

# **Substation Digitization**and Robotics

**Digital Solutions @ Grid** 



# Agenda



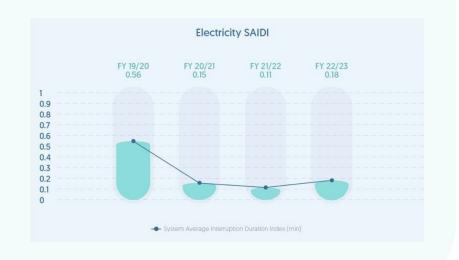
- 1. Introduction
- 2. Digitalization –Why and How?
- 3. Condition Monitoring
- 4. Use of robotics and push towards Al
- 5. Q&A

# **Company Introduction**





**SP Group** a leading utilities group in the Asia Pacific and has the best **SAIDI** in the world



1996 - end Aug 2025, *Power Automation* operates as a Joint Venture between SP Group and Siemens

Today, Power Automation is wholly-owned subsidiary of SP Group

Taking on the role as a systems integrator wellversed in utility automation solutions based on open-systems technologies while adhering strictly to industry standards, we produce quality products and services to our clients and customers.

# **Projects Shaping Singapore's Infrastructure**



SCADA<sup>1</sup> System for longest underground tunnel in Southeast Asia

Ensuring Reliable Journey on the North-South East-West Line

Sustainable Energy Management in Buildings

Promoting Sustainability in Educational Institutions





Welcome
Electricity Vending System

To purchase electricity, please enter your Meter ID.

NUS has a NO refund/cancellation/transfer policy for the student housing air-con credits.

Meter ID:

Submit Reset

Supply of **SCADA System** for high and low voltage electrical distribution networks with interface to the Integrated Traffic and Plant Management System (ITPMS)

Supply of **SCADA System** for the monitoring and control of Power Supply, Environmental Control and Passenger Station facilities, providing high availability to railway operations

Supply and maintain **Energy Management System** that provides energy monitoring and billing for various JTC buildings

Implement **Electricity Vending System** in National University of Singapore, Nanyang Technological University and Singapore University of Technology and Design which operates on a pay-as-you-use model.

<sup>&</sup>lt;sup>1</sup> Supervisory Control and Data Acquisition





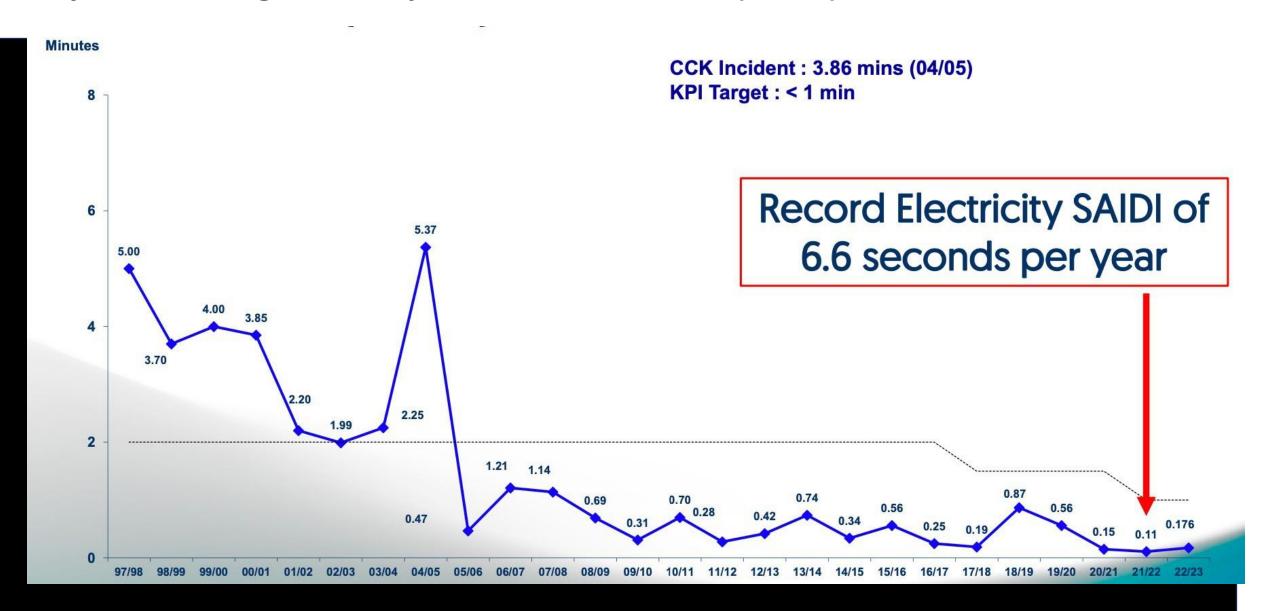
# Our Expertise in Power Systems Control

