PJM Guidance for NERC MOD-026-027

Generation Owner Preparation & Submittal

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Aug 28th , 2022

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Contents

Introduction

The purpose of this document is to provide guidance to Generator Owners (GOs) on PJM's dynamic model verification requirements. These requirements meet or exceed those required under NERC Standards MOD-026 and MOD-027.

In NERC standards MOD-026 and MOD-027, Transmission Provider (TP) shall provide GO instructions on obtaining the following:

1. The acceptable model list: PJM complies with NERC, and provides web link access to NERC acceptable mode list.
2. The model block diagram and/or data sheet, or model data of the current models: PJM provides the current (in-use) models and technical reference document, as applicable.

In Addition, PJM provides some information to assist GO preparation and submittal.

NERC MOD-026/027-R1 is available in the appendix A-1.

Section I – Acceptable Model List

The dynamic model, both of excitation control system model and governor model, must be in the NERC's Acceptable Models List. The link for NERC Acceptable Models List can be found here:

https://www.nerc.com/pa/RAPA/ModelAssessment/Pages/default.aspx

While not exhaustive, the dynamic model must, comply with the below rules:

- For individual synchronous machines, the generator excitation control system includes the generator, exciter, voltage regulator, impedance compensation and power system stabilizer.
- For an aggregate generating plant, the Volt/Var control system includes the voltage regulator & reactive power control system controlling and coordinating plant voltage and associated reactive capable resources.
- Turbine/governor and load control applies to conventional synchronous generation.
- Active power/frequency control applies to aggregate inverter based generators.
- Momentary cessation is mandatory for inverter-based resources.
- For Battery Energy Storage System (BESS), REPCA for plant level control is optional, instead of mandatory.

User-defined models are not acceptable. PJM requires submittal of generic models with appropriate due diligence made to closely match unit performance.

If after developing generic models, a GO has technical concerns about the generic model's performance, GO shall provide PJM the technical documents[1] demonstrating the concern. The documents shall consist and contain the following:

1) GO shall provide PJM the technical document to demonstrate the in-adequacy of currently available generic model. The demonstration shall consist of comparison to the real response acquired via lab or field test, which allows for comparison of the UDM and generic model performance;

2) GO shall provide PJM UDMs for two commercial software platforms: PTI PSS/e and PowerTech PSAT. According NERC MOD-026-1 R2.1.4 and NERC MOD-027-1 R2.1.4 GO must provide PJM the model structure, data, control closed loop;

3) GO shall provide PJM a minimum of one generic model; and

[1] 1) The GO must permit PJM to discuss the evidence documents with third parties, such as but not limited a test labs, consultants, or research institutes.

4) GO shall provide PJM the UDM DLL, which is workable with PJM's current software versions for PTI PSS/e or PowerTech PSAT. If PJM updates its version of either software, GO shall provide updated UDM DLL within 30 days on receiving notice from PJM.

PJM will make the final decision whether a currently available generic model cannot adequately represent the unit response.

Some exceptions to this exist such as HVDC circuits and FACTs device.

The dynamic model list from some plants are listed in the appendix A-2 as for the reference.

Special requirement of Momentary Cessation is in the appendix A-3.

Section II – Obtain the model block diagram and data sheet

GO, or contracted third party, shall verify Generator Excitation Control System or Plant Volt/Var Control Functions according NERC MOD-026-R2.

GO, or contracted third party, shall verify the Turbine/Governor and Load Control or Active Power/Frequency Control Functions according to NERC MOD-027-R2.

In the appendix A-4, there are some technical documents listed as the reference. Industry standards and technical methods to acquire dynamic model are available in these documents, which contain technical information on system block functionality, modeling, and testing.

Section III – current in-use model

PJM provides GO the current in-use dynamic model, which consists of *.dyr, *.raw, and *.lis.

The dyr file is a dynamic data file, describing the component dynamic behavior when the power system is undergoing the transient status.

The raw file is a collection of unprocessed data that specifies a Bus/Branch network model for the establishment of a power flow working case.

The lis file is not a native PSSE file format. This file contains the output of the dynamics DOCU function, which reports on dynamic models found in the network. The lis file is provided to assist user understanding of the model.

Both of raw file and dyr are required when GO submit the MOD-026/027 case. The lis file is not required when GO submit MOD-026/027 case.

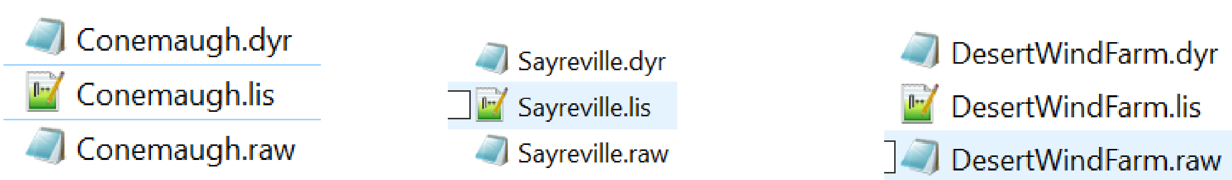

Figure 1 Example of current in-use model

Section IV – Submittal

GO shall submit the MOD-026/027 case via PJM Planning Community website: https://pjm.force.com/planning/s/.

