WORLD BANK GROUP | KOREA GREEN GROWTH TRUST FUND | Ministry of Finance and Economy | SEJONG CITY

KGID 2026 SEJONG

Global Energy & Solution Leader

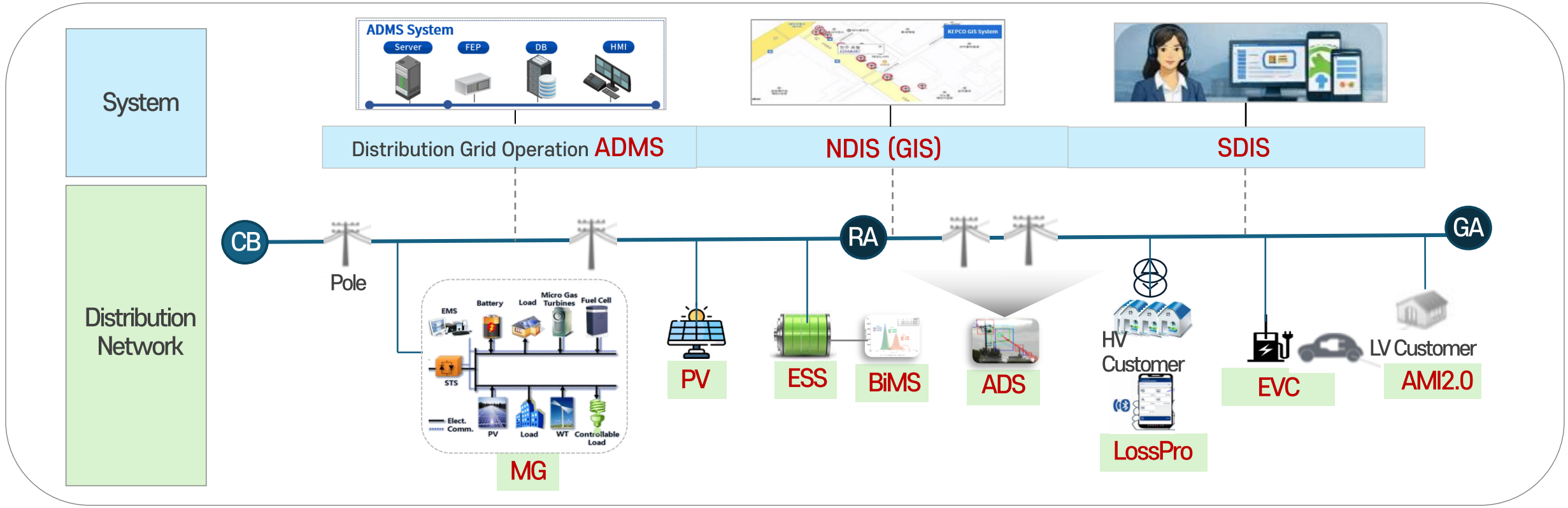
Digitalization in Power Grid

KEPCO

Global Business Department

Energy Solution Team

Digitalization in Power Grid



ADMS

- DMS
- DERM
- OMS
- FLISR
- SCADA
- Protection Coordination

MG

- ESS
- PV, Fuel Cell
- PCS, EMS
- Grid/Off Grid

NDIS

- Geo-Enabled Grid
- Spatial Intelligence Asset Mapping
- Design
- Construction
- O&M

BiMS

- ESS Battery diagnostics (SoC/SoH)
- Degraded Cell Detection
- Life Prediction

ADS

- AI diagnosis of facilities
- Camera & Sensor on Vehicle
- GIS

LossPro

- Non-Technical Loss Reduction
- [Step1] Metering Error diagnosis using AMI Data
- analysis
- [Step 2] Reference Meter

AMI 2.0

- Standard S/W
- Value-added Service
- IoT PLC
- Enhanced Security

SDIS

- Tariff Management
- Customer Service
- Distribution GIS

Contents

World first, only, safe, fast, effective, economical Loss Reductio

1

LossPro

AI-based smart metering power loss reduction solution

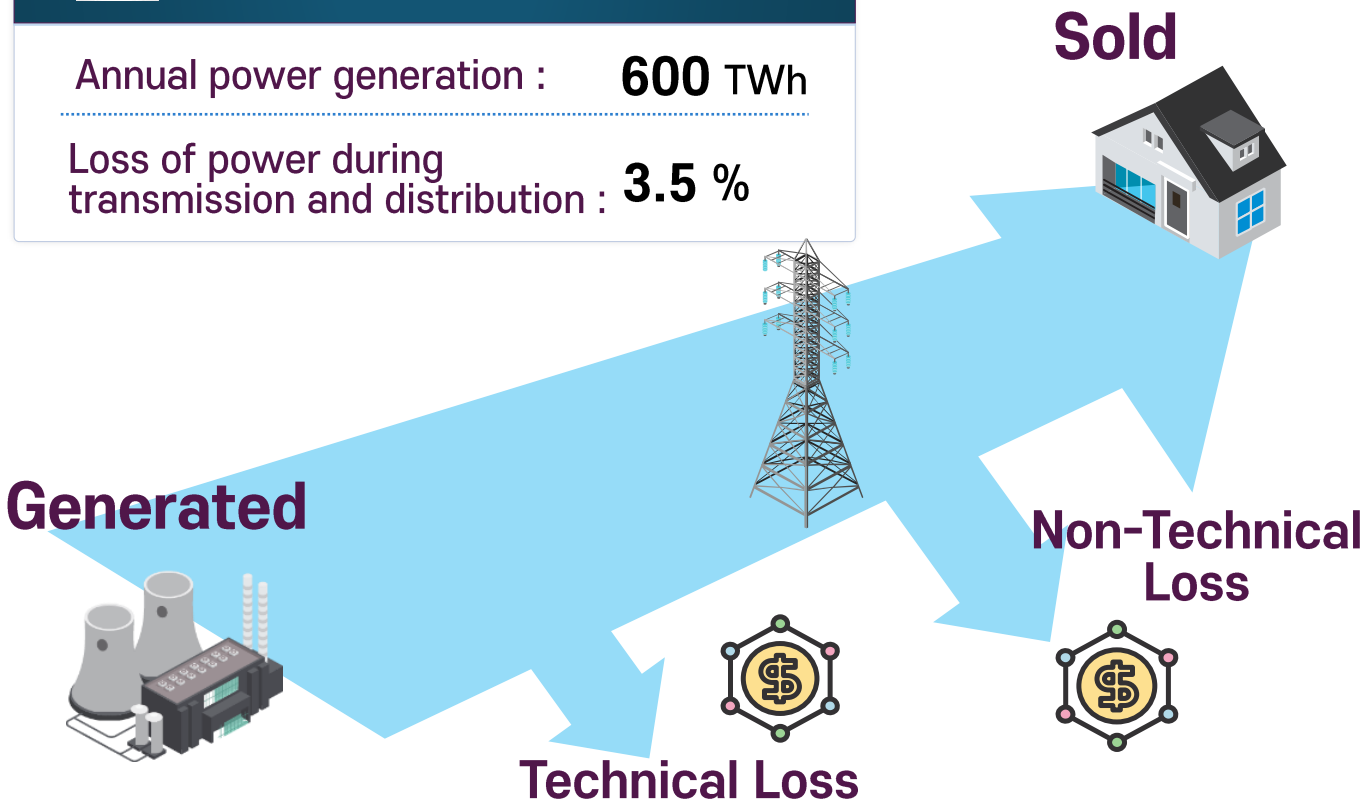
Power Loss

KEPCO's efforts to reduce power loss

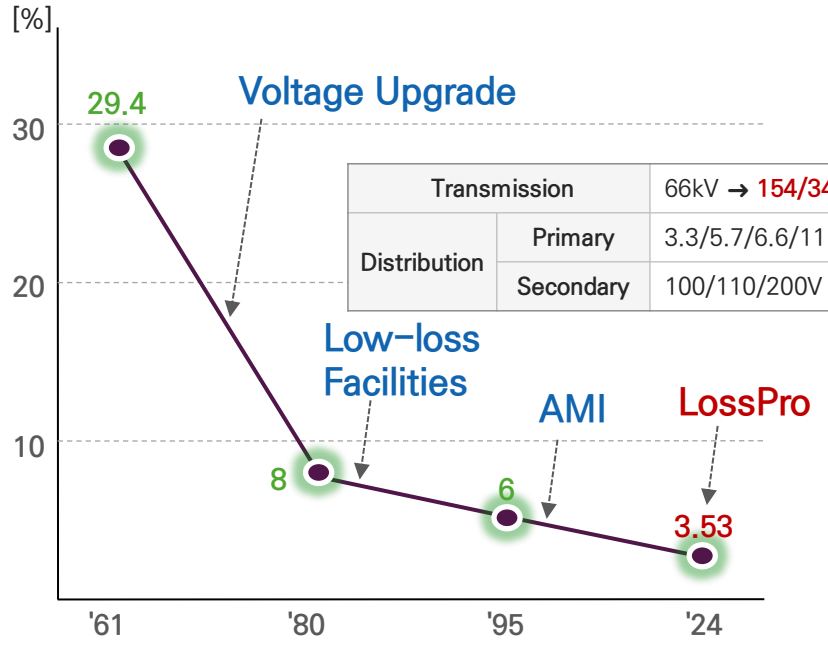
KOREA

Annual power generation : **600** TWh

Loss of power during transmission and distribution : **3.5** %



T&D Loss Rate



Transmission		66kV → 154/345/765kV
Distribution	Primary	3.3/5.7/6.6/11.4kV → 22.9kV
	Secondary	100/110/200V → 220/380V

Reducing just 1%p of annual Power loss(6TWh)

= 1 Thermal plant's Generation = USD 70mil saved per year

Power Loss

KEPCO's efforts to reduce power loss

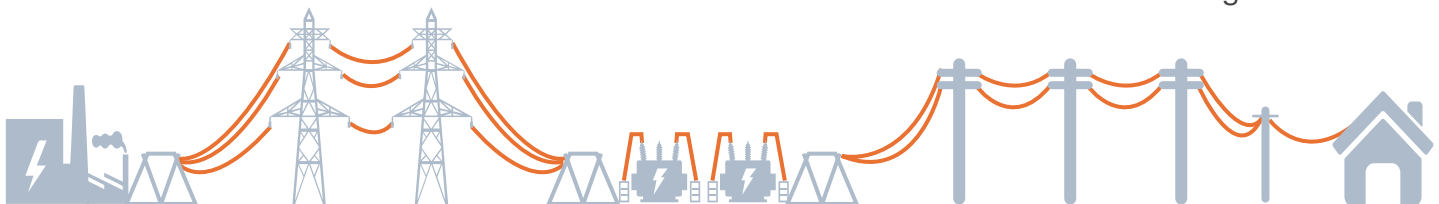
	Technical Loss	Non-technical Losses
Cause	Heat Dissipation (P loss= $3I^2RLcos\theta$)	Pilferage / Metering Error
Solution	Voltage Upgrade (22/14/6.6/3.3⇒22.9[kV])	Incentive & Penalty by government
	DAS (Distribution Automation System)	Fix Watt Hour Meter & Wiring Error
	Power Factor Improvements (PF based tariff, Time-of-Use tariff)	Dedicated Team for Pilferage detection
	Conductor Upgrade Highly efficient equipment	Fix CT malfunctions & wrong Multiples
	3 Phase conversion Work	
	Improving phase balancing	
	Phase load balancing	
	Use of Amorphous Core TR	

Costly & long-term

Practically Impossible
And needs national-level Economic growth

LossPro

The most cost-effective
Tackling the metering error is the most effective solution

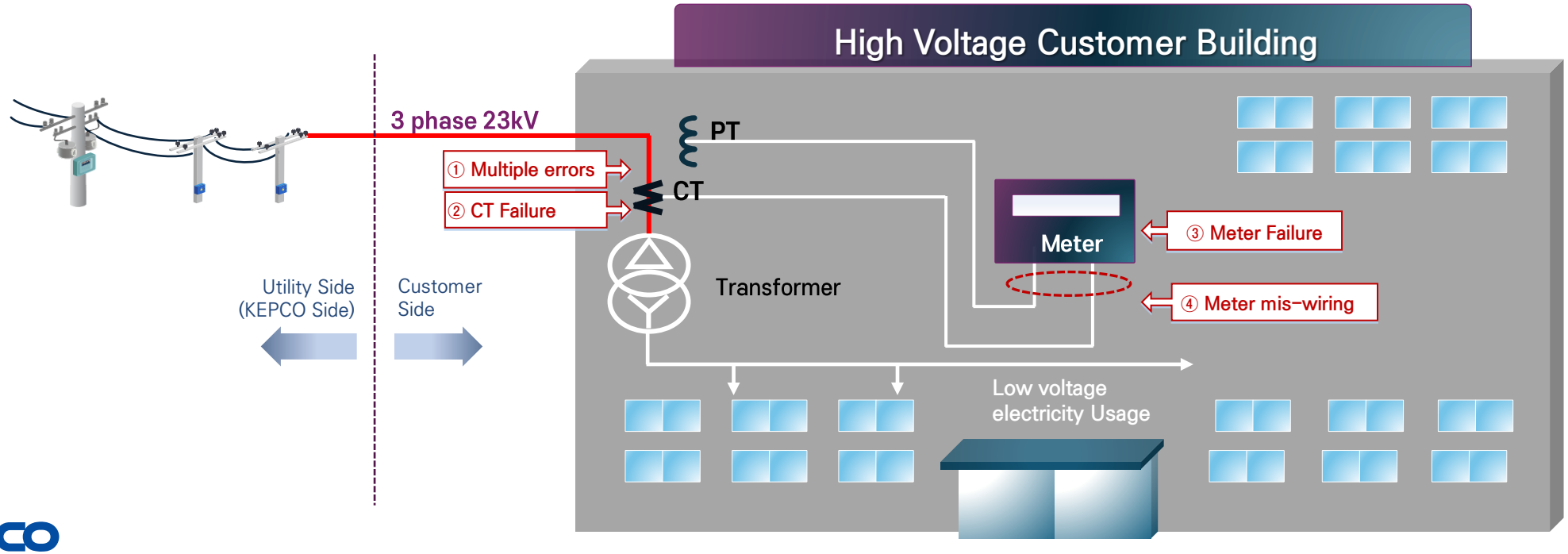


Why Metering Error Management Matters Most

✔ In Korea, only 1% of customers (240,000 high-voltage customers) consume approximately 70% of total electricity

