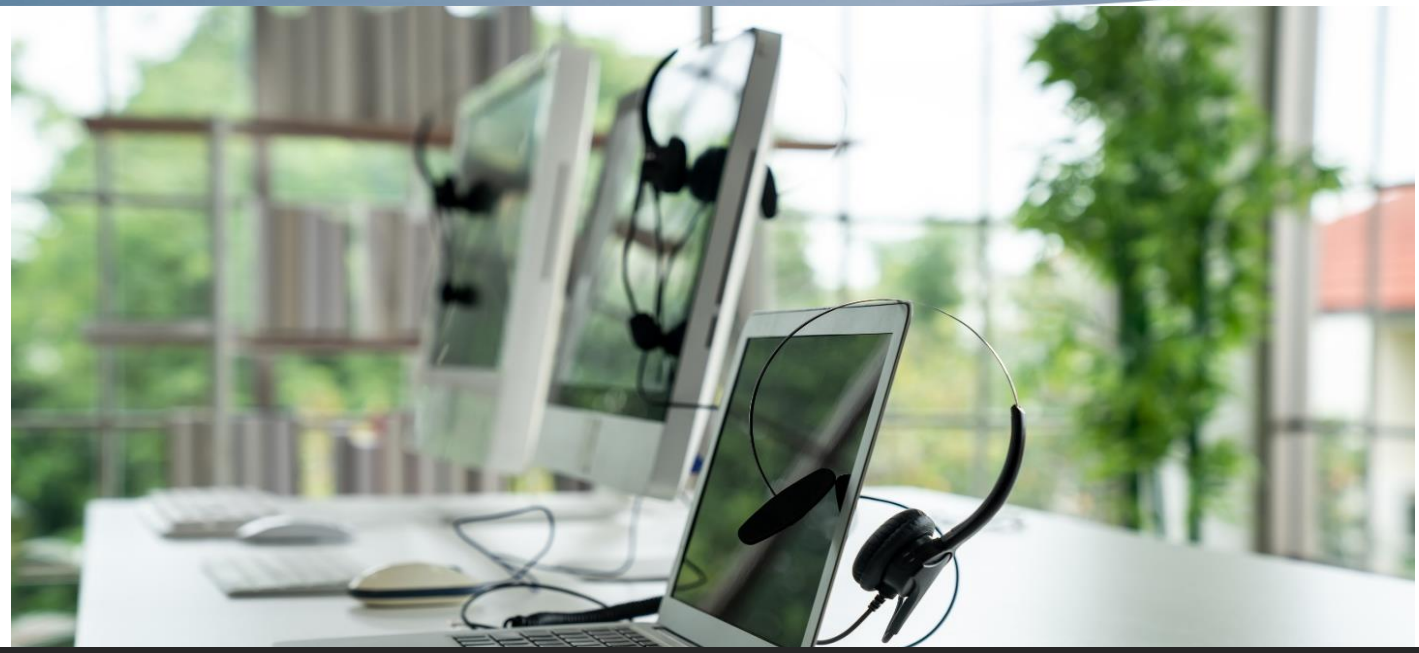
California ISO



Primary Frequency Response (PFR)
May 2024

Welcome

Our presentation will begin shortly.

Today's Presenter: Ali Miremadi

Housekeeping

Keep yourself muted to minimize background noise

Unmute to ask verbal questions or write questions in the chat pod

Raise your hand using WebEx interactivity tools

Definitions

Primary Frequency Response (PFR)

- the first stage of frequency control and is the response of generator governors and loads to arrest locally detected changes in frequency

Droop (FERC Order 842)

- the variation in real power (MW) output due to variations in system frequency and is typically expressed as a percentage (e.g., 5% droop)
- reflects the amount of frequency change from nominal (e.g., 5% of 60 Hz is 3 Hz) necessary to cause the main prime mover control mechanism of a generating facility to move from fully closed to fully open

Deadband (FERC Order 842)

- represents a minimum frequency deviation (e.g., ±0.036 Hz) from nominal system frequency (i.e., 60 Hz in North America) that must be exceeded in order for the generating facility to provide primary frequency response

Overview of Primary Frequency Response

- Primary Frequency Response (PFR) is an Essential Reliability Service
  - First line of defense against a frequency event – critical for system stability
  - FERC mandated PFR for generators (Order 842 – Pro forma LGIA)
  - Necessary for BAL-003 (PFR) and BAL-001 (power balancing) compliance

