

Reactive Reserves & Unit Testing

PJM Initial Training Program

Student Guide

Prepared by:
State & Member Training
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Objectives

- Identify the process for monitoring and maintaining reactive reserves
- Identify the reactive capability testing process and requirements

Capability Curve/Limitations



Reactive Capability

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Capability Curve/Limitations

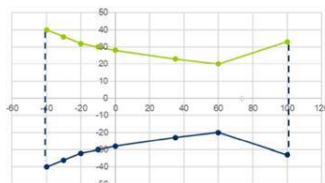
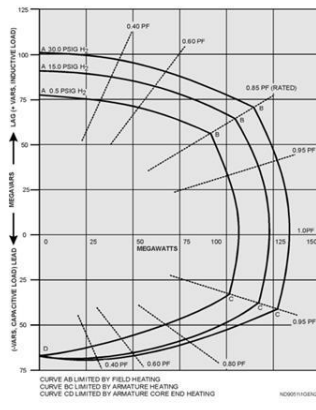


Exhibit 13: Example of inverter-based AC-coupled open-loop Hybrid Resource with solar and 40 MW battery.

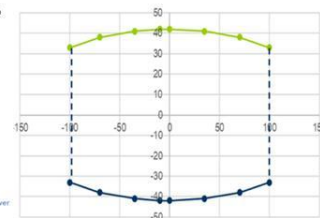
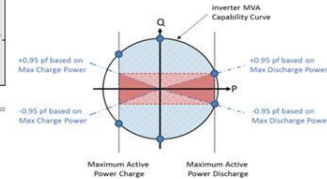


Exhibit 16: Example of inverter-based DC-coupled open-loop solar-storage Hybrid Resource with 100 MW solar and 100 MW battery.

Reporting Reactive Capability Data to PJM

Reporting Reactive Capability Data to PJM

Dispatchable Unit

Unit Info	MW	Min MVAR	Max MVAR	Comment
Point 1	50	-80	250	Typical net ECO Min
Point 2	100	-75	240	
Point 3	150	-70	230	
Point 4	200	-65	220	
Point 5	250	-60	210	
Point 6	300	-55	190	
Point 7	350	-50	180	Typical net ECO Max
Point 8	375	-45	170	*

*Max possible unit net output considering ideal operating conditions such as winter ambient temperatures, low cooling water temps, optimum fuel conditions, etc.

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Reporting Reactive Capability Data to PJM

Unit that can also operate as a synchronous condenser

Unit Info	MW	Min MVAR	Max MVAR	Comment
Point 1	0	-50	150	Synchronous Condensing operating point
Point 2	70	-25	240	Typical net ECO Min
Point 3	75	-22	230	
Point 4	80	-20	220	
Point 5	85	-18	210	
Point 6	90	-15	190	
Point 7	95	-12	180	Typical net ECO Max
Point 8	100	-10	170	*

*Max possible unit net output considering ideal operating conditions such as winter ambient temperatures, low cooling water temps, optimum fuel conditions, etc.

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Reporting Reactive Capability Data to PJM

Inverter-based Energy Storage Resource

Unit Info	MW	Min MVAR	Max MVAR	Comment
Point 1	-20	-22	22	Max Active Power Charging (Min MW)
Point 2	-14	-26	26	
Point 3	-7	-29	29	
Point 4	0	-30	30	Inverter MVA Capability Curve Rating
Point 5	6	-29	29	
Point 6	12	-27	27	
Point 7	18	-24	24	
Point 8	25	-17	17	Max Active Power Discharging (Max MW)

Reactive Capability Seasonal Review

January

Sun	Mon	Tue	Wed	Thu	Fri	Sat
				1	2	
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

February

Sun	Mon	Tue	Wed	Thu	Fri	Sat
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29					

March

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Gen Pre-summer review

April

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

Transmission Pre-summer review

May

Sun	Mon	Tue	Wed	Thu	Fri	Sat
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

June

Sun	Mon	Tue	Wed	Thu	Fri	Sat
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

Gen Pre-winter review

October

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

Transmission Pre-winter review

November

Sun	Mon	Tue	Wed	Thu	Fri	Sat
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

December

Sun	Mon	Tue	Wed	Thu	Fri	Sat
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

What Reactive Information is Reported?

What Reactive Information is Reported?

New Generator Ticket

User ID: studentgen50

Company: SBT Gen Comp 0

Generation Type:

Unit Name:

Company Ticket ID:

Description:

Est./Ramp Start:

Est. End:

End Date Unknown: ☐

Informational: ☐

Date: (MM/DD/YYYY)

Hour: (HH24:MI)

Daily Job: ☐

Days:

Start Day Delta:

MW

Volt. Reg.

