two anchors and three tugs. The installation was partially successful with the need for a new operation two months later for the connection of the turbine to her export cable. For the retrieval operation, only the turbine was retrieved, while the foundation remained on the seabed. This operation was carried out by MOJO MARITIME using an OCV vessel, with dynamic positioning (DP). This kind of vessel proved to be much more reliable and safer than the first installation vessel, and perfectly adapted to this kind of operation. Specific procedures and tools had to be developed for this operation, including an offshore berth and a "Launch And Recovery System". Another operation was performed by SABELLA and MOJO MARITIME in order to install a new connector at the end of the export cable, for which the vessel had to leep perfectly her position during more than 48 hours with the cable hanging on her side. This was made possible thanks to a good choice of vessel, a perfect planning and a good management onboard. These innovative methods bring cost reduction opportunities by enabling the use of smaller vessels with lower lifting capacities and result in shorter operating times through adapted tools and well-prepared procedures.

AWTEC 2018-353

Optimization of resistive load for a wave energy converter with linear generator power take off

Tatiana Potapenko*[1], Irina Temiz[1], Mats Leijon[1, 2]

[1]Department of Engineering Sciences, Uppsala University, SE-751 21, Uppsala, Sweden

[2]Department of Electrical Engineering, Chalmers University of Technology, 412 96 Gothenburg, Sweden

**Corresponding author, tatiana.potapenko88@gmail.com*

The concept of the wave energy converter, developed at Uppsala University is based on a linear generator. Direct power take-off mechanism is applied in the system. Optimization of wave energy converter by maximizing its average output power is carried out. In this paper, the passive control by a resistive load is applied in the model. The generator damping force is modelled using the equivalent electrical circuit representation of the generator with the resistive load connected. The resistive load of the outer circuit Rload is the optimized parameter. Matlab function pattern search is used in the optimization algorithm to obtain the optimal opt Rload for the maximum value of the average output power. The problem is solved for regular plane-parallel waves and the annual average power output is estimated for the wave climate at the Lysekil test site. Cummins equation and State Space Method are utilized to calculate the body motion in time domain.

AWTEC 2018-354

No evidence of long-term displacement of key wildlife species from wave and tidal energy testing

Caitlin Long*

The European Marine Energy Centre Ltd, Old Academy Business Centre, Stromness, Orkney Scotland

Corresponding author, caitlin.long@emec.org.uk

There is a regulatory need to understand the potential for marine renewable energy developments to significantly impact the marine environment and a site's integrity. To increase certainty, it is necessary to identify whether marine renewable energy devices have any impact on the abundance and distribution on wildlife in the vicinity. The European Marine Energy Centre (EMEC), in Orkney, Scotland, has completed an extensive wildlife observation programme to collect surface-visible wildlife observation data since the site's inception. Following the observation programme, an in-depth analysis has been undertaken to understand species displacement relative to the operational status of devices. The analysis has been completed on observational data from both EMEC's wave and tidal test sites. The data analysis utilised statistical package MRSea to quantify any spatially-explicit change attributable to marine renewable energy devices. The results from the analysis demonstrated a change in distribution and, in some cases, abundance with installation works, but typically the density recovered during the operational phase of the development. The study found little evidence to suggest that there are any long-term effects on seabirds or marine mammals associated with the installation and operation of marine renewable energy devices and it is anticipated that they will continue to use the waters around such devices when operational.

AWTEC 2018-357

Preliminary design of a horizontal axis tidal turbine for low-speed tidal flow

Job Immanuel Encarnacion*, Cameron Johnstone

Mechanical and Aerospace Engineering, University of Strathclyde Glasgow, United Kingdom

Corresponding author, job.encarnacion@strath.ac.uk

The renewable energy in the Philippines has a very low share in the country's power generation. It is then determined that the total potential of tidal in-stream energy in the Philippines is more than 80GW, which is more than enough to supply the 75GW target ORE capacity by 2025. However, the tidal flow around the country averages only at about 0.40-0.80m/s. This inhibits the development of tidal turbine technology since TSTs are currently very expensive and the low velocity flow will translate to very low energy captured per turbine. Thus, a preliminary blade design that is optimized for low velocity flow is implemented using computer simulations. Low velocity flow allows for the usage of high-tip speed ratio blades since cavitation is not a big issue; the linear speed of the blade is low even if the blade is operating at a high tip speed ratio. The NACA 63-8xx series blades are able to have maximum Cp values at higher tip speed ratios (TSR > 5.5). The study investigates the blades as they are made more slender to enable maximum output at even higher tip speed ratios (TSR = 7). The most slender blade is found to have a lower power output relative to the base case although the decrease is only at 3%. Thrust loads are also lower, however, the smaller cross-sectional area results in higher stresses. Nonetheless, static load simulation shows that the stresses are well below the allowable yield stress of a typical GFRP blade. This means that the slender blade may be considered in a low speed tidal flow condition and minimisation of cost due to lower loads and lower torque requirements for generators.

AWTEC 2018-359

PLAT-O #2 at FloWave: A tank-scale validation of ProteusDS at modelling the response of a tidal device to currents (Part 2)

Ilie Bivol*[1], Penny Jeffcoate[2], Lars Johanning[3], Ryan Nicoll[4], Jeffrey Steynor[5], Vengatesan Venugopal[6]

[1]IDCORE, University of Edinburgh, Scotland.

[2]Sustainable Marine Energy Ltd, Scotland

[3]University of Exeter, England

[4]Dynamic Systems Analysis, Canada

[5]FloWave Test Facility, Scotland

[6]University of Edinburgh, Scotland

Corresponding author, zhiyung.tay@singaporetech.edu.sg

PLAT-O #2 is a subsea floating tidal energy generator. A scaled-down physical model of this device was tested at FloWave in steady axial currents of up to 6.2 m/s (full-scale). The platform's motion and mooring tensions were measured to validate a tankscale numerical model in ProteusDS. In currents above 3.5 m/s (full-scale) the platform with turbines was observed to squat in an arc motion about the upstream lines to a stable lower depth, to balance the forces of drag, thrust, net buoyancy and lift. Hydrodynamic characteristics of the platform are derived from these experiments to aid the model calibration. A significant downward lift towards the bed is observed when the platform (with turbines) pitches bow-up to the flow. The downward lift acts to lower upstream line tensions but encourages the squatting motion. The platform's drag coefficient is observed to reduce with the tank flow, by up to 15% at 1.24 m/s (critical, $Re \approx 2\times10^5$) relative to the value at 0.40 m/s (sub-critical, $Re \approx 5\times10^4$). Representing the downward lift and the Reynolds-dependent drag in the numerical model resulted in accurate predictions of mooring tensions (< 5%) and motion (< 1 standard deviation). Further work includes: a wave-current validation, the flumetesting of the platform for more comprehensive lift and drag characteristics; the optimisation of the mooring geometry to control squatting, and CFD studies to predict lift in the sea.

AWTEC 2018-360

Tidal stream power development in San Bernardino Strait, Philippines

Blandine Battaglia*

SABELLA 7, rue Félix Le Dantec – 29000 Quimper - FRANCE

Corresponding author, b.battaglia@sabella.bzh

San Bernardino Strait is a passage located in the Eastern Visayas, Philippines, well-known for the strength of its marine currents. H&WB and SABELLA aim to develop the Philippines' and the ASEAN region's first commercial ocean power plant deploying tidal in-stream turbines, harnessing the energy of marine currents in San Bernardino Strait. The turbines will be connected to the electrical network of Capul, an off-grid island currently relying on a 750 kW diesel power plant. The first stage of the project consists in a 1.5 MW power plant featuring three SABELLA marine current turbine with a 20m rotor diameter, coupled with energy storage, as a reliable, sustainable and cost-competitive alternative to the fossil-based power generation. This pilot tidal power plant will be commissioned in 2021 for a 25-year operational lifetime.

AWTEC 2018-363

PRIMRE: A vision for a portal and repository for information on marine renewable energy

Frederick Driscoll[1], Andrea Copping[2], Kelley Ruehl[3], Jon Weers[1], Ann Dallman[3]

[1]National Renewable Energy Laboratory Golden, CO, USA

[2]Pacific Northwest National Laboratory Seattle, WA, USA

[3]Sandia National Laboratories Albuquerque, NM USA

Corresponding author, Frederick.driscoll@nrel.gov

The sharing of knowledge, experience, and lessons learned facilitates solving common problems and accelerating the development of the MRE industry. In order to increase the dissemination of such information, the US Department of Energy, through its national laboratories has engaged the international MRE community to understand online information needs. Six thematic needs were determined: outreach & communication, discoverability, data integrity, tools & codes, accessibility & security, and best practices & guidelines that lead to a vision for an online information system: PRIMRE (the Portal and Repository for Information on Marine Renewable Energy). PRIMRE is an online framework that will enable all MRE stakeholders to store, organize and access broad sets of information, data, and tools. The PRIMRE framework aims to be a centralized collection and dissemination point for MRE information, an access point to discover and access online tools, a place to discover existing knowledge, and an honest and neutral broker for the use of existing data.

AWTEC 2018-366

The design of semi-submersible wind-tidal combined power generation device

Chao Hu*[1], Yuhan He[2], Yong Ma[2], Binghao Zhou[2]

[1]College of Ship Engineering, Harbin Engineering University, Harbin, China

[2]College of Civil Engineering, University of Jinan, Jinan, China

Corresponding author, huchao@hrbeu.edu.cn

Energy shortage is becoming more and more severe worldwide, so does the environment pollution. Conventional fossil fuels is not sustainable and the storage capacity is decreasing faster than ever before. The exploitation and utilization of renewable energy has become an effective measure to deal with the present energy shortage situation. In order to improve the power production capacity, power output quality, income investment ratio, the comprehensive marine energy has become a new trend of marine renewable energy. At present, the research of offshore renewable energy power generation devices mainly focuses on tidal energy, wave energy and offshore wind energy. For the scale deployment of offshore renewable energy power generation device, safe and reliable platform is essential. The development of safe and reliable, cost effective platform is the basis of the whole industry. Furthermore, single renewable energy power generation device limits the development of the industry due to the poor stability and low income investment ratio. To solve the above problem, a new type of Wind-Flow combined power generation device was designed, including turbine and the wind turbine design. Then, an initial mooring system was designed according to the property of the device. The feasibility of mooring system design is verified by the timedomain calculation of the irregular wave by using AQWA DRIFT. The platform was verified according to CCS Classification of offshore mobile platforms. The static hydrostatic curve of the power plant was calculated by Maxsurf software, the maximum static heeling angle is equal to 30.9°. The stability of the platform was verified according to the IMOA.749 (18) -Ch3 standard. The maximum offset surge value of the power generation device is below 20m in the target sea area. The maximum tension of the mooring line in the complete survival condition is 1198kN, the safety factor is 3.08. The results Can provide reference for future research in this area.

AWTEC 2018-367

Assessment of the turbulent flow upstream of the Meygen Phase 1A tidal stream turbines

Daniel Coles*[1], Charles Greenwood[2], Arne Vogler[2], Tom Walsh[1], David Taaffe[1]

[1]Simec Atlantis Energy, 4th Floor, Quay 2, 139 Fountainbridge, Edinburgh, UK, EH3 9QG.

[2]University of the Highlands and Islands, Lews Castle College, Stornoway, Isle of Lewis, UK, HS2 0XR.

[3]Hebrides Marine Services Ltd, Fasgadh, Shawbost, Isle of Lewis, UK, HS2 9BD.

Corresponding author, daniel.coles@simecatlantis.com

New tidal flow measurements have been obtained upstream of the Meygen Phase 1A turbines from recent bed mounted acoustic doppler current profiler deployments. This paper presents a preliminary assessment of the flow speed and direction, streamwise turbulence intensity and wave climate at two of the turbine locations. Flow speeds and directions are strongly influenced by proximity to Stroma, which diverts the flow into the Inner Sound, resulting in higher speeds and available energy at the north of the site. Comparisons of the average flood and ebb flow directions at each of the turbine locations show differences of 10°. Streamwise turbulence intensities were found to be greatest during ebb tides at the two study locations. Initial results suggest that this is caused by both bed and wave generated turbulence. Large roughness features located to the east (ebb side) of the turbines are the likely cause of eddy shedding and increased shear in the outer flow. Wave measurements show that wave height and zero up crossing period were greatest during ebb tides when wave propagation opposes the flow direction. Preliminary power curve testing shows that the average coefficient of power of the Meygen Phase 1A turbines is 0.41, which exceeds their contractual requirement by 8%. Preliminary results indicate that the turbines are performing well in response to the different turbulent onset flows observed at the Meygen site.

AWTEC 2018-369

Study of vortex characteristics of a VATT wake based on CFD simulation

Zheng Yuan[1], Wei Qi Liu[2], Liang Zhang*[3]

College of Shipbuilding Engineering, Harbin Engineering University, Harbin, China.

Corresponding author, zhangliang@hrbeu.edu.cn

The performance and array layout of the tidal turbine are closely related to wake flow and wake vortex characteristics. In this paper, the flow field of a 2D vertical axis tide turbine (VATT) model is simulated with CFD. The numerical simulation shows that the wake of VATT can be divided into 3 regions with different vortex characteristics. Compared the wake vortex characteristics with the different inflow velocity, the number of blades and the tip speed ratio (TSR), respectively, it found that the wake is significantly affected by the TSR. At the low TSR, the apparent blade stall makes the vortex distribution of near wake field very disorganized; at the optimal TSR, the wake field is relatively stable; at the high TSR, the distribution of the tail vortex in the far field obviously similar to the Kármán vortex street. The change regulation between the circulation and the TSR is found by monitoring the circulation of the shed vortex. The formula of the vortex motion trajectory is fitted by tracing the shed vortex with the tracer particles released from the trailing edge.

AWTEC 2018-370

Parameter study of a low frequency two body wave energy converter

Xueyu Ji*[1], Elie Al Shami[1], Xu Wang[1], Lei Zuo[2]

[1]School of Engineering, Royal Melbourne Institute of Technology University, Melbourne, Victoria, Australia.

[2]Department of Mechanical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA.

*Corresponding author, xu.wang@rmit.edu.au

This paper studies a two-body wave energy converter which is a two-degrees-of-freedom oscillating point absorber. The two-body wave energy converter oscillating in heave with a floating body of variable geometry connected to a submerged body is designed for the Australian ocean wave conditions with excitation frequency ranging from 0.08 Hz to 0.12 Hz and wave height of 1 m. Taguchi method has been applied to investigate the system model parameters' influences on the average power output where the main input variable parameters are the power take-off stiffness and damping coefficients, submerged and floating body geometries, depth of the submerged body, floating body draft, diameter and geometry inclination angle. ANSYS AQWA is employed to obtain the hydrodynamic parameters in the regular wave conditions in order to calculate the output power. Both linear and non-linear dynamic models of the two-body wave energy converter will be analysed and simulated in both the time and frequency domains. The Power-take-off stiffness coefficient and submerged body geometry have been identified to be the most important parameters in influencing the average power output in the studied frequency range.

AWTEC 2018-371

A wave energy research centre in Albany, Australia

Christophe Gaudin*[1], Ryan Lowe[1], Scott Draper[1], Jeff Hansen[1], Hugh Wolgamot[1], Conleth O'Loughlin[1], Jonathan Fievez[2], Daniel Taylor[2], Alexandre Pichard[2]

[1]Oceans Graduate School, The University of Western Australia 35 Stirling Highway, Crawley WA 6009, Australia

[2]Carnegie Clean Energy 21 Barker Street, Belmont WA 6104, Australia

*Corresponding author, christophe.gaudin@uwa.edu.au

This paper presents some of the research currently undertaken by the newly established Wave Energy Research Centre at the University of Western Australia to support Carnegie Clean Energy in deploying a 1.5MW grid connected wave energy converter in Torbay, Albany, Western Australia. This includes the modelling of the wave resources in Torbay, wave tank testing and hydrodynamic modelling to characterise and predict the motion of the wave energy converter and some aspects of geotechnical engineering to optimise the foundations of the device.

AWTEC 2018-372

Observation of biofouling by using test plates in Hirado Strait of Nagasaki, Japan

Yusaku Kyozuka*[1], Seiji Kobayash[i2]

[1]Organization for Marine Science and Technology, Nagasaki University 1-14 Bunkyo-Machi, Nagasaki 852-8521, Japan

[2]Fukushima Branch, Japan NUS Co., Ltd. Sahei Building 8F-C, 1-29 Okitama-Cho Fukushima 960-8034, Japan

*Corresponding author, kyozuka@nagasaki-u.ac.jp

Relating the cost of the tidal power generation, the bio-fouling effects on the tidal turbine may be important since it is relevant to the maintenance cost of the power device for a long time. Field measurement results of the bio-fouling effects on test plates at the Hirado-Seto Strait in Nagasaki Prefecture are reported. Test plates include 5 plates without paint and a plate with silicon paint and 4 plates with anti-fouling offshore structure and ship bottom paints. The experimental frame with the test plates are hung from the breakwater into the sea and are raised from the sea every month regularly to observe the biofouling by taking pictures and measuring the weight of the plates. It is clarified that the dominant species around the adjacent sea are the triangle- and red-barnacles which do not newly attach if seawater temperature becomes below 20 degree in centigrade, but it continues to grow even in winter if it once attached. Observation is still running since September 2013 and the results for more than 3 years are presented.

AWTEC 2018-373

Dynamic model testing of a combined C-Gen magnetic gear system for an oscillating wave surge converter

Richard Crozier, Ben McGilton*, Markus Mueller

Institute for Energy Systems, University of Edinburgh, Scotland, United Kingdom

**Corresponding author, ben.mcgilton@ed.ac.uk*

The high operation and maintenance (O&M) costs of wave energy converters are a large impediment to the technology's development. Magnetic gears present a promising development in this area as, operating through contactless torque transfer, suffer considerably less wear than mechanical alternatives. This paper presents the results of a dynamic analysis of a magnetically geared power take off system that has been designed for use with an oscillating wave surge converter. The results provide a deeper understanding of the behaviour of a magnetically geared system in normal and extreme operation. Particular focus is given to the self-correcting behaviour of the system when rotor slip occurs.

AWTEC 2018-374

Using structured innovation techniques to assess and develop potential technology for wave energy power conversion

Anna Stegman*[1], Henry Jeffrey[2], Lars Johanning[3], Stuart Bradley[4]

[1]IDCORE, Energy Technologies Institute, Loughborough, UKanna.stegman@eti.co.uk

[2]Institute of Energy Systems, University of Edinburgh, Scotland, UK

[3]College of Engineering, Mathematics and Physical Sciences, University of Exeter, Penryn, UK

[4]Energy Systems Catapult, Derby, UK

**Corresponding author, anna.stegman@eti.co.uk*

This paper proposes a method that could be of use to developers when considering designs improvements, or to investors considering a range of opportunities. The methodology shows how improvements to designs can be developed using systematic problem solving tools and the Theory of Inventive Thinking (TRIZ). The methodology is demonstrated in this study, using high level functional requirements for a wave energy converter, and a range of commonly used design metrics. The simple example uses baseline data from published developers, and results are calculated, using Monte Carlo analysis, to show potential scenarios that would offer an overall improvement. In this case, the mass, level of control, and load variation are shown to be the parameters with the greatest impact on the overall design score, and are used as initial examples to apply the TRIZ tools.

