EE309: Term Project

Topic:- Voltage Stability Assessment in Assessment in Real-Time (VSI)

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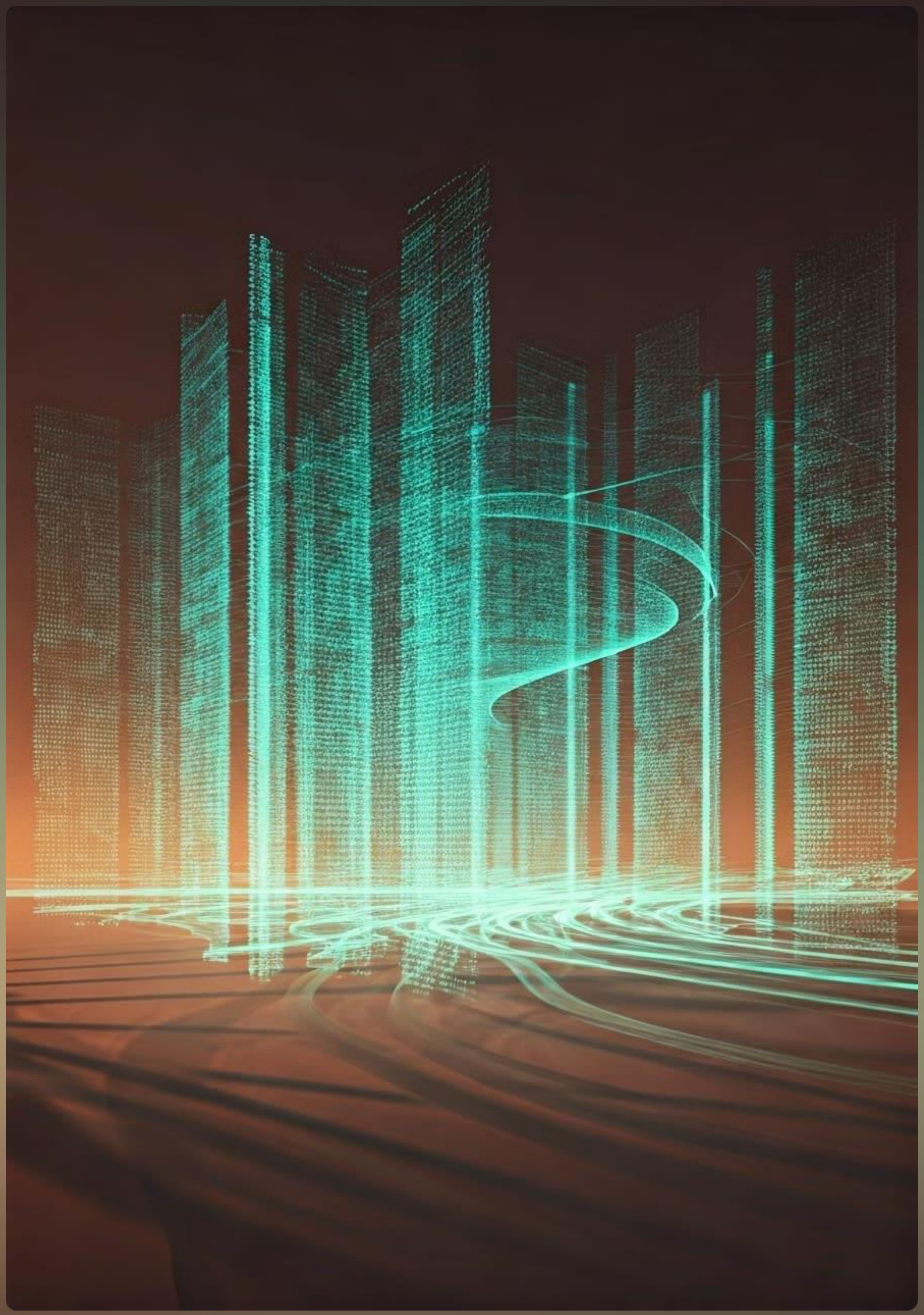


Phasor Measurement for Voltage Stability

Using synchrophasor sensors to assess long-term voltage stability in smart grids. Synchrophasor technology offers high-resolution, time-synchronized measurements across wide geographical areas, enabling a more accurate and comprehensive assessment of voltage stability. This approach facilitates early detection of potential voltage collapse scenarios and allows for proactive control actions, enhancing the overall resilience and reliability of the smart grid.

