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EMPOWERING CONSUMERS

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AI for Smarter DISCOM Operations

Strengthening Reliability, Efficiency, and Decision-Making in DISCOM Operations

Presented by Dr. Adarsh Nagarajan

About me:

Adarsh Nagarajan,
Ph.D.

On a sabbatical at BSES Rajdhani Power Ltd.

Bridging innovation and real-world utility planning — from U.S. Depart of Energy's NREL labs to power grids around the globe.

Adarsh.Nagarajan@reliancegroupindia.com

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My research breadth

Capacity Expansion & Electricity Markets

Analyzing the **long-term evolution of bulk power systems** and interactions among technologies, markets, and policies

Grid Operations Planning

Investigating the potential impacts of changes to the power system (e.g., renewables, storage, extreme events) on **reliable grid operations**

Transmission

Conducting analyses in which **transmission** (investments, operations) plays a large role or is the primary focus

Transmission & Distribution (T&D) Interactions

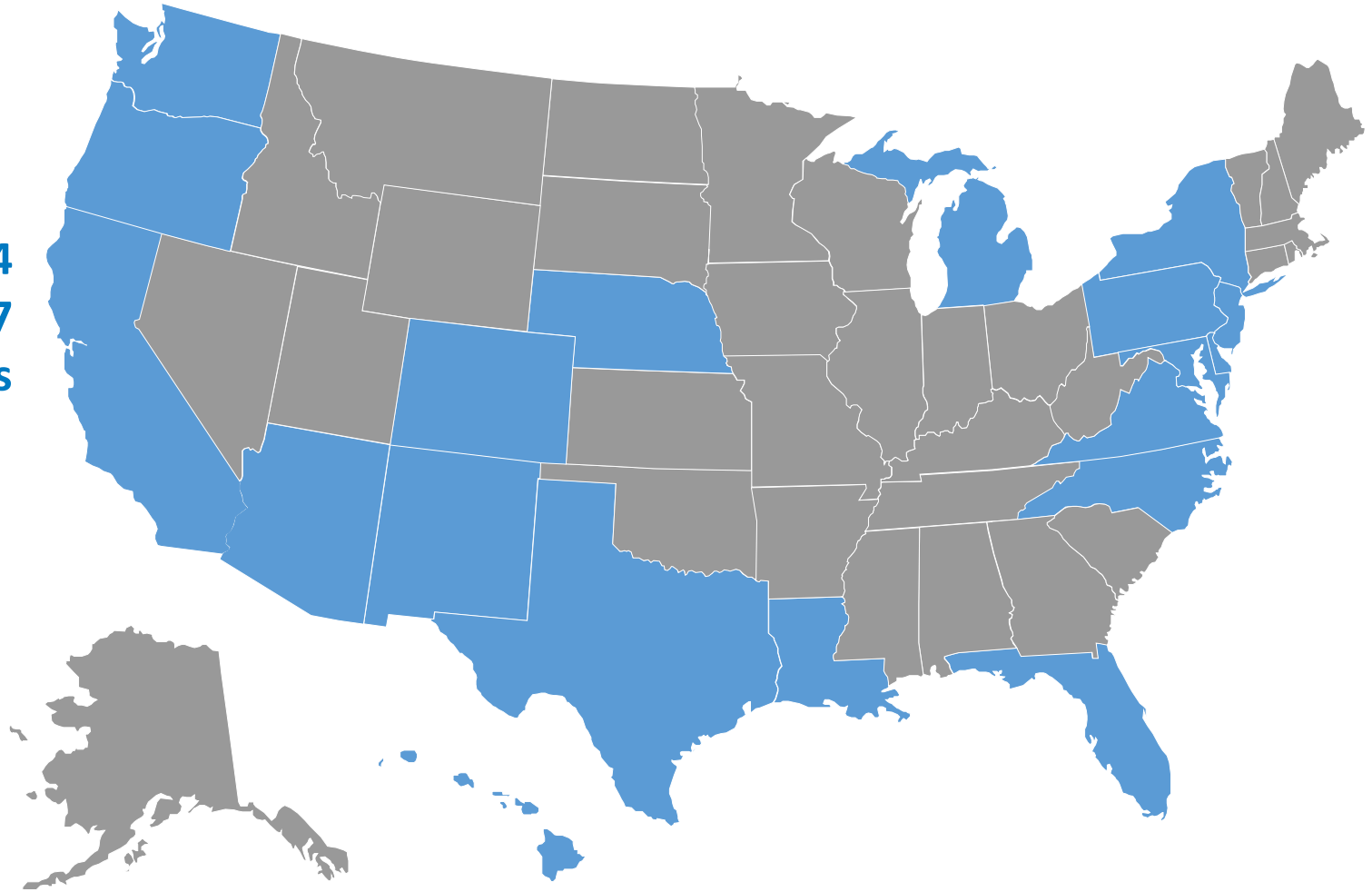
Conducting analyses and developing tools that inform planning and investments for reliable, equitable operations from an **integrated T&D perspective**

Distribution Edge

Informing **next-generation distribution planning of distributed energy resources** by advancing analysis and tools for planning and operations

My contributions to distribution systems research

Dr. Nagarajan has worked with 24 states in the U.S.A and 7 countries on distribution systems futures