#### **Singapore**

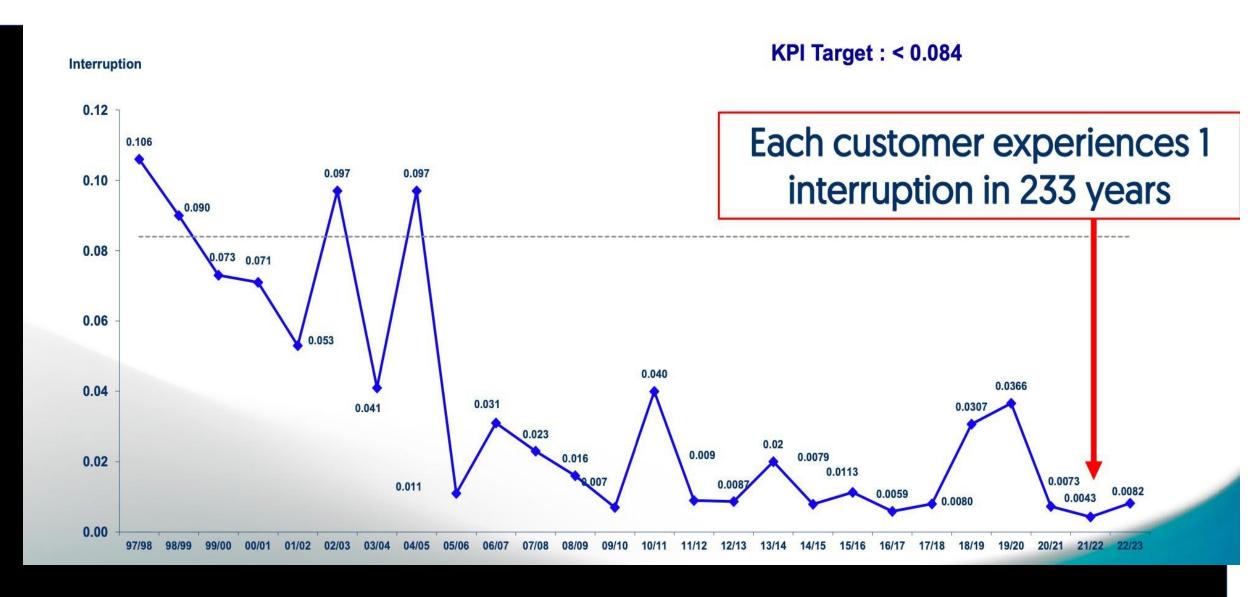




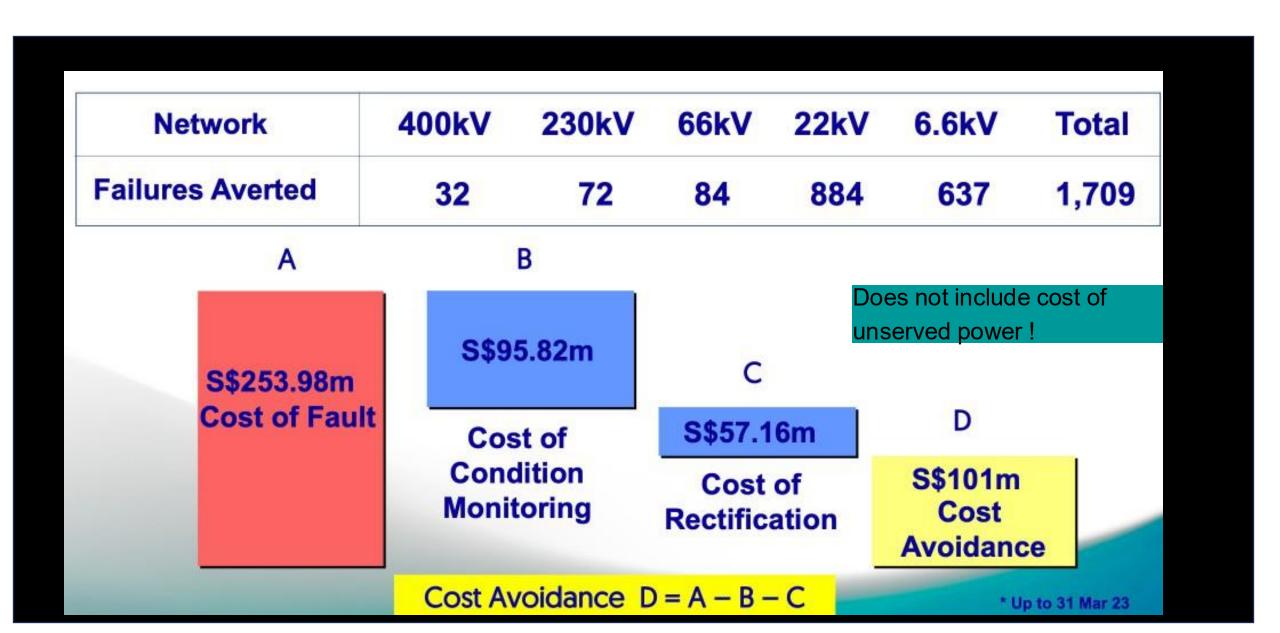
# **System Average Interruption Duration Index (SAIDI)**



# System Average Interruption Frequency Index (SAIFI)



#### **Cost Avoidance**



## **Outcome Tabulation**

# **Network Failures Averted by Condition Monitoring**



Network	FY 01/02	FY 02/03	FY 03/04	FY 04/05	FY 05/06	FY 06/07	FY 07/08	FY 08/09	FY 09/10	FY 10/11	FY 11/12	FY 12/13	FY 13/14	FY 14/15	FY 15/16	FY 16/17	FY 17/18	FY 18/19	FY 19/20	FY 20/21	FY 21/22	FY 22/23	Total
400kV	0	1	1	2	0	3	1	1	1	0	1	0	5	1	1	0	1	2	7	1	0	3	32
230kV	1	3	0	1	10	7	5	8	5	8	3	2	6	3	1	1	5	0	1	0	2	0	72
66kV	1	3	2	7	6	4	13	5	11	2	5	3	2	1	3	5	8	2	0	0	1	0	84
22kV	27	11	23	31	36	45	11	15	15	40	28	10	20	28	30	18	18	20	36	102	154	166	884
6.6kV	1	5	41	39	3	34	39	14	23	31	21	27	15	39	56	26	33	42	39	44	34	31	637
Total	30	23	67	80	55	93	69	43	55	81	58	42	48	72	91	50	65	66	83	147	191	200	1709 *

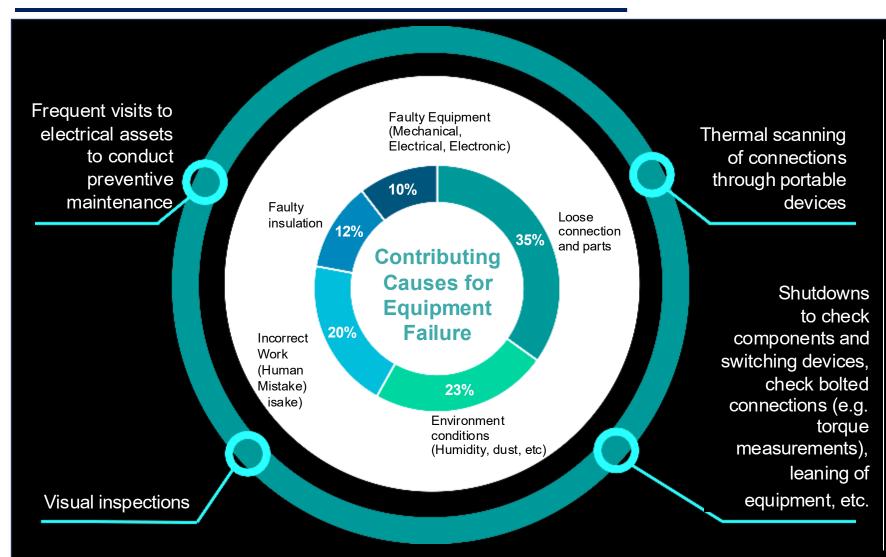
# **Reasons for Digitalisation & Condition Monitoring**





