

Reactive Study Scope v10

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# Purposes of the Reactive Study

* 1. Show the entire reactive capability of the resource or resources
	2. Show the plant design will be able to meet Voltage Support Services required for the range of anticipated operating conditions
	3. Note: Although a passing reactive study is a requirement for Initial Synchronization, a passing reactive study does not guarantee that a plant will meet protocol requirements once in operation. Thoughtful, coordinated design of plant reactive controls is paramount. It is up to the plant designers and operators to make sufficient allowance and margin for real-world operating conditions; designing plants that barely meet standards on paper is risky and not recommended.

# Which resources have to do a reactive study?

* 1. All resources going through the Generation Resource Interconnection or Change Request process including those smaller than 20 MVA that are not required to provide Voltage Support Services
	2. ERCOT staff may waive this requirement for some repower projects if the reactive study has been successfully completed in the past and is well-documented and not expected to change. (Send request to Resource Integration engineer assigned to the project.)

# Acronyms and Definitions

* 1. IA = Interconnection Agreement
	2. ESR = Energy Storage Resource
	3. HSL = High Sustainable Limit of a generation resource
	4. IRR = Intermittent Renewable Resource, a Generation Resource that can only produce energy from variable, uncontrollable Resources, such as wind, solar, or run-of-the-river hydroelectricity
	5. LSL = Low Sustainable Limit of a generation or energy storage resource
	6. Low Output Point (LOP)= LSL for conventional generators; 10% of maximum real power output for IRRs; LSL (maximum charging) for ESRs
	7. MPT = Main Power Transformer
	8. P = real power output of a generation resource
	9. POI = Point Of Interconnection
	10. Q = reactive output or consumption of a generation resource
	11. RARF = Resource Asset Registration Forms
	12. RIOO = Resource Integration Ongoing Operations
	13. STATCOM = Static Synchronous Compensator
	14. SVC = Static Var Compensator
	15. VSS = voltage support services

# Required Documentation

* 1. Description of resource that matches RARF, RIOO, and the IA
	2. Description of the resource connection to ERCOT, including at least:
		1. POI bus name, nominal voltage
		2. Length, voltage, and conductor of gen-tie, if any
		3. Size and impedance of MPT
		4. Description of MPT load tap changer (LTC) if any, including which side is controlled, and how quickly (seconds) it can change positions
	3. Manufacturer’s real versus reactive power curve (also known as “D-curve” or “PQ curve”)
	4. Manufacturer’s reactive power versus terminal voltage curve (“QV curve”)
	5. Table 1 (shown below) – Reactive Device Inventory
	6. Table 2 (shown below) – Study Results

# Operating Points to study (see Figure 1)

* 1. POI voltage = 0.95 per unit, reactive power = maximum supplying (lagging)
		1. HSL
		2. LOP
	2. POI voltage = 1.0 per unit, reactive power = maximum absorbing (leading)
		1. HSL
		2. LOP
	3. POI voltage = 1.04 per unit, reactive power = maximum supplying (lagging)
		1. HSL
		2. LOP
	4. POI voltage = 1.05 per unit, reactive power = maximum absorbing (leading)
		1. HSL
		2. LOP
	5. *Note 1: these four operating points are the extreme corners of Figure 1 below and they are required even if a different POI Voltage Profile has been provided.*

# General Description of the Study

* 1. Check #1, Dynamic Reactive Capability (Gross)
		1. Use the PQ curve for V = 1.0 pu from the manufacturer: draw one line at P = HSL and another at the LOP. Multiply the results by the number of turbines or inverters of this type. Repeat for each type of inverter or turbine and sum.
		2. The resulting Q ranges in Mvar should be no less than +/- 0.329\*Pmax in MW, where Pmax is the maximum net real power deliverable to the POI. If either Q range is too small, the resource will need dynamic reactive support, such as a STATCOM or SVC.
		3. If the equipment is sensitive to ambient temperature, use the PQ curve for max design ambient temperature. Design ambient temperature should be no less than 35C.
		4. Fill out the Reactive Device Inventory (Table 1).
		5. The resulting Q range should not be artificially limited but should reflect the actual equipment capability.
	2. Check #2, Reactive Performance at POI (Net)
		1. Use a steady-state loadflow program. Model a slack bus with one extremely big generator and matching load at the same bus. The TSP will provide a preliminary short circuit capability of the POI (PGRR076, approval pending). Use this generator to set the POI voltage. Model the transmission line gen-tie, if any, from the slack bus to the high-side of the MPT. Model the MPT. Model the entire collector system including each cable segment and all the transformers and all turbines or inverters. Model all switched capacitor banks and reactors. If a STATCOM or SVC will be part of the resource, then model it.
		2. *Note 1: The model should be detailed down to whatever voltage level is represented by the PQ and QV curves. For wind turbines this may be 690 volts, but for photovoltaic solar resources this may be 34.5kV at the individual skid. The model may include auxiliary or station service loads if they are known but this is not required. If loads are modeled this should be noted in the resource interconnection description.*
		3. Use the slack bus generator to set Vpoi to 0.95 per unit, adjust the MPT LTC and other variables to maximize the Mvar provided to the POI. Check individual terminal voltages. If any terminal voltage is outside the permissible operating range then this iteration must be excluded. Adjust variables again (MPT tap, capbank, reactor, transformer taps, generator Vsched, etc) until an iteration is found with maximum Mvars supplied to POI (lagging) while all generator terminal voltages are within range. Record this in the Study Results Table (Table 2).
		4. *Note 2: The resulting Q values should not be limited by anything other than the voltage operating limits at the generator or inverter terminals but should reflect the actual equipment capability.*
		5. Repeat for Vpoi = 1.0 per unit and maximize Mvar absorbed from the POI (leading).
		6. Repeat for Vpoi = 1.04 per unit and maximize Mvar supplied to POI (lagging).
		7. Repeat for Vpoi = 1.05 per unit and maximize Mvar absorbed from the POI (leading).
		8. These four points are shown as the outside corners of Figure 1 below and are required for ERCOT. The engineer doing the study may wish to evaluate and document other operating conditions for other reasons, including calculations that will be used to complete the RARF or to consider a known Voltage Profile.

