# **DWG Questions and Comments on NPRR-815 Studies**

**Table 1 on Page 3 (Study Document) / Slide 6 (Presentation)**

1. Please explain the calculation/formula for the 1150 MW PFR Minimum.  Is the Interconnection Frequency Response Obligation (IFRO) of 381 MW/.1Hz multiplied by three (to the LaaR 59.7 Hz setting) then rounded up from 1143 MW?

Response:

Yes. Based on the interconnection IFRO, Minimum PFR is calculated as 381MW/.1Hz\*0.3Hz =1143 MW and rounded up to 1150 MW.

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| --- | --- | --- | --- | --- | --- |
| **Table A1: Recommended IFROs for Operating Year 2017** | | | | | |
|  | **Eastern (EI)** | **Western (WI)** | **Texas (TI)** | **Québec (QI)** | **Units** |
| **IFRO** | **‐1,015** | **‐858** | **‐381** | **‐179** | **MW/0.1Hz** |

For additional details about the IFROs, please refer to the imbedded report below.



1. Is it correct to apply the ERCOT IFRO of 381 MW/.10 Hz in such a way as to maximize the use of load resources when the IFRO has already been adjusted for load resource use?

Response:

The combination of minimum PFR and Load Resources (LRs) triggered at 59.70 Hz is designed to keep the frequency above 59.40 Hz for a loss of 2750 MW. The minimum PFR requirement ensures that minimum 1150 MW of RRS will be provided by Generators, the remaining amount can be provided by Generators and Load Resources.

1. Please explain the calculation/formula for the PFR requirement without LRs.  Or was this the PFR amount, empirically determined from simulation, necessary to prevent frequency from dropping below 59.4 Hz for each of the different inertia levels?

Response:

PFR without LRs is the amount of RRS-PFR needed when all of the RRS is provided by PFR (RRS Gen) and is derived using results from Dynamic Simulations. For example, in Case 2, if all RRS was provided by Generators, a total of 5200 MW of RRS is needed to prevent frequency from dropping below 59.40 Hz for loss of 2750 MW. Following explains how PFR without LRs is determined.

1. Dynamic Simulations show 1150 MW of PFR and 1841 MW of LRs are necessary to keep frequency just above 59.40 Hz.
2. PFR (without LRs) = 1150 + 1841\*2.2 = 5200 MW; 2.2 is the Equivalency Ratio between PFR and LRs, it indicates that 1 MW LRs is equivalent to 2.2 MW of PFR in terms of the effectiveness of preventing frequency from dropping below 59.40 Hz because of the speed at which LRs are deployed.



1. Please explain the calculation/formula for LRs (row 5).  Is this the amount of LaaR at 59.7 Hz equivalent to the PFR excess over 1150 MW?  Example column 1: 2638 MW of LaaR load shedding at 59.7 Hz is equivalent to 7350-1150=6200 MW PFR?

Response:

Yes that is correct. For Case1, the total amount of PFR needed without any LRs was 7350 MW. Out of this 7350 MW, 1150 MW is reserved as RRS Gen and 2638 MW of LRs can provide equivalent response for the remaining 6200 MW of PFR. Therefore, the combination of 1150 MW PFR on Gen and 2638 MW on LRs (total 3788 MW of RRS) is sufficient to keep the frequency above 59.40 Hz.

Dividing 6200 MW/2638 MW gives the Equivalency Ratio of 2.35 shown in row 3 of the table below.



1. Please explain row 3.  Why are the ratios in row 3 not equal to LRs / PFR ratio of row 5 to row 4?

Response:

For Case1, the total amount of PFR needed without any LRs was 7350 MW. Out of this 7350 MW, 1150 MW is reserved as RRS Gen and 2638 MW of LRs can provide equivalent response to remaining 6200 MW of PFR. Therefore, the combination of 1150 MW PFR on Gen and 2638 MW on LRs (total 3788 MW of RRS) is sufficient to keep the frequency above 59.40 Hz.

Dividing 6200 MW/2638 MW gives the Equivalency Ratio of 2.35 show in row 3 of the table below.

