Modeling and Validation of Solar PV Plants

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September 17, 2020

Modeling Solar PV Plants

- REGC_A or REGC_B (as applicable)
    - Generator/converter model
    - REGC_B is appropriate for use in weak grid situations

- REEC_A or REEC_D (as applicable)
    - Renewable energy electrical control model
    - REEC_B is no longer WECC approved and must be converted to REEC_A/REEC_D
    - REEC_A/REEC_D can be used to model momentary cessation

- REPC_A or REPC_B (as applicable)
    - Power Plant Controller
    - REPC_A controls a single PV generator
    - REPC_B controls multiple PV generators

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Test Report Validation

1. Verify that all models are WECC approved
2. Check for common errors/mistakes:
   - Baseload Flag
   - Power Plant Controller Modeling
   - Momentary Cessation
3. Perform dynamic model validation
4. Perform Electromagnetic Transient (EMT) model validation

Baseload Flag

- Check that baseload flag is set correctly

- Solar PV baseload flag must either be 1 or 2

- Baseload Flag Settings:
    - **0**: not at maximum output, can increase or decrease output in response to frequency events
    - **1**: at maximum output, can decrease output in response to frequency events
    - **2**: at limits, cannot increase or decrease the output in response to frequency events

Power Plant Controller

- REPC_A and REPC_B
  - Power Plant Controller that can control one or more PV generators

- Requires a branch to be specified in model invocation if any of the P or Q branch inputs are active
  - Frequency Flag (frqflg) = 1: branch always required
  - If frqflg = 0, a branch is required if:
    - Refflg and Vcmpflg = 0
    - Refflg = 0 and Vcmpflg = 1
    - Refflg = 1 and Vcmpflg = 0

- Does not require a branch when frqflg = 0 and Refflg/ Vcmpflg = 1

- Initialization warning will be given if a branch is required but not included

$$| V_{reg} - (R_c + j X_c) I_{branch} |$$
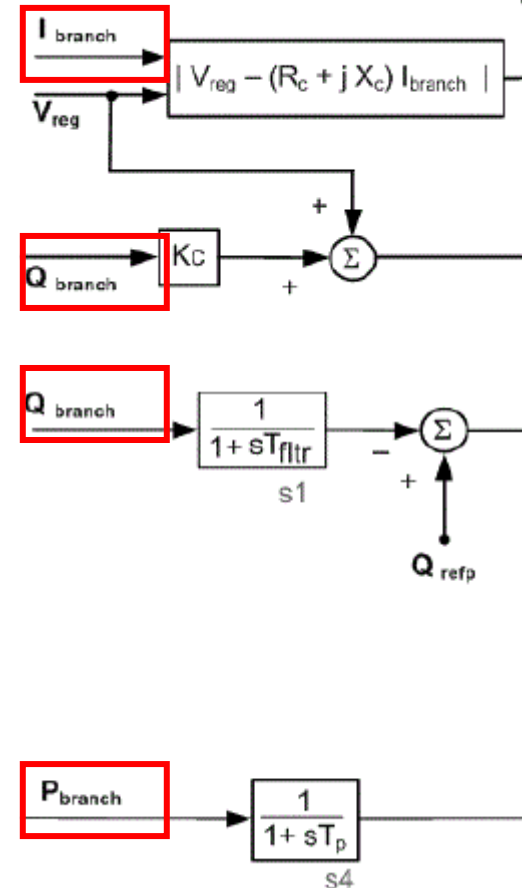
Power Plant Controller (cont.)

- REPC_A
  - Used when a PV plant consists of one equivalent generator

- REPC_B
  - Should be used when a single PV plant consists of multiple equivalent generators
  - Provides better control coordination between PV plants

- Multiple REPC_A models should not monitor the same remote bus and branch.
  - Can result in oscillations between the generators
  - REPC_B model should be used instead