☞ **Therefore, managing metering errors of high-voltage customers delivers the fastest and most cost-effective loss reduction**

Common Metering Error Types	CT Fault, PT Fault, Meter Accuracy, CT Ratio, PT Ratio, 3 Phase Mis-wiring



Metering Error

Metering Error Diagnosis Process

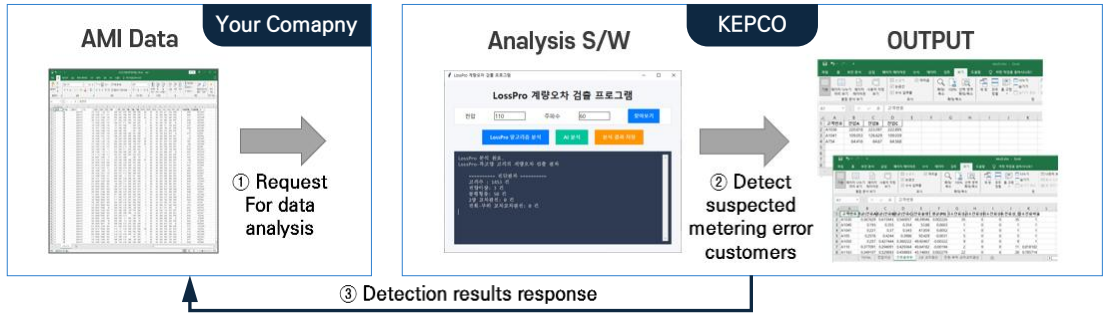
Step 1 AI Engine Analysis (Algorithm Analysis)

Solution 1 **AMI Data Analysis** (AI & Algorithm Analysis)

- Analyze AMI data to identify suspected metering error customers(less than 1%)

Detectable Issues

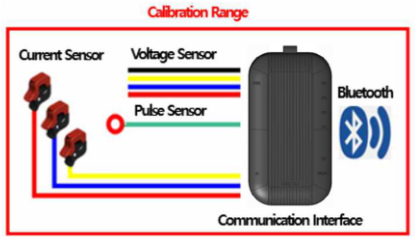
① CT Fault ② PT Fault ③ 3Phase Meter Mis-wiring
④ Phase loss ⑤ Abnormal voltage

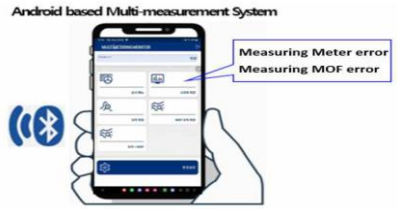


Step 2 Reference Meter

Solution 2

- Testing CT/PT under live conditions is possible without the need for power outage
- Can be applied to all customers even in the absence of AMI data from Solution1





Overseas Field Cases (July 29, 2025)

Method

On-site inspection of suspicious customers and diagnosis

❶ Utility provided **1,770 AMI** data samples
❷ **23 suspicious customers** identified by AI engine
❸ **3 customers** selected for priority on-site diagnosis
❹ **100%** meter faults **detected**

Results **100% Meter Faults Detected (Proven with High Accuracy)**

Miswiring

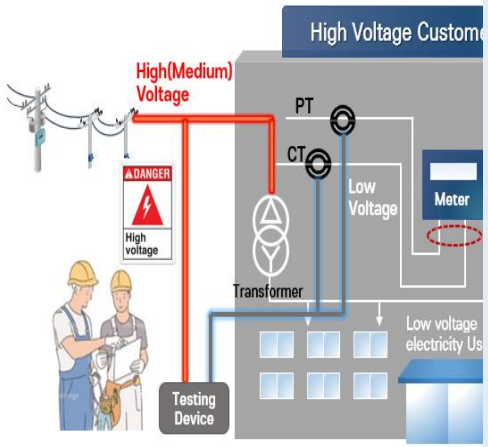
Abnormal Voltage

	R상	S상	T상
전압	58.34184	58.59898	64.40066
전류	3.0078	3.15074	3.1067
전압/전류 위상각	25.96289	26.22656	36.08789

CT Defect

As-Is (Current Method)

- High-risk diagnosis using high/medium voltage lines
- Long installation and testing time (30 minutes)
- Diagnosis possible only when load is above 30%
- Low accuracy due to time-delay relay method



(Diagnosis Method) Now banned in Korea !!

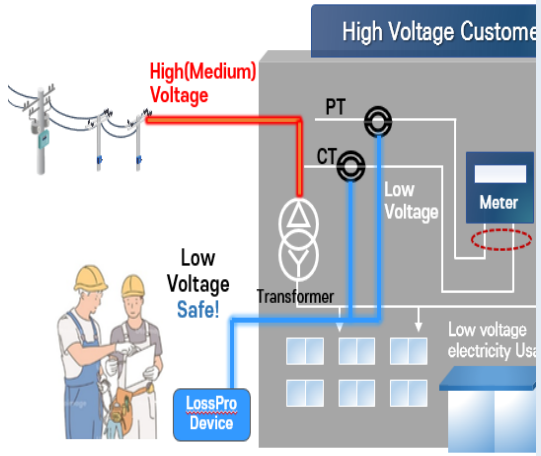
① Primary current measurement

② Secondary current measurement

③ Comparison of primary and secondary

To-Be (LossPro CT Fault Detector)

- Safe diagnosis at low voltage level
- Diagnosis available after clamp installation (within 10 seconds)
- CT abnormality detection possible during live operation or power outage
- Real-time fault detection



(Diagnosis Method) Safe, Portable, Fast !!

CTFD(CT Fault detector)

① Connect low-voltage clamp

② Check abnormal status

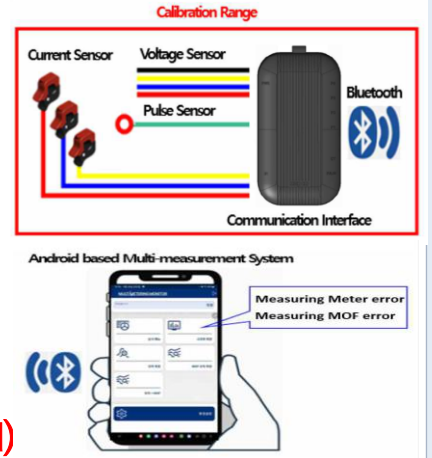
As-Is (Current Method)

- Active (Reactive) energy measurement
- Meter accuracy test
- Phase angle and harmonic measurement
- CT ratio measurement not
- Size: 210 × 150 × 95 mm
- Weight: 500 g
- Output: LCD display

VS

To-Be (LossPro Multi Reference Meter)

- Active (Reactive) energy measurement
- Meter accuracy test
- Phase angle and harmonic measurement
- CT ratio measurement (fault diagnosis supported)
- Size: 196 × 98 × 40 mm
- Weight: 200 g
- Output: Bluetooth (Android app based)



Detect all metering errors with a single measurement!!

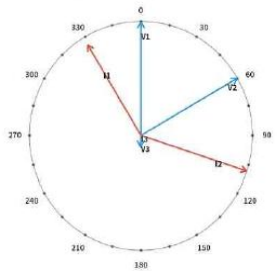
Existing Functions

- Active (Reactive) energy measurement
- Meter accuracy test
- Phase angle and harmonic measurement

