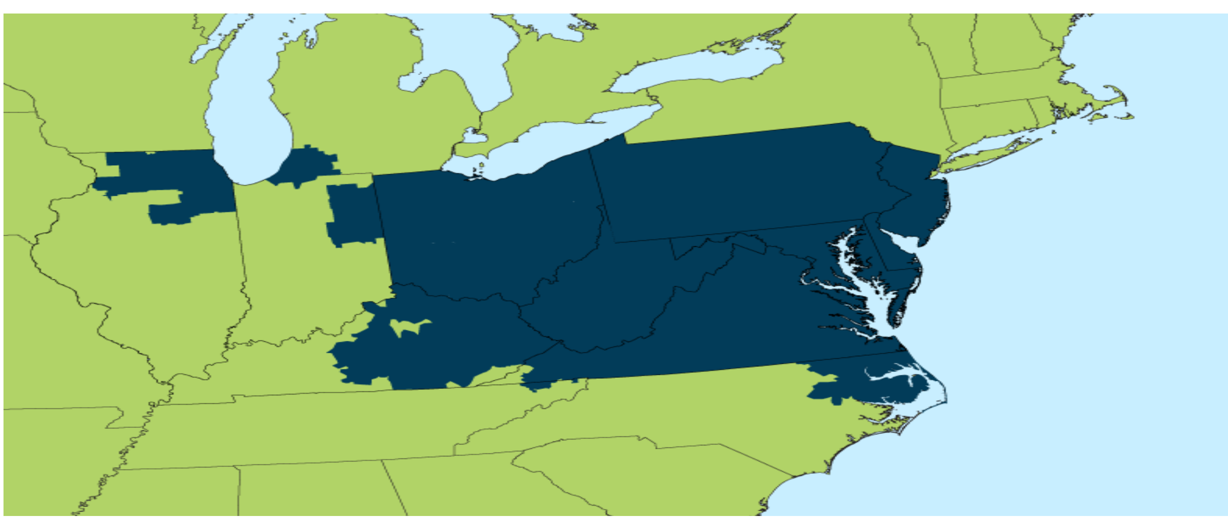
# PJM Guidance for NERC MOD-026-027

# Generation Owner Preparation & Submittal



## 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.

# Contents

## 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.

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.

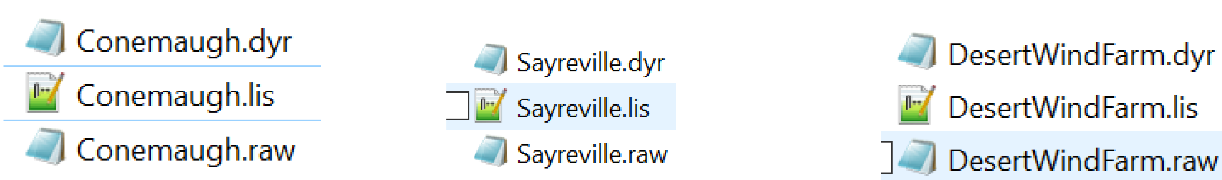



*Figure 1: Example of current in-use model*

## Section IV – Submittal

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

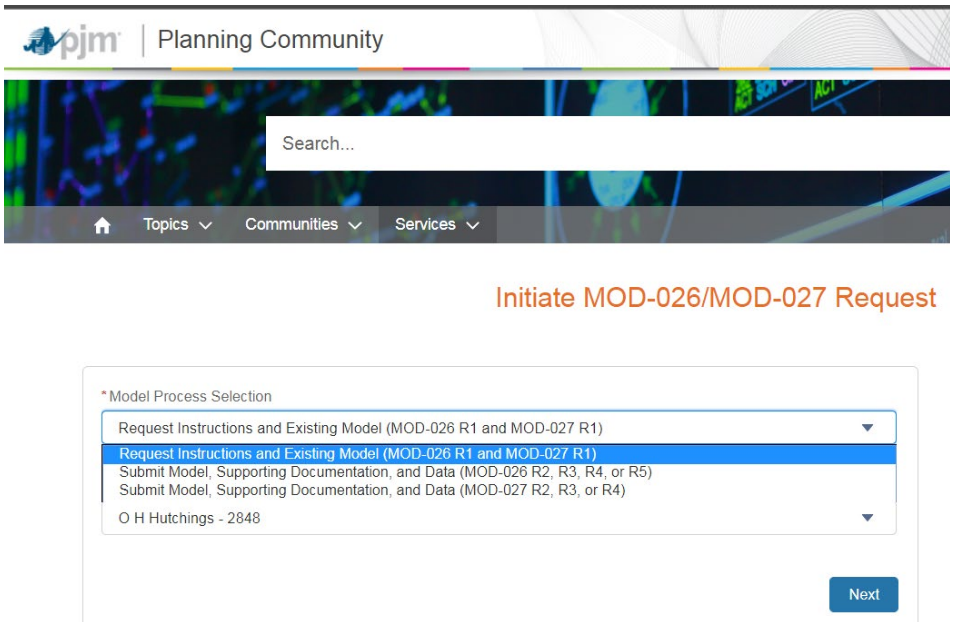



*Figure 2: User Interface of PJM Planning Community*

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<br>Power Angle shall be flat, no change<br>Voltage, Etrm & EFD, shall be flat, no change |
| 2 | disturbance | Apply LLL fault at POI bus for 5 cycles,<br>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.<br>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<br>Speed change to the set value then stable |
| 7 | Voltage ride through (Vrt) | Apply LLL fault at POI bus for 9 cycles,<br>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.

