पावरग्रिड
POWERGRID

# Best Practices in Maintenance of Transmission System

BIMSTEC
BIMSTEC ENERGY CENTRE
Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation

Online Knowledge Sharing Workshop

8-Feb-26

# Overview

## India's **FLAGSHIP** Power Transmission Utility

MAJOR SHAREHOLDING
GoI: **51.34%** | FIIs: **24.73%** | DIIs: **20.26%**

SUBSIDIARIES: **78** | JOINT VENTURES: **13**

MOU RATING: **"Excellent"** since inception

Gross Fixed Assets: **> ₹3 Trillion**

## CREDIT RATINGS

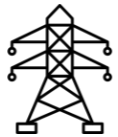
| Domestic | | | International* | | |
|---|---|---|---|---|---|
| **AAA** (Highest Safety) | **AAA** (Highest Safety) | **AAA** (Highest Safety) | **BBB** (Outlook: Stable) | **BBB-** (Outlook: Stable) | **Baa3** (Outlook: Stable) |
| Crisil Ratings | ICRA | CareEdge Ratings | S&P Global Ratings | FitchRatings | Moody's |

*All information as on 31.12.2025* **At par with Sovereign*

# Transmission Assets

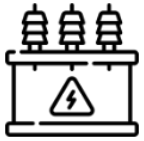
STRENGTHENING THE NATIONAL GRID TO MEET **CURRENT** AND **FUTURE POWER DEMAND**

**Transmission Lines**



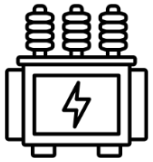
**1,566 nos.**
**1,83,174 ckm**

**Sub-Stations**



**288 nos.**
**5,99,016 MVA**

**IR* capacity**



**~101 GW**
**84% of total IR**

**System Availability**

**99.84%**

** Inter-Regional Capacity*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **>2,92,000** TRANSMISSION TOWERS | **18** HVDC SUBSTATIONS | **70** 765 kV SUBSTATIONS | **169** 400 kV SUBSTATIONS | **31** SUBSTATIONS (below 400 kV) | **22** SVC/ STATCOMS | **201** AIS SUBSTATIONS | **68** GIS SUBSTATIONS | **>4,000** TRANSFORMERS & REACTORS |

WORLD'S LARGEST **765kV** TRANSMISSION NETWORK IS OPERATED BY POWERGRID

*Availability as on 31.12.2025 and all other information as on 31.01.2026*

# Best Practices

## Factors leading to high Transmission Asset Management Performance Levels

# POWERGRID Asset Management Policy

Bureau Veritas Certification

POWER GRID CORPORATION OF INDIA LIMITED

SAUDAMINI, PLOT NO. 2, SECTOR-29, GURGAON – 122 001, HARYANA, INDIA.

*Bureau Veritas Certification Holding SAS – UK Branch certifies that the Management System of the above Organisation has been audited and found to be in accordance with the requirements of the Management System Standard detailed below.*

*Standard*

**ISO 55001:2014**

*Scope of certification*

**Asset Management of transmission system upto +/- 800 KV HVDC and 765 KV AC network including NTAMC (National Transmission Asset Management Centre) & RTAMC (Regional Transmission Asset Management Centres)**

Original cycle start date: **06 June 2024**
Expiry date of previous cycle: **Not Applicable**
Certification Audit date: **31 March 2024**
Certification cycle start date: **06 June 2024**

Subject to the continued satisfactory operation of the Organisation's Management System, this certificate is valid until: **05 June 2027**

Certificate No. **IND.24.3009/A/U-1** Version: **1** Issue date: **06 June 2024**

*Signed on behalf of BVCH SAS UK Branch*
*Jagdheesh N. MANIAN*
*Director – CERTIFICATION, South Asia*
*Commodities, Industry & Facilities Division*

UKAS MANAGEMENT SYSTEMS 0008

*Certification body address: 5th Floor, 66 Prescot Street, London, E1 8HG, United Kingdom.*

*Local office: Bureau Veritas (India) Private Limited (Certification Business) 72 Business Park, Marol Industrial Area, MIDC Cross Road "C", Andheri (East), Mumbai – 400 093, India.*

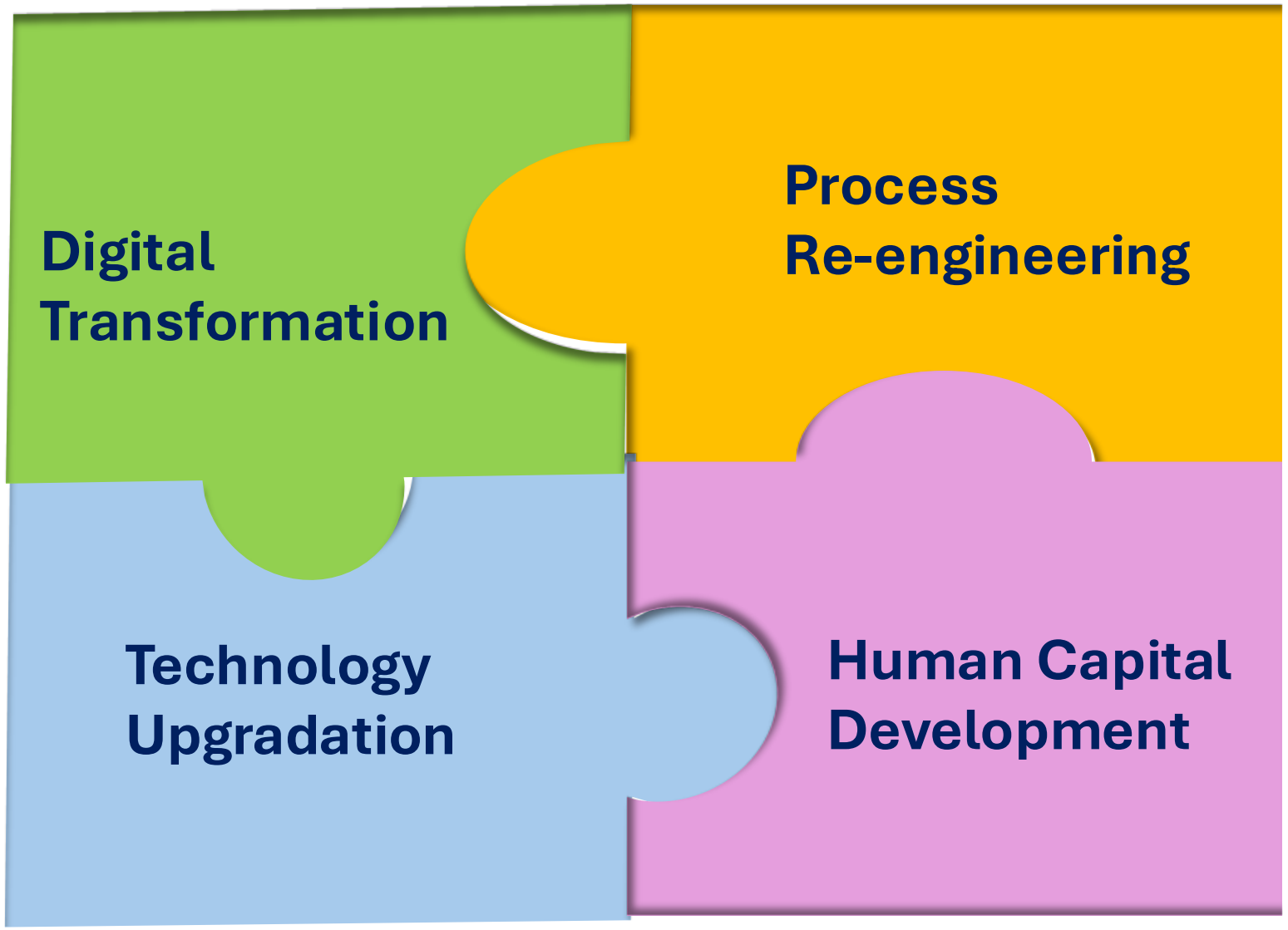
Further clarifications regarding the scope of this certificate and the applicability of the management system requirements may be obtained by consulting the organisation.
To check this certificate validity please call **+ 91 22 6274 2000.**

The policy reaffirms POWERGRID's commitment towards:

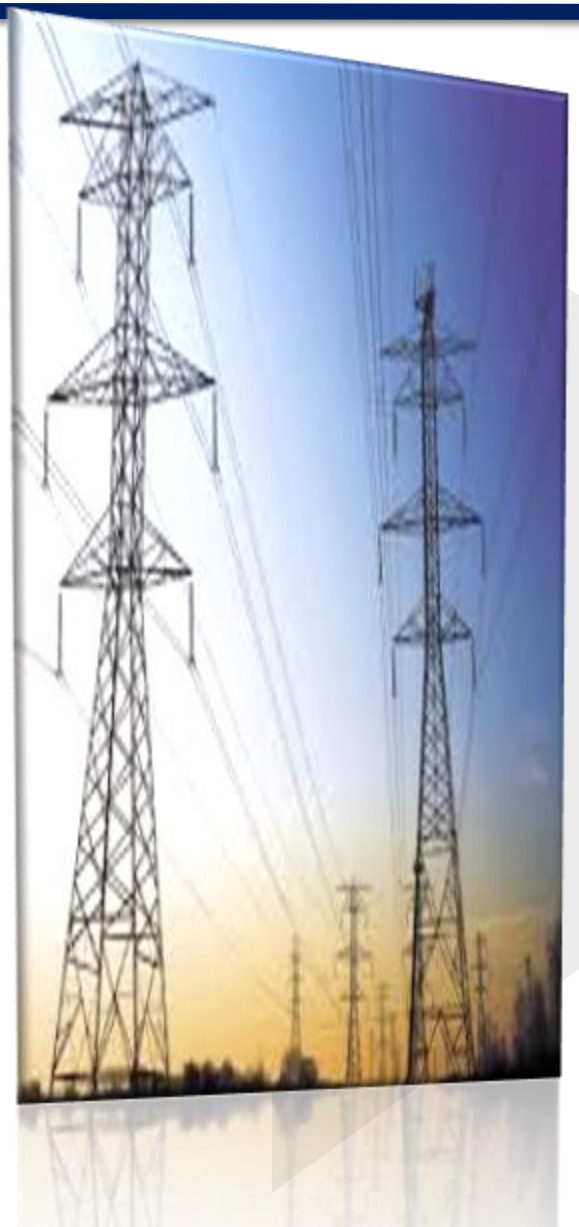
- **Safety**, **Sustainability and Resilience**
- **Lifecycle thinking** from concept → design → construction → operation → renewal → disposal
- **Risk-based, evidence-driven decisions**
- **Continuous improvement** through innovation and digital transformation
- Stakeholder value creation
- Regulatory compliance and transparent governance

It established Asset Management not merely as a function, but as a **culture and organisational philosophy**.