Additional Functions of LossPro RM

① Simultaneous measurement of metering data and CT ratio

② Phase angle vector diagram generation



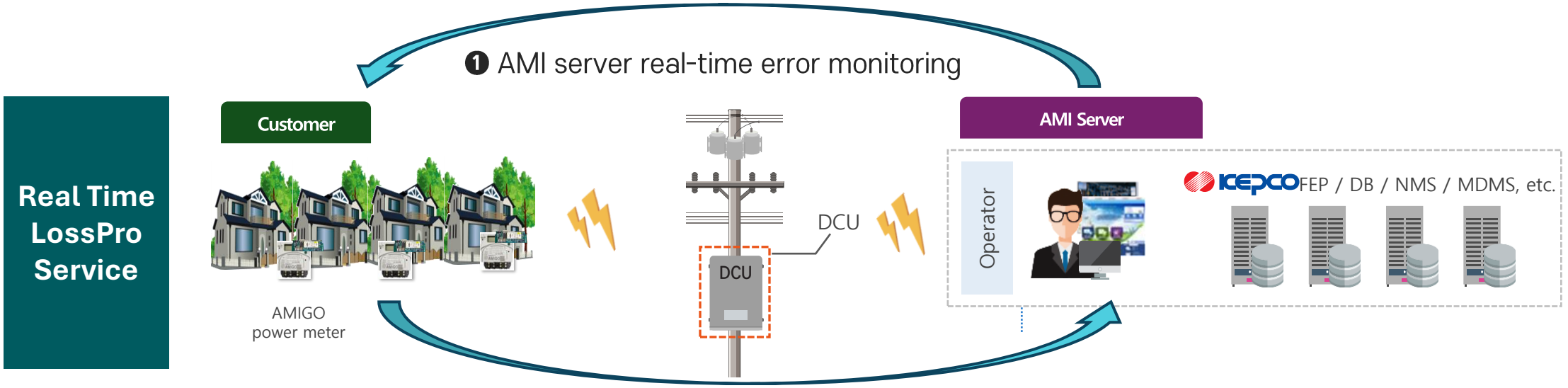
③ Automatic diagnostic report

④ Sensor installation applicable to all meter types

Real Time "LossPro" Service based on AMI 2.0

❶ AMI server : Metering error monitoring in real time

❷ KEPCO Amigo Meter : On-device metering error diagnosis and server alarming



World first manufacturer independent & power utility Driven AMI software

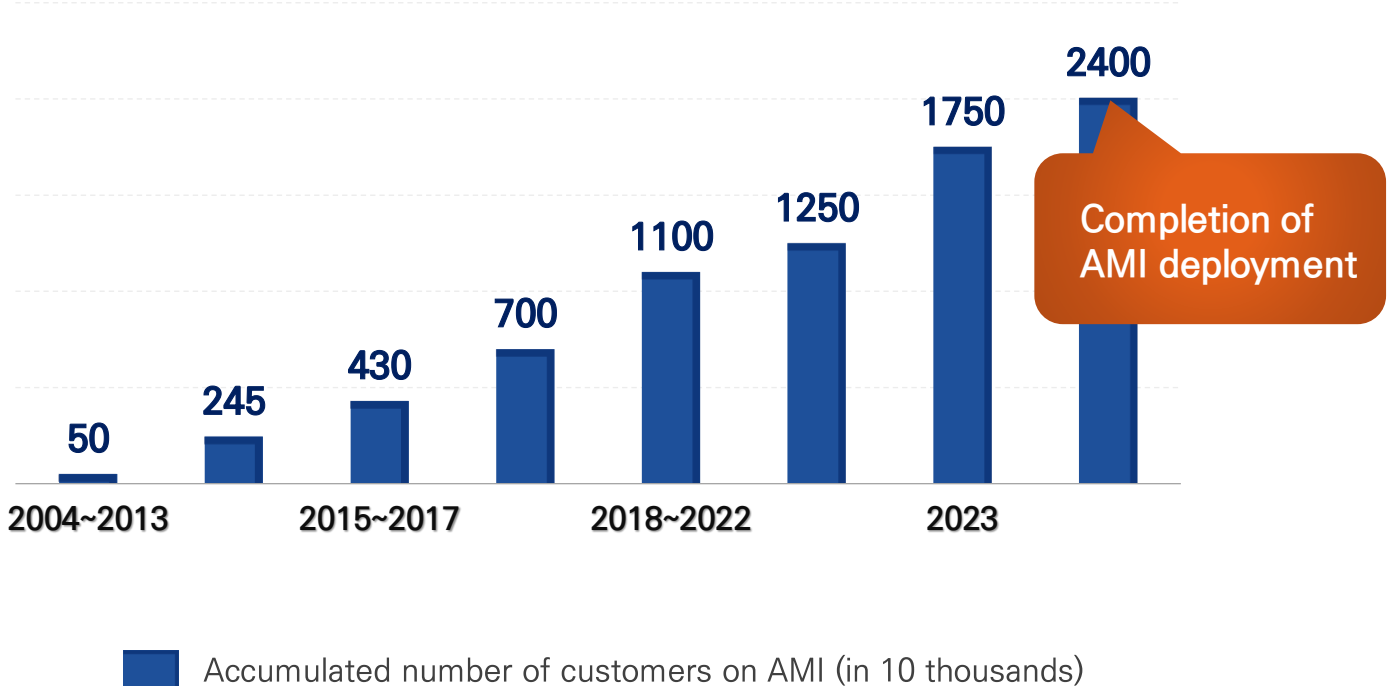
2

AMI 2.0

- Standard S/W
- Value added services
- Enhanced security
- IoT PLC

KEPCO's Implementation of AMI2.0

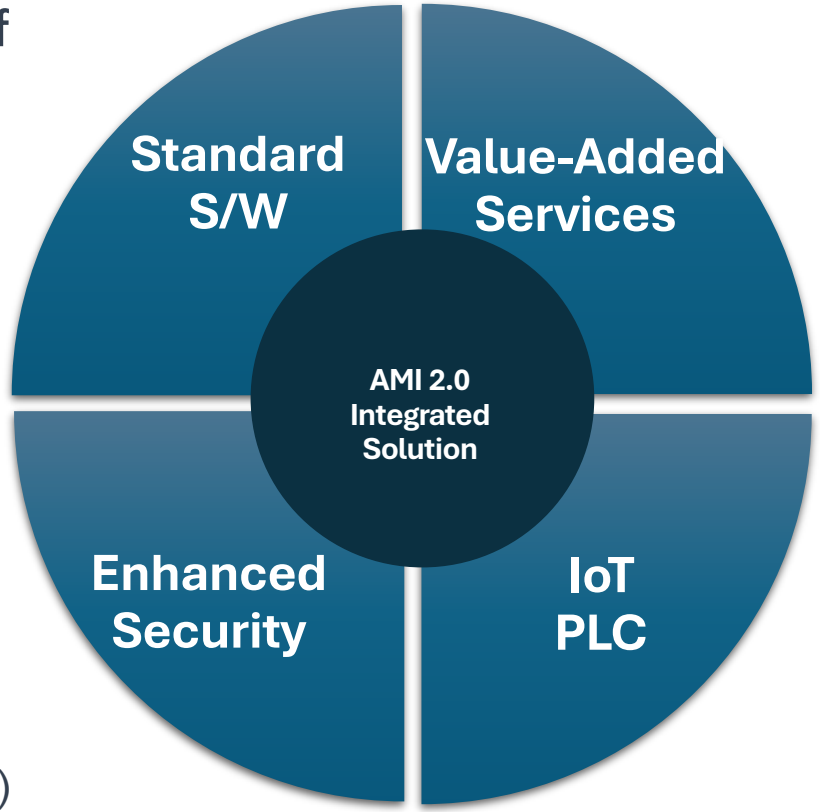
- KEPCO has completed nationwide AMI deployment, covering 24 million customers by 2025
- Proven performance and stability from the meters, to the servers, and to the end users' data access screens over the two decades of development, field application, and experiences



KEPCO AMI2.0 – Unique Features

KEPCO AMI is developed by the utility, for the utility, with cost-efficiency in mind

❶ Efficiency-driven software for power companies, independent of specific manufacturers
- Compatible with all manufacturers and versions
- Simplified upgrade process
- Reduces operational costs



❷ Development of various services using real-time monitoring data
- Renewable energy monitoring
- Power loss analysis
- Real-time operation management
- Power usage monitoring
- Outage management
- Distribution network monitoring
- LossPro Solution

❸ End-to End Security application
- Secure communication between Meter ↔ Modem, DCU ↔ Server
- Completed nationwide security application (certification, encryption)

❹ High-performance PLC with world-class reliability
- Enables high-speed, large-volume data transmission(compared to low-speed PLC)
- Simplifies and improves Smart Grid implementation

KEPCO AMI2.0 – Unique Features

Background and Necessity

- Various manufacturers and communication types make system compatibility and data integration difficult across local utilities

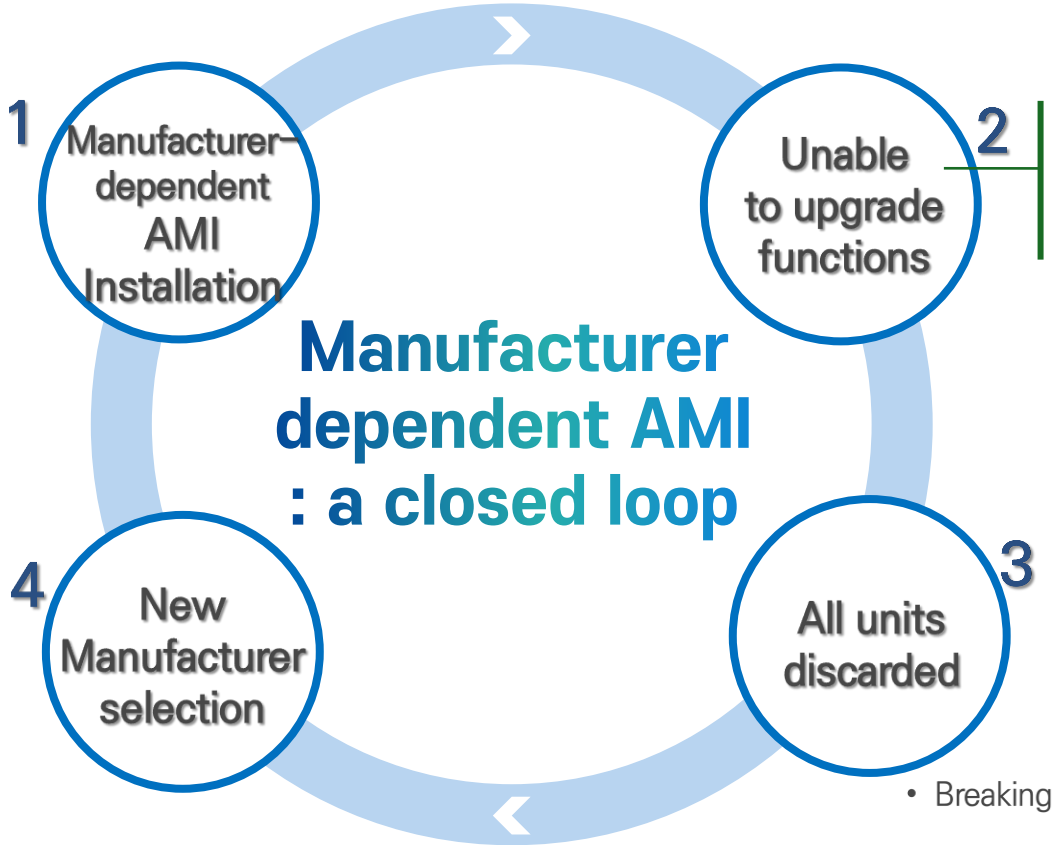
KEPCO's Solution

KEPCO's unified AMI solution connects all regional systems into one platform, enabling seamless data integration and maximizing operational efficiency

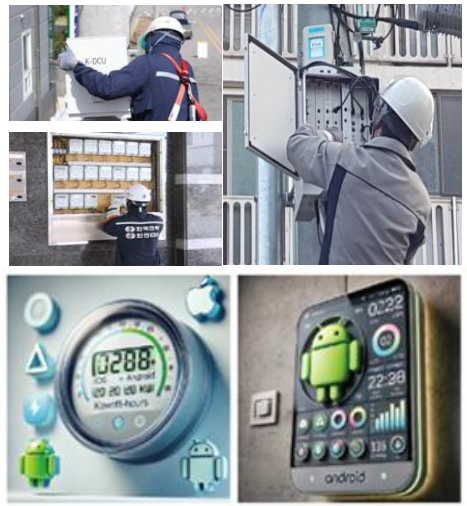
Over 50% of meter device recalls are caused by meter software issues

→ No recall needed when KEPCO's standard software is installed

→ Utilities can upgrade the software directly

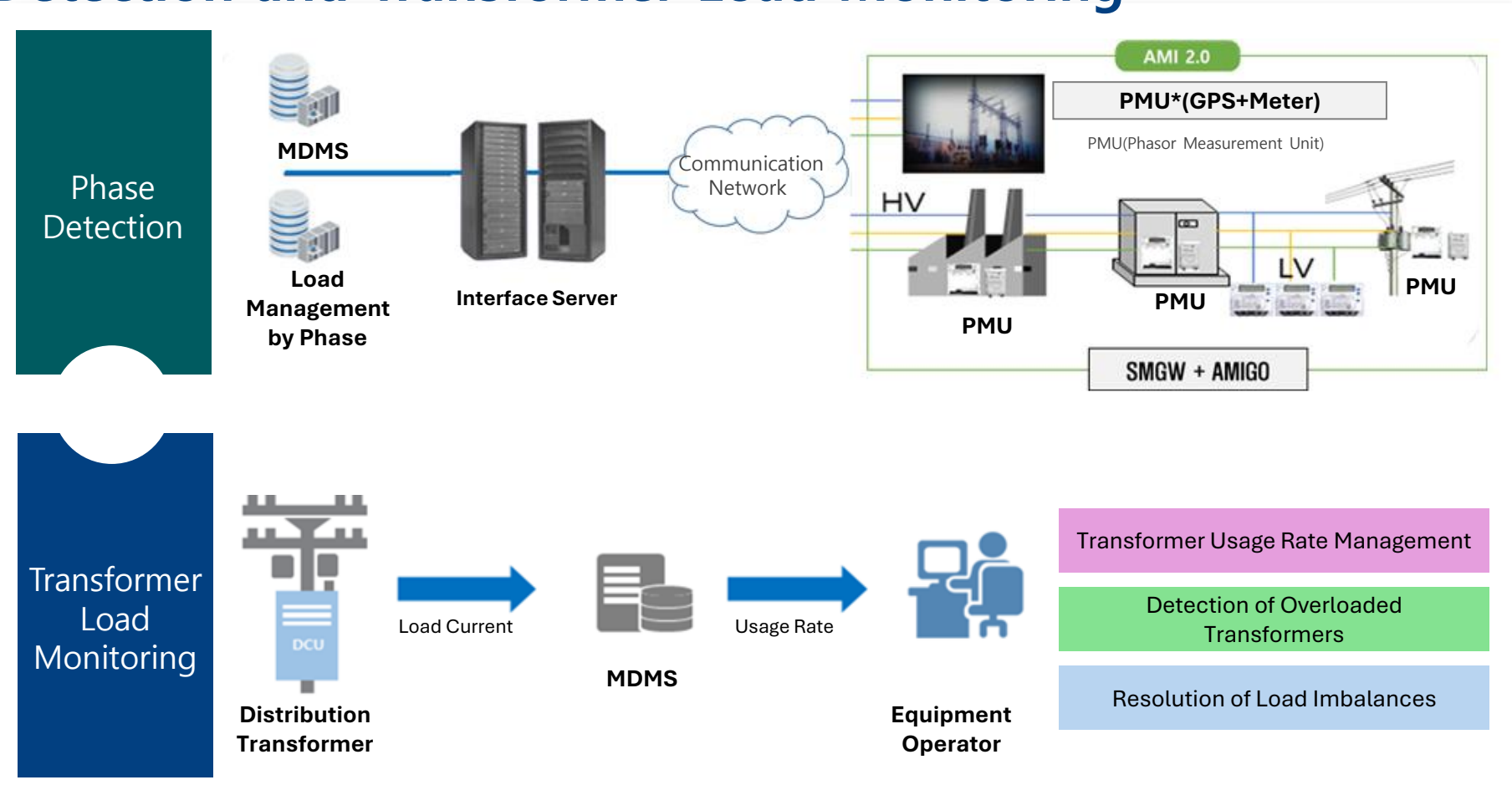


- Required functions (DER, LossPro, outage management)
  – Upgrade is not possible



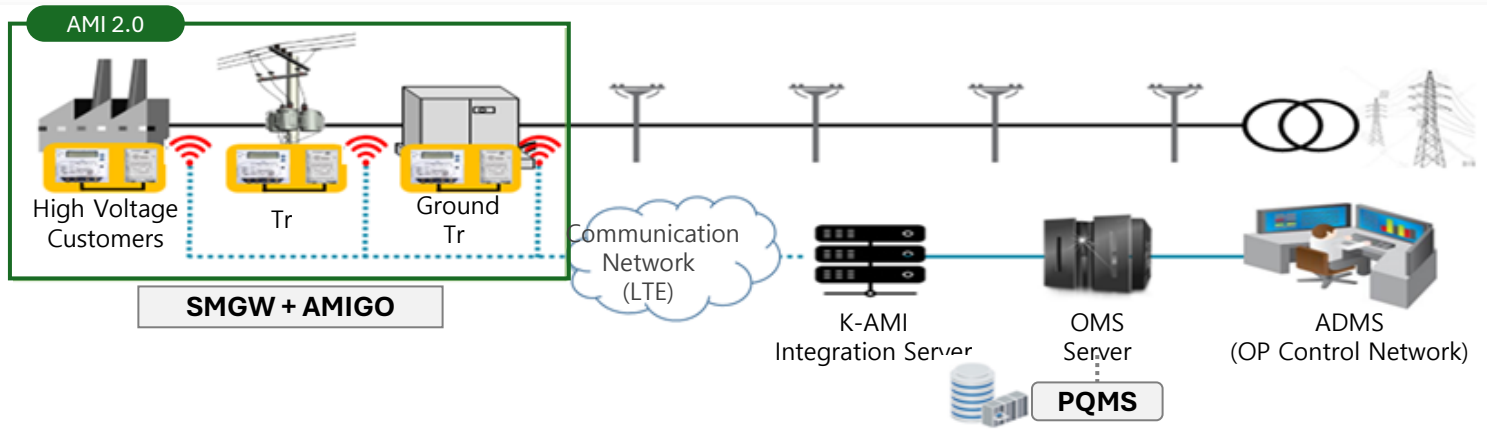
- Breaking Free from Manufacturer Dependency

