SPgroup
Empowering the Future of Energy

Substation Asset Management and Condition Monitoring – A SP PowerGrid Case Study

Kerk See Gim, Power Automation

Thanks to
Er. Lim Liang Kuang, PowerGrid

OBJECTIVES

- Share and compare traditional maintenance and condition-based maintenance model
- Encourage customers to practise Condition Monitoring to prevent equipment failures
- Share condition monitoring & condition-based maintenance experiences
- Share how to prevent or reduce voltage dip incidents
- Our Way forward

Impact of Power Outage

Largest-Ever Blackout Hits Eastern U.S.

Aug. 14, 2003

A huge power blackout hit U.S. and Canadian cities Thursday, Aug. 14, 2003, driving workers in New York, in this image from television, into the streets, shutting subways in blistering heat and closing four nuclear power plants in Ohio and New York state. New York City Mayor Michael Bloomberg said there was no evidence of terrorism as a cause. (AP Photo/Courtesy WNBC-NY)

Power outage caused inconvenience to the public

Largest-Ever Blackout Hits Eastern U.S.

Aug. 14, 2003

Stranding people in sweltering subways and sending office workers streaming into the streets in 90-degree F heat.

The blackout, affecting a large portion of north-eastern United States, caused major disruption of businesses and daily life for millions

Power outage caused inconvenience to the public

PD failure leading to a fire (15 Feb 2019)

Carlton Hotel equipment failure leads to power outage

This article is more than **12 months old**

CHOO YUN TING & NG HUIWEN

Feb 15, 2019 06:00 am

First, there was equipment failure at a substation supplying power at Carlton Hotel yesterday.

Then a fire forced the evacuation of around 1,000 people from the Bras Basah building, while lights went out in parts of Bugis, City Hall, Marina and Somerset.

Shops and restaurants at the likes of Chijmes, Plaza Singapura and The Gateway were hit as power was cut off a little after 1pm.

While the trains continued to run, stations on the North-East Line - HarbourFront, Outram Park, Chinatown, Clarke Quay, Dhoby Ghaut, Boon Keng and Potong Pasir - were also affected by blackouts.

The power outage, which lasted for 12 minutes from 1.09pm to 1.21pm, was later linked to the fire.

(Above) Clarke Quay MRT station was one of those affected by blackouts. TNP PHOTOS: KELVIN CHNG, SAHIBA CHAWDHARY

Equipment failure at the electrical substation at Carlton Hotel had led to the power outage and an electricity flashover, or an abnormal electrical discharge.

TOP STORIES THIS MONTH

SINGAPORE

What is the purpose of conducting maintenance service for switchgear, transformer?

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

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

Past Time-based maintenance on Small Oil-Volume Circuit Breaker
- Complete overhaul of circuit breaker

Nameplate and Panel No. must be Visible

All indicator LED/ flags must be clear and visible

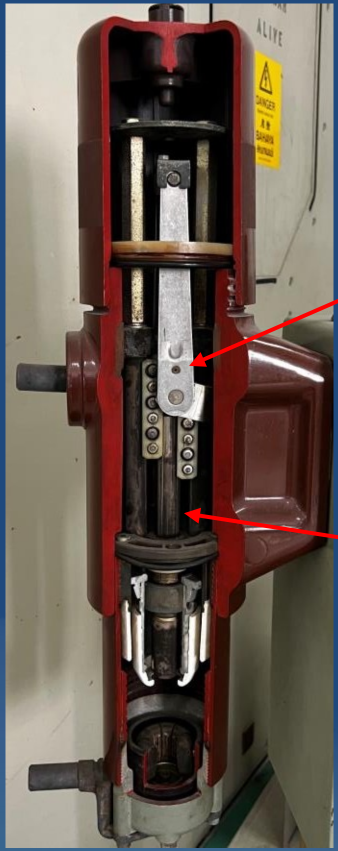
Battery and supporting accessories

Time-based Maintenance
22kV Substation

Complete overhaul of circuit breaker

Time-based Maintenance
22kV Substation

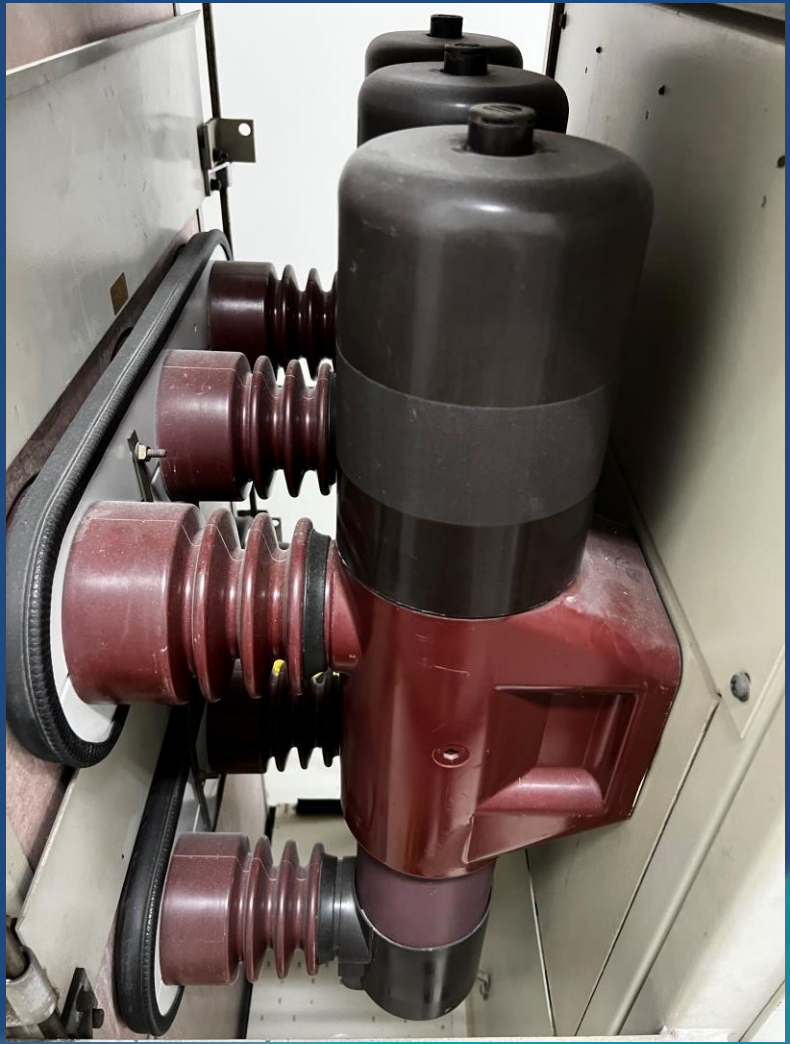
Internal structure of the small oil-volume circuit breaker