# Creating Advanced AM Framework



# Transmission Line Maintenance Practices



**Asset Inspection & Maintenance**

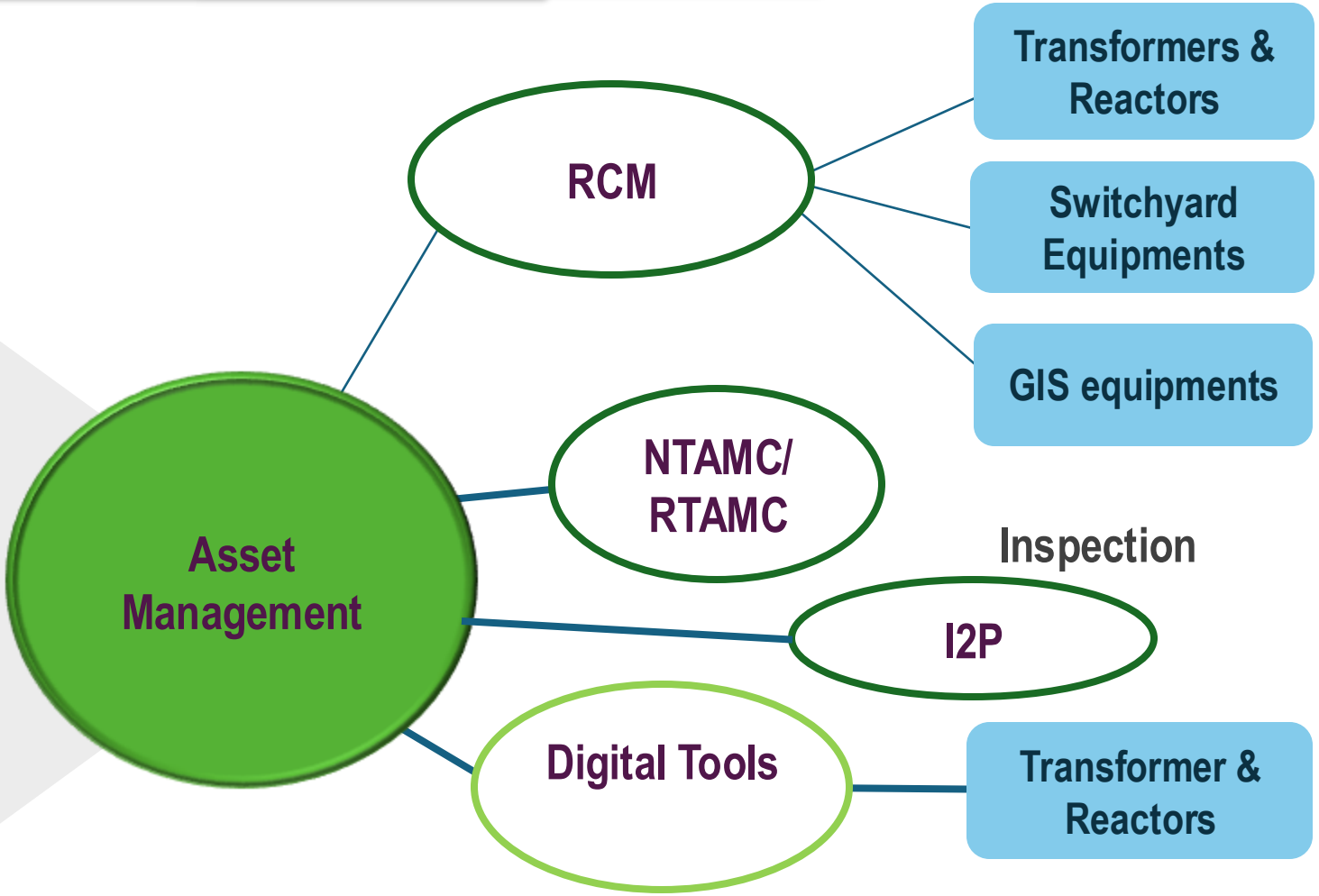
- Use of GPS Enabled App
- Use of Drone
- Satellite Image Intelligence

*Inspection*

- Emergency Restoration Systems
- Hotline Maintenance Systems upto 765kV

*Maintenance*

# Substation Maintenance Practices



# National Transmission Asset Management Centre

## Remote Operation & Monitoring of all substations from a centralized location – Largest such center in world for Transmission Assets

- Optimization of human resources – No shift operations at substation
- Faster restoration in case of tripping through online diagnostics of real time parameters & disturbance records.
- Enhance the asset life by ensuring operation of equipment within rated parameters.
- Safe & Secured operations with minimum human intervention and interlocking applicability at multiple stages.
- Enhanced reliability - Centralized real time monitoring of relays

# Centre of Excellence (CoE) – Control & Protection

- Enabling remote access of Protection Relays & SAS of substations from CoE at NATMC.
- Centralized Management of Protection & SAS database /configuration.
- Troubleshooting and Providing Support to sites during commissioning and O&M.
- Uniformity of Configuration in IEDs & SAS Gateways.
- Management of patch/ firmware/ anti-virus upgrade of IEDs & SAS Gateways.
- Remote Audit of IEDs & SAS Gateways.

