

Improved Understanding of Actual System Events Using Synchrophasor Visualization

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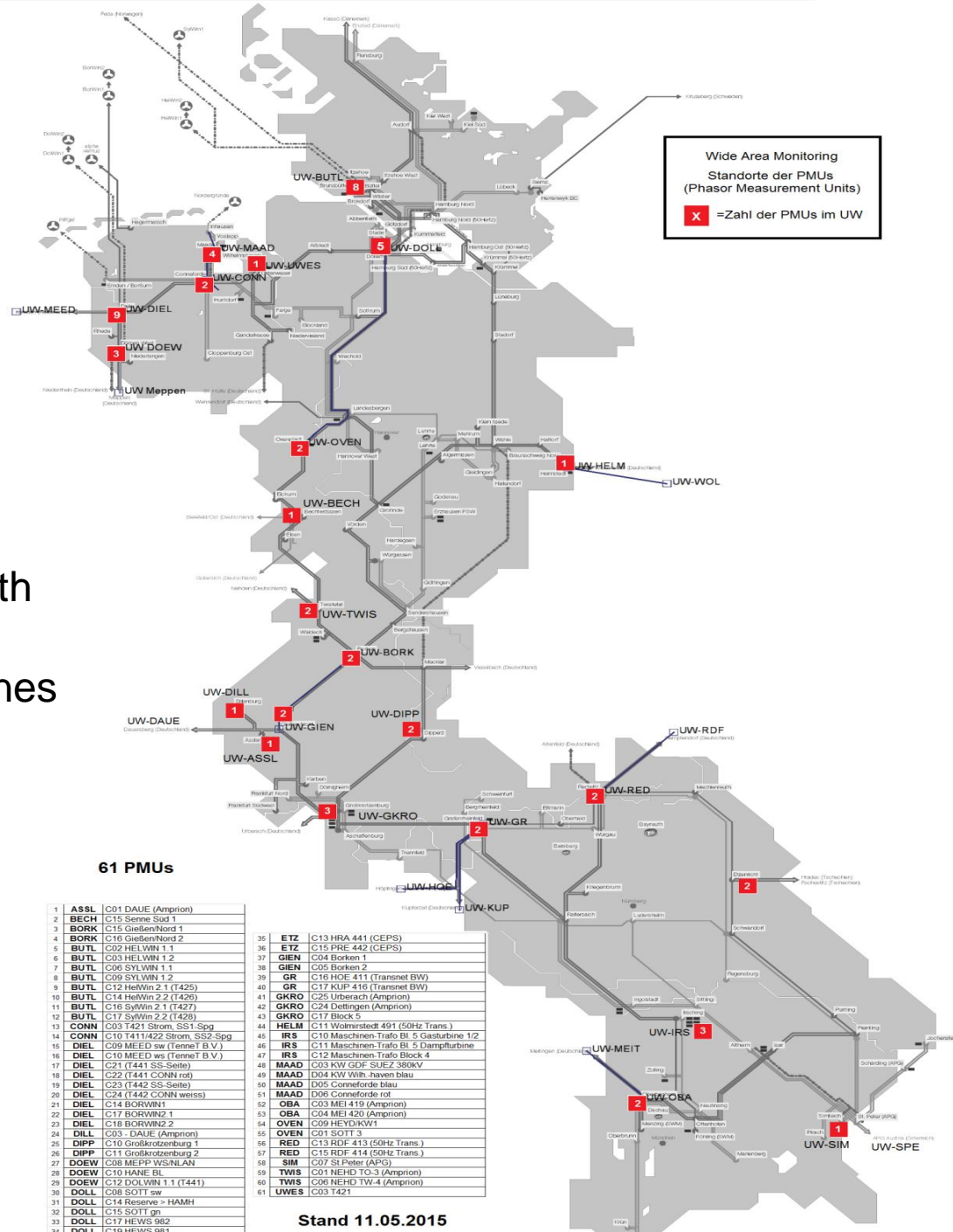
Roy Moxley, Siemens, USA



TenneT Service Area

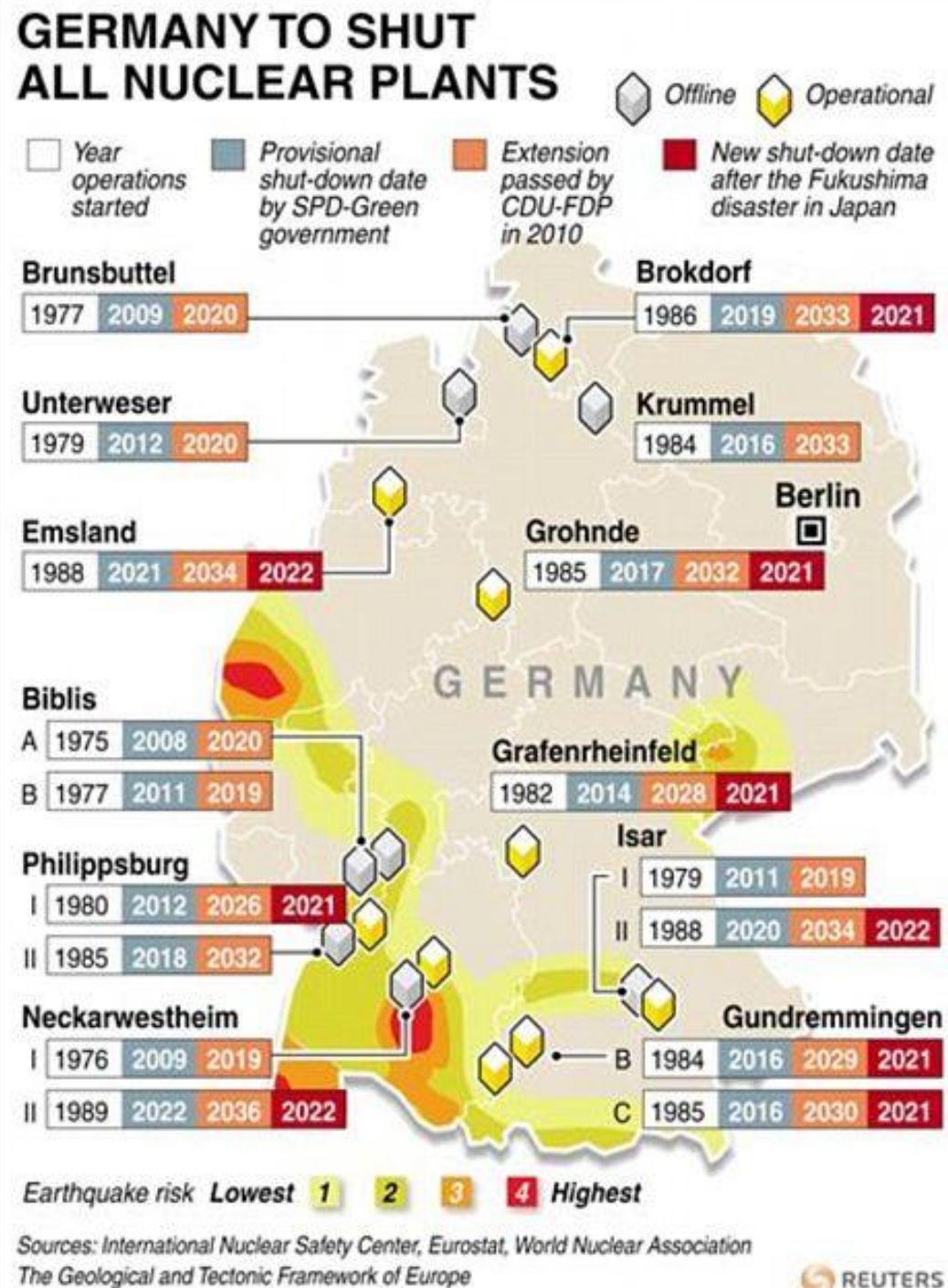
Covers area from North Sea to Swiss Alps along Germany's Western Edge and Central South

- 21,000 km 400 and 110 kV lines
- 403 Substations
- 67 GW installed Generation
- 182,000 km² supplied area



