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MINISTRY OF POWER

GOVERNMENT OF INDIA

CENTRAL ELECTRICITY AUTHORITY

India SMART UTILITY Week 2025

20th, March 2025 (14:00 ~ 16:30 Hrs., India Time)

Session : DEEP DIVE SESSION ON AI, ML AND ROBOTICS USE CASES FOR UTILITIES

AI-ML APPLICATIONS FOR TRANSMISSION, DISTRIBUTION UTILITIES RENEWABLE ENERGY SOURCES AND GRID OPERATORS.

DR. AMIT RAMCHANDRA KULKARNI, ADDITIONAL EXECUTIVE ENGINEER , MAHATRANSCO .

MAHATRANSCO

Maharashtra State Electricity Transmission Co. Ltd.

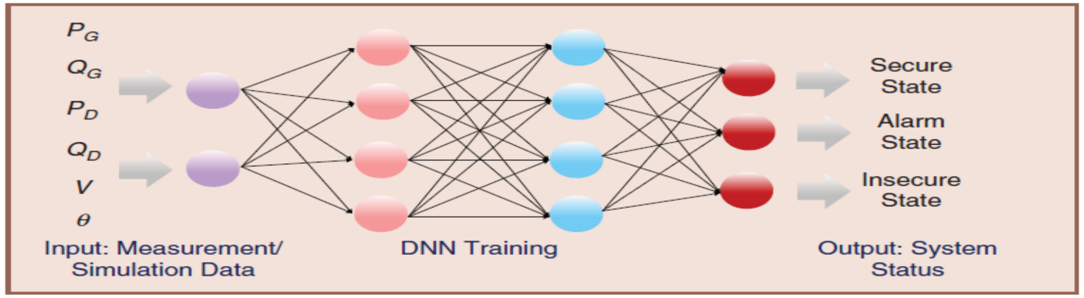
INTRODUCTION

- 64% of Energy CEOs agree that, investing in **AI-ML has an Edge** with 48% agreeing on **Return on Investment in 3-5 years**.
- **AI-ML Market in Energy Utilities** is expected to **Grow** to **USD 196.63 Billion by 2030**.
- **10,000+ Phasor Measurement Units (PMUs)** are Installed **Globally in Power Grids** streaming **Big Data** to Control Centres.
- Digitized Wind Turbine across the Globe generate 400 Billion Data Points Annually. **Microgrids**, **EVs**, **DERs**, **VPPs**, **Smart Grids** adding to this Data Volume.
- **2,34,80,201 SMART METERS** for **Consumers**, **DT**, and **Feeders** Installed **in India** by **04-03-2025**, Apart from this, Data from **SCADA**, **REMCs**, **O&M**, **Automation**, Asset Management, ERP, Energy Accounting, Trading etc generates **HUGE DATA**.

