NERC Libraries of Standardized Powerflow Parameters and Standardized Dynamics Models

Version 1 – October 15, 2015

Introduction

There is a growing need for accurate interconnection-wide powerflow and dynamics simulations that analyze phenomena such as:

- Frequency response,
- inter-area oscillations, and
- interactions between the growing numbers of wide-area control and protection systems.

This requires that validated interconnection-wide powerflow and dynamics cases be developed and available to the industry. These powerflow and dynamics cases are far more detailed than those envisioned when the original "basic data groups" were formed to provide outside-world models for local analyses.

Interconnection-wide powerflow and dynamics cases are constructed from thousands of individual component models. Currently, there is a proliferation of component model structures that can be used to represent a particular type of equipment. This multitude of model structures causes problems in the interchange of data, particularly for the construction of interconnection-wide cases. Some of the model structures have information that is considered to be proprietary or confidential, which impedes the free flow of information necessary for interconnection-wide power system analysis and model validation. An industry-wide forum for discussing the validity of these various model structures is needed. The industry should agree upon standardized component model structures and associated parameters for particular types of equipment. Furthermore, an industry-wide forum is also needed to identify the need for new component models and for tracking changes to existing model structures.

To address this problem, the Planning Committee (PC) directed the NERC Modeling Working Group (MWG) to develop, validate, and maintain a library of standardized component models and parameters for powerflow and dynamics cases. These libraries are henceforth referred to as the NERC libraries of standardized models ("standardized models"). The standardized models in these libraries have documentation describing their model structure, parameters, and operation. This information has been vetted by the industry and thus deemed appropriate for widespread use in interconnection-wide analysis. Standardized models promote the submittal of component model data that is required by the NERC MOD Reliability Standards and facilitate the free flow of information necessary to validate model parameters, assess model performance, and perform the associated system reliability analyses.

An initial library of standardized models was created using the contemporary regionally-approved dynamic model libraries. Additional models from the Institute of Electrical and Electronics Engineers (IEEE) and other appropriate organizations were added as appropriate. Models for new technological innovations are added to the library of standardized models following their development and vetting. The library of standardized models is subject to the review and approval of the MWG, which is composed of industry subject matter experts and representatives from regional modeling working groups.

The libraries of standardized models are documented in two lists: the NERC Library of Standardized Powerflow Parameters and the NERC Library of Standardized Dynamics Models. The NERC Modeling Working Group (MWG) has established criteria for what constitutes a standardized model. MWG has also developed requirements for submitting, evaluating, and making changes to the NERC Library of Standardized Powerflow Parameters and NERC Library of Standardized Dynamics Models. These requirements address modeling developments and "black box[1]," proprietary, and user-defined models. This manual presents both the criteria for standardized models and the process for updating and maintaining the lists of standardized models.

NERC Library of Standardized Powerflow Parameters

The NERC Library of Standardized Powerflow Parameters is a library of parameters that have been vetted by the industry for use in Interconnection-wide powerflow cases. Each parameter in the NERC library has been reviewed by MWG and deemed to meet all of the criteria for a standardized powerflow parameter. The parameters are for positive sequence powerflow cases. Some of the parameters are designated as having enumerated values; conventional powerflow programs generally use an integer coding for the different values that these variables can have.

Some parameters for powerflow elements are not standardized in the industry. For example, some entities only enter two ratings for a transmission line in a powerflow case, while others enter up to 8. Only those powerflow modeling parameters which, in the view of MWG, have truly standardized definitions across the industry and do not have conflicting definitions among the major Interconnections are included in the NERC library. Each Interconnection may (and does) use parameters in addition to those in the library of standardized parameters. Some interconnections may also accept enumerated values for parameters other than those listed in the NERC Library.

The modeling requirements for each Interconnection may require the use of additional powerflow parameters. The modeling requirements for each Interconnection supercede this list and should be consulted directly.

NERC Library of Standardized Dynamics Models

The NERC Library of Standardized Dynamics Models is a library of component models that have been vetted by the industry for use in Interconnection-wide models. Generators, excitation systems, and turbine-

[1] "Black box" refers to a user-written model which does not have sufficient documentation to fully represent the model dynamics. Documentation includes a block diagram, values and names for all model parameters, a list of all state variables, and any dynamic characteristics of the model.

governors are examples of components, and each can have an individual dynamics model. Each of the component models in the NERC library has been reviewed by MWG and deemed to meet all of the criteria for a standardized dynamics model.

Some dynamics component models are not used in some Interconnections. (In fact, some models are prohibited for use in some Interconnections.) However, as long as a particular model meets the criteria established by MWG for a standardized model, MWG includes that particular component model in the NERC library. In particular, IEEE models used in the industry are included as they have clear definitions. Given the large variety of equipment in use, MWG believes that the largest variety of models that meet the criteria for inclusion ought to be included in the Library so that the broadest choices are available to represent equipment. Accordingly, any dynamics model in use in at least one of the major Interconnections is included in the library so long as it meet the criteria. Some Interconnections may accept or require parameters for component models in addition to the parameters identified in the model documentation.