# **Common Causes and Challenges**





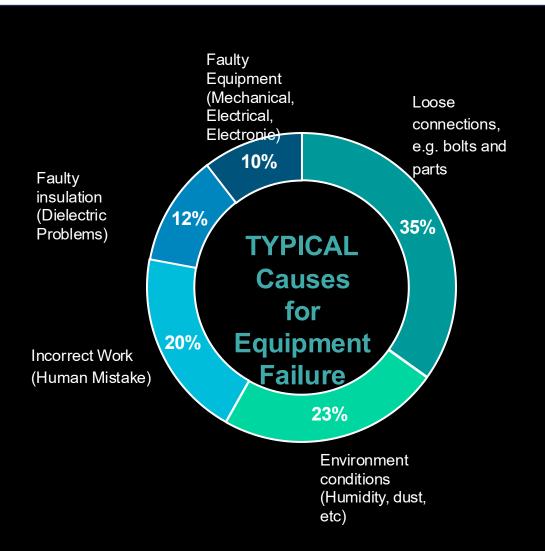
# These measures imply the following **challenges**:

- Most of the time manual process, which calls for visit at site.
- Manual data collection and analysis for decision making.
- Dependency on experts with domain critical knowledge.
- Risk of overlooking of gradual degradation or failure not visible at the time of inspection.
- The optimization of OPEX & improved risk management is not taken

Source: https://www.hsb.com/TheLocomotive/ElectricalPreventiveMaintenance.aspx

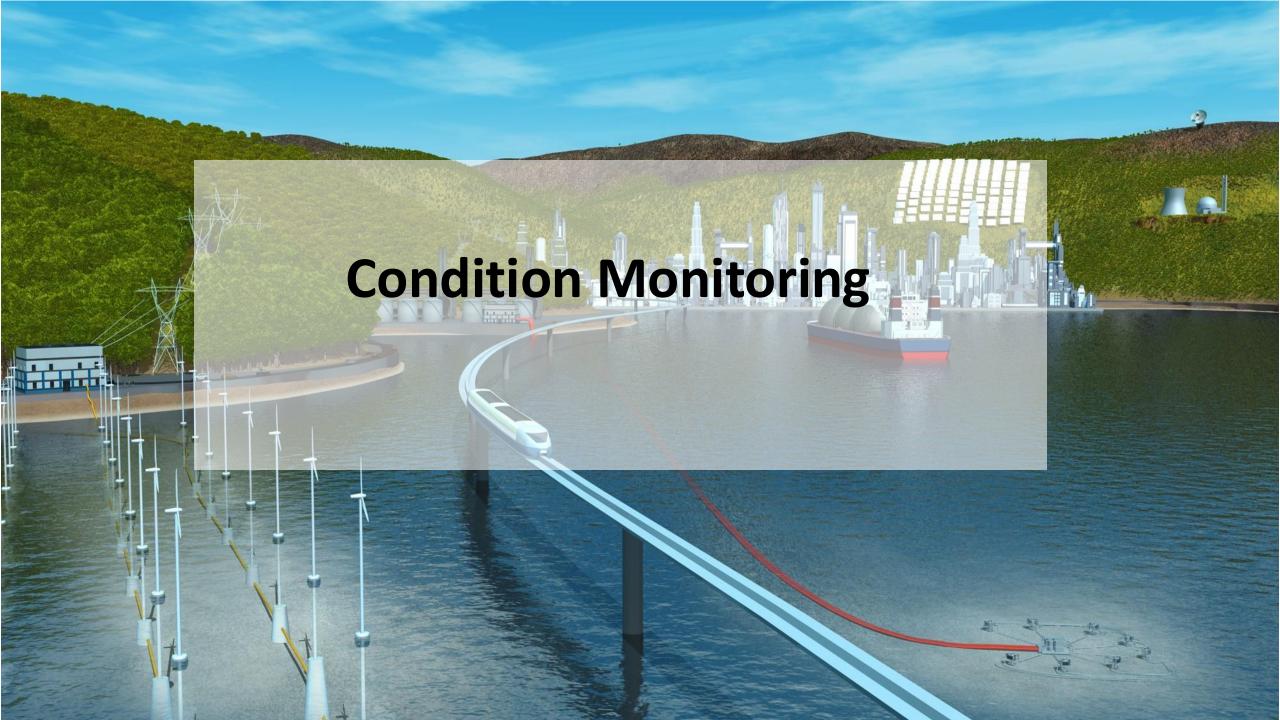
# Unplanned Shutdowns can be reduced 85% by using a proper condition monitoring system





# Examples of early failure detection (e.g. slow changes of behavior/ measured values)

- Temperature Monitoring
  Can detect loose connections (e.g. bolted busbar connections or cable terminations)
  and insufficient contacting (e.g. withdrawable VCB)
- VCB Monitoring
  Can detect faulty VCB mechanism / components (e.g. trip coils, spring charge motors, switching time)
- Partial Discharge Monitoring
  Can detect faulty components / installations (e.g. MV cables, insulators, bushings, voltage transformers)
- Humidity Monitoring
  Can prevent condensation and corrosion (which might lead to mechanical and electrical failures)



#### WHAT Can we do?



#### **Time Based Maintenance on Switchgears**

#### **Primary Elements**

- AC Pressure tests on Circuit breakers
- Insulation tests on power cables and control wires
- Contact resistance tests

#### Secondary Elements

- Lubricate operating and link mechanism
- Check control wire for loose connections
- Secondary injection tests