Row 3 provides the equivalency ratio relating the effect of 1 MW of LRs to 1 MW of PFR for an event when 2750 MW of generation tripped. Because LRs are more effective during lower system inertia condition, if 1 MW of LRs and 1 MW of PFR were to be procured then the net effect on frequency response would be equivalent to procuring 2.35\*1 + 1\*1 or 3.35 MW of PFR alone.

1. What is the maximum time delay of LR once the 59.7 Hz threshold is reached?

Response:

In the study, all LRs are assumed to have a 0.333 seconds of relay delay and 0.083 seconds of breaker action time. Therefore the total delay time for LRs is 0.333 + 0.083=0.416 second. This is explained in Table IV in the study report. In reality, the largest relay delay is 0.333 seconds and can be as low as 0.2 seconds.

1. Please give a brief discussion on the 13 cases in Table 1.

Response:

Case 2 thru Case 13 are real-time snapshots from Transient Stability Analysis Tool (TSAT). To study an even lower inertia condition than Case2, Case 1 was built from Case 2 by turning off some of the online units that contribute inertia. Case 1 represents the potential lowest inertia condition (100 GW\*s).

1. How did you determine the PFR requirement? In the conference call, you mentioned that for this, there are no LRs. Trip 2750 MW generation, to see how many generators with active governors are needed to make the frequency nadir just above 59.4 Hz. Is this right?

Response:

See response to Questions 1 & 3 above.

1. How is the LRs/PFR ratio calculated? In case 2, LRs is 1841 MW, PFR requirement is 5200 MW. Why is the ratio only 2.2 (5200/1841=2.8)?

Response:

See response to Questions 3, 4 & 5 above.

1. Which specific generators were tripped that total 2750 MW? How would tripping other generators affect the results which determine the minimum PFR from generators? What would happen if generators that carry PFR capabilities were tripped?

Response:

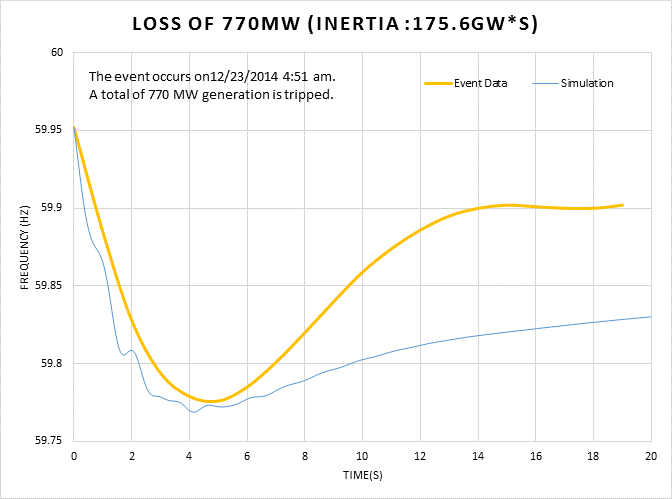
The criteria for procuring RRS is based on Resource Contingency Criteria (RCC) as defined by NERC, for ERCOT loss of 2750 MW (two STP Nuclear units) reflects the RCC. ERCOT protocols prohibits nuclear units from providing RRS.

**Overshoot study**

1. Has there been any benchmarking of simulated governing response on over-frequency to an over-frequency event?

Response:

ERCOT routinely bench marks TSAT cases against the system events (one example of such a study is shown below). For the purpose of studying RRS requirements for under frequency events, real-time TSAT cases were used. Selected TSAT cases were verified to ensure the frequency response was either similar to or worse than actual events so that estimated RRS requirements were conservative. ERCOT has not benchmarked TSAT performance for over-frequency events because there were no suitable (large enough) over-frequency events against which the case’s response could be benchmarked.

