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Incorporating Electromagnetic Transient Studies into the Generator Interconnection Process at ATC

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Agenda

- Introduction
- Pre-Kick Off – SCR Screening
- Phase 1 – PSCAD Model Verification & PSCAD Transmission Network Model Development
- Phase 2/3 – PSCAD Analysis
- Post Phase 3 – Material Modification Study
- Summary

Introduction – ATC Footprint

- A multi-state, transmission-only electric utility
- Own and operate more than 560 substations and more than 9,800 miles of transmission lines
- Have a peak load of about 13,000 MW
- Have about 600 employees
- MISO TO member

Introduction – Recent ATC GI Queues

- ATC had over 7 GW of IBR requests in three recent queues

Queue Cycle	Wind (MW)	Solar (MW)	Energy Storage (MW)
2017 August WI Cycle	341	1,299	0
2018 April Cycle	300	3,240	170
2019 April Cycle	232	1,239	269

Introduction – MISO & ATC PSCAD Study Requirements

MISO BPM-15

- PSCAD models required for all IBRs
- Study to be determined by local Planning Criteria in combination with MISO's evaluation

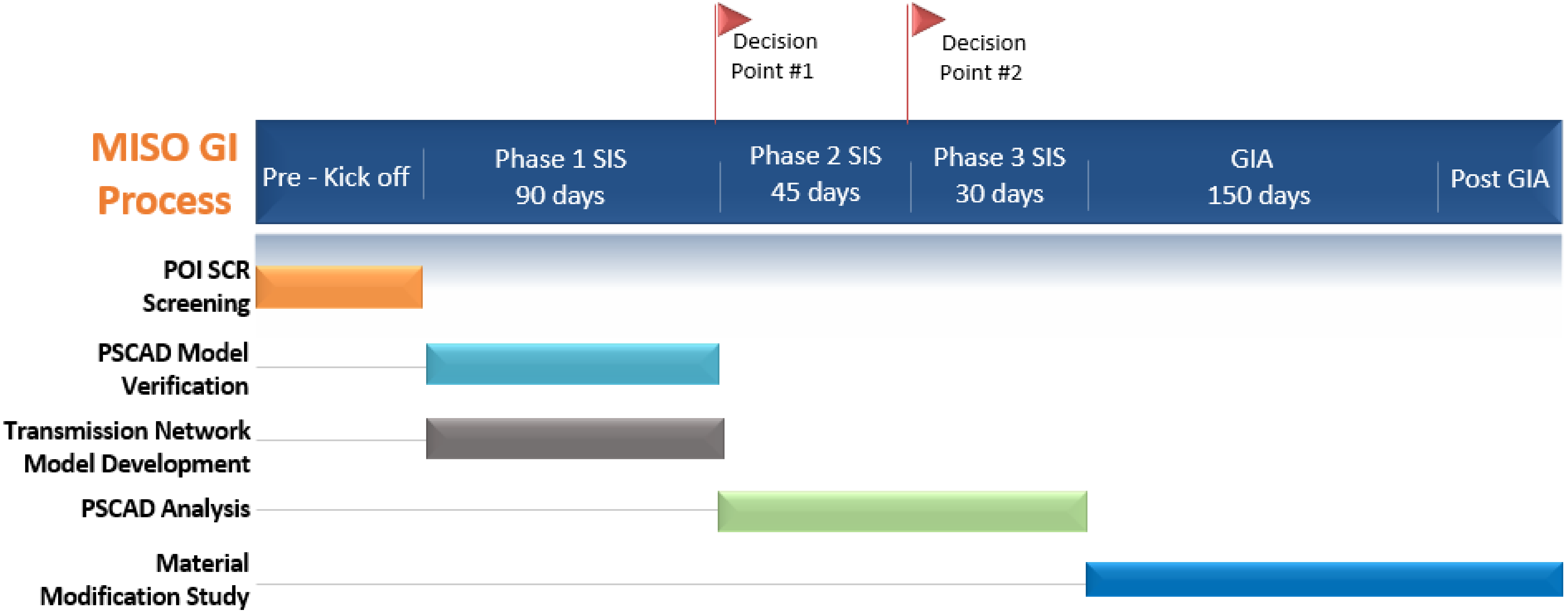
ATC Planning Criteria

- PSCAD models required for all IBRs
- PSCAD studies required for IBR connecting to an area with low short circuit strength

Introduction - ATC PSCAD Study in MISO GI Process

- The Overarching Challenge
  - Hard to complete in MISO System Impact Study (SIS) timelines and require significant stakeholder collaborations
    - MISO (RTO)
    - ATC (TO)
    - Consultant hired by ATC
    - Interconnection Customer (IC)
    - Consultant hired by IC
    - Inverter manufacturer

Introduction - ATC PSCAD Study in MISO GI Process



Pre-Kick Off - SCR Screening

- Problems to solve
  - What G-T requests require a PSCAD study?
  - If a PSCAD study is required what faults need to be studied?

