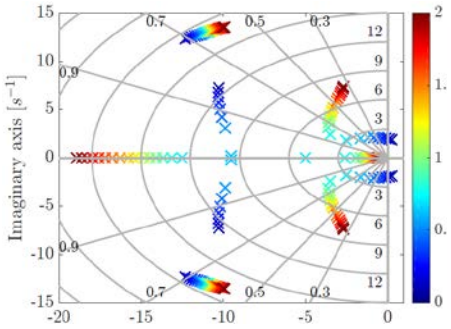
Evaluation of Inverter-Based Resources with Conventional Generation: Natural Gas CTs and HRSGs

Barry Mather Ph.D. – Oct. 1st,2024

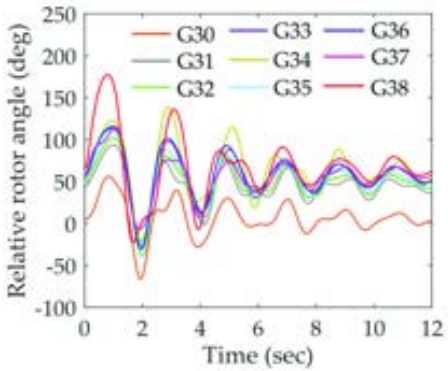
Current Challenges of High IBR Operation

Power Electronics Grid Interface (PEGI) Platform

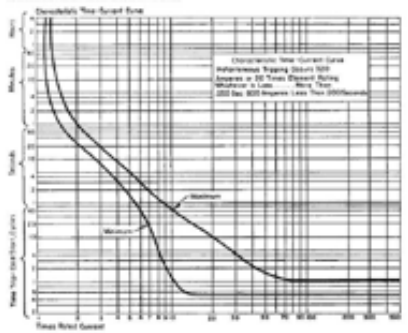
Enabling ever-higher levels of power electronic-interfaced/inverter-based generation (and loads) is critical for continued renewable energy growth in our power grids requiring the following technical challenges to be addressed:



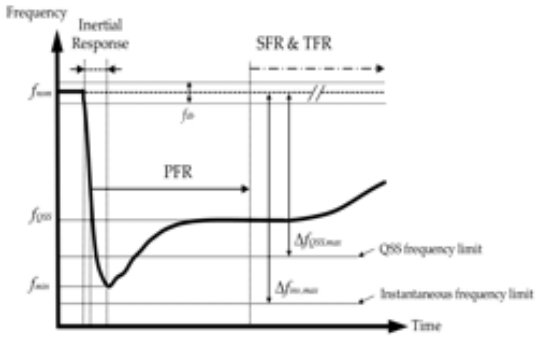
Small-signal stability



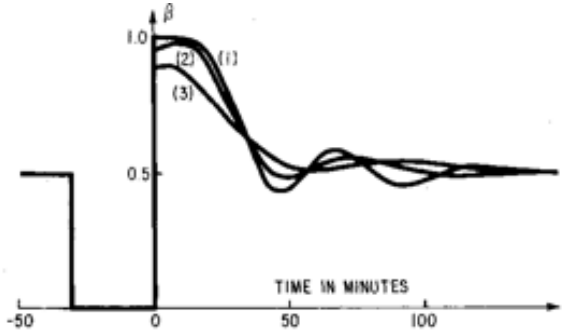
Large-signal stability



System protection



Frequency Response

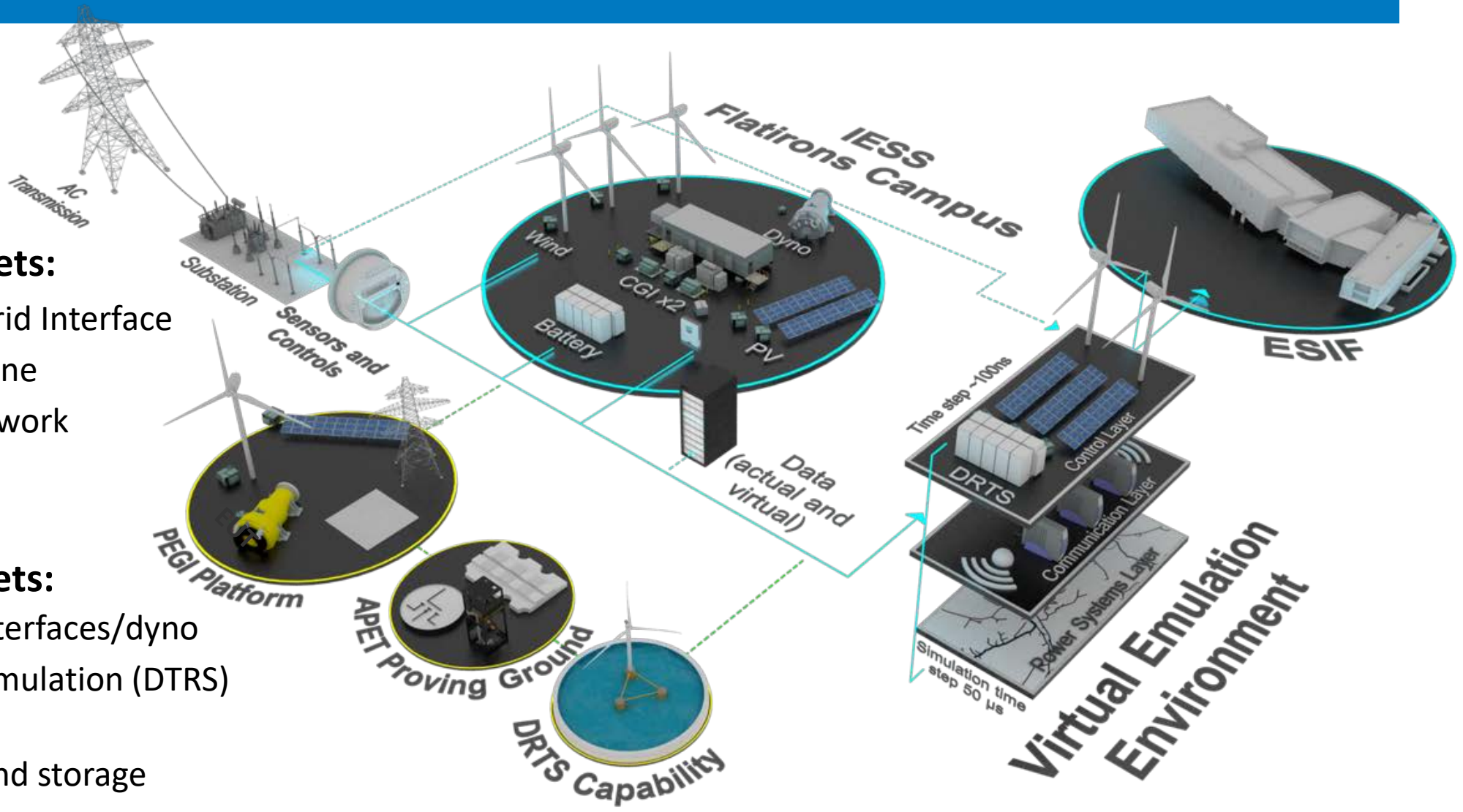


Black Start

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 Advanced Research on Integrated Energy Systems (ARIES) Capability Set



PEGI Platform Assets:

- Power Electronic Grid Interface
- Synchronous machine
- MV impedance network
- EUT connection

Related ARIES Assets:

- Controllable grid interfaces/dyno
- Digital Real Time Simulation (DTRS) capabilities (RTDS)
- Other generation and storage within IESS et al.

Equipment Comprising the Foundational Elements of the PEGI Platform

2.5 MVA Synchronous Machine (driven by 2.5 MW Dyno)

Isolation Transformer

13.2kv

Medium Voltage Impedance Network

13.2kv

Controllable Grid Interface (CGI-2)