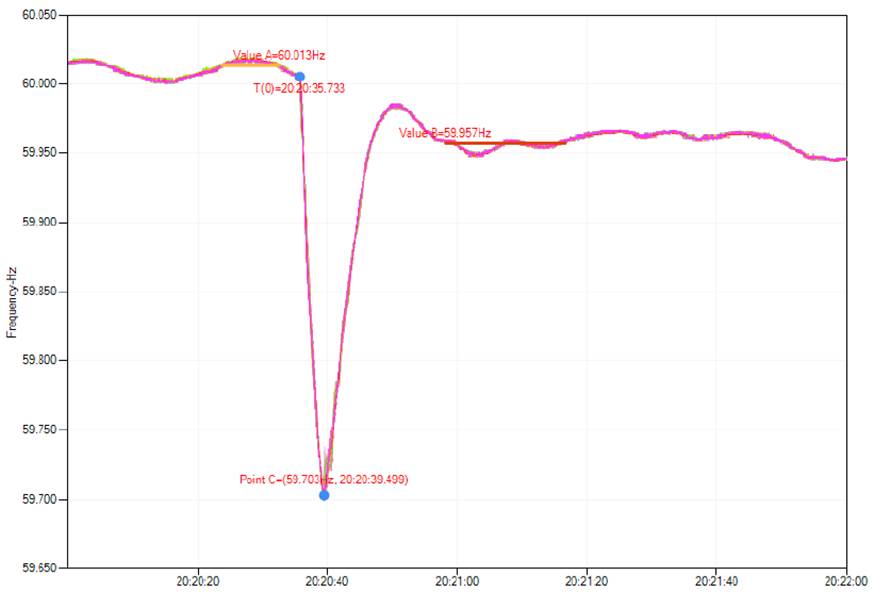


1. Please provide PMU frequency records and analysis of any LaaR activation events in recent past.  What was the difference, if any, between expected and actual LaaR tripping?

Response:

Included below is PMU frequency plot from a frequency event on May 1, 2016 caused by 1311 MW unit trip that resulted in activation of LRs. LRs providing RRS are required to set their under-frequency relays no lower than 59.70 Hz, so some portion of load resources are set at frequency slightly higher than 59.70 Hz and their response avoid tripping all the LRs. Not only are the frequency set-points slightly different but the delay settings are also slightly different. On top of that there is some sensitivity to where the Loads are located (e.g. Far West versus Coast Weather Zone, transmission connected vs distribution connected). During this event we had 1323.1 MW that were providing RRS-LRs, 927.1 MW of LRs carrying RRS tripped and 9.1MW of LRs were not awarded RRS tripped.

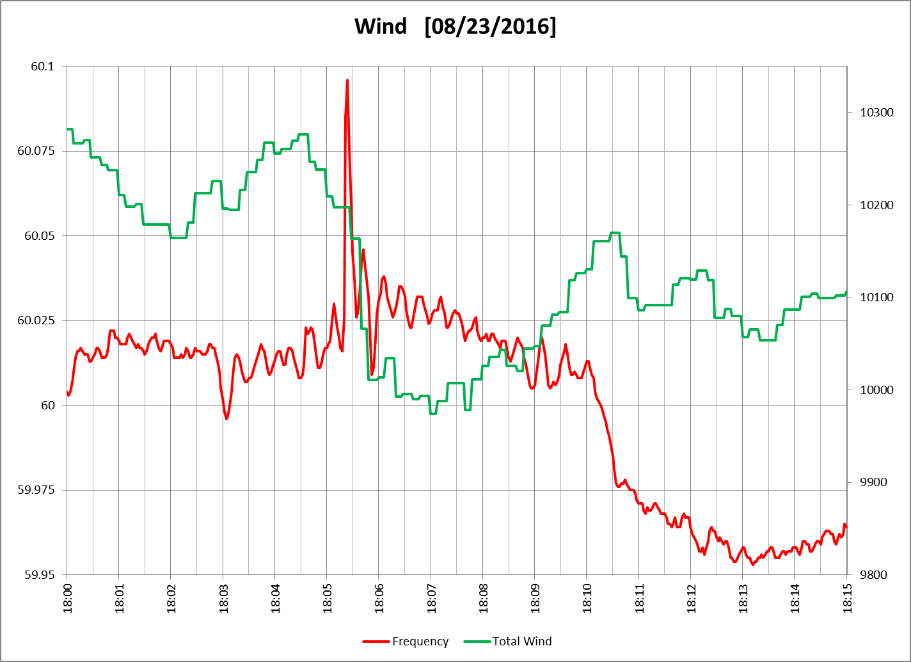
ERCOT’s simulation studies assume all LRs providing RRS to have a 0.333 seconds of relay delay and 0.083 seconds of breaker action time. This assumption of all LRs having the same delay and the same frequency trigger level would result in higher magnitude of LRs tripping compared to actual response due to their slightly different settings in actuality. Also, please note that in the studies all governors except the ones providing minimum RRS-PFR are turned off.