Pre-Kick Off - SCR Screening

- ATC Criteria to Determine if a PSCAD Study is Needed
  - Proximity to known weak grid area
  - Proximity to Mackinac HVDC, Benson Lake SVC
  - SCR below 3 (N-0, N-1, N-2)
  - WSCR below 1.5 (N-0, N-1, N-2)

Pre-Kick Off - SCR Screening

- ATC developed python tool for rapid SCR evaluation of numerous IBR plants

Inputs

1. List of POI buses
2. List of Plant MW capabilities
3. Starting bus
4. # of branches away from starting bus

→

Python SCR Screening Tool

→

Output

Excel File with SCRs under N-0, N-1 and N-2

Pre-Kick Off - SCR Screening

- Use the output of the python SCR screening tool to select the contingencies to study in PSCAD

Study Contingencies with low SCRs

BUS #	BUS NAME	CONTINGENCY	SCR
123456	SOLAR POI 138.00	SOLAR POI 138.00 - GREEN SUB 138.00 + RED SUB 138.00 - PURPLE SUB 138.00 1	1.069278
123456	SOLAR POI 138.00	SOLAR POI 138.00 - GREEN SUB 138.00 + FARM SUB 138.00 - TOWN SUB 138.00 1	1.932069
123456	SOLAR POI 138.00	FARM SUB 138.00 - TOWN SUB 138.00 1 + DISCO SUB 138.00 - BLUES SUB 138.00 1	2.71061
123456	SOLAR POI 138.00	SOLAR POI 138.00 - GREEN SUB 138.00 1	3.012894
987654	WIND POI 138.00	WIND POI 138.00 - BLUE SUB 138.00 1 + RED SUB 138.00 - PURPLE SUB 138.00 1	4.104188
123456	SOLAR POI 138.00	FARM SUB 138.00 - TOWN SUB 138.00 1 + FACTORY SUB 138.00 - TOWN SUB 138.00 1	5.713749
123456	SOLAR POI 138.00	TURKEY SUB 138.00 - ITALIAN SUB 138.00 1	6.401166
123456	SOLAR POI 138.00	BASE CASE	10.39853
987654	WIND POI 138.00	WIND POI 138.00 - BLUE SUB 138.00 1	11.12908
987654	WIND POI 138.00	BASE CASE	13.45873

Pre-Kick Off - SCR Screening

- SCR Screening Results for Three MISO Queue Cycles

Queue Cycle	# IBR Requests	# Requiring PSCAD Study	# Contingencies
2017 August WI Cycle*	12	9	8
2018 April Cycle	24	14	36
2019 April Cycle	18	13	33

* Prior to ATC Python Screening Tool and Contingency Selection Guidelines

Phase 1 – PSCAD Model Verification

- Model Challenge
  - Although the PSCAD model requirements were provided to ICs prior to model submittals, the requirements were usually not fulfilled.

http://www.electranix.com/publication/pscad-requirements-rev-9-may-2020/

Phase 1 – PSCAD Model Verification

- Common Modelling Issues
  - Generic Models (not “real code”)
  - No Power Plant Controller (PPC)
  - Use Default Parameters
  - Not Project Specific
  - Not Matching Application Data

Phase 1 – PSCAD Model Verification

- Model Verification Statistics

Queue Cycle	# IBR PSCAD Models Studied	# IBR PSCAD Models Needing Tuning	Longest Time to Get Model Resolution (Weeks)
2017 August WI Cycle	9	2	12
2018 April Cycle	14	12	24

Phase 1 – PSCAD Model Verification

Visual Inspection		
1	The manufacturer's name and the specific version of the inverter model should be clearly observable in the .psc file.	
2	The PSCAD model documentation should be provided. It should match the model version in the .psc file and should include instructions for setup and running of the model.	
3	The .psc file should contain the modeling of all the facilities from the inverters to POI including, but not limited to, the following facilities listed in 3a - 3h. The facilities should be site specific. The data in the .psc file should match PSSE steady state modeling data.	
	3a	Generator dispatched at the requested MW level
	3b	Equivalent pad mount transformer
	3c	Equivalent collector system
	3d	Main step-up transformer
	3e	Gen-tie line
	3f	Cap banks, STATCOM or any other types of voltage control device
	3g	AC equivalent source at the POI with manufacture designed minimum stable SCR for the inverter
	3h	60 Hz grid frequency base

