Primary Frequency Response
BAL-001-TRE-2
ERCOT Region

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Agenda

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Primary Frequency Response – ERCOT

BAL TRE 001-2

Initial Primary Frequency Response:

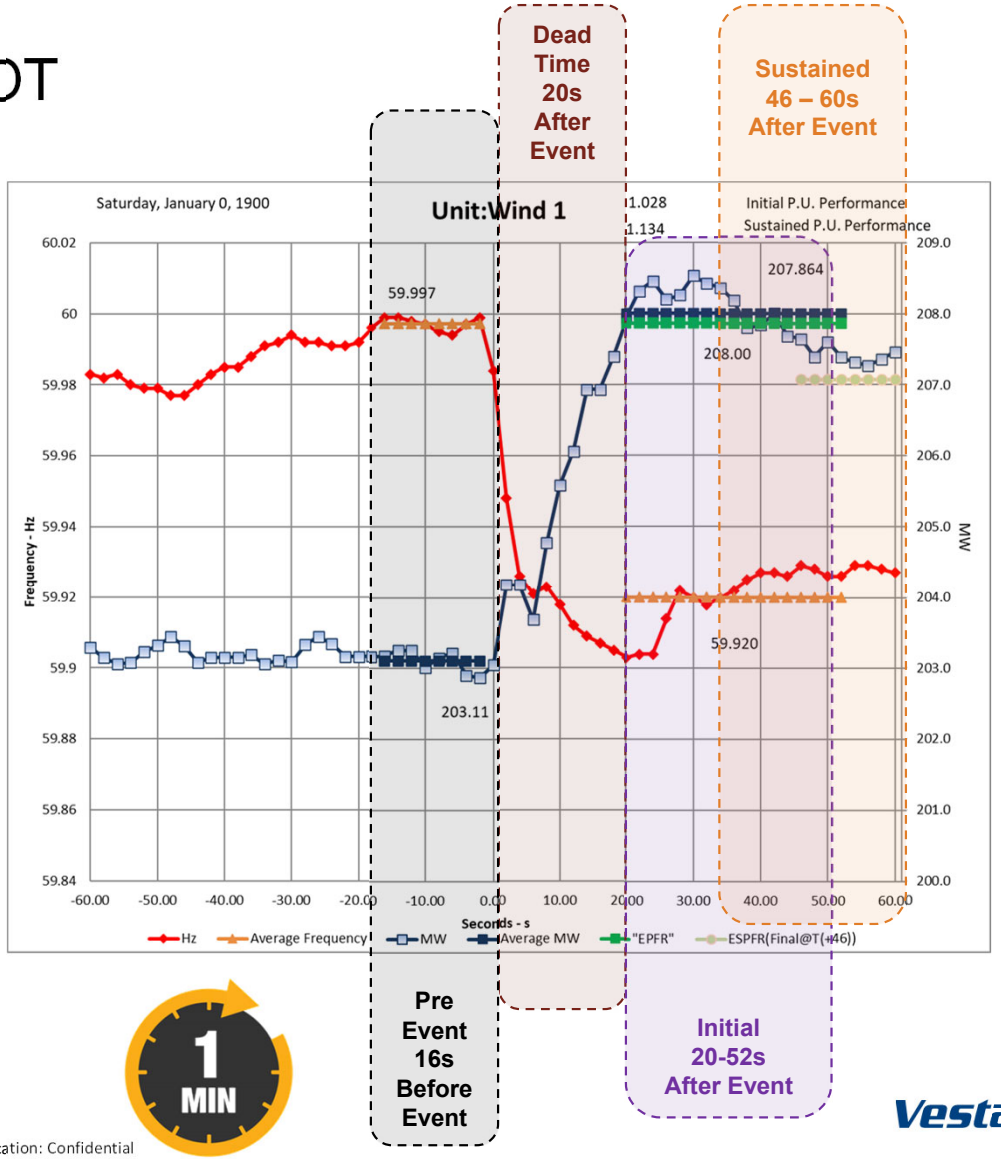
EPFR is the initial response of a generation resource or balancing authority to a grid frequency deviation, measured between 20 and 52 seconds after the disturbance.

The initial Primary Frequency Response performance shall be the ratio of the Actual Primary Frequency Response to the Expected Primary Frequency Response during the initial measurement period following the FME

Sustained Primary Frequency Response Calculations

ESPFR measures the sustained frequency response of a resource after the initial reaction, between 46 and 60 seconds.