13.2kv

Connection to other ARIES/FC Equipment

3 MVA/2 MW PV Inverter & Transformer

13.2kv

Equipment-Under-Test Pad

Synchronous Machine

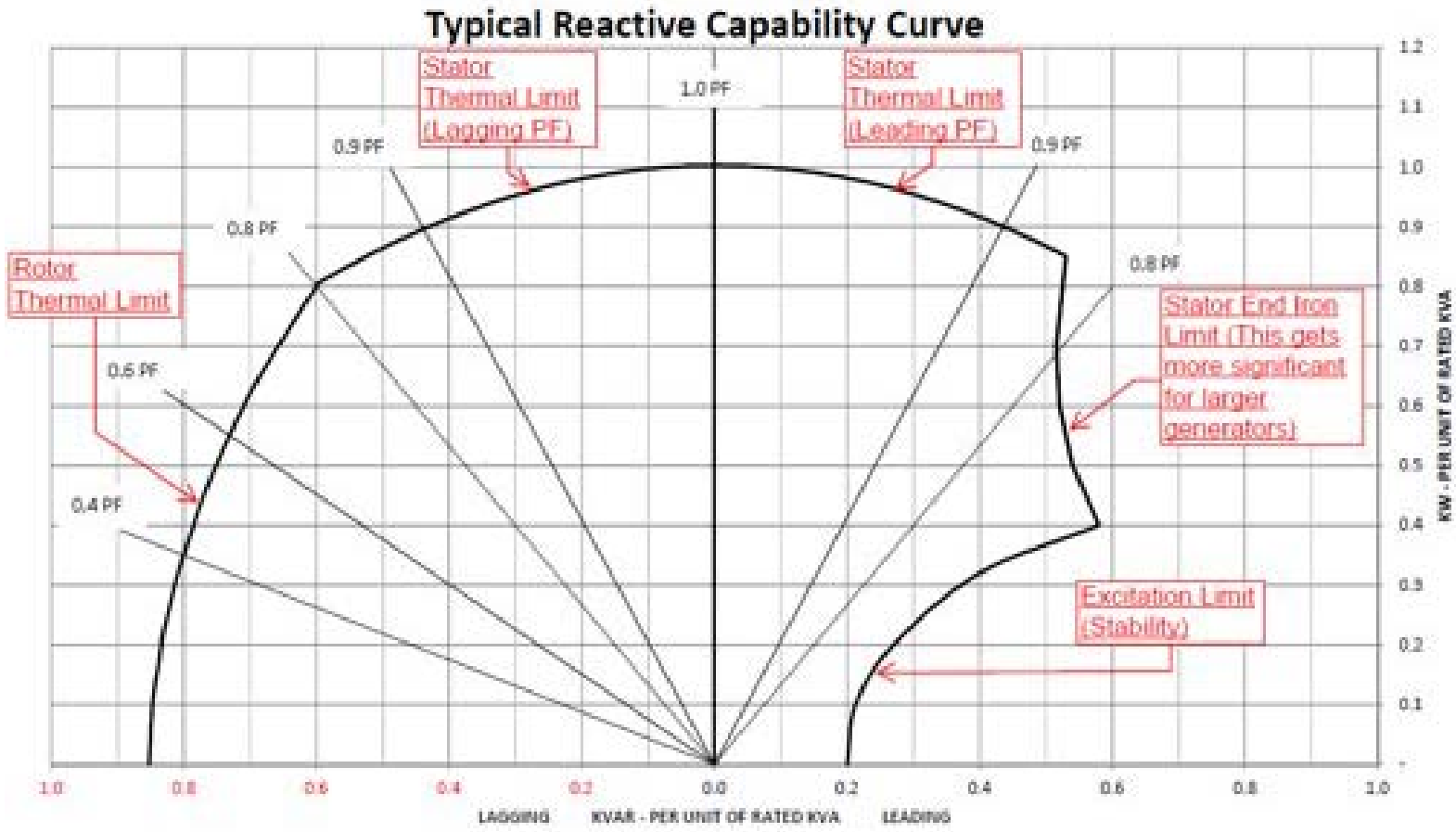
Marathon Generator model 1020FDH1248 is a 13.2 kV three-phase wye-configured 2 MW generator that operates at 1800 rpm and 60 Hz. This generator features a wide reactive capability curve to output power factors from 0.4 lagging to 0.8 leading.