- MW Response of a Resource is a function of
  - Droop setting
  - Available stored energy
  - Available headroom
  - Physical or manually set restriction on the resource
  - Control mode of the resource

Large Generator Interconnection Agreement Battery Storage Frequency Response Tariff Requirements

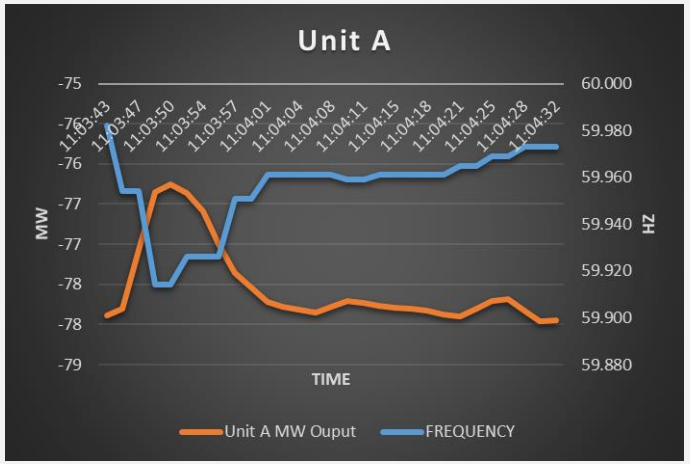
LGIA Section 9.6.4.4

- **9.6.4.4** Electric Storage Resources. Interconnection Customer interconnecting an electric storage resource shall establish an operating range in Appendix C of this LGIA that specifies a minimum state of charge and a maximum state of charge between which the electric storage resource will be required to provide primary frequency response consistent with the conditions set forth in Sections 9.6.4, 9.6.4.1, 9.6.4.2, and 9.6.4.3 of this Large Generator Interconnection Agreement (LGIA). Appendix C shall specify whether the operating range is static or dynamic, and shall consider: (1) the expected magnitude of frequency deviations in the interconnection; (2) the expected duration that system frequency will remain outside of the deadband parameter in the interconnection; (3) the expected incidence of frequency deviations outside of the deadband parameter in the interconnection; (4) the physical capabilities of the electric storage resource; (5) operational limitations of the electric storage resource due to manufacturer specifications; and (6) any other relevant factors agreed to by the CAISO and Interconnection Customer, and in consultation with the relevant transmission owner or balancing authority as appropriate. If the operating range is dynamic, then Appendix C must establish how frequently the operating range will be reevaluated and the factors that may be considered during its reevaluation.
- Interconnection Customer's electric storage resource is required to provide timely and sustained primary frequency response consistent with Section 9.6.4.2 of this LGIA when it is online and dispatched to inject electricity to the CAISO Controlled Grid and/or receive electricity from the Participating TO's Transmission System or the CAISO Controlled Grid. This excludes circumstances when the electric storage resource is not dispatched to inject electricity to the CAISO Controlled Grid and/or dispatched to receive electricity from the Participating TO's Transmission system or the CAISO Controlled Grid. If Interconnection Customer's electric storage resource is charging at the time of a frequency deviation outside of its deadband parameter, it is to increase (for over-frequency deviations) or decrease (for under-frequency deviations) the rate at which it is charging in accordance with its droop parameter. Interconnection Customer's electric storage resource is not required to change from charging to discharging, or vice versa, unless the response necessitated by the droop and deadband settings requires it to do so and it is technically capable of making such a transition.

Most Battery Storage Facilities Currently Have the Wrong Droop Settings

LGIA Requirement Section 9.6.4.	"…The droop characteristic shall be: (1) based on the nameplate capacity of the Electric Generating Unit(s), and shall be linear in the range of frequencies between 59 to 61 Hz that are outside of the deadband parameter; or (2) based on Applicable Reliability Standards providing for an equivalent or more stringent parameter…"
FERC Order 842 Paragraph 186	"…We clarify that for all generating facilities, the calculation of the MW droop response is based on a generating facility's nameplate capacity (i.e., for a five percent droop curve, a generating facility would be expected to increase its output by 100 percent of its nameplate capacity for a five percent change in frequency)."
IEEE 2800 Section 6.1.1.	"…Frequency droop shall be based on the difference between IBR continuous rating (ICR) and zero output such that the slopes of the droop curves are always constant."

