Blackstart Study using RTDS in Dominion Virginia Power

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Agenda

- Blackstart study in Dominion
- Dynamic simulations of cranking paths
  - Governor control
  - Frequency control
  - Protection study
- Conclusion
- Future works

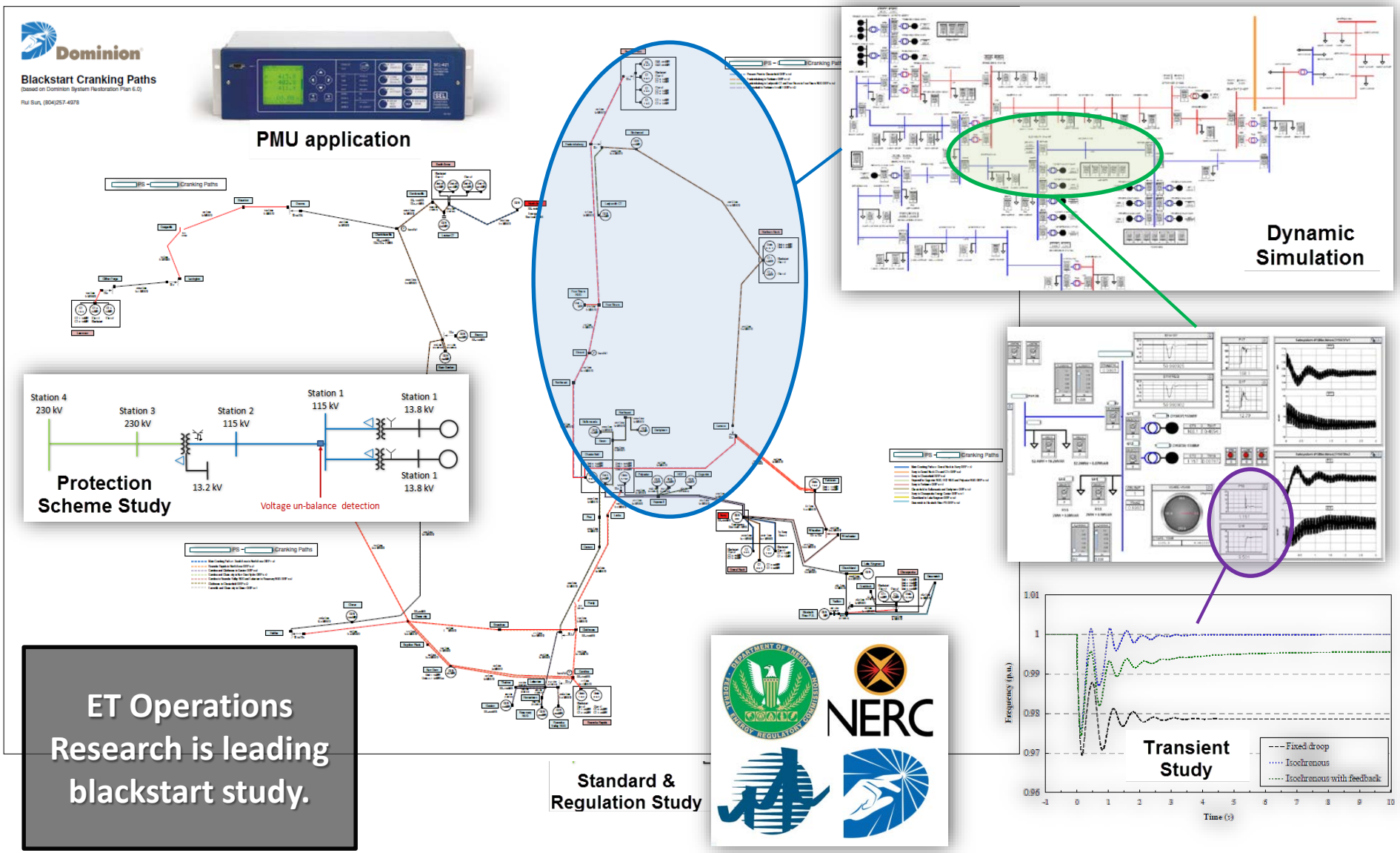
Blackstart Study in Dominion

- Background – Dominion Virginia Power Profile
  - Transmission operator of Virginia and West Virginia
  - 2013 revenue 13.2B$, rank no.9 in Fortune 500 utilities
  - 24,600 MW generation, 2 nuclear stations
  - 6,455 miles of transmission lines
    - 1,900 miles of 500kV EHV network
    - Free world's first 500kV transmission loop

