6th Asia-Pacific Forum on Renewable Energy
Project Progress Seminar of National Natural Science Foundation of China

Guide Book

HOSTED BY: Chinese Society of Engineering Thermophysics (CSET)
National Natural Science Foundation of China (NSFC)
Korean Society for New and Renewable Energy (KSNRE)

ORGANIZED BY: Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC)
Guangdong University of Technology (GDUT)

CO-ORGANIZED BY: Korea Institute of Energy Research(KIER)
China-Carriada Joint Centre on BioEnergy Research and Innovation(C-CJCBERI)
Guangzhou Association for Science & Technology (GZAST)

Guangzhou, China
November 9-12, 2016
About GIEC

Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC), was founded in 1978, of which the predecessor was known as Guangdong Geothermal Energy Research Laboratory. In 1998, the institute was determined as the base institute of high-tech research and development by CAS.

GIEC has been fully devoted into the R&D of new energy and renewable energy, such as biomass energy, solar energy, geothermal energy, ocean energy, natural gas hydrate and etc. Besides, energy conservation, environmental protection technologies and energy strategy research are also paid great attention in recent years.

In response to the needs of national energy strategic development, the institute sets up two important breakthrough targets in the period of 2011 to 2015. They are large scale & efficient biomass energy utilization and R&D of distributed renewable energy systems respectively. Moreover, natural gas hydrate exploitation and storage, large-scale power generation by using ocean and geothermal energy, solar functional materials, low-carbon development strategies, are also determined as the important incubation R&D areas.

By the end of 2016, there are 408 staffs including 141 senior researchers. 12 members were selected to CAS “Hundred Talents Program”, and one of them was awarded “National Outstanding Young Scientists Grants”. As one of the approved academic degree granting organizations, GIEC has been qualified to offer PhD Program on Power Engineering & Engineering Thermophysics, and Master Programs on Fluid Machinery and Engineering, Engineering Thermophysics, Environmental Engineering, Chemical Engineering, Materials Physics and Chemistry, and Marine Geology. In addition, the institute also has one post-doctoral research station. There are 161 postgraduate students in total.

The institute has gained more than 100 major research accomplishments. Particularly, GIEC has won twice the second prize of the State Sciences and Technology Progress Award in the field of biomass gasification and waste treatment & resource utilization, respectively. Over 440 national invention patents have been authorized. Many of the accomplishments have been industrialized, yielding significant economic and social benefits.

Aiming at international focuses and national demands, the institute has been engaged in numerous cooperative and exchange programs with universities, institutions and companies from more than 20 nations and regions. About 150 academic exchanges and more than 20 cooperation projects are carried out each year.
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Welcome Message

Renewable Energy is inevitable choice of history, as the world now is facing critical issues caused by the use of fossil fuels. The seriousness of the challenge calls upon the international society to work constructively together for the common good. With more than 60% of world’s population and over 40% of world’s energy consumption, the Asia-Pacific region has the largest and fastest-growing markets for clean and renewable energy.

In this regard, Asia-Pacific Forum on Renewable Energy (AFORE) provides a convenient platform for the discussion of renewable energy problems and for finding new ways to solve them. This year we will have AFORE 2016 in Guangzhou. It is the first time that this forum is held in China. We are preparing to make this event as fruitful as it has always been, to provide an excellent platform for people working in renewable energy to exchange their ideas, showcase research results, establish network and develop a new vision for the cooperative future of the renewable energy in Pacific-Asia area. The program consists of plenary talks, keynote speeches, oral sessions, posters, special sessions, and renewable energy site tour.

Guangzhou lies in southern China. It is the capital city and the political, economic and scientific center of Guangdong Province. With a long history of over 2200 years, Guangzhou is known as “the millennium-old capital of commerce”, “the best place in China for food”, “home of fruit” and “shopping paradise”. AFORE 2016 will provides a splendid opportunity for you to pay a visit to the city of Guangzhou.

On behalf of the organizing committee, I cordially welcome you to AFORE 2016 to be held during November, 2016.

Your participation will make AFORE 2016 more special and I expect to see you all in beautiful Guangzhou.

Prof. Longlong MA
Organizing Committee Chair of AFORE 2016
Committees

Forum Honorary Chair
Prof. Jianzhong XU (Former President, Chinese Society of Engineering Thermophysics, China)
Prof. Yong CHEN (Vice-President, Chinese Society of Engineering Thermophysics, China)
Prof. Jinsoo SONG (Professor, Silla University, Korea)

Forum Chair
Prof. Hongguang JIN (President, Chinese Society of Engineering Thermophysics, China)
Prof. Young-Ho LEE (President, Korean Society for New and Renewable Energy, Korea)

Forum Co-chairs
Prof. Longlong MA (President, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)
Prof. Xin CHEN (President, Guangdong University of Technology, China)
Prof. Keewoo LEE (President, Korea Institute of Energy Research, Korea)
Prof. Xiaotao BI (Professor, University of British Columbia, Canada)

International Advisory Committee

Chair
Prof. Yong CHEN (Vice-President, Chinese Society of Engineering Thermophysics, China)

Co-chair
Prof. Kyung Seop HAN (Pohang University of Science and Technology, Korea)

Members
Dr. Rafiuddin M. AHMED (University of South Pacific, Fiji)
Prof. Guangming CHEN (Zhejiang University, China)
Prof. Ying CHEN (Guangdong University of Technology, China)
Prof. Johnny C.L. CHAN (City University of Hong Kong, China)
Prof. Jing DING (SUN YAT-SEN University, China)
Prof. Liejin GUO (Xi’an Jiaotong University, China)
Dr. S.D.G.S.P. GUNAWARDANE (University of Peradeniya, Sri Lanka)
Prof. Yong HAO (Institute of Engineering, Thermophysics, Chinese Academy of Sciences, China)
Prof. Kyung Seop HAN (Pohang University of Science and Technology, Korea)
Mr. B. JIGJID (president of Mongolian Society of Asia Super Grid, Mongolia)
Prof. Kosuke KUROKAWA (Japan Council for Renewable Energy, Japan)
Prof. Xiaosen LI (Guangzhou Institute of Energy, Chinese Academy of Sciences, China)
Prof. Young-Ho LEE (Korea Maritime & Ocean University, Korea)
Prof. Gento MOGI (University of Tokyo, Japan)
Prof. Jinsoo SONG (Silla University, Korea)
Prof. Ali SAYIGH (Chairman of World Renewable Energy Network, U.K)
Prof. Bholu THAPA (Kathmandu University, Nepal)
Prof. Zhifeng WANG (Institute of Electrical Engineering, Chinese Academy of Sciences, China)
Prof. Ruzhu WANG (Shanghai Jiao Tong University, China)
Prof. Yongping YANG (North China Electric Power University, China)
Prof. Chunde YAO (Tianjin University, China)
Prof. Hyungkee YOON (Korea Maritime & Ocean University, Korea)
Prof. Tianshou ZHAO (Hong Kong University of Science and Technology, China)
Prof. Yangjun ZHANG (Tsinghua University, China)
Prof. Mingming ZHANG (Institute of Engineering Thermophysics, Chinese Academy of Sciences, China)

Technical Committee

Chair
Prof. Longlong MA (Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)

Co-Chair
Prof. Jin-Suk LEE (Korea Institute of Energy Research, Korea)

Members
Prof. Senlin CHEN (Wuhan University, China)
Prof. YoungDo CHOI (Mokpo National University, Korea)
Prof. Yanjun DAI (Shanghai Jiao Tong University, China)
Prof. Eunnyeong HEO (Seoul National University, Korea)
Dr. Ou-sam JIN (Korea District Heating Corporation, Korea)
Prof. Chul Hee JO (Inha University, Korea)
Dr. SungSeop KEE (Korea Institute of Energy Technology Evaluation and Planning, Korea)
Prof. Xiaokang LAI (China Electric Power Research Institute, China)
Prof. Deqing LIANG (Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)
Prof. Xiaofeng LIU (Chengdu Institute of Biology, Chinese Academy of Sciences, China)
Prof. Jang-Ho LEE (Kunsan University, Korea)
Dr. SangHoon LEE (Green Energy Strategy Institute, KSNRE, Korea)
Dr. TaeWon LEE (Posco Energy, Korea)
Dr. Yoonho SONG (Korea Institute of Geoscience and Mineral Resources, Korea)
Prof. Qinghua WU (South China University of Technology, China)
Prof. Rui XIAO (Southeast University, China)
Dr. Changkeun YI (Korea Institute of Energy Research, Korea)
Dr. Jae Ho YUN (Korea Institute of Energy Research, Korea)
Prof. Liang ZHANG (Harbin Institute of Technology, China)
Prof. Jialing ZHU (Tianjin University, China)
Prof. Jinyang ZHENG (Zhejiang University, China)
Prof. Daiqing ZHAO (Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)

Organizing Committee

Chair:
Prof. Longlong MA (Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)

Co-Chair:
Prof. Haibin LI (Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)

Executive Secretary
Prof. Hongying KE (Chinese Society of Engineering Thermophysics, China)
Prof. Yongming SUN (Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China)
General Information & Warm Tips

- **Registration**
  - **Time**: November 8 (Tuesday), 12:00-20:00
    November 9 (Wednesday), 9:00-22:00
  - **Place**: Lobby (1F) in Huatai Hotel

- **Registration Fee**

<table>
<thead>
<tr>
<th></th>
<th>Registration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular participant</td>
<td>US $600 (RMB 3900)</td>
</tr>
<tr>
<td>Student</td>
<td>US $200 (RMB 1300)</td>
</tr>
</tbody>
</table>

- **Forum Service**

<table>
<thead>
<tr>
<th>Group Name</th>
<th>Contact Person</th>
<th>Tel.</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Coordinator</td>
<td>Ms. Ying CHEN</td>
<td>86-13602873181</td>
</tr>
<tr>
<td></td>
<td>Ms. Yu BAI</td>
<td>86-13922795051</td>
</tr>
<tr>
<td>Reception group</td>
<td>Ms. Gaixiu YANG</td>
<td>86-18028041990</td>
</tr>
<tr>
<td></td>
<td>Mr. Xiangrong LUO</td>
<td>86-18028656652</td>
</tr>
<tr>
<td>Registration group</td>
<td>Ms. Shuna LIU</td>
<td>86-13678981515</td>
</tr>
<tr>
<td></td>
<td>Mr. Zhi YANG</td>
<td>86-18011886871</td>
</tr>
<tr>
<td>Forum on-site group</td>
<td>Ms. Fengyun WU</td>
<td>86-13926118627</td>
</tr>
<tr>
<td></td>
<td>Mr. Jianyong CHEN</td>
<td>86-13544552233</td>
</tr>
<tr>
<td>Catering group</td>
<td>Ms. Minren HONG</td>
<td>86-13580550704</td>
</tr>
<tr>
<td>News group</td>
<td>Ms. Chao XU</td>
<td>86-15820228650</td>
</tr>
</tbody>
</table>
◆ Forum Meal

- Welcome Banquet
  Date: November 10 (Thursday)
  Time: 18:00
  Place: Banquet hall on 2F

- Buffet
  Time: Breakfast 7:00-9:00
         Lunch  12:00-13:00
         Dinner 18:00-19:00
  Place: Banquet hall on 2F

◆ Accommodation

Huatai Hotel (华泰宾馆，先烈南路)

Address: 23 South Xianlie Road, Yuexiu District, Guangzhou 510060 China;
Tel: 86-20-87789888
Distance from the airport: 35 km (RMB 130 fare by taxi).

<table>
<thead>
<tr>
<th>Room Type</th>
<th>Room Price (including breakfast)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deluxe Twin Room</td>
<td>RMB 380</td>
</tr>
<tr>
<td>Business Single Room</td>
<td>RMB 590</td>
</tr>
<tr>
<td>Deluxe Suite</td>
<td>RMB 1230</td>
</tr>
<tr>
<td>Business Suite</td>
<td>RMB 1630</td>
</tr>
</tbody>
</table>

◆ Warm Tips

⚠️ The group photo is arranged after the opening ceremony. Please follow the instructions of the staff. Watch out for your safety and your belongings. After the photo, please return back to the meeting hall for the plenary speech session.

⚠️ Please give us your copy of PPT on the registration desk. If you need to temporarily change your report content or adjust the reporting order, please contact our staff as soon as possible in order to make timely adjustment.

⚠️ The Representative card will be provided to each participant. If it gets lost during the meeting, please contact our staff.
## Program at a glance

### Opening Ceremony

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Arrangement</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thur. 10 Nov.</td>
<td>9:00-9:55</td>
<td>Opening Ceremony</td>
<td>Main Hall, 3F</td>
</tr>
</tbody>
</table>

### Plenary Session & Keynote Session

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Arrangement</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thur. 10 Nov.</td>
<td>10:10-12:00</td>
<td>Plenary Session</td>
<td>Main Hall, 3F</td>
</tr>
<tr>
<td>Thur. 10 Nov.</td>
<td>13:30-15:10</td>
<td>Keynote Session</td>
<td>Zhuhai Meeting Room, 6F</td>
</tr>
</tbody>
</table>

### Technical Session

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Topics</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thur. 10 Nov.</td>
<td>15:30-17:15</td>
<td>Topic 1: Energy Storage System</td>
<td>Zhuhai Meeting Room, 6F</td>
</tr>
<tr>
<td>Thur. 10 Nov.</td>
<td>15:30-17:00</td>
<td>Topic 2: Geothermal Energy</td>
<td>Shantou Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>09:00-12:15</td>
<td>Topic 3: Marine Energy &amp; Small Hydro Power</td>
<td>Zhuhai Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>09:00-11:45</td>
<td>Topic 4: Solar Energy</td>
<td>Shantou Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>13:30-15:00</td>
<td>Topic 5: Hydrogen &amp; Fuel Cell</td>
<td>Zhuhai Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>15:15-16:30</td>
<td>Topic 6: Wind Energy</td>
<td>Zhuhai Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>16:30-17:30</td>
<td>Topic 7: Smart Grid</td>
<td>Zhuhai Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>13:30-14:45</td>
<td>Topic 8: Waste Energy &amp; Utilization</td>
<td>Shantou Meeting Room, 6F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>15:00-17:00</td>
<td>Topic 9: Bio-energy</td>
<td>Shantou Meeting Room, 6F</td>
</tr>
</tbody>
</table>

### Special Session

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Topics</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thur. 10 Nov.</td>
<td>15:30-17:30</td>
<td>Special Session I : Promoting New and Renewable Energy Projects in Asia</td>
<td>Meeting Room No.5, 3F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>13:30-15:00</td>
<td>AFORE International Advisory Committee Meeting</td>
<td>Meeting Room No.5, 3F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>09:00-17:00</td>
<td>Special Session II : 8th GIEC-KIER New &amp; Renewable Energy Workshop</td>
<td>Zhongshan Meeting Room, 6F</td>
</tr>
</tbody>
</table>

### Poster Session

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Activities</th>
<th>Venue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thur. 10 Nov.</td>
<td>12:00-13:30</td>
<td>Lunch &amp; Poster Viewing</td>
<td>Poster Exhibition Hall, 3F</td>
</tr>
<tr>
<td>Thur. 10 Nov.</td>
<td>17:30-18:00</td>
<td>Poster Viewing</td>
<td>Poster Exhibition Hall, 3F</td>
</tr>
<tr>
<td>Fri. 11 Nov.</td>
<td>12:00-13:30</td>
<td>Lunch &amp; Poster Viewing</td>
<td>Poster Exhibition Hall, 3F</td>
</tr>
</tbody>
</table>
Floor Plan

3层平面图
3rd Floor

6层平面图
6th Floor
# Opening Ceremony

**Thursday / 2016-11-10 / 9:00-9:55**  
Place: Main Hall, 3F  
Chair: Prof. Yongping YANG,  
President of North China Electric Power University, China

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:00</td>
<td>Welcome by Conference Chair</td>
</tr>
<tr>
<td></td>
<td><strong>Prof. Hongguang JIN</strong></td>
</tr>
<tr>
<td></td>
<td>President of Chinese Society of Engineering Thermophysics</td>
</tr>
<tr>
<td></td>
<td>Academician, Chinese Academy of Sciences, China</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:05</td>
<td>Greeting</td>
</tr>
<tr>
<td></td>
<td><strong>Prof. Jianzhong XU</strong></td>
</tr>
<tr>
<td></td>
<td>Former President of Chinese Society of Engineering Thermophysics</td>
</tr>
<tr>
<td></td>
<td>Academician, Chinese Academy of Sciences, China</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:10</td>
<td>Congratulatory Message</td>
</tr>
<tr>
<td></td>
<td><strong>Prof. KyungSeop HAN</strong></td>
</tr>
<tr>
<td></td>
<td>Pohang University of Science and Technology,</td>
</tr>
<tr>
<td></td>
<td>Former president of Korean Society for New and Renewable Energy, Korea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:15</td>
<td>Welcome Message from GIEC</td>
</tr>
<tr>
<td></td>
<td><strong>Prof. Longlong MA</strong></td>
</tr>
<tr>
<td></td>
<td>President of Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:20</td>
<td>Welcome Message from GDUT</td>
</tr>
<tr>
<td></td>
<td><strong>President</strong></td>
</tr>
<tr>
<td></td>
<td>President of Guangdong University of Technology, China</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:25</td>
<td>Message from NSFC</td>
</tr>
<tr>
<td></td>
<td><strong>Mr. Tao LIU</strong></td>
</tr>
<tr>
<td></td>
<td>Director of Department of Engineering &amp; Material Sciences, National Natural Science Foundation of China (NSFC), China</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>9:30</td>
<td>The Overall Performance of 2016 NSFC’s Funding and Management</td>
</tr>
<tr>
<td></td>
<td><strong>Mr. Jun Ji</strong></td>
</tr>
<tr>
<td></td>
<td>Director of Department of Engineering &amp; Material Sciences, National Natural Science Foundation of China (NSFC), China</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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</thead>
<tbody>
<tr>
<td>9:55 - 10:10</td>
<td>Group Photo &amp; Tea Break</td>
</tr>
</tbody>
</table>
# Forum Program

## Plenary Session

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
<th>Institution/University, Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:10</td>
<td>History of Renewable Energy Cooperation in Asia</td>
<td>Prof. JinSoo SONG, Silla University, Former President of Korean Society for New and Renewable Energy, Korea</td>
<td></td>
</tr>
<tr>
<td>10:35</td>
<td>Heat Transfer in Pulsed Fluidized Bed of Biomass</td>
<td>Prof. Xiaotao BI, University of British Columbia, Academician of Canadian Academy of Engineering, Canada</td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>Study on the Key Scientific Problems of High-Efficiency Photon-thermal Conversion, Heat Transfer, Heat Storage and Novel Power Cycles in the Concentrating Solar Power System</td>
<td>Prof. Yaling HE, Xi’an Jiaotong University, Academician of Chinese Academy of Sciences, China</td>
<td></td>
</tr>
<tr>
<td>11:25</td>
<td>Production of Aviation Biofuel from Biomass by Aqueous-phase Catalysis</td>
<td>Prof. Longlong MA, President of Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
<td></td>
</tr>
</tbody>
</table>

## Keynote Session

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
<th>Institution/University, Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>13:30</td>
<td>The Policy and Industry of Renewable Energy in Korea</td>
<td>Prof. Hyungkee YOON, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>13:50</td>
<td>Renewable Energy Development in Mongolia</td>
<td>Prof. Dugarjav BAYASGALAN, National University of Mongolia, Mongolia</td>
<td></td>
</tr>
<tr>
<td>14:10</td>
<td>Marine Energy - UK &amp; European Innovation</td>
<td>Mr. Craig MORLEY, British Consulate-General Guangzhou, U.K.</td>
<td></td>
</tr>
<tr>
<td>14:30</td>
<td>Heat Storage Technologies for Waste Heat Utilization for Low Carbon Processes</td>
<td>Prof. Noriyuki KOBAYASHI, Nagoya University, Japan</td>
<td></td>
</tr>
<tr>
<td>14:50</td>
<td>Reduction of PV module operating temperature through hybridization of solar collectors</td>
<td>Prof. Christophe MENEZO, University of Savoie Mont-Blanc, France</td>
<td></td>
</tr>
</tbody>
</table>

**15:10 - 15:30 Tea Break**
### Technical Session

**Thursday / 2016-11-10 / 15:30-17:15**  
**Place:** Zhuhai Meeting Room, 6F

**Topic 1: Energy Storage System**

**Chair:** Prof. Haisheng CHEN  
*Institute of Engineering Thermophysics, Chinese Academy of Sciences, China*

<table>
<thead>
<tr>
<th>Time</th>
<th>Description</th>
<th>Presenter</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:30</td>
<td>Thermodynamic characteristics of advanced compressed air energy storage system</td>
<td>Dr. Huan GUO</td>
<td><em>Institute of Engineering Thermophysics, Chinese Academy of Sciences, China</em></td>
</tr>
<tr>
<td>15:45</td>
<td>Market-Oriented Optimal Scheduling of Hybrid Wind-Battery Energy Storage System Based on Wind Forecasting</td>
<td>Prof. Hwachang SONG</td>
<td><em>Seoul National University of Science and Technology, Korea</em></td>
</tr>
<tr>
<td>16:00</td>
<td>Research on the Influence of Balancing Parameters on Battery Capacity Inconsistency Reduction</td>
<td>Dr. Jie LV</td>
<td><em>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</em></td>
</tr>
<tr>
<td>16:15</td>
<td>Operation Strategy of Energy Storage System for Frequency Regulation Service in Microgrid</td>
<td>Dr. Yong Sung KIM</td>
<td><em>Hanyang University, Korea</em></td>
</tr>
<tr>
<td>16:30</td>
<td>The Promoting Effect of Hydrophilic Materials on the Reaction Performance of LiOH•H₂O for Low Temperature Chemical Heat Storage</td>
<td>Dr. Shijie LI</td>
<td><em>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</em></td>
</tr>
<tr>
<td>16:45</td>
<td>Experimental Study of Energy Charging and Discharging Characteristics of Small Scale Hybrid Energy Storage System</td>
<td>Dr. Ji-Hoon PARK</td>
<td><em>Korea Maritime and Ocean University, Korea</em></td>
</tr>
<tr>
<td>17:00</td>
<td>An Analysis on Heat Transfer Characteristics of Multi-Component Molten Salt</td>
<td>Dr. Ha Neol KIM</td>
<td><em>Korea Institute of Energy Research, Korea</em></td>
</tr>
<tr>
<td>Time</td>
<td>Title</td>
<td>Presenter</td>
<td>Institution</td>
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<tr>
<td>15:30</td>
<td>Performance Analysis of Water-Source Heat Pump System Under the Numerous Operation Conditions of Pumps and Buffer Tank Temperature</td>
<td>Dr. Sanghoon Cha</td>
<td>K-water Institute, Korea</td>
</tr>
<tr>
<td>15:45</td>
<td>Analysis of 2D Flow Modeling in Fracture of Porous Medium</td>
<td>Dr. Xianbo Nian</td>
<td>Shandong University, China</td>
</tr>
<tr>
<td>16:00</td>
<td>Geothermal Utilization and Development in China</td>
<td>Dr. Chao Luo</td>
<td>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>16:15</td>
<td>Engineering chart for thermal performance of cast-in-place energy pile considering thermal resistance</td>
<td>Dr. Kwanggeun Oh</td>
<td>Korea University, Korea</td>
</tr>
<tr>
<td>16:30</td>
<td>A novel flow-resistor network model for characterizing enhanced geothermal system heat reservoir</td>
<td>Dr. Wenjing Cao</td>
<td>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>16:45</td>
<td>Thermal performance of energy slab equipped with horizontal ground heat exchanger</td>
<td>Dr. Seokjae Lee</td>
<td>Korea University, Korea</td>
</tr>
<tr>
<td>Time</td>
<td>Topic</td>
<td>Presenter &amp; Affiliation</td>
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<tr>
<td>9:00</td>
<td>On the Simulation of Regular Waves in a Numerical Wave Tank</td>
<td>Prof. Young-Ho LEE, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>9:15</td>
<td>Unit structure design and test of a floating solar desalination film</td>
<td>Dr. Qiu-Shi WANG, Beijing Institute of Technology, China</td>
<td></td>
</tr>
<tr>
<td>9:30</td>
<td>A Study on the Mooring System for U-Tube Type Floating Wave Energy Converter</td>
<td>Dr. Hui Seong JEONG, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>9:45</td>
<td>Backward bent duct buoy wave energy conversion technology and perspective in China</td>
<td>Prof. Bijun WU, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>Numerical Analysis of the Performance of A Pelton Turbine for the Pumped-Hydro Combined Compressed Air Energy Storage (CAES)</td>
<td>Dr. Tuvshintugs BATBELEG, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>10:15</td>
<td>Performance Analysis Of Micro-Class Francis Turbine By Cfd</td>
<td>Dr. Enkhtaivan BUTMUNK, Department of Mechanical Engineering, Graduate School, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>10:30</td>
<td>Tea Break</td>
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<tr>
<td>10:45</td>
<td>Experimental Analysis on the Positioning of a Counter Rotation Tidal Current Turbine Within Duct</td>
<td>Dr. In Cheol KIM, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>11:00</td>
<td>A Methodology Study of U-tube Type Floating Wave Energy Converter</td>
<td>Dr. Byung Ha KIM, Korea Maritime &amp; Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>11:15</td>
<td>A Study of a Cross-flow Air Turbine With Orifice for OWC Wave Energy Converter by CFD and Experiment</td>
<td>Dr. Hong-Goo KANG, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>11:30</td>
<td>Estimate of tidal energy resources in Cuiheng New District, Zhongshan City</td>
<td>Dr. Yunqiu ZHANG, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
<td></td>
</tr>
<tr>
<td>11:45</td>
<td>Study on Cross Flow Air Turbine Performance Characteristics for Oscillating Water Column Plants</td>
<td>Dr. Joji WATA, Korea Maritime and Ocean University, Korea</td>
<td></td>
</tr>
<tr>
<td>12:00</td>
<td>Numerical Study of A Novel Flex Mooring System of The Floating Wave Energy Converter in Ultra-Shallow Water and Experimental Validation</td>
<td>Dr. Shuo HUANG, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
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<td>9:00</td>
<td>Feasibility of Hydrogen Production from Solar in MEMA Region</td>
<td>Gento Mogi, The University of Tokyo</td>
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<td><strong>Topic 4: Solar Energy</strong></td>
<td><strong>Chair: Prof. Christophe MENEZO</strong></td>
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<td>University of Savoie Mont-Blanc, France</td>
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<tr>
<td>9:15</td>
<td>Potential Analysis of Solar Thermal Application for Industrial Process Heating in China</td>
<td>Prof. Yanjun DAI, Shanghai Jiao Tong University, China</td>
<td></td>
</tr>
<tr>
<td>9:30</td>
<td>Effects of Nano Particles attached onto a Heat Transfer Surface in the Thermal-Hydraulic System using an Oxidized Graphene Nano fluid</td>
<td>Dr. Young-Hun KIM, Jeju National University, Korea</td>
<td></td>
</tr>
<tr>
<td>9:45</td>
<td>A Sage-Based Stirling Engine Simulation Model for New Energy Application</td>
<td>Dr. Wenlian YE, Xi'an Jiaotong University, China</td>
<td></td>
</tr>
<tr>
<td>10:00</td>
<td>Thermodynamic Evaluation of A Novel Solar-Biomass Hybrid Power Generation System With Zero CO₂ Emission</td>
<td>Dr. Zhang BAI, University of Chinese Academy of Sciences, China</td>
<td></td>
</tr>
<tr>
<td>10:15</td>
<td>Design and Thermal Performances of a Scalable Linear Fresnel Reflector Solar System</td>
<td>Dr. Jifu SHI, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
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<td>10:30</td>
<td>Tea Break</td>
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<tr>
<td>10:45</td>
<td>Modeling of Radiation Absorption in Solar Photocatalytic Reactors</td>
<td>Dr. Junyi HOU, Xi'an Jiaotong University, China</td>
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<tr>
<td>11:00</td>
<td>Experimental Study on Direct Solar Concentrating Hydrogen Production System by Photocatalytic Water Splitting</td>
<td>Dr. Qingyu WEI, Xi'an Jiaotong University, China</td>
<td></td>
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<tr>
<td>11:15</td>
<td>Assessment of GHG reduction potential from solar assisted carbon capture and storage using life cycle approach</td>
<td>Dr. Junyao WANG, Tianjin University, China</td>
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<tr>
<td>11:30</td>
<td>Performance Investigation of A Novel Distributed Energy System Integrated A Solar Thermochemical Process With Chemical Recuperation</td>
<td>Dr. Taixiu LIU, University of Chinese Academy of Sciences, China</td>
<td></td>
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<tr>
<td>11:45</td>
<td>Performance Analysis of PETE/Methane Reforming Hybrid Solar Power Generation System</td>
<td>Dr. Wenjia LI, University of Chinese Academy of Sciences, China</td>
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<td>Time</td>
<td>Topic</td>
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<tr>
<td>13:30</td>
<td>Gas distribution by a modular manifold with multi-stage channels for a 16-unit fuel cell stack</td>
<td><strong>Dr. Jun DONG</strong>, Harbin Institute of Technology (Shenzhen), China</td>
<td></td>
</tr>
<tr>
<td>13:45</td>
<td>Preparation and Application of Various Carbon Composites for Low Temperature Fuel Cell</td>
<td><strong>Dr. Doo-Hwan JUNG</strong>, Korea Institute of Energy Research (KIER), Yonsei University, Korea</td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td>Systematic Control pH for More Hydrogen, A Promising Method That Can’t Be Ignored</td>
<td><strong>Dr. Jun HU</strong>, Xi’an Jiaotong University, China</td>
<td></td>
</tr>
<tr>
<td>14:15</td>
<td>Nanostructured oxygen carriers from air-liquid foam templates for hydrogen production via chemical looping water-splitting</td>
<td><strong>Dr. DeWang ZENG</strong>, Southeast University, China</td>
<td></td>
</tr>
<tr>
<td>14:30</td>
<td>The Experiment Study on the PEM Fuel Cell Reverse Voltage Starting Up at Low Inlet Gas Humidity</td>
<td><strong>Dr. Fengfeng LIU</strong>, Xi’an Jiaotong University, China</td>
<td></td>
</tr>
<tr>
<td>14:45</td>
<td>A Novel Droplet Microfluidic reactor for Photocatalytic Hydrogen production</td>
<td><strong>Dr. Chao WANG</strong>, Guangdong University of Technology, China</td>
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</table>

