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| NOGRR Number | [204](http://www.ercot.com/mktrules/issues/nogrr204) | NOGRR Title | Related to NPRR989, BESTF-1 Energy Storage Resource Technical Requirements |
| Date Posted | December 16, 2019 |
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| Requested Resolution  | Normal  |
| Nodal Operating Guide Sections Requiring Revision  | 2.2.5, Automatic Voltage Regulators2.2.7, Turbine Speed Governors2.2.8, Performance/Disturbance/Compliance Analysis2.2.10, Generation Resource Response Time Requirements2.3, Ancillary Services2.6.2, Generators2.7, System Voltage Profile and Operational Voltage Control2.7.1, Introduction2.7.2, Maintaining Voltage Profile2.7.3.2, ERCOT Responsibilities2.7.3.3, TO/TSP Responsibilities2.7.3.4, QSE Responsibilities2.7.3.5, Resource Entity Responsibilities and Generation Resource Requirements2.9, Voltage Ride-Through Requirements for Generation Resources2.9.1, Additional Voltage Ride-Through Requirements for Intermittent Renewable Resources3.3.2.1, Corrected Unit Reactive Limits (CURL)3.3.2.2, Reactive Testing Requirements6.2.6.3.4, Generator Protection and Relay RequirementsSection 8, Attachment C, Turbine Governor Speed TestsSection 8, Attachment J, Initial and Sustained Measurements for Primary Frequency Response |
| Related Documents Requiring Revision/Related Revision Requests | Nodal Protocol Revision Request (NPRR 989, BESTF-1 Energy Storage Resource Technical Requirements |
| Revision Description | This Nodal Operating Guide Revision Request (NOGRR), together with NPRR989, codifies concepts described in Battery Energy Storage Task Force (BESTF) Key Topics and Concepts #4 (KTC-4), which received consensus support at BESTF and were approved by the Technical Advisory Committee (TAC) at its November 20, 2019, meeting. This NOGRR establishes technical requirements for Energy Storage Resources (ESRs) in the following areas identified in KTC-4:* Reactive Power capability, including performance requirements during transient voltage disturbances, and testing criteria;
* Voltage ride-through requirements;
* Frequency ride-through requirements, and
* Governor Dead-Band and droop setting requirements.

More specifically, this NOGRR revises the Nodal Operating Guide as follows:* Revisions to Section 2.2.5 extend Generation Resource AVR testing and performance requirements to ESRs;
* Revisions to Section 2.2.7 extend existing Generation Resource Primary Frequency Response requirements, including dead-band and droop setting requirements, to ESRs;
* Revisions to Section 2.9 extend existing Generation Resource voltage ride-through requirements to ESRs and require ESRs to suspend charging during transient voltage disturbances to aid in voltage recovery;
* Revisions to Section 2.9.1 extend voltage ride-through performance criteria for Intermittent Renewable Resources (IRRs)—which are also inverter-based Resources—to ESRs;
* Revisions to Section 3.3.2.2 establish reactive testing performance criteria for ESRs comparable to those already in place for Generation Resources.
* Revisions to Section 8, Attachments C and J, establish PFR requirements and testing criteria for ESRs; and
* Revisions to other sections of the Nodal Operating Guide extend various existing Generation Resource requirements to ESRs.
 |
| Reason for Revision |  Addresses current operational issues. Meets Strategic goals (tied to the [ERCOT Strategic Plan](http://www.ercot.com/content/wcm/lists/144926/ERCOT_Strategic_Plan_2019-2023.pdf) or directed by the ERCOT Board). Market efficiencies or enhancements Administrative Regulatory requirements Other: (explain)*(please select all that apply)* |
| Business Case | This NOGRR establishes technical requirements for ESRs previously discussed at the BESTF and endorsed by TAC.  |

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| Market Rules Notes |

Please note that the following NOGRR(s) also propose revisions to the following section(s):

* NOGRR195, Generator Voltage Control Tolerance Band
	+ Section 2.2.10
	+ Section 2.7.3.4
	+ Section 2.7.3.5
* NOGRR196, Related to NPRR973, Add Definitions for Generator Step-Up and Main Power Transformer
	+ Section 2.9
	+ Section 3.3.2.1

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| Proposed Guide Language Revision |

***2.2.5 Automatic Voltage Regulators***

(1) A Resource Entity shall immediately notify its QSE and its interconnecting TO of any change in Automatic Voltage Regulator (AVR) status (i.e., AVR unavailability due to maintenance or failure and when the AVR returns to normal operation). A QSE shall immediately notify ERCOT of any change in AVR status and shall supply AVR status logs to ERCOT upon request per Protocol Section 6.5.5.1, Changes in Resource Status.

(2) Resource Entities shall conduct tests for the purpose of model verification on AVRs or verify AVR performance through comparison with operational data a minimum of every ten calendar years. All new Generation Resources and Energy Storage Resources (ESRs) shall conduct an AVR test as prescribed in paragraph (4) of Protocol Section 8.1.1.2.1.4, Voltage Support Service Qualification, within five years of the initial AVR test approved as part of the commissioning process. All subsequent tests shall be conducted on a ten year cycle. Additionally, if equipment characteristics are knowingly modified, an AVR test shall be conducted within 120 days of the modification. Industry accepted testing techniques shall be used for testing, measuring and calculating the modeling parameters. The test report must list the test(s) conducted or include the operational data used to verify the modeling parameters. Any models created from the test data must be a standard Power System Simulator for Engineering (PSS/E) dynamic model or ERCOT and Transmission Service Provider (TSP) approved user written model.

(a) Resource Entities will provide the test data or verified dynamic models to ERCOT by submittal to the Net Dependable Capability and Reactive Capability (NDCRC) application located on the MIS Secure Area or to the Resource Asset Registration Form respectively.

(b) All devices included in the AVR control system including but not limited to synchronous condensers, static VAr compensators, static synchronous compensators (STATCOMs), and switchable shunt reactive devices required to meet Protocol Section 3.15, Voltage Support, shall be included in the AVR test and set to regulate the transmission level voltage at the Point of Interconnection (POI).

(3) Resource Entities shall verify excitation systems model data upon initial installation, within 120 days of performance modifications, and a minimum of ten calendar years thereafter.

(4) An exemption may be granted for the testing requirements listed in paragraphs (2) and (3) above if the Resource on which the AVR or excitation system is installed has an Annual Net Capacity Factor (ANCF) of 5% or less over the most recent three calendar years preceding the planned testing calendar year. ANCF is calculated as follows:

**Annual Total Net Generation in MWHr/(Annual Hours \* Average Seasonal Net Max Sustainable Rating) \* 100%**

Wherein:

Annual Hours = Number of hours in the calendar year being reported. Hours in mothball or retired status are not included in the hour total;

and

Average Seasonal Net Max Sustainable Rating = Average of the Seasonal Net Max Sustainable ratings submitted via the NDCRC application located on the MIS Secure Area.

(a) At the end of this ten year timeframe, the current average three year ANCF (for years eight, nine, and ten) will be examined by ERCOT to determine if the exemption can be declared for the next ten year period. If no longer eligible for exemption based on the ANCF, then model verification must be completed within 365 calendar days of the date the capacity factor exemption expired. Under certain operating conditions, ERCOT may require a ten year test even if the current average three year ANCF is below the 5% threshold.

(5) Black Start designated units are not eligible for the ANCF exemption detailed in paragraph (4) above. If a Resource that had been granted an exemption detailed in paragraph (4) above is accepted for Black Start Service (BSS), the Resource has 365 days from the start date of BSS to submit modeling information detailed in paragraph (2) above.

(6) Generation Resource or ESR AVR modeling information required in the ERCOT Planning Criteria shall be determined from actual Generation Resource or ESR testing described in these Operating Guides. Within 30 days of ERCOT’s request, the results of the latest test performed shall be supplied to ERCOT and the TSP.

***2.2.7 Turbine Speed Governors***

(1) A Governor shall be in-service whenever the Generation Resource, ESR, or Settlement Only Generator (SOG) is connected to the ERCOT Transmission Grid.

(2) Generation Resources and ESRs that have not been evaluated in at least eight Frequency Measurable Events (FMEs) within 36 months shall conduct Governor performance tests within 12 months using one of the test methods or historical methods specified in Section 8, Attachment C, Turbine Governor Speed Tests. The Resource Entity shall then provide test results to ERCOT.

(3) Generation Resources and ESRs, except steam turbines of Combined Cycle Generation Resources, Settlement Only Transmission Generators (SOTGs), and Settlement Only Transmission Self-Generators (SOTSGs) shall have Governor droop characteristics and Governor Dead-Band settings no greater than those shown below in Table 1, Maximum Governor Dead-Band Settings, and Table 2, Maximum Governor Droop Settings, as defined below:

**Table 1: Maximum Governor Dead-Band Settings**

|  |  |
| --- | --- |
| **Resource Type** | **Max. Deadband** |
| Steam Turbines withMechanical Governors | +/- 0.034 Hz |
| Hydro Turbines with Mechanical Governors | +/- 0.034 Hz |
| All Other GeneratingUnits/Generating Facilities/ESRs | +/- 0.017 Hz |
| Controllable Load Resources  | +/- 0.036 Hz |

**Table 2: Maximum Governor Droop Settings**

|  |  |
| --- | --- |
| **Generator Type** | **Max. Droop % Setting** |
| Combustion Turbine (Combined Cycle) | 4% |
| All Other GeneratingUnits/Generating Facilities/ESRs/Controllable Load Resources | 5% |

(4) If ERCOT determines that ERCOT System reliability would be enhanced, for a defined period of time, ERCOT may direct Wind-powered Generation Resources (WGRs) under the control of a Remedial Action Scheme (RAS) to limit power increases due to frequency if there is risk of an RAS operation due to a low frequency FME.

***2.2.8 Performance/Disturbance/Compliance Analysis***

(1) Performance/Disturbance/Compliance analysis shall be performed by ERCOT for the purpose of ensuring conformance with the Protocols and Operating Guides. All Generation Resources, ESRs, SOTGs, SOTSGs, and Controllable Load Resources, except nuclear-powered Resources or WGRs with a permanent exemption approved by ERCOT, must respond to frequency disturbances with a Governor droop as specified in Section 2.2.7, Turbine Speed Governors. Each Generation Resource, ESR, SOTG, SOTSG, and Controllable Load Resource based on participation in at least eight FMEs, shall meet a minimum 12-month rolling average initial Primary Frequency Response performance and sustained Primary Frequency Response performance of 0.75 as calculated in Section 8, Attachment J, Initial and Sustained Measurements for Primary Frequency Response. When assessing conformance with the Protocols and Operating Guides, ERCOT shall evaluate the annual rolling average and may exclude from the performance analysis Generation Resources, ESRs, SOTGs, SOTSGs, or Controllable Load Resources in accordance with, but not limited to, the following conditions:

(a) Operating within the larger of five MW or 2% of the High Sustained Limit (HSL) or the maximum capacity for low frequency disturbances;

(b) Operating within the larger of five MW or 2% of the HSL or the maximum capacity above the LSL for high frequency disturbances;

(c) For an ESR, while discharging, if operating within the larger of 3 MW or 2% of the Maximum Operating Discharge Power Limit for low frequency disturbances;

(d) For an ESR, while charging, if operating within the larger of 3 MW or 2% of the Maximum Operating Charge Power Limit for high frequency disturbances;

(e) For any Generation Resource carrying power augmentation, the maximum capacity will be computed as the HSL minus Non-Frequency Responsive Capacity (NFRC); or

(f) Having a technical or physical limitation filed with the ERCOT client representative and approved by ERCOT.

(2) Market Participants shall request an exemption from, or correction of, performance during an FME within 30 days of the MIS posting date of the “Initial and Sustained Frequency Response Unit Performance” report.

(3) ERCOT will, on an as needed basis, utilize the Performance, Disturbance, Compliance Working Group (PDCWG) as a technical resource in providing input for types of technical or physical limitations that may be approved by ERCOT.