Blackstart Study in Dominion

- Dominion – System Restoration Plan
  - NERC Standard: EOP 005-02, 006-02
  - PJM regulation: Manual 36
  - Dominion/SOC system restoration procedures: SRP v7.0
- Dominion Blackstart Technical Study Project
  - Lead: ET Operations Research
  - Participants: System Protection, SOC, Planning, Generation, etc
  - Major Tasks:
    - Study SRP procedures
    - Conduct dynamic simulation/protection study
    - Contribute to the improvement of new SRP

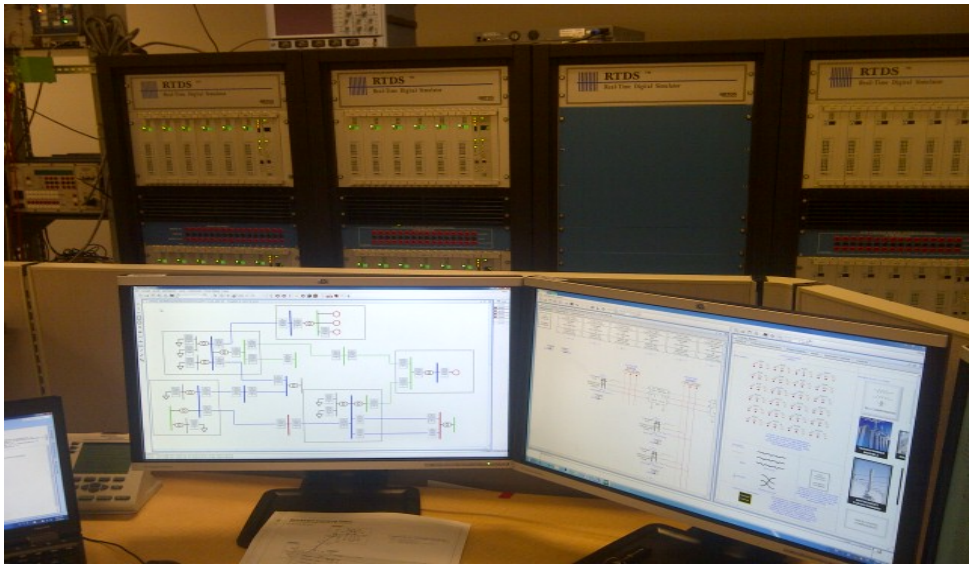
Blackstart Study in Dominion



ET Operations Research is leading blackstart study.

Dynamic Blackstart Study

- Research Environment
  - Hardware – RTDS (6 full racks of PB5, 2 racks of GTNET)