❷ Various Services :
Detection and Transformer Load Monitoring

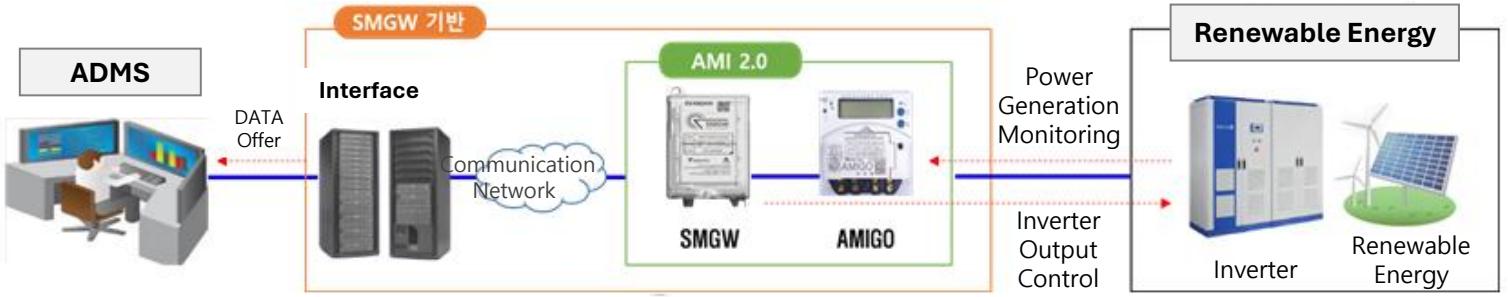


❷ Various Services :
Outage Monitoring and Renewable Energy Monitoring & Control

Outage Monitoring

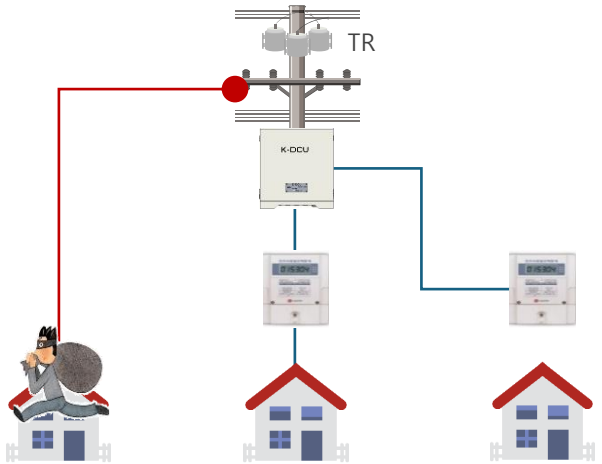


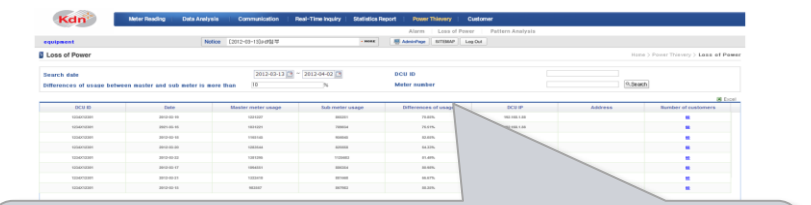
Renewable Energy Monitoring & Control



❷ Various Services :
Unauthorized Usage Monitoring via Line Status Detection

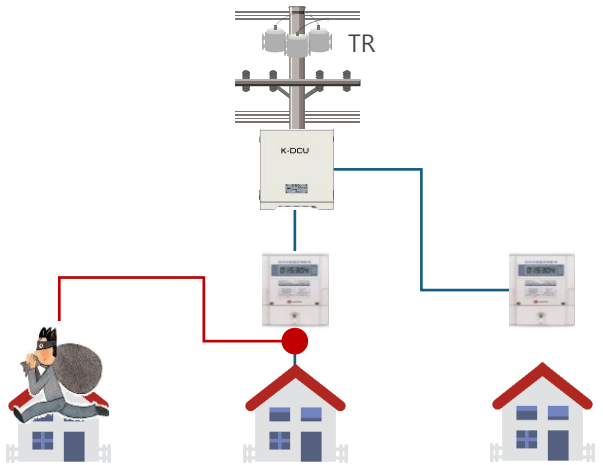
Analyzing power usage differences

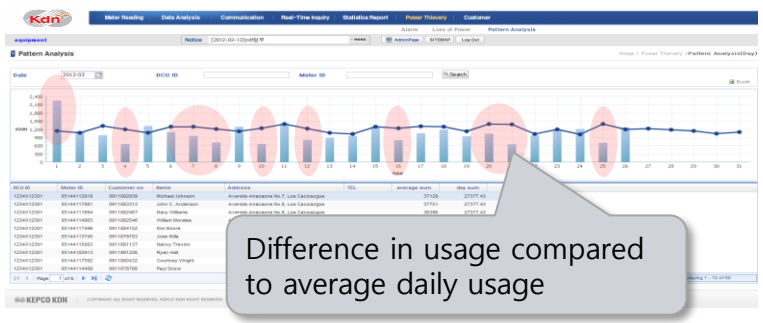




The loss ratio is calculated based on the difference between the usage of the master meter and the sum of usage of the meters belonging to the master meter.

Analyzing power usage patterns

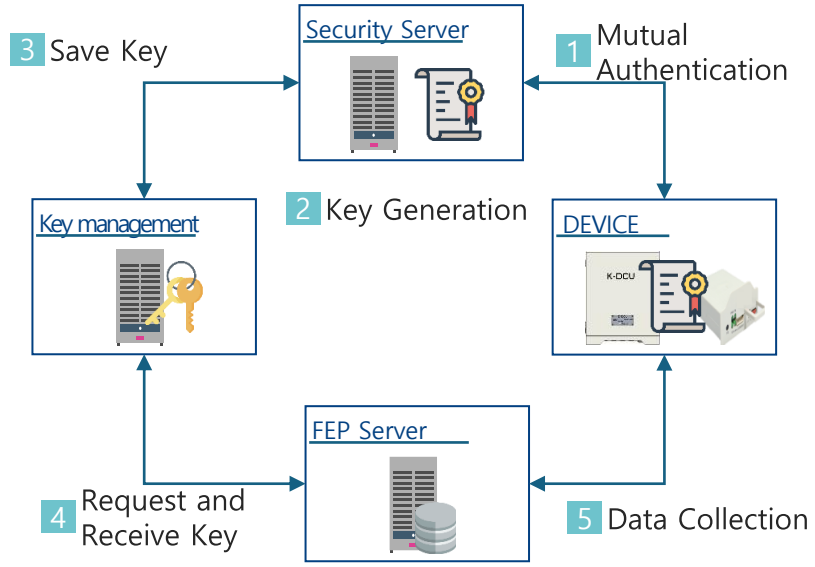




Difference in usage compared to average daily usage

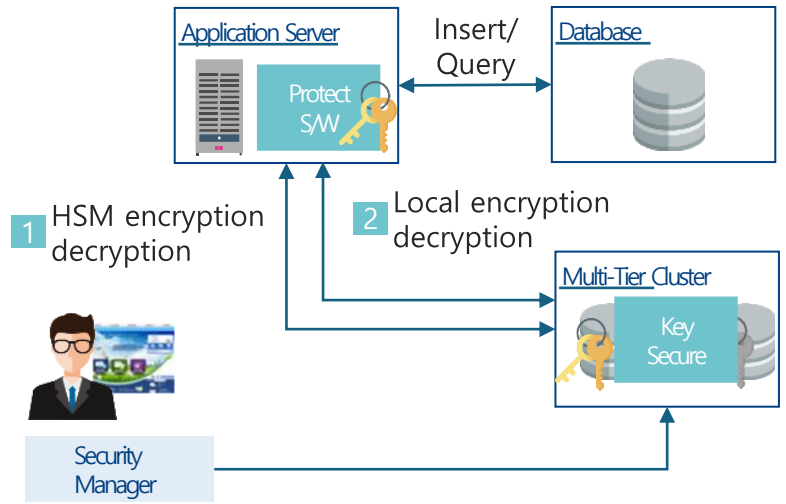
❸ Ensuring AMI security

Data transmission security



- Encryption of Device-FEP communication section
- KCMVP(Korean cryptographic module verification program)-based encryption function
- Safe storage of encryption keys for each device using a key management server

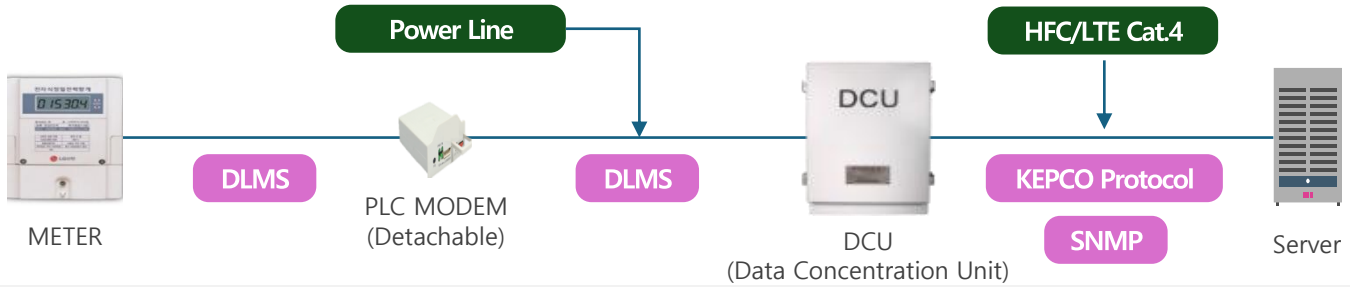
Database security



- Personal information and important information are encrypted and stored in the database
- Apply various encryption algorithms
- Provides redundancy configuration and automatic synchronization

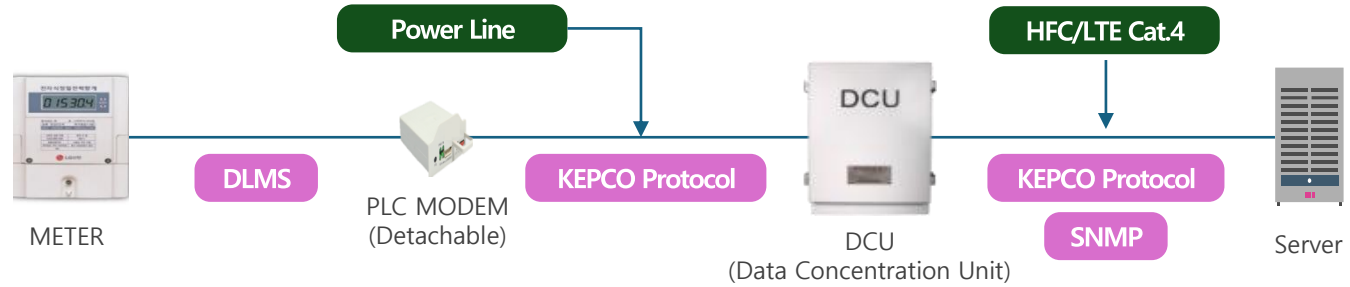
❹ The World's Fastest High-Speed IoT-PLC

Until 2020 (KS-PLC)



The PLC modem bypasses the data collected by DLMS from meter, collects it in the DCU and then transmits it to the server utilizing KEPCO protocol and SNMP
(Frequency Bandwidth: 4Mhz~23Mhz, Transmission Speed: 24Mbps, ISO/IEC 12139-1)

After 2021 (IoT-PLC)



The PLC modem converts the data collected by DLMS from meter into KEPCO Protocol and delivers it to the DCU and then to the server utilizing KEPCO protocol and SNMP
(Frequency Bandwidth: 9Khz~28Mhz, Transmission Speed: 15Mbps, Longer transmission distance, better noise resistance)

World first real-time precision battery diagnostics

3

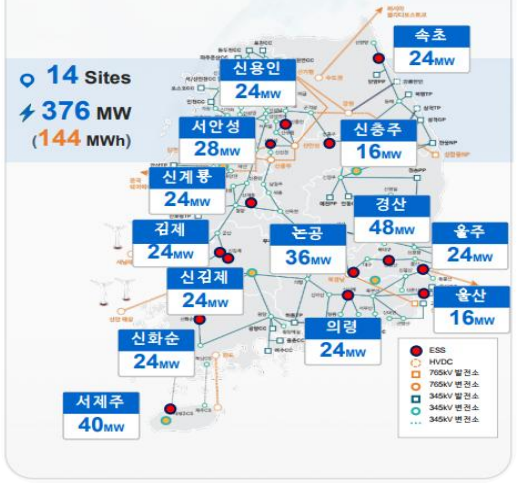
BiMS

Fire prevention and lifecycle management S/W through real-time precision ESS battery diagnostics

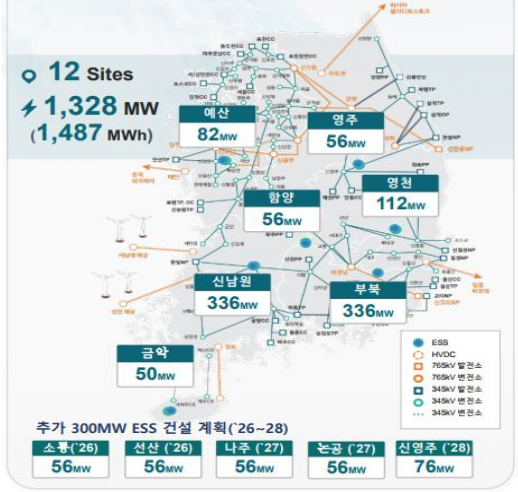
ESS Installation Status

2014 - 2017 → **Fire Incidents** → **2022 - 2028**

ESS for Frequency Regulation



ESS for Grid Stabilization



- From 2017 to 2019, a total of 26 ESS explosion incidents occurred in South Korea, with a cumulative capacity loss of 209,382kWh
- Main causes include cell degradation and thermal runaway, often triggered by overcharging
- To ensure safety, the government has established a comprehensive battery management plan at the national level

KEPCO's Extensive BESS Operation Experience

✓ In 2014, KEPCO became the first utility worldwide to install BESS for frequency regulation

Recognized Needs from the Operator's Perspective

✓ As an **owner and operator**, KEPCO needed independent and transparent analysis.