# Examples of More Complicated Studies Involving Multiple Resources at the Same POI

* 1. Resources which have different reactive requirements (See next section “Tricky Exceptions”) – Must be evaluated independently
	2. Resources which have same reactive requirements but different operating regimes. For example, if one resource is solar and the other is storage, it is expected that the storage may operate in generation mode at night while the solar is not generating. Evaluate the resources independently.
	3. Resources which have same reactive requirements and similar operating regimes, such as multiple types of wind turbines on separate feeders within the same project – the resources may be evaluated jointly or independently.
	4. Resources have same reactive requirements and similar operating regimes, such as multiple types of wind turbines but are on the same feeders – the resources should be evaluated jointly.
	5. Combined-cycle steam turbine – If GTs are sister units, a single reactive evaluation for one unit plus a second reactive evaluation for min(GT + steamer) and for max(GTs + steamer) is best. If the GTs are not sister units then each will need its own reactive evaluation plus the min(GT + steamer) and the max(GTs + steamer) evaluations.

# Tricky Exceptions to the Standard Requirements (Repowering Projects for Older Resources)

* 1. The 2010 Voltage Profile is posted at <http://www.ercot.com/gridinfo/generation/voltprof/> as “Voltage\_Profiles\_Summer-Fall2010\_051010.xls”
	2. The established reactive capability curve of existing resources is available to the owners in NDCRC and in the RARF.
	3. Nodal Protocols 3.15 (8), conventional generators online before 9-1-1999 whose designs do not meet the standard requirements
		1. Owner must provide documentation of initial reactive capability and this should generally agree with the most recent reactive tests
		2. No decrease of reactive capability is permitted
	4. Nodal protocols 3.15 (8) and (9), wind resources online before 2-17-2004 or online before 5-17-2005 and designed before 2-17-2004 (approx. 18 resources) whose designs do not meet the standard requirements
		1. Owner must provide documentation of initial reactive capability
		2. No decrease of reactive capability is permitted
		3. If the most recent reactive tests indicates that the documentation of initial reactive capability was overstated, then the owner shall make up the deficit as part of the repower project.
	5. Nodal Protocols 3.15 (7) (b), Wind Generation Resources online after 2-17-2004 and IA signed before 12-1-2009 with design capable of meeting standard reactive requirement
		1. Reactive capability requirement is +/- 0.95 power factor of maximum real power output, the “rectangle.”
		2. Reactive capability requirement applies to the 2010 Voltage Profile
		3. No decrease of reactive capability is permitted.
	6. Nodal Protocols 3.15 (7) (a), Wind Generation Resources online after 2-17-2004 and IA signed before 12-1-2009 with design **not** capable of meeting standard reactive requirement
		1. Reactive capability requirement is +/- 0.95 power factor of current real power output, the “triangle.”
		2. Reactive capability requirement applies to the 2010 Voltage Profile
		3. No decrease of reactive capability is permitted.
	7. For repower projects that will result in reduced real power output, the previous reactive capability curve should be truncated at the new maximum real power output but not otherwise reduced.

# References

* 1. Planning Guide 5.7.1(4)(d)(iii) and 5.9(4)(c)(ii)
	2. Nodal Protocols 3.15
	3. Operating Guide 2.7 plus NOGRR195

# Illustrations: Figure 1 Reactive requirements at POI per 100 MW, Table 1 Reactive Device Inventory, and Table 2 Study Results

## Figure 1: Reactive requirements at POI per 100 MW



Notes for Figure 1:

1. The solid lines are the minimum reactive capability requirement per 100 MW.
2. The dotted lines are the total reactive capability of the resource.
3. The reactive study should demonstrate both the total reactive capability of the resource with no artificial restrictions, and compliance with the minimum requirement.