**15:00 - 15:15**  **Tea Break**

### Topic 6: Wind Energy

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:15</td>
<td>An IDDES Based on a Transition Model and Its Applications</td>
<td><strong>Dr. Ming ZHAO</strong>, Institute of Engineering Thermophysics, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>15:30</td>
<td>Performance Test for the Small Sample of Vertical Axis Wind Turbine Using Digital Wind Tunnel</td>
<td><strong>Dr. Seong-Nam JO</strong>, Kusan National University, Korea</td>
</tr>
<tr>
<td>15:45</td>
<td>Analysis of the Wake behind a Wind Turbine Using a Calculation in Three-Dimensional Parabolic Navier-Stokes Equation</td>
<td><strong>Dr. Byeongho HWANG</strong>, Seoul National University, Korea</td>
</tr>
</tbody>
</table>
16:00 | GORI Demonstration Project of a Pilot Floating Offshore Wind Turbine  
**Prof. Hyunkyoung SHIN**, University of Ulsan, Korea

16:15 | Hierarchical Stability Control Strategy of Autonomous Microgrid With Wind Power  
**Dr. Zhuoli ZHAO**, South China University of Technology, China

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**Topic 7: Smart Grid**

Chair: Prof. Hwachang SONG  
Seoul National University of Science and Technology, Korea

16:30 | State of Charge Balance Strategy Using Coordination Control of AC/DC Hybrid Micro-grids  
**Dr. Dwi Riana ARYANI**, Seoul National University of Science and Technology, Korea

16:45 | System integration and optimal operation of distributed renewable energy generation  
**Dr. Lei HUANG**, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China

17:00 | Improving Power Balance Using PEV Scheduling in Micro-grid  
**Dr. Ho Jun JO**, Hanyang University, China

17:15 | Study on the Optimal Incentive Determination to Compensate User’s Discomfort for Demand Response in the Aspect of Load Aggregator  
**Dr. Yong-Sung KIM**, Hanyang University, China
**Friday / 2016-11-11 /13:30-17:00**  
**Place: Shantou Meeting Room, 6F**

**Topic 8: Waste Energy & Utilization**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
<th>Institution</th>
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<tbody>
<tr>
<td>13:30</td>
<td>Experimental Investigation on Adsorption / Desorption Kinetics in Silica-Gel Enhanced Thermal Conductivity</td>
<td>Dr. Yugo OSAKA, Kanazawa University, Japan</td>
<td></td>
</tr>
<tr>
<td>13:45</td>
<td>Design of A Partial Admission Axial Turbine for Small Scale Supercritical CO2 Power Cycles</td>
<td>Dr. Junhao TU, Tsinghua University, China</td>
<td></td>
</tr>
<tr>
<td>14:00</td>
<td>Thermo-economic Optimization of A Novel Zoetrope Fluid Waste Heat Driven Organic Rankine Cycle</td>
<td>Prof. Xianglong LUO, School of Material and Energy, Guangdong University of Technology, China</td>
<td></td>
</tr>
<tr>
<td>14:15</td>
<td>Application Prospect in the New Energy of Stirling Energy Conversion Technology</td>
<td>Dr. Faduo XU, Lanzhou Institute of Physics, Vacuum Technology and Physics Laboratory, China</td>
<td></td>
</tr>
<tr>
<td>14:30</td>
<td>The Spatial Distribution and Resources Potential Evaluation of “Urban-rural Mine”: A Case Study in Guangdong Province</td>
<td>Dr. Huhetaoli, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
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</tbody>
</table>

**14:45 - 15:00**  
**Tea Break**

**Topic 9: Bio-energy**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
<th>Institution</th>
</tr>
</thead>
<tbody>
<tr>
<td>15:00</td>
<td>Renewable Energy in Bangladesh: Present Status, Vision and Government Strategies</td>
<td>Prof. A. K. M. AHSAN KABIR, Department of Animal Science, Bangladesh Agricultural University (BAU), Bangladesh</td>
<td></td>
</tr>
<tr>
<td>15:15</td>
<td>Current Status and Prospects on Transport Biofuels in Korea</td>
<td>Prof. Jin-Suk LEE, Korea Institute of Energy Research, Korea</td>
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<tr>
<td>Time</td>
<td>Title</td>
<td>Speaker</td>
<td>Institution</td>
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<tr>
<td>15:30</td>
<td>Prediction of Product Distribution and Bio-oil Heating Value from Biomass Fast Pyrolysis Using Artificial Intelligence Models</td>
<td>Dr. Xing CHEN</td>
<td>Southeast University, China</td>
</tr>
<tr>
<td>15:45</td>
<td>Optimization of Three-phase Partitioning process for Lipid Extraction from High Water Content Bio-flocculated Microalgae Biomass for Biodiesel Production</td>
<td>Dr. Md. Asraful Alam</td>
<td>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>16:00</td>
<td>Catalyzed Oxidative Degradation of Lignin Using Dioxygen as the Oxidant in Acetonitrile/Water System</td>
<td>Dr. Chao LIU</td>
<td>Key Laboratory of Energy Thermal Conversion and Control of Ministry of Education, Southeast University, China</td>
</tr>
<tr>
<td>16:15</td>
<td>Production of aviation bio-fuel from lignocellulosic feedstock by aqueous-phase catalysis</td>
<td>Dr. Lungang CHEN</td>
<td>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>16:30</td>
<td>The Performance of Combined Heating and Power System by Biogas Production with Auxiliary of Solar Heating</td>
<td>Dr. Jinping LI</td>
<td>Lanzhou University of Technology, China</td>
</tr>
<tr>
<td>16:45</td>
<td>Selective Oxidation for Removal of Char and Tar from High-temperature Biomass Gasification Gas</td>
<td>Dr. Lin LANG</td>
<td>Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
</tbody>
</table>
### Special Session I

#### Promoting New and Renewable Energy Projects in Asia

**Thursday / 2016-11-10 / 15:30-17:30**
**Place: Meeting Room No.5, 3F**

**Organized by:**
Institute for Global Sustainability (IGS), Yonsei University, Seoul, Korea

**Chair:**
Prof. Tae Yong JUNG, Graduate School of International Studies (GSIS)
Deputy Director, IGS, Yonsei University, Korea

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speakers</th>
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</thead>
<tbody>
<tr>
<td>15:30</td>
<td>Opportunities and Challenges of Decentralized Roof PV Development in Shanghai</td>
<td>Prof. Xin WANG, Tongji University, Shanghai, China</td>
</tr>
</tbody>
</table>
| 15:45 | Cost/Benefit Analysis of Independent Solar Energy with Energy Saving System (ESS) for Small Island Countries: A Case of Maldives | Prof. Tae Yong JUNG, GSIS and Deputy Director, IGS, Yonsei University, Korea
Ms. Junghee HYUN, GSIS, Yonsei University, Korea
Ms. Haein KIM, Wisconsin University, USA |
| 16:00 | The Spill-over Effects of Environmental Policy Instruments over the Renewable Energy Generation among the EU and APP Countries | Dr. Takashi NISHIDA, Horoshima City, Japan
Prof. Shinji KANEKO, Associate Dean, Graduate School for International Development and Cooperation, Hiroshima University, Japan |
| 16:15 | New & Renewable Energy Market and Strategies for Industry Promotion in Korea | Dr. Jiwoon AHN, Korea Energy Economics Institute, Korea
Dr. Hyunje KIM, Korea Energy Economics Institute, Korea |
Mr. Jongwoo MOON, SAIS, Johns Hopkins University, Washington DC, USA |
| 16:45 | The Economic Analysis on Waste to Energy Project: Food Waste Treatment | Prof. Tae Yong JUNG, GSIS, and Deputy Director, IGS, Yonsei University, Korea
Dr. Jihyun SOHN, GSIS, Yonsei University, Korea |
| 17:00 | Floor Discussion (30 mins.)                                           |                                                                                              |
### Special Session II

#### 8th GIEC-KIER New & Renewable Energy Workshop

**Friday / 2016-11-11 / 8:30-17:00**  
**Place: Zhongshan Meeting Room, 6F**

**Organized by:**  
Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China  
Korea Institute of Energy Research, Korea

#### Topic 1: Bio-energy

**Chair:** Prof. Xiuli YIN (GIEC), Prof. Jin-Suk LEE (KIER)

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>8:30</td>
<td>KIER’s R&amp;D works on bio-jet fuel</td>
<td>Prof. Jin-Suk LEE, Korea Institute of Energy Research, Korea</td>
</tr>
<tr>
<td>8:50</td>
<td>Fuel and light alkene production from biomass based syngas</td>
<td>Dr. Chenguang WANG, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>9:10</td>
<td>Nanoparticle engineering approach for efficient bio-energy production</td>
<td>Dr. You-Kwan OH, Korea Institute of Energy Research, Korea</td>
</tr>
<tr>
<td>9:30</td>
<td>Combustion and Heat Release Characteristics of Biogas at Hydrogen and Oxygen Enriched Condition</td>
<td>Dr. Jun LI, Nagoya University, Japan</td>
</tr>
</tbody>
</table>

**9:50-10:10  Tea Break**

**Chair:** Prof. Xinshu ZHUANG (GIEC), Prof. Soon-Chul Park (KIER)

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker</th>
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<tbody>
<tr>
<td>10:10</td>
<td>Development of Microbial Electrolysis Coupled 2-Stage Anaerobic Digestion Process</td>
<td>Prof. Soon-Chul PARK, Korea Institute of Energy Research, Korea</td>
</tr>
<tr>
<td>10:30</td>
<td>Liquid Hot Water Pretreatment of Lignocellulosic Biomass to Enhance Total Sugar Recovery and Enzymatic Digestibility of Cellulose</td>
<td>Dr. Qiang YU, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</td>
</tr>
<tr>
<td>10:50</td>
<td>Optimization of microbial hydrogen production by applying high pressures</td>
<td>Dr. Jeong-geol NA, Korea Institute of Energy Research, Korea</td>
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<td>Time</td>
<td>Session</td>
<td>Speaker</td>
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<tr>
<td>13:30</td>
<td>Hydrogen production from industrial off-gas using by-product iron oxide as an oxygen carrier in chemical looping process</td>
<td><em>Prof. Wonchul CHO, Korea Institute of Energy Research, Korea</em></td>
</tr>
<tr>
<td>13:50</td>
<td>New materials and key technology research of hydrogen energy storage for renewable resources</td>
<td><em>Prof. Changfeng YAN, Guangzhou Institute of Energy Conversion, CAS, China</em></td>
</tr>
<tr>
<td>14:10</td>
<td>Degradation analysis and development of advanced solid oxide fuel cells with high durability</td>
<td><em>Dr. Rak-Hyun SONG, Korea Institute of Energy Research, Korea</em></td>
</tr>
<tr>
<td>14:30</td>
<td>Recent Advance about Microbial Fuel Cell in GIEC</td>
<td><em>Dr. Xiaoying KONG, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</em></td>
</tr>
<tr>
<td>14:50-15:10</td>
<td>Tea Break</td>
<td></td>
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<tr>
<td>15:10</td>
<td>Non-vacuum Processed CIS Solar Cell via Hybrid Ink</td>
<td><em>Dr. Ara CHO, Korea Institute of Energy Research, Korea</em></td>
</tr>
<tr>
<td>15:30</td>
<td>Vanadium Dioxide Thermochromic Smart Window</td>
<td><em>Dr. Xiudi XIAO, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</em></td>
</tr>
<tr>
<td>15:50</td>
<td>Development of salinity gradient power technologies in Korea Institute of Energy Research (KIER)</td>
<td><em>Dr. Namjo JEONG, Korea Institute of Energy Research, Korea</em></td>
</tr>
<tr>
<td>16:10</td>
<td>Research and Open sea tests of 10kW Wave Energy Convertor Sharp Eagle</td>
<td><em>Dr. Songwei SHENG, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China</em></td>
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<tr>
<td>16:30</td>
<td>Floor Discussion (30 mins.)</td>
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AFORE IAC Meeting

AFORE International Advisory Committee Meeting

Afternoon, November 11, 2016
Place: Meeting Room No. 5, 3F
(13:30-15:00)

Organized by:
Chinese Society of Engineering Thermophysics (CSET)
Korean Society for New and Renewable Energy (KSNRE)
Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC)

Chair: Prof. Hongguang JIN, President of Chinese Society of Engineering Thermophysics, China
     Prof. Kyung Seop HAN, Pohang University of Science and Technology, Korea

Participants:
Prof. Jianzhong XU, President of Chinese Society of Engineering Thermophysics, China
Prof. Longlong MA, Guangzhou Institute of Energy Conversion, CAS, China
Prof. Jinsoo SONG, Silla University, Korea
Prof. Young-Ho LEE, Korea Maritime & Ocean University, Korea
Prof. Xiaotao BI, University of British Columbia, Canada
Mr. B. JIGJID, Mongolian Society of Asia Super Grid, Mongolia
Prof. Dugarjav BAYASGALAN, National University of Mongolia
Prof. Hyungkee YOON, Korea Maritime & Ocean University, Korea
Prof. Gento MOGI, University of Tokyo, Japan

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## Poster Session

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| ESS-0005        | Fabrication of A Flexible Ruthenium Oxide/Graphene Electrode for High-Performance Supercapacitor Applications  
Sangeun CHO, Dongguk University, Korea |
| ESS-0007        | Thermal System Analysis of Compressed Air Energy Storage with Pre-cooler  
Long-Xiang CHEN, Kunming University of Science and Technology, China |
| ESS-0011        | Comparative Analysis on Electrochemical Characteristics between Cell-discrimination-based High-power and High-energy Battery pack in Electrochemical-powered Transportation  
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| ESS-0012        | Fabrications of A Flexible Ruthenium Oxide/Graphene Electrode for High-performance Supercapacitor Applications  
Sangeun CHO, Dongguk University, Korea |
| ESS-0013        | Electroforming Enhanced Electrochromic and Supercapacitive Energy Storage Properties in WO3  
Jongmin KIM, Dongguk University, Korea |
| ESS-0016        | Thermal behaviour of pouch battery based on multilayer electro-thermal model  
Mingbiao CHEN, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China |
| ESS-0017        | Research on non-uniform temperature characteristic of large capacity battery pack in parallel  
Fanfei BAI, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China |
### Topic 2: Geothermal Energy

| GE-0001 | The recharge rate increase technical development of the ATES using multi-secondary small diameter well  
**Seongmin PARK**, Corporation of Moum and Naum, Korea |
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**Songwoo PARK**, Korea University, Korea |
| GE-0007 | Estimation of the Energy Consumption and CO₂ Emission of an Open Loop and Closed Loop Ground Source Heat Pump  
**Samuel BOAHEN**, Hanbat National University, Korea |
| GE-0008 | A study on the performance evaluation facility of a ground source heat pump unit  
**Jong Min CHOI**, Hanbat National University, Korea |

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**JoongJin SHIN**, Hydro-power Design & Technology Group, Central Research Institute, KHNP, Korea |
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**Bongkun CHO**, Inha University, Korea |
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**Do Youb KIM**, Inha University, Korea |
| ME-0011 | Guide Wire Maintenance Method for Hat Tidal Current Converter  
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**Chanhoe GOO**, Inha University, Korea |
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**Zhenpeng WANG**, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China |
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**Yaqun ZHANG**, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China |
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Study on an extreme wave in the numerical wave tank for the wave energy utilization

Youlong HUANG, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China

**SHP-0002**

Characteristics Analysis Of Francis Turbine Performance From Experiment Model Test By Different Specific Speeds

Songhoon CHA, K-water Institute, Korea Water Resources Corporation, Korea

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A comparative study on module connections to minimize the degradation of photovoltaic systems due to bird droppings

Yasoon CHOI, Chaeyoung LEE, Pukyong National University, Korea

**SE-0007**

Co3(OH)2(HPO4)2 as novel photocatalyst for water oxidation under visible-light irradiation

Yazhou ZHANG, Xi’an Jiaotong University, China

**SE-0011**

Numerical simulation and wind tunnel test of wind loads on a parabolic trough solar collector based on similarity theory

Moucun YANG, Nanjing Tech University, China

**SE-0012**

Techno-economic analysis of the solar chimney PV/T power plant in Northwest China

Qingjun LIU, Hohai University, China

**SE-0014**

System and Performance Comparison of LFR Solar Absorption Cooling and PV Turbo Cooling

Jongkyu KIM, Korea Institute of Energy Research, Korea

**SE-0015**

Solar Thermal Heating and Seasonal Storage System Operation for Facility Horticulture

Jongkyu KIM, Korea Institute of Energy Research, Korea

**SE-0016**

Improved Rear-Side Passivation by SiNx/SiON Stack Layer for High Voc of n-Type Silicon Solar Cells

Junsin YI, Sungkyunkwan University, Korea

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Yan Qing ZHU, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, China

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Dynamic Simulation of Fuel Cell System via Variation of Operating Parameters

Mooncheong JUNG, Chungnam national university, Korea

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Study on Start-up Protocol of Diesel Reformer Using Hydrogen Peroxide for Subsea Applications

Gwangwoo HAN, Korea Advanced Institute of Science and Technology, Korea

**HFC-0005**

Fluid FlowAnalysis of Porous Flow Fields for Advanced Electrochemical System Applications

Joo-Hee PARK, Hanyang university, Korea
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Xiaowei DENG, University of Hong Kong, China |
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Bokyung GOO, Sangmyung University, Korea |
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BeomJun PARK, Sangmyung University, Korea |
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Deockho KIM, Sangmyung University, Korea |
| WE-0008 | Stress Based Reliability Analysis of Offshore Wind Turbine Support Structure  
GeeNam LEE, Kunsan National University, Korea |
| WE-0009 | RELIABILITY ANALYSIS OF OFFSHORE WIND TURBINES WITH SUCTION BUCKET  
Young Jin KIM, Kunsan University, Korea |
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Dong GUO, Hohai University, China |
| WE-0013 | reliability analysis of offshore wind turbines with suction bucket  
Young Jin KIM, Kunsan University, Korea |
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GeeNam LEE, Kunsan National University, Korea |
| WE-0015 | STRUCTURAL OPTIMIZATION FOR 5MW CLASS OFFSHORE WIND TURBINE BLADE USING RESPONSE SURFACE METHOD  
Yun-Jung JANG, Kunsan National University, Korea |
| WE-0016 | Development Of The Wind Turbine System For Low Wind Speed Region  
Jeonggi KIM, Unison Wind Energy R&D Center, Korea |
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Kooksun LEE, Seoul National University of Science and Technology, Korea |
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K. R. Ram, Division of Mechanical Engineering, The University of the South Pacific, Suva, Fiji  
Young-Ho LEE, Korea Maritime and Ocean University, Korea |
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About GDUT

Guangdong University of Technology (GDUT) is a multi-disciplinary university engaging with the international community. In the last 50 years the university has become a key educational and research institution in Guangdong province in Southern China with a reputation for producing highly qualified and respected graduates.

Located in Guangzhou, China’s third largest city, GDUT has several campuses with a total land area of more than 2.23 square kilometers and a floor space of over 1.42 square kilometers. The University offers a wide range of courses in engineering, science and technology, business management, liberal arts and law, with major emphasis on the study of engineering. More than 2000 full-time teachers in the University support a student population of over 47,000 attaining degrees at Bachelor’s, Master’s and Doctoral levels. GDUT also enrolls international students and various levels of continuing education students.

GDUT boasts 19 faculties and schools, offering diverse courses in its 68 bachelor’s programs, 61 master’s programs, 19 PhD programs, and 4 post-doctoral mobile stations. GDUT attaches great importance to scientific research and disciplinary development and has a strong record of achievement. According to the data published by ESI data base in 2012, the University’s engineering discipline is listed in ESI world’s top 1% ranking. National, province and local government projects have benefited for years from the contribution of GDUT research expertise. Furthermore, GDUT is developing an excellent overseas reputation as a valued partner in international joint research projects. University investments in research and teaching infrastructure include:

1) 484 million RMB of equipment and devices to support teaching and research
2) The University Library has a collection of over 3.31 million volumes and over 6,957GB of electronic journals.
3) A network of research institutes, centers and labs across various fields and in collaborations with major companies and universities in China and abroad.
4) Undertaking major research across a diverse range of fields.

GDUT pursues a range of international exchanges and partnerships with over 90 international universities, enterprises and research institutes in countries such as Australia, Britain, Canada, France, Germany, Japan, Korea, New Zealand, Russia, Thailand and the United States among others.

GDUT is committed to quality teaching and learning and provides all students with all-round development with a caring environment. All degree programs are focused on applied and innovative learning to ensure that graduates are work-ready, innovative and equipped to succeed in their chosen career path. GDUT graduates have a high reputation in the community and business sectors and actively contribute to society. This explains why the employment rate of GDUT graduates is among the best of universities in Guangdong province.
Innovative, Low-carbon, Sharing

Chinese Society of Engineering Thermophysics (CSET)

Korean Society for New and Renewable Energy (KSNRE), Korea

Guangdong University of Technology (GDUT), China

China-Canada Joint Centre on BioEnergy Research and Innovation (C-CJCBRI)

National Natural Science Foundation of China (NSFC), China

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

Korea Institute of Energy Research (KER), Korea

Guangzhou Association for Science & Technology (GZAST), China
Abstract Collection

Keynote Session
POLICY AND INDUSTRY OF RENEWABLE ENERGY IN KOREA

Hyungkee YOON, Ph.D.

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Due to strong demand on economic development and inevitable responsibility on climate change, low carbon green growth has been one of national primary agenda in Korea. Especially, since there is almost no fossil fuel reserve except little anthracite coal with low heating value, the development of alternative energies has been essential. Furthermore, as the world market of renewable energy is forecast to grow faster than any other industry, the Korean government has strongly promoted the policy and industry of renewable energy. In addition, Korea is the 9th biggest CO2 emission country in the world and shows also the fastest CO2 emission increase rate in OECD countries. In COP 21 held in Paris, President Park announced that Korea would cut down 37% of CO2 emission based BAU in 2035. One of strategies to meet this goal is the innovative technology development, the related industry promotion and the widespread deployment of renewable energy.

The target goal of renewable energy in Korea is 11% in 2035. As of end of 2014, the NRE supply was 11.5 thousand toe, which consisted of 4.08% of total primary energy supply. The installed NRE capacity was 10,688MW, accounting for 11.5% of total generation capacity as of end of 2014. In 2014, the number of companies in the NRE industries was 485. The number of employees was 15,707. The sale was 10, 128 billion KRW (approximately 10 billion USD). The amount of export was 3,059 million USD. The NRE investment was 874 billion KRW. There are various NRE promotion programs, such as Building subsidy program, Home subsidy program, regional deployment subsidy program, Feed-in-Tariff, Renewable Portfolio Standards, Renewable Fuel Standard, NRE Mandatory Use for public buildings, Solar PV rental program and etc.. The policy and Industry status of NRE in Korea will be presented.
RENEWABLE ENERGY DEVELOPMENT IN MONGOLIA

Bayasgalan Dugarjav\textsuperscript{1*}, Joon-Hyung Park\textsuperscript{2} and Jun-Seok Cho\textsuperscript{3}

\textsuperscript{1}School of Engineering and Applied Science, National University of Mongolia, Mongolia  
\textsuperscript{2}BJ Power Co.,Ltd, Daejeon, South Korea  
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In this paper we would like to introduce about renewable energy development possibilities, current state and future plan of Mongolia. Mongolia has a huge energy source, especially renewable energy such as wind solar. Unfortunately, Mongolian population is much smaller, therefore energy market has a limitation. In order to use energy resources in Mongolia we have to export energy to neighboring country such as PRC, Korea and Japan. For this purpose North east super grid is international kea project in between the NEA countries. Fortunately, those countries also wondering to establish this super grid and would like to connect. In this paper we will introduce some activities for super grid. In other hand Mongolian herders are using renewable energy for daily life because of special life style as nomadic in remote area. Nowadays energy demand for herders is still increasing with improving life condition. Finally we would like to introduce about our developing project for Mongolian market. Our project is aiming to develop solar based residential power supply system which is optimized for Mongolian ger under cooperation between private sector of Korea as BJ Power and EESYS and National university of Mongolia with support of Korean government.
HEAT STORAGE TECHNOLOGIES FOR WASTE HEAT UTILIZATION FOR LOW CARBON PROCESSES

Noriyuki Kobayashi
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**Background**
Thermochemical energy storage is one of heat management technology that shows potential for reducing waste heat and fuel consumption. The system stores a working medium utilize waste heat by repetitive heat charging and discharging operations using reversible endothermic and exothermic reactions. This material is commonly used because of its low cost, nontoxicity, and thermochemical stability. We have investigated the potential use of the CaCl$_2$/H$_2$O reversible reaction.

To achieve practical application of such a system, a higher volumetric power density and longer-term durability are required. Few studies have attempted to quantify the long-term durability of heat input/output performance for assessing practical application. In this study, we studied a bench scale reactor using CaCl$_2$/H$_2$O reaction system over 1000 repetitions to quantify the long-term durability of heat input/output performance.

**Experimental procedure**
We used a reagent anhydrous CaCl$_2$ powder (> 95 % purity) dried in an electric furnace at 180 °C for 24 h. The CaCl$_2$ particles were sieved by diameter ($d_p = 125–250$ μm) and placed in the reactor. The experimental apparatus used for the repetitive experiments, which consists an evaporator, a condenser, and a reactor. Each component was connected to a thermostat bath as a heat source. A heat exchanger for reactor had 1.1 L in whole volume capacity and measured 250 mm × 200 mm × 20 mm (without the header). The pitch of the fluid flow path was 8 mm, and the pitch of the corrugated fin was 1 mm. The reactor was filled with 530g of the anhydrous CaCl$_2$ particles (the filling fraction based on filling space was 0.42).

**Result and discussion**
Figure 1 shows the result of working characteristics for CaCl$_2$ anhydrate/dehydrate reaction system for the condition of 155 °C in reactor temperature, 97 °C in evaporator temperature and 30 °C in condenser temperature. Discharging or charging reaction almost finished within 1200s for both reaction system. The heat discharging rate for anhydrate/dihydrate system was twice higher than that for another system due to their original reaction heat. The amount of heat discharged within 1200 seconds were 1.03 MWh/m$^3$-HEX for (1->2), 1.75 MWh/m$^3$-HEX for (0->2), respectively. Figure 6 shows the conversion ratio, $X$, by repetition during 1200 s of discharging operations. However the conversion ratio decreased during the long-term repetitions, this decreasing trend gradually flattened, and a fluctuating conversion ratio of approximately 0.7 was reached after repetition 500 times.
REDUCTION OF PV MODULE OPERATING TEMPERATURE THROUGH HYBRIDIZATION OF SOLAR COLLECTORS

Ankita Gaur*, C. Ménézo*

*LOCIE UMR 5271, University Savoie Mont Blanc, Le Bourget du Lac, France
Correspondence author.

PV modules consist of many solar cells packaged in an environmentally protective laminate. A solar cell is basically a PN junction cell in which photons having energy lower than the $E_g$ are not readily absorbed and transmitted through the material. When the solar cell is heated, current $J_{sc}$ increases marginally but voltage $V_{oc}$ decreases. Since the voltage drop is faster than the current increase, the electrical efficiency goes down. This electrical performance is primarily influenced by the material of PV used. Temperature rise is influenced by the material properties of the semiconductors as c-Silicon, a-Si, CdTe, CIGS etc, used in the making of the solar cell. In present communication, heat generated in each type of PV model has been calculated by thermal model. The electrical efficiency of PV cells can be sustained by operating the PV module at relatively lower temperatures, which can be achieved by extracting out the excess allied heat with module. The effect of water flow on the front surface of all PV module has been investigated and the reduction of generated heat has also been calculated for each technology.
Technical Session
Topic 1: Energy Storage System
NUMERICAL ANALYSIS OF THE PERFORMANCE OF A PELTON TURBINE FOR THE PUMPED-HYDRO COMBINED COMPRESSED AIR ENERGY STORAGE (CAES)

Tuvshintugs Batbeleg\textsuperscript{a}, Young-Ho Lee\textsuperscript{b,\textast}

\textsuperscript{a}Department of Mechanical Engineering, Graduate School, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-Gu, Busan 49112, South Korea

\textsuperscript{b}Division of Mechanical Engineering, Korea Maritime and Ocean University, 727 Taejong-ro, Yeongdo-Gu, Busan 49112, South Korea

\textast Corresponding author: lyh@kmou.ac.kr

The pumped-hydro combined CAES system research is being developed in many countries. The Pelton turbine has an advantage which is it can be worked for a varied range of heads and flows. For this reason, Pelton turbine can be used effectively in a pumped hydro combined CAES system. In this paper designing of the micro Pelton turbine and performance analysis are presented for the further research work. The turbine has one nozzle and a spear valve. The basic dimensions of the bucket are based on pitch circle diameter percentage and bucket outward slope is 15°. The numerical analysis of the turbine performance carried out in Ansys CFX. The results of this paper will be compared with experimental results in the future work.

THERMODYNAMIC CHARACTERISTICS OF ADVANCED COMPRESSED AIR ENERGY STORAGE SYSTEM

Huan Guo, Yujie Xu, Haisheng Chen and Xuezhi Zhou

Institute of Engineering Thermophysics, Chinese Academy of Sciences, Beijing 100190, China.

\textasteriskcentered Corresponding author: guohuan@iet.cn

A novel supercritical compressed air energy storage (SC-CAES) system is proposed by our team to solve the problems of conventional CAES. The system eliminates the dependence on fossil fuel and large gas-storage cavern, as well as possesses the advantages of high efficiency by employing the special properties of supercritical air, which is significant for the development of electrical energy storage. The thermodynamic model of the SC-CAES system is built, and the thermodynamic characters are revealed. Through the exergy analysis of the system, the processes of the larger exergy destruction include compression, expansion, cold storage/heat exchange and throttle. Furthermore, sensitivity analysis shows that there is an optimal energy releasing pressure to make the system achieve the highest efficiency when energy storage pressure is constant. The efficiency of SC-CAES is expected to reach about 67.41\% when energy storage pressure and energy releasing pressure are 120 bar and 95.01 bar, respectively. At the same time, the energy density is 18 times larger than that of conventional CAES. Sensitivity analysis also shows the change laws of system efficiency varying with other basic system parameters. At last, the off-design model of the SC-CAES system is established, and its off-design performance is explored, such as revealing the effects of power load, ambient temperature and cold storage form on the off-design performance. The study provides support for the design and engineering of SC-CAES.
MARKET-ORIENTED OPTIMAL SCHEDULING OF HYBRID WIND-BATTERY ENERGY STORAGE SYSTEM BASED ON WIND FORECASTING

Wonbin Choi\textsuperscript{a}, Hwachang Song\textsuperscript{b,}\textsuperscript{*}

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With constant concerns for preventing climate change and preparing for Paris agreement starting in 2020, attention on RES (Renewable Energy Sources) has been increasing in worldwide electric power markets. BESS (Battery Energy Storage System) connected to RES has usually been installed to regulate renewable energy output by charging or discharging itself, which is so-called smoothing control or capacity firming. In micro-grid concept, however, according to increment in the number of prosumer which refers to a consumer could become a producer at the same time, another strategy to get much profit for prosumers needs to be proposed. South Korea government has made a policy which owners of RES and BESS can be bidding for. This policy called RPS (Renewable Portfolio Standard) encourages RES operators to participate in certain time period. In this paper, a strategy to maximize profit for prosumer in micro-grid is proposed. MILP (Mixed Integer Linear Programming)-based optimization problem has the objective function to maximize operational profit which is based on SMP (System Marginal Price) and REC (Renewable Energy Certificate). In order to formulate this optimization problem, linearized lithium-ion battery equivalent circuit model is applied with its physical limits which include min./max. of charge and discharge power and SOC (state of charge) and loss factors. Additionally, out of all constraints, one is devised in terms of system reliability. In addition, this algorithm requires 24-hour wind generation schedule which is obtained by putting wind speed forecasting data from Jeju, South Korea in DFIG (Doubly-Fed Induction Generator) wind farm model in Simulink. Simulation is conducted in Matlab/Simulink.
RESEARCH ON THE INFLUENCE OF BALANCING PARAMETERS ON BATTERY CAPACITY INCONSISTENCY REDUCTION

Jie Lv, Wenji Song, Wei Luo, Shili Lin, Mingbiao Chen, Ziping Feng

Guangdong Key Laboratory of New and Renewable Energy Research and Development, Key Laboratory of Renewable Energy, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Guangzhou 510640, China

* Corresponding author: lvjie@ms.giec.ac.cn

Inconsistency among cells is a serious problem in battery energy storage systems, in which the lithium batteries have to be connected in series to meet the voltage and capacity requirements of the application. Due to the surrounding environments, self-discharge rates and fabrication process of batteries, the charge level tends to vary from cell to cell. Battery inconsistency is usually expressed as differences in internal resistance, voltage and charge imbalance. The inconsistency reduces battery lifetimes and increases their usage costs. For the purposes of bringing cells to the same charge level and achieving high performance, cell equalization technology (CET) has been developed.