AWTEC 2018-375

Numerical study on the behavior of an oscillating wave surge converter

Huifeng Yu*, Yongliang Zhang

Department of Hydraulic Engineering, State Key Laboratory for Hydroscience and Engineering, Tsinghua University, Beijing 100084, China

**Corresponding author, yuhuifeng09@foxmail.com*

A mathematical model is presented for the performance of an oscillating wave surge converter with a linear electric generator. The model is based on the equivalent electric circuit theory. Equations of pitch motion for the oscillating wave surge converter and a conversion relation between hydrodynamic parameters and their electrical equivalents are employed and a series electric circuit as an adjustable load of the generator is introduced, which give rise to coupled second-order ordinary differential equations governing electric current and voltage drop. The performance of the oscillating wave surge converter is investigated under three load and restriction conditions. The effects of wave frequency on capture width ratio, rotation angle complex amplitude

modulus, average absorbed power and electric current phase are examined and the great benefits of a control system are demonstrated. The working process and working principle of the control system and the effect of maximum rotation angle are investigated.

AWTEC 2018-379

Hydrodynamic performance analysis of the turbine of 2×100kW tidal current energy generation device based on tidal bladed software

Zhichuan Li*, Ting Yu , Yonghu Wu , Juan Yue

New Energy Research Center, CNOOC Research Institute Ltd. Block B(306), CNOOC Plaza, No.6, Taiyanggong South Str.,Beijing 100028, China

Corresponding author, lizhichuan77@163.com

500kW Ocean Energy Isolated Power System demonstration project is the first batch of project, which funded by the National Marine Renewable Energy Special Fund. The 2×100kW tidal current energy generation device is an important part of the demonstration project. The hydrodynamic performance analysis of tidal current turbine is the most critical basic work in the design of turbine, and it is the foundation for subsequent design and analysis of tidal current energy generation device design. Based on the Tidal Bladed software, the calculation model hydrodynamic performance of the turbine of 2×100kW tidal current energy generation device was established in this paper. The efficiency curve and load of turbine have been calculated under steady flow velocity, and the influence of tower shadow and turbulence intensity on the hydrodynamic performance of the turbine have been studied. Keywords—Tidal current energy turbine, hydrodynamic performance, Tidal Bladed, tower shadow, turbulence intensity.

AWTEC 2018-380

Initial design of OWC WEC applicable to breakwater in remote islands

Kyong-Hwan Kim*, Bowoo Nam, Sewan Park, Jeong-Seok Kim, Gilwon Kim, Chang-Hyuck Lim, Keyyong Hong

Marine Renewable Energy Research Department, 32 Yuseong-daero 1312 beon-gil, Yuseong-gu, Daejeon, KOREA.

Corresponding author, kkim@kriso.re.kr

It is not easy to install a power generation system with renewable energy in the island such as wind power or solar power generation system because the space of the island area where the grid connection is difficult is limited. However, the island has a large ocean space, so it is easy to apply wave energy converter(WEC). Particularly, there is a breakwater in the island and it is economically advantageous to apply WEC to the breakwater. This study considers the basic design of an oscillating water column(OWC) and an impulse turbine of a small WEC system applicable to a breakwater in the island where the grid is not connected. Considering the connectivity of the breakwaters and the operability in the island area, an oscillating water column with a sloping shape is adopted. The basic design is carried out through potential flow analysis, CFD analysis, and model tests. The impulse turbine is adopted, which has been applied recently, and the basic design is evaluated through sensitivity analysis on design parameters. Based on these, a method for the basic design of a small OWC wave energy converter(WEC) applicable to breakwater is proposed and discuss what is important in the design of a small OWC wave energy converter.

AWTEC 2018-381

Blade element momentum theory to predict the effect of wave-current interactions on the performance of tidal stream turbines

Stephanie Ordonez-Sanchez*[1], Kate Porter[1], Matthew Allmark[2], Cameron Johnstone[1], Tim O'Doherty[2]

[1]Energy Systems Research Unit, University of Strathclyde, Glasgow, G1 1XJ, United Kingdom.

[2]School of Engineering, Cardiff University, Cardiff CF24 3AA, United Kingdom.

Corresponding author, s.ordonez@strath.ac.uk

The durability and reliability of tidal energy systems can be compromised by the harsh environments that the tidal stream turbines need to withstand. These loadings will increase substantially if the turbines are deployed in exposed sites where high magnitude waves will affect the turbine in combination with fast tidal currents. The loadings affecting the turbines can be modelled using various numerical or analytical methods; each of them have their own advantages and disadvantages. To understand the limitations arising with the use of numerical solutions, the outcomes can be verified with practical work. In this paper, a Blade Element Momentum coupled with wave solutions is used to predict the performance of a scaled turbine in a flume and a tow tank. The analytical and experimental work is analysed for combinations of flow speeds of 0.5 and 1.0 m/s, wave heights of 0.2 and 0.4 and wave periods of 1.5 and 1.7 s. It was found that good agreement between the model and the experimental work was observed when comparing the data sets at high flow conditions. However, even if the average values were similar, the model tend to under predict the maximum and minimum values obtained in the experiments. When looking at the results of low flow velocities, the agreement between the average and time series was poorer.

AWTEC 2018-382

Effect of mooring line materials on FKT system dynamics

Jo-Ti Wu*[1], Jiahn-Horng Chen[1], Ching-Yeh Hsin[1], Forng-Chen Chiu[2]

[1]Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University 2 Pei-Ning Road, Keelung 202, Taiwan

[2]Department of Engineering Science and Ocean Engineering, National Taiwan University 1 Roosevelt Road Sec. 4, Taipei 104, Taiwan

Corresponding author, rortyaa@gmail.com

In Taiwan, a floating Kuroshio turbine (FKT) system is under development by the joint research team of National Taiwan University and National Taiwan Ocean University. One of the issues which need be studied is its dynamics moored in deep sea. To understand the effects of mooring line materials on the system dynamics, we studied computationally the dynamic behaviors of the FKT moored with flexible ropes, chains, and 6x19 wire with wire core. In this study, we integrated several commercial and in-house packages. The system buoyancy and weight and their centres were estimated using the Rhino software. The system hydrodynamic coefficients were obtained through WAMIT, system drag coefficient through FLUENT, turbine propulsive force through lifting surface code, and system dynamics through OrcaFlex. We investigated the dynamic responses of the FKT system under waves with single frequency and random waves with different typical spectra.

AWTEC 2018-384

Structural safety evaluation for the driving part of 15kW-class HATCT model by FSI analysis

Ming Guo[1], Seung-Jun Kim[1], Young-Do Choi[2]

[1]Graduate School, Department of Mechanical Engineering, Mokpo National University, 1666 Youngsan-Ro, Cheonggye-Myeon, Muan-gun, Jeonnam, 58554, Republic of Korea.

[2]Department of Mechanical Engineering, Mokpo National University, 1666 Youngsan-Ro, Cheonggye-Myeon, Muan-gun, Jeonnam, 58554, Republic of Korea.

Corresponding author, guominglab@163.com

For the design of tidal current turbine, there are hydrodynamic design and structural design, which should be considered. The design methods must be satisfied with the performance and structural safety for its feasibility. Most of the tidal current turbine requires hydrodynamic design in

order to improve the efficiency and performance. It is necessary to have a clear understanding of the characteristics of the blade adjacent flow field. The casing and shaft of tidal current turbine driving part, which is affected from flow field, needs to be designed and evaluated for structure safety to withstand all the harsh conditions of the sea. In this study, driving part of tidal current turbine was investigated by evaluating structural safety with analysis of one-way fluid structure interaction (FSI) analysis. The fluid structure interaction analysis of driving part was conducted for different shapes of driving part with same 15kW-class tidal current turbine blade. For conducting reliable evaluation of structural safety, the surface load (pressure) of the tidal current turbine driving part is obtained from CFD analysis for initial condition of FSI analysis.

AWTEC 2018-385

Creating regulatory certainty: A pathway to success in Nova Scotia, Canada

Sandra Farwell*

Nova Scotia Department of Energy, 1690 Hollis Street, 12th Floor, Halifax, Nova Scotia, Canada.

**Corresponding author, Sandra.Farwell@novascotia.ca*

Nova Scotia, Canada is home to one of the largest and most accessible tidal energy resources globally in the Bay of Fundy. Nova Scotia has been focused on the development and success of this tidal resource for over a decade. Harnessing this resource and creating a new industry requires dedication and commitment to the industry. The government of Nova Scotia remains committed to developing the tidal industry and being an international leader by creating a regulatory pathway for this industry in Nova Scotia.

In Nova Scotia, the ocean is our competitive advantage and we envision making the most of this advantage. Nova Scotia is home to the highest number of ocean technology companies in North America. We have over 400 PhD’s in ocean related disciplines, equating to over 251 high qualified persons (HQP’s) for the tidal industry alone. Our local academic institutions are collaborating with others across Atlantic Canada through the Ocean Frontier Institute, and Acadia’s Tidal Energy Institute. The Centre for Ocean Ventures and Entrepreneurship (COVE) will offer a unique innovation centre for ocean industries and academics. Our industry leaders are currently developing an ocean supercluster to accelerate the growth of our ocean technology, companies, and expertise for the economic growth and benefit of Nova Scotia with potential funding awarded from the Canadian government. In Nova Scotia, we are doubling down on our strengths and securing our place as leaders in ocean technology and innovation. Marine renewable energy is an important part of our ocean advantage.

In 2012, the Province introduced its Marine Renewable Energy Strategy, which outlines a high-level plan to continue research, development, and regulatory efforts to get the most out of this resource. Specifically, the Strategy articulates a phased and adaptive approach to reaching commercialization of the marine renewable energy sector. Nova Scotia, along with federal and private sector investments have developed the Fundy Ocean Research Centre for Energy (‘FORCE’) — Canada’s leading test centre for in-stream tidal energy— where 5 berth holders are able to demonstrate technology and answer challenges of an emerging industry. Nova Scotia has also awarded three Community Feed-in-tariffs for small-scale community development of tidal technology.

Nova Scotia is now preparing for the next phase of marine renewable energy for up to 50 MW within the Bay of Fundy over the next five years. The Province has recently amended and passed its Marine Renewable-energy Act. This sectorspecific legislation was developed in advance of commercialscale deployments to ensure the safe, sustainable, and responsible growth of the industry that both respects and benefits Nova Scotians. Recent amendments to the Act include a demonstration permit. The permits will allow projects up to five megawatts in size, and give companies the ability to sell the electricity they generate. A total of 10 megawatts will be available through this permit and developers will be provided with a guaranteed power purchase agreement for 15 years. This will make it easier for developers to assess innovative, lower-cost tidal energy technologies and bring them to market faster. Our work is laying a road for success developing the technology to produce environmentally sustainable and competitively-priced electricity from the ocean.

The next phase of marine renewable energy development will focus on achieving the goals in our Strategy, and building upon them. These goals include reducing the cost of energy to ensure tidal is competitive with other sources of renewable energy, continue to collaborate and build partnerships, supply chain capacity development, public education, research and continuing to seek and provide funding and investment opportunities. This presentation outlines the process the Province of Nova Scotia and its partners have undergone to support the development of the tidal industry and create regulatory certainty for the growing in-stream tidal energy industry.

AWTEC 2018-386

Hydrodynamic performance of a towed floating Kuroshio current turbine

Jing-Fa Tsai*, Yi-Hsiang Liao, Forng-Chen Chiu

Department of Engineering Science and Ocean Engineering, National Taiwan University No. 1, Sec.4, Roosevelt Road, Taipei, Taiwan

**Corresponding author, jftsai@ntu.edu.tw*

A 20 kW floating current turbine prototype was designed for operation in the Kuroshio Current, which passes along the eastern coast of Taiwan. The location and speed of the Kuroshio Current are generally consistent, which offers Taiwan a stable and secure energy source. A test apparatus, including a 1/5 scale model of the proposed turbine with a direct drive permanent magnet generator, was used to measure the rotation, torque and thrust. The test was conducted in a towing tank at four loads of 728, 364, 242, and 182 ohm. The tension force of the towing rope was measured using a tension meter. The pitch and roll angles of the floating current turbine were measured with angle meters. The power coefficient, torque coefficient, thrust coefficient and total efficiency were calculated from the measured data. The measured power coefficient and torque coefficient agreed with the calculated results. However, the measured thrust coefficient was higher than the calculated values. The hydrodynamic efficiency of the turbine was approximately 0.45, which meets the design requirements.

AWTEC 2018-388

An energy harvester for Kuroshio power

Shang-Yu Tsai, Bang-Fuh Chen*

Department of Marine Environment and Engineering, National Sun Yat-Sen University, Taiwan

**Corresponding author, chenbf5065@gmail.com*

In the response of the increasing energy demand and the global trend in renewable energy development, Kuroshio energy harvesting becomes an important issue of Taiwan. In this study, the feasibility of nozzle-diffuser duct as a Kuroshio energy harvester is investigated. The computation fluid dynamics (CFD) software ANSYS-Fluent was used to calculate the drag and added mass of the duct. The simulation of single duct anchored on the seabed under normal and storm waves was established by Orcaflex. Under normal wave condition, the high Power Take Off (PTO) was assured when the duct siting near free surface location. However, the duct must be sink to deeper location (100 m below sea surface) to avoid the assaulting of Typhoon wave action. The PTO of the proposed nozzle-diffuser duct is 15 kW if the Kuroshio speed is 1.0 m / s. To implement a Mega PTO system, 66 ducts are needed and a suitable platform is needed to carry as many ducts as possible.

AWTEC 2018-389

Design of hydraulic power take-off for wave energy converter on artificial breakwater

Xu Jianan*, Xu Tao

College of mechanical & electrical engineering, Harbin Engineering University, Harbin, China

**Corresponding author, xujianan@hrbeu.edu.cn*

With the increasing use of the present social resources, fossil energy resource is at risk. So it's imperative to tap the renewable resource. The ocean resource is a kind of reproducible green resource. Oscillating-buoy becomes a main kind of wave energy converter (WEC) which could extract wave energy from its oscillating motion. In this paper，a hydraulic power take-off device for oscillating buoy wave energy converter on artificial breakwater is designed, the hydrodynamic analysis of the oscillating-buoy is performed with ANSYS-AQWA, including added mass and radiation damping coefficient. The mathematical model of linear PTO is established and simulated with SIMULINK to get the power generating ability of the oscillating-buoy with the linear PTO. In addition, a hydraulic PTO system is designed and the its dynamics is simulated with AMESim. Finally, the control strategy of constrained motion of PTO is proposed to ensure safe operation under high sea states.

AWTEC 2018-390

Effect of chord-wise flexibility to the power extracting efficiency of tidal current energy

Xu Jianan*, Guan Daitao, Zhu Haiyang

College of mechanical & electrical engineering, Harbin Engineering University, Harbin, China.

**Corresponding author, xujianan@hrbeu.edu.cn*

Based on the bionics principle, this paper studies the influence of chord-wise flexibility on the energy extraction efficiency of the oscillating wing in turbulent environment. The energy acquisition performance of flexible oscillating hydrofoils with chord-wise deformation and rigid oscillating hydrofoils are numerically calculated by using computational fluid dynamics software Fluent. The power of hydrofoil with different flexibility coefficient and maximum offset at trailing edge under different conversion frequencies are compared. The differences between the rigid wing and the flexible wing are analysed from the lift coefficient, momentum coefficient, energy extraction efficiency, streamline and hydrofoil surface pressure composite diagram. The results show that the flexible hydrofoil can change the direction of partial streamlines, increase the hydrofoil surface pressure difference and enhance the instantaneous lift force in a single period, thus improving the energy efficiency of the hydrofoil.

AWTEC 2018-391

The numerical analysis of a vertical axis turbine for current energy conversion

Min-Hsiung Yang*, Zih-Duan Ciou, Syue-Sinn Leu, Jun-Lum Cai, Wei-Ren Chau

Department of Naval Architecture and Ocean Engineering, National Kaohsiung Marine University

**Corresponding author, mhyang@webmail.nkmu.edu.tw*

The ocean current energy is plentiful on the coastline of Taiwan. The conversion effect of a current turbine is the important issue in application. The purpose of this study is to analyze the performance of a vertical axis turbine consisting of deflectable blades applied in ocean current energy conversion. The detailed flow field analyses and the characteristics of the turbine are investigated numerically. Finally, the performance and optimal prediction of the turbine are obtained. The variable blades could increase the torque and decrease the resistance of the vertical axis turbine. The commercial code ANSYS-Fluent CFD is employed to simulate and calculate the performance of the novel vertical axis turbine. The results of the velocity contours of calculation domain are reported. Furthermore, the torque and power coefficient of the vertical axis turbine at various rotation angle are obtained. The maximum power coefficient and the corresponding optimal tip speed ratio are also reported numerically.

AWTEC 2018-392

Equivalent circuit for mechanical-motion-rectifier based power take-off in wave energy harvesting

Chien-An Chen*[1], Xiaofan Li[2], Lei Zuo[2], Khai Ngo[1]

[1]Department of Electrical and Computer Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, United States.

[2]Department of Mechanical Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, United States.

Corresponding author, cacee14@vt.edu

While a new type of power take-off (PTO) based on mechanical-motion-rectifier has been developed, its dynamic model is over simplified and cannot properly predict its nonlinear system characteristics. There is a need to develop a high fidelity PTO model to predict the system dynamics. An equivalent circuit would be a convenient tool to model the system behaviour and can easily apply to a circuit-based wave-to-wire (W2W) model. In this paper, a methodology for deriving a circuit-based high-fidelity model through the PTO design is introduced following by the extraction of the parameters through experimental results. Finally, the PTO circuit model is validated by the bench test results under the time domain.

AWTEC 2018-393

Arrangement optimization of three tidal turbines considering efficiency and productivity

Chul-hee Jo[1], Hong-jae Park[1], Johnny C. L. Chan[2], Su-jin Hwang*[1]

[1]Department of Naval Architecture and Ocean Engineering, Inha University 100 Inha-ro, Nam-gu, Incheon, Korea.

[2]School of Energy and Environment, City University of Hong Kong, Hong Kong, China, 83 Tat Chee Ave, Kowloon Tong, Hong Kong, China.

Corresponding author, sjhwang@inha.edu

Tidal current power is one of the promising renewable energy resources with high energy density, reliable energy supply and predictability of energy production. Recently many countries, especially the U.K., announced and launched a number of tidal farm projects. For these projects to be successfully developed, each project should maximize its efficiency and productivity. The optimization of the tidal turbine arrangement is one of the key issues to maximize the economic feasibility of tidal farms. This study introduces the diagonal arrangement of three tidal turbines and investigates the performance of these tidal turbines in various arrangements using 3D CFD (Computational Fluid Dynamics) analysis. A tidal turbine of which maximum power coefficient is 47.5% was used to simulate the diagonal arrangement of three turbines. The results show that the diagonal arrangement increases the rear turbine efficiency by 3% and decreases the front turbine efficiency by 0.5%.

AWTEC 2018-394

Tidal currents characterization with large eddy simulation

Adrien Bourgoin*[1], Sylvain Guillou[1], Riadh Ata[2], Jérôme Thiébot[1], Sofiane Benhamadouche[2]

[1]Normandie Universite, UNICAEN LUSAC, EA 4253, 60 rue Max Pol Fouchet, CS 20082, 50130 Cherbourg-en-Cotentin, France

[2]LNHE/MFEE, EDF R&D, 6 quai Watier, 78400 Chatou, France.