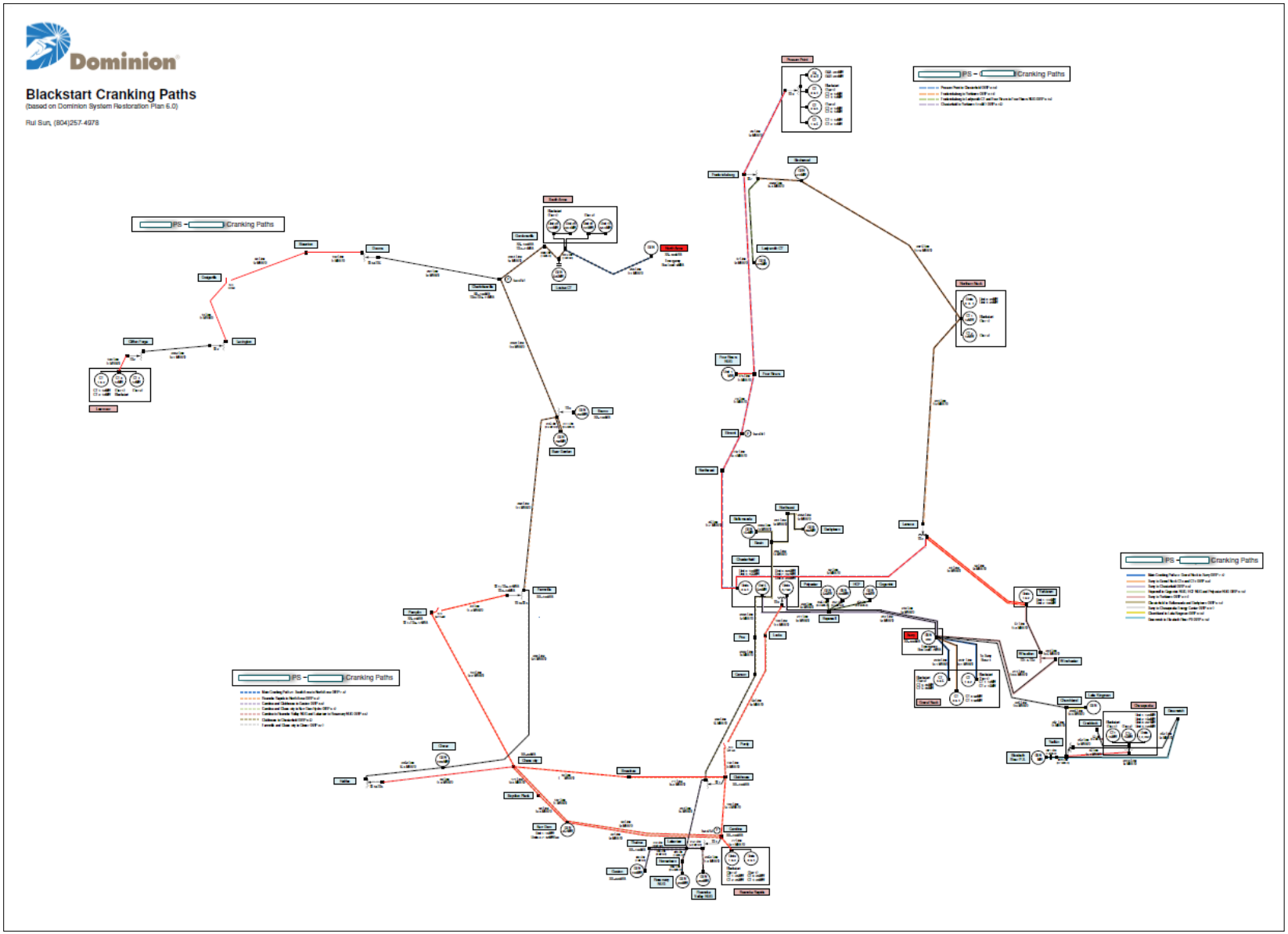


  - Relay panels – Major Protective Relays (SEL-311/351/421/487, RTU, data concentrators, SVC switch, doble, etc)
  - Software: RSCAD, PSS\e, PSCAD, etc