The aim of equalization is to reduce the inconsistency among batteries in series. Many approaches for equalization have been investigated and can be divided into active and passive balancing. Passive balancing removes excess charge in the form of heat through a parallel shunt resistor, which wastes energy and generates a significant amount of heat. Active balancing is more efficient and diverts charge from higher energy batteries or external auxiliary sources to lower energy batteries. Many methods for equalization are proposed. The majority of the previous studies on this topic focus on the electrical hardware design and realization of the equalization systems to obtain high efficiency and fast energy transfer between the cells. However, in fact, it is not only the circuit parameters, but also the balancing parameters determine the CET performance. At present, there are few reports about how the balancing parameters improve battery inconsistency. The quantitative analysis of improvement has never been studied. The influence of battery parameters on CET performance is still unclear. In order to improve the battery performance, it is important to know the influence of equalization upon battery inconsistency, such as balancing current. In addition, when to begin the balancing, should also be considered. Balancing parameter optimization is essential for battery pack lifetimes and performance.

A quantitative analysis method based on an active balancing circuit is developed to explain how battery capacity inconsistency is affected by balancing parameters. Four balancing parameters, including charge/discharge current rate, initial capacity difference before balancing, balancing current and balancing time, have been considered to explain the effects on battery capacity consistency. The results indicate that: 1) We can reduce the inconsistency of batteries more effectively in discharging with active balancing at small current rates. 2) For the purpose of an improved balancing effect, a high ratio (β) of balancing current to charging/discharging current is necessary. 3) At large initial battery capacity differences, capacity difference reduction ratio (α) increases more obviously. 4) When the balancing current gets little changes, with the increase of current rate, the ratio (γ) of balancing time to charging duration reduces and the effect of balancing becomes inconspicuous. While, in discharging, γ rises and the balancing effect decreases.
OPERATION STRATEGY OF ENERGY STORAGE SYSTEM FOR FREQUENCY
REGULATION SERVICE IN MICROGRID

Yong-Sung Kim\textsuperscript{a}, Yong-Seung Lee\textsuperscript{b} and Jin-O Kim\textsuperscript{c,*}

\textsuperscript{a}Department of Electrical Engineering, Hanyang University, Seoul, KS013, South Korea

* Corresponding author: hallscomfort@hanyang.ac.kr

Nowadays, the Frequency Regulation Service (FRS) has been implemented by governor with Governor
Free (GF) and Auto Generation Control (AGC). Because of this condition that thermal power plants are operated
at its 95% capacity to use the rest of generation which is 5% for emergency frequency drop and this will cause
serious economic losses. In this sense, the government, also private companies, studies how to cover the FR
service economically using Energy Storage System (ESS). The ESS has a rapid response characteristic and it is
easy to make large volume. Therefore, it is suitable for the FR service. The 48-MW ESS are installed and
operated for FR service up to now and total sized ESS will be expanded to 500 MW in 2017. In general, the P-f
droop control is applied to ESS mechanism and represented in power output change rating based on the
frequency fluctuations when the ESS is operated for FR service. However, the State of Charge (SOC) is not
considered in P-f droop control, thus fully charging or discharging ESS has a significant impact on the battery’s
lifespan and when the fully discharging occur, the ESS is not available to perform the FR service as well. In this
study, the frequency is divided into two sections, and different controls are applied on each section to provide a
reliable FR service. In the case study, based on the frequency sample the three control strategy are introduced.
The previous P-f droop control which is specialized in frequency recovery, the variable droop control
specialized in SOC maintenance and the combined droop control. All the result in this study are calculated in
RMS value.
THE PROMOTING EFFECT OF HYDROPHILIC MATERIALS ON THE REACTION PERFORMANCE OF LIOH·H2O FOR LOW TEMPERATURE CHEMICAL HEAT STORAGE

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The effective use of thermal energy such as waste heat and solar thermal energy is essential today to decrease the consumption of fossil energy and the emission of greenhouse gas. As an efficient thermal energy utilization technology chemical heat storage could solve the problem of mismatching between supply and demand of energy. In this study LiOH·H2O as a promising material was chosen to efficiently store the low-temperature thermal energy at the range of 50-100 °C due to its high energy density and mild reaction process, however the slow hydration reaction rate dominantly limit its further application.

Hence, some hydrophilic materials such as PEG, CaCl2, NaY-zeolite was selected to improve the hydrophilic property of LiOH·H2O and promote the hydration reaction rate of the whole composited thermochemical materials (TCMs) which was synthesized by impregnation method. These hydrophilic materials provided efficient hygroscopic reaction interface and also showed catalytic effect to the hydration reaction. Because of the addition of PEG, CaCl2, NaY-zeolite the reaction rate and the heat storage performance of the LiOH·H2O system was greatly increased. XRD, SEM and TEM characterization results showed that small LiOH·H2O nanoparticles existed in the composite TCMs. During the TG-DSC test LiOH·H2O/ NaY-zeolite composite TCMs showed the highest heat storage capacity which reached 894 kJ/kg and 1.4 times higher than the pure LiOH·H2O. It indicated that LiOH·H2O/ NaY-zeolite showed higher reaction rate than pure LiOH·H2O during the exothermic hydration reaction. In summary, the reaction rate and the heat storage performance of LiOH·H2O thermochemical materials was successfully enhanced by the hydrophilic materials.
EXPERIMENTAL STUDY OF ENERGY CHARGING AND DISCHARGING CHARACTERISTICS OF SMALL SCALE HYBRID ENERGY STORAGE SYSTEM

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Generally, power generation from renewable energy sources are largely influenced by the local environment or natural conditions and thus large variations in power generation currently make renewable energy sources ineffective as primary sources of energy for power production or for meeting demand. In order to solve this, energy storage systems (ESS) allow for the storage of energy during periods low demand and supply extra energy during high periods of demand. ESS also allows for storage of energy from highly variable renewable energy sources and then output smooth and constant power to match demand. A hybrid mechanical ESS that uses combination of pumped hydro storage (PHS) and compressed air energy storage (CAES). This system contains a multistage pump, a hydro turbine and two tanks with water that serve as reservoirs. The charging process occurs when excess energy needs to be stored. In this process, a multistage pump pumps water from a tank open to the atmosphere to a closed tank that is partially filled with water and compresses the air within the closed tank as the water fills the tank. When additional power is required, the water from the closed tank is driven by the compressed air through a turbine to the open tank reservoir.

For this research, a small scale hybrid energy storage system which consists of a pressure tank, reservoir, multistage pump and pressure valve instead of a hydro turbine was built as a closed system. A variation of internal pressure of the pressure tank during the charging process and of exhaust pressure by the pressure valve during the discharging process have been investigated in order to study the characteristic of both charging and discharging process of the energy storage system.
A ANALYSIS ON HEAT TRANSFER CHARACTERISTICS OF MULTI-COMPONENT MOLTEN SALT

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In this paper, heat transfer characteristics analysis was experimentally conducted for multi-component molten salt mixture. Experimental facilities consist of three type, which is convective heat transfer measurement system, steam generator system and molten salt solar receiver system. Heat transfer correlations were developed that it is suitable for molten salts in the range of transition and turbulent. Counter flow heat exchanger was used to confirm whether molten salt is suitable for generating power as heat transfer media. Superheated steam was generated at 100 bar, 400 \textdegree C by heat exchange between the high temperature molten salt and water with 81 ~ 91 \% efficiency. Molten salt solar receiver was manufactured and installed at 40 kW solar furnace in KIER to confirm the performance that it is concerned with solar thermal input energy, receiver shape and temperature distribution between inlet and outlet. Experiments were conducted at the inlet temperature range of 300 – 400 \textdegree C with solar input energy of 2.7 – 4.7 kW, which showed the average efficiency of 56.4 \%.
Topic 2: Geothermal Energy
PERFORMANCE ANALYSIS OF WATER-SOURCE HEAT PUMP SYSTEM UNDER THE NUMEROUS OPERATION CONDITIONS OF PUMPS AND BUFFER TANK TEMPERATURE.

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Recently, based on the new climate change system started from COP21, which was held in Paris, France, Korean government settled a new reduction target of greenhouse gases by 2030, and started to make new renewable energy plan which includes water heat related renewable energy. A water source heat pump system is one of the new renewable energy systems using temperature differences between water and atmosphere. K-water have installed and been operating 10 heat pump systems in water treatment plant buildings and multipurpose dam buildings. In this study, Sungnam water treatment plant heat pump system was selected as a pilot and simulation model was developed with TRNSYS which is specialized in simulation for a heat pump system. Sungnam heat pump system is a water to water type system and composed of a raw water pump, a brine water pump, a heat exchanger, a heat pump, a buffer tank, FCUs, etc. The water source of this system is the raw water coming from HAN river to sungnam water treatment plant. A heat exchanger is usually used to exchange heat between raw water and brine water. Therefore, flow rate of raw water and brine water pump is a critical factor of system COP. These pumps are controlled by inverter, and data acquisition is being carried out with various measuring instruments of RTD sensors, flow meters, electricity meters. The efficiency of heat pump system generally shows different values according to the various operation conditions of raw water pump, brine water pump, buffer tank temperature. In order to analyze the system COP under the different operation condition, 100 cases of operation condition have been used for simulation, and the results of simulation were verified by measured data. As a result of this study, changing the pump flow rates and buffer tank temperature was identified as an significant effects to change system COP as much as 5~10% and TRNSYS using simulation methods wer
ANALYSIS OF 2D FLOW MODELING IN FRACTURE OF POROUS MEDIUM

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Flow within porous medium is a complex coupling of free flow and seepage. The flow law have very important application in the exploit of Geothermal. As speed slippage occurs in the interface of free flow and porous media, the traditional no-slip or free-slip wall boundary condition no longer applies. Targeting at the problem of speed slippage, firstly, based on permeable wall model of Terrill and Shrestha, two-dimensional coupling model between free flow and seepage of porous medium was build; secondly, a two dimensional numerical model is established by using the continuous boundary condition between fracture and porous media, the present numerical model was a macroscopic model which solved the Reynolds Averaged Navier-Stokes Equation (RANS) with the low-Reynolds number k-ε turbulence model for the free flow region and Forcheheimer-extended Darcy model with the macroscopic k-ε turbulence model for the porous region. The results of analysis for two models show that the coupling model of fracture and two dimensional numerical models are in good agreement with Kuznetsov model in a laminar flow state; simulated results of the flow over the porous media were coincided with the existing experimental data and microscopic computed data. This study will provide a new solution to the coupling of free flow and seepage, which has important theoretical significance on the study of mass transfer law of porous medium and free flow.
GEOTHERMAL UTILIZATION AND DEVELOPMENT IN CHINA

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In China, the high-temperature geothermal resources are mainly distributed in southern Tibet, western Sichuan, western Yunnan; Mid-low temperature geothermal resources are mainly distributed in coastal areas of southeastern China, including Guangdong, Hainan, Jiangxi, Hunan and Fujian. Vigorous expansion of geothermal can ease the energy shortage, and largely solve the serious problem of air pollution caused by the massive use of fossil fuels. In China, geothermal development planning should be drawn up, according to distribution characteristics of geothermal resources and local social characteristics. In the west and southwest of China, geothermal power should be priory developed. Because the grade of geothermal resources is relatively high in this area, density of population is small, the effect of geothermal power on human’s life and production is little, electricity is easy to transport and it can ease the pressure on the national electricity demand to a certain extent. In the southeast coastal areas, temperature is high in summer, the hot weather lasts long, and thus the energy consumption for refrigeration is quite large. The rich geothermal resources can be used for refrigeration. In the northeast and north of China, the demand for heating is huge. The ground source heat pump can be developed in the area where geothermal resource grade is relatively low, which is the effective way of saving energy and reducing energy’s consumption.

The development of geothermal energy is of important strategic significance for At present, the policies on geothermal energy are applicable to the macro-control, and there is no detailed rule on the development of geothermal industry, so it is difficult to implement those policies. So following suggestions are put forward. Firstly, subsidy policy on utilizing geothermal energy should be implemented as soon as possible to stimulate people’s investment enthusiasm. Secondly, the industrial access threshold should be elevated to improve the technology level of productions. Finally, industry development plan should be enacted to make the exploitation of geothermal resources ordered.
ENGINEERING CHART FOR THERMAL PERFORMANCE OF CAST-IN-PLACE ENERGY PILE CONSIDERING THERMAL RESISTANCE

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An energy pile is one of the novel ground heat exchangers (GHEXs) that is an economical alternative to the conventional closed-loop vertical GHEX. The energy pile contains heat exchange pipes inside the pile foundation, and circulates a working fluid through the pipe inducing heat exchange with the surrounding ground formation. Using existing foundation structure, the energy pile can reduce the initial construction cost such as drilling cost, and eliminate the need for additional construction space. However, most commercial design programs and analytical models for estimating the thermal performance of GHEX system are mainly applicable to the conventional closed-loop vertical GHEX. In this study, an engineering chart was provided for easily evaluating the thermal performance of cast-in-place energy piles even with various layout configurations of heat exchange pipe. The engineering chart was developed with the aid of a series of numerical analyses performed on various ground and operation conditions. Since the numerical simulations were exclusively carried out for the typical 5-pair-parallel U-type energy pile, the concept of thermal resistance was adopted for estimating the thermal performance of other types of cast-in-place energy piles. The accuracy of the developed engineering chart was verified by comparing the thermal performance evaluated in the field test results along with an estimation error within 5%.
A NOVEL THERMAL-HYDRAULIC-MECHANICAL MODEL FOR THE ENHANCED GEOTHERMAL SYSTEM HEAT EXTRACTION

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The present work reports on the development of a three-dimensional transient model, which describes the multi-physical coupling of thermal (T), hydraulic (H), and mechanical (M) processes during heat extraction of enhanced geothermal systems (EGS). The model encompasses: 1) local thermal non-equilibrium to formulate the convective heat exchange between rock matrix and heat transfer fluid in the reservoir, 2) sub-modules describing temperature- and pressure-dependent thermophysical properties of water, and 3) a thermo-poroelastic model, which is used to calculate the effective stress in the rock matrix and to determine the time-changing local porosity and permeability in the reservoir. Analyses for an idealized EGS indicate that an increased effective stress in the rock matrix yields significant mechanical effects upon the EGS heat extraction performance, namely: for a given injection pressure the mass flow rate of fluid is enhanced, leading to improved heat extraction, while the life expectancy of the EGS is shortened. It is found from additional simulations that: 1) a decrease in injection temperature and an increase in injection pressure can lead to an increase at the magnitude of the negative effective stress, which, in turn, can enlarge the porosity and permeability in the heat reservoir, and 2) a smaller value of ha reduces the heat exchange between the rock and the fluid as it reduces the magnitude of the effective stress.

THERMAL PERFORMANCE OF ENERGY SLAB EQUIPPED WITH HORIZONTAL GROUND HEAT EXCHANGER.

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The energy slab is a ground coupled heat exchanger consisting of the horizontal ground heat exchanger (HGHE). The HGHE allows circulation of a working fluid through the heat exchange pipes, which are buried underground with a horizontal layout, inducing heat transfer between the fluid and the surrounding ground. The energy slab is installed as one component of the floor slab layers in order to utilize the underground structure as a hybrid energy structure. When the energy slab is installed in the floor slab, however, fluctuant temperature of the heat exchange pipe due to the heating and cooling operation affects the air temperature inside the underground space, which causes condensation and thermal stress inside the slab surface. Therefore, it is important to thermally insulate the energy slab from indoor air. In this study, bottom ash was considered as a replacement for natural fine aggregates of concrete, which can be constructed between the energy slab and finishing floor surface. In order to evaluate the applicability of bottom ash, a series of laboratory tests was carried out to compare the thermal conductivity and compressive strength. The thermal performance of the energy slab system was evaluated by CFD analyses with consideration of the effects of insulating materials. In addition, a parametric study with the aid of the numerical model was carried out with various layouts and shapes of heat exchange pipes to provide an optimum arrangement.
Topic 3: Marine Energy
ON THE SIMULATION OF REGULAR WAVES IN A NUMERICAL WAVE TANK

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Renewable energy sources act as a countermeasure against global warming and rising sea levels. Warming of the globe and rising sea levels are issues that one can no longer ignore. Here in Fiji communities are losing land to the rising water which infiltrates inland and makes their farm useless. This dramatically reduces their harvest. In addition to this, Fiji is highly dependent on fossil fuel for power generation. This makes Fiji vulnerable as increase in fuel prices would hinder its economic growth. Therefore, it is important to find alternative energy source. Generating power from waves offers a good option. Waves are highly consistent, can be accurately predicted beforehand and power flux is more compared to wind and solar. Currently there is no wave energy converter (WEC) in Fiji which is tailor-made to its needs. Hence in the present study commercial computational fluid dynamics (CFD) code ANSYS – CFX which solves the Reynolds Averaged Navier-Stokes Equations (RANSE) is used to model a 3D Numerical Wave Tank (NWT). Regular waves are generated using a piston type wave-maker and the free surface is captured using Volume of Fluid (VOF) method. An actual NWT is constructed to generate desired wave climate (namely minimum, mean and maximum wave conditions) based on field measurements at a site in Fiji. The effect of grid size and time-step on the simulation is also investigated. Optimum grid size and time-step was 400000 nodes and 0.05 s respectively. The CFD results show very good agreement with field measured wave height and field measured wave power. The CFD results compared well with computational solutions. The difference in results is within 3\%, indicating the validity of the CFD code.
UNIT STRUCTURE DESIGN AND TEST OF A FLOATING SOLAR DESALINATION FILM

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Proposing the concept of Micro concentrating to directly seawater evaporation to realize desalination process, and implementing in the micro structure of floating transparent membrane plate, that is to use cavity inside the film to achieve high efficiency solar concentrator, making sunlight directly heat and evaporate seawater in the cavity by the hydrophilic material, and realizing seawater desalination process. The biggest advantage is the desalination unit and the solar collector combined, so as to save the cost of land, and can be made by metalloid material. This paper does optimized design for the condenser water-producing unit structure, does simulation analysis for the concentration process, and the concentration efficiency of solar light at different incident angles is given. And in the sample structure, the steady state experiment is carried out to prove that the maximum temperature of the device can reach \(70^\circ\text{C}\), the yield can reach 1.67g/h, and achieve the conversion efficiency of solar energy by 37.4%.

A STUDY ON THE MOORING SYSTEM OF U-TUBE TYPE FLOATING WAVE ENERGY CONVERTER

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In this research, a full scale model of floating type wave energy convertor (WEC) is investigated. The WEC has as U-type internal chamber and double hull structure which allows it to use the potential and kinetic energy in waves. The advantage of this WEC is that the double hull structure protects the turbine from bio-fouling. There are two floating systems, the WEC and the mooring system that keeps the WEC within the operating area. The mooring system affected by the currents and waves which can have a significant effect on the performance on the efficiency of the turbine. For each type of mooring method applied, the device’s movement characteristics are different. Because of this, the selection of an optimum mooring system for the WEC is an important factor for the overall Wave Energy System. Currently, there is a lot of studies that is conducted on mooring systems and this study will use Computer Fluid Dynamics (CFD) to study the effect of the mooring system on the WEC.
In this paper, the Backward Bent Duct Buoy (BBDB) wave energy conversion technology is summarized in China. Based on new ideas and new tested data, the novel performance and perspective of the BBDB conversion technology have been presented. Based on previous studies, through improvement of the BBDB model shape and 2D and 3D tank experiments under regular and random waves, the experimental result shows that the maximum Capture width ratio (CWR) of the new model is 121.34% in 2D tank, far more than the best historical literature peak value 79.1%, and the peak average CWR is 89.1% in 3D tank under random waves, far more than the best historical literature peak average value 52%. Comparing to the characteristics of other wave energy conversion technologies present in the world, combining with the latest air turbine technology, which is at nearly 60% conversion efficiency from pneumatic energy to electricity in sea trial, and the inference based on the experimental and sea trial results of Japan's "Mighty Whale" technology, the BBDB converter presents the best cost performance. Under the condition of real sea waves, the wave conversion efficiency from the wave energy to wire has the potential to exceed 50%.
A STUDY OF A CROSS-FLOW AIR TURBINE WITH ORIFICE FOR OWC WAVE ENERGY CONVERTER BY CFD AND EXPERIMENT

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Ocean energy which includes tidal energy, ocean thermal energy conversion, wave energy and other marine energy currents, hold an enormous amount of untapped energy that, if exploited extensively, have a potential for contributing significantly to the electricity supply of countries facing the sea. One of the most successful and most extensively investigated devices for extracting wave energy is the Oscillating Water Column (OWC). OWCs have been widely developed due to its potential deployment if various water conditions and its simplicity in design. The common OWC wave energy converter consists of fixed or floating structure, which opens to the sea below the water surface and absorbs wave energy, and a turbine coupled to a generator. Wave motion inside the chamber induces an exhalation and inhalation of the trapped air which drive the bi-directional turbine at the opening of the device. The turbine is connected to a generator so that mechanical motion from the rotating blade is converted to an electrical energy.

A cross-flow air turbine is a candidate for use of a self-starting turbine due to its characteristic, high coefficient at a low tip speed ratio. In addition, it has excellent stability and low noise. With its characteristics this turbine may be more suitable at places where require low noise compared to typical commercialized air turbines such as Wells and impulse turbine. In this research, a numerical study of a small-scale cross-flow air turbine for OWC wave energy converter have been undertaken in order to acquire a performance characteristic of the turbine. Model scale analysis was processed to design a test model of the turbine for experiment, and 1/16 model scale was determined. The analysis of the orifice plate to simulate the behavior of the turbine by numerical analysis and experiment have been conducted to verify the result of the turbine simulation by CFD. The size of the orifice plate was determined with through matching the pressure drop between upstream and downstream of turbine and orifice. Thus, the comparative study between orifice plates and turbine simulation have been investigated.
A METHODOLOGY STUDY OF U-TUBE TYPE FLOATING WAVE ENERGY CONVERTER

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The Wave Ship is a caisson type floating wave energy converter which are a large category of wave energy converters for deployment offshore. The pitching movement of these devices cause a column of sea water to go up and fall periodically in the double-hull housed in the caisson, making a bi-directional flow, driving an interior turbine. A cross-flow turbine is applied as the interior turbine which uses a bi-directional flow to self-start and to rotate in one direction only. The working fluid inside the double-hull is fresh water. The cross-flow turbine does not have direct contact with sea water and is thus free from bio-fouling and is easy to maintain. A small opening to the atmosphere is provided to prevent pressure build up in the double-hull due to water motion. The power conversion system in this device is a buffered system, since a working fluid use the wave energy to rotate a turbine, which then transfers energy to the generator. A feasibility study of the ocean wave energy resource in a given location is essential for design of WEC’s. The designs of offshore marine structures require a thorough understanding of the ocean characteristics and behavior. The important parameters to describe waves are the wavelength, wave height, period, and the water depth over which they are propagating. There are some well researched theories which are able to predict the wave characteristics at different water depths.

In addition, mooring systems for the floating WEC are required to keep the device at the desired place and underwater cables are necessary for transmission of electricity to the land. Although similarities are available between the energy converting systems and other floating platforms, the mooring design requirements will have some important distinctions between them, one of these differences associated with this idea that regarding a wave energy converter, in the case of a wave energy converter, the mooring line connections may significantly change its energy absorption properties by coupling with its oscillations.
EXPERIMENTAL ANALYSIS ON THE POSITIONING OF A COUNTER ROTATING TIDAL CURRENT TURBINE WITHIN DUCT

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Tidal current turbines can be classified according to the axis of rotation of the turbine. These are known as HATs (Horizontal Axis Turbine) and VATs (Vertical Axis Turbines). HATs are currently more technologically advanced and economically attractive than their counterparts.

HAT’s operate by generating lift from the current stream to rotate the turbine. The operating principles are similar to the operation of wind turbines and the advancements made in the wind industry have also benefitted the tidal current sector. Usually, HAT’s use a single rotor configuration to produce the required power for output and the Betz theorem indicates a theoretical limit of efficiency of 59.3% for a single rotor. By the same theorem, a dual rotor setup has been calculated to have a higher limit of 64%.

This study looks at the design of 40W counter-rotating HAT model that uses the airfoil NACA-63421 for the profile of the blade. The profile was designed by using the Blade Element Momentum Theory (BEMT). In addition, using the CFD and experimental results from previous studies, the optimized turbine model was found. With the aim to improve the turbine’s performance, the turbine was placed within a floating duct and experiments were conducted.

ESTIMATE OF TIDAL ENERGY RESOURCES IN CUIHENG NEW DISTRICT, ZHONGSHAN CITY

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In order to promote the construction of Green Smart Grid and the new energy application in the special planning of power engineering further in Cuiheng New District, Zhongshan City, one of renewable resources in its precinct, tidal energy, is estimated. West water wave of Hengmen in this area is selected as the sample collection position of tidal data. And tidal levels measured from the Hengmen station are employed as a reference to estimate the tide resources of Cuiheng New District. By the estimation of two-year tidal data, monthly maximum tidal range, monthly mean tidal range, annual mean maximum tidal range and annual mean tidal range are obtained. Through harmonic analysis of these tide data, the local tide pattern is determined. The tidal energy annual theoretical reserves and the amount of exploitable resources are also calculated by using the theoretical formula. Results show that the local tidal type is irregular half-day tide and its tidal energy resources are not abundant. And they provide a reference for the comprehensive utilization of renewable energy in Cuiheng New District.
STUDY ON CROSS FLOW AIR TURBINE PERFORMANCE CHARACTERISTICS FOR OSCILLATING WATER COLUMN PLANTS

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As the demand for more energy increases in modern economies, countries with access to oceans have a variety of options for energy production from the ocean. One of these methods is to use Oscillating Water Column (OWC) plants at the coast, near-shore or even floating offshore. OWCs use the periodic motion of the waves to drive a mass of air through an opening where the kinetic energy of the air is converted using air turbines. Currently, two types of air turbines (Wells and Impulse turbines) are used for energy conversion. Both types have their advantages and disadvantages. Thus in this study a different type of turbine, the cross flow turbine, is proposed for use in OWC plants. The performance characteristics of the turbine is simulated by CFD and compared to similar Wells and Impulse turbine characteristics. The objective of this paper is to conduct experiments on a small scale model cross flow turbine and compare its performance to CFD results.

NUMERICAL STUDY OF A NOVEL FLEX MOORING SYSTEM OF THE FLOATING WAVE ENERGY CONVERTER IN ULTRA-SHALLOW WATER AND EXPERIMENTAL VALIDATION

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The paper proposes a novel superflex design for the mooring system of the floating wave energy converter (WEC) in shallow water under typhoon Sea state. It is composed of three hybrid lines, each one with a segment of superflex ropes respectively connected to the buoy and clump chain, the buoy which is connected through chain to floating WEC, and a part of chain that contacts with the sea bottom and ends at the anchor.

In critical conditions, the quasi-static and dynamic analysis of the WEC and mooring system coupled motion in time-domain are implemented within ARIANE. These conditions include environmental conditions and directions in which the mooring system produces the maximum tension. The mooring analyses are established in survival sea-state 50-years return.

Model experiments are carried out in an Eagle WEC with mooring system coupled motion under wind, current and wave. The mooring line tension and the motion of WEC numerically and experimentally are compared with each other. It is observed that the present superflex design is reliable and effective. The above experience is significant for other mooring system of floating WEC design in ultrashallow water.
Topic4: Solar Energy
POTENTIAL ANALYSIS OF SOLAR THERMAL APPLICATION FOR INDUSTRIAL PROCESS HEATING IN CHINA

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As the biggest developing country in the world, China has been experiencing high energy consumption, especially in the industrial energy section. Almost 70\% of the total energy is consumed by various kinds of industrial processes, of which more than half energy is used by industrial process heat, mainly provided by fossil fuels, which also brings about violent impacts on the environment. In addition, the temperature level for most of the industrial process heat is in the range of 80-250°C, which can be provided by solar thermal energy to a great extent. This provides a favorable condition for solar thermal application. Solar heat for industrial processes (SHIP) get more and more attention in the world and becoming a promising market for solar thermal applications. The application of SHIP in China is developing rapidly in recent years, covering various industrial sectors. Many solar plants can be built to supply heat for industrial process. The aim of this paper is to investigate the replacement potential of solar thermal energy to fossil fuels in the industrial process heat, to identifying the applicable solar thermal technologies, et al. In particular, 10 industrial sectors of China are selected, and the potential of SHIP are analyzed. It is found that if solar thermal contributes to industrial process heating by different ratios in these industrial fields, it is expected 42.42 million tons of coal equivalent and 105.77 million tons of CO2 emission can be reduced. SHIP is of great potential in China.
EFFECTS OF NANO PARTICLES ATTACHED ONTO A HEAT TRANSFER SURFACE IN THE THERMAL-HYDRAULIC SYSTEM USING AN OXIDIZED GRAPHENE NANOFLUID

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The flow boiling heat transfer system is used in various industries such as power generation, air-conditioning and refrigeration, and renewable energy systems et al.. In the flow boiling heat transfer system, the critical heat flux (CHF) is the important factor. It is also meant to be safety of the system. Thus, it has kept up studies on the CHF enhancement for improving the efficiency and the safety of the system. Particularly, the CHF characteristic is essential in boiling heat transfer system because the CHF is connected directly with the safety. Recently, it has been recently reported that CHF can be enhanced when nanofluids, with outstanding thermal properties, are used as the working fluids. However, when a nanofluid is used in the heat transfer system, nano-fouling phenomena can take place on the heat transfer surface due to deposition of the nanoparticles. The phenomenon is known to be problem when a nanofluid is used as a working fluid. But it is lacked of study on effect of efficiency and safety in the system. Therefore, this work experimentally explored the influence of nano-fouling, and it was also compared and analyzed CHF, flow boiling heat transfer coefficient, contact angle, and surface roughness. The working fluids in this study were used as purewater and a 0.01 vol% oxidized graphene nanofluid. The flow velocity conditions are established at 0.5, 1.0, and 1.5 m/s. Also, the nanoparticles of oxidized graphene were deposited on a heat transfer surface, and artificial spray coating times for nano-fouling are established at 120, 180, and 240 sec. As the results, it was found that the superheated temperature to the CHF extremely increased in case of nano-fouling, it is caused by physical damage of heat transfer system. The flow boiling heat transfer coefficient in an oxidized graphene nanofluid increased up to 28.14% without any treatment on the heat transfer surface, but the coefficient in case of nano-fouling decreased down to 11.74% more than in the purewater. Also, the contact angle and surface roughness decreased when the flow velocity and nano-fouling were increased.

