



Open-Phase Validation Test

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Open-Phase Test

- Conducted at Bellefonte Nuclear Plant
 - construction status plant
 - representative offsite power supply and auxiliary power system design
- First full-scale open-phase test ever attempted at a nuclear plant
- Required months of planning, several days to configure plant for testing, coordination with multiple TVA divisions (nuclear, construction, transmission) and EPRI

Purpose of Open-Phase Test

- TVA exploring several options to detect open-phase fault conditions and mitigate any vulnerability of the Class 1E power systems
- These design concepts need validation

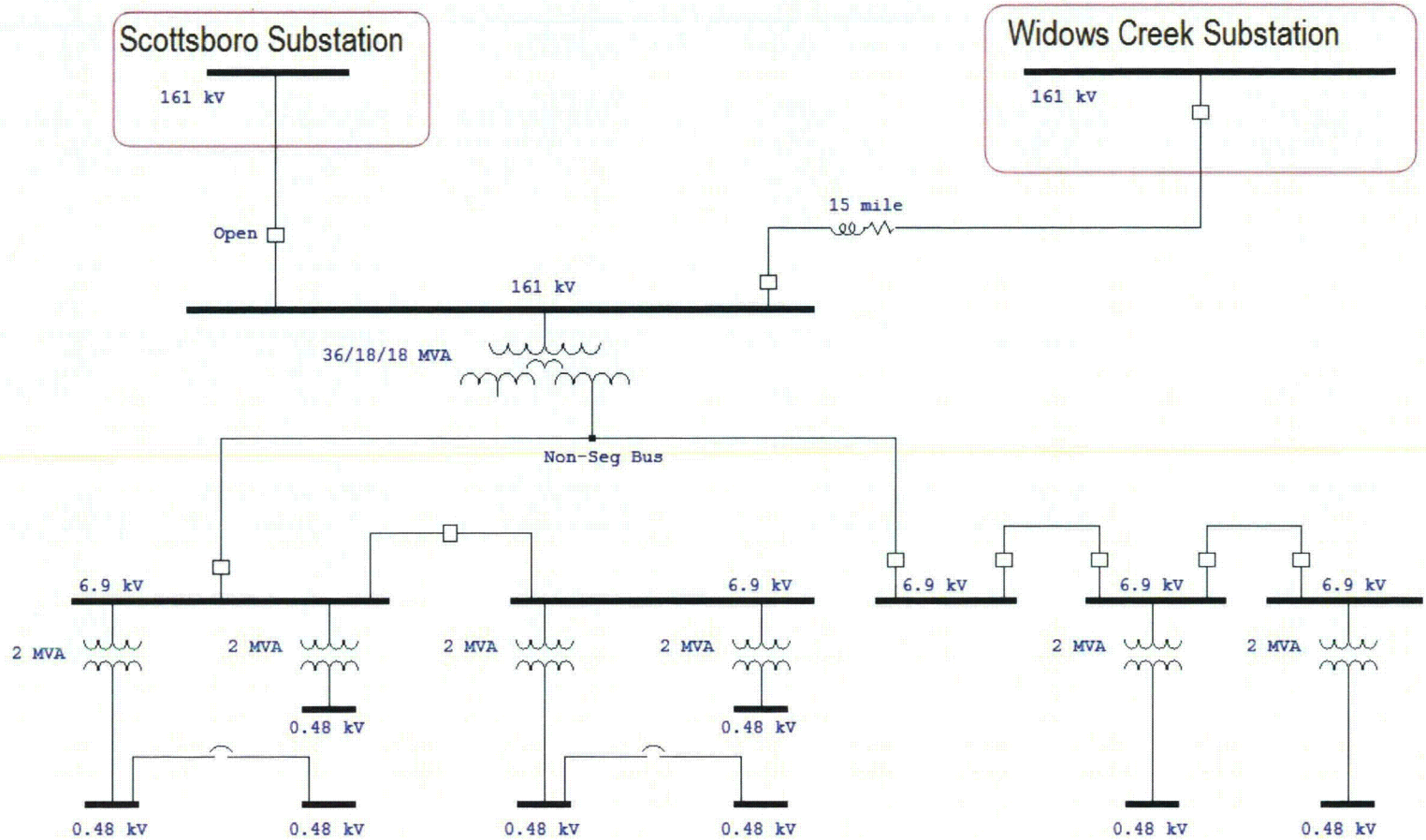
Test Objectives

- Collect detailed event data from an actual open-phase fault condition to allow validation of consequences
- Provide opportunity for EPRI to validate their Open-Phase Detection System (OPD) in a full-scale field test
- Demonstrate viability of a protective relay scheme for load protection

- Install the EPRI OPD System on one offsite power transformer (36 MVA, 161-13.8/6.9 kV)
- Create an open-phase condition by removing a single 161kV conductor (stinger)
- Test with transformer unloaded
- Test with plant buses/loads connected
 - 13 total buses (switchgear and MCCs), both BOP and Class 1E systems
 - Energize 6.9kV-480V transformers (6-2000 kVA)
 - Start largest available motors (2-250 HP)