Link to high voltage insulating operating arm

High speed pole

Tulip contact



Oil-filled Circuit Breaker

Time-based Maintenance 22kV Substation

Common Defective Components….

Faulty tulip contact assembly

Faulty high voltage insulating operating arm

Time-based Maintenance

- Uncovered hidden components within circuit breaker & bus-bar
- But It cannot prevent power failures

What do we do in Singapore Power?

Maintenance Development

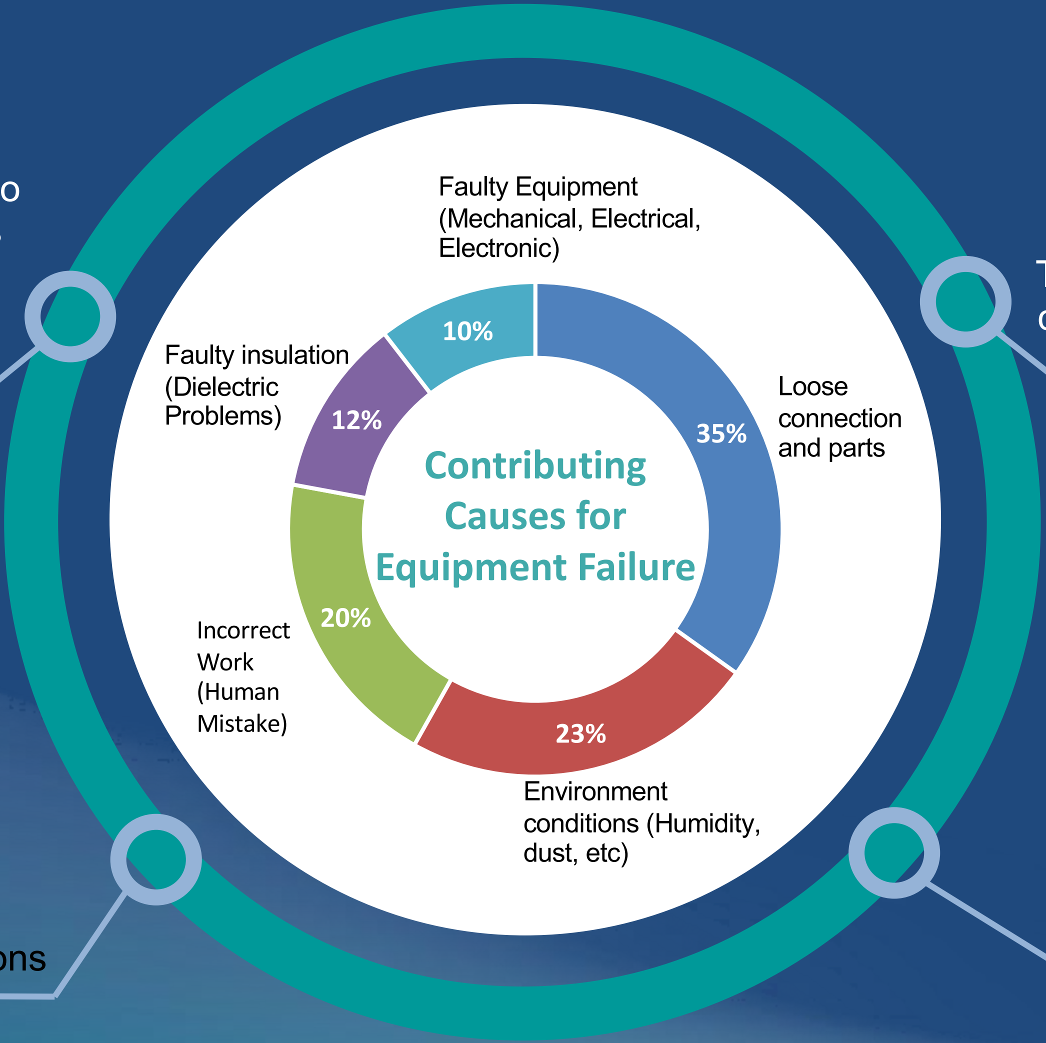
Inspection + Time-based Preventive Maintenance

(Before 1997)

Predictive Maintenance (1998 - 2001)

Condition Monitoring & Condition-based Maintenance (Since August 2001)

The most common causes of electrical distribution asset's failures are well-known and operation/ maintenance managers implement several measures to monitor SWGRs, but this implies some challenges too.



Frequent visits to electrical assets to conduct preventive maintenance

Thermal scanning of connections through portable devices

Shutdowns to check components and switching devices, check bolted connections (e.g. torque measurements), cleaning of equipment, etc.