Objectives included accident prevention, optimal operation, battery life management, maximizing profitability

KEPCO's Answer : BiMS

✓ Developed by KEPCO Research Institute (KEPRI) through a decade of R&D
✓ Proven effectiveness, now mandated for all new BESS installation

As of 2026	1,052 MW across 8 sites
Target for 2028	1,704 MW across 26 sites

Maximizing BESS Value with KEPCO BiMS

KEPCO BiMS drives higher BESS ROI by enhancing:

Increased BESS ROI

Reliability

- Independent validation leveraging KEPCO's extensive BESS operation data
- **Early anomaly & risk detection** beyond conventional BMS capabilities

Efficiency

- **Reduced downtime** enabled by predictive analytics
- **Optimized dispatch** & load balancing for utility-scale BESS

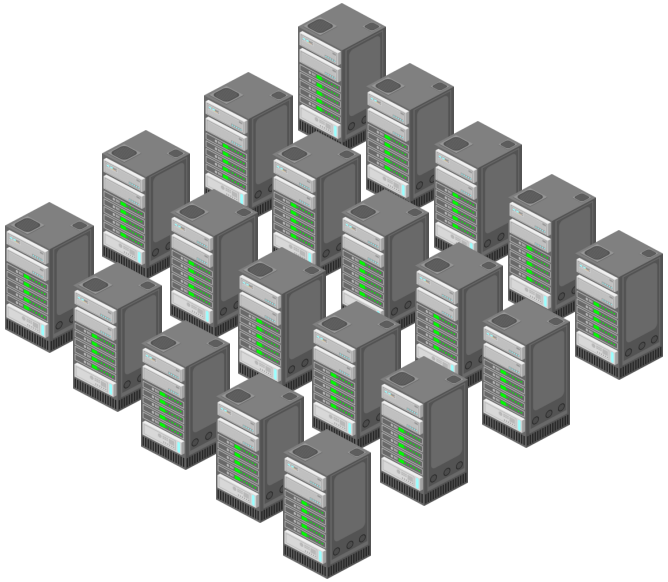
Sustainability

- **Battery degradation** monitoring & recycling insights
- Preserving **long-term asset value** through KEPCO's proprietary models

BMS vs BiMS : Fragmented vs Integrated Monitoring

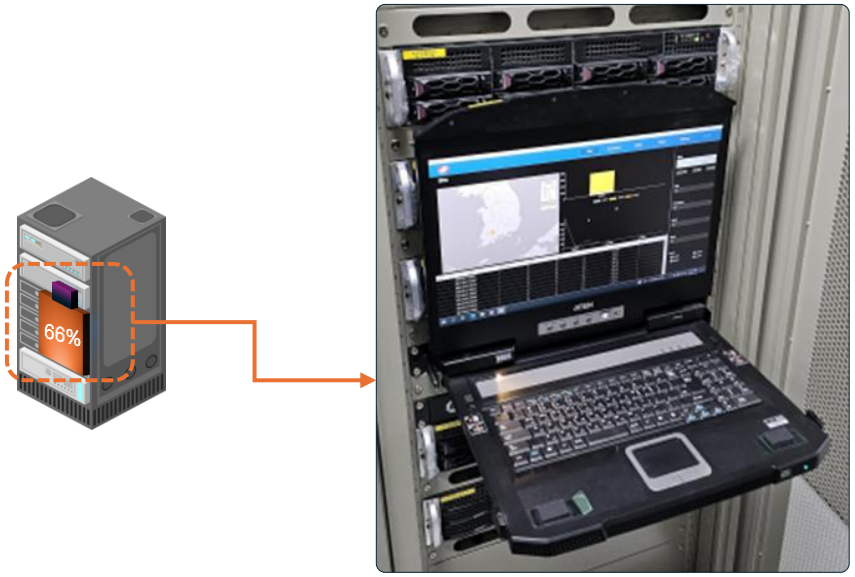
BMS

- ✓ Installed per 2MW PCS, requiring inefficient manual monitoring



BiMS

- ✓ Provides an integrated platform, enabling efficient large-scale ESS monitoring with a single system



How BiMS Enhances ESS Safety and Reliability

Real-Time Monitoring

- ☑ High-resolution, rack-level monitoring every second; detects risks such as thermal events and degradation

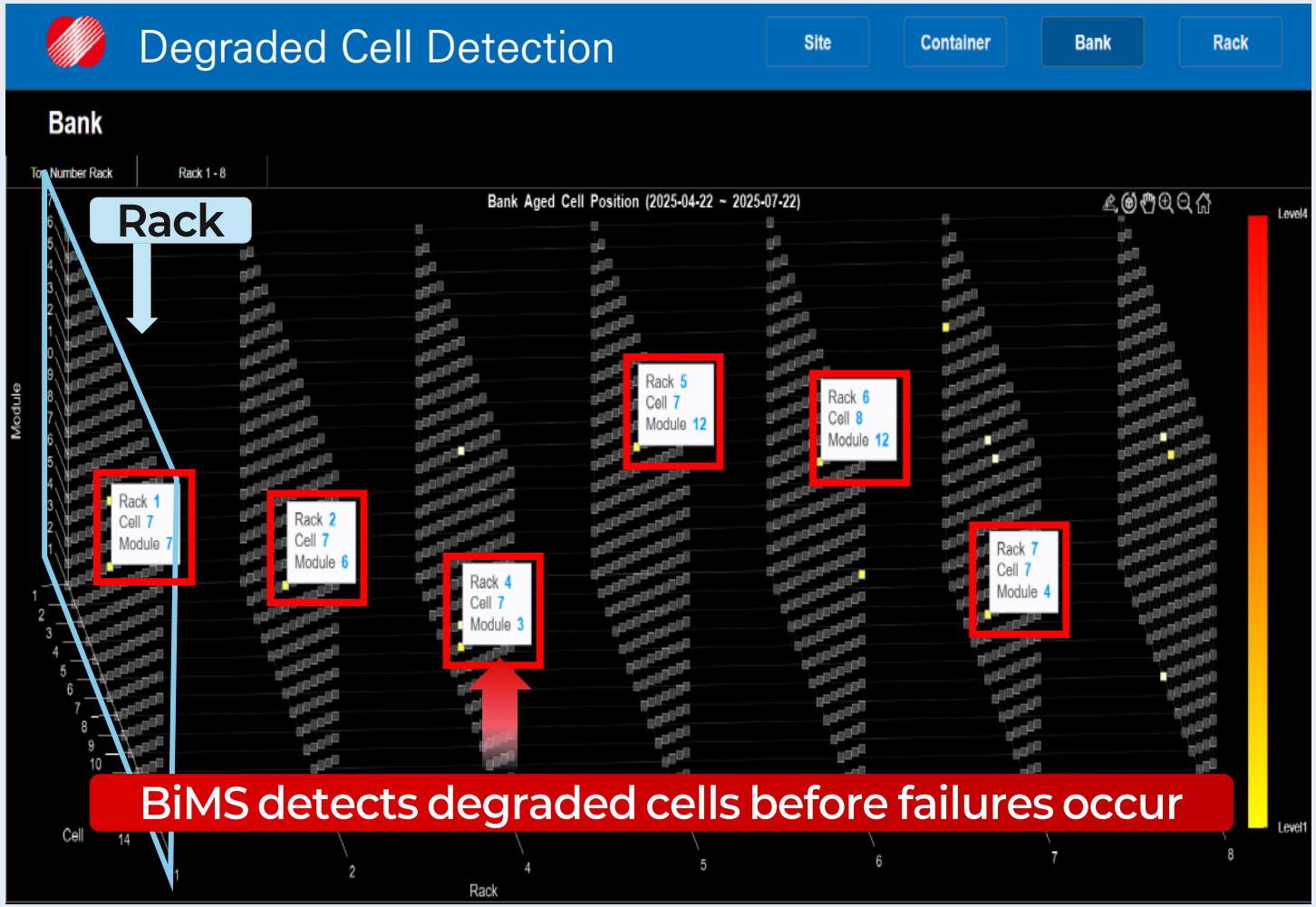
Degraded Cell Detection

- ☑ Identifying the location of degraded cells by diagnosing anomalies at the individual cell level

Battery Life Prediction

- ☑ SOH-based algorithm with dual SOH_Power & Capacity analysis for precise lifecycle insights

Real-time monitoring in ESS control room



Case Study : SOC Deviations Detected & Resolved by BiMS

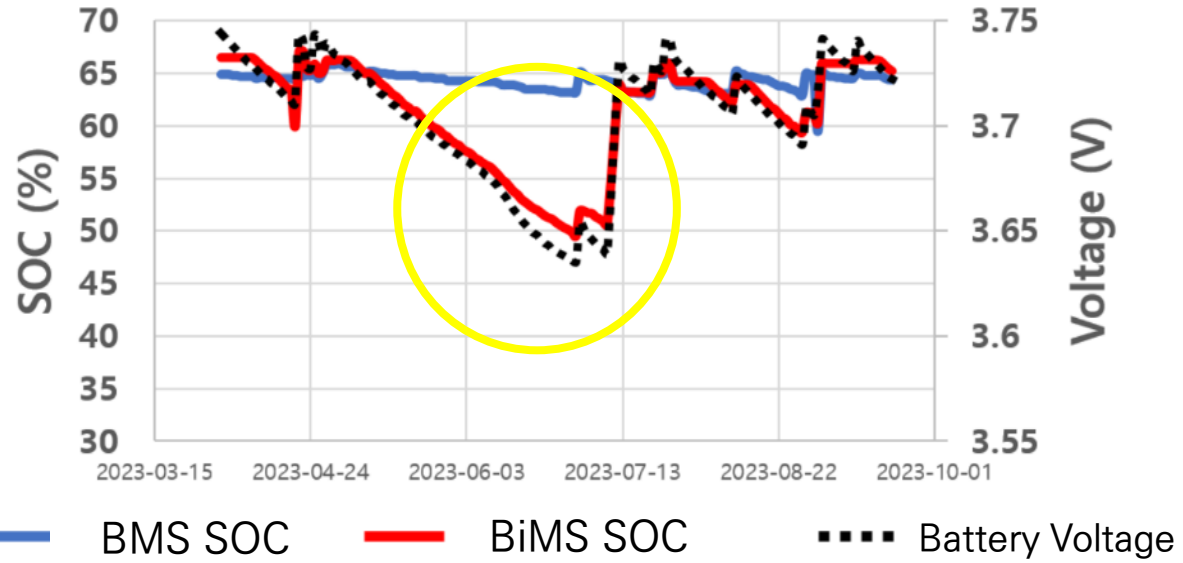
NCM

BiMS detected what BMS missed.

- After BiMS installation, abnormal SOC behavior in the BMS was detected.
  - SOC was expected to remain at 65%, but miscalculation caused discharge down to 50%.
- KEPCO reported the issue, and the manufacturer corrected the algorithm.

SOC (%)	Voltage (V)
70	3.76
60	3.7
50	3.64
40	3.61

Battery SOC–Voltage Relationship

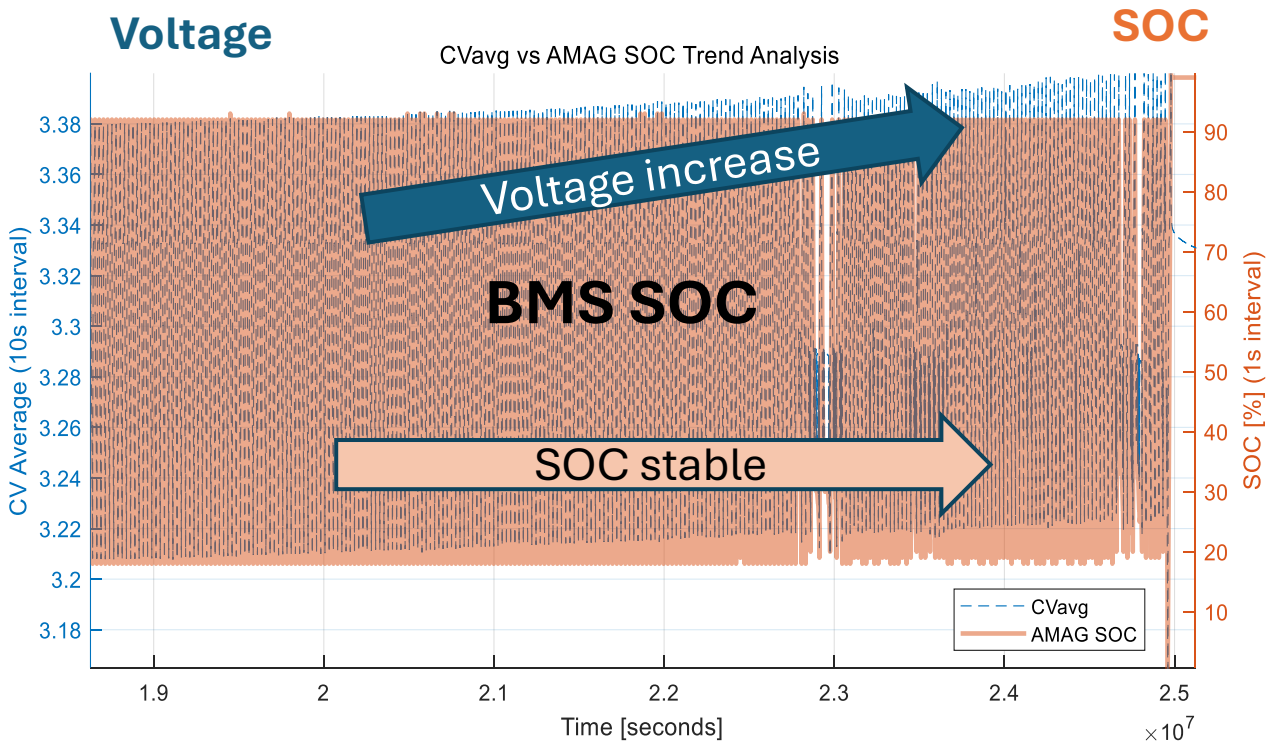


Estimated SOC Results (Geumak ESS)