MVAR

Governor

MVAR Test

PSS

MW Ticket Info

Date: (MM/DD/YYYY)

Hour: (HH24:MI)

Ticket Reduction:

Inst. Cap: 0

Company Switch Start:

Cause:

Company Switch End:

Outage Type:

Unplanned

Clear

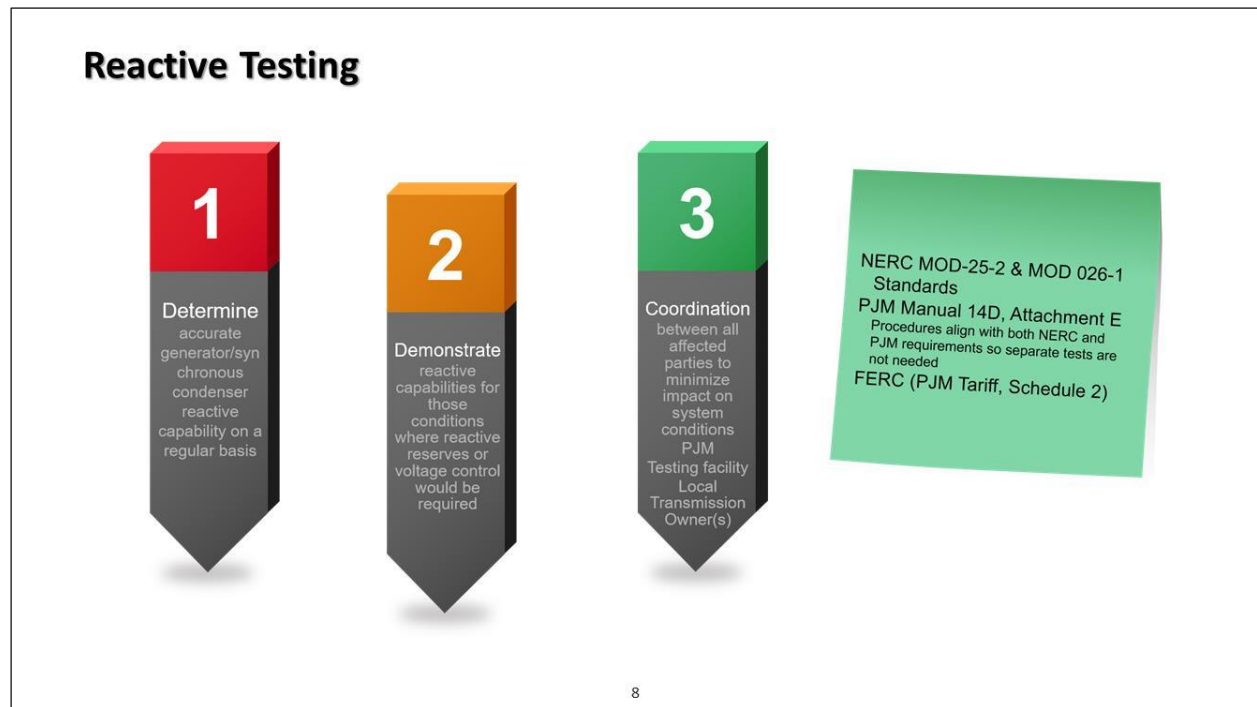