## Table 1: Reactive Device Inventory

Please include the below template in the study report:

* Generation Resource High Sustained Limit, net power deliverable to POI: \_\_\_\_\_\_\_\_\_ MW.
* Generation Resource LOP net power deliverable to POI: \_\_\_\_\_\_\_\_\_ MW.
* Required VAR capability @ POI, calculated as 32.9% of HSL: ± \_\_\_\_\_\_MVAr.
* Inventory total gross reactive capability (nominal, @ device terminals, excluding losses):
	1. Generating Units (LOP): \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
	2. Generating Units (HSL): \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
	3. Switchable Shunts: \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
	4. Auxiliary Dynamic Devices (SVC, STATCOM)[[1]](#footnote-1): \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
	5. Grand Total (add #2, 3, 4): \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
	6. Total Dynamic at low output point (add #1, 4): \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
	7. Total Dynamic at HSL (add #2, 4): \_\_\_\_\_\_\_ MVAr lag / \_\_\_\_\_\_\_ MVAr lead
* Reminders:
	+ The resource shall have Automatic Voltage Regulation
	+ The AVR is required to be in automatic voltage control mode controlling the dynamic reactive output and switching static reactive devices
	+ No alternative control schemes are permitted
	+ The resource must be capable of maintaining a voltage setpoint at the POI
* What is the estimated response time of the shunts to a low voltage? \_\_\_\_\_\_ seconds
* Paste manufacturer charts showing:
	+ Reactive capability versus real power output (“PQ chart”, or “D-curve”).
	+ Reactive capability versus terminal voltage (“QV chart” or family of D-curves).
* List acceptable steady-state voltage ratings:
	+ Generating units: \_\_\_\_\_\_\_volts low / \_\_\_\_\_\_\_ volts high
* Notes about Droop and Deadband:
	+ Deadband is the % voltage set-point error range which causes no reactive output
	+ Droop is defined as additional % voltage set-point error (after deadband) causing 100% reactive power dispatch
	+ Voltage droop + deadband should be small enough to keep the POI within the tolerance band in the table from NOGRR195 (approval pending):

|  |  |
| --- | --- |
| POI Voltage | Tolerance Band KV |
| 345 | +/- 4kV |
| 230 | +/- 3kV |
| 138 | +/- 2kV |
| 115 | +/- 2kV |
| 69 | +/- 1kV |

* Notes about switchable shunt timing. Unless doing so would lead to instability or oscillation, the following guidelines are recommended for controlling shunt reactive devices:
	+ Static reactive devices that are used to meet VSS requirements should be able to switch quickly as part of the AVR system.
	+ The AVR system should be configured to control shunt devices with the aim of preserving dynamic capability of the unit(s).
	+ Shunt devices should not wait for the units’ reactive capability to be exhausted before switching.
	+ The first shunt device is expected to switch in less than a minute after an AVR set-point change or voltage event that would require the device to provide reactive power. Subsequent shunt devices can wait up to a minute the since last device switched in before switching. A reasonable lockout-timer (typically, 5 minutes) which prevents the devices from switching out is acceptable.

## Table 2: Study Results

This template shows the minimum data required to report the study results. Rows and columns may be added to enable error-checking and to assist filling out the RARF.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| POI Vol-tage | Dis-patch | Reactive Test | MW Real Power Delivered to POI | Mvar Reactive Power Delivered to POI | Shunts in Service(+Mvar cap, or -Mvar react) | Total Mvars at all turbine or inverter terminals | Lowest voltage at turbine or inverter terminals, pu | Highest voltage at turbine or inverter terminals, pu |
| 0.95 pu | HSL | Max Lagging |  |  + |   |  |  |  |
| LOP | Max Lagging |  |  + |   |  |  |  |
| 1.00 pu  | HSL | Max Leading |  |  – |   |  |  |  |
| LOP | Max Leading |  |  – |   |  |  |  |
| 1.04 pu  | HSL | Max Lagging |  |  + |   |  |  |  |
| LOP | Max Lagging |  |  + |   |  |  |  |
| 1.05 pu | HSL | Max Leading |  |  – |   |  |  |  |
| LOP | Max Leading |  |  – |   |  |  |  |

Notes:

* A generator operating in **lagging** excitation injects reactive power similar to a capacitor. A generator operating in **leading** excitation absorbs reactive power similar to a reactor.
* Total Mvars at all turbine or inverter terminals is the straight summation of the reactive power delivered by each turbine, wind turbine, solar inverter, or ESR inverter. (Purpose of this column is to allow ERCOT to estimate total losses and compare to size of installed switched shunts.)
* The steady-state rating of any STATCOMs (and not the overload rating) should be used when computing reactive power deliverable to the POI.
* It is okay to add a column to record the total reactive power delivered to the central low-side bus from all the generator feeders, excluding the output of all shunts and auxiliary dynamic devices. This data is not used to evaluate the resource’s ability to meet ERCOT reactive standards but it will be helpful to whoever is responsible for filling out the Reactive tab of the RARF.
* The purposes of the final two columns are
	+ To demonstrate that the solution does not put any equipment outside its allowable voltage range
	+ To give an idea how much the reactive capability of the final turbines or inverters had to be derated with respect to the QV curve
1. The overload rating of the STATCOM can be used on this line. If so, provide documentation from the manufacturer stating the overload multiplier and how many cycles or seconds that overload can be sustained. [↑](#footnote-ref-1)