To POI

Monitored Branch and Bus

One REPC_B model to control both generators
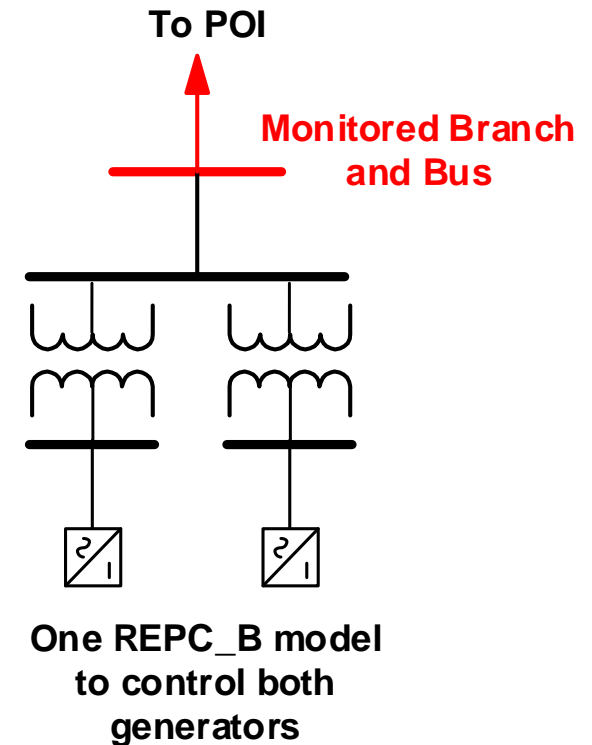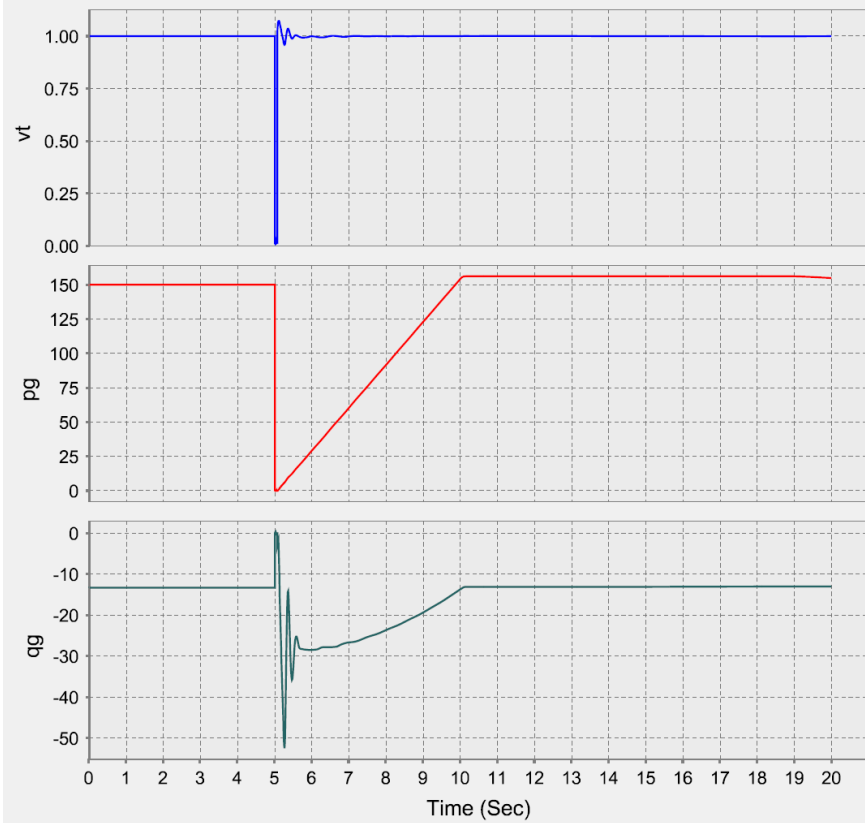
- Branch required but not included in the REPC_A/B model.
- Flat no-disturbance simulation.
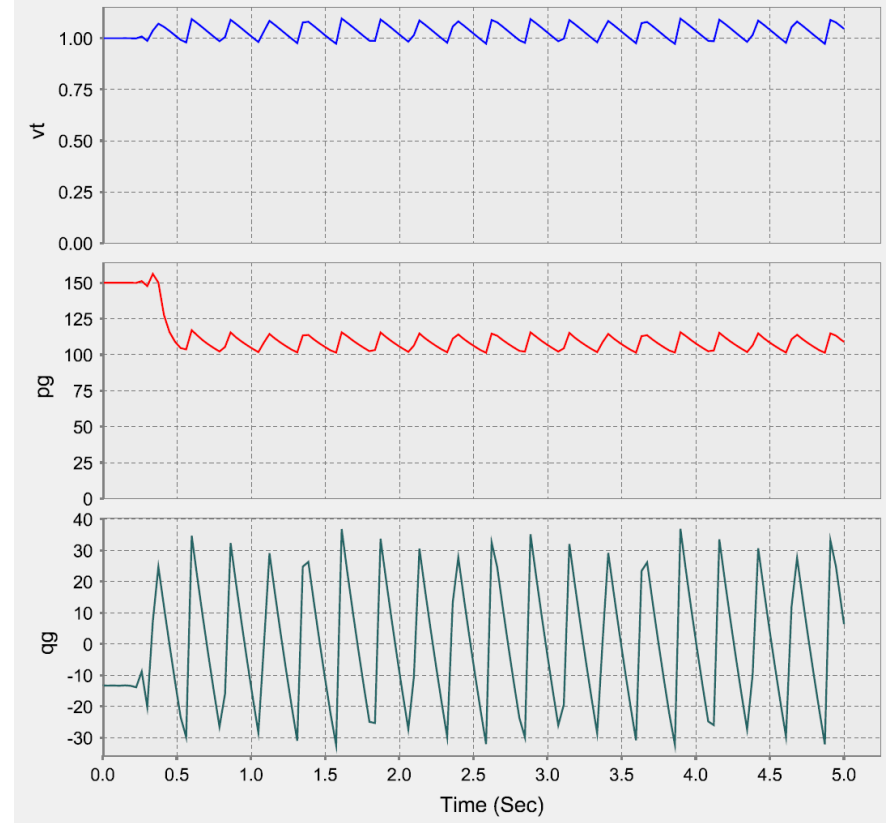
- Branch included in the REPC_A/B model.
- Unstable no-disturbance simulation.
- GO required to resubmit dynamic models.