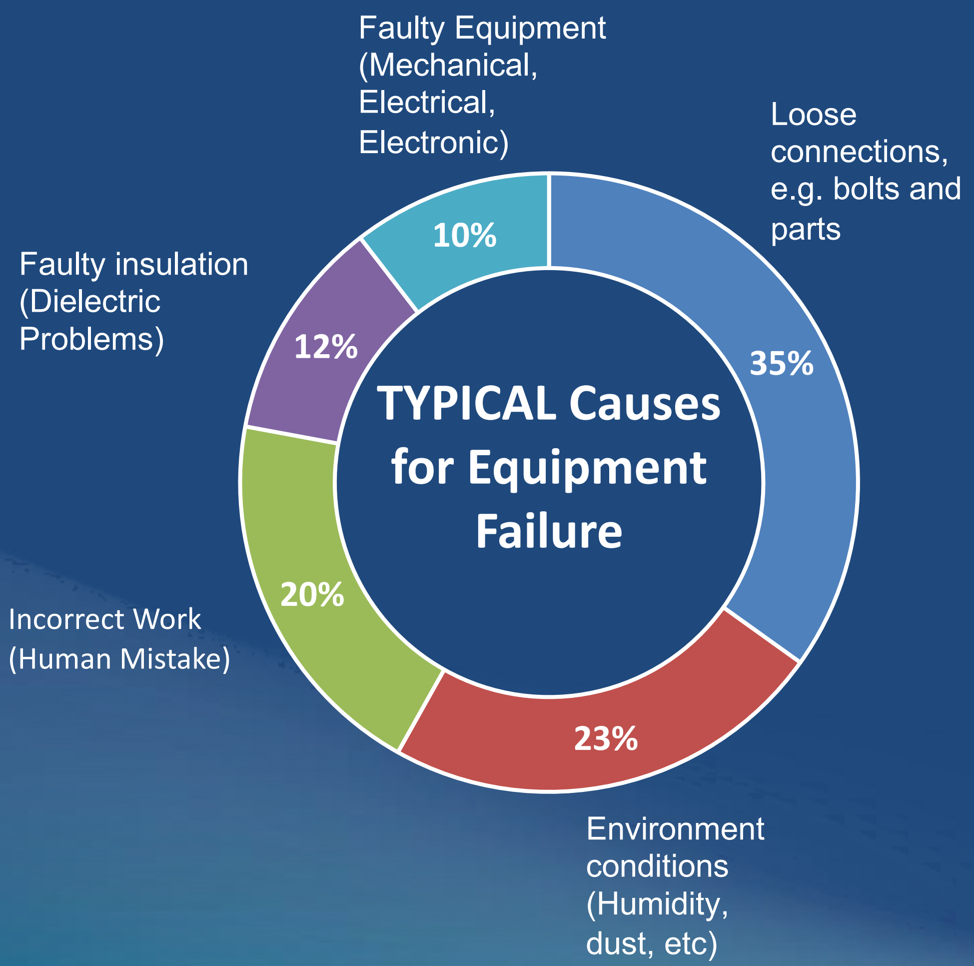
Visual inspections

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 care of

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)

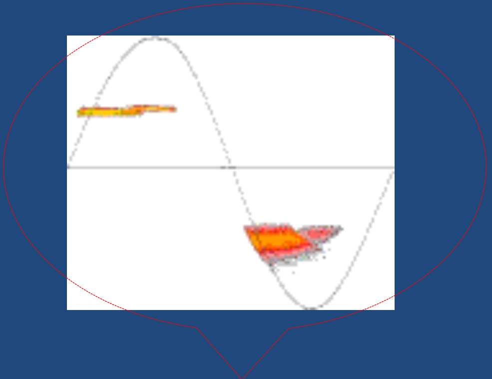
1. **Temperature Monitoring**
   Can detect loose connections (e.g. bolted busbar connections or cable terminations)
   and insufficient contacting (e.g. withdrawable VCB)

2. **VCB Monitoring**
   Can detect faulty VCB mechanism / components (e.g. trip coils, spring charge motors, switching time)

3. **Partial Discharge Monitoring**
   Can detect faulty components / installations (e.g. MV cables, insulators, bushings, voltage transformers)

4. **Humidity Monitoring**
   Can prevent condensation and corrosion (which might lead to mechanical and electrical failures)