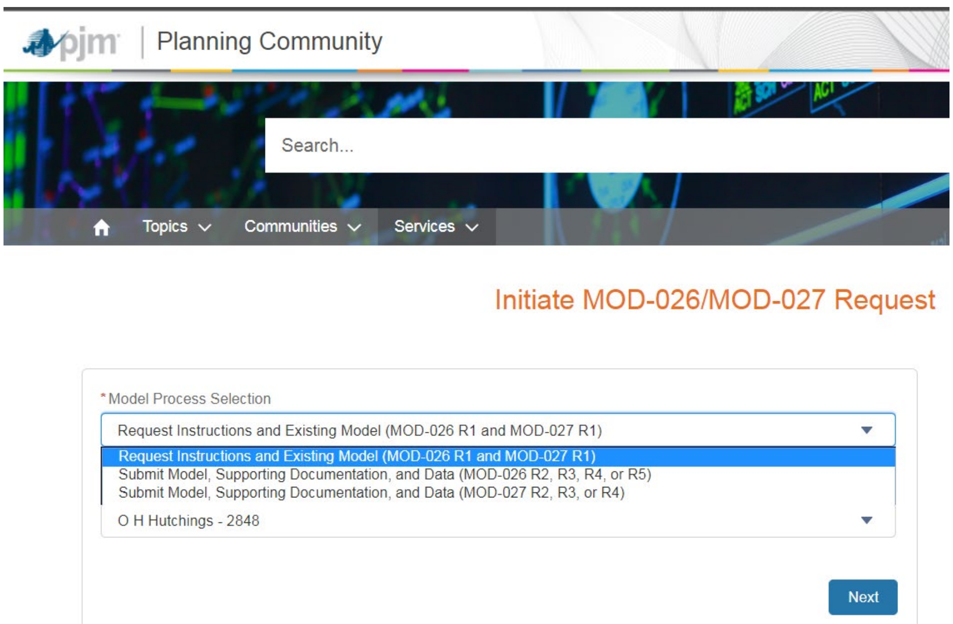

Figure 2 User Interface of PJM Planning Community

PJM Planning Community will assign a case with a tracking ID for each submittal. Within the case, the GO shall attach all related documents. The documents shall consist of the laboratory test report, dyr file, raw file, and any other related documents or explanation if needed. The Single Line Diagram (*.sld) is recommended to be included also.

The test report shall be produced and certified by the tester.

The additional information on system model and dynamic model is listed in Appendix A-5 as the reference.

The user guide for PJM Planning Community is available:

https://www.pjm.com/-/media/committees-groups/community-user-guide.ashx.

https://www.screencast.com/t/Ndhzq9Yt4

Section V – GO self-review

It is optional instead of mandatory for GO to have a self-evaluation test before submitting the model. The system model performance to be checked is shown in the below table.

Table 1 check list for GO self-review

	Test	Action	Conventional Generator	Renewable (Wind Machine, Solar PV, BESS)	Result check
1	No fault	Initial transient simulation, then 6 cycles	√	√	Power, P & Q shall be flat, no change Power Angle shall be flat, no change Voltage, Etrm & EFD, shall be flat, no change
2	disturbance	Apply LLL fault at POI bus for 5 cycles, Then trip and run simulation 20 seconds	√	√	Power, angle, and voltage shall settle down quickly after the short period oscillation
3	Voltage step Reference	Utilize PSS/e command BAT_INCREMENT_VREF to test Exciter response, Incremental of Gref ±0.03pu	√	√	Etrm reponse shall match the lab test result. Pmech shall keep to be stable
4	Open Circuit	Utilize PSS/e command BAT_ESTR_OPEN_CIRCUIT_TEST to test the excitation open circuit response	√		EFD and ETRM shall stable flat after a few seconds
5	Response Ratio	Utilize PSS/e command BAT_ESTR_RESPONSE_RATIO_TEST to test Exciter response ratio, power factor set to be 0.85	√		EFD shall quickly (within 1second) rise to 4-12pu then stable flat.

6	Governor step reference (Gref)	Utilize PSS/e command BAT_INCREMENT_GREF to test Governor response, Incremental of Gref ±0.005pu	√		Speed and mechanical power shall be stable after the change.
	Governor response (Grun)	Utilize PSS/e command BAT_GSTR to initialize and Test the governor response, initial load is set to 0.75pu with 0.1 loading step, Run to 120 seconds	√		Pmech keep flat Speed change to the set value then stable
7	Voltage ride through (Vrt)	Apply LLL fault at POI bus for 9 cycles, Then trip and run simulation 60 seconds		√	After fault cleared, all output shall be stable.
8	Frequency reference	Incremental of frequency ±0.005pu with PSS/e command: BAT_CHANGE_WNMOD_VAR,**,'1','REPCA1',3, -0.005		√	Frequency change to the set value then stable
9	LVRT	Check Low voltage ride through in the simulation log file		√	The protection relay breaker shouldn't open and trip the branch.

Section VI – PJM's review

PJM will identify the models as either usable or not useable per the standard. If the model is useable, PJM will update the system model. If the model is not useable, the initial case will be closed with the reasons for determining the case not useable. The final evaluation result, either "usable" or "not usable," will be posted on the PJM Planning Community where the original case submitted.

Section VII – Responding to a not useable finding

If not usable, the GO shall follow NERC MOD-026/027-R3 requirement within 90 days and create a new case in Planning Community to correct or update the dynamic files associated with a not useable finding. As with an initial submittal, within the new case, the GO shall attach all related documents. The documents shall consist of the laboratory test report, dyr file, raw file, and any other documents. The response shall include an explanation of the updated information.

NERC MOD-026/027-R3 is in Appendix A-6.

