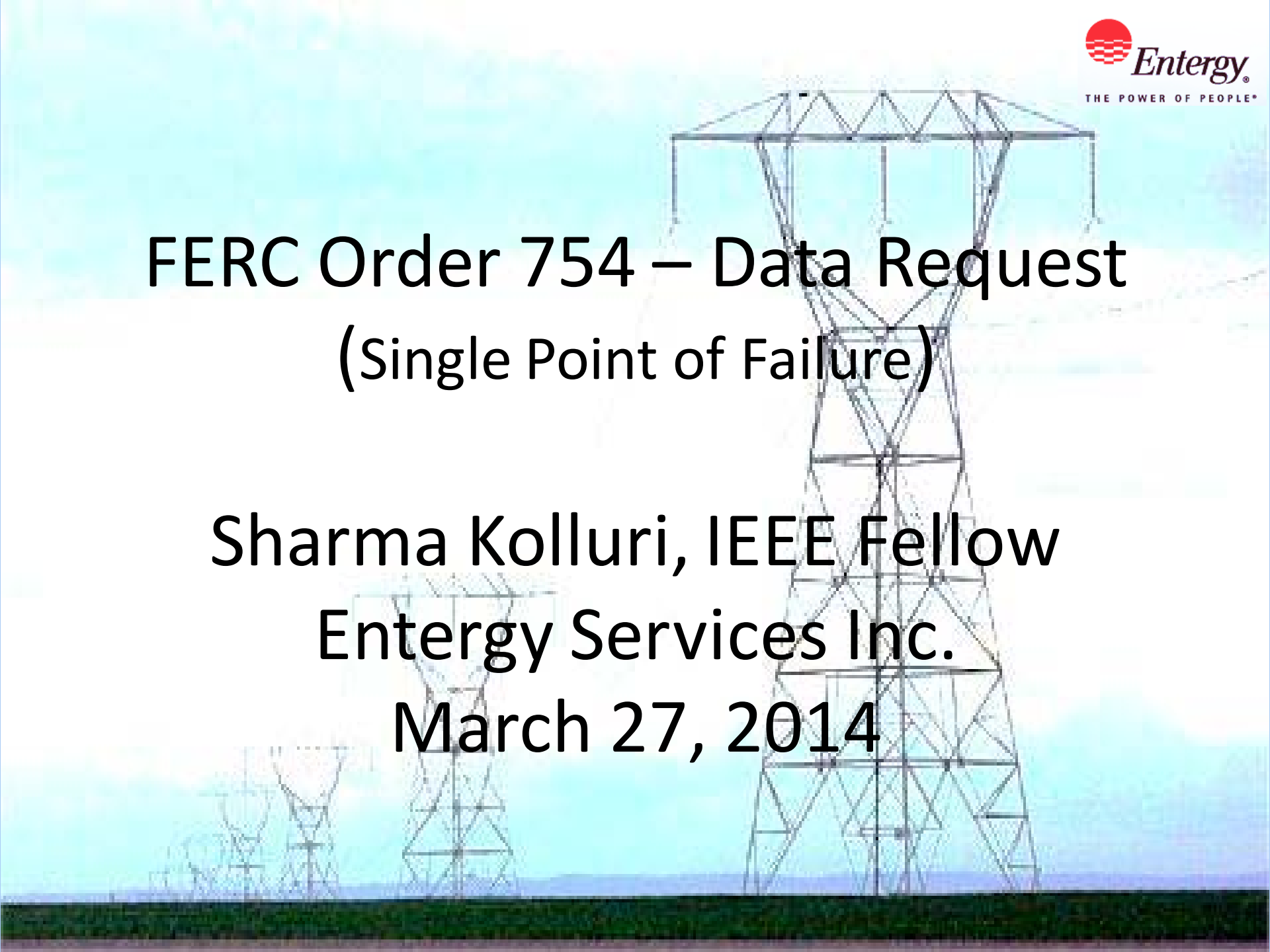


FERC Order 754 – Data Request
(Single Point of Failure)

Sharma Kolluri, IEEE Fellow
Entergy Services Inc.
March 27, 2014

Overview

- Transmission Planners are directed to:
  - Develop a list of stations where protection system failures can result in potential reliability risks to the BES (Table A).
  - Assume worst case faults occur (3 phase faults) coupled with a protection system failure.
  - Report statistical information to NERC such that NERC can determine if there is a need for additional action to avoid adverse reliability impacts to the BES.
    - Concerning the buses evaluated in the study
    - Attributes of protection system design