(4) ERCOT shall make a regular report on selected system disturbances, documenting the response of individual Generation Resources, ESRs, and Controllable Load Resources. In addition, Resource Entities, QSEs, and individual members of the PDCWG are encouraged to work within their respective companies to enhance the performance of individual Generation Resource’s, ESR’s, or Controllable Load Resource’s control systems through application of the results of the PDCWG studies.

***2.2.10 Generation Resource and Energy Storage Resource******Response Time Requirements***

(1) All Generation Resources and ESRs providing Voltage Support Service (VSS) as described in Protocol Section 3.15, Voltage Support, shall maintain the necessary procedures and processes plus communications, telemetry, remote control, automation, and staffing in order to normally comply with the response times listed below when a VSS Dispatch Instruction or a TO Voltage Set Point instruction, as described in Protocol Section 6.5.7.7, Voltage Support Service, is given. Compliance is based upon normal operating conditions where VSS Dispatch Instructions respect all equipment operating limits and other restrictions that are periodically placed on equipment. The response time to a VSS Dispatch Instruction or a TO Voltage Set Point instruction shall commence with the successful receipt by the QSE, Generation Resource, or ESR either through a verbal or telemetered instruction.

(2) A Resource Entity, TO, or QSE is not required to comply with a VSS Dispatch Instruction or Voltage Set Point instruction if compliance with such an instruction is impossible due to either a Force Majeure Event or one or more of the conditions described in paragraphs (1) and (2) of Protocol Section 6.5.7.9, Compliance with Dispatch Instruction. In the event compliance with an instruction is precluded under this paragraph:

(a) An affected Resource Entity shall, as soon as practicable, notify its QSE, and the Resource Entity or its QSE shall, as soon as practicable, notify the Entity issuing the instruction; and

(b) An affected TO shall, as soon as practicable, notify ERCOT.

(3) The required VSS response times for Generation Resources and ESRs are:

(a) For automatically switchable static Volt-Ampere reactive (VAr) capable devices, when voltage or reactive measurements at the POI are outside of the Voltage Set Point tolerance band identified in paragraph (4) of Section 2.7.3.5, Resource Entity Responsibilities and Generation Resource or ESR Requirements; then the response must be fully deployed in no more than five minutes. If a TO and a Resource Entity have determined that a longer response time is appropriate and have entered into a written agreement reflecting that response time, then the Generation Resource or ESR shall be required to comply with that agreed response time so long as it does not exceed ten minutes.

(b) Response to a TO Voltage Set Point instruction shall be completed in no more than five minutes from receipt of the instruction.

(c) Response to a VSS Dispatch Instruction that requires a change to the real power output of the Generation Resource or ESR shall be completed as soon as practicable.

(4) Shutting down and disconnecting Generation Resources or ESRs from the ERCOT Transmission Grid:

(a) On-Line Generation Resources or ESRs must be able to commence their shutdown sequence within five minutes of receipt of a Dispatch Instruction from ERCOT. Nuclear-fueled Generation Resources shall comply with the procedural requirements of the Nuclear Regulatory Commission (NRC) when receiving Dispatch Instructions from ERCOT to disconnect the Generation Resource from the ERCOT Transmission Grid.

(b) If the ERCOT Transmission Grid condition requires breaker or switch operations to disconnect a non-MW producing Generation Resource or ESR from the system, such operations shall be completed as soon as practicable, but no longer than 15 minutes of the receipt of a Dispatch Instruction from ERCOT. Once disconnected from the ERCOT Transmission Grid, a Generation Resource or ESR shall complete as soon as practicable, but no longer than 15 minutes, the required switching to return the system to a normal configuration except for nuclear-fueled Generation Resources, which shall comply with the procedural requirements of the NRC when receiving Dispatch Instructions from ERCOT to disconnect the Generation Resource from the ERCOT Transmission Grid.

**2.3** **Ancillary Services**

(1) The types of Ancillary Services required by ERCOT are described below:

| **ANCILLARY SERVICE TYPE** | **DESCRIPTION** | **ERCOT AUTHORITY ACTION** |
| --- | --- | --- |
| Regulation Down Service (Reg-Down)andRegulation Up Service (Reg-Up)(for Generation Resources and Energy Storage Resources (ESRs))***Reference: Protocol Section 2, Definitions and Acronyms*** | Resource capacity provided by a Qualified Scheduling Entity (QSE) from a specific Generation Resource or ESR to control frequency within the system which is controlled second by second, normally by an Automatic Generation Control (AGC) system. | a. Reg-Down energy is a deployment to increase or decrease generation at a level below the Generation Resource’s or ESR’s Base Point in response to a change in system frequency.b. Reg-Up energy is a deployment to increase or decrease generation at a level above the Generation Resource’s or ESR’s Base Point in response to a change in system frequency. |
| Reg-DownandReg-Up(for Load Resource)***Reference: Protocol Section 2*** | Load Resource capacity provided by a QSE from a specific Load Resource to control frequency within the system. | a. Reg-Down is a deployment to increase or decrease Load as deployed within its Ancillary Service Schedule for Reg-Down below the Load Resource’s Maximum Power Consumption (MPC) limit in response to a change in system frequency.b. Reg-Up is a deployment to increase or decrease Load as deployed within its Ancillary Service Schedule for Reg-Up above the Load Resource’s Low Power Consumption (LPC) limit in response to a change in system frequency. |
| Responsive Reserve (RRS) Service ***Reference: Protocol Section******2*** | Operating reserves on Generation Resources, ESRs, and Load Resources maintained by ERCOT to help control the frequency of the system. RRS on Generation Resources, ESRs, and Controllable Load Resources that are qualified to provide Regulation Service can also be used as a backup Regulation Service and energy during an Energy Emergency Alert (EEA) event. | RRS may only be deployed as follows:a. Through automatic governor action or under-frequency relay in response to frequency deviations; b. By electronic signal from ERCOT in response to the need; andc. As ordered by an ERCOT Operator during EEA or other emergencies. |
| Non-Spinning Reserve (Non-Spin) Service***Reference: Protocol Section 2*** | a. Off-Line Generation Resource or ESR capacity, or reserved capacity from On-Line Generation Resources or ESRs, capable of being ramped to a specified output level within 30 minutes, and operating at a specified output for at least one hour b. Controllable Load Resources that are capable of ramping to an ERCOT-instructed consumption level within 30 minutes consuming at the ERCOT-instructed level for at least one hour. | Deployed in response to loss-of-Resource contingencies, Load forecasting error, or other contingency events on the system. See Protocol Section 6.5.7.6.2.3, Non-Spinning Reserve Service Deployment. |
| Voltage Support Service (VSS)***Reference: Protocol Section* *3.15, Voltage Support*** | Reactive capability of a Generation Resource or an ESR that is required to maintain transmission and distribution voltages on the ERCOT Transmission Grid within acceptable limits. All Generation Resources and ESRs with a gross rating greater than 20 MVA shall provide VSS. | Direct the scheduling of VSS by providing Voltage Profiles at the point of interconnection. The Generation Resource or ESR is obligated to maintain the published voltage profile within its Corrected Unit Reactive Limit (CURL). |
| Black Start Service (BSS)***Reference: Protocol Section* *3.14.2, Black Start*** | The provision of Generation Resources under a Black Start Agreement, which are capable of self-starting without support from within ERCOT in the event of a Partial Blackout or Blackout. | Provide emergency Dispatch Instructions to begin restoration to a secure operating state after a Partial Blackout or Blackout. |
| Reliability Must-Run (RMR) Service***Reference: Protocol Section* *3.14.1, Reliability Must Run*** | The provision of Generation Resource capacity and energy under an RMR Agreement. | Enter into contractual agreements to retain units required for reliable operations. Direct the operation of those units that otherwise would not operate and that are necessary to provide reliable operations. |

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| ***[NOGRR187: Replace paragraph (1) above with the following upon system implementation of NPRR863:]***(1) The types of Ancillary Services required by ERCOT are described below:

| **ANCILLARY SERVICE TYPE** | **DESCRIPTION** | **ERCOT AUTHORITY ACTION** |
| --- | --- | --- |
| Regulation Down Service (Reg-Down)andRegulation Up Service (Reg-Up)(for Generation Resources and Energy Storage Resources (ESRs))***Reference: Protocol Section******2, Definitions and Acronyms*** | Resource capacity provided by a Qualified Scheduling Entity (QSE) from a specific Generation Resource or ESR to control frequency within the system which is controlled second by second, normally by an Automatic Generation Control (AGC) system. | a. Reg-Down energy is a deployment to increase or decrease generation at a level below the Generation Resource’s or ESR’s Base Point in response to a change in system frequency.b. Reg-Up energy is a deployment to increase or decrease generation at a level above the Generation Resource’s or ESR’s Base Point in response to a change in system frequency. |
| Reg-DownandReg-Up(for Load Resource)***Reference: Protocol Section******2*** | Load Resource capacity provided by a QSE from a specific Load Resource to control frequency within the system. | a. Reg-Down is a deployment to increase or decrease Load as deployed within its Ancillary Service Schedule for Reg-Down below the Load Resource’s Maximum Power Consumption (MPC) limit in response to a change in system frequency.b. Reg-Up is a deployment to increase or decrease Load as deployed within its Ancillary Service Schedule for Reg-Up above the Load Resource’s Low Power Consumption (LPC) limit in response to a change in system frequency. |
| Responsive Reserve (RRS) ***Reference: Protocol Section******2*** | Operating reserves on Generation Resources, ESRs, Load Resources, and Resources capable of providing Fast Frequency Response (FFR) maintained by ERCOT to help control the frequency of the system. RRS on Generation Resources, ESRs, and Controllable Load can be used as energy during an Energy Emergency Alert (EEA) event. | RRS may only be deployed as follows:a. Through automatic Governor action or under-frequency relay in response to frequency deviations; b. By electronic signal from ERCOT in response to the need; andc. As ordered by an ERCOT Operator during an EEA or other emergencies. |
| ERCOT Contingency Reserve Service (ECRS)***Reference: Protocol Section******2*** | a. Off-Line Generation Resource or ESR capacity, or reserved capacity from On-Line Generation Resources or ESRs, capable of being ramped to a specified output level within ten minutes, and operating at a specified output for the entire duration of the ECRS obligation and are dispatchable by Security-Constrained Economic Dispatch (SCED).b. Controllable Load Resources dispatchable by SCED that are capable of ramping to an ERCOT-instructed consumption level within ten minutes and consuming at the ERCOT-instructed level for the entire duration of the ECRS obligation.c. Load Resources other than Controllable Load Resources that may or may not be controlled by under-frequency relay that are capable of interrupting within ten minutes at ERCOT instruction for the entire duration of the ECRS obligation. | Deployed in response to loss-of-Resource contingencies, Load forecasting error, or other contingency events on the system. See Protocol Section 6.5.7.6.2.4, Deployment and Recall of ERCOT Contingency Reserve Service. |
| Non-Spinning Reserve (Non-Spin) Service***Reference: Protocol Section 2*** | a. Off-Line Generation Resource or ESR capacity, or reserved capacity from On-Line Generation Resources or ESRs, capable of being ramped to a specified output level within 30 minutes, and operating at a specified output for the entire duration of the Non-Spin obligation. b. Controllable Load Resources that are capable of ramping to an ERCOT-instructed consumption level within 30 minutes and consuming at the ERCOT-instructed level for the entire duration of the Non-Spin obligation. | Deployed in response to loss-of-Resource contingencies, Load forecasting error, or other contingency events on the system. See Protocol Section 6.5.7.6.2.3, Non-Spinning Reserve Service Deployment. |
| Voltage Support Service (VSS)***Reference: Protocol Section* *3.15, Voltage Support*** | Reactive capability of a Generation Resource or ESR that is required to maintain transmission and distribution voltages on the ERCOT Transmission Grid within acceptable limits. All Generation Resources and ESRs with a gross rating greater than 20 MVA shall provide VSS. | Direct the scheduling of VSS by providing Voltage Profiles at the point of interconnection. The Generation Resource or ESR is obligated to maintain the published voltage profile within its Corrected Unit Reactive Limit (CURL). |
| Black Start Service (BSS)***Reference: Protocol Section* *3.14.2, Black Start*** | The provision of Generation Resources under a Black Start Agreement, which are capable of self-starting without support from within ERCOT in the event of a Partial Blackout or Blackout. | Provide emergency Dispatch Instructions to begin restoration to a secure operating state after a Partial Blackout or Blackout. |
| Reliability Must-Run (RMR) Service***Reference: Protocol Section* *3.14.1, Reliability Must Run*** | The provision of Generation Resource capacity and energy under an RMR Agreement. | Enter into contractual agreements to retain units required for reliable operations. Direct the operation of those units that otherwise would not operate and that are necessary to provide reliable operations. |