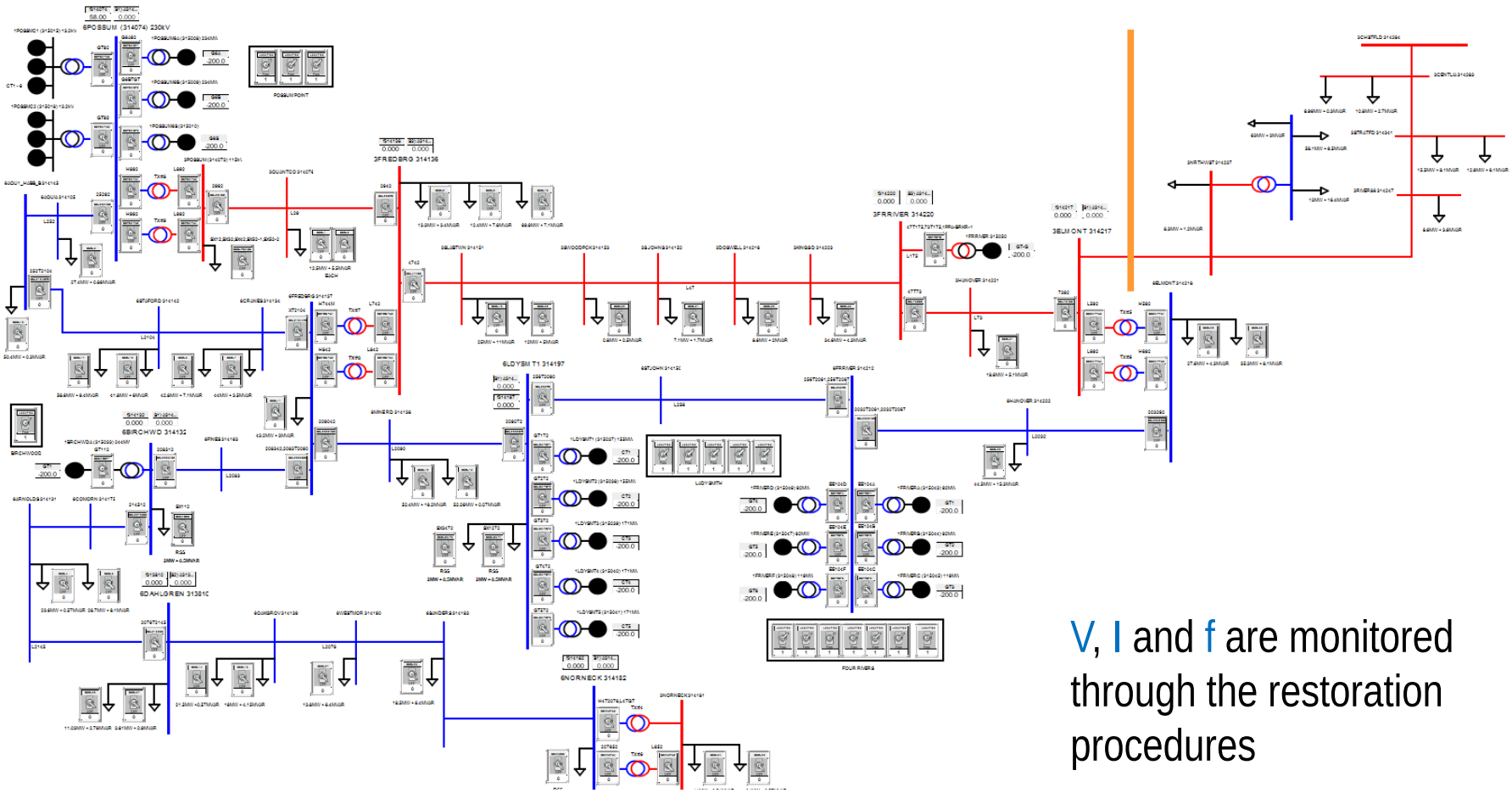
Dynamic Blackstart Study

- Dynamic Simulation
  - Test Feasibility of Cranking Paths
    - Voltage profile
    - Frequency (transients, continuous)
  - Transients
  - N-1 situations