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

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

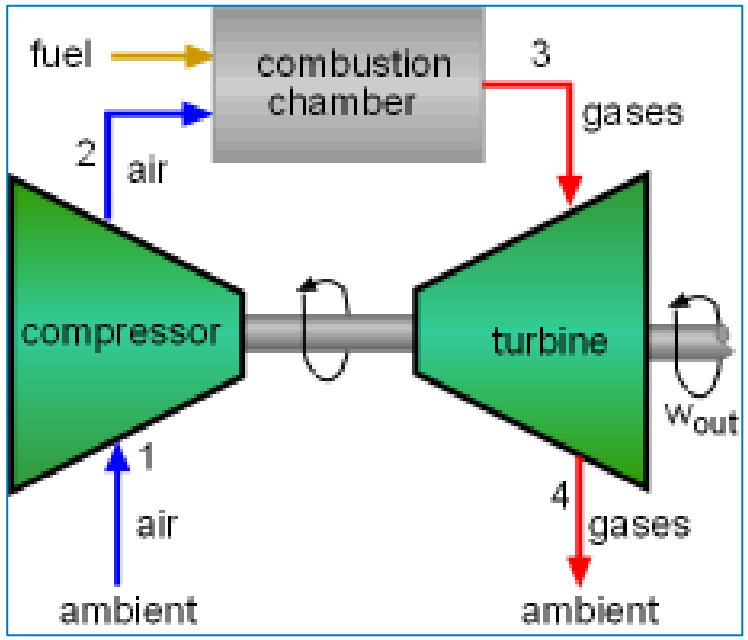
Synchronous Machine Capability

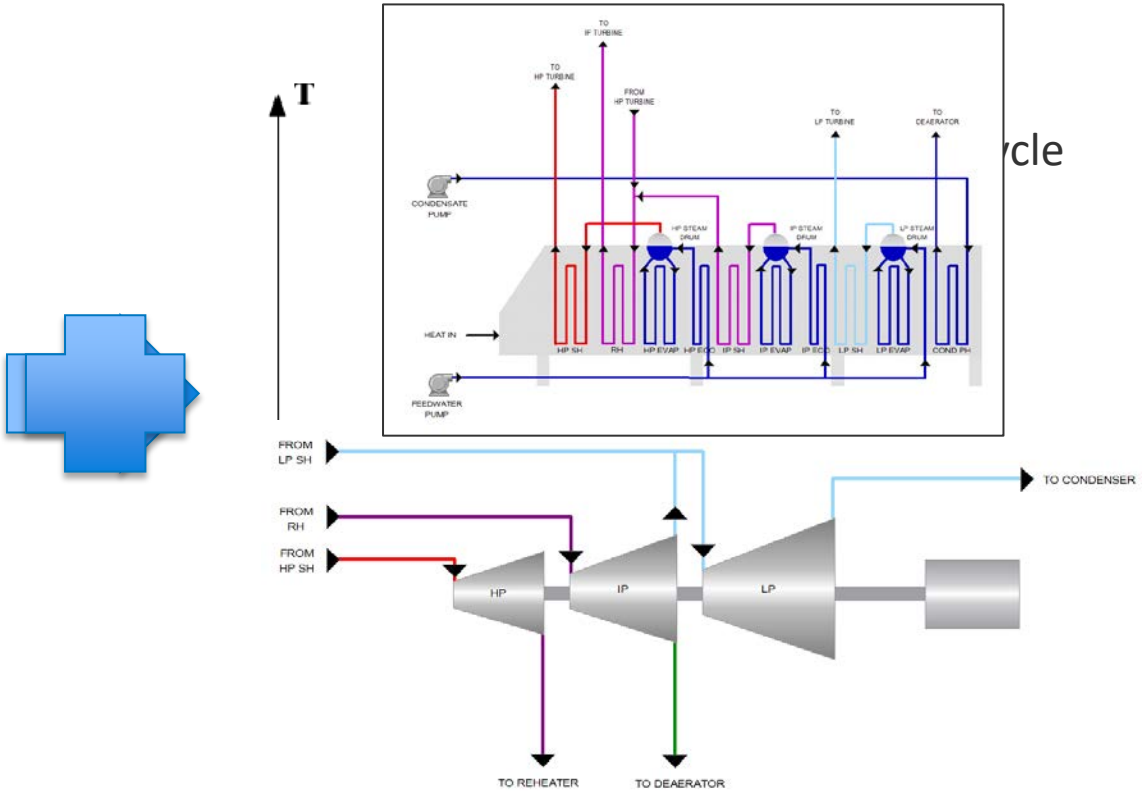


- Primary limitation is during under excited operation as a synchronous condenser
- Synchronous condenser range of operation 400 kVA capacitive to 1.7 MVA inductive