# Appendix

## 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.

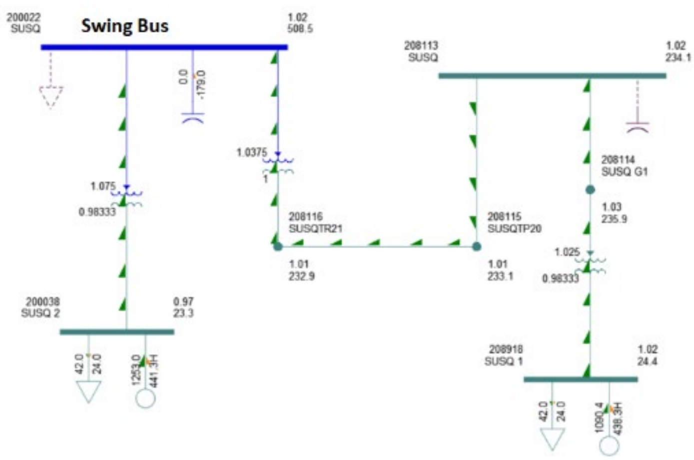



*Figure 7: Example of SMIB system model from one conventional power plant*

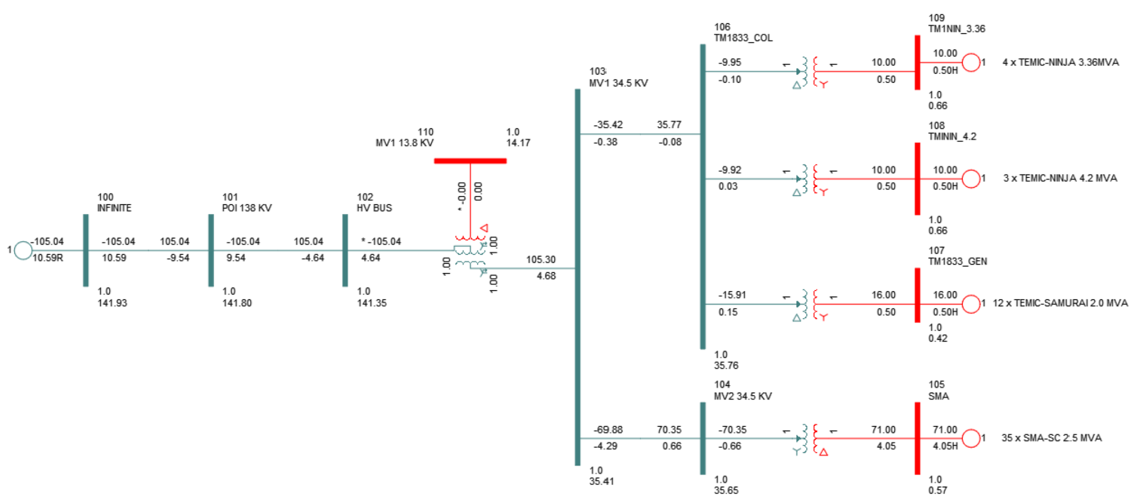



*Figure 8: Example of SMIB system model from one renewable (aggregated) power plant*

### 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).

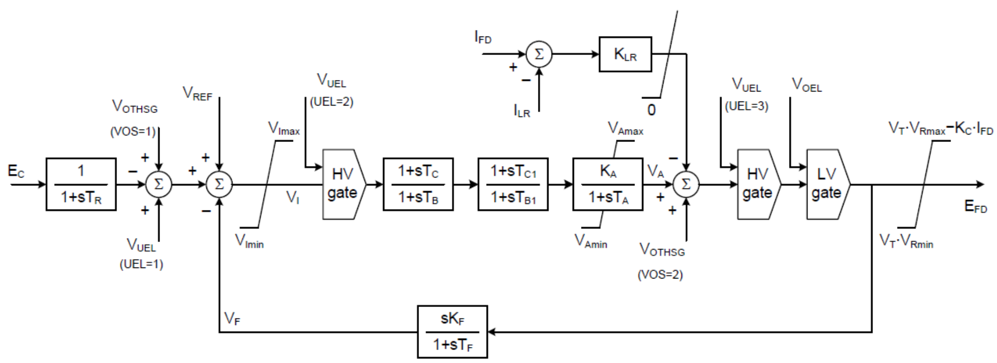



*Figure 12: Example of tabular dynamic model file from one conventional power plant*

## 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*