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***2.6.2 Generators and Energy Storage Resources***

(1) If under-frequency relays are installed and activated to trip the unit, these relays shall be set such that the automatic removal of individual Generation Resources or Energy Storage Resources (ESRs) from the ERCOT System meets or exceeds the following requirements:

|  |  |
| --- | --- |
| **Frequency Range** | **Delay to Trip** |
| Above 59.4 Hz | No automatic tripping(Continuous operation) |
| Above 58.4 Hz up toAnd including 59.4 Hz | Not less than 9 minutes |
| Above 58.0 Hz up toAnd including 58.4 Hz | Not less than 30 seconds |
| Above 57.5 Hz up toAnd including 58.0 Hz | Not less than 2 seconds |
| 57.5 Hz or below | No time delay required |

(2) If over-frequency relays are installed and activated to trip the unit, they shall be set such that the automatic removal of individual Generation Resources or ESRs from the ERCOT System meets or exceeds the following requirements:

|  |  |
| --- | --- |
| **Frequency Range** | **Delay to Trip** |
| Below 60.6 Hz down to and including 60 Hz | No automatic tripping (Continuous operation) |
| Below 61.6 Hz down to and including 60.6 Hz | Not less than 9 minutes |
| Below 61.8 Hz down to and including 61.6 Hz | Not less than 30 seconds |
| 61.8 Hz or above | No time delay required |

(3) This Operating Guide is not intended to conflict with the plant operator’s responsibility to protect Generation Resources and ESRs from potentially damaging operating conditions.

(4) The Resource Entity that owns Generation Resources that are unable to comply shall provide to ERCOT an explanation of the limitations including, but not limited to, study results or manufacturer’s advice.

***2.7.1 Introduction***

(1) The system Voltage Profile is the set of normally desired Voltage Set Points for those Generation Resources and Energy Storage Resources (ESRs) required to provide Voltage Support Service (VSS).

(2) ERCOT coordinates and conducts studies with the Transmission Service Providers (TSPs) to determine and establish the Voltage Profile.

(3) ERCOT and/or the Transmission Operators (TOs) adjust Voltage Set Points to maintain system voltages within established limits.

***2.7.2 Maintaining Voltage Profile***

(1) ERCOT has the responsibility for monitoring and controlling the Voltage Profile and should use the following:

(a) Operations Engineering

(i) All voltage limits must be based on sound engineering studies that use the appropriate Network Operations Model. TSP study results should be made available to ERCOT; and

(ii) Transfer limits shall reflect voltage and/or reactive restrictions.

(b) Coordination

(i) Entities must coordinate high voltage limits in order to guarantee that the maximum continuous over-voltage of equipment is not exceeded. TOs shall notify ERCOT of normal operating voltage limits and post-contingency voltage limits for each bus;

(ii) Low voltage limits must be coordinated in order to prevent one Entity from being a burden to another;

(iii) Voltage limits shall not be violated during all normal and Credible Single Contingency conditions; and

(iv) The operation of all Reactive Power devices under the control of a TO or a Qualified Scheduling Entity (QSE) will be coordinated under the direction of ERCOT to maintain transmission voltage levels within normal limits and post-contingency voltages within post contingency limits. Static reactive devices will be managed to ensure that adequate dynamic reactive reserves are maintained at all times.

(c) Notification

(i) Generation Resources or ESRs with voltage problems shall notify the TO to whom they are directly connected. TOs shall notify other affected TOs and ERCOT; and

(ii) ERCOT will monitor events and may direct actions to solve the problem.

(d) Response

(i) When the voltage levels deviate from established limits, ERCOT or the TO shall take immediate steps to relieve the condition using all available reactive resources.

(e) Monitoring

(i) TOs shall provide telemetry to ERCOT on all major transmission bus voltages.

(f) Controls

(i) ERCOT must be aware of the location of and availability of reactive capability;

(ii) ERCOT shall maintain displays to monitor Voltage Profiles and reactive flows; and

(iii) Controls to maintain Voltage Profiles may include but are not limited to capacitor switching, reactor switching, auto-transformer tap changing, Generation Resource and ESR reactive dispatch, transmission line switching, and Load shedding.

(g) Documentation

(i) Each TO must maintain a voltage/reactive plan for normal and Emergency Conditions and will provide this plan to adjacent TOs as well as ERCOT upon request.

(h) Emergency or Abnormal Conditions

(i) Transmission systems shall be designed so that effective reactive reserves shall be available without de-energizing other Facilities or shedding Load under normal conditions;

(ii) Major transmission lines shall be kept in service during light Load as much as possible. Lines should only be removed after all applicable reactive controls are implemented and studies show that reliability will not be degraded; and

(iii) Voltage reduction should not be done on the transmission system unless coordinated with adjacent TOs.

**2.7.3.2 ERCOT Responsibilities**

(1) ERCOT shall be responsible for ordering necessary Generation Resources or ESRs On-Line to regulate transmission voltage and reactive flow.

(2) When voltage levels deviate from normal operating limits in the pre-contingency (base case) condition or from emergency operating limits in the post-contingency condition, ERCOT shall take immediate steps to restore voltage levels within the applicable operating limits using all available reactive resources. ERCOT may allow additional time for a TO to correct the voltage levels to within limits on sub-100kV facilities prior to ERCOT taking further steps to restore voltage levels. The steps ERCOT may take include, but are not limited to:

(a) Evaluating TO actions taken to correct voltage levels;

(b) Directing additional Generation Resources or ESRs On-Line;

(c) Redispatching Generation Resources or ESRs;

(d) Deploying additional Resources;

(e) Directing static Reactive Power resources to be put in service;

(f) Utilizing temporary changes to limits of Resources or Transmission Facilities;

(g) Developing a Constraint Management Plan (CMP);

(h) Adjusting a Voltage Set Point; and

(i) Shedding firm Load.

(3) ERCOT shall issue a VSS Dispatch Instruction to the designated QSE for adjustments that would require a Generation Resource or ESR to operate outside its Unit Reactive Limit (URL).

(4) For multi-generator busses, ERCOT may not instruct any single Generation Resource or ESR to operate beyond its Corrected Unit Reactive Limit (CURL) or URL until all Generation Resources and/or ESRs On-Line and interconnected at the same transmission bus are operating at their respective CURLs or URLs.

(5) ERCOT shall coordinate Automatic Voltage Regulator (AVR), dynamic and static reactive device Outages to ensure adequate reactive reserves are maintained.

(6) ERCOT shall maintain a performance log of QSE acknowledgements of VSS Dispatch Instructions.

(7) ERCOT shall be aware of the location of and availability of reactive power resources, including AVRs and Power System Stabilizers (PSSs), and shall monitor their statuses.

(8) ERCOT shall maintain displays to monitor Voltage Profiles and reactive flows.

(9) ERCOT shall, for each Generation Resource and ESR, telemeter the Real-Time desired Voltage Set Point and the TSP-designated Point of Interconnection (POI) kV measurement via Inter-Control Center Communications Protocol (ICCP) to the QSE representing that Generation Resource or ESR.

(10) ERCOT shall instruct the TO to make Voltage Set Point adjustments, as necessary, within the Generation Resource’s or ESR’s URL provided to ERCOT.

**2.7.3.3 TO/TSP Responsibilities**

(1) Each TO shall be responsible for directing Voltage Set Points for each Generation Resource and ESR interconnected to its TSP’s Facilities. Each TO will adjust the Voltage Set Point by communicating directly with the Resource Entity or QSE responsible for the operation of the Generation Resource or ESR. Normal communication is to request voltage or Reactive Power be raised or lowered at a specified bus by a stated number of kV or MVAr (e.g., + 1 kV, +20 MVAr, or -1 kV, -20 MVAr).

(2) Each TO shall monitor system voltages and shall operate voltage control equipment, including, but not limited to, static Reactive Power resources such as capacitors, reactors and transformer tap changers to maintain system voltages within limits.

(3) Each TO shall operate static Reactive Power resources within its operating area as required by its criteria while maintaining dynamic reactive reserves provided by Generation Resources and ESRs.

(4) Each TO shall telemeter to ERCOT via ICCP the Real-Time desired Voltage Set Point and actual voltage at the POI for each Generation Resource or ESR interconnected to its system. Each TO shall modify the telemetered Voltage Set Point as soon as practicable in order to match any verbal Voltage Set Point instruction issued.

(5) Each TO shall know the status of static transmission Reactive Power resources in its operating area and shall provide such information to ERCOT.

(6) When voltage levels deviate from established limits, the affected TO shall take immediate steps to relieve the condition using available reactive resources under its control.

(7) Each TSP shall, as soon as practicable, notify ERCOT of any temporary transmission voltage limit changes and shall coordinate with ERCOT to update the Network Operations Model with any permanent or long-term changes to voltage limits that deviate from those identified in Section 2.7.3.1, Operational Guidelines.

|  |
| --- |
| ***[NOGRR177: Replace Section 2.7.3.3 above with the following upon system implementation of NPRR857:]*****2.7.3.3 TO/TSP/DCTO Responsibilities**(1) Each TO shall be responsible for directing Voltage Set Points for each Generation Resource and ESR interconnected to its TSP’s Facilities. Each TO will adjust the Voltage Set Point by communicating directly with the Resource Entity or QSE responsible for the operation of the Generation Resource or ESR. Normal communication is to request voltage or Reactive Power be raised or lowered at a specified bus by a stated number of kV or MVAr (e.g., + 1 kV, +20 MVAr, or -1 kV, -20 MVAr). (2) Each TO shall monitor system voltages and shall operate voltage control equipment, including, but not limited to, static Reactive Power resources such as capacitors, reactors and transformer tap changers to maintain system voltages within limits.(3) Each TO shall operate static Reactive Power resources within its operating area as required by its criteria while maintaining dynamic reactive reserves provided by Generation Resources and ESRs.(4) Each TO shall telemeter to ERCOT via ICCP the Real-Time desired Voltage Set Point and actual voltage at the POI for each Generation Resource and ESR interconnected to its system. Each TO shall modify the telemetered Voltage Set Point as soon as practicable in order to match any verbal Voltage Set Point instruction issued.(5) Each TO shall know the status of static transmission Reactive Power resources in its operating area and shall provide such information to ERCOT.(6) When voltage levels deviate from established limits, the affected TO shall take immediate steps to relieve the condition using available reactive resources under its control.(7) Each TSP and DCTO shall, as soon as practicable, notify ERCOT of any temporary transmission voltage limit changes and shall coordinate with ERCOT to update the Network Operations Model with any permanent or long-term changes to voltage limits that deviate from those identified in Section 2.7.3.1, Operational Guidelines.  |

**2.7.3.4 QSE Responsibilities**

(1) Each QSE shall ensure that any Generation Resource or ESR that it represents and that is required to provide VSS responds to any VSS Dispatch Instruction including VSS Dispatch Instruction to exceed its CURL or URL or TO Voltage Set Point instruction within the time requirements specified in paragraph (3)(b) of Section 2.2.10, Generation Resource and Energy Storage Resource Response Time Requirements. If the Resource Entity notifies the QSE that a Generation Resource or an ESR cannot comply with the VSS Dispatch Instruction or TO Voltage Set Point instruction, either the Resource Entity or its QSE shall, as soon as practicable, notify the Entity that issued the instruction. The Resource Entity or its QSE shall provide the reason for not being able to comply and an estimated time for resolution, when known.

