Frequency Response Phase 2 Working Group Meeting

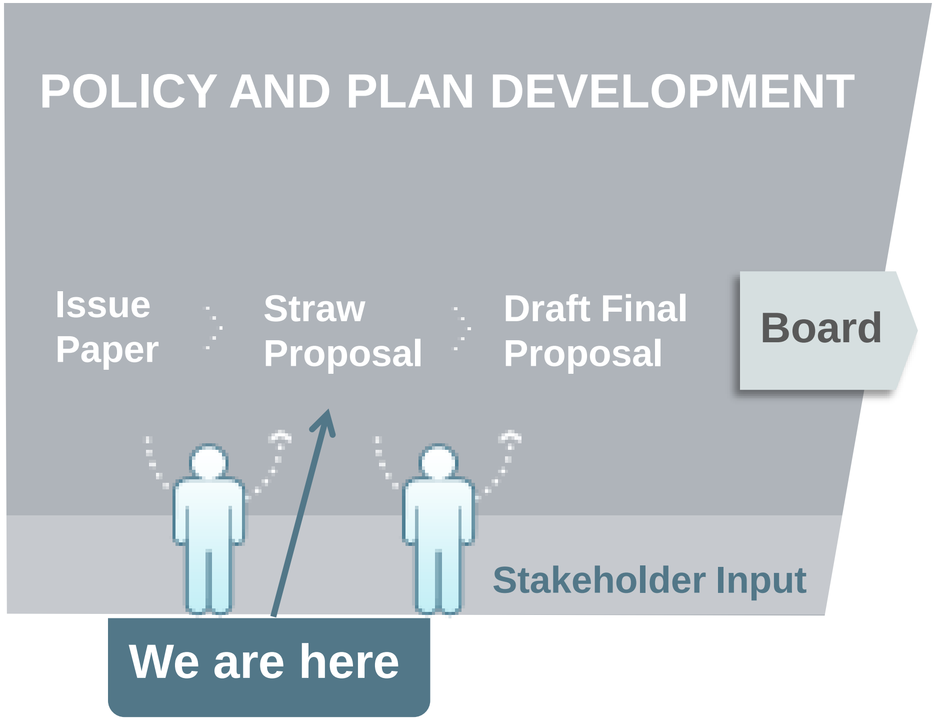
February 9, 2017

Cathleen Colbert
Market and Infrastructure Policy

February 9 working group agenda

Time	Topic	Presenter
10:00 – 10:05	Introduction	Kim Perez
10:05 – 10:15	NERC & FERC guidance on frequency response	Cathleen Colbert
10:15 – 10:25	Comparing frequency control and operating reserve markets	Cathleen Colbert
10:25 – 10:35	California Energy Storage Association Presentation	Alex Morris
10:35 – 12:00	Brainstorm Session	
12:00 – 1:00	Lunch	
1:00 – 1:45	Frequency responsive controls	Sebastian Campos
1:45 – 2:30	Primary frequency response design options	Sebastian Campos
2:30 – 3:50	Discussion	
3:50	Next Steps	Kim Perez

ISO policy initiative stakeholder process



INTRODUCTION

Objectives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Frequency Response Phase 2

- ISO expects frequency response will continue to worsen as non-conventional technologies increase

- Without explicit procurement of primary frequency response:
  - ISO cannot ensure it will position the fleet to provide sufficient frequency response
  - ISO needs to mitigate risk of non-compliance by procuring transferred frequency response

- ISO is concerned with relying on procuring compliance instrument to meet reliability requirement in the long term and believes it has received guidance to pursue other approaches

NERC & FERC GUIDANCE ON FREQUENCY RESPONSE

NERC's Essential Reliability Services

Essential Reliability Services (ERS) are the reliability building blocks necessary to maintaining reliability

	ERSs in Functional Terms	Effects of Lack of ERS Availability
Voltage Support	• The primary objective of Voltage Support is to maintain the voltages in the transmission system within a secure, stable range. • Voltage Support is location-specific and requires reactive power control from reactive resources distributed throughout the power system.	• Localized voltage issues can spread to a wider area, causing loss of load. • Exceeding design voltage parameters can destroy equipment by breaking down insulation. • Undervoltage conditions can lead to motor stalls and equipment overheat. • Voltage collapse can lead to cascading drop in voltage and cause undesirable events.
Frequency Support	• Frequency Support ensures the frequency of the BPS can be synchronized and stabilized for both normal and contingency conditions. • Controlling frequency can be broken into four stages: 1. Inertial Response 2. Primary Frequency Response 3. Secondary Frequency Response 4. Tertiary Frequency Response • Daily operation of the BPS requires a continuous balance of load and resources (generation and demand-side resources). • Operational flexibility is needed to manage real-time changes in load and generation.	• Large frequency deviations can result in equipment damage and power system collapse. • Interconnection frequency deviation can result in: o Loss of generation o Load shedding o Interconnection islanding • Puts BPS stability and the reliability area at risk. • Imbalance in generation and load can overload transmission facilities. • Protection equipment can malfunction or be damaged. • Prolonged imbalance can result in violation of NERC Reliability Standard (BAL-001-1).

NERC Essential Reliability Services Task Force Concept Paper, 2014, Page 1

Frequency support from frequency control is a fundamentally different service than voltage support

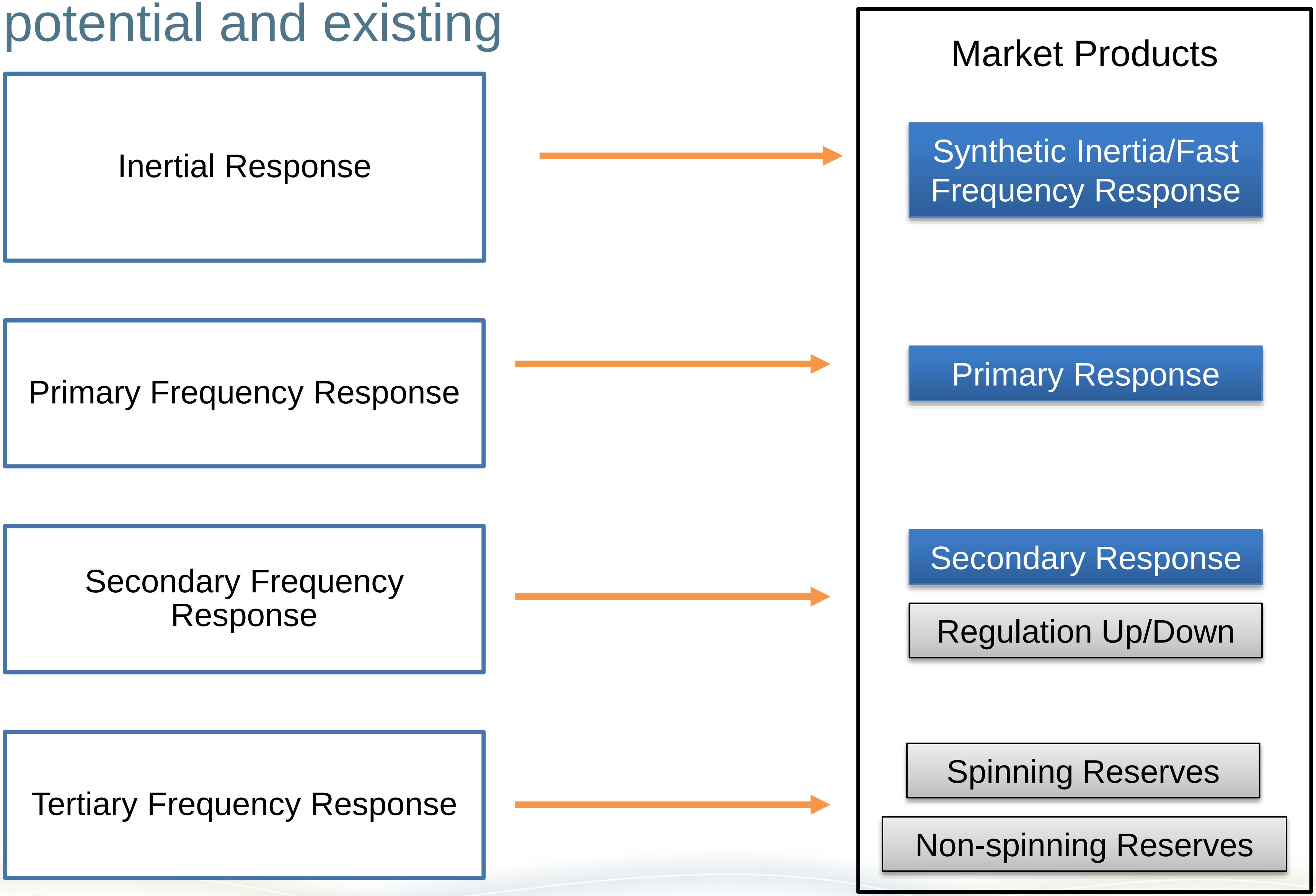
Frequency control services :