A-1 NERC MOD-026/027-Requirement 1

A-1.1, NERC MOD-026-R1

R1. Each Transmission Planner shall provide the following requested information to the Generator Owner within 90 calendar days of receiving a written request : *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

- Instructions on how to obtain the list of excitation control system or plant volt/var control function models that are acceptable to the Transmission Planner for use in dynamic simulation,
- Instructions on how to obtain the dynamic excitation control system or plant volt/var control function model library block diagrams and/or data sheets for models that are acceptable to the Transmission Planner, or
- Model data for any of the Generator Owner's existing applicable unit specific excitation control system or plant volt/var control function contained in the Transmission Planner's dynamic database from the current (in-use) models, including generator MVA base.

Figure 3 MOD-026 Requirement 1

A-1.1, NERC MOD-027-R1

R1. Each Transmission Planner shall provide the following requested information to the Generator Owner within 90 calendar days of receiving a written request: *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

- Instructions on how to obtain the list of turbine/governor and load control or active power/frequency control system models that are acceptable to the Transmission Planner for use in dynamic simulation,
- Instructions on how to obtain the dynamic turbine/governor and load control or active power/frequency control function model library block diagrams and/or data sheets for models that are acceptable to the Transmission Planner, or
- Model data for any of the Generator Owner's existing applicable unit specific turbine/governor and load control or active power/frequency control system contained in the Transmission Planner's dynamic database from the current (in-use) models.

Figure 4 MOD-027 Requirement 1

A-2 Dynamic Model Example

A-2.1, Example for Conventional Synchronous Generator

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Exciter	Model Status	Type	Turbine Governor	Model Status	Type	Stabilizer	Model Status	Type	Min Exciter	Model Status	Type	Max Exciter	Model Status	Type	Compensator	Model Status	Type	Turbine Load Controller	Model Status	Type
200022	SUSQ 500.0	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
200038	SUSQ 2 24.00	2	1354.00	☑	GENTPJ1	☑	Stnd	AC6A	☑	Stnd	None	☐		PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
208918	SUSQ 1 24.00	1	1354.00	☑	GENTPJ1	☑	Stnd	ESAC3A	☑	Stnd	None	☐		PSS2A	☑	Stnd	None	☐		None	☐		COMP	☑	Stnd	None	☐	

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Exciter	Model Status	Type	Turbine Governor	Model Status	Type	Stabilizer	Model Status	Type	Min Exciter	Model Status	Type	Max Exciter	Model Status	Type	Compensator	Model Status	Type	Turbine Load Controller	Model Status	Type
213955	SOUTHWK2 6	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
213957	STHWK3-4 13.	1	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
213957	STHWK3-4 13.	2	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
213958	STHWK5-6 13.	1	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	
213958	STHWK5-6 13.	2	21.90	☑	GENROE	☑	Stnd	DC4B	☑	Stnd	GGOV1DU	☑	Wrtn	None	☐		UEL2	☑	Stnd	MAXEX2	☑	Stnd	IEEEVC	☑	Stnd	None	☐	

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Exciter	Model Status	Type	Turbine Governor	Model Status	Type	Stabilizer	Model Status	Type	Min Exciter	Model Status	Type	Max Exciter	Model Status	Type	Compensator	Model Status	Type	Turbine Load Controller	Model Status	Type
270803	LASCO STA; R3	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
274660	LASCO STA;1U	1	1355.40	☑	GENROU	☑	Stnd	ESDC1A	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
274661	LASCO STA;2U	2	1355.00	☑	GENTPJ1	☑	Stnd	AC6A	☑	Stnd	None	☐		PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Exciter	Model Status	Type	Turbine Governor	Model Status	Type	Stabilizer	Model Status	Type	Min Exciter	Model Status	Type	Max Exciter	Model Status	Type	Compensator	Model Status	Type	Turbine Load Controller	Model Status	Type
272433	SABROOKE ; R1	EQ	100.00	☑	GENCLS	☑	Stnd	None	☐		None	☐		None	☐		None	☐		None	☐		None	☐		None	☐	
274822	ROCKFORD ;11	11	186.00	☑	GENTPJ1	☑	Stnd	ST6B	☑	Stnd	GGOV1DU	☑	Wrtn	PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
274823	ROCKFORD ;21	21	198.00	☑	GENTPJ1	☑	Stnd	ST6B	☑	Stnd	GGOV1DU	☑	Wrtn	PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	
274824	ROCKFORD ;12	12	186.00	☑	GENTPJ1	☑	Stnd	ST6B	☑	Stnd	GGOV1DU	☑	Wrtn	PSS2B	☑	Stnd	None	☐		None	☐		None	☐		None	☐	

A-2.2, Example for Wind machine – Type III

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
773000	26ARMNA MT 0.6900	W1	111.89	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
931011	AB1-150 GEN 0.6900	1	62.40	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
270201	AC2-176 GEN 0.6900	W1	162.76	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
902355	W2-048 GEN 0.6900	1	205.56	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	WTDTA1	☑	Stnd	WTPTA1	☑	Stnd	WTARA1	☑	Stnd	None	☐		REPCTA1	☑	Stnd	WTTQA1	☑	Stnd

A-2.3, Example for PV Solar Energy and Battery Storage Power Station

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
924154	AB2-059 GEN 0.6000	1	132.30	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	

Model	Model Status	Model Instance	Type
VTGTPAT	☑	92415401	Stnd
VTGTPAT	☑	92415402	Stnd
VTGTPAT	☑	92415403	Stnd
VTGTPAT	☑	92415404	Stnd
VTGTPAT	☑	92415405	Stnd
VTGTPAT	☑	92415406	Stnd
FRQTPAT	☑	92415407	Stnd
FRQTPAT	☑	92415408	Stnd
FRQTPAT	☑	92415409	Stnd
FRQTPAT	☑	92415410	Stnd