Main Menu

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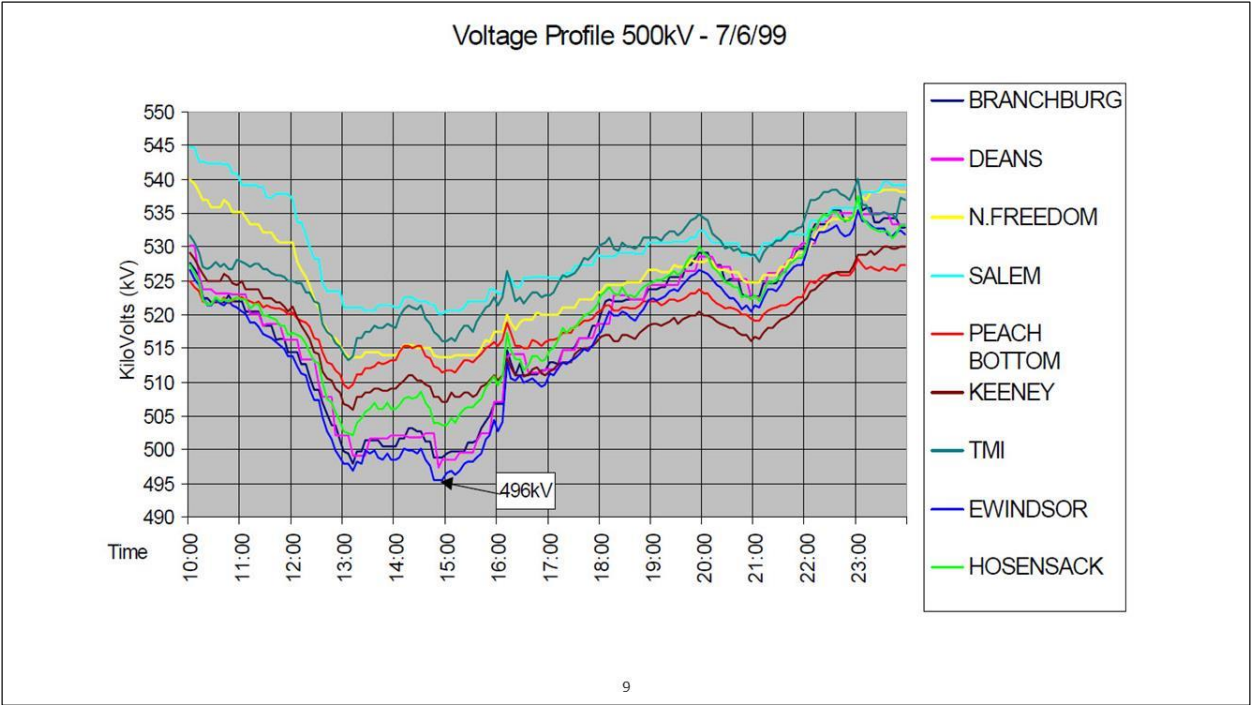
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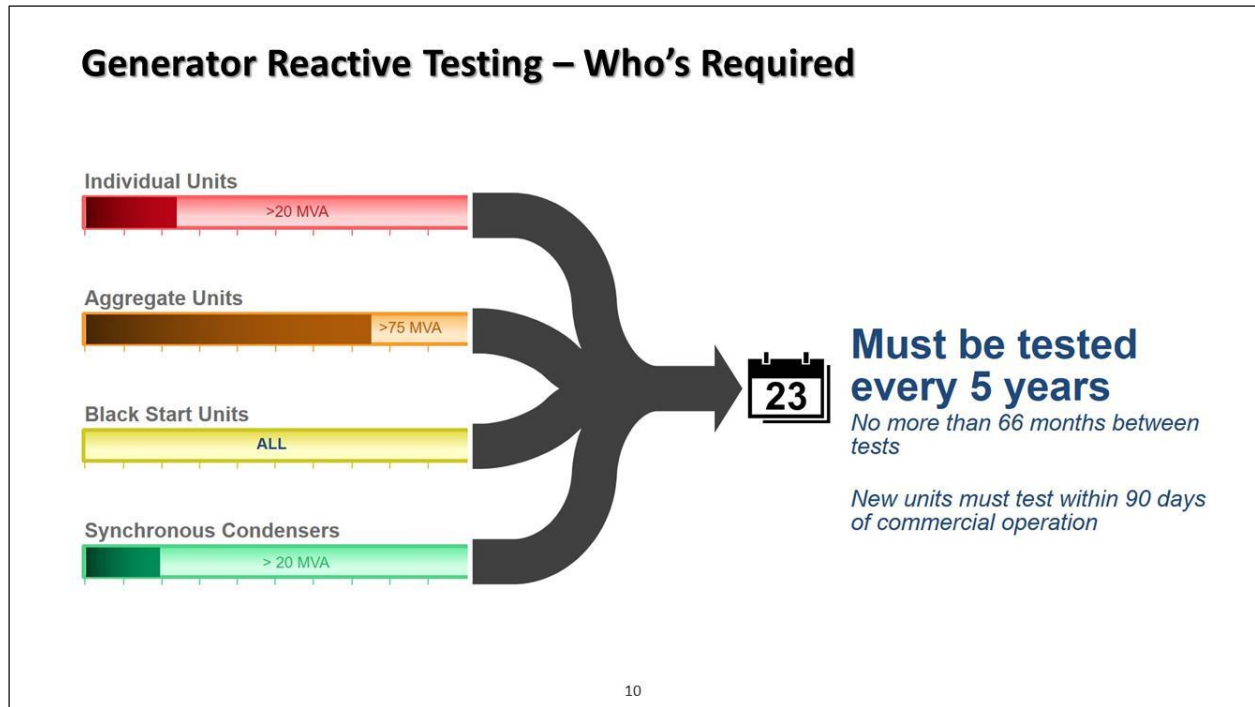
Reactive Testing



