Current and Future of Floating Photovoltaic Technology

Dr. Chang-sub, Won

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1. About Chang-sub, Won

- **Name**: Chang-sub, Won
- **Nationality**: Republic of Korea
- **Affiliation**: SCOTRA.CO. LTD., R&D Center
- **Position**: Chief Technical Officer
- **Research Area**: FPV System

- Chief Technical Officer, SCOTRA.CO. LTD., R&D Center, 2019.2.25 ~ present
  - Research on the improvement of stability, anti-corrosion, long-term reliability and power performance of raft-type floating photovoltaic systems.
  - Principal Researcher of the government grant project for offshore Floating PV systems
- Lecturer, Electrical Department graduate School, Konkuk university, 2023.3.1 ~ present
- Visiting Research Fellow, UNSW(University of New South Wales), 2022.9.3 ~ present
- Principal Researcher, LS Electric, R&D Division, Power conversion Team, 2010~2019
  - Research on photovoltaic modules with anti-moisture, waterproofing, lead-free, and anti-PID properties
- 10 patent Inventor related floating PV system
1. About SCOTRA

“EVERYTHING ON THE WATER”

- 2004 developed 1st float product
- 2007 established SCOTRA Co., Ltd.
- 2009 obtained Venture Business Certification
- 2010 established R&D Center
- 2011 obtained INNO-BIZ certification
- 2012 constructed world 1st commercial floating PV system on hydroelectric power plant dam
- 2018 Complete 18.7MW Gunsan FPV project
- 2019 Complete 25MW Namjeong reservoir
- 2020 Construct Gunshan Factory
- 2021 Complete 41MW Hapcheon Dam
- 2022 Complete 13.7MW Taiwan Wushantou Dam

Company: SCOTRA Co., Ltd.
CEO: Jong Mok Lee
Employees: 78 (as in Apr. 2022)
Hq. office: Pyeongtaek City, South Korea
Factory: Gunshan city
Business Area: FPV buoys / Structure, Leisure,
1. About SCOTRA

Hapcheon Dam / 41MW / 2021
2.0 Floating PV Systems : Introduction

CNBC released a floating PV System in December, 2011.
1. About Floating PV Systems: major component
1. About Floating PV Systems: Benefits

**Business**
- Conservation of Forest & Farmland
  - No Deforestation Damage
    - by green system
- Use of Water Surface
  - The Efficient Use of Land
    - by eco-friendly system
- High Efficiency
  - 10% Generation Increase
    - by natural cooling effect

**Environment**
- Preventing Green Tide
  - Green tide can be controlled
    - by blocking sunlight
- Saving the Water Resources
  - by blocking sunlight
- Eco-friendly System
  - Natural Fish Farms
    - under the floating platform
A 99kW FPV system was installed in the fall of 2011. As of 2023, 107MW has been installed, and the total cumulative installed volume reaches 360MW.
2. Korea Economy FPV Market: FPV category

- Electrical generation Dam: 11 system, 61MW
- Agricultural reservoir: 65 system, 60MW
- Reclaimed lake: 4 system, 216MW
- Industrial reservoir: 3 system, 23MW
2. Korea FPV Market : FPV Business environment

1. Korea Economy supports renewable energy by implementing the RPS system. In the case of FPV, the RPS support weight is 1 to 1.5 times higher than that of land-based PV.

2. Korea Economy has an established permitting process for floating solar power projects. However, the public is very interested in conserving the natural environment, and the permitting process includes a procedure to obtain consent from residents.

3. In Korea, it is mandatory for floating photovoltaic systems to use dedicated solar modules suitable for the water environment. This defines product performance in KS, a national standard.
1. In Korea, when installing a floating Photovoltaic generation system, it is required that a dedicated floating Photovoltaic module must be used.

2. The KS C 8561 Crystalline silicone photovoltaic(PV) module (performance) regulation used in Korea includes the required performance and test methods for modules for installing solar power generation on water.

3. The performance test of the water module has three characteristics: 3000h damp heat test, mechanical load test including dynamic load, and restriction on the use of heavy metals.
3. Global FPV Market: Size Forecast

![Bar chart showing capacity (MW) from 2020 to 2030. Capacity increases significantly over the forecast period. Source: Wood Mackenzie]
3. Global FPV Market: Major Economy