Bus Number	Bus Name	Id	Mbase (MVA)	Machine Status	Generator	Model Status	Type	Electrical	Model Status	Type	Mechanical	Model Status	Type	Pitch	Model Status	Type	Aerodynamic	Model Status	Type	Gust	Model Status	Type	Auxiliary control	Model Status	Type	Torque control	Model Status	Type
105	SMA 0.5500	1	87.50	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	
107	TM1833_GEN 0.4000	1	24.00	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	
108	TMININ_4.2 0.6300	1	12.60	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	
109	TM1NIN_3.36 0.6300	1	13.44	☑	REGCA1	☑	Stnd	REECA1	☑	Stnd	None	☐		None	☐		None	☐		None	☐		REPCA1	☑	Stnd	None	☐	

Model	Model Status	Model Instance	Type
VTGTPAT	☑	10501	Stnd
VTGTPAT	☑	10502	Stnd
VTGTPAT	☑	10503	Stnd
VTGTPAT	☑	10504	Stnd
VTGTPAT	☑	10505	Stnd
VTGTPAT	☑	10506	Stnd
VTGTPAT	☑	10507	Stnd
VTGTPAT	☑	10508	Stnd
FRQTPAT	☑	10509	Stnd
FRQTPAT	☑	10510	Stnd
FRQTPAT	☑	10511	Stnd
FRQTPAT	☑	10512	Stnd
FRQTPAT	☑	10513	Stnd
FRQTPAT	☑	10514	Stnd
VTGTPAT	☑	10701	Stnd
VTGTPAT	☑	10702	Stnd
VTGTPAT	☑	10703	Stnd
VTGTPAT	☑	10704	Stnd
VTGTPAT	☑	10705	Stnd
VTGTPAT	☑	10706	Stnd
VTGTPAT	☑	10707	Stnd
VTGTPAT	☑	10708	Stnd
FRQTPAT	☑	10709	Stnd
FRQTPAT	☑	10710	Stnd
FRQTPAT	☑	10711	Stnd
FRQTPAT	☑	10712	Stnd
FRQTPAT	☑	10713	Stnd
FRQTPAT	☑	10714	Stnd
VTGTPAT	☑	10801	Stnd
VTGTPAT	☑	10802	Stnd
VTGTPAT	☑	10803	Stnd
VTGTPAT	☑	10804	Stnd
VTGTPAT	☑	10805	Stnd
VTGTPAT	☑	10806	Stnd
VTGTPAT	☑	10807	Stnd
VTGTPAT	☑	10808	Stnd
FRQTPAT	☑	10809	Stnd
FRQTPAT	☑	10810	Stnd
FRQTPAT	☑	10811	Stnd
FRQTPAT	☑	10812	Stnd
FRQTPAT	☑	10813	Stnd
FRQTPAT	☑	10814	Stnd
VTGTPAT	☑	10901	Stnd
VTGTPAT	☑	10902	Stnd
VTGTPAT	☑	10903	Stnd
VTGTPAT	☑	10904	Stnd
VTGTPAT	☑	10905	Stnd
VTGTPAT	☑	10906	Stnd
VTGTPAT	☑	10907	Stnd
VTGTPAT	☑	10908	Stnd
FRQTPAT	☑	10909	Stnd
FRQTPAT	☑	10910	Stnd
FRQTPAT	☑	10911	Stnd
FRQTPAT	☑	10912	Stnd
FRQTPAT	☑	10913	Stnd
FRQTPAT	☑	10914	Stnd

A-3, Momentary Cessation requirement to inverter based

1. GOs should contact their inverter manufacturer(s) to understand whether the specific makes and models of their inverters, as configured at each specific generating facility, use momentary cessation.

2. GOs should obtain the following information from the inverter manufacturer(s) for any inverters that use momentary cessation:

a) Momentary Cessation Low Voltage Threshold or Curve: The low voltage at which the inverter enters momentary cessation (ceases firing of power electronics commands such that the inverter does not produce active or reactive current). If the limit is based on a time duration (i.e., different levels for different times), then a curve should be provided.

b) Momentary Cessation High Voltage Threshold or Curve: The high voltage at which the inverter enters momentary cessation (ceases firing of power electronics commands such that the inverter does not produce active or reactive current). If the limit is based on a time duration (i.e., different levels for different times), then a curve should be provided.

c) Recovery Delay: The time following restoration of terminal voltage to above the momentary cessation low voltage threshold within acceptable levels[7] before the inverter begins injecting current once again.

d) Active Current Recovery Ramp Rate: The ramp rate (expressed in terms of percent of rated current per second) of recovery in active current injection following momentary cessation.

e) Reactive Current Recovery Limits: Any limits imposed on the reactive current should be described. This may be a ramp rate limit, a reduced current limit for a specified period of time, or no limit imposed. Most inverters may not have these limits on reactive current injection, but this should be verified with the manufacturer.