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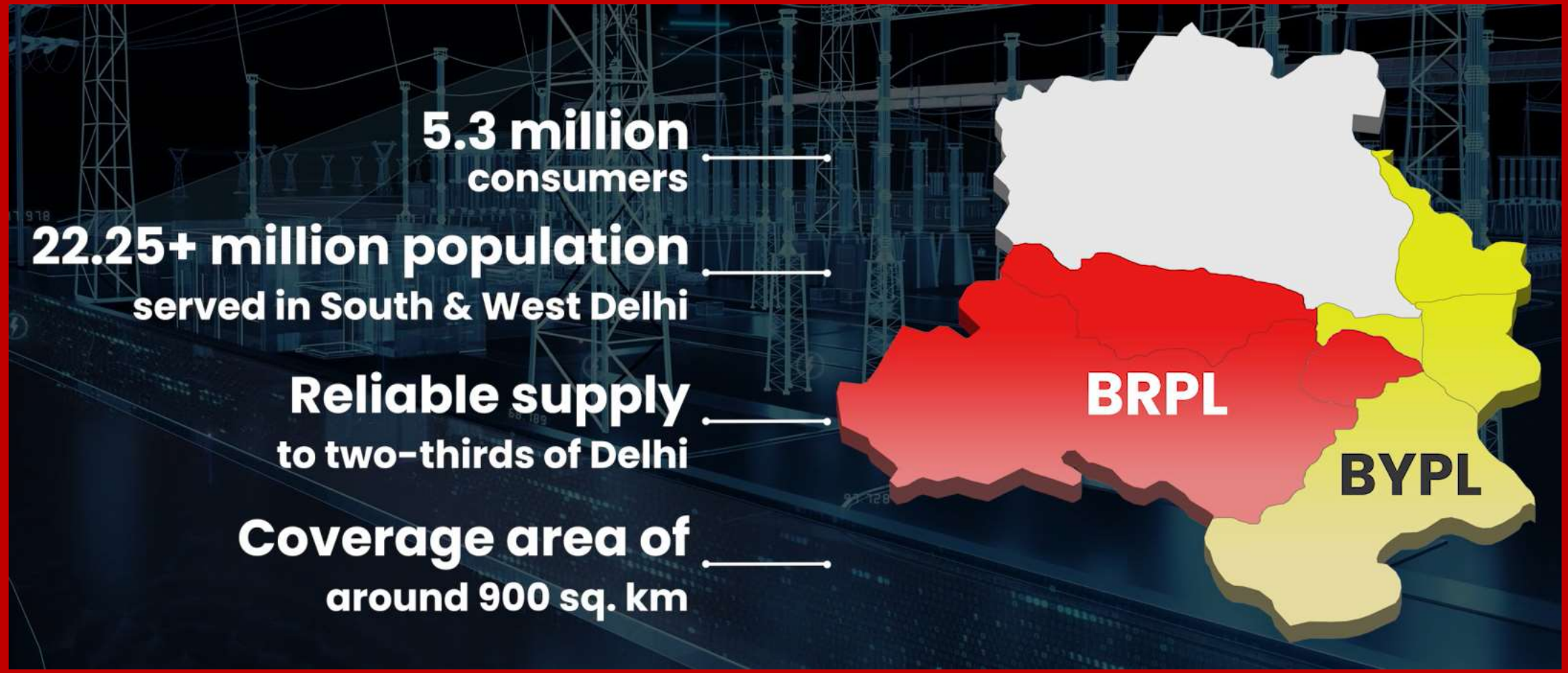
About BSES


5.3 million
consumers
22.25+ million population
served in South & West Delhi
Reliable supply
to two-thirds of Delhi
Coverage area of
around 900 sq. km
BRPL
BYPL

BSES Operational Excellence Journey

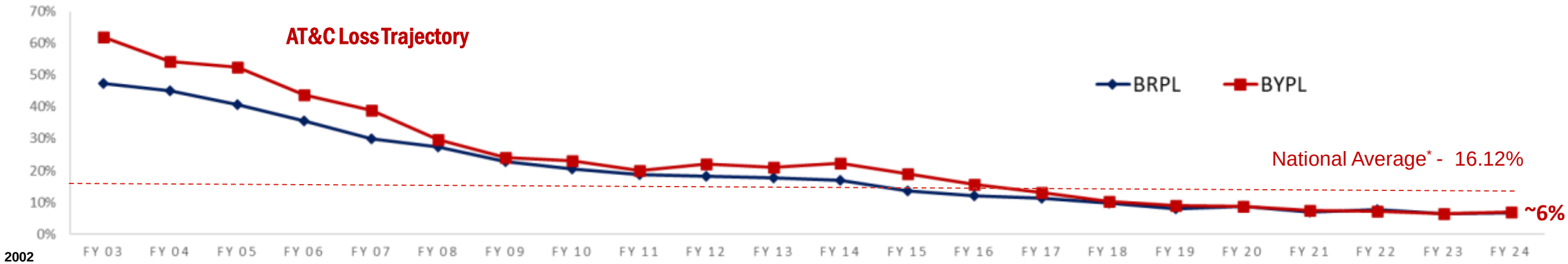
52 Lakh (BRPL 31.7; BYPL 20.3)
Consumers - **every 2 out of 3** Delhiites are served by BSES. Touching 2+ Cr. lives

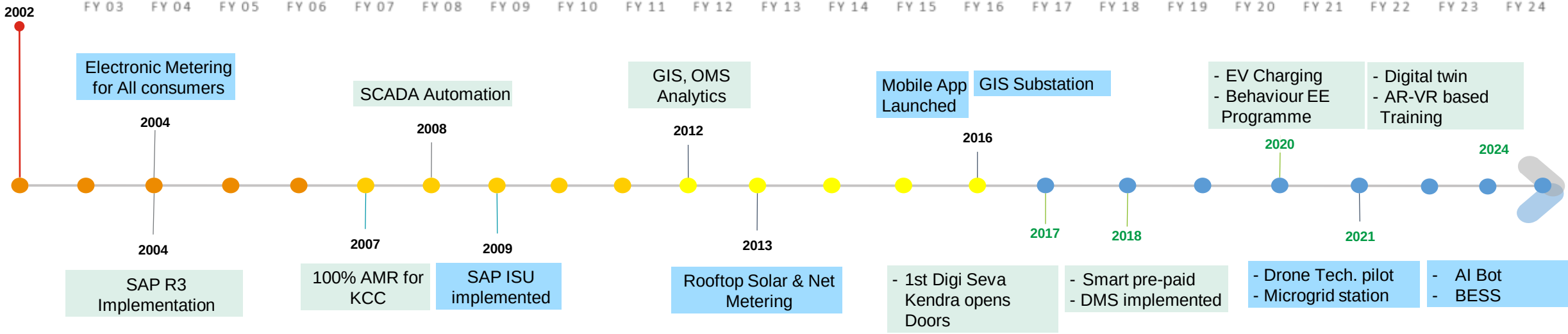
24 x 7
Quality & Reliable Power Supply

5,691 MW (BRPL 3,809; BYPL 1,882)
2024 Peak Demand managed *(more than that of all metros combined)*