From Marathon – notated by V. Gevorgian - NREL

Sync. Machine Capability – Emulating a Conventional Combustion Turbine Plant



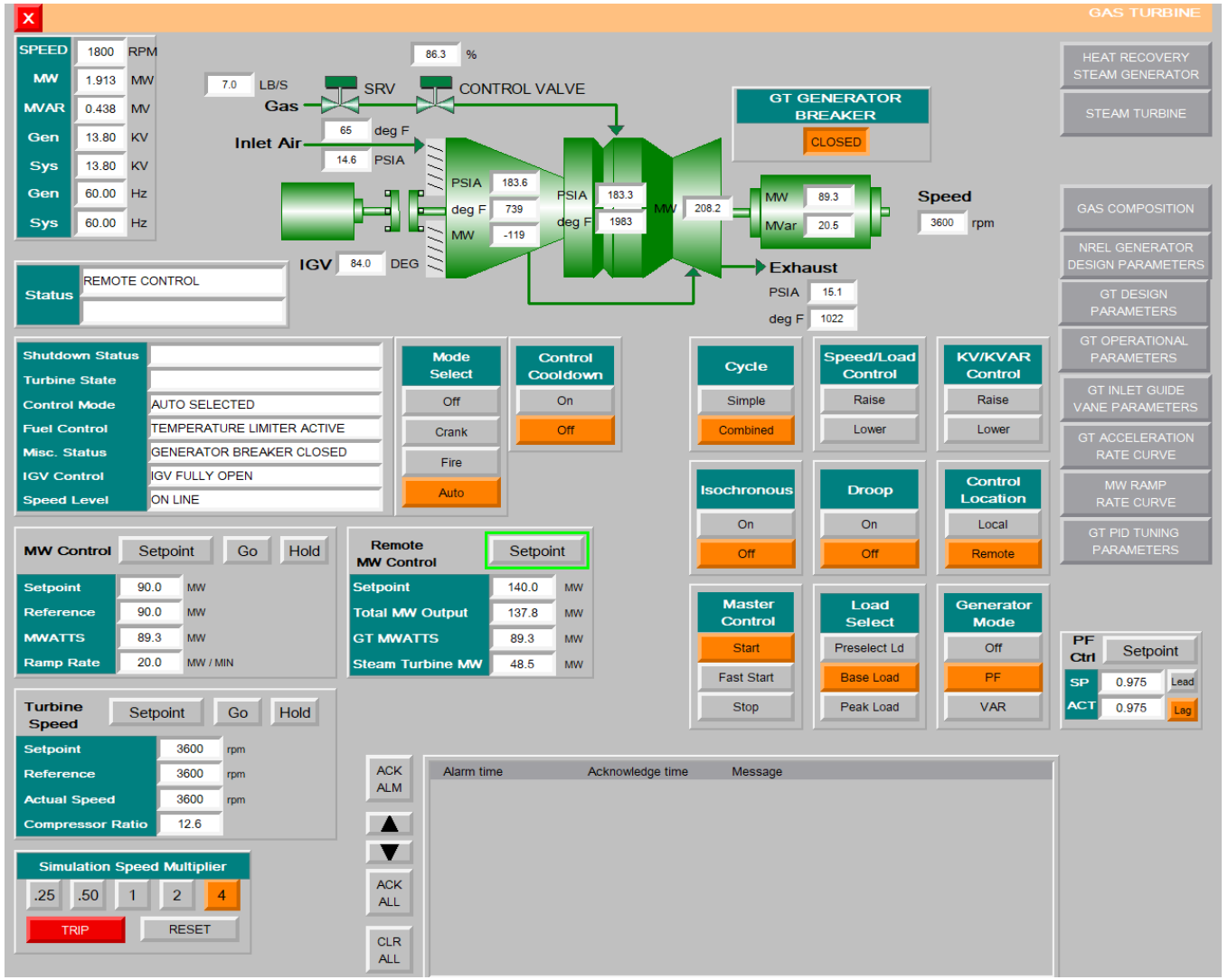


- Emulates a natural gas turbine (GE 7EA – 90MW) including a real, industry relevant governor controller
- Prime-mover dynamics are emulated and realized via the dyno driving the sync. machine
- Enables experiments where changes in conventional generation controls is considered (e.g., value of IBR-based FFR vs. “fast-valving” options for conventional gen.

Emulating all the Controls

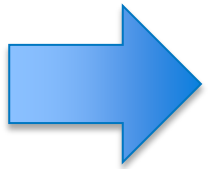
Control emulation included:

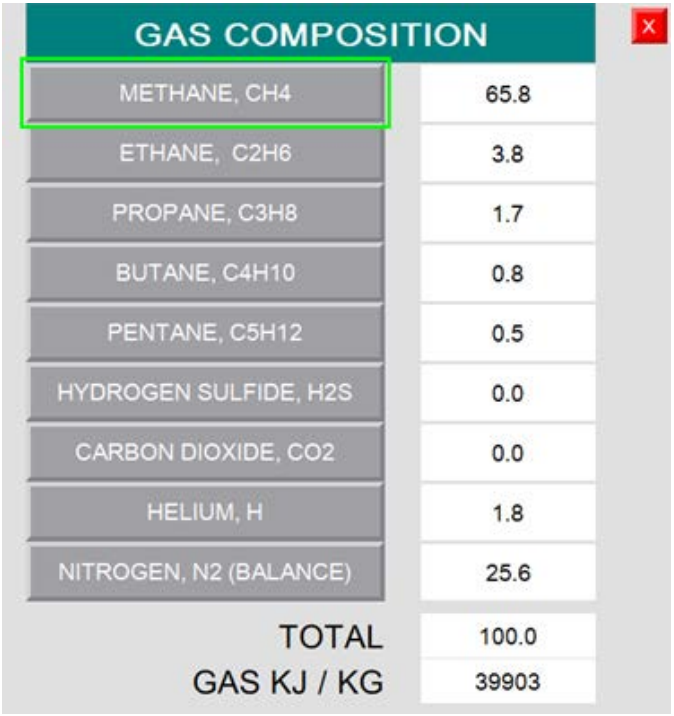
- Gas value dynamics
- Inlet guide vane (IGV) operations
- Start-up/Shutdown sequences:
  - Purge speed/duration
  - Lightoff speed
  - Ramp up rate
  - Grid synchronization/disconnection
  - Ramp down rate
  - Cooldown speed
- Fuel composition
- PID control gains
- HRSG:
  - Superheat pressure drop curves
  - First stage steam pressure curves
  - Condenser back pressure