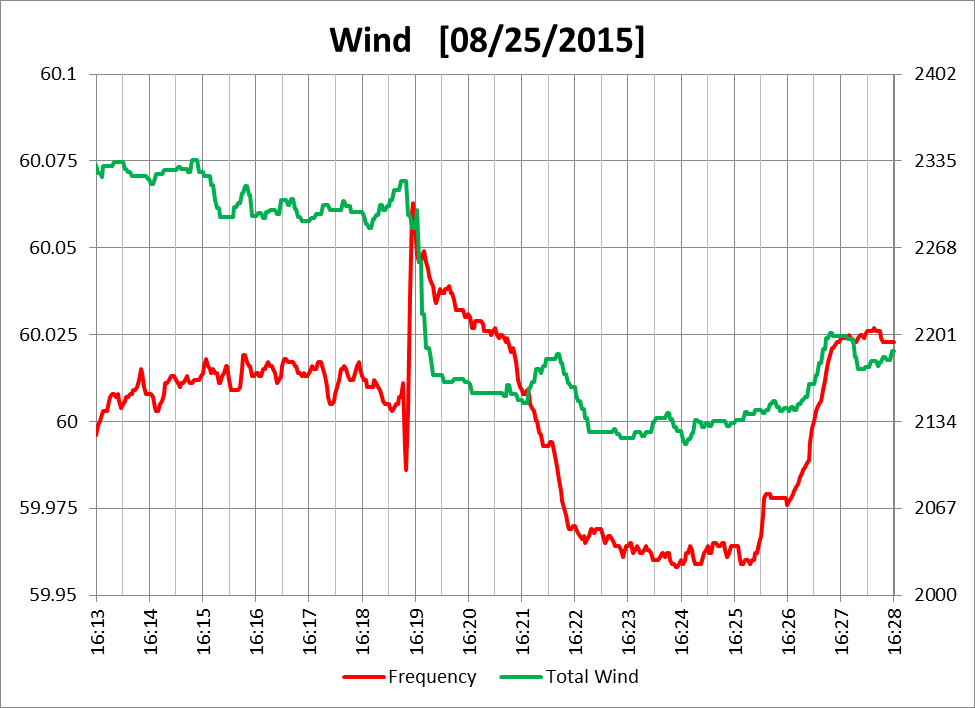


1. What is the confidence level that all on-line generators, including 80 percent of wind and solar, respond to high frequency conditions by decreasing power according to 5 percent droop?

Response:

Generators including Wind Resources are not limited by their headroom when responding to high frequency response. While high frequency events do not occur as often, ERCOT in conjunction with PDCWG reviews primary frequency response of all online generators for every high frequency event. Included below are charts depicting response from Wind Generation Resources to two recent high frequency events.





1. Could the decrease of PFR to a minimum level allowing for greater LaaR amounts possibly result in more frequent activation of LaaR?

Response:

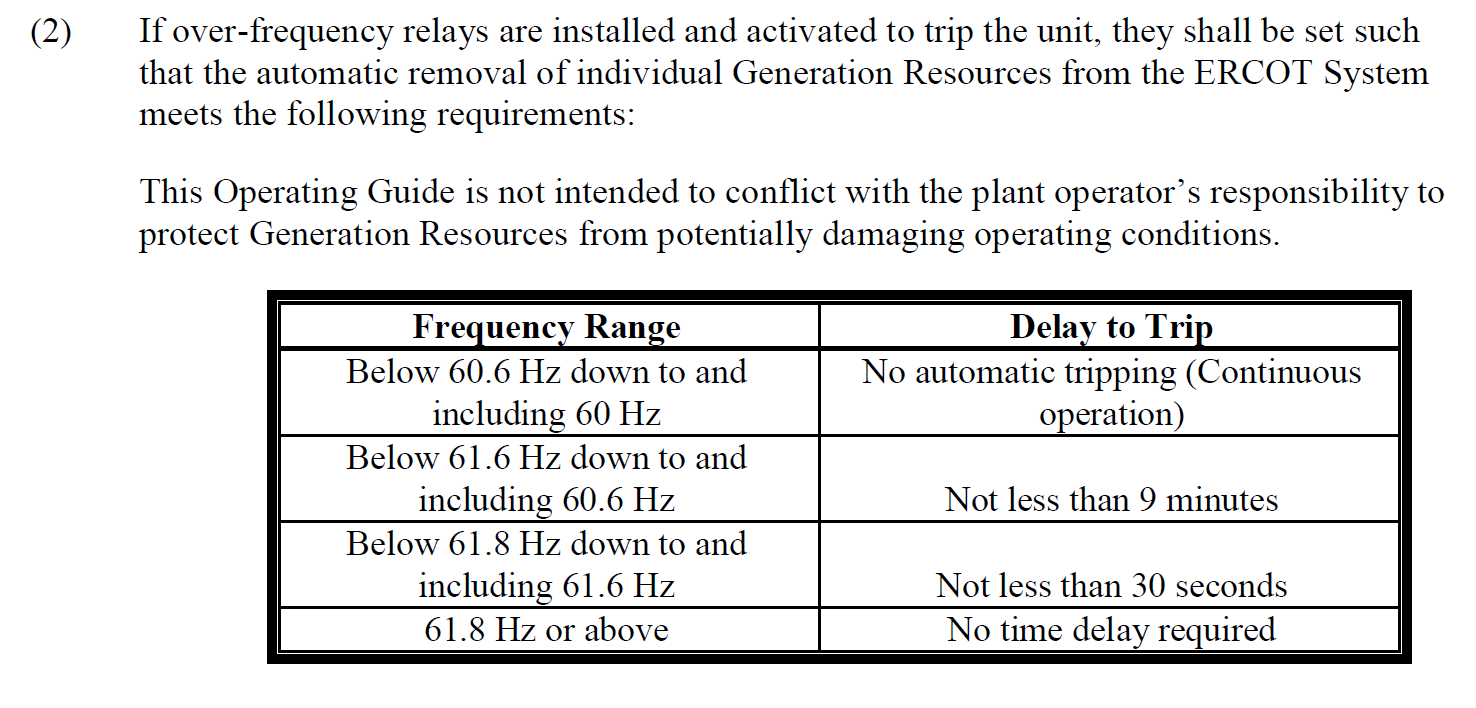
LRs response is more a function of the size of unit loss and the system inertia. Based on the overshoot study, LRs would generally only be activated for unit trips greater than 985 MW at low inertia conditions, and a larger unit trip would be required during higher inertia conditions to trigger these; such trips are rare. LRs are designed to respond if system frequency stays below 59.70 Hz for more than 20 cycles. The Operating Guide requirement allows for a breaker opening time of up to 10 cycles for a combined response of no more than 30 cycles. The combination of minimum PFR (1150 MW) and LRs triggered at 59.70 Hz is sufficient to keep the frequency above 59.40 Hz for a loss of 2750 MW. ERCOT does not design its minimum PFR requirements to avoid tripping LRs. Historically, events that cause frequency to drop to 59.7 Hz are not common and are sufficiently large to trigger LRs deployment with or without the changes proposed by NPRR-815.

1. Did you use 60.6 Hz as the threshold instead of 60.4 Hz?  Shouldn’t we leave some margin?

Response:

Operating Guide Section 2.2.6 below requires Generators with over-frequency relays to meet the requirement below. ERCOT did not add a margin, because of the time delay associated with generator tripping if frequency exceeds 60.6 Hz. The max RRS requirement for 2017 is 2808 MW. The minimum RRS Gen requirement from Generators automatically enforces a limit on how much LRs can participate. If 50% limit were to be removed for 2017, LRs would be limited to slightly below 59%. See below for 2017 minimum ancillary service requirements.

[ERCOT Methodology for Determining Ancillary Service Requirements](http://www.ercot.com/content/wcm/key_documents_lists/89135/ERCOT_Methodology_for_Determining_Ancillary_Service_Requirements.zip)



1. In this study, you identify 985 MW generation loss is what is needed to cause the system frequency drop below 59.7 Hz. Then you use 985 MW generation loss for all the studies. Is this understanding right? If yes, we would like to see what happens if 2750 MW generation is lost. We would expect the frequency nadir goes lower and more LRs are tripped, which will cause the overshoot to be higher.  Is there a relationship between frequency nadir and the amount of activated LRs?