# UDAAN (Unified Digital Assessment of Asset Network)

KPIs Monitoring

Equipment Health Analysis

Outage Management Tools

Daily Operational History

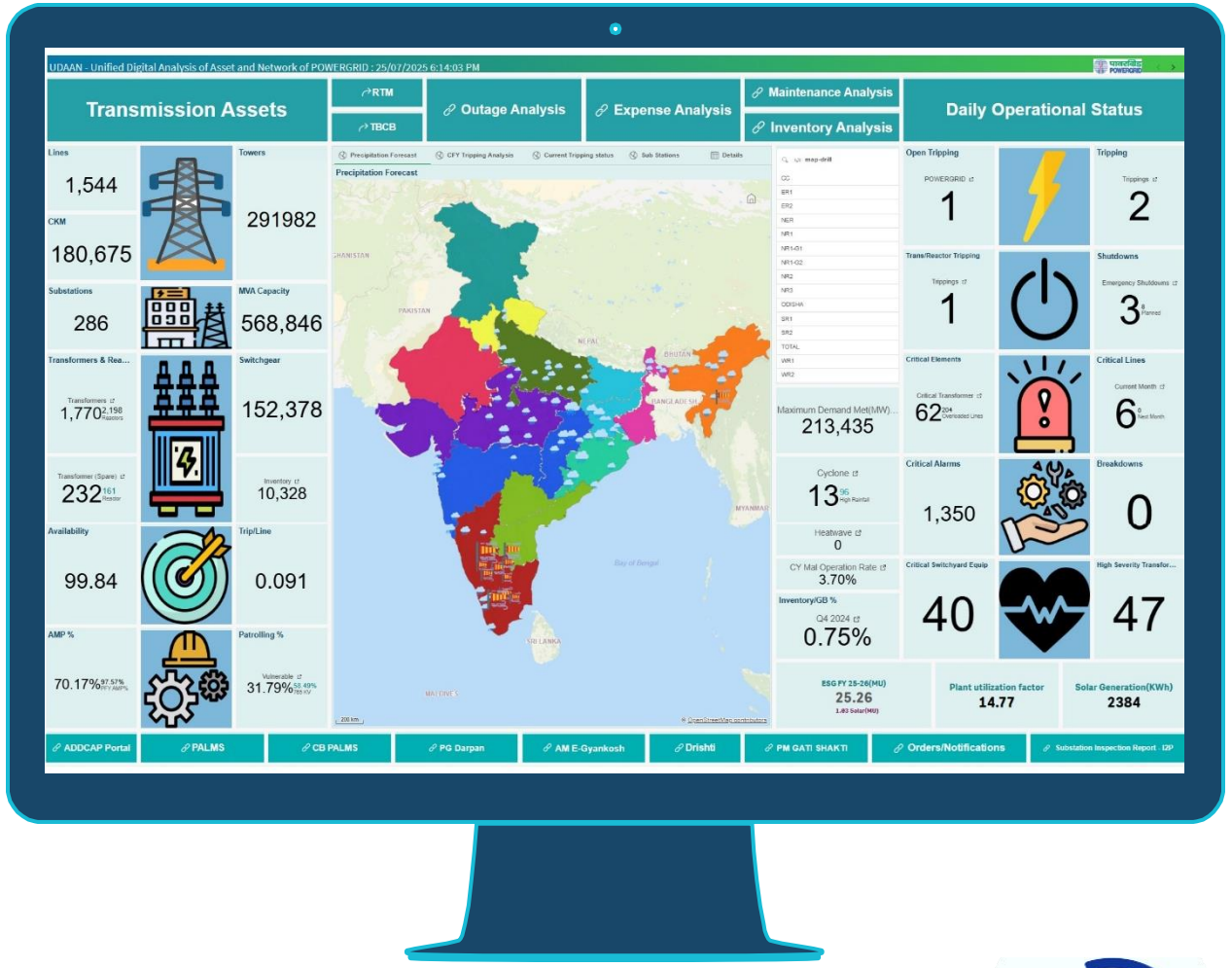
Inventory Analytics

Maintenance trends

Maloperation Details

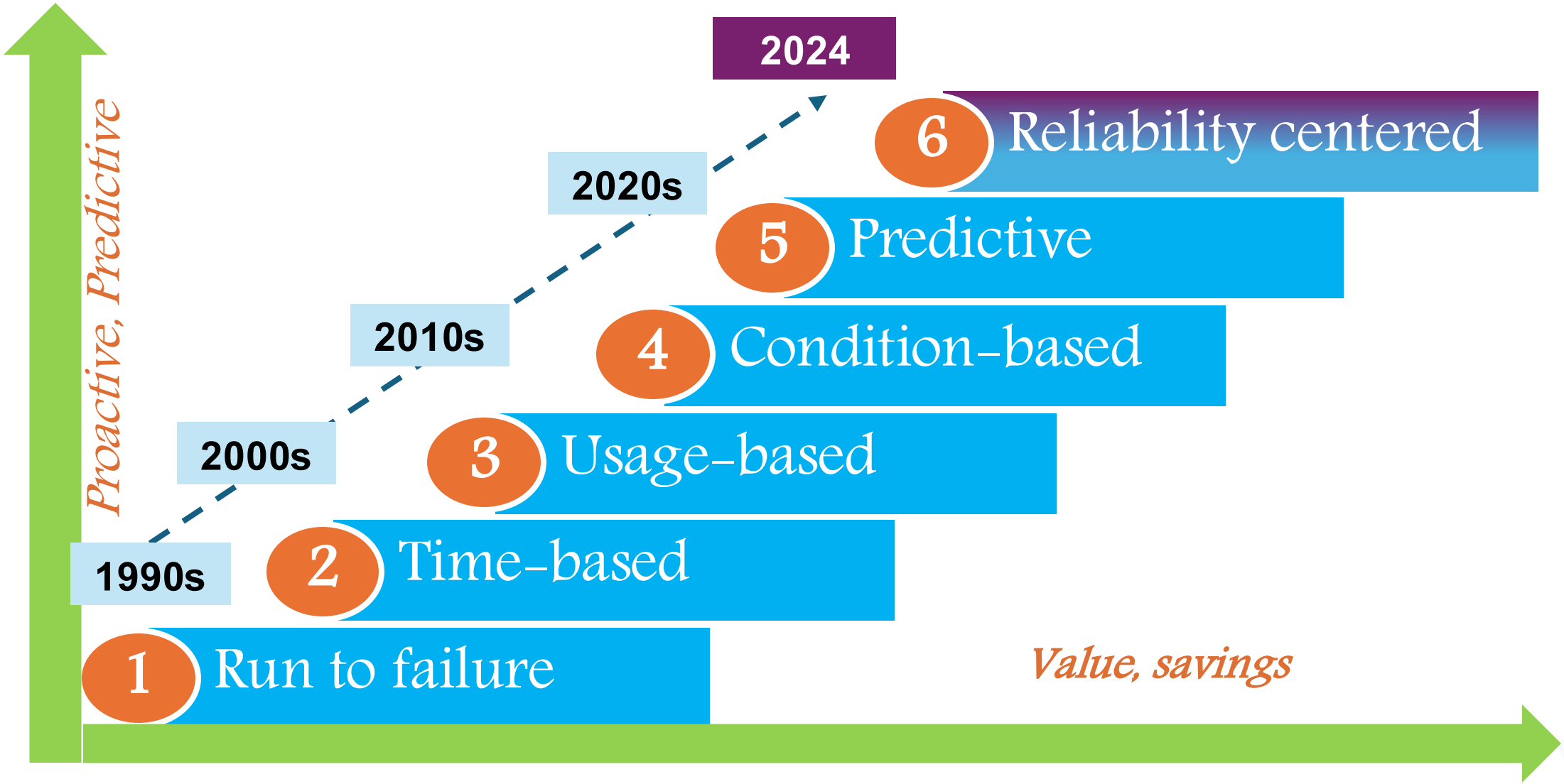
Critical Asset Identification

Weather Forecast Models



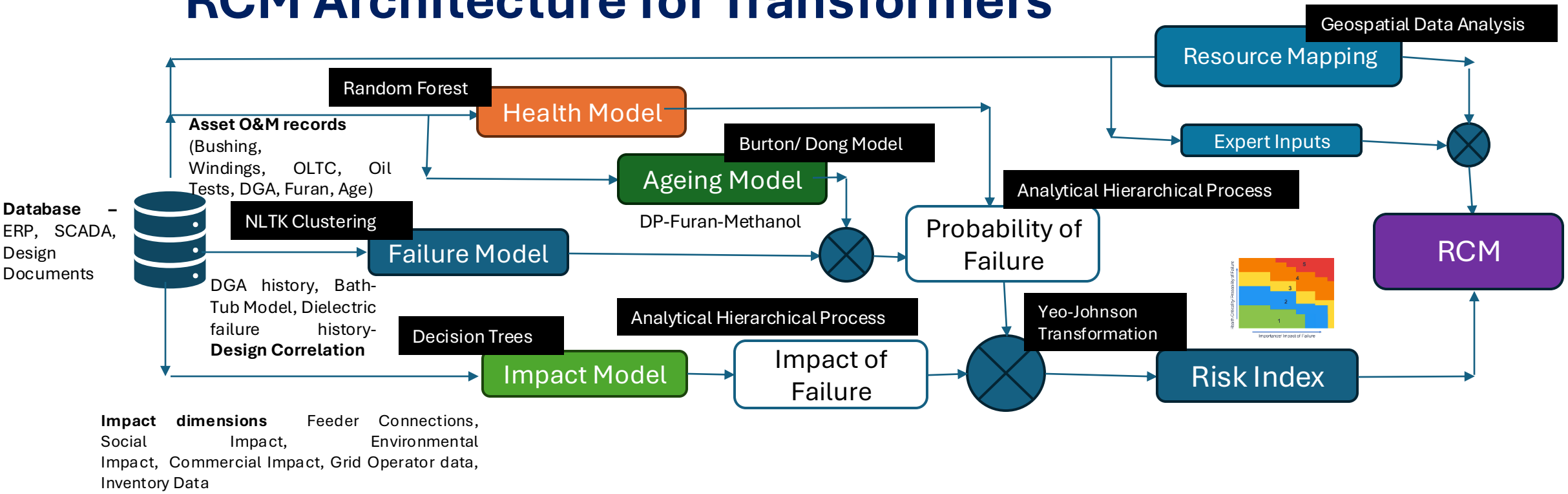

Bird's eye view for management over AM performance and issues

# Evolution of Asset Maintenance Framework



# RCM Framework

## RCM Architecture for Transformers



# POWERGRID ASSET LIFE MANAGEMENT SYSTEM (PALMS)

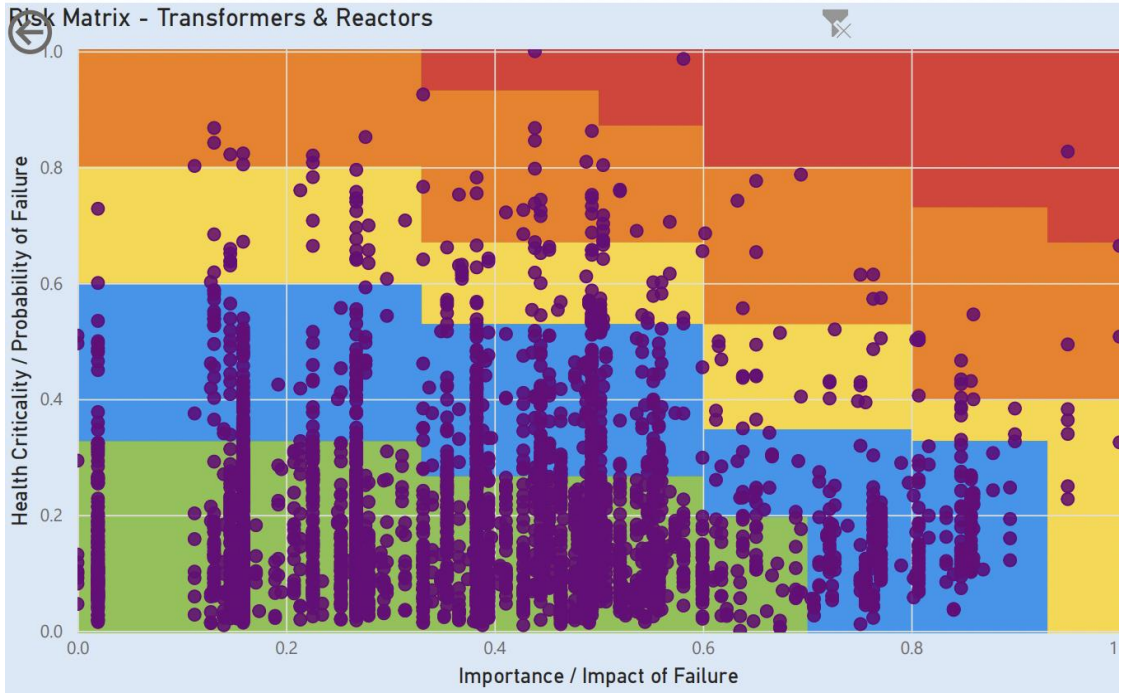
- Application developed in-house for real-time health assessment of about 4200 Transformers/ Reactors in POWERGRID.
- Patent received in 2025
- Categorization of critical equipment based on operational experience and latest International standards

***Advantages:***

- Risk Based severity indexing of transformers/ reactors
- Dashboard for monitoring of critical equipment
- Age assessment models integration
- Dynamic Maintenance plan scheduling based on severity grade


# Outcome and Value Delivered

## RELIABILITY CENTERED MAINTENANCE (RCM)




- Real Time Health Indexing along with Risk-Impact Mapping
- Lower Maintenance Cost
- Inventory Optimization
- Optimized Resource Planning
- Data Driven Decision Making

**~ 20% Manhour requirement reduced in Asset Maintenance**

# RCM Framework

## RCM Architecture for Transmission Lines

### Health of Assets

| | |
|---|---|
| Susceptibility | Tree Growth, River Crossing, River Course change, Hill Slope, Tower member theft etc. |
| Tower Critical defects | Defects from PG Darpan |
| Asset life | Tower Age |
| Failure History | Tower Failure Hardware failure Insulator failure |
| Seasonal Impact | Line Tripping due to clearance , Storm, Jhum Fire, Fog etc. |
| Geographical Condition | Change of higher wind zone then the designed , Coastal area |
| Environmental affected on Tower | Pollution, Lightning |

### Impact of Failure

| | |
|---|---|
| Loss in system Availability | Line Tripping |
| Revenue Loss | Tariff |
| Social & Political impact | Feeding Capital city Feeding Industrial Plant |
| Impact on Grid condition | Line Loading |
| Failed to deliver power to critical load | Discom, radial feeder, Railway Traction Load, Any other Criticality |
| Failed to Evacuate Generation | Connected to generation Link/ RE generation |

