Introduction to the Power Electronics Grid Interface (PEGI) Platform and Industry Engagement Projects

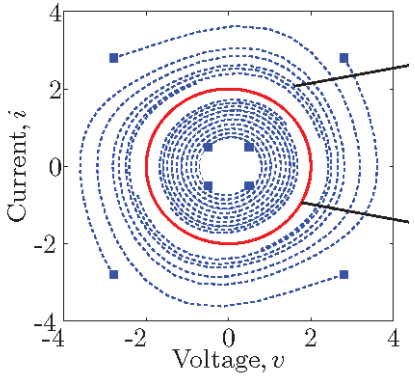
Barry Mather Ph.D. – May 24th,2023

Multiple Challenges Being Seen in Current Systems

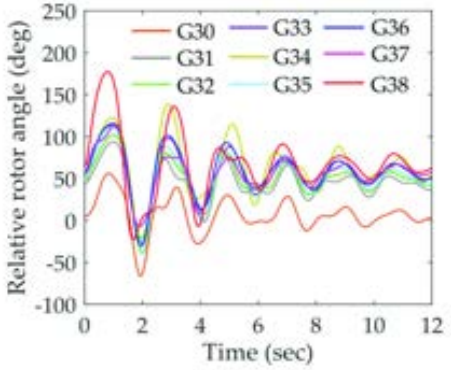
PEGI Platform: Enabling Higher-Levels of Power Electronic-Interfaced Renewable Generation

Enabling ever-higher levels of power electronic-interfaced/inverter-based generation (and loads) is critical for continued renewable energy growth in our power grids:

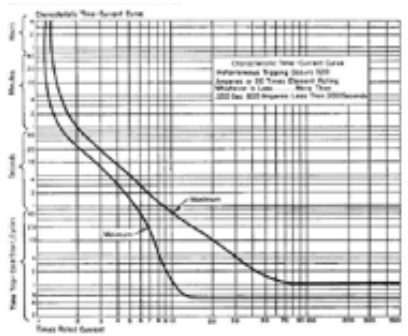
Technical challenges to be addressed include:



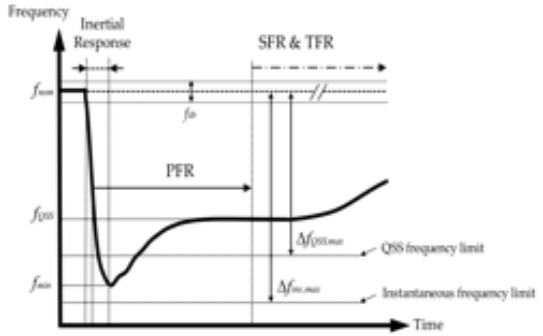
Small-signal stability



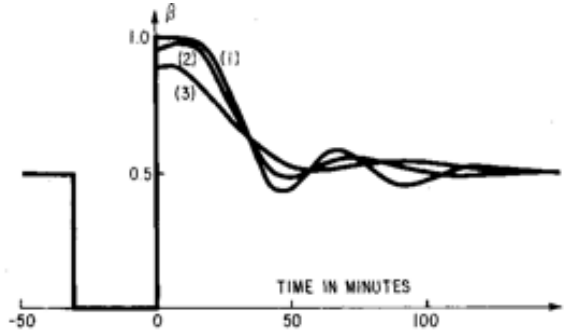
Large-signal stability



System protection



Frequency Response



Black Start

The PEGI Platform is designed to enable research relevant to developing solutions for these challenges and particularly focuses on the ability to develop advanced grid control functionality for power electronic-interfaced equipment. Capabilities aim at realizing accurate fast-time-scale responses of equipment at a scale that is relevant to industry.