Dominion's Blackstart Paths

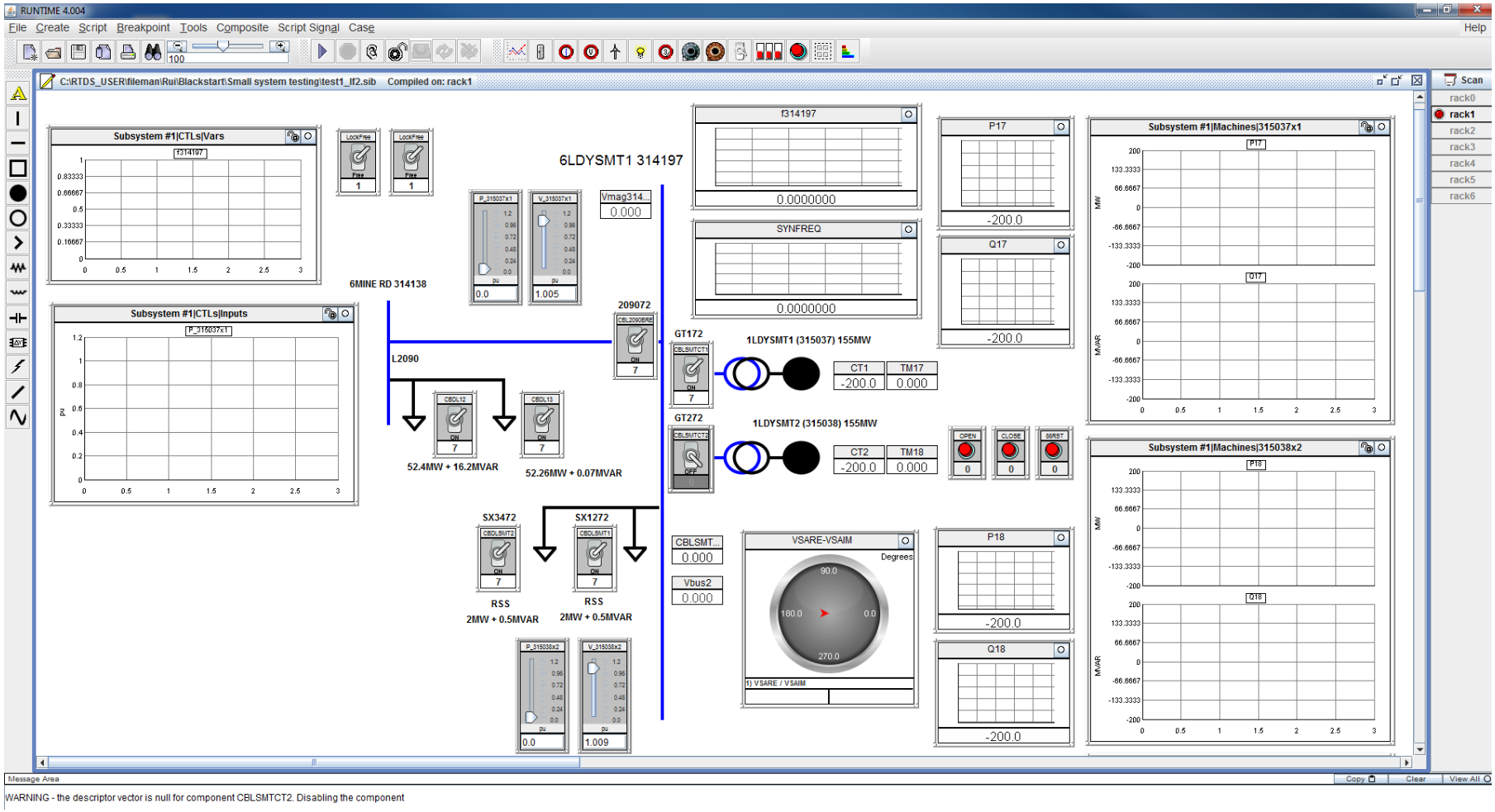


Case 1: 5 Plants, 22 Blackstart Generators, Total of 2500 MW Capacity



V, I and f are monitored through the restoration procedures

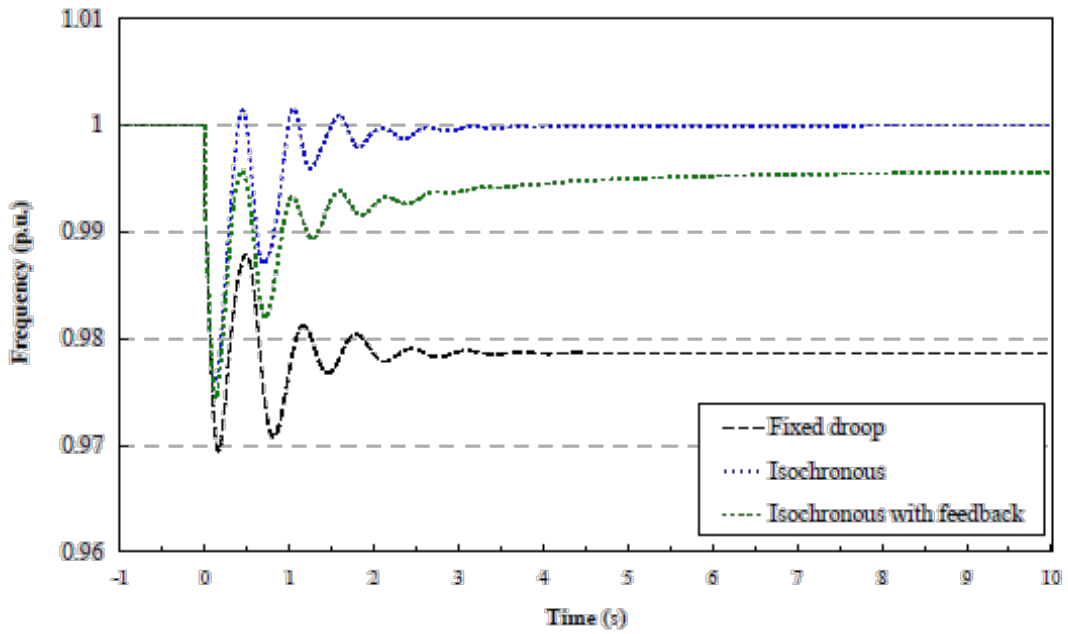
The initialization of Blackstart paths

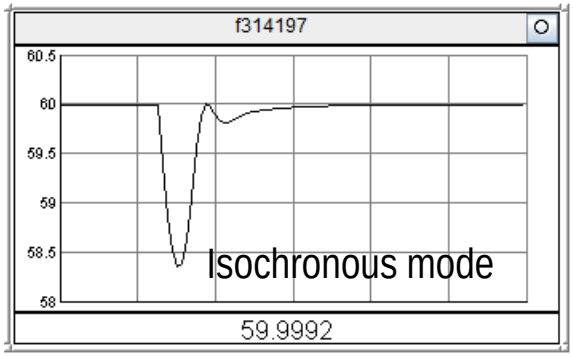


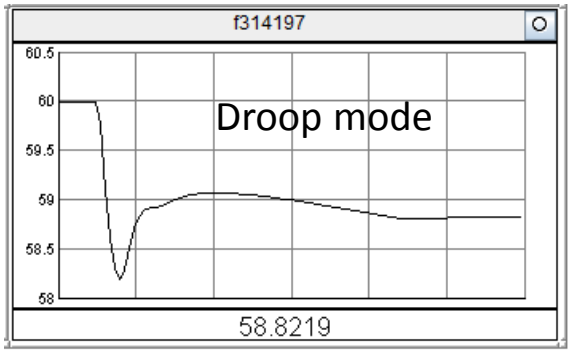
- In the diagram: V, f, P, Q, Tm and generator closing angle are monitored
- Generator synchronized closing scheme is well modeled

Study and Findings

- Generator operating modes
  - Isochronous mode vs. Droop mode
  - AGC is performed in wide area system by PJM (Droop mode)
  - Blackstart initializes with isochronous mode
  - Mode switching when synchronizing two islands