3518 MW (BRPL 2531; BYPL 987)
Long Term RE tied-up
- Towards Green DISCOM (Hydro Capacity not included)

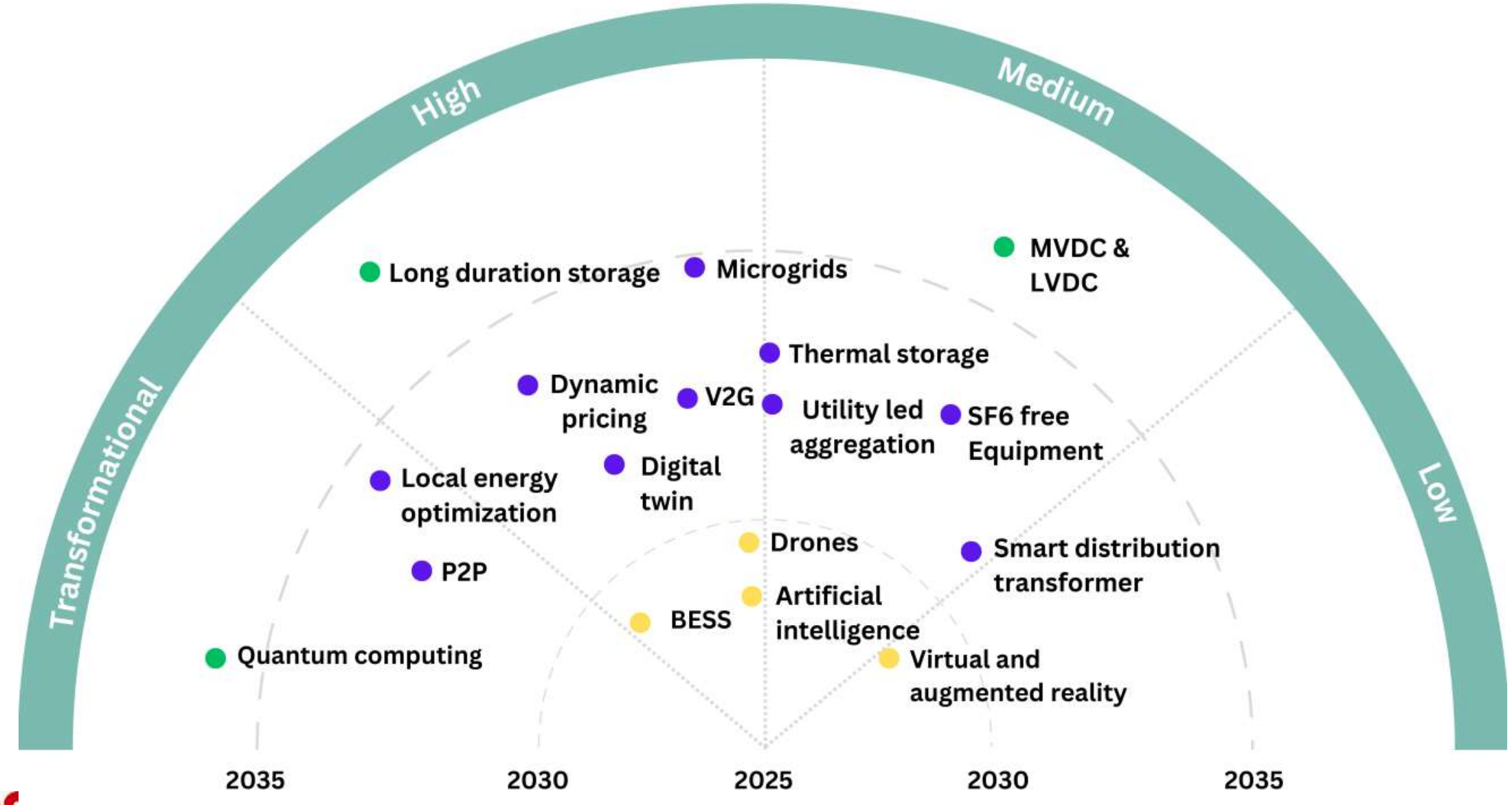
18,000+
Employment Opportunities





** As per PFC Report FY 23-24*

Innovation radar at BRPL



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AI Journey at BRPL

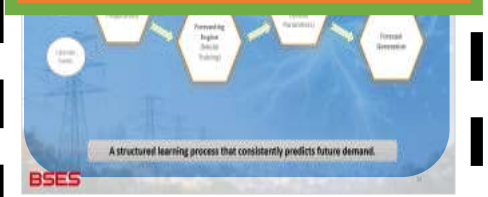
What makes AI function?

- **Classification**: Where a large data set is explored to identify classes of objects. This could be to sort operational and failure modes, or performance regions.
- **Regression**: Where data needs to be analysed to identify categories of objects, identify against known labels, or improve labelling.
- **Data Structure Exploration**: Where data needs to be explored to identify patterns or in the case of unsupervised learning, to identify potential labels
- **Generation**: Where large data sets are explored and used to develop structured and data-driven outcomes. An example of this would be ChatGPT.

Today's in-house developed solutions showcase

In-house developed

Regression and data exploration



Demand forecast

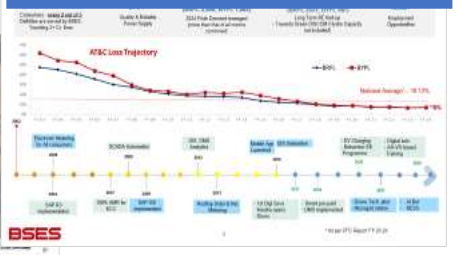
In-house developed

Regression

Customer experience automation

In-house developed

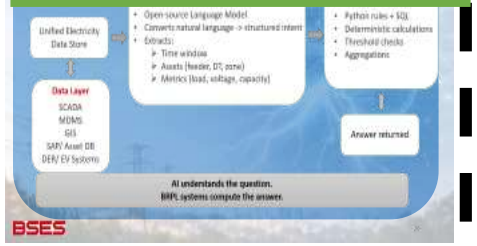
Data Exploration



Theft detection (K-means clustering)

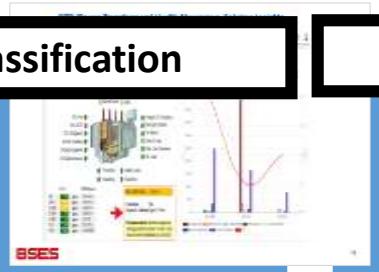
In-house developed

Generation



AI-Based Decision Intelligence

Classification



Asset health monitoring

Classification

Predictive maintenance

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AI-enabled demand forecast

Demand Forecasting Is a Daily Battle for DISCOMs around the Globe

Small forecasting errors now create disproportionate operational and financial impact.

Dynamic, Unpredictable Demand

Electricity demand is becoming more dynamic and less predictable.

Increasing Weather Variability

Demand shifts sharply with small weather changes.

Rising Expectations

Reliability and affordability are under constant scrutiny.

Faster Decisions

Decisions must be taken quickly, with limited margin for error.

Current costs in India are estimated to be in the range of INR 2000-2500 per MW for generating forecast*.

These developments require a fundamental evolution in how power distribution systems are planned and operated.

*https://cercind.gov.in/2015/regulation/SOR7.pdf

Why Traditional Forecasting Is No Longer Sufficient

Traditional Forecasting

- Based on averages and heuristics
- Limited weather consideration
- One forecast per day
- Manual interventions

AI- Driven Forecasting

- Multi-source data (load + weather + calendar)
- Continuous learning
- Intraday updates
- Weather-aware planning

AI fills a critical gap with ease. AI Links external factors such as weather condition, calendar, and more and self learns.

What We Set Out to Build

Objective

To build a production-grade, automated demand forecasting capability that DISCOM operations can rely on every day.

- Designed for daily operational use
- Stable, repeatable and continuous running
- Integrated into existing planning workflows

Forecasting scope

Day Ahead Forecasting
96 timeblocks at 15-minute resolution

Intraday Forecasting
Rolling updates every 15 minutes

Fortnightly Outlook
Long term demand outlook for planning

Each forecast directly supports a specific operational decision.