Objective

Model-Free Technique

Develop a model-free technique for accurate voltage stability assessment by directly using synchrophasor measurements, avoiding reliance on complex system models.

Optimal Sensor Placement

Minimize the number of sensors required while ensuring complete system observability, using strategic placement algorithms to reduce costs and complexity.

Real-Time Prediction

Achieve early prediction of system collapse conditions through real-time data analysis and predictive algorithms, enabling proactive control actions to prevent voltage instability.

Methodology

- **Sensor Placement**

Optimal placement of Phasor Measurement Units (PMUs) ensures complete observability of load buses.

This minimizes the number of PMUs required while maintaining system reliability.

- **Jacobian Estimation**

PMU measurements construct a measurement-based Jacobian matrix.

The Jacobian is estimated in real-time using the Ornstein–Uhlenbeck process.

- **Quick System Check**

Use sensor data to build a real-time system map.

This shows how the system responds to load and generation changes, helping identify potential voltage stability issues.

- **Real-Time Execution**

The voltage stability assessment algorithm executes in less than 0.1 seconds.

This enables immediate corrective actions based on real-time data.

- **Spotting Weak Points**

Use advanced math to identify vulnerable areas that could cause voltage instability.

This helps target mitigation strategies to improve grid resilience.

- **Voltage Collapse Indicator**

Develop an early warning system using sensor data and algorithms to predict voltage stability issues, enabling proactive steps to maintain grid reliability.

Optimal Sensor Placement

Strategic sensor placement optimizes cost, ensures observability, and accounts for potential failures in PMU deployment.

Minimize Cost

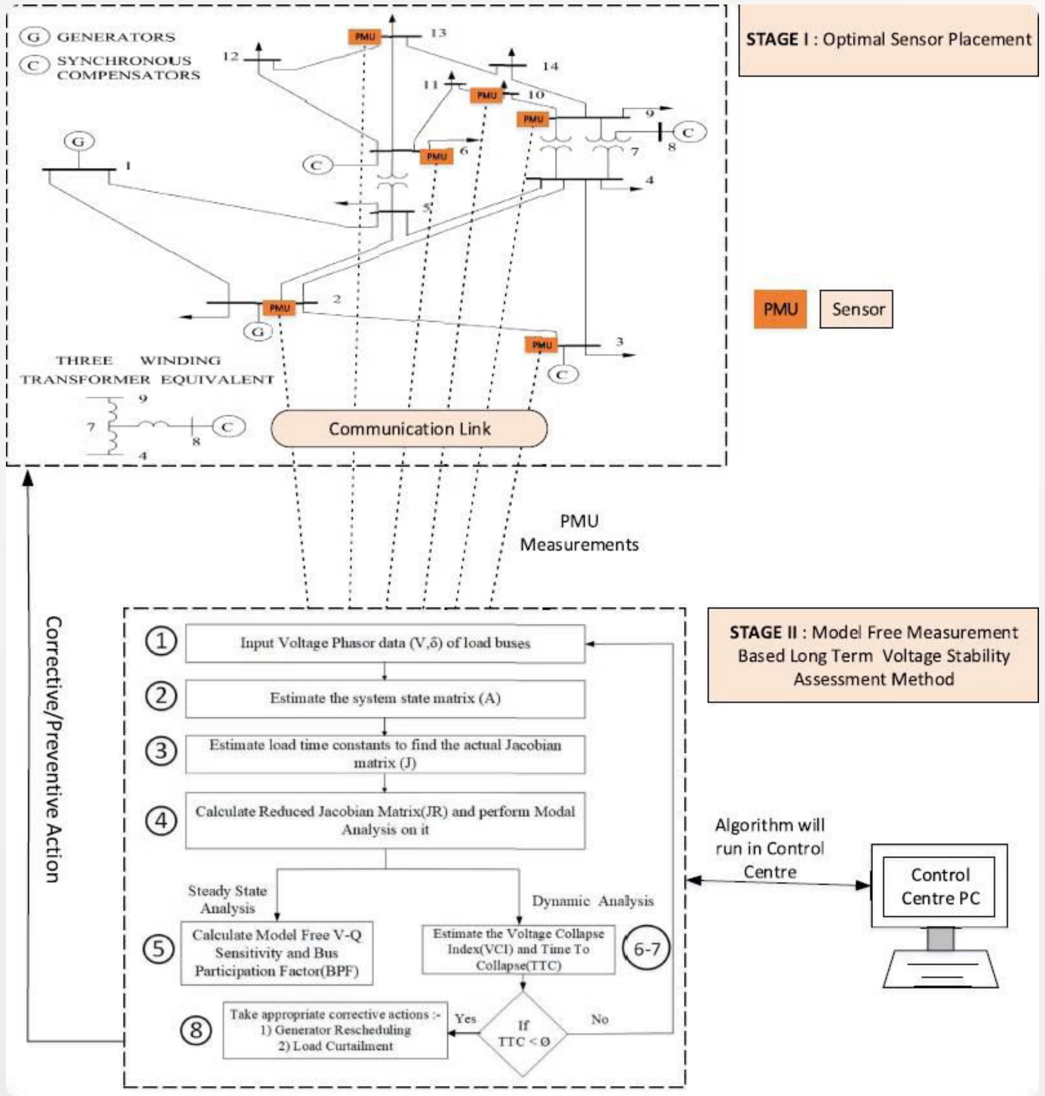
Reduce the number of PMUs to lower initial investment and maintenance costs, optimizing resource allocation.