A-4, Acquire Dynamic Model

A-4.1 NERC MOD-026-R2

R2. Each Generator Owner shall provide for each applicable unit, a verified generator excitation control system or plant volt/var control function model, including documentation and data (as specified in Part 2.1) to its Transmission Planner in accordance with the periodicity specified in MOD-026 Attachment 1. *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

2.1. Each applicable unit's model shall be verified by the Generator Owner using one or more models acceptable to the Transmission Planner. Verification for individual units less than 20 MVA (gross nameplate rating) in a generating plant (per Section 4.2.1.2, 4.2.2.2, or 4.2.3.2) may be performed using either individual unit or aggregate unit model(s), or both. Each verification shall include the following:

2.1.1. Documentation demonstrating the applicable unit's model response matches the recorded response for a voltage excursion from either a staged test or a measured system disturbance,

2.1.2. Manufacturer, model number (if available), and type of the excitation control system including, but not limited to static, AC brushless, DC rotating, and/or the plant volt/var control function (if installed),

2.1.3. Model structure and data including, but not limited to reactance, time constants, saturation factors, total rotational inertia, or equivalent data for the generator,

2.1.4. Model structure and data for the excitation control system, including the closed loop voltage regulator if a closed loop voltage regulator is installed or the model structure and data for the plant volt/var control function system,

2.1.5. Compensation settings (such as droop, line drop, differential compensation), if used, and

2.1.6. Model structure and data for power system stabilizer, if so equipped.

Figure 5 MOD-026 Requirement 2

A-4.2 NERC MOD-027-R2

R2. Each Generator Owner shall provide, for each applicable unit, a verified turbine/governor and load control or active power/frequency control model, including documentation and data (as specified in Part 2.1) to its Transmission Planner in accordance with the periodicity specified in MOD-027 Attachment 1. *[Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*

2.1. Each applicable unit's model shall be verified by the Generator Owner using one or more models acceptable to the Transmission Planner. Verification for individual units rated less than 20 MVA (gross nameplate rating) in a generating plant (per Section 4.2.1.2, 4.2.2.2, or 4.2.3.2) may be performed using either individual unit or aggregate unit model(s) or both. Each verification shall include the following:

2.1.1. Documentation comparing the applicable unit's MW model response to the recorded MW response for either:

- A frequency excursion from a system disturbance that meets MOD-027 Attachment 1 Note 1 with the applicable unit on-line,
- A speed governor reference change with the applicable unit on-line, or
- A partial load rejection test,[2]

2.1.2. Type of governor and load control or active power control/frequency control[3] equipment,

2.1.3. A description of the turbine (e.g. for hydro turbine - Kaplan, Francis, or Pelton; for steam turbine - boiler type, normal fuel type, and turbine type; for gas turbine - the type and manufacturer; for variable energy plant - type and manufacturer),

2.1.4. Model structure and data for turbine/governor and load control or active power/frequency control, and

2.1.5. Representation of the real power response effects of outer loop controls (such as operator set point controls, and load control but excluding AGC control) that would override the governor response (including blocked or nonfunctioning governors or modes of operation that limit Frequency Response), if applicable.

Figure 6 MOD-027 Requirement 2

A-4.3 Industrial Stands and technical documents

Conventional Generator

1. *IEEE 421.1 Definitions for Excitation Systems for Synchronous Machines*
2. *IEEE 421.2 Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems*
3. *IEEE 421.5 IEEE Recommended Practice for Excitation System Models for Power System Stability Studies*
4. *IEEE Task Force on Generator Model Validation Testing of the Power System Stability Subcommittee, "Guidelines for Generator Stability Model Validation Testing," IEEE PES General Meeting 2007, paper 07GM1307*
5. *L. Pereira "New Thermal Governor Model Development: Its Impact on Operation and Planning Studies on the Western Interconnection" IEEE POWER AND ENERGY MAGAZINE, MAY/JUNE 2005*
6. *D.M. Cabbell, S. Rueckert, B.A. Tuck, and M.C. Willis, "The New Thermal Governor Model Used in Operating and Planning Studies in WECC," in Proc. IEEE PES General Meeting, Denver, CO, 2004*
7. *S. Patterson, "Importance of Hydro Generation Response Resulting from the New Thermal Modeling-and Required Hydro Modeling Improvements," in Proc. IEEE PES General Meeting, Denver, CO, 2004*

PV Gednerator and BESS

8. *NERC. Modeling Notification Recommended Practices for Modeling Momentary Cessation Initial Distribution: February 2018*
9. *K. Clark, R.A. Walling, N.W. Miller, "Solar Photovoltaic (PV) Plant Models in PSLF," IEEE/PES General Meeting, Detroit, MI, July 2011*
10. *K. Clark, N.W. Miller, R.A. Walling, "Modeling of GE Solar Photovoltaic (PV) Plants for Grid Studies," version 1.1, April 2010*

Wind Plant

11. *M. Asmine, J. Brochu, J. Fortmann, R. Gagnon, Y. Kazachkov, C.-E. Langlois, C. Larose, E. Muljadi, J. MacDowell, P. Pourbeik, S. A. Seman, and K. Wiens, "Model Validation for Wind Turbine Generator Models", IEEE Transactions on Power System, Volume 26, Issue 3, August 2011*
12. *A. Ellis, E. Muljadi, J. Sanchez-Gasca, Y. Kazachkov, "Generic Models for Simulation of Wind Power Plants in Bulk System Planning Studies," IEEE PES General Meeting 2011, Detroit, MI, July 24-28*
13. *N.W. Miller, J. J. Sanchez-Gasca, K. Clark, J.M. MacDowell, "Dynamic Modeling of GE Wind Plants for Stability Simulations," IEEE PES General Meeting 2011, Detroit, MI, July 24-28*
14. *A. Ellis, Y. Kazachkov, E. Muljadi, P. Pourbeik, J.J. Sanchez-Gasca, Working Group Joint Report – WECC Working Group on Dynamic Performance of Wind Power Generation & IEEE Working Group on Dynamic Performance of Wind Power Generation, "Description and Technical Specifications for Generic WTG Models – A Status Report," Proc. IEEE PES 2011 Power Systems Conference and Exposition (PSCE), March 2011, Phoenix, AZ*
15. *K. Clark, N.W. Miller, J. J. Sanchez-Gasca, "Modeling of GE Wind Turbine Generators for Grid Studies," version 4.5, April 16, 2010, Available from GE Energy*
16. *R.J. Piwko, N.W. Miller, J.M. MacDowell, "Field Testing & Model Validation of Wind Plants," in Proc. IEEE PES General Meeting, Pittsburg, PA, July 2008*
17. *W.W. Price and J. J. Sanchez-Gasca, "Simplified Wind Turbine Generator Aerodynamic Models for Transient Stability Studies," in PROC IEEE PES 2006 Power Systems Conf. Expo. (PSCE), Atlanta, GA, October 1, 2006, p. 986-992*
18. *J.J. Sanchez-Gasca, R.J. Piwko, N. W. Miller, W. W. Price, "On the Integration of Wind Power Plants in Large Power Systems," Proc. X Symposium of Specialists in Electric and Expansion Planning (SEPOPE), Florianopolis, Brazil, May 2006*