A SAGE-BASED STIRLING ENGINE SIMULATION MODEL FOR NEW ENERGY APPLICATION

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In order to realize the environment pollution problems which were brought by the internal-combustion, some new measures to promote the compositive utilization of energy and change the use of only one oil energy had been developed in the decade. In this paper, a 1-D sage-based stirling engine model of the utilization of the energy such as solar energy, natural gas, mash gas, etal. was built. The change of the heat source temperature and charge pressure were the most important factors to the performance of the stirling engine, some different calibration parameters, concluding piston seal, appendix gap, heater/ cooler transfer multiplier, regenerator porosity were selected to study. The efficiency and the output power of the stirling engine were shown respectively. This research provides guidelines for performance optimization of the stirling engine.
Solar energy and biomass are regarded to be promising renewable energies for advantages of clean and sustainability, and can contribute to the alleviation of current energy and environment concerns. In this paper, a novel concentrated solar power (CSP) generation hybrid system with biomass was developed, which realized the efficient utilization of the renewable energies and achieved zero CO\textsubscript{2} emission. This system mainly consists of a solar thermal energy collection subsystem, a biomass steam boiler and a steam turbine power generation block. The solar thermal energy is concentrated by parabolic trough collectors (PTCs) and used to heat the feed-water to the superheated steam of 370\textdegree C, then the generated steam was fed into the biomass boiler employed the dual-furnace technique for second-stage heating to a higher temperature of 540\textdegree C.

Thermodynamic performances and economic analysis of the proposed system have been investigated in this work. The cotton stalk from Xinjiang in the western China was selected the biomass feedstock, and the system power generation capacity was about 50 MW. Compared with the existing parabolic trough solar thermal systems, the Rankine efficiency of the proposed system can be increased by 7.14\% with the assistance of the higher temperature heat resource from biomass combustion. Moreover, according to the Exergy Utilization Diagram (EUD) analysis, the heat transfer processes within the biomass boiler can be optimized with the irreversible loss reduction.

The performances analysis of the proposed system on off-design conditions for representative days in four seasons and a year period were implemented. Various parameters, such as solar irradiations and solar collection efficiencies were considered. Results indicate that the system net solar-to-electricity efficiency can be enhanced and the yearly averaged efficiency reaches to 15.9\%. In order to optimize the hybrid power generation system, the influence of the solar multiply (SM) and the solar thermal storage capacity were analyzed. Because of the biomass collection cost is an important factor for system operation & maintenance, the renewable energies share ratio of the system need to be coordinated strongly depended on the local biomass resource. Finally, through the preliminary economic analysis, the LCOE of the proposed system was about 0.14–0.15 €/kW·h.

By the hybrid utilization in this work, the distinct natures of the solar energy and biomass can be fully used, and research findings can provide a promising approach for efficient utilization of the abundant renewable energies resources in western China and realize reductions of CO\textsubscript{2} emission.
DESIGN AND THERMAL PERFORMANCES OF A SCALABLE LINEAR FRENSEL REFLECTOR SOLAR SYSTEM

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Linear Fresnel reflector (LFR) is another commercialized concentrating solar power technologies in addition to the parabolic trough concentrator (PTC). LFR is a type of solar collectors which collects sunlight by using long, narrow, flat mirrors to reflect the sun rays onto a linear receiver. Due to the advantages of simple production, easy maintenance, and low cost, LFR is well developed and extensively applied in solar thermal system. However, the shading and blocking of adjacent mirrors and the end losses of the receiver are two problems existing in the traditional LFR system. In order to solve the above problems, a scalable linear Fresnel reflector (SLFR) solar system is proposed in this paper.

Figure 1 (a) SLFR solar system, and (b) SLFR solar system with extended support

The scalable SLFR solar system can be seen in figure 1. The optical mirror field contains an array of linear plat mirrors located at a straight line. The linear plat mirrors are close to each other and track the sun as a whole, which can avoid the shading and blocking of adjacent mirrors effectively. Moreover, the optical mirror is scalable by placing changeable numbers of mirrors in the extend support, which can be applied in different focusing multiples and temperature requirements. The end losses of the receiver are reduced by employing the design of mechanical structure which is adjustable to solar altitude angle. The thermal performance of linear evacuated absorber for the SLFR solar system is simulated numerically as well. The radiation distribution of the absorber pipe is influenced by the tracking accuracy of the system, and its homogeneity will affect the efficiency of heat transfer from the heat pipe to the working fluid.

Herein, two different light areas of SLFR system are presented and studied. The numerical and experimental results are as follows:

1. The SLFR has high ground utilization and has no shading and blocking of adjacent mirrors.
2. The design of mechanical structure adjustable to solar altitude angle can reduce the end losses of the receiver.
3. The radiation distribution of the absorber pipe is nonuniform and it will affect the heat transfer of the working fluid.
(4) The larger area system can supply the higher temperature, and the heat loss increases along with the elevated temperature.
MODELING OF RADIATION ABSORPTION IN SOLAR PHOTOCATALYTIC REACTORS

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Modeling of radiation absorption of solar heterogeneous photocatalytic systems, used in environmental applications and renewable energy generation, is the base of the further development of these technologies. The Monte Carlo (MC) stochastic method is particularly suitable for modeling of radiation absorption in complex photocatalytic reactors. In this study, MC method is used to model the complex absorption fields in solar surface uniform concentrators (SUC), solar compound parabolic collectors (CPC) and tubular photoreactors. In order to make an accurate description about photon scattering, the MC is coupled to the Henyey–Greenstein (HG) scattering phase function. The absorption of solar radiation represented by the spatial distribution of the local volumetric rate of photon absorption (LVRPA) relates strongly to catalyst loading and geometry. Compared with the tubular reactor, the CPC has on 69% higher absorption efficiency, so the CPC only requires 41% less catalyst. LVRPA of the SUC is more uniform than the CPC, which may make SUC has a better performance on subsequent chemical reaction.

EXPERIMENTAL STUDY ON DIRECT SOLAR CONCENTRATING HYDROGEN PRODUCTION SYSTEM BY PHOTOCATALYTIC WATER SPLITTING

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In this paper, a SUC-based direct solar concentrating hydrogen production system is designed. A north-south orientated, adjustable, single axis tracking with low precision and truncated SUC is designed as the photoreactor unit. Around the photocatalytic hydrogen production experiment system, hydrogen production experiments under one working condition (different catalyst concentrations) are carried out, with the photocatalyst being NiS-Cd,Zn,S. The results have showed that the system has better performances with higher catalyst concentration. The hydrogen production rate and energy conversion efficiency with the catalyst agent with two times improve by 91.63% and 81.32% than those with the haploid catalyst agent. The hydrogen production rate and energy conversion efficiency with the catalyst agent with three times improve by 201.97% and 200% than those with the haploid catalyst agent.
ASSESSMENT OF GHG REDUCTION POTENTIAL FROM SOLAR ASSISTED CARBON CAPTURE AND STORAGE USING LIFE CYCLE APPROACH

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Integration of solar thermal energy into coal fired power plant offers a promising possibility to offset the output penalty due to the intensive energy consumption of CO\textsubscript{2} separation process. Nevertheless, it is not yet been commercialized in large scale and its inclusion into countries’ energy roadmap depends on the realistic assessment of GHG reduction benefits. This study carries out a life cycle assessment (LCA), integrated with solar thermal energy or not, for a 300MWe power plant with carbon capture and storage (CCS) located in China. Results show that, the life cycle GHG emissions for the power plant with CCS (PC-CCS) are 324.31 gCO\textsubscript{2}eq/kWh. While, with the solar fraction of around 30\%, life cycle emissions from SOL-CCS, which utilize solar thermal energy directly for reboiler heating decrease to 310.89 gCO\textsubscript{2}eq/kWh. As for PC-SOL-CCS, which use solar thermal energy to replace part of the steam extractions to heat the high pressure feed water, the life cycle emissions are less than 260 gCO\textsubscript{2}eq/kWh. Thus both SOL-CCS and PC-SOL-CCS are competitive in terms of life cycle emissions reduction.
PERFORMANCE INVESTIGATION OF A NOVEL DISTRIBUTED ENERGY SYSTEM INTEGRATED A SOLAR THERMOCHEMICAL PROCESS WITH CHEMICAL RECUPERATION

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A novel distributed energy system that integrates a solar thermochemical process with a chemical recuperation cycle was proposed. The endothermic decomposition of the methanol is driven into synthesis fuel by mid-and-low temperature solar energy through solar receivers/reactors which is positioned along the focal line of parabolic-trough collector at about 453-573 K under 0.5 MPa pressure, and thus the mid-and-low temperature solar thermal energy is upgraded to chemical energy of synthesis fuel. The synthesis fuel releases its chemical energy in a micro gas turbine to drive the combined cooling, heating and power system. A part of flue heat from the synthesis fuel is stored as the sensible heat of thermal oil, and thus the sensible heat of thermal oil drives the decomposition reaction of methanol in the fixed bed reactor to replenish the synthesis fuel when the synthesis fuel produced by solar energy receiver/reactor can’t meet the load demands. Energy analysis and exergy analysis of the system are implemented to evaluate the thermodynamics performances of the proposed system. With considerations of varied solar irradiations, changes of user loads and off-design performances of the micro gas turbine, the on-design and off-design thermodynamic performances and the characteristics of the system are investigated. Results indicate that the proposed system achieves a primary energy ratio with 77.09\% and a net efficiency of solar to electricity with 22.88\% on the design condition. Performance analysis on the mid-and-low solar thermochemical process has been intensively investigated, and key processes have been validated based on a modified 100kW experimental system of solar thermochemical power generation. Owing to the combined operation of solar thermochemical and chemical recuperation process, less scale solar field is required compared with traditional parabolic trough solar power plants. Due to the interaction of thermochemical process and energy storage, the power generation is insensitive to the variations of solar radiations, and has a good performance under varied user load demands. The promising results show the integration of the mid-and-low temperature solar thermochemical process with chemical recuperation can provide an efficient and stable utilization approach of both the solar thermal energy and the chemical energy of clean fuel in distributed energy systems.
PERFORMANCE ANALYSIS OF PETE/METHANE REFORMING HYBRID SOLAR POWER GENERATION SYSTEM

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Photon-enhanced thermionic emission (PETE) solar energy converter combines photovoltaic and thermionic effects into a single physical process to utilize the full spectrum solar energy: the cathode of the PETE converter receives solar photons; the photons, whose energy is greater than the band gap of the cathode material, excite valance electrons to the conduction band, while part of the lower energy photons are converted to thermal energy and the rest penetrate through the cathode; the excited electrons are emitted via thermionic effects, during which part of thermal energy from solar energy is converted into electricity; the emitted electrons, cathode radiant heat and the unabsorbed photons are all absorbed by the anode and the first one is converted to electricity and the last two are both converted to thermal energy.

The appropriate utilization of the thermal energy from the anode will further enhance the solar energy utilization efficiency, which should take both the unsteady supply of the anode thermal energy and the steady power supply requirements into consideration. Methane wet reforming (CH\textsubscript{4} + H\textsubscript{2}O→CO + 3H\textsubscript{2}) has been attracting considerable attention due to its capability of converting intermittent solar energy into stable chemical energy. Integrating methane reforming with membrane separation allows the application of mid-temperature heat, setting the stage for the combination of PETE converters and methane thermochemistry.

In this study, a hybrid power generation system integrating PETE converters, methane reforming thermochemistry and heat engines/fuel cells is proposed. In the system, sunlight is concentrated by Fresnel collectors onto the surface of PETE converters and partially converted to electricity and partially converted to thermal energy. The thermal energy is absorbed by the endothermic methane reforming and stored in CO/H\textsubscript{2} in the form of chemical energy. The stored chemical energy is converted to electricity via power generation approaches (e.g. internal combustion engines or fuel cells). By adjusting the electricity output from the stored chemical energy, fluctuations in PETE outputs could be offset and stable electricity supply of the whole system is possible.

The process of methane chemistry and power generation (i.e. gas-steam combined cycle) is simulated by ASPEN PLUS. The process of sunlight concentration and PETE conversion is calculated by an in-house program. Based on the analysis of the hybrid system, at concentration ratio of 1000, cathode temperature of 1000K, membrane-assisted methane reforming temperature of 825K and mole ratio of H\textsubscript{2}O to CH\textsubscript{4} 2:1, the net solar-to-power efficiency can reach 45%, which is higher than the efficiency of PETE-only system of 20% and the efficiency of solar methane reforming-only system of 36%. Furthermore, in the hybrid system, the solar energy share is up to 40%, higher than 28.2% of the solar methane reforming only system. The electricity from PETE converter accounts for 44%, meaning more than half of the solar energy is stored and stable electricity supply is possible. In sum, the novel hybrid system is characterized by high efficiency, low fossil fuel ratio and stable electricity supply.
Topic 5: Hydrogen & Fuel Cell
GAS DISTRIBUTION BY A MODULAR MANIFOLD WITH MULTI-STAGE CHANNELS FOR A 16-UNIT FUEL CELL STACK

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The voltage output of a single fuel cell is typically between 0.5 to 1 V, therefore multiple fuel cells are generally connected in series to produce a sufficiently high power output. One critical challenge of a fuel cell stack is the uniform distribution of fuel and air delivered to each individual cell, because the maldistribution of fuel and air flows can cause detrimental effects on the fuel cell stack performance. Since the electrochemical reactions in a fuel cell are significantly influenced by the reactants, the fuel cell unit which receives the minimum amount of reactants determines the overall performance of a fuel cell stack. Usually a manifold is employed to improve the reactant flow distribution between different unit cells. Internal manifolds and external manifolds are the two commonly used types in a fuel cell stack. To date the flute-type manifolds are still the dominated type of fuel cell stack manifold in practical applications. U-shape and Z-shape are the two most commonly used configurations of the flute-type manifold, and in both cases the inlet and outlet manifold flows are always perpendicular to the flow directions in the electrode channels. However, the maldistribution of flow in both U-shape and Z-shape manifolds is still significant. Therefore researchers and engineers continue to develop new configurations of manifolds. The present study optimized a tree-type modular manifold with 5-stage rectangular channels based on the work in previous literature. The modular manifold was designed to evenly distribute fuel and air to a modular short fuel cell stack with 16 cells. The modular short stack can be easily connected in series or in parallel to supply a large power. The modular short stack also has advantages of easy maintenance and replacement. Channel widths of the modular manifold were determined by using the minimum entropy generation in channels method. CFD analysis was conducted to investigate the effects of channel widths, channel lengths, and Re on flow distribution uniformity and pressure loss. Optimized dimensions of a small modular manifold for a short stack with 16 cells were determined. The results show that in order to obtain relatively uniform flow distribution, widths of 16, 12.7, 10.1, 8.0 and 6.3 mm are recommended for each stage channel. Length of each stage channel needs to be at least 7.5 folds of its width. Flow distribution uniformity gets worse with the increase of flow rate. However, the flow uniformity is still in the acceptable level when the inlet air flow rate increases up to 54.4 L/min.
PREPARATION AND APPLICATION OF VARIOUS CARBON COMPOSITES FOR LOW TEMPERATURE FUEL CELL

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The support material for catalysts used in fuel cells is carbon. There are basic requirements to improve the carbon support about a high surface area, leading to the deposition of small platinum particles, improved stability under fuel cell operating conditions, and high conductivity. CNFs have gained increasing attention over the last few years due to their high strength and chemical inertness, features that make them suitable for use as composite materials, electrode materials, and catalyst supports. Recently, Shanahan et al. found that the heat-treatment process of PCNFs produced a degree of graphite, and as a result, the conductivity of the PCNF increased. Preparation of the catalyst support to increase the durability of a low-temperature fuel cell. First, the heating method is as follows: the high-heat-treated PCNFs obtained were further heat-treated at 1700 °C for 1 h in a stream of high-purity nitrogen (denoted Ht-PCNF). Second, the SiOx coating method is as follows: PS of a prescribed amount (0.008 g) was completely dissolved in 200 ml of toluene under stirring at room temperature for 30 min. The high-heat-treated SiOx coating on the PCNF was produced using both of the methods (the silica-coated PCNF after heat treatment: denoted HtSc-PCNF). The resulting structure, HtSc-PCNF, offers performance advantages with its specific surface properties and oxidation stability characteristics. The mesoporous volume is 0.0972 cm\textsuperscript{3}/g higher than that of the pristine PCNF. The HtSc-PCNF shows the highest onset potential (0.894 V vs. NHE) and ECSA (39.78 m\textsuperscript{2}/g). The HtSc-PCNF also exhibits a greatly reduced loss of catalytic surface area: 40.0% for HtSc-PCNF vs. 69.4% for pristine PCNF for 2000 cycles. Physical and electrochemical qualities were analyzed after several ratio(1:1, 2:1, 4:1, 6:1, KOH:Carbon) KOH activation of direct methanol fuel cell using needle coke as anode supported Pt and Ru. Several ratio types of porous carbon samples derived from KOH activation were used as a catalyst support for this purpose. Next process was a heat treatment and carbonization. The samples show a porous structure and high specific surface areas of 290–400 m\textsuperscript{2}/g by BET method using the nitrogen isothermal adsorption curve. Also, Energy Disoersive Spectrometer (EDS) as the elemental analysis, KC sample has Pt/Ru ratio. The maximum and rated(0.4V) power densities of MEA with KC-6-PtRu/C were 119.8 and 112.6 mW/cm\textsuperscript{2}, respectively, at 60°C. These power densities were increased by 19% and 26%, respectively, than that of TANAKA-PtRu/C.
SYSTEMATIC CONTROL PH FOR MORE HYDROGEN, A PROMISING METHOD THAT CAN’T BE IGNORED

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Biological hydrogen production has been considered a promising alternative to fossil fuels and research aimed at advancing this process to an industrial production of hydrogen fuel has been performed for decades of years. As one of photosynthetic purple non-sulfur bacteria (PNSB), \textit{R. sphaeroides} has long fascinated researchers for its metabolic versatility. \textit{R. sphaeroides} can use sugars, such as glucose and xylose, for photoheterotrophic growth and it is also well known for its ability to utilize a wide variety of organic acids and alcohols. During photo-fermentative hydrogen production with glucose, \textit{R. sphaeroides} showed strong pH dependence and VFAs accumulated as metabolic byproducts, which could also be used for H\textsubscript{2} production. The pH of bio-hydrogen experiments with glucose, acetate, butyrate and lactate at the time when hydrogen production rate reached the top point was 6.6±0.2, 7.3±0.1, 7.4±0.1, 7.4±0.15, respectively. Hydrogen production with sugars obtained its high hydrogen production rate (HPR) in weak acid environment, while that with organic acids got its high HPR in weak alkali environment. With consideration of enzyme activity, hydrogen yields and HPR, we regulated the metabolic pathways towards hydrogen production by multi-stage controlling pH in the process of hydrogen production with glucose. Through systems regulation the microenvironment, we made substrate molecules fully degraded and HPR as high as possible. The hydrogen yield was 1.96 times more than the un-regulated one, and the maximum HPR reached 148.2 mL/(L·h), which was 1.37 times as much as that of the un-regulated one. Additionally, the results were better than the gene engineering bacteria we constructed before, even better than most of genetically modified bacteria reported in literature. It is systematic control microenvironment that cannot be ignored in the age of genetic engineering.
NANOSTRUCTURED OXYGEN CARRIERS FROM AIR-LIQUID FOAM TEMPLATES FOR HYDROGEN PRODUCTION VIA CHEMICAL LOOPING WATER-SPLITTING

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Chemical looping is a novel process in clean energy conversion with CO₂ capture. However, the material always suffers from serve sintering during high temperature redox cycles. In this study, we applied an air-liquid foam templated sol-gel synthesis route to produce anti-sintering material. By virtue of the tunable sol precursors, we obtained a series of materials with different porous characteristics, and found these initial textures could significantly affect the activity and stability of the materials in chemical looping. In the first cycle, material with larger exposed surface had better reactivity. However, small pore closure and particle shrinkage occurred in the subsequent cycles. All of these factors determined the instable nature of the materials, and our current results suggested materials derived from templated sol solutions with more large pores were more robust during chemical looping. For other clean energy applications, we also hope the explored method can be extended to produce more materials with high reactivity and stability.
THE EXPERIMENT STUDY ON THE PEM FUEL CELL REVERSE VOLTAGE STARTING UP AT LOW INLET GAS HUMIDITY

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To reduce cost and system complexity, fuel cells consider decreasing the inlet gas humidification. However, operating fuel cells at very low inlet gas humidity can lead to performance instability and an increased risk of voltage reversals, while the reasons for reverse performance are not clear for the attention of amount of study is paid to the reverse voltage effect caused by gas starvation.

This study leads an experiment of single cell starting up at different inlet gas humidity and loads under which the cell is observed to suffer severe voltage reverse at figure a and c, drying and rehydration during starting up at figure b. By monitoring cell voltage evolution, high frequency impedance (HFR) responses and outlet gas humidity, the anode dehydration and the instant rising of high frequency impedance from figure a and b is proposed to offer a qualitative explanation for these reverse voltage performance. Meanwhile, an optimized method named step voltage starting up is suggested to reduce the reverse performance.

Figure (a) The voltage evolution during cell starts up; (b) Anode outlet humidity evolution during cell starts up; (c) The voltage evolution with step voltage methods during cell starts up.
A NOVEL DROPLET MICROFLUIDIC REACTOR FOR PHOTOCATALYTIC HYDROGEN PRODUCTION

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The increasing world energy consumption burning fossil fuels is believed to lead to the emissions of an enormous amount of greenhouse gases associating with the global climate change. To address the energy and environmental issues, the technology that can produce clean and high efficient energy using renewable resources becomes attractive. Employing sunlight to excite a semiconductor photocatalyst to produce electron-hole charge carriers that will produce hydrogen from renewable resources is a promising avenue for achieving sustainable and clean energy carrier. However, the biggest challenge so far is the low resources conversion rate and inefficient utilization of sunlight. Among many factors affecting the conversion rate, transport efficiency referring the kinetics of reactants adsorption and activation on the active site of catalysts is believed to be most important one. Microfluidics is the science and technology of systems that process or manipulate small amounts of fluids, using channels with dimensions of tens to hundreds of micrometers. Microfluidics as a valuable tool have the advantages of the superior mass and heat transfer, reduced axial dispersion, well-defined gas-liquid interfacial areas and the ability to vary reagent concentration in a high-throughput manner. In this work, droplet microfluidic method is introduced to design a photoreactor which could improve transport efficiency (shown in Figure 1). We use microfluidic method to fabricate pickering emulsion droplets wrapped with photocatalyst particles, and the oil and water resources could be “photo-reformed” to produce H2 on the oil-water interface under the effect of the catalyst. The surface of the photocatalyst particles should be modified before use in order to ensure the stability of the formed emulsion during photo-reaction. This Microfluidic Photo-Reactor (MPR) is designed to enhance reactant adsorption and activation, promoting the interfacial effects of reactants and catalyst and thus enhancing reaction kinetics.

Figure 1. Illustration of the proposed microfluidic photo-reactor for hydrogen production.
Topic 6: Wind Energy
AN IDDES BASED ON A TRANSITION MODEL AND ITS APPLICATIONS

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This paper introduced an IDDES (Improved Delayed Detached Eddy Simulation) method based on a transition model through the modification of turbulence length and the limitation of intermittency factor and it was validated through quantitative comparisons with experimental results, such as subcritical flow around cylinder and subsonic airfoil flow. Utilizing the developed method, the unsteady transition process and flow separation around cylinder could be depicted. In addition, the flow transition of subsonic airfoil flow at low angle of attack could also be captured together with the massive flow separation at high angle of attack. After the verification of present method, the flow field of wind turbine airfoil with and without leading-edge protuberances was investigated. As a result, it was found that flow transition took place near the leading-edge of smooth airfoil while the condition was more complicated for tubercled airfoil. In detail, flow transition occurred near the leading-edge of troughs and peaks; meanwhile, complex vortex structures initially emerged at troughs along with flow separation. Eventually, the influences of incoming flow conditions (e.g., the turbulence intensity and intermittency factor) were investigated to further validate the compatibility of present method.
PERFORMANCE TEST FOR THE SMALL SAMPLE OF VERTICAL AXIS WIND TURBINE USING DIGITAL WIND TUNNEL

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In this study, the performance of vertical wind turbine is tested and analyzed using digital wind tunnel which is used for supplying well controlled wind flow. For the performance measurement, torque and rotational speed are measured directly from the rotating axis of the sample of wind turbine. Axis power is calculated by multiplying these two measurements, and the power coefficient is deduced by dividing it by the inlet kinetic power of air flow. The digital wind tunnel consists of ninety six fans on the one side of tunnel to supply linear windy air flow without circular flow, and the other side is open as an outlet of wind flow. It is controlled to supply constant wind speed with the turbulent intensity and the uniformity of about 3%. The tip speed ratio of the rotating blade is controlled with rotating speed which is operated with DC motor and power supply system. The power coefficient can be shown with various tip speed ratios and the maximum point of power coefficient also easily shown the trends of power coefficient and the tip speed ratio.

The test sample has two vertical blades with rotational diameter of 26cm, and two cases of the blade attaching angles of 5 and -2 degree from the tangential line of circular rotating path. The test result shows that the maximum power coefficient is about 20-30% with tip speed ratios of 2-3. It'll also shown how it can be changed in the different angle of blade attaching to rotational arm.

This study will show how the power coefficient can be measured with digital wind turbine in the measurement of laboratory scale. Once the maximum point is analyzed with this test, the wind turbine can be controlled to keep the tip speed ratio in the maximum point. So, it is really useful and important to find out the maximum point of power coefficient with the test in this study.

\textit{WE-0020}
ANALYSIS OF THE WAKE BEHIND A WIND TURBINE USING A CALCULATION IN THREE-DIMENSIONAL PARABOLIC NAVIER-STOKES EQUATION

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Numerical method for calculating a wake profiles on wind farm were developed. In order to add to an optimization tool of a wind farm layout, TOPFARM, a parabolic Navier-Stokes equation was used because of its low computing cost. To calculate coefficient matrix and reduce computing cost, tri-diagonal matrix algorithm, which can neglect time-step iteration was used. The Monin-Obukhov length was used for modelling the properties of the non-uniform incident flow over the wind turbine. The developed numerical method is based on the k-\(\varepsilon\) method for the closure of the turbulent flow equation. The model has been validated with experimental results obtained from Technical university of Denmark.

GORI DEMONSTRATION PROJECT OF A PILOT FLOATING OFFSHORE WIND TURBINE

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We will make an overall introduction to ‘Gori Demonstration Project’ for the development of technologies of design, building, installation, operation, monitoring and performance test of a pilot 750kW floating offshore wind turbine installed at 50m deep about 4km off the Gori Coast of the East Sea, Korea.
HIERARCHICAL STABILITY CONTROL STRATEGY OF MEDIUM-VOLTAGE AUTONOMOUS MICROGRID WITH WIND POWER

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In this paper, an islanded medium-voltage (MV) microgrid is presented, which integrates renewable-energy-based distributed generations (DGs), energy storage system (ESS), and local loads. In an isolated microgrid without connection to the main grid to support the frequency, it is more complex to control and manage. Thus in order to maintain the frequency stability in multiple-time-scales, a hierarchical control strategy is proposed. The proposed control architecture divides the system frequency in three zones: (A) stable zone, (B) precautionary zone and (C) emergency zone. In this way, dynamic stability control that cope with disturbances in short-time scale is implemented by microgrid central controller (MGCC) within Zone B and Zone C. Meanwhile, steady-state stability control to solve the peaks and valleys problem of loads and DGs in long-time scale is executed by microgrid energy management system (MEMS) within Zone A. Furthermore, based on the developed complete small-signal state-space model, sensitivity analysis of the eigenvalues is conducted in order to reveal the dynamic stability margin of the MV microgrid, and to identify the proper range of the control parameters of Zone B. Theoretical analysis, time-domain simulation and field test results under various conditions and scenarios are presented to prove the validity of the introduced control strategy.
Topic7: Smart Grid
STATE OF CHARGE BALANCING STRATEGY USING COORDINATION CONTROL OF AC/DC HYBRID MICROGRIDS

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In AC/DC hybrid microgrid, the AC subgrids and DC subgrids are connected by interlink bidirectional AC/DC converters (ICs). ICs have an important role for the power management of the entire system by sharing the power proportionally among all sources in both subgrids, according to the frequency and voltage deviations. Utilizing battery energy storage systems (BESSs) in AC/DC hybrid microgrid could improve the frequency and voltage control performance. Besides balancing the frequency and voltage deviations, ICs also could be controlled to balance the state of charge (SOC) of the BESSs that are installed in both subgrids coordinates with the battery converters. This paper proposed an SOC balancing strategy controlled by ICs and battery converters, which the BESSs are located in AC and DC subgrids, in order to obtain a better power sharing between both subgrids as well as the BESSs. The simulation hybrid microgrid model consists of sources, loads, and one BESS for each subgrid, using the tool of PSCAD/EMTDC software.
SYSTEM INTEGRATION AND OPTIMAL OPERATION OF DISTRIBUTED RENEWABLE ENERGY GENERATION

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As energy shortage and environment pollution problems become increasingly serious, research and development of renewable energy arouses the world's great interest and investment. At present, wind power and photovoltaic power generation are the fast growing and widely applied renewable energy generation modes. However, the stochastic and intermittent intermittence of renewable energy will cause great challenges to dispatching and reserve capacity of utility grid. To solve this problem, microgrids are used as a good solution for distributed power integration. As a kind of network structure of distributed generation, demand side is the main service object of microgrids. As shown in figure 1, microgrids integrate a variety of power generation modes, energy storages and loads, achieve bidirectional energy flow, and operate in CHP (combined heat and power) mode and various control modes.

