KEPCO 전력연구원

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AND SUSTAINABILITY
CONFERENCE 2024

Progress of AI based nationwide CMD system in KEPCO

Jong-Geon Lee
jg.lee@kepco.co.kr

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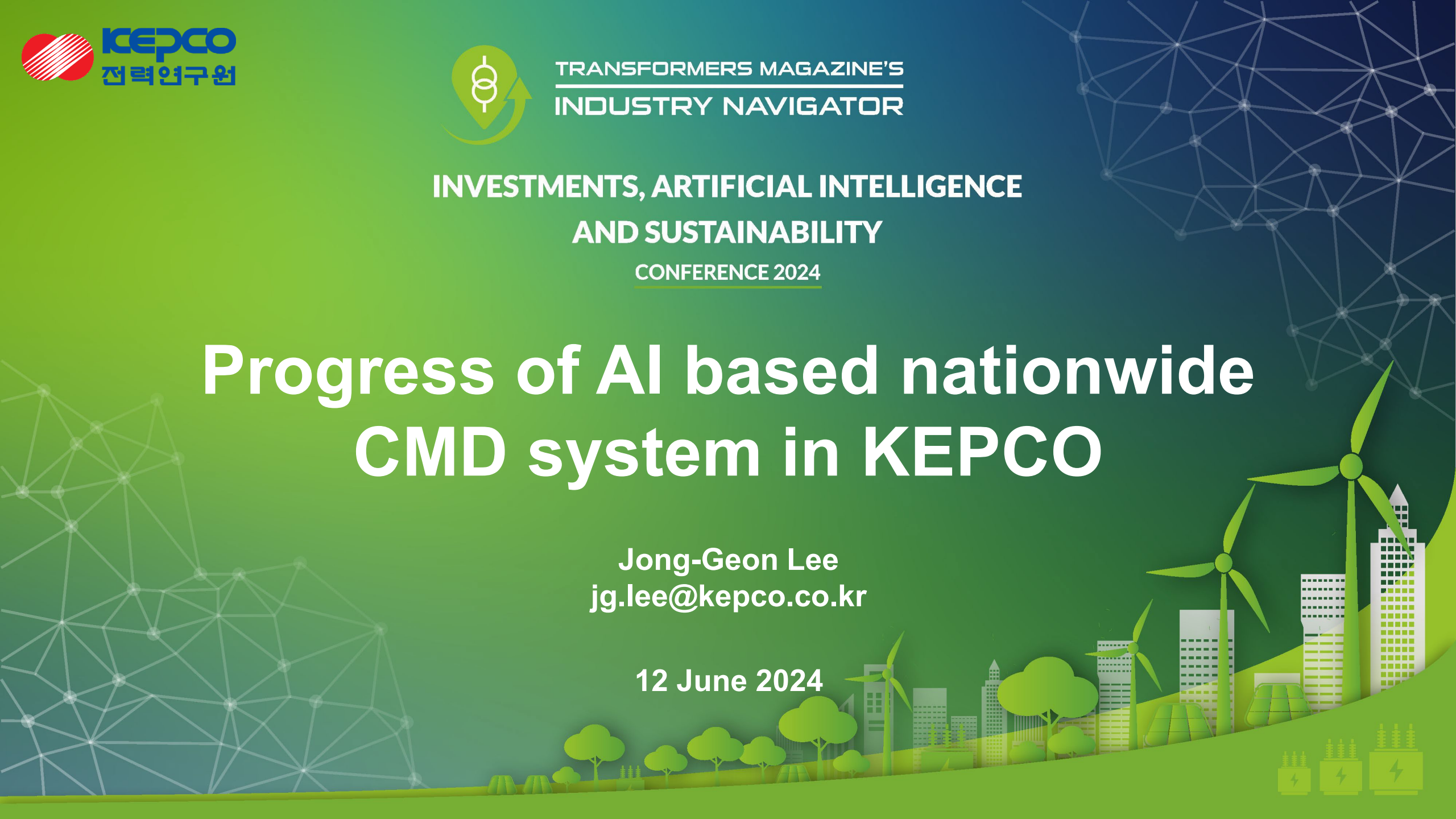
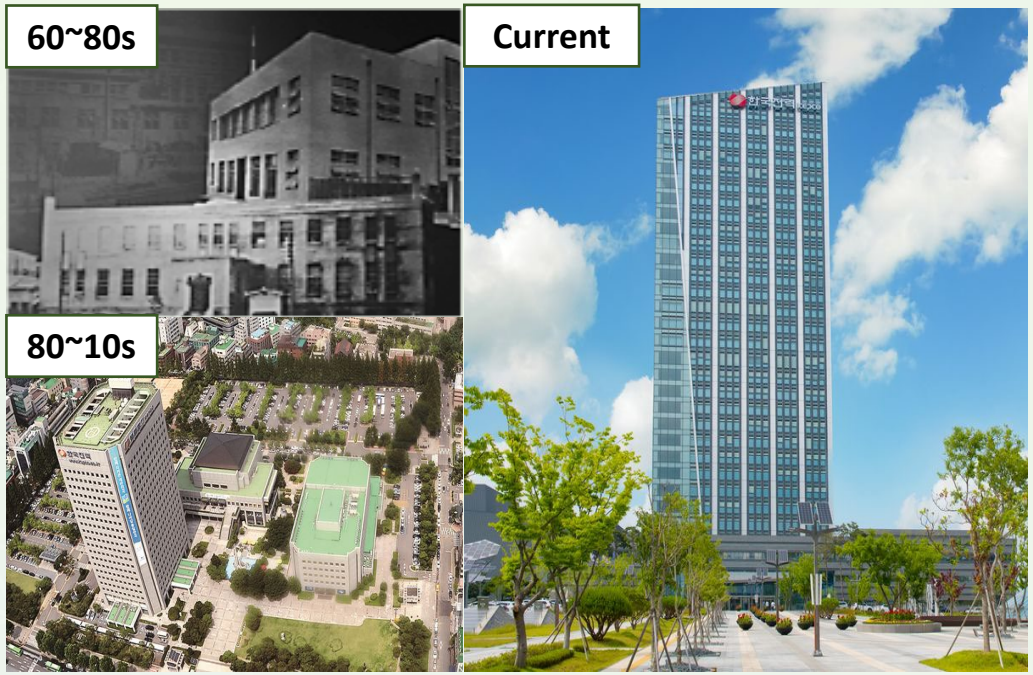