Misc

19. *P. Pourbeik, C. Pink and R. Bisbee, "Power Plant Model Validation for Achieving Reliability Standard Requirements Based on Recorded On-Line Disturbance Data", Proceedings of the IEEE PSCE, March, 2011*

A-5, System Model

A-5.1, Power flow case model

The system power flow model can be formatted in*.raw, *.sav, and described as the Single Machine Infinite Bus System. Some examples are shown below.

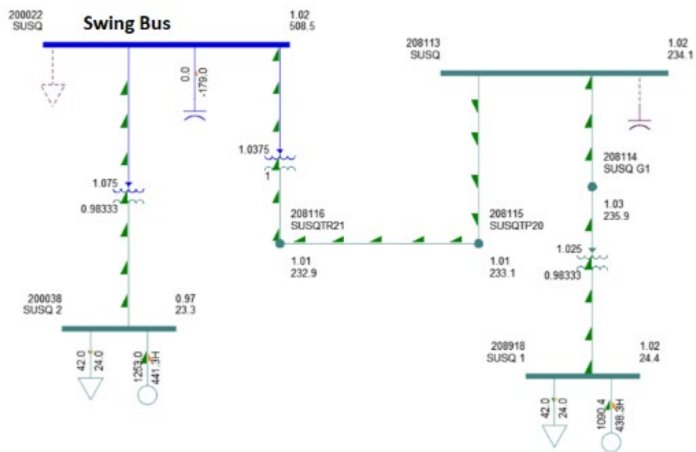

Figure 7   Example of SMIB system model from one conventional power plant

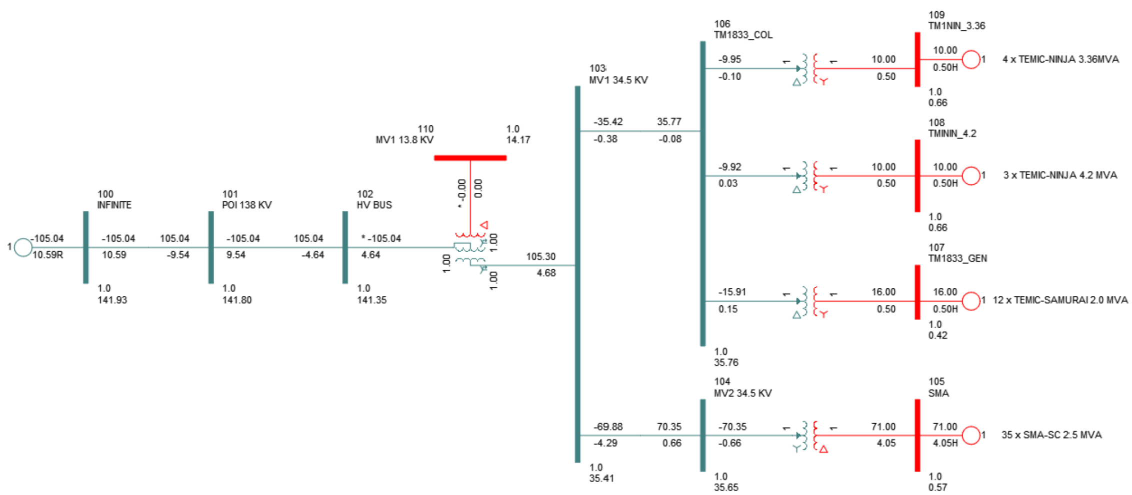

Figure 8   Example of SMIB system model from one renewable (aggregated) power plant

A-5.2, Dynamic Model Format

The dynamic model shall be either in the table or dyr formatted in PSS/e Ver.34, or both. Some examples are shown below.

```
243188 'GENROE' 1     6.1500      0.42000E-01  0.68000      0.61000E-01
         3.1400      0.0000      2.3970       2.3640      0.41500
        0.59400     0.33300     0.24200      0.16200      0.63000      /
243188 'IEEEVC' 1     0.0000     -0.30000E-01  /
243188 'ESST1A' 1          1            1       0.0085       99.000
        -99.000      1.0000      5.6250      0.10000      0.10000
         405.00     0.0000    5.9400      -5.3300       5.9400
        -5.3300     0.57000E-01   0.0000       1.0000       0.0000
         5.6800    /
243188 'IEEEG1' 1          0            0       16.800       0.0000
         0.0000     0.30000      0.10000     -0.10000      1.0000
         0.0000     0.21000      0.21000       0.0000       11.800
        0.19000      0.0000       6.4000      0.60000       0.0000
         0.0000      0.0000       0.0000    /
```