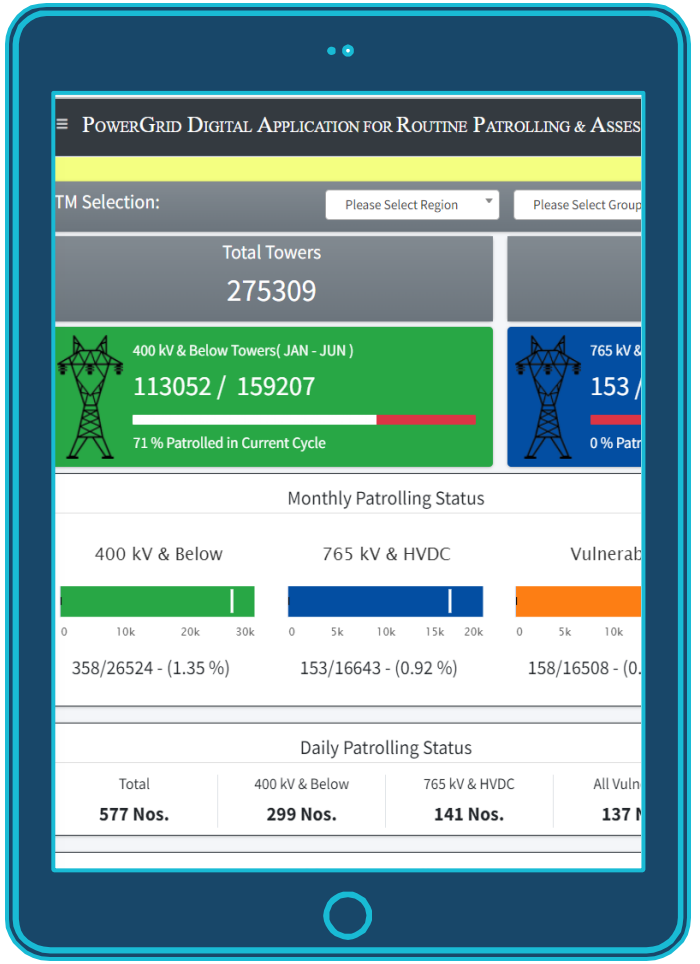
# Revision of TL Patrolling norms

**Focus on Zero Defect → Zero Effect**


- Risk-Impact based Patrolling
- Mandatory use of high zoom cameras
- App based Ground Patrolling
- Drone and Aerial Patrolling for selected lines
- Use of AI/ ML for defect identification

# POWERGRID Digital Application for Routine Patrolling and Assessment of Network (PG- DARPAN)

In-house developed model and Application for Transmission line patrolling activities

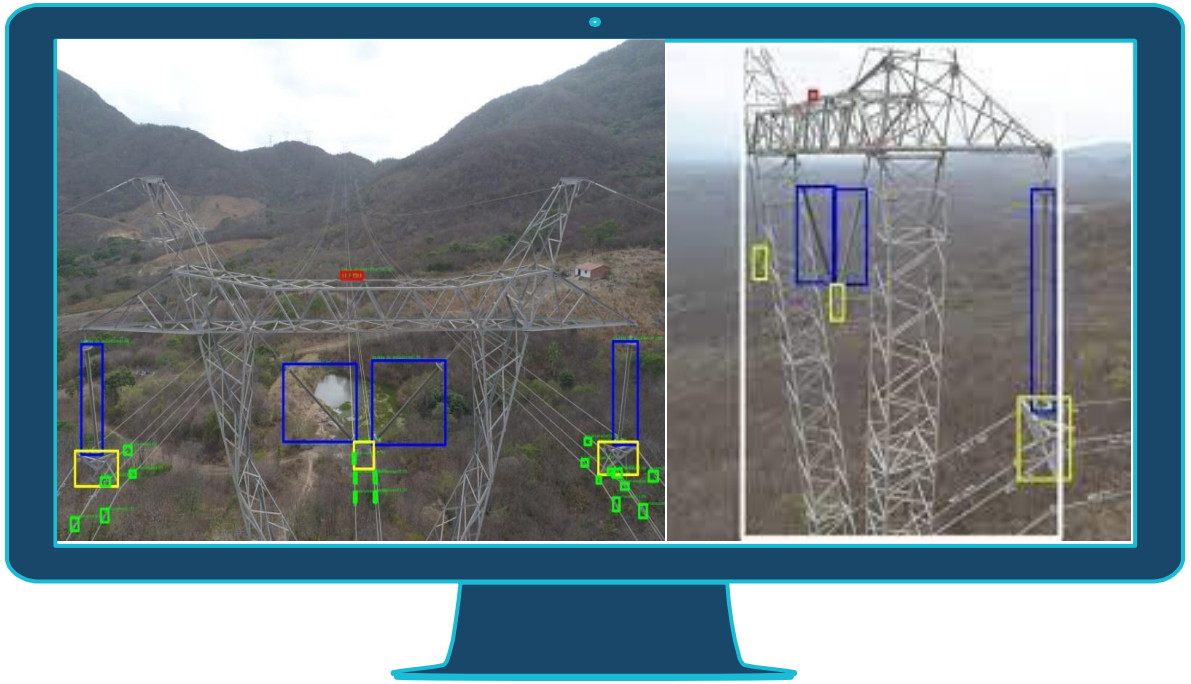



## *Features*

- Real Time Monitoring of Patrolling Efficiency
- Complete Geographical Asset Mapping
- Automated MIS and Legacy Reports
- Defect Catalogue and Rectification Record monitoring
- Resource Planning

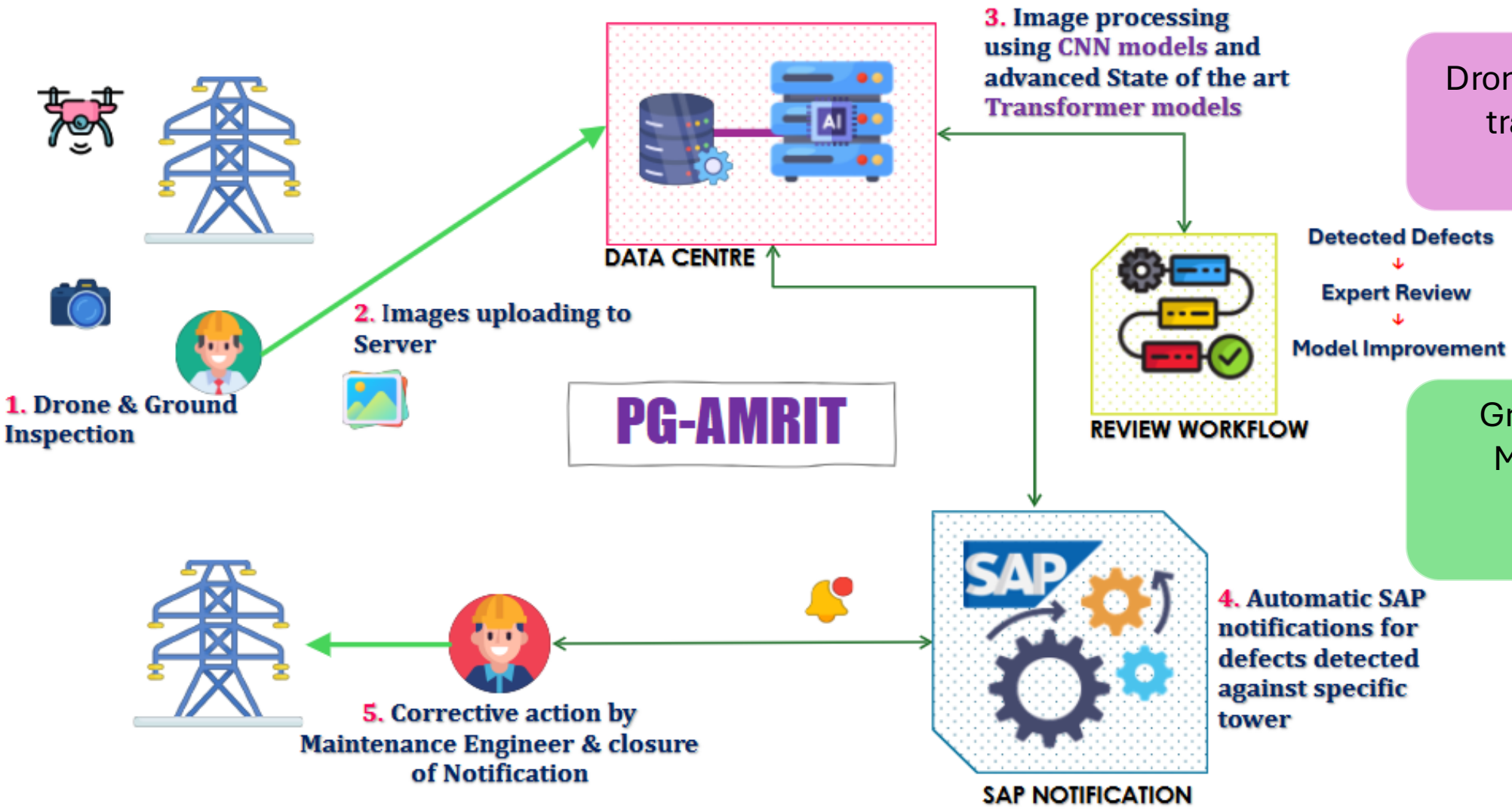
# AMRIT (Asset Management through aRtificial Intelligence in Transmission)

*Image Processing based Defect identification in Transmission Line Towers along with geospatial* defect tags – developed in-house



- *Identification of more than 30 types of defects*
- *Processing Speed – 400 photographs / minute*
- *Accuracy is upto 90%*
- *Deployment of Convolutional Neural Network Algorithm & Transformer models*