PEGI Platform Foundational Project funded by: U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY SOLAR ENERGY TECHNOLOGIES OFFICE

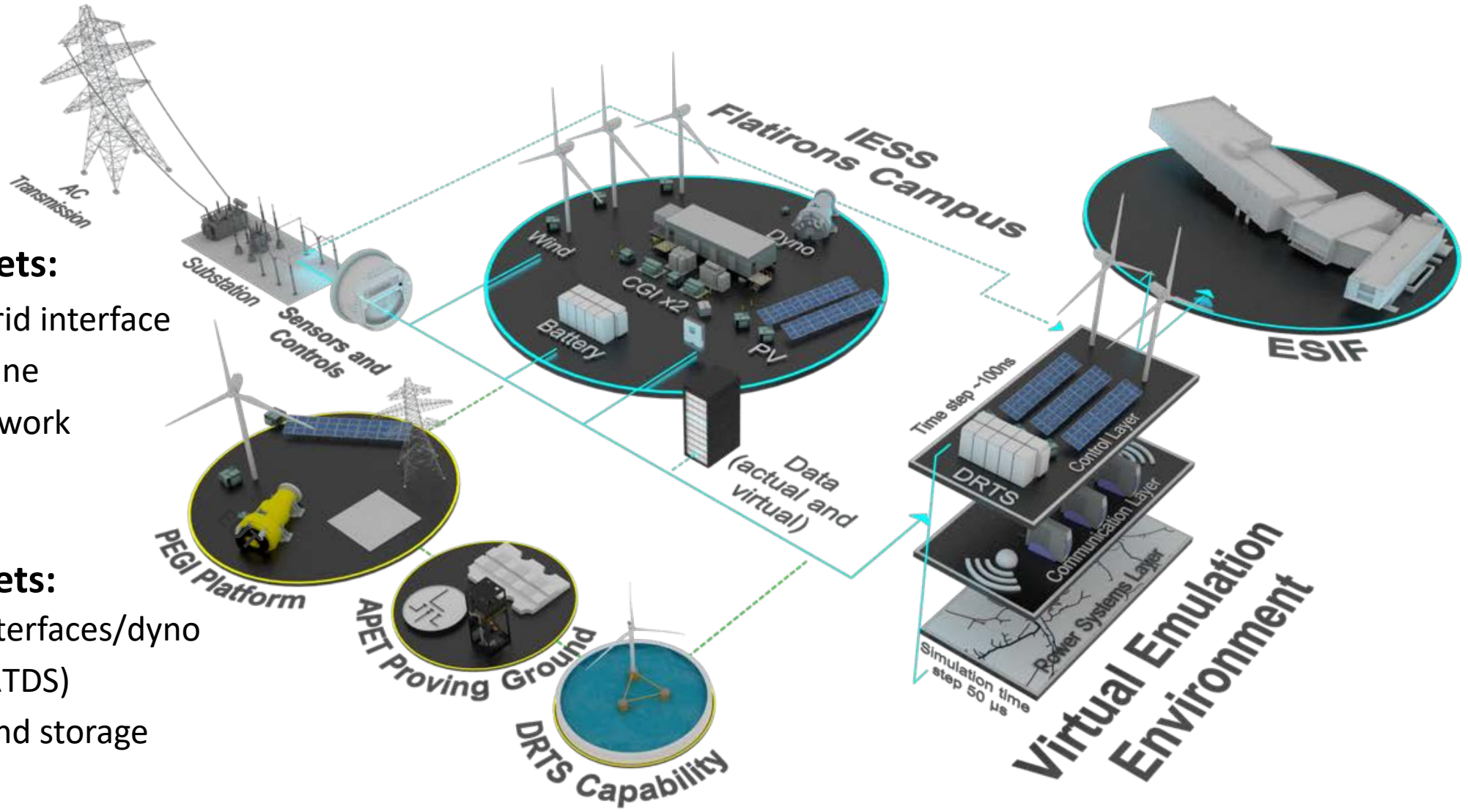
PEGI – Part of the Greater ARIES Capability Set

PEGI Platform Assets:

- Power-electronic grid interface
- Synchronous machine
- MV impedance network
- EUT connection

Related ARIES Assets:

- Controllable grid interfaces/dyno
- DRTS capabilities (RTDS)
- Other generation and storage within IESS et al.