- Active/real power output
- Requires maintaining reserves
- Grid service
- Fungible service between resources
- Overlaps with energy capacity

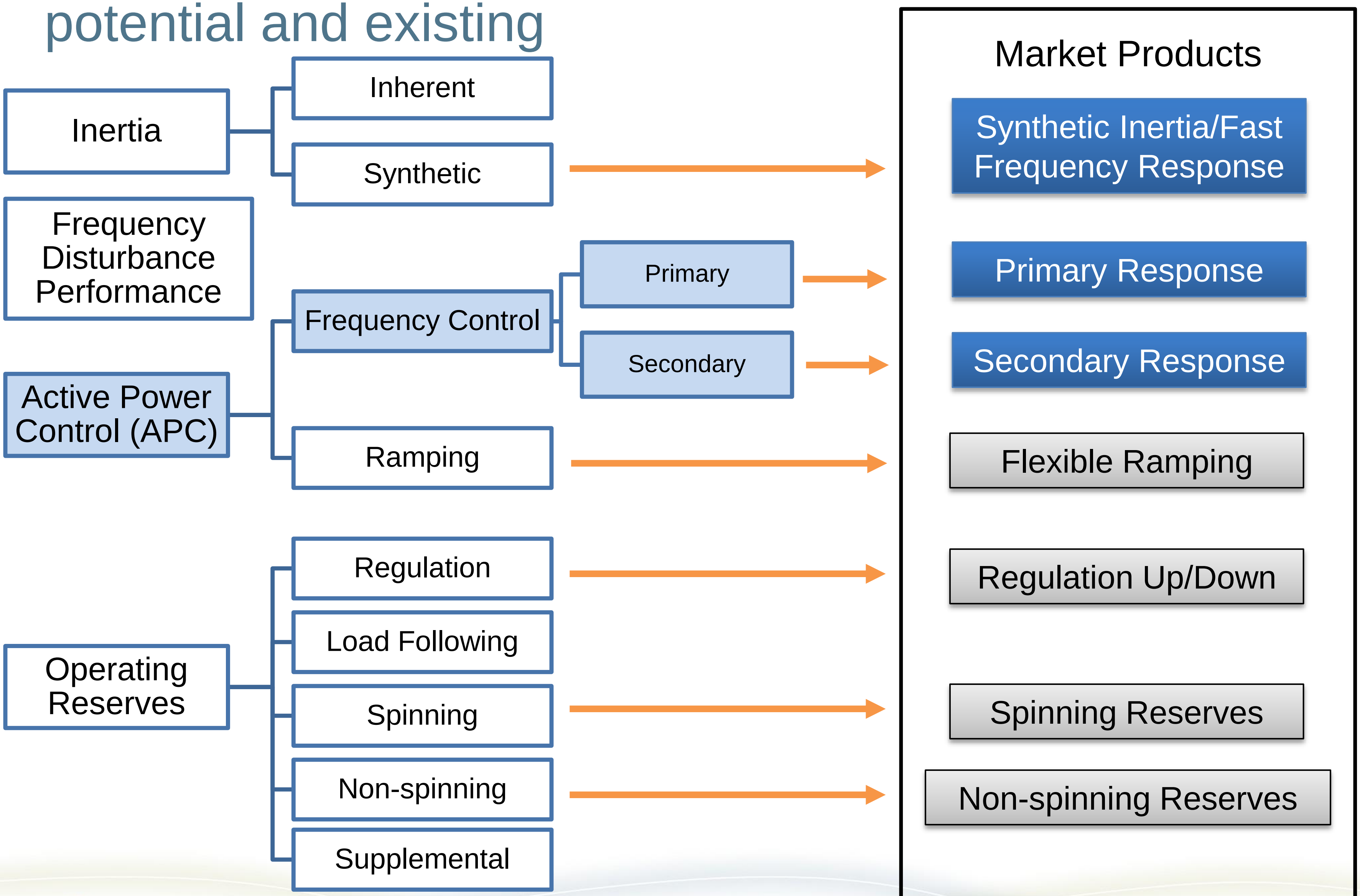
Voltage support services :

- Reactive power output
- Does not require maintaining reserves
- Location specific service (necessary for generator to deliver energy)
- Not fungible service between resources
- Doesn't overlap with energy capacity

Frequency control stages compared to products – potential and existing



Frequency support services compared to products – potential and existing



NERC Essential Reliability Services Task Force Concept Paper, 2014, Page 1-2

FERC proposed rules on primary response

FERC proposes to require all resources submitting a new interconnection request that results in filed executed/unexecuted interconnection agreement to:

- Install frequency response capability

  Policy Change

- Set governor or equivalent controls to be operated, **at a minimum**, with maximum 5 percent droop and ±0.036 Hz deadband settings

  Existing Policy

- Provide sustained response until frequency returns to a stable value within the governor's deadband setting

  Policy Change

- Not inhibit provision of primary frequency response, with certain exceptions

  Existing Policy

- Base droop settings on nameplate capability with a linear range of 59-61 Hz

  Policy Change

COMPARING FREQUENCY CONTROL AND OTHER MARKETS

Frequency control services are fundamentally different services than operating reserves

Frequency control services:

- Automatic active/real power output to stabilize frequency
- Requires maintaining reserves
- Grid service providing Interconnection security
- Energy will not be delivered as byproduct of response
- Fungible
- Does not require transfer capability

Operating reserve services:

- Operator controlled active/real power output
- Requires maintaining reserves
- Generation & demand balancing service
- Energy may be delivered as byproduct of balancing function
- Largely fungible
- Requires transfer capability to ensure feasible delivery

Frequency control services require reserves above operating reserves that are not procured for RA

- Frequency responsive reserves are reserves:
  - Automatically deployed to arrest & stabilize frequency
  - Not ISO dispatchable to manage gen & load balance
  - Must be maintained above firm demand and operating reserves margin
- ISO believes that resource adequacy or flexible resource adequacy capacity procured to ensure RA to ensure energy deliverability cannot be awarded frequency responsive reserves since these reserves cannot be released by ISO dispatch to ensure deliverability during peak or ramping needs

Operating reserves considerations important to evaluating frequency response product