# AMRIT (Asset Management through aRtificial Intelligence in Transmission)



# Digitally Connected Employees

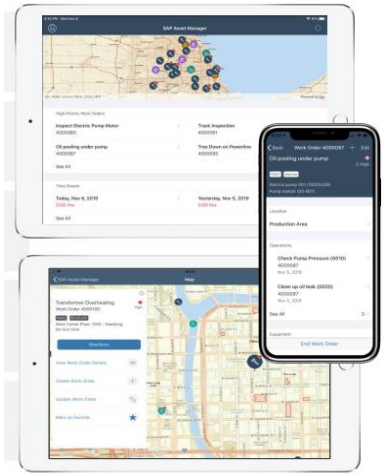
## Intelligent Inspection in POWERGRID – I2P

### AR based Digital Headgear

Headgear being utilized to enable Remote Virtual Supervision & Assistance during O&M

Reduces chances of human error in maintenance

### Tablet based Intelligent Inspection

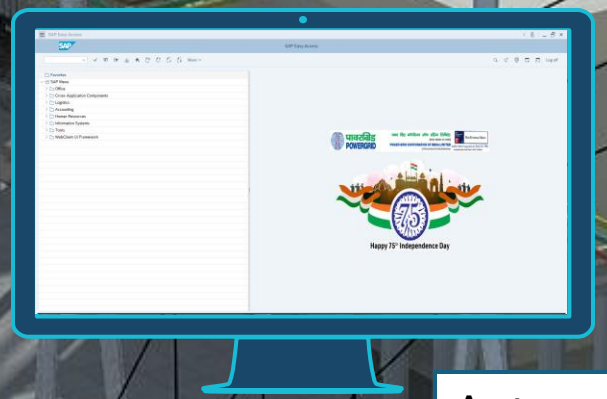



End-to-end asset management on the go, online or offline

QR Code based Asset Tracking

Efficient and paperless execution of O&M works

# Empowering People through Intelligent Inspection in POWERGRID module



Digital Entry of Substation Daily Log data

Automatic Data log in SAP

**SAP Asset Manager**

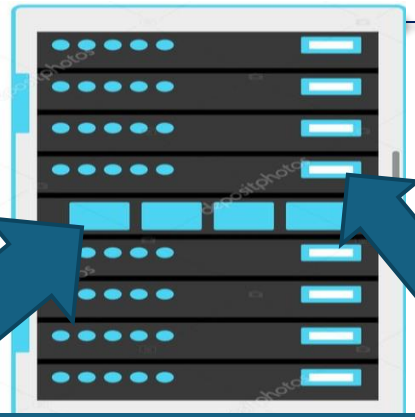
WTI- 70
OTI- 65
Bushing Oil level –
OK ✓ Not OK
MOG level –
OK ✓ Not OK
Silica gel –
OK ✓ Not OK

**ICT-1 400/220kV**

SUBMIT

# Data Flow Process

Real-time transfer of Data to ERP



SAP Asset Manager Cloud Server

Data transfer to Station In-charge for approval


Test Data being filled in Tablet by Engineer in Online/ Offline Mode

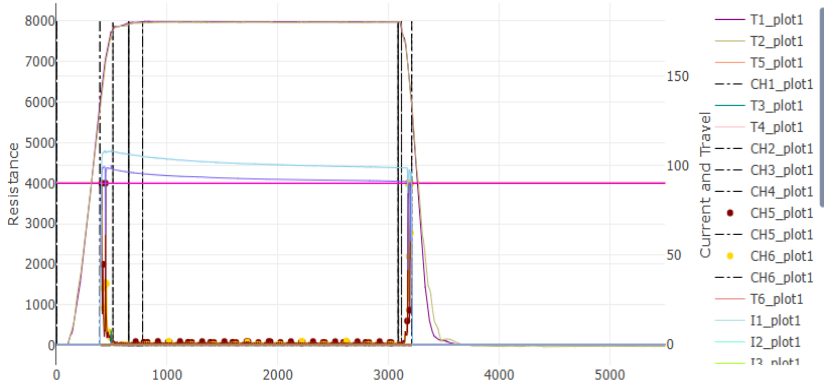
Monitoring and approval by Station In-charge

# Automated analysis of Advanced Test Results

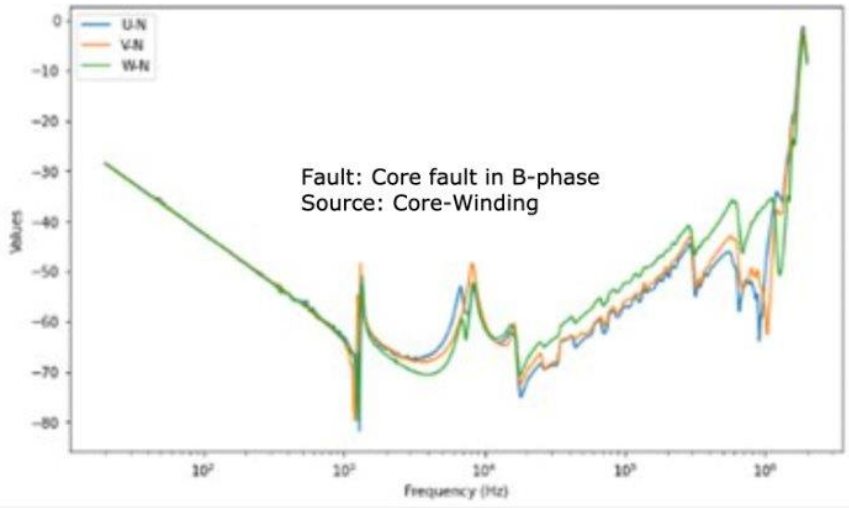
- Tests like SFRA (for mechanical condition assessment of Transformers and Reactors) and DCRM (for health analysis of Circuit Breakers) are performed

- Traditionally, these tests have been analyzed based on manual human interpretation like X-Ray/ MRI interpretation

- POWERGRID has developed objective interpretation models based on Big Data Analytics tools such as Clustering/ Ensemble models to objectively interpret these test signatures and remove subjective bias in analysis.




| Ref./Act. | Break | DCRM Date | Arc Cnt Res Cls | Arc Cnt Res Opn | Arc Cnt Wipe Cls | Main Cnt Res | Stroke | Vel Cls | Vel Opn | DCRM graph |
|---|---|---|---|---|---|---|---|---|---|---|
| Act. values | BBreak1 | 2024-01-24 | 355.58 | 870.05 | 44.54 | 46.31 | 180.45 | 5.77 | 7.73 | See DCRM Graph |
| Act. values | BBreak2 | 2024-01-24 | 286.83 | 976.28 | 44.01 | 54.22 | 180.45 | 5.78 | 8.59 | |
| Act. values | RBreak1 | 2024-01-24 | 410.76 | 1000.98 | 47.47 | 23.01 | 180.75 | 5.78 | 9.00 | See DCRM Graph |
| Act. values | RBreak2 | 2024-01-24 | 250.86 | 993.98 | 45.65 | 28.92 | 180.75 | 5.77 | 8.44 | |
| Act. values | YBreak1 | 2024-01-24 | 280.2 | 687.62 | 53.28 | 36.58 | 181.22 | 5.63 | 8.54 | See DCRM Graph |
| Act. values | YBreak2 | 2024-01-24 | 372.44 | 884.42 | 71.8 | 46.14 | 181.22 | 5.51 | 8.12 | |



# Alcohol Based Ageing Markers

**POWERGRID** has become the 4th utility worldwide to establish facility for Alcohol Based Ageing Markers test (set up at Manesar, Haryana in 2022)

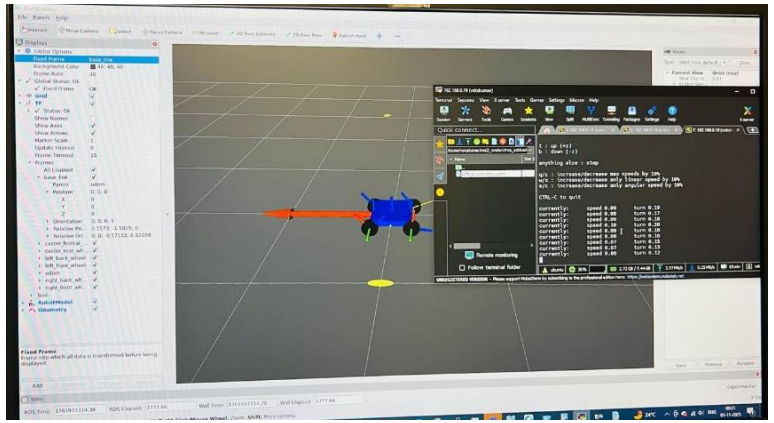
**Advantages:**

- Detects early stage ageing of paper
- Easily differentiates between normal ageing and localised overheating
- Higher recovery rate than Furans after degassing of old units
- Higher detectability at temperatures >100°C than furans

# Valve Hall Inspection Robot

- Automation of Valve Hall Inspection including wireless Thermo-vision scanning by using IOT working model has been successfully carried out at Vizag S/s and Kolar S/s.

- Improved Professional customized version of such remote inspection will be helpful for critical equipment monitoring in STATCOM and for areas of specific suspected asset monitoring safely.




Robotic Platform in Vizag S/s

# Rapid Response – ERS teams

*POWERGRID has used Emergency Restoration System* towers to **Quickly, Safely and Efficiently restore power** interrupted by natural disasters, sabotage or vandalism.

Indigenously developed ERS sets available upto 400kV level

# Operational resilience – Hot-Line Maintenance

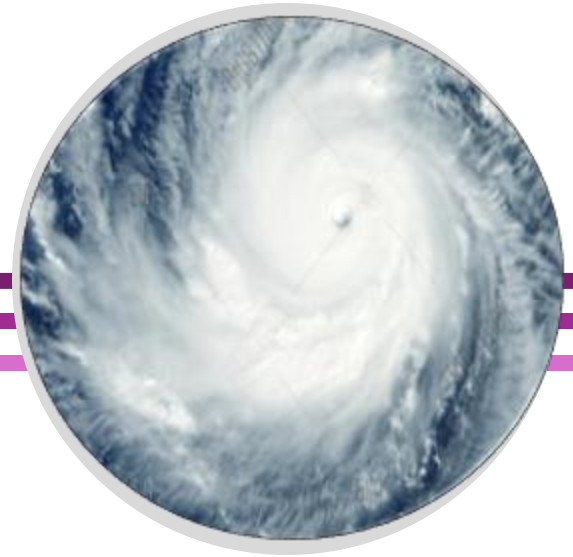
- Replacement/ Rectification/ Tightening of spacers, Spacer cum damper Tightening of Jumpers.
- Replacement of Suspension insulator string.
- Replacement of tension insulator string.