Corresponding author, adrien.bourgoin@unicaen.fr

The hydrodynamics of tidal energy sites is generally characterized by rough seabed, as shown in Figure 1. Such configuration favours the formation of powerful turbulent flow structures that strongly affect both the performance, and the lifespan of the turbine installations. To optimize the placement of the turbines, the effect of turbulent flows has to be understood, thus requiring a

detailed description of the physical processes of turbulence. As part of the THYMOTE project, a Large-Eddy-Simulation (LES) approach is being developed which aims at computing the unsteady aspect of turbulent flows. LES approaches dedicated to environmental free surface flows are nowadays gaining popularity thank to the increasing power of supercomputers. This paper presents the implementation of a LES approach into the TELEMAC-3D solver, a hydrodynamic free surface flow model included in the open TELEMACMASCARET suite of numerical solvers. The TELEMAC-3D model [1] originally includes a Reynolds Averaged Navier-Stokes (RANS) solver dedicated to the simulation of environmental flows. The implementation of the LES method in TELEMAC-3D consists of adding turbulence models [2] to mimic the effect of smallest motion scales as well as including suitable schemes to reduce numerical dissipation. The implementation of the LES approach to TELEMAC-3D is validated using experimental measurements of a flow above dunes [3]. Future applications of the LES approach will deal with the characterization of currents at the tidal energy site named Raz Blanchard (which is also referred as Alderney Race). We expect that the LES will enable more accurate representation of the real world turbulent phenomena, including inherent turbulence and complex processes of vortex shedding.

AWTEC 2018-395

Numerical modelling of the Laminaria concept with coupled mooring and PTO system

Rémy CR Pascal*[1], Benjamin Gendron[2], Adrien Combourieu[2]

[1]INNOSEA Ltd, ETTC, Alrick Building, Max Born Crescent, Edinburgh – UK

[2]INNOSEA, 1 rue de la No, 44321 Nantes Cedex 03, France

**Corresponding author, remy.pascal@innosea.fr*

Within the LAMWEC project, INNOSEA has been responsible for the tank test of the Laminaria WEC. This WEC concept solves the compromise between security and performance by introducing a dual load management system. The average loads are controlled by gradually lowering the device in the water column for increasing HS. In addition, a PTO overdrive limits extreme loads. The dual load management system allows nearly constant loads and power production irrespective of HS. The objectives of the 1: 16th scale tests in the COAST lab were to prove the dual load management system and to characterize the mooring loads in representative sea conditions. Laminaria provided the model. INNOSEA designed the test plan, analysed the data and produced the final report. The loads' histograms show that the PTO overdrive concept can effectively limit extreme loads. Indeed, the histograms of the tests which activated the PTO overdrive are distorted compared to the typical expectations, showing a limited tail and a bulge of occurrences close to the PTO overdrive threshold. The analysis of the statistical distributions parameters fitted to the mooring load histograms shows that gradually submerging the device is an effective way to manage the average loads.

AWTEC 2018-396

Shallow and intermediate water wave energy converter

Ramuel T. Maramara, Masoud Masoumi*

Brimes Energy Inc 1347 Lincoln Ave #9, Holbrook, NY 11741.

**Corresponding author, mmasoumi@brimesenergy.com*

This paper represents both an analytical formulation and a series of experimental testings for a flap-type seabed-mounted WEC. The analytical modeling provides an insight into the parameters affecting the design and optimization for the maximum power output. Experimental testings in the wave flume are designed to study the effects of damping due to the PTO mechanism on both power output and efficiency of the device.

AWTEC 2018-399

Prediction of the stability of a floating tidal turbine platform under towing conditions

Martin Koh*, Alex Ng

OceanPixel Pte Ltd, Cleantech Loop, #02-16 Cleantech One Singapore 637141

Corresponding author, martinkoh@oceanpixel.org

Floating tidal turbine systems are seen as being preferred to fixed bottom and mid-column systems due to cheaper deployment and maintenance costs. As such, the stability of the floating system under varying flow and surface conditions is as important as the performance of the tidal turbine. The stability of a floating tidal turbine system at various velocities in a tow test was predicted using ProteusDS, and compared against the physical tow test results of the same floating tidal turbine system. The model was calibrated against the static case of the floating tidal turbine system floating in water, and was found to work well with the other cases. The position of the centre of gravity of the platform and the position of the turbine was found to affect the platform stability, with the centre of gravity having a larger influence. The model was also tested under different wave conditions, and an operating envelope was developed. The ability to perform quick and accurate predictions of the stability of the floating tidal turbine system would allow technology developers to optimise the design to fit the site conditions easily, thus saving time and cost.

AWTEC 2018-400

Mooring system design for an underwater floating tidal current power device

Chul-Hee Jo, Su-Jin Hwang, Hong-Jae Park*

Department of Naval Architecture and Ocean Engineering, Inha University Incheon, S. Korea

Corresponding author, hj920110@inha.edu

Support structures for tidal current power (TCP) generators can be divided into self-weight embedment, fixed-pile, and mooring types. Mooring-type TCP systems use buoyancy and mooring lines to stay afloat. Mooring-type support structures can be installed in any depth of water, so the installation process is simple, and costs can be significantly reduced. However, compared to other types of support structures, the motion of mooring structures is relatively large and requires an optimal system design to maximize power generation and secure dynamic motion stability. In this study, an optimal design is suggested for the mooring system of a floating TCP system using OrcaFlex 10.1a, a time-domain analysis program. The mooring system was developed by considering the sea environment and meets the design criteria for a wave energy converter (WEC) and TCP. Its pitch motion and yaw motion were maintained within approximately 3° . The results of this study could be used as basic information for the application of underwater floating TCP systems in various sea conditions.

AWTEC 2018-401

Design of a 100 kW pilot wave energy system based on a ballscrew electro-mechanical generator (EMG)

L. Castellini, M. Martini*, G. Alessandri, R. Maccaglia

UMBRAGROUP spa, Via V. Baldaccini 1, 06034 Foligno (PG) – Italy.

Corresponding author, mmartini@umbragroup.com

This paper presents the design of a 100 kW pilot wave energy system designed by UMBRAGROUP spa in the context of the “Electro-MEchanical Reciprogating GEnerator” (EMERGE) project, commissioned by Wave Energy Scotland (WES). The Electro-Mechanical Generator (EMG) is an innovative Power Take-Off (PTO) concept capable of converting slow-speed, reciprocating linear motion into three-phase electricity at high efficiency and reliability. The aim of the EMERGE project is to advance the TRL of the EMG from 5 to 7 for wave energy applications, demonstrating its performance and survivability in real sea conditions. In order to develop a realistic and appropriate PTO testing platform, the EMG is integrated with a

Point-Pivoted Buoy (PPB) and a Power, Control and Monitoring (PCM) system to form a stand-alone Wave Energy Converter (WEC). The WEC has been designed on a risk-mitigation approach at the technological, methodological and logistical level. This work provides an insight into the design process of the WEC, focusing on sub-systems integration and system performance and reliability. Also, it highlights the importance of correctly defining system requirements and functionalities and parallelizing design activities within sub-systems. The WEC is currently being manufactured and will be tested in Scapa Flow, Orkney Islands, Scotland in Summer 2018.

AWTEC 2018-405

Numerical simulation research on output characteristics of tidal turbine in time-varying flow

Junzhe Tan*[1,2], Zhishuang Zheng[1], Peng Yuan[1,2], Shujie Wang[1,2], Xiancai Si[1,2], Xiaodong Liu[1]

[1]College of Engineering, Ocean University of China No.238 Songling Road, Qingdao City, Shandong Province, P.R. China, 266100.

[2]Ocean Engineering Key Laboratory of Qingdao, No.238 Songling Road, Qingdao City, Shandong Province, P. R. China, 266100.

Corresponding author, tanjunzhe_cn@163.com

In real ocean environment, direction and velocity of the tidal stream change frequently, therefore the output characteristic of the tidal turbines would be affected. Case study on a 50kW tidal turbine was carried out by numerical simulation. Based on the measured hydrological data of a certain observation point in the sea area of Zhaitang Island, the output of the turbine under time-varying flow conditions was analyzed by CFD to determine the turbine's optimum installation orientation. Result of simulation of a tidal periodicity (15 days) showed that the power output of tidal turbine may be influenced by the change in the velocity and direction of tide and its installation orientation. The maximum power output would be reached if the turbine was installed facing the direction of about 62° (WGS-84) in current observation point, which was about 2500kWh in a tidal periodicity. Therefore, velocity asymmetry between flood and ebb tides should be fully considered to determine the installation orientation of the turbine, which provides references for the development of tidal energy in the actual marine environment.

AWTEC 2018-406

Aerodynamic analysis of a large wind farm with actuator line model

Ping Cheng, Xinze Duan, Yang Huang, Decheng Wan*

Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China

Corresponding author, dcwan@sjtu.edu.cn

Aerodynamic analysis of a large wind farm consisting of 48 NREL-5MW wind turbines with same layout of Lillgrund wind farm are conducted. The Actuator Line Model (ALM) is embedded into OpenFOAM, and the ALMWindFarmFoam solver for aerodynamic simulations of wind farm is established. The 3D large-eddy simulations of an offshore wind farm are carried out using this solver. Numerical investigations are conducted to discuss the aerodynamic loads, complex wake effects and significant wake interactions in this offshore wind farm. The investigation indicates that when the wind turbines aligned with in-line model, the minimum power output occurs on the third wind turbine in the downstream, and because of the recovery of wake speed, power output increased and finally tends to reach a stable value. Furthermore, when the first wind turbine operates in rated condition, there is maximum wake speed deficit, result in other downstream wind turbine lower power output. Due to the serious wake interaction, the wake flow becomes more unstable and result that the wake speed loss area alternates obviously, which may cause significant fatigue loads on the blades.

AWTEC 2018-407

Numerical simulation for hydrodynamic response of wave energy converter in extreme waves

Di Wang, Decheng Wan*

Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration, State Key Laboratory of Ocean Engineering, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiao Tong University, Shanghai, China.

**Corresponding author, dcwan@sjtu.edu.cn*

The survivability of wave energy converter(WEC) in extreme sea conditions is key index that affects its overall performance. In this paper, CFD method is used to simulate the response of a cylindrical WEC in waves. The naoe-FOAM-SJTU solver based on the open source CDF platform OpenFOAM is used for the simulation. Focused waves of certain amplitude and period are generated using Waves2Foam solver, and the accuracy of the waves is verified through comparison with experiments. The interaction between the fixed cylinder and floating cylinder with the focused wave is simulated respectively, then the pressure and force of the cylinder together with surface elevation are analysed. The results show that the influence of cylinder motion on surface elevation is significant. The change of wave pressure on the fixed cylinder is more likely to cause damage to the structure. The interaction between the cylinder and the wave affects the amplitude and period of the force on the floating body.

AWTEC 2018-408

Sloshing and violent in-chamber water column movement in an OWC wave energy converter Krisna Adi Pawitan*, William Allsop, Tom Bruce

Institute for Energy Systems (IES), University of Edinburgh King's Buildings, Edinburgh EH9 3JL, United Kingdom

**Corresponding author, k.pawitan@ed.ac.uk*

The development of oscillating water column (OWC) wave energy converter (WEC) has been very extensive in the last couple of decades with the successful grid connection of the European pilot projects such as, LIMPET, OWC Pico power plant, and Mutriku wave energy plant. The water column behaviour in the OWC chamber, however, usually assumed to be well behaved during operation in the design process. This assumption later proven to be not accurate with damaged received inside the caisson chamber, most likely due to chamber sloshing. This paper aims to observe the water column behaviour during various type of wave condition for both regular and irregular wave settings. The experiment involves a small-scale physical model, pressure transducer, and wave gauges in the University of Edinburgh long wave flume facility. The results show that sloshing is more likely to occur in the longer wave length relative to the chamber width, higher wave height, and less chamber pressure generated. Four types of water column behaviours (well behaved/no sloshing, low sloshing, medium sloshing, and high sloshing) was characterised. A ceiling impacts up to at least 1.25ρgH was observed during sloshing.

AWTEC 2018-409

Experimental investigation of a five WECs array hydrodynamics

Sergej Antonello Sirigu*, Mauro Bonfanti, Panagiotis Dafnakis, Giovanni Bracco, Giuliana Mattiazzo

Department of Mechanichal and Aerospace Engineering (DIMEAS), Polytechnic of Turin Corso Duca d'Abruzzi 24, Turin, Italy.

**Corresponding author, sergej.sirigu@polito.it*

In this paper, the experimental test of five 1:20 scale pitching floating Wave Energy Converters (WEC) arranged in two different array layouts is presented and described. A particular attention is given to the challenging experimental setup and the first analysis of the hydrodynamic

interaction occurring among the different bodies. The Response Amplitude Operators (RAO) of the array WECs are compared against the dynamics of the isolated floater test, in order to evaluate the bodies' interaction and thus the devices performances. The regular waves are performed for two wave steepness 1:50 and 1:35. A free decay analysis is conducted in order to identify the natural frequency, linear and quadratic damping term for the pitch Degree of Freedom (DoF).

AWTEC 2018-410

Global optimization of a horizontal axis tidal current turbine with shroud

Daisaku Sakaguchi*[1], Yusaku Kyozuka[2]

[1]Graduate School of Engineering, Nagasaki University

[2]Organization for Marine Sci. & Tech., Nagasaki University, 1-14 Bunkyo-machi, Nagasaki 852-8521, Japan.

Corresponding author, daisaku@nagasaki-u.ac.jp

A global search optimization system is applied for design of a horizontal axis tidal current turbine with shroud. 11 design parameters of the turbine blade and 4 design parameters of the shroud casing are considered for the optimization search by a genetic algorithm. For reducing the simulation cost, a neural network is applied as the meta-model of the RANS solver. Multiobjectives of a power coefficient at different tip speed ratio are applied for giving a function of wide operating range of the turbine. A proposed optimized design of the turbine shows a high output shaft power under a low tip speed ratio. Internal flow of the optimized horizontal axis tidal current turbine is discussed in detail. It is found that the optimized blade generates swirling flow and suppress flow separation at the diffuser wall. The wide angle of the diffuser successfully achieves higher pressure recovery ratio and results in a high suction power at the inlet of the turbine. It is found that the high performance tidal turbine is possible to design if both the blade and the shroud diffuser are optimized in same time.

AWTEC 2018-411

A cost-efficient seabed survey for bottom-mounted OWC on King Island, Tasmania, Australia

Remo Cossu*[1], Craig Heatherington[1], Alistair Grinham[1], Irene Penesis[2], Scott Hunter[3]

[1]School of Civil Engineering, The University of Queensland, Australia

[2]National Centre for Maritime Engineering and Hydrodynamics, Australian Maritime College, University of Tasmania

[3]Wave Swell Energy Ltd, 50 Camberwell Road, Hawthorn East, VIC, 3123, Australia

Corresponding author, r.cossu@uq.edu.au

This paper presents results from a site assessment for a gravity foundation Oscillating Water Column (OWC) Wave Energy Converter (WEC) designed by Wave Swell Energy (WSE), an Australian wave energy developer. A potential candidate site for this device is the west coast of King Island, Tasmania in relatively shallow water (~ 10 m LAT). The survey included geotechnical data obtained by sub-bottom profiles, seabed imagery, benthic samples and cores with the aid of SCUBA diving as well as short-term deployment of hydromechanics instruments. Our results show that the device can be placed in an area with enough sand coverage and sufficient bearing capacity. However, the location exhibits evidence of scour and an active sediment regime, which requires a more detailed analysis of the long-term sediment transport processes and associated environmental impacts on a gravity foundation structure.

AWTEC 2018-414

Wave energy experiment in the Maldives

Tsumoru Shintake*[1], Katsutoshi Shirasawa[1], Jun Fujita[1], Shuji Misumi[1], Tamotsu Nagahama[2], Toshio Shindou[3], Hamish Taggart[4], Hideki Takebe[1]

[1]Okinawa Institute of Science and Technology (OIST), Tancha 1919-1, Onna-son Okinawa, 904-0495 Japan.

[2]Nagahama Factory, 243 Yamada, Onna-son, Okinawa, 904-0416 Japan.

[3]ICHINOMIYA DENKI CO., LTD; 1-1179 Kouto, Shingu-cho, Tatsuno, Hyogo, 679-5165 Japan.

[4]Ocean Paradise Maldives PVT. LTD. Fehivinamaage, Meheli Goalhi, Male, Republic of Maldives.

Corresponding author, shintake@oist.jp

A Wave Energy Converter (WEC) to harness the power of breaking waves was discussed in previous papers (AWTEC2016[1], EWTEC2017[2]). We use a number of small rotating turbines (< 1m diameter) to harness energy from breaking waves on shore. Because the water flow inside the breaking wave is much faster than that in the ocean wave in deep sea area, we may use smaller devices. During the first phase of R&D (FY2014~2017), we have developed two half-scale prototypes which have been installed in Kandooma Island in the Maldives and sending information of power generation to us through internet. The full-scale prototype will be ready and soon tested also from this year. Our WEC devices are suitable for small islands where the electricity costs are high, that are not connected to power grid, and fuel consumption needs to be reduced by development of renewable energy sources. Here we report the current status of the field test at the Maldives.

AWTEC 2018-415

Analysis of development status of wave energy development and utilization technology

Ting Yu*, Zhichuan Li, Yonghu Wu

New Energy Research Center, CNOOC Research Institute Ltd., Block B(306), CNOOC Plaza, No.6, Taiyanggong South Str.,Beijing 100028, China.

Corresponding author, yuting2@cnooc.com.cn

Wave energy has been one of the key directions in the research of marine energy development and utilization, due to its rich resources, green, clean, renewable and other characteristics. There have been a number of wave energy devices which were commercialized. In contrast with tidal current energy technologies, the development of the wave energy field has slowed down over the past few years. The confidence of investors has been reduced by technological drawbacks of wave energy. At the end of 2016, the situation of the wave energy development field has improved significantly. At present, there are 21 commercialized pre projects or pre commercialization projects running in the world and several array projects have been moving forward; current installations have a power rating of 1MW. In this paper, firstly, a comprehensive survey of the current situation of wave energy technology in global has been given; Secondly, sorting of wave energy devices and comparing the advantages and disadvantages of various types of devices have been combed and the technical difficulties and challenges have been analysed. Finally, combined with the characteristics of wave energy resources distribution of China, the future development trend of wave energy devices and the direction suggestions for wave energy development work have been given.

AWTEC 2018-417

Numerical analysis of two different hydraulic power take-off configurations for renewable energy applications

Daniele Chiccoli, Mauro Bonfanti*, Giovanni Bracco, Panagiotis Dafnakis, Sergej Antonello Sirigu, Giuliana Mattiazzo,

Department of Mechanical and Aerospace Engineering (DIMEAS), Politecnico di Torino

C.so Duca degli Abruzzi, 14, 10129 Torino (TO), Italy
*Corresponding author, mauro.bonfanti@polito.it

Renewable sources of interest for the development of Hydraulic Converters are wave and wind energy. In both areas of application, the size of the installed machine is growing. This means handling more torque at the crankshaft, approaching the limit for electromechanical components available in series production. The hydraulic PTO stands out as an answer to the problem, being able to convert high torques at low speeds into low torques at high speeds, through robust and well-known systems and components.

Alongside a review of the state of the art of hydraulic PTOs and the main control strategies applicable to wave energy extraction systems, the present work applies a hydraulic PTO to the ISWEC, an Inertial Sea Wave Energy Converter designed for the Adriatic Sea. When designing such hydraulic PTOs, it is necessary to consider components and control methods allowing control of the force - torque applied by the PTO to the prime mover and guaranteeing a constant generator speed. Sub-optimal configuration can result in very inefficient energy conversion, so understanding the design trade-offs is key to the success of the technology.