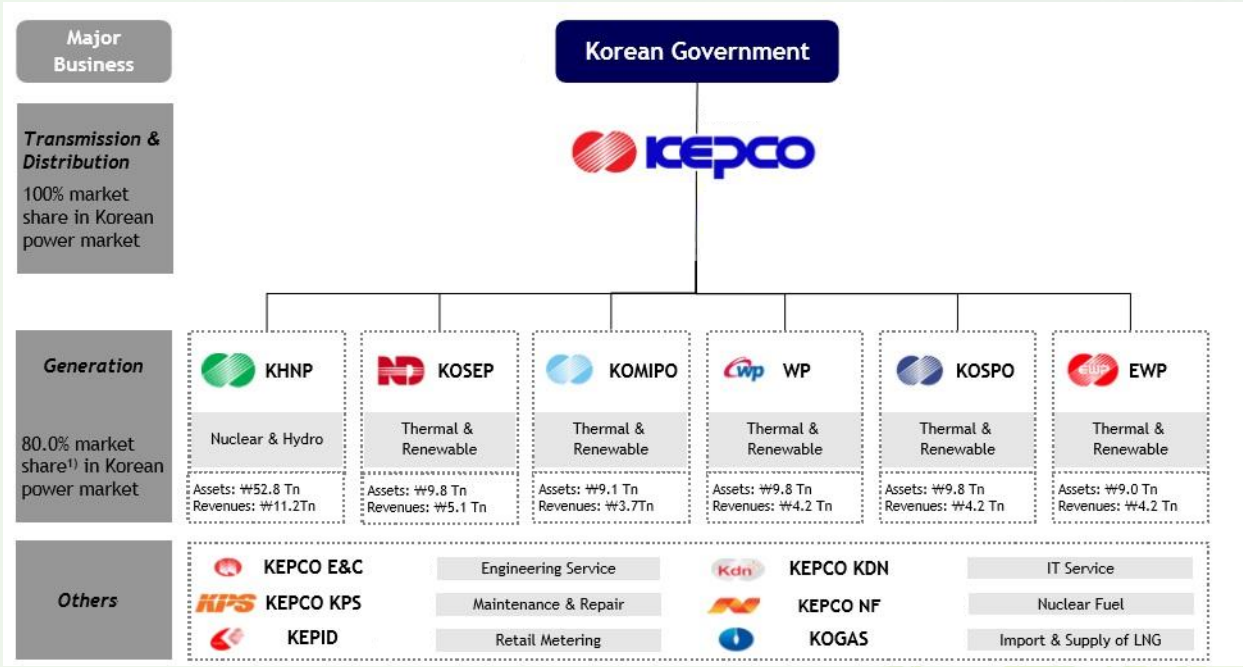
0. Introducing KEPCO

❖ KEPCO (Korea Electric Power Company)

- Public Corp. established in 1898, Korean Empire, a unique energy utility in South Korea
- Operating transmission and distribution (T&D) system, and managing generation affiliates



[KEPCO HQ]



[Corporation Structure]

