The KEPCO AC* V2G** Pilot using IONIQ 5 EVs

*AC-Alternating Current, **Vehicle to Grid

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KEPCO Research Institute
Introduction

The KEPCO Research Institute

- Renewable Energy
  - Offshore Wind
  - ESS
  - Materials

- Digital Solution
  - Power Platform
  - Wireless Com.
  - Data Service

- Energy & Environment
  - CCUS*
  - Hydrogen
  - Find Dust

- Power Generation
  - Intelligent PG
  - Clean Gen.
  - High Efficiency Gen.

- Transmission & Substations
  - Grid Planning
  - Digital Substation
  - Green Equipment

- Distribution
  - Dist. Planning
  - Advanced DMS
  - xEMS, V2G, AMI

- Convergence
  - AMS*, Drone
  - RE Connection
  - Flex Operation, Safety/Disaster Response

*CCUS: Carbon Capture, Utilization and Storage

* AMS: Asset Management System
Electric Vehicle Sales Forecast: 2023~2030

- EVs: 10,855 (2016) ➔ 389,855 (2022) ➔ 505,971 (Aug. 2023) ➔ 4.2M (2030) ➔ >15M (2040)
- 2x in 17 months (191k ➔ 389k), CAGR: >73% (5 years)

Source: MoLIT, MoE, KEPRI (LDT = 115,342)
Status of EV and Charging infrastructure

- Charging Landscape: Public Chargers
  - EVSEs: 240,695 (Public Fast: 25,548; Public Slow: 215,147 as of May 2023)
  - 18.9 EVs/DC Fast, 2.1 EVs/Public Slow, 7 kW/EV (*IEA, World Best!*)
    - KEPCO share: 10,852 (Fast: 5,072; Slow: 5,780) at 4,755 stations

Source: [https://evor.kr](https://evor.kr), [https://evc.kepco.co.kr](https://evc.kepco.co.kr) (KEPCO-Plug), [http://keco.or.kr](http://keco.or.kr), IEA EV Outlook
Balancing of Fluctuating Renewables with EV (V2G)

*VGI: Electric Vehicle-Grid Integration
EV Charging method

- AC/L2 Chargers of current deployment: Dumb supply of electricity and transaction function
  - Add Communication & control: Smart Charging (V1G) ➔ bi-directional power transfer (V2G)

**Dumb Charger (As-is)**
- Charge Starts
- Charging Stop
- Stop Charging At 100%
- Unplug Depart

**Smart Charge (V1G)**
- Stop as Needed

**Bi-directional (V2G)**
- Discharge At peak
- Charging Stop
V2G Method

- **(AC type)** On-board Charger (OBC) converts DC output of battery to AC 220V
  - EV (DC 800V) ➔ OBC (DC ↔ AC 220V) ➔ EVSE ➔ Distribution line (220V, 1-phase)

- **(DC type)** External EVSE converts the EV DC output of battery to AC
  - EV (DC 400~800V) ➔ EVSE (DC ↔ AC) ➔ Distribution line (380V, 3-phase)

Source: KEPCO
FYI: VGI - V2G for Grid Flexibility

V2G Approach: CHADEMO (DC) vs. CCS Type-1 (AC)

<table>
<thead>
<tr>
<th>Type</th>
<th>CHADEMO (DC)</th>
<th>CCS Type 1 (AC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Voltage</td>
<td>DC 350 ~ 500 V</td>
<td>AC 220~240 V</td>
</tr>
<tr>
<td>Power</td>
<td>3.3 ~ 30 kW (3-Phase)</td>
<td>3.3 ~ 11 kW (1-Phase)</td>
</tr>
<tr>
<td>Power conversion</td>
<td>EVSE</td>
<td>OBC</td>
</tr>
<tr>
<td>Cost (6.6 kW)</td>
<td>&gt; €5,991</td>
<td>&lt; $1000 (~$500)</td>
</tr>
<tr>
<td>EVSE Mfgs.</td>
<td>ABB, Delta, Denso, Nichicon, Fermata</td>
<td>ULVAC, etc.</td>
</tr>
<tr>
<td>EV OEMs</td>
<td>Nissan, Mitsubishi, Toyota,</td>
<td>Hyundai, KIA, Genesis, Audi, BMW,</td>
</tr>
<tr>
<td></td>
<td>Honda, Peugeot</td>
<td>Mercedes-Benz, Volkswagen, Ford, GM,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peugeot, Porsche, Polestar</td>
</tr>
<tr>
<td>Countries</td>
<td>Japan, EU, NA</td>
<td>Korea, NA, EU (type 2)</td>
</tr>
</tbody>
</table>

