Role of Ocean Energy in the Stand-alone Microgrid System for Green Energy-Independent Island

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Ocean Energy Development in Korea

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)
- To be completed on July 2016

Uldolmok Tidal Current Power Pilot Plant
- Capacity of 1,000kW (500kW x 2)
- Helical type Vertical Axis Turbines
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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 counter measure, 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 2011.8~2014.12**

<table>
<thead>
<tr>
<th>Period</th>
<th>Power Output (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011.08 ~ 2011.12</td>
<td>52,304 MWh</td>
</tr>
<tr>
<td>2012.01 ~ 2012.12</td>
<td>465,924 MWh</td>
</tr>
<tr>
<td>2013.01 ~ 2013.12</td>
<td>483,777 MWh</td>
</tr>
<tr>
<td>2014.01 ~ 2014.12</td>
<td>492,172 MWh</td>
</tr>
</tbody>
</table>
Sihwa Lake Tidal Power Plant

- Water Level Variations & Restored Tidal Flat
- Variation of ignition Loss in tidal flat
Tidal Current Power Generation System with active-control device

- **Medium Scale Model(1:5) Outdoor Experiment**
  - 2013~2014 / Uldolmok Test Site
  - Rotor Dia.: 2.4m
  - Blade Active Pitch Control
  - Passive/Active Yawing by Rudder

- **Design of KS200**
  - 2014~2015
  - Based on Experimental Results

- **Fabrication of KS200**
  - 2015~2016

- **Installation**
  - 2016. 9 ~ 10
  - Near Uldolmok Test Site

- **Verification Test**
  - 1\textsuperscript{st}: 2016. 11 ~ 2017. 12.
  - 2\textsuperscript{nd}: 2018 ~ 2020
  - Performance Assessment
  - Environmental Impact Monitoring

- **KS200 (Korean Shark 200)**

  **Specification**

<table>
<thead>
<tr>
<th>Rotor</th>
<th>Diameter</th>
<th>12m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Swept Area</td>
<td>113\text{m}^2</td>
</tr>
<tr>
<td></td>
<td>Rotor speed</td>
<td>16 rpm</td>
</tr>
<tr>
<td></td>
<td>Power regulation</td>
<td>Active blade pitch regulation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Yawing system</th>
<th>Type</th>
<th>Rudder pitch control</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control type</td>
<td>Passive/Active</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Transmission system</th>
<th>Type</th>
<th>Direct drive</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Mechanical brake</th>
<th>Type</th>
<th>Hydraulically released</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Generator</th>
<th>Type</th>
<th>Permanent Magnet Synchronous Generator (PMSG)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rated power</td>
<td>230kW</td>
</tr>
<tr>
<td></td>
<td>Voltage</td>
<td>36.575 \text{V}</td>
</tr>
<tr>
<td></td>
<td>Cooling system</td>
<td>Direct to passing sea water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Monitoring system</th>
<th>SCADA system</th>
<th>Server-client</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Remote control</td>
<td>Full turbine control</td>
</tr>
</tbody>
</table>

  | Tower & Substructure | Type of tower | Cylindrical tubular steel |
  |                     | Type of substructure | Gravity type circular caisson |
  |                     | Hub height | 1.1m from seabed |

  | Operational data    | Cut-in current speed | 1m/s |
  |                     | Rated current speed | 2.3m/s |

  | Weight              | Nacelle & Drive train | Less than 60 tons |
  |                     | Tower & Substructure | Less than 700 tons |
Hybrid-OTEC Power Plant (200kW, 2014)

- Combined operation with wood chip gasification power plant
- Using multiple heat sources

500kW Wood Power Plant (MOTIE)

200kW H-OTEC Plant (MOF)

Solar Energy
Wind energy
[Heat storage tank]

Pump
Condenser
Turbine
Evaporator
Intake
Discharge

substituted by Geothermal or Solar heat sources for SIDS
SWAC plant to reduce energy demand

- Cooling source can be acquired from
  1) direct heat exchanger by cold deep ocean water
  2) cold heat of evaporator of heat pump by use of seawater as a condensing heat source

- Test bed (100RT & 500RT) were established in 2014 and 2015
Technology Development