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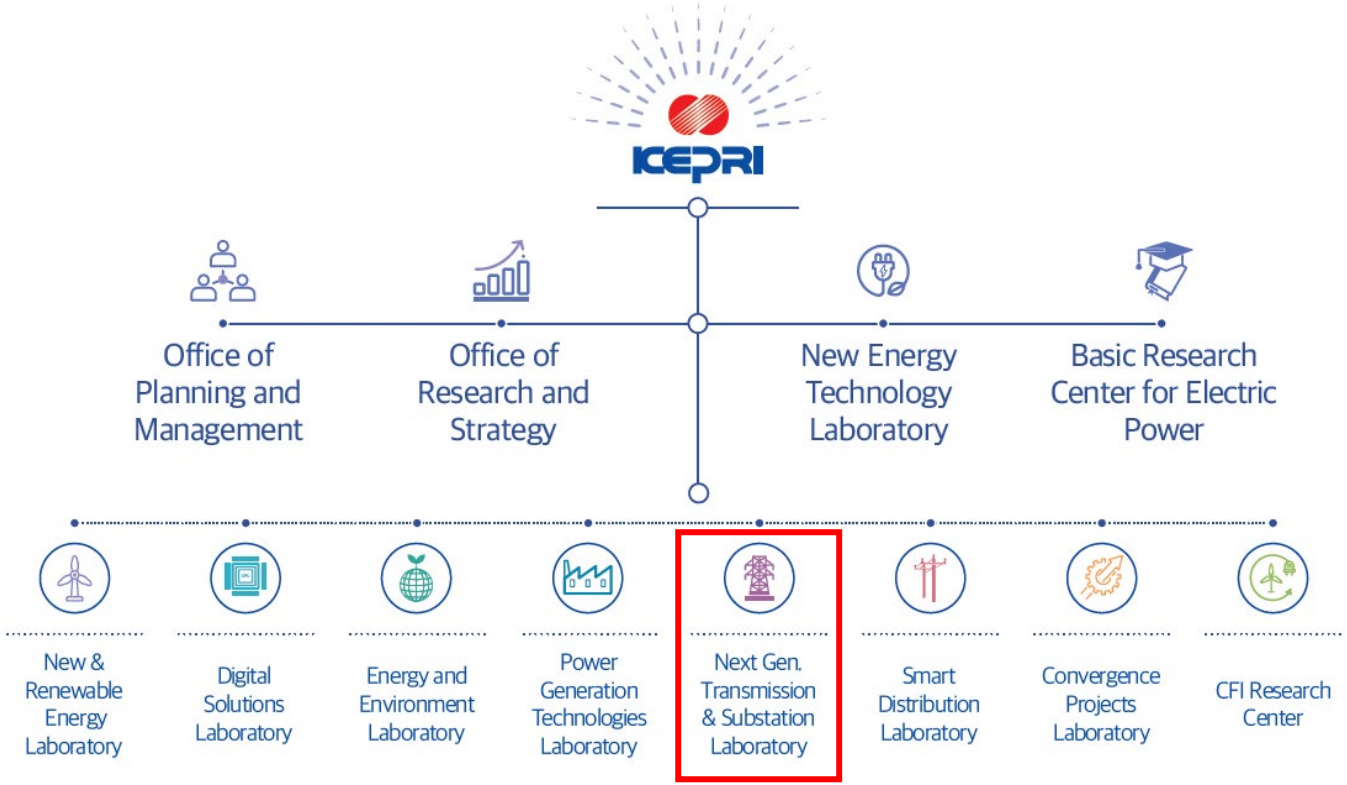
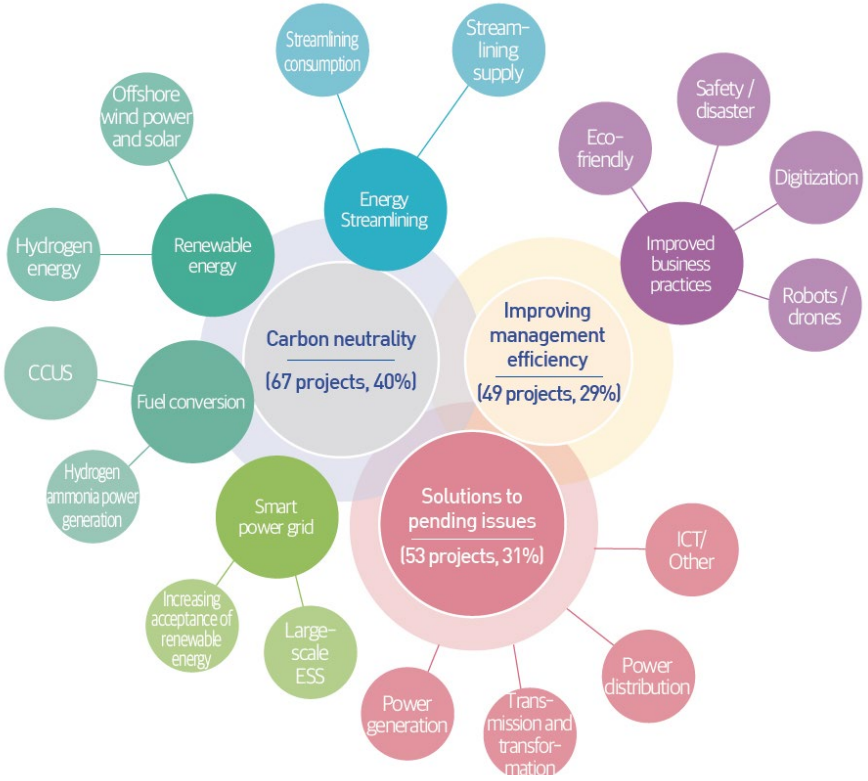
0. Introducing KEPCO

❖ KEPRI (Korea Electric Power Research Institute)





Launched in 1961, performs a wide range of research on T&D and Gen. for 60 years

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Contents

1. Introduction

❖ CMD Fundamentals (Condition Monitoring and Diagnosis)

Three fundamental technologies have evolved with the 3rd and 4th industrialization

Measurement

Late 20th, from 1980s

- **Key technology**
  - Automation, Digitalization
  - Equipment, sensors
- **Characteristics**
  - Interface to CMD and Equip.
  - Offline to online diagnosis
- **Challenges**
  - High cost of sensor and device
  - Noise interference

Monitoring

Early 21th, from 2000s

- **Key technology**
  - IT tech., data network
  - Data storage, communication
- **Characteristics**
  - Predictive diagnosis available
  - Measurement area increased
- **Challenges**
  - Increasing CMD data
  - Reliability, and data cleansing