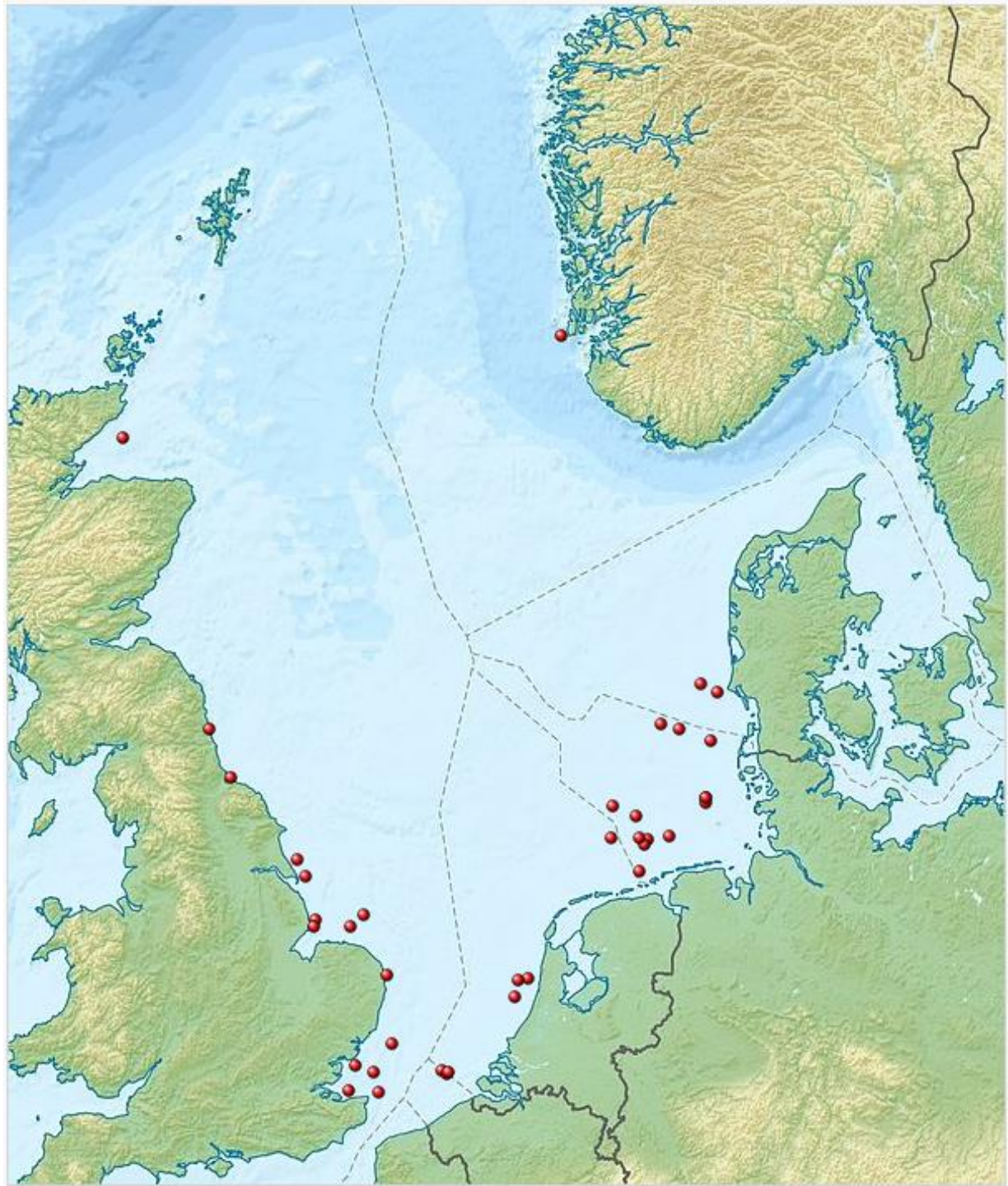
Headlines Impact System Stability

Note the Concentration of
Nuclear Plants along the West
Edge and the SouthWest



Massive Wind Farms Installed and Planned for the North Sea

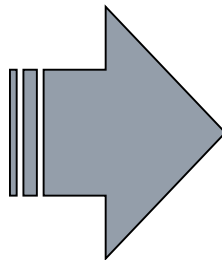
8 GW Installed and 2.9
Awaiting Installation