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Momentary Cessation

- Operating mode where inverters will cease to inject active or reactive current for voltages that exceed a defined limit

- Momentary Cessation can be modeled using the second-generation renewable models
  - REGC_A/REGC_B
  - REEC_A/REEC_D
  - REPC_A/REPC_B

- PV plants that use momentary cessation are required to submit dynamic models that properly model it

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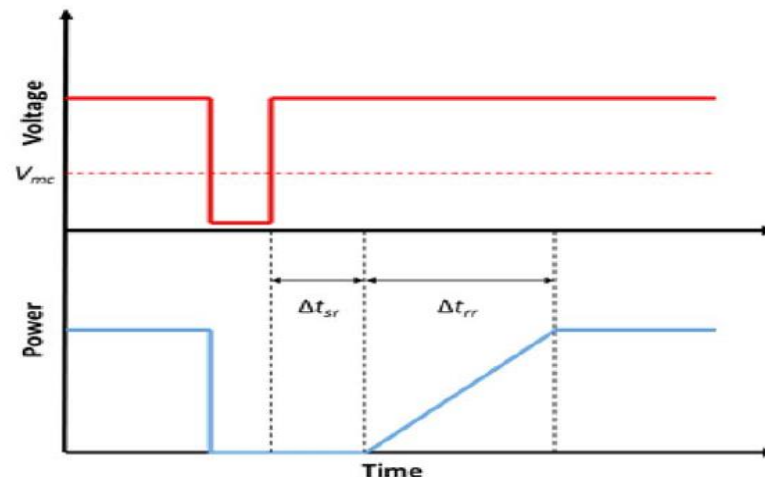
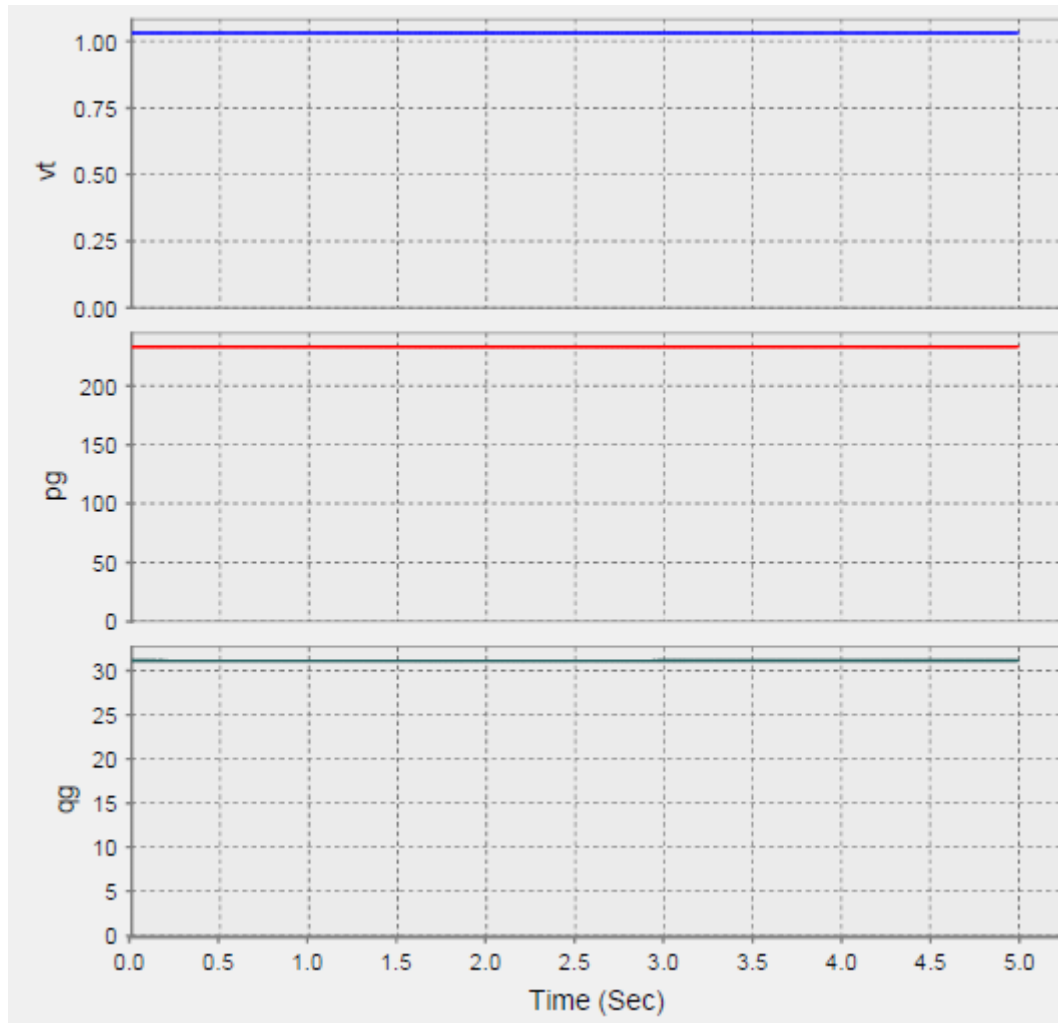# Simulation with Momentary Cessation

