# EMT Studies in CAISO

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# Introduction/Context

- As of 8/14/2023, 33.2 GW of IBRs are connected to the CAISO system
- Installed IBR capacity in CAISO system is expected to reach to ~120 GW by 2035 and ~200 GW by 2045
- Disturbance analysis of events across different systems indicates the need for more accurate modelling of IBRs
- NERC standards are being updated to include EMT studies in planning and interconnection studies


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# Challenges with Phasor-Domain Studies (Transient Stability Studies)

- NERC disturbance reports indicate the need for EMT studies due to limitation of phasor-domain models and studies
- Capturing the details of IBR controls and protection systems is not feasible in generic phasor-domain models
  - There are examples that phasor-domain studies have not assessed the system performance correctly


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# Approach: EMT Simulation for Interconnection Studies

- Existing IBRs are required to provide PSCAD models as per CAISO Tariff and Transmission BPM
  - It is expected that by 2025 almost all the PSCAD models of the existing IBRs are verified/validated
- IBRs are required to provide PSCAD models in the Generation Interconnection Process
- PSCAD models are reviewed with main objective being to ensure they reflect the equipment in the field (where applicable)
  - CAISO EMT Requirements: http://www.caiso.com/Documents/CaliforniaISOElectromagneticTransientModelingRequirements.pdf
  - IBR EMT Checklist: http://www.caiso.com/Documents/DataTemplateforGeneratorsinCategory1and2.xlsx

# Approach: IBR EMT Model Validation Process (1/2)

- The checklist includes 55 questions on supporting documentation, model accuracy, usability, and performance to ensure the model meets all the requirements

1. Are the supporting documentation submitted? GO, please list the files below.
2. Does the documentation include instruction for setup and running the model?
3. Does the documentation provides a clear way to identify site-specific settings and equipment configuration?
4. Are the complete model files submitted? GO, please list the files below.
5. Is the model supplied with a sample test case including site specific plant representation?
6. Does the model schematic align with the single line diagram and include all devices from the inverters to the Point of Interconnection?
7. Does the model use the actual firmware code from the inverter for power electronic controls ("real code")?
8. If not using real code, is a model validation report included?
9. Does the model include the plant level controller? List all the plant level controller below, e.g. power plant controller, customized phase locked loop systems, ride-through controllers, sub-synchronous control interaction damping controllers, etc.
10. Does the plant level controller control generating resources other than the subject resource in this model submission?
11. Are the operating modes which require system specific adjustment accessible? Please describe how to access mode settings below.
12. Does the model include automatically controlled capacitor and reactor banks?
13. Are the transformer magnetizing curves included?
14. Does the model include pertinent electrical and mechanical features, such as gearboxes, pitch controllers, or other features which impact the plant performance in the simulation period?
15. Are all protections which could impact ride-through performance modeled in detail? Please list the protections included in the model below.
16. Has the model being validated at different operating conditions ranging from minimum power through maximum power?
17. Is the model configured for the specific site being evaluated, as far as they are known?
18. Are pertinent control or hardware options accessible to the user (e.g., adjustable protection thresholds, real power recovery ramp rates, or Sub-Synchronous Control Interaction damping controllers)
19. Are there diagnostic flags accessible? Please provide the description of the diagnostic flags below.
20. Please provide the grid strength in terms of simple short circuit ratio at POI that the model is designed for.
21. Does the model run at a time step between 10 μs to 20 μs? Please specify the time step required by the model below.
22. Is the model restricted to the time step provided above?
23. Does the model initialize itself?
24. Does the model initialize to P, Q, V setpoints in 5 seconds or less?
25. Does the model accept external reference variables for active and reactive power?
26. Could the external references be changed dynamically during the simulation?
27. Could the protection models be disabled for troubleshooting?
28. Is the active power capacity scalable?
29. Is the active power dispatchable?
30. Is the model compatible with Intel FORTRAN version 12 and higher? Please specify Intel FORTRAN version required below.
31. Does the model compile using PSCAD version 4.6.3 or higher?
32. Does the model support multiple instances of its own definition in a single PSCAD case?
33. Does the model support the PSCAD "snapshot" feature?
34. Does the model support the PSCAD "multiple run" feature?
35. Does the model support "copy transfer" feature to replicate the components in a different PSCAD case?
36. Is it true that the model does not use PSCAD layer functionality?
37. The Vendor's name and the specific version of the model should be clearly observable in the .pscx case file.
38. Documentation and supporting model filenames should not conflict with model version shown in the .pscx case file.
39. Parameters of the gen-tie line, collectors, transformers align with the PSLF models.
40. Number of inverters, inverter capacity and operating modes for voltage control and frequency control match the PSLF models.
41. Power plant controller voltage control and frequency control match the PSLF models
42. PPC accepts an external active power setpoint.
43. PPC accepts a voltage or reactive power setpoint.
44. PPC has a mechanism to implement a settable voltage droop.
45. If the primary frequency response is enabled, the plant responds to frequency changes by increasing or decreasing its active power as appropriate.
46. Model initializes to the setpoints specified in the PPC. If droops or deadbands are utilized, the initial values may differ from the setpoints.
47. If external voltage control devices (STATCOM/DVAR, SVC, MSCs) are included in the plant, ensure that the voltage control of these devices is coordinated with the PPC, with no potential for VAR looping or oscillations.
48. Protection settings are implemented. These could be available as inputs in the model, or hard-coded in the black-boxed controls.
49. Instantaneous voltage and current waveforms have minimal distortion, and no oscillations are observed.
50. Model is able to ride-through and recover from a temporary (no line outage or drop in SCR), 6-cycle, zero-impedance, three-phase fault at the high side of the station transformer, with a POI level SCR of 3.
51. Model responds to a step change in PPC voltage setpoint, reaching 90% of the new value between 1 and 10 seconds in a test system with POI level SCR of 3.
52. Model responds to a step change in PPC active power setpoint, reaching 90% of the new value between 1 and 10 seconds in a test system with POI level SCR of 3.
53. Model trips or blocks when terminal voltage rises above 1.3 pu for 1.5 second.
54. Model trips or blocks when terminal voltage falls below the protection setting for specified time period.
55. Model clearly displays trip / diagnostic signals indicating the status of all pertinent protection elements.