(2) Each QSE representing a Generation Resource or ESR shall provide in Real-Time the desired Voltage Set Point and the associated POI kV measurement to the Generation Resource or ESR.

(3) Each QSE will continuously monitor the status of its Resources’ AVRs and PSSs.

(4) Each QSE must, as soon as practicable, notify ERCOT when a Generation Resource or ESR experiences a change that affects its reactive capability, including any change to the operation mode of the Generation Resource’s or ESR’s AVR.

**2.7.3.5 Resource Entity Responsibilities and Generation Resource and Energy Storage Resource Requirements**

(1) Each Resource Entity shall ensure that its Generation Resource(s) and ESR(s) responds to all VSS Dispatch Instruction or a TO Voltage Set Point instruction from its QSE or interconnecting TO within the time requirements specified in paragraph (3)(b) of Section 2.2.10, Generation Resource and Energy Storage Resource Response Time Requirements.

(2) Generation Resources or ESRs with high reactive loading resulting from abnormal conditions shall not reduce their reactive loading without the consent of ERCOT unless equipment damage is imminent based on the sole and reasonable judgment of the Resource Entity. In that case the Resource Entity will notify its QSE and its TO as soon as practicable of its action.

(3) Each Resource Entity shall monitor Real-Time provided Voltage Set Point instructions it receives. The Resource Entity shall inform its QSE and either the Resource Entity or its QSE shall notify the Resource Entity’s TO, as soon as practicable, if it cannot comply with TO Voltage Set Point instructions. If a Resource Entity cannot comply with a VSS Dispatch Instruction, the Resource Entity shall inform its QSE and its QSE shall notify ERCOT as soon as practicable.

(4) A Resource Entity required to provide VSS shall maintain the Resource’s voltage or Reactive Power schedule within 2% of the Voltage Set Point while operating at less than the maximum reactive capability of the Generation Resource or ESR.

(5) Required reactive capability must be maintained at all times that the Generation Resource or ESR is On-Line. When a Generation Resource or ESR experiences a change that affects its reactive capability, the associated Resource Entity shall notify its QSE and TO, as soon as practicable.

(6) Each Resource Entity shall communicate any Resource Entity-owned transmission voltage limits that deviate from those identified in Section 2.7.3.1, Operational Guidelines, to ERCOT and to its QSE.

**2.9 Voltage Ride-Through Requirements for Generation Resources and Energy Storage Resources**

(1) Generation Resources and Energy Storage Resources (ESRs) must be designed and their voltage relays must be set to remain connected to the transmission system during the following operating conditions:

(a) Generator or inverter terminal voltages are within 5% of the rated design voltage and volts per hertz are less than 105% of generator rated design voltage and frequency;

(b) Generator or inverter terminal voltage deviations exceed 5% but are within 10% of the rated design voltage and persist for less than ten seconds;

(c) Generator or inverter volts per hertz conditions are less than 116% of rated design voltage and frequency and last for less than 1.5 seconds; and

(d) A transmission system fault (three-phase, single-phase or phase-to-phase), but not a unit bus fault, is cleared by the protection scheme coordinated between the Resource Entity and the Transmission Service Provider (TSP) on any line connected to the Resource’s Point of Interconnection (POI), provided such lines are not connected to induction generators described in paragraph (9) of Protocol Section 3.15, Voltage Support.

(2) In the case of a unit bus fault or a primary transmission system relay failure, the unit protective relaying may clear the unit independent of the operation of any transmission protective relaying.

(3) During operating conditions listed in paragraph (1) above, each Generation Resource or ESR shall not, during and following a transient voltage disturbance, cease providing real or reactive power except to the extent needed to provide frequency support or aid in voltage recovery. Each ESR, if it is consuming active power from the ERCOT System when operating in the charging mode, shall reduce or cease power consumption as necessary to aid in voltage recovery during and following transient voltage disturbances.

(4) Synchronous Generation Resources required to provide Voltage Support Service (VSS) shall have and maintain the following capability:

(a) Over-excitation limiters shall be provided and coordinated with the thermal capability of the generator field winding and protective relays in order to permit short-term reactive capability that allows at least 80% of the unit design standard (ANSI C50.13-1989), as follows:

Time (seconds) 10 30 60 120

Field Voltage % 208 146 125 112

After allowing temporary field current overload, the limiter shall operate through the automatic AC voltage regulator to reduce field current to the continuous rating. Return to normal AC voltage regulation after current reduction shall be automatic. The over-excitation limiter shall be coordinated with the over-excitation protection so that over-excitation protection only operates for failure of the voltage regulator/limiter.

(b) Under-excitation limiters shall be provided and coordinated with loss-of-field protection to eliminate unnecessary generating unit disconnection as a result of operator error or equipment malfunction.

(5) Generation Resources and ESRs shall have protective relaying necessary to protect their equipment from abnormal conditions as well as to be consistent with protective relaying criteria described in Section 6.2.6.3.4, Generation Resource and Energy Storage Resource Protection and Relay Requirements.

(6) The Voltage Ride-Through (VRT) requirements do not apply to faults that occur at or behind the POI, or when clearing the fault effectively disconnects the Resource from the ERCOT System.

***2.9.1 Additional Voltage Ride-Through Requirements for Intermittent Renewable Resources and Energy Storage Resources***

(1) All Intermittent Renewable Resources (IRRs) and ESRs shall also comply with the requirements of this Section, except as follows:

(a) An IRR that interconnects to the ERCOT System pursuant to a Standard Generation Interconnection Agreement (SGIA) (i) executed on or before January 16, 2014 and (ii) under which the IRR provided all required financial security to the TSP on or before January 16, 2014, is not required to meet any high VRT requirement greater than 1.1 per unit voltage unless the interconnected IRR includes one or more turbines that differ from the turbine model(s) described in the SGIA (including any attachment thereto), as that agreement existed on January 16, 2014. Notwithstanding the foregoing, if the Resource Entity that owns or operates an IRR that was interconnected pursuant to an SGIA executed before January 16, 2014, under which the IRR provided all required financial security to the TSP on or before January 16, 2014, demonstrates to ERCOT’s satisfaction that the high VRT capability of the IRR is not lower than the capability of the turbine model(s) described in the SGIA (including any attachment thereto), as that agreement existed on January 16, 2014 that IRR is not required to meet the high VRT requirement in this Section.

(b) An IRR that interconnects to the ERCOT System pursuant to an SGIA executed prior to November 1, 2008 is not required to meet VRT requirements presented in this Section. However, any WGR that is installed on or after November 1, 2008 and that initially synchronizes with the ERCOT System, pursuant to a Standard Generation Interconnection Agreement (SGIA) (i) executed on or before January 16, 2014, and (ii) under which the IRR provided all required financial security to the TSP on or before January 16, 2014 (except for an IRR installed pursuant to an SGIA executed before November 1, 2008) shall be VRT-capable in accordance with the low VRT requirements in this Section and high-voltage requirements in this Section up to 1.1 per unit voltage unless the interconnected IRR includes one or more turbines that differ from the turbine model(s) described in the SGIA (including any attachment thereto), as that agreement existed on January 16, 2014 in which case the IRR shall also be required to comply with the high VRT requirements of this section, subject to the exemption described in paragraph (a), above.

(c) An IRR that is not technically capable of complying with a 1.2 per unit voltage high VRT requirement and that is not subject to either of the exemptions described in paragraphs (a) or (b), above, is not required to meet any high VRT requirement greater than 1.1 per unit voltage until January 16, 2016.

(d) Notwithstanding any of the foregoing provisions, an IRR’s VRT capability shall not be reduced over time.

(2) Each IRR or ESR shall provide technical documentation of VRT capability to ERCOT upon request.

(3) Each IRR or ESR is required to set its voltage relays to remain in service for at least 0.15 seconds during all transmission faults and to allow the system to recover as illustrated in Figure 1, Default Voltage Ride-Through Boundaries for IRRs and ESRs, below. Recovery time to 90% of per unit voltage should be within 1.75 seconds. Faults on individual phases with delayed clearing (zone 2) may result in phase voltages outside this boundary but if the phase voltages remain inside this boundary, then Resource voltage relays are required to be set to remain connected and recover as illustrated in Figure 1.

(4) Each IRR or ESR shall remain interconnected during three-phase faults on the ERCOT System for a voltage level as low as zero volts with a duration of 0.15 seconds as measured at the Point of Interconnection (POI) unless a shorter clearing time requirement for a three-phase fault specific to the POI is determined by and documented by the TSP in conjunction with the SGIA. The clearing time requirement shall not exceed nine cycles.

(5) Each IRR or ESR shall set its voltage relays to remain interconnected to the ERCOT System during the following high-voltage conditions, as illustrated in Figure 1: any per-unit voltage equal to or greater than 1.175 but less than 1.2 for up to 0.2 seconds, any per-unit voltage equal to or greater than 1.15 but less than 1.175 per unit voltage for up to 0.5 seconds, and any per-unit voltage equal to or greater than 1.1 but less than 1.15 for up to 1.0 seconds. The indicated voltages are measured at the POI.

(6) An IRR or ESR may be tripped Off-Line or curtailed after the fault clearing period if this action is part of an approved Remedial Action Scheme (RAS).

(7) VRT requirements may be met by the performance of the Resource; by installing additional reactive equipment behind the POI; or by a combination of Resource performance and additional equipment behind the POI. VRT requirements may be met by equipment outside the POI if documented in the SGIA.

(8) If an IRR or ESR fails to comply with the clearing time or recovery VRT requirement, then the Resource Entity and the interconnecting TSP shall be required to investigate and report to ERCOT on the cause of the Resource’s trip, identifying a reasonable mitigation plan and timeline.

**Figure 1: Default Voltage Ride-Through Boundaries for IRRs and ESRs**

**3.3.2.1 Corrected Unit Reactive Limits (CURL)**

(1) A reactive capability curve and associated data for each unit on the ERCOT System shall be submitted to ERCOT through the Market Information System (MIS) Certified Area and must contain the most limiting elements for the leading and lagging reactive output. The limiting factors such as under-excitation limiters, over-excitation limiters, ambient temperature limitations across the MW range of the unit at the unit terminals or any other factor that limits the reactive output of the unit and is verifiable through engineering calculations or testing shall be updated and provided on the corrected reactive capability curve. The corrected reactive capability curve establishes the Corrected Unit Reactive Limits (CURL) at the unit terminals that ERCOT Planning and ERCOT Operations, and TSPs will use for their studies. For Intermittent Renewable Resources (IRRs) and Energy Storage Resources (ESRs) the CURL data shall be reported at the low side of the unit’s step up transformer to the Point of Interconnection (POI). Resources will provide these updated curves and associated test data to ERCOT by submitting test information to the Net Dependable Capability and Reactive Capability (NDCRC) application located on the MIS Secure Area. Once approved by ERCOT per Section 3.5, ERCOT Implementation, Resources will provide updated data by submitting changes to the appropriate ERCOT Resource Asset Registration Forms in accordance with Planning Guide Section 6.8, Resource Registration Procedures. Prior to including the submitted data into the Network Operations Model, ERCOT will notify the TSP to which the Resource Entity is interconnected that the test data is posted on the MIS Secure Area. ERCOT and TSPs may review the data and provide any comments within ten Business Days. ERCOT will include these changes in the future Network Operations Model and forward the changes to the TSPs and the Steady State Working Group (SSWG) for use in their studies. The CURL should be available in the Resource Entity’s control room where the tests are conducted and at the QSE’s Real-Time Resource dispatch desk. During any test, the Generation Resource or ESR must maintain its cooling system at normal operating conditions, the Automatic Voltage Regulator in service and all auxiliary equipment in service that is needed for expected normal operation.

**3.3.2.2 Reactive Testing Requirements**

(1) Reactive testing may be performed as either “Coordinated,” or “Non-Coordinated,” the difference being the amount of notification provided to ERCOT and the TO, and level of their involvement in testing.

(a) Coordinated Testing

(i) Coordinated testing is the preferred method for new or larger-capacity units, as it provides a greater amount of coordination with ERCOT and the TO, allowing testing impacts and any potential adjustments to local voltage levels to be studied in advance.