Condition Monitoring



Network Doctor

Network Health Screening

Human Health Screening

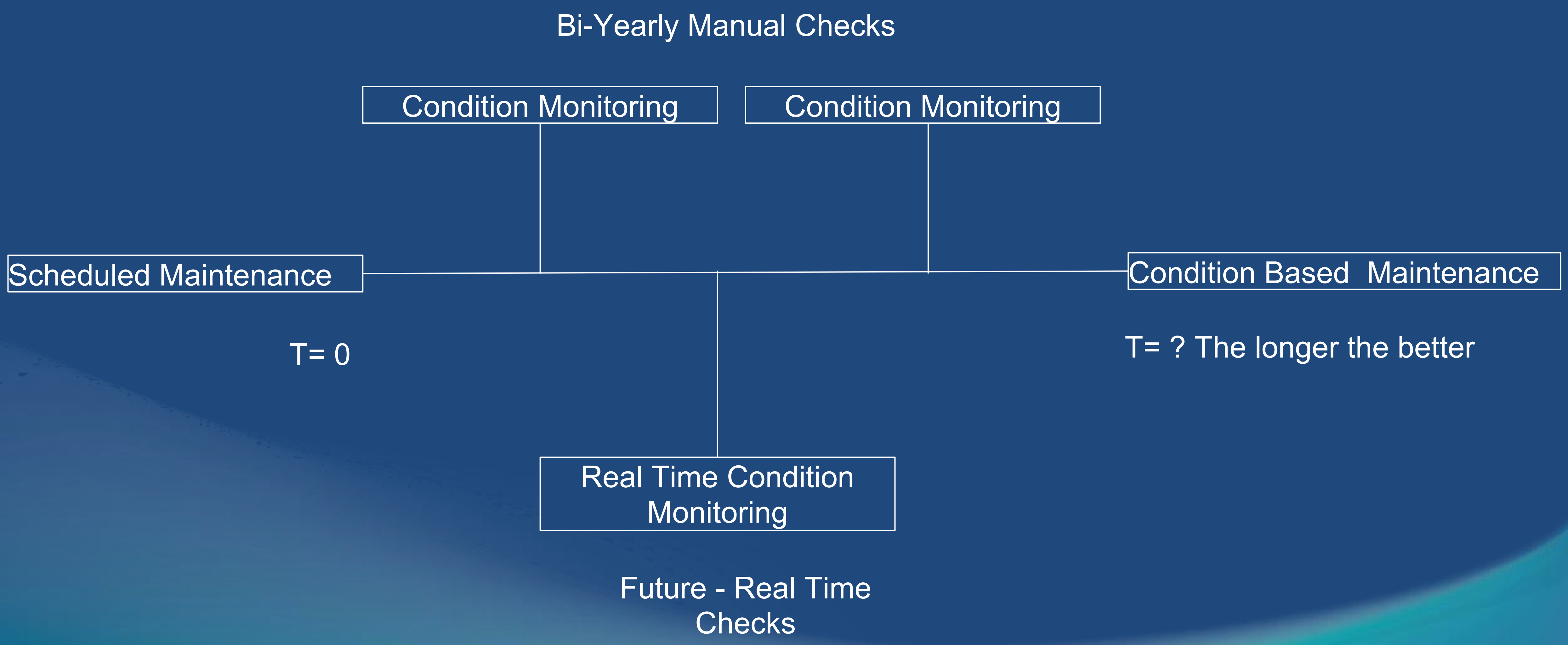
Diagnostic tools for Network Health Screening

Maintenance Strategy

Current maintenance model inclusive of

- Inspection
- Time-based Maintenance
- Condition Monitoring
- Condition-based Maintenance