It is necessary to apply intelligent control and decision dispatching through energy management and system optimal operation to guarantee microgrids to operate efficiently and stably. Energy management of microgrids includes short-term and long-term management. The short-term management provides power settings for distributed power to make the system power balance, meets the user's power quality requirements, and provides fast dynamic response for the \( V/f \) control to restore stability. On the other hand, long-term management minimizes network losses and operating costs, maximizes renewable energy utilization, provides demand side management and reserve capacity configuration.

The basic functions of the energy management system include renewable energy generation forecast, load forecast, fuel generation optimization, energy storage charge and discharge arrangement, controllable load management and system stability maintenance. In specific, under the premise of meeting the load demand and ensuring system stability, energy management optimization modeling selects the appropriate decision variables, optimization objectives and constraints to establish a mathematical model. The main optimization goals of energy management mainly include economic, reliability and environmental protection. These optimization goals can be used singly or in combination. The constraints are established mainly according to the control conditions of microgrid system and the distributed energy at normal operation, including power balance constraints, the minimum unit start-stop time, etc. Microgrid energy management problems are nonlinear problems. Therefore, artificial intelligence algorithms such as genetic algorithm and simulated annealing algorithm are often used to solve the energy management optimization problems.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{The composition of a grid-connected microgrid}
\end{figure}
IMPROVING POWER BALANCE USING PEV SCHEDULING IN MICROGRID

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The advent of vehicle-to-grid (V2G) in the smart grid realizes its ideal concept such as more flexible operation during peak-hours and emergency conditions without expansion of any other plants. The plug-in electric vehicle (PEVs) are matched to this ideal concept since PEVs do double duty which can charge and discharge their batteries similar as a battery energy storage system (BESS). Unlike the BESS, the PEVs should be used basically as a transportation so that they are expected to generate the significant impacts on the grid as much as their energy consumptions every day. Therefore, it is mandatory that the system administrator regulates the charging and discharging of PEVs toward the way to be more stable and profitable. Examining the impacts on the system, first of all, the PEVs fleet which are clustered based on their maximum capacities will lead to new peaks (as called as peak rebounds) on the balance curve created by power imbalance between supply and demands while being charged. Secondly, SOC level of the PEV wouldn’t be reached in their desired one because of the limit of charging amount of the PEVs fleet in certain period in a day. Those impacts on the system will be even worse as increasing the penetration of PEVs which means increasing the loads in the system. In this paper, a scheduling of the V2G is proposed for valley filling and cost-effectiveness evaluation. The PEVs are divided into 3 groups depending on the connecting period of the PEVs. The standard deviation of the difference between with and without PEVs are measured. The results show that valley filling has been improved by using proper V2G scheduling proposed in this paper.
STUDY ON THE OPTIMAL INCENTIVE DETERMINATION TO COMPENSATE USER’S DISCOMFORT FOR DEMAND RESPONSE IN THE ASPECT OF LOAD AGGREGATOR

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As the next generation power grid, smart grid has emerged to operate more efficiently and flexibly through introducing IT technology. Among major technologies of smart grid, Demand Response (DR) is widely being introduced as the solution to reduce peak demands and to respond to contingency conditions of the power system. The typical concept of DR is to induce the change of in user’s electricity consumption pattern in response to the time-varying electricity price or other signals. It is expected that DR prevents price spike (peak hours in a day) and improves supply reliability and social welfare. In order to integrate the large number of residential customers and control their demand more efficiently, Load Aggregator (LA) should be required to perform as an intermediary between utilities and individual customers. LA tries to modify individual customers’ electricity use schedule for several purposes such as more benefits, load leveling and more convenience. For this, LA should provide an incentive to individual customers to compensate a customer’s discomfort which occurs by changes in their usage pattern of household appliances. This paper deals with the optimal incentive in aspect of LA. The objective of LA is to maximize their profits while considering the characteristics of the residential customers. In order to reflect the features, the discomfort for the household appliances is modeled based on the probability of the use of appliances. The different values of the users’ discomfort are applied to the individual customers. Therefore, LA can offer the appropriate incentive according to customers’ allowable discomfort for LA’s maximum profits. The results of case study show that each customer can reduce electricity cost without significant losses in their comfort level. It leads to more voluntarily Participations in demand response.
Topic 8: Waste Energy & Utilization
EXPERIMENTAL INVESTIGATION ON ADSORPTION / DESORPTION KINETICS IN SILICA-GEL ENHANCED THERMAL CONDUCTIVITY

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Desiccant air conditioning process by heat exchanger with adsorbent driven with waste heat has a potential to be a highly efficient because latent and sensible heat can be controlled independently. But, mass and heat transfer phenomena occurred in the heat exchanger with adsorbent cannot be expressed because of its complexity. Therefore, we have tried to clear the effect of thermal conductivity to an adsorption kinetics by using volumetric method. Adsorption kinetic of silica gel layer is investigated experimentally. The thermal conductivity in silica-gel layer has been changed in the range of 0.2-2.0 W/(m*K) at 30℃. The increase of thermal conductivity cause a dramatic increase in adsorption kinetics. However, it is clear that there is an optimization point in water adsorption power per volume because of relationship between packing density and content ratio of carbon fiber.

DESIGN OF A PARTIAL ADMISSION AXIAL TURBINE FOR SMALL SCALE SUPERCRITICAL CO2 POWER CYCLES

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Fluid-like density of CO2 make power density of the supercritical CO2 power cycle system much higher than the ordinary organic Rankine cycle system, which results in compact size make it more suitable for applications of vehicle engine exhaust energy recovery. But high power density cause the low flow coefficient which brings the design of the expander many challenges. This study aims to design a turbine expander for a 5 kW class supercritical CO2 power cycle. The type of partial admission axial turbine is selected. The primary turbine design parameters (such as work coefficient and flow coefficient) were studied and optimized to obtain good efficiency meanwhile ensure a reasonable partial admission degree. The free vortex type blade shaping method was applied to establish the blade geometry. Detailed flow analysis was performed on a full three dimensional CFD model. The commercial CFD software ANSYS CFX was applied to perform the numerical simulation. The properties of CO2 were modelled by Redlich-Kwong-Aungier equation. The performance and flow fields of the turbine design with different partial admission degrees are compared.
THERMO-ECONOMIC OPTIMIZATION OF A NOVEL ZOETROPE FLUID WASTE HEAT DRIVEN ORGANIC RANKINE CYCLE

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The decrease in fossil energy reserves and the increase in energy prices have resulted in a strong interest in utilizing renewable heat sources or waste heat for power generation. The organic Rankine cycle (ORC) is a promising heat-to-power conversion technology due to its simplicity, flexibility, low maintenance requirements, and favorable operating pressures. Given the nature of low-temperature energy sources, the thermal efficiency of the ORC is relatively low and its investment cost is higher than that of traditional power generation technologies that use high-grade energy. Therefore, improving conversion efficiency and reducing electricity production costs are popular topics in ORC research.

In the present study, a novel ORC using a liquid-vapor separation condenser and zoetrope working fluid is proposed. The cycle thermodynamic model and detailed component configuration model are developed for the thermodynamic analysis and economic optimization of the proposed ORC. The aim of the optimization is to find the optimum operating conditions of a basic cycle and the novel cycle, mass fraction of zeotropic mixtures, and structure parameters of heat exchangers. The objective function is the minimization of the specific investment cost. Genetic Algorithm is used to solve the optimization problem. A waste heat driven ORC is demonstrated to test the proposed novel ORC and the methodology. R245fa and pentane mixtures are used as working fluid. The results show that the optimum specific investment cost of the novel ORC is in all cases lower than that of the basic ORC. The minimum specific investment cost of the novel ORC is achieved at 10% of R245fa in mass fraction. The specific investment cost of the novel ORC is 4.5% lower than that of the basic ORC at 90% of R245fa in mass fraction. And the area of the novel ORC is 14% lower than that of the basic ORC.
APPLICATION PROSPECT IN THE NEW ENERGY OF STIRLING ENERGY
CONVERSION TECHNOLOGY

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Stirling generator is a kind of dynamic thermoelectric conversion technology, which use thermal energy, such as radioisotope, solar energy, nuclear energy, etc, and then transfer those thermal energy into mechanical energy, the power of is output by coupling the stirling engine and linear alternator. The stirling generator technology have been concerned on the new energy development and utilization by some research institutions owing to its characteristics of high efficiency, long life, micro-vibration, miniaturization, etc. The basic principles of Stirling generator, key technologies, and domestic and foreign research progress were introduced, meanwhile, the application prospect and the future development in the new energy of Stirling generator technology are proposed.

THE SPATIAL DISTRIBUTION AND RESOURCES POTENTIAL EVALUATION OF “URBAN-RURAL MINE” : A CASE STUDY IN GUANGDONG PROVINCE

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“Urban-rural Mine” is a kind of waste which is discharged from the city, rural life and industrial production by human. These wastes, if not properly disposed, will become a huge source of pollution. However, if developed and utilized appropriately, these wastes can become a potential rich “mine” of energy and resource. Guangdong province is the largest economic province in China, and it is also the main area of urban-rural waste. According to statistics, among the provinces in China, Guangdong province have a smaller production in the general industrial solid waste, agricultural waste, but the productions of the city domestic waste, construction waste, forestry residues, electronic waste, livestock manure and imports waste are among the nation. Therefore, the systematic analysis of the production and the spatial distribution of the “urban-rural mine” resources is of great significance to the construction of the renewable resources processing industry and the logistics and recycling network system. From a regional perspective, this study makes a statistics and estimate to the production of waste of 21 cities of Guangdong province and the subordinate counties. The spatial distribution models are given to evaluate characteristics of various regions. Furthermore, the analysis and assessment of development potential of various types of waste are also investigated. This study provides a decision-making basis for layout of industrial development space, industry environmental management and the formulation of relevant policies and measures of the “Urban-rural Mine” in Guangdong province.
Topic 9: Bioenergy
RENEWABLE ENERGY IN BANGLADESH: PRESENT STATUS, VISION AND GOVERNMENT STRATEGIES

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Bangladesh, a south-east Asian, energy hungry country is lying between 20.34° and 26.38° north latitude and between 88.01° and 92.41° east longitude. Power infrastructure of Bangladesh is small and insufficient but the demand is rapidly increasing. The country has a total area of 147,570 km² with a population of about 162 million. Only 30% of the total population had access to electricity. As on August 2016, total power was generated around 7000 MW among which, 61.79%, 21.56%, 8.20%, 4.92%, 1.89% and 1.64% from natural gas, furnace oil, diesel, power import, hydro and coal, respectively. The sector wise primary energy consumption is 47.8%, 30.5%, 11.5%, 5.3% and 4.8% in industry, residence, transport, agriculture and commercial purpose. Although there are a lot of challenges, the Bangladesh government has set a target to generate 24,000MW energy by 2021 of which 3,168MW from renewable energy focusing on addition of 1,740MW of solar power, 1,370MW of wind energy capacity, 47MW from development of biomass-based power generation technologies, 7MW from biogas and 4MW from mini hydropower projects. Recently, Bangladesh has adopted three priority projects for expedited implementation. These are Rooppur Nuclear Power Plant, Rampal Imported Coal Based Power Plant and LNG Terminal. Indeed, it is critical to ensure energy security for all by 2021 due to grid access is extremely limited, required huge investment, absence of economic pricing, energy conservation and efficiency, inappropriate supporting institutional arrangement requiring restructuring and reforms of institutions, inadequate modern technology, lack of technical, financial and managerial capacity, appropriate fuel mix, absence of economic diplomacy to access regional grid, protracted decision making process, corruption and governance issues, renewable energy is one of the most cost effective, pragmatic solutions for providing electricity to disconnected areas of Bangladesh specially for rural and peri-urban areas. Meanwhile, renewable energy deployment would reduce dependence and positively impact on Bangladesh balance of payments and the overall economy. Additionally, renewable energy is more environmentally friendly thus will help to minimize threaten from various natural calamities due to climate change of Bangladesh.
CURRENT STATUS AND PROSPECTS ON TRANSPORT BIOFUELS IN KOREA

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Transport biofuels are now recognized as one of the most potential options to reduce CO₂ emissions of transport sector in Korea. Ambitious national target for biofuels implementation was announced in 2015. According to the action plan, implementation of biofuels in 2035 should be increased to 3.2 x 10⁶ toe/yr, about 6 times higher than the current supply. Among many challenging issues to achieve the target, limited biomass resources and lack of commercially feasible mass production technologies are the major hurdles to overcome. Active works have been performed to resolve the issues. In this presentation, some major R&D activities on production of the advanced biofuels.

PRECITION OF PRODUCT DISTRIBUTION AND BIO-OIL HEATING VALUE FROM BIOMASS FAST PYROLYSIS USING ARTIFICIAL INTELLIGENCE MODELS

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Predictive models, based on artificial neural network (ANN) and support vector machine (SVM), were developed in this paper to prognosticate the product distribution of biomass fast pyrolysis and bio-oil HHV. Samples of correlative data were collected from the literatures about biomass pyrolysis in fluidized beds as data set. The modeling results showed that both ANN and SVM models can estimate the pyrolysis product yield and bio-oil HHV successfully. The difference between the actual values and the predicted values was relatively small. Additionally, with the application of some statistical parameters, such as MAE, MSE and R², the performance and accuracy of the predictive models were quantitatively evaluated and compared. In all cases, the ANN model accorded well with the experimental data in the training set while SVMs performed better in the prediction set. Statistical parameters indicated that SVM model has a more satisfactory predicting performance, due to its better generalization ability. The results of sensitivity analysis showed that the moisture and carbon element content have significant influence on bio-oil heating values, while the pyrolysis product (char, bio-oil and non-condensing gas) yields are affected greatly by the operating conditions, for instance pyrolysis temperature.
OPTIMIZATION OF THREE-PHASE PARTITIONING PROCESS FOR LIPID EXTRACTION FROM HIGH WATER CONTENT BIOFLOCCULATED MICROALGAE BIOMASS FOR BIODIESEL PRODUCTION

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Microalgae are considered as a promising source of biomass that can complement traditional agricultural biomass for the production of feed, food, nutraceutical and biofuel. One of the keys obstruct to obtain lipids from microalgae cells in energy-efficient and economical way is the difficulty to release them from the intracellular location of the cell, avoiding the consumption of large amounts of solvent and existence of water in biomass. In our present study, a proposing nontoxic three-phase partitioning (TPP) process displayed the capability of extracting lipids from non-broken and high water content microalgae Chlorella vulgaris spp which was harvested using bioflocculation method. In order to enhance the performance of TPP, various parameters including incubation duration, temperature, extraction duration, ratio of ethanol to salt were investigated. Experimental results suggested that, temperature, incubation duration and extraction duration were positively correlated with lipid extraction efficiency. Ethyl acetate: ethanol (1:1 v/v) showed optimal as a solvent and achieved best extraction efficiency (68%) with a supplement of dipotassium hydrogen phosphate (DKP) salt at a ratio of 1:1.5 (w/w). Additionally, similarities in fatty acid profile indicated the avoidance of influence on lipid quality from chemicals. This study demonstrated the feasibility of TPP for microalgae lipid extraction for biodiesel production.
CATALYZED OXIDATIVE DEGRADATION OF LIGNIN USING DIOXYGEN AS THE OXIDANT IN ACETONITRILE/WATER SYSTEM

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In recent years, with the shortage of fossil energy, reasonable exploitation and utilization of renewable biomass resource have attracted wide attention in the field of energy and chemical industry. Lignin, as the second most abundant natural polymer on the earth, is an important bioresource, accounting for 15-35% content and 40% energy content of lignocellulose biomass. However, so huge potential valued organic polymer was usually directly subjected to combustion as a fuel conventionally, which means the high value-added utilization of lignin has not been completely achieved. Therefore, it is necessary to develop the rational and value-added utilization of lignin in the field of biomass conversion. Herein, thermochemical conversion is regarded as the effective methods compared with biochemical conversion. However, the shortcomings of pyrolysis and hydrogenolysis, such as the complex products and harsh reaction conditions, limit their development. Thus, attentions turn to be paid on lignin oxidative degradation. In this study, a biorefinery lignin obtained from the hydrothermal treatment before cooking was selected as the rare material to investigate the oxidative degradation characteristics of lignin using vanadium(III) acetylacetonate as the catalyst and dioxygen as the oxidant in acetonitrile/water system. The oxidative degradation was carried out in a bath reactor. After reaction, the gases were collected and off-line determined by gas chromatography. For further analysis, the mixture was filtrated, rotary evaporated, and then the internal standard substance (n-dodecane) was added. Results showed that the char yield was about 5%, which was much lower than that from the pure acetonitrile system. The phenomenon suggested that the acetonitrile/water system could inhibit the repolymerization very well. Oxidative degradation products were mainly phenolic aldehydes, phenolic ketones, phenolic acids, and quinones. These products benefitted from the creaking of Cα-Cβ and Cβ-O bonds within lignin, as well as the oxidation of the hydroxyl group at α-position. Furthermore, according to the different aromatic rings, i.e. the different methoxyl groups, these products could be divided in p-hydroxylphenyl (H-type), guaiacyl (G-type), and syringyl (S-type) compounds, which were consistent with the initial substructures within lignin. Meanwhile, demethoxylation reaction was recognized, which could be proofed by the reduction of S-type compounds and the existence of CH₄ in gaseous products. After reaction, the molecular weight of liquid product dropped to 300 Da, which suggested the formation of dimeric and trimeric compounds.
PRODUCTION OF AVIATION BIOFUEL FROM LIGNOCELLULOSIC FEEDSTOCK BY AQUEOUS-PHASE CATALYSIS

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As a result of limited fossil fuel reserves and strict environmental regulations, there is an urgent demand for renewable fuel production from non-edible lignocellulosic biomass. Since the pioneering work on the production of liquid alkanes by aqueous-phase processing of biomass-derived carbohydrates proposed by Dumesic group, recent studies on this lignocellulosic biomass reaction have attracted intensive interest. In current study, we proposed the production process of aviation biofuel from lignocellulosic feedstocks, such as cornstalk and sorghum stalk.

This conversion process includes some consecutive steps: acid-catalyzed steam stripping-hydrolysis of lignocellulosic biomass to platform compounds such as furans and levulinic acid, base-catalyzed aldol condensation of platform compounds to form the oxygenated hydrocarbons with the increased carbon-chain length (C10+), and the subsequent hydrogenation/hydrodeoxygenation (HDO) of condensation products to liquid alkanes (C8-C15) over the supported metal multifunctional catalysts.

As shown in Fig.1, the integrated aviation biofuel synthesis system in the pilot-scale facilities is made up of four main units: platform compound production, aldol condensation, hydrotreating and waste treatment.

Fig.1 Flowsheet for the integrated aviation biofuel synthesis system from lignocellulosic feedstock
THE PERFORMANCE OF COMBINED HEATING AND POWER SYSTEM BY BIOGAS PRODUCTION WITH AUXILIARY OF SOLAR HEATING

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It is environment-friendly and high-efficient way to cogenerate power and heat with biogas from the anaerobic fermentation process of cow manure. However, in northwest China, it is difficult for a cogeneration system of heat and power (CHP) to run normally in winter. In this study, two generators are made in Czech Republic by company TEDOM the maximum power output of 76 kW and power generation efficiency and thermal efficiency are 31.5\% and 50.2\%, respectively. The total volume of two digesters which is Upflow Solid Reactor and gasholder which is water sealed and bell-shape is 1200 m\(^3\) and 300 m\(^3\), respectively. Waste heat power generation recovery warmed and insulated the biogas plant is one of the most cost-effective ways to warm the biogas plants. In this study, methane concentrations must be bigger than 52\%. The biogas generators use themselves high temperature exhaust and heat of jacket water for heating the circulating water that is a mixture of water and ethylene-glycol of about 40\% by weight to avoid frozen in winter. Large and medium-sized biogas plants heat loss consists of fermentation tank, feedstock and gasholder. According to the ambient temperature, feedstock temperature, soil temperature at different depths and average daily heat load in different months are calculated by the formula of heat transfer. But it is not enough for the preheating of feedstock and the maintenance of thermostatic anaerobic fermentation and the feedstock frozen cannot be delivered into the fermentation tank due to the low temperature in the winter. Therefore, solar thermal collector is introduced to a CHP built at Huazhuang town in Lanzhou City, Gansu Province, China, preheats the feedstock and heats the fermentation tanks and the gasholder. The results showed that the whole biogas project in January the average daily heat needs 7377.7 MJ, solar energy aided CHP biogas plant system provides 7378.6 MJ, which can meet the heat demand of the whole system, thus the temperature of the anaerobic fermentation system in the whole year can maintain at above 37\degree C and the temperature of feedstock can increase from -2.5\degree C to 5\degree C. This method manages the problem in the biogas plant system and has a good effect for the system. The solar energy aided CHP biogas plant system provides a reference for northwest China.
SELECTIVE OXIDATION FOR REMOVAL OF CHAR AND TAR FROM HIGH-TEMPERATURE BIOMASS GASIFICATION GAS

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A novel fiber ceramic filter candle was modified with a silicon-zirconium composite film by sol-gel method, in order to efficiently separate the solid impurities from the crude biomass fuel gas and run stably for a long time. Through the 100 h continuous hot gas filtration experiment for biomass air gasification (BAG) (100 Nm3/h), it was systematically studied on the influence of different ash, tar and operating conditions on the filtration behavior. Experiment results showed that the filtration resistance of biomass fuel gas was mainly affected by tar; under the tar < 0.5 g/Nm3 and ash < 20 g/Nm3 condition, the system could be operated stably; when tar > 5.0 g/Nm3, high temperature N2 blowback gas would be necessary; but the back purge would be needless for a long time with ash <1.5 g/Nm3. The filtration failure frequently occurs when filter media is blocked by the accumulated solid particles with high tar content. This study puts forward a new process on hot-gas filtration for cake cleaning by partial oxidation of the solid particles collected from biomass gasification gas (PBG). Meanwhile, the mechanism of the PBG partial oxidation is investigated at 300 - 600 ℃ in a ceramic filter which is set and heated in a lab-scale fixed reactor. Results indicated that the best operation temperature should be at 350 - 400 ℃. When the BAG gas without PBG particles passed through the ceramic filter at 300~500 ℃, its component concentration had nearly no change with O2 content lower than 6 %. For the BAG gas containing PBG particles (PBG content on the surface of ceramic filter media is about 6.37 kg/m2), a large number of PBG particles could be oxidized to yield CO and CO2 at 350~400 ℃ in the presence of 2% O2 content while only a small amount of BAG gas generated oxidizing reaction at the same conditions. Moreover, the PBG were characterized by using the FTIR, SEM and BET before and after partial oxidation. The FTIR analysis revealed that the partial oxidation of the PBG can result in a remarkable decrease of the C-H (alkyl and aromatic) groups and an increase of the C=O (carboxylic acids) groups. The SEM and BET analysis suggested that PBG in the process of partial oxidation subsequently underwent pores or pits formation, expansion, amalgamation and destruction.
Special Session I

Promoting New and Renewable Energy Projects in Asia
OPPORTUNITIES AND CHALLENGES OF DECENTRALIZED ROOF PV DEVELOPMENT IN SHANGHAI,

- A CASE STUDY OF PUDONG HITACHI FACTORY PROJECT

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Under the policy promotion, pressure of carbon emission reduction and relatively mature development of PV technology, enterprises with suitable conditions using decentralized energy system are working together with the decentralized PV power generators to install this kind of new power producing system in their spare space. Depends on the installed capacity of the project, it can reduce the power usage in varying degrees from the national grid. If there are any left electricity generated from PV, it can be sold to national grid.

This project with 2.5MW designed electricity generation capacity, is installed on the roof of 3 different buildings of one company, which is located at Pudong District, Shanghai. It was designed to provide up to 30% power consumption of the whole company according to the current power requirement. The first phase of project with 1.7MW generation capacity has been installed in late 2015 and began to operating. The contract of this project was signed in May 2015 and the first phase 1.7MW capacity roof facility has been finished in December 2015.

This project was selected to be one case study with the reasons as follows: 1) this project is one typical demonstration decentralized solar power project in china, which is a profitable, replicable and sustainable commercial model can be referenced by other areas and countries. 2) Following the definition of decentralized energy system in China, this project is one typical project with a certain size (installed capacity and technical operation) can be a reference for other areas. 3) the relative mature experience on implementation of policy, subsidy incentives and cooperation between different stakeholders.

As the investment cost and efficiency of PV power generation, the profit-making of the generator still mostly rely on the subsidy from the government, and it will take different years to get the investment cost back depending on the size of the project. There are still some challenge and difficulties faced by the frontrunner of decentralized power generator, such as looking for the suitable consumer with good condition for project implementation, funding-raising for investing new projects, etc. However, experience of running this project on technical cooperation and operation mechanism can be shared with other area with similar condition for developing decentralized PV energy system.
● COST/BENEFIT ANALYSIS OF INDEPENDENT SOLAR ENERGY WITH ENERGY SAVING SYSTEM (ESS) FOR SMALL ISLAND COUNTRIES: A CASE OF MALDIVES

Prof. Tae Yong Jung
(GSIS and Deputy Director, IGS, Yonsei University, Republic of Korea), Ms. Junghee Hyun (GSIS, Yonsei University)&Ms. Haein Kim (Wisconsin University, USA)

The conventional, large-scale, fossil fuel based grid system cannot be sustainable especially in small island countries. Despite high costs and volatility of fossil fuels, small island countries continue to power 90% of economic and social activities with imported fossil fuels. Meanwhile, the Maldives is one of the most vulnerable countries to climate change impacts as a small island country and their low height above sea level. Therefore, a more sustainable energy option for the Maldives is a keen interest and agenda item for the local government as well as the international community. This research provides a concrete example of ‘leap-frogging’ strategies, suggesting application of new climate technologies and implementation of an adaptation and GHG mitigation integrated project for off-grid areas. The goal was to evaluate whether a hybrid system combining diesel and renewable energy power generation with ESS (Energy Storage System) is appropriate to small island countries as a sustainable energy system. The economic and technical feasibility was tested using HOMER (Hybrid Optimization of Multiple Electric Renewables) program. The sensitivity analysis showed that among four system configurations including diesel-only and hybrid systems, the PV-diesel-ESS hybrid system became more economical than the current diesel only system.

● THE SPILL-OVER EFFECTS OF ENVIRONMENTAL POLICY INSTRUMENTS OVER THE RENEWABLE ENERGY GENERATION AMONG THE EU AND APP COUNTRIES

Ms. Takashi Nishida (Hiroshima City, Japan) &Prof. Shinji Kaneko (Associate Dean, Graduate School for International Development and Cooperation, Hiroshima University, Japan)

Support of international and/or domestic public environmental policies play a significant role for the diffusion of renewable energy since energy generation from renewable sources are relatively more expensive than from fossil-fuels. Whilst substantial earlier literatures have investigated the impacts of domestic environmental policy instruments on the diffusion of renewable energy at the same country, little attention has been paid to their spill-over effects across the borders. However, due to the recent amelioration in international frameworks and mechanism to jointly cope with the issues upon climate change, it is anticipated that the diffusion of renewable energy level has also been influenced by environmental policy instruments implemented in other countries. The chief objective of this paper lies at empirically estimating these spill-over effects, particularly focusing on how countries (destination countries) alter the renewable energy generation share when alliance countries (origin countries) implement more stringent environmental policy instruments among the EU countries and the member states of Asia-Pacific Partnership on clean Development and Climate (APP). The EU countries have further categorized into the Inner Six, leaders and precursors of the current EU system, and the rest of the EU countries when deemed necessary.

From the analysis, this study concludes that the spill-over effects of environmental policy instruments are different depending on the affiliation status. They may be influenced by whether they have enacted the legally binding scheme or not. In addition, the power struggle among the club might be another factor determining the direction of the spill-over effects. To fully understand its mechanism, further studies are needed.
NEW & RENEWABLE ENERGY MARKET AND STRATEGIES FOR INDUSTRY PROMOTION IN KOREA
Dr. Jiwoon Ahn & Dr. Hyunje Kim

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The new & renewable energy market of Korea has been developed in recent years. Moreover, the 4th basic plan for new & renewable energy, established in 2014, promoted the new & renewable energy industry growth. The policies for energy new industry of present government include the new & renewable energy technologies as major fields.

This study presents the market status and policy directions for new & renewable energy industry in Korea, focusing on 4th basic plan for new & renewable energy. Firstly, the market growth after 3rd basic plan and deployment status by resources is presented, and various policy directions for industry promotion and deployment increase are summarized.

The deployment and maturity of renewable energy market seem to be insufficient although the new & renewable energy market size of Korea has been increased rapidly. Therefore, the cooperative efforts of public and private sector are required. The policy direction and strategies are especially expected to be shifted to market friendly directions.

IMPACT ANALYSIS ON FINANCIAL FEASIBILITY OF SOLAR PROJECTS IN INDIA IN APPLICATION OF ALTERNATIVE POLICIES

Mr. Jongwoo Moon (SAIS, Johns Hopkins University, Washington DC, USA)
& Ms. Elizabeth Jung (Seoul Urban Solutions Agency, Republic of Korea)

India has been facing serious energy issues in meeting its rapidly surging energy demands caused by its fast economic and social development for decades. To meet its energy demand in a climate-friendly path, India set a target to promote the penetration of solar PV technologies in its electricity grid. This paper intends to find policy implications to enhance the effectiveness of renewable policies in India. This paper selects existing solar PV projects in India, and conducts financial and policy analysis of those projects by applying different renewable policy options, using Discounted Cash Flow and Monte Carlo Simulation Methods. Findings from the analysis could suggest possible policy options to enhance the financial feasibilities of solar PV projects in India that can contribute to achieving its National Renewable Targets. Moreover, the framework used in the financial and policy analysis and the implications of the research could be applied further to other cases in developing countries.
THE ECONOMIC ANALYSIS ON WASTE TO ENERGY PROJECT: FOOD WASTE TREATMENT

Prof. Tae Yong Jung (GSIS, and Deputy Director, IGS, Yonsei University, Republic of Korea)
&Ms. Jihyun Sohn (GSIS, Yonsei University)

Evidences show that the higher the rate of economic development and urbanization, the larger the amount of solid waste generated. Therefore, handling the rapidly increasing amount of solid waste becomes one of major challenges that most developing countries is now facing. Without consideration of economic, health and environmental problems that can be caused by carelessly managed wastes, wastes can pose threats to a country’s sustainability. Ulaanbaatar, where severe pollution of both soil and air generated from wastes in transition process to market economy, currently requires proper waste management system. Introduction of waste to energy with various technological options including utilization of energy storage system will be considered. Using simulation software HOMER (Hybrid Optimization of Multiple Energy Resources) developed by the National Renewable Energy Laboratory of the United States, different power system configurations including waste to technology options with energy storage system will be compared to existing technology options in terms of technical and economic feasibilities. In consideration of economic viability, different types of tax incentives will also be considered.
Special Session II

8th GIEC-KIER Forum on New and Renewable Energy
KIER'S R&D WORKS ON BIO-JIT FUEL

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Bio-jet fuel is recognized as an effective tool for CO₂ mitigation in air transport sector. Among the various technology options, hydrotreated esters and fatty acids (HEFA) technology was reported to be the most close to commercialization. To produce HEFA from the lipids, hydrodeoxygenation (HDO) is needed to remove oxygen in lipids that requires a big amount of hydrogen, 300-400Nm³/m³ oil. In fact, big consumption of hydrogen in the process is a major hurdle for mass production of bio-jet fuel. To reduce the hydrogen consumption for deoxygenation of lipids, decarboxylation process has been studied by my research team. For decarboxylation process, stability of the catalyst is the major concern. Therefore we try to screen an efficient catalyst and improve the catalyst stability through the process optimization. In this presentation, several major R&D outputs will be introduced.