Replacing Nuclear with Wind

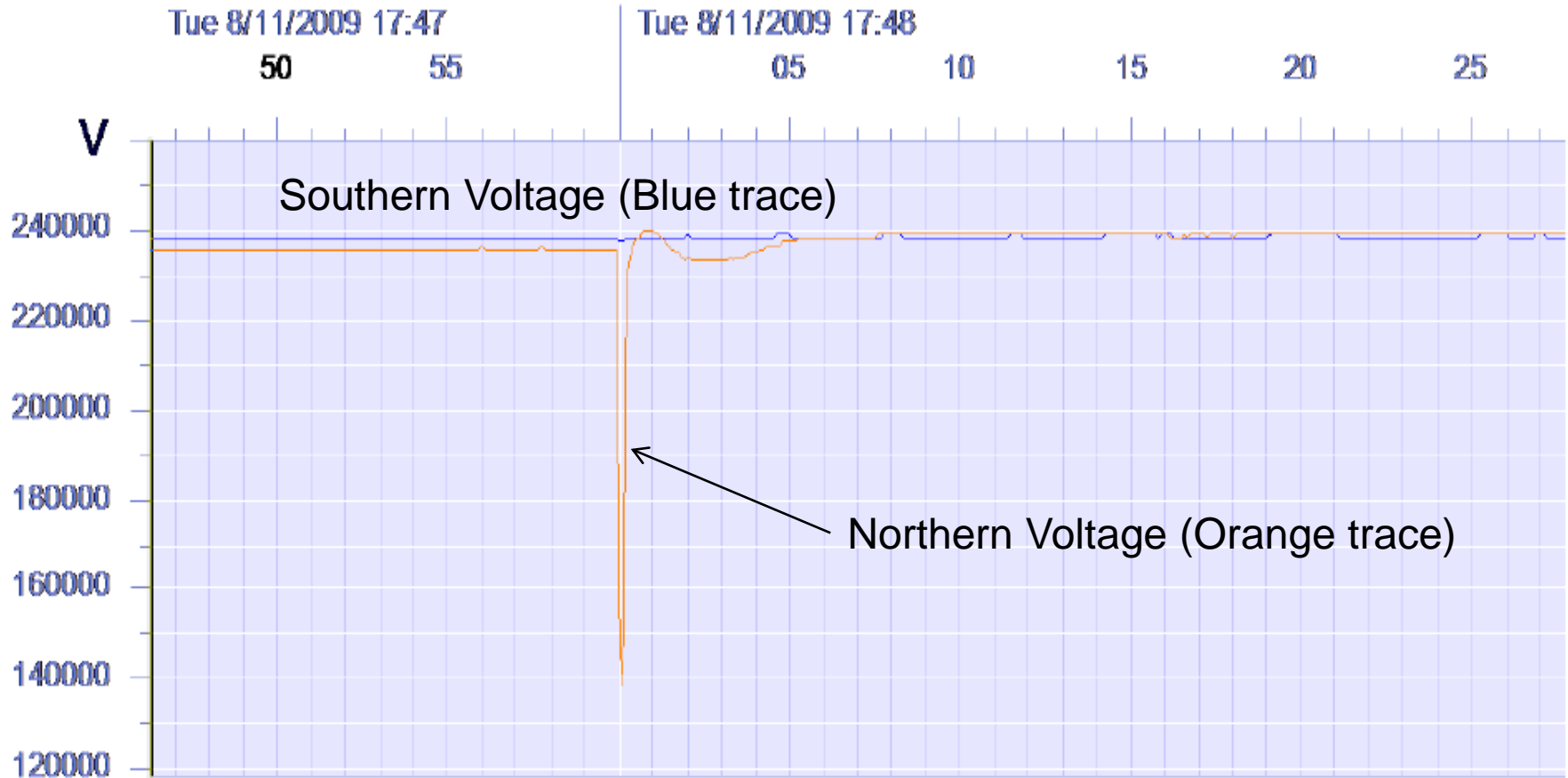


High Availability
High Inertia
Dynamic Voltage Support

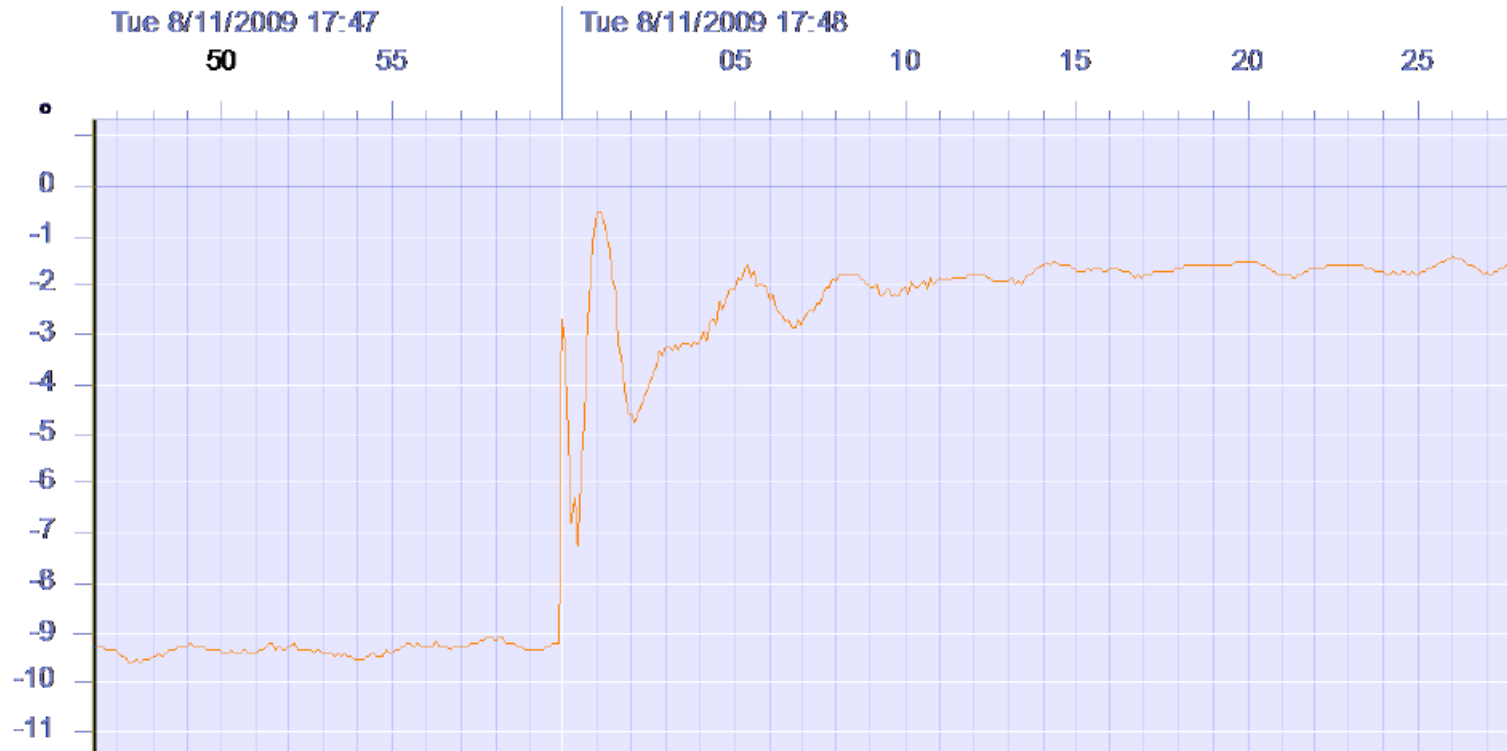


Non-Dispatchable
Low Inertia
No Dynamic Voltage Support

Loss of Northern Power Plant

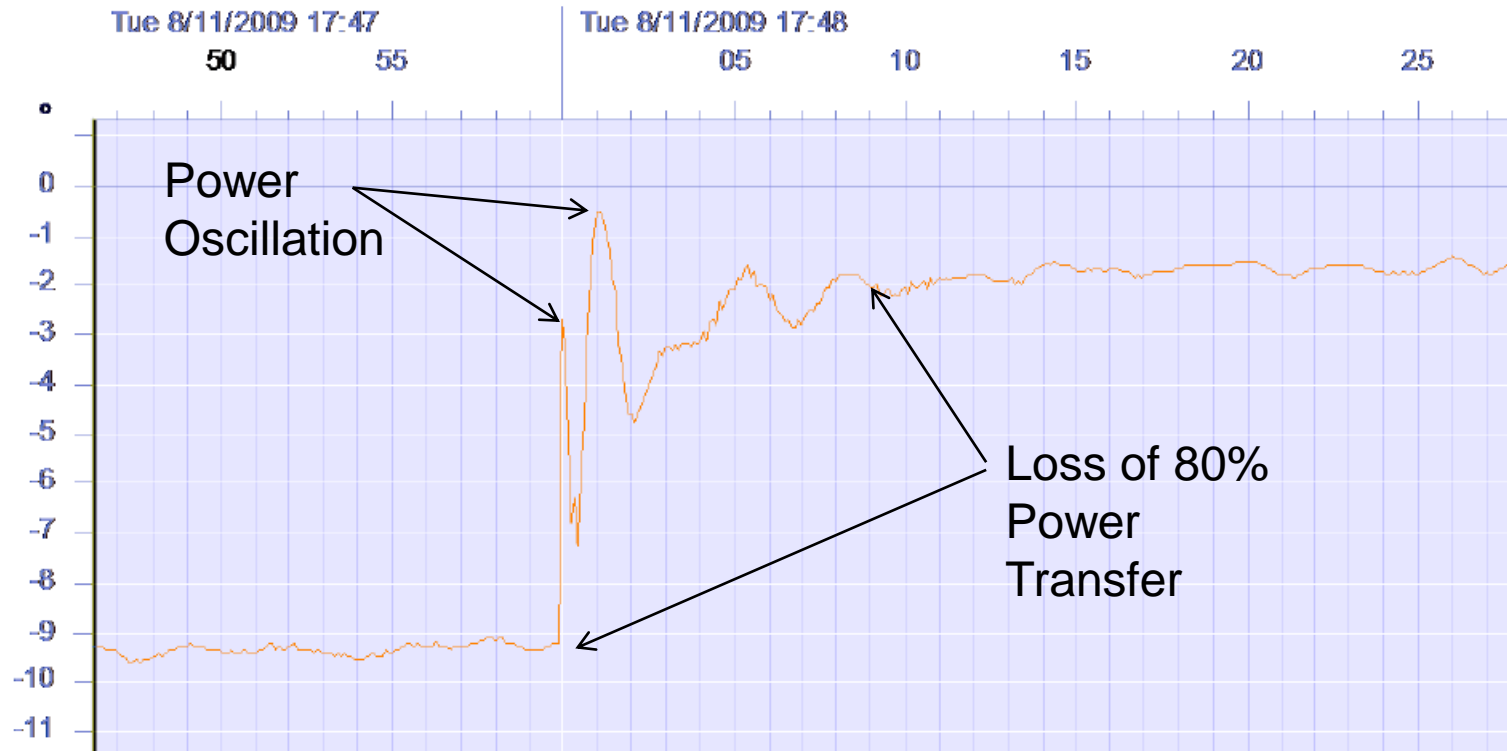


Loss of Northern Power Plant



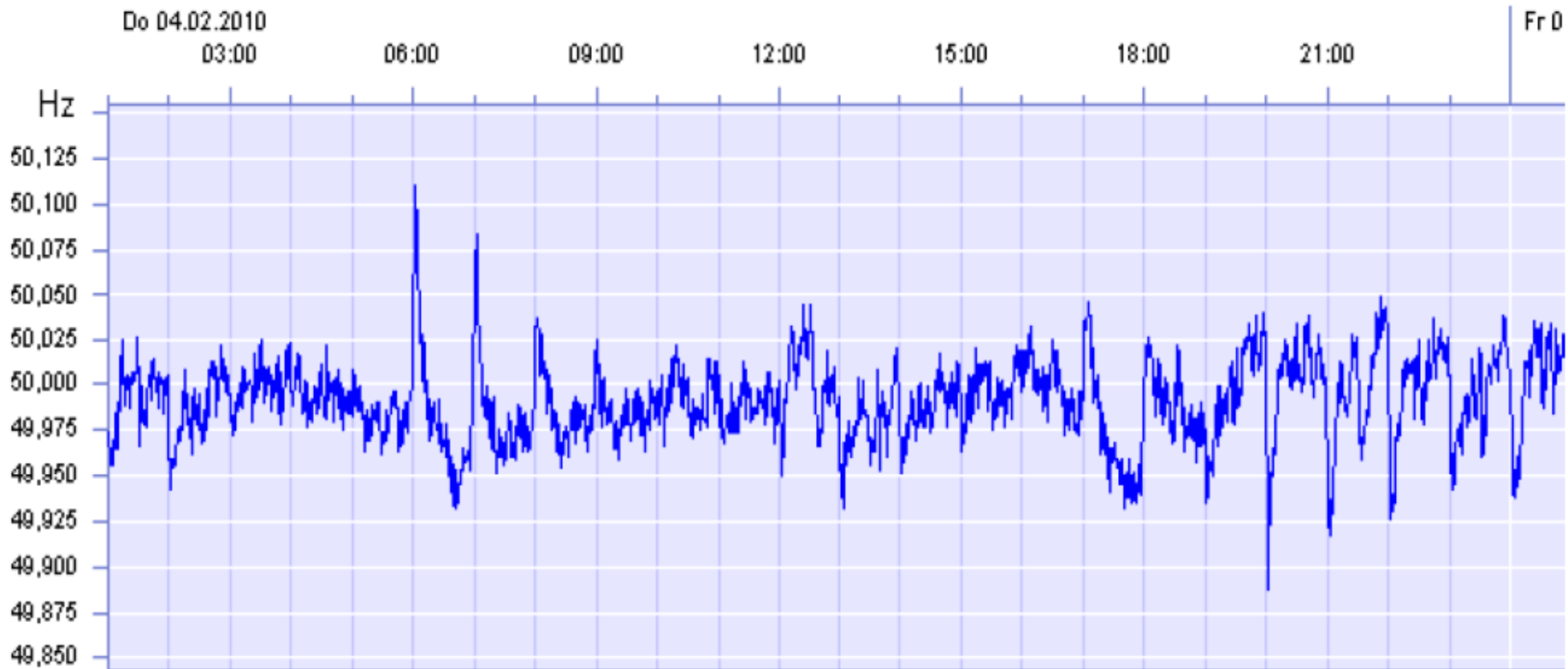