#### Past Time-based maintenance on Small Oil-Volume Circuit Breaker

Complete overhaul of circuit breaker

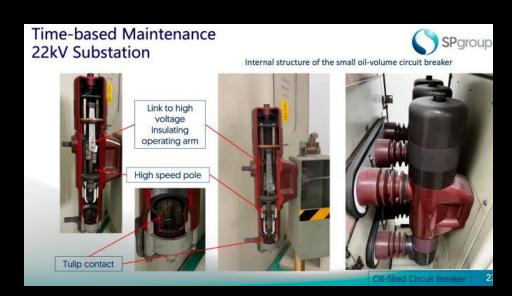
#### **Time Based Maintenance on Transformers**

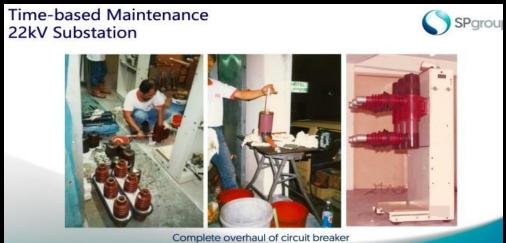
**Primary Elements** 

- Dielectric test on oil
- Purify oil in main tank or replace if necessary
- Replace oil in tap changer compartment
- Ratio test on all tap positions
- Insulation resistance test
   Secondary Elements
- Calibrate and check gauges & relays
- Clean cable termination
- Replace all gaskets
- Check control wire for loose connections

#### **Time Based Maintenance**







Time-based Maintenance 22kV Substation Common Defective Components....







Once a year annual shutdowns Annual maintenance

IS IT ENOUGH?

# **Condition Monitoring (Manual)**







Acoustic Partial Discharge detection

TEV Partial Discharge detection



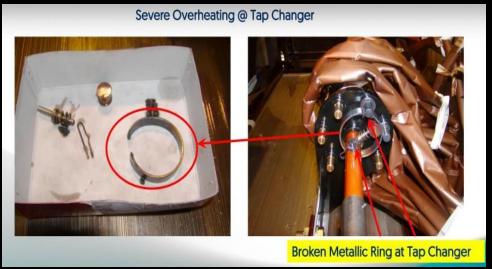
Hot Spot detection



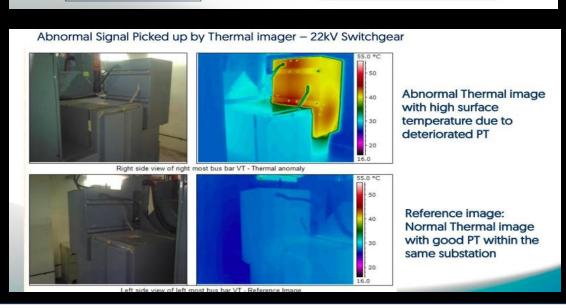
We currently conduct manual condition monitoring every 6 months for 11,000+ stations

# **Condition Monitoring & Findings**





# Discovered by condition monitoring Transformer: HT 22kV Cable termination Picked TEV signals Suspected void discharge



# **Condition Monitoring for Digitalisation**



#### Asset transparency

#### Pain points:

Missing transparency Periodical travel to substations No centralized local/remote HMI Weak basis to make any decisions

#### Customer values:

- Data Collection
- Support on KPIs to help decision making
- Easy to access

### **Energy Monitoring**

#### Pain points:

Missing transparency on loads Missing energy saving potentials

#### Customer values:

- Visualize energy consumption trends
- Visualize electrical parameters
- Develop performance targets for energy management programs





- CAPEX deferment
- Risk management
- Sustainability
- Safety, Cybersecurity



#### Condition Monitoring, Predictive Maintenance

#### Pain points:

Unplanned shutdown
Manual & frequent preventive
maintenance

Weak basis to make CAPEX decisions

#### Customer values:

- Online health status of connected equipment
- Continuous monitoring, instant alarms, early warning of upcoming needs for actions
- Accurate diagnosis of possible faults



#### **Documentation**

#### Pain points:

Missing documents, when needed most Incomplete documents

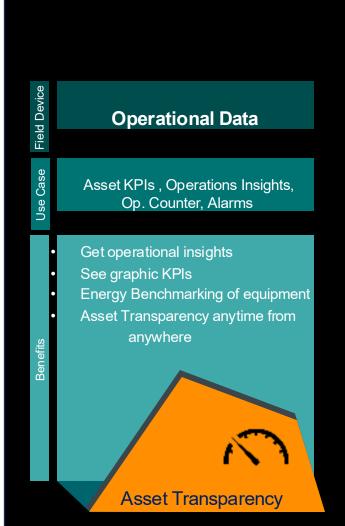
#### **Customer values:**

- Important baseline for continuous improvement
- Manuals, drawings & Reports in one place



# IoT connectivity and Condition Monitoring Modular Options available and their Benefits





# Monitor Busbar Joints & Cables' Terminations

Health Index, Condition Monitoring Time Series, Maintenance (Alarms)

- Identify local overheating at terminals to prevent power outages.
- Awareness of ambient conditions that lead to main failures: humidity (Dew Point), corrosion, oxidation
- terminals
  resulting from explanation
  cable isolation
  can be determinals

Main failures start in cable

Temperature & Unitoring

#### **Monitor Circuit Breaker**

Health Index, Maintenance (Alarms)

- Aging of the main contact based on I2T.
- Aging on mechanical components based on operations.
- Performance based on breaking timing.
- Auxiliary component status based on trip coil analysis and motor spring charger to identify potential issues on command execution and