Example of a Unit With Droop Setting set to 0-Pmax



Unit A PFR

PFR = $f(\Delta Freq; Pc\ (0, PMax))$

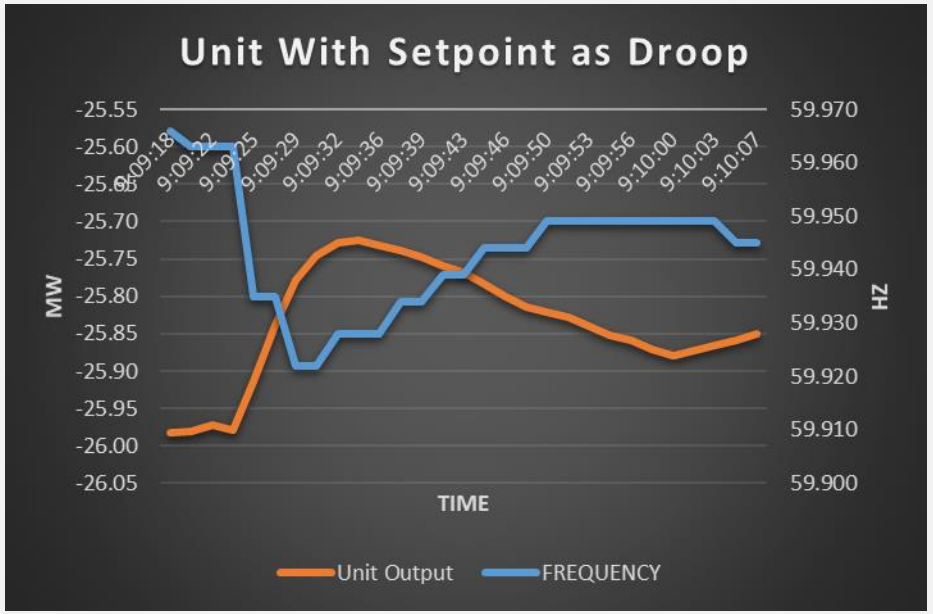
Expected PFR 0-Pmax	
Nominal	60
Act FRE	59.92
Deadband	0.036
Delta Freq	0.044
5% Droop	0.014667
Capability	100
PFR	1.5

Actual PFR = 1.54 MW at Frequency NADIR

FERC Order 842 PFR

PFR = $f(\Delta Freq; Pc\ (Nameplate))$

Example of a Unit With Droop Setting set to Set Point



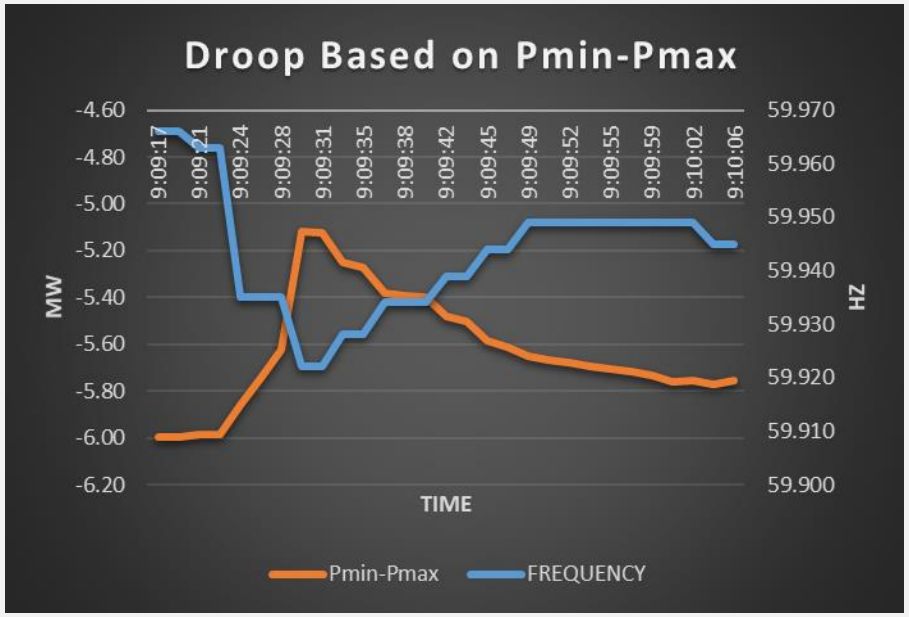
Actual PFR = 0.3 MW
at Frequency NADIR

Expected PFR 0-Pmax	
Nominal	60
Act FRE	59.92
Deadband	0.036
Delta Freq	0.044
5% Droop	0.014667
Capability	132
PFR	1.94