Voltage Profile 500kV - 7/6/99



Generator Reactive Testing - Who's Required



Unit Types

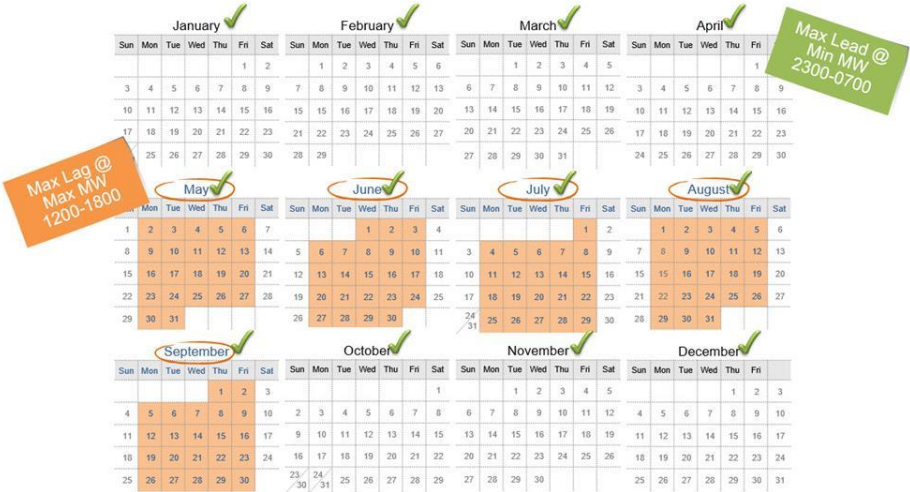
Unit Type	MW Output	MVAR Output	Test Duration
Fossil, Hydroelectric & Blackstart	Max	Max Lag	One Hour
	Max	Max Lead	When limit reached
	Min	Max Lag	When limit reached
	Min	Max Lead	When limit reached
Synchronous Condenser or Generator that operates in the condensing mode to provide reactive support	-	Max Lag	One Hour
	-	Max Lead	When limit reached
Nuclear	Max	Max Lag	One Hour
	Max	Max Lead	When limit reached
Variable (e.g. Wind and Solar) (Testing done with at least 90% of turbines or inverters on line)	Variable	Max Lag	When limit reached
	Variable	Max Lead	When limit reached
Inverter based energy storage resources Max MW Output = fully discharging Min MW Output = fully charging	Max	Max Lag	When limit reached
	Max	Max Lead	When limit reached
	Zero	Max Lag	When limit reached
	Zero	Max Lead	When limit reached
	Min	Max Lag	When limit reached
	Min	Max Lead	When limit reached

Unit Types

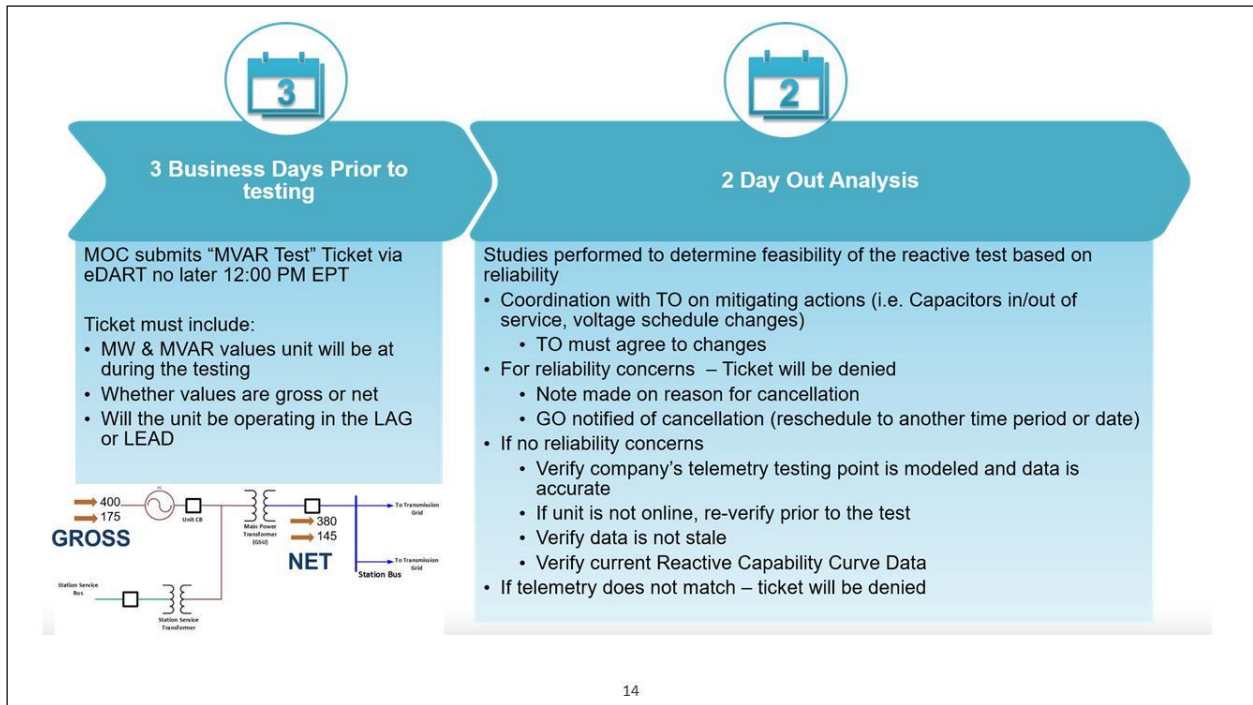
Unit Type	MW Output	MVAR Output	Test Duration
DC-Coupled Inverter Based Hybrid Resource	Max	Max Lag	When limit reached
	Max	Max Lead	When limit reached
	Zero	Max Lag	When limit reached
	Zero	Max Lead	When limit reached
AC-Coupled Inverter Based Hybrid Resource	Min	Max Lag	When limit reached
	Min	Max Lead	When limit reached
	Max	Max Lag	When limit reached
	Max	Max Lead	When limit reached
	Max Inverter Operating Point	Max Lag	When limit reached
	Max Inverter Operating Point	Max Lead	When limit reached
	Zero	Max Lag	When limit reached
	Zero	Max Lead	When limit reached
	Min	Max Lag	When limit reached
	Min	Max Lead	When limit reached