Diagnosis

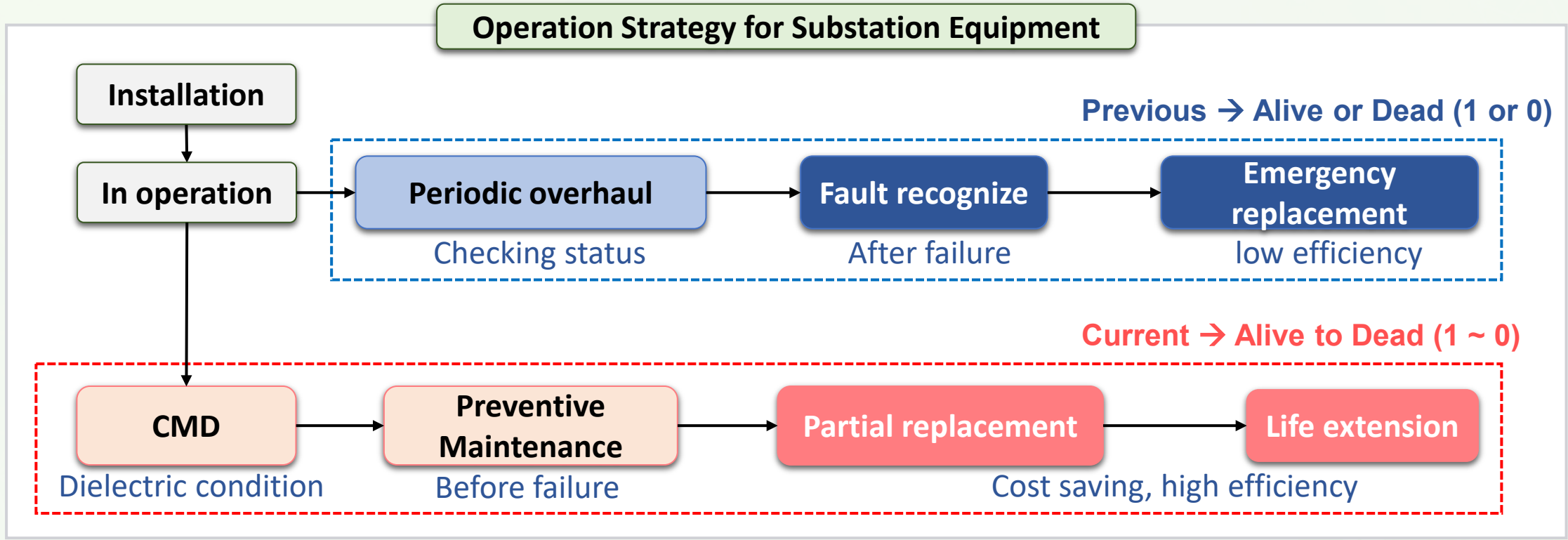
Mid 21th, from 2020s

- **Key technology**
  - AI, Big data analysis
  - Machine learning
- **Characteristics**
  - Knowledge-based machine learning
  - Automated CMD and fault prediction
- **Challenges**
  - AI algorithm
  - More computing power required

1. Introduction

❖ Operation paradigm changed

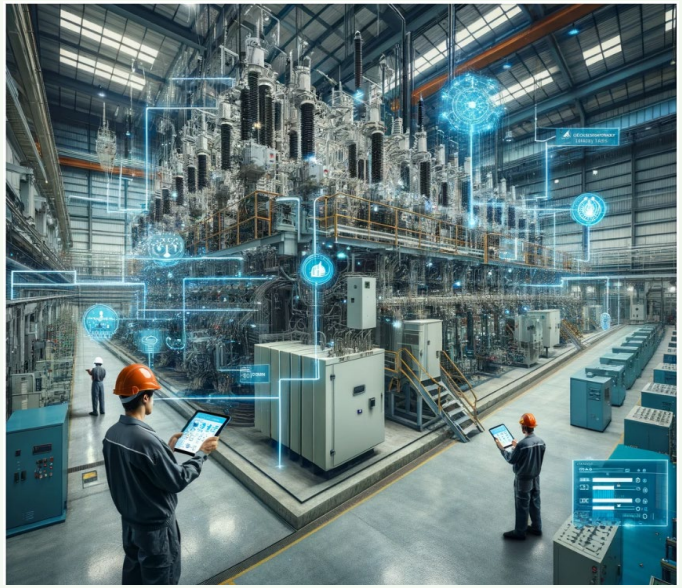
After CMD, an approach to aging process between Alive to Dead available



2. Recent changes

❖ Introduction of AI

- Power equipment CMD industry is directly affected by the 4th industrialization
- Automated real-time online monitoring and predictive diagnostics enabled
- AI provides data-driven insights to user → smarter-decision making



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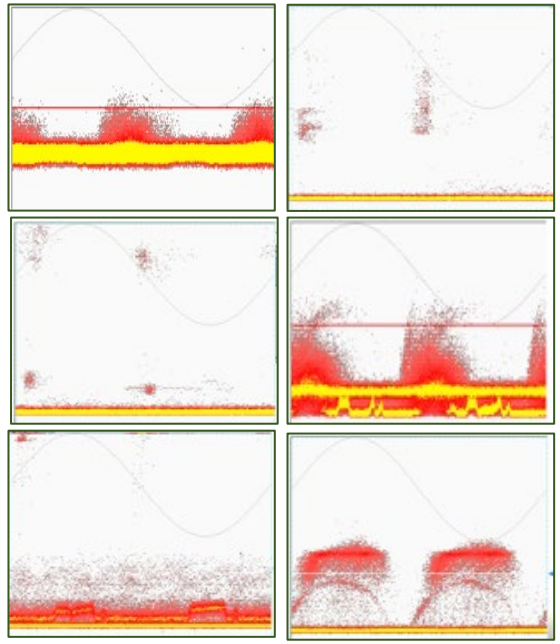
2. Recent changes

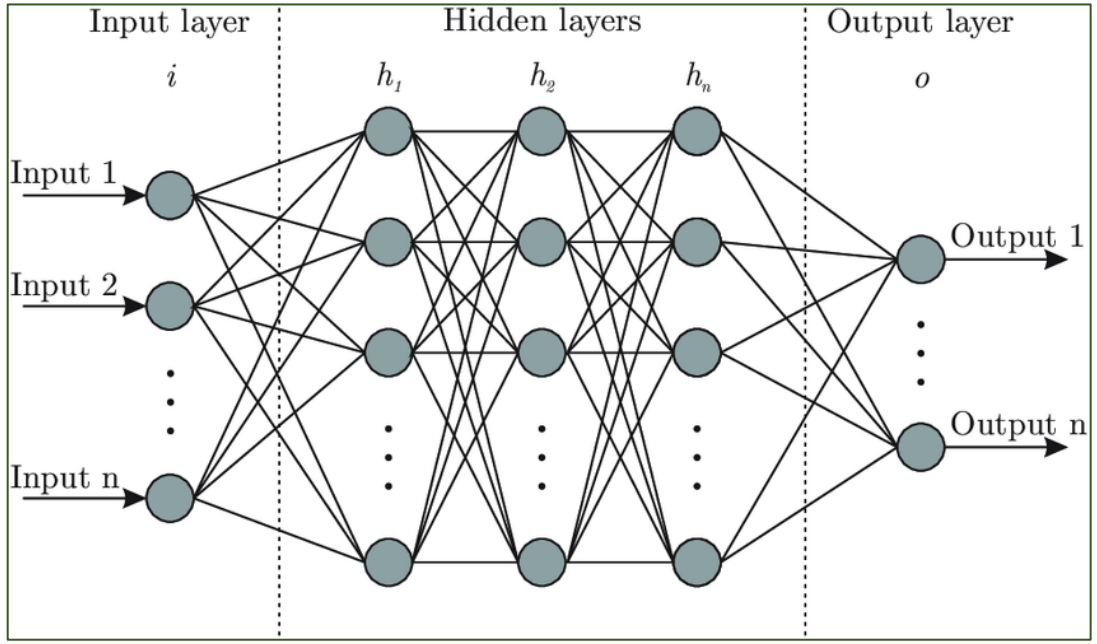
❖ Not a new technology

- AI based CMD for power equipment is not a 'completely new' technology
- Since the 1980s, an early type of expert knowledge system has been partially utilized for PD

PD patterns



Neural Network



Classification of Defects
(Type, magnitude, etc.)
Void
Surface discharge
Metallic particle
.
.
.

