Outline

• Development of Load Model used in FIDVR Exposure Assessments
  – Steady State vs. Dynamic Analysis
  – Load Model development per event reconstruction
  – Future Load Model refinements

• Questions / Discussion
Approximate Distribution of 1900 MW of Lost Load as a result of the July 30th 1999 Union City - East Point event
Aggregate Load Model Development

- Motivation to replicate the Union City event so that exposure for more probable events could be assessed.

- Steady state load flow evaluations are used for the majority of Transmission Planning evaluations. Characteristics include:
  - A “snap shot” in time evaluation
  - Short term dynamics of generators, exciters, governors, and loads are ignored
  - Key results include steady state power flows and voltage levels
Aggregate Load Model Development

- Steady state load flow evaluations are not suited for FIDVR assessments
  - Induction motor loads, when presented low enough voltages, slow down and result in increased loadings at degraded power factors
  - Unit response to low voltages are based in part on excitation system dynamics
  - Thus, load and unit dynamics over time have to be considered in order to assess if / when transmission system voltage recovers
  - Steady state evaluations with a single “snapshot in time” result are insufficient
Aggregate Load Model Development

• Dynamic Simulation are required to evaluate FIDVR events
  – Dynamic simulation programs include, in part, generator, exciter, governor, and load models represented by sets of differential equations
  – Numerical techniques are utilized to solve differential equations at discrete time steps
  – Results are power system quantities over a period of time
  – The modeling of loads, particularly the induction motor component, is critical
Aggregate Load Model Development

• Traditionally, dynamic simulation studies have been used to quantify exposure to unit instability
  – Constant static load model work well as large voltage deviations are, compared to FIDVR events, short in duration
    • 90% constant current, 10% constant power for Active Power
    • 100% constant impedance for Reactive Power
  – However, these load models were not appropriate for analysis of FIDVR events
Per unit voltage (Morrow 230 kV bus)

- Solid Line – voltage dependent static load model
- Dashed line – constant MVA static load model

Time (Seconds)
Transmission Bus

\[ P = V^1 \]

\[ Q = V^2 \]

0.98 pu

Distribution Bus

transformer and feeder impedance

Load Bus

\[ P \approx V^1 \]

\[ Q \approx V^2 \]
Dynamic Simulation with Different Load Models

Per unit voltage (Morrow 230 kV bus)

Time (Seconds)
Motor MVA

Motor Power Factor

Time (Seconds)
Additional Model Validation Activities

• Since the 1999 Union City event, additional system events creating opportunities for further model validation have occurred
  – Compared to the 1999 event, these events were significantly less severe
  – Post-mortem simulations using the aggregate load model resulted in good, though not perfect, correlation
DFR recording of a less severe FIDVR event

Per unit voltage (Metro Atlanta 230 kV bus)

Time (Seconds)
Dynamic Simulations of a less severe FIDVR event
Possible Load Model

Refinements

• Aggregate Load Model is being used in Planning and Operational assessments
  – High confidence that it results in appropriately conservative results
  – However, reality is that real-world aggregate load is more complex than currently modeled
  – Thus, a “user written” aggregate load model is under consideration which could include:
    • Residential loads
    • Commercial loads
    • Industrial loads
Transmission Bus

User defined transformer and feeder impedance

Small I.M.
(Replace with Lock Rotor Impedance upon stalling)

Large I.M.

Large I.M.

Unlatched Contactor

Unlatched Contactor

U.V. Relay

P ≈ V^1

Q ≈ V^2
Conclusions

• The aggregate load model currently in use by Southern Company Transmission was developed as a result of post mortem activities after the Union City 1999 event.

• Induction Motor dynamics is the most critical component of the aggregate load model.

• Southern Company Transmission is currently investigating a more detailed aggregate load model – The more detailed aggregate load model will be used only after detail analysis confirms that use of this model results in superior correlation with recorded system events.
DISCUSSION and QUESTIONS