Response:

In the overshoot study we identified that loss of 985 MW would be enough to cause frequency to reach 59.70 Hz to trigger tripping of LRs and lead to a high frequency overshoot. The frequency results in the study report shows the trend of overshoot for all scenarios where 2200 MW, 2400 MW and 2638 MW of LRs tripped. That was the maximum LRs that was modeled in the case. If we consider 2750 MW trip then there would be no overshoot concerns.

1. The overshoot is mainly caused by LRs, but the generator governor also has some effects on it. Do you have a way to separate the effects of LRs and governors?

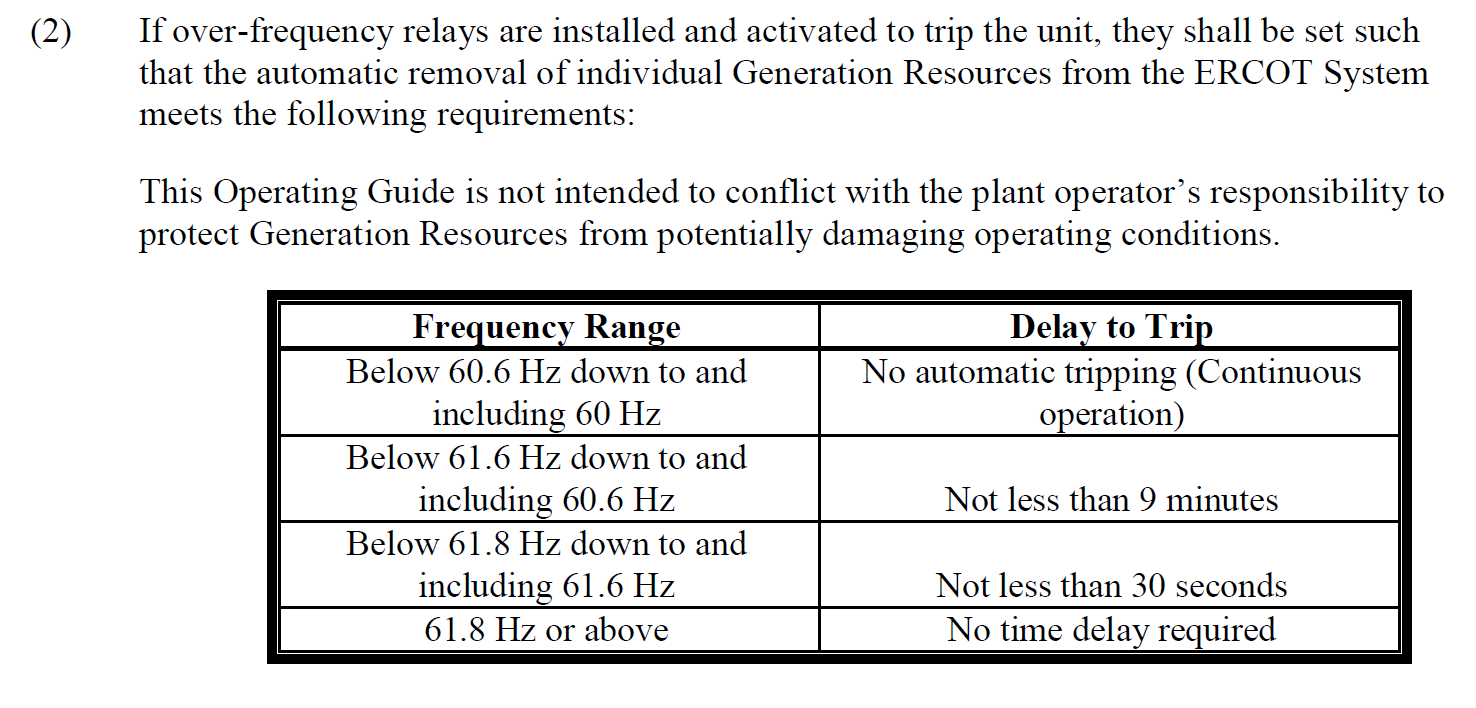
Response:

Governor response would be proportional to the frequency deviation; it would not contribute to the overshoot.

1. On page 7, it is mentioned “this conclusion is conservative from two aspects.”  We do not fully understand aspect 2. In the simulation, the generators should not be tripped if the frequency is less than 60.6 Hz, which is the same as the real generator over-frequency setting.  Why does it make the results more conservative?