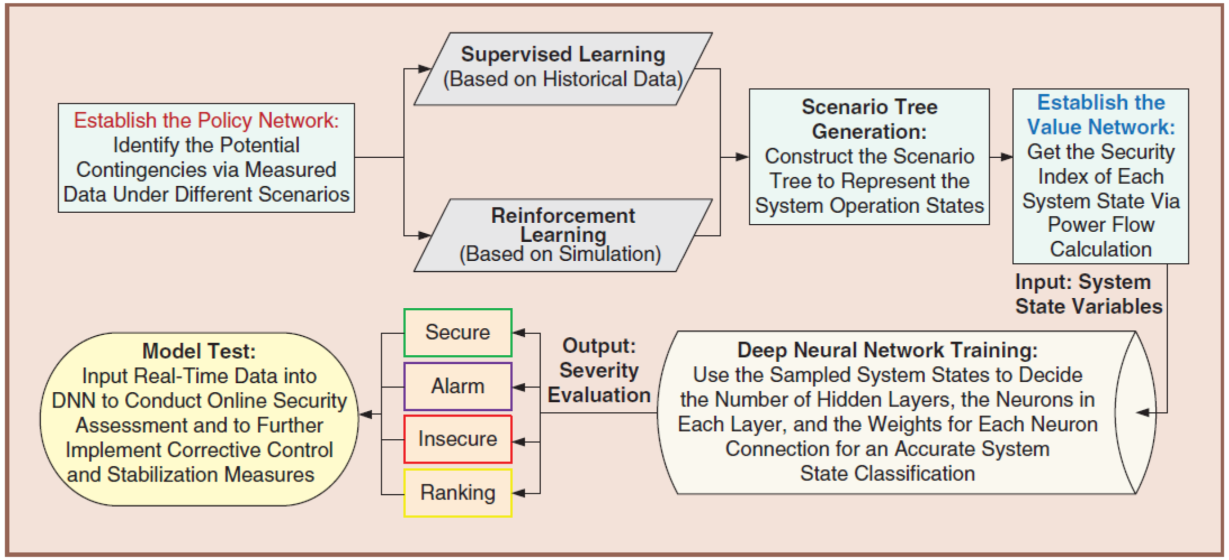
AI-ML SIGNIFICANCE FOR ENERGY UTILITIES

E.ON (the European Multinatinational Utility) **ML Algorithm forecasts when Medium Voltage Cables in the grid needs to be replaced.** Its research further indicates that, **Predictive Maintenance based on this could reduce Electrical Outages by 30% compared to Traditional Methods.**

Source: IEEE



Training the Deep Neural Network (DNN)



DNN BASED ONLINE SECURITY ASSESSMENT

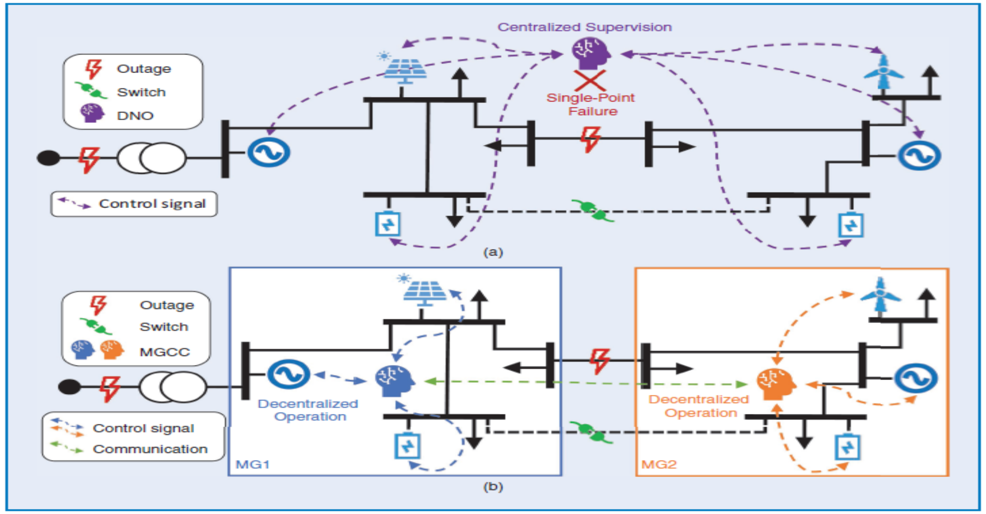
SOME AI-ML APPLICATIONS IN POWER SYSTEMS..