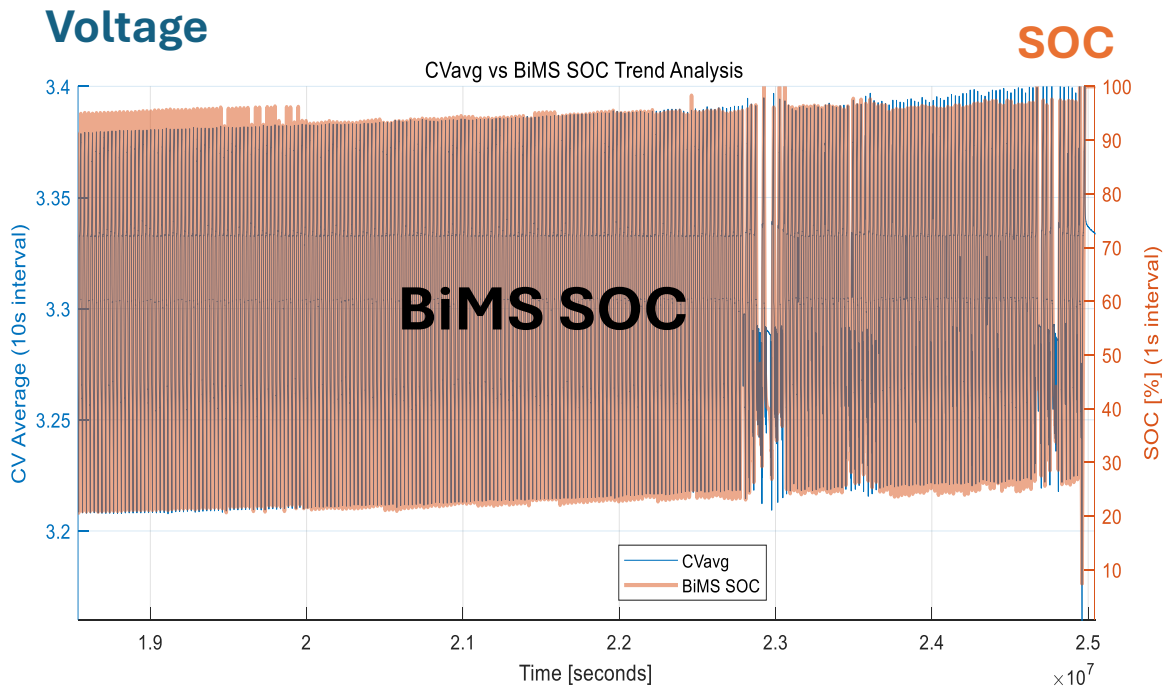
Case Study : Superior Accuracy of BiMS in SOC Analysis

LFP

BiMS detected what BMS missed.



BMS SOC Accuracy analysis result



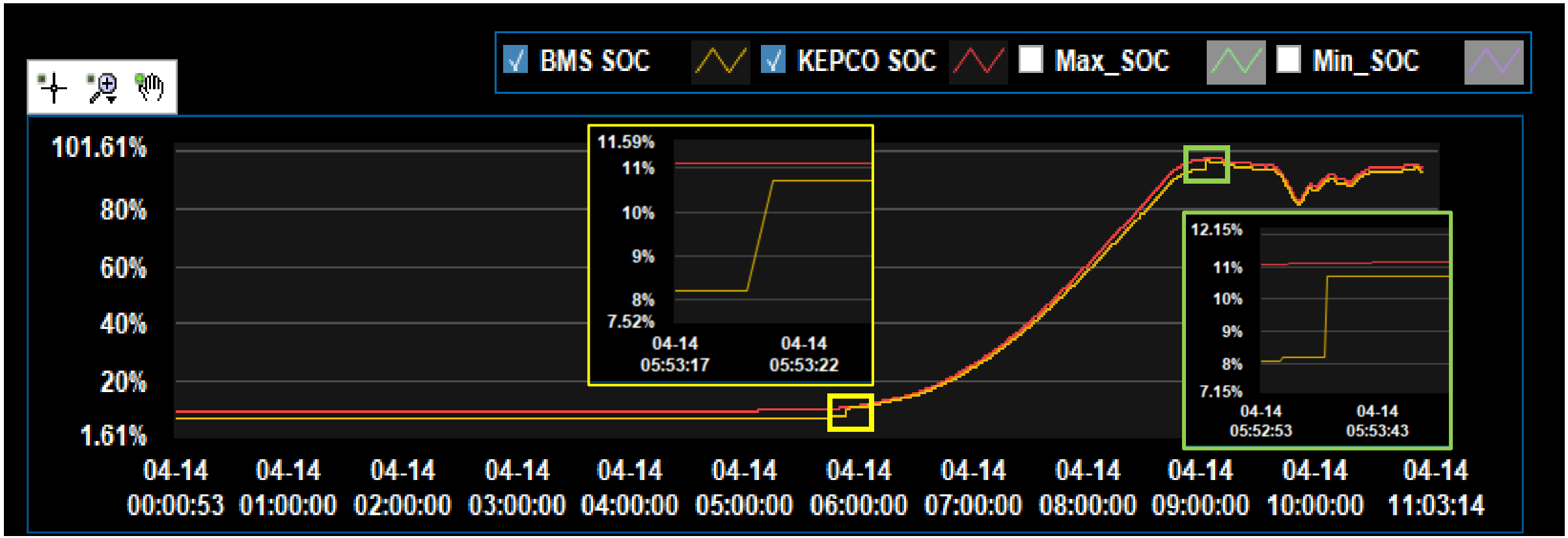
BiMS SOC Accuracy analysis result

Accurate SOC & analysis ensures reliable control and prevents early degradation.

Case Study : Superior Accuracy of BiMS in SOC Analysis

NCM

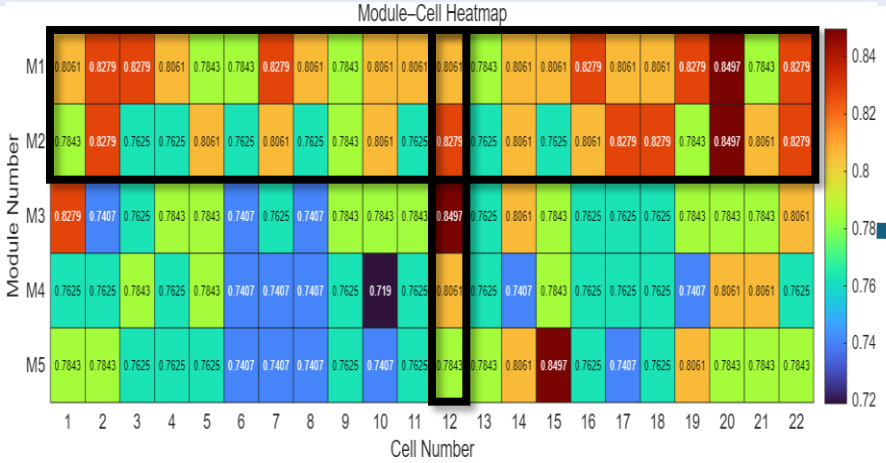
BiMS detected what BMS missed.

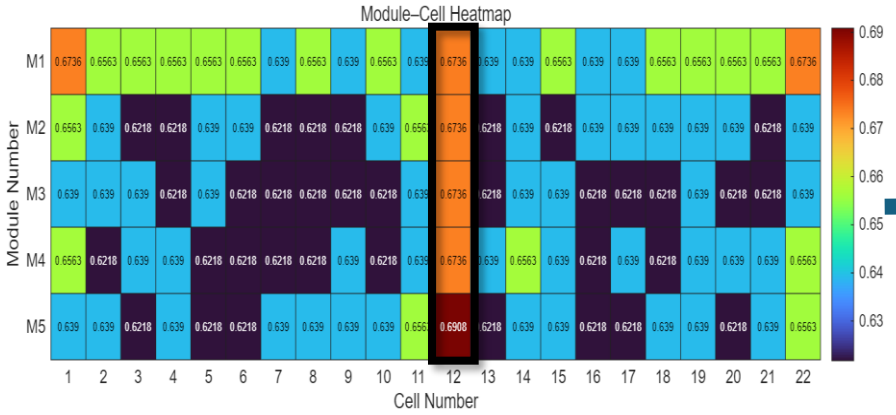


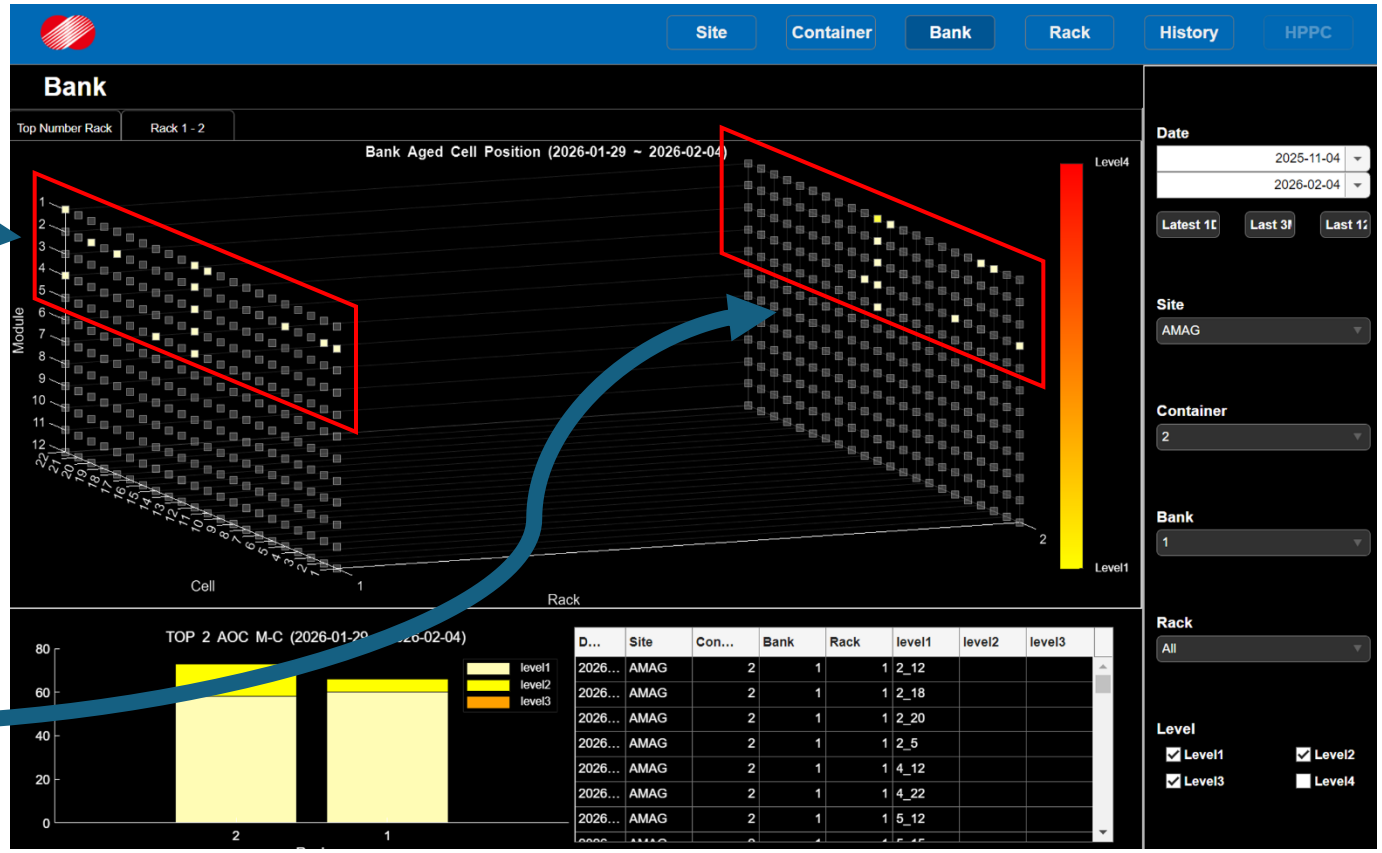
Case Study : Detection of Highly Degraded Cells