Phase 1 – PSCAD Model Verification

Visual Inspection (cont.)		
4	Protection settings are implemented.	
	4a	Generator voltage and frequency protection settings should match PSSE .dyr file.
	4b	Option to disable protection models is present.
5	Model uses a simulation timestep of 10 µs or higher.	
6	Model compiles using Intel FORTRAN version 12 or higher.	
7	Model uses PSCAD version 4.6 or higher.	
8	Model supports the PSCAD "snapshot" feature.	
9	Model supports the PSCAD "multiple run" feature.	
10	Model can be scaled to represent any number inverters/turbines, either using a scaling transformer or internal scaling. Model should not be using current injection to scale the plant.	
11	Model includes power plant controller (PPC)	
12	PPC accepts an external active power setpoint.	
13	PPC accepts a voltage setpoint of 1.02 pu at POI. PPC is in voltage control mode.	
14	PPC has a mechanism to implement a settable voltage droop	

Phase 1 – PSCAD Model Verification

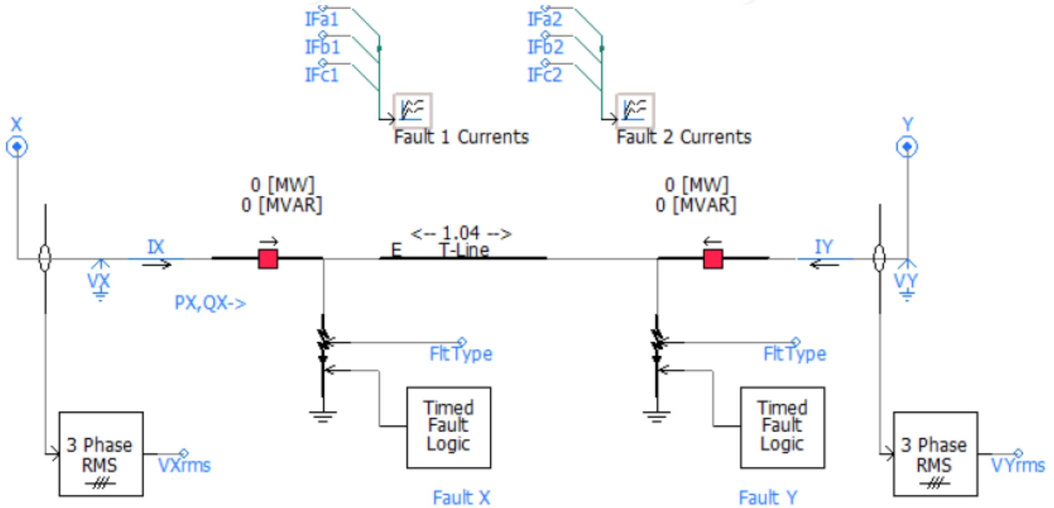
Performance Evaluation		
15	Model initializes to the setpoints specified in the PPC in 5 sec or less and meets ATC Stability Criteria for 20 sec of simulation after all values have initialized.	20 sec flat run
16	If auxiliary plant voltage control devices are included in the plant, the voltage control of these devices should be coordinated with the PPC to prevent circulating VARs.	20 sec flat run
17	Model is able to ride-through, recover and meet ATC Stability Criteria from a 6-cycle, 3PG fault at the POI while dispatched at 100% of PMAX.	20 sec run with a 3PG fault
18	Model is able to ride-through, recover and meet ATC Stability Criteria from a 6-cycle, 3PG fault at the POI while dispatched at 20% of PMAX.	20 sec run with a 3PG fault
19	Determine the actual minimum stable SCR for the plant.	Minimum stable SCR test
20	Model responds to a step increase in frequency (overfrequency excursion event) by decreasing its active power meeting the performance specified in Table 2.1 of NERC IRPTF 2019 Reliability Guideline.	FERC Order 842 test

