Ocean Energy Development in Korea

2017. 11. 13.

Kwang Soo Lee
kslee@kiost.ac.kr

Coastal Engineering Research Division
Korea Institute of Ocean Science and Technology (KIOST)
**Ocean Energy Development since 2000**

**Sihwa Lake Tidal Power Plant**
- Capacity of 254MW (25.4MW x 10)
- 8 Sluices
- Completed in 2011

**Jeju OWC Wave Power Pilot Plant**
- Capacity of 500kW (250kW x 2)
- Impulse turbine of 1.8m(dia.), 26 blades
- 37.0m(L) x 31.2m(B) x 27.5m(H)
- Completed in 2016

**Uldolmok Tidal Current Power Pilot Plant**
- Capacity of 1,000kW (500kW x 2)
- Helical type Vertical Axis Turbine
- Completed in 2009

**Goseong OTEC/SWAC Pilot Plant**
- 200kW OTEC
- 60RT SWAC

---

Korea Institute of Ocean Science and Technology
Sihwa Lake Tidal Power Plant

- **History**
  - Completion of Sea Dyke of 12.7km in 1994
  - Severe Lake water pollution
  - Tidal Power Plant was proposed as a countermeasure, based on the findings from national R&D
  - Construction: 2004 ~ 2011
  - Total Project Cost: USD 355 million

- **Effects of Sihwa Tidal Power Plant**
  - Improve water quality in Sihwa Lake and environmental recovery
  - Generate renewable clean energy
  - Enhancement of regional economy by forming waterfront and tourist attraction

- **Power Output in 2011.8~2016.12**

<table>
<thead>
<tr>
<th>Year</th>
<th>Power Output</th>
<th>Year</th>
<th>Power Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 (8 ~12)</td>
<td>52,304 MWh</td>
<td>2014</td>
<td>492,172 MWh</td>
</tr>
<tr>
<td>2012</td>
<td>465,924 MWh</td>
<td>2015</td>
<td>496,354 MWh</td>
</tr>
<tr>
<td>2013</td>
<td>483,777 MWh</td>
<td>2016</td>
<td>495,556 MWh</td>
</tr>
</tbody>
</table>
Uldolmok TCP Pilot Plant (VAT)

- **Construction of 1MW Uldolmok tidal current power pilot plant**
  - Completion: 2009. 3.

- **Field verification tests**
  - System Efficiency: 26.2%
  - Turbine Efficiency: 37% at TSR 2.5

![Image of Uldolmok TCP Pilot Plant (VAT)](image)

![Graph showing the relation between current and power at UDM with the equation: $Y = -109.3848 + 127.5465X - 49.3753X^2 + 9.2733X^3$ and $R^2 = 0.991$)](graph)
MOF Policies

- **2030 Strategy of Ministry of Oceans and Fisheries (MOF)**
  - Energy Policy of President Moon Government
    - **3020 Strategy** (20% of national electricity demand from renewable resources by 2030) for reducing CO₂ emission, solving fine dust issue, etc.
  - MOF’s **2030 Plan** is to construct the total installed capacity of 1GW commercial plants to follow up the governmental energy policy including 254MW tidal range, 120MW wave energy, 500MW tidal current energy and 200MW wave-wind / tidal current-wind hybrid energy by 2030.

- **Key Actions**
  - Priority on Infrastructures and accelerating commercial development
  - Construction of open sea testing facilities for WEC and TEC
  - Activating open sea tests of WEC & TEC pilot plants
  - Enhancing promotion policy on ocean energy by adjusting the REC for wave and tide energy
  - Training program for graduate students in ocean energy systems
R&D Activities 1 : TEC with Active Controlled HAT

- **Medium Scale Model (1:10)**
  - Outdoor Experiment
    - 2013~2014 / Uldolmok Test Site
    - Rotor Dia. : 2.4m
    - Blade Active Pitch Control
    - Passive/Active Yawing by Rudder

- **Design of KS200 (1:2)**
  - 2014~2015
  - Based on Experimental Results

- **Fabrication of KS200**
  - 2016~2017

- **Installation**
  - 2017. 11 ~ 12
  - Near Uldolmok Test Site

- **Verification Test**
  - 1st : 2018
  - 2nd : 2019 ~ 2020
  - Performance Assessment
  - Environmental Impact Monitoring

**KS200 (Korean Shark 200)**

**Specification**

<table>
<thead>
<tr>
<th>Rotor</th>
<th>Diameter: 12m</th>
<th>Swept Area: 13m²</th>
<th>Rotor speed: 16 rpm</th>
<th>Power regulation: Active blade pitch regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yawing system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transmission system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mechanical brake</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Generator</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated power</td>
<td>250kW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td>34.575 kV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cooling system</td>
<td>Direct to passing sea water</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monitoring system</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCADA system</td>
<td>Server-client</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remote control</td>
<td>Full turbine control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tower &amp; Substructure</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of tower</td>
<td>Cylinderical tubular steel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of substructure</td>
<td>Gravity type circular casing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hub height</td>
<td>11m from seabed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operational data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cut-in current speed</td>
<td>1m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rated current speed</td>
<td>2.1m/s</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nacelle &amp; Drive train</td>
<td>Less than 60 tons</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tower &amp; Substructure</td>
<td>Less than 700 tons</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
R&D Activities 1: TEC with Active Controlled HAT