Expected PFR Pmin - Pmax	
Nominal	60
Act FRE	59.92
Deadband	0.036
Delta Freq	0.044
5% Droop	0.014667
Capability	264
PFR	3.87

Expected PFR Setpoint as Droop	
Nominal	60
Act FRE	59.92
Deadband	0.036
Delta Freq	0.044
5% Droop	0.014667
Capability	26
PFR	0.38

Example of a Unit With Droop Setting set to Pmin-Pmax



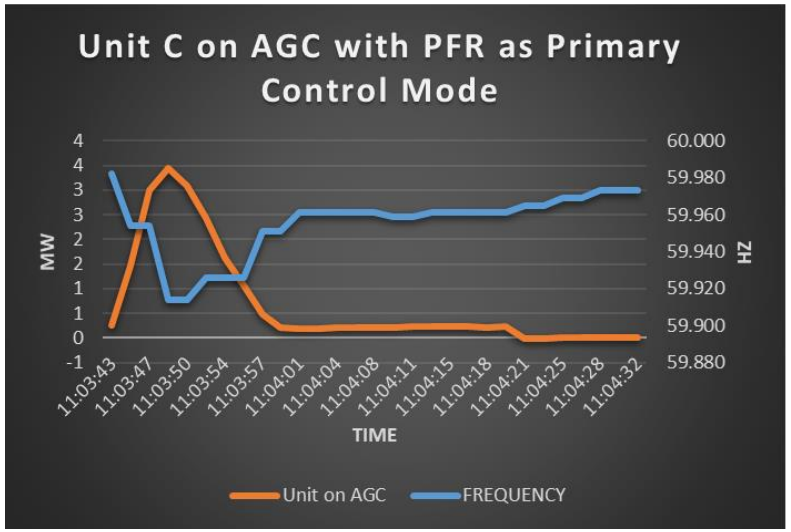
Expected PFR 0-Pmax	
Nominal	60
Act FRE	59.92
Deadband	0.036
Delta Freq	0.044
5% Droop	0.014667
Capability	28
PFR	0.41

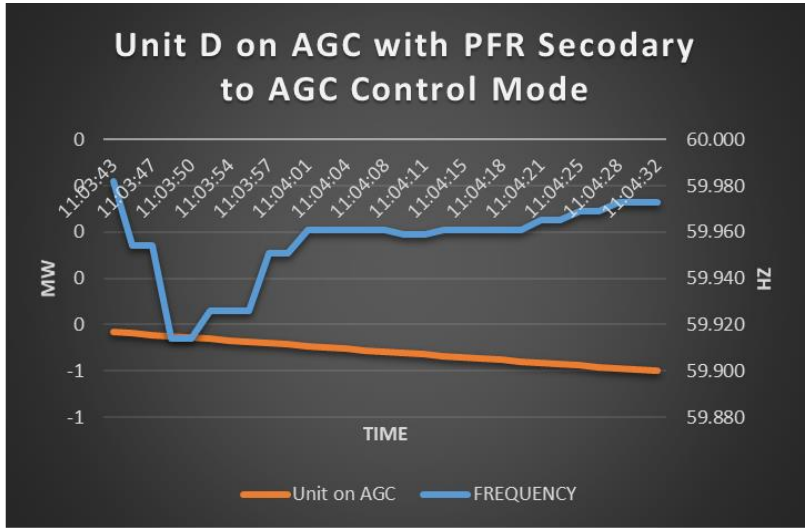
Expected PFR Pmin - Pmax	
Nominal	60
Act FRE	59.92
Deadband	0.036
Delta Freq	0.044
5% Droop	0.014667
Capability	56
PFR	0.82

Actual PFR = 0.82 MW at Frequency NADIR

PFR Needs to be the Primary Control Mode

- Most Battery storage facilities have AGC as the primary control mode
- PFR must be the **primary control mode and be additive** to other control modes





Two Similarly Sized Battery Storage Units on AGC at the Time of Frequency Event

Wrap Up

Summary, Q&A

Thank you for your participation!

For more detailed information on anything presented, please visit our website at: www.caiso.com or send an email to: CustomerReadiness@caiso.com.

For resource specific questions or concerns, please submit a CIDI ticket.