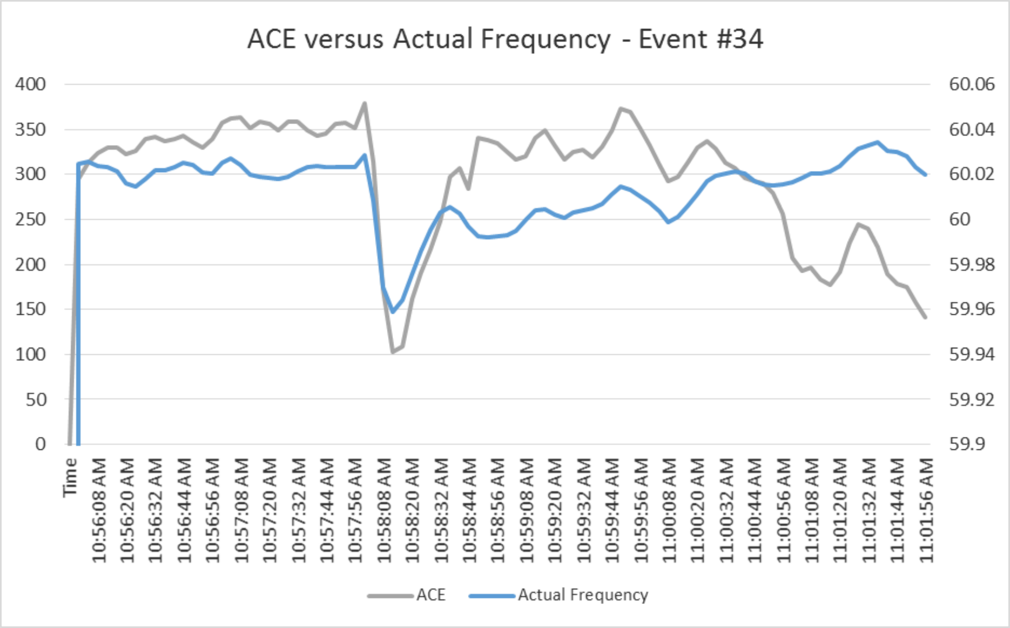
- The manner of response from regulation as well as the potential primary response from unloaded capacity could impact the amount of frequency response needed ➔ amount of reserves needed

- For example, may need to adjust when regulation signals are sent as ISO frequently observes notable secondary response around 20 or 30 seconds following an event and if ACE is positive may send Reg Down dispatch signals while primary response is provided ➔ regulation might dampen measured response impacting amount

- For example, may need to adjust requirement based on expected frequency response performance from regulation or spin since both are expected to be frequency responsive ➔ operating reserves might result in reducing frequency response requirement

Can regulation undermine the FRM if ACE signal is moving units down when response is measured?

- ISO analyzed 36 frequency response events from Jan – Nov 2016 to see what direction Regulation signal was moving regulation units
- 7 of the 36 events had an ACE signal on average that was positive



- Should the ISO consider deeper analysis to determine whether it should account for an upward bias needed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FREQUENCY RESPONSIVE CONTROLS

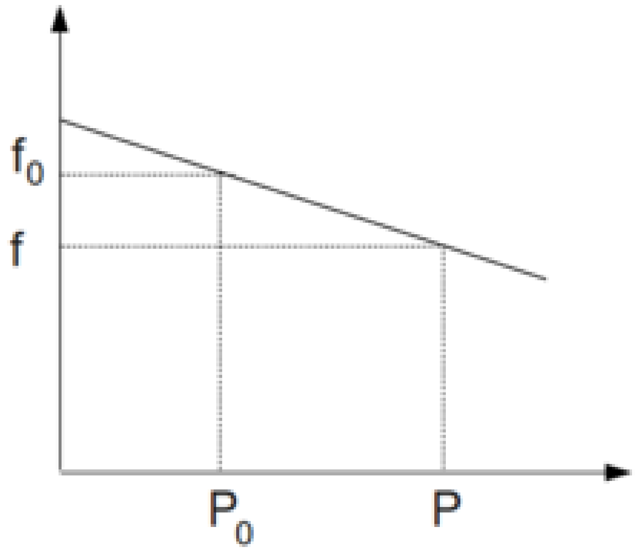
Overview

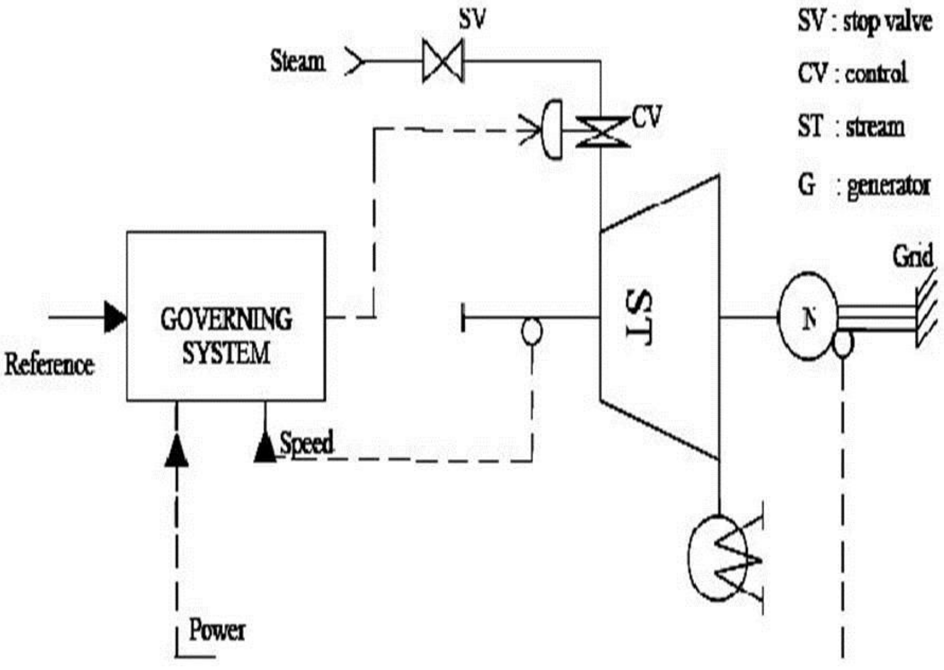
This section will discuss:

- Governor control functionality (theoretical and observed)
- Inverter control functionality
- Under-frequency relay device functionality