FUEL AND LIGHT ALKENE PRODUCTION FROM BIOMASS BASED SYNGAS

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Fuel and chemical production from biomass is an important biomass utilization technology. In our group, fuel and light alkene were produced from biomass based syngas by using designed catalysts. Different ion based catalyst and catalysis systems were designed, synthesized and carefully investigated, the effect of structures, promoters and carriers were explained. By control the catalyst structure, different carbon chain length can be adjusted. Light alkenes like ethylene and propylene can be produced by using promoters.
NANOPARTICLE ENGINEERING APPROACH FOR EFFICIENT BIOENERGY PRODUCTION

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Microbial biofuels such as biohydrogen and biodiesel have attracted intense interest as a potential fossil-fuel replacement candidates. However, the overall process, starting from cultivation and ending in conversion to biofuels, entails complicated processes, and moreover, faces technological and economic challenges for commercialization. Nanoparticle engineering generally covers the development and application of artificially-synthesized and decorated nanoparticles on nanometer scale. Additionally to an extraordinarily larger surface area, nanoparticles could offer characteristic physicochemical and mechanical properties in terms of reactivity, tenacity, elasticity, strength and electricity. In this presentation, along with recent, integrative concepts of nanoparticle engineering and conventional bioenergy process from our group, we would discuss research directions to improve efficiency and economics of biorefineries.
COMBUSTION AND HEAT RELEASE CHARACTERISTICS OF BIOGAS AT HYDROGEN AND OXYGEN

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As a favorable energy source, biogas is widely considered as a fuel of heating facilities, power generation, and vehicles. Biogas can be produced from anaerobic digester of biomass or biodegradable organic wastes. The main compositions of biogas are methane and carbon dioxide, together with small amount of water, nitrogen and hydrogen. Unfortunately, biogas has a relatively lower heating value as well as lower heat release rate than that of conventional fuels, which limits the application of biogas in the practical combustion devices. Several researches have been experimentally and numerically performed to explore the fuel characteristics of biogas. Among them, high quality fuels such as liquid petroleum gas and liquefied natural gas are blended with biogas to improve relatively poor combustion characteristics of biogas. Numerous researches are paid attention to combustion characteristics of biogas premixed flame. However, non-premixed combustion of a fuel in the practical application is necessary and worthwhile to be studied for its practical application.

In this research, biogas combustion at hydrogen enriched and oxygen enriched conditions has been proposed as potential methods for improving biogas combustion in order to use biogas as a practical fuel. The non-premixed flames of biogas at various hydrogen enriched and oxygen enriched conditions have been focused. Combustion and heat release characteristics of biogas non-premixed flames at various hydrogen enriched and oxygen enriched conditions have been numerically investigated. A non-premixed combustion model of biogas is established. The GRI 3.0 mechanism with 53 species and 325 elementary chemical reactions is employed. The P1 radiation model is considered. All elementary chemical reaction rates and heat release rates are programed. The contents of methane in biogas, hydrogen addition ratios, and oxygen enrichment levels are ranged from 40\% to 80\%, 0\% to 50\%, and 21\% to 35\%, respectively. The results show that the net reaction rate of biogas increases with increasing hydrogen addition ratio and oxygen levels, leading a higher net heat release rate of biogas flame. Furthermore, the formation of free radicals such as H, O, and OH are enhanced with increase of hydrogen addition ratio and oxygen levels. Higher reaction rate of exothermic elementary reactions, especially those with free radical of OH are increased, which is benefited to the improvement of combustion and heat release characteristics of biogas in the practical application.
DEVELOPMENT OF MICROBIAL ELECTROLYSIS COUPLED 2-STAGE ANAEROBIC DIGESTION PROCESS

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Anaerobic digestion technology was used for the reduction of organic waste such as wastewater sludge or food waste. Recently it is used for the production of biogas including methane and hydrogen. Recently several anaerobic digestion coupled with microbial electrolysis cell are studied to increase the production and purity of biogas simultaneously. It is mentioned that redundant carbon dioxide produced from AD can be in-situ converted to additional methane by electromethanogens utilizing hydrogen formed from microbial electrolysis cell as an electron donor, generating high quality biogas.

In this study, a 2-stage anaerobic digestion process coupled with microbial electrolysis is developed for the enhancement of biogas production and quality. An anode is placed in acid reactor, and a cathode is placed in methane reactor, and electrodes are connected with DC power supply providing from 0 to 0.7V DC power from external sources. The experimental system (2 set) are continuously operated, monitored with the pH, VFAs, alkalinity in the reactors. Organic removal rate, specific methane production and methane yield etc. of the system are compared with a 2-stage AD system without electrolysis.
LIQUID HOT WATER PRETREATMENT OF LIGNOCELLULOSE BIOMASS TO ENHANCE TOTAL SUGAR RECOVERY AND ENZYMATIC DIGESTIBILITY OF CELLULOSE

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Several processes are required in cellulosic ethanol production from lignocellulosic feedstocks such as pretreatment, enzymatic hydrolysis, fermentation, and product separation/distillation. The native lignocellulosic biomass has limited its accessibility to enzymes and microorganisms due to its complex cell wall structure of cellulose-hemicellulose-lignin. Therefore, pretreatment is an essential prerequisite to overcome recalcitrance of biomass and enhance the bio-chemical conversion ratio of polysaccharides. An effective pretreatment can reduce the downstream pressure by making cellulose more accessible to the enzymes and minimize the formation of degradation products that inhibit the growth of fermentative microorganisms. For the advantages of without additional chemicals, less inhibitory products and higher pentosan recovery, liquid hot water pretreatment become attractive.

The process of step-change flow rate (SCF) liquid hot water pretreatment and step-change temperature (SCT) liquid hot water pretreatment were developed in GIEC, respectively, for the sweet sorghum bagasse (SSB) and eucalyptus wood chips (EWC) to enhance sugar recovery and enzymatic digestibility of cellulose. Furthermore, the decomposition mechanism of hemicellulose and lignin in the liquid hot water was investigated. Moreover, different structural changes at the plant tissue, cellular, and cell wall levels were investigated to understand the decomposition mechanism of sugarcane bagasse cell wall in the liquid hot water pretreatment. The transmission electron microscopy (TEM) images showed that sugarcane bagasse cell walls were composed of the middle lamella (ML) layers, the primary wall (P) layers, and the secondary wall layers. While after the pretreatment, the boundaries among the S1, S2 and S3 layers in the secondary wall of treated samples could not be distinguished exactly. The data from the scanning electron microscopy and energy dispersive X-ray analysis (SEM-EDXA) shows that the migration of lignin happens among different cell wall layers. Moreover, pseudo-lignin, the degradation products of lignin and xylan, appeared on the surface of pretreated sugarcane bagasse. Furthermore, Raman spectra of treated sugarcane bagasse indicated that the distribution of cellulose in the cell wall was homogenized, and the difference in the chemical composition was reduced. All of these changes on the ultrastructural level of the cell wall were responsible for the improvement of the enzymatic digestibility of treated samples.
OPTIMIZATION OF MICROBIAL HYDROGEN PRODUCTION BY APPLYING HIGH PRESSURES

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Hydrogen energy is attracting more interests as a fossil-fuel alternative due to its carbon free character. Nowadays most hydrogen is commercially produced by steam reforming from natural gas however this process is not only energy intensive but also harmful to environment. Biological processes for hydrogen production can be suggested as an alternative based on its milder and eco-friendly reaction conditions. \textit{Thermococcus onnurineus} NA1 can work as a live catalyst producing hydrogen via water gas shift reaction from carbon monoxide (CO+H\textsubscript{2}O \rightarrow CO\textsubscript{2}+H\textsubscript{2}). This activity has been enhanced successfully by genetic engineering however the mass transfer limit between liquid and gas phases still remains as an obstacle for getting higher productivity for commercialization. Gas dissolution rate can be determined by mass transfer coefficient ($k\textsubscript{L}$), interfacial area ($a$) and gas saturation concentration ($C^*$). In biotechnology field many studies have suggested ways to increase $k\textsubscript{L}$ or $a$ values such as stirring media or breaking large bubbles. Changing gas saturation concentration by applying high pressures has been tried rarely. In this study carbon monoxide pressures ranging from 1 to 10 bars were applied for cell growth. The effects of increasing CO solubility on cell growth and hydrogen production by pressurizing were examined and the stress imposed by pressure will be discussed in this presentation.
HYDROGEN PRODUCTION FROM INDUSTRIAL OFF-GAS USING BY-PRODUCT IRON OXIDE AS AN OXYGEN CARRIER IN CHEMICAL LOOPING PROCESS

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The chemical looping strategy for hydrogen production (CLH2) offers a potentially viable option for efficient fuel conversion to highly pure hydrogen with the simultaneous capture of CO₂. Typically, this process uses an iron-based composite as an oxygen carrier and syngas or methane as a fuel. The environmental and economic concerns motivate the use of abundant by-product iron oxide and the industrial off-gas for CLH2. Here we show that highly pure H₂ can be simply recovered from the industrial off-gas in a circulating fluidized bed with a mixture of the inexpensive raw material of by-product iron oxide and sand particle. The fluidization of the by-product iron oxide powder, which shows poor fluidization behavior, is improved by adding 60 vol% of sand particle. The industrial off-gas is completely converted to CO₂ and H₂O in a two-stage fluidized mode with a solid reactant of Fe₂O₃ of the binary particles, and then highly pure H₂ is produced by oxidizing the reduced by-product iron oxide powder with steam. The binary particles show consistent catalytic activity under multiple redox cycles. These findings provide valuable information for the future development of CLH2 based on by-products.

NEW MATERIALS AND KEY TECHNOLOGY RESEARCH OF HYDROGEN ENERGY STORAGE FOR RENEWABLE RESOURCES

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Electricity from renewable resources can be converted into hydrogen through water electrolysis. The hydrogen can be stored and eventually re-electrified by fuel cell. PEM (proton exchange membrane) fuel cells and water electrolyzers are more efficient than alkaline systems, however they are still face some challenges, such as high cost of the systems. To promote the large scale application of PEM fuel cells and water electrolyzers, this work focus on preparing new type and more efficient electrodes in both fuel cell and water electrolyzer with reduced noble metal loading. Block copolymer (BC) self-assembling nano-structures were used as templates for synthesis of platinum nanoparticle (Pt NP) catalysts, the structure and catalytic activity, stability of the Pt NP arrays for fuel cell application were also presented. Open pore architecture IrO2 were prepared by electrodeposited on hydrogenated TiO2 nanotube arrays for OER. It was found that hydrogenated TiO2 can facilitate the electro-deposition of IrO2, and elevate the OER activity compared to non-annealed and air-annealed TNTA. Titanium oxide nanotube arrays (TNTA) were also used as sacrificed template to form IrO2 nanorod arrays, then the arrays were hot pressed in nafion membrane as a highly ordered anode in water electrolyzers.
DEGRADATION ANALYSIS AND DEVELOPMENT OF ADVANCED SOLID OXIDE FUEL CELLS WITH HIGH DURABILITY

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A solid oxide fuel cell (SOFC) is an electrochemical energy conversion device that can generate electricity directly from a wide range of fuels. As compared to low-temperature fuel cells, SOFCs operating at relatively high temperatures (600–900 °C) have a number of attractive features, such as high energy conversion efficiency, fuel flexibility, and rapid reaction kinetics. SOFCs are complex electrochemical devices that consist of four basic components – a porous anode, an electrolyte membrane, a porous cathode, and an interconnect, and there are still many challenges to be addressed. In particular, high-temperature degradations of SOFC materials, cells, and stacks present major technical challenges in the widespread commercialization of SOFCs. This talk provides an overview of research work on the degradation analysis of SOFCs, including (i) diagnostic techniques to identify the main mechanisms that cause time-based degradation of SOFCs; (ii) accelerated test methodologies to improve efficiency of test resources; and (iii) promising strategies to develop SOFC cells and stacks with improved power and durability.

RECENT ADVANCE ABOUT MICROBIAL FUEL CELL IN GIEC

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Microbial fuel cell are devices that can convert chemical energy into electrical energy by microorganisms. In recent years, it has been widely concerned by researchers due to its application in wastewater treatment and energy harvesting. Too many previous reports has been reported.

The MFC related research in Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences (GIEC) include the preparation of cathode materials, such as core-shell Au-Pd nanoparticles, Pt-Ru nanoparticles and the biomass carbon. Besides, We also built a double chamber microbial fuel cell to treat molasses wastewater aiming at achieving resource utilization. The change of Volatile fatty acids in the degradation process was also studied. The results indicated that MFC has a wide application prospect in the field of molasses wastewater treatment. The combination of MFC and anaerobic fermentation has also been well investigated in the current study.

The studies showed that MFCs have great prospects in wastewater treatment, While its performance still needed to be improved. Through unremitting efforts, a better achievement can be obtained.
NON-VACUUM PROCESSED CIS SOLAR CELL USING HYBRID INK

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Cu(In,Ga)\textsubscript{2}Se\textsubscript{2} (CIGS) chalcopyrites have been widely investigated in the field of environmentally friendly solar renewable energy using photovoltaic cells. Especially, non-vacuum processed CIGS has been in the spotlight recently, despite its low conversion efficiency, because of the high production costs and material waste from vacuum-based processes.

We already reported a non-vacuum hybrid ink to form CIS thin films. The concept of our hybrid ink is that the merge of the advantages of particle-based and solution-based processes, and it is possible to make dense thin films with little organic residue. The hybrid ink consists of synthesized binary nanoparticles (Cu-Se, Cu-S, In-Se, In-S, Ga-Se, or Ga-S) and an indium (In) precursor solution with a chelating agent, monoethanolamine (MEA). In the hybrid ink, the chelating agent, MEA, plays an important role in forming the CIS thin films.

In the hybrid ink without MEA, fabricated CIS thin film solar cells failed to show good device performance because many pores existed in the CIS thin layer after the reaction. In this case, nanoparticles were not grown large enough to make a dense CIS thin layer in this precursor solution during the reaction. On the other hand, the hybrid ink with MEA produced quite good device performance due to the formation of dense CIS thin layers. In addition, the combination of components and reduction of organic residues were controlled by mixing a moderate number of binary compounds and precursor solutions.

Here we show hybrid ink processed CIS solar cell. If time permits, research areas covered in the photovoltaic laboratory, KIER will be briefly introduced as well.

VANADIUM DIOXIDE THERMOCHROMIC SMART WINDOW

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Smart window, defined as windows that can dynamically and selectively block solar radiation and heat, can assist building to keep higher energy performance. Chromic material is one of the most common active smart windows. Vanadium dioxide (VO\textsubscript{2}) as one of thermochromic materials attracts great attention due to the change of transmission in NIR range with temperature. In our lab, VO\textsubscript{2} smart window prepared by solution and vapor methods are investigated. The luminous transmission and solar modulation is up to 60\% and 15\%, respectively. Especially, the phase transition temperature can be depressed to 45°C without doping, which means the properties can be approximate practical utilization. The film especially by solution method can be batched production in small-scale.
DEVELOPMENT OF SALINITY GRADIENT POWER TECHNOLOGIES IN KOREA INSTITUTE OF ENERGY RESEARCH (KIER)

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Sources of marine renewable energy include waves, tides, ocean currents, ocean thermal energy conversion, and salinity gradient power. Among them, the salinity gradient power is a specific energy available from the difference in the salt concentration between salt water and fresh water. Experts have reported that the theoretical maximum global potential of salinity gradient power is estimated at 2.6~3.0 TW. Although numerous methods have been discussed to recover this energy, two practical methods, having the most potential for energy extraction, are pressure retarded osmosis (PRO) and reverse electrodialysis (RED). In this presentation, we elucidate development trend of salinity gradient power technologies and its future prospect. Also, we introduce the development strategy of salinity gradient power technologies in KIER. Our works focus on the development of kW-class RED system and the related core technologies, including stack, membrane, electrode, and pre-treatment process. In current, we are operating 2kW-class RED system and have a long-term plan to develop 5kW-class RED pilot plant by 2020.

RESEARCH AND OPEN SEA TESTS OF 10KW WAVE ENERGY CONVERTOR SHARP EAGLE

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To develop wave energy convertor (WEC) in low wave energy flux, efficiency is an issue greatly concerned. The efficiency of WECs must be high enough so that the device is economic. Efforts have been paid to increase the capture ability and power take-off (PTO) efficiency. A novel floating wave energy converter, Sharp Eagle, has been invented, which is characterized in that an eagle-head-shaped wave energy absorber, a ship-shaped underwater appendage and a door-shaped support arm are assembled in a semi-submersible barge. After a series of hydrodynamic research and test, a 10 kW Sharp Eagle WEC has been deployed in China Southern Sea for real sea test, which has continuously worked for more than one year since December 28, 2012. During the operation, it has effectively withstood the typhoon Haiyan. In addition, the new generation – the 100kW Sharp Eagle has been successfully constructed and launched since 2015.
Poster Session
Topic 1: Energy Storage System
INVESTIGATION OF PUMP-TURBINE ENERGY STORAGE SYSTEM FOR ENERGY INDEPENDENT ISLAND IN KOREA

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The study focuses on numerical analysis of a 30kW-class pump-turbine system for energy independent islands in South Korea. The purpose of the study is to design a pump-turbine system and conduct CFD analysis for performance prediction. The pump turbine system for ocean renewable energy storage system may include hybrid system with offshore wind, tidal current, wave, solar, thermal and any other new renewable energy in focus. This kind of hybrid system can reduce the usage of diesel generators and help to contribute to the environment in a positive manner by reducing carbon emissions.

The system can be applied in South Korea because of the availability of many islands. Currently, some of the islands are not connected to the grid of the main land so the only means of electricity generation is by diesel generators. Additionally, a 30kW pump turbine does not require a large head and a head of approximately 30m is sufficient for the design and application. Several other renewable energy systems like wind turbines, tidal turbines and solar energy can be used to make a hybrid system.

The pump-turbine system consists of spiral casing, 20 stay vanes and 20 guide vanes with 7 impeller blades and elbow type draft tube. The specific speed, Nq of pump mode is 40m·m³/s and turbine mode is ~120m·kW. The design head is 30m and flow rate is 0.11m³/s in turbine mode; 34m head and 0.10m³/s flow rate in pump mode including loss in pipe.

A full domain computation was conducted that consists of the spiral casing with stay vanes and guide vanes, impeller, and draft tube. A total of 6.5×106 nodes and 6.3×106 elements were used to generate the numerical grid. All the components were meshed using hexahedral grids. The shear stress transport model is utilized for the numerical analysis, which has been widely used for turbomachinery applications. In the present study, the CFD analysis on 30kW-class pump-turbine model has shown satisfactory results.
FABRICATION OF A FLEXIBLE RUTHENIUM OXIDE/GRAFHENE ELECTRODE FOR HIGH-PERFORMANCE SUPERCAPACITOR APPLICATIONS

Sangeun Cho, Jongmin Kim, Yongcheol Jo, Seoungwoo Lee, Hyeonseok Woo, Abu Talha A. A, H. S. Chavan, A. I. Inamdar, S. M. Pawar, Hyungsang Kim, Hyunsik Im*

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Integration of flexible/wearable technologies and energy storage devices plays a key role in developing high-performance supercapacitors. In this study, RuO2 thin film is fabricated by using electrodeposition on a graphene-coated Cu foil, and its electrochemical energy storage properties are investigated. The RuO2/graphene electrode exhibits specific capacitance of 1194 F/g at a scan rate of 10 mV/s with excellent cycling stability under an applied external force. The high-performance RuO2/graphene electrode is due to the synergetic effect of high-capacitance RuO2 and graphene–enhanced robustness at the RuO2 and Cu interface.

THERMAL SYSTEM ANALYSIS OF COMPRESSED AIR ENERGY STORAGE WITH PRE-COOLER

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Energy storage is regarded as an important solution to handle the mismatch between power generation and consumption, due to the increasing of intermittent power feed-in by wind power and solar photovoltaic. Compressed air energy storage (CAES) system as one of the industrial energy storage technologies have become a popular research topic in the past few years. It can be divided into two parts: one is charge process, and the other is the discharge process. Increasing energy efficiency of either process can improve the round trip efficiency (RTE) of the system. In this paper, an integrated energy system consisting of a CAES system and precooling system (PC-CAES) is proposed to decrease the energy consumption of compressor in charge process, and enhance the RTE of the system. Air conditioner was used as pre-cooler to precool the inlet air for compressor. The thermodynamic analyses including energy analysis and the parametric analysis are evaluated by using steady-state mathematical model and thermodynamic laws. The calculations show that proposed PC-CAES system can reduce input power consumption by 10%, and its RTE improved more than 2%, compared to that of the conventional CAES system.
COMPARATIVE ANALYSIS ON ELECTROCHEMICAL CHARACTERISTICS BETWEEN CELLDISCRIMINATION-BASED HIGH-POWER AND HIGH-ENERGY BATTERY PACK IN ELECTROCHEMICAL-POWERED TRANSPORTATION

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Research and/or Engineering Questions/Objective:
Nowadays, the rechargeable Li-ion cell-configured battery packs have been elaborately recognized as an optimal solution for electric-powered transportation that requires high-power and high-energy output. The most important consideration for expecting a better performance of the Li-ion battery pack is to maintain the cell’s uniformity within the battery pack. Without additional equalization circuits, our cell-discrimination which selects cells with similar electrochemical characteristics, enables us to provide a unique solution for stable configuration of the battery pack. Therefore, our approach clearly showed the validity of the cell-discrimination through detailed comparative analysis on electrochemical characteristics of high-power and high-energy battery packs in electric-powered transportation.

Methodology:
This study used two kinds of Li-ion cells, a high-power (INR18650-20S, 2.05Ah/15C-rate) cell and a high-energy (INR18650-29E, 2.85Ah/1C-rate) cell produced by Samsung SDI. Three key factors of discharge capacity, direct current internal resistance (DCIR), and open-circuit voltage (OCV) at the lowest/highest SOC points were orderly taken for account to implement the cell-discrimination of a total of 1000 cells (an identical pcs/lot, each 500 cells). The significant rule of this discrimination is to re-select cells (in the next step) previously selected in the previous step, therefore the correctness of this discrimination is improved. After three-step-based discrimination, the selected cells that have similar electrochemical characteristics are used for stable configuration of the series/parallel battery pack. In case of the high-power battery pack, a total of 336 cells are finally selected and used in series (12S) and parallel (28P) connection. The high-energy battery pack is connected in series/parallel (14S20P) using the selected 280 cells.

Results:
Our comparative analyses on electrochemical characteristics from discharging and charging voltage data of two battery packs were performed. Experimental data can be obtained from information on the first cell in each parallel connection (12S28P:12points/14S20P:14points) of the battery pack. The first analysis is to check the cell-to-cell voltage variation in the battery packs. All experimental results definitely showed that there is little voltage difference among the cells. The second analysis is to check the relation between the cell and battery pack voltages. With the number of the first cells in each parallel connection, the magnitudes of the discharging and charging voltages can be properly determined. All voltages of the high-power and high-energy packs are almost identical with those of 12 and 14 times of each unit cells, respectively. From this perspective, irrespective of battery pack’s specification, our approach can surely guarantee the stable configuration and efficient operation of the battery pack.

Limitations of this study:
Three key factors obtained at nominal temperature 25°C were only used for cell-discrimination. Our future work should be absolutely considered additional information on temperature effect. What does the paper offer that is new in the field in comparison to other works of the author: Simple implementation of the equivalent-circuit model (ECM)-based state-of-charge (SOC) estimation and state-of-health (SOH) prediction of the series/parallel battery pack

Conclusion:
This approach sufficiently suggests that cell-discrimination-based battery packs play an important role in electric-powered transportation.
FABRICATIONS OF A FLEXIBLE RUTHENIUM OXIDE/GRAPHENE ELECTRODE FOR HIGH-PERFORMANCE SUPERCAPACITOR APPLICATIONS

Sangeun Cho, Jongmin Kim, Yongcheol Jo, Seongwoo Lee, Hyeonseok Woo, Abu Talha A. A, H. S. Chavan, S. M. Pawar, A. I. Inamdar, Hyungsang Kim, Hyunsik Im*

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Integration of flexible/wearable technologies and energy storage devices plays a key role in developing high-performance supercapacitors. In this study, RuO2 thin film is fabricated by using electrodeposition on a graphene-coated Cu foil, and its electrochemical energy storage properties are investigated. The RuO2/graphene electrode exhibits specific capacitance of 1194 F/g at a scan rate of 10 mV/s with excellent cycling stability under an applied external force. The high-performance RuO2/graphene electrode is due to the synergetic effect of high-capacitance RuO2 and graphene-enhanced robustness at the RuO2 and Cu interface.

ELECTROFORMING ENHANCED ELECTROCHROMIC AND SUPERCAPACITIVE ENERGY STORAGE PROPERTIES IN WO3

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This study investigates the electrochromic and electrochemical energy storage properties of tungsten oxide with an embedded metallic filament array. The metallic filament array is created by electroforming, and the initially insulating region is switched into a metallic one. The electrochromic and electrochemical supercapacitor properties of the tungsten oxide film are investigated in a 1 M LiClO4 + PC electrolyte. The coloration efficiency and optical modulation of the metallic tungsten oxide film are much higher than those of the insulating tungsten oxide film. The specific capacitance value of the metallic tungsten oxide electrode is significantly improved more than ~ 60% of its initial value. The cycling stability of the metallic film (~ 92%) is significantly improved compared to that of the insulating film (~ 75%). We clearly demonstrate that metallic filaments embedded in an insulating metal oxide electrode plays a key role in improving the electrochromic and electrochemical energy storage properties.
THERMAL BEHAVIOUR OF POUCH BATTERY BASED ON MULTILAYER ELECTRO-THERMAL MODEL

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As the electrical and thermal characteristic will affect the batteries’ performance, calendar life and capacity fading, an electro-thermal coupled model is developed to analysis the thermal behaviour of the battery. The model discretizes battery into many cell elements which are united as 2D network equivalent circuit. Non-uniformity of current distribution and temperature distribution is simulated and the result is validated with experiment data at various discharge rates. The reason of non-uniformity is analyzed and the hear source is distributed. It is found that the uneven heat source of single battery will aggravate the non-uniformity of battery pack. It is observed that increasing heat transfer coefficient is a good way to reduce temperature and the non-uniformity of temperature for single battery. Only cooling the tabs is proposed to decrease the temperature deviation for battery module because it is simple and money saving.
RESEARCH ON NON-UNIFORM TEMPERATURE CHARACTERISTIC OF LARGE CAPACITY BATTERY PACK IN PARALLEL

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As the electrical and thermal characteristic will affect the batteries’ safety, performance, calendar life and capacity fading, the effect of electrical line position on temperature characteristic of large capacity parallel battery pack is studied. The results show that the temperature of area near the positive electrical line is highest in charge and discharge process; the temperature of area near the negative electrical line takes second place. The closer the area is to electrical line, the higher the temperature is. The maximum temperature and the maximal temperature difference increase when the positive electrical line and negative electrical line is closely installed. The maximum temperature and the maximal temperature difference of battery pack in discharge process is higher than that in charge process at the same rate. The distance between positive connection and negative connection is increased in order to optimize the temperature field when design the parallel battery pack. The battery thermal management system will be improved if the heat dissipation of area near the electrode is increased.
Topic 2: Geothermal Energy & Natural Gas Hydrate
THE RECHARGE RATE INCREASE TECHNICAL DEVELOPMENT OF THE ATES USING MULTI-SECONDARY SMALL DIAMETER WELL

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Geothermal system use natural temperatures for heating and cooling to achieve energy savings. Aquifer Thermal Energy System (ATES) of Open loop geothermal system has many advantages in terms of thermal efficiency, but in order to use this efficiently we need to increase injection rate. Therefore, we installed multi-secondary small diameter well (6ea-installation(Diameter 50mm, Depth 20m) surround injection well(Diameter 200mm, Depth 45m) in order to increase up to 100% of recharge rate(Figure 1). Pumping rate of PW-1, PW-2 is measured in 380m³/day, 480m³/day and Injection rate of PW-1, PW-2 is measure in 350m³/day, 450m³/day. Injection test results, PW-1 is injected 92% of pumping rate and PW-2 is injected 93.7% of pumping rate using multi-secondary small diameter well.