(ii) The Resource Entity requesting a Coordinated test must submit a test request to ERCOT and the TO via their QSE, by no later than 15:00, one day prior to the proposed test date. ERCOT and the TO then have until 17:00 of the day prior to the proposed test date, to either approve or disapprove the test request.

(iii) Both ERCOT and the TO have the right to deny or cancel a test at any time, if they feel that system reliability may be adversely impacted by the test.

(iv) The test requests should contain the proposed time and date of the test, type of test (leading or lagging), expected unit MW and MVAr output range during the test, and a copy of the reactive capability curve.

(b) Non-Coordinated Testing

(i) The Resource Entity representing the resource requesting a Non-Coordinated test must inform ERCOT and the TO via their QSE at least two hours prior to the proposed start of the test.

(ii) Both ERCOT and the TO have the right to deny or cancel a test at any time, if they feel that system reliability may be adversely impacted by the test.

(2) Lagging Reactive Testing

(a) It is recommended, but not required, that lagging reactive tests be performed when system voltage is within the voltage profile, such as during high load periods.

(b) For Generation Resources, lagging tests should meet the following performance criteria:

(i) Lagging Test 1: Test at or above 95% of the unit’s High Sustained Limit (HSL) for at least 15 minutes. IRRs should test at or above 60% of their HSL. Testing acceptance criteria is met if the unit achieved no less than 90% of the unit’s most recent CURL.

(ii) Lagging Test 2: Test at the unit’s HSL for at least one hour. IRRs should test with at least 90% of photovoltaic inverters or wind turbines on-line. Testing acceptance criteria is met if the unit achieved at least 50% of the units CURL for one hour.

(iii) Lagging Test 3: Test at the unit’s normally expected minimum real power output during system light load conditions for at least one minute. IRRs, ESRs, and nuclear units are exempt from this test. Testing acceptance criteria is met if the unit achieved at least 50% of the unit’s CURL.

(c) For inverter-based ESRs, lagging tests should meet the following performance criteria:

(i) Lagging Test 1a: Test at or above 95% the unit’s Maximum Operating Discharge Power Limit for at least 15 minutes or entire duration if less than 15 minutes.

Testing acceptance criteria is met if the unit achieved no less than 90% of the unit’s most recent CURL.

(ii) Lagging Test 1b: Test at or above 95% of the unit’s Maximum Operating Charge Power Limit for at least 15 minutes or entire duration if less than 15 minutes.

Testing acceptance criteria is met if the unit achieved no less than 90% of the unit’s most recent CURL.

(iii) Lagging Test 2: Test with all inverters on-line for at least one hour. Testing acceptance criteria is met if the unit achieved at least 50% of its CURL for 1 hour.

(3) Leading Reactive Testing

(a) It is recommended, but not required, that leading reactive tests be performed when system voltage is within the voltage profile, such as during low load periods.

(b) For Generation Resources, leading tests should meet the following performance criteria:

(i) Leading Test 1: Test at the unit’s normally expected maximum real power output during system light load conditions for at least 15 minutes. IRRs should test at or below 60% of their HSL. Testing acceptance criteria is met if the unit achieved no less than 90% of the unit’s original manufacturer reactive curve or most recent CURL.

(ii) Leading Test 2: Test at the unit’s HSL for at least one minute. IRR units and ESRs are exempt from this test. Testing acceptance criteria is met if the unit achieved at least 50% of the unit’s CURL.

(iii) Leading Test 3: Test at the unit’s normally expected minimum real power output during system light load conditions for at least one minute. IRRs and nuclear units are exempt from this test. Testing acceptance criteria is met if the unit achieved at least 50% of the unit’s CURL.

(c) For ESRs leading tests should meet the following performance criteria:

(i) Leading Test 1a: Test at or above 95% of the unit’s Maximum Operating Discharge Power Limit for at least 15 minutes or entire duration if less than 15 minutes.

Testing acceptance criteria is met if the unit achieved no less than 90% of the unit’s most recent CURL.

(ii) Leading Test 1b: Test at or above 95% of the unit’s Maximum Operating Charge Power Limit for at least 15 minutes or entire duration if less than 15 minutes.

Testing acceptance criteria is met if the unit achieved no less than 90% of the unit’s most recent CURL.

(4) The Resource Entity shall measure the tested reactive capability on the generator output terminals for non-IRR Generation Resources. The value recorded shall represent the gross MVAr output of the Generation Resource or ESR. Additionally, the net reactive capability shall be measured at the high side of the GSU transformer and at the POI, if metering is available. The high side values shall have the Generation Resource’s or ESR’s auxiliary reactive consumption and the GSU losses deducted from the Generation Resource’s or ESR’s gross reactive output. The POI values shall have the plant’s auxiliary load and any additional load deducted from the Resource’s gross reactive output. If metering is not available at the high side, the Resource Entity shall calculate the reactive capability at the high side and at the POI. These values are required and must be submitted through the MIS Certified Area. CURLs shall be attached to the test results submitted, and shall be clearly defined. All applicable test data shall be submitted on the form in the NDCRC application.

(5) The QSE representing a Generation Resource or ESR shall be responsible for scheduling reactive verification tests when requested by the Resource Entity in accordance with the conditions outlined above. If ERCOT does not issue a specific request for a Generation Resource or ESR reactive capability verification, the Generation Resource or ESR shall complete a reactive verification test at least every five years.

(6) ERCOT shall have the option to waive the requirement to perform Leading Test 1 for any Generation Resource or ESR that seldom runs during such light Load periods. The granting of such a waiver shall be effective for five years.

(7) The Resource Entity representing a Generation Resource or ESR shall be responsible for the timely and accurate reporting of test results to ERCOT and to the QSE representing the Generation Resource or ESR. The Resource Entity representing a Generation Resource or ESR must properly complete all required data fields in the NDCRC application for a test to be considered valid.

***6.2.6.3.4 Generator and Energy Storage Resource Protection and Relay Requirements***

(1) Generator or Energy Storage Resource (ESR) faults shall be detected by more than one protective relay system. These may include faults in the unit or unit leads, unit transformer, and unit-connected station service transformer.

(2) Generators and ESRs shall be protected to keep damage to the equipment and subsequent outage time to a minimum. In view of the special consideration of generator unit protection, the following are some of the conditions that should be detected by the protection systems:

(a) Unbalanced phase currents;

(b) Loss of excitation;

(c) Over-excitation;

(d) Field ground;

(e) Inadvertent energization or reverse power;

(f) Uncleared system faults; and

(g) Off-frequency.

It is recognized that the overall protection of a generator will also involve non-electrical considerations. These have not been included as part of this criteria.

(3) The apparatus shall be protected when the generator is starting up or shutting down as well as running at normal speed; this may require additional relays, as the normal relays may not function satisfactorily at low frequencies.

(4) A generator or ESR shall not be tripped for a system swing condition except when that particular generator is out of step with the remainder of the system. This does not apply to protective relay systems designed to trip the generator as part of an overall plan to maintain stability of the ERCOT System.

(5) The loss of excitation relay shall be set with due regard to the performance of the excitation system.

(6) In the case of a generator or ESR bus fault or a primary transmission system relay failure, the generator protective relaying may clear the generator independent of the operation of any transmission protective relaying.

(7) If requested by ERCOT, within 30 days of ERCOT’s request, Generation Resources or ESRs shall provide ERCOT with the operating characteristics of any generating unit’s or ESR’s equipment protective relay systems or controls that may respond to temporary excursions in voltage with actions that could lead to tripping of the generating unit or ESR.

**ERCOT Nodal Operating Guides**

**Section 8**

**Attachment C**

**Turbine Governor Speed Tests**

**November 3, 2016**

Turbine Governor Speed Regulation Test for Mechanical-Hydraulic Governor

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of test:

QSE: Resource Entity:

***Steady State Speed Regulation at High-Speed Stop***



Where:

A = Speed with speed changer set at high-speed stop and with throttle (or stop) valves open and machine running idle on the Governor.

B = Speed with speed changer set at high-speed stop and when governing valves just reach wide-open position.

***Steady State Speed Regulation at Synchronous Speed*** *[[1]](#footnote-1)*



Where:

C = Speed with speed changer set for synchronous speed and with throttle (or stop) valves open and machine running idle on the Governor.

D = Speed with speed changer set at the same position as in C above and when governing valves just reach wide open position.

***Steady State Speed Regulation at Low-Speed Stop***



Where:

E = Speed with speed changer set at low-speed stop and with throttle (or stop) valves open and machine running idle on the Governor.

F = Speed with speed changer set at low-speed stop and when governing valves just reach wide-open position.



E, F @ Low Speed Stop

C, D @ Sync. Speed

A, B @ High Speed Stop

**Test Data**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Point** | **A** | **B** | **C** | **D** | **E** | **F** |
| Speed, RPM |  |  |  |  |  |  |
|  |  |  |  |  |  |  |
| Frequency Hz |  |  |  |  |  |  |

**Speed Changer Travel Time:**

(a) From Low-Speed Stop to High-Speed Stop in \_\_\_\_\_\_\_\_\_seconds.

(b) From High-Speed Stop to Low-Speed Stop in \_\_\_\_\_\_\_\_\_seconds.

Over-speed Trip Test Speed at \_\_\_\_\_\_\_\_\_rpm.

Comments:

***Submittal***

Resource Entity Representative:

QSE Representative:

Date submitted to ERCOT Representative:

Example of a Turbine Governor Speed Regulation Test for Mechanical-Hydraulic Governor

***Steady State Speed Regulation at High-Speed Stop***



Where:

A = Speed with speed changer set at high-speed stop and with throttle (or stop) valves open and machine running idle on the Governor.

B = Speed with speed changer set at high-speed stop and when governing valves just reach wide-open position.

***Steady State Speed Regulation at Synchronous Speed [[2]](#footnote-2)***



Where:

C = Speed with speed changer set for synchronous speed and with throttle (or stop) valves open and machine running idle on the Governor.

D = Speed with speed changer set at the same position as in C above and when governing valves just reach wide open position.

***Steady State Speed Regulation at Low-Speed Stop***



Where:

E = Speed with speed changer set at low-speed stop and with throttle (or stop) valves open and machine running idle on the Governor.

F = Speed with speed changer set at low-speed stop and when governing valves just reach wide-open position.



E, F @ Low Speed Stop

C, D @ Sync. Speed

A, B @ High Speed Stop

**Test Data**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Point** | **A** | **B** | **C** | **D** | **E** | **F** |
| Speed, RPM | 3850 | 3570 | 3600 | 3310 | 3500 | 3210 |
|  |  |  |  |  |  |  |
| Frequency Hz | 64.2 | 59.5 | 60.0 | 55.0 | 58.3 | 53.5 |

**Speed Changer Travel Time:**

(a) From low-speed stop to high-speed stop in 73 seconds.

(b) From high-speed stop to low-speed stop in 74 seconds.

Over-speed trip test speed at 3965 rpm.

Comments:

**Turbine Governor Speed Regulation Test for Electro-Hydraulic Governor**

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of test:

QSE: Resource Entity:

***Turbine Governor Speed Regulation Test Procedures***

(a) Simulate unit On-Line and turbine speed at 3600 RPM.

(b) Set Load reference at minimum value.

(c) Monitor valve demand signal and record as value “A” (in %).

(d) Reduce speed until valve demand just reaches maximum value.
Record valve demand as value “B” (in %) and speed as value “C” (in RPM).

(e) Set speed at 3600 and Load reference at maximum value.

(f) Monitor valve demand signal and record as value “D” (in %).

(g) Increase speed until valve demand just reaches minimum value.
Record valve demand as value “E” (in %) and speed as value “F” (in RPM).