MAINTENANCE STRATEGY



Condition Monitoring

Ultrasonic Detection

TEV Detection

Temperature Detection

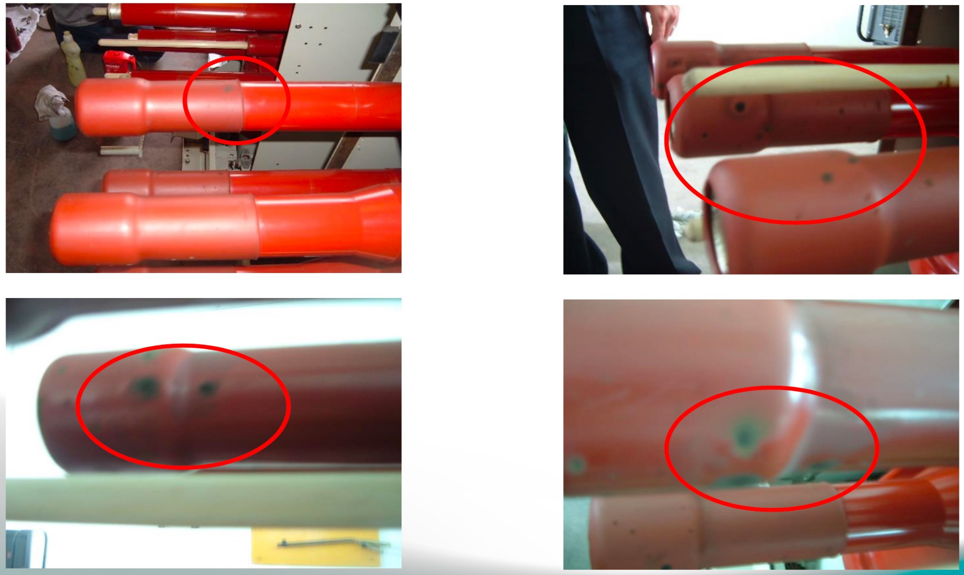
Condition Monitoring

Acoustic Partial Discharge detection

TEV Partial Discharge detection

Hot Spot detection

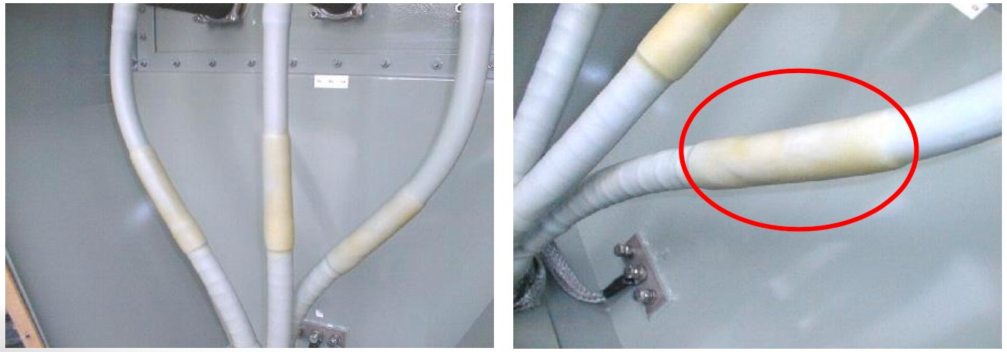
CONDITION BASED MAINTENANCE



Tracking spots showed high electrical stress at circuit breaker arms

Discovered by condition monitoring

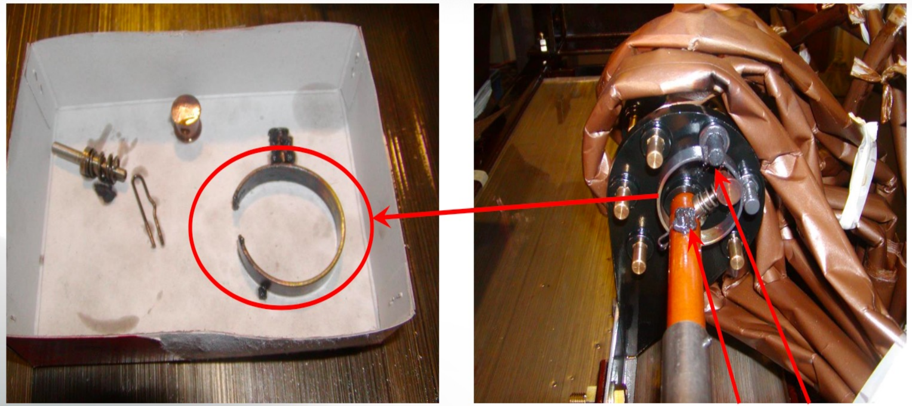
Transformer : HT 22kV Cable termination



Picked TEV signals

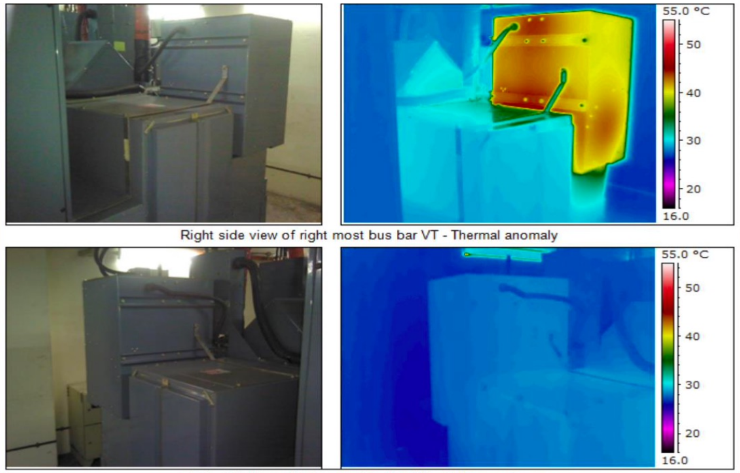
Suspected void discharge

Severe Overheating @ Tap Changer



Broken Metallic Ring at Tap Changer

Abnormal Signal Picked up by Thermal imager – 22kV Switchgear



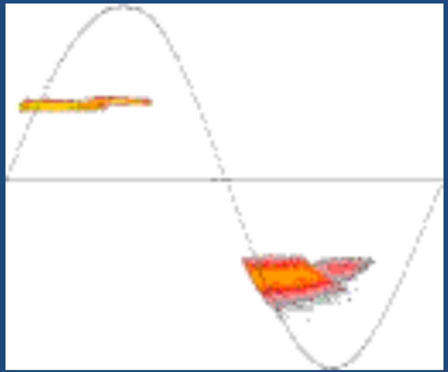
Right side view of right most bus bar VT - Thermal anomaly

Abnormal Thermal image with high surface temperature due to deteriorated PT

Left side view of left most bus bar VT - Reference Image

Reference image: Normal Thermal image with good PT within the same substation

Condition Monitoring Tools for Distribution Assets



Acoustic Instrument
- Air mode
- Contact mode

Transient Earth Voltage (TEV) Instrument

Thermal Imaging Instrument

Outcome of Condition Monitoring

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 *

Network Failures Averted by Condition Monitoring

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Network	400kV	230kV	66kV	22kV	6.6kV	Total
Failures Averted	32	72	84	884	637	1,709