*Figure 1* The ATES using multi-secondary small diameter well
NUMERICAL EVALUATION ON BOREHOLE THERMAL RESISTANCE OF LARGE-DIAMETER CAST-IN-PLACE ENERGY PILE

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The pumped-hydro combined CAES system research is being developed in many countries. The Pelton The borehole thermal resistance (mK/W) means the ability to stop the heat transfer between the circulating fluid and borehole wall in the Ground Heat Exchanger (GHEX) component. In other words, it represents heat transfer behavior inside the GHEX including the convective resistance of fluid, and the conductive resistance of pipe and grout. Therefore, most commercial design programs for GHEXs adopt the borehole thermal resistance as an input parameter. In estimating the borehole thermal resistance, the equivalent diameter method and the multipole method are generally used in practice. However, both the method will overestimate the borehole thermal resistance of a cast-in-place energy pile that is usually composed of heat exchange pipes with large space between each pipe. In this paper, a series of numerical simulations was carried out to analyze influence factors on the borehole thermal resistance, and to provide simple means for estimating the borehole thermal resistance of cast-in-place energy piles. Two-dimensional numerical model was developed to estimate the borehole thermal resistance of cast-in-place energy pile equipped with parallel U-type heat exchange pipes. Empirical equations for the borehole thermal resistance of parallel U type 3-pair, 5-pair, 8-pair, and 10-pair energy piles were provided by means of parametric studies with the developed numerical model. In addition, the borehole thermal resistance of coil-type cast-in-place energy pile was evaluated by performing three-dimensional Computational Fluid Dynamic (CFD) analysis according to the various effective diameters of spiral circle and coil pitches.
CHARACTERIZATION OF THE HOLLOW FIBER MEMBRANE BASED DEHUMIDIFICATION AND AIR-CONDITIONING SYSTEM FOR THE DIRECT UNDERGROUND AIR SOURCE SYSTEM

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Geothermal systems (water to water, water to air, air to air etc.) for use in controlled horticulture farms has the heating, cooling, dehumidifying function because it uses the heat pump. It also applies to indirect underground air source systems. However, it has the disadvantage that the initial cost is higher than the direct underground air source systems. The direct underground air source system is used in a volcanic area, such as Jeju Island in South Korea. It has the effect that reducing the heating costs in winter season because underground air source temperature is almost constant throughout the year. Despite these advantages, the direct underground air source system should control the humidity by using the additional dehumidifiers because relative humidity is almost 100%. Therefore, this study was applied to the hollow fiber membrane in the direct underground air source systems, it was proposed the economical way that can be applied to the controlled horticulture farms, also, it was suggested the considerations when applying the hollow fiber membrane based dehumidification and air-conditioning system.
ESTIMATION OF THE ENERGY CONSUMPTION AND CO$_2$ EMISSION OF AN OPEN LOOP AND CLOSED LOOP GROUND SOURCE HEAT PUMP

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Heating and cooling systems contribute greatly to the energy consumption and CO$_2$ emissions of many countries. The need for energy saving and new and renewable heating and cooling systems is therefore necessary. Ground source heat pumps (GSHPs) have been found to be better energy systems than conventional heating and cooling systems, and are known to be the most efficient new and renewable energy system as far as space heating and cooling are concerned. Most of the research done on energy savings and CO$_2$ emission of GSHPs have not discussed comprehensively the methodology for estimating the energy consumption and CO$_2$ emission of the GSHP, taking into account the determination and use of the seasonal performance factors of the GSHP in the energy consumption and CO$_2$ emission calculation process. This work discusses the methodology to estimate the energy consumption and CO$_2$ emission of GSHPs using seasonal performance factors and the temperature bin approach. The discussed methodology is then used to estimate the energy consumption and CO$_2$ emission of a closed loop and open loop GSHP using results from a field test carried out on a residential building. The heating and cooling demands of the residential facility are covered by an air-source heat pump, and the closed loop and open loop GSHPs used for this study. The closed loop and open loop GSHPs have the same rated capacity and COP, and cover the heating and cooling demand of the building up to their rated capacity. The rest of the heating and cooling demand of the building are covered by the air-source heat pump. The closed loop and open loop GSHPs were assumed to be operated using electricity from nuclear and coal power plants. It was observed that the open loop GSHP system saves about 28% energy and has 28% CO$_2$ emission reduction than the closed loop GSHP system during the cooling season. The closed loop GSHP also has about 2.3% advantage over the open loop GSHP system during the heating season as far as energy savings and CO$_2$ emission reduction are concerned. However, for the combined heating and cooling season, the open loop GSHP has 6% annual energy savings and 6% annual CO$_2$ reduction than the closed loop GSHP for all energy sources used. Therefore, for energy savings and CO$_2$ reduction, the open loop GSHP system is recommended over closed loop GSHPs for use in residential buildings.
A STUDY ON THE PERFORMANCE EVALUATION FACILITY OF A GROUND SOURCE HEAT PUMP UNIT

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Performance evaluation facilities such as a ground source heat pump calorimeter are used to investigate the performance and reliability of a the ground source heat pump unit. It consumes energy through cooling with a refrigerator and heating with an electric heater in order to control and maintain the test conditions of the ground source heat pump unit obtained from domestic or international standards organizations such as ASHRAE and ISO. In this study, a ground source heat pump unit with variation in capacity from 3 to 9 kW and COP from 3 to 6 was tested in a water-to-water heat pump performance evaluation facility in both cooling and heating modes. The standard entering water temperature test conditions of the test unit considered for the indoor heat exchanger and outdoor heat exchanger were 40 °C and 5 °C respectively in the heating mode whiles in the cooling mode, entering water temperature of 12 °C and 25 °C were used respectively. The heating and cooling capacities of the test unit were determined with measured temperatures and flow rates at relevant locations in the experimental set up to generate the energy consumption data for the refrigerator as well as the outdoor and indoor side heaters of the calorimeter. The test results from the experiment showed that the total energy consumed by the facility in testing the heat pump decreased as capacity and COP increases in both operating modes but the decrement according to COP variations were smaller than capacity variation. However, the total energy consumption of the performance evaluation facility in heating mode of the ground source heat pump unit increased much more than it in cooling mode.
PREDICTION OF PHASE EQUILIBRIUM CONDITIONS FOR CH4 OR CO2 HYDRATE FORMED IN THE PRESENCE OF TETRABUTYLPHOSPHONIUM BROMIDE (TBPB)

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Tetrabutylphosphonium bromide (TBPB), as a quaternary salt, could be used as a thermodynamic promoter in the development of hydrate-based technique, since it could form semiclathrate hydrates with vacant cages to capture gas molecules under milder conditions. To study the stabilization effect on gas capture and storage, the phase equilibrium data were investigated by many researchers. However, it is a hard work to describe accurately the phase behavior of gas hydrate in the presence of TBPB due to its special structure of semiclathrate hydrate. In this work, a thermodynamic approach was proposed to determine the phase equilibria of semiclathrate hydrates formed with TBPB and guest gas (CH4, or CO2) based on the van der Waals-Platteeuw theory. The Peng-Robinson equation of state (PR-EOS) and electrolyte-Non-Random Two-Liquid (e-NRTL) activity model were employed to calculate the fugacity of gaseous hydrate formers and activity coefficients of species in aqueous phases, respectively. In addition, the Langmuir constants relating to the salt concentration in aqueous solution and temperature were modified based on the structural properties of TBPB. It was shown that the model results were in acceptable agreement with the experimental data for studied systems.

INHIBITION OF GAS HYDRATE USING PHENYL-TERMINATED POLYVINYL PYRROLIDONE

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Gas hydrate blockages in gas and oil industry often lead to huge economic losses, and even cause safety accidents. Kinetic inhibition is an effective and increasingly widely used way of preventing pipeline and equipment blockage by natural gas hydrates in the field. Kinetic hydrate inhibitor (KHI) is a branch of low-dosage hydrate inhibitor (LDHI), which can delay hydrate nucleation and/or crystal growth even in the hydrate thermodynamic stability zone. A new kind of polymer-based KHI named phenyl-terminated polyvinyl pyrrolidone (PVPC6H5) has been synthesized and its performance of preventing methane hydrate formation has been tested in a high-pressure sapphire reaction cell in this study. Compared with the commercially available poly vinyl pyrrolidone (PVPK90), PVPC6H5 was shown to be a superior KHI under the same working conditions. PVPC6H5 was tested at varying concentration from 0.1 wt % to 2.0 wt %. The results illustrate that the highest subcooling degree that PVPC6H5 could bear was 13 °C. This better inhibitory performance maybe attribute to the terminal phenyl group added to the polymer.
Topic 3: Marine Energy & Small Hydro Power
METHOD FOR DESIGN AND POSITIONING OF TURBINES IN TIDAL CURRENT POWER FARMS USING CFD

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There are many sites suitable for the application of TCP (Tidal Current Power) in KOREA. Strong currents are being generated in narrow channels between the numerous islands in the southwest regions. TCP is one of the ocean renewable energies that could reduce the environmental impact of energy production. The energy produced from the TCP can be precisely predicted regardless of weather conditions. The utilization factor is relatively high. There are tidal current turbines designed for TCP in Korea. Analyses to determine the optimum power conditions for TCP were performed using CFD (Computational Fluid Dynamics). For the calibration of the boundary effects, a series of experiments were performed in a CWC (Circulating Water Channel). The methods developed in this study were useful for simulating the unsteady flows and wake effects typical of TCP. In this paper, a method is proposed for optimal design and positioning of turbines in TCP farms, using CFD.

\textbf{Fig.1 Wake effects on the downstream distances from two upstream turbines}
GUIDE WIRE MAINTENANCE METHOD FOR HAT TIDAL CURRENT CONVERTER

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This study has been conducted to develop maintenance system for 200kW horizontal tidal current power which plans to be installed in Uldolmok. Unlike constructions in land, those in offshore take much more time and need more expenses. Therefore, it is essential that the retrieving and installing duration against harsh offshore environment should be minimized. To develop the maintenance system for a pile fixed horizontal axis tidal energy converter which will be installed at Uldolmok for sea trial, guide wire system is applied that can support the lowering the turbine to the sub structure easier. In this paper, the necessity of guide wire is experimentally investigated considering environmental conditions of Uldolmok area. Physical model is designed and arranged in circulating water channel. A series of two-point lifting tests with guide wires are carried out. And the optimized location of crane, maximum flow speed and other important values that can facilitate an effective maintenance for TCP system are found. A new design of guide wire maintenance method for HAT tidal current converter is introduced.

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A STUDY ON THE DYNAMIC ANALYSIS OF SINGLE POINT MOORING TO ENHANCE THE STATION KEEPING OF FLOATING BODY OF TIDAL CURRENT DEVICE

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Among the various ocean energy sources, tidal current power (TCP) has been recognized as the most promising energy source in terms of predictability and reliability. The enormous energy potential in TCP fields will be exploited with the increase of installing TCP systems. A floating type structure for TCP system could become more economical than a bottom-founded structure system. To limit the excursion of a floating TCP structure, the SPM (Single Point Mooring) can be designed. SPM system can be applied without limitation of water depth, and it is highly cost effective. And the simple procedure of installation and maintenance are also the merits for SPM system. In this study, SPM system for duct-type TCP device in shallow water was designed. The SPM mooring concepts are investigated using the commercial mooring analysis software WADAM and OrcaFlex. The TCP structure is modeled as a panel mode, and global response analysis was performed for a system consisting of a hydro-model and a mass model. Due to other floating structures operating within the neighboring area, the station-keeping is essential in order to keep the motions of a floating duct structure within permissible boundary. In this study, methods for optimizing the mooring system of a floating duct-type tidal current power system in shallow water are investigated, such as line length, fairlead points. As a result, designed SPM mooring system was confirmed as a well-functioning supporting type stabilizing the motions of floating TCP system can be an effective way to generating power by reducing the cost of installation. Based on the mooring analysis of the 10 kW floating duct-type TCP system, a new design for a small capacity floating TCP system is introduced.
GUIDE WIRE MAINTENANCE METHOD FOR HAT TIDAL CURRENT CONVERTER

Chul H. Jo\textsuperscript{a}, Kwang O. Ko\textsuperscript{b}, Do Y. Kim\textsuperscript{a}, Chan H. Goo\textsuperscript{a} and Bong K. Cho\textsuperscript{a}\textsuperscript{*}

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This study has been conducted to develop maintenance system for 200kW horizontal tidal current power which plans to be installed in Uldolmok. Since Uldolmok has a fast flow rate, it is a suitable place to install tidal current converter. Unlike constructions in land, those in offshore take much more time and need more expenses. Therefore, it is essential that the retrieving and installing duration against harsh offshore environment should be minimized. To develop the maintenance system for a pile fixed horizontal axis tidal energy converter which will be installed at Uldolmok for sea trial, guide wire system is applied that can support the lowering the turbine to the sub structure easier. In this paper, the necessity of guide wire is experimentally investigated considering environmental conditions of Uldolmok area. Physical model is designed and arranged in circulating water channel. A series of two-point lifting tests with guide wires are carried out. And the optimized location of crane under various flow speed and other important values that can facilitate an effective maintenance for TCP system are found. A new design of guide wire maintenance method for HAT tidal current converter is introduced.

VALIDATION OF TIDAL TURBINE INTERACTION BY NUMERICAL AND EXPERIMENTAL APPROACHES

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To develop the economically feasible tidal energy farm in the ocean, dozens of TECs (tidal energy converter) are required and installed. The efficiency of TEC can be greatly affected by the interaction between devices. Therefore, the multi-arrangement layout is to be optimized to maximize the power production in the limited offshore project site. The multi-array can create the interaction in TECs and the interaction rates in axial and transversal and diagonal directions are to be investigated before determination of layout of the farm. There are several researches presented in the past. However, due to the complexity of analysis and long computing time, the limited cases were introduced. As the power production is directly related to the economic feasibility of the farm, it is very important to understand the interaction effects among turbines in the multi arrangement. Based on this research, the tidal farm array can be optimized. This research aims to develop CFD method for understanding the interference effect for the turbine deployed in wake area. The CFD analyses were conducted and also experimental studies carried out with turbine mockup models to investigate the interaction between turbines. And also an uncertainty analysis on the experimental studies was conducted to confirm the reliability of study. The results of CFD and experiments were compared to validate CFD method for further studies for various turbine arrangements.
OPEN SEA TESTS OF HYDRAULIC AUTONOMOUS CONTROL SYSTEM IN WAVE ENERGY CONVERTOR SHARP EAGLE WANSHAN

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As one of the most abundant energy recourses in renewable energy, wave energy has been widely studied in the research of ocean energy utilization recently. And how to absorb unstable wave energy and output steady is a hot topic till today. Because of the characteristics of steady output and easy to control, hydraulic system has more and more widely application in the wave energy devices. The working principle and application of hydraulic autonomous control system in 100kW wave energy convertor Sharp Eagle Wanshan are described. To testify the feasibility and stability of autonomous control system, two groups of contrast experiments were carried out during the open sea test of Sharp Eagle Wanshan. The wave conditions in both groups were similar, and the wave power in unit width was about 5kW. In experimental group, the autonomous controllers were in working condition, which were turned off in control group. During tests, the data of output voltage, current and efficiency of generators was recorded. Besides, to collect changes of oil pressure and current capacity, flow transducers and pressure sensors were set in front-end and back-end of hydraulic motors. Results show good performance and high-efficiency of autonomous control system. With the management of autonomous controller, the range in generation parameters (voltage, current and efficiency, et, al) reduces, and energy conversion efficiency remains higher than 80%. In addition, the feasibility of adjusting generating power adaptively according to the wave power by hydraulic autonomous control system was proved. In general, the application of hydraulic autonomous control system will not only be helpful in improving the device designing and further system optimization, but also provide certain reference implications for the design and test of similar device.
DESIGN, SIMULATION AND TESTING OF THE HYDRAULIC POWER TAKE OFF SYSTEM FOR THE SHARP EAGLE WAVE ENERGY CONverter

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A wave energy converter (WEC) concludes an energy capture system and a power take-off system (PTO). The PTO is the key of the efficiency of a WEC. The hydraulic PTO due to convert the intermittent and unstable wave power into sustained and stable electric power makes it an extensive application for WECs. This paper describes a hydraulic PTO employed in the Sharp Eagle WEC. The design and the development process of the system is presented, including structure and working principle, power generation system and hydraulic system, physical model tests at laboratory and real sea experiments at full scale. At last, results are also presented and analyzed, shows that the PTO is important, helpful and valuable for a WEC.

STUDY ON AN EXTREME WAVE IN THE NUMERICAL WAVE TANK FOR THE WAVE ENERGY UTILIZATION

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Ocean wave energy is recognized as clean and renewable energy. At the time of wave energy resource utilization, the dangerous situation is to meet the extreme waves, and freak waves is one of the disastrous waves that may be encountered. With the help of efficient phase modulation method for simulating freak waves, a numerical wave tank based on powerful modeling and secondary development function of FLUENT was established, which can make the freak waves occurred at the assigned time and place. By analyzing the numerical calculation results in time domain and frequency domain, it was found that the results not only keep agreement with the target wave train, but also keep the real structure of the target spectrum, showing effectiveness of the numerical wave tank.
Hydropower is the largest source of renewable energy. Francis hydro turbines are the world’s most widely used hydro turbine. In this paper CFD software used to simulate for the performance analysis of micro class Francis hydro turbine. This study focused on prediction of 3D flow behavior and numerical results obtained the hydraulic performance of micro Francis turbine with the inlet pipe, a spiral casing with 12 guide vanes, 6 stay vanes and the runner having 13 blades and a draft tube.. The Reynolds-average Navier-Stokes (RANS) equation with Shear stress transient (SST) k-ω turbulent model were discretized by the finite volume method during numerical calculation procedure. Additionally, results from the CFD simulation and experimental results will be compared to 3KW micro-Francis turbine with misaligned guide vane.
CHARACTERISTICS ANALYSIS OF FRANCIS TURBINE PERFORMANCE FROM EXPERIMENT MODEL TEST BY DIFFERENT SPECIFIC SPEEDS

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Hydraulic turbine efficiency test in small hydro power system is the most important as a comprehensive measure of device performance. Hydraulic turbine develop have to go through trial and error and It takes too much cost and time consumption if the tests have been by prototype hydraulic turbine. Instead of prototype, we can validate and develop hydraulic turbine efficiency through model turbine laboratory test. In the Fig. 1, between efficiency measurement on a real hydraulic turbine built with laboratory development and without it, there is difference and turbine with laboratory development has higher efficiency. The main purpose of this study is to analysis performance characteristic of newly designed francis hydraulic turbine through the model test. To validate the hydraulic turbine performance, we made three model for the hydraulic turbines by different specific speeds (120, 200, 300 m-kW). Specific speed means rotation-speed of turbine when a turbine has unit flow and makes unit power. It can be a measure of the turbine shape and it indicates performance of the turbine. Specific speed has formula of \( N = \frac{Q}{H^{(3/4)}} \) where : Specific speed(m-kW), N : Rotational speed(rpm), H : Head(m), Q : discharge(cms), P : Power(kW). In this study, the tests was carried out the model test by the international standard of Hydraulic turbines model acceptance test; IEC 60193. The facility uses pump and pressure tank to make head and flow, measure the discharge from the electromagnetic flowmeter, and measure the torque from the dynamometer. The facility has maximum test head of 40m, maximum test discharge of 1.2cms, maximum hydraulic dynamometer speed of 2500rpm and uncertainty of the efficiency of measurement is calculated by IEC 609193. The tests are performed based on IEC 60193 and with variation of guide vane open rate, rotational speed and load. In the conclusion, the maximum efficiency of model is appeared in the different specific speeds, and we were plotted the hill-chart of a N11-Q11-efficiency with the experiment data.
Topic 4: Solar Energy
A COMPARATIVE STUDY ON MODULE CONNECTIONS TO MINIMIZE THE DEGRADATION OF PHOTOVOLTAIC SYSTEMS DUE TO BIRD DROPPINGS

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Bird droppings on the array surface of photovoltaic (PV) systems can significantly reduce the electric power production. However, the removal of bird droppings on the PV array surface is difficult when the PV systems are installed in remote or offshore locations. Therefore, in such a case, PV modules should be connected by considering the degradation effect of PV systems due to the bird droppings. The objective of this study is to compare different methods for connecting PV modules to minimize the degradation of electric power production from PV systems due to bird droppings. The PV array consisting of nine modules (3 x 3) and 37 connection patterns were examined with three types of shading mask representing the bird droppings. The electric power productions from the PV arrays with different module connections and shading masks were analyzed by experiments under the conditions of 1000 W/m² and 35°C. The results showed that the degradation effect of PV arrays with the combined serial and parallel connection pattern is less than others (Fig. 1).

Fig. 1. Degradation effect of PV system with the module connection pattern No. 10 and different types of shading masks
CO$_3$(OH)$_2$(HPO$_4$)$_2$ AS NOVEL PHOTOCATALYST FOR WATER OXIDATION UNDER VISIBLE-LIGHT IRRADIATION

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For photocatalytic water splitting, the half reaction of O$_2$ generation involves a complicated four-electron transfer, which requires the generation of four proton-electron pairs as well as the formation of an oxygen-oxygen double bond.$^{[1]}$ Therefore, study on photocatalytic water oxidation for water oxidation is necessary and significant. Cobalt phosphate showed great potential as electrocatalyst or cocatalyst loaded on photocatalyst for O$_2$ evolution, but has not yet been successfully used as photocatalyst for O$_2$ evolution so far.$^{[2,3]}$ Herein, a kind of cobalt phosphate, i.e., Co$_3$(OH)$_2$(HPO$_4$)$_2$ (Co$_3$(PO$_4$)$_2$·2H$_2$O), was prepared by a simple hydrothermal method, and was proved to be a novel, stable photocatalyst for O$_2$ evolution under visible-light irradiation for the first time (around 11.7 μmol h$^{-1}$). The photocatalytic mechanism of Co$_3$(OH)$_2$(HPO$_4$)$_2$ was revealed by comprehensively comparing the physicochemical properties of Co$_3$(OH)$_2$(HPO$_4$)$_2$ with those of another kind of cobalt phosphate, i.e., Co$_3$PO$_4$·8H$_2$O, which was prepared by a precipitation method and showed little photocatalytic activity for O$_2$ evolution under visible-light irradiation. The significantly improved photocatalytic activity on Co$_3$(OH)$_2$(HPO$_4$)$_2$, compared with Co$_3$(PO$_4$)$_2$·8H$_2$O, was mainly attributed to the synergistic promotion of photocatalytic process by the following physicochemical properties of Co$_3$(OH)$_2$(HPO$_4$)$_2$, i.e., the distortion of Co$^{2+}$ octahedra, and the difference in electronic properties and the linkage of oxo bridges between the adjacent Co(1) and Co(2) octahedra. This work extended the application of cobalt phosphate in photocatalysis and presented an effective route to explore new O$_2$-evolution photocatalysts by modifying the appropriate materials that were commonly employed as cocatalysts.

Figure 1. (left) Time courses of O$_2$ evolution on Co$_3$(OH)$_2$(HPO$_4$)$_2$ and Co$_3$(PO$_4$)$_2$·8H$_2$O under visible-light irradiation or in dark; (right) Crystal structures of Co$_3$(OH)$_2$(HPO$_4$)$_2$ and Co$_3$(PO$_4$)$_2$·8H$_2$O.
NUMERICAL SIMULATION AND WIND TUNNEL TEST OF WIND LOADS ON A PARABOLIC TROUGH SOLAR COLLECTOR BASED ON SIMILARITY THEORY

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Large parabolic trough solar collector (PTC) is mostly located at relatively flat and open areas. Its stability and the focusing accuracy of PTC is affected easily by wind loads. In the paper, due to the high cost of simulation and the difficulty of wind tunnel test for large PTC, the scale models of the large PTC was investigated based on similarity theory with numerical simulation, experimental measurement and theoretical analysis. First of all, aiming at the aerodynamics of PTC, the aerodynamic coefficient of the scale model of PTC in wind speed of 13.8m/s were simulated and analyzed. Then, the simulation with Fluent of the scale model of PTC were done and the results show that the most dangerous working conditions is at elevation angle of 60°. At last, wind tunnel tests were carried out on small-scale models and the results were compared with Fluent simulation results. The results of simulation and experiment show that: 1) The results of the simulation and wind tunnel experimental coincide with each other, with an average error of 16.7%, which indicates Fluent model is reasonable. 2) In the analysis of the results of Fluent simulation, it’s more reasonable to take the wind loads of windward as well as leeward into account. 3) The comparison of simulation results between the full size concentrator and the scale model conform to the similarity theory. Therefore, The performance of the larger concentrator can be predicted through the results of small-scale concentrator with good accuracy based on similarity theory.
TECHNO-ECONOMIC ANALYSIS OF THE SOLAR CHIMNEY PV/T POWER PLANT IN NORTHWEST CHINA

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The solar chimney power plant (SCPP) is one of the large-scale solar thermal power generation systems without solar concentration. The SCPP is affected by the large solar collector and high chimney. Previous studies indicate that the SCPP obtains low investment and low power efficiency, due to the low energy flux, randomness and discontinuousness characteristics of solar energy. On the other hand, the PV power plant has large investment but high efficiency. It is thus possible to combine the PV modules into the SCPP to reach the best investment rate and the maximum returns. Considering the large area of solar collector, the PV modules are introduced into the solar collector of the SCPP to increase the power capacity, leading to a solar chimney PV/T power plant (SCPVTPP). In the present study, techno-economic analyses of the SCPVTPP are carried out. The investments of the solar collector, the PV modules, the chimney and the power conversion unit are respectively calculated by taking Northwest China as the case. The Levelised Energy Cost (LEC), the cash flow during system life span and the system payback period are analyzed under different power capacities and PV area ratios by taking into consideration of the building investment, maintenance costs, generation benefits, emission reduction benefits and inflation. The results show that the SCPVTPP investment is influenced by its configuration and the material price. For a 5MW level SCPVTPP, the total investment is 0.507 billion Yuan, in which the solar thermal takes 29.4% and the solar PV takes 70.6% of the total investment. On increasing the ratio of the PV module area, the investment increases, but the payback period first decreases then maintains. When the ratio of the PV module area is 0.21, the cost-optimized payback period is 19 years. The SCPP is more stable than the PV module during the system life span, needing less operation and maintenance cost. The ratio of the installed PV cell has a significant impact on investment and benefits, and is one of key technical parameters for a cost-optimized SCPVTPP.
SYSTEM AND PERFORMANCE COMPARISON OF LFR SOLAR ABSORPTION COOLING AND PV TURBO COOLING

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In this study, cooling performance and cost evaluation of photovoltaic(PV) turbo cooling and LFR absorption cooling in Saudi Arabia Riyadh were compared and the calculation results were obtained by using SAM program provided by NREL(National Renewable Energy Laboratory).

Cooling capacity of the two cooling systems are 100 \text{usRT} in the irradiation condition at 12 PM on March and in addition on June for the LFR. Yearly average solar-to-cooling ratio is similar each other of around 0.8.

PV turbo cooling capacity is maximum 100 \text{usRT} in June and September, however it is decreased to 80 \text{usRT} in December because of low irradiation. In case of LFR absorption cooling, direct normal irradiation in June is 50 \% higher than in March. But cooling capacity in June is increased up to 1.4 times at comparing with march. LFR absorption cooling system based on the irradiation condition in March showed over one solar-to-cooling ratio in June and September.

Initial investment cost of the PV turbo cooling system is \text{4,280,000 W/usRT}, which is 3 \% cheaper than the LFR absorption cooling system.
SOLAR THERMAL HEATING AND SEASONAL STORAGE SYSTEM OPERATION FOR FACILITY HORTICULTURE

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This paper reports on the demonstrative operation of a solar thermal heating system integrated with facility horticulture and summarizes the performance of the system.

The facility horticulture was consisted of solar collectors and large seasonal thermal storage tank, and glass- and greenhouses and installed on Jeju Island in Rep. of Korea. Solar energy captured in 331.3 m\textsuperscript{2} of four different types of solar collectors, was stored in 600 m\textsuperscript{3} seasonal storage, was extracted and distributed through glass- and greenhouses as of space, bed, and ground heating.

The operation was carried out for 25 months in the first and second stages and had undergone detailed monitoring since it was operated to obtain characteristics of its performance. During the first stage, 164.8 MWh was collected, 138.0 MWh was charged, and 75.0 MWh was extracted for facility horticulture. 54.3 \% of stored energy was used and solar fraction was 52.1 \%. In the second stage period, 140.0 MWh was collected, 113.7 MWh was charged, and 34.3 MWh was extracted. 30.2 \% of stored energy was used and solar fraction was 39.2 \%. The system efficiency of solar-to-end use was 16.1 \% and 6.8 \% during the first and second stage respectively.

IMPROVED REAR-SIDE PASSIVATION BY SIN\textsubscript{x}/SION STACK LAYER FOR HIGH \textit{V}_{oc} OF N-TYPE SILICON SOLAR CELLS

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High-quality surface passivation and improved internal reflectance at the rear side of crystalline silicon (c-Si) solar cells which is essential for obtaining high efficiency solar cells. In the presented paper the cost effective simple innovative approach to fabricate stack layer combining the benefits of Si-rich Si\textsubscript{x} layer which can provide high qualities of passivation and SiON layer with low refractive index and low extinction coefficient by plasma enhanced chemical vapor deposition (PECVD). The incorporation of SiNx layer with refractive index 2.41 provide high qualities of passivation and SiON layer with refractive index 1.52 were used as the inside and outside layers, respectively. Very low surface recombination velocity <5 cm/s was obtained for SiN\textsubscript{x}/ SiON stack layer with SiN\textsubscript{x} thickness of 30 nm.

The incorporation of SiN\textsubscript{x}/SiON stack on the rear side of n-type solar cells results in an energy conversion efficiency of 18.64\% compared to the one with SiNx (n = 2.05) single layer showing 17.55\% efficiency. The short circuit current density and open circuit voltage increase by up to 2.3 mA/cm\textsuperscript{2} and 14 mV respectively compared to SiNx single layer on the rear side of n-type solar cells due to the good surface passivation and improved internal reflectance at the rear side.
DESIGN AND THERMAL PERFORMANCES OF A SCALABLE LINEAR FRESNEL REFLECTOR SOLAR SYSTEM

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Linear Fresnel reflector (LFR) is another commercialized concentrating solar power technologies in addition to the parabolic trough concentrator (PTC). LFR is a type of solar collectors which collects sunlight by using long, narrow, flat mirrors to reflect the sun rays onto a linear receiver. Due to the advantages of simple production, easy maintenance, and low cost, LFR is well developed and extensively applied in solar thermal system. However, the shading and blocking of adjacent mirrors and the end losses of the receiver are two problems existing in the traditional LFR system. In order to solve the above problems, a scalable linear Fresnel reflector (SLFR) solar system is proposed in this paper.

The scalable SLFR solar system can be seen in figure 1. The optical mirror field contains an array of linear plat mirrors located at a straight line. The linear plat mirrors are close to each other and track the sun as a whole, which can avoid the shading and blocking of adjacent mirrors effectively. Moreover, the optical mirror is scalable by placing changeable numbers of mirrors in the extend support, which can be applied in different focusing multiples and temperature requirements. The end losses of the receiver are reduced by employing the design of mechanical structure which is adjustable to solar altitude angle. The thermal performance of linear evacuated absorber for the SLFR solar system is simulated numerically as well. The radiation distribution of the absorber pipe is influenced by the tracking accuracy of the system, and its homogeneity will affect the efficiency of heat transfer from the heat pipe to the working fluid.

Herein, two different light areas of SLFR system are presented and studied. The numerical and experimental results are as follows:

1. The SLFR has high ground utilization and has no shading and blocking of adjacent mirrors.
2. The design of mechanical structure adjustable to solar altitude angle can reduce the end losses of the receiver.
3. The radiation distribution of the absorber pipe is nonuniform and it will affect the heat transfer of the working fluid.
(4) The larger area system can supply the higher temperature, and the heat loss increases along with the elevated temperature.
CHIMNEY EFFECT ANALYSIS FOR WALL THERMAL FLUX INJECTION

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The application targeted by this study is the localized control of passive cooling of building integrated photovoltaic components (BIPV). The objective is the determination of the optimal heat flux distribution on the walls, limiting hot spots under a given thermal stress. This allows limiting both a decrease of instantaneous electrical performance and aging. Identifying the particular configurations which improve heat transfer is of great importance in applications where maximizing the heat transfer rate is a primary concern. Furthermore, given that the interest of this type of study is the cooling (electronics, nuclear engineering or PV modules), most of the work has been based on heat transfer fluid/wall for mixed or forced convective regimes.