***Turbine Governor Speed Regulation Test Results***

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **A** | **B** | **C** | **D** | **E** | **F** |
| Valve Demand (%) |  |  |  |  |  |  |
| **Speed (rpm)** |  |  |  |  |  |  |

***Speed Regulation With Decreasing Speed***



***Speed Regulation With Increasing Speed***



Comments:

***Submittal***

Resource Entity Representative:

QSE Representative:

Date submitted to ERCOT Representative:

**Definitions**

|  |  |
| --- | --- |
| **System Frequency Response** | This response is a function of two key variables: the Primary Frequency Response from Governors and Load dampening of the connected Load. |
| **Percent Droop Settings** | Also known as Frequency Regulation, Speed Regulation, Speed Sensitivity, Speed Error and others. Percent droop is the percent change in nominal frequency that will cause generator output to change from no Load to full Load. For synchronous Resouces, it is the change in steady state rotor speed, expressed in percent of rated speed, when power output is gradually reduced from rated to zero power. A common percent droop setting is 5% for both high and low frequency excursions. |
| **Dead-Band** | The range of deviations of system frequency (+/-) that produces no Governor response, and therefore, no frequency (speed) regulation. It is expressed in percent of rated speed, Hz, or RPM. |
| **Valve Position Limiter** | A device that acts on the speed and Load governing system to prevent the Governor-controlled valves from opening beyond a pre-set limit. |
| **Blocked Governor Operation** | Operating the generating unit with the control system adjusted to prevent the turbine governor from responding to system frequency (speed) variations. In an effort to reduce speed Governor operation in some generating units, turbine control systems can be adjusted to block the operation of the Governor after the unit is in parallel with the system and is running at its desired output. Selection of a high percent droop characteristic or a large Governor Dead-Band constitutes a form of blocked Governor action. |
| **Variable Pressure Operation** | Varying the boiler pressure to improve turbine efficiency at lower Loads. Two methods are normally used. The first method, the turbine control (G.E.) or Governor (Westinghouse) valves are positioned in the wide-open position and the generator is changed by changing the boiler pressure. With this method, there is very little, if any response to frequency excursions. The second method, the valves are positioned at approximately 50% open. The valves are still able to respond to system disturbances. Normal changes in generation requirements are made by varying the boiler pressure until the unit is at rated pressure. After full pressure is reached, the turbine valves are used to make the required generation changes. |

#

# Generation Resource Frequency Response Test Procedure

***Description of the Test***

1. The frequency response function of the Generation Resource is tested On-Line at a Load level that allows the Generation Resource to increase or decrease Load without reaching low operating limits or high operating limits. If the Generation Resource cannot be tested On-Line then it will notify ERCOT that it will be conducting an Off-Line test. The recommended level is 92% Base Load or below.

2. The test is performed by adding a frequency offset signal that exceeds the Governor Dead-Band value to the measured frequency signal. This should create immediate step change in the measured frequency signal.

3. The test starts at time t0 when the frequency Dead-Band is exceeded and signal “Generation Resource Frequency Response On” becomes active.

4. The following signals should be recorded at least two seconds: Unit MW Output, “Generation Resource Frequency Response On.”

5. The duration of the test is 100 seconds. After 100 seconds, the offset signal should be removed and the Generation Resource should return to pretest power output.

6. The test should be conducted both with positive and negative frequency offsets.

7. The test is considered successful after the signal becomes active if at least 70% of the calculated MW contribution is delivered within 16 seconds and the response is maintained for an additional 30 seconds.

8. Governor droop and Governor Dead-Band settings shall be set in accordance with Section 2.2.7, Turbine Speed Governors.

***Definitions***

**Generation Resource Base Load =** maximum Load capability for the season when frequency response test is performed

**Gain MW for 0.1Hz** = 

Where:

*P* = Generation Resource Base Load (MW)

*Droop* = droop (%)

**Frequency Offset** = +0.2 Hz and -0.2 Hz (+12 rpm and -12 rpm, for 3600 sync speed machines), outside Governor Dead-Band

**Test frequency** = Measured Frequency + Frequency Offset

**MW Contribution** = Gain MW to 0.1 Hz \*10\*Frequency Offset

**Calculated droop** = - 

Where:

P = Generation Resource Base Load (MW)

ΔHz = Change in frequency (Hz), taking into account Governor Dead-Band

ΔMW = Change in power output (MW)

***Example***

Generation Resource Base Load = 150 MW

Droop = 0.05 or 5% (use 0.05 for calculation)

Governor Dead-Band = 0.034

Gain MW to 0.1 Hz =  = +/- 5.06 MW/0.1 Hz

MW Contribution = 5.06\*10\*+/- (0.2) = +/-10.12 MW

Expected under-frequency response: +10.12 MW in 16 sec. for -0.2 Hz offset

Expected over-frequency response: -10.12 MW in 16 sec. for +0.2 Hz offset

Minimum accepted under-frequency response: +7.08 MW in 15 sec. for -0.2 Hz offset

Minimum accepted over-frequency response: -7.08 MW in 15 sec. for +0.2 Hz offset

Calculated droop for 8 MW increase in power output in 16 sec. for -0.2 Hz offset:

Calculated droop = - = 0.0625 or 6.25%

**Generation Resource FREQUENCY RESPONSE TEST FORM**

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of Test:

QSE: Resource Entity:

***Test Results***

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Test with +0.2 Hz** | **Test with -0.2 Hz** |
| **1** | **Generation Resource Base Load** |  |  |
| **2** | **GAIN MW to 0.1Hz** |  |  |
| **3** | **Calculated** **MW Contribution** |  |  |
| **4** | **MW at test start (t0)** |  |  |
| **5** | **MW at t0 + 16 sec** |  |  |
| **6** | **MW Contribution****at t0 + 16 sec** |  |  |
| **7** | **MW at t0 + 46 sec** |  |  |
| **8** | **Calculated droop** |  |  |
| **9** | **CONCLUSION****(PASSED/FAILED)** |  |  |

***Comments***: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

***Submittal***

Resource Entity Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

QSE Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date submitted to ERCOT Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_

Energy Storage resource Frequency Response Test Procedure

***Description of the Test***

1. An Energy Storage Resource (ESR) is tested On-Line in both maximum charging and discharging modes at a level that allows the ESR to increase or decrease Load without reaching its operating limits. If the ESR cannot be tested On-Line then it will notify ERCOT that it will be conducting an Off-Line test.

2. The test is performed by adding a frequency offset signal that exceeds the Governor Dead-Band value to the measured frequency signal. This should create an immediate step-change in the measured frequency signal.

3. The test starts at time t0 when the frequency dead-band is exceeded.

4. The following signals should be recorded for at least two seconds: unit MW level and frequency offset signal.

5. The duration of the test is 100 seconds. After 100 seconds, the offset signal should be removed and the Energy Storage Resource should return to the pretest MW level.

6. The test should be conducted with both positive and negative frequency offsets.

7. The test is considered successful after the signal becomes active if at least 70% of the calculated MW contribution is delivered within 16 seconds and the response is maintained for an additional 30 seconds.

8. Governor droop and Governor Dead-Band settings shall be set in accordance with Section 2.2.7, Turbine Speed Governors.

***Definitions***

**Energy Storage Resource Base Load =** for low frequency test maximum charging capability; for high frequency test maximum discharging capability

**Gain MW for 0.1Hz** =

10

\*

)

60

\*

(

*Band*

*GovernorDead*

*Droop*

*P*





Where:

*P* = Energy Storage Resource Base Load (MW)

*Droop* = droop (%)

**Frequency Offset** = +0.2 Hz and -0.2 Hz (+12 rpm and -12 rpm, for 3600 sync speed machines), outside Governor Dead-Band

**Test frequency** = Measured Frequency + Frequency Offset

**MW Contribution** = Gain MW to 0.1 Hz \*10\*Frequency Offset

**Calculated droop** = - 

Where:

P = Energy Storage Resource Base Load (MW)

ΔHz = Change in frequency (Hz), taking into account Governor Dead-Band

ΔMW = Change in power level (MW)

***Example***

Energy Storage Resource Base Load = 150 MW, when discharging

Droop = 0.05 or 5% (use 0.05 for calculation)

Governor Dead-Band = 0.017

Gain MW to 0.1 Hz = $\frac{150}{\left[\left(0.05\*60\right)-0.017\right]\*10}$ = +/- 5.03 MW/0.1 Hz

MW Contribution (injection) = 5.03\*10\*+/- (0.2) = +/-10.06 MW

Expected under-frequency response (injection): +10.06 MW in 16 sec. for -0.2 Hz offset

Expected over-frequency response (withdrawal): -10.06 MW in 16 sec. for +0.2 Hz offset

Minimum accepted under-frequency response (injection): +7.04 MW in 15 sec. for -0.2 Hz offset

Minimum accepted over-frequency response (withdrawal): -7.04 MW in 15 sec. for +0.2 Hz offset

Calculated droop for 8 MW increase in power output in 16 sec. for -0.2 Hz offset:

Calculated droop = - = 0.0625 or 6.25%

**Energy Storage Resource FREQUENCY RESPONSE TEST FORM**

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of Test:

QSE: Resource Entity:

***Test Results***

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Test with +0.2 Hz** | **Test with -0.2 Hz** |
| **1** | **Energy Storage Resource (ESR) Base Load** |  |  |
| **2** | **GAIN MW to 0.1Hz** |  |  |
| **3** | **Calculated** **MW Contribution** |  |  |
| **4** | **MW at test start (t0)** |  |  |
| **5** | **MW at t0 + 16 sec** |  |  |
| **6** | **MW Contribution****at t0 + 16 sec** |  |  |
| **7** | **MW at t0 + 46 sec** |  |  |
| **8** | **Calculated droop** |  |  |
| **9** | **CONCLUSION****(PASSED/FAILED)** |  |  |

***Comments***: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

***Submittal***

Resource Entity Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

QSE Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date submitted to ERCOT Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_

**Generation Resource, ENERGY STORAGE RESOURCE, and Controllable Load Resource Primary Frequency Response test Procedures Based on Historical Data**

***Description of Historical Verification***

The purpose of this template is to allow the Entity that operates a Generation Resource, Energy Storage Resource (ESR), or a Controllable Load Resource to demonstrate acceptable frequency response of its Generation Resource(s), ESR(s), or Controllable Load Resource(s) based on historical data in order to minimize testing costs, scheduling conflicts and the risk of damage to equipment or Forced Outage.

1. All verifications will be based on at least one of the events from the published list of Frequency Measurable Events (FMEs).

2. Governor droop and Governor Dead-Band settings shall be set in accordance with Section 2.2.7.

3. For clarification purposes, the time of FME (t(0)), pre-perturbation average frequency and post-perturbation average frequency, as defined in Section 8, Attachment J, Initial and Sustained Measurements for Primary Frequency Response, will be used for the verification process. The values of these metrics will be identified in the FME Report.

4. The test is considered successful if the Generation Resource, ESR, or the Controllable Load Resource is able to meet a minimum of 75% of its initial Primary Frequency Response and 75% of its sustained Primary Frequency Response as calculated in the FMEs report posted on the Market Information System (MIS) Certified Area. Any Generation Resource, ESR, or Controllable Load Resource may use the FME report in lieu of testing.

a. The calculation of Generation Resources, ESRs, or Controllable Load Resources initial and sustained Primary Frequency Response is detailed in Section 8, Attachment J.

b. ERCOT shall evaluate initial and sustained Primary Frequency Response using an expected performance Governor droop of 5.78% for combined-cycle Resources.

5. Intermittent Renewable Resources (IRRs) located behind one point of interconnection, metered by one ERCOT-Polled Settlement (EPS) Meter, and operated as an integrated Facility may combine IRRs for the purposes of this test.

***Definitions***

Generation Resource, ESR, or Controllable Load Resource Base Load = maximum rated capability (this value is not reduced for temporary output limitations of the Generation Resource, ESR, or Controllable Load Resource due to auxiliary equipment outages, weather conditions, or fuel limitations, it is the “nameplate” rating of the Generation Resource, ESR, or Controllable Load Resource). For the IRR, the Base Load for purposes of this test shall be the Real-Time telemetered High Sustained Limit (HSL) (MW) of the IRR at the time of the FME. The IRR shall use only a FME in which the IRR’s HSL is greater than 50% of the IRR’s total design output capability.