Equipment Comprising the Foundational Elements of the PEGI Platform

2MVA Synchronous Machine (driven by 2.5MW Dyno)

Isolation Transformer

13.2kv

Medium Voltage Impedance Network

13.2kv

Controllable Grid Interface (CGI-2)

13.2kv

Connection to other ARIES/FC Equipment

2MVA PV Inverter & Transformer (next to Research Pad-5)

13.2kv

Equipment-Under-Test Pad

Synchronous Machine

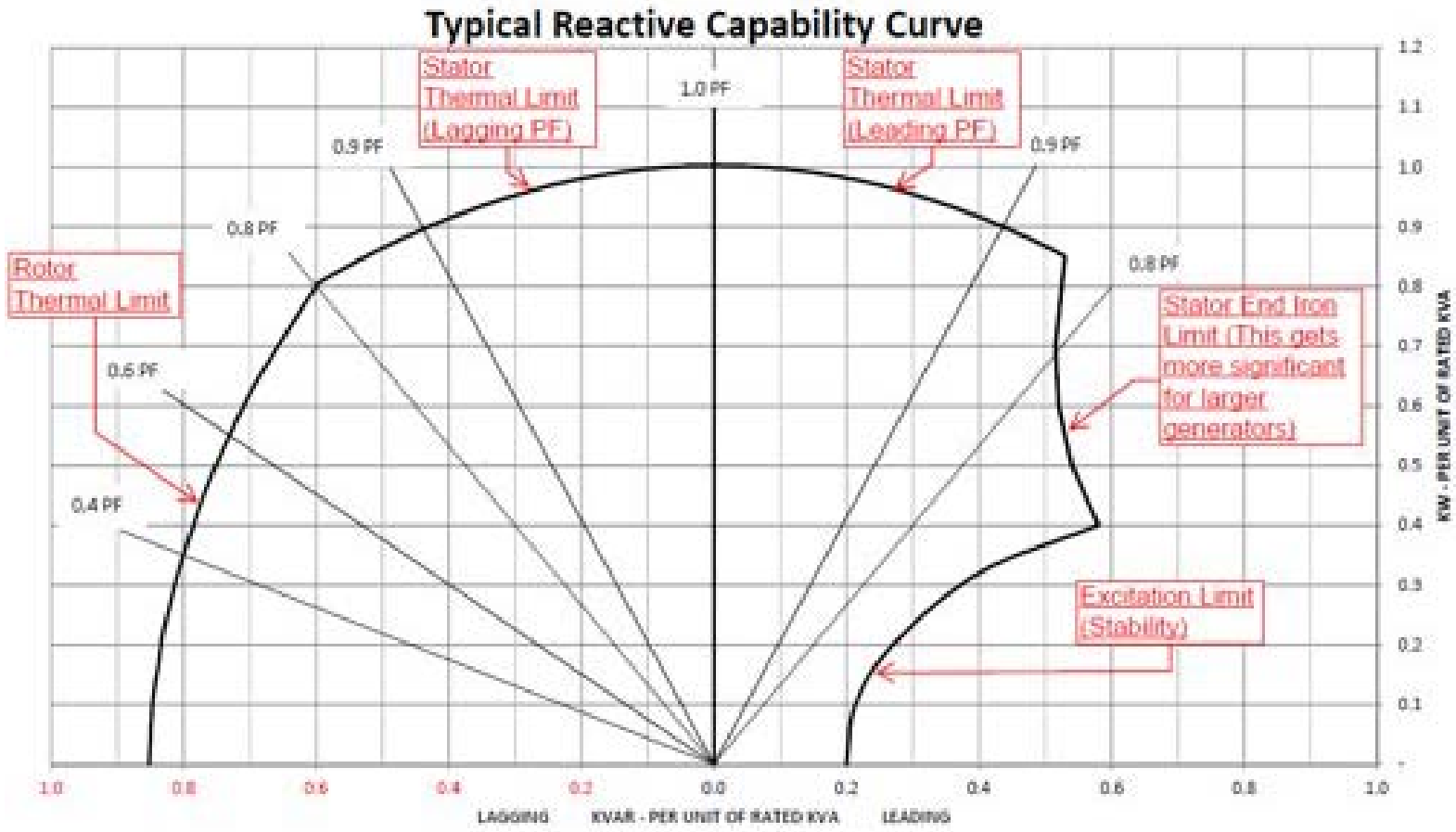
Marathon Generators model 1020FDH1248 is a 13.2 kV three-phase wye-configured 2 MW generator that operates at 1800 rpm and 60 Hz. This generator features a wide reactive capability curve to output power factors from 0.4 lagging to 0.8 leading.