Requirements

Buses to be Tested

- 200 kV +, 4 or more elements
- 100-200 kV, 6 or more elements
- 100 kV+, Nuclear Off-Site Power
- 100 kV+, TP Additions

Short List

Create a list of buses where a 3 phase fault coupled with a protection system failure results in adverse reliability impact – does not meet the performance requirements

Report to NERC

- Buses and terminals without protection redundancies
- Protection system attributes
- Station DC supply attributes

Entergy

Study Objectives

- Perform dynamic simulations to support Entergy's FERC 754 compliance reporting process.
  - Select and review dynamic case for assessment .
  - Establish performance criteria to be utilized to assess the results of dynamic simulation.
  - Develop automation scripts to create and run dynamic events from the "excel event files".
  - Assess impact of out-of-step protection on the results (loss of synchronism).
- Evaluate selected stations for protection system issues.
- Develop short list of stations that meet FERC 754 criteria for further investigation.

Entergy
THE POWER OF PEOPLE®

Study Approach Overview

Location: Sub #1 **230kV**

Study Condition: Remote Clearing Time Study

Clearing times shown are with all sources in.

Fault Condition: Fault on Sub #1 230kV Bus - No Breaker Failure

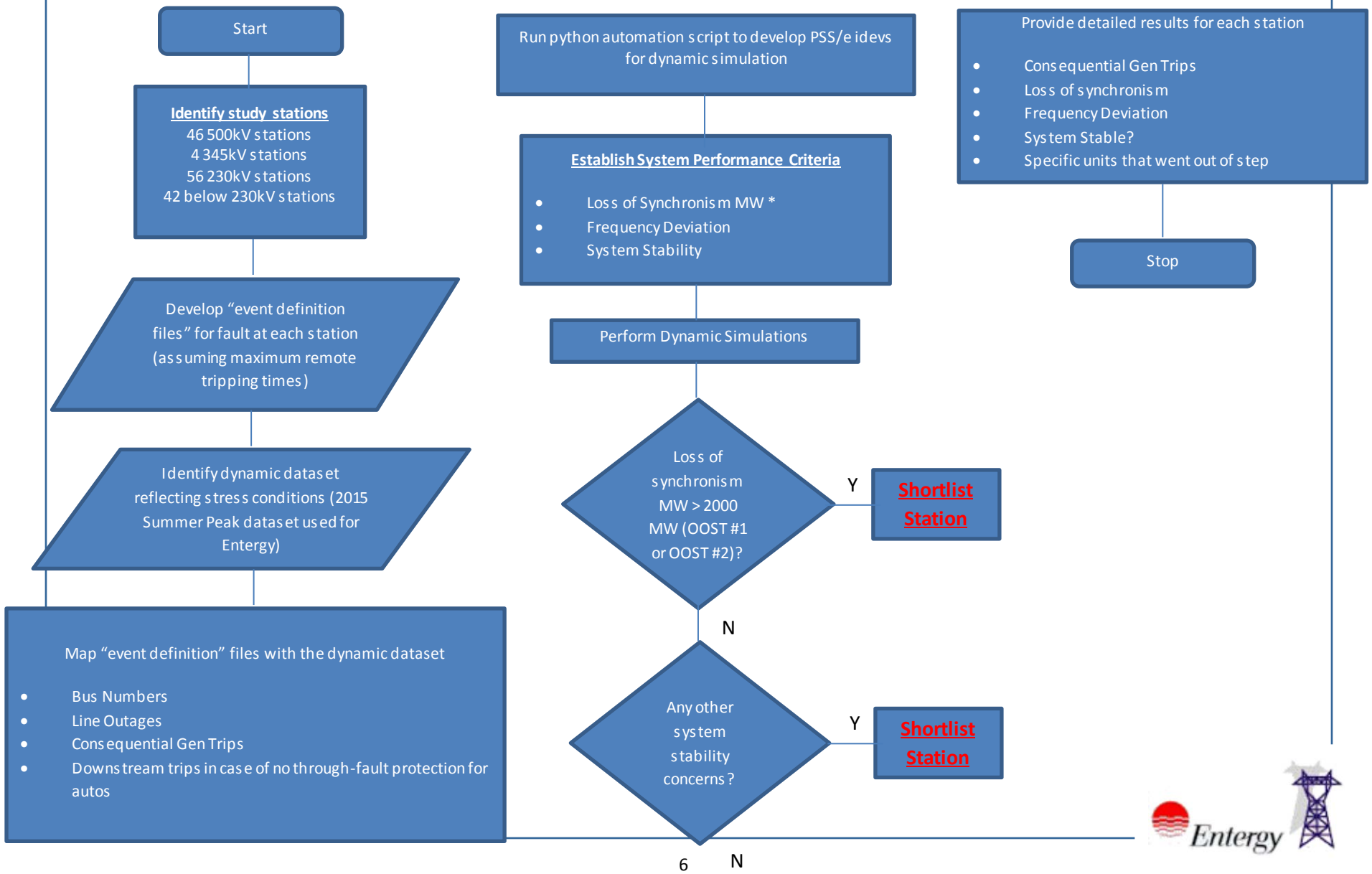
Relay Location	Breaker	Relay Type	Fault Type	Aspen Time	Breaker Op Time	Relay Op Time	Breaker Failure Scheme	Total Clearing Time
A	21770 &	LFZP	1LG (cyc)	20.4	3	2.25	0	25.65
	21790	LFZP	LL (cyc)	20.4		2.25	0	25.65
		LFZP	3LG (cyc)	20.4		2.25	0	25.65
Step distance and or time overcurrent relaying clears A terminal.								
B	21700 &	LFZP	1LG (cyc)	20.4	3	2.25	0	25.65
	21775	LFZP	LL (cyc)	20.4		2.25	0	25.65
		LFZP	3LG (cyc)	20.4		2.25	0	25.65
Step distance and or time overcurrent relaying clears B terminal.								
C	21230	SEL 321	1LG (cyc)	20	5	2.25	0	27.25
		SEL 321	LL (cyc)	20		2.25	0	27.25
		SEL 321	3LG (cyc)	20		2.25	0	27.25
Step distance and or time overcurrent relaying clears C terminal.								
D	14315	SDG	1LG (cyc)	20	3	2.25	0	25.25
		KD	LL (cyc)	20		2.25	0	25.25
		KD	3LG (cyc)	20		2.25	0	25.25
Step distance and or time overcurrent relaying clears D terminal.								
E	13355 &	SEL 311C	1LG (cyc)	20	5	2.25	0	27.25
	13360	SEL 311C	LL (cyc)	20		2.25	0	27.25
		SEL 311C	3LG (cyc)	20		2.25	0	27.25
Step distance and or time overcurrent relaying clears E terminal.								
F	58211	SEL 321	1LG (cyc)	50	3	2.25	0	55.25
		SEL 321	LL (cyc)	50		2.25	0	55.25
		SEL 321	3LG (cyc)	50		2.25	0	55.25
Step distance and or time overcurrent relaying clears F terminal.								