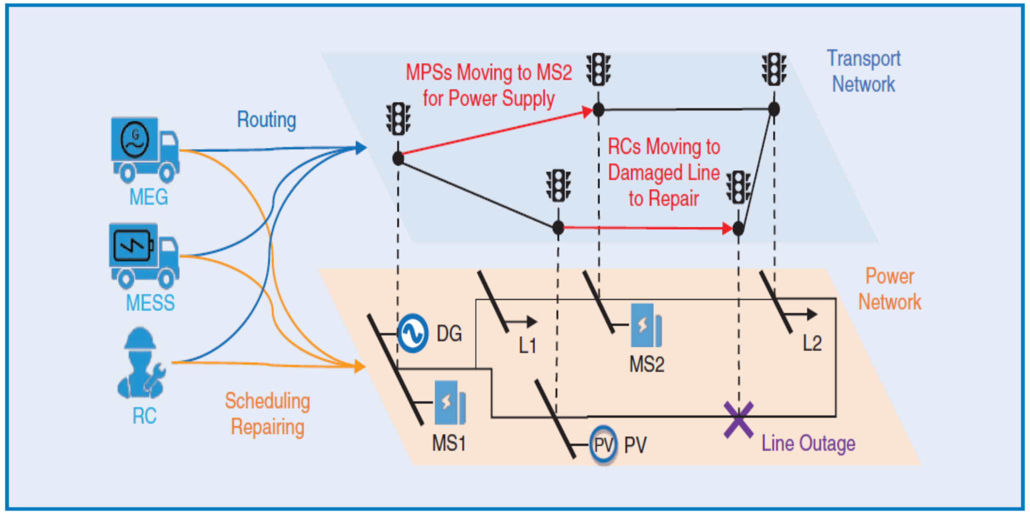
Objectives	AI-ML Technology	Source of Data	Methodology	Outcome
Designing Demand Response (DR) Programs for Prosumers.	**Clustering Algorithms**	**Smart Meter Data from Italian Utility**	**K-Means** Clustering	**For effective DR Implementation**
Optimize EV Charging/ Discharging for V2G Integration	**Reinforcement Learning**	**KEPCO's EV charging Data**	**M**arkov **D**ecision **P**rocess **(MDP)** and **D**eep **D**eterministic **P**olicy **Gradient (DDPG)** Algorithms	**Cost effective to User and Battery lifespan extension**
Improving Short Term Solar and Wind Power Prediction	**Deep Learning**	**Chinese State Grid**	**C**onvolutional **N**eural **N**etwork **(CNN)**-**L**ong –**S**hort **T**erm **M**emory **(LSTM)**	**Forecasting Error Reduction in Hourly and Day Ahead Predictions**
Optimal Energy Storage Planning under RE Uncertainty	**Deep Reinforcement Learning (DRL)**	**California ISO Curtailment Data, Edison Time Of Use (TOU) Plans**	DRL	**Outperformed scenario based stochastic optimization and achieved 90% Profit Accuracy**
Accurate RES prediction to reduce consumer Energy cost	**Deep Learning**	**NREL, National Solar Radiation Data Base (NSRDB)**	Multiple Heads Convolutional Neural Network (**MH-CNN)**	**Decrease Energy Bills with and Without Energy Storage Systems (ESS)**

Approach To be adopted while implementing AI-ML Techniques Vis-a-Vis, Power System Applications :

The Good (*To be Adopted*), The Bad (*Avoid at All Costs*), and The Ugly (*To be Adopted with Caution*)..

RELEVANCE: T&D, Microgrid, Energy Markets To Grid Control



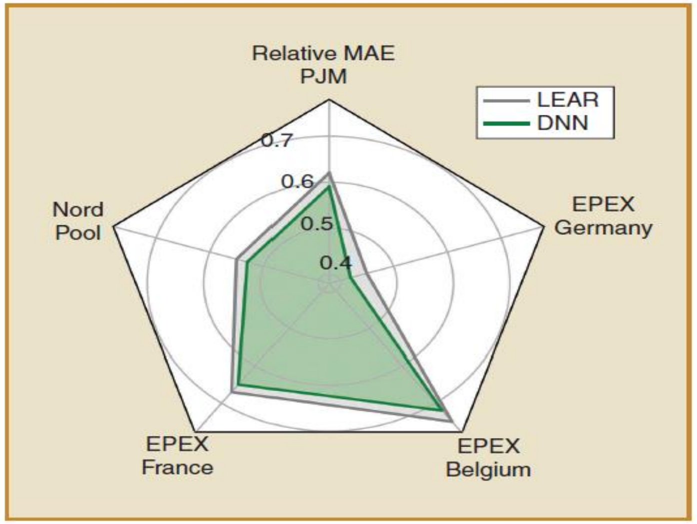


MICROGRID APPLICATIONS:

Rerouting, Scheduling of Generation Sources, Battery Sources And Repair & Maintenance Crew (R&MCs).