Numerical analyses of a wave to wire time domain model are performed to compare the performances of two different hydraulic circuit configurations, both aiming to optimize the power production of the wave energy converter (WEC) considered.

AWTEC 2018-418

A numerical calculation for hydrodynamic response analysis of a multi-buoy WEC platform

Sanghwan Heo*[1], Weoncheol Koo[1], Min-Su Park[2]

[1]Department of Naval Architecture and Ocean Engineering, Inha University Incheon, Republic of Korea.

[2]Korea Institute of Civil Engineering and Building Technology, Gyeonggi, Republic of Korea.

*Corresponding author, wckoo@inha.ac.kr

In this study, numerical analysis was performed to obtain the hydrodynamic responses of a multi-buoy WEC platform. The hydrodynamic forces acting on the submerged slender-type structure members and the buoys were calculated using the modified Morison equation and commercial software. The natural frequencies and mode shapes of the platform were determined by using the modal analysis. The Newmark-beta time-integration method was employed to produce time series of displacement and bending stresses.

AWTEC 2018-422

Release of a reliable open-source package for performance evaluation of ocean renewable energy devices

Yingyi Liu*[1], Shigeo Yoshida[1], Hiroshi Yamamoto[2], Akinori Toyofuku[2], Changhong Hu[1], Makoto Sueyoshi[1], Hongzhong Zhu[3]

[1]Research Institute for Applied Mechanics, Kyushu University, Kasuga 816-8580, JAPAN

[2]Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Kasuga 816-8580, JAPAN

[3]Research and Education Center for Advanced Energy Materials, Devices and Systems, Kyushu University, Kasuga 816-8580, JAPAN

*Corresponding author, liuyingyi@riam.kyushu-u.ac.jp

Marine renewable energy (MRE) devices, such as offshore wind turbines, wave energy converters and tidal energy converters, are usually in the form of floating types and anchored by mooring systems. To analyze the feasibility of these floating systems in an efficient manner with respect to a wide band of frequency, frequency domain methods are good options to choose. In

the present work, we developed an efficient software package for evaluating the performance of floating renewable energy systems in the coastal and offshore regions. It aims to contribute an open-source effort to numerical simulations for ocean energy converters. The interface and structure of the software package are introduced in detail so as to let it be well understandable by the readers. Computations of a benchmark geometry and two practical applications of floating wind turbine are conducted and compared with theoretical results, experimental data and results from commercial software Hydrostar, justifying the effectiveness of the developed software package.

AWTEC 2018-423

The viscous effect in power capture of bottom-hinged oscillating wave surge converters

Chen-Chou Lin*[1], Yi-Chih Chow[2], Shiaw-Yih Tzang[3]

[1]Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, Keelung, Taiwan.

[2]Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University, Keelung, Taiwan.

[3]Department of Harbor and River Engineering, National Taiwan Ocean University, Keelung, Taiwan.

Corresponding author, cclin@ntou.edu.tw

The numerical simulations were conducted for Bottom-Hinged Oscillating Wave Surge Converters (BH-OWSCs) using the computational-fluid-dynamics (CFD) software FLOW3D, and based on the wave climate of the offshore sea in northeast Taiwan, that is, 1.5 meters of wave height and 7 seconds of the wave period. The results were compared with that using the simulation toolbox for wave energy converter (WEC), WEC-Sim, which is a based on the potential-flow assumption. Therefore, the viscous effect of the fluid in the BH-OWSC problem can be elucidated. This paper investigated the power capture of the BH-OWSC with various parameters including flap width, flap thickness, flap density, and position of center of mass. The results showed that, on average, the viscous loss of fluid would reduce the capture factor (CF) of the BH-OWSC by 19.1%.

AWTEC 2018-424

Bottom-hinged flap-type wave energy converter with efficient mechanical motion rectifier

Jia Mi*[1], Lin Xu[1], Beibei Liu[1], Liang Sun[1], Lei Zuo[2]

[1]Wuhan University of Technology, Wuhan, Hubei 430070, China.

[2]Virginia Tech, Blacksburg, VA 24061, USA.

Corresponding author, mj@whut.edu.cn

Ocean wave energy is a renewable source that could reduce environmental impacts significantly than the traditional fossil energy. Many different ocean wave energy converters (OWECs), of various categories, have been proposed and prototyped, and power takeoff (PTO) system has been widely recognized as the most significant element for OWECs. Mechanical motion rectifier (MMR) has been used as a PTO system to harvest vibration energy for different applications and can achieve high energy conversion efficiency. This paper proposed a novel bottom-hinged flap-type energy converter with MMR to convert the bidirectional oscillation of the wave-surge flap to the unidirectional rotation of the generator. The working principle and dynamic modeling have been described in details, and the performance of MMR-based PTO has been verified by equivalent electric model. A small scale prototype has been tested in wave flume and the results show it can obtain 0.54W average power and 3.04W peak power with the excitation of 0.09 m/2s.

AWTEC 2018-425

Control-oriented modelling for wave energy converter M4

Zhijing Liao[1], Nian Gai*[1], Peter Stansby[2], Guang Li[1]

[1]School of Engineering and Material Science, Queen Mary University of London Queen Mary University of London, London, E1 4NS UK.

[2]School of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester M13 9PL, UK.

**Corresponding author, n.gai@qmul.ac.uk*

This paper aims to establish a control-oriented statespace model for the M4 wave energy converter for the purpose of controller design. The Euler-Lagrangian equation is used to describe the dynamics of M4 in a unified and concise format. The linear wave radiation damping term is expressed as a state-space subsystem, which is then integrated into a state-space model for the whole device. A model order reduction technique is used to reduce the order of the state-space model. The fidelity of the resulting state-space models with different orders is validated in both frequency domain and time domain. The result of this paper paves the way for the future research on developing model-based controller for M4 device to further improve its energy conversion efficiency. The modeling procedure can be transferred to other types of multi-float multi-motion WECs.

AWTEC 2018-429

Lessons learned from practical asset management (429)

Jamie Ian MacDonald, Mike Allan*

Xodus Group Huntly Street, Aberdeen, Scotland

**Corresponding author, Mike.Allan@xodusgroup.com*

Renewable energy devices of many types are at the start of their lifecycle evolution developing technology and striving for commercialisation and the thought of multiple project developments and regular operations and maintenance seems a far-off problem if not a desired dream. However offshore wind, which is an industry with 30yrs of onshore experience to learn from, has already fallen victim to many issues that have been experienced before: Now experiencing spiralling O&M costs and project overruns. Was this a consequence of the very strong sentiment within the industry that they didn't want to, in fact couldn't afford to, end up like oil and gas with its high cost base and low productivity? By ignoring all things Oil and Gas did they fail to absorb the very reasons that the high cost base and low productivity evolved in the first place. After all Oil and Gas didn't set out with an intention to harm their own profitability. To avoid the common and costly problems and pitfalls that numerous industries before them have fallen into and, in some cases, learned from Renewable energy should be looking to these industries for the issues that have been solved and the structural problems that remain in place to maximise their chances of success. This presentation/ paper will discuss the common problems that lead to so many inefficiencies and major issues to make the developer aware of the problems that they are likely to face and provide some thoughts and solutions on how developers can structure their organisations and the systems that they need to put in place from the start to avoids these pitfalls. Also, how these solutions for the development and operating phases of their lifecycle can be tested and optimised during commercialisation in parallel with their devices at no extra cost and increased operational efficiency.

AWTEC 2018-427

Numerical analysis and validation of a pressure-differential wave energy converter

Fabian Wendt*[1], Yi-Hsiang Yu[1], Aurelien Babarit[2], Mike Delos-Reyes[3]

[1]National Renewable Energy Laboratory (NREL), Golden, Colorado 80401, USA

[2]EC Nantes, LHEEA Lab., Nantes, France.

[3]M3 WAVE, Corvallis, OR, USA.

Corresponding author, fabian.wendt@nrel.gov

A pressure-differential wave energy converter (WEC) is a unique design, compared to conventional kinematic WECs. It contains two flexible, air-filled bags that turn pressure fluctuations caused by ocean waves and swells into alternating expansion and compression cycles. The two bags are strategically oriented based on the dominant wave environment and exchange air back and forth with each passing wave. A turbine is located between the two bags and used to extract power from the internal airflow. A fixed-bottom pressure-differential design can be directly analyzed in the frequency domain by modeling the bag motion as a generalized body mode. However, for a floating system, the device motion influences its power output and a coupled analysis approach is required. As a result, the authors developed a time-domain numerical model to analyze the floating pressure differential WEC system. The equations of motion describing the bag and rigid body motion of the device are solved in a coupled fashion. The hydrodynamic diffraction and radiation coefficients for all relevant system motions have been computed via WAMIT. The bag motion was introduced within WAMIT as an additional generalized body mode. The hydrodynamic performance of the system is validated against 1:50-scale wave tank measurements and the influence of motion coupling on the power performance is characterized.

AWTEC 2018-431

Study on high-frequency fluctuations in tidal current direction

Patxi Garcia Novo*[1], Yusaku Kyozuka[2]

[1]Nagasaki Marine Industry Cluster Promotion Association 1-43 Dejima-machi, Nagasaki 850-0862, Japan

[2]Organization for Marine Science and Technology, Nagasaki University 1-14 Bunkyo-Machi, Nagasaki 852-8521, Japan

Corresponding author, patxi@galaxy.ocn.ne.jp

Despite the great advances achieved in the last decade, tidal stream energy technology still has to advance some steps before becoming competitive in the energy market. One of the challenges to face is the understanding and prediction of currents. Although harmonic analysis has provided good results in the estimation of averaged current velocity and direction, in-situ measurements show a notable importance of shorter period flow fluctuations, such as those generated by turbulence conditions of the flow (<1 minute). The present paper provides a new approach for the estimation of turbulence related velocity direction fluctuations based on data measured by two ADV and two ADCP at four different locations in Goto Islands, Japan. Dividing data in short period groups (3 minutes for ADV data, 5 minutes for ADCP data), results show a lineal correlation between different percentiles of opening angle and turbulence intensity. Due to the capability of numerical models to estimate this second parameter, this approach opens the door to prediction of high frequency fluctuations on flow direction.

AWTEC 2018-432

InSTREAM: characterizing and simulating turbulence from tank test to ocean

Justine M. McMillan*[1], Peter Stern[1], Thomas H. E. Clark[2], Rolf G. Lueck[1], Alex E. Hay[3], Thomas Davey[4], Rachel Horwitz[3]

[1]Rockland Scientific Inc., 520 Dupplin Rd. Victoria, BC V8Z 1C1, Canada.

[2]Octue Ltd., 3 Charles Babbage Road, Cambridge, CB3 0GT, United Kingdom.

[3]Department of Oceanography, Dalhousie University, Halifax, NS, B3H 4J1, Canada.

[4]School of Engineering, University of Edinburgh, EH9 3BF, United Kingdom.

Corresponding author, justine@rocklandscientific.com

To mitigate the risk and uncertainty associated with turbulent flows in tidal channels,

developers often use tank experiments and numerical simulations to assess the performance of a turbine. However, it remains unclear if these controlled flows can be accurately scaled up to represent the natural turbulence present in tidal channels. The difficulty in translating between model, tank and full scale turbulent effects motivated the InSitu Turbulence Replication, Evaluation And Measurement (InSTREAM) project. InSTREAM included the development of a set of sensors that combined acoustic and non-acoustic technology to measure turbulence in both laboratory and field applications. The sensors were successfully deployed at the FloWave Ocean Energy Research Facility and in the Minas Passage, Bay of Fundy. The measurements from both the lab and the field were used to perform numerical simulations of turbine performance, and a direct comparison between the "tank" and "ocean" conditions was obtained by implementing a scaling method to translate the length scales between the two flow regimes. The results – from both the measurements and the simulations – highlight that there are significant differences in the turbulence characteristics between the tank and the field.

AWTEC 2018-434

Application of vortex method to performance analysis of wave energy converter: vorticity creation method from the boundary

Shuichi Nagata*[1], Yasutaka Imai[1], Tengen Murakami[1], Shigeki Okubo[2], Yutaka Okamoto[2]

[1]Institute of Ocean Energy, Saga University 1-Honjo-machi, Saga 840-8502, Japan.

[2]Hitachi Zosen Corporation, 7-89, Nanko-kita, 1-chome, Suminoe-ku, Osaka 559-8559, Japan.

Corresponding author, nagata@ioes.saga-u.ac.jp

Authors proposed 2D numerical method in time domain, using vortex method that can consider the fluid viscosity and calculated primary conversion efficiency of a floating OWCtype wave energy converter in waves. In this method, two models, that is, vorticity layer model and vorticity shedding model, for vorticity creation from the body surface and diffusion of the vorticity into the fluid region are used. In this paper, by comparing the calculation results with experimental results on the flow field around the circular cylinder in uniform flow and the vertical force acting on the oscillating submerged horizontal plate in vertical direction under still water surface, calculation accuracy of two vorticity creation models from the body surface is showed.

AWTEC 2018-436

Recommend ultra low-head mini-hydro turbinegenerator system for coastal river application

Joe Martin[1], Jacek Swiderski[2], Liuchen Chang[3], Tony T Tung*[4], Wagner A. Barbosa[5], G Lucio Tiago Fiho[6], Antonio Carlos B Botan[7]

[1]Norcan Hydraulic Turbine Inc. ON Canada jmartin@norcanhydro.com

[2]Swiderski Engineering Inc. jacekswiderski@rogers.com

3University of New Brunswick, NB Canada lchang@unb.ca

[4]T Tung Hydraulic and Renewable Energy Technologies Inc. tonytptung@gmail.com

[5]ClamperIndústria e Comércio S.A. Brasil wagner@clamper.com.br

[6]Univ. Federal de Itajuba CERPCH MG Brasil.

Corresponding author, tonytptung@gmail.com

Over the past five years, Canadian small and medium hydro turbines manufacturer Norcan Hydraulic Turbines Inc. lead the team members, as in co-authors above, in the development of an "Innovative Ultra-Low Head (ULH) MiniHydro Turbine-Generator System". International Science and Technology Partnerships Canada (ISTPCanada) and Brazilian partners, together with the Natural Sciences and Engineering Research Council (NSERC), supported this R&D project. This industry-led collaborative R&D project has been carried out from 2013 to 2015. The proposed ULH Hydro-Turbine technology will bridge the gap between low-head hydro and marine hydrokinetic

technologies by developing a cost-effective innovative “pit” type ULH hydro-turbine system to allow head application range extended to less than 2 meter and capture kinetic energy at freestream zero-head. Detailed test results explained. Pre-commercialization demonstration has been planned in Canada. Recommend this ULH Turbine system can be applied effectively at coastal river mouth, sea-lock gates, and tidal estuary where there is about 2 meter or more water-head available and further allow operation during river-current or tidal-current periods.

AWTEC 2018-438

A seesaw shaped floating wave energy converter

Jiangbin Zhao*[1], Xin Wei[1], Jianlin Zhou[1], Yong Jin[1], Chenxing Sheng[2]

[1]School of Energy and Power Engineering, Wuhan University of Technology, Wuhan, China.

[2]Reliability Engineering Institute, National Engineering Research Center for Water Transport Safety (WTS), Wuhan, China.

**Corresponding author, zhaojiangbin@whut.edu.cn*

A floating seesaw shaped Wave Energy Converter (WEC) is proposed, composed of double pontoons and a vertical damping plate deep into water. The double pontoons are shaped in cylinder, and are rigidly connected. A damping plate is placed deeply underwater, connected with the double pontoons by a slender rod. Roll moment will be generated when ocean waves hit surface floated double pontoons, and a generator is placed to convert this roll moment into electricity. The motion model of the WEC is set up to estimate averaged power.

AWTEC 2018-441

Enhancing the relative capture width of submerged point absorbing wave energy converters

Boyin Ding*, Nataliia Sergiienko, Fantai Meng, Benjamin Cazzolato, Peter Hardy, and Maziar Arjomandi

Ocean Wave Energy Research Group, School of Mechanical Engineering, the University of Adelaide South Australia, Australia, 5005

**Corresponding author, boyin.ding@adelaide.edu.au*

Point absorbing wave energy converters account for 53% of the existing wave energy converter prototype designs. Generally, point absorbers are designed to operate on or just below the water surface, extracting wave power from the heaving motion. In recent years, an increasing amount of attention has been given to fully submerged point absorbers that demonstrate better survivability under storm conditions and capability of extracting wave power from motion in multiple degrees of freedom. This paper investigates three submerged point absorber designs operating in three degrees of freedom: a generic axisymmetric spherical buoy with a single tether power-take-off; and two modified types, one employing an asymmetric mass distribution buoy and the other employing a three tether power-take-off arrangement. Simulations in the frequency domain were used to study the behaviour of the three point absorber designs from the perspectives of dynamic response, power absorption principles and capabilities, and power-take-off requirements. Compared to the generic single tether spherical buoy design, both modified submerged point absorber designs demonstrate considerable improvements in their performance indices (e.g. the relative capture width and the power to PTO force ratio), while exhibit additional challenges in their implementations.

AWTEC 2018-442

Pseudo-nonlinear hydrodynamic coefficients for modelling point absorber wave energy converters

Benjamin W. Schubert*[1], Fantai Meng[1], Nataliia Y. Sergiienko[1], Will Robertson[1], Benjamin S. Cazzolato[1], Mergen H. Ghayesh[1], Ashkan Rafiee[2], Boyin Ding[1], Maziar Arjomandi[1]

[1]Ocean Wave Energy Research Group, School of Mechanical Engineering, The University of Adelaide South Australia, Australia, 5005

[2]Carnegie Clean Energy limited, Perth, WA, Australia

Corresponding author, benjamin.schubert@adelaide.edu.au

This study presents dynamic simulation results of two point absorber wave energy converters comparing between linear, pseudo-nonlinear, and CFD models. When modelling wave energy converters, linear assumptions are commonly used to simplify calculations. One such assumption is that the hydrodynamic parameters do not change with pose. This study proposes the inclusion of position and orientation dependence in force estimation, specifically the hydrodynamic terms. A comparison between linear, the proposed pseudo-nonlinear, and CFD models show the effect of the linear assumption for cylindrical and spherical submerged buoys in three degrees of freedom, subject to regular waves. For the case of strong nonlinear hydrodynamic coupling between degrees of freedom, the linear and pseudo-nonlinear models are compared with published literature trends. Accounting for pose dependence of hydrodynamic forces, drag forces, and infinite frequency inertial effects showed trends closer to CFD results but with generally higher motion amplitudes. Significant differences in results for the cylinder are due to the presence of near-surface nonlinear effects that are not captured using linear potential flow solvers. Furthermore, a second order effect was observed in the results, suggesting the proposed method may be well suited to model sufficiently submerged buoys.