Max Lag and Max Lead

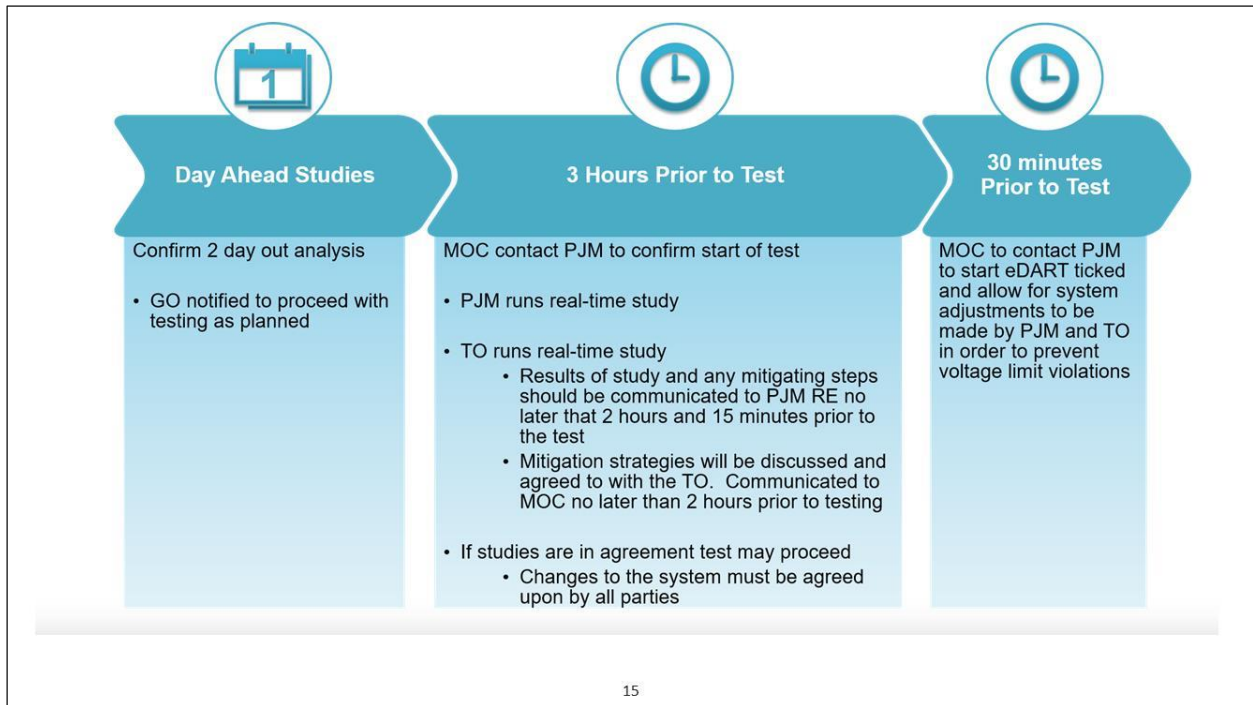
Max Lag and Max Lead



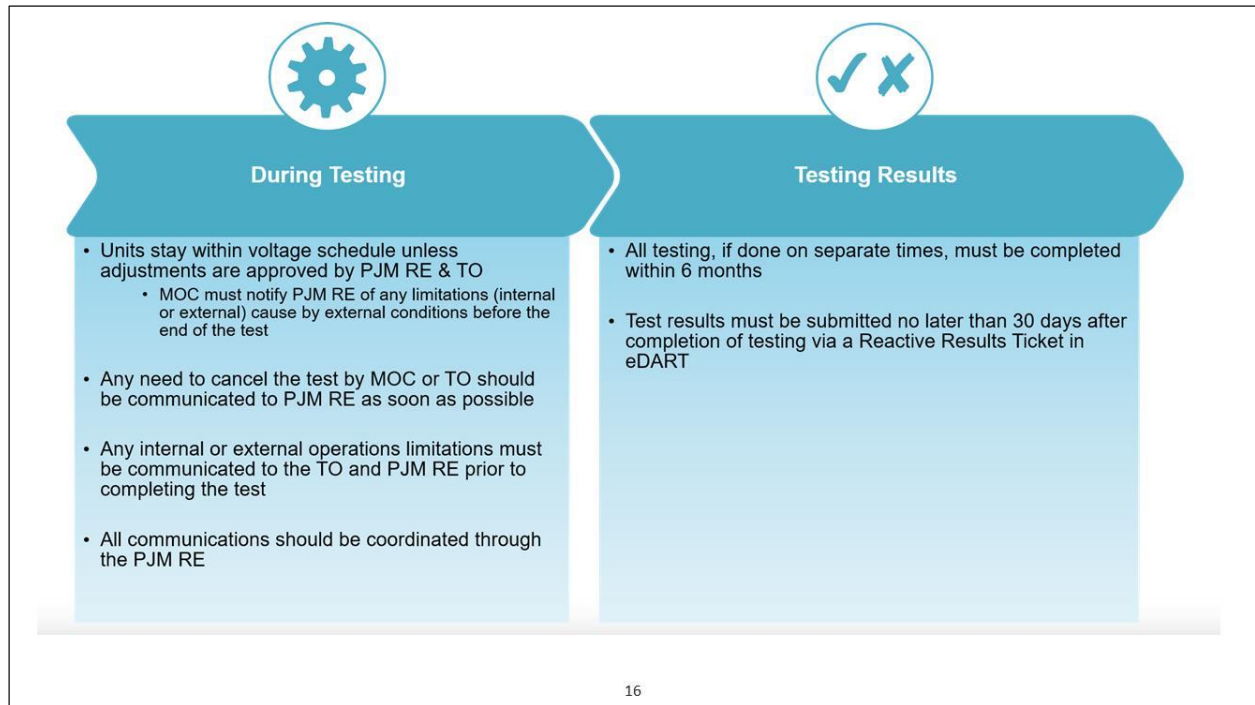
Testing Process



Testing Process



Testing Process



Reactive Capability Testing - Reporting Results

Reactive Capability Testing – Reporting Results

- Generator Owner shall complete the Reactive Capability Testing Form within 30 calendar days from the test date

Reactive Capability Testing Form

Reactive Demand Ticket ID: T31 Test: [Max Load Logging](#) Unit Name: UNIT 1 Company: Electric Company
 eGART MVAR Test Ticket: 271004 Date of Test: 09/01/2019 Previous Test Date: 09/26/2015

Tested By: _____ Cooling Water Temperature: _____ Ambient Temperature, F: _____ Black Start: ☐ Yes ☒ No
 Test Analyst Contact: _____ Start Time of the Test: _____ (MM/DD/YYYY) Ambient Relative Humidity: _____ Data Type: ☐ Test Results Limited by System Conditions and PJM notified ☐ Automatic Voltage Regulator verified in service
 Analysis Contact Email: _____ End time of the test will be calculated by PJM based on the test time Normal Hydrogen Pressure, PSIG: _____ Test Results Limited by System Conditions and PJM notified ☐ Automatic Voltage Regulator verified in service