a) Centralized operation of DISCOMS

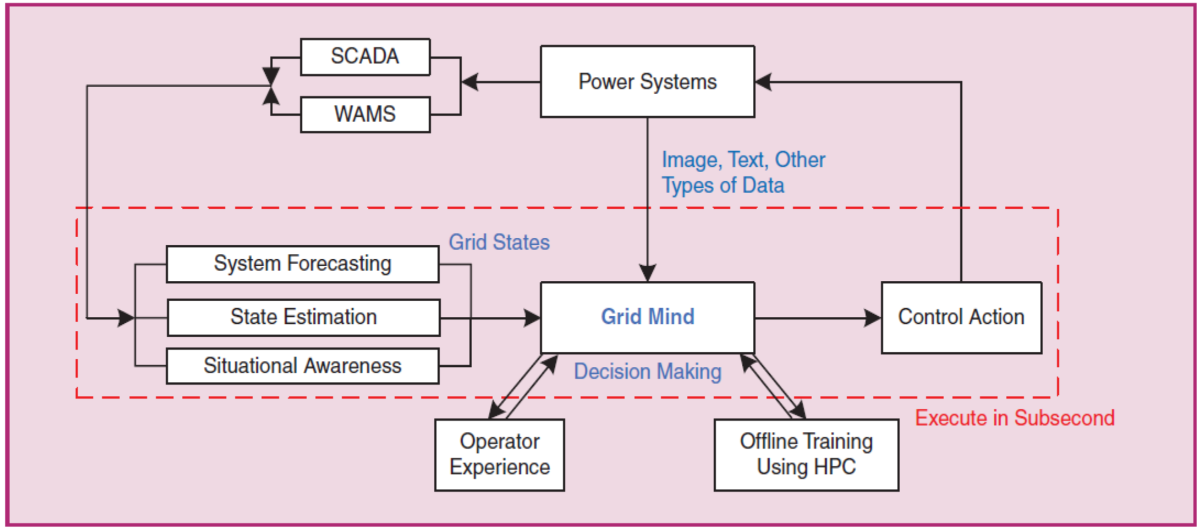
b) Decentralized operation of DISCOMS with multiple Microgrids



RADAR Plot for Relative Mean Absolute Error (rMAE) for Electricity Price Forecasts.

➢AI Models used: LASSO Estimated Auto Regression (LEAR) And Deep Neural Network (DNN)

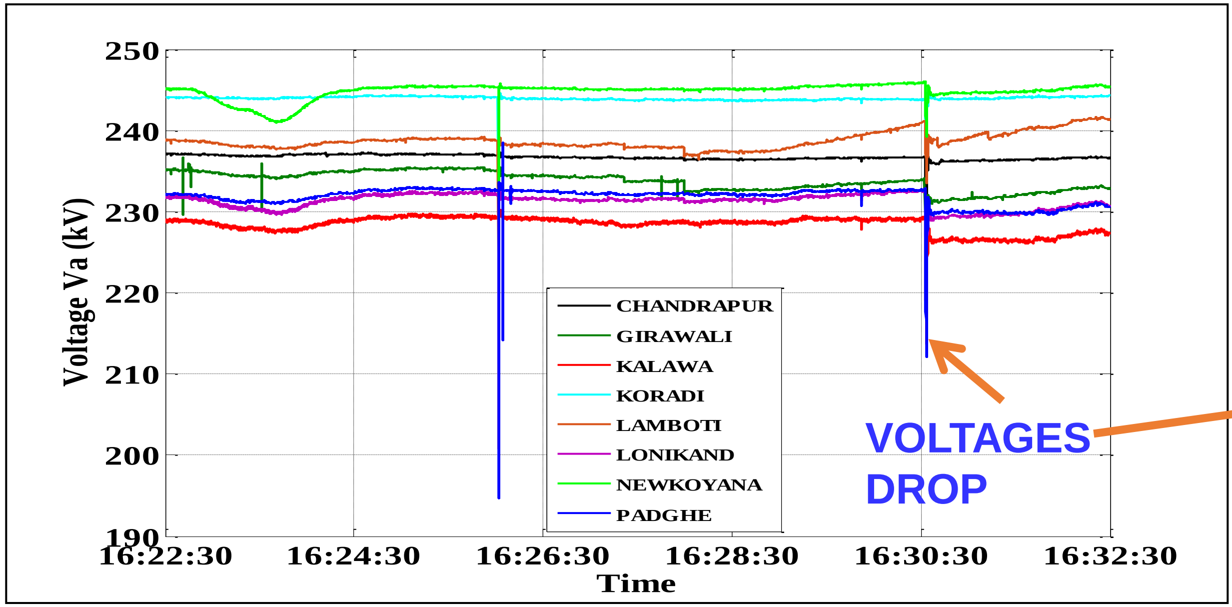
➢Study based on 2-Year periods for 5 Major Day Ahead (DA) Power Markets .