WEATHER DATA – SOURCES AND PARAMETERS

Weather has a significant impact on electricity demand, particularly for cooling and heating behavior. To improve forecast reliability, multiple weather sources were evaluated, and key weather parameters are explicitly incorporated.

Based on consistency, coverage, and reliability, IBM Weather is currently used as the primary source for forecasting.

Temperature – Influence heating and cooling load.
Apparent Temperature – Account for humidity and wind effects.
Humidity – Moisture content in air affecting cooling demand intensity.
Wind Speed – Air movement influencing heat loss and cooling efficiency.
Dew Point – Indicator of air moisture and thermal discomfort.
Cloud Cover – Affect solar heating and cooling load.
Precipitation – Influence human activity and electricity usage patterns.

Weather parameters are selected based on their observed impact on demand behavior and operational relevance.

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CALENDAR & EVENTS DATA

Electricity demand follows strong calendar-driven patterns influenced by work schedules, holidays, and social activity.
Calendar and event information helps distinguish expected behavior from abnormal demand changes.

Calendar and Event Signals

- Public holidays
- Festival days
- Pre and post holiday effects

Why Calendar Context Is Important

- Prevents misclassification of normal behavior as anomalies
- Improves forecast stability during holidays and festivals
- Enables better planning around known demand shifts

Calendar context allows the system to anticipate structured demand changes.

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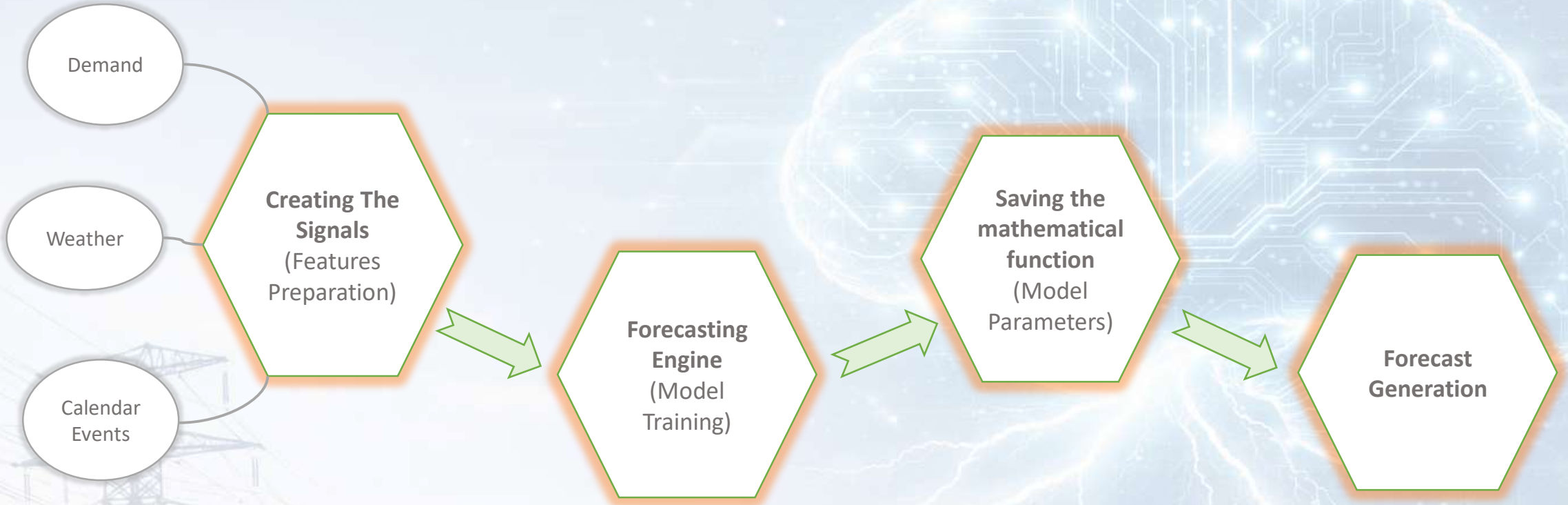
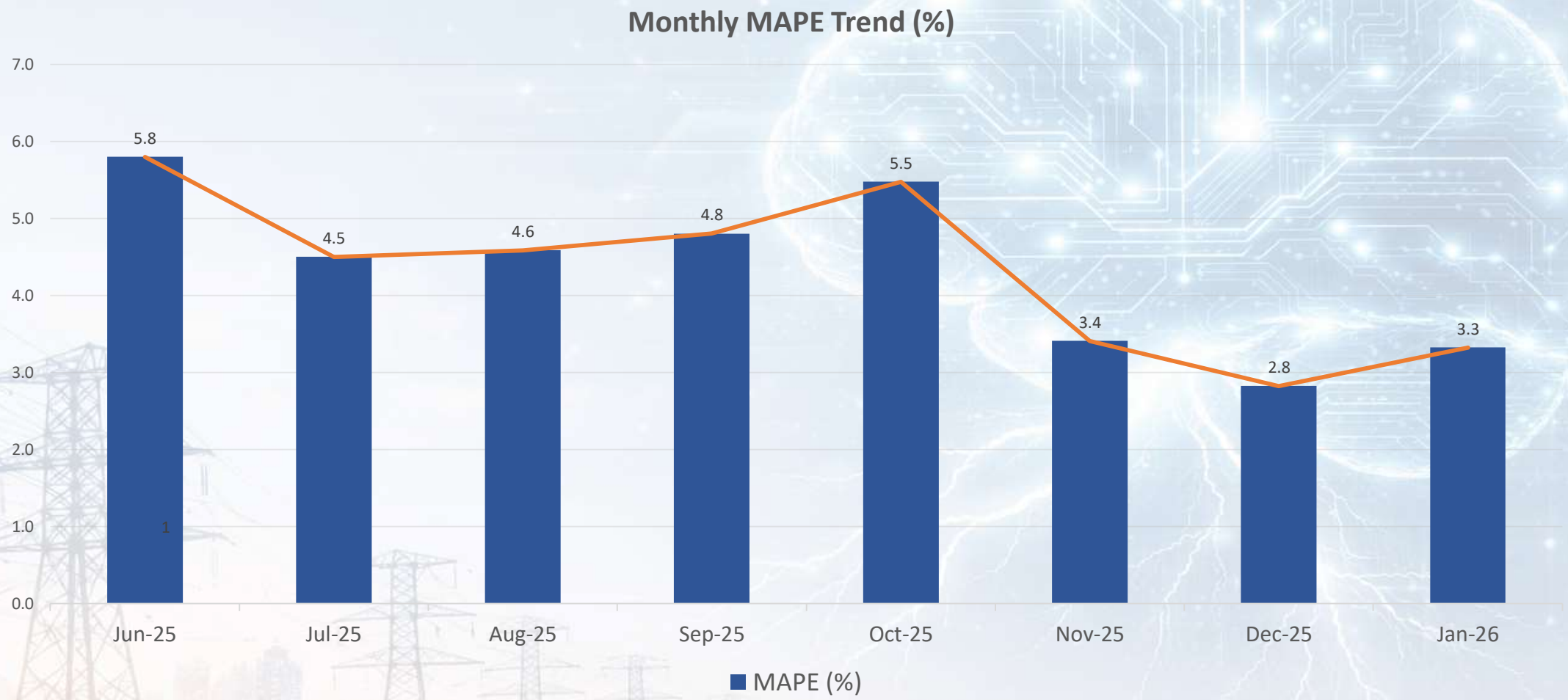
How the demand knowledge is learned and reused



A structured learning process that consistently predicts future demand.