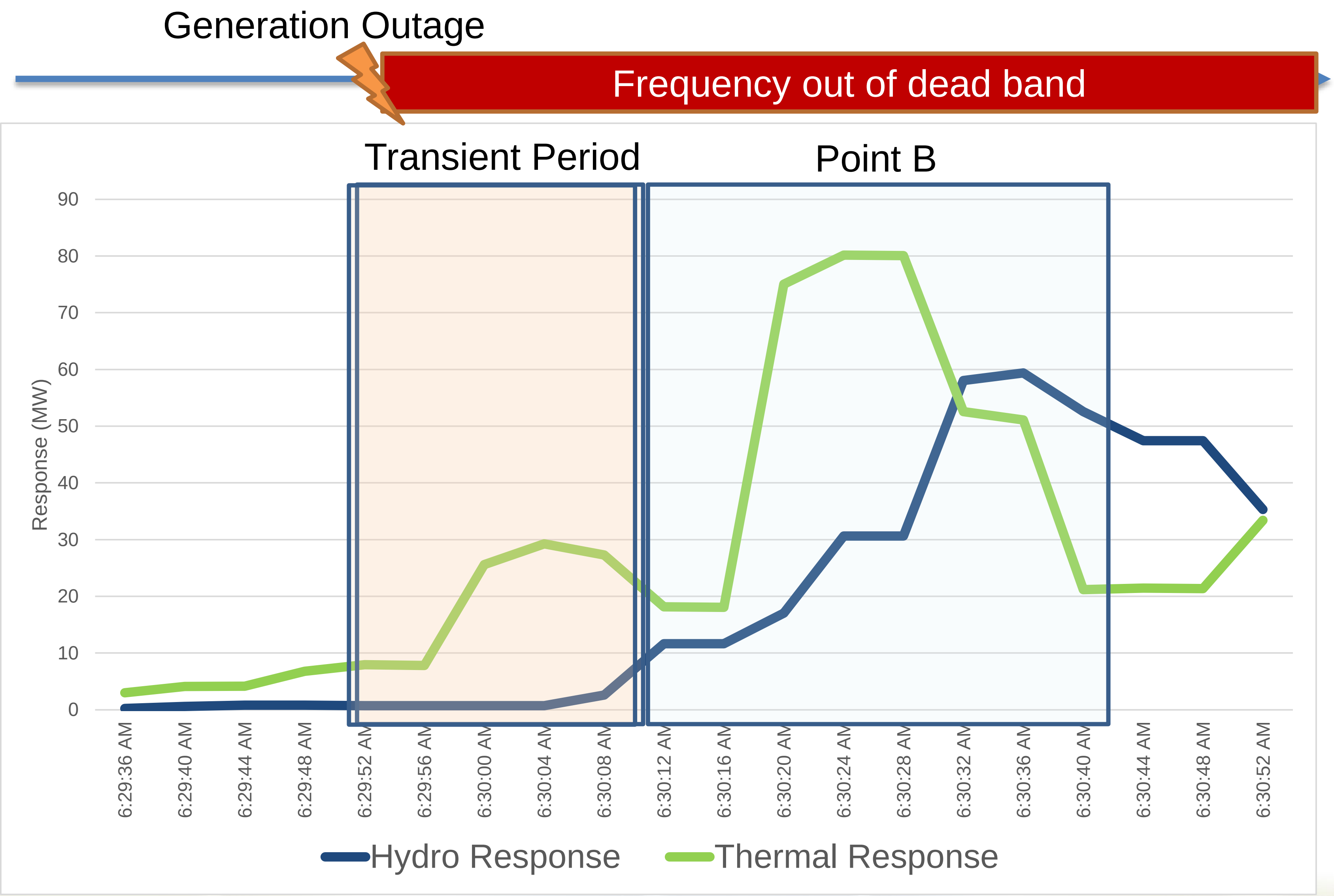
Governor controls allow conventional generators to provide frequency response

- Governor controls, i.e speed controls, determine the speed and rate at which a conventional resource provides real power output in response to changes in system frequency to provide frequency response in MW/0.1Hz