Ensure Observability

Guarantee complete system visibility by optimally placing sensors, enabling accurate state estimation and real-time monitoring.

Account for Failure Failure

Incorporate redundancy in sensor placement to maintain system observability even in the event of sensor failures, ensuring continuous monitoring.



Dynamic Load Modelling

- Models load behaviour with differential equations.
- Considers real and reactive power demands.
- Linearized around a steady-state point.

1

Real Power

Models active power recovery, reflecting the load's response to changes in voltage and frequency. Captures the dynamics of motor loads and their impact on system stability.

2

Reactive Power

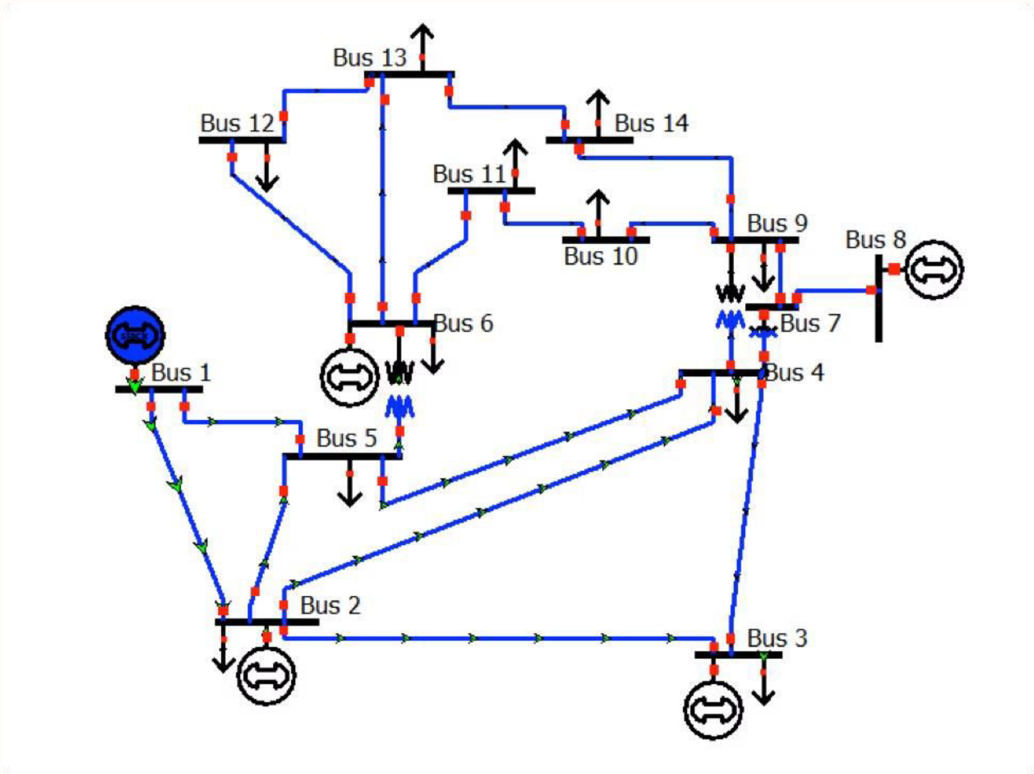
Models reactive power recovery, essential for understanding voltage stability issues. Represents the behavior of reactive power compensation devices and their interaction with the grid.