**CB** Monitoring

#### **Monitor Insulation**

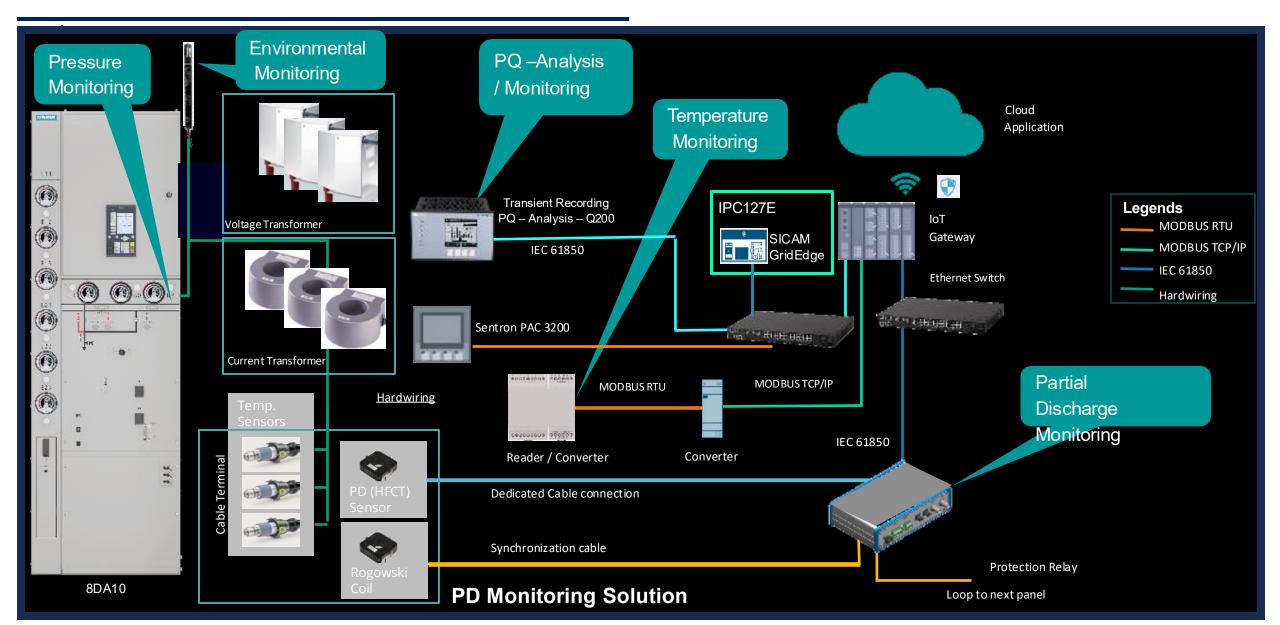
Health Index, Maintenance (Alarms)

- Detect the quality of isolation before an arc flash is produced.
- Determine the deterioration of the insulation before fatal switchgear breakdown and associated power outage.



# **Condition Monitoring in GIS – Sample Architecture**





## **SP-NTU Joint Lab**



- An initiative partially funded by EMA
- Several projects were considered and PA was involved in the following:
  - Distribution Cable Insulation Health Assessment System
  - Insulation resistance (IR) test (typical test only)
  - Polarisation index (PI) test –insulation quality at 1/10 mins
  - Dielectric absorption ratio (DAR) test-insulation quality over time
  - Dielectric discharge (DD) test identify increased aging
  - Step voltage (SV) test- controlled over-voltage test
  - Ramp test (RT) to determine trip current
  - Partial Discharge Monitor and supporting Al analysis software
    - Managed to reduce the cost of monitoring from USD10 k/panel to USD400/panel
    - Budget for entire system would save the utility 800 MUSD (~ 1.1 Billion SGD), including the system costs



SP Group Embarking on \$\$30 million in Research and Education Initiatives with NTU Singapore





Singapore, 19 August 2020





# Case Study on using Condition Monitoring - An industrial Office Operator

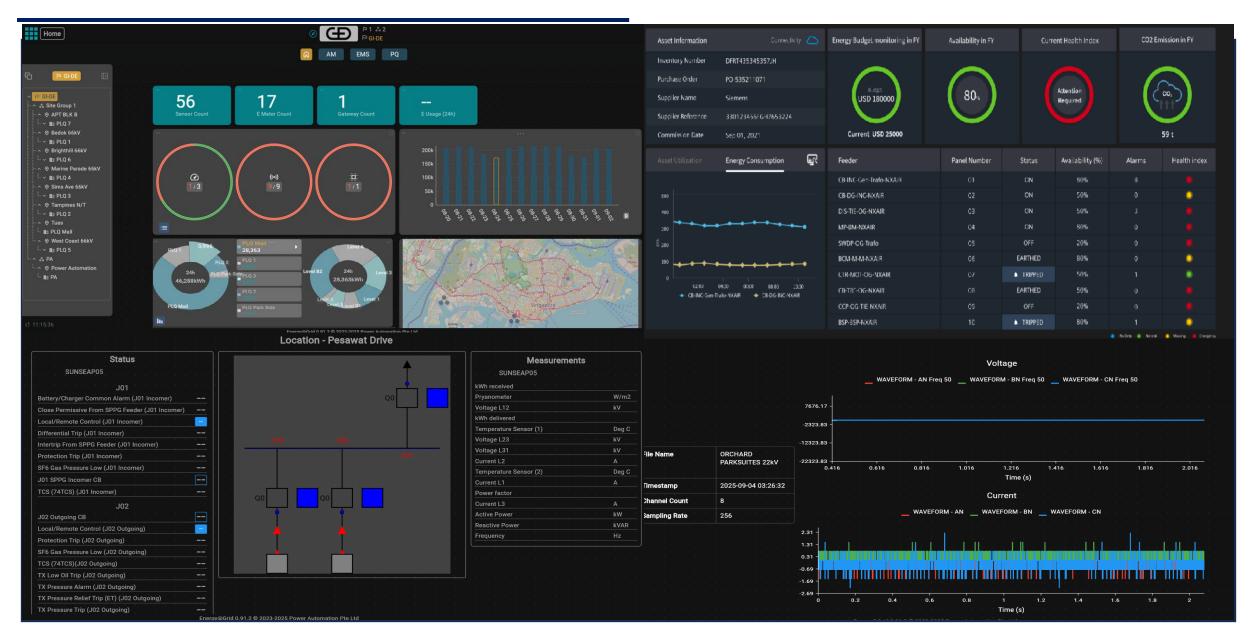


- 300 buildings
- Typically cost 70K USD/building to perform annual shutdown and maintenance
- Budget per year 21 MUSD
- SPPG do maintenance on when the condition monitoring triggers the need. Average time to service – once every 5- 6 years
- Potential savings up to 100 MUSD/every 5 years

- Other advantages
  - Less disruptions
  - More maintenance lead to more accidents
  - Allows target maintenance, knowing what cause it