**Technology Readiness Levels**

<table>
<thead>
<tr>
<th>Energy Resources</th>
<th>Europe</th>
<th>Korea</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Barrage</td>
<td>TRL 9</td>
<td>TRL 9</td>
</tr>
<tr>
<td>Tidal Current</td>
<td>TRL 8</td>
<td>TRL 6-7</td>
</tr>
<tr>
<td>Wave</td>
<td>TRL 8-9</td>
<td>TRL 5-6</td>
</tr>
<tr>
<td>OTEC/SWAC</td>
<td>TRL 8-9</td>
<td>TRL 5-6</td>
</tr>
</tbody>
</table>

**Technology Topics**

1. Proving reliable operation
2. Device design: cost reduction and development of promising technologies
3. Enabling technologies (cabling and electrical connection)
4. Innovation: novel technologies, new components and subcomponents
5. Knowledge sharing

Wave and Tidal Energy Strategic Technology Agenda. SI Ocean (2014)
Microgrid

- Microgrid is a local energy system which incorporates three key components; Generation, Storage and Demand all within a bounded and controlled network. It may or may not be connected to the grid.
- Benefits
  - Economic: Improved efficiency and long term predictable energy cost
  - Resiliency: Field-proven reliability improvement against natural disasters such as earthquakes, tsunamis and storms
  - Environmental: Reduction in harmful emissions resulting from optimal use of renewable resources and energy efficiency programs
Microgrid/Smart Grid: WEC Perspective

SMART GRID
A vision for the future - a network of integrated microgrids that can monitor and heal itself.

From: “Smart grids: best practice fundamentals for a modern energy system”, WEC, 2012
Microgrid/Smart Grid: DOE Perspective

From: “DOE Microgrid Demonstration Project”, NETL, 2013
Microgrid/Smart Grid: EU Perspective

http://www.eurelectric.org/media/26140/broch.10steps_lr-2011-030-0304-01-e.pdf
Gasa-Island Energy-Independent (KEPCO, 2014)

Project General
- 168 Households (286 Inhabitants)
- Average Load : 95 kW
- Average Wind Speed : 5.8 m/s
- Average Solar Radiation : 3.88 kWh/m²
- Total Project Cost : 8 Mil. US$
- Fuel Cost Saving : 0.28 Mil US$/year

Installed Facilities
- Operation : SCADA+EMS (Automatic Source Control)
- Inverter : 2 x 500 kVA, 1 x 250kVA
- Lithium Battery : 3MWh
- Wind Generator : 4 x 100kW (PMSG)
- Solar Generation : 314 kW (8 Places)
- Demand Management : Water Supply Tank & Air Conditioner
- Diesel Generator : 3 x 100kW (existing)
Uldolmok Experimental Station for Hybrid System

- **Modification of Existing Plant**
  - Wind Energy
  - Solar Energy
  - Tidal Energy
  - Energy Storage System (Micro-CAES; Compressed Air Energy Storage)

- **Installation**
  - 2016 ~ 2017

- **R&D Purpose**
  - Developing Technologies
  - Performance Assessment
  - Environmental Impact Monitoring
Seawater Pumped Hydropower Storage (PHS)

- **Pumping**
  - Wind
  - Wave (combine with Breakwater)
  - Tide (Current)

- **Pumped Seawater**
  - Aquaculture
  - Cultivation of *Ulva pertusa* → Biofuel / Fertilizer
  - Heated by Solar Energy → Air Conditioning

- **Micro-Hydropower**
  - Energy Storage for Microgrid
  - Easy Control of Power -in / -off
  - Saving O&M Cost (??)
Technologies for ocean energy development have been improved rapidly, and several machines for wave and tidal energy is at the pre-commercial stage.

Ocean energy could play an important role as energy supplier and storage in the microgrid for energy-independent island.

In order to support to green energy-independent island project of Korea including ESS (Energy Storage System), CAES (Compressed Air Energy Storage) combined with breakwater and seawater pumped hydropower storage (PHS) using wind, wave and tide energy are proposed.

Ocean energy resources, environmental and economic conditions are different from country to country and site to site. For the cost-effective and environmentally sound development of an isolated microgrid of an island, the energy scheme and system should be carefully studied at the design stage.
Thank You