$$P = V_1 V_2 \sin \Theta / X$$

Loss of Northern Power Plant



$$P = V_1 V_2 \sin \Theta / X$$

Frequency Change with Hourly Scheduled Plant Startup and Shutdown



The Power System Runs on Models



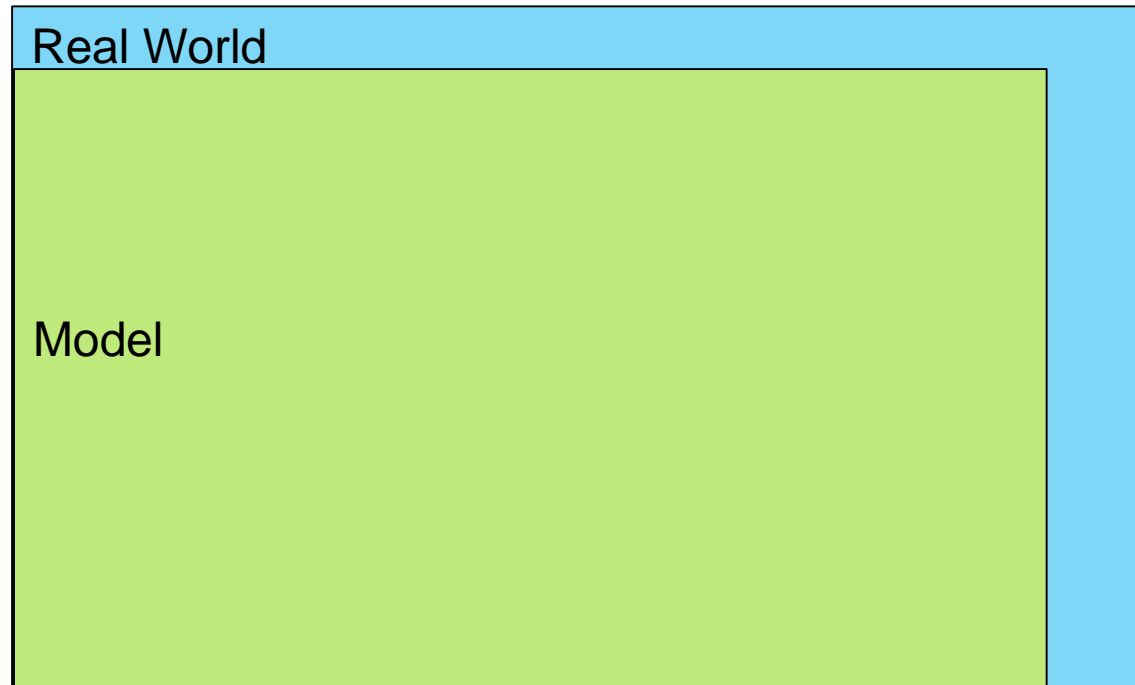
Test Contingencies

Plan Additions

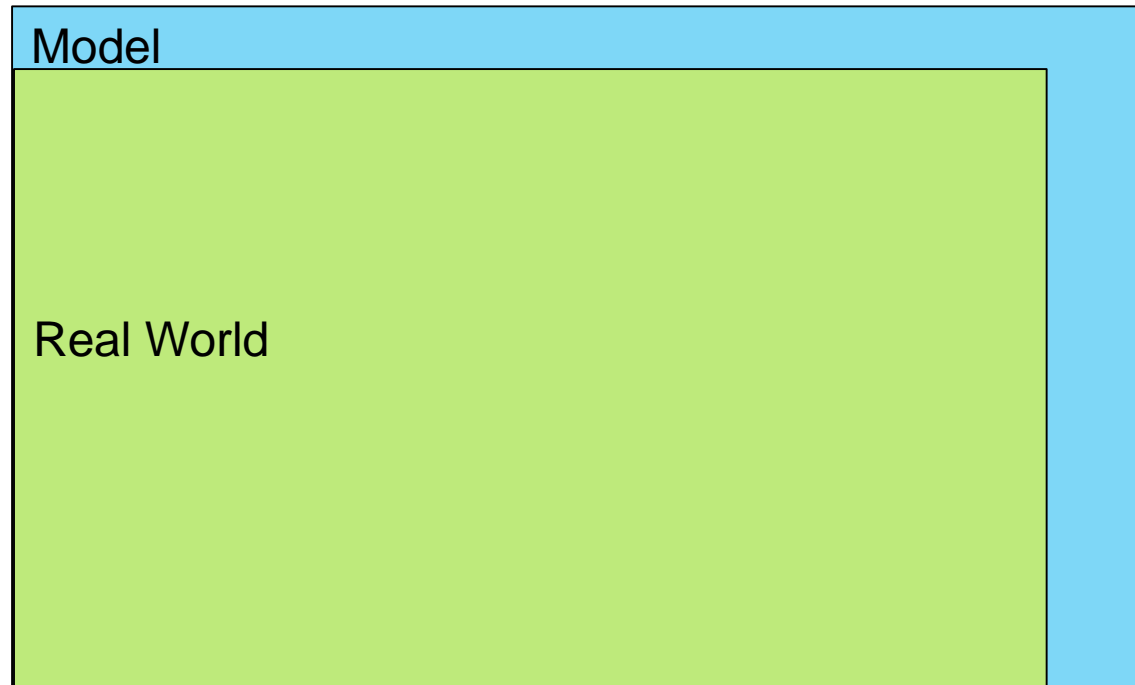
Evaluate Options

Maximize Economic Loading