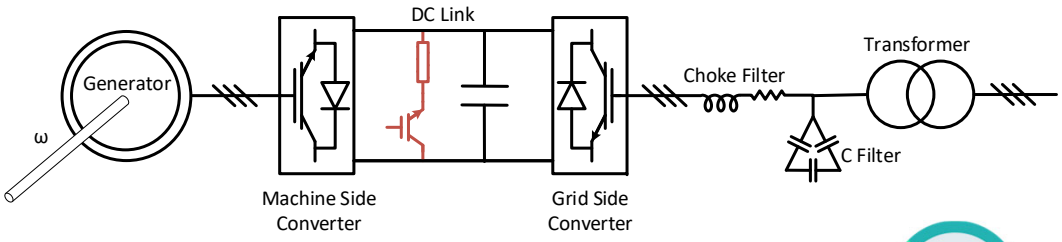
The Expected Sustained Primary Frequency Response (ESPFRfinal) is calculated using the actual frequency at T+46, HZT+46. This ESPFRfinal is the MW value a unit should have responded with if it is properly sustaining the output of its generating unit/generating facility in response to an FME.



Limitation # 1

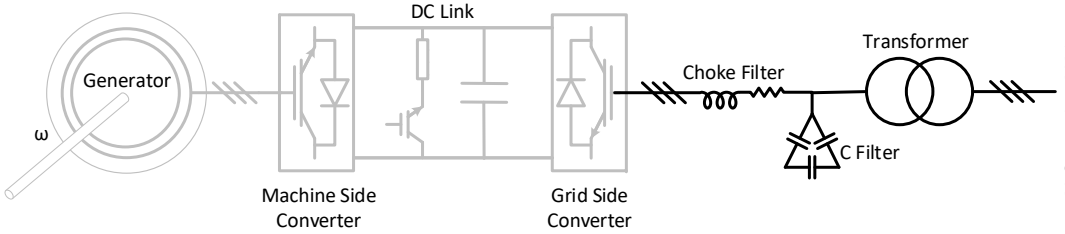
Under Frequency Event with High Wind and **No Power Production**

WTG Producing Power



- Generator might be fully stopped
- PWMs from Machine Side Inverter and Grid Side Inverter might have stopped
- DC Ling might be fully discharged

- Blades might have fully pitched out
- Yaw might not be at the optimal angle for power production
- Aux services might be off



WTG Stopped or Paused

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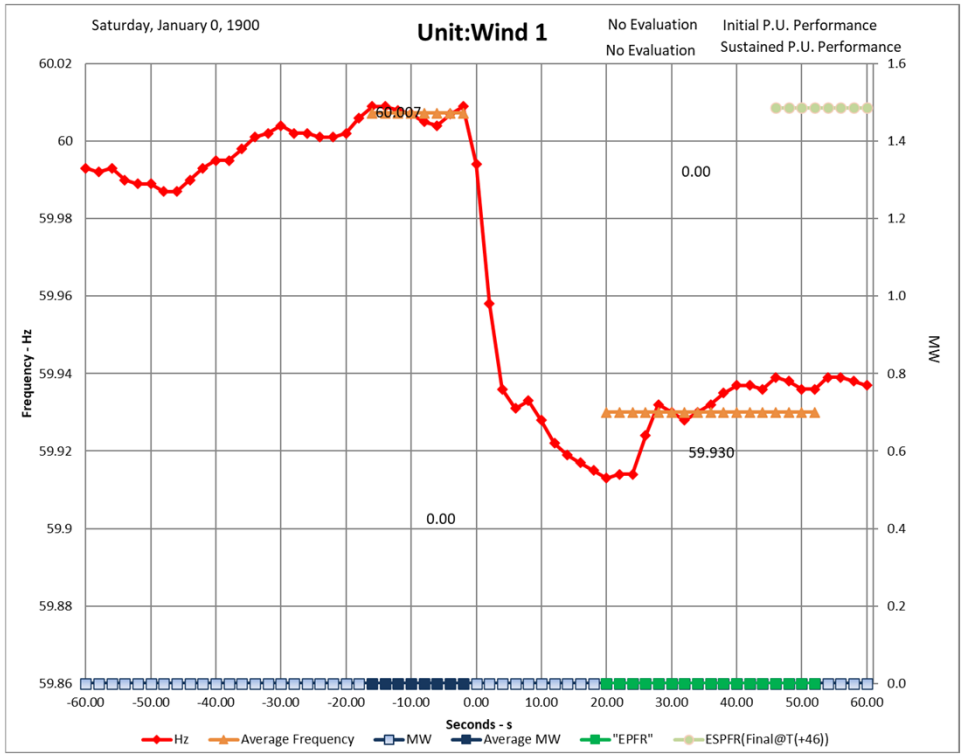
Vestas

Limitation # 1

Under Frequency Event with High Wind and **No Power Production**

- When the plant is fully curtailed (zero power production), all turbines are either paused or disconnected.
- High sustained limits might be 100% (or above zero) due to the available resource.
- IBRs (wind turbines) have a reaction time when turbines are paused.
- Quantifying reaction time is nearly impossible; it will depend on the state the turbines are in.
- Engaging mechanical systems might require several minutes.