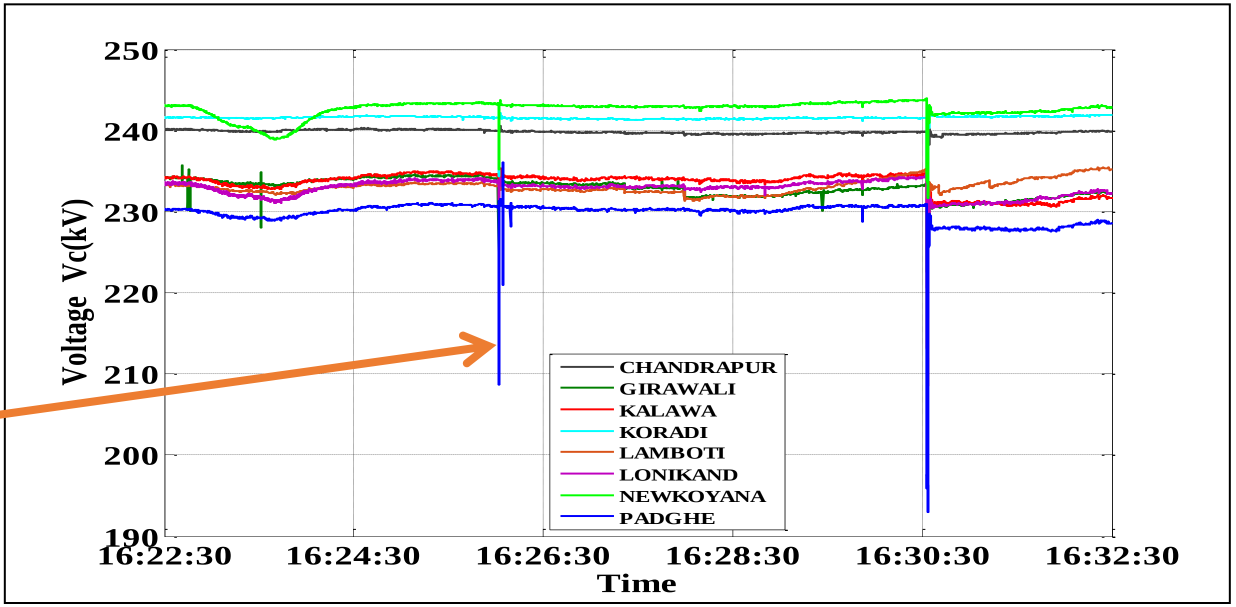


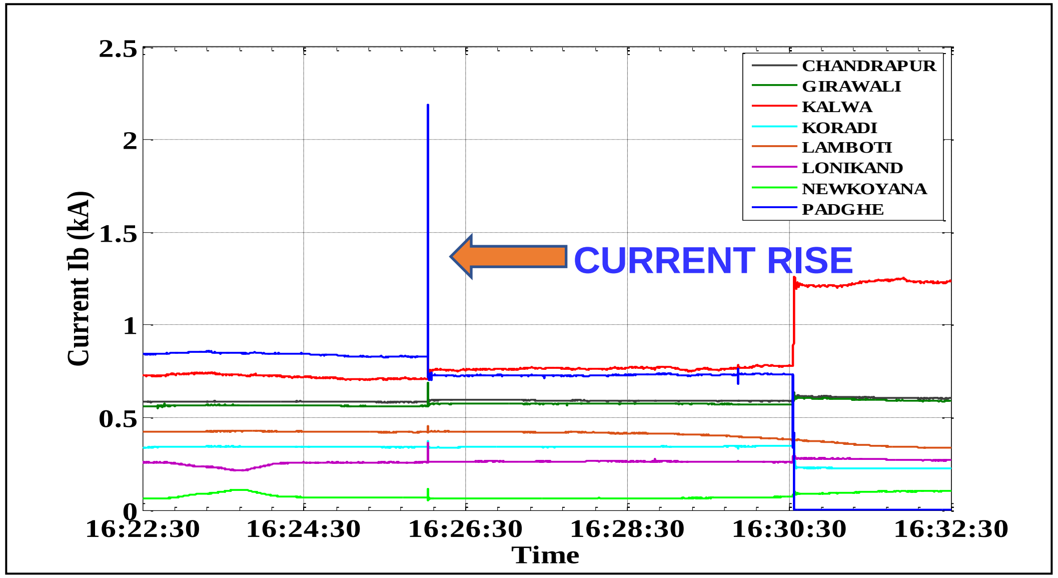
Generalized Grid Mind Framework: Supervisory Control And Data Acquisition (SCADA); Wide Area Measurement Systems (WAMS) ; High Performance Computing (HPC)