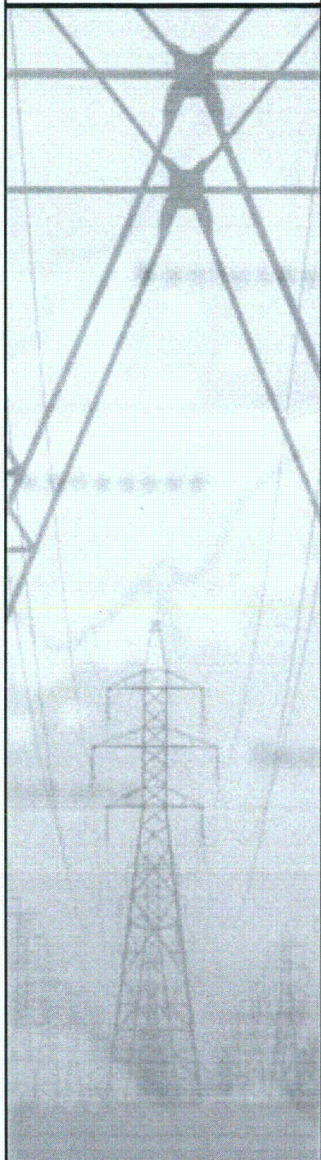


Test Configuration



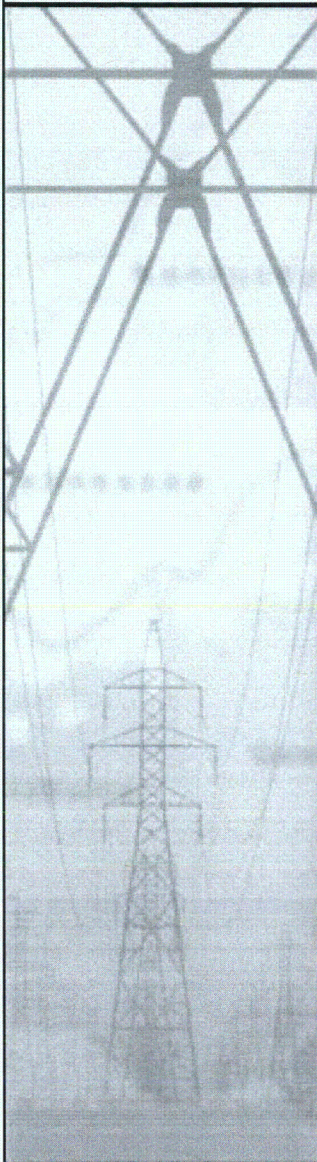


Test Configuration



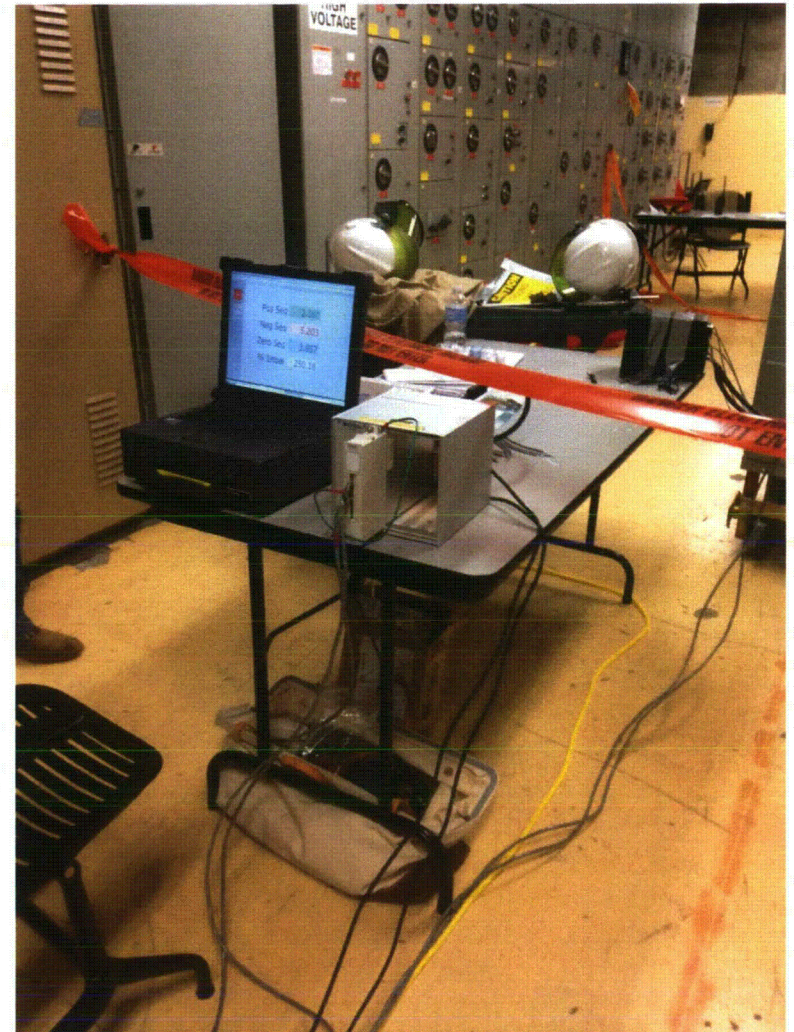


Test Configuration



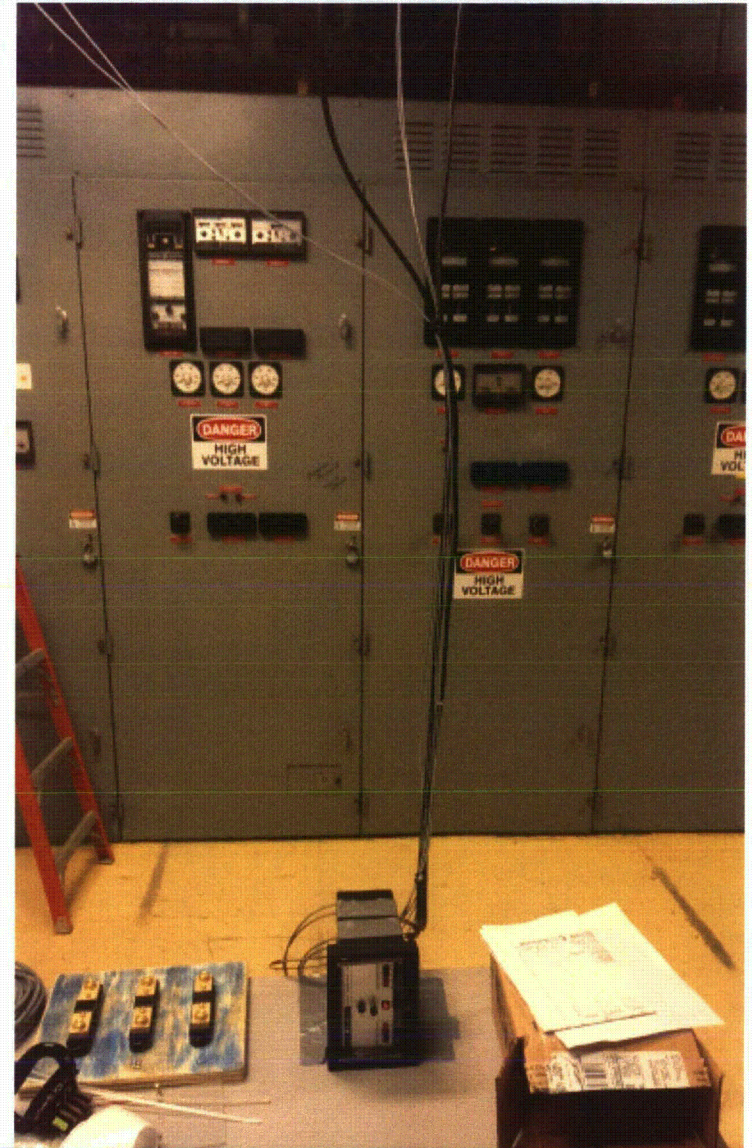
Test Configuration

- High-speed recorders were installed to capture voltage and current waveforms for all plant buses and the switchyard
- TVA-developed system was used for real-time monitoring of in-plant voltage balance throughout the test