- **Source**: SERIS

### Installed Capacity (kWp) and Number of Projects

<table>
<thead>
<tr>
<th>Continent</th>
<th>Country</th>
<th>Installed Capacity (kWp)</th>
<th>Number of projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>China</td>
<td>1,327,230</td>
<td>45</td>
</tr>
<tr>
<td></td>
<td>Taiwan</td>
<td>305,266</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>287,729</td>
<td>186</td>
</tr>
<tr>
<td></td>
<td>Vietnam</td>
<td>167,530</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>South Korea</td>
<td>106,947</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Thailand</td>
<td>61,982</td>
<td>44</td>
</tr>
<tr>
<td>Europe</td>
<td>Netherlands</td>
<td>111,123</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Israel</td>
<td>112,136</td>
<td>NA</td>
</tr>
<tr>
<td>Mixed</td>
<td>Others</td>
<td>156,259</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td><strong>2,638,202</strong></td>
<td><strong>578</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Continent</th>
<th>Total surface area available (km²)</th>
<th>Number of water bodies assessed</th>
<th>FPV potential (GWp)</th>
<th>Possible annual energy generation (GWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Percentage of total surface area used</td>
<td>Percentage of total surface area used</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1%</td>
<td>5%</td>
</tr>
<tr>
<td>Africa</td>
<td>101,130</td>
<td>724</td>
<td>101</td>
<td>506</td>
</tr>
<tr>
<td>Middle East and Asia</td>
<td>115,621</td>
<td>2,041</td>
<td>116</td>
<td>578</td>
</tr>
<tr>
<td>Europe</td>
<td>20,424</td>
<td>1,082</td>
<td>20</td>
<td>102</td>
</tr>
<tr>
<td>North America</td>
<td>126,017</td>
<td>2,248</td>
<td>125</td>
<td>630</td>
</tr>
<tr>
<td>Australia and Oceania</td>
<td>4,991</td>
<td>254</td>
<td>5</td>
<td>25</td>
</tr>
<tr>
<td>South America</td>
<td>36,271</td>
<td>299</td>
<td>36</td>
<td>181</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>404,454</strong></td>
<td><strong>6,648</strong></td>
<td><strong>404</strong></td>
<td><strong>2,022</strong></td>
</tr>
</tbody>
</table>


*Note: GWh = gigawatt-hour; GWp = gigawatt-peak; km² = square kilometers; PV = photovoltaic.*
The environment of dams and reservoirs in which water-based photovoltaic systems are installed is very humid and covered with fog in the early hours of the morning, and when the fog clears, there is considerable moisture on the surface of the module.

Site name: Dea-do reservoir
Site coordinate: 35°04'06.5"N, 126°37'14.1"E
Inst Capacity: 500kW
Installation Date: Sept 2015
Water Depth: 3~7m
Module Type: c-Silicon
For the development of floating PV modules, we refer to two modules. One is a module installed on the island 20 years ago, and the other is one on a buoy that is replaced every five years.
### FPV Module Research: FPV Module Specifications

#### Special Features

<table>
<thead>
<tr>
<th>Applicable Installation Site</th>
<th>Customized PV Module</th>
<th>Conventional PV Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reservoir, Dam Lake, etc.</td>
<td></td>
<td>Building Rooftop, Land</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IP Class</th>
<th>IP67</th>
<th>IP64</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity</td>
<td>High</td>
<td>Normal</td>
</tr>
<tr>
<td>PID</td>
<td>PID Free</td>
<td>PID Free or Non-PID</td>
</tr>
<tr>
<td>Encapsulant</td>
<td>Polyolefin Elastomer(POE)</td>
<td>Ethylene vinyl acetate(EVA)</td>
</tr>
<tr>
<td>Material of Ribbon</td>
<td>Lead(Pb) Free</td>
<td>Lead(Pb) used</td>
</tr>
</tbody>
</table>

**PID**: Potential Induced Degradation
The 100 sample for floating pv modules were tested under STC conditions every two years, resulting in an average power reduction of 0.07%. The standard deviation increased by 0.59% over four years. If you predict a 25 year output degradation, We expect a decrease of 13.5%
4. FPV Module Research : Anti Moisture Characteristics

5000 hours Damp Heat Test

- 5,000 hours long test for water installation with hard condition.
- Condition: Damp Heat(85°C, RH 85%), 5000 hours by KTL

<table>
<thead>
<tr>
<th>Time(hr)</th>
<th>0</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVA</td>
<td>BS S11</td>
<td>100.0%</td>
<td>99.7%</td>
<td>90.9%</td>
<td>49.4%</td>
<td>12.8%</td>
</tr>
<tr>
<td></td>
<td>BS S16</td>
<td>100.0%</td>
<td>100.0%</td>
<td>94.8%</td>
<td>48.1%</td>
<td>10.8%</td>
</tr>
<tr>
<td>Poly olefin</td>
<td>PVM S300F</td>
<td>100.0%</td>
<td>100.1%</td>
<td>99.5%</td>
<td>98.4%</td>
<td>97.8%</td>
</tr>
<tr>
<td></td>
<td>PVM S250P</td>
<td>100.0%</td>
<td>100.4%</td>
<td>99.5%</td>
<td>99.9%</td>
<td>98.1%</td>
</tr>
</tbody>
</table>
5. FPV System Research : FPV Installation site

- **Agricultural reservoir**
- **Electrical generation Dam**
- **Reclaimed lake**
- **Off-shore**

- Fresh water
- Salt water
5. FPV System Research: FPV test bed

- Agricultural reservoir
- Electrical generation Dam
- Terrace land on the river
- Reclaimed lake
- Off-shore
- Port
5. FPV System Research : Cooling Effect