A

S$253.98m
Cost of Fault

B

S$95.82m

Cost of Condition Monitoring

C

S$57.16m

Cost of Rectification

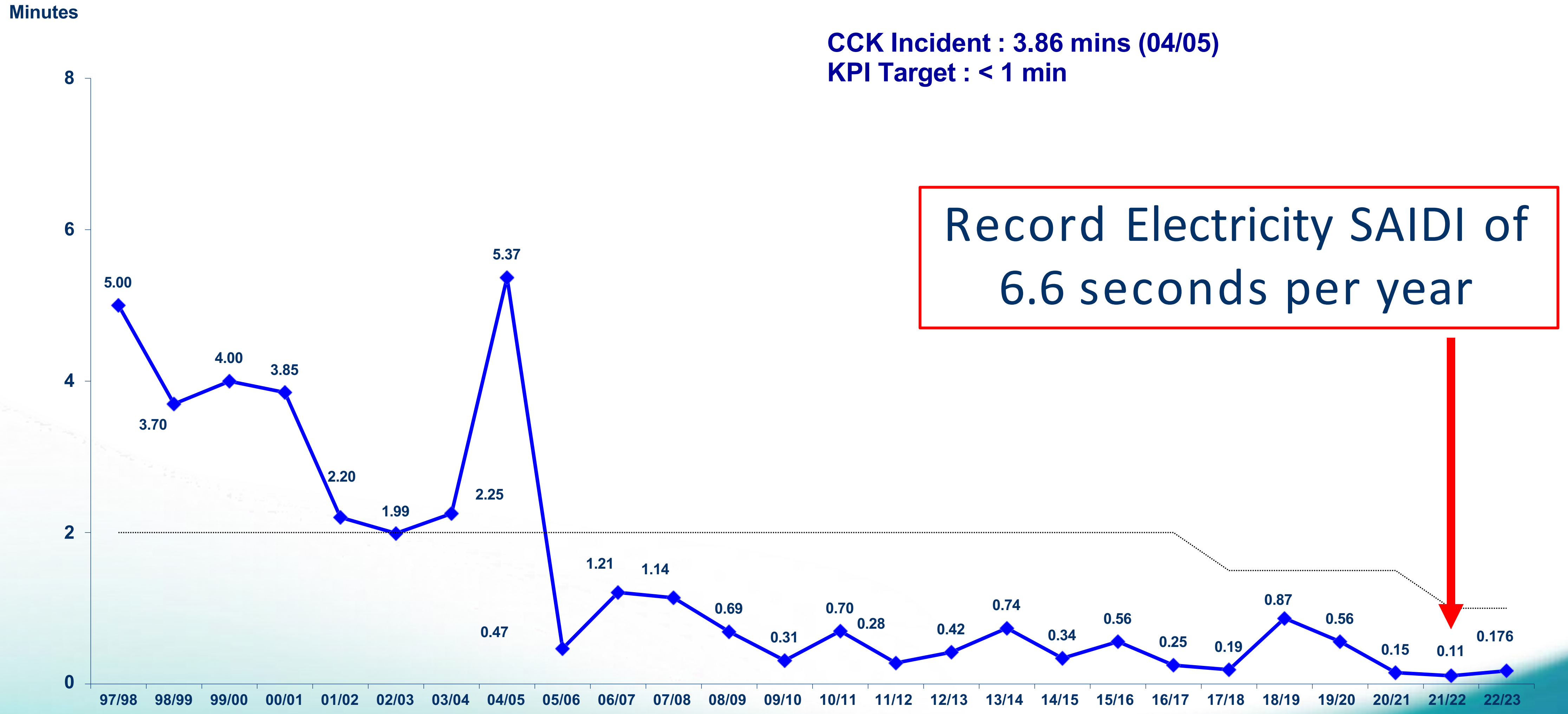
D

S$101m
Cost Avoidance

Cost Avoidance D = A – B – C

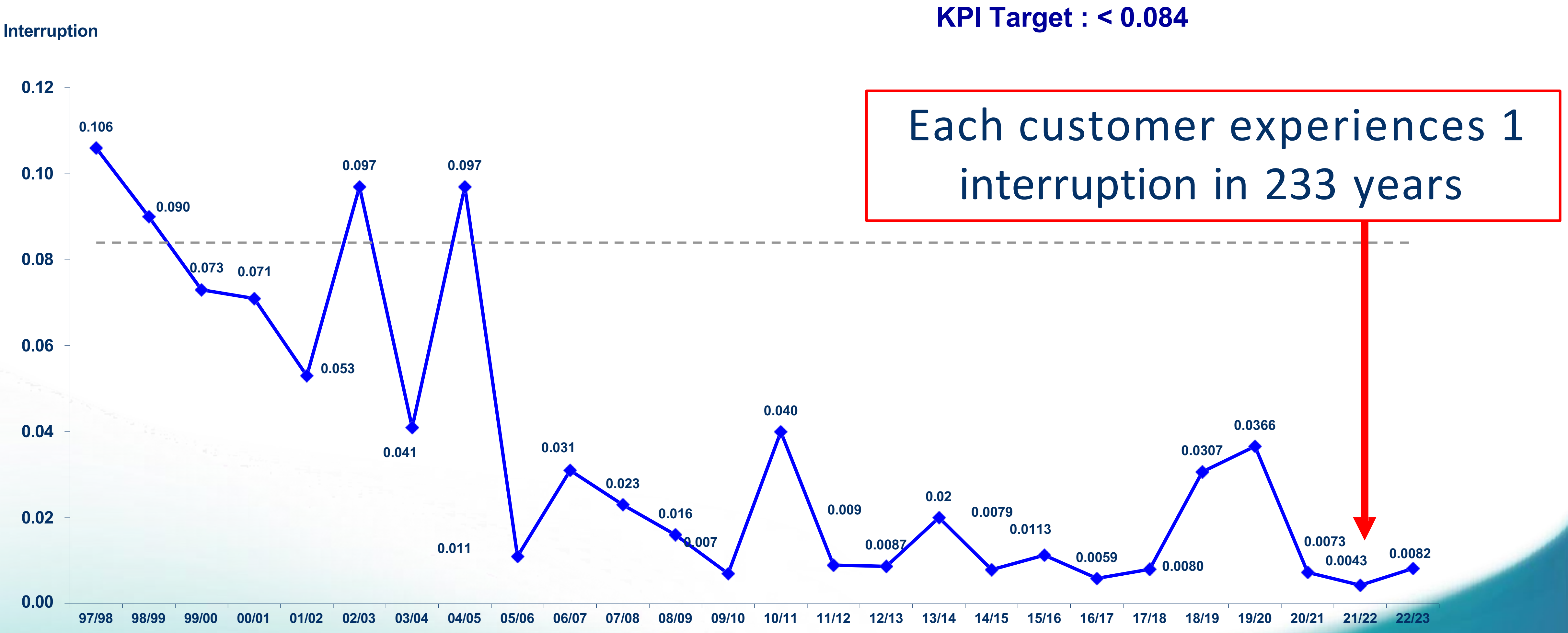
*** Up to 31 Mar 23**

System Average Interruption Duration Index (SAIDI) - Elect



Up to 31 Mar 2023

System Average Interruption Frequency Index (SAIFI) - Elect



Up to 31 Mar 2023

Going Forward

Condition Monitoring: Circuit Breaker Monitoring

Crucial component monitoring
(e.g. Circuit Breaker Monitoring)

- Faulty equipment
  e.g. faulty trip coils, VCB spring charging mechanism, VCB timing

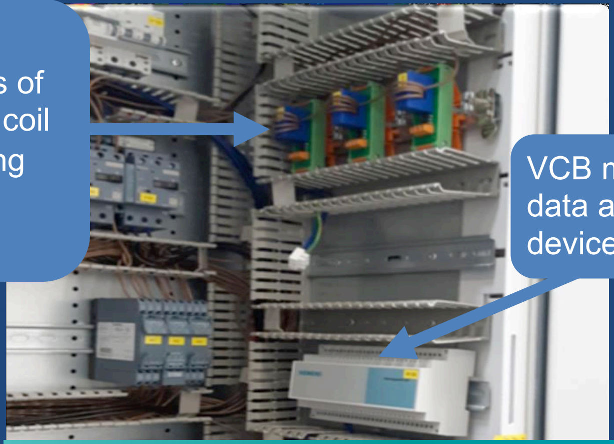
- Electrical Lifetime
  of the main VCB contacts based on I2t