Summary:
Step distance and/or time overcurrent relaying clears all the terminals for the fault on the Sub #1 230kV. The worst case clearing is 55.25 cycles for ground faults and 55.25 cycles for phase faults.

Conversion of event data to dynamic simulation idevs

```
PDEV
2 0 0
LOGS\Sub #1-230kV_Remote-Clearing-Time-Study_PWR.log
ODEV
2 0 0
LOGS\Sub #1-230kV_Remote-Clearing-Time-Study_PWR.log
@input drift_pwr.idv
@input _change_ generator _PSS_para_pwr.idv
@input _trip_outofstep_pwr.idv
@input _setAngRef_pwr.idv
PSAS
1
PSAS0.DAT
START OUTPUT OUTs\Sub #1-230kV_Remote-Clearing-Time-Study_PWR.out
RUN PRE-FAULT TO 0.1 SECONDS PRINT 15 PLOT 15 CRTPLT 0
APPLY FAULT AT BUS 335536 ADMITTANCE 0.0 -2E+09 MVA
RUN TO 0.520833333333 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335536 TO BUS 335665 CKT 1
RUN TO 0.5275 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335536 TO BUS 335537 CKT 1
RUN TO 0.5275 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335536 TO BUS 335537 CKT 2
RUN TO 0.554166666667 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335536 TO BUS 335635 CKT 1
RUN TO 0.554166666667 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335635 TO BUS 335636 CKT 1
RUN TO 0.554166666667 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335536 TO BUS 303000 CKT 1
RUN TO 1.02083333333 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335536 TO BUS 335535 CKT 1
RUN TO 1.02083333333 SECONDS PRINT 5 PLOT 5 CRTPLT 0
OPEN BRANCH FROM BUS 335535 TO BUS 336015 CKT 1
CLEAR FAULT AT BUS 335536
RUN POST-FAULT TO 10 SECONDS PRINT 15 PLOT 15 CRTPLT 0
END
```