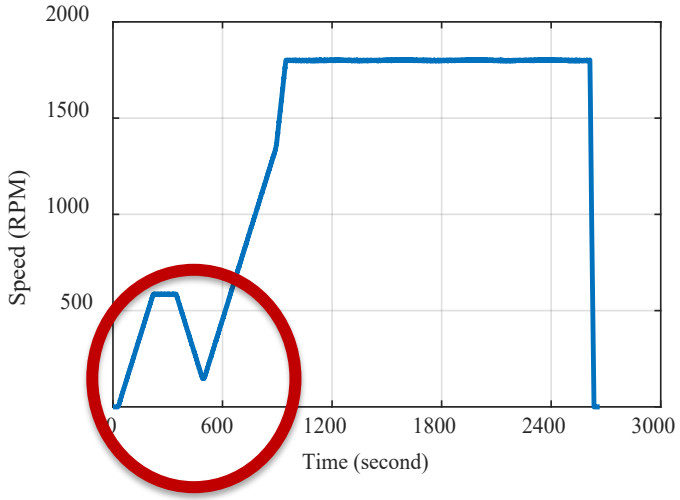
Example of Flexibility – Fuel Composition

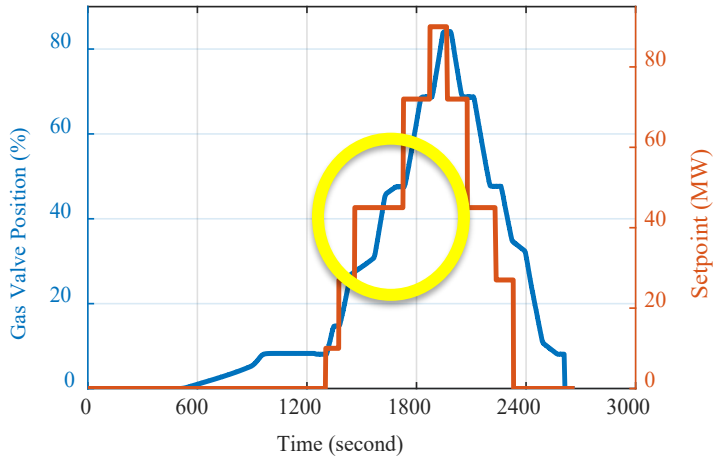
Gas	Canada	Kansas	Texas	HHV (btu/ft^3)	HHV (btu/lb)	HHV (kJ / kg
Methane	77.1	73.0	65.8	1011	23811	55384
Ethane	6.6	6.3	3.8	1783	22198	51633
Propane	3.1	3.7	1.7	2572	21564	50158
Butane	2.0	1.4	0.8	3225	21640	50335
Pentane	3.0	0.6	0.5	3981	20908	48632
H2S	3.3	0.0	0.0	672	7479	17396
CO2	1.7	0.0	0.0	0	0	0
N2	3.2	14.5	25.6	0	0	0
He	0.0	0.5	1.8	0	0	0
Total Gas	100.0	100.0	100.0			
Average HHV (btu/scf)	1,183.0	1,014.6	822.4			
Average HHV (btu/lb)	21,798	20,006	17,155			
Average HHV (kJ / kg)	50,703	46,535	**39,903**			