Phase 1 – PSCAD Model Verification

Performance Evaluation (cont.)		
21	Model responds to a step change in PPC voltage setpoint meeting the performance specified in Table 2.2 of NERC IRPTF 2019 Reliability Guideline.	POI voltage step change test
22	Model trips or blocks when terminal voltage rises above 1.3 pu for 1 sec.	High voltage protection test
23	Model trips or blocks when terminal voltage falls below 0.2 pu for 1 sec.	Low voltage protection test
24	The closed-loop dynamic response of the overall inverter-based resources, as measured at the POM, should have the capability to meet or exceed the performance specified in Table 2.3 of NERC IRPTF 2019 Reliability Guideline.	Large disturbance test
25	Model is compliant with NERC PRC-024 with momentary cessation disabled.	PRC-024 test
26	Model is compliant with FERC order 827.	FERC order 827 test

Phase 1 - Transmission Network Model Development

- For each PSCAD study
  - Define modeling area in the vicinity of the new IBRs using engineer judgement
  - Develop detailed frequency dependent transmission line models based on conductor types, bundle configurations, and tower geometries
  - Develop fault logics
  - Generation dispatch sensitivities



Phase 2/3 - PSCAD Analysis

- Problems to solve
  - How to define IBR stability performance deficiency?
  - What are the mitigation options to consider?

Phase 2/3 - PSCAD Analysis - ATC IBR Control Stability Criteria

- No tripping for any Planning Events
- Continue current injection inside PRC-24 “No Trip Zone”
- No re-entering fault ride-through mode more than once in the time period beginning 6 cycles after the fault clears until the end of the 20 second simulation

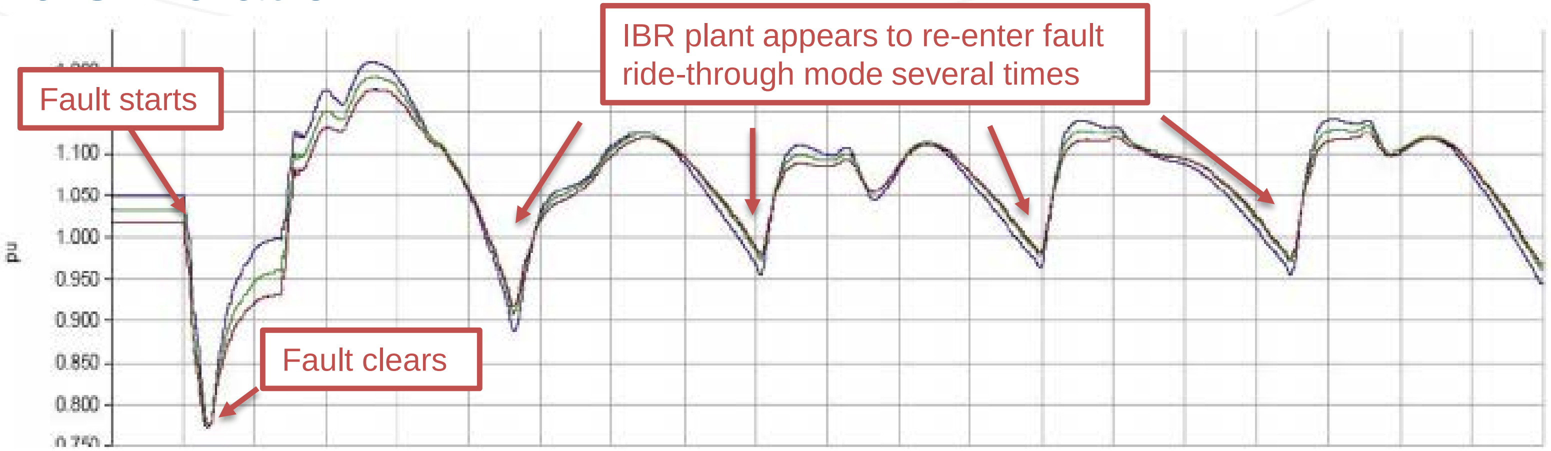
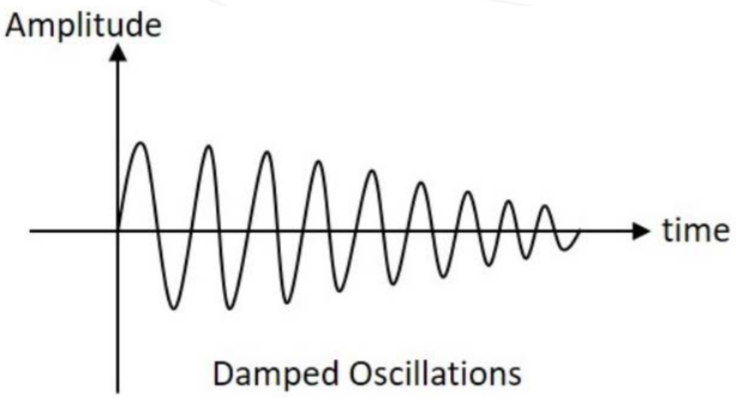


