Frequently Asked Questions: Test Requirements for Advanced Grid Support Energy Storage Resources (AGS-ESR)

Version 1

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1 Frequently Asked Questions

Q1: Does ERCOT require ESRs to maintain headroom for AGS during real-time operations?

R1: The test requirements are designed to confirm whether an ESR possesses AGS capability through model quality tests when an ESR has a headroom available. ERCOT's proposed NOGRR 272 and PGRR 121 do not mandate that ESRs maintain headroom for AGS during real-time operations.

Q2: Is it clear whether plant controls should be considered in the testing process? Should all plant controls be included in the site-specific test?

R2: All plant controls that are needed to represent the ESR's performance at Point of Interconnection must be included in the site-specific test

Q3: Why are there no tests conducted at full charge power or with reactive power?

R3: ERCOT evaluated various dispatched scenarios when developing the proposed test requirements. ERCOT believes that the selected dispatch scenarios that Resource Entities and Interconnecting Entities must conduct to meet the test requirements are sufficient to verify ESR with AGS characteristics.

Additionally, all generation projects must undergo further evaluation during the full interconnection study including dynamic stability study conducted based on ERCOT Protocol, Planning Guide and NERC Reliability Standards. Various scenarios are evaluated during the system impact analysis.

Q4. Why are reactive step tests, such as the series compensation step test, not included in the ERCOT test requirements?

R4: It was presented in the ERCOT AGS ESR Test requirement document and discussed at IBRWG in September 2024: Reference: **ERCOT Advanced Grid Support ESR Test Requirement .pdf**

Q5. How does ERCOT ensure that AGS-ESR models account for converter limitations on the DC side, including active power limits?

R5: The dynamic model of an AGS-ESR should include converter controls that account for current or voltage limits on the DC side if necessary to represent appropriate dynamic behavior, as well as interactions with the AC system.

Q6: Why does Small Voltage Disturbance Test indicate very tight V(Q) droop and/or closed-loop plant controls?
R6: For the model quality test, we do not prescribe specific control requirements. Instead, we evaluate the resource's response at the Point of Interconnection (POI). The 3% voltage step test is an existing requirement that all inverter-based resources (IBRs) must pass. This step change is deliberately set outside the tolerance bands specified in Section 2.7.3 of the ERCOT Nodal Operating Guide (NOG) to ensure a measurable response.

Q7: Why is the frequency change and inertia response test only conducted at zero active and reactive power? Does ERCOT require a specific response beyond a 1Hz/s rate of change of frequency (ROCOF)? Why are there no tests for conditions exceeding 60Hz? Was this omission intentional? How realistic is an instantaneous 0.3Hz frequency step? Doesn't this represent an effectively infinite rate of change?
R7: The primary purpose of the inertia response test is to evaluate the ESR's energy response during the initial frequency decay within the first 0.5 seconds. The initial dispatch of the ESR is set to zero active power with approximately zero reactive power. This approach ensures that the performance related to ESR's energy response can be observed without complicating the response with other factors.

ERCOT had evaluated various dispatched scenarios when developing the proposed test requirements. ERCOT believes that the selected dispatch scenarios that the Resource Entities and developers must conduct to meet the test requirements are sufficient to verify ESR with AGS characteristics. The frequency step test is not intended to assess RoCoF ride-through capability of an IBR. It is an existing test requirement applicable to all IBRs. The main purpose of this test is to examine the active power response during a frequency step change and when the frequency is not ramping.

Q8: For Frequency Change and Inertia Response Test, what are the performance criteria for the instantaneous provision of active current? The passing criteria could potentially be met by a fast Grid-Following (GFL) inverter, which inherently introduces dead time due to metering, control delays, and communication latency. Furthermore, the statement "Voltage should not deviate from steady state for any significant amount of time" lacks specificity. Since inertial power is delivered through plant impedance, some voltage deviation is expected. How is the allowable duration of voltage deviation defined? Additionally, plant controls can impact ΔE. Should the Power Plant Controller (PPC) be activated or deactivated during this test? Does this imply GFM-Droop is required on convertor or Plant level frequency controls?

R8: See the response to Q7 for the overall purpose of this test. Even if a GFL-ESR meets the inertia response criteria, it must pass all other required tests to qualify as an AGS-ESR.