Source: IEEE

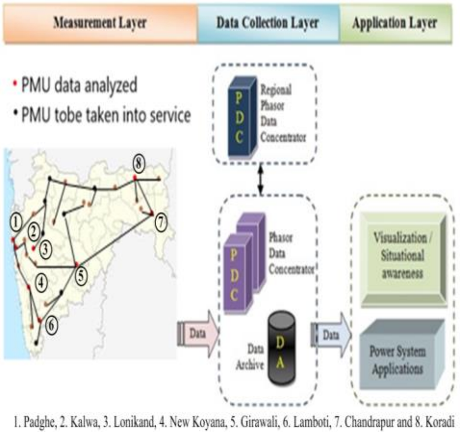
MAHATRANSCO EVENT ANALYSIS USING WAMS







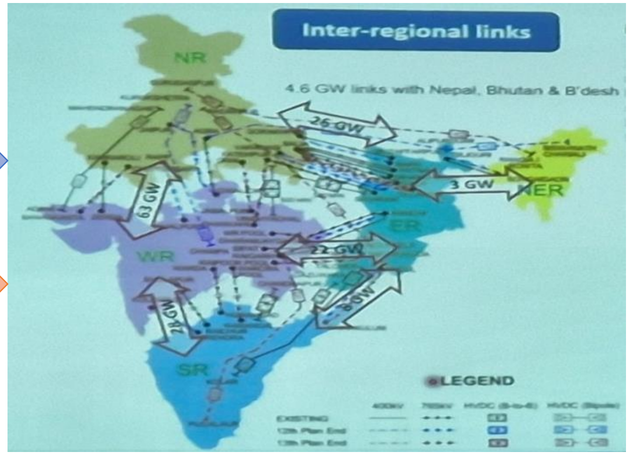
MAHARASHTRA STATE GRID WITH WAMS



Scalability

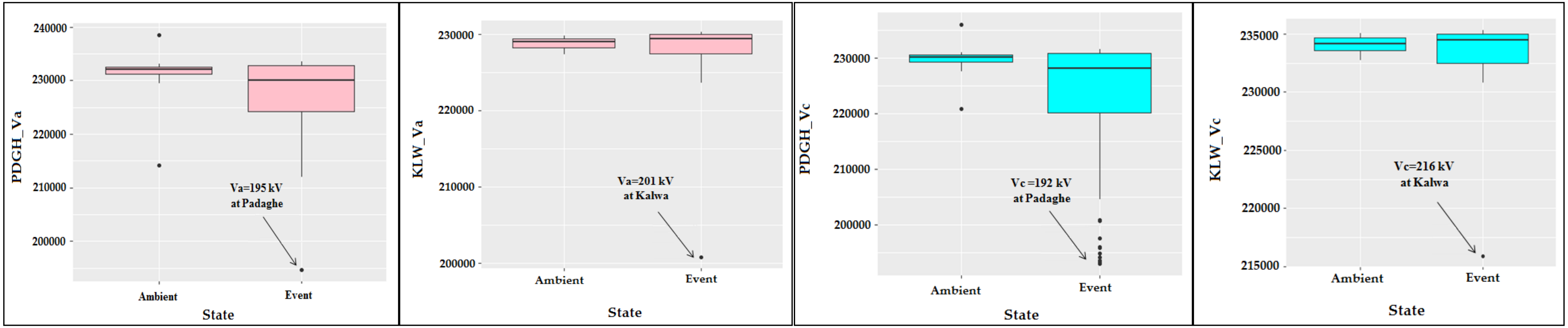
Replication

INDIAN GRID INTERCONNECTIONS

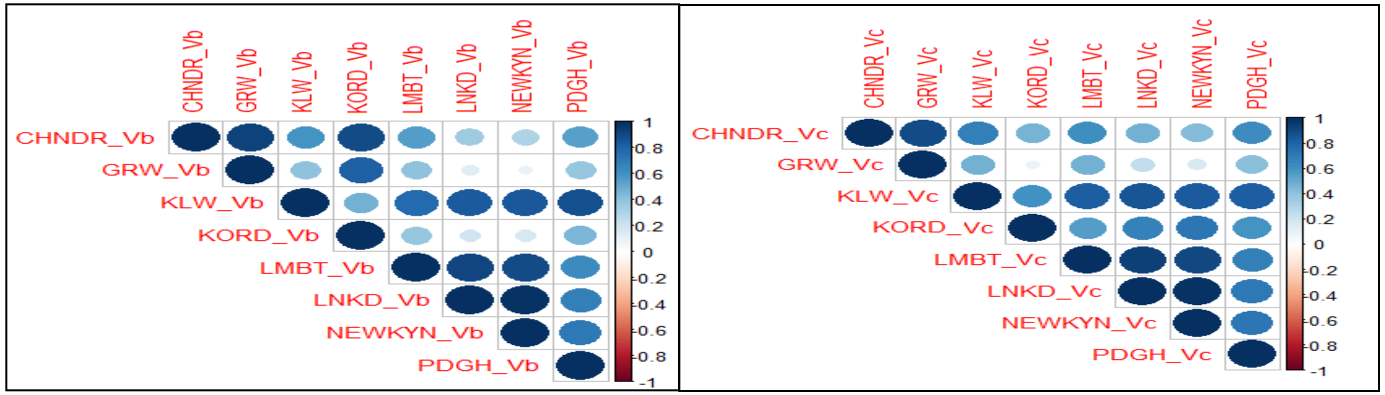


ANALYSIS WITH MACHINE LEARNING TECHNIQUES AND PMU DATA: A CASE STUDY

BOX PLOT ANALYSIS WITH PMU DATA:



CORRELATION ANALYSIS WITH PMU DATA:



Correlation Indication for 400kV Substation Voltages based on PMU Data for Event

Sr. No.	Correlation Pair of 400kV Substation Locations	Correlation coefficient for voltage V_b during Event 1	Correlation Indication
1)	Padaghe-Lonikand	0.69	Moderately Correlated
2)	Padaghe-Kalwa	0.87	Highly Correlated

AI-ML AND Using SMART GRID DATA FROM PMUs

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- **Improved Inference** from **Big Data** from **smartgrid devices like Phasor Measurement Units (PMUs) from Transmission And Distribution Utilities**, and its **use by Electric Power utilities for grid Monitoring, Operation and related Control with Enhancement in Visualization and Situational awareness of the Grid.**

- **Pioneering work by MAHATRANSCO in India** towards facilitating use of PMU data streams for **DECISION-MAKING** and Improved control of the power system via **BOX PLOTS**, **CORRELATION, CLUSTERING and IDENTIFICATION OF VARIOUS EVENT SIGNATURES.**

- **The framework defined is extremely useful not only for Power System's Monitoring, but th**at **for Decision Support, and Planning Purposes** as well.