3

Linearization

Simplified for real-time use by linearizing the dynamic load model around a steady-state operating point. This reduces the computational burden, enabling faster analysis and control.

Test System



IEEE 14-Bus System

The IEEE 14-bus system, a widely used benchmark for power system studies, has been configured with six optimally placed PMUs to ensure comprehensive network observability. These PMUs are strategically located to capture critical system dynamics and enable accurate state estimation. Dynamic loads are modeled at eight load buses to represent realistic load behavior and assess the system's response to disturbances.

NE 39-Bus System

The New England 39-bus system, known for its complex network topology and diverse load characteristics, features seventeen sensor locations to provide extensive monitoring capabilities. Dynamic load models are implemented in 19 load buses, capturing the intricate interactions between loads and the grid. This detailed modeling approach allows for a thorough evaluation of voltage stability and control strategies.

Key Results

1

Early Warning

Provides early warning of collapse, allowing operators to take proactive measures to prevent voltage instability. This early detection capability is crucial for maintaining grid reliability and preventing cascading failures.

2

Accurate TTC

Estimates time to collapse accurately, enabling timely intervention strategies. The precise estimation of Time To Collapse (TTC) allows for the implementation of effective mitigation techniques, ensuring system stability.

3

Robustness

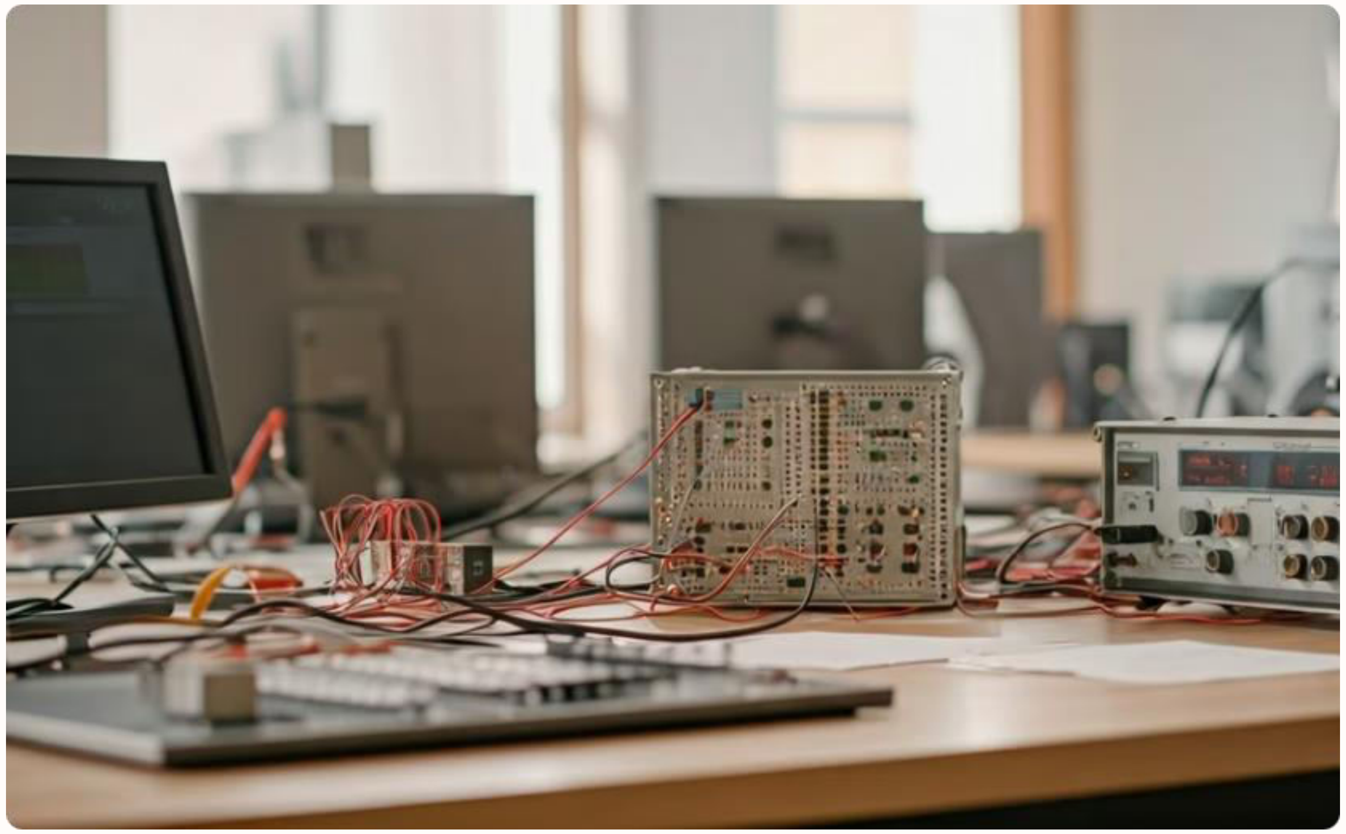
Immune to measurement noise, ensuring reliable performance in real-world conditions. The robustness of the method against measurement noise guarantees the accuracy and dependability of the voltage stability assessment, even in noisy environments.