Role with the PEGI Platform:

- Serves as a representative of conventional generation technology
  - Allows the adjustment of PEGI grid operating conditions from 0<SNSP<100%
  - Realizes fast-time-scale operation of conventional generation (i.e., response to voltage/frequency disturbances, faults, etc.)
  - Provides inertia for interoperability evaluation of power electronic-interfaced equipment controls
  - Enables control oscillation research between generation of different technologies
- Operates as a synchronous condenser enabling grid evaluations (e.g., weak grids) with conventional mitigation solutions

$$SNSP = 100 \times \frac{MVA_{Synchronous}}{MVA_{Non-synchronous}}$$

Synchronous Machine Capability



From Marathon – notated by V. Gevorgian - NREL

- **Primary limitation is during under excited operation as a synchronous condenser**
- **Synchronous condenser range of operation 400 kVA capacitive to 1.7 MVA inductive**

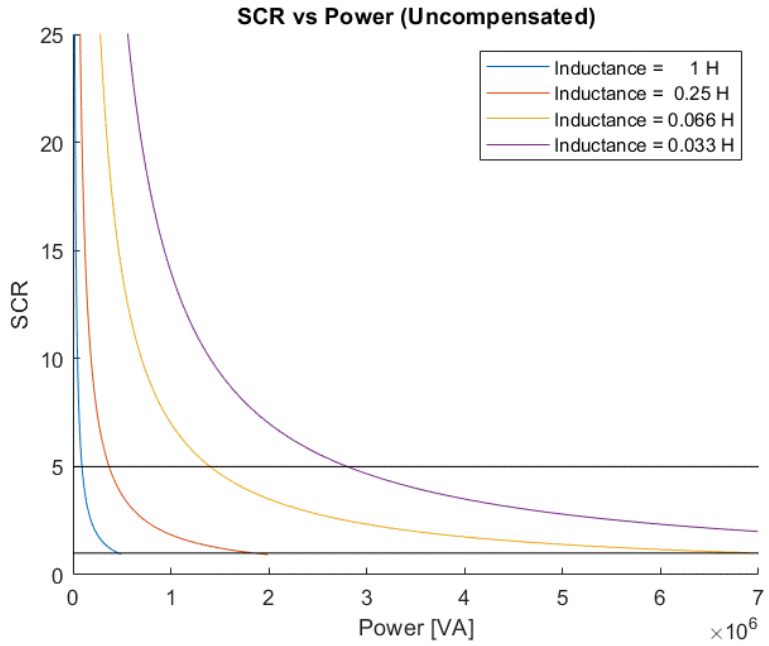
NEPSI - Medium-Voltage Impedance Network (MVIN)

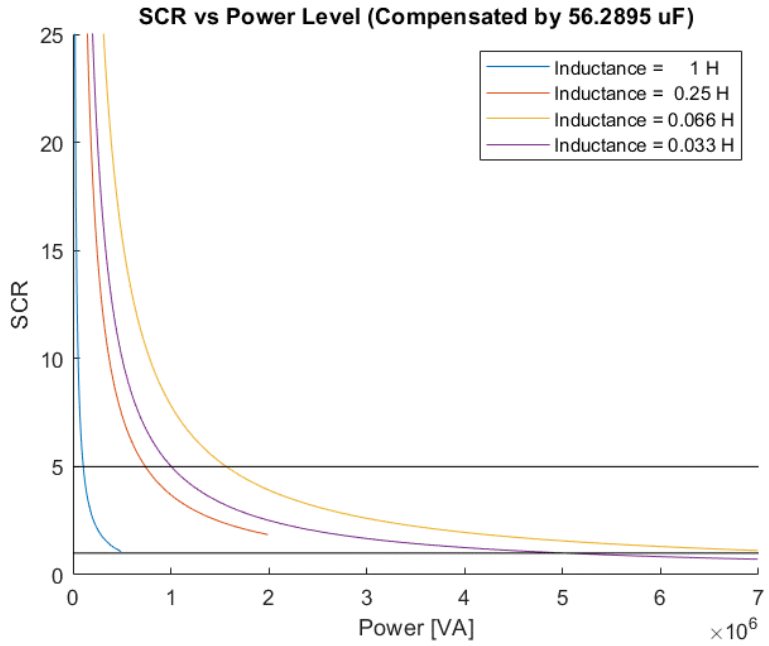
Role within the PEGI Platform:

- Extends the capability of the CGIs to emulate weaker grid connections
  - The CGIs can emulate, via PHIL methods, weak grid conditions (low SCR) but the fidelity of grid emulation (i.e., the control bandwidth) is limited
  - The inclusion of actual impedances in the grid allows high-fidelity weak grid realization
- Realizes on-site power systems on the PEGI Platform with more than one “point of interconnection”
- Enables research related to sub-synchronous resonance issues often exacerbated by series capacitor compensated transmission lines

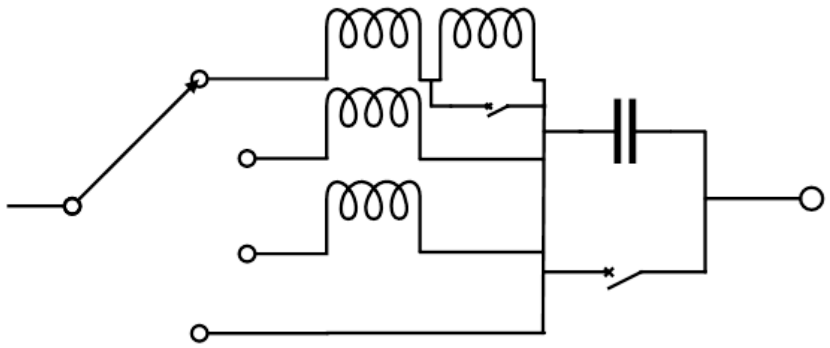
$$SCR = {S_{SC,Grid}}\Big/{S_{SC,Local\_gen}}$$