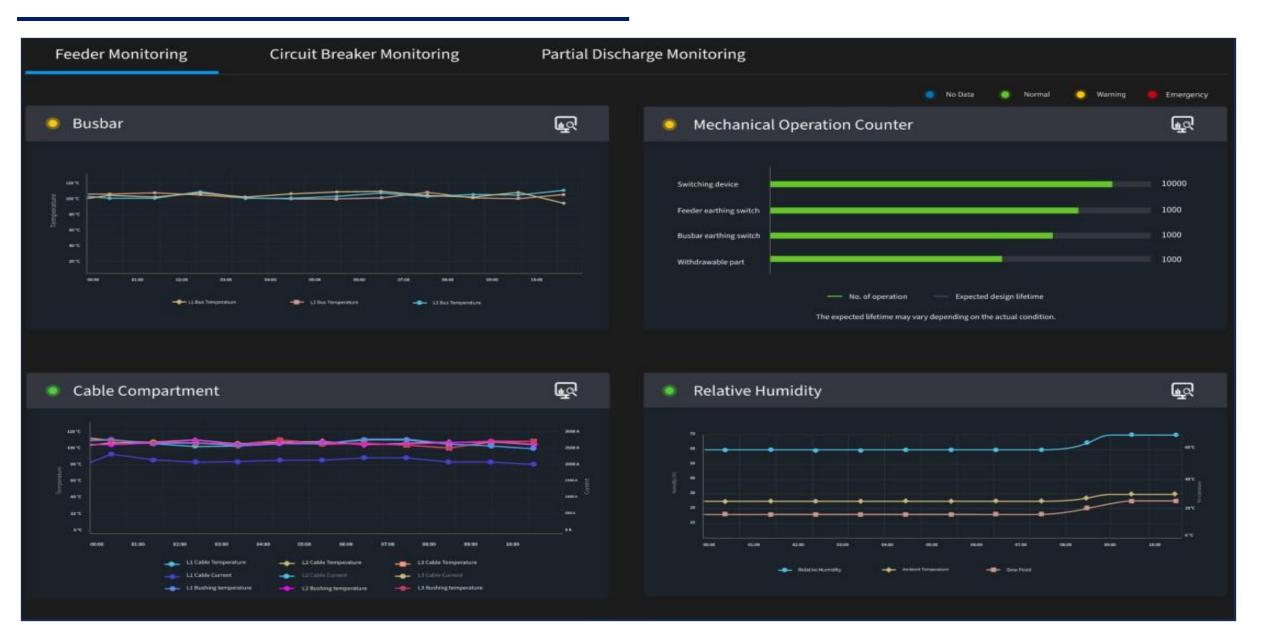
# **Digital Platform in One**





# **Digital Platform in One**

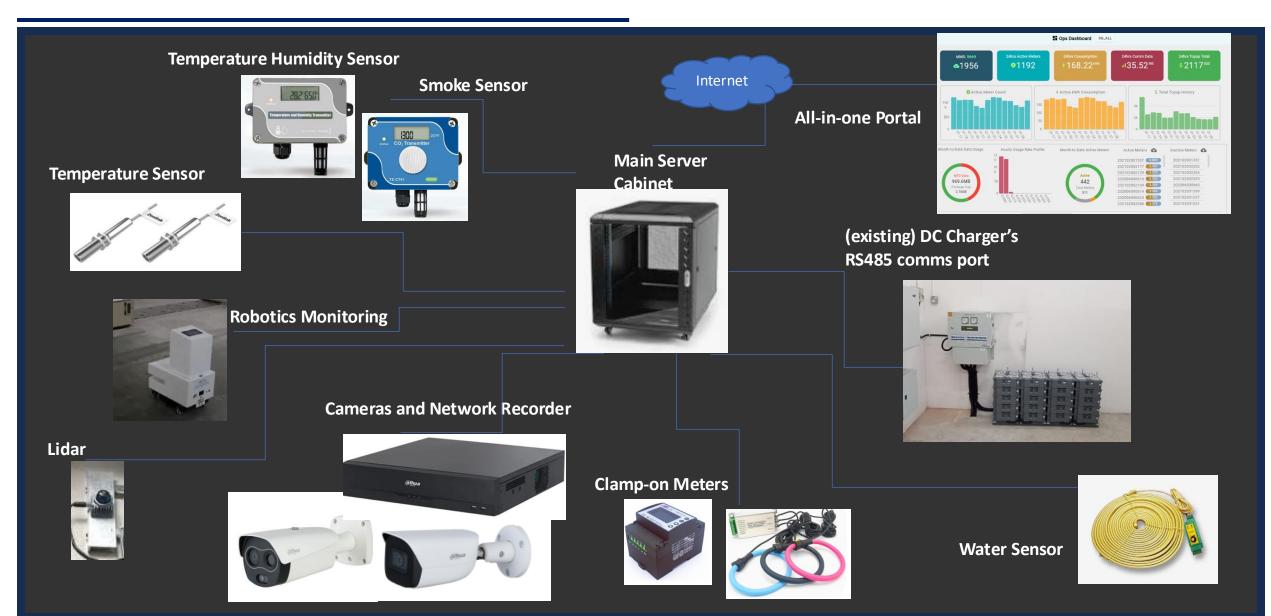






# **Digital Substation Implementation**



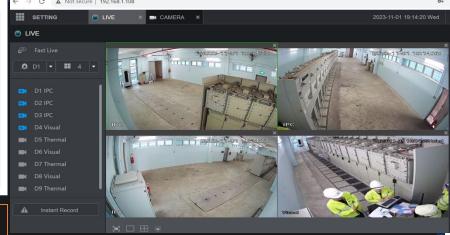


# **Digital Substation @ SP**





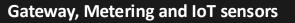


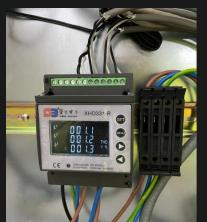
















# Video – Al for PPE





# **Video – Al People Counting**





# **Actual Deployment – Real-time Condition Monitoring with PT/ CT Sensor**







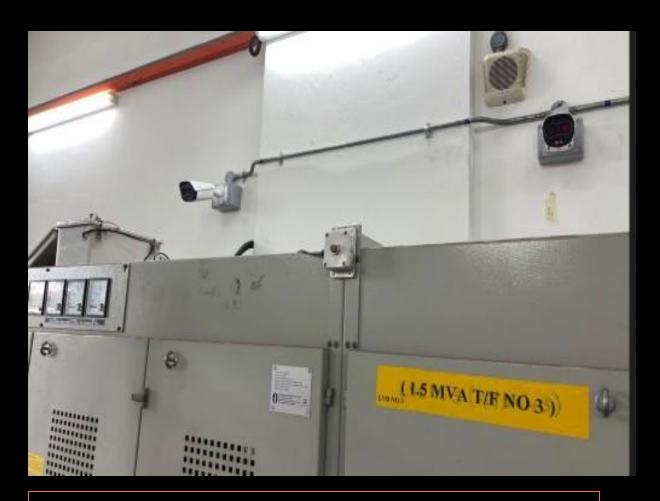


**Incoming and harmonics metering** 

# **Constant Monitoring – Temperature, Humidity and Thermal Sensor**

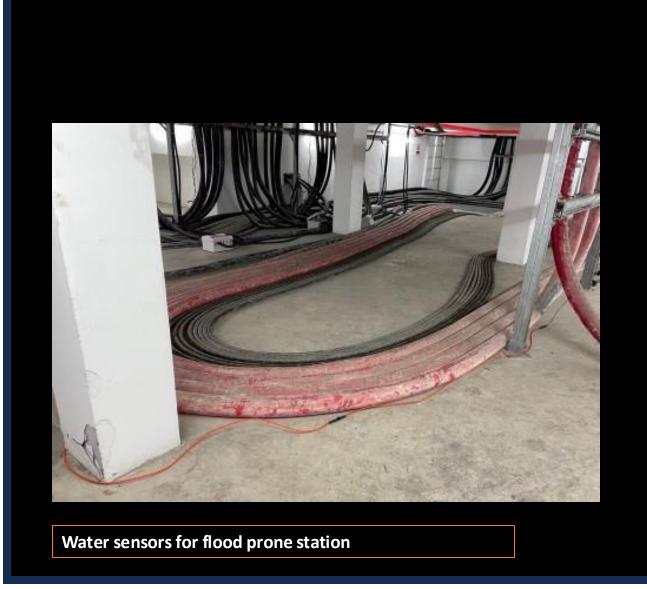


**Temperature Monitoring at the LVB** 



Ambient and environment monitoring within the station

## Other Sensors as site calls for – Water Sensor and Harmonic Sensor





Vibration sensor and temperature sensor for panel

# List of parameters

#### **Definition:**

#### Site ID Site Type 1 400kV Station \*running 5-digit number based on Digital Substation deployment 2 230kV Station 00000 RANGOON 400kV 3 66kV Station 00001 WEST COAST 66kV 4 22kV Station 00002 BRIGHT HILL 66kV 5 6.6kV/LV station 00003 TAMPINES N/T 66kV 9 General - others 00004 BEDOK 66kV 00005 MARINE PARADE 66kV 00006 SIMS AVE 66kV 00007 14 TUAS AVE 5 00008 CAPITAL ONE NO.1 00009 KYODO PRINTING 00010 S'PORE EDAL 99999 Demobox

#### Asset Type General 01 400 kV Switchboard 02 230kV Switchboard 03 66kV Switchboard 04 38kV Switchboard 05 22kV Switchboard 06 500MVA transformer

07 200MVA transformer