 Analysis Contact Phone: _____ Actual Hydrogen Pressure, PSIG: _____

Location **Current Test** **Static Capability**

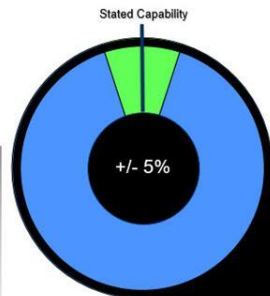
Location	Substation	Line	Phase	Voltage (KV)	Real Power (MW)	Reactive Power (MVAR)	Reactive Power (MVA)	Reactive Power (MVA)	Additional Comments
A	Low Side	Line	Phase						
B	Low Side	Line	Phase						
C	Low Side	Line	Phase						
D	Low Side	Line	Phase						
E	Low Side	Line	Phase						
F	High Side	Line	Phase						
G	High Side	Line	Phase						

Data Telemetry Verified between the plant, the MCC and PJM as per M4D, E 4.1

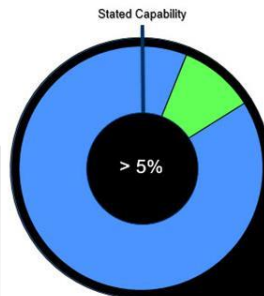
Generator Voltage Schedule: _____ KV G/G Nameplate Date: _____
 Generator Voltage PT Ratio: _____ KV Tap Setting: _____
 System Voltage Schedule: _____ KV Impedance: _____
 System Voltage PT Ratio: _____ KV Generator Voltage PT Ratio: _____ MVA

Test Results

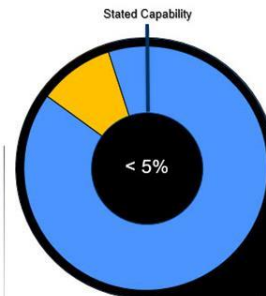
Test Results



- Fully demonstrated capability
- PJM will notify MOC or TO units achieved their reactive capability and no further action is required