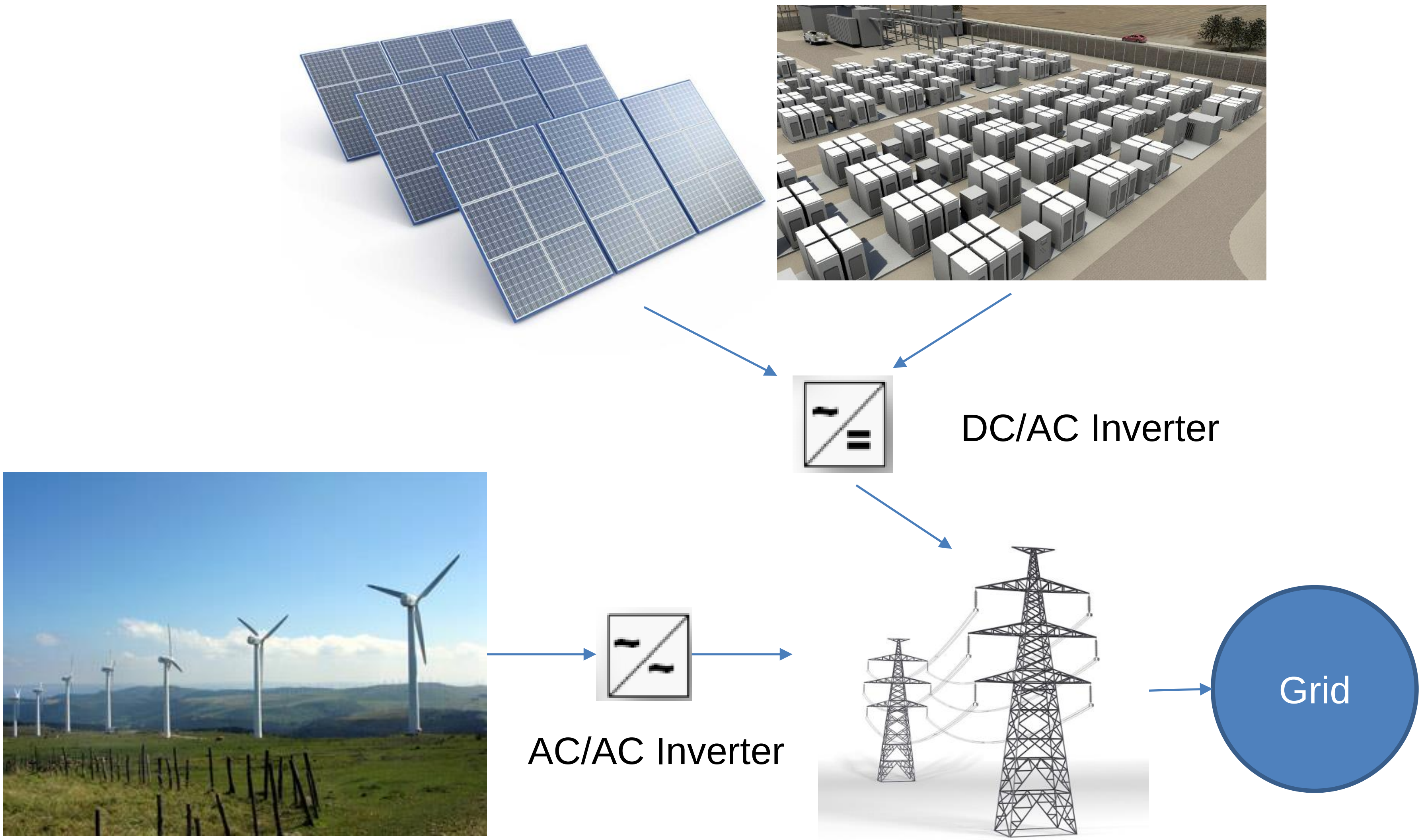




ISO observation of actual thermal and hydro response

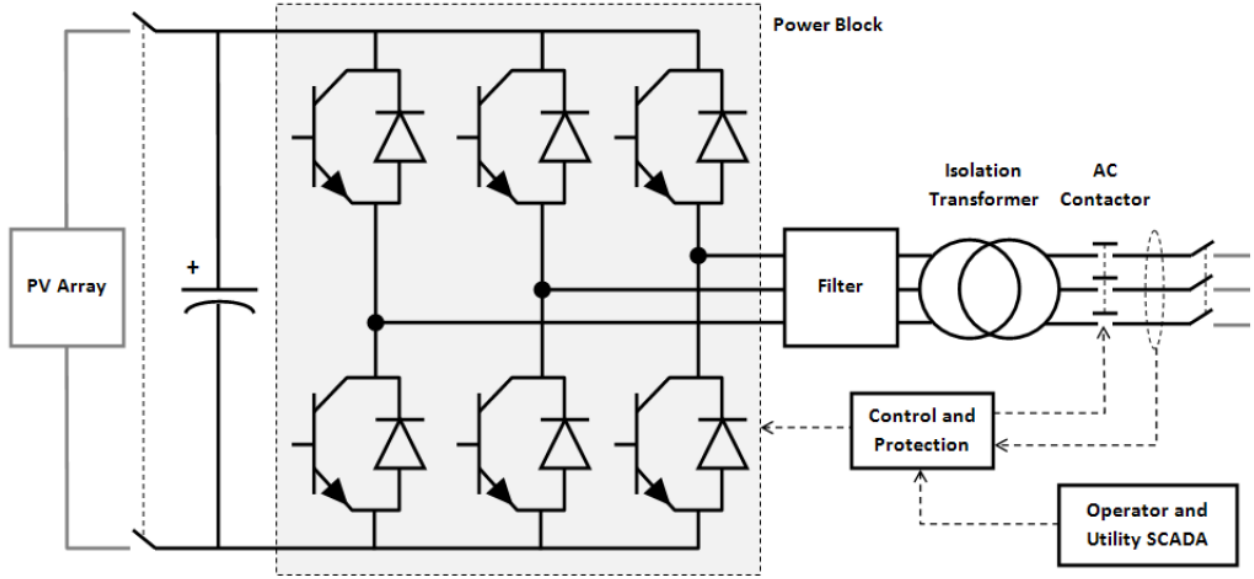


Inverter Technology



Inverter Technology

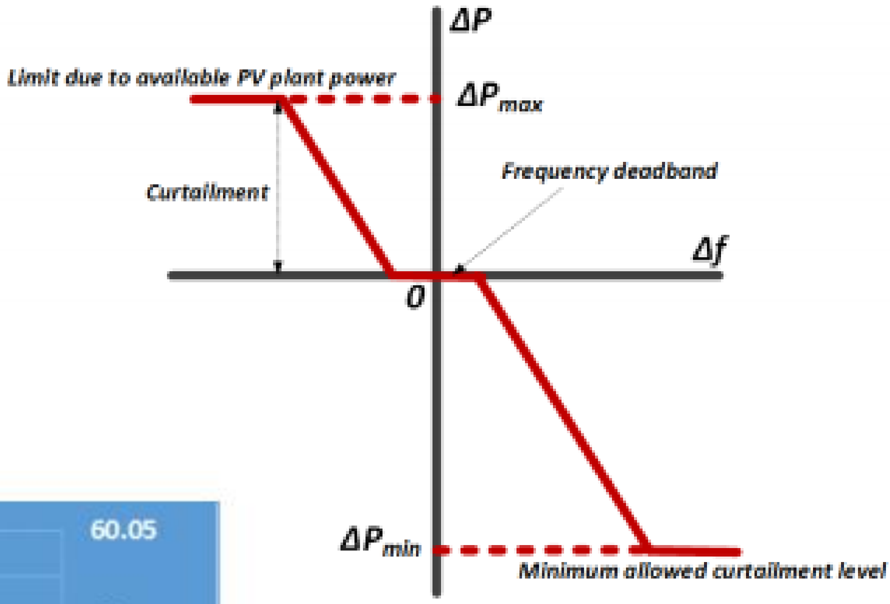
- Requires unloaded capacity or battery charge available to deploy
- Inverters typically operate as controlled current sources. This means that the highfrequency switching of the inverter is controlled so that the output current from the inverter is actively forced to follow a reference signal.
- With an optimum design the output current control can be extremely fast (<1ms response) and accurate (<1%)

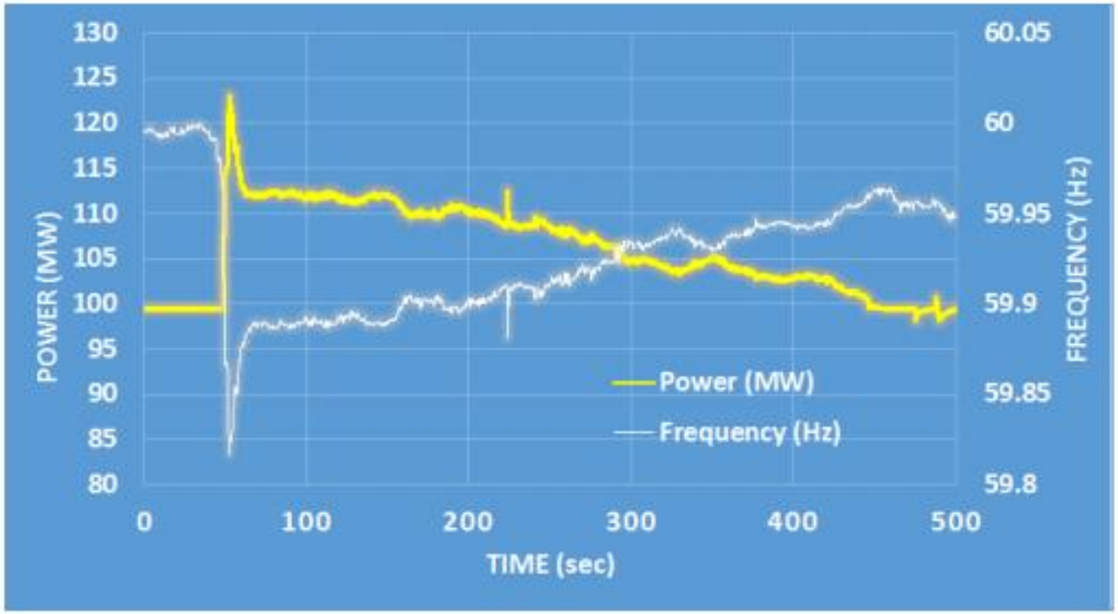


Source: WECC REMTF,WECC Guide for Representation of Photovoltaic Systems In Large-Scale Load Flow Simulations

PV Units test

- Droop response of PV Units can be set on Controls of the Plant





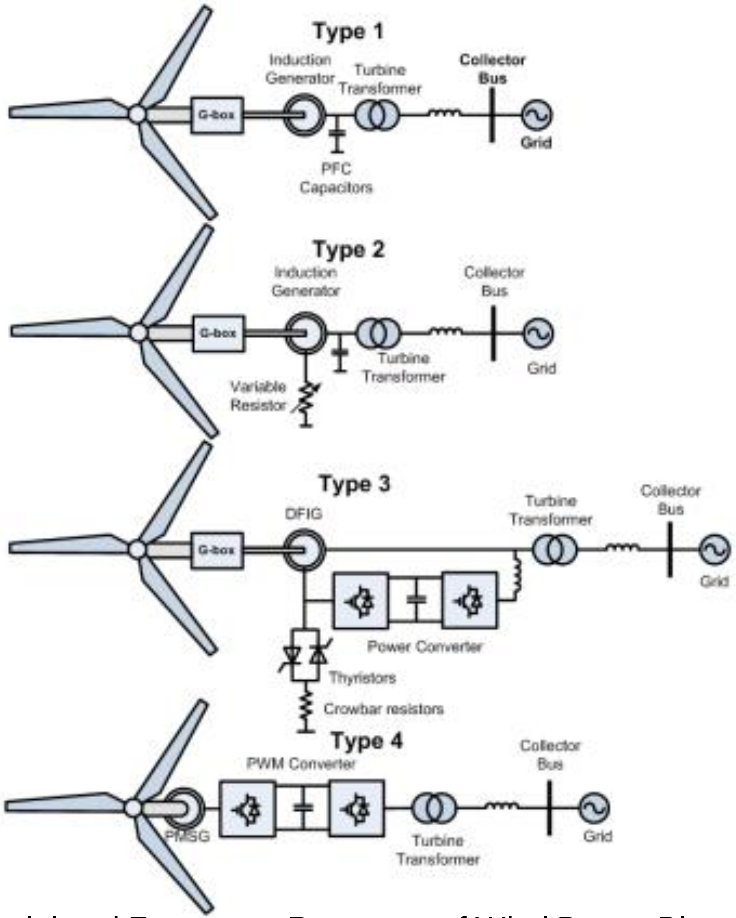
The ISO conducted test with First Solar to measure the ability of PV Units.

Source: Using Renewables to Operate a Low-Carbon Grid – California ISO

Wind Turbines Generators (WTG)

- Advanced controllers that combine torque and pitch control to implement primary control during frequency events are required.