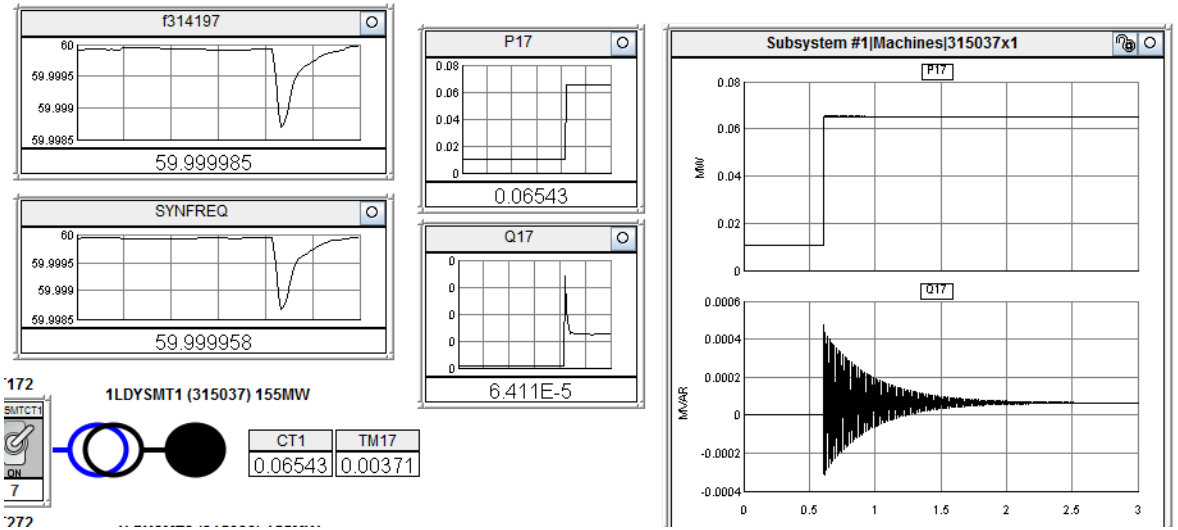


Study and Findings

- Generator operating modes
  - RTDS is used to study blackstart units initialization
    - The problem: if you have multiple generators at same bus, running in different modes – what the dynamic behaviors will be?
  - Findings: they run against each other – power oscillations
    - Having droop mode and isochronous mode units at the same bus
    - Checking with Generation Division on actual machine performance
    - The findings may help us to re-consider the blackstart procedures

Study and Findings

- Frequency Study and Control
  - Transient (switching, load pickup/shedding) frequency is not very well regulated under standards/Manuals
  - General guideline is to maintain frequency within 59.5 - 60.5 Hz
    - PJM prefers frequency to be regulated between 59.75 Hz and 61.0 Hz
    - Non-utility generators (NUGs) will begin to trip on over-frequency at 61.1 Hz
  - Dominion applies UFLS at 59.3 Hz, 58.9 Hz and 58.5 Hz
  - RTDS is used to study the transient frequency:

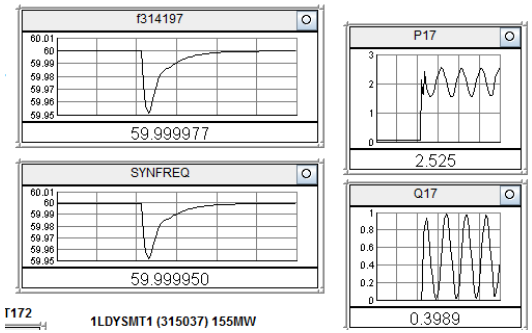


First generator starts up

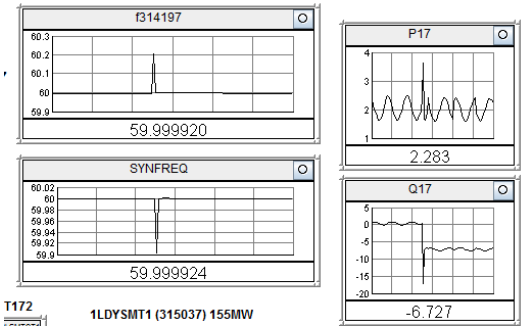
Study and Findings

- Frequency Study and Control
  - RTDS is used to study the transient frequency:

