# Aurora Vulnerability

## *Issues & Solutions*

## *Hardware Mitigation Devices (HMDs)*

*July 24, 2011*

*Emanuel E. Bernabeu, Ph.D. (Dominion)*
*Farid Katiraei, Ph.D. (Quanta Technology)*

# Outline

- Introduction.
  - Aurora definition.
  - Idaho National Lab demonstration.
- Aurora Alert:
  - Mitigation & report.
- Reliability Assessment of HMDs:
  - Test methodology.
  - Simulation results.
- Conclusion.



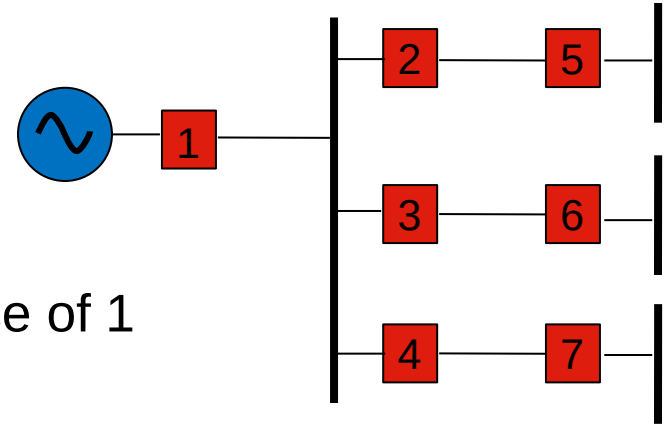


QUANTA TECHNOLOGY

Dominion

# What is Aurora?

- NERC's definition:
  - Aurora is a "gap in protection".
- Aurora characteristics:
  - Out-of-synch, open/close sequence of 1 or more breakers.
  - Induced torques can cause permanent damage to the generator.
  - Open/close as fast as 10 to 15 cyc, i.e., traditional protection will not trip (gap).
  - Physical/Cyber attack.








QUANTA TECHNOLOGY

Dominion

# Idaho National Lab demostration

- March 2007 Demonstration:
  - 3.8 MVA diesel generator operated at 60% rated power.
- Damage:
  - 13 iterations: abnormal vibrations.
  - 22 iterations: smoke.
- Traditional Gen protection:
  - Synch-check (25) disabled.






QUANTA TECHNOLOGY

Dominion

# Aurora Alert

- **New alert issued October 13, 2010**
  - Requires responses by December 13, 2010; June 13, 2011; and every six months until fully mitigated
- Alert allows for engineering judgment.
- 1) Protection and Control Engineering Practices.
  - Hardware Mitigation Devices (“fence line solution”).
- 2) Electronic and Physical Security:
  - Access control.
  - Monitoring and reporting.
  - Training.
  - Personnel risk assessment.
  - Information protection.

# Hardware Mitigation Devices (HMDs)

- HMDs:
  - Relays specifically designed to mitigate Aurora.
  - Evaluated 2 commercially available relays, and a third custom solution.





QUANTA TECHNOLOGY

Dominion

# Reliability assessment: methodology

- Reliability: Security/Dependability
- RTDS: Closed-loop testing.
- Four highly detailed models:
  - Strong and weak zones in DVP.
  - Different topology & load flow.
  - Machine sizes and inertia and load characteristics.






QUANTA TECHNOLOGY

Dominion

# Reliability assessment: methodology

- Test set applied to each model:

| Category A | Category B | Category C | Category D | Category E |
|---|---|---|---|---|
| ▪ Aurora: $BC_{GEN}$<br>▪ Aurora + Δf | ▪ Adjacent line switch.<br>▪ Sustainable island. | ▪ Faults & reclosing. | ▪ Non-linear load.<br>▪ Cap bank switch<br>▪ Load switch | ▪ Black Start |