MAPE Trend Over Recent Months



Mean average percentage error - $\mathrm{MAPE} = 100\frac{1}{n}\sum_{t=1}^{n}\left|\frac{A_t - F_t}{A_t}\right|$

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Extending analytics stack beyond forecasting

AI-Based Decision Intelligence on DISCOMs data

Operational Challenges

Data available, insights require manual analysis
Repetitive operational questions across teams
Delayed decisions during peak and contingency events

What this layer enables

Natural-language analytical queries
Direct answers from trusted DISCOMs data
Consistent logic and results every time

Network Planning & Expansion

- Which feeders are loaded >90% in peak summer evenings in the last 3 months?

Asset Management & Maintenance

- List all distribution transformers older than 15 years with loading >80%.
- Which DTs have oil temperature >90°C more than 5 times this year?

This layer reduces dependence on manual analysis while ensuring faster, consistent, and auditable operational decisions.

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System Architecture: How the AI Layer Works

Unified Electricity Data Store

Data Layer

SCADA
MDMS
GIS
SAP/ Asset DB
DER/ EV Systems

AI Reasoning Layer

- Open-source Language Model
- Converts natural language -> structured intent
- Extracts:
  - Time window
  - Assets (feeder, DT, zone)
  - Metrics (load, voltage, capacity)

Analytics Engine

- Python rules + SQL
- Deterministic calculations
- Threshold checks
- Aggregations

Answer returned

AI understands the question.
BRPL systems compute the answer.

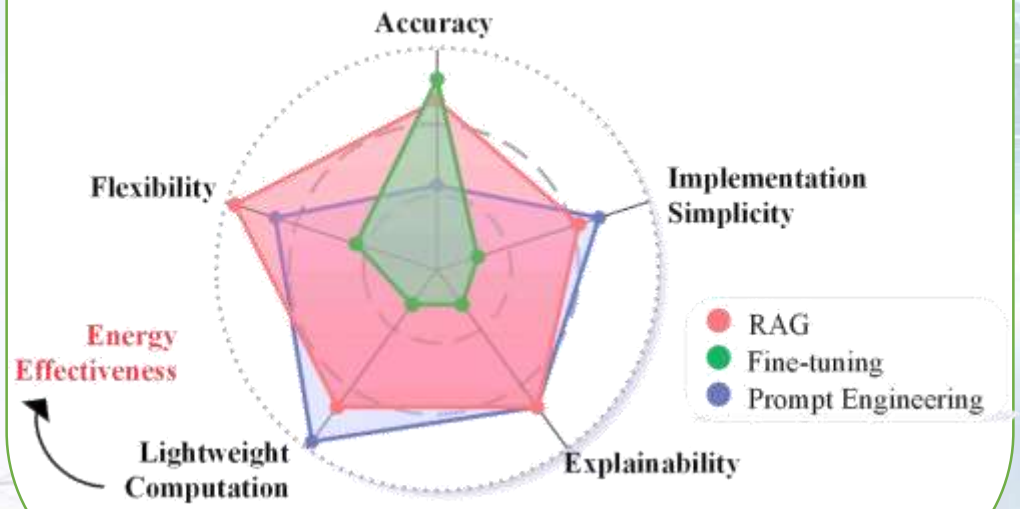
LLM customization

Off-the shelf LLM

Off-the-shelf LLM solutions are pre-trained on generic data

Customizing off-the-shelf LLM

- Prompt engineering,
- Retrieval augmented generation (RAG)
- Model finetuning



LLM Inference

Sever at the host utility

Prompt engineering is a process of crafting an instruction in order to have optimal outputs of an LLM model

RAG optimizes the output by referring to an external knowledge base outside of the training data.

Model finetuning is the process of further training a pre-trained LLM on a smaller and specialized dataset.

How a Question Is Answered

Step 1	User asks a question in simple language
Step 2	System understands what the user is asking (what, where, when)
Step 3	Question is converted into a clear analysis request
Step 4	Analytics engine executes on BRPL data
Step 5	Result validated and formatted
Step 6	Final answer is returned with context

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Thank You

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BSES Rajdhani Power Limited
BSES Bhawan, Nehru Place,
New Delhi – 11 00 19

BSES Yamuna Power Limited
Shakti Kiran Building, Karkardooma,
New Delhi – 11 00 32