2. Recent changes

❖ Difference

- **Increasing computing power**
  - (Previous) Rule-based systems → (Current) Complex machine learning
  - Sophisticated algorithms → more condition layers (NN), variables
- **Measuring equipment and sensors**
  - Increasing online monitoring component → GIS PD + TR PD, OLTC, Bushing, DGA,
- **Big data analysis and technology integration**
  - Data storage → Progress to vast amounts of diagnostic data enabled
  - AI + IoT sensor device + Cloud computing + Big Data analytics
- **Increasing industry expertise**
  - A significant accumulation of industry knowledge and expertise in CMD

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3. Progress of CMD in KEPCO

❖ KEPCO power grid system

- **Power grid**: located in a specific geopolitical region → an isolated system
- **Max. Ratings and capacity**: 154 kV, 1,200 MVA (1960s) → 765 kV, 350,000 MVA (2020s)
- **Substations**: Outdoor to indoor, 8,000 switchgear and 3,000 TR have been operated


154kV Substation


345kV Substation


765kV Substation


Outdoor switchyard


Outdoor GIS


Indoor GIS

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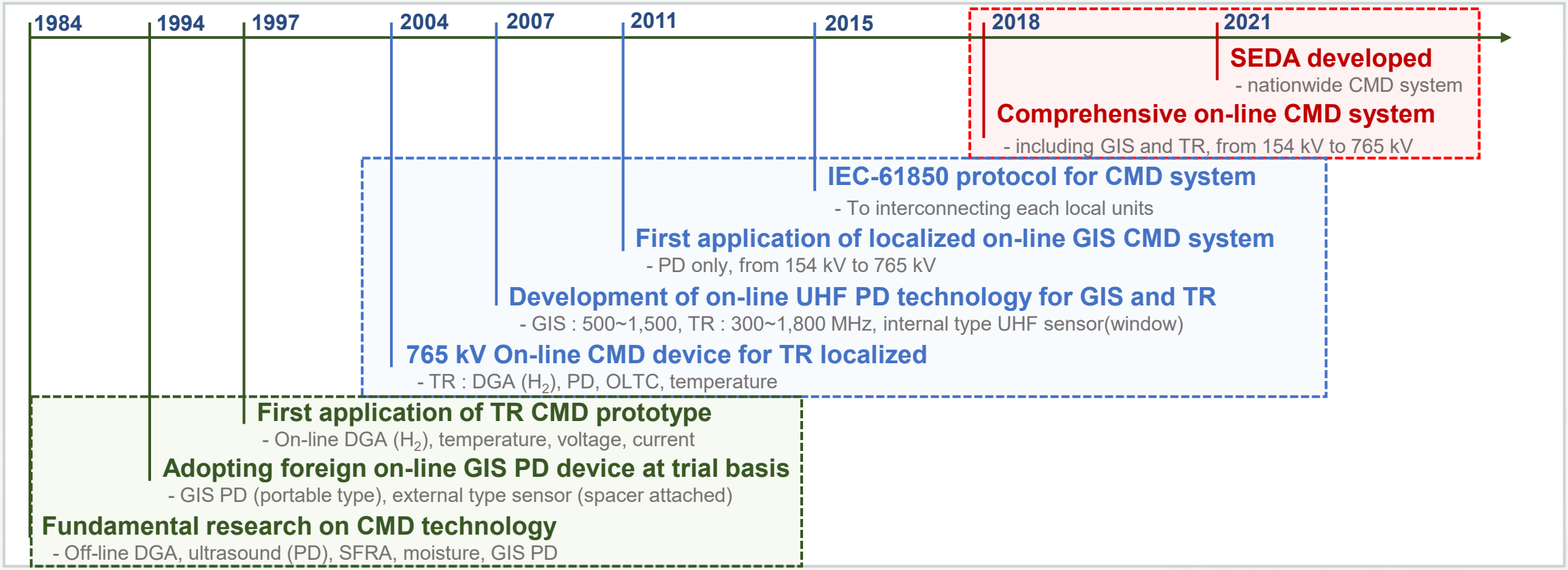
3. Progress of CMD in KEPCO