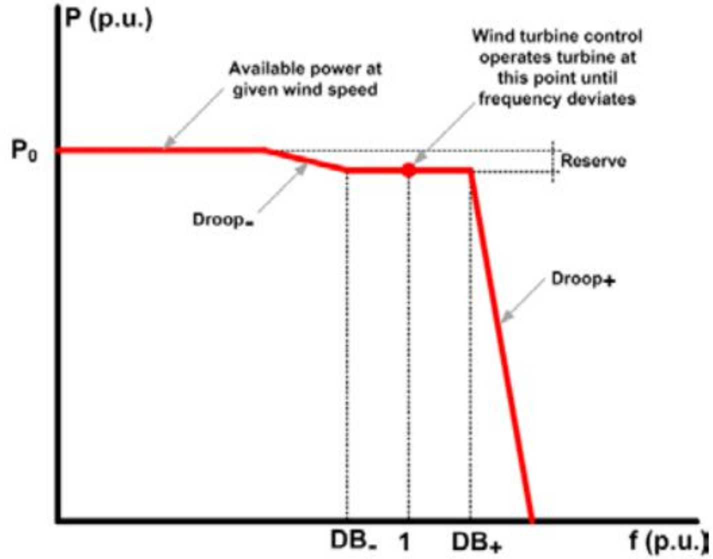
The variable-speed WTG can provide the power boost during the frequency decline if the generator, power converter, and wind turbine structure are designed to withstand the overload necessary. (Type 3 and 4)



Source: Understanding Inertial and Frequency Response of Wind Power Plants – NREL

Wind Turbines Generators (WTG)

Inertial response of the conventional generators is dependent on their physical mass, and the physics of the synchronous machine, and cannot be changed. In the case of wind turbines, the inertial response can be tuned to improve power system performance during the initial decline of the frequency after loss of generation.

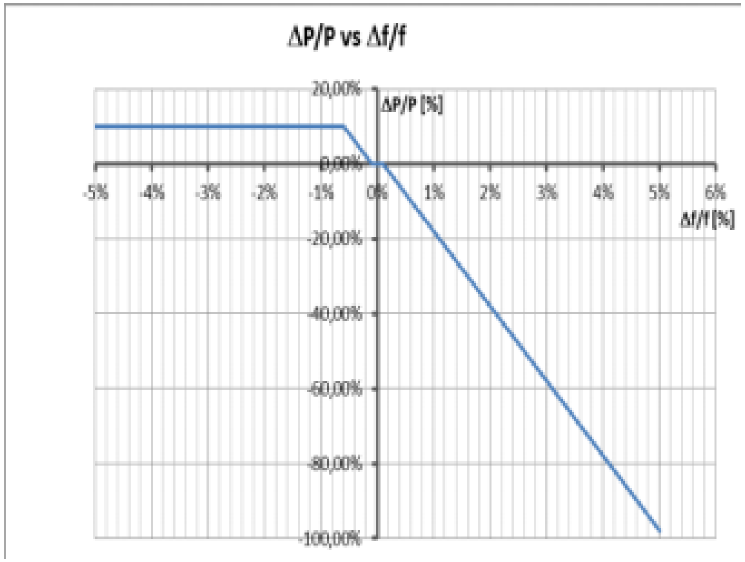


Depending on the technology of the WTG this units could provide FFR/PFR without reserving Headroom, but with high dependency of wind speed.

Source: Understanding Inertial and Frequency Response of Wind Power Plants – NREL

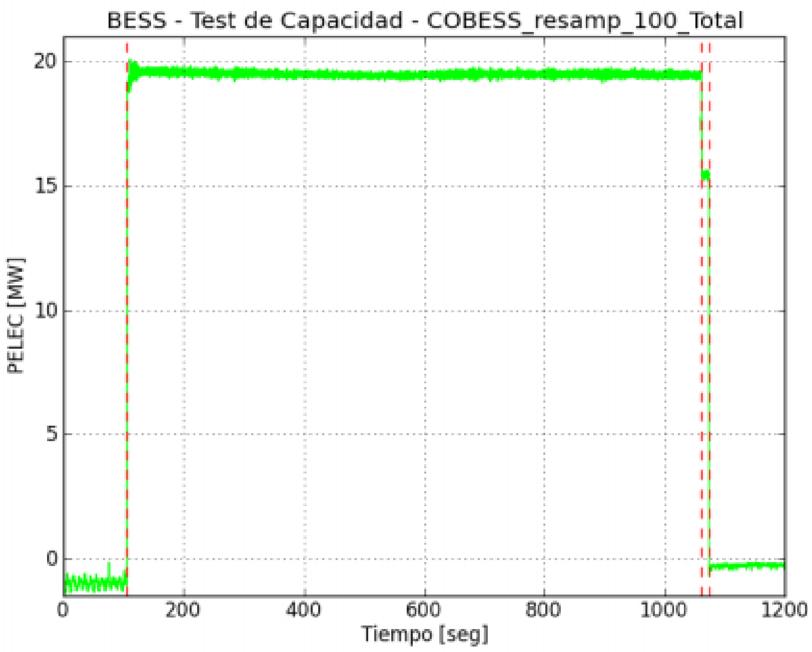
Batteries Energy Storage System (BESS)

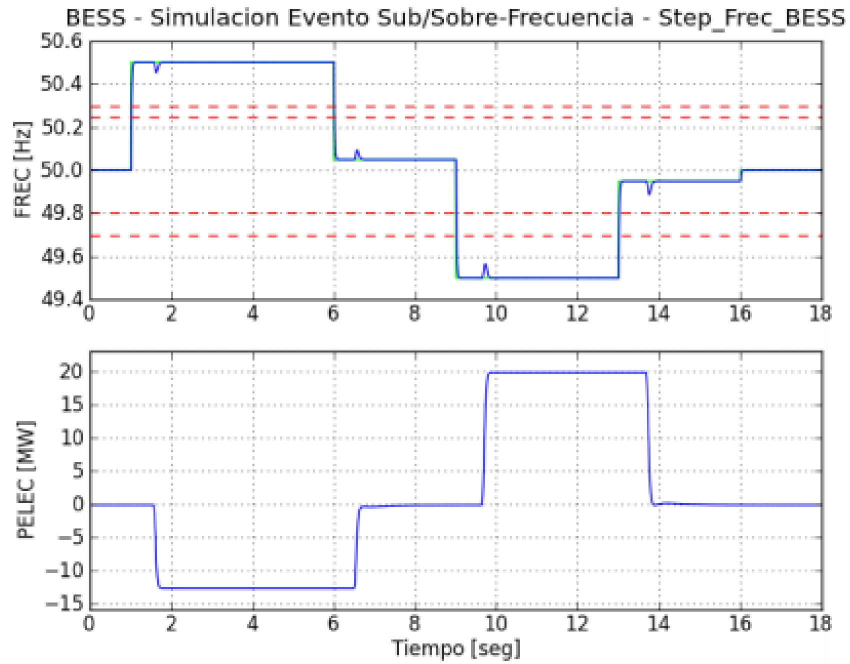
- BESS have the capability to respond against frequency changes, this response can be through a droop control or through a pick up regarding its frequency settings.
- These technologies can have autonomous response, or be controlled through an ISO signal if its required.