Limitation # 1

Under Frequency Event with High Wind and **No Power Production**

Proposed Solution #1

Create a BAL-001-TRE-2 Primary Frequency Response (PFR) Responsibility Exclusion Process – Response Limitation

Operating Conditions	Response Limitation
Operation at or near auxiliary equipment operating limits	Boiler feed pumps transitions, condensate pumps, pulverizer operating limits or transition points, and forced draft fans limiting steam flow
Data telemetry failure	Due to telemetry failure, actual generator response data was not communicated to ERCOT
External system conditions impacting generator performance	Ambient Conditions • This should not include unit limitations due to seasonal ambient conditions as an alternative to updating the telemetered HSL sent to ERCOT • Temperature control overrides to protect against mechanical damage • Environmental constraints
Combined Cycle Configuration Transitions	• Transition to or from different combined cycle configurations such as 1x1 to 2x1 or vice-versa as well as other combined cycle configurations if there are more units. • Combined Cycle configuration changes does not change the Resource Status
Unit ramping transition points affecting Ramp Magnitude Calculations	• Unit did not continue to ramp in the gradient level of the pre-perturbation period after the event • Reached base load or lower ramping transition output levels prior to or during the event.
Other operating conditions	• Governor off/out of service (with evidence ERCOT was notified) • System stability limits • Control logic issues • Specific design conditions limiting responses • Weather related issues

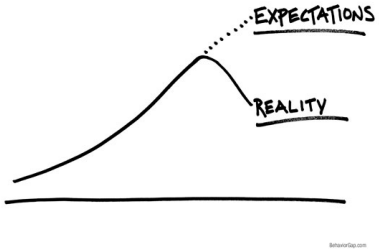
Proposed Solution #2

Separate HSL for Dispatching vs. PFR

Telemetry point for High Sustainable Limit (HSL) used for dispatch purposes should not be the same as the HSL used for Primary Frequency Response (PFR) or Fast Frequency Response (FFR).

Realistic PFR Expectations:

HSL for PFR must account for NTON turbine generation resources to provide a realistic expectation of PFR support from Inverter-Based Resources (IBR), such as wind turbines.



High Wind

HSL: Installed Capacity

HSL (PFR): Zero

Limitation # 2

Over Frequency Event with Low Power Production (due to wind or curtailment)

- Wind Turbines have a technical minimum controllable operating point. This point might range from 5 -30% depends on the manufacturer and turbine technology (Type III or IV)
- Most Power Plant Controller will dispatch TSO/ISO setpoints/curtailment evenly among all generating units.
- Power Plant Controllers will pause or disconnect any generation unit that is outside its controllable active power range.
- Theoretically. Wind Farm could be controlled by having n-1 WTG Paused/Disconnected and 1 WTG operating at TM. Control Range would be from (HSL x TM)/n – HSL (considering losses, virtually from 0MW- HSL)

*100 Wind Turbines of 5 MW each – 500 MW Wind Farm. Each Wind Turbine has a Technical Minimum of 10% 0.5MW. Theoretically. Wind Farm could be controlled by having 99 WTG Paused/Disconnected and 1 WTG operating at TM. Control Range would be from 0.5MW – 500MW (considering losses, virtually from 0MW- 500MW)

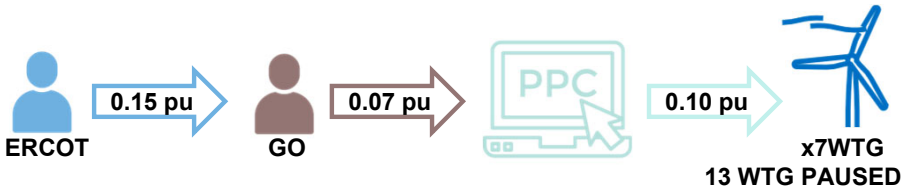
Assuming a Curtailment setpoint of 0.15pu and a **unit** Technical **Minimum of 10%** in a 20 WTG Wind Farm