AWTEC 2018-443

Combined ocean renewable energy system (Cores) for islandic area on Malaysian Seas

Omar bin Yaakob*[1,3], Md. Afendi bin M. Yusuf[1], Jasrul Jamani bin Jamian[2], Muhammad Ariff bin Baharudin[2], Kang Hooi Siang[1,3], Nik Mohd Ridzuan bin Shaharuddin[1], Farah Ellyza binti Hashim[1], Zulfakar bin Aspar[2], Muhammad Adli bin Mustapa[1], Mohd Arif bin Ismail[1], Ahmad Mustaqim bin Abd Rahim[1], Muhammad Syazwan bin Bazli[1], Nurhaslinda binti Khaliddin[1], Siti Sarah binti Jupri[1]

[1]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

[2]Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

[3]Marine Technology Centre (MTC), Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia

Corresponding author, omar@fkm.utm.my

The island communities in Malaysia heavily depend on diesel or combined solar-diesel power plants. High cost of diesel, difficulties of transporting diesel during the monsoon seasons, low and variable solar flux, and the high maintenance cost of solar cells and batteries are perennial issues associated with these conventional energy systems on the islands. Hence, the next resort is to rely on renewable energy from the sea. However, Malaysian coastlines have low wave heights and low current speeds, giving rise to more challenges in optimizing devices for extracting wave and tidal energy sources. This paper presents study on the development of a combined offshore energy harvesting system in Malaysia seas condition. The main objectives are to develop, construct, and test a prototype demonstrator and test platform of the Combined Ocean Renewable Energy System (CORES) for the Malaysian sea. In order to harvest large power from the ocean, CORES combines wave and current devices on the same shared floating platform. Wave and tidal energy data from the chosen site location, Pulau Tinggi, in the state of Johor, Malaysia was assessed to estimate the output power to be produced. Meanwhile, a comprehensive study was conducted to optimize the CORES concept to verify its reliability, safety, and cost-effectiveness. Numerical simulations on the behaviors of the platform and oscillating water column, point absorber, savonius current turbine and solar devices were carried out at Marine Technology Centre at Universiti Teknologi Malaysia. Finally, a full scale prototype was built and deployed near an island in the South China Sea. The findings in this research are expected to bring significant reference towards more reliable large-scale ocean energy systems for the welfare of island communities in the tropical regions.

AWTEC 2018-444

Uncertainty analysis for a wave energy converter: the Monte Carlo method

Jarrah Orphin*, Irene Penesis, Jean-Roch Nader

National Centre for Maritime Engineering & Hydrodynamics, Australian MaritimeCollege, University of Tasmania Lockedbag 1395, Launceston, Tasmania, 7250, Australia.

Corresponding author, jjorphin@utas.edu.au

Developing wave energy converter technology requires physical-scale model experiments. To use and compare such experimental data reliably, its quality must be quantified through an uncertainty analysis. To avoid uncertainty analysis problems for wave energy converter models, such as providing partial derivatives for time-varying quantities within numerous data reduction equations, we explored the use of a practical alternative: the Monte Carlo method (MCM). We first set out the principles of uncertainty analysis and the MCM. After, we present our application of the MCM for propagating uncertainties in a generic Oscillating Water Column wave energy converter experiment. Our results show the MCM is a straightforward and accurate method to propagate uncertainties in the experiment; thus, quantifying the quality of experimental data in terms of power performance. The key conclusion of this work is that, given the demonstrated relative ease in performing uncertainty analysis using the MCM, experimental results reported in the future literature of wave energy converter modelling should be accompanied by the uncertainty in those results. More broadly, this study aims to precipitate awareness among the wave energy community of the importance of quantifying the quality of modelling data through an uncertainty analysis. We therefore recommend future guidelines and specifications pertinent to uncertainty analysis for wave energy converters, such as those developed by the International Towing Tank Conference (ITTC) and International Electrotechnical Commission (IEC), to incorporate the MCM with a practical example.

AWTEC 2018-446

Status for development of open sea test site for wave energy converters in Korea

Jong-Su Chou*[1], JeongKi Lee[1], Chang Hyuck Lim[1], Tae Kyeoung Ko[1], Ji Yong Park[1], Kilwon Kim[1], Keyyong Hong[1], Seungho Shin[1], Jeong Seok Kim[1], Jeong-Hwan Oh[1], Kyong-Hwan Kim[1], Young-Duck Kim[2], Il-Hyoung Cho[3]

[1]Marine Renewable Energy Research Department, Korea Research Institute of Ships and Ocean Engineering, Korea.

[2]Korea Research Institute of Ships and Ocean Engineering, Korea.

[3]Department of Ocean System Engineering, Jeju National University, Jeju, Korea.

Corresponding author, jschoi@kriso.re.kr

The status of development of the open sea test site for wave energy converters in Korea was described in this paper. In order to promote the dissemination of wave energy and to accelerate the technology development of wave energy converters (WECs), Ministry of Oceans and Fisheries in Korea is supporting the project for the development of the open sea test site from 2016. Site selection, design and consent for test site have been completed by the mid of 2018. Constructions of submarine cable & connectors, substations, SCADA system, onshore buildings, performance assessment system, and test site operation system are being under development. They will be finished by the next year (2019). In this paper, the backgrounds, the achievements, and ongoing process for development of the open sea test site for WECs in Korea were reported.

AWTEC 2018-449

Experimental analysis into the effects of air compressibility in OWC model testing

Damon Howe*, Jean-Roch Nader, Gregor Macfarlane

National Centre for Maritime Engineering & Hydrodynamics, Australian Maritime College, University of Tasmania Locked Bag 1395, Launceston, Tasmania 7250, Australia.

*Corresponding author, damonh@utas.edu.au

It is well documented that the effect of air compressibility will potentially influence the performance of an Oscillating Water Column (OWC) device, with a number of previous theoretical studies examining these effects [1-5]. The implications of air compressibility have the most significant effect at full scale, which can be attributed to the large air chamber volume and the increase in associated pressure and flow rate. However, the development of wave energy converter technology relies significantly on model scale testing, which is often scaled using the Froude criterion. This scaling method are not appropriate for the modelling of air compressibility and introduces uncertainties in the prediction the performance results at full-scale. To account for these effects, methods have been derived to more accurately represent the effect of air compressibility at small scale, one of which requires scaling the air chamber volume by the scale factor squared as opposed to the traditional scale factor cubed following the Froude criterion methodology [1]. This paper examines a preliminary investigation into the effect of air compressibility through hydrodynamic experimentation of a bent duct OWC device, from which the behaviour of the obtained results are compared with the expression proposed analytically by Sarmento and Falcao [1].

AWTEC 2018-451

Performance analysis of an OWC device integrated within a porous breakwater

Rebecca Grennell, Damon Howe*, Jean-Roch Nader, Gregor Macfarlane

National Centre for Maritime Engineering & Hydrodynamics, Australian Maritime College, University of Tasmania Locked Bag 1395, Launceston, Tasmania 7250, Australia.

**Corresponding author, damohowe93@gmail.com*

The oscillating water column (OWC) wave energy converter is arguably the most heavily researched ocean renewable energy concept currently in development. Many variations of the concept have been proposed and explored, of which the bent duct type OWC has presented itself as one of the most effective concepts for absorbing ocean wave energy. The integration of wave energy converters within maritime structures presents a number of advantages from an economic perspective, where it has been found that costs associated with construction, maintenance and grid connection can attribute as little as 3% toward the total cost of a traditional vertical caisson type breakwater [1]. Previous studies into the concept of breakwater integrated oscillating water column devices has focused on vertical caisson type breakwaters, or a generic rubble mound type breakwater, however little research has been conducted into the effect of breakwater reflectivity on the performance of the integrated OWC devices. The experimental investigation was conducted in the Australian Maritime College's Model Test Basin facility, where a breakwater with controllable porosity was configured within an experimental set up with the aim of investigating the performance of an OWC device integrated within a porous breakwater. The results indicate that an increase in breakwater reflection, along with a solid fitting increases device performance without major changes to the overall response curve of the device, with the greatest performance correlating to integration within a fully reflective breakwater.

AWTEC 2018-452

Characterising the effect of turbine operating point on momentum extraction of tidal turbine arrays

Christoph Hachmann*[1], Tim Stallard[1], Binliang Lin[2], Peter Stansby[1]

[1]School of Mechanical, Civil and Aerospace Engineering, The University of Manchester, Oxford Road, M13 9PL, Manchester, United Kingdom.

[2]State Key Laboratory of Hydro-science and Engineering, Tsinghua University, Beijing 100084, China.

**Corresponding author, christoph.hachmann@manchester.ac.uk*

Due to the predictable nature of the tides, power generation from tidal streams could play a significant role in addressing future power network challenges by providing an auxiliary frequency balancing service. A requirement of such services is that power output may be rapidly adapted. This can be achieved by several alternative operating strategies applied to individual turbines, to entire farms or to clusters of turbines within a farm. The onset tidal flow speed to an array is sensitive to the net resistance provided by the array and so it is necessary to consider how such strategies would affect power output, net resistance and the flow onset to the farm. Investigations using a Reynolds-averaged Navier-Stokes Actuator Disc (RANS-AD) model and experiments in a shallow channel are conducted to assess the influence of rotor operating point on individual turbine loading and hence aggregate resistance of an array. Array- and row-specific values for the local thrust coefficient and corresponding disc porosities are chosen to represent three typical operating values of turbine thrust and power. Both studies are assessed separately for turbine array configurations with up to 12 turbines deployed over 3 rows and in bi-directional flow. The results show good agreement with previous experimental and numerical publications. Additionally, similar trends are observed for the variation of the net array thrust coefficient with array layout and operating point for both studies. Application of these array operating points within a simple channel model indicates that the imposed net thrust can be reduced by 12.3% whilst the energy yield reduction over a 12-hour period is almost negligible. Thus, an adaptive operating strategy does not only provide more accurate information of the power output from tidal farms and reduces the environmental footprint of the latter, but also promotes a more flexible array operation which can facilitate a better grid integration of future large-scale tidal stream turbine arrays.

AWTEC 2018-456

Numerical study on the performance of a wave energy dissipator array

WenChuang Chen*[1], YongLiang Zhang[2], HuiFeng Yu[2], JinXiong Zhang[1], ZhiGang Wang[1]

[1]State Key Laboratory of Simulation and Regulation of Water Cycle in River Basin, China Institute of Water Resources and Hydropower Research, Beijing 100038, China.

[2]State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing 100084, China.

**Corresponding author, cwc12@tsinghua.org.cn*

In this paper, a wave energy dissipator (WED) array consists of heaving floaters is proposed. A mathematical model based on Navier-Stokes equations for the hydrodynamics and structure dynamics of a heaving WED array is present. The model is validated by a comparison of the numerical results with the experimental results of other researchers, and then used to examine the effect of WED space on WED motion, wave energy capture, wave reflection, wave transmission and dissipation. Our preliminary results indicate that turbulent dissipation around the array increases with increasing longitudinal separation of the middle and side WEDs. For the examined cases, wave energy capture width ratio varies slightly when the longitudinal separation varies within one WED length, whereas decrease significantly when the longitudinal separation reaches one WED length.

AWTEC 2018-457

Laboratory study of tidal turbine performance in irregular waves

Kate Porter[1], Stephanie Ordonez-Sanchez*[1], Matthew Allmark[2], Robert Ellis[2], Catherine Lloyd[2], Tim O'Doherty[2], Cameron Johnstone[1]

[1]Department of Mechanical and Aerospace Engineering, University of Strathclyde James Weir Building, 75 Montrose Street, Glasgow, G1 1XJ, UK.

[2]School of Engineering, Cardiff University, Queen's Buildings, The Parade, Cardiff, CF10 3AA, UK.

**Corresponding author, kate.porter.10@ucl.ac.uk*

Wave loading on tidal turbines is of key concern for determining blade and drive train design loads and the fatigue life of components. Furthermore, irregular waveforms are likely to add complexity to the loading patterns, and represent more realistic conditions. To investigate this

issue, a set of laboratory tests was conducted in a large wave-tow facility at CNR-INSEAN, Rome. A 0.9 m diameter three bladed horizontal axis turbine model was fixed to the tow carriage and tested under tow, regular wave-tow and irregular-wave-tow conditions at a range of turbine rotational velocities. Thrust and torque on the blades and rotor were measured dynamically during testing using strain gauges. The control mode was switched between constant speed and constant torque to understand how this influenced turbine power capture and thrust loading, and assess the potential to use control methods to mitigate loading fluctuations. It was found that average power and thrust values were not affected by the control mode or the addition of regular or irregular waves. However, using torque control resulted in increased thrust fluctuations per wave period of the order of 40% of the mean thrust compared to under speed control. Therefore, the operational mode must be taken into consideration.

AWTEC 2018-459

Planning on establishment of sea test-bed for tidal current energy converters in Jindo, Korea

Jin-Soon Park, Dong Hui Ko*, Jin-Hak Yi

Coastal Development Research Center, Korea Institute of Ocean Science and Technology (49111) 385, Haeyang-ro, Yeongdo-gu, Busan Metropolitan City, Korea.

**Corresponding author, kodh02@kiost.ac.kr*

Tidal current power is the nearest technology for the commercialization of marine energy. In particular, southwestern sea of Korea is the optimal candidate site for the development of tidal current energy. In addition, Uldolmok and Jang-Juk straits have abundant tidal current energy resources. This paper aims to introduce the plan for the establishment of 4.5MW sea test bed titled K-TEC for tidal current energy converters in Jind located at southwestern sea of Korea.

AWTEC 2018-460

Development of two-way type tidal power optimization program (K-TOP3.0)

Song-yi Lee*, Tae-hyun Jang, , Hee-gon Kim, Yong-ho Lee, Jae-beak Choi, , Hyo-keun Kown

Korea Water Resources Corporation (K-water), 1927, Daebuhwanggeum-ro, Danwon-gu, Ansan-si, Gyeonggi-do, 15637 Korea.

**Corresponding author, song2@kwater.or.kr*

Recently, the development of new and renewable energy is progressing actively. There is growing interest in infinite and clean tidal energy generated by the effects of sun and moon movement. There are two methods for tidal power generation. The first one is two-way type(interactive) which is generating both rising (tide) and ebb (tide), and second one is a single type which applies only one of them. Single-type is divided into a flood type that generates when seawater rise, and ebb type that generates when seawater going down. The flood type tidal power optimization operation program has already been applied to the Sihwa tidal power plant of Korea to produce optimum and maximum power generation. Development of interactive Tidal Power Program(K-TOP3.0) can be applied to various types of tidal power plants all over the world. In addition, tidal energy business is expected to expand by optimizing tidal power generation operation technology.

AWTEC 2018-461

Experimental study on the efficiency of an OWC under different incident wave conditions

Yaw-Huei Lee*, Duy-Tong Nguyen, Yi-Chih Chow

Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University Keelung, Taiwan.

**Corresponding author, lyh@email.ntou.edu.tw*

The Oscillating Water Column (OWC), one type of the wave energy converter (WEC), has been the focus of many researches of marine energy because of its simplicity. The efficiency of an OWC is apparently affected by the incident wave conditions. This paper studies the effect of the incident wave conditions on the efficiency of an OWC using experiments with a model whose geometry is similar to that of the LIMPET. Under different incident wave conditions, we perform experiments with an outlet orifice of two diameters to simulate different pneumatic damping levels of the air turbine. Time-series images of the water level inside the OWC are first obtained by high-speed imaging, and then processed and analysed with a procedure to find the position and velocity of the water level. The capture factor of the OWC is related to the water level's kinematic characteristics using a simple hydrodynamic theory. The results indicate that the OWC's efficiency is strongly related to the incident wave conditions as well as the pneumatic damping levels.

AWTEC 2018-462

Learning curves for marine operations in the offshore renewable energy sector

Ben Hudson*[1, 2], Edward Kay[1, 2], Mark Lawless[2], Tom Bruce[1]

[1]Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE), University of Edinburgh The Kings Building, West Mains Road, Edinburgh, EH9 3JG, United Kingdom.

[2]JBA Consulting Ltd. South Barn, Broughton Hall, Skipton, North Yorkshire, BD23 3AE, United Kingdom.

**Corresponding author, b.hudson@ed.ac.uk, ben.hudson@jbaconsulting.com*

This paper presents some of the research currently undertaken by the newly established Wave Energy Research Centre at the University of Western Australia to support Carnegie Clean Energy in deploying a 1.5MW grid connected wave energy converter in Torbay, Albany, Western Australia. This includes the modelling of the wave resources in Torbay, wave tank testing and hydrodynamic modelling to characterise and predict the motion of the wave energy converter and some aspects of geotechnical engineering to optimise the foundations of the device.

AWTEC 2018-463

Dynamic analysis of jack-up platform structure in environment loads

Hung Chien Do*[1], Jianh-Horng Chen[2], Phan Van Quan[1]

[1]Faculty of Naval Architecture, Ho Chi Minh city University of Transport, 2D3, ward 25, Binh Thanh district, Ho Chi Minh City, 700000, Vietnam.

[2]Systems Engineering and Naval Architecture, National Taiwan Ocean University, 2 Pei-Ning Road, Keelung 202, Taiwan.

**Corresponding author, chien_kttt@hcmutrans.edu.vn*

A jack-up platform is subjected to complicated loads such as wave, wind and currents. The aim of present paper is to study the effect of environment conditions on jack-up platform structures. A simple finite element model under both regular and irregular wave loads is analysed. The obtained results describe dynamic response of structures and structural capacity when operating at different depths.

AWTEC 2018-464

Development of passive oil compensated shaft seal module for Kuroshio Turbine

Jenhwa Guo*, Ling-Ji Mu, Sheng-Wei Huang

Engineering Science and Ocean Engineering Department, National Taiwan University 73 Chou-Shan Road, Taipei, Taiwan, R.O.C.

**Corresponding author, jguo@ntu.edu.tw*

The Kuroshio turbine is a submersible power generator designed to be working against

Kuroshio Current with an exclusively long system maintenance period. The long-term operational reliability of the shaft seal is one of the key factors in designing the Kuroshio turbine. Inspired by the ROV oil compensation system for thruster bearings and electrical junction boxes, a passive oil compensated shaft seal module, which is integrated with an oil compensator and shaft seals, is developed for a Floating Kuroshio Turbine (FKT). The passive oil compensator balances the surrounding seawater and the oil pressure, the internal spring evenly maintains the oil pressure slightly higher than the surrounding seawater to prevent water ingress. The new design of the passive oil compensated shaft seal module features high reliability, maintenance free and adaptability to any water depths, which will benefit and prolong FKT working endurance significantly. This study introduces different types of shaft seal and the concept of passive oil compensated shaft seal module. Then, a 1:25 scaled experimental model is established for several pressure tests and its performance is demonstrated.

AWTEC 2018-466

Numerical study on performance analysis for OWC WEC applicable to breakwater

Sewan Park*, Kyong-Hwan Kim, Bo Woo Nam, Jeong-Seok Kim, Keyyong Hong

Korea Research Institute of Ships and Ocean Engineering 32 Yuseong-daero 1312 beon-gil, Yuseong-gu, Daejeon, Korea.

**Corresponding author, sewanpark@kriso.re.kr*

The present paper introduces CFD (Computational Fluid Dynamics) analysis results to evaluate the performance of the sloped OWC (Oscillating Water Column) chamber. The CFD analysis method is validated by comparing the results of the 2D wave flume model test for the opened chamber without considering the turbine interaction. The performance of the sloped OWC chamber is evaluated through the 3D CFD analysis by modelling the orifice to take into account the interaction between turbine and oscillating water column in the chamber for various size of the orifice.

AWTEC 2018-467

Simulation of composite suction foundation to topography change

San-Shan Lin*[1], Hsing-Yu Wang[1], Yun-Chih Chiang[2], Hui-Ming Fang[1], Sung-Shan Hsiao[1]

[1]Department of Harbor and River Engineering, National Taiwan Ocean University No.2, Beining Rd., Jhongjheng District, Keelung City 202, Taiwan (R.O.C)

[2]General Education Center, Tzu Chu University No.701, Sec. 3, Zhongyang Rd. Hualien 97004, Taiwan (R.O.C)

**Corresponding author, hywang1108@gmail.com*

The objective of this study was to adequately examine potential wave fields, flow fields, and coastal geomorphological changes in an ocean near an offshore wind farm after installation of a wind power-generating set. The simulation results revealed that geomorphological changes (i.e., scouring and silting variations), from a macroscopic perspective, the installation of the wind turbines did not sufficiently affect the geomorphology of the study area. But a microscopic perspective, changes in the seabed geomorphology were only limited to areas surrounding the submerged piles after the installation of the wind turbines.