Batteries Energy Storage System (BESS)

- FR provided in less than 500 ms
- BESS responds in over and under frequency events



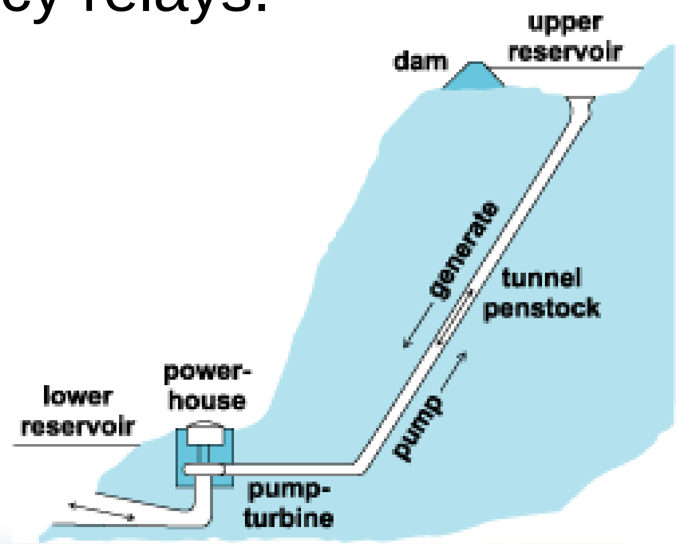


Source: Model Homologation Report - BESS Power Plant Cochrane – AES Gener Chile

Pump Storage Hydro

- Pump storage hydro can provide PFR in different ways, depending on the operation mode.
- If the unit is generating, can provide PFR through its governor control.
- If the unit is pumping, could provide PFR by losing its pumping load with under-frequency relays.

Can it provide PFR through modulated load shedding response that could be similar to a droop response?



Source: The Silver Creek Pumped Storage Project

Demand Response

- Load usually provides frequency response based on under-frequency relay technologies. This could impact its proportional response to frequencies greater than their pick up.
  - Could load perform on a proportional response? What types of devices should be implemented?
- Load characterization allows industries to detect non-critical process that can be stopped for short periods, and allows them to provide PFR.
  - Has the industry developed this type of study?

Take Aways

- ISO continues to believe there is no ground for excluding any technology types from any future frequency response product

- ISO believes that governor and inverter frequency control devices can be programmed to provide proportional response and proportional decline of response as frequency stabilizes

- ISO will consider input on its questions as to whether pumped storage and demand response controls would provide proportional response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PRIMARY FREQUENCY RESPONSE DESIGN OPTIONS

ERCOT

Primary Frequency Response Instantaneous proportional increase or decrease in real power output 12 to 14 sec to fully deployed	Attained to GOV response
	Arrest the Frequency Decay and re-set frequency closer to 60 Hz.
	Resources providing PFR must be able to respond proportionally to frequency deviation
	Droop setting not to exceed 5% - Governor DB <= +/- 0.036 Hz
	Generators without PFR responsibility may have bigger DB
Fast Frequency Response Fully deployed within 30 cycles (0.5 seconds)	Increase the time to reach the frequency nadir and mitigate the RoCoF in the same period.
	Sustained for at least 10 minutes
	Needed in periods with low inertia.
	Requires PMU measurement.
	Mainly provided by demand resources
	2 trip setpoints: 59.8 & 59.7
Fast Responding Regulation Fully deployed within 60 cycles (1 second)	Must be able to be deployed up to 8 minutes
	Fast Resources e.g. Batteries
	Requires high speed data recorder for verification.
	Two modes of providing regulation service:
	Self deploy in response to locally sensed frequency deviation (over a prescribed dead-band)
	Response to special signal from ISO AGC
	Load can participate with percentages of responsibility according with frequency bands.

National Grid

Mandatory frequency response Report monthly basis costs and capability associated with providing the frequency response	Capability for all large resources (>100MW [>30MW in Scotland]) connected to the grid
	Generators instructed to provide the service must De-Load its energy provision to a level that at least can provide the amount of primary response required
	Holding payment and energy payment
Firm frequency response Market available to every market participant Can be bid from one to 23 months	Availability fee: a per-hour fee for the hours a generator will provide services.
	Window initiation fee: a fee awarded each time the generator provides firm frequency response.
	Nomination fee: a per-hour fee for each hour the units provides frequency response.
	Response energy fee: a per-MW fee for the frequency response actually provided.
Frequency response by demand management	Demand resources can apply each year to become frequency responders.
	Bilateral contracts with the NG to interrupt their supply should the system frequency fall below 49.7 Hz.
	Load must be shed within 2 seconds and remain offline for up to 30 minutes
	Minimum response of 3 MW
Enhanced frequency response Contracted on no more than 48 months, through a competitive tender process.	Respond in under 1 second and provide response for up to 15 minutes.
	Resources will be compensated on a per-MW basis, scaled by an availability factor determined by how accurately the unit followed the supplied response curve.

AEMO (Australia)

- The AEMO performs this procurement in real time only, FCAS are not procured in the day-ahead market.
- The registered resources will submit simultaneous bids for energy, regulation, and contingency reserves. AEMO co-optimizes these bids to create six different clearing prices for contingency market
- The MW amount that a unit can provide as frequency response is limited by the MW amount of energy the unit is generating at as well as its droop's technical parameters.
- All units are paid at the marginal bid.

	Raise	Lower
Fast contingency FCAS	6 second response to a major drop in frequency sustained for 60 seconds	6 second response to a major rise in frequency sustained for 60 seconds
Slow contingency FCAS	60 second response to a major drop in frequency sustained for 5 minutes	60 second response to a major rise in frequency sustained for 5 minutes
Delayed contingency FCAS	5 minute response to a major drop in frequency sustained indefinitely	5 minute response to a major rise in frequency sustained indefinitely

50 Hz (Germany)

- Deployment of activated primary control reserve (PCR) has to be realized within 30 seconds
- PCR is procured in weekly tenders that means that successful offers of PCR have to be able to guarantee a provision over a weekly period.
- Outcomes will reflect capacity price merit-order
- The minimum bid amount is 1 MW
- PCR will be paid as bid, considering only provision, the energy is not getting payed separately
- PCR is considered a symmetric product
- Technical pre-qualification is required with physical evidence.


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NEXT STEPS

Next Steps

Stakeholders are asked to submit written comments by **February 23, 2017** to InitiativeComments@caiso.com.

ISO will host another working group meeting to present an initial straw proposal with options as result of this working group meetings discussion and follow-up comments prior to releasing the straw proposal.

ISO will notice the next working group meeting and does not have a firm date at this time.