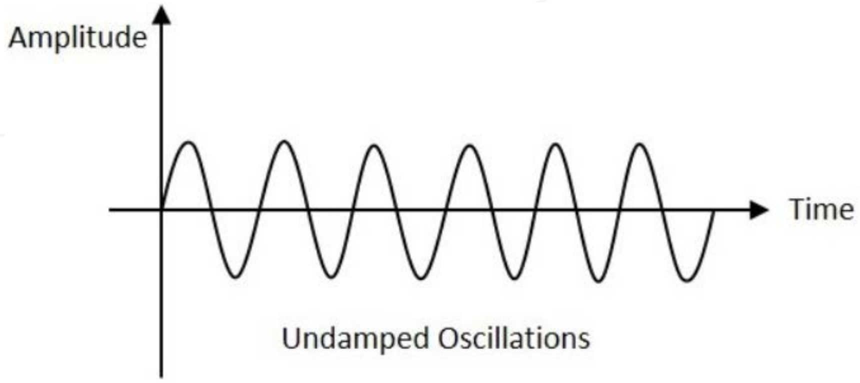
Figure 3.3: Example of Control Instability (Mode Cycling) at Wind Plant Connected to Weak Grid [Source: Electranix]

Phase 2/3 - PSCAD Analysis - ATC IBR Control Stability Criteria

- Damping Criteria for P & Q at terminal buses, V at POIs
  - 50% or greater reduction in oscillation magnitude over the last four oscillation periods of the 20 second simulation

    OR
  - Peak-to-peak magnitudes during the last two sec of the 20 sec simulation not exceeding 3% of their rated values





Phase 2/3 - PSCAD Analysis - Mitigation Development

- Interconnection Customer Options:
  - Control System Tuning
  - Lower Impedance from Generator to POI
  - Reduced Plant Capacity
  - Temporary RAS (not preferred)

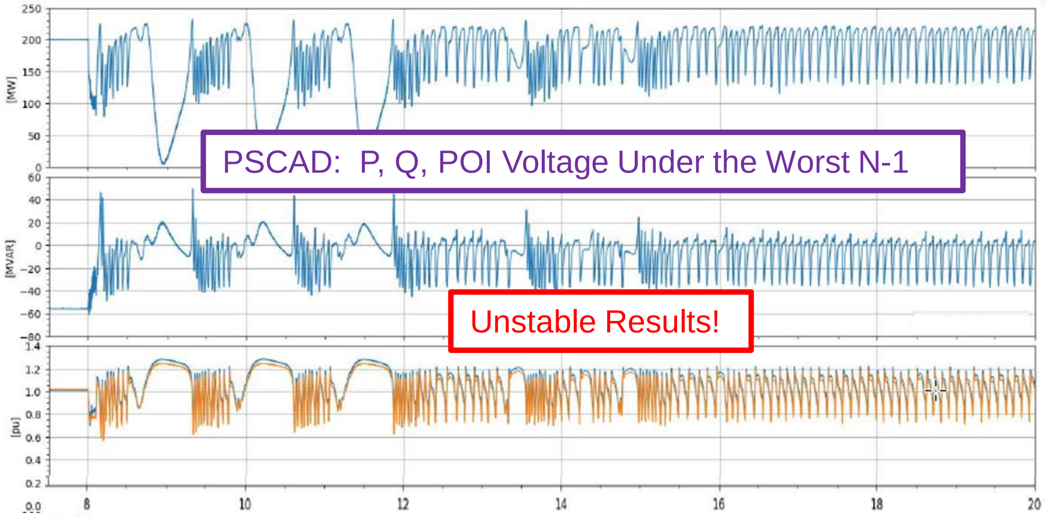
- TO Options:
  - Transmission Reinforcement
  - Operating Restrictions for N-1-1