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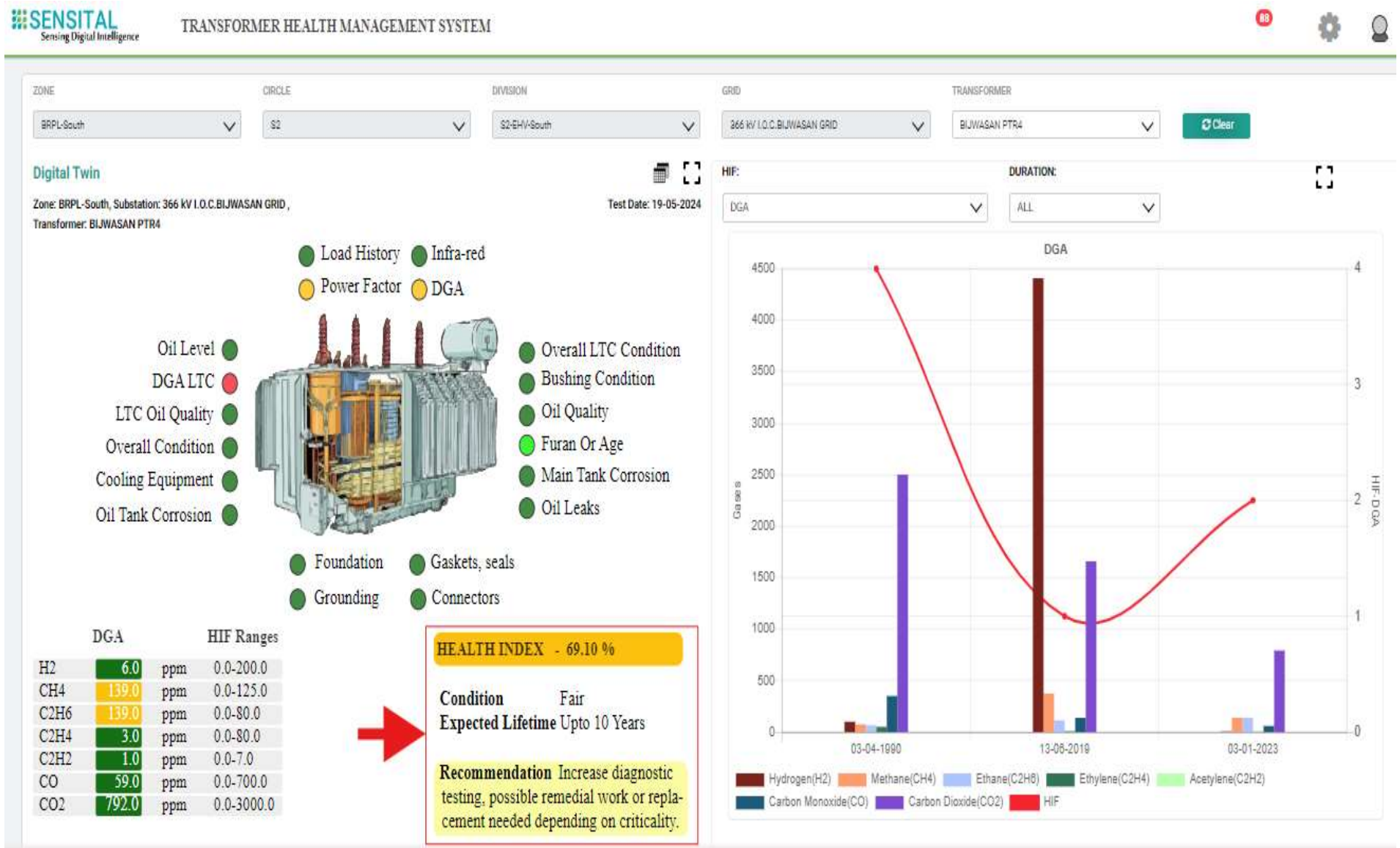
PTR (Power Transformers) Health Monitoring- Solution Insights



VR Based Training Modules

Air Circuit Breaker (LT-ACB)

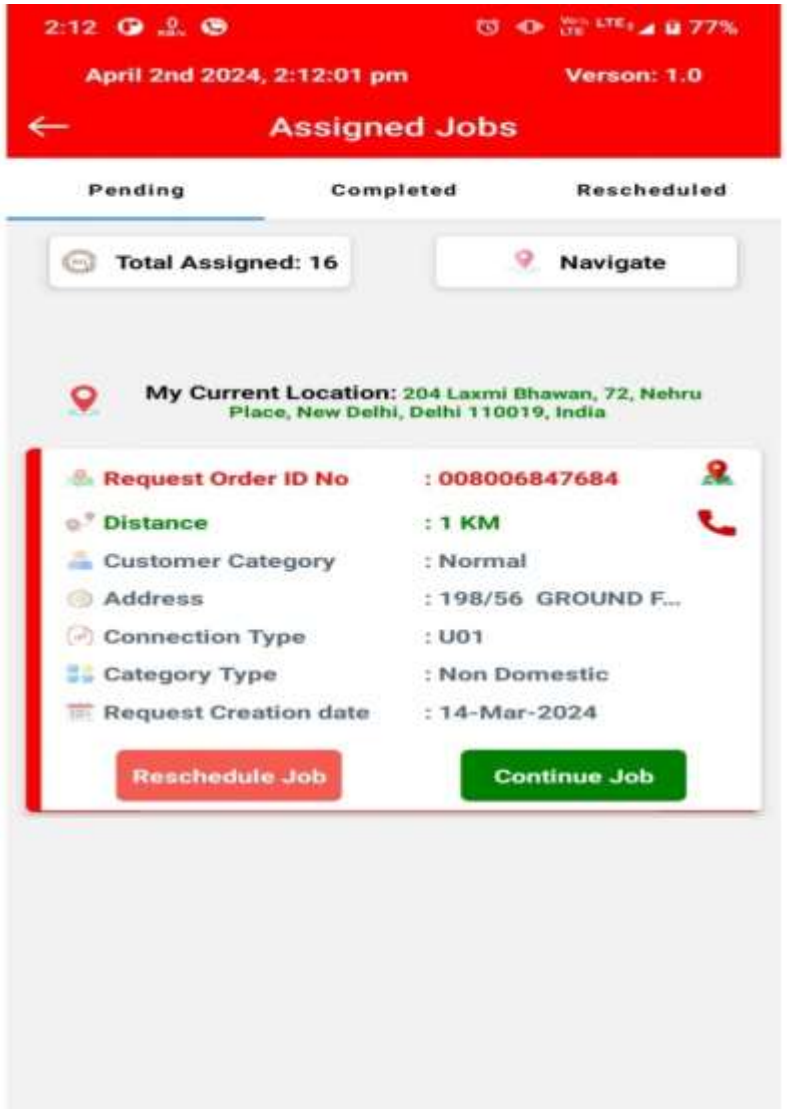
Ring Main Unit (RMU)

Protection Relay (PR)