08 1.5 MVA transformer

09 LV Board

10 DC Unit

#### Asset No running 2-digit number based on asset number start from 00 General

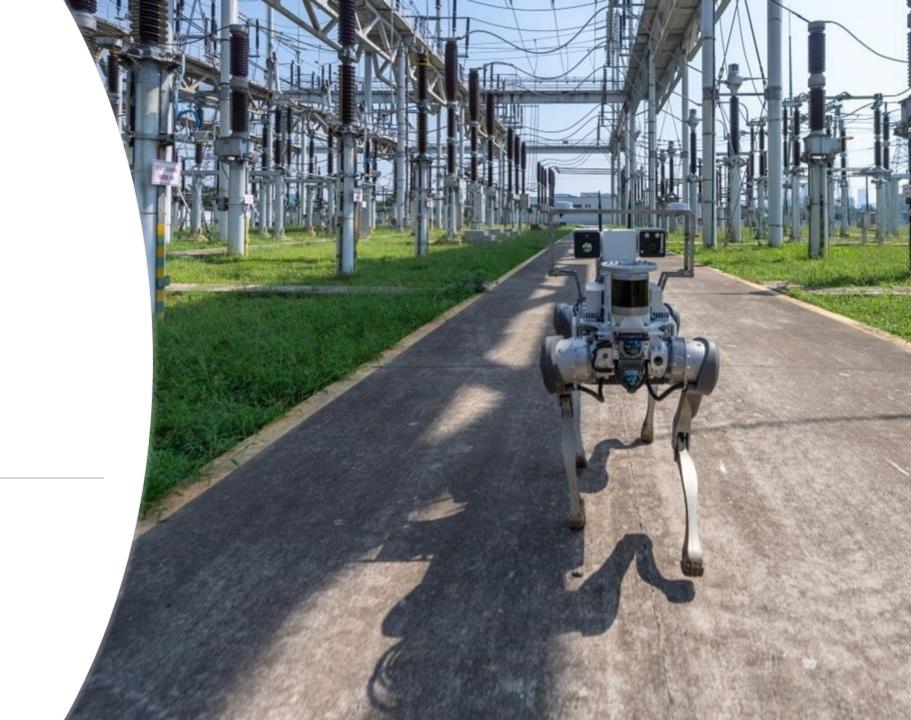
#### Sensor Type 01 IR Temperature Sensor Temperature Sensor - Weld pad 03 Ambient Temperature Multi-CT Meter Smoke Sensor Flood Sensor 07 Saltwater Battery Charger

Data Type 000 Default (to specific sensor) 001 Phase A Current 002 Phase B Current 003 Phase C Current 004 Phase A Voltage 005 Phase B Voltage 006 Phase C Voltage 007 Active Power 008 Reactive Power 009 Apparent Power 010 Active Energy 011 Reactive Energy 012 Phase A Power 013 Phase B Power 014 Phase C Power 015 Power Factor 016 Frequency 017 IR 1 018 IR 2 019 IR 3 020 AC Voltage 021 Output Voltage 022 AC Frequency 023 Output Current 024 Battery Voltage 025 Load Current 026 Inner Temperature 027 Battery State 041 Battery Temp 028 Battery Current 029 Voltage output OverVoltageProtection 030 HardwareFailure 031 Voltage batt OverVoltageProtection 032 AC Power Failure 033 Voltage ac LowVoltageProtection 034 Voltage ac OverVoltageProtection 035 ChargeFail 036 BatReverse 037 DCEarthResWarn 038 BatChgErrWarn 039 Ambient Temperature 040 Ambient Humidity