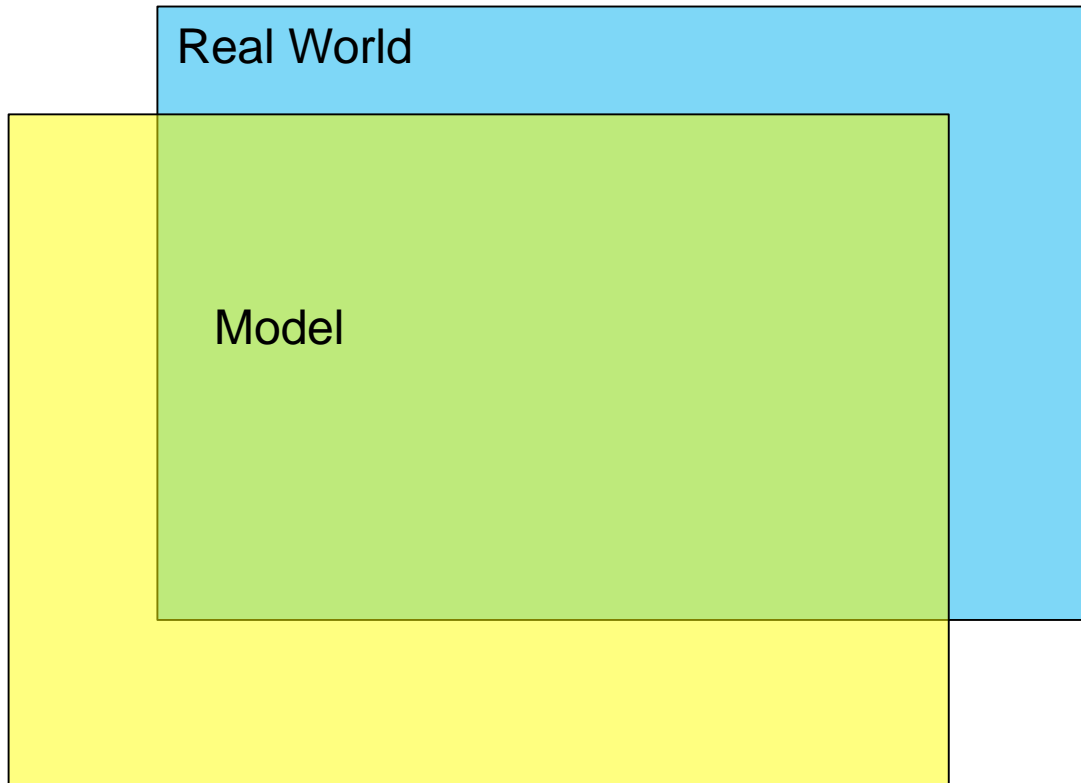
Too Weak a Model Loses Real Capacity



Too Strong a Model Risks Instability

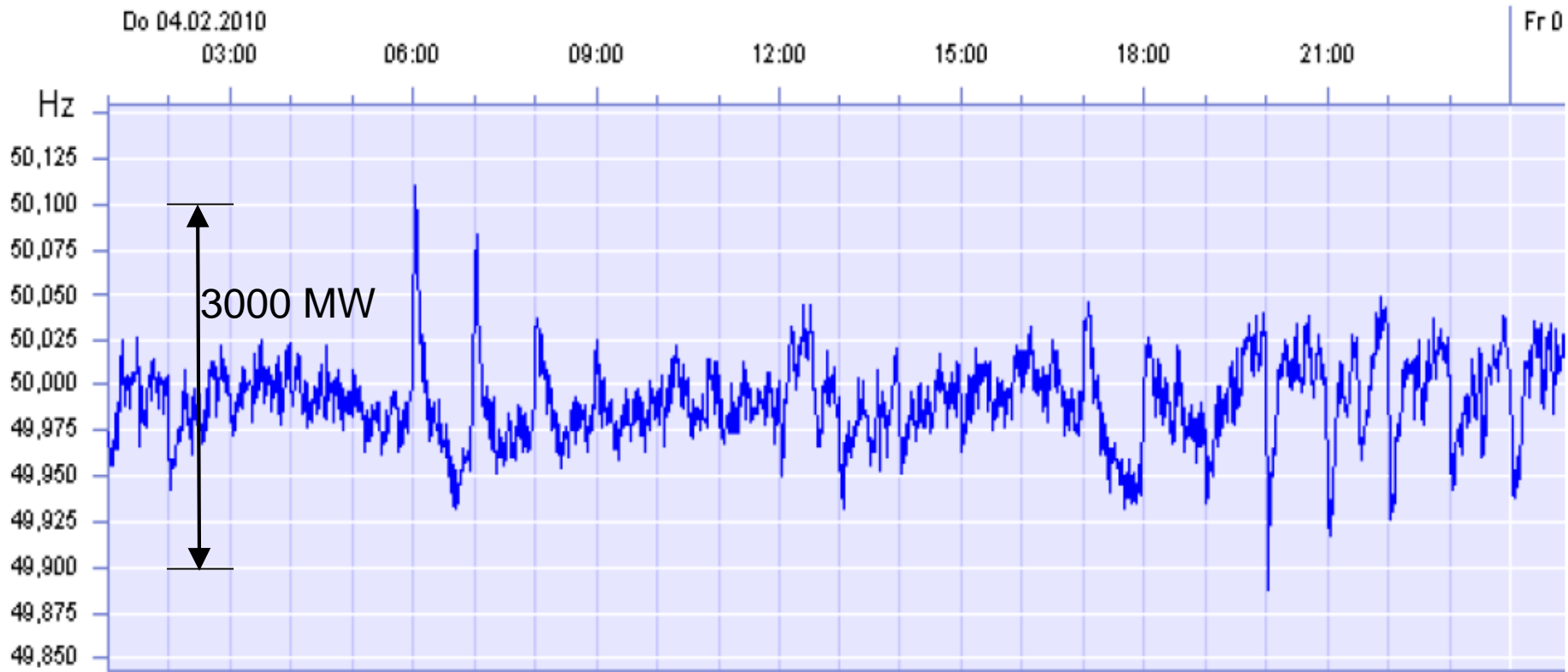


Wrong Model Weakens Security and Economy



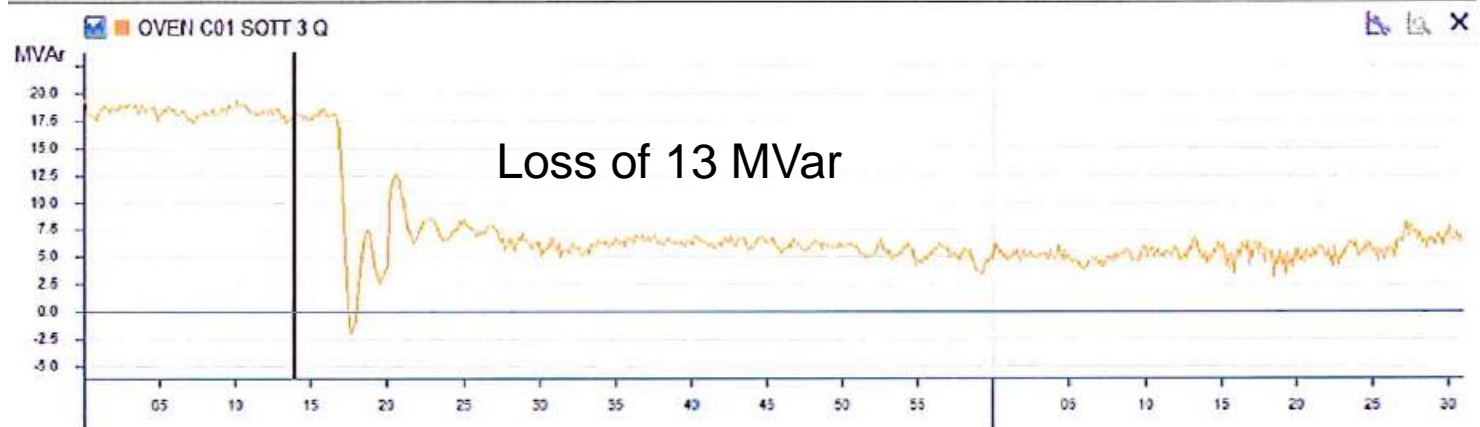
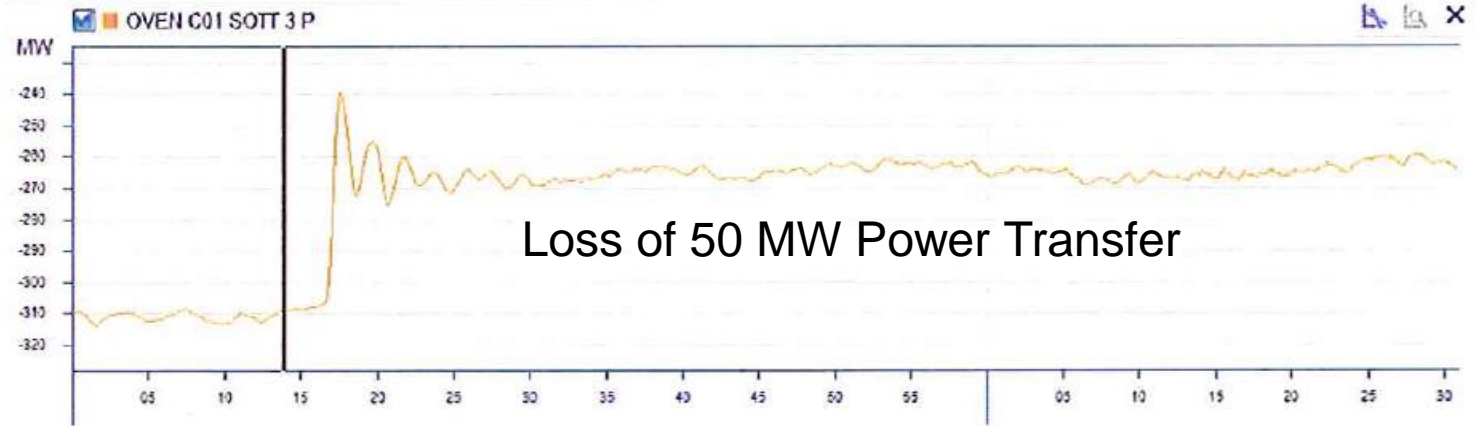
Frequency Change with Hourly Scheduled Plant Startup and Shutdown