- **KS200 Fabrication and Test**

- **Supporting Structure**
Commercialization Plan of Tidal Current Energy

**Planning Study (KIMST)-'17**
- Necessities, Technical Demand, Technical Roadmap
- RD&D Planning

**National RD&D (Gov&Private)-'18~'21**
- 1MW Commercial Prototype of Tidal Energy Converter
- 10MW Tidal Energy Pilot Array Basic Planning and Feasibility Study

**10MW Pilot Array (Gov&Private)-'21~'24**
- 10MW Pilot Array Development
- 100MW Commercial Plant Basic Planning and Feasibility Study & EIA

**500MW C.Array (Private)-'25~'30**
- 5x100MW Commercial Tidal Energy Plant Development
- Monitoring of Environmental Impact

**TRL 8 ➔ TRL 9**

**TRL 7 ➔ TRL 8**
R&D Activities 2 : Floating Pendulum WEC

- **Principal specification**
  - Dimension: 23m (B) x 30.5m (L) x 10m (H)
  - PTO : Hydrostatic Power Transmission
  - Synchronous Generator (300kW)
  - 4 Points 8 lines Catenary mooring
  - Grid Connection

- **Key schedule**
  - R&D Periods : Aug. 2010~
  - Completion of Prototype : May. 2016 (now waiting for Real sea test)
  - Installation and demonstration at Jeju wave energy test site : June 2018
R&D Activities 3: Breakwater-Connected OWC

- Development of Breakwater-Connected OWC
  - Period: May 2016 ~ Dec 2020
  - Budget: 12 mil. USD
  - Funded by MOF and Charged by KRISO

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual Design &amp; Metocean Data</td>
<td>Basic Design &amp; Unit Performance Evaluation</td>
<td>Detail Design &amp; Integrated Performance Evaluation</td>
<td>Pilot Plant Manufacturing &amp; Installation</td>
<td>Pilot Plant Test Operation</td>
</tr>
</tbody>
</table>

- Selection of Site
- Basic Design
- Company Selection
- Manufacturing
- Test Operation

- 2016.05: Start
- 2016.12: Conceptual Design
- 2017.10: Unit Test
- 2017.12: Integrated Test
- 2018.06: Detail Design
- 2018.10: Installation
R&D Activities 3 : Breakwater-Connected OWC

- Basic Design of WEC applicable to Breakwater (2016-2917)
  - Sloped OWC : Principal dimension, arrangement of OWCs
  - Impulse Turbine : Principal dimension, effect of sweep angle & ring
  - Generator (PMSG)/PCS & ESS/Micro-grid & SCADA
R&D Activities 4: K-WETEC

**K-WETEC (Korea Wave Energy Test & Evaluation Center)**

- **Outlines**
  - Period: May 2016 ~ Dec 2019
  - Budget: 17 Million USD
  - Location: Yongsoo-ri, Hankyung-myeon, Jeju
  - Funded by MOF and Charged by KRISO and JNU
  - No. of Berths: 5 (OWC(turbine test), 2 x 15m, 40m, 60m in water depth)
  - Capacity: 5MW in total and 2MW maximum in each berth

- **Current stages**
  - Survey on each berth and its submarine cable route
  - Basic and detail design for submarine cable and offshore substation
  - Study on international standard activity of performance assessment for wave energy converters

- **Future Plan**
  - Permission on ocean space occupation and electrical power sales
  - Installation of submarine cable and offshore substation
  - Construction of control center and SCADA
  - Establishment of open sea test site operation system
R&D Activities 4: K-WETEC

[Diagram showing various components and connections related to ocean energy, including wave measurement instruments, floating pendulum WEC, submarine cable, air turbine for OWC, and offshore substations.]
R&D Activities 5: TEC Test Bed Project (KMEC)

- **Outlines**
  - Period: May 2017 ~ Dec 2021
  - Budget: 24 Million USD
  - Location: Jangjook Strait and Uldolmok Strait, Jindo
  - Funded by MOF and Charged by KIOST
  - No. of Berths and Capacity: 5 (1MW x 4, 0.5MW x 1)

- **Current stages**
  - Establish a comprehensive development plan for TEC
  - Establish a KOLAS testing laboratory accreditation plan for TEC
  - Study on international standard activity of performance assessment for tidal energy converters

- **Future Plan**
  - Design, construction and operation for TEC
  - Acquisition and operation a KOLAS testing laboratory accreditation for TEC
R&D Activities 5: TEC Test Bed Project
Reference for LCOE of Tidal Energy Converter

- IEA-OES 2016 Annual Report

**UK Contract for Difference (CfD) for less established technologies: Draft Strike Prices (£/MWh)**

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>2021/22</th>
<th>2022/23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offshore wind</td>
<td>105</td>
<td>100</td>
</tr>
<tr>
<td>Advanced conversion technologies (with or without CHP)</td>
<td>125</td>
<td>115</td>
</tr>
<tr>
<td>Advanced conversion technologies (with or without CHP)</td>
<td>140</td>
<td>135</td>
</tr>
<tr>
<td>Dedicated biomass with CHP</td>
<td>115</td>
<td>115</td>
</tr>
<tr>
<td>Wave</td>
<td>310</td>
<td>300</td>
</tr>
<tr>
<td>Tidal stream</td>
<td>300</td>
<td>295</td>
</tr>
</tbody>
</table>

* £ 300 = 435,000 Won  
* £ 295 = 427,750 Won (£ 1 = 1,450 Won)

- Goal: 300,000 Won/MWh in 2030 (= £200)
Thank You