**Hub Number** 2 digits - For PA to fill in

**Hub Channel** 1 digit - For PA to fill in

# Robotic Inspection



# **Robotic Inspections**



#### 1. ROBOT+ THERMAL INSPECTION ROUNDS

- Automatic inspection of each substation
- Image analysis
- Early Warning signs/ Risk Mitigation

#### 2. LIDAR Analysis

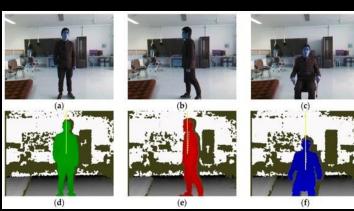
- Real time Analysis of facility
- Intrusion Alerts, Motion Detection

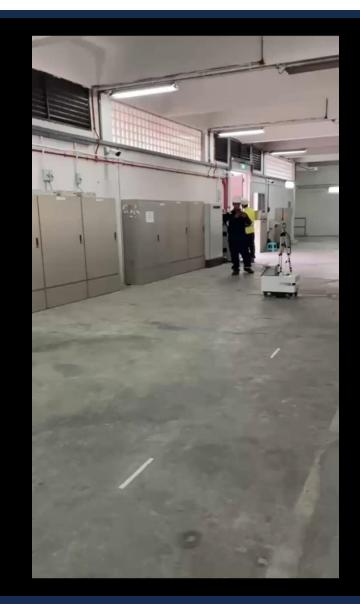
#### 3. Video Analytics and Surveillance

- Video recording and analysis
- Real time Analysis and alerts of situations/ event eg PPE wearing, Personnel falling down/ not moving







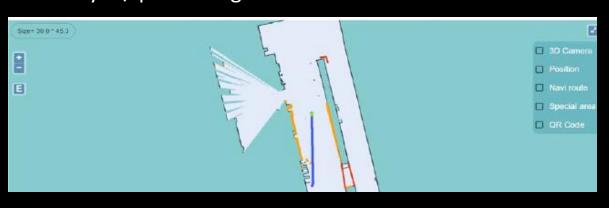


# **Robotic and Learnings**



#### **Robots related activities:**

- Learn and optimize operation path within the station
- Based map plotted, the inspection points will be scheduled in the robotic to visit the allocated points
- Thermal Inspection and image taken at the inspection points
- Other than thermal images, the dial meters are also read for further backend analysis/ processing













# **Lidar and Recording**



The robotic is able to record images at low light, however, it may need to be complemented with detection sensor such as lidar.

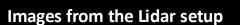
#### **Lidar Testing**

- Further monitors scenario of
- low-light and
- off work-hours

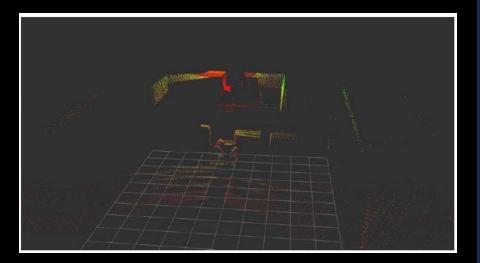
The lidar installed is able to pick up movements within the enclosed stations with low/ no light.

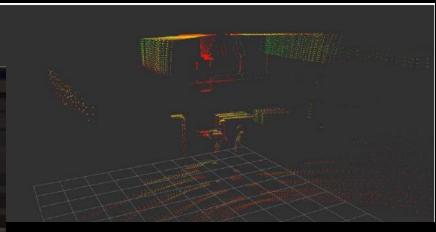


**Images from the Robotic setup** 









# **Monitoring Platform**



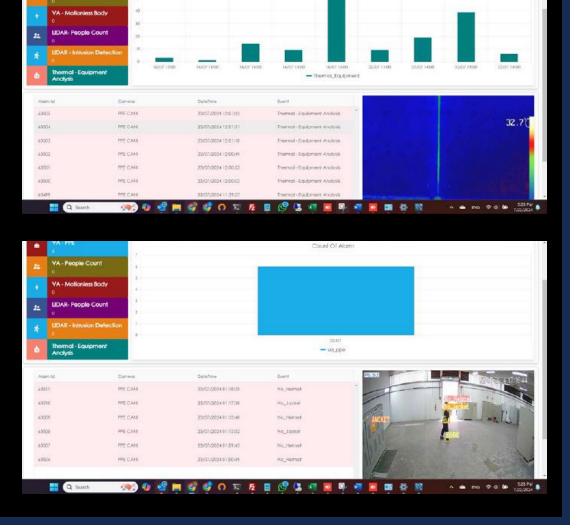
With the data collected at the substation, the data are sent back to the server for further analysis and trending.

The platform information can be view by stakeholders via the web or mobile application.

Notifications and alarms from the site are promptly sent out to stakeholders.

Trending of statistics and site data are conducted at the backend for asset and condition monitoring





# Push towards a common gateway (Trial for 400 stations)

Supports different protocols

Interface to sub-systems

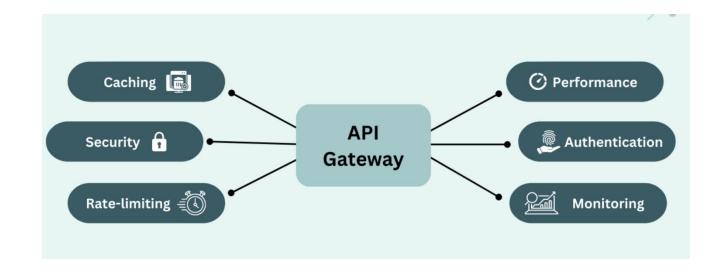
Perform Edge AI analysis

Reduce amount of data stored

Distributed storage of non-critical data

Some examples

- 1. Video Analytics (VA) incident reporting
- 2. Drones control and alarm management
- 3. Transformer condition monitoring
- 4. Partial Discharge monitoring



# Digitalisation's 24/7 Digital Care-Taker