❖ History of CMD

- From 1984, R&D activities for both TR and GIS has been progressed



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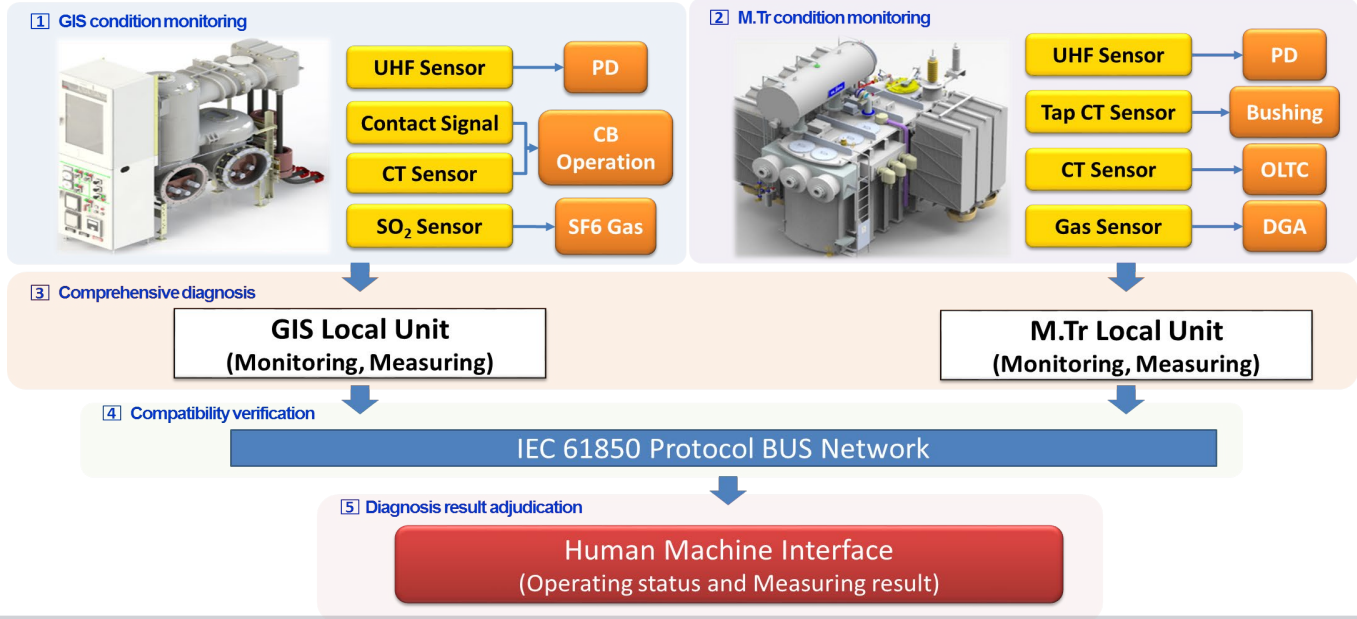
3. Progress of CMD in KEPCO

❖ Comprehensive on-line CMD system

- **Paradigm shift was necessary : (Conventional)** GIS only → **(Required)** GIS and TR
- A **comprehensive system commercialized** with automated on-line CMD capability (2018)

  - Based on IEC-61850 protocol, communication between sensor, LU and HMI were enabled



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3. Progress of CMD in KEPCO

❖ Monitoring components

TR/GIS PD	Classifying type of defect using PRPD/PRPS and ANN algorithm
DGA	On-line monitoring for three key gas (H2, C2H2, CO)
OLTC	Motor current, operating time, TPI monitoring
Bushing	Capacitance, leakage current, power factor monitoring
CB	Coil current, operating times, time difference, interrupting current,

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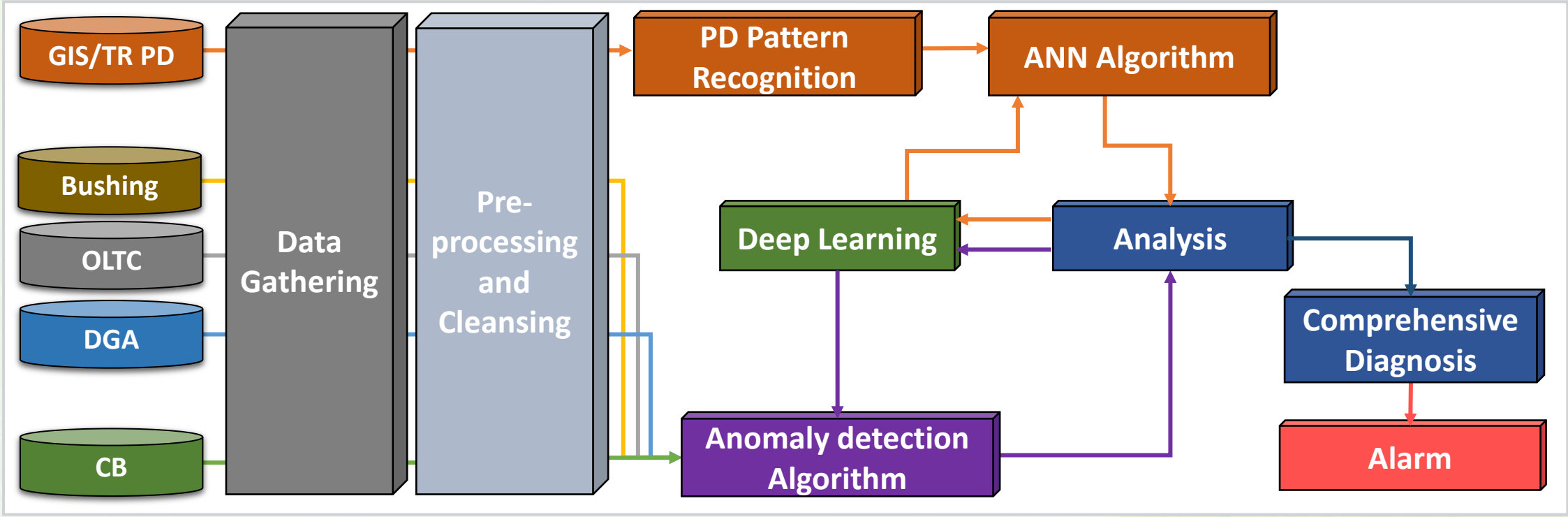
3. Progress of CMD in KEPCO

❖ Main algorithm

- Two main algorithms : ANN (Artificial Neural Network) for PD, anomaly detection for others
- Not a 'completely new', but complex diagnosis with machine learning available



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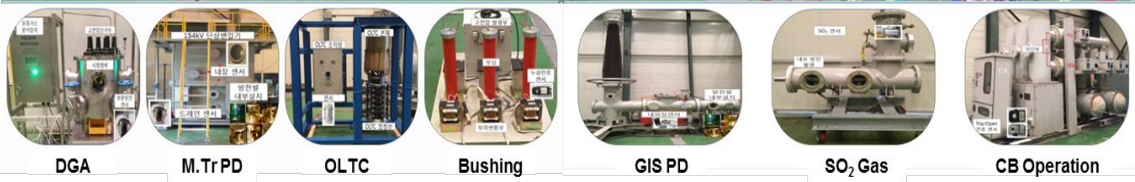
3. Progress of CMD in KEPCO

❖ Qualification test for comprehensive system

- Equipment, sensor standards, protocol (IEC-61850) and test procedure were established
- Test-bed for evaluating the CMD system was built, and a qualification test was performed
  - Domestic manufacturers got approved, and the system was commercialized successfully



GIS Monitoring	CB Operation
	SO2 Analysis
M.Tr. Monitoring	Leakage Current of Bushing
	OLTC Operation
PD Test	GIS/M.Tr./OLTC/Cable
Sensitivity test	UHF/CT Sensor Sensitivity
AC Withstand Voltage	Breakdown test/A.L.T.