ERCOT's approach is to avoid overly prescriptive criteria, particularly regarding the response during the transition to the stabilization period. Instead, engineering judgment will be applied to assess performance. For further details on damping criteria, please refer to ERCOT Planning Guide Section 4.

Plant controls must be included in the site-specific test. The model quality test does not prescribe specific control requirements but instead evaluates the response at the Point of Interconnection (POI).

Q9: For System Strength Test, why is the test only conducted during discharge mode? Why is there no reactive power response, despite GFM inherently providing reactive power support? Experience indicates that GFM controls most frequently fail under asymmetrical fault conditions, particularly during phase C-to-ground (C-GND) faults. Should all fault types be considered in the test?

R9: This test is the same as the existing system strength test required for all IBRs. The primary objective is to evaluate the performance of the AGS-ESR across different system strength levels. Various test scenarios can be considered; however, the intent of these test requirements is to establish a minimum set of tests necessary to determine whether an ESR demonstrates AGS capability.

Additionally, new generation projects must undergo a full interconnection study, including a dynamic stability study conducted in accordance with ERCOT Protocol, the Planning Guide, and NERC Reliability Standards (e.g., TPL-001-5.1 and FAC-002-4). Please also refer to the response to Q3.

Q10: Regarding the Loss of Synchronous Machine Test, if there is concern about plant-to-plant oscillation, should this first be tested within a single plant (block-block), or should more onerous tests be applied? No specific performance criteria are mentioned for Scenario 3. What is the justification for the 5- and 10-seconds? Can a check be added to ensure that there is no opposing active (P) or reactive (Q) power exchange between the two plants? The current setup suggests that f(P) and V(Q) droop controls are required at the converter level—was this intentional?

R10: The inclusion of two machines primarily serves to evaluate the appropriate real and reactive power responses from the ESRs and to identify any control interactions, particularly when one machine reaches its operational limits.

The duplicate ESR is an identical copy of the project ESR, with the only difference being its initial dispatch. As a result, there should be no circulating active or reactive power between the two machines. Performance criteria are clearly defined in Table 6.

Regarding the criteria "system frequency and voltage should settle to a stable operating point (within 5 seconds) and be damped within 10 seconds", without excessive oscillation or deviation from steady state levels ", the 5- and 10-seconds are based on testing various OEM models and past experiences.

For the model quality test, we do not prescribe which specific control is required. Instead, the evaluation focuses on the response at the Point of Interconnection (POI).

Q11: For the phase angle jump test, is an increase of 0.2 pu required for a 10-degree angle drop?

R11: Yes, it is required. However, if the inverter reaches its current limit when the angle jump is applied, the performance criteria may not be applicable.

Q12: According to analysis and simulation results, the Phase Angle Jump Test outcomes are dependent on site-specific impedance. It is recommended to add flexibility to the requirement based on site-specific impedance, as power change is a function of total impedance, and the requirement may not always be achievable.

R12: Theoretically, voltages at the terminal and voltage source should be higher than the commenter's analysis assumption (e.g., assumed constant at 1.0 pu). ERCOT's success criteria for each 10 degree angle jump are based on the worst-case total impedance of approximately 70% (i.e., maximum plant impedance of approximately 37% at an X/R ratio of 10). Additionally, the criteria were established through testing with various OEM models. Please refer to the knee curve in Appendix.

Q13: Does the one-cycle criteria for rise time apply to the case with a 25-degree jump, or is it only relevant to the 10-degree case?

R13: The response time to 90% of the initial change in instantaneous active power should occur within one cycle. This criterion is applicable to both 10-degree and 25-degree angle jump tests. The time to reach the power peak (one cycle) is not dependent on the input (i.e., angle step size); it is based on the plant inductance between the two sources. Therefore, it should satisfy the one-cycle requirement. However, if the current limit in the inverter is reached when the angle jump is applied, the performance criteria may not apply. The criteria are also based on tests of various OEM models and a review of practices in other regions.

Q14: Does the 3-cycle criteria in the Phase Angle Jump Test apply only when the plant reaches the current limit?

R14: ERCOT has updated the criteria to clarify that "*The active power must not return to the pre-disturbance level for at least 3 cycles.*" If the current limit in the inverter is reached during the angle jump, the performance criteria may not apply. However, the active power must still return to the pre-disturbance level in a stable manner.

Q15: Commenter recommended to use quantitative requirements instead of qualitative ones, as the latter can be subject to interpretation.