AWTEC 2018-469

Conversion characteristics of permanent magnet synchronous generator on wave energy converter

Yasutaka Imai*, Shuichi Nagata, and Tengen Murakami

Institute of ocean energy, Saga University Honjo 1, Saga, 8408502, Japan.

**Corresponding author, imaiy@cc.saga-u.ac.jp*

Wave energy converters transform ocean energy which varies irregularly into electricity with a constant voltage and constant frequency. The converted electricity must satisfy the grid-connection requirements [1] in the frequency fluctuations and voltage fluctuations, and must be maximized as much as possible.

To maximize the power that satisfies the requirements, it is necessary to optimize the rating of the electrical components, which include generators, inverters and converters. However, a method of selecting electric parts have not been established. This is because the input energy is irregular and it covers several disciplines such as machinery, electricity, hydrodynamics and control. Therefore, it is necessary to fabricate a power conversion system in the laboratory and select elements and control that maximize power conversion under input conditions simulating ocean waves.

AWTEC 2018-470

Structural integrity monitoring of hybrid offshore-wind and tidal-current turbines

Wonsul Kim, Jin-Hak Yi*, Jin-Soon Park

Coastal Development Research Centre, Korea Institute Ocean Science & Technology Haeyang-ro, Yeongdo-gu, Busan, Korea

**Corresponding author, yijh@kiost.ac.kr*

As one of the efforts to harness energies from ocean, the hybrid offshore-wind and tidal-current turbines (HOTTs) have been studied for several years. In the HOTTs, the supporting structural parts including tower and foundation play an important role to secure the power generation facilities such as blades, hub and nacelle and to resist environmental loadings from wind, wave, and tidal current. The purpose of this study is to develop the structural integrity monitoring system and the damage detection method for the HOTT supporting structures through laboratory experiments. The laboratory experiments for the HOTT supporting structure have been performed using the scaled HOTT model in water flume. The dynamic characteristics of the HOTT model are estimated by least-squared frequency domain decomposition (LS-FDD) using the measured responses, and compared with those calculated by the commercial FEA software. The natural frequencies estimated by LS-FDD are very close to those of the FEA. To detect structural damages in the HOTT supporting structure, two different approaches are considered, (1) coherence-based method and (2) improved autoregressive (AR) model based method. It is found that the improved AR model based method is superior to the coherencebased method and structural damage can be alarmed by the proposed improved AR model method.

AWTEC 2018-472

Coastal Erosion and Measures at Ketzeliau Coast, Taiwan

Jen-Yi Chang[1], Tai-Wen Hsu*[2], Li-Chang Hsu[3,4], Yi-Shing Chang[3,4], and Shin-Jye Liang*[5]

[1]Department of Business Administration, Tainan University of Technology, Tainan, Taiwan

[2]Department of Harbor and River Engineering, National Taiwan Ocean University, Keelung, Taiwan

[3]Water Resources Agency, Ministry of Economic Affairs, Taipei, Taiwan

[4]Department of Hydraulic and Ocean Engineering, National Cheng Kung University, Tainan, Taiwan

[5]Department of Marine Environmental Informatics, National Taiwan Ocean University, Keelung, Taiwan

**Corresponding author, sjliang@ntou.edu.tw, twhsu@mail.ntou.edu.tw*

This paper examines major factors of coastal erosion and measures against beach erosion at the Ketzeliau Coast, Taiwan. Historical shoreline and costal cliff recession as a result of the attack of storm surges and waves were analyzed and discussed. The most important impact of beach

erosion at the Ketzeliau Coast includes beach erosion, wave overtopping, coastal flooding, damages of homes built on properties. This study investigates impact of coastal damages and examines various measures adopted in response to coastal erosion during the past 60 years at the Ketzeliau Coast. The improper prevention work of the hard solution of coastal structures against beach erosion is reviewed based on their effectiveness in protecting life, properties, and harmony with the adjacent environment. Alternative defense solutions are suggested to be implemented, and their benefits are addressed at the Ketzeliau Coast.

AWTEC 2018-480

Simulation of Typhoon Soudelor (2015) induced Typhoon waves using multiple-resolution method

Tien-Hung Hou*[1], Shih-Chun Hsiao[1], Tai-Wen Hsu[2], Chia-Cheng Tsai[3], Meng-Ling Chiao[4]

[1]Department of Hydraulic and Ocean Engineering, National Cheng Kung University No. 1 University Road, Tainan 701, Taiwan.

[2]Center of Excellence for Ocean Engineering (CEOE), National Taiwan Ocean University No. 2 Pei-Ning Road, Keelung 202, Taiwan.

[3]National Kaohsiung University of Science and Technology No. 142 Haijhuan Rd., Nanzih District, Kaohsiung 811, Taiwan.

[4]Chung Cheng Institute of Technology, National Defense University No.75, Shiyuan Rd., Daxi Dist., Taoyuan City 335, Taiwan.

**Corresponding author, houtienhung@gmail.com*

Typhoon waves induced by Typhoon Soudelor (2015) were numerically investigated using the Quadtree-Adaptive Model (QAS) developed by Tsai et al. (2013). Multiple-resolution modes to integrate different scaled wind fields is implement. This method is able to determine the initial and boundary conditions by the height-resolution data. The QAS simulation reproduces the main factures of Typhoon Soudelor and significant Typhoon waves. By comparing the simulated waves with the measurements by data buoys, it is found that the present method could increase the model prediction accuracy and efficiency.

AWTEC 2018-481

A meshless method for the two-dimensional extended Boussinesq equations

Wan-Rong Chou*[1], Chia-Cheng Tsai[2], Tai-Wen Hsu[3], Shih-Chun Hsiao[1]

[1]Department of Hydraulic and Ocean Engineering, National Cheng Kung University, Tainan, Taiwan 1 University Road, Tainan 701, Taiwan.

[2]National Kaohsiung University of Science and Technology 142 Haijhuan Rd., Nanzih District, Kaohsiung 811, Taiwan.

[3]Center of Excellence for Ocean Engineering (CEOE), National Taiwan Ocean University 2 Pei-Ning Road, Keelung 202, Taiwan.

**Corresponding author, chouwanrong@gmail.com*

Coastal and offshore area are extremely dynamic regions. Near-shore wave current field affects the layout and design of hydraulic constructions. This paper focuses on establishing a new two dimensional (2D) Boussinesq model with a meshless method, using the local radial basis function collocation method (LRBFCM). The main concept of the LRBFCM is the interpolation function values which is only associated with the neighbouring nodes in the entire domain. The theoretical formulation has been conducted. In contrast to the fully dense matrices with the global methods, the localized approach results in sparse matrices, which could promote the computation efficiency. In the theory of Boussinesq equations (BEs), different types of BEs are relevant to different horizontal velocities and higher-order terms. The model would be implemented to solve ocean engineering, coastal engineering and harbor engineering related wave motion problems.

AWTEC 2018-491

Design and analysis of the floating Kuroshio turbine blades

Fang-Ling Chiu*[1], Sin-An Lai[1], Chi-Fang Lee[2], Yu-An Tzeng[1], Ching-Yeh Hsin[1]

[1]Dept. of Systems Engineering and Naval Architecture, National Taiwan Ocean University, 2, Pei-Ning Rd., Keelung, Taiwan 20224.

[2]CR Classification Society, 8th Fl., No.103, Sec. 3, Nanking E. Rd., Taipei, Taiwan 10491.

Corresponding author, cy_hsin@hotmail.com

The most common devices used for extracting the ocean current energy are the current turbines. Most people use the wind turbine blade design methods for the horizontal axis current turbine design; however, the current turbines operate in the water, and their physical behaviours are more like marine propellers. In this paper, two turbine blade design procedures are adopted. The first design procedure is similar to the propeller designs, and the second design procedure is to use Genetic Algorithm and boundary element method (BEM) to find a geometry which can provide the maximum torque. After completing the designs, hydrodynamic performances of the marine current turbine are then computed and analysed by the potential flow BEM and the viscous flow RANS method. The computational results show the geometries designed by the presented procedures can not only satisfy the hydrodynamic design goal, but also predict the delivered power very close to the experimental data. After the blade performance meets the design target, the performances of designed 20kw floating type Kuroshio turbine including the floating body at different operation conditions are demonstrated in the paper. Also, the structural strength of the turbine blade is computed by FEM, and the results are evaluated to see if the design complies the rule requirements.

AWTEC 2018-493

Hydrodynamic effects of waves on a floating Kuroshio turbine

Forng-Chen Chiu*, Jun-Yen Shieh, Yu-Sheng Peng

Department of Engineering Science and Ocean Engineering, National Taiwan University, No.1, Sec.4, Roosevelt Road, Taipei 106, Taiwan.

Corresponding author, fcchiu@ntu.edu.tw

Waves are inevitable environmental factor to all marine structures. In the present study, we are going to study wave exciting forces and moment acting on a Floating Kuroshio Turbine (FKT) when long waves propagate over it. FKT will have corresponding motion responses due to the wave exciting forces and moment. In general, FKT may have to face the challenge when weather is severe. Long waves may make FKT do some significant movements, and these movements will affect its performance and the tension force of mooring line. Therefore, for the development of FKT the wave exciting forces and moment acting on FKT need to be investigated and its motions due to these forces and moment need to be evaluated in advance.

In the present study, the CFD software ANSYS FLUENT is applied for dealing with the hydrodynamic problems. To simulate the situation that FKT operating under waves, we add different wavelength and wave height keeping wave slope constant at the inlet, and then calculate the wave exciting forces in both x and y direction as well as moment in z direction for a 20kW rated FKT operating at the depth of 25 meters. In addition, Fast Fourier Transformation was applied to investigated the frequency components of these wave exciting forces and moment. Then a simulation tool OrcaFlex was used to simulate the motions of FKT operating in current with applying of these wave exciting forces and moment on it. After that, we changed the depth of FKT, make it to the depth of 10 and 40 meters respectively and compare their results to clarify the variation depending on depth.

The results show that the longer the wavelength or the higher the wave height will make the wave exciting forces and moment larger, and it is obvious that when FKT goes down deeper, the wave exciting forces and moment reduced significantly, motions and tension force of mooring line as well. The validity of the present approach of combining application of CFD tool and simulation

tool to evaluate the hydrodynamic effects of waves on FKT operating in current was confirmed.

AWTEC 2018-497

Future prospects of marine energy technologies – status and readiness?

AbuBakr S Bahaj*

Energy and Climate Change Division, Sustainable Energy Research Group, University of Southampton, Southampton, SO17 1BJ, United Kingdom.

**Corresponding author, A.S.Bahaj@soton.ac.uk*

Sustainable energy technologies have become a critical part and a major contributor to the global energy supply mix especially in the electricity sector. This is driven by our desire to use sustainable resources to reduce pollution emanating from the current use of fossil fuels, and to provide a pathway to achieve national and internationally agreed emission reductions targets. Although sustainable energy technologies are in most cases, still driven by what is termed as support mechanisms or subsidies, the sustainable or renewable energy industry has matured, with huge investments being ploughed into it globally. For instance, in 2016 global new investment in renewable energy (excluding large hydro-electric projects) was around US$241.6 billion, providing an added installed capacity of ~138.5GW of renewable power mainly from solar and wind.

The utilisation of oceans resources, such as offshore wind, waves and marine currents (or tides) is also gathering pace and their exploitation offer one of the appropriate routes for the production of sustainable electrical power. Marine energy mainly refers to power generation from wave and tides and there are now tangible plans for multi MW deployment in farms or arrays. This was mainly sparked off in 2010 by the UK's Crown Estate who announced concessions to deploy over 1.6 GW of multi-megawatt mix wave and tidal technology farms and arrays in the Pentland Firth by 2020. It also announced recently, further concessions of sites to exploit the marine resource spanning both north and south of the UK. Globally, there were announcements for technology and energy yield support for the deployment of multiple devices in arrays, especially those announced for the Bay of Fundy in Canada, France and other announcements such as those in South Korea and China. The paper provides the status of these developments addressing issues related to their infancy as compared to others renewable technologies such as offshore wind, and provides a discourse to current technology readiness at commercial scale deployment. The paper also discusses the future prospects of marine energy and asks the question, where the wave and tidal energy industry fits in relation to global investments in term of support of appropriate technologies and the readiness of deploying these at scale.

AWTEC 2018-498

Motion instabilities in tethered buoy WECs

J. Orszaghova*[1], H. Wolgamo[1], S. Draper[1], A. Rafiee[2]

[1]Oceans Graduate School, University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

[2]Carnegie Clean Energy Ltd, 21 Barker Street, Belmont, WA 6104, Australia.

**Corresponding author, jana.orszaghova@uwa.edu.au*

Theoretical and experimental investigation of yaw motion instability in a submerged axi-symmetric wave energy converter is presented. The device is a truncated vertical cylinder which is taut-moored via three tethers. Assuming linear hydrodynamics, but retaining non-linear geometry associated with the tethers, governing equations are derived in 6 degrees of freedom. Due to the axi-symmetry of the system, there is no hydrodynamic excitation moment in yaw. However, the yaw governing equation - correct to second order in buoy motions - reveals a time-varying restoring moment coefficient. Such systems can undergo large oscillations given a small initial perturbation, through the well-known Mathieu instability. Targeted regular wave experiments were used to verify the model predictions on the onset of yaw motion instability in the

first two instability branches. The yaw motion in a three-tethered system is analogous to sway motion in a single-tethered device. The yaw instability and the transverse/sway motion instability both arise due to coupling with heave. Due to small damping, the instabilities can be prevalent. The theoretical analysis presented is applicable to other floating WECs.

AWTEC 2018-500

Dynamic simulation of the mooring system with a shock-absorbing mechanism for floating Kuroshio turbine

Chau-Chang Chou*[1], Ping-Yang Huang[1], Jiahn-Horng Chen[2], Ching-Yeh Hsin[2], Forng-Chen Chiu[3]

[1]Department of Mechanical and Mechatronic Engineering, National Taiwan Ocean University, No.2 Pei-Ning Road, Keelung 20224, Taiwan.

[2]Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University, No.2 Pei-Ning Road, Keelung 20224, Taiwan.

3Department of Engineering Science and Ocean Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Road, Taipei, 10617 Taiwan.

Corresponding author, cchou@mail.ntou.edu.tw

Ocean current energy is a very promising natural power source due to its steady and enormous flow. However, the implementation of the energy harvesting device is more complicated and difficult from the off-shore and deep-ocean environments. A floating Kuroshio turbine system (FKT) which is developing in Taiwan also faces various challenges and concerns. For the mooring system, the instant tension shock from the ocean flow and the wave, especially during the launching process, might cause the destructive damage to the FKT system. In this study, we used the simulation data of the FKT system by OrcaFlex software in a preliminary study to investigate the dynamic response of the FKT's mooring system with two shock-absorbing mechanisms. The original mooring system without these mechanisms was compared as a benchmark. All these components were built as a lumped system by the physical-based modelling software, MapleSim. The weight and mechanical properties of the cable, the shear and buoyance forces from the fluid, the model's degree of freedom, and the parameters of the shock-absorbing mechanism were all considered and addressed in this study.

AWTEC 2018-501

The role of georisk management in marine renewable energy projects

John M. Reynolds*[1, 2], Ana B. Fernandes[1], Lucy M.L. Catt[1]

[1]Reynolds International Ltd Suite 2, Broncoed House, Broncoed Business Park, Mold, Flintshire, CH7 1HP, United Kingdom.

[2]North Wales Tidal Energy & Coastal Protection Co. Ltd Groes Hall, Groes, Conwy, LL16, 5RS, United Kingdom

Corresponding author, jmr@reynolds-international.co.uk

There are ambitious goals around the world to install 748 GW by 2050 through the development of marine renewable energy generation in Offshore Wind, Tidal Stream, and Tidal Range projects. A key development arising out of the latest round of offshore wind farm developments in UK coastal waters is the significant potential benefit of a reduction in ground investigation costs to project developers in managing risks associated with seabed and sub-seabed conditions. Optimisation of a geological Ground Model is a key part of this process. The role of Georisk Management in marine renewable energy projects is ultimately to understand, reduce where possible, and quantify the risks associated with the dynamic geological and marine systems at and around proposed infrastructure projects, and ultimately to mitigate those risks. This has been discussed through consideration of three strategic approaches, namely, (a) the use of best practice guidelines; (b) determination of the geohistory of a site; and (c), by gaining an understanding of the potential physical impacts of the environment on a renewable energy project.

Consequently, we are recommending that for near-shore offshore renewable energy projects consideration is given to the broader panoply of processes, both terrestrial and marine, including impacts of changing climate.

AWTEC 2018-502

Dynamic sandbanks in close proximity to sites of interest for tidal current power extraction

L.S. Blunden*, S.G. Haynes, A.S. Bahaj

Energy and Climate Change Division, University of Southampton University Road, Southampton, SO17 1BJ

**Corresponding author, lsb1@soton.ac.uk*

A validated numerical model of tidal flows and sediment transport around the Alderney South Banks was used to investigate the potential effects of large (300 MW) tidal turbine arrays at different locations in Alderney territorial waters. Two methods were used, firstly looking at hydrodynamic changes only and secondly modelling sediment transport over a non-erodible bed. The baseline hydrodynamic model was validated relative to ADCP velocity data collected in the immediate vicinity of the sandbank. Real-world sand transport rates were inferred from sand-wave migrations and agree favourably with sediment transport residuals calculated from model outputs. Outputs from the sediment model reproduced realistic morphological behaviours over the bank. Seventeen different locations were considered; most did not result in significant hydrodynamic changes over the South Banks, however three array locations were singled out as requiring extra caution if development were to occur. The results provide a means of optimizing.

AWTEC 2018-504

Environmental effects monitoring of tidal in-stream energy converters in the Bay of Fundy, Canada: Challenges and research needs

Craig Chandler*

Mersey Consulting Ltd., Halifax, Nova Scotia, Canada

**Corresponding author, craig@mersey.ca*

One of the primary technical constraints to the development of tidal in-stream energy converters (TISECs) is uncertainty associated with their potential environmental effects. As the industry moves toward commercialization, international research is focused on the deployment and monitoring of TISECs to observe effects in a variety of real-world situations and thereby better understand potential effects on marine life and the physical environment. Understanding these effects is important to device optimization as well as project consenting in most jurisdictions.

In Canada, most Marine Renewable Energy (MRE) research and development is focused on TISEC demonstrations, with the Province of Nova Scotia's Bay of Fundy being the centre of activity. Between 6 and 8 demonstration projects are planned for deployment over the next 3 years, including those at the Fundy Ocean Research Centre for Energy (FORCE) and others permitted under the Nova Scotia Department of Energy's Demonstration Permit program.

The broad variety of devices demonstrated through these projects include utility scale TISECs (e.g., having a rated capacity of 1 MW or more), small scale devices (having a rated capacity in the tens or hundreds of kWs), devices that rest on the seabed, floating devices, devices with traditional rotating turbines, and resistance-based devices that move through the water. Environmental Effects Monitoring Programs (EEMPs) are requirements for all device deployments.