**Insulated bucket can also be used for:**

- Replacement/Repair of damaged sections of the conductor
- Maintenance and replacement of mid-span joints.
- Rectification/tightening/replacement of vibration dampers
- Strengthening of dead-end hardware
- Placement of insulating tape/sleeve on conductor
- Replacement of arcing horn and corona ring hardware,

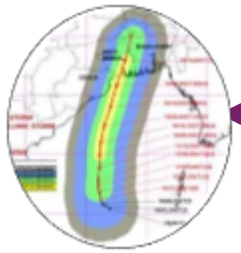

# Climate Resiliency – Cyclone Preparedness

**Preparedness activities after getting cyclone warning from IMD**



### Element Identification

Identification of critical transmission elements using satellite imagery



### Control Rooms

Setting up of 24X7 control rooms for monitoring

### Resource Planning

Availability of resources in nearby stations

### Special Patrolling

Special patrolling and defect liquidation of critical elements

### Transportation Tie-up

Advance transportation tie-up for swift movement

### Manpower Pooling

ERS Expert, Fitter Gangs etc.

**With above efforts, POWERGRID has successfully endured last 14 cyclones without any major damage**

# Self-reliance in O&M repairs

First Site repair of 765kV Reactor in 2020 at Aurangabad

Successful GIS module repair at various Substations


Fabricating parts for repair of TCSC modules using 3D printing method at Raipur

**Resolving O&M issues without OEM support has become the norm rather than exception**

POWERGRID's collaborative efforts have also led to growth of indigenous vendors in the field of AIS & GIS (upto 765kV), HVDC (upto 800kV), RIP bushings (upto 400kV), ERS towers (upto 400kV) etc.

# VR based Safety Training

- In line with the POWERGRID's commitment to adopting **innovative and effective training methods**, **Virtual Reality (VR)** based **safety training modules** have been developed to simulate critical work scenarios in a **highly immersive and controlled environment**.

- These modules are designed to **enhance learning retention, improve hazard perception**, and **promote safe behavior** among fitters / workers.

- VR based Safety modules developed and used for:
  - Use of Ladders
  - Tower Climbing Training
  - Cardiopulmonary Resuscitation (CPR) Procedure
  - Electrical Maintenance of Line Terminal Equipment
  - Safety in Insulator String Replacement

# Human Capital Development

- Capacity Development through Skill Building
- Documentation of Best Practices
- Sharing of learning in National & International Forums
- Formation of Maintenance Specialist Groups
- Monthly Benchmarking Scheme
- Best Employee of the Month Scheme
- Competency Mapping and Job Description

# Creation of Maintenance Specialist Groups

**8**
Disciplines

TL-ERS, TL-Hotline, Transformer & Reactor, AIS, GIS, Protection, HVDC & FACTS, SAS

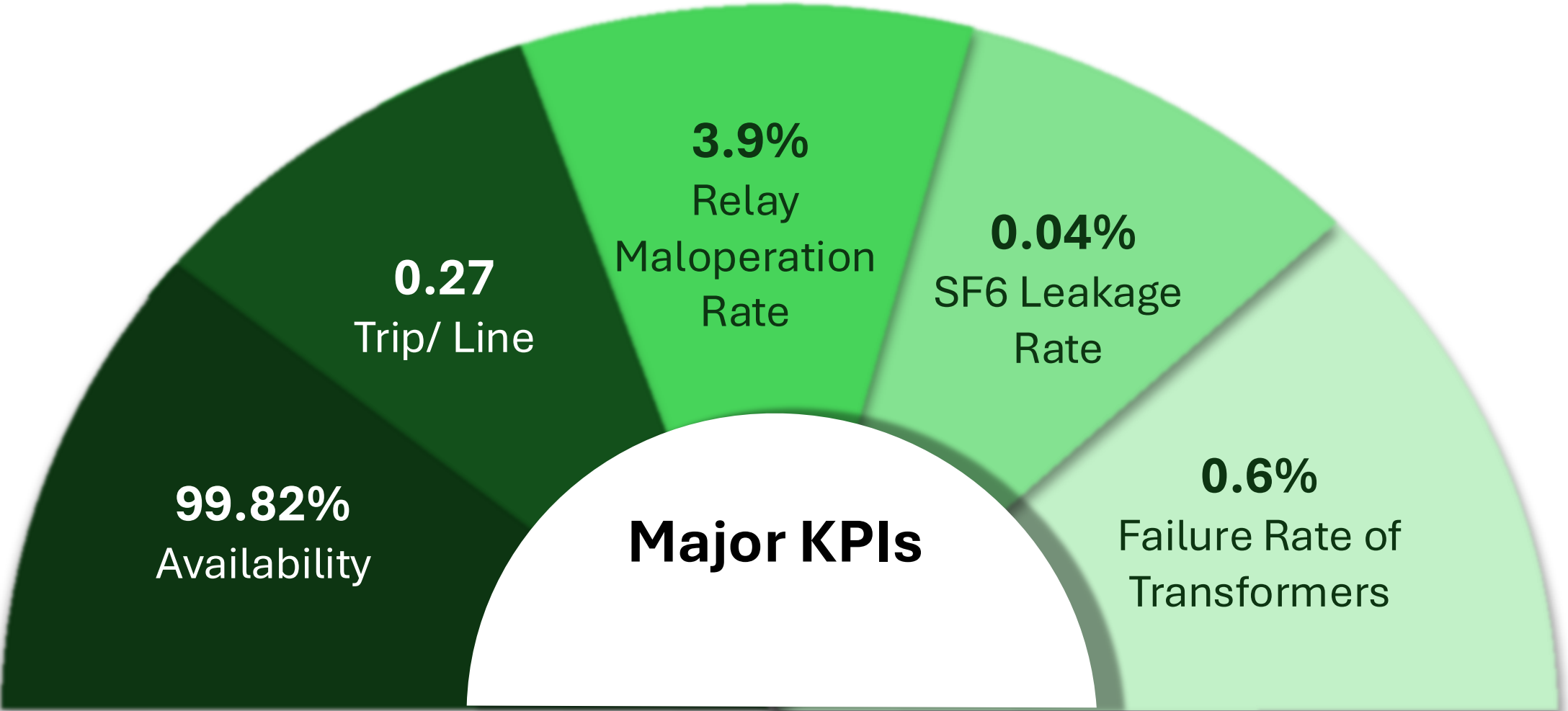
87
MSG Groups

~ 700
MSG members across regions

MSG involved in:

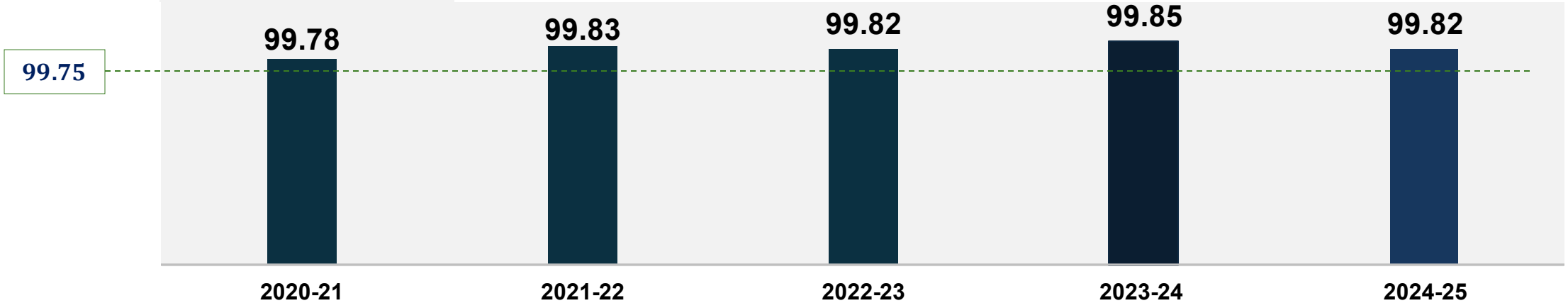
- ***Failure Investigations at site***
- ***Revision of Controlled Documents/ Procedures***
- ***Pre-Commissioning activities***
- ***Mentoring of Young Engineers***