Study Process Chart



Sample Study Results

Station	kV	Consequential Trip (MW)	Loss of Synchronization (MW)	Total Tripping (MW)	Fail to recovery voltage to 0.85pu 3 sec after fault (MW)	Frequency Drop (Hz)	System Stable?
A	500	1947	150	2097	0	-0.010	YES
B	500	526	0	526	0	-0.003	YES
C	500	648	2145	2793	0	-0.011	YES
D	500	0	2263	2263	0	-0.004	YES
E	500	1536	1060	2596	0	-0.009	YES
F	500	0	1635	1635	0	-0.002	YES
G	500	53	0	53	0	0.000	YES

Relay Attributes

230 kV Station Name	230 kV Bus	Two Relays (Y/N): Q3	PS 1: High Speed (Y/N)	PS 2: High Speed (Y/N)	Independent Communication Channel (Y/N)	Two High Speed Protection (Y/N): Q4	Independent CTs (Y/N)
Substation "A" 230 KV	Ring Bus	N/A	N/A	N/A	N/A	N/A	N/A
Substation "B" 230 KV							
	230 kV Bus	Y	Y	N	N/A	N	Y
Substation "C" 230 KV							
	North Bus	Y	Y	N	N/A	N	Y
	South Bus	Y	Y	N	N/A	N	Y
Substation "D" 230 KV							

230 kV Station Name	Independent Secondary PT Windings (Y/N)	Independent AC Current and Voltage: Q5	Independent Auxiliary Tripping Relay or Lockout Relay if App. (Y/N)	Trips 2 Trip Coils (Y/N)	Independent DC Circuit (Y/N): Q6	Satisfy All Table B Criteria: Q2
Substation "A" 230 KV	N/A	N/A	N/A	N/A	N/A	N/A
Substation "B" 230 KV						
	N/A	Y	Y	Y	Y	N
Substation "C" 230 KV						
	N/A	Y	Y	Y	Y	N
	N/A	Y	Y	Y	Y	N
Substation "D" 230 KV						

Summary

- Developing process methodology for addressing FERC Order 754 investigation is critical.
  - Identifying the events associated with remote tripping times
  - Converting the event definitions to those applicable to planning cases / dynamic datasets
  - Develop idev files for dynamic simulation
  - Establishment and application of performance criteria
  - Iterative approach to screen stations and test final candidates
- Automation routines critical to approach adopted by Entergy
  - More number of stations subjected to dynamic simulation which was used for screening instead of the protection / communication scheme redundancy review
- Impact of OOST option application
- Potentially need to look at “locally stressed scenarios”?

FERC Order 754

- FERC stated that "lack of comprehensive assessment of non-redundant primary protection systems is a reliability concern e.g., the study of a single point of failure on protection systems."

- FERC directed NERC to initiate a process "to explore this reliability concern, including where it can best be addressed and identify any additional actions necessary to address the matter."

Study Approach Overview

- Dynamic Event Definitions Review – Checklist
  - Preparation for automation
    - Identify PSS/e bus number for faulted bus
    - Identify PSS/e bus numbers for from and to buses for each tripped line
    - Identify PSS/e bus number and Gen ID for units tripped consequentially
- Develop and run automation scripts to convert “excel dynamic event files” into idevs for simulating dynamic events
- Establish system performance criteria
- Run dynamic simulations and evaluate results vis-à-vis performance criteria
- Shortlist stations requiring further investigation by Entergy

Study Approach Overview

- Establishment of performance criteria
  - Consequential generation trips
  - Generation lost due to loss of synchronism (>= 2000 MW)
  - Events that result in failure of voltage to recover to 0.85 per unit within 3 secs
  - Frequency Deviation (post-event)
  - Over-all system stability
- Loss of synchronism evaluation performed using Out-of-Step Trip (OOST) setting options in PSS/E