Real-Time Implementation

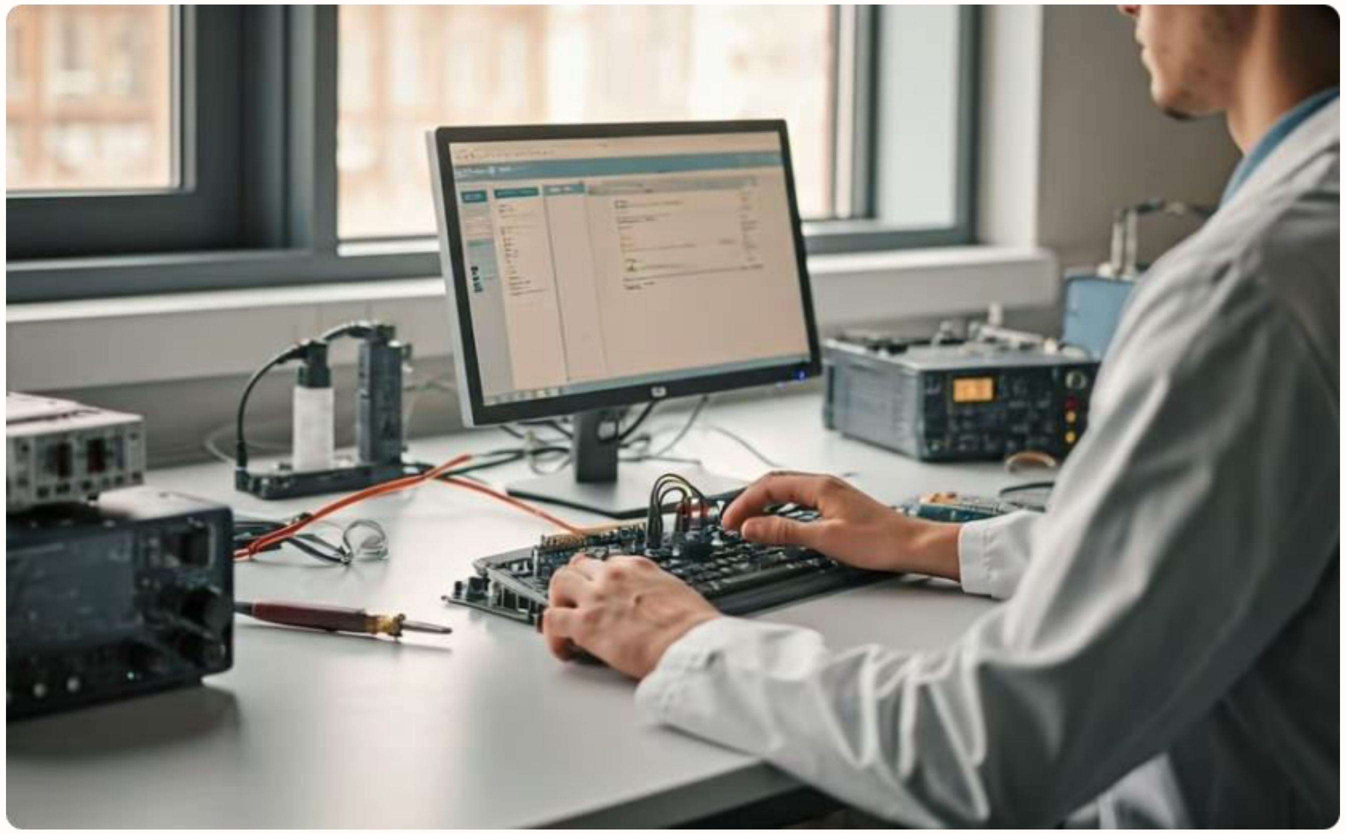
The viability of the proposed voltage stability assessment method is rigorously assessed through a real-time hardware setup. This ensures that the algorithm can perform effectively and reliably under realistic operating conditions.