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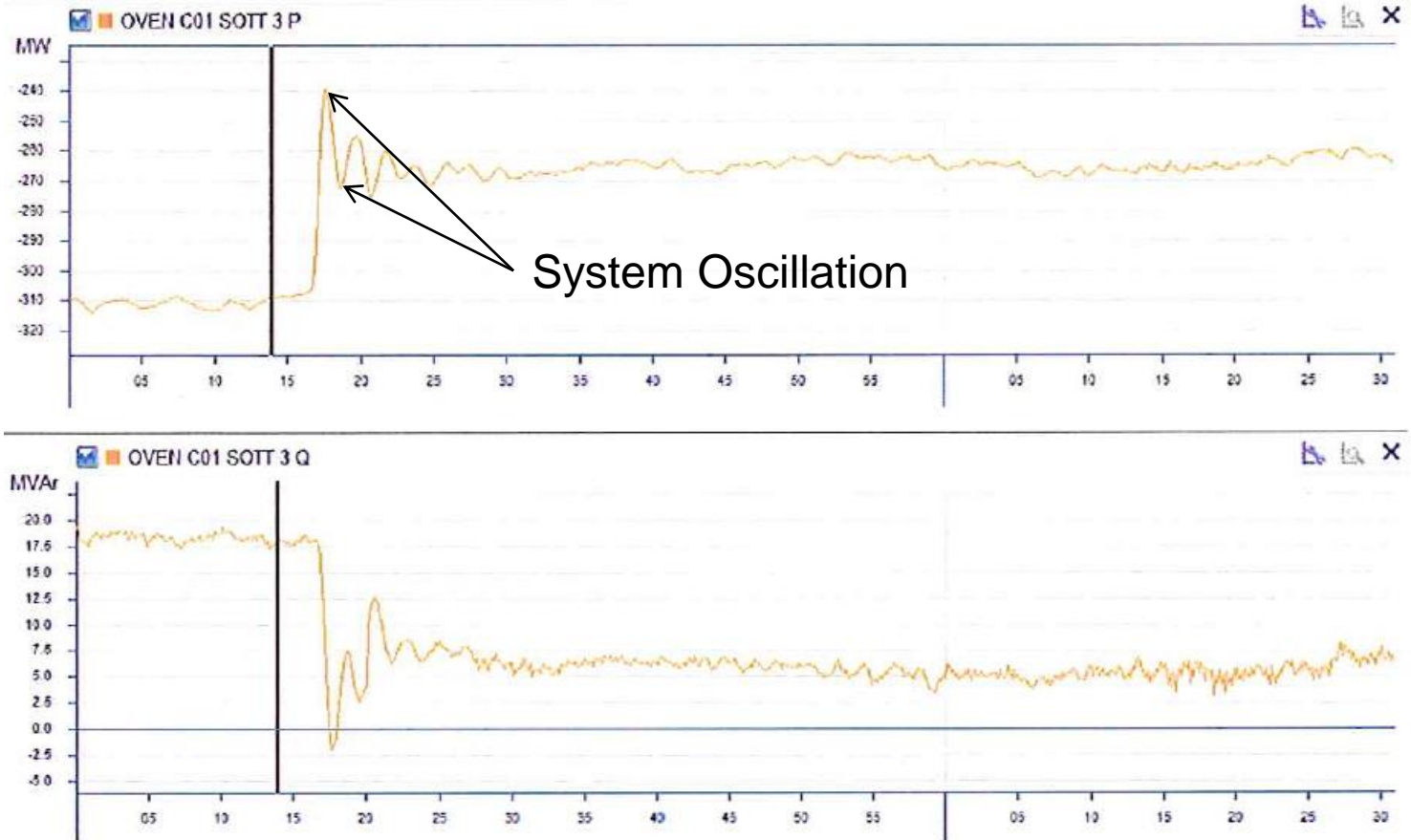