An Over Frequency Event of **0.255 Hz** occurs in the system. Considering a **5%** slope as per Grid Code and 17mHz DB. A PFR reduction of around **0.08pu** is expected

Expected Power Production = P_Setpoint – PFR = **0.07pu**

Below Technical Minimum

7 WTG producing their TM (10%) and 8 WTG paused



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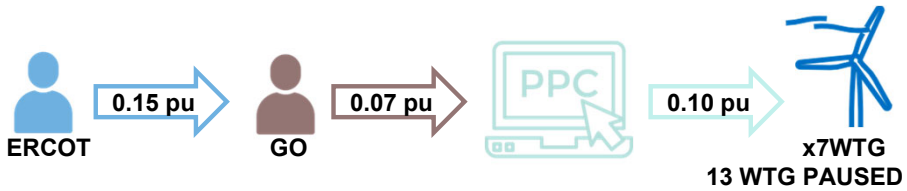
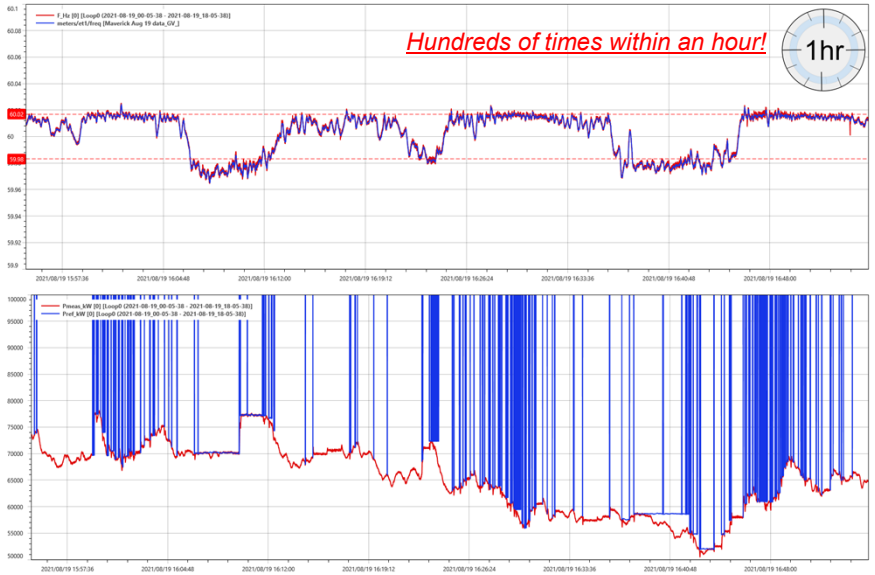


During the frequency event, a set of WTG will be paused. Once the frequency event is over. PPC will reconnect the paused WTG to go back to “normal”

But What IF this happens frequently!?

The above cycle will be repeated… But How often this might occur?



Limitation # 2

Over Frequency Event with Low Power Production (due to wind or curtailment)

Proposed Solution #1

Introduce a Low Sustained Limit above zero.

This is a proven solution available that can avoid the unnecessary pause and release of turbines when the wind farm is close to the collective technical minimum of individual turbines

Therefore, PFR will regulate from LSL to HSL. Being LSL the summation of Technical Minimum of each generation unit.

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Expected Power Production = P_Setpoint – PFR = **0.07pu**

Below Technical Minimum

ALL WTG running at their TM

Above Expected PFR

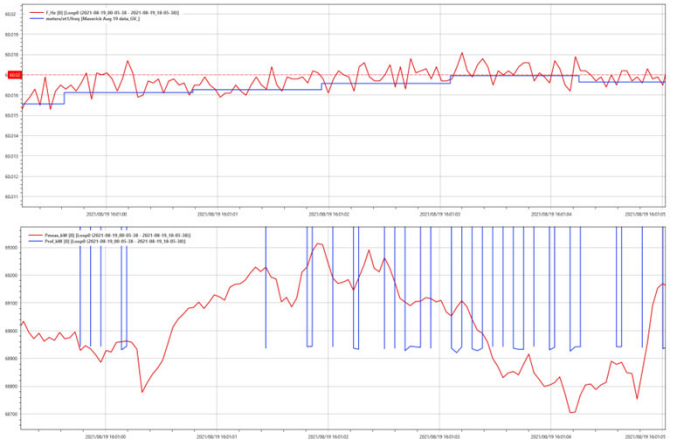
Limitation # 2

Over Frequency Event with Low Power Production (due to wind or curtailment)