Figure 9 Example of dynamic dyr file from one conventional power plant

```
105  'REGCA1'  1
         0
     0.0200       10.000      0.9000      0.50000     1.0000
     1.2000       0.001       0.00000    -1.0         0.0000
     0.0000       20.000     -20.0000     0.7000 /
105  'REECA1' 1
     0    0    1    0    0    0
     0.9000       1.1000       0.010     -0.100          0.1000
     2.0000       2.0         -2.0        0.0000          1.0
     0.0          0.0          0.05       0.6            -0.4
     1.200        0.800        0.0        1.0             0.0
     1.0          0.0          0.46       1.0            -1.0
     1.0          0.0          1.0        0.01            0.0
     1.0          0.33         1.0        0.66            1.0
     1.0          1.0          0.0        1.0             0.33
     1.0          0.66         1.0        1.0             1.0 /
105 'USRMDL' 1 'REPCAU1' 107 0 7 27 7 9
     101    102    101    '1'    0    1    0
     0.04         0.05        0.35        0.0           0.04
     0.88         0.0019      0.007       0.053          999.0
    -999.0        0.00        0.00        0.60          -0.80
     0.0          0.50        0.04        0.000          0.000
     999         -999         1.0         0.0           0.04
     0.04         0.04 /

 10501   'VTGTPAT'     105    105  '1'  -1.0000      1.2000      0.0010      0.0000      /
 10502   'VTGTPAT'     105    105  '1'  -1.0000      1.1500      0.2000      0.0000      /
 10503   'VTGTPAT'     105    105  '1'  -1.0000      1.1300      0.5000      0.0000      /
 10504   'VTGTPAT'     105    105  '1'  -1.0000      1.1000      1.0000      0.0000      /
 10505   'VTGTPAT'     105    105  '1'   0.4300      5.0000      0.1500      0.0000      /
 10506   'VTGTPAT'     105    105  '1'   0.6200      5.0000      0.3000      0.0000      /
 10507   'VTGTPAT'     105    105  '1'   0.7200      5.0000      2.0000      0.0000      /
 10508   'VTGTPAT'     105    105  '1'   0.8700      5.0000      3.0000      0.0000      /
 10509   'FRQTPAT'     105    105  '1'  -100.00      61.400      30.000      0.0000      /
 10510   'FRQTPAT'     105    105  '1'  -100.00      61.750      10.000      0.0000      /
 10511   'FRQTPAT'     105    105  '1'  -100.00      62.000      0.0010      0.0000      /
 10512   'FRQTPAT'     105    105  '1'   58.450      100.00      30.000      0.0000      /
 10513   'FRQTPAT'     105    105  '1'   58.200      100.00      10.000      0.0000      /
 10514   'FRQTPAT'     105    105  '1'   57.600      100.00      0.0010      0.0000      /
```

Figure 10   Example of dynamic dyr file from one renewable (aggregated) power plant

Table 1: Parameters for the *REGCA1* model, on the WTG base. The MVA based of the aggregated WTG models is given in Appendix A, Figure A-5.

ICON	WTG 1	WTG 2	Explanation
M	0	0	OEM Data (*Lvplsw*)
CONs			**Explanation**
J	0.02	0.02	OEM Data (*Tg*)
J+1	1.1	1.1	OEM Data (*rrpwr*)
J+2	0.9	0.9	OEM Data (*Brkpt*)
J+3	0.4	0.4	OEM Data (*Zerox*)
J+4	1.2	1.2	OEM Data (*Lvpl1*)
J+5	1.1	1.1	OEM Data (*Volim*)
J+6	0.001	0.001	OEM Data (*Lvpnt1*)
J+7	0.0	0.0	OEM Data (*Lvpnt0*)
J+8	-1.3	-1.3	OEM Data (*Iolim*)
J+9	0.02	0.02	OEM Data (*Tfltr*)
J+10	0.7	0.7	OEM Data (*Khv*)
J+11	99	99	Disable per OEM Data (*Iqrmax*)
J+12	-99	-99	Disable per OEM Data (*Iqrmin*)
J+13	1.0	1.0	Accel, acceleration factor (0 < Accel <= 1)

Table 2: Parameters for the *REECA1* model, on the WTG base. The MVA based of the aggregated WTG models is given in Appendix A, Figure A-5.

ICONs	WTG 1	WTG 2	Explanation
M	0	0	This module must control its own terminal voltage
M+1	0	0	OEM Data (*PFFLAG*)
M+2	1	1	OEM Data (*VFLAG*)
M+3	0	0	OEM Data (*QFLAG*)
M+4	0	0	OEM Data (*PFLAG*)
M+5	0	0	OEM Data (*PQFLAG*)
CONs			**Explanation**
J	0.85	0.85	Disable (*Vdip*)
J+1	1.1	1.1	Disable (*Vup*)
J+2	0.02	0.02	Verified by test (*Trv*)
J+3	-0.1	-0.1	Disable (*dbd1*)
J+4	0.1	0.1	Disable (*dbd2*)
J+5	2.11	2.11	Disable (*Kqv*)
J+6	1.0	1.0	Disable (*Iqh1*)
J+7	-1.0	-1.0	Disable (*Iql1*)
J+8	1	1	Irrelevant since *Vdip* disabled (*Vref0*)
J+9	0	0	Disable (*Iqfrz*)
J+10	0	0	Disable (*Thld*)
J+11	0	0	Disable (Thld2)
J+12	0.05	0.05	OEM Data (*Tp*)
J+13	0.4675	0.4675	OEM Data (*QMax*) – confirmed limit
J+14	-0.425	-0.425	OEM Data (*QMin*) – confirmed limit