3. Progress of CMD in KEPCO

❖ Application result and its effect

- Pilot installation carried out at 50 substations during the first two years (2018-2020)
- Failure rate has been gradually reduced → HQ considered expanding nationwide
- A new business market emerged, and diagnostic technologies in Korea started to advance

❖ Challenges remaining

- Measurement and monitoring → Partially completed, but 'diagnosis' still remained
- Increasing watch-list more than 350 S/S → Effective supervising system needed
- Still performs diagnosis on individual parts → expanding to entire substation required
- Integration was incomplete between online and offline

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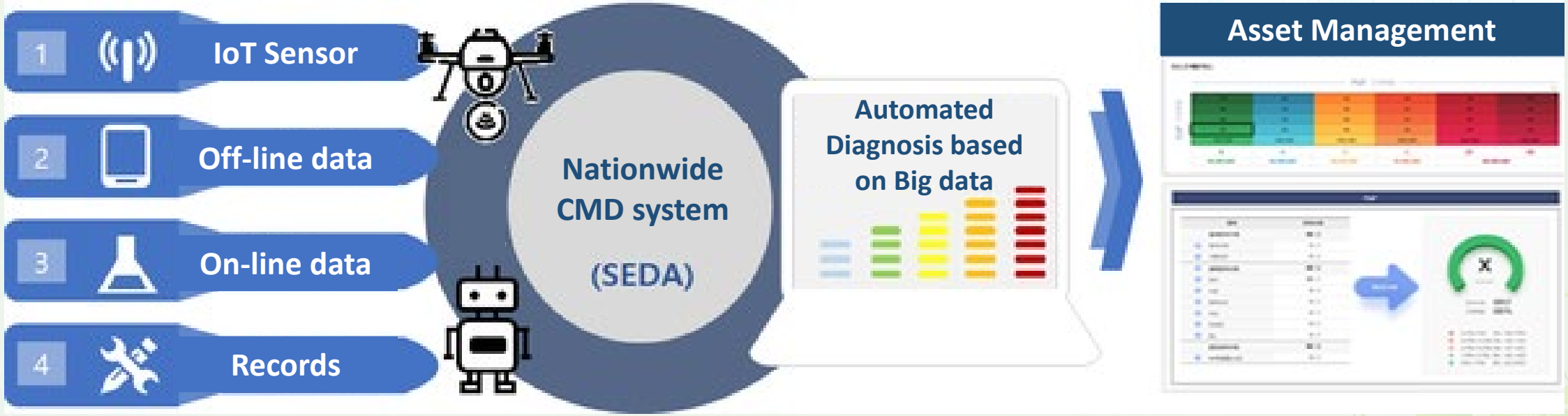
4. Nationwide Monitoring system

❖ SEDA (Substation Equipment Diagnosis and Analysis system)

- SEDA launched in 2021, under the supervision of KEPCO HQ
- All the substation monitoring in KEPCO power grid has gradually been enabled
- Combining offline legacy data with online CMD result to perform complex diagnostics



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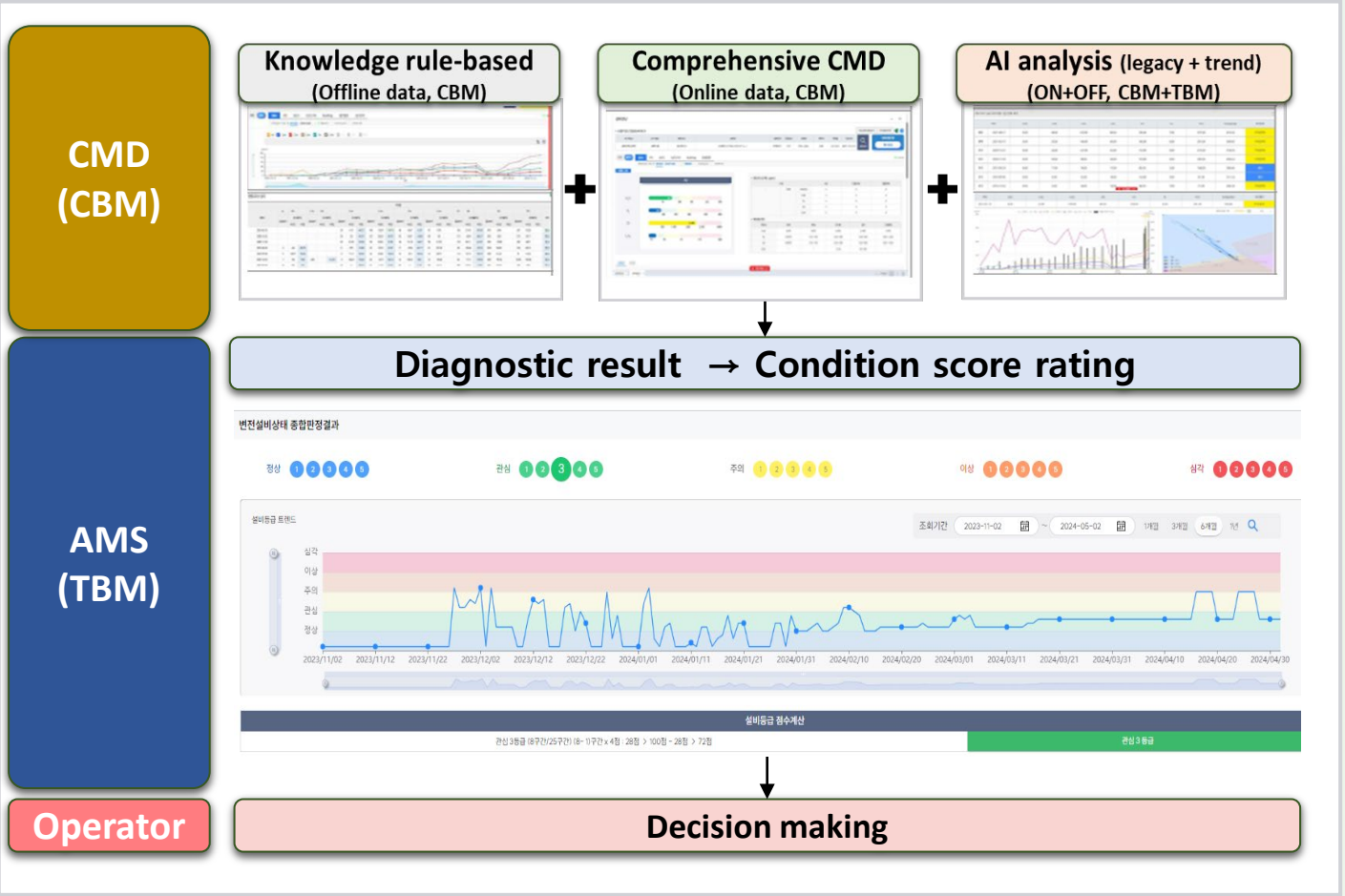
4. Nationwide Monitoring system