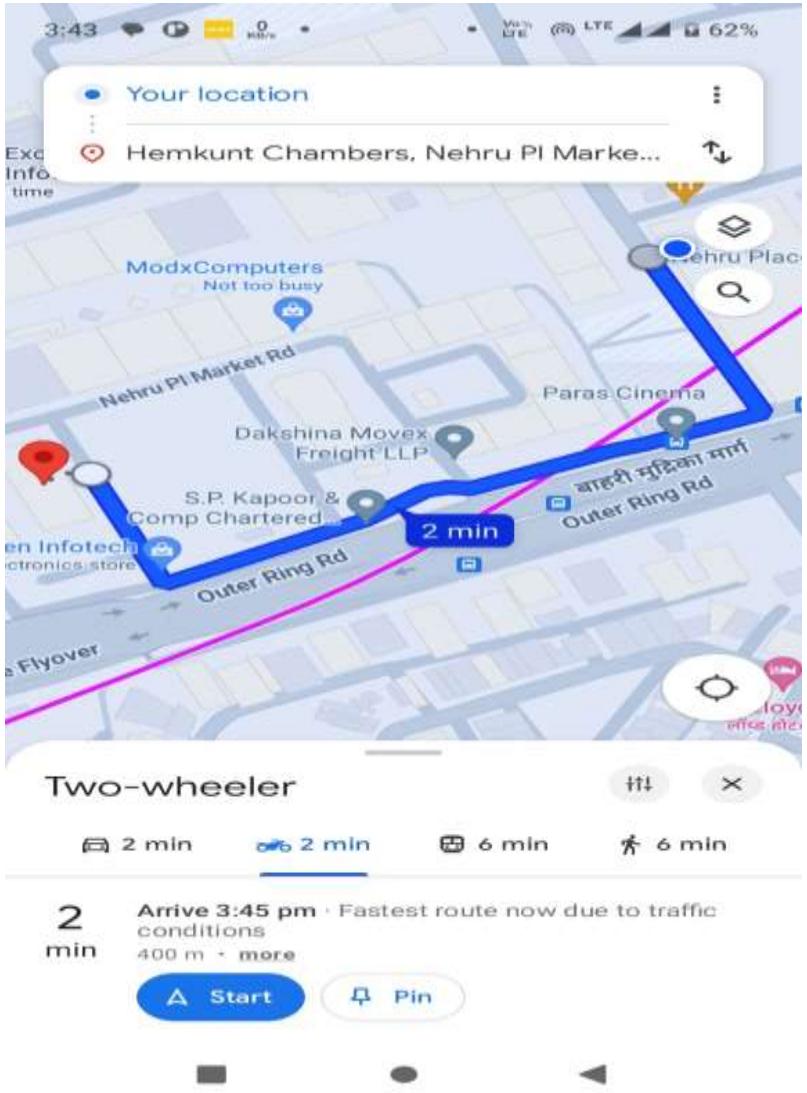
Technical Feasibility App

Dashboard

Job Assignment



Location Navigation



Digital Twin : From Network to Intelligence

POC at C4E & C3 blocks in Janakpuri (~3000 consumers)

About Digital Twin

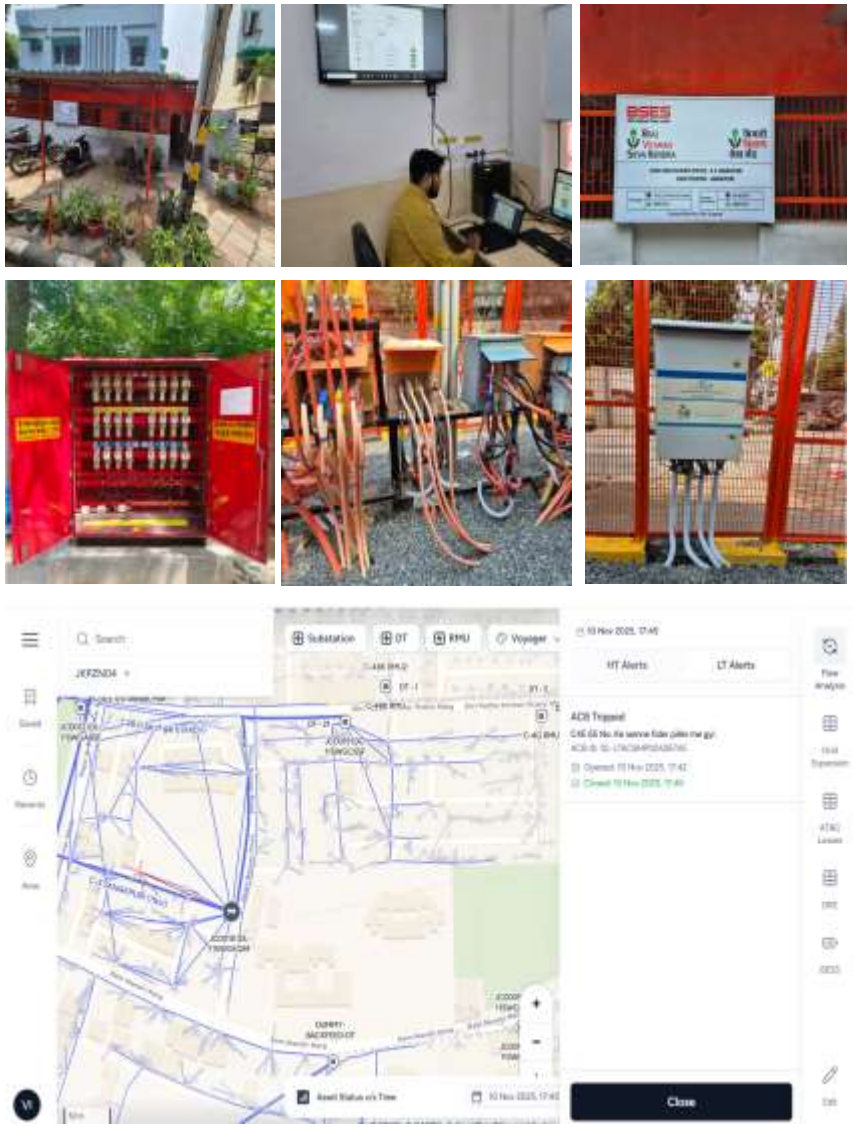
1. A **Digital Twin** is a real-time virtual replica of physical electrical assets like Grid, PTR, HT Feeder, Substations, transformers, LT network, etc.
2. It continuously **mirrors the status and behavior** of the power distribution network using both static and live data.
3. Integrates inputs from SCADA, GIS, SAP, iOMS, IoT sensors, GPR survey data, FRTUs, and smart meters.
4. Provides **real-time visualization**, system health monitoring, and operational insights.
5. Simulates scenarios such as **faults, load variations, outages, and switching actions**.
6. Enables **predictive maintenance**, helping prevent failures and reduce downtime.

Digital Twin – Key Value Propositions

1. **Reliability Improvement**
(Advanced Situational Awareness)
a. Faster fault localization
b. Rapid power restoration
c. Accurate outage insights for customer communication
d. Continuous monitoring of power quality & asset health
e. Outage prediction using historical + real-time data
f. Optimized crew deployment