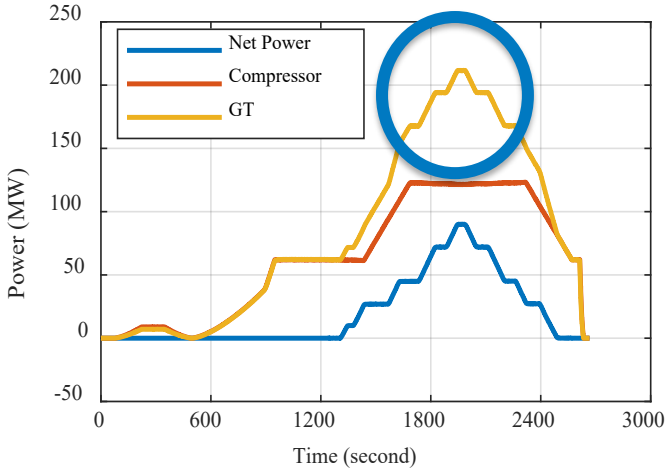


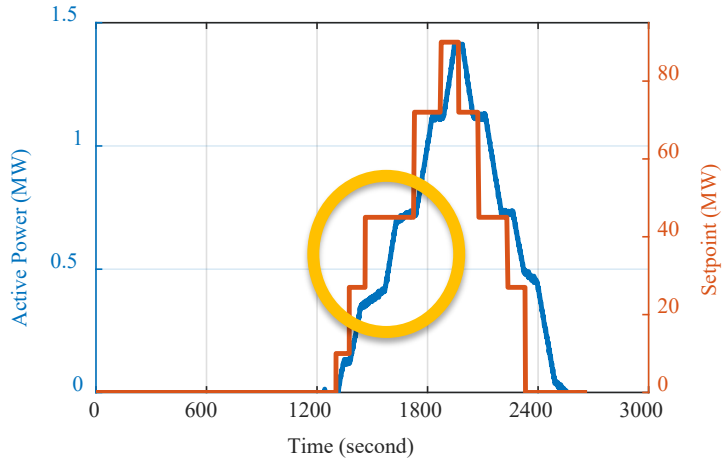


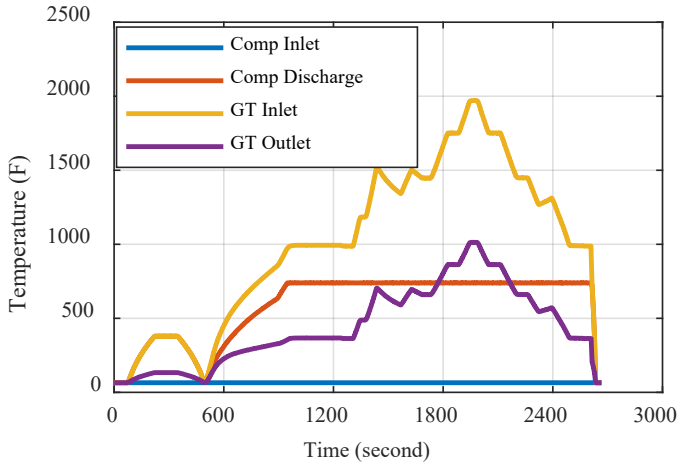
Grid-Connected Natural Gas Combustion Turbine

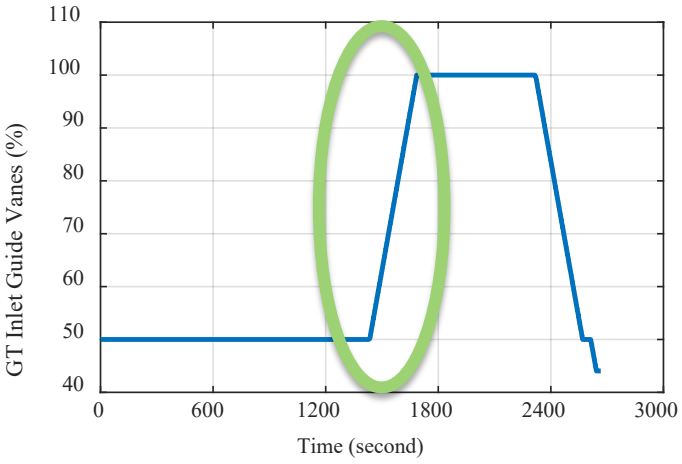












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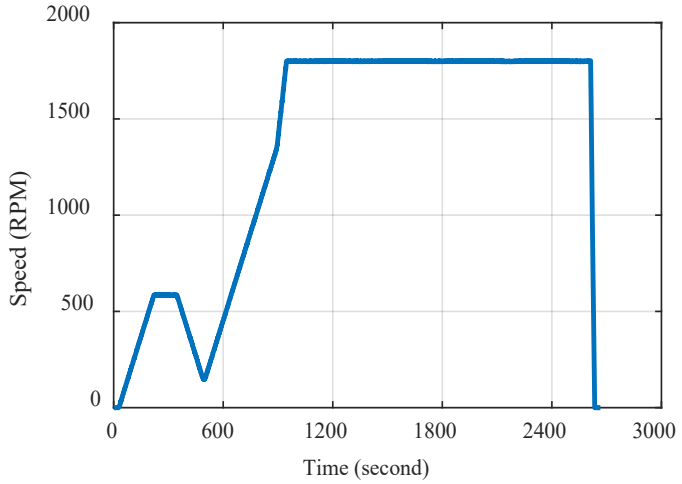