# HISTORICAL GENERATION RESOURCE, ENERGY STORAGE RESOURCE, OR CONTROLLABLE LOAD RESOURCE FREQUENCY RESPONSE TEST FORM

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of FME:

QSE: Resource Entity:

***Historical Results***

|  |  |
| --- | --- |
| ***Evaluation Point*** | ***Frequency*** |
| ***Time (sec) of FME (t(0))*** |  |
| ***Pre-Perturbation Average Frequency (t(-2) to t(-16))*** |  |
| ***Post-Perturbation Average Frequency (t(20) to t(52))*** |  |

|  |  |  |
| --- | --- | --- |
| **1** | **Pre-Perturbation Average MW [T(-2 ) to T(-16)]** |  |
| **2** | **Post-Perturbation Average MW [T(+20 to T(+52)]** |  |
| **3** | **Expected Initial Primary Frequency Response (MW)** |  |
| **4** | **Expected Sustained Primary Frequency Response (MW)** |  |
| **5** | **Adjusted Actual Initial Primary Frequency Response (MW)** |  |
| **6** | **Adjusted Actual Sustained Primary Frequency Response (MW)** |  |
| **7** | **Initial Response P.U. Performance** |  |
| **8** | **Sustained Response P.U. Performance** |  |

***Comments:*** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

***Submittal***

Resource Entity Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

QSE Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date submitted to ERCOT Representative:

Intermittent renewable resource (IRR) Frequency Response Test Procedure

***Description of the Test***

1. The frequency response function of the Intermittent Renewable Resource (IRR) is tested On-Line at a Load level that allows the IRRs to increase or decrease Load without reaching low operating limits or high operating limits.

2. The test is performed by adding a frequency offset signal that exceeds the Governor Dead-Band value to the measured frequency signal. This should create immediate step change in the measured frequency signal.

3. The test starts at time t0 when the frequency Dead-Band is exceeded.

4. The MW output signal should be recorded at least every two seconds.

5. The duration of the test is 100 seconds. After 100 seconds, the offset signal should be removed and the IRR should return to pretest power output.

6. The test should be conducted both with positive and negative frequency offsets.

7. The test is considered successful after the signal becomes active if at least 70% of the calculated MW contribution is delivered within 16 seconds and the response is maintained for an additional 30 seconds.

8. Governor droop and Governor Dead-Band settings shall be set in accordance with Section 2.2.7.

9. IRRs located behind one Point of Interconnection (POI), metered by one ERCOT-Polled Settlement (EPS) Meter, and operated as an integrated Facility may combine IRRs for the purposes of this test.

***Definitions***

**IRR Base Load =** IRR telemetered High Sustained Limit (HSL) at the time of the test. The test shall be performed at an output level which is greater than 50% of IRR’s total design output capability.

**Gain MW for 0.1Hz** consistent with a selected droop percentage =



Where:

*P* = IRR telemetered HSL (MW)

*Droop* = droop (%)

**Frequency Offset** = +0.2 Hz and -0.2 Hz, outside Governor Dead-Band

**Test frequency** = Measured Frequency + Frequency Offset

**MW Contribution** = Gain MW to 0.1 Hz \* 10 \* Frequency Offset

**Calculated droop** = - 

Where:

*P* = IRR telemetered HSL (MW)

*ΔHz* = Change in frequency (Hz), taking into account Governor Dead-Band

*ΔMW* = Change in power output (MW)

***Example***

IRR telemetered HSL = 150 MW

Droop = 0.05 or 5% (use 0.05 for calculation)

Governor Dead-Band = 0.017 Hz

Gain MW for 0.1 Hz =  = +/- 5.03 MW/0.1 Hz

∆MW Contribution = 5.03 \* 10\* +/-0.2 = +/-10.06 MW

Expected under-frequency response: +10.06 MW in 16 sec. for -0.2 Hz offset

Expected over-frequency response: -10.06 MW in 16 sec. for +0.2 Hz offset

Minimum accepted under-frequency response: +7.04 MW in 16 sec. for -0.2 Hz offset

Minimum accepted over-frequency response: -7.04 MW in 16 sec. for +0.2 Hz offset

Calculated droop for 8MW increase in power output in 16 sec. for -0.2 Hz offset:

Calculated percent droop = - \*100 = 6.25%

**Intermittent renewable resource (IRR) FREQUENCY RESPONSE TEST FORM**

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of Test:

QSE: Resource Entity:

***Test Results***

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Test with +0.2 Hz** | **Test with -0.2 Hz** |
| **1** | **IRR Base Load** |  |  |
| **2** | **GAIN MW to 0.1Hz** |  |  |
| **3** | **Calculated Minimum****MW Contribution** |  |  |
| **4** | **MW at test start (t0)** |  |  |
| **5** | **MW at t0 + 16 sec** |  |  |
| **6** | **MW Contribution****at t0 + 16 sec** |  |  |
| **7** | **MW at t0 + 46 sec** |  |  |
| **8** | **Calculated droop** |  |  |
| **9** | **CONCLUSION****(PASSED/FAILED)** |  |  |

***Comments***: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

***Submittal***

Resource Entity Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

QSE Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date submitted to ERCOT Control Area Authority Rep.: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

# Controllable Load Resource Frequency Response Test Procedure

***Description of the Test***

1. The frequency response function of the Controllable Load Resource is tested On-Line at a Load level that allows Controllable Load Resources to increase or decrease Load without reaching Low Power Consumption (LPC) or Maximum Power Consumption (MPC).

2. The test is performed by adding a frequency offset signal that exceeds the Governor Dead-Band value to the measured frequency signal. This should create an immediate step change in the measured frequency signal.

3. The test starts at time t0 when the frequency Dead-Band is exceeded.

4. The MW output signal should be recorded at least every two seconds.

5. The duration of the test is 100 seconds. After 100 seconds, the offset signal should be removed and the Controllable Load Resource should return to pretest power output.

6. The test should be conducted both with positive and negative frequency offsets.

7. The test is considered successful after the signal becomes active if at least 70% of the calculated MW contribution is delivered within 16 seconds and the response is maintained for an additional 30 seconds.

8. Governor droop and Governor Dead-Band settings shall be set in accordance with Section 2.2.7.

***Definitions***

**Controllable Load Resource Base Load =** Controllable Load Resource telemetered MPC at the time of the test. The test shall be performed at an output level that allows the Controllable Load Resource to increase or decrease Load without reaching LPC or MPC.

**Gain MW for 0.1Hz** consistent with a selected droop percentage =



Where:

*P* = Controllable Load Resource telemetered MPC (MW)

*Droop* = droop (%)

**Frequency Offset** = +0.2 Hz and -0.2 Hz, outside Governor Dead-Band

**Test frequency** = Measured Frequency + Frequency Offset

**MW Contribution** = Gain MW to 0.1 Hz \* 10 \* Frequency Offset

**Calculated droop** = - 

Where:

*P* = Controllable Load Resource telemetered MPC

*ΔHz* = Change in frequency (Hz), taking into account Governor Dead-Band

*ΔMW* = Change in power output (MW)

***Example***

Controllable Load Resource telemetered MPC = 150 MW

Droop = 5%

Governor Dead-Band = 0.036 Hz

Gain MW to 0.1 Hz =  = +/- 5.06 MW/0.1 Hz

∆MW Contribution = 5 \* 10\* +/-0.2 = +/-10.12 MW

Expected under-frequency response: -10.12 MW in 16 sec. for -0.2 Hz offset

Expected over-frequency response: +10.12 MW in 16 sec. for +0.2 Hz offset

Minimum accepted under-frequency response: -7.08 MW in 16 sec. for -0.2 Hz offset

Minimum accepted over-frequency response: +7.08 MW in 16 sec. for +0.2 Hz offset

Note: The negative sign in expected under-frequency response and minimum accepted under-frequency response denotes the required reduction in power consumption. Similarly the positive sign in expected over-frequency response and minimum accepted over-frequency response denotes the required increase in power consumption.

Calculated droop for 8 MW increase in power output in 16 sec. for -0.2 Hz offset:

Calculated percent droop = - = 6.25%

**Controllable load resource FREQUENCY RESPONSE TEST FORM**

***General Information***

Unit Code (16 characters): Location (County):

Unit Name: Date of Test:

QSE: Resource Entity:

***Test Results***

|  |  |  |  |
| --- | --- | --- | --- |
|  |  | **Test with +0.2 Hz** | **Test with -0.2 Hz** |
| **1** | **Controllable Load Resource Base Load** |  |  |
| **2** | **GAIN MW to 0.1 Hz** |  |  |
| **3** | **Calculated Minimum****MW Contribution** |  |  |
| **4** | **MW at test start (t0)** |  |  |
| **5** | **MW at t0 + 16 sec** |  |  |
| **6** | **MW Contribution****at t0 + 16 sec** |  |  |
| **7** | **MW at t0 + 46 sec** |  |  |
| **8** | **Calculated droop** |  |  |
| **9** | **CONCLUSION****(PASSED/FAILED)** |  |  |

***Comments***: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

***Submittal***

Resource Entity Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

QSE Representative: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Date submitted to ERCOT Control Area Authority Rep.:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**ERCOT Nodal Operating Guides**

**Section 8**

**Attachment J**

**Initial and Sustained Measurements for Primary Frequency Response**

**Initial Primary Frequency Response Performance Calculation Methodology**

This section establishes the process used to calculate initial Primary Frequency Response (PFR) performance for each Frequency Measurable Event (FME) for Generation Resources, Energy Storage Resources (ESRs), Settlement Only Transmission Generators (SOTGs), Settlement Only Transmission Self-Generators (SOTSGs), and Controllable Load Resources.

This process calculates the initial Per Unit PFR of a Resource (P.U.PFRResource) as a ratio between the Adjusted Actual PFR (APFRAdj), adjusted for the pre-event ramping of the unit, and the Final Expected PFR (EPFRfinal) as calculated using the Pre-perturbation and Post-perturbation time periods of the initial measure.

* This comparison of actual performance to a calculated target value establishes, for each type of Resource, the initial P.U.PFRResource for any FME.
* **Initial Primary Frequency Response Measurement**

P.U.PFRResource is the per unit measure of the initial PFR of a Resource during identified FMEs.



Where P.U.PFRResource for each FME is limited to values between 0.0 and 2.0.

* The Adjusted Actual PFR (APFRAdj) and the Final Expected PFR (EPFRfinal) are calculated as described below.
* EPFR calculations use Governor droop and Governor Dead-Band values as stated in Section 2.2.7, Turbine Speed Governors, with the exception of combined-cycle facilities while being evaluated as a single resource (MW production of both the combustion turbine generator and the steam turbine generator are included in the evaluation) where the evaluation Governor droop will be 5.78%
* **Actual Primary Frequency Response (APFRadj)**

The Adjusted Actual Primary Frequency Response (APFRadj) is the difference between Post-perturbation Average MW and Pre-perturbation Average MW, including the ramp magnitude adjustment.



where:

**Pre‐perturbation Average MW**: Actual MW averaged from T‐16 to T‐2



**Post‐perturbation Average MW**: Actual MW averaged from T+20 to T+52



* Ramp Adjustment: The Actual PFR number that is used to calculate P.U.PFRResource is adjusted for the ramp magnitude of the generating unit/generating facility during the pre‐perturbation minute. The ramp magnitude is subtracted from the APFR.
* Ramp Magnitude = (MWT‐4 – MWT‐60)\*0.59

(MWT‐4 – MWT‐60) represents unit’s MW ramp for a full minute prior to the FME. The factor 0.59 adjusts this full minute ramp to represent the ramp that should have been achieved during the post‐perturbation measurement period.

* **Expected Primary Frequency Response (EPFR)**

For all Generation Resources, ESRs, SOTGs, SOTSGs, and Controllable Load Resources, the ideal Expected PFR (EPFRideal) is calculated as the difference between the EPFRpost‐perturbation and the EPFRpre‐perturbation.



When the frequency is outside the Governor Dead-Band and above 60Hz:



When the frequency is outside the Governor Dead-Band and below 60Hz:



For each formula, when frequency is within the Governor Dead-Band the appropriate EPFR value is zero. The deadbandmax and droopmax quantities come from Section 2.2.7.