Response:

Generators over-frequency trip settings has to meet at a minimum the requirement below from the Operating Guide Section 2.2.6. ERCOT study criteria were designed for frequency overshoot to not exceed 60.60 Hz post LRs activation. The overshoot study that ERCOT conducted had frequency stay below 60.40 Hz. Beyond 60.60 Hz, the Generators are required to continuously operate for at least 9 minutes.



1. What is the connection between the Minimum Requirement of RRS study and Frequency Overshoot Study?

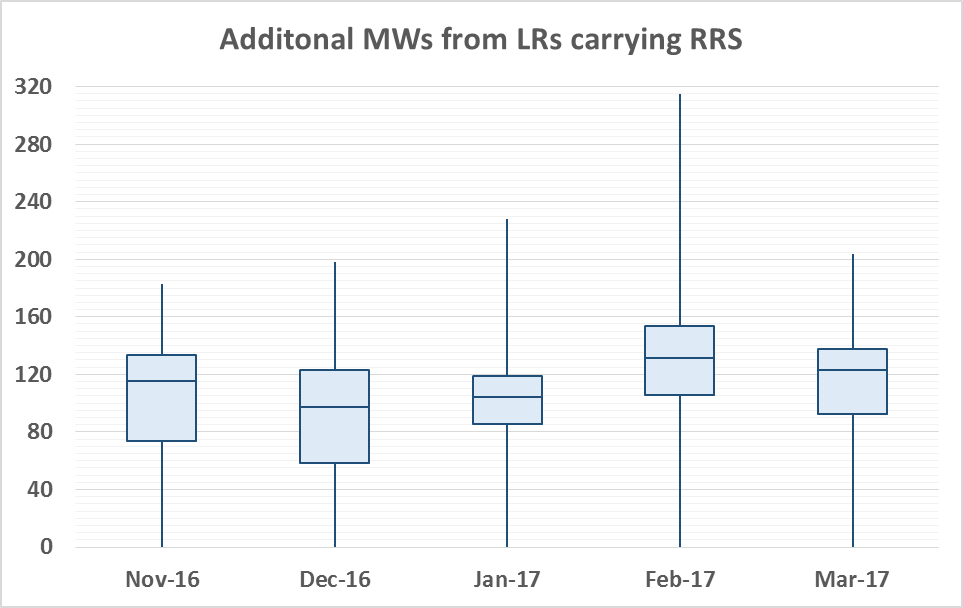
Response:

The RRS studies provides guidance on combination of Generation RRS and the RRS provided by LRs to keep the frequency nadir above 59.40 Hz. The overshoot study uses the same case to see if there is overshoot concern if a smaller unit trip causes LRs to trip.

1. It was shown that 4095 MW is needed with an inertia of 100 GW\*s to bring the frequency overshoot to 60.6 Hz. How close is 4095 MW to the actual number of LR’s qualified to provide RRS?

Response:

The sum of maximum interruptible load that is registered for every qualified Load Resource is about 4230 MW. The chart below shows the additional load that would be activated/tripped above and beyond this RRS contribution from Load Resources.



1. Regarding the modeling of LR’s, is it realistic to assume that all LR’s would trip with the same time delay or at the same frequency level?

Response:

LRs providing RRS are required to set their under-frequency relays no lower than 59.70 Hz, so some portion of load resources are set at frequency slightly higher than 59.70 Hz and their response avoid tripping all the LRs. Not only are the frequency set-points slightly different but the delay settings are also different. On top of that there is some sensitivity to where the Loads are located (e.g. Far West versus Coast Weather Zone, transmission connected vs distribution connected). The assumption of all LRs having the same delay and the same frequency trigger level in the study would result in higher frequency overshoot than would be expected in reality; as a result, the study provides conservative results for frequency overshoot assessment.

1. Which specific generators were tripped that total 985 MW? What would happen if generators that carry PFR capabilities were tripped?

Response:

The 985 MW total trip was simulated using Oak Grove Unit 1A (~840.5 MW) & Lamar Power Partners Combustion Turbine CT21 (~144.3 MW).