Medium-Voltage Impedance Network Design





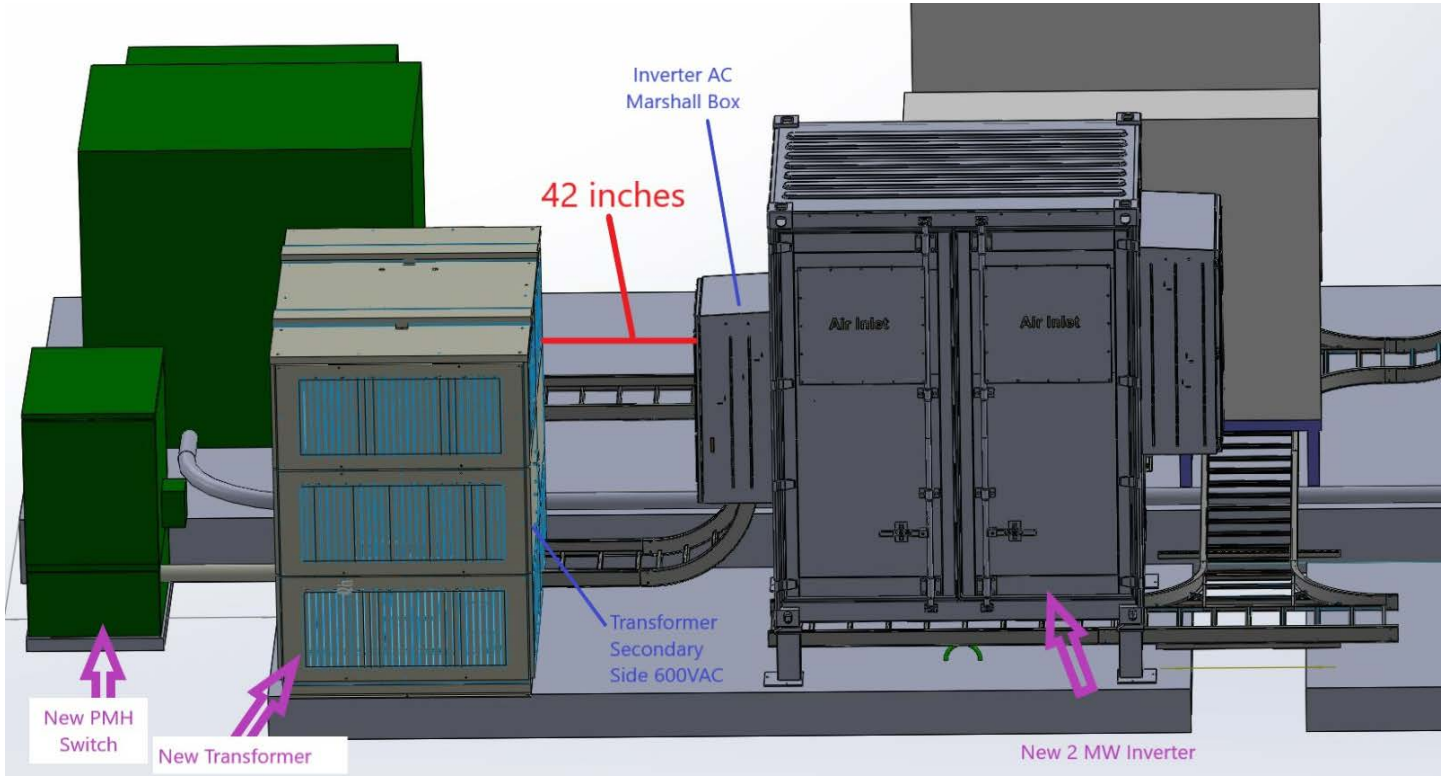
One-line topology



- Reactors sized to realize SCR=1 (i.e., very weak grid conditions) at 500 kVA, 2 MVA & 7 MVA
- Reactor values also selected to offer higher SCR ratios (e.g., 2, 3, or 5) at the same power ratings for direct comparison of SCR-sensitive evaluations
- Series capacitor values selected to provide 50% compensation at 2 MVA

CGI-2 Yard Construction Nearing Completion

2 MVA PV Inverter System



Role with the PEGI Platform:

- Serves as the primary power electronic-interfaced generator (i.e., a PV inverter) for grid controls research
- Enables rapid implementation of a wide array of PV inverter related grid controls including grid forming algorithms/methods, response to abnormal conditions, controller interaction, fault current contribution and protection studies

Example Use Case – SNSP Stability Evaluation

2MVA Synchronous Machine (Operating as a generator)

13.2kv

Medium Voltage Impedance Network

13.2kv

Controllable Grid Interface

Represents the rest of the grid system

13.2kv

2MVA PV Inverter System (GE LV5+ running off 2 MW PV Emulator)

Represents a generation pocket (with two types of generation tech.) in a relatively weakly connected grid

Concept is to evaluate the point at which the implemented controls on the PV inverter become unstable – determine SNSP ratio at stability limit

Example Use Case – GFM/GFL Stability Evaluation

13.2kv

Additional PV/BESS Inverter

13.2kv

2MVA PV Inverter System (GE LV5+ running off 2 MW PV Emulator)

13.2kv

Medium Voltage Impedance Network

Controllable Grid Interface

Represents the rest of the grid system

Represents co-located PV plants with legacy and advanced GFM inverter control

Concept is to evaluate the share of GFM inverters needed for weak grid interconnection areas

Example Use Case – IBR SSCI Mitigation

13.2kv

Additional PV/BESS Inverter

Medium Voltage Impedance Network

Controllable Grid Interface

13.2kv

2MVA PV Inverter System (GE LV5+ running off 2 MW PV Emulator)

Represents multiple PV plants separated by considerable grid impedance and/or series compensation

Concept is to reliably demonstrate sub-sync. control interactions as a function of separating grid impedance and develop mitigation methods

PEGI Platform Industry Engagement

NREL is looking for industry partners to collaboratively complete impactful research using the PEGI Platform!

Ideal project characteristics:

- Uses the PEGI Platform to answer critical questions for the industry
- Ready to start research in early FY24
- 50%/50% cost shared projects (i.e., funded equally by DOE SETO and industry funds)
- Multi-party collaboration encouraged (ISO, utility, vendor…)

How to engage:

- Start by letting NREL know of your potential interest
- Aligned projects will develop draft SOWs via an identified NREL PI
- Currently looking for about 6-8 projects with an individual project value of $300-600k

Contact likely NREL PI or Barry Mather (barry.mather@nrel.gov)

Thank You

www.nrel.gov

NREL/PR-5D00-86616

Please contact Barry Mather (barry.mather@nrel.gov) with any feedback, comments or questions.

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