APPENDICES

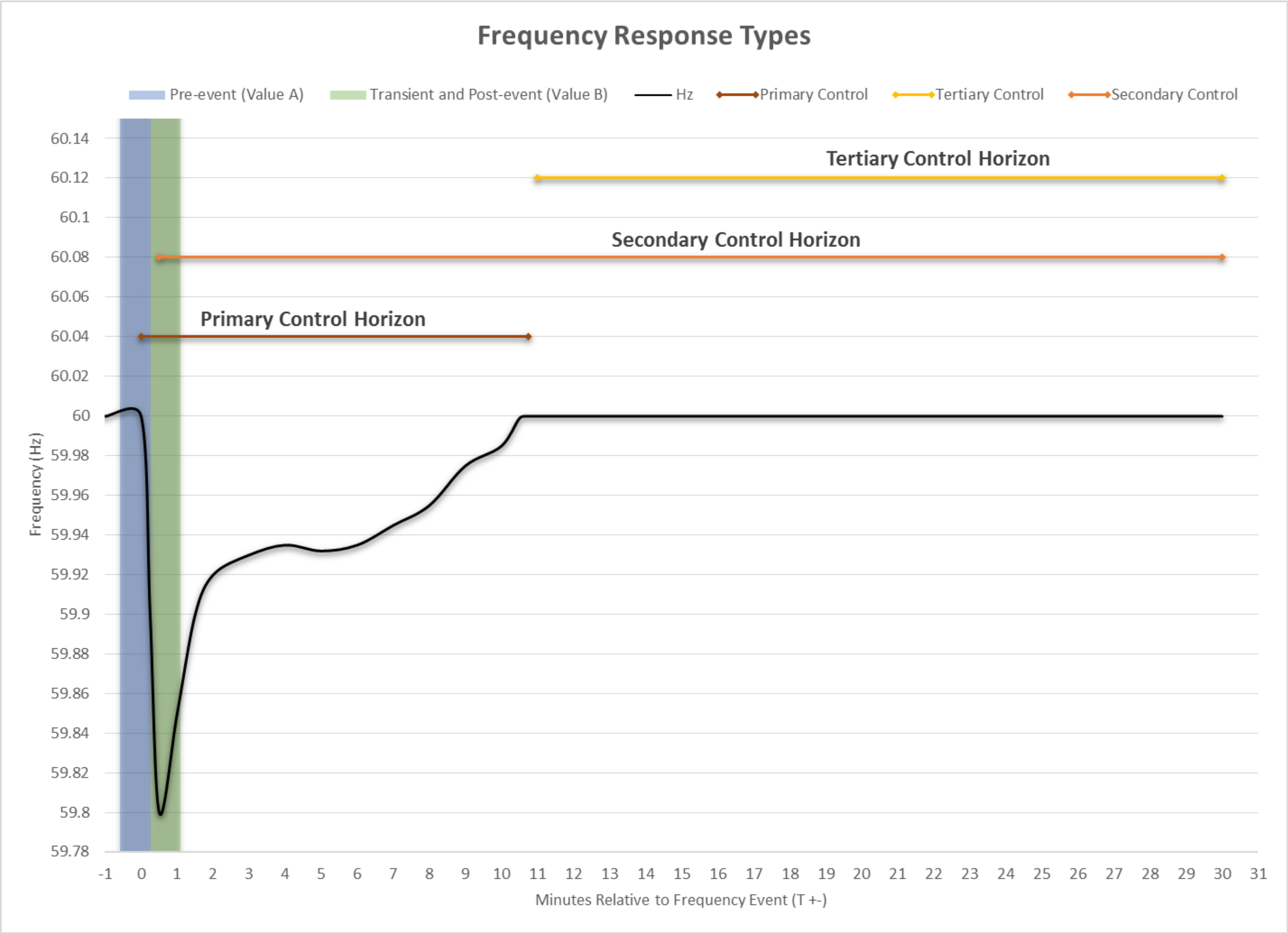
Frequency Control Stages

Frequency support - frequency control stages

NERC defines 4 frequency control stages:

- Inertia - Ability of a machine with rotating mass inertia to arrest frequency decline and stabilize the system
- Primary – automatic & autonomous deployment at unit
  - Fast primary – automatic & autonomous deployment at unit within matter of cycles after event
- Secondary – manual or automated dispatch from signal
  - Fast Secondary – dispatch from signal tuned to faster deployment than conventional secondary signals
- Tertiary – reconfigure reserves and dispatch generation

NERC frequency control stages



Categories of Operating Reserves and Frequency Control

Frequency Control Categories

Table 2: Frequency Control			
ERS Element	**Definition**	**Type of Service**	**Response Time**
Primary FC	Automatic and autonomous response to frequency variations through a generator's droop parameter and governor response.	• Local frequency sensing • Provided through generator governor control • Can be provided through deliberate control of electronically coupled wind, solar, storage, and DR resources. • Less communication infrastructure • May include automatic load shedding.	t ~ seconds
Secondary FC	This is a service that returns frequency to nominal value and minimizes unscheduled transient power flows due to power imbalance between neighboring control areas.	• Centralized within control centers through AGC • Significant communication infrastructure • Typically provided by generation but some DR can provide this service.	Slower than Primary Primary < t > 15 minutes

NERC Essential Reliability Services Task Force Concept Paper, 2014, Page 6

Operating Reserves Categories

Table 1: Operating Reserves Categories	
	Description and Operation
Regulation	• Used to manage the minute-to-minute differences between load and resources and to correct for unintended fluctuations in generator output to comply with NERC's Real-Power Balancing Control Performance Standards (BAL-001-1, BAL-001-2)
Load Following	• Follow load and resource imbalance to track the intra- and inter-hour load fluctuations within a scheduled period
Spinning Reserve	• On-line resources, synchronized to the grid that can increase output in response to a generator or transmission outage and can reach full output within 10 minutes to comply with NERC's Real-Power Balancing Control Performance Standards (BAL-001-1, BAL-001-2) • Usually utilized after a contingency • Generally provides a faster and more reliable response • VERs may be non-spinning, but can be utilized as spinning reserves
Non-Spinning Reserve	• Similar in purpose to spinning reserve; however, these resources can be off-line and capable of reaching the necessary output within 15 minutes • Usually utilized after a contingency
Supplemental Reserve	• Resources used to restore spinning and non-spinning reserves to their pre-contingency status • Deployed following a contingency event • Response does not need to begin immediately

NERC Essential Reliability Services Task Force Concept Paper, 2014, Page 4

Reliability Standards

BAL-001-2 Standard, Real Power Balancing Control Performance

- BAL-001-2 Standard, Real Power Balancing Control Performance
  - Control Interconnection frequency within defined limits
  - Requires operating so that Control Performance Standard 1 (CPS1) is above defined limit in prior 12 month period
  - Requires reported ACE does not exceed ACE limit for more than 30m

$$ACE = (NI_A - NI_S) - 10\beta(F_A - F_S)$$

BAL-002-WECC-2a Standard, Contingency Reserve

- R1 - contingency reserves requirement (BAL-002) Requires each BA to maintain a minimum ancillary service requirement that is the greater of either:
    - Loss of single most severe single contingency (G-1)
    - Sum of 3% of hourly integrated load plus 3% of hourly integrated generation
  - Amount of capacity must be deployable within 10m
- R2 - 50% of contingency reserves requirement must come from operating reserves that are spinning and that are:
  - Immediately and automatically responsive to frequency deviations through governors or other control systems
  - Capable of fully responding within 10m
- R3 – Any interchange transactions designated as operating reserve supplemental must be backed by addtl. Contingency reserves by sink BA
- Exception for first 60 minutes after needing to activate reserves

BAL-002-2

- New standard effective 1/1/2018
- ISO still reviewing the new standard
- Maintains policy that operating reserves should be frequency responsive

BAL-003-1 Standard, Frequency Response and Frequency Bias Setting

- R1 – achieve an annual performance measure (FRM) that is less than or equal to its frequency response obligation (FRO) to demonstrate sufficient frequency response to disturbances after an event where FRM is:
  - Change in net interchange actual between average value 20 – 52 seconds after an event and average value 16 seconds prior to the event
  - Median response across sample of events
- R2 – BA not receiving overlap regulation service using a fixed frequency bias setting consistent with NERC methodology in Area Control Error
- R3 – BA not receiving overlap regulation service using a variable frequency bias setting shall maintain setting less than zero at all times and less than or equal to BA FRO when frequency outside deadband 36 mHz
- R4 – BA performing or receiving overlap regulation service shall modify bias setting in ACE calculation to represent:
  - BA providing will report sum of bias settings for combined BAA
  - BA receiving will set setting equal to zero

BAL-003-1.1 sets performance obligation

- Primary objectives of the first requirement are:
  - Determine whether BA has sufficient frequency response for reliable operations
  - Provide feeder information needed to calculate control performance standard and frequency bias settings
- BA allocated share of interconnection obligation, which:
  - Protects against resource loss of 2 PV Units of 2,506 MW
  - Designed to limit excursion to a max drop of 0.292 Hz
  - Allocated based on share of generation and load

California ISO's Estimated Requirement	2017 FRO	Units
Western IFRO	858	MW/0.1Hz
Estimated ISO FRO (30% share)	258	MW/0.1Hz
Actual ISO FRO (22.9% share)	196	MW/0.1Hz

BAL-003-1 standard is for frequency response performance shows overlap of primary and secondary