Model Validation, Scheduling Confirmation

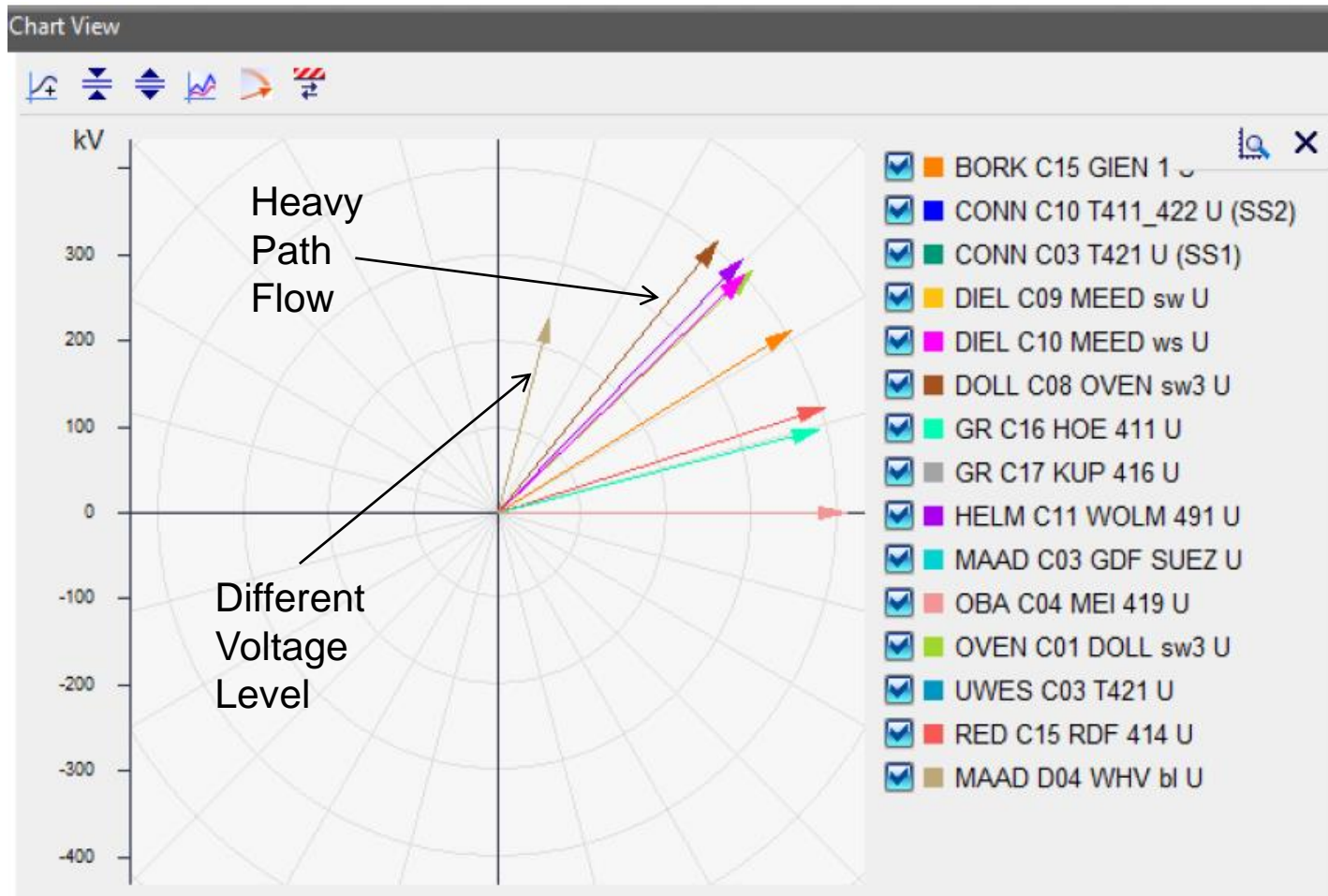
System Impact of a Line Trip



System Impact of a Line Trip

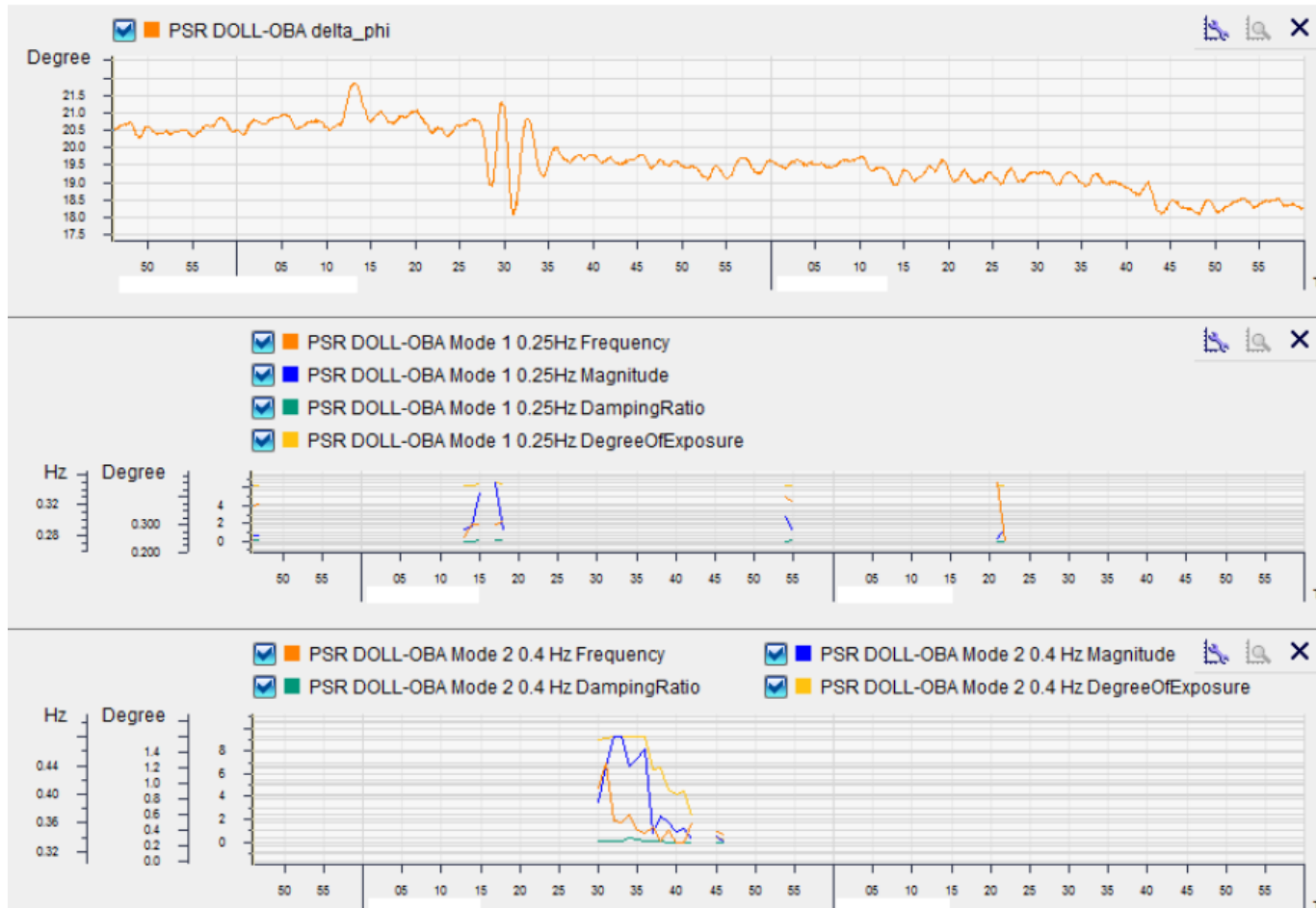


Phasor View in High Load Situation

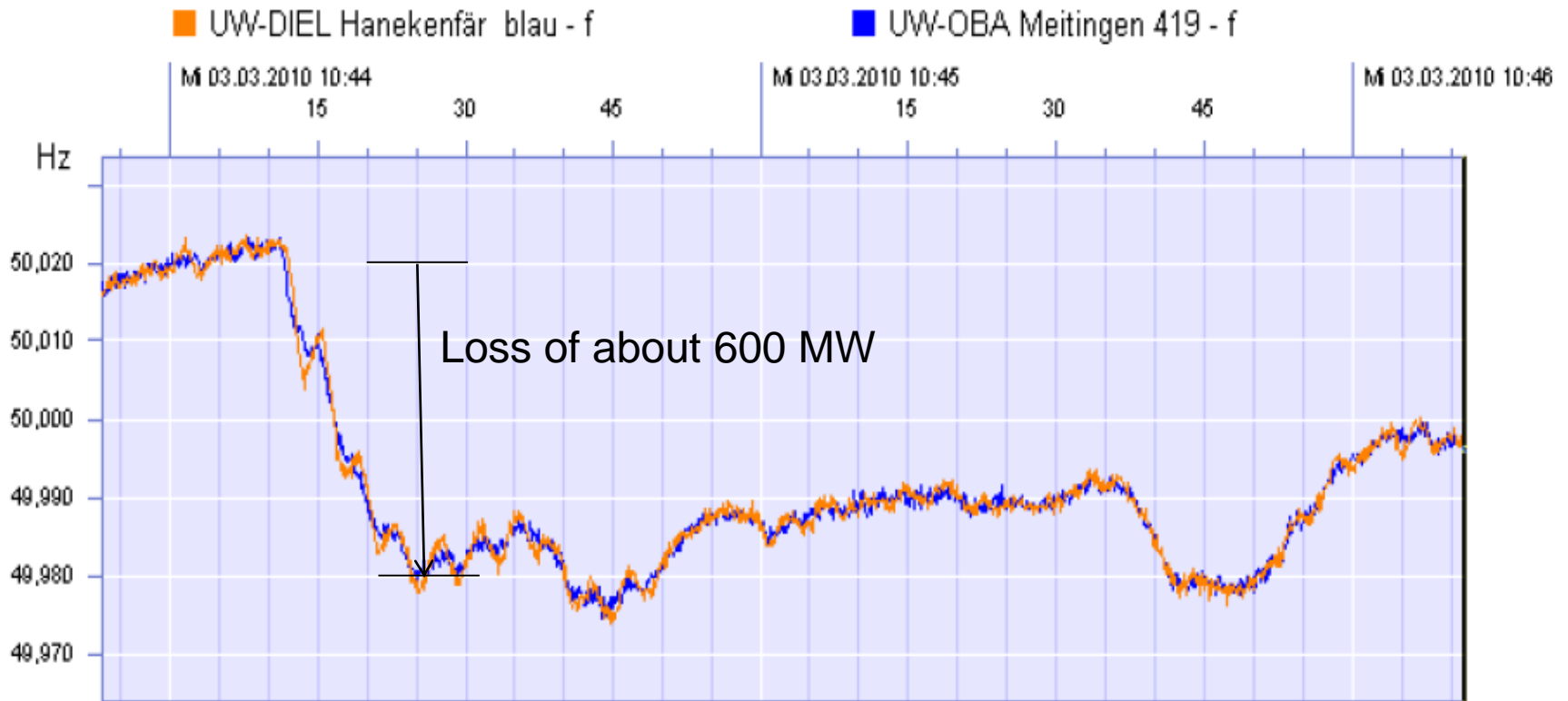


Parallel Paths Included, Summing Paths not Necessary

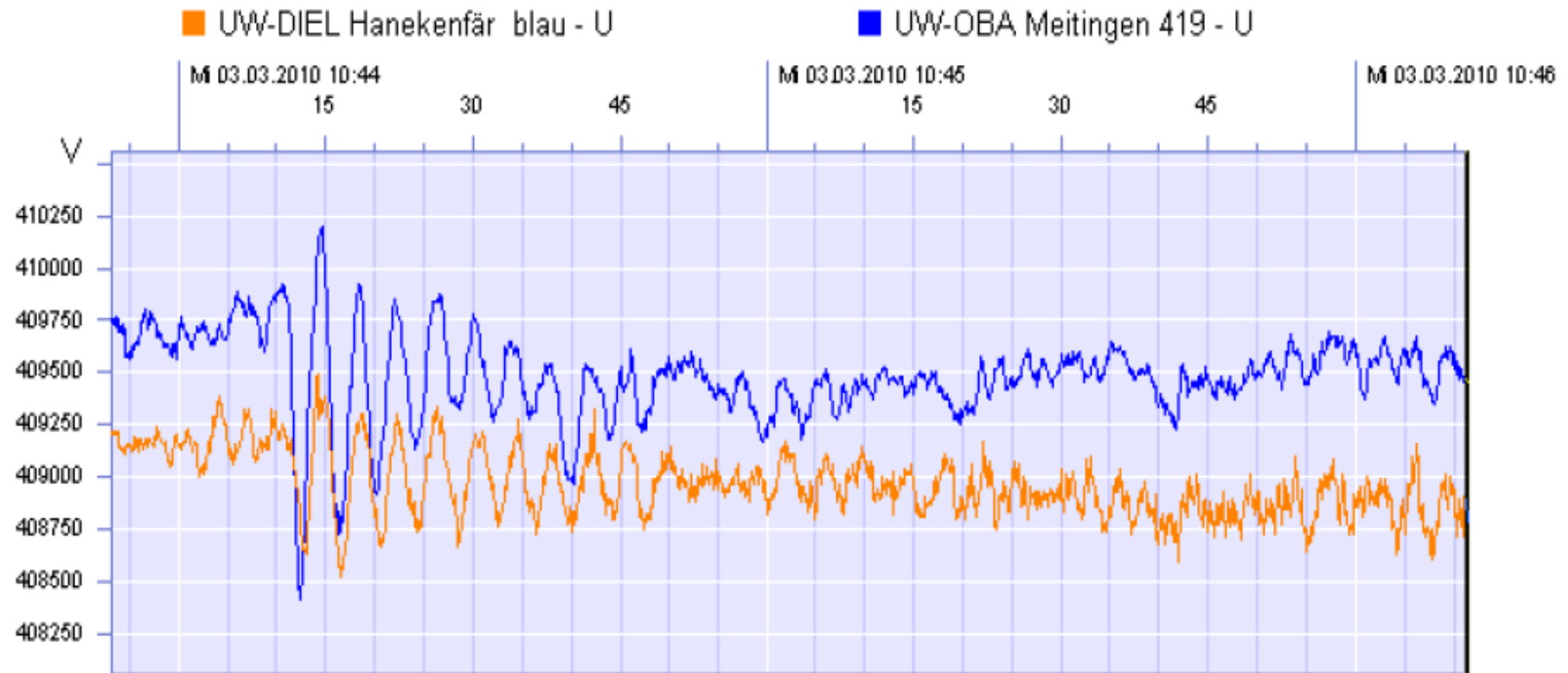
Power Swing Recognition, Alarm and Analysis