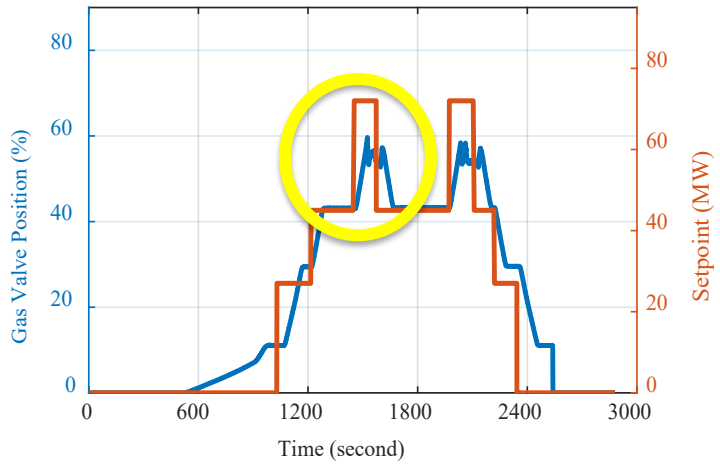

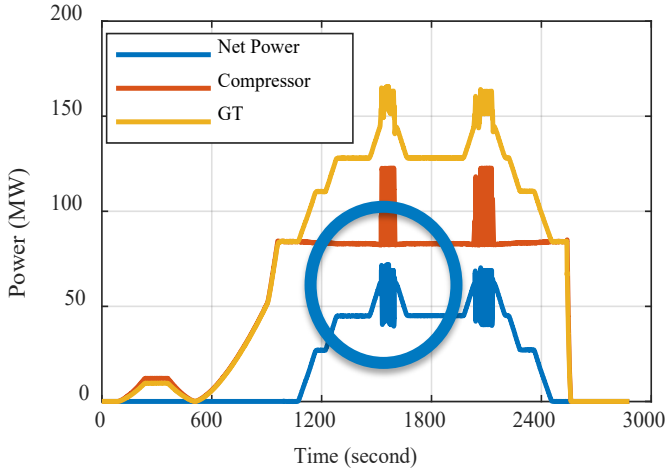

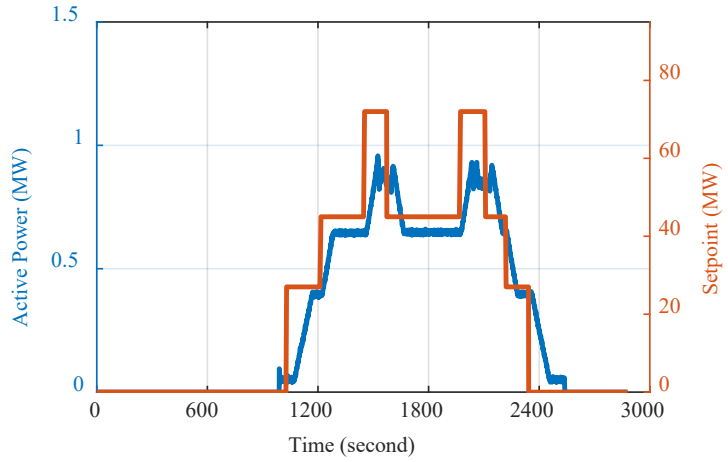

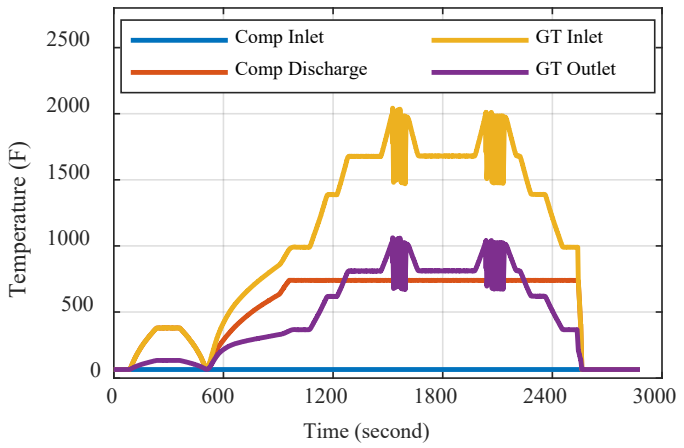

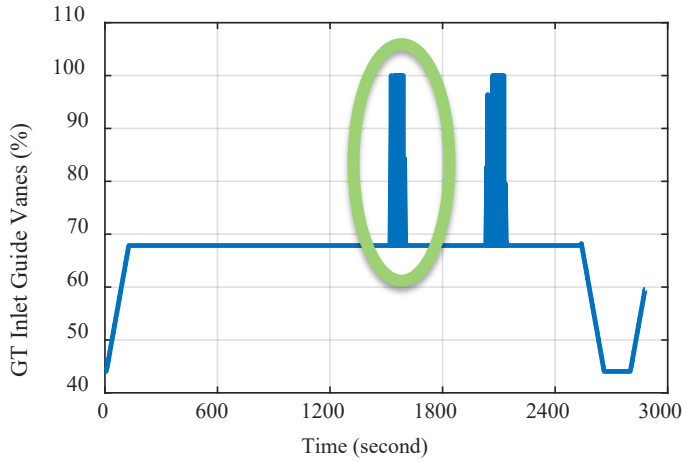

PEGI Platform Industry Engagement

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 first half of FY25
- Project may be 50%/50% cost shared
  - 40% of cost share should be funds in
- Multi-party collaboration encouraged (ISO, utility, vendor…)

How to engage:

- Start by letting Barry know of your potential interest
- Aligned projects will develop draft SOWs via an identified NREL PI
- Currently looking for about 4-5 projects

Contact Barry Mather (barry.mather@nrel.gov) for more information

Thank You

www.nrel.gov

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

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