Figure 11 Example of tabular dynamic model file from one renewable (aggregated) power plant

Excitation Model IEEE 421.5 Std. ST1A
PSS/E Model ESST1A

Description	Parameter	Value	Units	ICON
UEL connection code (1, 2 or 3)	UEL	1		M
PSS connection code (1 or 2)	VOS	1		M+1
Description	**Parameter**	**Value**	**Units**	**CON**
voltage transducer time constant	Tr	0	s	J
maximum voltage error	Vimax	99	pu	J+1
minimum voltage error	Vimin	-99	pu	J+2
1st lead-lag numerator time constant	Tc	1	s	J+3
1st lead-lag denominator time constant	Tb	5.625	s	J+4
2nd lead-lag numerator time constant	Tc1	0.1	s	J+5
2nd lead-lag denominator time constant	Tb1	0.1	s	J+6
AVR gain	Ka	405	pu	J+7
rectifier bridge time constant	Ta	0.01	s	J+8
maximum voltage regulator output	Vamax	5.94	pu	J+9
minimum excitation voltage	Vamin	-5.33	pu	J+10
maximum excitation voltage	Vrmax	5.94	pu	J+11
minimum excitation voltage	Vrmin	-5.33	pu	J+12
rectifier regulation factor	Kc	0.057	pu	J+13
rate feedback gain	Kf	0	pu	J+14
rate feedback time constant	Tf (>0)	1	s	J+15
field current limiter gain	Klr	0	pu	J+16
field current limit	Ilr	5.68	pu	J+17

Notes:

1) The PSS/E program requires the smallest time constant to be greater than 2 times the integration time step. For TR, TA < (2 x integration step), set TA=0 and TR=smallest allowable value. Kestrel suggests using 0.017 seconds as the smallest allowable value if the integration time step is 1/2 cycle (PSS/E default). A value of 0.0085 seconds can be used as the smallest allowable value if the integration time step is 1/4 cycle (common value in many regions in North America).

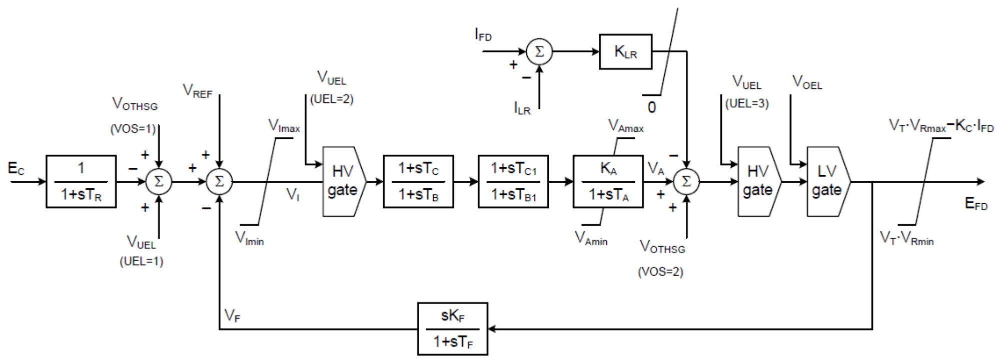

Figure 12 Example of tabular dynamic model file from one conventional power plant

A-6, NERC MOD-026/027 Requirement 3

A-6.1, NERC MOD-026 R-3

R3. Each Generator Owner shall provide a written response to its Transmission Planner within 90 calendar days of receiving one of the following items for an applicable unit:

- Written notification from its Transmission Planner (in accordance with Requirement R6) that the excitation control system or plant volt/var control function model is not usable,
- Written comments from its Transmission Planner identifying technical concerns with the verification documentation related to the excitation control system or plant volt/var control function model, or
- Written comments and supporting evidence from its Transmission Planner indicating that the simulated excitation control system or plant volt/var control function model response did not match the recorded response to a transmission system event.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification[3] (in accordance with Requirement R2). *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

Figure 13 MOD-026 Requirement 3

A-6.2, NERC MOD-027 R-3

R3. Each Generator Owner shall provide a written response to its Transmission Planner within 90 calendar days of receiving one of the following items for an applicable unit.

- Written notification, from its Transmission Planner (in accordance with Requirement R5) that the turbine/governor and load control or active power/frequency control model is not "usable,"
- Written comments from its Transmission Planner identifying technical concerns with the verification documentation related to the turbine/governor and load control or active power/frequency control model, or
- Written comments and supporting evidence from its Transmission Planner indicating that the simulated turbine/governor and load control or active power/frequency control response did not approximate the recorded response for three or more transmission system events.

The written response shall contain either the technical basis for maintaining the current model, the model changes, or a plan to perform model verification[4] (in accordance with Requirement R2). *[Violation Risk Factor: Lower] [Time Horizon: Operations Planning]*

Figure 14 MOD-027 Requirement 3

Development History

Revision: 0	Date: 05/02/2022
Author:	DengJun Yan Senior Engineer, System Planning Modeling and Support
Reviewers:	David Egan Manager, System Planning Modeling and Support
Approver:	
Reason for Review	

Revision: 1	Date: 07/28/2022
Author:	Tao He Senior Engineer, System Planning Modeling and Support DengJun Yan Senior Engineer, System Planning Modeling and Support
Reviewers:	David Egan Manager, System Planning Modeling and Support
Approver:	
Reason for Review	