LFP

BiMS identified Degraded Cells Missed by BMS



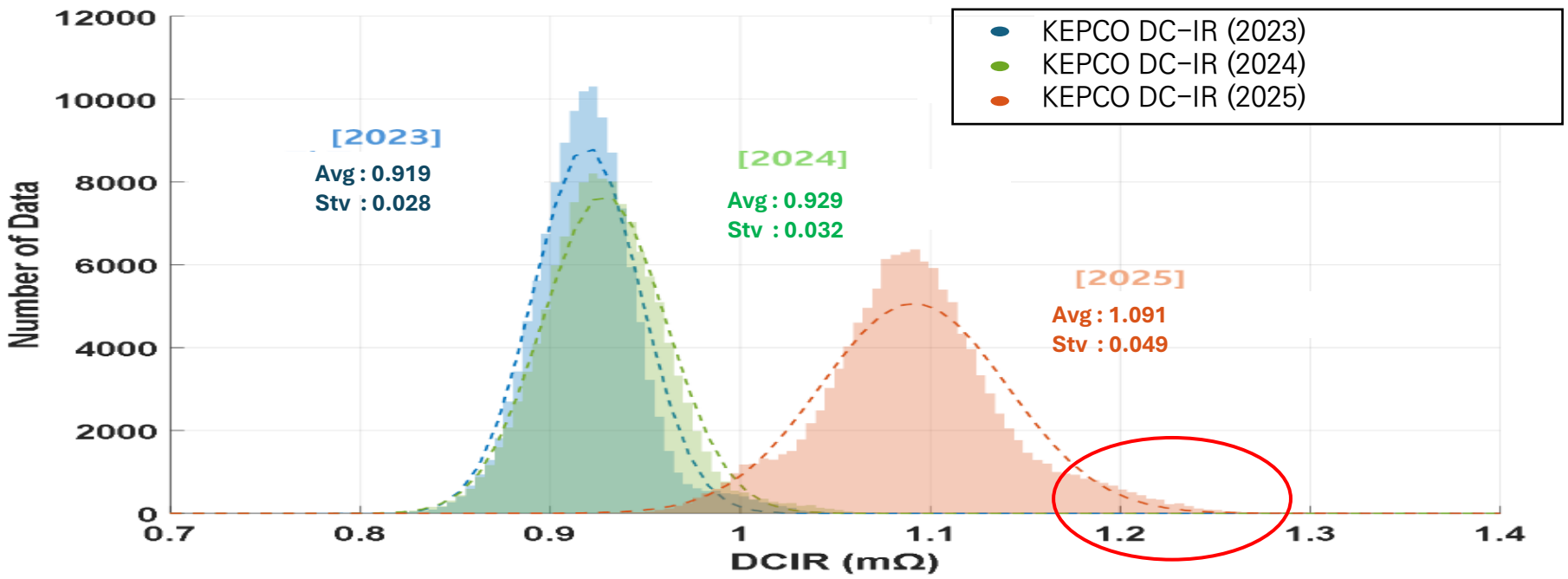




Case Study: BiMS vs Manufacturer Diagnostics

BiMS : Accurate End-to-End Battery Lifecycle Management

- BiMS : End-to-end lifecycle management with cell level diagnostics (140,000 Cells)



DC-IR Diagnosis Results

BiMS ensures safe, cost-effective, and optimized ESS lifecycle management

One KEPCO BiMS Strategy

- Accurate SOC/SOH
- Stress Index Analysis
- Aged Cell Detection

BiMS-Based BESS

- Optimized Operating
- Smart Facility O&M
- Risk Detection

Creating Service

- Customer Revenue
- New Energy Services
- Improve Reliability

Making Value

BESS Value = BESS Capacity * SOC $^{\text{BiMS}}$ * SOH $^{\text{Optimized By BiMS}}$

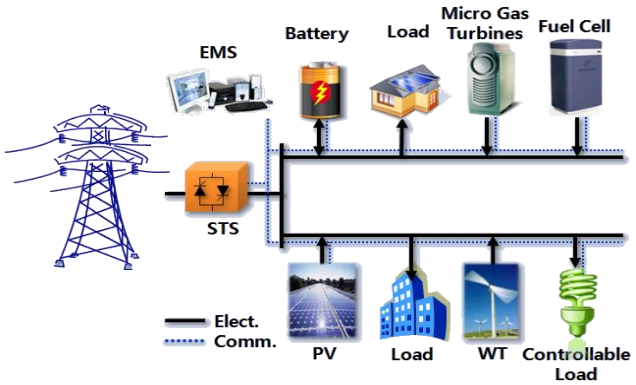
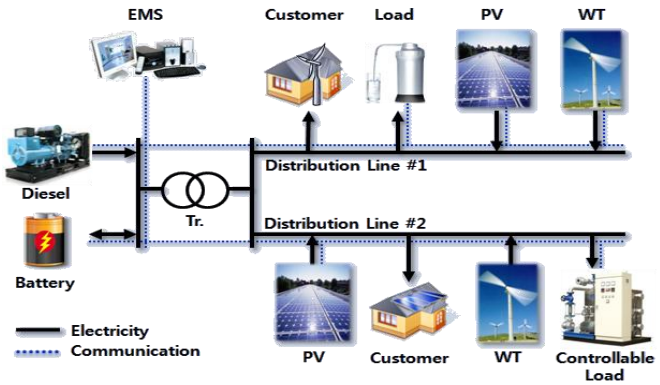
Additional Solutions

- MG
- ADMS
- ADS & GIS

MG - Micro Grid

Definitions

MICROGRID is defined as an efficiently Integrated Energy Supply System, including diverse distributed energy resources(DERs) and multiple loads, which is isolated or connected with utility grid

	Grid connected Type	Off grid isolated Type
Diagram		
Feature	Grid-connected operation, Electric power trade	Always isolated from grid
Target	Building, Campus, Military Camp, Industrial Complex	Island, Remote Village
Purpose	Cost Benefit, Improve Reliability	Cost down, Reduction of CO2 Emission
Operation	Economic Operation, Power Reliability	Regular Voltage & Frequency, Reserve Capacity

MG - Micro Grid

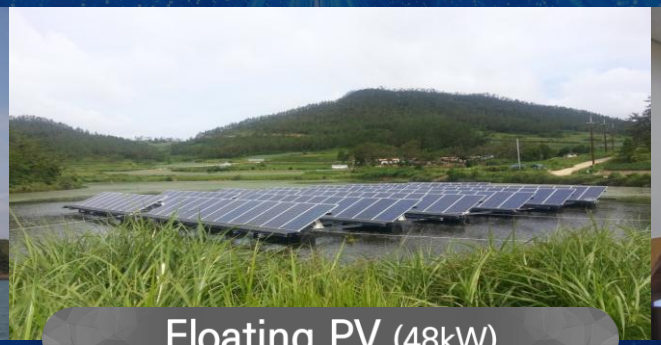
Objective of Demonstration

- Area 0.85km2, Population 281, Main island ⇔ Gapado(5.5km)
- Adoption Rate of Renewable Energy : 80% for Average Load
- Maintenance Rate of Regular Voltage & Frequency : 99%

Demonstration Test

- Automatic generation control, Economic dispatch
- Cooperative control of ESS, Load control and Emergency control
- Demonstration of optimal combination of renewable energy

Wind Turbine (100kW x 4)



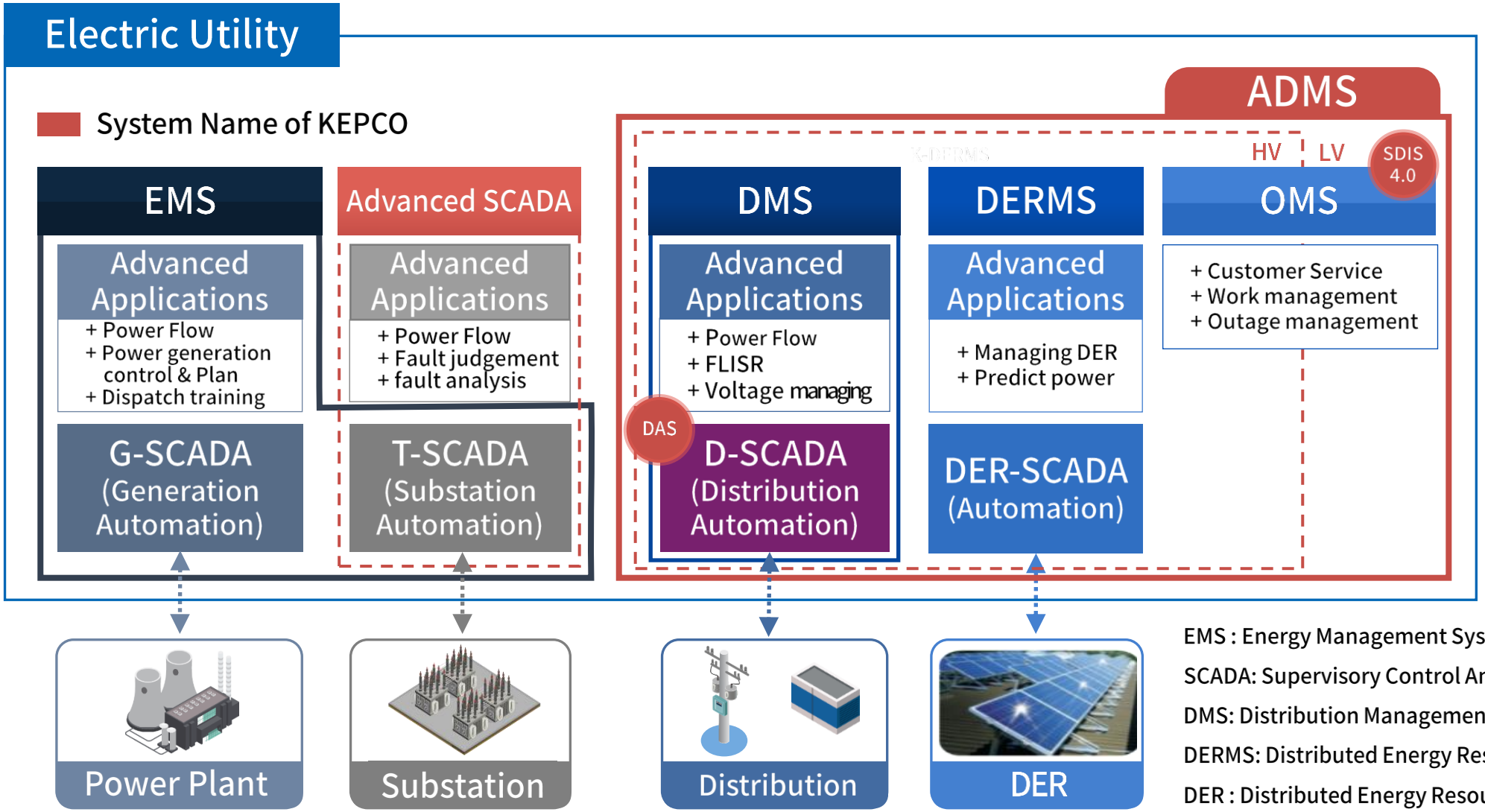
Floating PV (48kW)

Microgrid Control System

In-commercial service after completion ceremony (Oct. 2014)

ADMS – Advanced Distribution Management System

KEPCO's 3 representative power management systems : EMS, SCADA, ADMS



EMS : Energy Management System

SCADA: Supervisory Control And Data Acquisition

DMS: Distribution Management System

DERMS: Distributed Energy Resource Management System

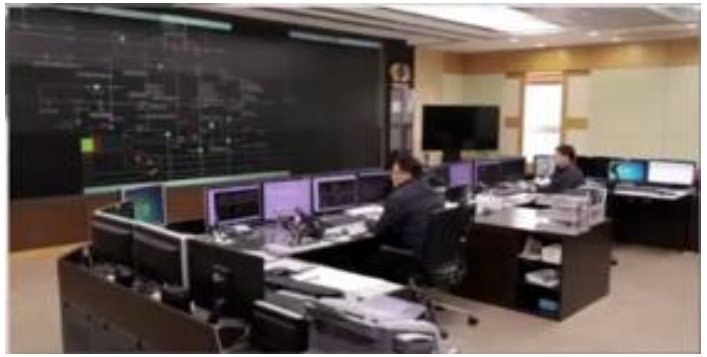
DER : Distributed Energy Resources

OMS: Outage Management System

ADMS – Advanced Distribution Management System

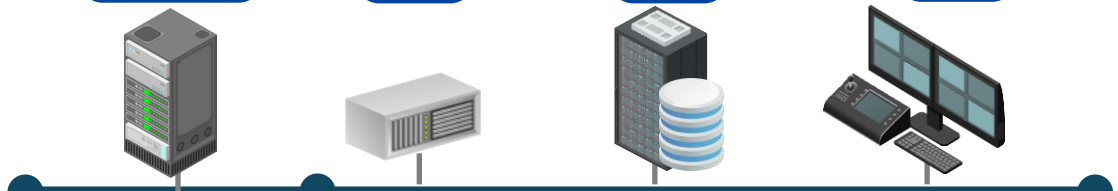
- D-SCADA of ADMS consists of Switch, FRTU, Communication equipment, ADMS system and Distribution Control Center

Distribution Control Center(DCC)