In developing an appropriate EEMPs for a TISEC demonstration project, researchers and practitioners require a broad knowledge base that includes a sound understanding of the operational capabilities of sensor technologies, and the state of science and research priorities as identified by Canadian and international MRE organizations such as ORJIP and Annex IV. The regulatory regimes applicable to the intended demonstration site must be thoroughly understood, along with those in future deployment sites to ensure that the utility of EEMP results is maximized.

This paper discusses environmental effects monitoring methods being employed in projects planned for Canada's Bay of Fundy and describes the decision-making processes employed by the author in designing EEMPs for multiple project developers. The methods and technologies used in EEMPs are discussed along with the limitations of the various sensor technologies. Finally, opportunities to advance environmental monitoring capabilities through research and development activities are identified.

EEMPs may include a variety of tools including direct visual observation, physical sampling, video surveillance, and acoustic monitoring. Of these, acoustic monitoring is the standard for traditional marine monitoring because it is the most versatile and holds the best potential for the acquisition of robust datasets. High flow environments such as those in the Bay of Fundy present unique challenges to most commercially-available sensors used in marine data collection. While acoustic technologies and data analysis methods continue to develop as in-stream tidal technologies mature, environmental factors such as turbulence, high turbidity, and noise associated with high-flow environments presents challenges to the effective collection and analysis of data.

Monitoring of floating TISECs is further challenged by increased turbulence near the surface of the water column, wave activity, air entrainment, acoustic reflection off the water's surface and floating ice and debris. These conditions introduce acoustic and physical interferences that may limit the ability of the sensor to collect adequate data, or function effectively. Bottom-mounted TISECs present different challenges for environmental monitoring, including the inability to easily access sensors for maintenance, repair, or replacement, and difficulty observing the condition of sensors.

Beyond the technical requirements, the cost of EEMP systems must be proportional to the scale of the platforms and to the impacts that these devices are likely to have on the environment. Managing and analyzing the terabytes of data that can be generated from active acoustic and video sensors can also represent significant costs. Finding a way to capture adequate environmental data while keeping the costs to a reasonable percentage of overall CapEx and OpEx may be critical to the feasibility of some demonstration projects.

Nova Scotia, Canada is home to world-leading ocean technology companies that develop marine sensing equipment for the defense and energy industries as well as the scientific community. From within this sector several companies have partnered with academic institutions over the past several years to conduct research aimed at developing new sensor systems and monitoring techniques. These activities include collecting discrete data within the water column, designing methods for combining datasets from various sensors, and developing advanced sensors for deployment on TISEC devices.

An example of this work is the development of a coherent hydrophone array by Geospectrum Technologies and Dalhousie University. A hydrodynamic, four-element horizontal hydrophone array was developed to more effectively collect baseline ambient acoustic data by reducing flow noise from data collected by hydrophones mounted on TISECs. Accurate baseline ambient sound level data are essential to the quantification of the additional noise that a TISEC may contribute to the environment. The coherent array was tested in the Bay of Fundy and data collected during highflow conditions. Signal processing methods were used to analyse datasets from each of the hydrophones in the array and allowed flow noise to be identified and suppressed. The results yielded a lower critical frequency at all flow speeds than that of a single hydrophone.

Many TISEC developers are partnering in the development of new technologies such as the coherent array as part of their overall R&D program. Such technologies and methods can provide an advantage to developers better informing their testing programs and facilitating consents.

The overall goal of developers, researchers and practitioners is the development of lower-risk means of demonstrating TISEC technologies in conjunction with EEMP systems to allow environmental effects to be more easily assessed. Ongoing work by the author and associates includes the development of methods for increasing the effectiveness and resiliency of monitoring systems for small-scale floating platforms to lower environmental risks associated with smallscale tidal developments, which are inherently cost sensitive.

AWTEC 2018-505

Proposed guidelines for preliminary assessments of the physical impacts of wave energy deployments

Mark Hemer*[1], Kathleen McInnes[2], Julian O'Grady[2], Ron Hoeke[2], Stephanie Contardo[3]

[1]CSIRO Oceans and Atmosphere Hobart, TAS. Australia

[2]CSIRO Oceans and Atmosphere Aspendale, VIC. Australia

[3]CSIRO Oceans and Atmosphere Indian Ocean Marine Research Centra, WA. Australia

*Corresponding author, Mark.Hemer@csiro.au

To support development of the wave energy industry in Australia, we present guidance for assessing the influence of arrays of Wave Energy Converters (WECs) on the hydrodynamic attributes of the surrounding ocean, as a means for providing a first level impact assessment for proposed wave energy deployments. These guidelines have been developed as part of the ARENA and CSIRO-funded Australian Wave Energy Atlas Project (AWavEA). A wave energy project cycle typically consists of four stages: Preliminary evaluation; Feasibility study; Project design; and Implementation and operation. The guidelines presented in this paper aim to support preliminary assessments of the suitability of a proposed site to deployment of wave energy converters. A series of idealised simulations of WEC array installations using SNL-SWAN was performed to underpin development of the guidelines, under a range of conditions (device types, array sizes and configurations, wave climate conditions, bed slope, distance offshore). Results are generalised via empirical equations to represent the zone of impact (area, cross-shore distance, and longshore width). These equations provide a basic tool to inform design of more detailed modelling and monitoring assessments of the environment adjacent to proposed wave energy developments.

AWTEC 2018-506

Stabilized offshore floating wind platform using a dual-function wave energy converter

Dillon Martin*, Wei Che Tai, Lei Zuo

Department of Mechanical Engineering, Virginia Tech, Blacksburg, VA 24061, USA

*Corresponding author, dilmart@vt.edu

Offshore wind is an attractive source for renewable energy. However, the development and deployment of large scale (>2 MW) offshore wind turbines is hindered by a lack of efficacious methods to develop a stable floating platform in ocean environments at depths greater than 100 m. A stable platform enables direct usage of large scale onshore wind turbines for offshore wind. In this paper, a system of three energy regenerative tuned mass dampers (TMD) is proposed as a means to both mitigate wave-induced structural motion of a floating platform of the DeepCwind 5 MW semisubmersible system and to harvest otherwise inaccessible ocean wave energy. Optimal tuning frequency and electrical damping of the TMD were obtained via the $\mathcal{H}2$ norm optimization method. When the root mean square of the semisubmersible response was minimized, the TMD was shown to reduce the structural motion by more than 40%. Meanwhile, the harvested power was shown to reach 40~55 kW per significant wave height squared.

AWTEC 2018-507

Tidal energy in Australia - Assessing resource and feasibility to Australia's future energy mix

Irene Penesis[1], Mark Hemer[2], Remo Cossu[3], Jenny Hayward[2], Jean-Roch Nader*[1], Uwe Rosebrock[2], Alistair Grinham[3], Saad Sayeef[2], Peter Osman[2], Philip Marsh[1], Camille Couzi[1]

[1]Australian Maritime College, University of Tasmania Launceston Tasmania, Australia.

[2]CSIRO Canberra ACT, Australia

[3]School of Civil Engineering, The University of Queensland Brisbane QLD, Australia.

*Corresponding author, JeanRoch.Nader@utas.edu.au

This paper presents an overview and progress of a recently commenced three-year project funded by the Australian Renewable Energy National Agency led by the Australian Maritime College, (University of Tasmania), in partnership with CSIRO and University of Queensland. The project has a strong industry support (OpenHydro Ltd, Atlantis Resources Limited, MAKO Tidal Turbines Ltd, Spiral Energy Corporation Ltd and BioPower Systems Ltd) and aims at assessing the technical and economic feasibility of tidal energy in Australia, based on the best understanding of resource achievable. The project consists of three interlinked components to support the emerging tidal energy sector. Component 1 will deliver a National Australian high-resolution tidal resource assessment; in Component 2, case studies at two promising locations for energy extraction will be carried out; lastly, Component 3 will deliver technological and economic feasibility assessment for tidal energy integration to Australia's electricity infrastructure. The outcomes of this project will provide considerable benefit to the emerging tidal energy industry, the strategic-level decision makers of the Australian energy sector, and the management of Australian marine resources by helping them to understand the resource, risks and opportunities available.

AWTEC 2018-508

New hybrid HST pump development for wave energy applications-study on the slipper bearing of an axial piston pump

S.D.G.S.P. Gunawardane*[1], Sudesh Ratnayak[1], Tomiji Watabe[2]

[1]Dept. of Mechanical Engineering, Faculty of Engineering, University of Peradeniya, Peradeniya, Sri Lanka, 20400

[2]T-Wave Consultant 5-23-3, Misono, Noboribetsu, 059-0036, Japan

*Corresponding author, sdgspg@eng.pdn.ac.lk

Design of wave energy devices to withstand extreme conditions is a major challenge in wave energy development. Oscillating body devices use relative motion between the bodies to harness the energy though the motion limitation is necessary due to the motion restrictions of the power take off (PTO) mechanisms. This paper focuses on the development of an axial piston pump, which is an integral part of a new hydraulic PTO system that does not need motion restrictions. Since the axial piston pump rotates at relatively slow speed than typical speeds, the effect of lubrication at the motion transfer parts (mainly between swash plate and the slipper bearing) is the key focus of this study. Conventional grove design of the slipper bearing and proposed pocket design were studied and compared using analytical and CFD methods. It is found that, at very slow speeds, the new pocket design shows higher ability to maintain self-balancing on the lubrication layer than that of the conventional slipper bearing. Hence, new design has prospective for further development to enhance the lubrication ability at very slow speeds suitable for wave energy applications.

AWTEC 2018-509

Improvement of self-starting of Darrieus turbine by pitch variation

Koju Hiraki*, Katsuhiro Henzan

Department of Mechanical and Control Engineering, Kyushu Institute of Technology 1-1 Sensui-cho, Tobata, Kitakyushu, Fukuoka 804-8550, Japan

*Corresponding author, hiraki@mech.kyutech.ac.jp

Darrieus turbine with straight blades has an advantage over a horizontal-axis turbine in the simplicity and in independency to a current direction. In order to improve the selfstarting performance of Darrieus turbine, the pitch angles of the blades are varied and tested in a low-speed wind tunnel. First, the pitch angles of the blades are varied coarsely to evaluate the possibility of the improvement. The generated torque on the turbine is measured by the torque meter in a tip-speed ratio from 03 to 1.2. Then, based on the obtained results, the pitch angles of

the blades are again varied but in a range from -15 to 15 degrees. As a result, it is found out that the pitch angle of -10 degrees gives the largest torque below 0.8 in a tip-speed ratio. Once the turbine reaches 1 in a tip-speed ratio, then the blades with a pitch angle of 4 and 6 degrees are advantageous to accelerate the turbine.

AWTEC 2018-511

A modified reactive control method for direct-drive linear wave energy converters using excitation force identification

Xuanrui Huang*, Xi Xiao

Department of Electrical Engineering, Tsinghua University Beijing, China.

**Corresponding author, hxr503@gmail.com*

Based on the dynamic equation of a direct-drive linear wave energy converter, a linearized and modified model including linearization of nonlinear parts and identification of parameters that are hard to measure is proposed. An equivalent sixth-order model is obtained using either a transfer-function or a state-space model. Based on the state-space model, a real-time identification of wave excitation force is proposed through the Kalman filter. The characteristics of power extraction are analyzed in detail in the frequency domain for the wave energy converter under real wave excitation, and furthermore, the optimal power extraction conditions are obtained. An optimal power control method in real time is proposed for a resonance operation between the ocean waves and the float by controlling the velocity of the linear generator. Simulation and experimental results demonstrate that the proposed method is valid, and capable of achieving a high power extraction efficiency.

AWTEC 2018-512

Turbulence characteristics in tidal flows using LES and ALM to model the tidal power plant Deep Green

Sam T. Fredriksson*[1], Göran Broström[1], Björn Bergqvist[2], Johan Lennblad[2], Håkan Nilsson[1]

[1]Department of Marine Sciences, University of Gothenburg, Gothenburg, Sweden.

[2]Department of Mechanics and Maritime Sciences, Chalmers University of Technology, Gothenburg, Sweden.

**Corresponding author, sam.fredriksson@gu.se*

The turbulence in tidal flows affects the design and operation of tidal plants, e.g., through control system and dynamical loads. Present work is focused on a specific site west of Holy Island along the north west cost of Wales and a specific tidal power plant, Deep Green. Although, specific and applied, the work is generally applicable regarding findings and modelling techniques for other sites and designs.

Large Eddy Simulations (LES) are used to study first the undisturbed tidal flow and then the flow with a power plant in operation. The undisturbed tidal flow simulations show that the turbulence characteristics differ between the acceleration and deceleration phase of the tidal cycle. The turbulence statistics are also used to estimate dynamical loads on the tidal plant with respect to, e.g., fatigue.

Secondly, a novel Actuator Line Method (ALM) tidal power plant model, that e.g., takes the arbitrary trajectories of the power plant wing into account, is used. It's used to study how the power plants affect the environment, available power downstream, and turbulence characteristics affecting other power plants in possible power plant arrays. It is shown that the width of the trajectory can be used as a measure to estimate the wake extent.

AWTEC 2018-515

Wave energy resources at the test site in Keelung, Taiwan

Shiaw-Yih Tzang*[1], Chun-Che Chen[1], Yung-Lung Chen[3], Huan-Ru Chen[1], Jiahn-Horng Chen[2]

[1]Department of Harbor & River Engineering, National Taiwan Ocean University, 2 nd Pei-Ning Rd. Keelung, 202, Taiwan, ROC.

[2]Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University, 2nd Pei-Ning Rd. Keelung, 202, Taiwan, ROC.

[3]Minesto Taiwan Ltd. 24F, No. 333 Keelung Rd. Sec. 1, Taipei 11012, Taiwan, ROC.

Corresponding author, sytzang@ntou.edu.tw

Wave energy comprises the most abundant resource among the marine renewable energy in the world. Offshore Taiwan, it is also one of the prior marine energy resources and higher nearshore wave energy resources are located in the northeastern (NE) waters. Thus, to facilitate the development of the wave energy conversion technology, a permitted field-test site offshore Keelung was established in 2011. The associated wave energy resources had been collected with a data buoy being deployed at the offshore boundary of the test site since 2012. This study presents the analysed results from May 2012 to May 2015. Typical joint probability distributions between wave height H and period T in four seasons and monsoon seasons were first shown. The calculated monthly variations of averaged wave energy resources were also presented. The results clearly illustrate that in the NE Monsoon season (Oct. to next March) waves are higher and longer resulting in average wave power density to be about 15 kW/m with directions from ENE to NE.

AWTEC 2018-516

The field study of current estimation for Kuroshio Power-Generating Pilot facilities

Chang-Wei Lee*, Po-Feng Chen, Wan-Ting Chang, Yih Yang, Wen-Chang Yang

Taiwan Ocean Research Institute, National Applied Research Laboratories Kaohsiung, Taiwan

Corresponding author, cwlee@narlabs.org.tw

Due to the natural environment of eastern Taiwan— the low current speed of the Kuroshio Current (1-1.5 m/s), and deep water (deeper than 1000 m in parts), and 3-5 typhoons that pass through annually—the mooring system is difficult. From 2016/7/24 to 2016/7/30, a pilot field experiment of a 50 kW Kuroshio Current energy system was performed at the Kuroshio Current in Taiwan. The mooring system for a deep-water floating platform, which was located at a depth of 900 m, was installed. The deep-water mooring system includes a floating platform and gravity foundation. In this research, the strength of the main structure of floating platform was analysed. The strength of the main structure of floating platform which diverting to submerged 30m was considered. Resonance of 50KW Kuroshio energy system and floating platform under wave action was analysed that including the tension of mooring line, the platform weight and platform area on the system. The gravity foundation sinking speed was computed.

AWTEC 2018-517

Dynamic stability of a surfaced current turbine system

Shueei-Muh Lin[1], Yang-Yih Chien*[2], Hung-Chu Hsu[3], Meng-Syue Li[3]

[1]Department of Mechanical Engineering, Kun Shan University

[2]Department of Marine Environment and Engineering, National Sun Yat-sen University

[3]Tainan Hydraulics Laboratory, National Cheng Kung University

Corresponding author, yichen@faculty.nsysu.edu.tw

Taiwan is with the presence of Kuroshio Current in the east part of the island. This ocean energy source is stable and rich so that it is potential to be developed and utilized. Due to maintain

and water-proof of system, the design of surfaced ocean turbine system is made. However, the ocean velocity and direction will vary. The wave will change with the wind. These factors significantly affect the stability of a surfaced turbine. The investigation about the instability of a surfaced turbine is helpful for the practical design of current power plant. In this study, the system is composed of turbine, buoyance platform, traction rope and mooring foundation as shown in Figure 1. In addition to the current velocity and wave, the gravity, buoyance, drag force of turbine structure on the stability are also great. The mathematical model of the system is presented. The coordinate of the ocean current turbine system is shown in Figure 2. The analytical solution of the general system is proposed. The effects of current velocity, wave, geometry parameters of structure on the pitching motion and stability are investigated.

AWTEC 2018-524

Wave energy converter with wave direction tracking function

Ming-Yu Tsai*

National Cheng Kung University, Chiayi County, Taiwan (R.O.C.)

**Corresponding author, s053431177@gmail.com*

If its floater is parallel to sea wave, the wave energy converter can sweep more wave energy at the same construction cost. To keep the floater parallel to wave, a self-modify design is proposed. The sea level difference of the floater will create a force to push the floater. And the force due to the rotation center will create a torque to force the wave energy converter aligned with waves. Increasing the sea level difference and the distance of the rotation center can increase the self-modify torque and the stability of the wave energy converter. After it keeps parallel to the wave, the floater will be able to collect more horizontal wave energy and extend the time which sea wave works on the wave energy converter.

AWTEC 2018-525

River turbines controlled by mechanical three variable speed converters

Kyung Soo Han*

Differential Dynamics Corporation (DDMotion) 11403 Cronhill Drive, Suite B, Owings Mills, Maryland USA 21117

**Corresponding author, key.han@ddmotion.com*

The Company has developed mechanical three variable rotary motion controls that are capable of converting variable rotational speed to constant, and named them “speed converters”. The name speed converters is in contrast to variable frequency converters or more commonly called “power converters” that are converting variable power to constant. The similarity of the two converters is that both of them are using three variable controls: the speed converters are using the Company invented “transgears” and power converters are using transistors. The difference is the energy of which the converters are controlling: the speed converters are controlling mechanical kinetic energy of rotary motion (torque & speed) and power converters are controlling electrical energy (voltage & current). The objectives of this paper are to describe the Company developed building block “transgear”, the speed converter “Hummingbird”, the experimental efficacy of converting speed prior to generating electricity, and the advantages of converting speed instead of frequency. The advantages of using speed converters are power rating of speed converters can be higher than that of power converters (due to its all-gear configuration and the use of mechanical three variable controls), generating grid-quality constant frequency, and generating grid-quality electricity without grid, i.e., “Distributed Generation”.

AWTEC 2018-526

High performance synthetic ropes for wave and tidal PTO applications

Gabrielle Maassen*, Rafael Chou, Paul Chong

Samson Rope Technologies, 2090 Thornton Street, Ferndale, WA, 98248, Unites States

**Corresponding author, gmaassen@samsonrope.com*

High-performance synthetic ropes (HPSR) offer many benefits in wave and tidal energy applications across all phases of deployment, from installation and operation through decommissioning. In these applications, rope performance, demands are typically much higher. Exceedingly high break strengths, long fatigue life, stiffness or compliance, and safety are often required in proposed systems. Through lab-scale testing and ongoing research, performance expectations can be better defined, hence more effectively managed. Though high-performance synthetic ropes have properties that favour these stricter demands, there are also technical considerations for performance expectations we can require from a rope. With these technological factors, system designers should take a holistic approach to ensure maximum safety, design life, and operational efficiency for a system. This paper explains these considerations and properties of high performance synthetic ropes, to assure that performance expectations can be achieved.