STUDY OF A VENTILATED EARTH/AIR HEAT EXCHANGER INTEGRATED IN A BUILDING FUNDATION

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Regarding building users’ thermal comfort requirements and energy consumption reduction trend, passive systems seems to be relevant solution to supply thermally suitable environment. Depending on the season, earth-to-air heat exchangers (EAHE, known as “Canadian well” or “Provencal well”) enable to preheat or refresh air before injection into the building, thanks to the thermal charge/discharge ground potential. The air low in buried pipes is induced by a fan, which need an accurate sizing and control regulation to ensure provide effective energy savings.

The aim of this presented work is concerning the modeling is to of the a heat and mass transfer thermo-air flow model of within the geothermal foundation, and the his coupling with a solar chimney. The foundation model use 3D finite volume method, and takes into account sensible and latent heat transfer between air and wall. An experimental study is also led in situ on a full-scale system integrated to in parallel with numerical study.
Topic 5: Hydrogen & Fuel Cell
DYNAMIC SIMULATION OF FUEL CELL SYSTEM VIA VARIATION OF OPERATING PARAMETERS

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Surge in an unstable operating mode of compressor systems which occurs at low mass flow where the pressure delivered by the compressor is less than the plenum pressure. It can damage compressor and fuel cell system. When a control algorithm is developed to protect automotive compressor surges, the simulation model typically selects an empirically determined look-up table. However, it is difficult for a control oriented empirical model to show surge characteristics of the supercharger. In this study, a dynamic fuel cell model is developed to predict the performance of a centrifugal compressor under dynamic load follow-up. The model is developed using Simulink\textsuperscript{®} environment, and is composed of a compressor, DC motor, throttle valves, and fuel cell stack. Greitzer's compressor model is used, and the geometric parameters are achieved by the actual supercharger. The simulation model is validated with experimental data. It is shown that compressor surge is effectively predicted by this dynamic fuel cell model under various operating conditions.
STUDY ON START-UP PROTOCOL OF DIESEL REFORMER USING HYDROGEN PEROXIDE FOR SUBSEA APPLICATIONS

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The novel type diesel reformer using hydrogen peroxide as an oxidant was developed and investigated at KAIST. This reformer was specialized to enhance submerged operation of the applications operated in subsea environments such as submarine or unmanned underwater vehicles (UUV). By using this reformer, hydrogen could be effectively obtained to drive fuel cell air-independent propulsion for underwater applications. According to steady-state results from our previous study, it was confirmed that diesel reformer using hydrogen peroxide can be considered as a good option for fuel cell AIP. However, start-up issue is still remained to be resolved for a competitive solution for fuel cell AIP. In this research, novel start-up strategy for diesel reformer using the heat of hydrogen peroxide decomposition was introduced. From this novel strategy, improved transient-state operation results such as reduction of start-up time and simplification of start-up protocol were confirmed when compared to previous start-up technology.

FLUID FLOW ANALYSIS OF POROUS FLOW FIELDS FOR ADVANCED ELECTROCHEMICAL SYSTEM APPLICATIONS

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Performance of electrochemical systems strongly depend on pore structures of key elemental components and fluidic properties (i.e., porosity and permeability) of the porous transport media. In this study, effects of permeability of porous materials on the electrochemical system performance were investigated in terms of mass flux distribution. Fluid-flow study is first conducted to analyze flow distribution in porous flow fields including metal foam and gas diffusion media. Particularly, directional preference of reactant gases through void flow paths in the porous media is explored to account for the anisotropic flow characteristics. For this purpose, volumetric flow rates at the interfaces between gas diffusion media and catalyst layers are compared to figure out the dominance of permeability on the amount of gas transport for electrochemical reactions. It is found that two perpendicular directions of in-plane permeability have more significant effects on enhanced mass transport for the catalytic reactions than through-plane permeability. These results indicate the importance of micro-pore structure optimization and the balanced interaction between key porous elemental components of electrochemical systems. Further research in this work would be expanded to structural variations of porous media under various stack assembly conditions for more accurate numerical prediction.
Topic 6: Wind Energy
HIGH PERFORMANCE COMPUTING (HPC) OF WIND TURBINE SYSTEM INCLUDING 3D FLUID-STRUCTURE INTERACTION (FSI) AND FATIGUE DAMAGE SIMULATIONS

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Wind energy, as an alternative to fossil fuels, is plentiful, renewable, widely distributed, clean, produces no greenhouse gas emissions during operation. Wind turbines, converting mechanical energy to electricity, must extract as much wind energy from air flow as possible while resisting huge forces and deformations over a lifespan of 20 years. The size of wind turbine has been steadily increasing over the past few years with the limit of blade length expanding from 30 meters to 80 meters. Therefore the design challenge of large wind turbines is to balance aerodynamic performance and structural integrity. The primary goal of this project is to develop a high-fidelity simulation platform that are capable of modeling the interaction of full scale wind turbine structures with air flow and ocean water and capture the fatigue behaviors of the large wind turbine blade under millions of loading cycles over the long life span.

Full-scale wind turbine structure is modeled with Kirchhoff-Love shell and rotation-free beam using isogeometric analysis. Residual based variational multiscale simulations (RBVMS) combined with the techniques of enforcement of weak boundary conditions and track of non-matching meshes have been applied to the problem of wind and turbine interaction for high Reynolds number aerodynamics. With assistance of level set method, the free-surface flow is modeled by two-phase Navier-Stokes equations, which enables the simulations of the interaction between the free-surface ocean waves and floating wind turbines. A framework of fatigue damage model based on continuum damage mechanics and residual stiffness approach and driven by the dynamic data application system (DDDAS) was established by exploiting recent developments in geometric modeling, computational mechanics, high-performance computing (HPC), aiming at simulating high-cycle fatigue of wind turbine composite blades.

In this talk, the following numerical methodology involves: (1) a recently developed and validated fatigue-damage model for multilayer fiber-reinforced composites; (2) a validated coupled fluid–structure interaction (FSI) framework; and (3) coupling of the FSI and fatigue-damage models. The coupled FSI and fatigue-damage formulations are deployed on the Micon 13M wind turbine equipped with the Sandia CX-100 blades. The final results indicate accurate prediction of the structural behaviors of wind turbines subject to wind loads, especially illustrating the full picture of the damage zone formation, damage progression, and eventual failure of the composite turbine blades.
WIND POWER FORECASTING USING LINEAR REGRESSION WITH TIME-SHIFTED SERIES DATA

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Compared to the existing generation resources, the variable and uncertain nature of the wind generating resources are considered. It is essential to forecast short-term wind power generation for reducing the variability and uncertainty of wind power and integrating wind generating resources into power grids. Generally, the analysis of historical time series of wind speed or wind power output is performed to forecast short-term wind power generation. In this paper, we propose a new method for wind power forecasting using linear regression with timeshifted series data. The time-shifted series data are generated by shifting the values forward in time. The correlation analysis between the time series data and the time-shifted series data at a regular interval is performed to apply linear regression to the time-shifted series data. The proposed method is verified by empirical data from Jeju Island’s wind farms.

SHORT-TERM WIND POWER FORECASTING USING THE SUPPORT VECTOR MACHINE BASED ON LINEAR REGRESSION

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Short-term wind power forecasting is a technique which informs system operators of how much wind power can be expected at a specific time. Due to the increasing penetration of wind generating resource into power grids, short-term wind power forecasting is becoming an important issue for grid integration analysis. Generally, linear regression model is used to forecast short-term wind generation. Linear regression is an approach for modeling the relationship between a scalar dependent variable and one or more explanatory variables. In order to enhance wind power forecasting errors, we propose the short-term wind power forecasting using support vector machine based on linear regression. Support vector machine is a kind of supervised learning and is a method for recognizing pattern and analyzing data. The proposed method is verified by empirical data from Jeju Island’s wind farms.
STOCHASTIC ESTIMATION OF WIND POWER OUTPUTS USING THE WEIBULL DISTRIBUTION

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Due to intermittency of wind power generation, it is very hard to manage them in system operation and planning. In order to incorporate higher wind power penetrations into power systems maintaining a secure and economic power system operation, the accurate prediction of wind power outputs is needed. Generally, wind power generation is estimated using the fitted or provided power curves. The method for estimating the wind power outputs through the power curve can be a deterministic approach. In this paper, we propose the stochastic estimation of wind power outputs using the Weibull distribution. Probability density function (PDF) is used to estimate the probability of wind speed using the Weibull distribution. The wind speed data is classified according to the designated ranges. The probability of wind speed is also granted in accordance with the designated ranges. The average of wind power output is estimated in the form of a confidence interval. The empirical data from Jeju Island’ wind farms is used to validate the proposed method comparing the measured wind power outputs with the estimated wind power outputs calculated through the wind power curve provided by manufacturer.

STRESS BASED RELIABILITY ANALYSIS OF OFFSHORE WIND TURBINE SUPPORT STRUCTURE

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Considering dynamic stress, reliability analysis of offshore wind turbine support structure under earthquake is presented. Reliability analysis using dynamic response requires a lot of time when using not only level 3 approach but level 2 such as first order reliability method (FORM). Moreover, if a limit state is defined by using maximum stress at structural joint where stress concentration occurs, three dimensional finite element stress analysis should be done. This makes computational work much heavier and thus reliability analysis inefficient. Therefore, it is very necessary to reduce computational effort in dynamic reliability analysis of offshore support structure. In this study, two techniques are suggested. One is to apply quasi-static structural analysis in reliability analysis with taking dynamic amplification effect into account. The other is to use stress concentration factor to estimate maximum local stress. The proposed reliability analysis is done through FORM and verified by using level 3 simulation approach.
RELIABILITY ANALYSIS OF OFFSHORE WIND TURBINES WITH SUCTION BUCKET FOUNDATION

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Reliability analysis of offshore wind turbine with suction bucket foundation is performed. Interaction of bucket surface with ground soil is modeled by using spring element in three directions. Then, structural behavior of the equivalent model is compared with three dimensional full model which is composed of soil with bucket structure. After validating suction bucket equivalent model, reliability analysis is done under wind and wave load. Uncertainties of external load, structural properties, and soil properties are considered. Limit state of the foundation is defined by using horizontal displacement of foundation. Dynamic amplification under dynamic load is considered in reliability analysis. Numerical example is shown to verify the reliability analysis.

ON THE DISK WAKE MODEL AND ITS APPLICATION TO THE OPTIMAL DESIGN OF AN OFF-SHORE WIND FARM

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The objective of this research lies in obtaining a simplified numerical model in the wake region of a wind turbine. The flow is modeled in three-dimension as a disk shape using the data of NREL 5MW wind turbine, where the rated wind velocity and the rotational speed are imposed as boundary conditions of the computational domain. A commercial code ANSYS-CFX is utilized for the analysis of computational fluid dynamics (CFD). The result of computation is compared with that of classical actuator disk theory. The change of wake flow field is predicted for off-shore wind turbines with superposition of the present model.
SHORT-TERM WIND SPEED FORECASTING BASED ON MINIMUM ERROR ABSOLUTE VALUE EMPOWERMENT ALGORITHM

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The article aims to study a high-accuracy combination forecast algorithm of short-term wind speed. Taking an example of ARIMA-GARCH and Elman neural network model, the optimal linear combination forecasting model of short-term wind speed is proposed based on minimum error absolute value empowerment algorithm. Through ARIMA-GARCH and Elman neural network forecast short-term wind speed of a certain wind farm respectively, prediction error of each model are obtained. In order to minimize prediction error absolute value of combination model, combined with linear programming ideas, combination forecast model predictive value is obtained by giving suitable weights on prediction error of single model. Numerical analysis shows that combinatorial optimization algorithm of short-term wind speed forecasting accuracy is better than that of single forecast model accuracy. Meanwhile, it plays a reference role in the relevant forecasting research field of short-term wind speed.

RELIABILITY ANALYSIS OF OFFSHORE WIND TURBINES WITH SUCTION BUCKET FOUNDATION

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Reliability analysis of offshore wind turbine with suction bucket foundation is performed. Interaction of bucket surface with ground soil is modeled by using spring element in three directions. Then, structural behavior of the equivalent model is compared with three dimensional full model which is composed of soil with bucket structure. After validating suction bucket equivalent model, reliability analysis is done under wind and wave load. Uncertainties of external load, structural properties, and soil properties are considered. Limit state of the foundation is defined by using horizontal displacement of foundation. Dynamic amplification under dynamic load is considered in reliability analysis. Numerical example is shown to verify the reliability analysis.
STRESS BASED RELIABILITY ANALYSIS OF OFFSHORE WIND TURBINE SUPPORT STRUCTURE

Gee Nam LEE\textsuperscript{a}, Jang Ho LEE\textsuperscript{b}, Dong Hyawn KIM\textsuperscript{c}, So Yeon KIM\textsuperscript{d}

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Considering dynamic stress, reliability analysis of offshore wind turbine support structure under earthquake is presented. Reliability analysis using dynamic response requires a lot of time when using not only level 3 approach but level 2 such as first order reliability method (FORM). Moreover, if a limit state is defined by using maximum stress at structural joint where stress concentration occurs, three dimensional finite element stress analysis should be done. This makes computational work much heavier and thus reliability analysis inefficient. Therefore, it is very necessary to reduce computational effort in dynamic reliability analysis of offshore support structure. In this study, two techniques are suggested. One is to apply quasi-static structural analysis in reliability analysis with taking dynamic amplification effect into account. The other is to use stress concentration factor to estimate maximum local stress. The proposed reliability analysis is done through FORM and verified by using level 3 simulation approach.
In order to supply the increasing demand for renewable energy, recent wind turbines are increasingly larger. Since the cost of manufacturing large-sized blade accounts for 15% to 20% of the manufacturing cost of the wind turbine, necessity for shape design importance and economics improvement of blade are on the rise. For this, blade was manufactured to use composite material in high strength and low weight. Thus, appropriate structural design using the material will have economics improvement. However, because blade is exposed to the outside, it is necessary to have structural safety. Thus, this paper suggested method in structural safety and economics. Thus, this paper suggested method for assure structural safety and economics.

This study aims to perform structural optimization using response surface method for NREL 5MW wind turbine composite blade to assure the structural integrity. First, the composite blade was modeled according the NREL report. Here, consider to the anisotropy of composite materials, the blade layup was designed using PreComp(Pre-Processor for Computing Composite Blade Properties) developed by the NREL(National Renewable Energy Laboratory). And, the optimization was performed using the response surface method of the design of experiment (DOE). The goal is to minimize the whole weight of blade in case of the maximum stress is less than the allowable stress. So, we selected the thicknesses of the spar cap, shear web and trailing edge, which may be the influence factors on structural integrity. According to the optimal design result, we identified the optimal design variable of the composite blade under the ultimate loads. Finally, the subsequent optimal design was verified through the FE analysis on the blade.
DEVELOPMENT OF THE WIND TURBINE SYSTEM FOR LOW WIND SPEED REGION

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As fewer favourable high-wind speed sites are available, onshore wind energy markets are moving on to low wind regions of wind speeds below 7m/s. Thus, wind turbines are being developed to target this market with state-of-the-art technologies. The key point is to maximize annual energy production (AEP) and to achieve competitive cost of energy (COE). Korea has mostly low wind regions while hazardous typhoons are frequent at the end of the monsoon season. Therefore it is important to develop a wind turbine system that is both effective in capturing energy and robust enough to withstand typhoons.

In this work, a new wind turbine system for low wind speed market was developed based on the existing 2MW wind turbine system. Through the use of a proven drive train, lead time for the development as well as costs involved were significantly reduced, enabling quick access to the low wind market. The rotor diameter was increased by 21.5\%, from 93m to 113m, the hub height was increased by 25\%, from 80m to 100m and the rated power was increased by 15\%, from 2.0MW to 2.3MW to achieve economically viable energy yields. By improving the control scheme and its algorithm, increase of bending moment on the main shaft was limited such that the 2MW drive train system including the hub, main frame, main shaft and main bearing etc. could be retained without modification. The IEC/GL type class is S, where the extreme wind speed for the 50 year recurrence period ($V_{ref}$) is 42.5m/s and the annual average wind speed ($V_{ave}$) is 7.5m/s. The new turbine development started in 2011, installation and testing finished by 2014 and the commercial production commenced in January 2015. A single testing turbine has so far produced about 6960MWh. This result compares favourably, as an AEP increase of 29\% at 6.5m/s is projected towards the existing 2MW wind turbine system.
MPC BASED BIDIRECTIONAL CONVERTER CONTROL FOR CAPACITY FIRMING

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This paper presents MPC (Model Predictive Control) based capacity firming algorithms using BESS for wind generation. In order to smoothen the output of wind farm or make it follow a pre-specified reference, MPC based charging and discharging algorithms are proposed. The proposed algorithm not only achieves the objective but also satisfies constraints in the BESS. For instance, SoC (State of Charge) constraint is handled very efficiently by the proposed MPC based charging and discharging algorithm.

- Motivation for the study described in the paper
  Due to intermittency of wind generation, it is important to make its output smooth or follow a pre-defined reference using BESS.

- Objectives
  This paper presents an MPC (Model Predictive Control) based charging/discharging algorithm.

- What was done
  Due to its formulation, a fast computable MPC is proposed which makes the output of the wind farm track a pre-specified reference while SoC constraints on the BESS is satisfied.

- How it was done and validated
  Mathematic proof and simulation study are shown for the main result.

- Major results
  An MPC based charging/discharging algorithm for capacity firming for wind generation is proposed.

- Conclusions
EXPERIMENTAL STUDY OF WAVE FORCES ON AN OFFSHORE WIND TURBINE TOWER MODEL

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Most Pacific island countries have a high sea to land area ratio and it is only reasonable to use the vast ocean to harvest energy. Due to lower wind velocities available onshore, wind turbine farms are not able to operate at their optimum level and hence the returns on investments are low. Offshore wind turbines may hold the answer to the energy demands in the South Pacific. An offshore wind turbine is defined as a wind turbine with a support structure which is subject to hydrodynamic loading. Offshore wind turbines also have a greater area available for siting large projects near large population areas where land area is not easily available. Turbulence intensity at offshore locations is lower than locations on land. A major component of the offshore wind turbine is the turbine tower – which has to withstand the harsh ocean environment unlike land based turbines. A study of a tapered wind turbine tower is performed using particle image velocimetry (PIV) and numerical methods. A scaled-down model of a 1.5 MW wind turbine base was studied in a wave channel. The horizontal loading distribution along the submerged portion of the tapered wind turbine tower was determined from the experimental velocity measurements using PIV. The diffraction parameter shows that the linear wave theory is not valid for inertial co-efficient calculations. A direct value of 2.0 resulted for the inertial coefficient values while a lower drag influence was noted at coefficient of drag = 0.315. The turbine tower’s horizontal force profile is improved in this study to yield a 69% reduction in the overturning moment.
Topic 7: Smart Grid
DC MICROGRID OPTIMAL POWER FLOW USING NONLINEAR INTERIOR POINT METHOD

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This paper proposes an optimal power flow implementation on DC microgrids with voltage droop controlled DC sources. Optimal power flow is an integral part of power system operation. With the trend toward adopting DC distribution networks, power flow analysis is essential for DC microgrids. Optimal power flow of DC microgrids based on droop control is implemented using nonlinear interior point method. The results are verified by comparing with a detailed time-domain simulation results.
Topic 8: Waste Energy & Utilization
STUDY ON THE PERFORMANCE OF COMPACT ADSORPTION CHILLER WITH VAPOR VALVES

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Adsorption refrigeration is considered a green refrigeration technology that can be driven by a low-grade heat source to generate cooling power. This process saves energy and involves the use of friendly adsorption working pair. Adsorption refrigeration has been demonstrated successfully over the last 10-15 years. However, the large bulk of the adsorption chiller can limit its use especially using in vehicle. The size of adsorption chiller is very important question for applying in the vehicle. The new type of compact adsorption chiller applied in the vehicle was proposed corresponding with the specification of the vehicle installation, and was about 40L by volume in this paper. A vacuum valve was used to increase the adsorption chiller size obviously. Thus, the new adsorption chiller has four pieces of vapor valves instead of vacuum valves. And the new adsorption chiller contains two pieces of adsorbers, an evaporator, a condenser, and four pieces of vapor valves. The vapor valve was controlled by the pressure difference at both sides. The use of vapor valves can reduce the chiller size without any pipe connection and decrease the refrigerant gas pressure difference during the flow of the refrigerant gas through different parts. Thus, the adsorption process of mass transfer is enhanced. Furthermore, other advantages of the use of the vapor valve include its simple structure and ease of manufacturing. The prototype adsorption chiller was manufactured, and the performances of the cooling power and coefficient of performance for the prototype adsorption chiller were obtained by testing the inlet and outlet temperatures of the evaporator, flow rate of chilled water, and cycled time. The maximum cooling power was approximately 1.5 kW at a driving temperature of 368 K and a cycled time of 90 s. The cooling power per liter of adsorption chiller can reach 37.7 W/L, which is higher than those of other adsorption chillers.
CFD MODELING OF BIOCRUDE-OIL COMBUSTION IN A PILOT-SCALE SPRAY BURNER

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Biomass is considered one of the promising renewable energy sources due to the depletion of fossil fuels and the global warming issue. Biocrude-oil can be produced through fast pyrolysis of various biomass feedstocks such as wood, crops, agricultural and forestry residues. Biocrude-oil has a relatively smaller heating value at about 40% of conventional petroleum fuels in mass basis due to its higher water content together with other oxygen contents in organic compounds. Also, its higher viscosity and char content lower the spray and atomization characteristics from the fuel nozzle. These characteristics lead to difficulties in direct application of biocrude-oil to conventional oil burners, and it would be essential to develop a burner for biocrude-oil combustion. In previous study, a burner system with capacity of 30,000 kcal/h was designed for the combustion of biocrude-oil and ethanol blends. It was found that stable combustion could be achieved with up to 90 vol% of biocrude-oil. In the present study, CFD modeling was performed to investigate the characteristics of biocrude-oil spray combustion. The Lagrangian multiphase model was adopted to simulate the droplet breakup and evaporation. Because biocrude-oil consists of hundreds of species derived from cellulose, hemicellulose, and lignin compounds, therefore five compounds were selected, which are acetic acid, formic acid, levoglucosan, phenol, and water. The fuel droplet was injected into the computational domain and the KHRT breakup model was applied to model the secondary breakup. The KHRT breakup model combines two submodels, one based on Kelvin-Helmholtz (KH) theory and one based on Rayleigh-Taylor (RT) theory. The k-ε model was used for turbulent flow. For gas-phase combustion, a presumed probability distribution function (PPDF) model was adopted. The CFD simulation was performed by STAR-CCM+ software. It was found that the time-averaged flame shape and location was successfully predicted. The results in the present study could be used as a predictive tool for biocrude-oil burner.
THE COMBUSTION CHARACTERISTICS OF FLUIDIZED DED BOILER FOR SRF

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For the first time in Korea, a pilot scale fluidized bed boiler is constructed and developed in order to demonstrate efficient and safe utilization of SRF (solid refuse fuel). The capacity of the facility is 8 steam tons per hour with the steam quality of 450°C and 38ata. It was designed and constructed by KIER and whole construction process was supervised by research team. KIER also established the operation system for commissioning and normal operation. The design data for commercial scale boiler was secured by long-term operation and repeated experiments.

The commercial scale (60ton/hr) CFB boiler for SRF was designed based on the research results. The capacity of the boiler is suitable for 10MWe power generation and 12ton/h steam supply. The specification could be used in industry and cogeneration power plant for district heating. It was constructed in Wonju, Gangwon province 2015. The combustion of RPF (refuse plastic fuel) and RDF produced in Korea was performed to identify and compare the operation characteristics. The combustion characteristics of solid waste fuel such as pellet type RDF in CFB boiler were stable and excellent in long term operation. The emission characteristics were satisfactory. The test operation proved the high combustion efficiency of 99% and up. The emissions of NOx, Sox, HCl in flue gas are below 100, 60,10ppm respectively emission control.
CHARACTERISTIC OF AIR DISTRIBUTER FOR COMBUSTION OF WASTE FUEL IN THE FLUIDIZED BED COMBUSTOR

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Coal one of fossil fuels has used the resources in the field of the industry. For this reason, coal reserves show a rapid decreasing and increased of price. Increase in cost has a significant impact on the operation of small boilers. So that each country developing alternative energy to solve that. One of the solution is using the alternative energy. But utilization of alternative energy has to settle the problem, from the high cost of facility investment and low efficiency. A study using the waste fuel in many combustion plants in progress in order to solve this problem. On the domestic side, the original solid fuel; RDF, RPF, WCF, RDF, are being consolidated, categorized by SRF and Bio-SRF, and managed through 2013 resources recycling law. Waste fuel is difficult to produce combustion in FBC because it contains a lot of incombustible matter. The incombustible matter have incurred a problems of fluidization in combustor. Such as non-ferrous metals are blocking the air distributor nozzle in attach with incombustible matter in combustor.

In this study, we aims in developing the device to smoothly discharge the incombustible matter resulting from the combustion of waste. We have modify the inverted pyramid structure type air distributor designs. The cold mode test equipment designed to determine the behavior characteristics of the bed material and fuel in FBC device. Test equipment height is 2500 mm and diameters are bottom 500 mm, free board 800 mm. inverted pyramid structure type air distributor has 6 flower and air hole size is 7\textbackslash\textmu{}.

The result of experiment,

1. Differential pressure measurement was confirmed through the fluidized state uniformity.
2. Fluidizations can be uniformed in bubbling fluidization. And increased gas velocity, center pressure of reactor was increased.
3. increased the air flow rate from 0.72 m/s to 1.1 m/s, discharged the incombustible matter ratio is 35\% to 87.5\%.


COMPARISON OF CHEMICAL STRUCTURE AND COMBUSTION CHARACTERISTIC OF CHARS PREPARED VIA PYROLYTIC AND HYDROTHERMAL CARBONIZATION

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Hydrothermal and pyrolytic carbonizations are two effective pathways to utilize biomass, and char are the main products from these thermal processes. This study aimed at comparing the effect of hydrothermal-produced char and pyrolysis-produced char on chemical composition and combustion characteristic. Results showed that hydrothermal char obtained higher HHV, more carbon content and less ash content than pyrolytic char. Additionally, the atomic ratios of hydrogen to carbon (H/C) and oxygen to carbon(H/C) of hydrothermal char were found in the range of coal within Van-Krevelen diagram, while that of char is observed in an empty range, indicating that hydrothermal char had similar properties of coal as its deeper degree of coalification. To summarize, if just concentrate on the potential ability to be solid fuel and ignore other realistic factors such as energy consumption and equipment investment, hydrothermal carbonization is superior to pyrolysis.
Topic 9: Bioenergy
PRODUCTION OF BTX COMPOUNDS FROM CATALYTIC FAST PYROLYSIS OF BIOMASS WITH MODIFIED HZSM-5 CATALYSTS

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Catalytic fast pyrolysis of biomass is one of the most important ways to prepare aromatic compounds from solid biomass. Typically, benzene, toluene, and xylene (BTX) are primary aromatic products. In this study, a series of bimetallic zeolite catalysts including Co-Mo, Co-Fe, Co-Ni, Mo-Fe, Mo-Ni and Fe-Ni supported on HZSM-5 were successfully prepared using wet impregnation method. Moreover, metals like Co, Mo, Fe and Ni were also supported on HZSM-5 for comparison. Catalytic fast pyrolysis experiments of biomass were performed at 550 °C to investigate the effects of catalysts on the product distribution. The results showed that the addition of synthesized bimetal/HZSM-5 improved the arene selectivity up to 73-85% compared with metal/HZSM-5 (55-71%). For bimetal/HZSM-5, Fe-Ni/HZSM-5 revealed the highest BTX selectivity of 60% and the highest arene selectivity of 85% with polycyclic aromatic hydrocarbons (PAHs) selectivity of 17%. And Mo-Fe/HZSM-5 showed the least PAHs selectivity of 16%. For metal/HZSM-5, Fe/HZSM-5 had the highest BTX selectivity of 44% and PAHs selectivity of 14%. While Ni/HZSM-5 showed the least PAHs selectivity of 16%, but its BTX selectivity was less than 35%. What’s more, pure HZSM-5 showed the highest arene selectivity of 89%, but its PAHs selectivity was over 22%. Overall, Fe and Ni could reduce unfavorable PAHs such as 2-methyl-naphthalene and naphthalene. And the synergy of Fe and Ni could enhance the selectivity of BTX. Hence Fe-Ni/HZSM-5 was supposed to be the most efficient catalyst.
Effects of Operational Parameters on the Formation of NOx Precursors (NH3 and HCN) during the Pyrolysis of Industrial Biomass Wastes

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Abstract: Industrial biomass wastes (IBWs) with an annual amount of more than 400 million tons have been identified as dominant biomass resources in China. To investigate the formation mechanism of NO\textsubscript{x} precursors during IBWs pyrolysis is significant for their clean utilization as the relatively high nitrogen content contained will cause some environmental issues during the utilization process. However, the mechanisms of operational parameters affecting the formation of NO\textsubscript{x} precursors are still not fully developed. Based on the pyrolysis of typical IBWs—medium density fibreboard waste (MFW), tea stalk waste (TSW) and Chinese herb residue (CHR) on a horizontal tubular quartz Reactor, the factors of the thermal conditions, the pyrolysis atmosphere, the particle size, the intrinsic moisture and the components in fuels influencing the formation of NO\textsubscript{x} precursors were studied with the help of XPS and TG technologies. The results indicated that NH\textsubscript{3} was the predominant NO\textsubscript{x} precursor for three IBWs pyrolysis at any operating condition, which revealed that the dominance species of NO\textsubscript{x} precursors wouldn’t be related to the operational parameters but probably depended on the nitrogen functionalities in fuels. Nevertheless, these operational parameters could inevitably alter both the yield and the ratio of NO\textsubscript{x} precursors. Any operational parameter such as high temperature, rapid pyrolysis type or small particle size would not only largely increase the total yield of NO\textsubscript{x} precursors but also be more favourable for the production of HCN compared with that of NH\textsubscript{3}. In addition, it was demonstrated that the pyrolysis atmosphere and the intrinsic moisture had a limited effect on the formation of NO\textsubscript{x} precursors. Also, each IBWs presented some unique characteristics in the formation of NO\textsubscript{x} precursors due to its special components. Consequently, the influence on the NO\textsubscript{x} precursors by each operational parameter could be intrinsically attributed to its different impact on the formation pathway of NO\textsubscript{x} precursors. And the total yield was observed at a range of 20–45 wt\% under a mild operational condition. These might provide some effective guideline for the clean energy reutilization of IBWs.

Keywords: IBWs; NO\textsubscript{x} precursors; Operational parameters; NH\textsubscript{3}; Pyrolysis