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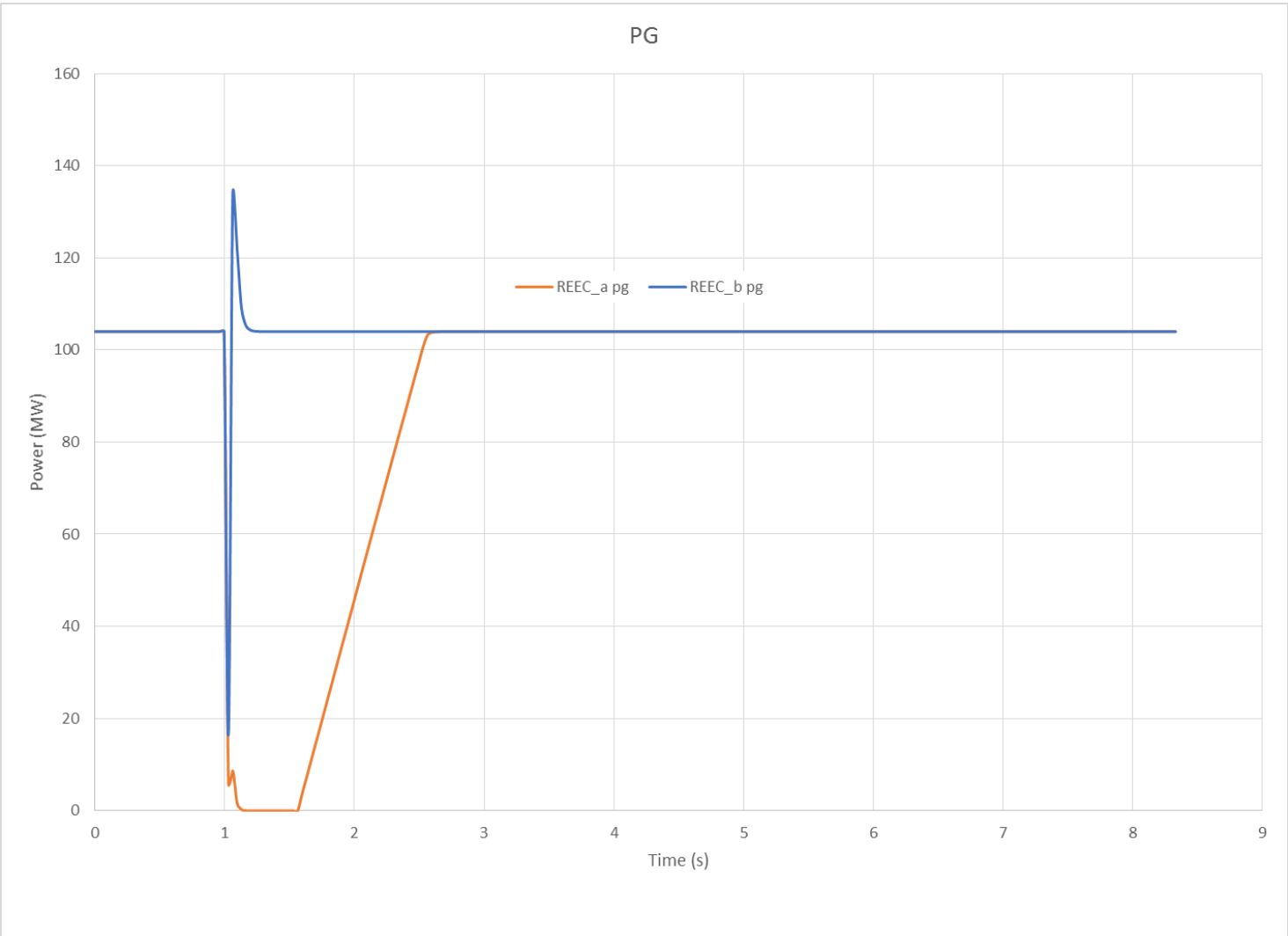
Dynamic Model Validation