Power Plant Trip in Southern Area

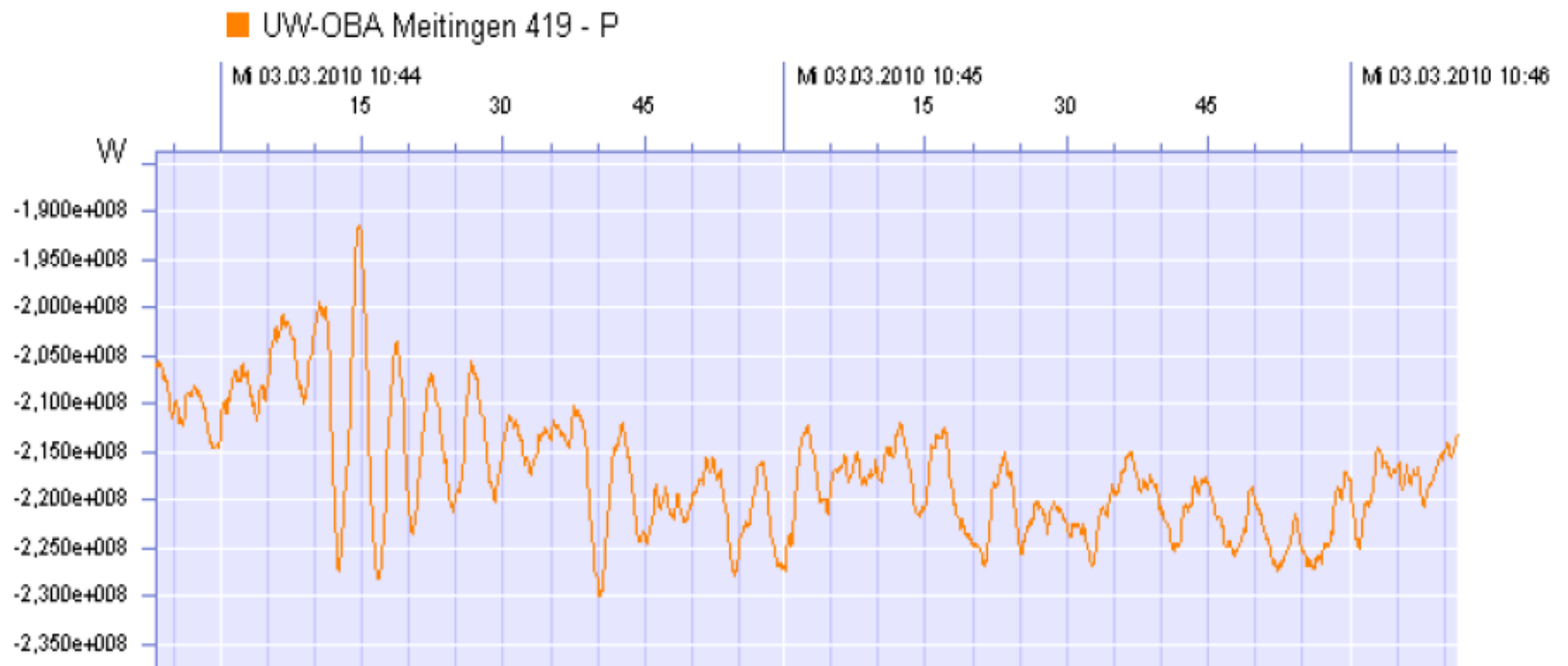


Voltage Oscillations

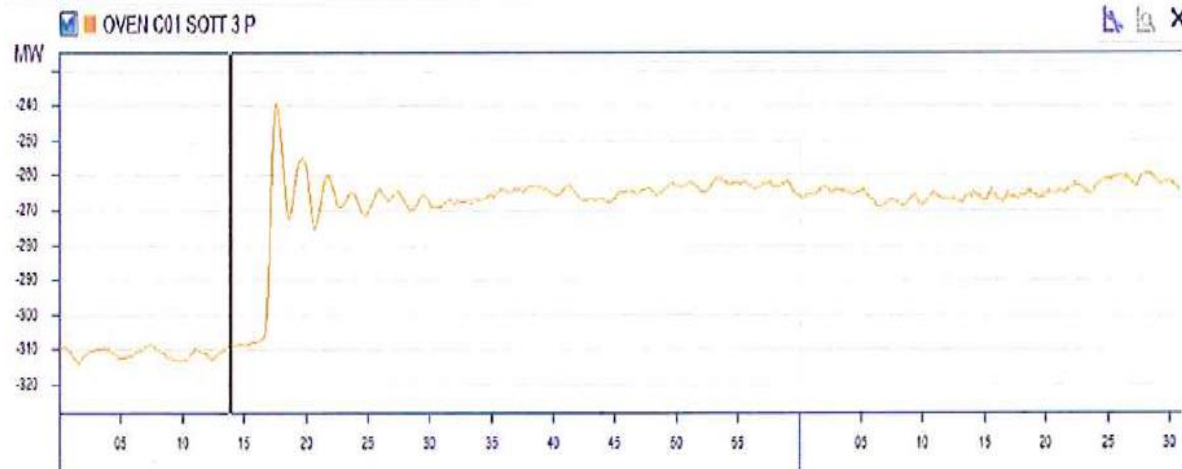


Magnitude not Bad but Poor Damping

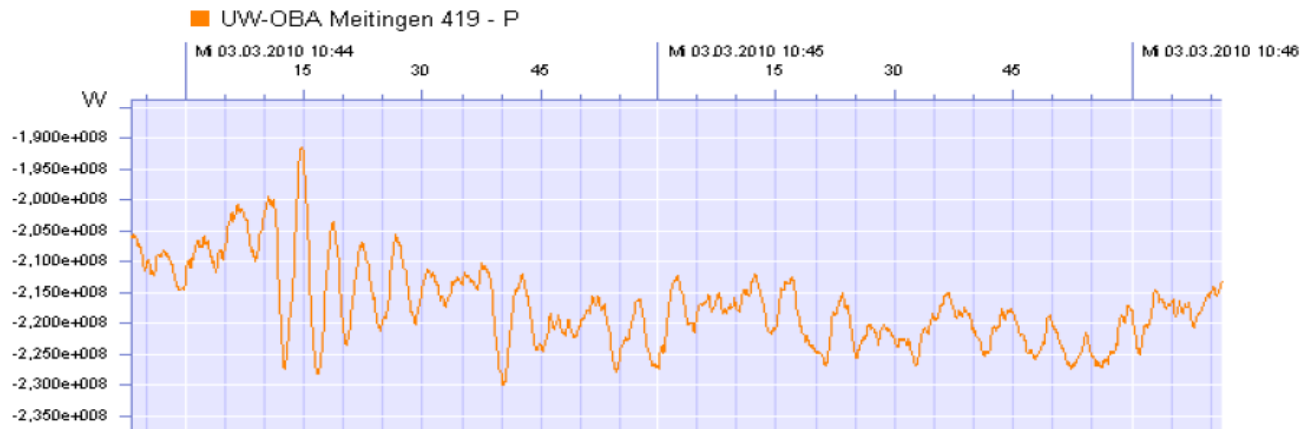
Power Oscillations



Compare Line Trip and Generation Trip



Line Trip



Southern
Generator Trip

Conclusions and Future Developments

- A Major Addition to PMU Numbers is Planned as a Result of this Pilot
- Synchrophasors Provide Improved Visualization to Operators of the Severity of System Events
- Different Synchrophasor Views Show Events Better – There is no Single Best Viewer
- Synchrophasors can Reduce the Number of Screens Viewed
- Lower System Inertia Means Faster Event Evolution
- Automatic Action to Mitigate Events Will Be Required

Questions



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