- Mechanical lifetime
  of the VCB based on number of operations

CT sensors for AC supply

Assetguard IoT - VCB monitoring data acquisition device

Hall Sensors (monitor currents of trip coil , closing coil and VCB charging motor



VCB monitoring data acquisition device

Hall sensors and VCB monitoring device in LV Compartment

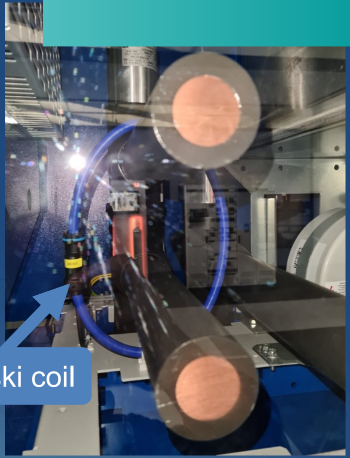
Condition Monitoring: Partial Discharge Monitorir

- Defective components
  e.g. damaged insulators, bushings, voltage transformers
- Degradation of insulating media
  e.g. aging
- Faulty manufacturing
  e.g. sharp edges of busbars instead of rounded edges
- Faulty installation
  e.g. wrong installation of voltage transformers at GIS
- Aggressive environment conditions
  e.g. ingress of dust and moisture

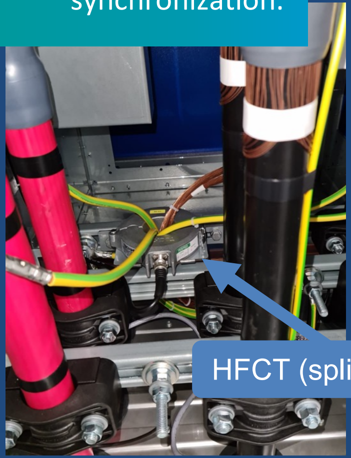
PD Monitoring unit

GIS: Earth screens of all MV cables in a feeder through an HFCT (High-frequency-CT) and one Rogowski coil per busbar section for synchronization.

AIS: Same Antennas used to receive temperature values from SAW sensors will be used for partial discharge detection



Rogowski coil



HFCT (split core)

ROBOTIC INSPECTION

Siemens AG | NXpower Monitor | powered by SIEMENS MindSphere

Locate
Summary
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Health
Maintenance
Configure
Notification
Language
Help

Mumbai › Kalwa-Substation-H4161 › SWG-NXAIR

Asia/Kolkata 2022-07-29 11:03 AM

SWG-NXAIR

2D 3D

SWG-NXAIR

Asset Information

Connectivity

Inventory Number	DFRT435345357JH
Purchase Order	PO-535211071
Supplier Name	Siemens
Supplier Reference	330123456FGH7653224
Commission Date	Sep 01, 2021