1) Initialize the dynamic models
   - No initialization errors or warning

2) Run a no-disturbance simulation
   - Pgen is set to Pmax or contract limit at POI
   - Ensure a "flat line" with no oscillations

3) Run a disturbance simulation
   - 3PH fault is applied at point of interconnection
   - Ensure models exhibit positive damping
   - No oscillations after recovery
   - Momentary Cessation is modeled properly (if applicable)
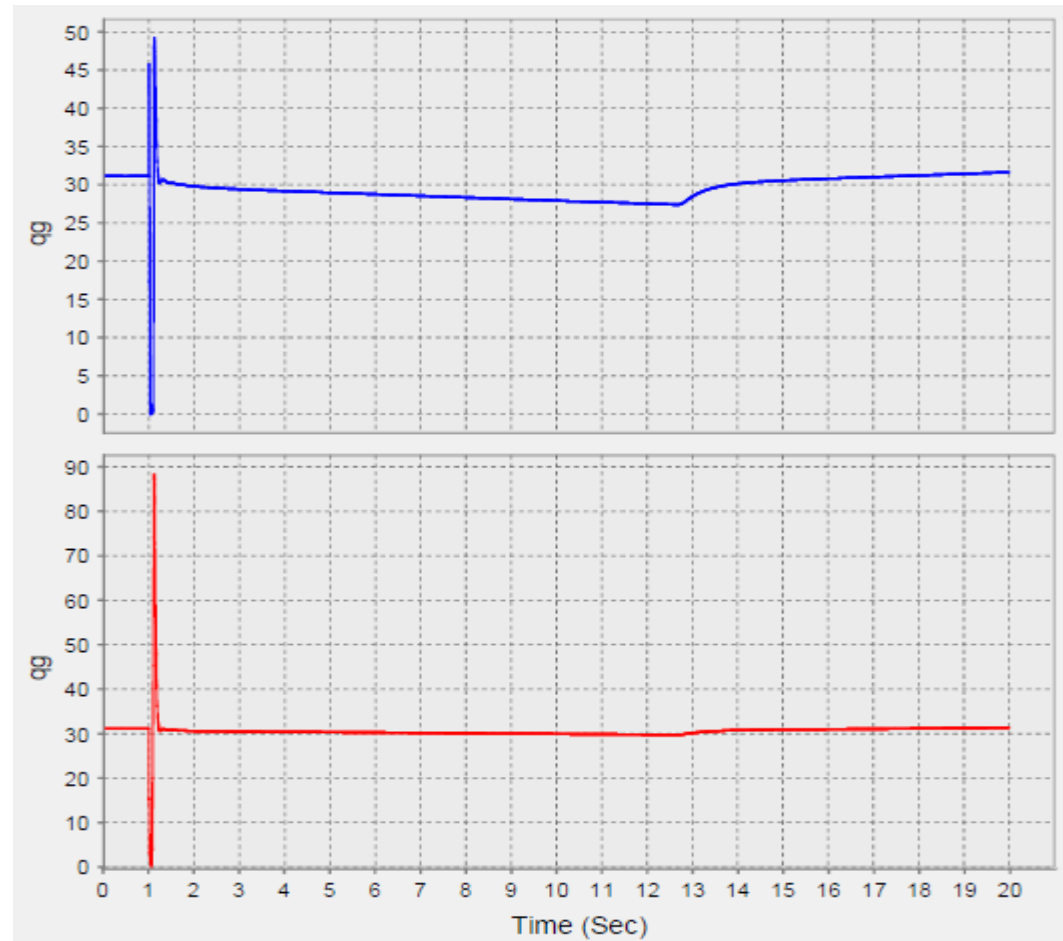
No-disturbance Simulation

Disturbance Simulation

- PV plant consists of two equivalent generators.