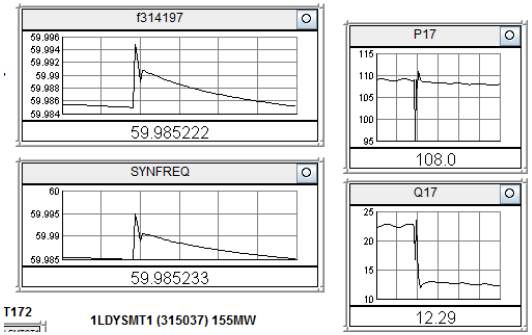
SS load online



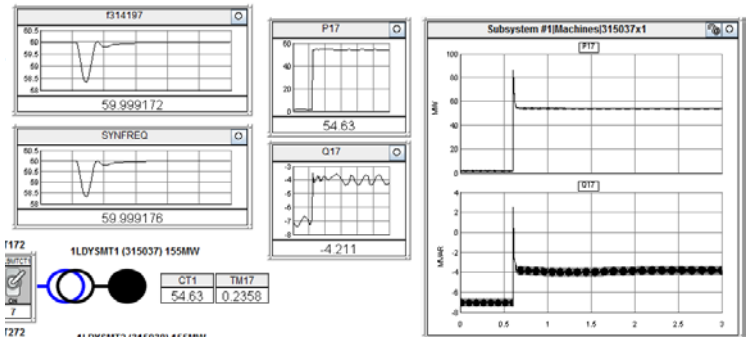
Energize a line



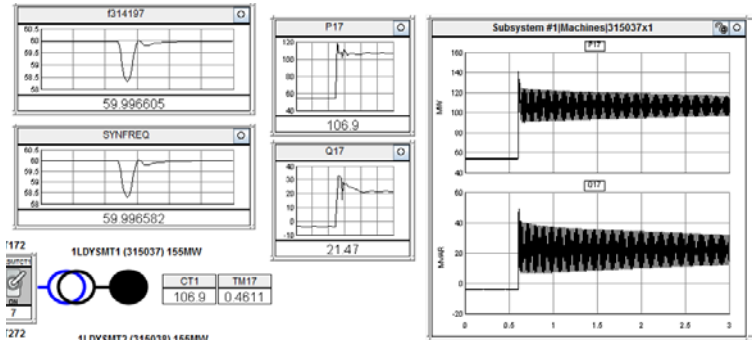
Second unit online



Pick up a 50MW load



Pick up another 50MW load



  - Findings: in the beginning phase of blackstart, adding loads may violate the UFLS settings – the normal setting should be defeated for BS scheme

Study and Findings

- Protection Study
  - Fault current availability for proper relay operation
    - Problem defined: the reduced fault currents and relay pick up currents setting
  - Synchronizing islands/ sub-systems (Angles)
  - RTDS is used to simulate fault events and calculate fault currents
    - A short path is tested
    - Relay panel with actual field settings for line protective relay is used
    - The relay setting has passed the test

      – Time inverse over-current element for “phase to ground fault” responded slow

Study and Findings

- Other Problems detected
  - Voltage magnitude rises when long transmission line energized, (capacitive power introduced)
    - RTDS simulation has confirmed this phenomena
    - Checking with Planning/SOC on possible mitigation ways to improve voltage profile:
      - Add tap stations to the line
      - Use TX LTCs to control voltage (not in current scope)
      - Energize more loads in the path (most feasible)

Conclusion

- RTDS is a powerful tool in DVP's blackstart analysis
  - Dynamic simulation – dynamic system status monitoring
    - Feasibility of blackstart paths
    - V, P and Q quality during the restoration
    - Transients
  - Protection Study
    - Some relay schemes are Intergraded in the model (i.e.: generator synchronized closing)
    - Capable of connecting to actual protective relays to validate the settings

Future Works (regarding simulation study)

- Validation on more comprehensive protection schemes
- Island synchronization
- Study the adjustment of LTCs on the paths
- System VAR control
- N-1 study

Thank you! Questions?

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