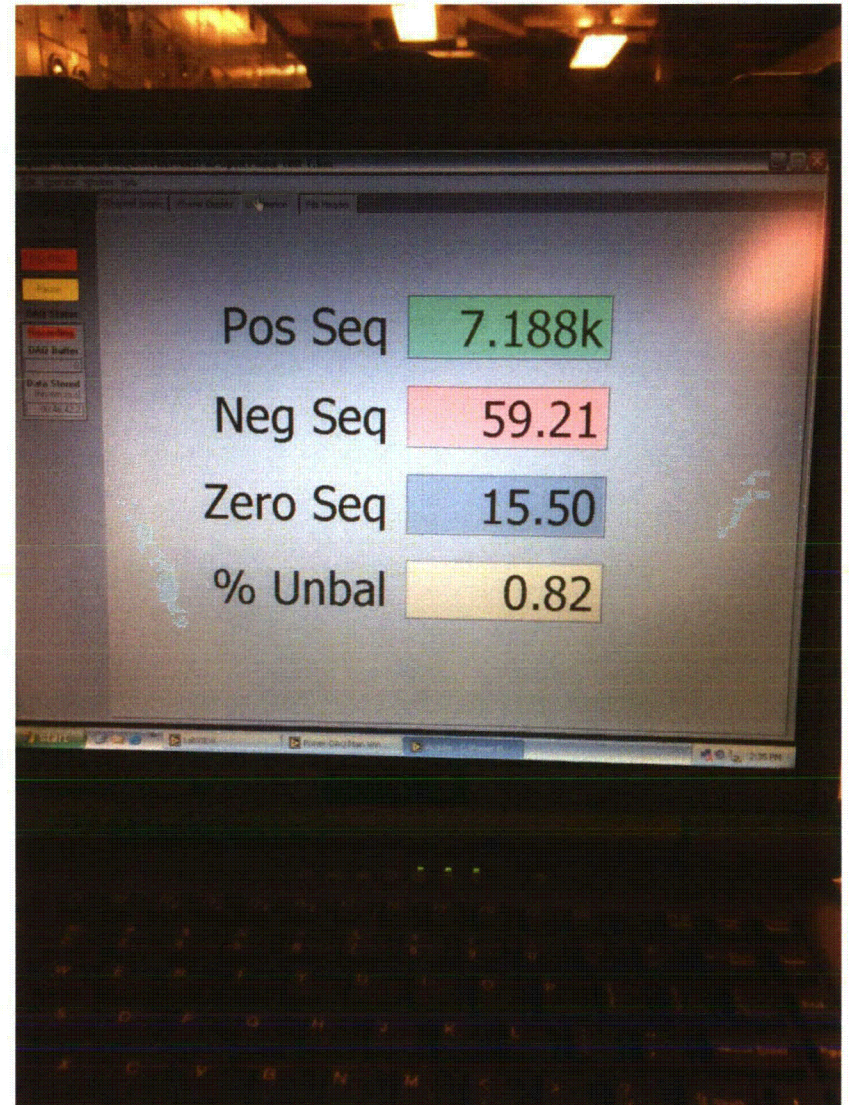
Test Configuration

- A voltage balance protective relay was installed to protect plant loads in case of unexpected results
- Provided opportunity to study relay's behavior during normal plant operation (transformer inrush, motor starting, bus transfers, etc.)



Open-Phase Test Results

- Plant exposed to open-phase condition for ~30 minutes without consequence
- At light loading (5%), in-plant voltages remain nearly balanced (<1%), as predicted