❖ CMD + Asset Management (partially)



- **Legacy data integrated**

  (Online) GIS + Comp.CMD

  (Offline) Overhaul, Patrol

- **AI algorithm added**

  - To analyze trend and legacy data

- **CBM+TBM available**

  - Normal → Caution → Danger

- **Objective decision-making**

  - maintain, overhaul, replacement

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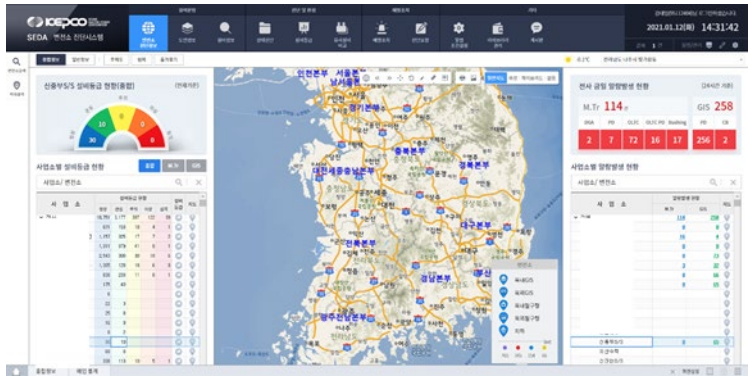
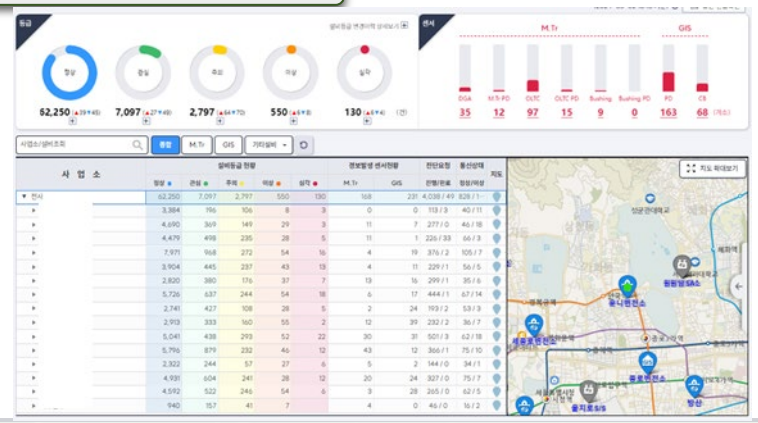
4. Nationwide Monitoring system

❖ Operation procedure

1. Nationwide monitoring

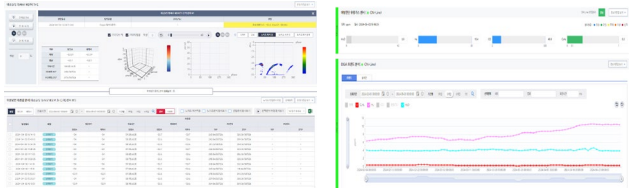


2. Select Substation



3. Complex diagnosis

Online CMD data



TR/GIS PD

DGA

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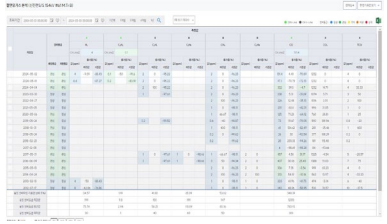
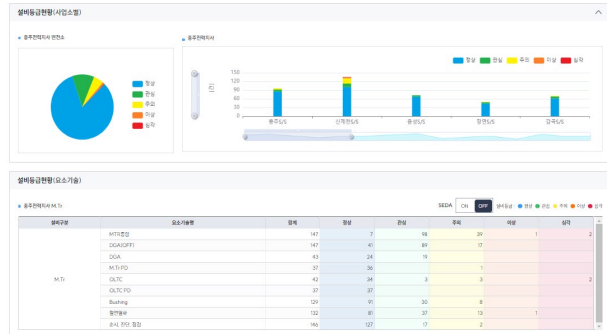
Field patrol data



Offline data(overhaul)

4. Determining status ranking

5. Report and decision-making



5. Conclusion

❖ Remarks

- Application of AI algorithm has achieved effective CMD compared to before
- Nationwide SEDA system capable of complex CMD with AI has been utilized in KEPCO.
  - Failure rate of GIS and TR has been gradually reduced during the last five years
- The CMD system have deployed to 350 S/S as of 2023, 580 S/S in the coming decades
  - Widely employed in other sectors, such as railway network and private sectors, since 2019

❖ What we have to do

- **Measurement** : Reliability (sensor, device), Accuracy (detection), Precision (error rate)
- **Monitoring** : Additional component (SA, LA, reactor, etc.,), Storage, Data communication
- **Diagnosis** : Computing power, Sophisticated algorithms

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Thank you for your attention