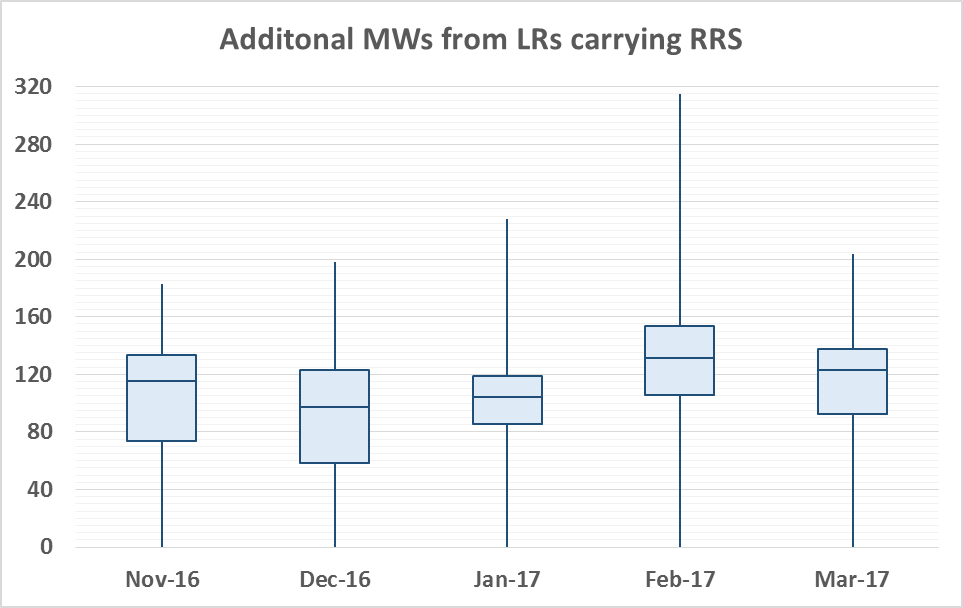
ERCOT maintains safety margin in its studies to account of potential loss of PFR capability. In the dynamic studies ERCOT maintains frequency at or above 59.40 Hz and keeps 0.1 Hz margin above the 59.30 Hz UFLS set-point. In the dynamic study case, ERCOT deactivates all the governor models other than the ones needed to carry minimum 1150 MW of PFR making the cases further conservative.

**General Comments/Questions**

1. A concern back in 2007 was that ERCOT protocol allows for load to shed up to 150% of their obligation. The DWG was worried about raising the percentage of load used for RRS due to frequency overshoot caused by 150% of committed load tripping.

Response:

ERCOT expects QSE’s to manage their portfolios after they receive their RRS awards and make sure that on a portfolio basis they don’t provide more than 150% of their obligation. That said, ERCOT tracks the additional load that would be activated/tripped above and beyond the RRS obligation from Load Resources. The box-plot below shows a trend of this excess capacity from Nov, 2016 thru Mar, 2017. On an average this value is around 120 MW.



1. We didn’t see any benchmarking done in the ERCOT study. Has ERCOT studied actual event data to analyze how the wind would perform for an under- or over-frequency event?  We did a lot of benchmarking and governor tuning in 2007.

Response:

See response to Question 11 above.

1. Should caution be taken regarding generator high frequency protection setting assumptions? We know from experience that generators sometimes don’t respond to events as simulated in off-line studies.

Response:

See response to Question 15 above.

The 2008 study and the recently updated study shows that frequency does not overshoot above 60.40 Hz allowing a healthy margin of 0.2 Hz from 60.6 Hz.

1. It would be interesting to study the high wind events (from LCRA’s NPRR-815 presentation) as a NERC Extreme event (since there has been only 2 in 21 years). Such an event would allow for RRS and UFLS.  The study would give us a glimpse of how the system would respond to an extreme but credible event. Would the system remain secure?

Response:

Wind Generation ramped down by approximately 1550 MW over a two hour period during the 2007 event (See: [Report for Event on February 24, 2007](http://www.ercot.com/content/meetings/ros/keydocs/2007/0315/07._ERCOT_OPERATIONS_REPORT_EECP022407_final.doc)). Dynamic studies are to help determine the need for RRS to protect against the rapid loss of generation, such as losing two largest units in a frequency event, not to study this type of ramp-down scenario that stretches overs hours.