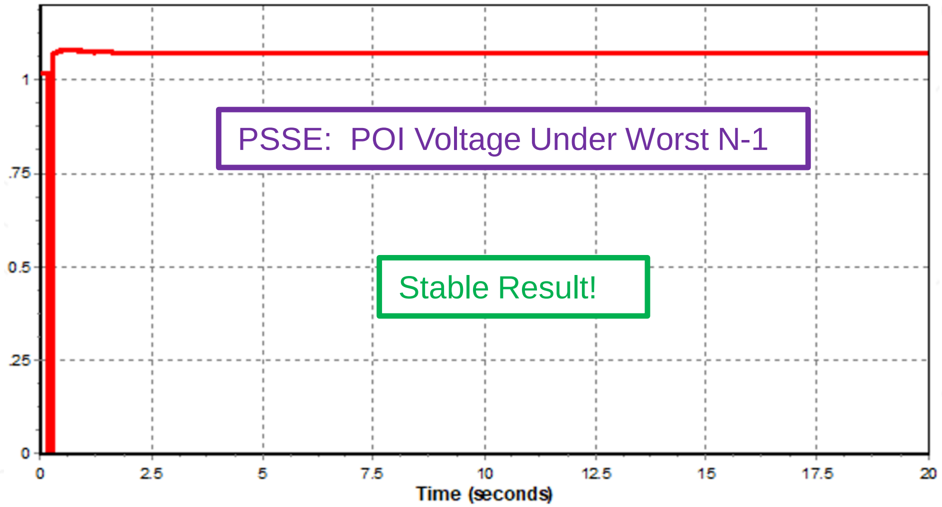
Phase 2/3 - PSCAD Analysis - Mitigation Development

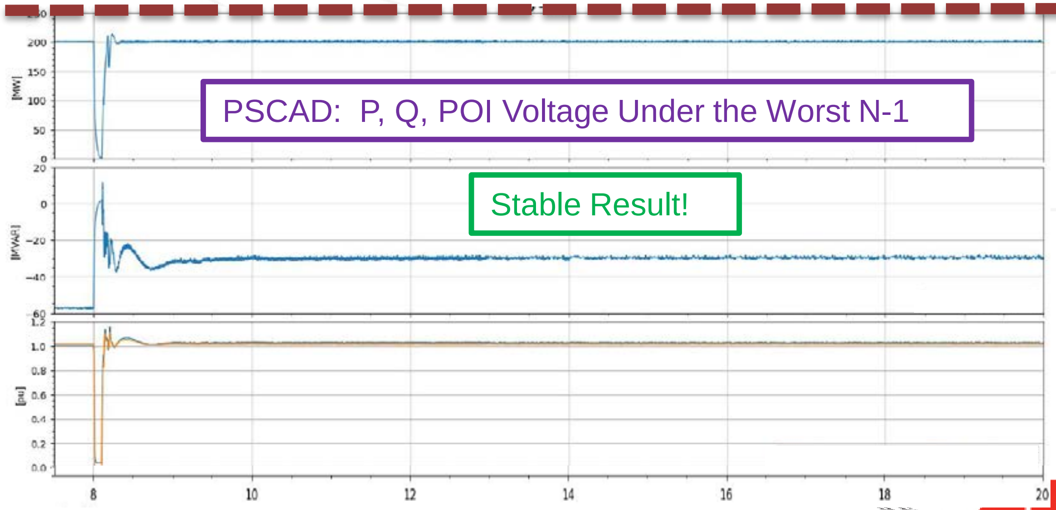
- Identified Mitigations for Two MISO Queue Cycles

Queue Cycle	IC Control System Tuning	Transmission Reinforcement	EMT Stability Operating Restriction for N-1-1
2017 August WI Cycle	2	1	5
2018 April Cycle	12	0	10

Phase 2/3 - PSCAD Analysis - Mitigation Development







After the New Transmission Line Project is Included

Post Phase 3 - Material Modification Study

Post Phase 3 - Material Modification Study

- Interconnection Customer to Submit a Detailed Analysis
  - To demonstrate that the proposed change is not a Material Modification
  - Steady-state, reactive power, short circuit, and stability analyses
- PSCAD Restudy Required by ATC
  - If a PSCAD study including the generator was performed during SIS
  - Same study scope after model verification

Summary

Key Issues	Recommendations
What to study in PSCAD?	Develop screening criteria and a screening tool
Is the PSCAD model appropriate?	Develop a model verification process and complete it prior to PSCAD analysis
How to identify performance deficiency?	Develop IBR control stability criteria
How to efficiently implement the PSCAD study in GI process?	Get the models and faults ready as early as possible


PSCAD
Studies
GI Study Timeline
Tools & Processes
HYSTER

Questions?

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