- The Traditional Linearized Slow Coherency approach **cannot track the varying coherent Generator Groups appropriately in Dynamic Power System, But application of Machine Learning Techniques to BIG DATA from PMUs can be adopted to accurately realize Coherency of Generators, Nodes/Areas Vis-a-Vis Power System Dynamics. This input can also be used for improving System Integrity Protection Schemes (SIPS).**

- **Thus, Adoption of Machine Learning Techniques for Real Time PMU Data from the Grid Results in Improved Grid Operations, Management and Control** further **achieving BETTER GRID RESILIENCY .**

KEY TAKEAWAYS / RECOMMENDATIONS

MAJOR AI-ML APPLICATIONS FOR ELECTRICAL POWER SYSTEMS UTILITIES TO ADOPT:

- ✓Load and Generation (Including RE sources) forecasting accuracy enhancement by using AI-ML Techniques.
- ✓Developing ML based data driven power system dynamic models and developing Dynamic Security Assessment (DSA).
- ✓Improving performance of Energy Management Systems (EMS) using AI to predict Stability Accurately.
- ✓ML techniques can be applied to PMU data to Classify Fault Types and Suggest Corrective Actions.
- ✓Improve Protection And Automation System Performance.
- ✓Grid Monitoring, Diagnosis, Fault Detection, and Suggesting Remedial measures to improvise Grid Operations, Monitoring and Relevant Controls.

ARTIFICIAL INTELLIGENCE (AI) AND MACHINE LEARNING (ML) USAGE BRINGS AN EDGE TO INTERPRET ELECTRICAL POWER SYSTEM, ASSIST ENHANCE APPLICATIONS, & FUNCTIONALITIES OF ELECTRICAL POWER GRIDS.

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THANK YOU

For discussions/suggestions/queries email: isuw@isuw.in

www.isuw.in

Links/References (If any)