R15: ERCOT’s proposed test framework includes specific criteria when applicable and also qualitative expectation to avoid overly prescriptive criteria that could negatively impact the grid. This approach provides flexibility to fit various system conditions

2 Appendix

A) Quantifying Inertia Response of ESR

To estimate the inertia response of an ESR in opposing frequency change and estimate its equivalent inertia constant, the swing equation can be used.

$$\frac{2H}{f_n} = \frac{\Delta P}{df/dt} , \qquad (A1)$$

where

H is the equivalent inertia constat of the ESR in s,

f_n is the nominal frequency,

ΔP is the change of output power in pu based on the ESR rating,

df/dt is the rate of change of frequency (RoCoF) in Hz/s.1

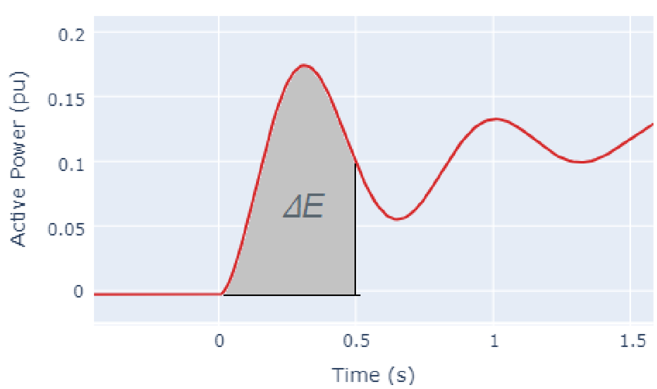
To quantify the inertia response of a resource using the swing equation, a disturbance needs to be applied. For this purpose, the frequency of the controllable voltage source is changed by a fixed rate and the output active power is measured. Since the output power changed during the time, the average ΔP (ΔP_{av}) during the study time is used for quantifying the inertia constant. Therefore,

$$H = 0.5\, f_n \frac{\Delta P_{av}}{df/dt} = 0.5\, f_n \frac{\frac{1}{T}\overbrace{\int_{t_0}^{t_0+T} \Delta P(t)\, dt}^{\Delta E}}{df/dt} = 0.5\, f_n \frac{\Delta E/T}{df/dt}\ [s], \qquad (A2)$$

Considering, f_n =60 Hz, *df/dt* = 1 Hz/s, and T= 0.5 s, then:

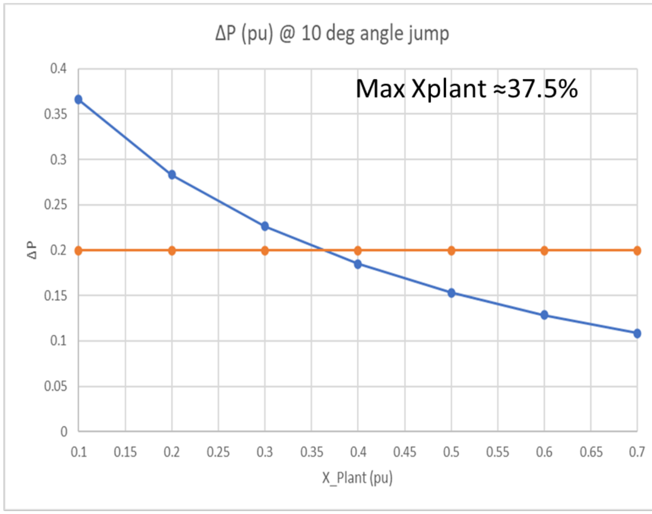
$$H = 60 * \Delta E\ [s], \qquad (A.3)$$

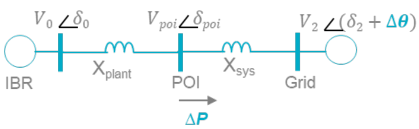
where ΔE is the area under the active power production change of the ESR from *0* to *0.5* s in pu. Figure 4 illustrates how to calculate ΔE *from the active power output of the resource.*



The output active power of the resource and illustration of ΔE

B) Knee Curve for Theoretical Steady-State ΔP versus X_{plant} with a 10-Degree Angle Jump.





$$\Delta P = \frac{V_0 V_2 [\sin(\delta_0 - \delta_2 - \Delta\theta) - \sin(\delta_0 - \delta_2)]}{X_{plant} + X_{sys}}$$

* Assumed that R is negligible