Floating System vs. Rooftop Temperature Characteristics

- Floating PV module op. temp. 5°C~10°C lower based on annual and monthly averages
- Higher Yield distribution & System Operation time at corresponding low module temperature ranges

[Graph showing temperature distribution over months and years]
5. FPV System Research : Corrosion

<table>
<thead>
<tr>
<th>Corrosivity category</th>
<th>Low-carbon steel Mass loss g/m²</th>
<th>Thickness loss μm</th>
<th>Zinc Mass loss g/m²</th>
<th>Thickness loss μm</th>
<th>Exterior</th>
<th>Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1 very low</td>
<td>&lt; 10</td>
<td>&lt; 1.3</td>
<td>&lt; 0.7</td>
<td>&lt; 0.1</td>
<td>Heated buildings with clean atmospheres, e.g., offices, shops, schools, hotels.</td>
<td></td>
</tr>
<tr>
<td>C2 low</td>
<td>&gt; 10 to 200</td>
<td>&gt; 1.3 to 25</td>
<td>&gt; 0.7 to 5</td>
<td>&gt; 0.1 to 0.7</td>
<td>Atmospheres with low level of pollution. Mostly rural areas. Unheated buildings where condensation may occur, e.g., depots, sports halls.</td>
<td></td>
</tr>
<tr>
<td>C3 medium</td>
<td>&gt; 200 to 400</td>
<td>&gt; 25 to 50</td>
<td>&gt; 5 to 15</td>
<td>&gt; 0.7 to 2.1</td>
<td>Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity. Production rooms with high humidity and some air pollution, e.g., food-processing plants, laundries, breweries, dairies.</td>
<td></td>
</tr>
<tr>
<td>C4 high</td>
<td>&gt; 400 to 650</td>
<td>&gt; 50 to 80</td>
<td>&gt; 15 to 30</td>
<td>&gt; 2.1 to 4.2</td>
<td>Industrial areas and coastal areas with moderate salinity. Chemical plants, swimming pools, coastal chip- and boatyards.</td>
<td></td>
</tr>
<tr>
<td>C5-I very high (industrial)</td>
<td>&gt; 650 to 1500</td>
<td>&gt; 80 to 200</td>
<td>&gt; 30 to 60</td>
<td>&gt; 4.2 to 8.4</td>
<td>Industrial areas with high humidity and aggressive atmosphere. Buildings or areas with almost permanent condensation and high pollution.</td>
<td></td>
</tr>
<tr>
<td>C5-M very high (marine)</td>
<td>&gt; 650 to 1500</td>
<td>&gt; 80 to 200</td>
<td>&gt; 30 to 60</td>
<td>&gt; 4.2 to 8.4</td>
<td>Coastal and offshore areas with high salinity. Buildings or areas with almost permanent condensation and high pollution.</td>
<td></td>
</tr>
</tbody>
</table>

NOTES
1. The loss values used for the corrosivity categories are identical to those given in ISO 9223.
2. In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.
5. FPV System Research: conservation of nature

- Service Organization: Korea Environment Institute (KEI)
- (service fee, Period) $130,000/year, 2011-2016.
- (Service Contents)
  - Establish guidelines and environmental monitoring
  - Conduct environmental monitoring for conservation of nature
  - Verification and sharing of environmental safety through governance operation
- Environmental monitoring

<table>
<thead>
<tr>
<th>Item</th>
<th>Cycle</th>
<th>Sampling point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quality / Phytoplankton</td>
<td>1 times / Month</td>
<td>4 point</td>
</tr>
<tr>
<td>Fishes</td>
<td>1 times / Month</td>
<td>2 point</td>
</tr>
<tr>
<td>Deep water invertebrate</td>
<td>1 times / Month</td>
<td>6 point</td>
</tr>
<tr>
<td>Sediment</td>
<td>1 times / Quater</td>
<td>6 point</td>
</tr>
<tr>
<td>Birds</td>
<td>1 times / Quater</td>
<td>1 point</td>
</tr>
</tbody>
</table>

- Result
  - Monitoring does not have negative environmental impact
  - Does not affect water quality in terms of chemistry

No impact on surrounding ecosystem environment
5. FPV System Research: Reclaimed lake FPV Testbed
5. FPV System Research: off-shore FPV Testbed
6. Future work: Bird soiling
6 Future work: ship wave (small wave-fatigue failure)
6. Future work: Energy transfer - Floating PV – H2 production system
6. Future work: Energy transfer - Floating PV – H2 production system

- Floating PV
  - Junction Box
  - Isolation Inverter
  - Power Conditioner
  - DC/DC Converter

**Power Source**

- Mass Flowmeter
- Low Pressure tank
- Dryer
- Gas/Liquid separator

**H2 Storage**

- Storage tank
  - Pressure Transmitter (PT)
  - Safety Valve (SV)
  - N2 tank

**Electrolysis cell**

- Anode
- Cathode

**Additional Components**

- DC/DC Converter
- Power Source
- Power Meter (PM)
Thank you for your attention