- One equivalent includes momentary cessation (top graph) and the other does not.

- No oscillation after recovery

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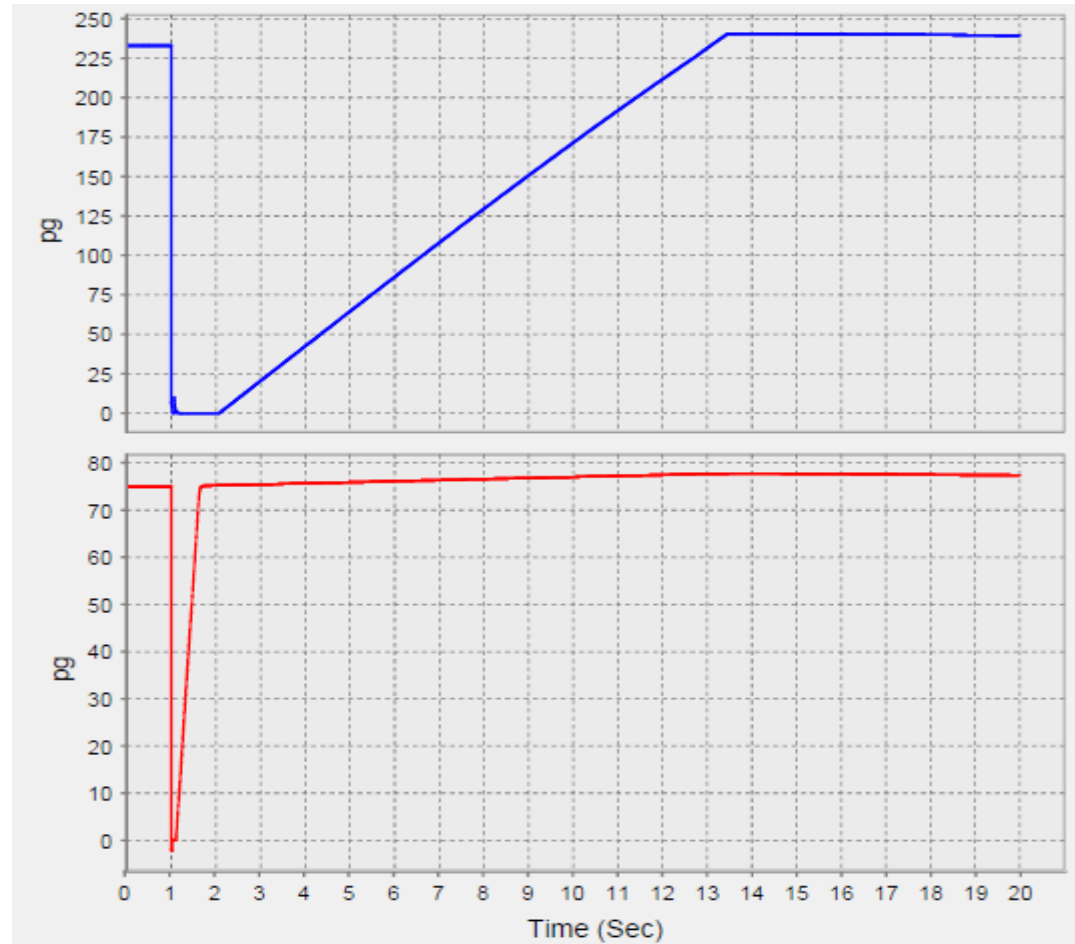
Disturbance Simulation

- No oscillations between Qgen of the two equivalent generators

EMT Model Submission Criteria

- Generation facilities which meet the following criteria are required to submit EMT models.

    a. Connected to facilities 60 kV or greater, and

    b. Individual or aggregate resource nameplate capacity greater than or equal to 10 MVA, and

    c. Meet any of the following interconnection criteria:

        i. Interconnected electrically close to series compensated line(s), and/or

        ii. Inverter-based resource

- Facilities which utilize legacy Type 1 and Type 2 wind turbines are exempt from the EMT model requirement.