# Impact of our AM practices



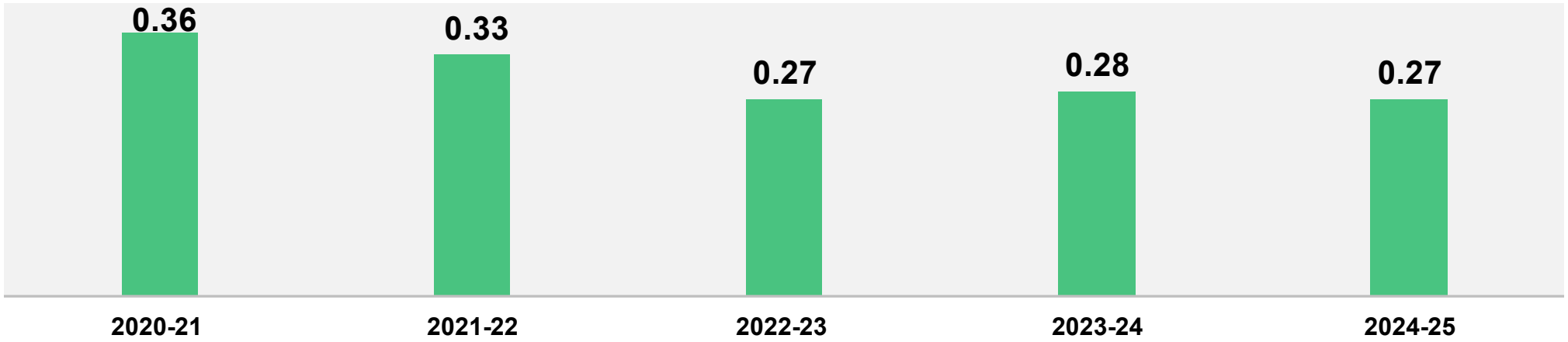
# Outcome and Value Delivered

## Availability(%)

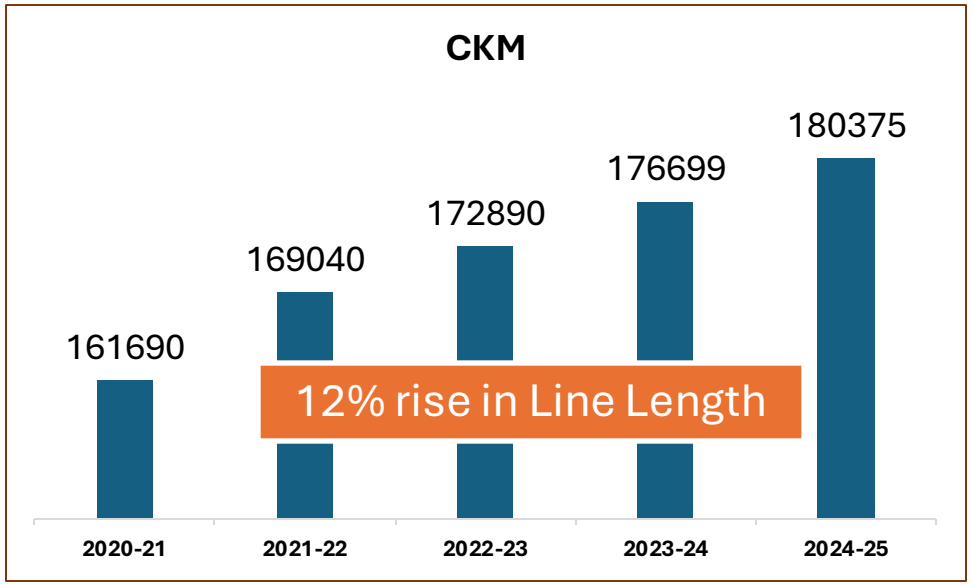


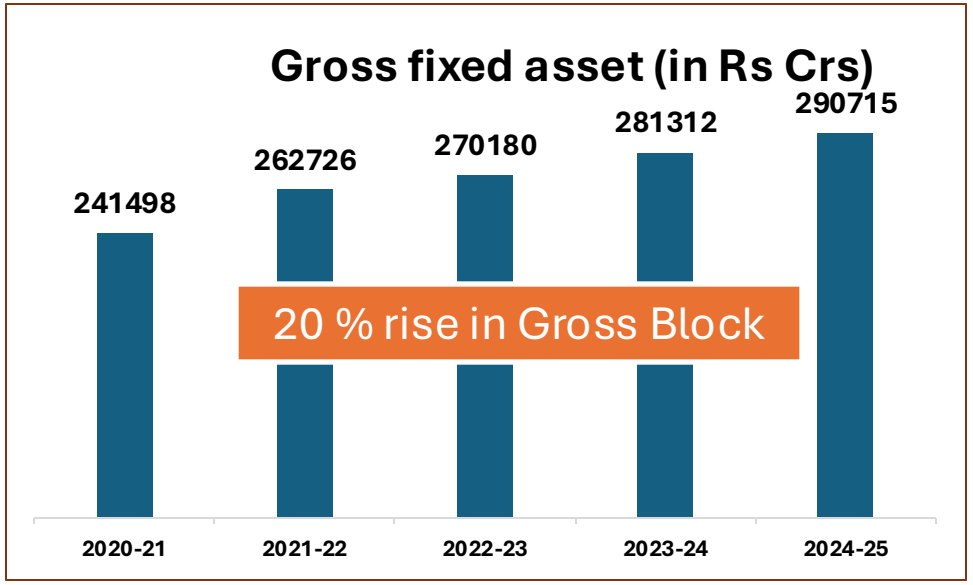

*Incentive capping at 99.75*

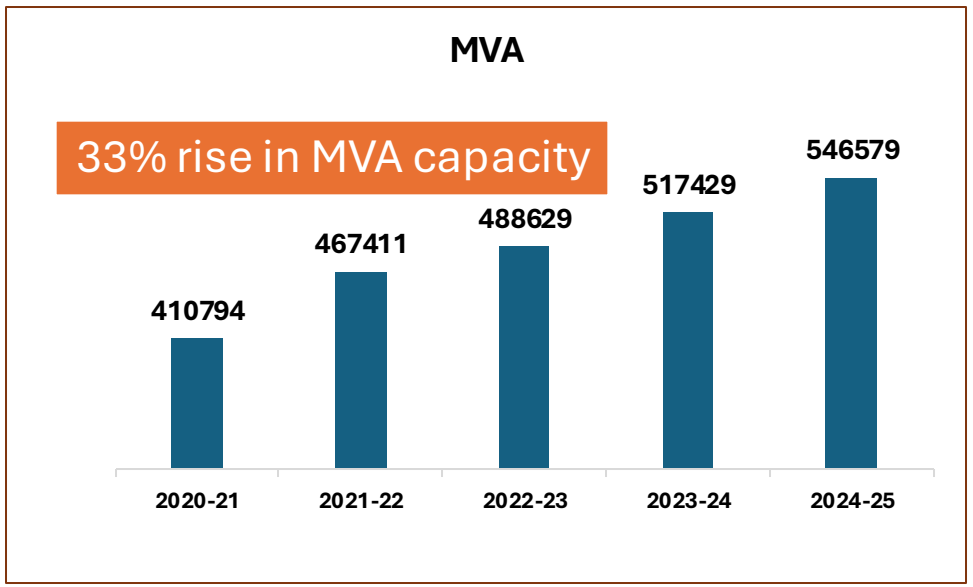
## Tripping/Line

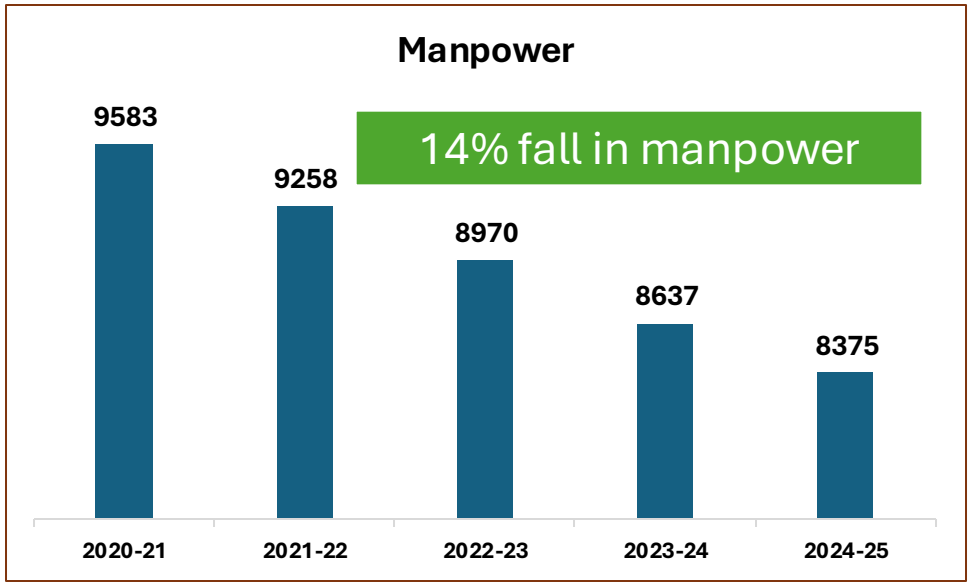


# Asset Base vs Manpower

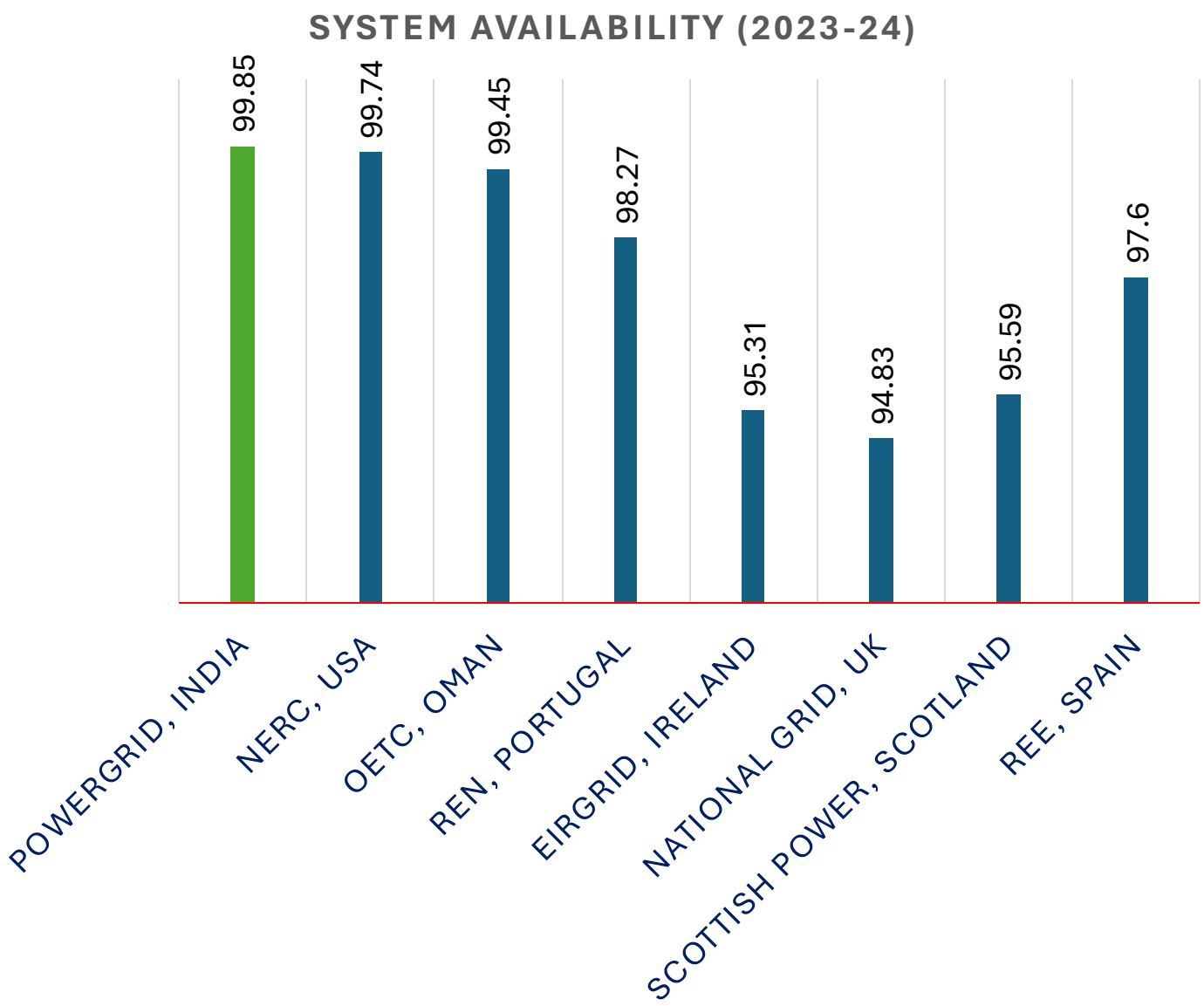


# Performance Comparison with major global utilities




| Utility | Trip / 1000ckm* |
|---|---|
| POWERGRID, India | 1.5 |
| National Grid, UK | 1.5 |
| REN, Portugal | 1.5 |
| EGAT, Thailand | 3.4 |
| ISA, Colombia | 2.5 |
| ISA, Peru | 5.6 |
| EirGrid, Ireland | 5.5 |
| ESKOM, South Africa | 8.3 |
| Red Electrica, Spain | 2.2 |