The real-time setup utilizes RTDS (Real-Time Digital Simulator) for power system simulation and dSPACE 1104 for control prototyping. These tools provide a comprehensive platform for testing and validating the performance of the voltage stability algorithm in a controlled environment.

The proposed algorithm demonstrates exceptional computational efficiency, requiring less than 0.1 seconds to execute. This rapid execution time makes it suitable for real-time applications, enabling timely intervention to prevent voltage instability and maintain grid reliability.



RTDS



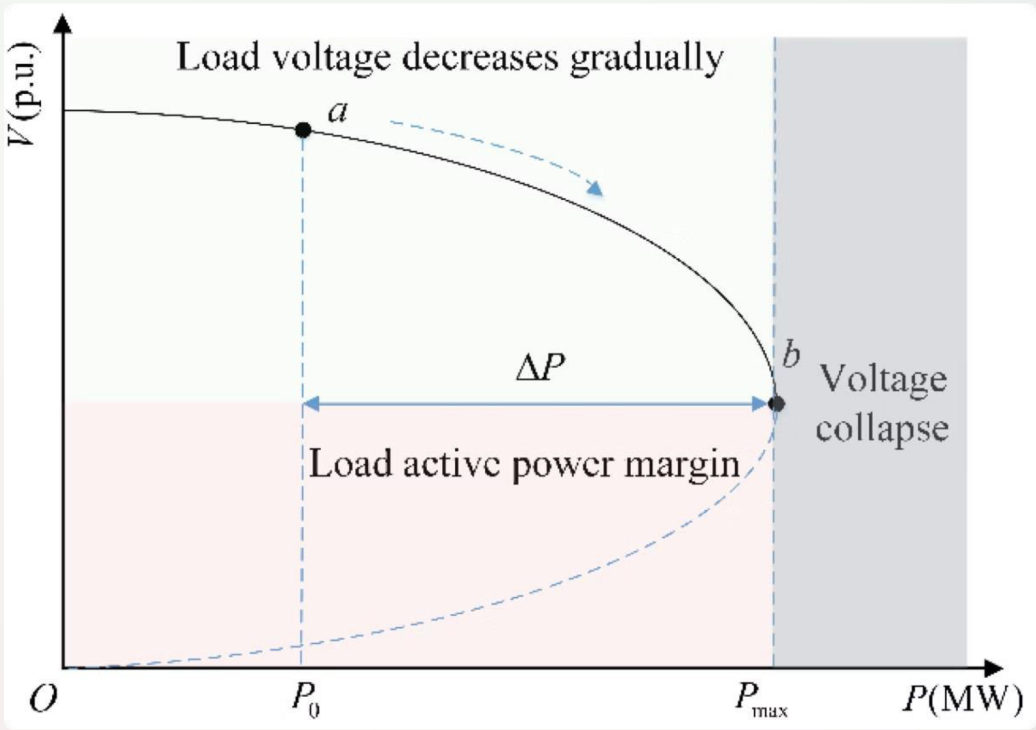
dSPACE 1104

Conclusion

- This method effectively assesses long-term voltage stability using real-time PMU data, giving a clear view of stability margins for better decisions.

- It’s cost-efficient, needing only a few strategically placed PMUs for complete monitoring and accurate stability checks. This placement maximizes coverage and cuts down on unnecessary spending.

- The system gives enough early warning for voltage collapse, letting operators act quickly to keep the grid stable and avoid big outages. This early warning is key for reducing risks and keeping the grid running safely.



Future Research Directions

Technique Enhancements

Future research could focus on integrating advanced machine learning algorithms. This would enhance the accuracy of voltage stability assessments.

New Application Areas

There is potential for applying voltage stability assessment techniques in the integration of renewable energy sources. These techniques could also be utilized in microgrid management to enhance reliability and efficiency.


Thank you