Open-Phase Test Results

Phasor Diagram

Phasor A Reference

Magnitude	Angle
6.776k	0

Phasor B

Magnitude	Angle
7.011k	-126.37

Phasor C

Magnitude	Angle
6.338k	114.7

Positive Sequence

Magnitude	Angle
6.7k	-3.89

Negative Sequence

Magnitude	Angle
428.8	76.31

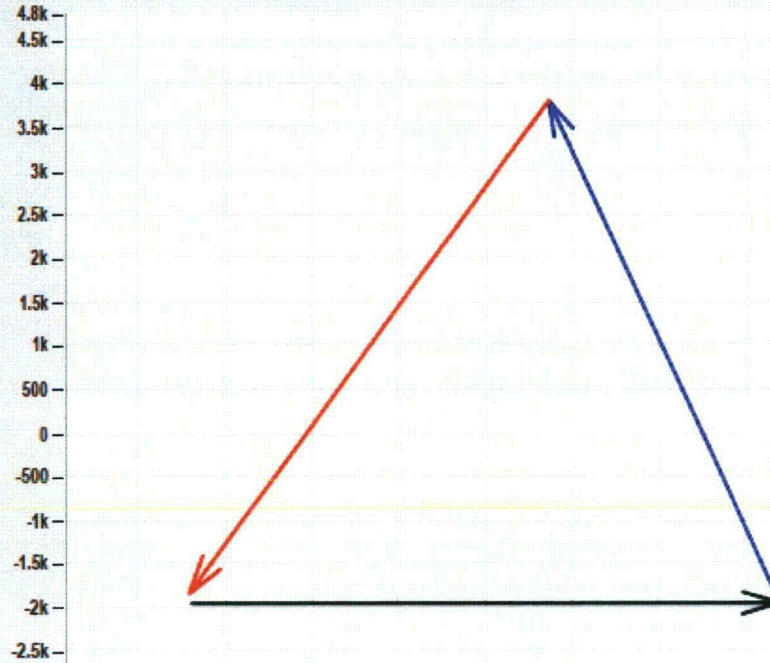
Zero Sequence

Magnitude	Angle
38.95	104.77