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# Approach: IBR EMT Model Validation Process (2/2)

- For the existing IBRs, the process starts with CAISO sending a letter to the GO to submit EMT model
- GOs will complete their section of the checklist and submit the model, the completed checklist along with all the required documents to CAISO
- Upon receiving the EMT model PTOs perform the primary review of the submission
- CAISO performs a secondary review of the submission
- GO will be informed of the deficiencies.
- Primary and secondary reviews will continue until the submission is compliant with the requirements.

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# Process: Interconnection Studies (EMT)

- PSCAD studies are performed as part of the interconnection process on a case by case basis based on transmission owner (PTO) criteria
- As per existing processes in CAISO system, if a PTO's screening analysis indicate system performance risk due to an IBR interconnection, an EMT studies will be performed to evaluate and mitigate the risk.
  - A local area of the system is modeled in such EMT studies
- There has been few PSCAD studies performed as part of the interconnection studies and for some projects it was required to install subsynchronous relay to trip the unit to mitigate the risk of oscillations.

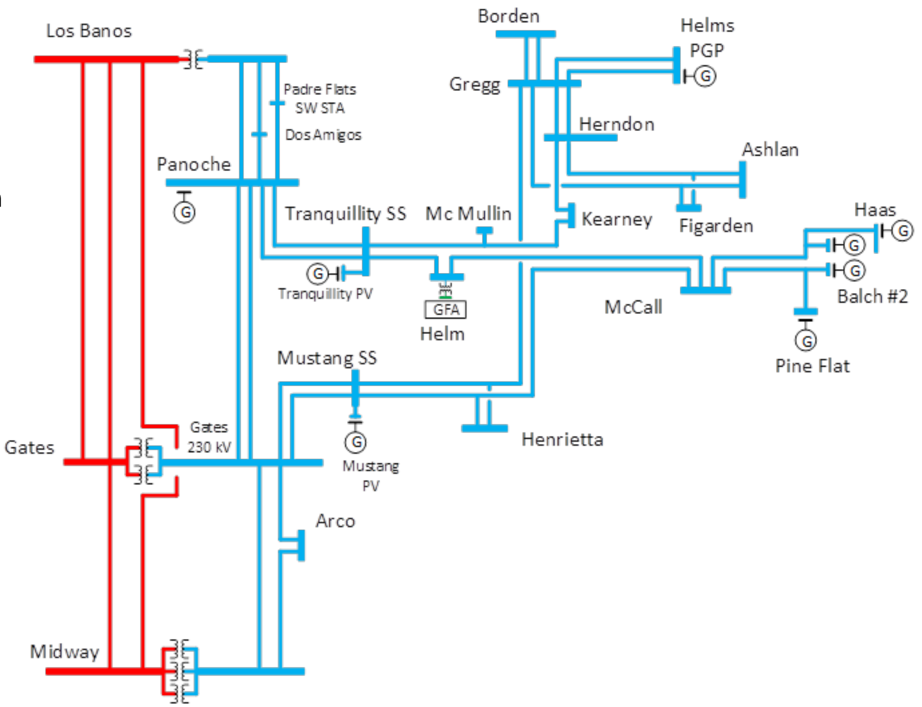
# Lessons Learnt

- Obtaining IBR PSCAD models for the units that are in service could be challenging. Some of the issues are:
  - Change of ownership
  - OEM not in business anymore
  - GOs not having SMEs familiar with PSCAD models and studies
  - It takes significant amount of time to go through the process and get a compliant PSCAD model
  - ...
- It is more efficient to get the models as part of the interconnection process before the unit goes into service.
- It will be more effective if NERC standards would require EMT models and studies

# CAISO’s Next Steps

- The next step after all the validated IBR PSCAD models are available is to perform system studies.
- CAISO is in the process of developing an EMT studies roadmap
- A pilot PSCAD studies are underway on a local area

Existing System in the Study Area




| | Existing Resources | Year 2035 Model in 2023-2024 TPP [1] |
|---|---|---|
| Number of IBR Plants | 18 | 78 |
| Total IBR Capacity (MW) | 2,100 | 12,500 |
| Synchronous generators (MW) | 3,500 | 3,300 |
| Pumped hydro (MW) | 1,600 | 1,600 |
| Pumps (MW) | 700 | 700 |

[1] Several approved transmission projects will be implemented in the area by 2035

# Objectives of Pilot PSCAD Studies

- A pilot PSCAD studies are underway with the following objectives:
  - The required software/tools
    - PSCAD, compilers, conversion of power flow models to PSCAD, co-simulation,...
  - The hardware requirement for sufficient computing power
  - Staff training requirement
  - Required consulting support
  - Estimate of the time required to perform the studies
  - Document the issues faced in setting up and running the studies along with how they were resolved.
  - Help to identify areas of the system that require PSCAD studies

# Gaps & Challenges Observed (Not Solved Yet)

- Lack of generic IBR EMT models
- Obtaining reliable EMT models of IBRs that accurately reflect the installed equipment in the field
- No industry-wide acceptable screening analysis to identify what areas of the system require EMT studies
- Limited number of SMEs to perform EMT-related studies
- While it is expected that due to NERC standards and other requirements, EMT studies will be incorporated in planning and interconnection studies, the need and the process of EMT studies in real time operation is not clear