Where:

**Pre‐perturbation Average Hz**: Actual Hz averaged from T‐16 to T‐2



**Post‐perturbation Average Hz**: Actual Hz averaged from T+20 to T+52



* Power Augmentation: For combined cycle facilities, Real-Time telemetered High Sustained Limit (HSL) is adjusted by subtracting the Real-Time telemetered Non-Frequency Responsive Capacity (power augmentation (PA) capacity). Other generator types may also have power augmentation that is not frequency responsive. This could be “over‐pressure” operation of a steam turbine at valves wide open or operating with a secondary fuel in service. The Resource Entity should provide ERCOT with documentation and conditions when power augmentation is to be considered in PFR calculations as described in paragraph (11) of Nodal Protocol Section 6.5.5.2, Operational Data Requirements.

**EPFRfinal for Combustion Turbines and Combined Cycle Facilities**

* 
* Note: The 0.00276 constant is the MW/0.1 Hz change per MW of capacity and represents the MW change in combustion turbine’s output due to the change in mass flow through the combustion turbine due to the speed change of the turbine during the post‐perturbation measurement period. This factor is based on empirical data from a major 2003 event as measured on multiple combustion turbines in ERCOT. 

**EPFRfinal for Steam Turbine**



where:



where:



*Throttle Pressure = Interpolation of Pressure* curv*e* a*t* MW*pre‐perturbation*

* The rated throttle pressure and the pressure curve, based on generator MW output, are submitted to ERCOT. This pressure curve is defined by up to six pair of pressure and MW breakpoints with the throttle pressure/MW output pair where rated throttle pressure is achieved as the first set and the throttle pressure/MW output pair where the minimum throttle pressure is achieved, as the last set of breakpoints. If fewer breakpoints are needed, the pair values will be repeated for different MW outputs (i.e. MW cannot be repeated on throttle pressure) to complete the six pair table.
* The K factor is used to model the stored energy available to the Resource. The value ranges between 0.0 and 0.6 psig per MW change when responding during an FME. The Resource Entity can measure the drop in throttle pressure when the Resource is operating near 50% output of the steam turbine during an FME and provide this ratio of pressure change to ERCOT. K is then adjusted based on rated throttle pressure and Resource capacity. An additional sensitivity factor, the steam flow change factor, is based on resource loading (% steam flow) and further modifies the MW adjustment. This sensitivity factor will decrease the adjustment at Resource outputs below 50% and increase the adjustment at outputs above 50%. The Resource Entity should determine the fixed K factor for each Resource that generally results in the best match between EPFR and APFR (resulting in the highest P.U.PFRResource). For any generating unit, K will not change unless the steam generator is significantly reconfigured.

**EPFRfinal for Other Generating Units/Generating Facilities and Energy Storage Resources**

 

Where X is an adjustment factor that may be applied to properly model the delivery of PFR. The X factor will be based on known and accepted technical or physical limitations of the Resource. X may be adjusted by ERCOT and may be variable across the operating range of a resource. X shall be zero unless ERCOT accepts an alternative value.

**SUSTAINED Primary Frequency Response Performance Calculation Methodology**

* This section establishes the process used to calculate sustained Primary Frequency Response (PFR) performance for each FME.
* This process calculates the Per Unit Sustained PFR of a Resource (P.U.SPFRResource) as a ratio between the maximum actual unit response at any time during the period from T+46 to T+60, adjusted for the pre‐event ramping of the unit, and the *Final* Expected Primary Frequency Response (EPFR) value at time T+46.[[3]](#footnote-3)
* This comparison of actual performance to a calculated target value establishes, for each type of Resource, the P.U.SPFRResource for any FME.
* **Sustained Primary Frequency Response performance measurement:**

**Sustained Primary Frequency Response Calculation (P.U.SPFR)**



*P.U.SPFRResource* is the per unit (P.U.) measure of the sustained PFR of a Resource during identified FME. The *P.U.SPFRResource* for each FME will be limited to values between 0.0 and 2.0.

**Actual Sustained Primary Frequency Response (ASPFR) Calculations**



where:

Pre‐perturbation Average MW: Actual MW averaged from T‐16 to T‐2.



and:

*MWMaximumResponse* ***=*** *maximum MW value telemetered by a unit from T+46 through T+60 during low frequency FMEs and the minimum MW value telemetered by a unit from T+46 through T+60 during a high frequency FME.*

**Actual Sustained Primary Frequency Response, Adjusted (ASPFRAdj)**



RampMW Sustained (MW) – Generation Resources, ESRs, SOTGs, SOTSGs, and Controllable Load Resources are required to sustain their response to an FME. An adjustment available in determining sustained PFR performance (*P.U.*SPFR*Resource* ) is to account for the direction in which a Resource was moving (increasing or decreasing output) when the FME occurred T=t(0). This is the *RampMW* Sustained adjustment:

* *RampMW* Sustaine*d* = (*MWT‐4 – MWT‐60*) x 0.821

*Note:* Th*e* terminolog*y* “MW*T‐4” refers to MW output at 4 seconds before the FME occurs at T=t(0).*

By subtracting a reading at 4 seconds before, from a reading at 60 seconds before, the formula calculates the MWs a generator moved in the minute (56 seconds) prior to T=t(0).

 The formula is then modified by a factor to indicate where the unit would have been at T+46, had the FME not occurred: the “*RampMW Sustained*.” It does this by multiplying the MW change over 56 seconds before the event (MWT‐4 – MWT‐60) by a modifier. This extrapolates to an equivalent number of MWs the generator would have changed if it had been allowed to continue on its ramp to T+46 unencumbered by the FME. The modifier is 

**Expected Sustained Primary Frequency Response (ESPFR) Calculations**

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 Generation Resource, ESR, SOTG, SOTSG, or Controllable Load Resource should have responded with, if it is properly sustaining the output of its generating unit/generating facility in response to an FME. Determination of this value begins with establishing where it would be in an ideal situation; considers proper Governor droop and Governor Dead‐Band values established in Section 2.2.7, HSL, Low Sustained Limit (LSL) and actual frequency. It then allows for adjusting the value to compensate for the various types of limiting factors each Generation Resource, ESR, SOTG, SOTSG, or Controllable Load Resource may have and any Non-Frequency Responsive Capacity (NFRC) that may be included in the HSL.

**Establishing the Ideal Expected Sustained Primary Frequency Response**

For Generation Resources, ESRs, SOTGs, SOTSGs, and Controllable Load Resources, the ideal Expected Sustained PFR (ESPFRideal) is calculated as the difference between the ESPFRT+46 and the EPFRpre‐perturbation. The EPFRpre‐perturbation is the same EPFRpre­-perturbation value used in the Initial measure.



When the frequency is outside the Governor Dead-Band and above 60Hz:



* When the frequency is outside the Governor Dead-Band and below 60Hz:

 

For combined cycle facilities, determination of frequency responsive capacity includes subtracting power augmentation (PA) capacity, if any, from the original telemetered HSL. Other generator types may also have power augmentation that is not frequency responsive. This could be “over‐pressure” operation of a steam turbine at valves wide open or operating with a secondary fuel in service. The Resource Entity is required to provide ERCOT with documentation and conditions when power augmentation is to be considered in PFR calculations as described in paragraph (11) of Nodal Protocol Section 6.5.5.2.

**ESPFRfinal for Combustion Turbines and Combined Cycle Facilities**



Note: The 0.00276 constant is the MW/0.1 Hz change per MW of capacity and represents the MW change in combustion turbine’s output due to the change in mass flow through the combustion turbine due to the speed change of the turbine at HZT+46. (This is based on empirical data from a major 2003 event as measured on multiple combustion turbines in ERCOT.)

**ESPFRfinal for Steam Turbine**



where:



where:



*Throttle* Pressur*e =* Interpolatio*n* o*f* Pressur*e* curv*e* a*t* MW*pre‐perturbation*

**ESPFRfinal for Other Generating Units/Generating Facilities and Energy Storage Resources**

 

where X is an adjustment factor that may be applied to properly model the delivery of PFR. The X factor will be based on known and accepted technical or physical limitations of the resource. X may be adjusted by ERCOT and may be variable across the operating range of a resource. X shall be zero unless ERCOT accepts an alternative value.

**Limits on calculation of PFR Performance (Initial & Sustained)**

For frequency deviations below 60Hz (HZpost-perturbation < 60)

If for a generating unit/generating facility

$MW\_{Pre-Perturbation} \geq min⁡(\left[\left(HSL-PA capacity\right)\*0.98\right],\left[\left(HSL-PA capacity\right)-5MW\right])$

Then Primary Frequency Response is not evaluated for this FME.

For frequency deviations above 60Hz (HZpost-perturbation > 60)

If for a generating unit/generating facility

$MW\_{Pre-Perturbation} \leq max⁡(\left[LSL+\left(HSL-PA capacity\right)\*0.02\right],\left[LSL+5MW\right]))$

Then Primary Frequency Response is not evaluated for this FME.

For ESRs, while discharging, if operating within the larger of 3 MW or 2% of the Real-Time Maximum Operating Discharge Power Limit for low frequency disturbances then Primary Frequency Response is not evaluated for this FME.

For ESRs, while charging, if operating within the larger of 3 MW or 2% of the Real-Time Maximum Operating Charge Power Limit for high frequency disturbances then Primary Frequency Response is not evaluated for this FME.

When Expected Primary Frequency ResponseFinal is greater than operating margin Caps and limits exist for resources operating with adequate reserve margin to be evaluated (greater of 2% of (HSL less PA Capacity) or 5 MW), but with Expected Primary Frequency ResponseFinal greater than the actual margin available.

(1) The $P.U. PFR\_{Resource}$ will be set to the greater of 0.75 or the calculated $P.U. PFR\_{Resource}$if all of the following conditions are met:

(a) The generating unit/generating facility’s or ESR’s pre‐perturbation operating margin (appropriate for the frequency deviation direction) is greater than 2% of its $\left(HSL-PACapacity\right)$ and greater than 5 MW; and

(b) The $EPFR\_{Final}$ is greater than the generating unit/generating facility’s or ESR’s available frequency responsive capacity[[4]](#footnote-4); and

(c) The generating unit/generating facility’s or ESR’s $APFR\_{Adj}$ response is in the correct direction.

(2) When calculation of the $P.U. PFR\_{Resource}$ uses the resource’s $HSL-PACapacity$ as the maximum expected output, the calculated $P.U. PFR\_{Resource}$ will not be greater than 1.0.

(3) When calculation of the $P.U. PFR\_{Resource}$ uses the resource’s $LSL-PACapacity$ as the minimum expected output, the calculated $P.U. PFR\_{Resource}$ will not be greater than 1.0.

(4) If the $APFR\_{Adj}$is in the wrong direction, then $P.U. PFR\_{Resource}$ is 0.0.

(5) These caps and limits apply to both the Initial and Sustained Primary Frequency Response measures.

**INITIAL PFR and SUSTAINED PFR PERFORMANCE REQUIREMENT**

ERCOT computes an average Initial PFR and Sustained PFR performance based on either all FMEs evaluated within 12 months or the last eight FMEs (applicable if a minimum threshold of eight FMEs within the 12 month period is not met). Each Generation Resource, ESR, SOTG, SOTSG, and Controllable Load Resource shall meet a minimum rolling average initial Primary Frequency Response performance and sustained Primary Frequency Response performance of 0.75.

**Initial PFR requirement:**



**Sustained PFR requirement:**



1. Westinghouse recommends using only this test. [↑](#footnote-ref-1)
2. Westinghouse recommends using only this test. [↑](#footnote-ref-2)
3. The time designations used in this section refer to relative time after an FME occurs. For example, “T+46” refers to 46 seconds after the frequency deviation occurred. [↑](#footnote-ref-3)
4. In this circumstance, when frequency is below 60 Hz, the EPFR\_final is set to operating margin based on HSL (adjusted for any augmentation capacity) AND when frequency is above 60 Hz, the EPFR\_final is set to operating margin based on LSL for the purpose of calculating PUPFR\_resource. [↑](#footnote-ref-4)