<u>Proposed Solution #2</u>

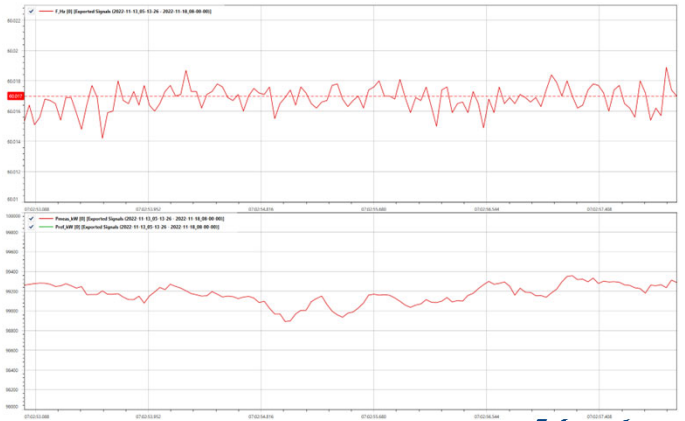
Introduce a “filtered” or “counter” frequency response.

- This will maintain the PFR full spectrum from 0% to full HSL active power but will slightly delay/ignore the response of PFR.
- According to current BAL TRE 001-2. Frequency events will be only evaluated after a 20s dead time.
- However, as per today requirements. Filter or delay frequency signal to calculate PFR is not permitted by ERCOT



No Filter/Delay

Vestas Solution for F “filtering”



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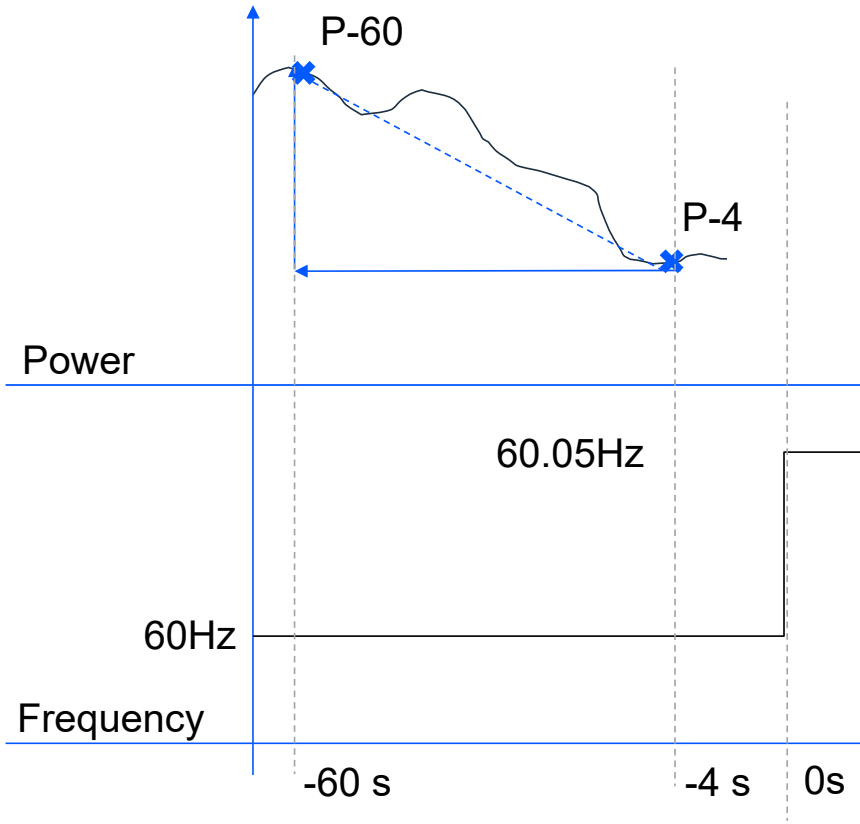
Improvement #1

Remove Inertia Adjustment Factor for IBRs



$$P.U.PFR_{\text{Resource}} = \frac{\text{Actual Sustained Primary Frequency Response}_{Adj}}{\text{Expected Sustained Primary Frequency Response}_{final}}$$

$$APFR_{adj} = MW_{post-perturbation} - MW_{pre-perturbation} - Ramp\ Magnitude$$

$$EPFR_{post-perturbation} = \left[\frac{(HZ_{post-perturbation} - 60.0 - deadband_{max})}{(60 \times droop_{max} - deadband_{max})} \times (-1) \times (HSL - PA\ Capacity)\right]$$

- When DeltaP >> RampP (Large Frequency Error), Score is typically high
- When RampP trend favors PFR, Score is typically high
- When DeltaP ~ or < RampP (Small Frequency Error), Score is low

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