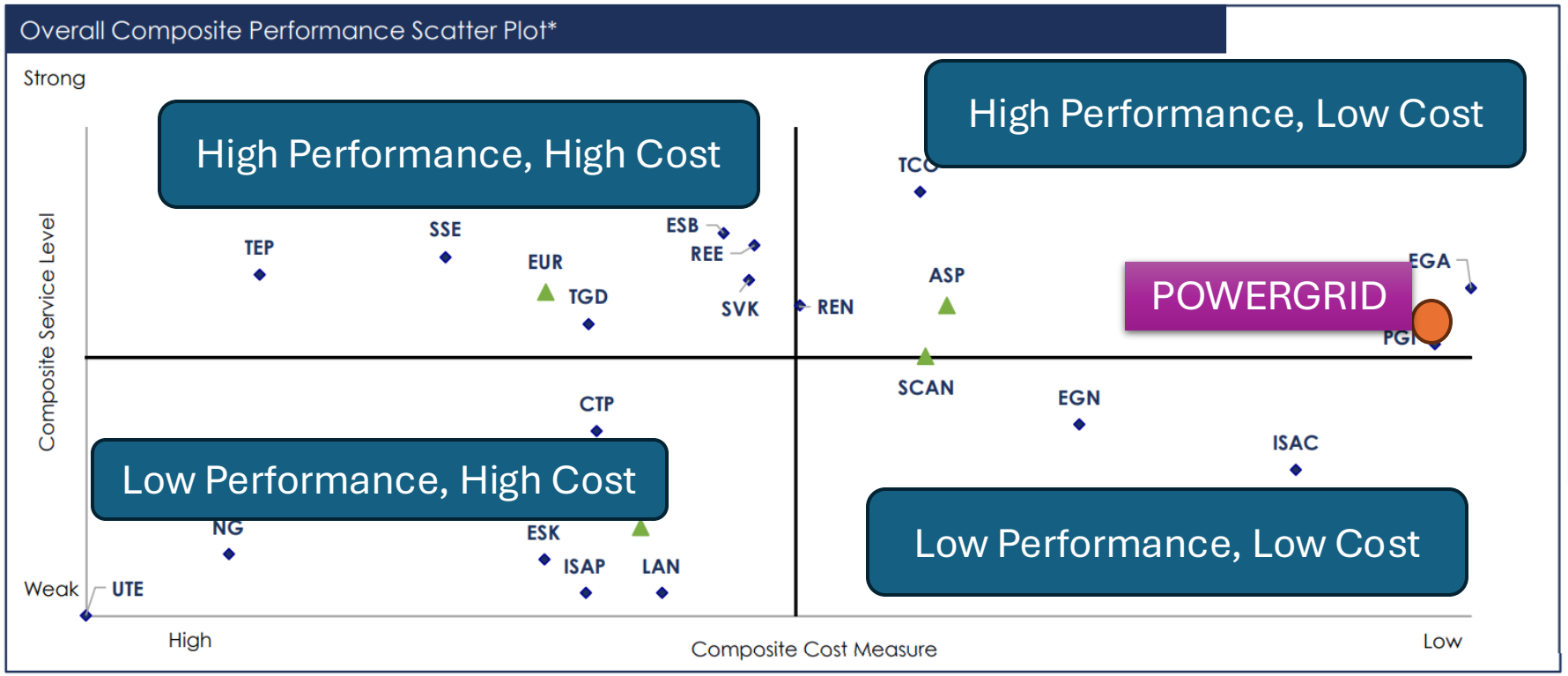
*Only those trippings considered which were caused due to sustained faults in transmission line (>5 minutes).

Further, NERC (USA) reports 1.06 trip/ 1000 ckm due to line faults caused by hardware failure. Corresponding figure for POWERGRID is 0.34 trip/ 1000 ckm.

Report for FY 2024-25 shall be published by December 2025

# ITOMS 2025 Results

## Overall Composite Benchmark – Weighted Average**

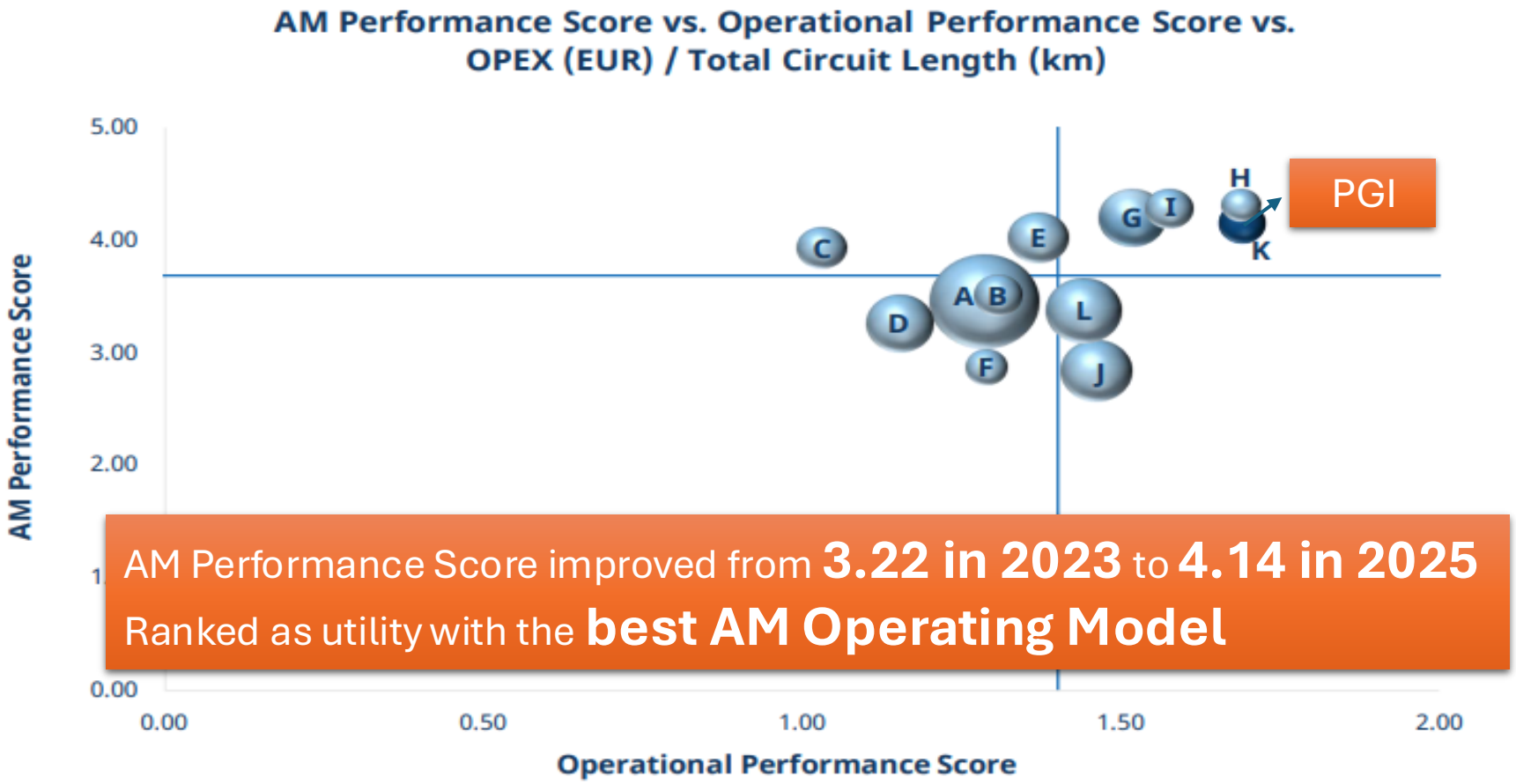



**POWERGRID** ranked among **first quadrant in overall composite benchmark** – best performing global utilities i.e. high operational performance at low operational cost.

**Ranked among best performers**

*Transmission Lines, Transformers, Circuit Breakers, Control & Protection, FACTS, Isolators*

# Global Benchmarking – ITAMS




AM Performance Score improved from **3.22 in 2023** to **4.14 in 2025**
Ranked as utility with the **best AM Operating Model**

**4.14 (>Avg.)**
*AM Performance Score*

**1.69 (>Avg.)**
*Operational Performance Score*

A – ElectraNet, Australia
B – TAQA, UAE
C – LitGrid, Lithuania
D – Transelec, Chile
E – SSE, Scotland
F – EirGrid, Ireland
G – REE, Spain
H – TERNA, Italy
I – FINGRID, Finland
J – RTE, France
K – POWERGRID, India
L – TransPower, New Zealand

# Technology Initiatives under Progress/ Pilot Project

- Asset Performance Management (APM) System
- Satellite based vegetation system
- Dynamic Line Loading (DLL)
- Green Gas in Place of SF6
- Offshore Substations
- Insulated Tower Cross Arm
- Full scale use of Drones & Robots
- Spatial Decision Support System
- Green Hydrogen & Energy Storage System

# THANK YOU