*OBC – Onboard Charger
### FYI: VGI - V2G for Grid Flexibility

#### Economics of Flexibility Resources (FYI)

<table>
<thead>
<tr>
<th>Category</th>
<th>Pumped Hydro</th>
<th>BESS (Li)</th>
<th>VGI (V2G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Capacity</td>
<td>200~400 MW</td>
<td>0.1~4 MW</td>
<td>7~10 kW</td>
</tr>
<tr>
<td>Geo. Location</td>
<td>☺ ☺ ☺</td>
<td>☺</td>
<td>☺ ☺</td>
</tr>
<tr>
<td>Occupied Area (m²/MW)</td>
<td>1,109</td>
<td>25</td>
<td>1,785 (Parking lot for 100)</td>
</tr>
<tr>
<td>Environmental</td>
<td>☺ ☺</td>
<td>☺</td>
<td>☺ ☺</td>
</tr>
<tr>
<td>Construction Time</td>
<td>&gt;7 years</td>
<td>&gt;6 Mo.</td>
<td>&lt;1 Mo.</td>
</tr>
<tr>
<td>Const. Cost* (1 GW) (billion KRW)</td>
<td>934 (~7-hr)</td>
<td>870 (1-hr)</td>
<td>130 (~6-hr)</td>
</tr>
<tr>
<td>T&amp;D Class</td>
<td>345kV</td>
<td>22.9kV / 154 kV</td>
<td>220V, 380V</td>
</tr>
<tr>
<td>Ramp rate</td>
<td>100~200 MW/min</td>
<td>&gt;MW/ms</td>
<td>~ kW/sec. (per EV)</td>
</tr>
<tr>
<td>RT Efficiency</td>
<td>72~81%</td>
<td>&gt;81%</td>
<td>&gt;85%</td>
</tr>
<tr>
<td>Source</td>
<td>YECEHON P.H.</td>
<td>KEPCO</td>
<td>KEPCO</td>
</tr>
</tbody>
</table>

* Excluding T&D and LNG terminal investment, US$1 ~ KRW 1,300
KEPCO VGI - V2G system

- Driver’s Charging Needs: Departure time & Charge Level (SoC, %) ➔ Charging Schedule (ToU optimized)
- Power System Needs: DR or VPP power needs ➔ Select Right Charging Session & Reschedule

V2G Mgt. Sys. (Forecast, Control, Monetize) ➔ V2G EVSE (Comm., Metering) ➔ V2G EV & Driver (Departure time, Target SoC)

ISO / DSO / DR / VPP
EVCI Service Platform
V2G Control System

GRID
KEPCO 3.0

Driver's Charging Needs: Departure time & Charge Level (SoC, %)
➔ Charging Schedule (ToU optimized)

Power System Needs: DR or VPP power needs
➔ Select Right Charging Session & Reschedule

Source: KEPCO, Hyundai Motor, ULVAC
The KEPCO V2G Project

- V2G Charge control performance for multiple EVs
  - Multi-channel power analyzer with real-time recording
  - Simultaneous control of many EV’s Charge/Discharge/Wait by Scheduling
  - Response time of aggregated EVSEs: < 20 sec.

Source: KEPRI
V2G demonstration for fleet and personal IONIQ5 owners

- **Period:** November 2021 ~ August 2023 (12+ months)
- **EV:** Hyundai IONIQ 5, >100 units (V2G Firmware Modification, August 2021~)
- **EVSE:** ULVAC AC V2G EVSE, 100 Units (Charge 7 kW / Discharge 5 kW, AC 220V)
- **Participants:** Private users (50), Participating organizations (30), KEPCO Fleet (10), SK Rental car (12)
- **V2G MS:** K-VGI System (KEPCO 3.0 & ISO15118-20 draft protocol)

Source: KEPRI, Hyundai Motor, ULVAC
The KEPCO V2G Project

- Studies of battery life effect of V2G and V1G (KATECH, KEPRI)
  - Charge-Discharge cycles: >1,300  (Equivalent to >350,000 km of Driving)
  - Difference: < 2%

Source: KEPRI, KATECH
Future Collaboration

- EV infrastructures and V2G pilot program for EV fleets
  - Charging infrastructure planning and development
  - V2G pilot program design, deployment and support
  - Charging infrastructure Specification and Standardization
  - R&D program for Grid Flexibility, Distribution Management, AMI, xEMS

Source: Hyundai, KIA, KEPCO
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