PSCAD Model Requirements

- All PSCAD model submissions must comply with the CAISO PSCAD Modeling Requirements:

  http://www.caiso.com/Documents/PowerSystemsComputerAidedDesignModelingRequirements.pdf

- Requirements for Solar PV PSCAD models include:
  - Representation of the full detailed inner control loops of power electronics
  - Representation of all plant level controllers
  - Representation of all installed protection, including Sub-Synchronous Oscillation (SSO) mitigation

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PSLF-PSCAD Model Validation

- PSCAD and PSLF models are benchmarked against each other
- Both models are subjected to a 3PH fault at the point of interconnection, and the generator response is compared
- This validation has helped planners identify issues in PSLF models

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PSLF-PSCAD Model Validation: Example 1

- PSLF and PSCAD models show good matching

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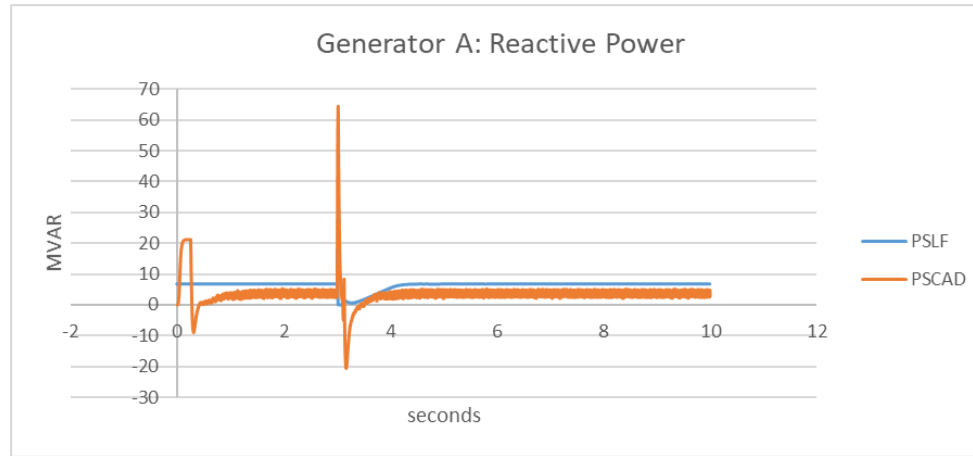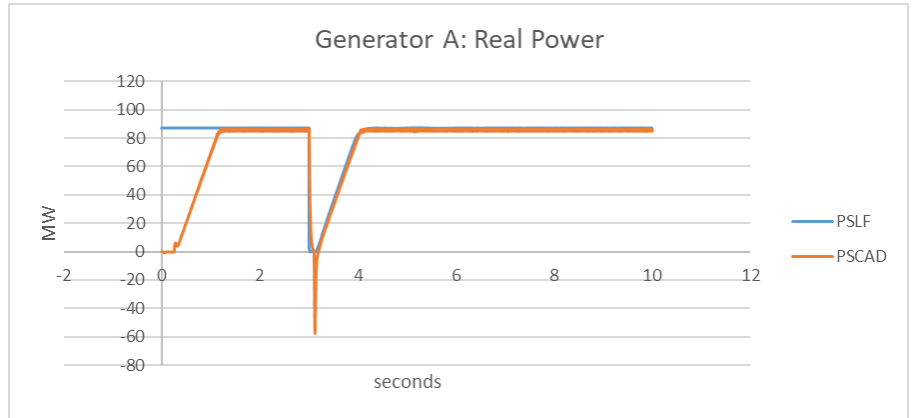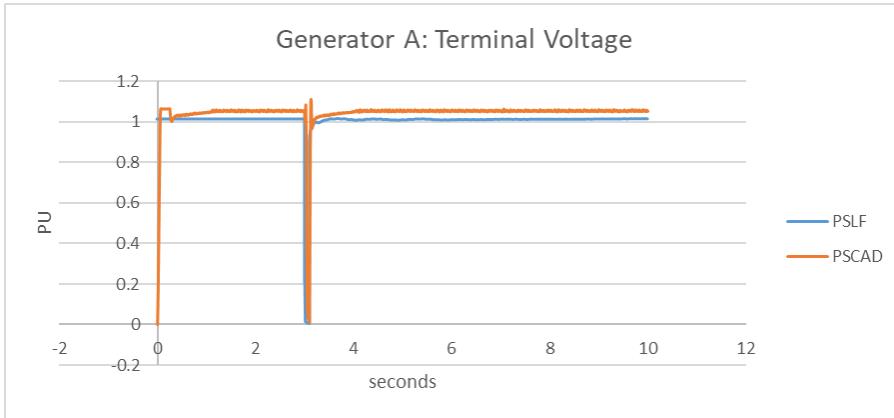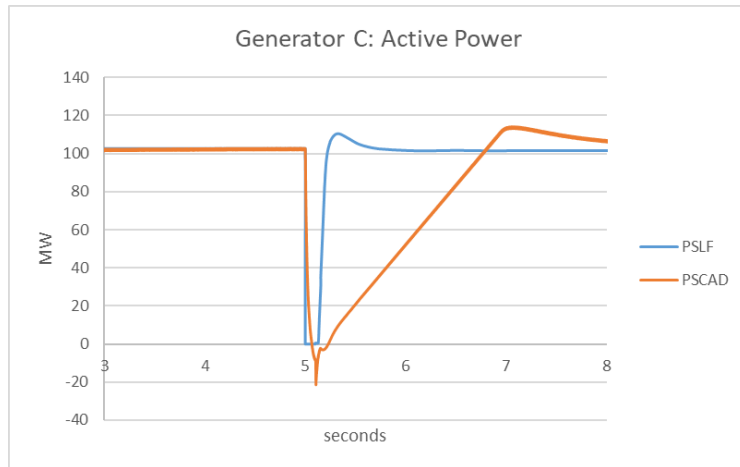
PSLF-PSCAD Model Validation: Example 2