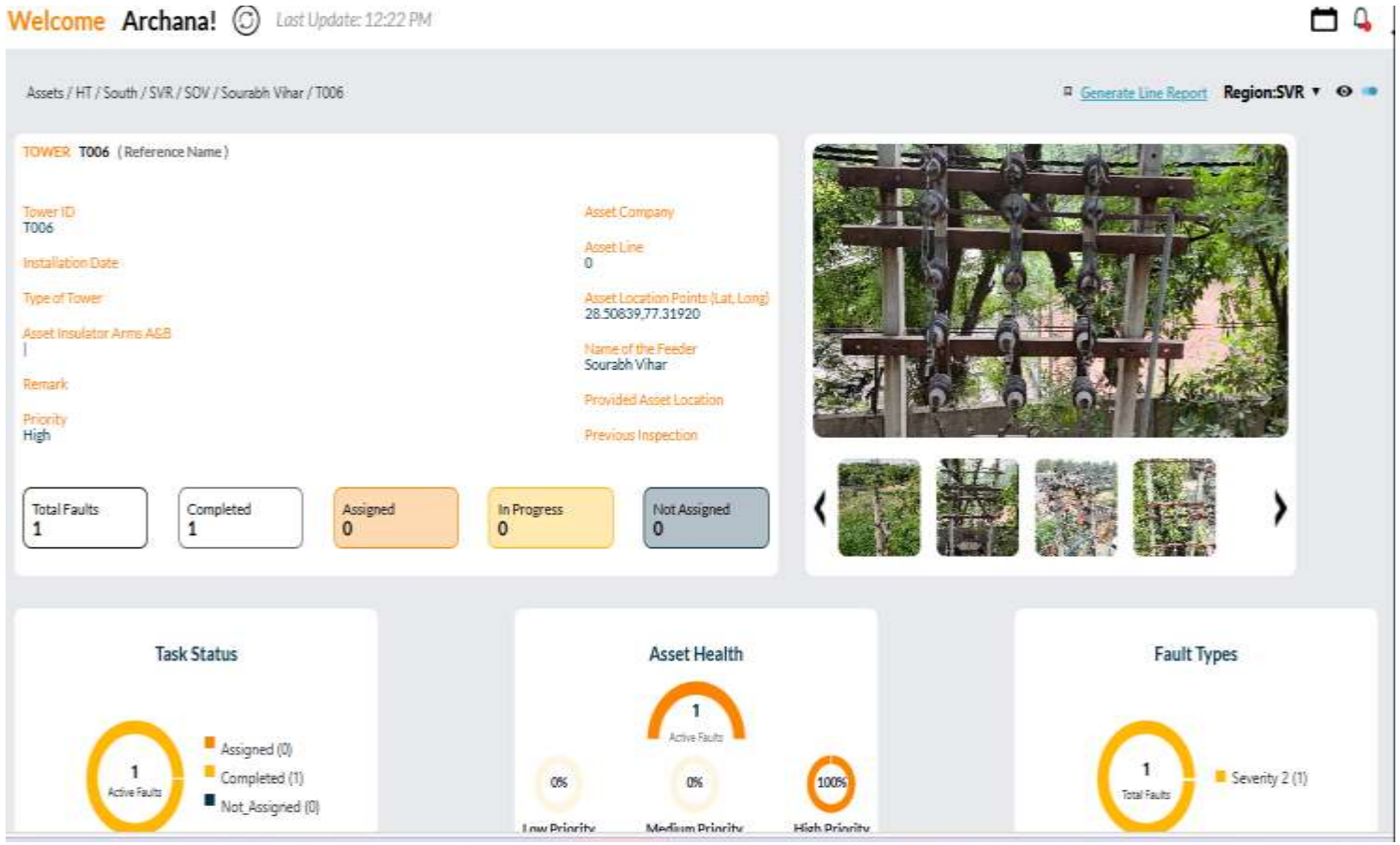
2. **Network Planning & Optimization**
(Impact Analysis & Predictive Insights)
a. Load flow analysis
b. Scenario-based network planning
c. Identification of bottlenecks & revenue leakage
d. Inputs for predictive maintenance
e. AI-enabled analytics and behaviour prediction

3. Utility Transformation
(Smart Grids & DSO Readiness)
a. End-to-end network visibility & control
b. Seamless DER integration
c. Transition towards Smart Grid / DSO operations



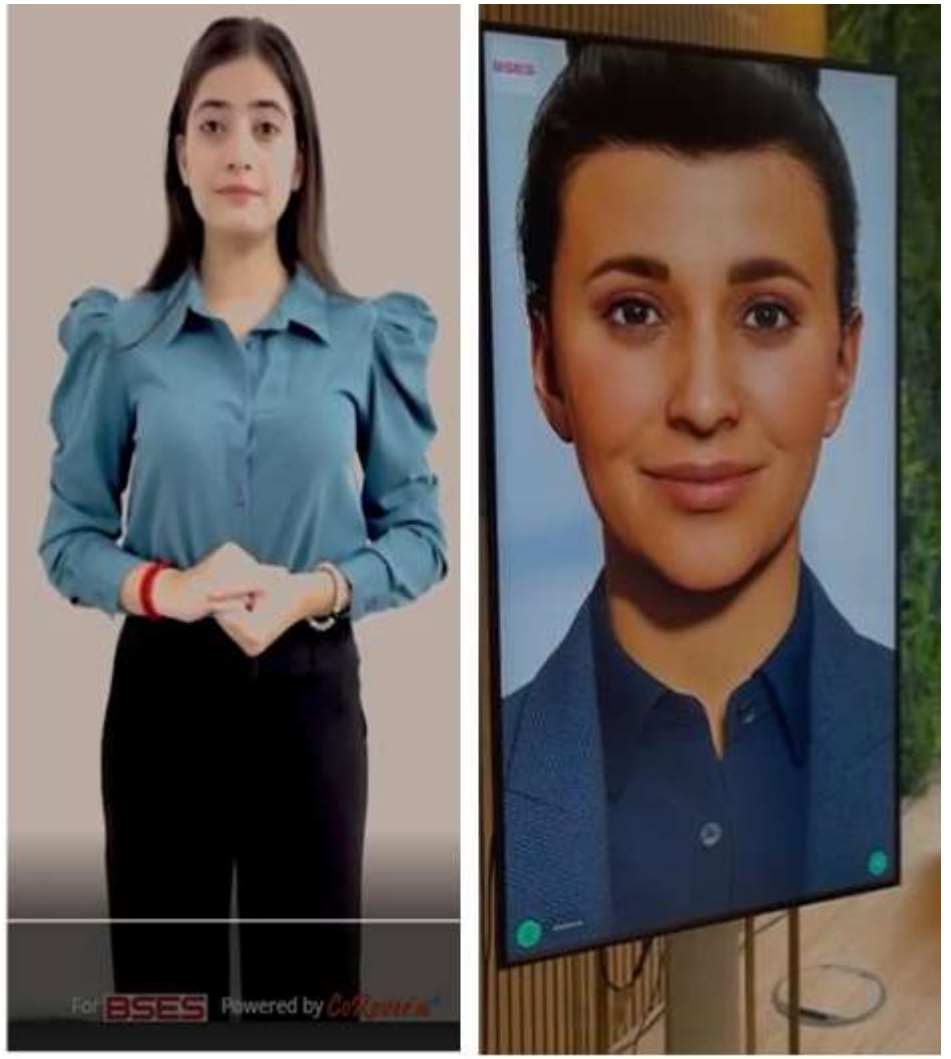
Impact: Reduction in avg. restoration time from 51 mins to 29 mins

Drone Survey for Overhead of EHV and 11 KV Lines



Fault identified

Era of Video bots in the service of customers



Inspired by Infosys Innovation Center, Dusseldorf