ADMS System

Server | FEP | DB | HMI

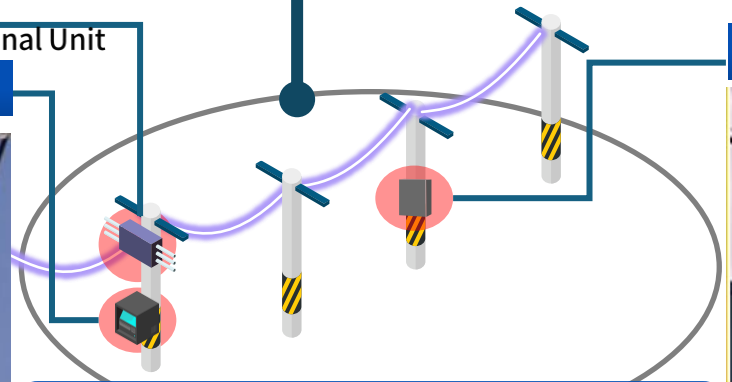


Communication Network

Switch

FRTU : Feeder Remote Terminal Unit

FRTU



Network Modem

Field Distribution Network

ADMS – Advanced Distribution Management System

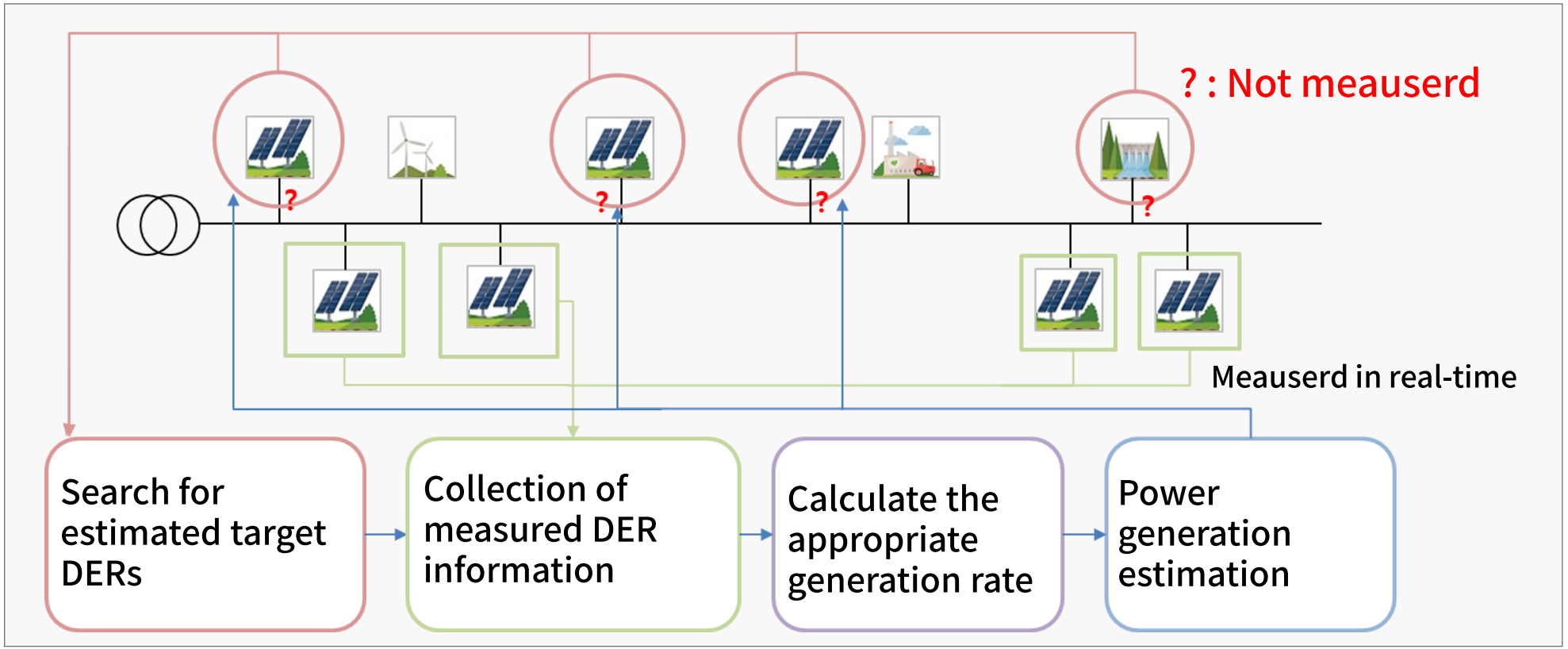
- ADMS will integrate all the other distributed systems
- To minimize the risks, ADMS will be developed step by step considering technical difficulty and necessity

D-SCADA	DMS	DERMS	OMS
Alarm window	Power Flow	Generation Estimation	Outage Management
Single line Diagram	FLISR	DER Management	Work Management
Schematic View	Short-Circuit Analysis	Voltage Optimization	Crew Management
Dashboard	Protection Analysis	DER Connection Analysis	
GIS	Contingency Restoration(SOP)	Network Reconfiguration	

- Application S/W is divided into real-time and non-real-time according to the operating method
  - Real-time (Blue) Operates in real time with D-SCADA and show through HMI
  - Non-real-time (Green) DB is shared, but is operated on PC in non-real time for technical review

ADMS – Advanced Distribution Management System

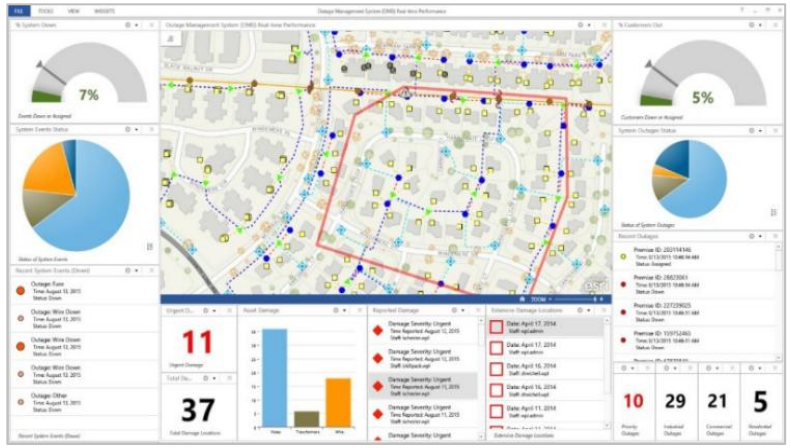
- Estimating the amount of power generation from DER that are not measured in real-time
- Estimated power generation is stored as data and used for operation



ADMS – Advanced Distribution Management System

Definition

It manages fault information, work section, worker, and work information and visualizes it in a system diagram/GIS. Also, support rapid recovery from power outage.



Switching & Work Management

Manage information and order of work in the distribution system
- Enhancement of safety management and efficiency through systematization of machine operation

Outage management

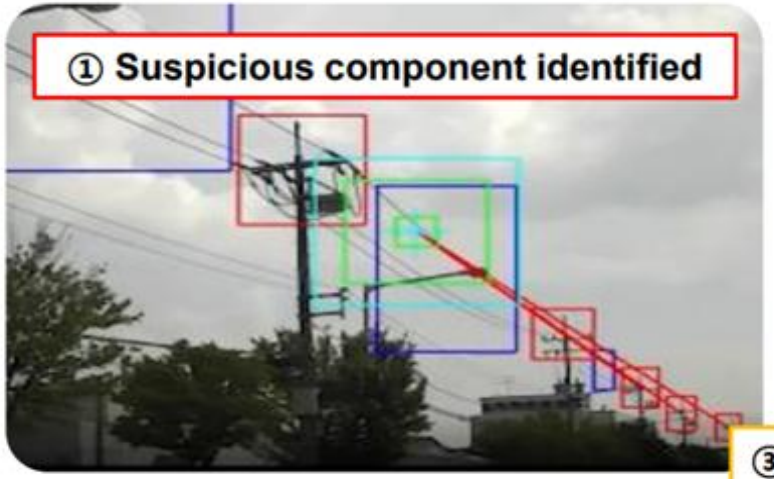
Support for all troubles from power outage to follow-up management
- Real-time display of power outage information (region, number of outage customers) on GIS and dashboard

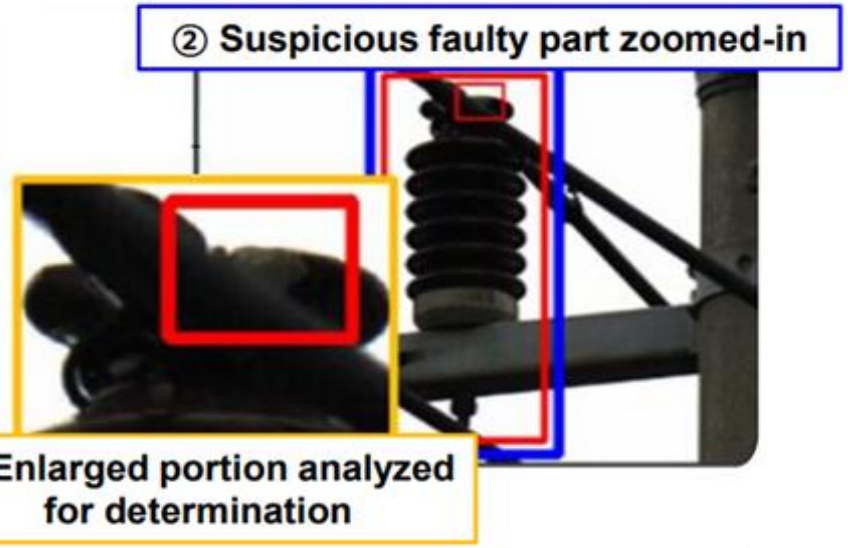
Crew Management

Provide system information on mobile
- Worker status and optimal placement, etc.

ADS&GIS – AI based Diagnosis of distribution facilities and GIS establishment for non-technical loss reduction

- KEPCO ADS consists of a set of optical camera and sensors mounted on a vehicle, which recognizes, traces and takes images of individual equipment.
- The AI analyzes the images to identify faults occurred in the individual equipment.

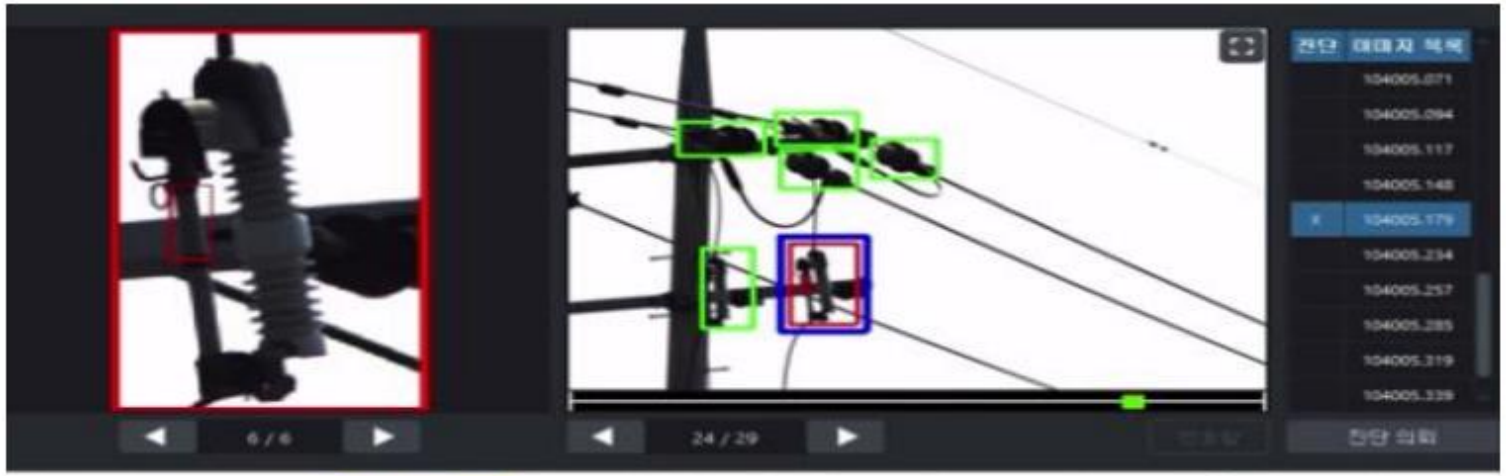


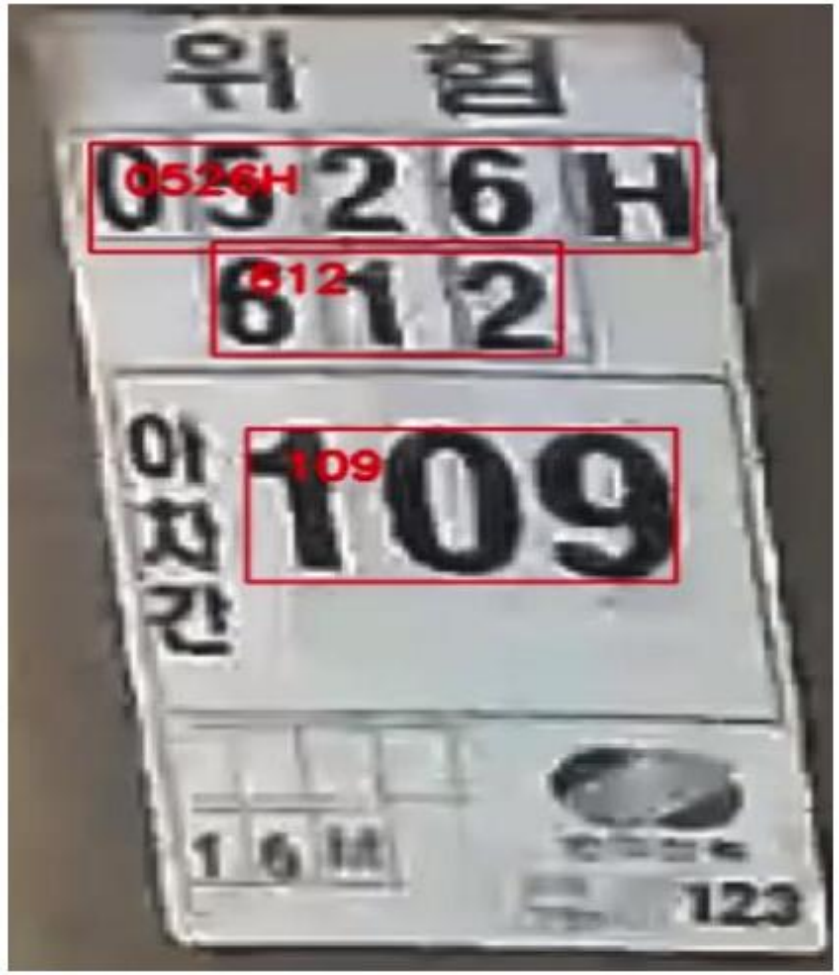


Key Advantages

- Quickly, accurately and safely diagnoses the health of distribution infrastructure.
- Efficiently and reliably diagnoses the faults by the AI's that recognize the components and analyzes the faults.

ADS&GIS – AI based Diagnosis of distribution facilities and GIS establishment for non-technical loss reduction





- ✓ Poles are indicated on the map according to their GPS coordinates.
- ✓ Captures the lower part of utility poles and recognizes the pole ID numbers by OCR.