Energy Budget monitoring in FY

Budget
USD 180000

Current USD 25000

Availability in FY

80%

Current Health Index

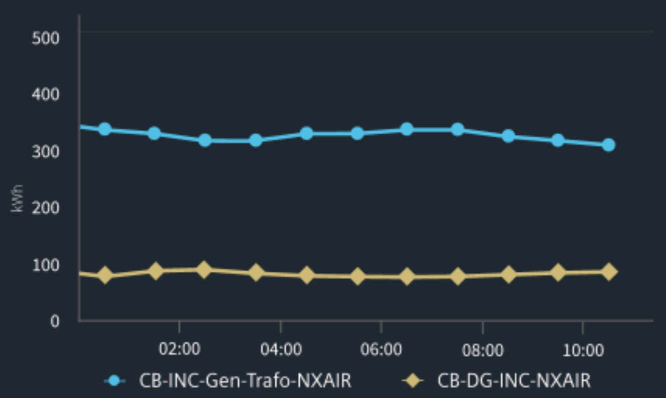
Attention Required

CO2 Emission in FY

CO_2

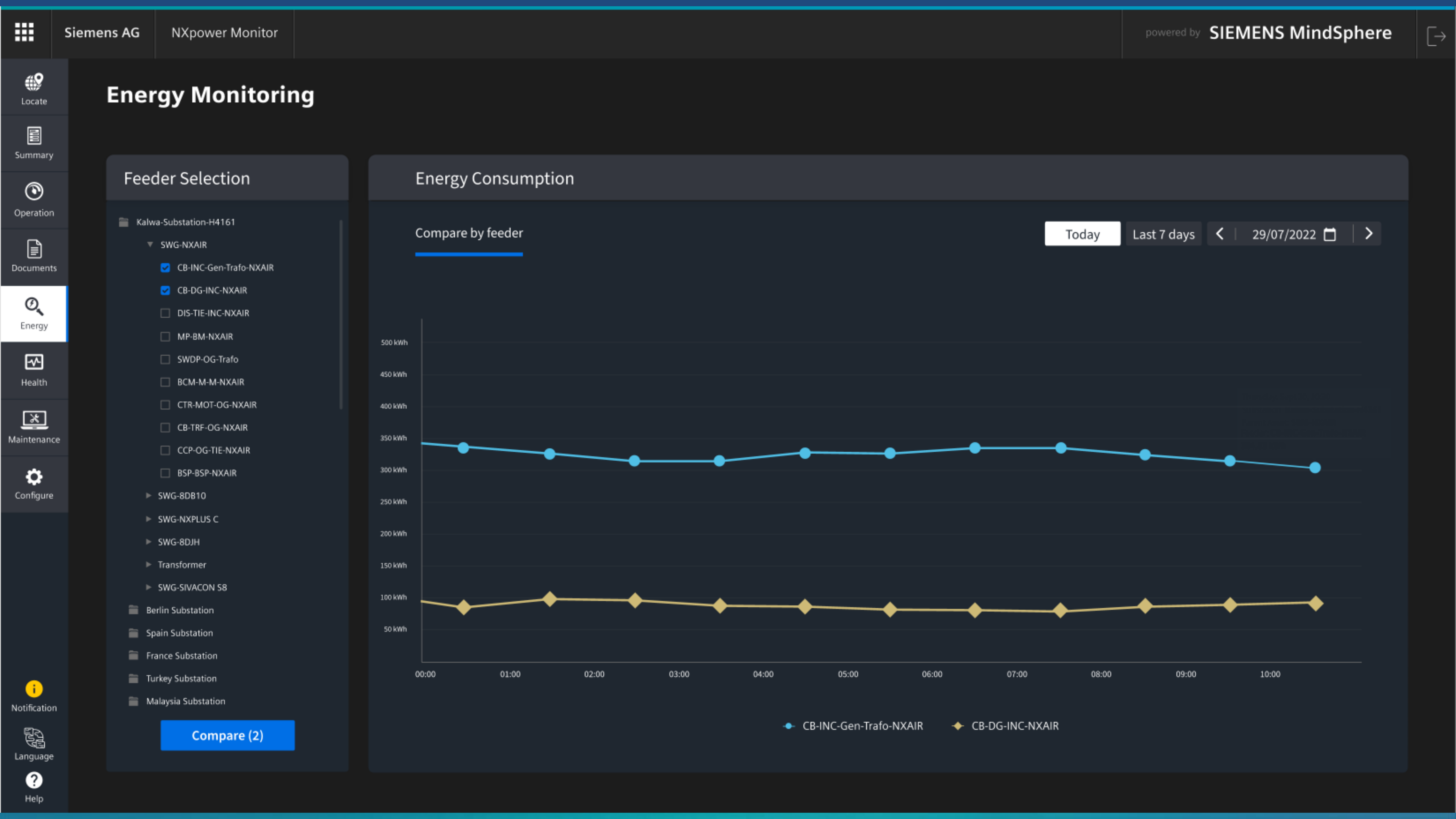
59 t

Asset Utilization | Energy Consumption



Feeder	Panel Number	Status	Availability (%)	Alarms	Health index
CB-INC-Gen-Trafo-NXAIR	01	ON	80%	8	
CB-DG-INC-NXAIR	02	ON	50%	0	
DIS-TIE-OG-NXAIR	03	ON	50%	3	
MP-BM-NXAIR	04	ON	80%	0	
SWDP-OG-Trafo	05	OFF	20%	0	
BCM-M-M-NXAIR	06	EARTHED	80%	0	
CTR-MOT-OG-NXAIR	07	TRIPPED	50%	1	
CB-TRF-OG-NXAIR	08	EARTHED	50%	0	
CCP-OG-TIE-NXAIR	09	OFF	20%	0	
BSP-BSP-NXAIR	10	TRIPPED	80%	1	

No Data · Normal · Warning · Emergency



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Energy Monitoring
Feeder Selection
Kalwa-Substation-H4161
SWG-NXAIR
CB-INC-Gen-Trafo-NXAIR
CB-DG-INC-NXAIR
DIS-TIE-INC-NXAIR
MP-BM-NXAIR
SWDP-OG-Trafo
BCM-M-M-NXAIR
CTR-MOT-OG-NXAIR
CB-TRF-OG-NXAIR
CCP-OG-TIE-NXAIR
BSP-BSP-NXAIR
SWG-8DB10
SWG-NXPLUS C
SWG-8DJH
Transformer
SWG-SIVACON S8
Berlin Substation
Spain Substation
France Substation
Turkey Substation
Malaysia Substation
Compare (2)
Energy Consumption
Compare by feeder
Today
Last 7 days
29/07/2022
500 kWh
450 kWh
400 kWh
350 kWh
300 kWh
250 kWh
200 kWh
150 kWh
100 kWh
50 kWh
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
CB-INC-Gen-Trafo-NXAIR
CB-DG-INC-NXAIR

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Locate
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Mumbai > Kalwa-Substation-H4161 > SWG-NXAIR > Conditioning Monitoring Overview

NXAIR - Condition Monitoring Overview

Kalwa-Substation-H4161 | NXAIR

Feeder	Panel No.	Temperature Monitoring			Humidity Monitoring	Mechanical Operation Counter				
		Busbar	Cable Compartment	Bushing		Switching Device	Withdrawal Part	Earthing Switch	Bus Earthing Switch	Busbar
CB-INC-Gen-Trafo-NXAIR	01	🟡	🟢	🟢	🟢	🟡	🟢	🟢	🟢	🔴
CB-DG-INC-NXAIR	02	🟢	🟡	🟡	🟢	🟢	🟡	🟡	🟢	🟢
DIS-TIE-OG-NXAIR	03	🟡	N/A	🟡	🟡	🟡	🔴	🔴	N/A	N/A
MP-BM-NXAIR	04	🔴	N/A	N/A	🔴	🔴	🔴	🔴	🔴	N/A
SWDP-OG-Trafo	05	🔴	🟡	N/A	🔴	🔴	🟡	🟡	N/A	N/A
BCM-M-M-NXAIR	06	🟡	🟢	N/A	🟡	🟡	🟢	N/A	🟡	🟢
CTR-MOT-OG-NXAIR	07	N/A	N/A	N/A	🟢	🟢	🟢	N/A	🟢	🟢
CB-TRF-OG-NXAIR	08	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
CCP-OG-TIE-NXAIR	09	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴	🔴
BSP-BSP-NXAIR	10	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡	🟡

🔵 No Data 🟢 Normal 🟡 Warning 🔴 Emergency

Notification
Language
Help

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Thank You

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