QUANTA TECHNOLOGY

Dominion

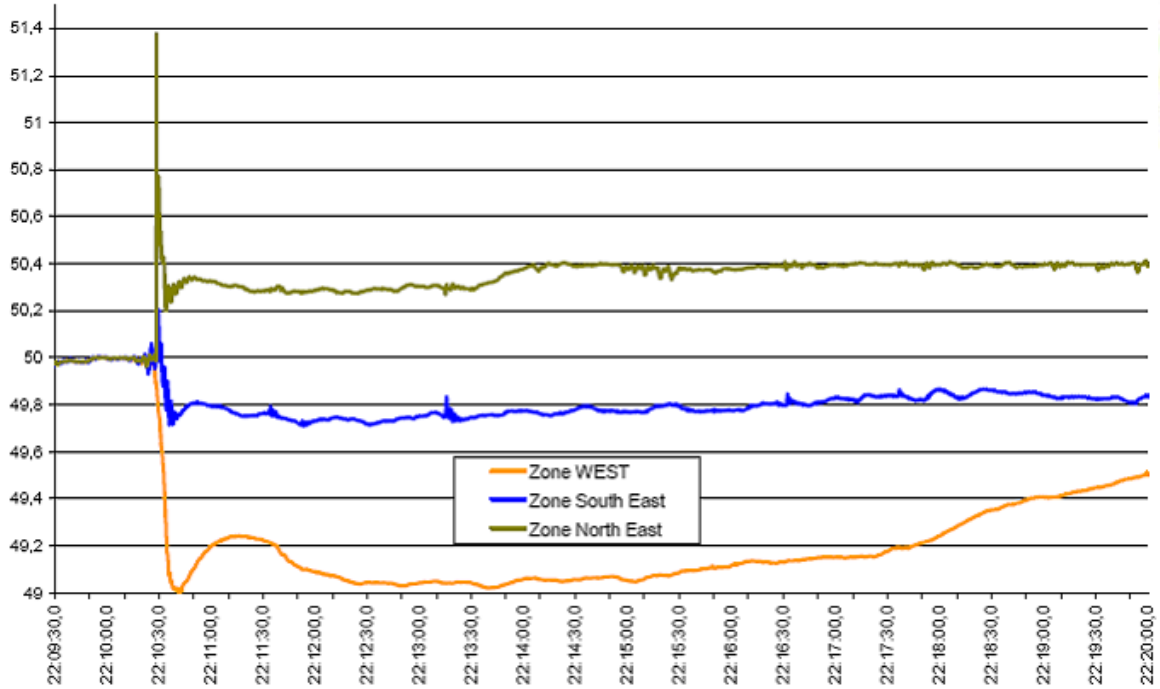
# Reliability assessment: results

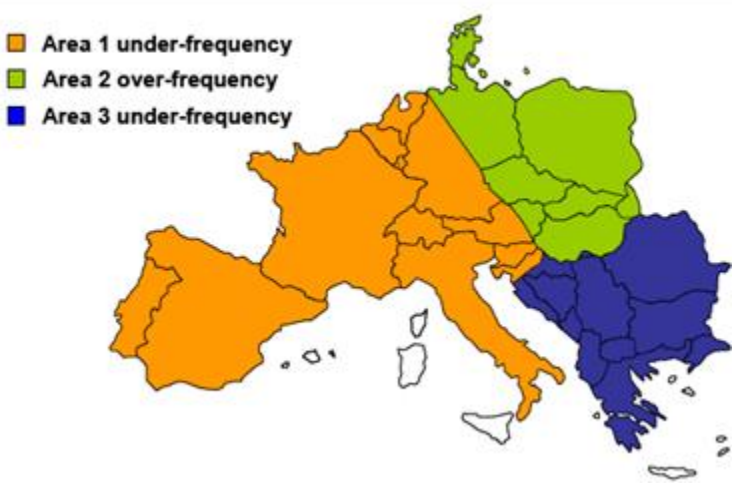
- Summary:

| | Category A | Category B | Category C | Category D | Category E |
|---|---|---|---|---|---|
| HMD-1 | FAIL | PASS | PASS | PASS | FAIL |
| HMD-2 | FAIL | FAIL | PASS | PASS | PASS |
| HMD-3 | FAIL | FAIL | PASS | PASS | PASS |

# Risks: UCTE example

- UCTE event 2006: HMDs could have exacerbated the disturbance.








QUANTA TECHNOLOGY

Dominion

# Conclusion: HMD Reliability

- Aurora:
  - High Impact Low Frequency event (HILF).
  - Mitigation solution must not interfere with, compromise, or jeopardize, the operation of the power system.
- RTDS testing methodology:
  - Detailed Models.
  - Comprehensive test: normal & abnormal system states.
- Reliability assessment:
  - Evaluate all possible solutions (e.g. reclosing timer, synch check)
  - HMDs are not dependable, nor secure.





QUANTA TECHNOLOGY

Dominion

# Questions?