AWTEC 2018-528

Alternative methods for offshore wind-wave resources and power assessments over the Gulf of Thailand and Andaman Sea

Woraluck Hongto[1], Worachat Wannawong[2], Donlaporn Saetae[1], Chaiwat Ekkawatpanit*[1], Peera Sakornmaneera[1]

[1]Department of Civil Engineering, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Bangkok 10140, Thailand.

[2]School of Atmospheric Sciences, Sun Yat-sen University, Guangzhou 510275, China.

**Corresponding author, chaiwat.ekk@kmutt.ac.th*

Offshore wind and waves are classified as major marine renewable energy sources. A reliable assessment of wind and wave energy resources is important to study over the Gulf of Thailand (GoT) and Andaman Sea (ADS). In this study, the surface wind and wave heights were used to investigate the offshore wind and wave energy resources over the GoT and ADS. Alternative methods for the assessment of wind and wave resources are through analysis of wind speeds, wave periods, fully developed wave height (Hf) and significant wave height (Hs) using a statistical analysis of 10-year hindcast datasets from QSCAT from NASA associated with WaveWatch-III (WW3) model results from NOAA. A short-term analysis of dynamical simulations and its comparison of the WW3 global model and Simulating WAves Nearshore (SWAN) regional model were also used to investigate the preliminary testing and possibility of offshore wind-wave resources and powers. Results of both models were relatively similar to those of buoys at the offshore locations in a case study of Typhoon Linda 1997 entering the GoT. In this study, the results of WW3 datasets revealed that wind and wave capacities at the lower GoT were in the ranges of 400-800 W m^{-2} and 1-1.5 kWm^{-1}, respectively. Over the ADS, WW3 model datasets with the QSCAT wind data provided wind and wave powers in the ranges of 300-600 W m^{-2} and 2-4 kW m^{-1}, respectively. The WW3 and QSCAT combinations, therefore, could be the potential alternative methods for 10-year long-term assessments of wind and wave power.

AWTEC 2018-535

Tidal turbine array design and energy yield assessment for Naru Strait, Japan

Daniel Coles*[1], Tom Walsh[1], Yusaku Kyozuka[2], Yoichi Oda[2]

[1]Simec Atlantis Energy, 4th Floor, Quay 2, 139 Fountainbridge, Edinburgh,UK, EH3 9QG.

[2]Organization for Marine Science & Technology, Nagasaki University, 852-8521.

**Corresponding author, daniel.coles@simecatlantis.com*

Preliminary results are presented from an assessment of phased tidal stream energy development in Naru Strait, Nagasaki Prefecture, Japan. Results from a validated 3D hydrodynamic model show that flow speeds exceed 3 m/s in depths ranging between 30 - 60 m within the strait. Tidal stream turbine energy yield is estimated across the strait using mid-depth ambient flow results from the model. Array scale blockage effects are limited by capping the practical array install capacity below levels shown to reduce turbine power generation in literature. Energy yield estimates are presented for a 45 MW array, built out in four phases. For each phase, rotor swept area and generator rated power are designed to maintain high capacity factor levels. Results show that the 45 MW array in Naru Strait generates an estimated yield of 119 GWh/year. This is equivalent to the average electricity demand of approximately 40,000 households in Japan.

AWTEC 2018-536

Wave powered desalination systems for developing countries and islands

P. William Staby*

Resolute Marine Energy, Inc., 3 Post Office Square – 3rd floor, Boston, MA, USA

**Corresponding author, contactus@resolutemarine.com*

Over 1 billion people suffer from the effects of water scarcity and the majority of those affected live in coastal areas in developing countries, islands and remote communities. Seawater desalination is an excellent potential solution, but desalination systems normally require a connection to a strong and reliable electrical grid which means that they are available to only a small handful of those in need. To solve this problem, Resolute Marine Energy (RME) has been developing and testing a wave-powered desalination system that can be deployed quickly, operate completely “off-grid” and supply large quantities of fresh water at competitive cost. The Water Power Technologies Office of the U.S. Department of Energy has expressed interest in supporting the development of marine renewable energy technologies that can quickly gain commercial traction by profitably addressing significant “alternative” market need.

AWTEC 2018-537

Current & tidal energy converters farm levelized cost of energy optimisation based on reliability assessment

Nicolas Lariviere-Gillet*[1], Karim Barrou[1], Frédéric Prevost[2], Julien Dalmas[2], Cyril Giry[3]

[1]Bureau Veritas Marine & Offshore

[2]Valemo

[3]Energie de la Lune

**Corresponding author, nicolas.lariviere-gillet@bureauveritas.com*

Tidal Current Energy Converter technologies are being developed today using various range of designs, shapes and sizes. The only way to compare the efficiency and integrity of the technologies is then to test the device in real conditions and perform power curve assessment based on comparable methods.

In this respect, IEC62600-200 is a technical specification describing the methodology to evaluate the performance of tidal converter in a marine environment. Regarding the small number of devices commissioned at sea and connected to the grid, this standard has been hardly applied.

In order to allow the machines to be tested in real conditions at a reasonable cost, test sites have been set up all over the world. As such, SEENEOH, an estuarine tidal test site for full-scale river and intermediate-scale ocean tidal devices which is located on the Garonne River in Bordeaux has been one of the pioneers in France and the site is now supporting two technology developers in their demonstration phase. Indeed, the test site enables technology developers to rigorously test their river / tidal energy converter solutions and valid performance criteria prior to stepping in the market. Multiple aspects are included in the testing phase: durability, wear and tear analysis, fish impact assessment, environmental impact, operation and maintenance procedures as well as any other factor that could be essential to ensure the energy converters are robust

enough and economically viable.

The additional value of SEENEOH is its capability to carry out power curve assessment based on a standardized methodology developed together with Valemo, Energie de la Lune and Bureau Veritas and thus, for the technology developers, to get their machines power performance certified by a recognized third party. This third-party assessment provided by Bureau Veritas and SEENEOH ensure the necessary reliability in front of investors and thus allow projects bankability.

The main goal of this power curve assessment is to demonstrate technology efficiency based on the existing relationship between water current speed and the electrical power output generated by the energy converter. In order to achieve a reliable and meaningful comparison of machines, it is then important to ensure that the measurement methods as well as the related post processing / results assessment efforts are made according to a fairly comparable method. For machine tested at sea, power curve certification guarantees that the procedure used by the technology developer to perform a power curve is compliant with the existing standards, such as IEC62600-200 (“Marine energy – Wave, tidal and other water current converters – Part 200: Electricity producing tidal energy converters – Power performance assessment”).

However, when it comes to test in an estuary that is constrained by high tide and low tide, and more particularly in a macro-tidal environment where the tidal range is high, no existing standard provides a strong enough procedure that would be able to measure machines performance in a similar or at least comparable way versus what could be found in open sea test sites. With respect to this major constraint, SEENEOH and Bureau Veritas have decided to develop together a power curve assessment methodology derived from IEC standards in order to allow SEENEOH users to get their power performance tests certified.

This paper will detail the procedure developed by SEENEOH & Bureau Veritas to perform the power curve assessment on SEENEOH test site as the adaptation from the existing IEC62600-200 and the IEC62600-300 draft. This has been one of the major works achieved within this collaboration. The document issued intends to be used as the basis for a future IEC standard to be submitted in the framework of IEC Technical Committee (TC) 114: Marine Energy – Wave, tidal and other water current converters.

The paper will also describe how SEENEOH has structured and equipped its test site in order to focus on both the integrity assessment of the machines as well as the performance assessment to allow their clients to achieve a recognized power curve certification.

A case study will be developed using the feedbacks of Hydroquest (subject to confidential data and with the authorization of the developer), which is the first turbine installed in the testing site of SEENEOH (commissioned forecasted at the end of December or early January for a period of 12 months).

AWTEC 2018-538

Current & tidal energy converters farm levelized cost of energy optimisation based on reliability assessment

Nicolas Lariviere-Gillet*[1], Loic Klein, Raoul Cabon[1], Gautier Maigret[2], Théo Laraignou[2]

[1]Bureau Veritas Marine & Offshore

[2]Naval Energies

**Corresponding author, nicolas.lariviere-gillet@bureauveritas.com*

With more and more Current & Tidal Energy Converter (CTEC) technologies and worldwide opportunities to develop pilot or commercial projects, the renewable energy industry is now moving forward to achieve cost competitive development. Even if the current electricity price is shown as a bottleneck impacting viability of new commercial projects, CTEC projects remain a priority for many countries as currents and tides are seen as predictable sources of energy. As very limited feedback is currently available, the industry is now looking towards the first projects to be on stream to validate economic models initially based on unstable assumptions. This paper aims at

demonstrating how reliability techniques such as Reliability, Availability & Maintainability (RAM) assessment can allow overall CTEC supply chain to adjust their economic model, to reach a lower Levelized Cost of Energy (LCOE) and design reliable and safe CTEC farm architectures. By using straight from concept stage an adapted RAM tool coupled with an efficient RAM assessment, it will be possible to ensure design has been conducted effectively with respect to production performance as well as optimized maintenance & repair strategy. Later on, by incorporating on a regular basis operational data coming from industry return of experience, companies will be able to capitalize on it for future projects. The paper will first give an overview of the CTEC market outlining the main challenges. Then, based on recent projects the authors have been involved with, it will detail the reliability methodology applied to ensure the profitability of such innovative developments. This second section will focus on the key parameters and assumptions to be considered in order to assess production availability of the full CTEC architecture and then LCOE in the most appropriate manner. Finally, after having pointed out the ins and outs of RAM analyses, a case study will be developed to illustrate and quantify the benefits of the proposed approach.

AWTEC 2018-541

Multi-year assessment of Reynolds stress and turbulent kinetic energy at the European Marine Energy Centre in the absence of waves

Gareth Wakelam*, Brian G. Sella, Vengatesan Venugopal

Institute for Energy Systems, The School of Engineering, The University of Edinburgh, Mayfield Road, EH9 3BF, Edinburgh, United Kingdom.

**Corresponding author, g.wakelam@ed.ac.uk*

To enable accurate prediction of performance, loading and lifetime fatigue, the operating environment of tidal stream turbines must be comprehensively characterised over a range of seasons and tidal cycles. The met-ocean dataset acquired at the European Marine Energy Centre (EMEC), UK as part of the Reliable Data Acquisition Platform for Tidal (ReDAPT) project covers a multi-year period with multiple sensor deployments and provides an opportunity to characterise both mean turbulent flow parameters and their statistical properties. Results from the analysis of Reynolds stresses and turbulent kinetic energy density are presented along with corresponding statistical distributions at turbine hub-height. Two distinct methods of calculating turbulent kinetic energy density are compared and the need for accurate determination of turbulence anisotropy is discussed based on the resulting values. Evidence of consistent trends over inflow velocities and vertical position in the water column is presented, and ongoing work to quantify these trends described.

AWTEC 2018-542

Annex IV State of the Science - sharing what we know about environmental effects of marine renewable energy development internationally

Andrea Copping*

Pacific Northwest National Laboratory

**Corresponding author, andrea.copping@pnnl.gov*

Early deployments of wave and tidal energy projects are providing information on environmental effects of the devices, moorings, and power cables; these data will help inform later deployments and guide regulatory decisions as the industry moves towards the commercial scale. However, there is still considerable uncertainty about many potential interactions of devices and systems with the marine environment that concern regulators and stakeholders.

Overall risks to the marine environment have been investigated from single marine renewable energy (MRE) devices, and larger arrays. Annex IV, an initiative under the Ocean Energy Systems, has produced a report on the State of the Science for Environmental Effects of MRE development. The final report was published in April 2016 and is available online at http://tethys.pnnl.gov/publications/state-of-the-science-2016. Research and monitoring results

since the report publication have been added to the overall picture of potential environmental effects. Effects highlights and significant findings will be discussed, including a look at many of the interactions of MRE devices with marine animals and habitats that are slowing permitting (consenting) processes. This paper will also look at the overall risk from MRE devices, and how we can move forward in the face of considerable scientific uncertainty.

AWTEC 2018-543

Automated system for marine environmental and technical monitoring

Francis James Corpuz[1], Charles Ng[2], Marianne Eleanor Catanyag*[1], Ajay Vignesh Usha Sekar[1],
[1]OceanPixel Pte Ltd

[2]Efficient Network International (Singapore) Pte Ltd

**Corresponding author, maan@oceanpixel.org*

Efficient Network International (Singapore) Pte Ltd, together with its partners, OceanPixel Pte Ltd (Singapore) and Aquatera Ltd (United Kingdom), is working on a project, "Automated System for Marine Environmental and Technical Monitoring," with initial application around tidal turbine monitoring. The solution comprises of an automated remote data collection and transmission system with cloud-based data storage and processing and with archival system of reports for future reference.

Various sensors (flow sensors, proximity sensors) will be integrated into a camera system (with custom image processing applied) giving the system situational awareness (e.g., collision detection and prediction, etc.) With the advent of the new automated system, sensor data can be remotely transmitted from the project site into a cloud-based server for storage and processing. With this development, there will be significant improvements in how data is gathered, analyzed (either automatically or semi-automatically), transmitted and stored.

Ultimately, this Project will result in significant cost savings for marine energy industry whilst helping reduce scientific uncertainty regarding the greatest environmental challenges facing the emerging global ocean energy sector.

LIST OF CONTRIBUTED POSTERS

AWTEC 2018-282

Validation and update of the hybrid tidal system

Sheng Deng*, Carl Byrne, Allan Mason-Jones

Cardiff Marine Energy Research Group (CMERG), Cardiff School of Engineering, Cardiff University, Wales.

**Corresponding author, dengs2@cardiff.ac.uk*

AWTEC 2018-327

Design and analysis of segmented permanent-magnet transverse-flux tube linear synchronous generator

Qiu Shuheng*[1], Wang Haifeng[2]

[1]Institute of Electrical Engineering, Chinese Acamdey of Science, No.6 Beiertiao, Zhongguancun, Haidian, Beijing, China.

[2]University of Chinese Academy of Sciences, No.19(A) Yuquan Road, Shijingshan District, Beijing, P.R.China.

**Corresponding author, qiushuheng@mail.iee.ac.cn*

AWTEC 2018-402

OIST wave energy converter monitoring system for Maldives Island experiment

Hideki Takebe*, Katsutoshi Shirasawa, Jun Fujita, Shuji Misumi and Tsumoru Shintake

Shintake Unit, Okinawa Institute of Science and Technology (OIST), Tancha 1919-1, Onna-son Okinawa, 904-0495 Japan.

Corresponding author, hideki.takebe@oist.jp

AWTEC 2018-403

Submerged heaving and pitching flat plate - combined wave attenuation and WEC

Andrea Mueller*[1], Emre N. Otay[2]

[1]Department of Civil Engineering, NUAA, Nanjing, 210016, China.

[2]Department of Civil Engineering, Boğaziçi University, Istanbul, 34342, Turkey.

Corresponding author, andrea.mueller@nuaa.edu.cn

AWTEC 2018-420

Optimal design of vertical axis turbine using direct-forcing immersed boundary method

Jason Chao-Ching Kao[1], Ming-Jyh Chern*[1], Nima Vaziri[2]

[1]Department of Mechanical Engineering, National Taiwan University of Science and Technology, 43 Sec. 4 Keelung Road, Taipei 10607, Taiwan.

[2]Department of Physics, Islamic Azad University,Karaj Branch, Karaj, Iran.

Corresponding author, mjchern@mail.ntust.edu.tw

AWTEC 2018-440

Wave energy prize testing at Carderock's Maneuvering and Seakeeping (MASK) Basin

Budi Gunawan*[1], Ann Dallman[1], Vincent S. Neary[1], Frederick Driscoll[2], Dale Scott Jenne[2], Robert Thresher[2]

[1]Sandia National Laboratories, PO BOX 5800 Albuquerque, NM, 87185, USA.

[2]National Renewable Energy Laboratory, 15013 Denver West Parkway, Golden, CO 8040, USA.

Corresponding author, bgunawa@sandia.gov

AWTEC 2018-453

Analysis of surface current variation observed with HF-radar in the coastal water off the Sihwa Tidal Power Plant

Hyo-Keun Kwon*[1], Heegon Kim[1], Yongho Lee[2], SongYi Lee[2]

[1]Sihwa Tidal Power Plant Office, Korea Water Resources Corporation, 1927, Daebuhwanggeum-ro, Danwon-gu, Ansan-si, Gyeonggi-do, South Korea.

[2]Division of Mechanical Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-Gu, Busan 49112, South Korea.

Corresponding author, hkkwon@kwater.or.kr

AWTEC 2018-471

Simulation and experiment of the low-speed direct-drive generator for Kuroshio current energy

Po-Yu Chen*, Kung-Yen Lee, Yi-Wen Juan, Jia-Han Li, Forng-Chen Chiu

Department of Engineering Science and Ocean Engineering, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 10617, Taiwan.

**Corresponding author, r05525112@ntu.edu.tw*

AWTEC 2018-483

CFD Analysis of a 5kW marine current turbine and diffuser system

In Cheol Kim*, Young Ho Lee

Division of Mechanical Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-Gu, Busan 49112, South Korea.

**Corresponding author, kic3645@kmou.ac.kr*

AWTEC 2018-494

Methodology of mooring analysis for the U-tube type FWEC

Byung Ha Kimm[1], Mohammed Asid Zullah[1], Young Ho Lee*[2]

[1]Graduate school Department of Mechanical Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-Gu, Busan 606-791, South Korea.

[2]Division of Mechanical Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-Gu, Busan 49112, South Korea.

**Corresponding author, qudgktop@gmail.com*

AWTEC 2018-527

Tidal wave energy large scale conversion technology

Md. Moniruzzaman*

Power Grid Company of Bangladesh Ltd., Dhaka, Bangladesh.

**Corresponding author, mmzbabu@gmail.com*

AWTEC 2018-532

The development of interactive ocean energy education modules

Pai-Chen Guan*, Wei-Lun Lin, Wen-Kai Shih, Wen-Hsuan Chang, Yan-Ling Lu, Jia-Syuan Li

Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University, 2 Pei-Ning Road, Keelung 20224, Taiwan.

**Corresponding author, paichen@ntou.edu.tw*

AWTEC 2018-533

Numerical simulation of wave-induced oscillation in a circular open caisson by OpenFOAM

Yan-Xiang Lin, Da-Wei Chen, Jiahn-Horng Chen*

Department of Systems Engineering and Naval Architecture, National Taiwan Ocean University, 2 Pei-Ning Road, Keelung 20224, Taiwan.

**Corresponding author, b0105@mail.ntou.edu.tw*

AWTEC 2018-534

Applications of the generalized finite difference method to three-dimensional numerical wave flume

Chia-Ming Fan*, Chi-Nan Chu

Department of Harbor and River Engineering, National Taiwan Ocean University, 2 Pei-Ning Road, Keelung 20224, Taiwan.

**Corresponding author, cmfan@ntou.edu.tw*

AWTEC 2018-545

International standards and certification for marine energy converters

Bill Staby*

Resolute Marine Energy, Inc., 3 Post Office Square, 3rd floor, Boston, MA 02109

**Corresponding author, wstaby@resolutemarine.com*