- PSLF model unable to completely replicate PSCAD model performance
- Through use of "real code" models, PSCAD models can replicate actual inverter performance

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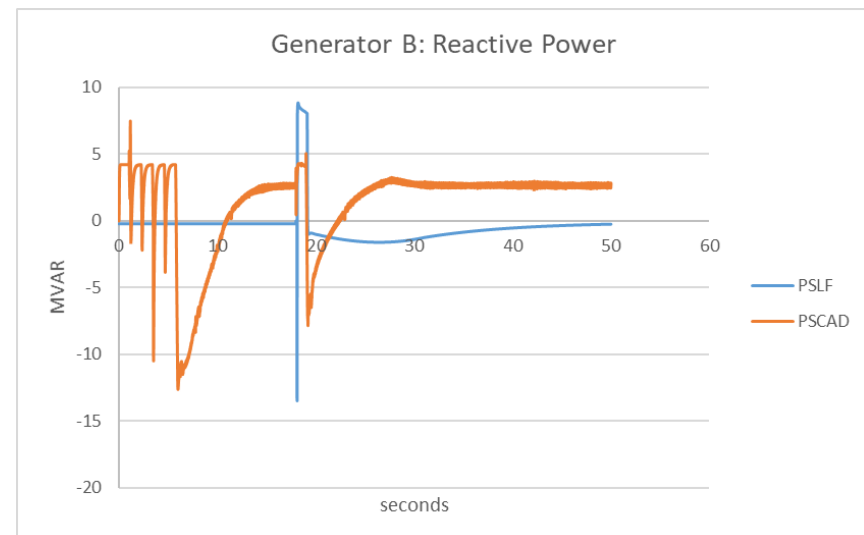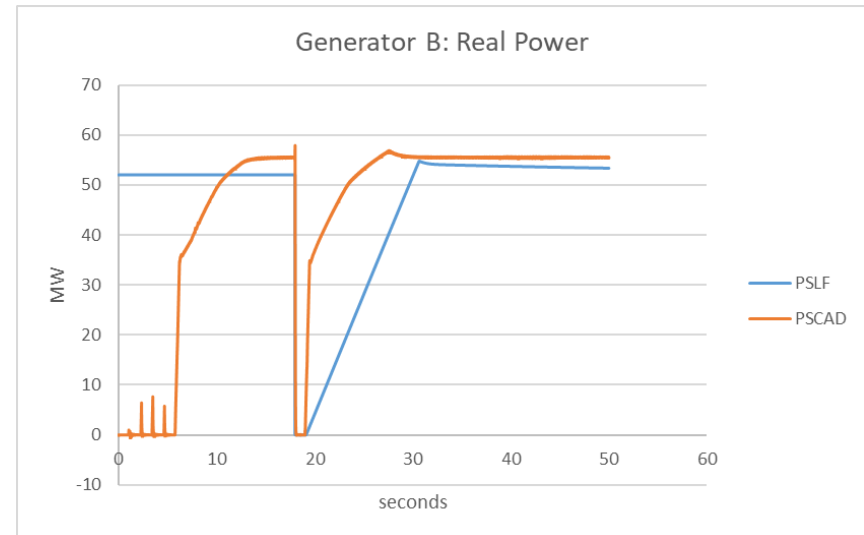
PSLF-PSCAD Model Validation: Example 3

- Initial PSLF model does not fully replicate generator behavior

Initial Submission

Revised Submission

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