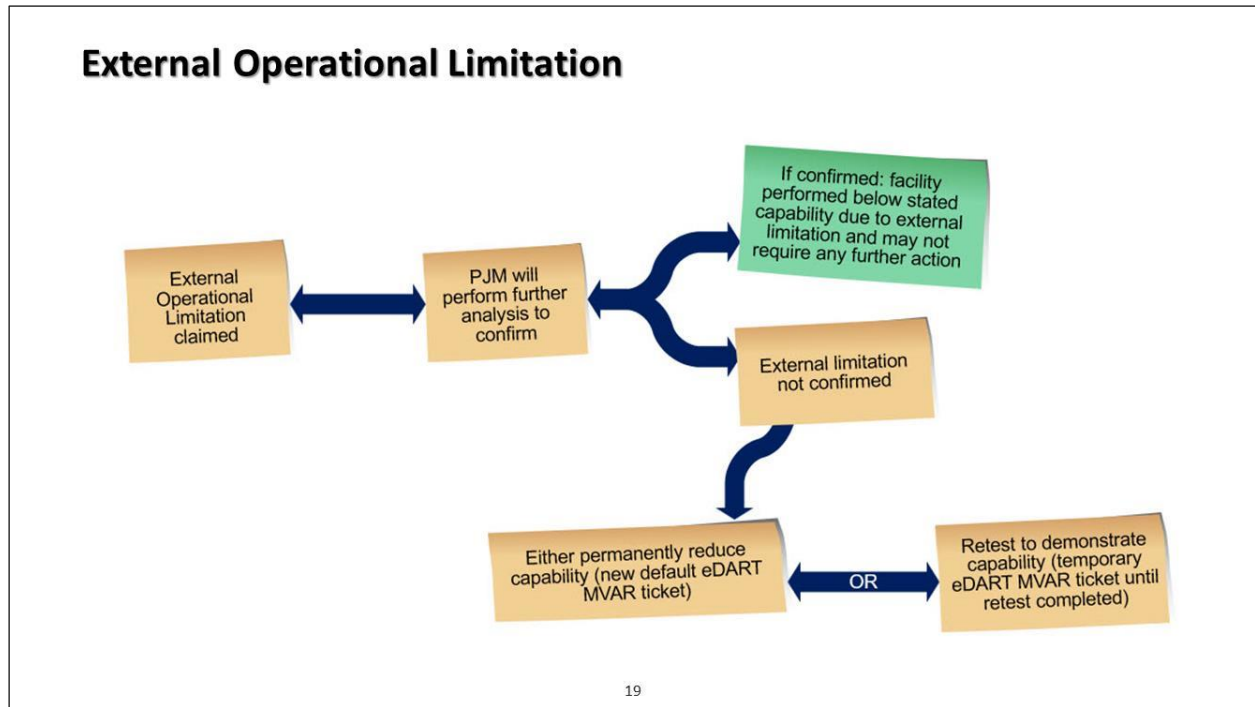


- Fully demonstrated capability
- PJM will notify MOC or TO units exceeded their reactive capability and request increase the capability modeled within the PJM EMS by entering new default eDART MVAR ticket