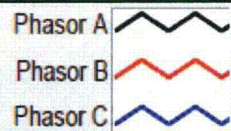
Unbalance

6.4 %

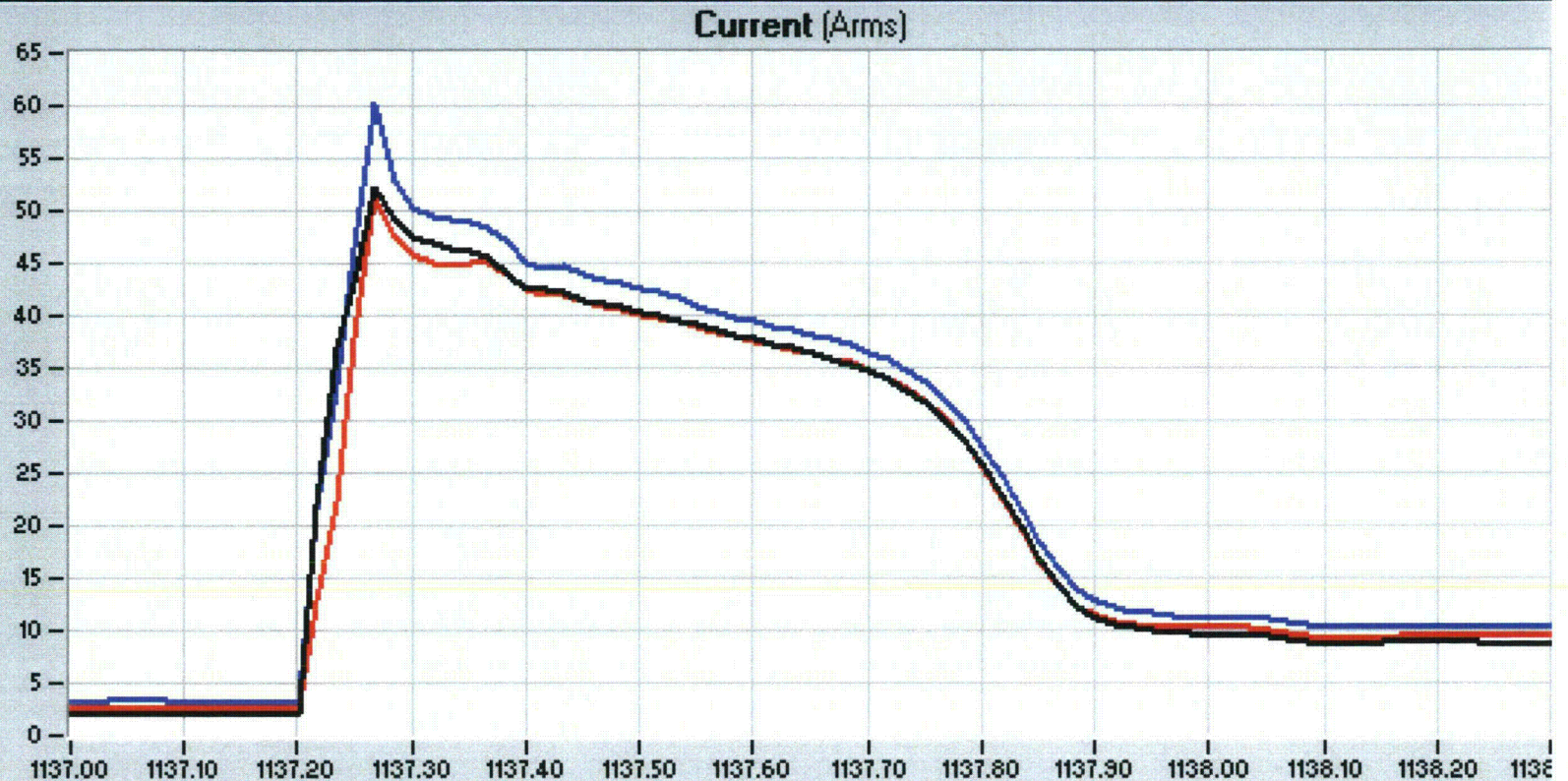
Phasor Type



During high peak loading conditions (~80%), in-plant voltages became more unbalanced (> 6%), as predicted



Open-Phase Test Results



- Motors started within normal timeframes, as predicted



Questions?

Discussion?

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