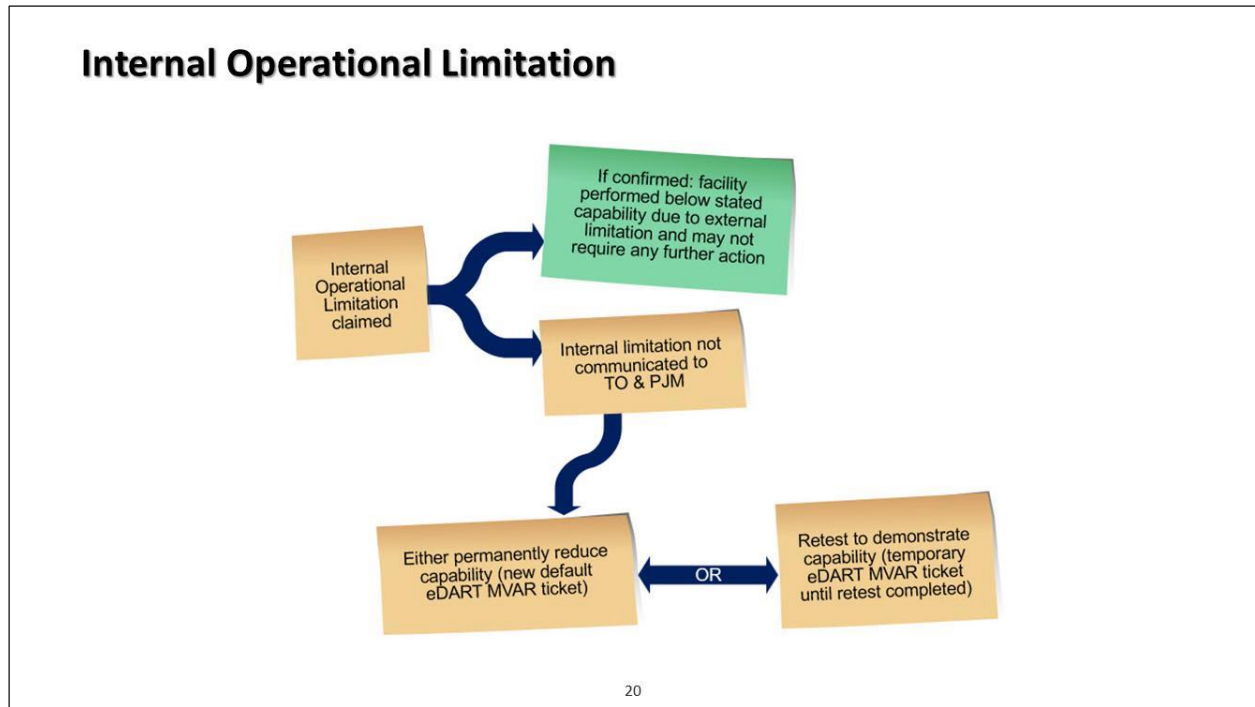


- Not demonstrated capability
- PJM will determine which units were affected by internal or external operational limitations based on reasons documented in the submitted test results

External Operational Limitation



Internal Operational Limitation



Knowledge Check

Let's Review

A graphic of a clipboard with a yellow clip at the top. The clipboard has two rows, each containing a green checkmark inside a square box, followed by two horizontal lines for text entry.

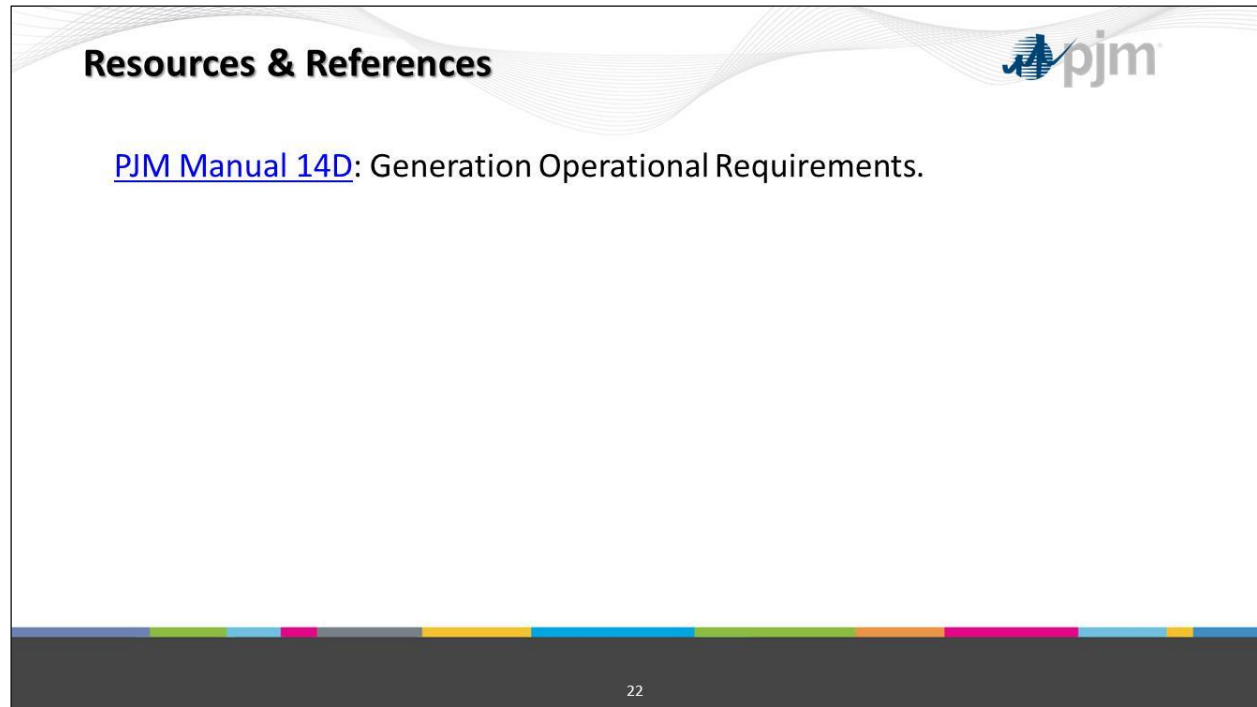
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1. All test results must be submitted to PJM within what time frame?

- a. 30 days
- b. 60 days

- c. *3 months*
 - d. *6 months*
- 2. A facility will be considered as passing its reactive capability test if it meets what criteria? (Select all that apply)**
- a. *Within 5% of stated limits*
 - b. *Greater than 5% of stated limits*
 - c. *Below 5% of stated limits*

Resources & References



Resources & References

[PJM Manual 14D](#): Generation Operational Requirements.

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Summary

Summary

In this presentation, we:

- Identified the process for monitoring and maintaining reactive reserves
- Identified the reactive capability testing process and requirements

Questions

Questions

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