Some of the models in this library may not be acceptable for use in all Interconnections. The modeling requirements for each Interconnection supercede this list and should be consulted directly. The Western Interconnection in particular has a library of dynamics models [W1] that are approved for use in Western Interconnection base cases.

Relationship Between Standardized Models and NERC Modeling Standards (MOD-032-1)

Use of the NERC Libraries of Standardized Powerflow Parameters and Dynamics Models is not specifically required by the NERC standards for data submittal for interconnection cases (i.e., MOD-032-1). However, the dynamics models in the library meet the documentation requirements of MOD-032-1.

Perspective on Common Information Model (CIM)

MWG appreciates the work done by various parties in developing the Common Information Model (CIM) and recognizes the value in standardizing parameters and models. CIM is a possible future means for standardizing powerflow parameters and dynamics models. However, at present, it is not in widespread use for exchanging Interconnection powerflow and dynamics cases. One reason for this situation is the enormous file sizes that result when employing the model for Interconnection cases.

Justification for Standardized Models

Standardized models are needed in the industry for a number of reasons:

1. Availability of industry approved and validated component models to be applied in all software that is used for powerflow and dynamics analysis
    a. Portability of data between programs
    b. Ability for new software to be developed
2. Assembly of data by equipment manufacturers and owners in a consistent format that can be reliably used in interconnection-wide models

3. Reliable simulation of the models in the programs
    a. Maintenance of the models in program version changes
    b. Facilitate comparison of component model behavior between programs
4. Documentation of the model characteristics, including block diagrams and model logic
5. Ease of use for newly planned and operating equipment
6. Identifies need for new model creation (if a new type of equipment cannot be properly represented by existing standardized models)
7. Allows for rapid dissemination of models of new, innovative equipment
8. Facilitates a group dialogue between equipment manufacturers, software developers, entities, and model users
    a. Thorough vetting of the models
    b. Informing software vendors, equipment manufacturers, and users regarding modeling needs and issues related to improving interconnection-wide powerflow and dynamics modeling
    c. Creates a subject matter expert (SME) forum for annual industry-wide dialogue that:
        i. fosters inclusion of operational and planned models, and
        ii. for update of library of standardized models
9. Enhances and strengthens the NERC modeling standards
    a. Creates an industry-wide submittal and posting process for operational and planned models
    b. Develops a library of standardized models
    c. Clarifies industry-wide modeling requirements for software vendors, equipment manufacturers, and users
    d. Supports industry-wide model development, validation, and maintenance through the SME forum
10. Minimize duplication of efforts in the creation and testing of new models

Criteria for Standardized Powerflow Parameters and Standardized Dynamics Component Models

1. Publicly available documentation
    a. Block diagrams
    b. Model logic
    c. List of parameters including description and units
    d. Typical parameter values with recommended range

2. The collection of standardized models is capable of representing all operating or planned equipment attached to the power system with reasonable accuracy
   a. Generally, standardized models represent equipment in widespread use
   b. A standardized model with enough options to replace installation-specific models should be used for equipment that are similar in function
   c. Where feasible, a standardized model that aggregates installation specific models may be used to represent multiple equipment installations, which are similar in function
   d. In some cases, a separate standardized model may need to be created to represent a single unique type of equipment
3. Thoroughly vetted, validated, and deemed acceptable for use by the industry by one or more of the following:
   a. WECC Modeling and Validation Work Group (M&VWG) model approval process
   b. Other Regional modeling working groups
   c. Task Force with subject matter experts organized under auspices of MWG
   d. IEEE
   e. North American Transmission Forum
4. Standardized, unique name that is recognized throughout the industry

Additions to NERC Library of Standardized Powerflow Parameters

Parameters for powerflow cases will be added to the NERC Library of Standardized Powerflow Parameters after the following steps:

1. A thorough vetting, validation, and approval for use by the industry by one or more of the following:
   a. WECC System Review Work Group (SRWG)
   b. ERAG Multi-regional Modeling Working Group (MMWG)
   c. Other Regional powerflow working groups
   d. Task Force with subject matter experts organized under auspices of MWG
   e. IEEE
   f. North American Transmission Forum
2. Approval by MWG

Additions to NERC Library of Standardized Dynamics Models

Dynamics component models will be added to the NERC Library of Standardized Dynamics Models after the following steps:

1. A thorough vetting, validation, and approval for use by the industry by one or more of the following:
    a. WECC M&VWG
    b. Other Regional modeling working groups
    c. Task Force with subject matter experts organized under auspices of MWG
    d. IEEE
    e. North American Transmission Forum
2. Approval by MWG

Any model added to the NERC Library of Standardized Dynamics Models will need to meet the criteria for standardized models listed above.

Removals from NERC Library of Standardized Powerflow Parameters

Parameters for powerflow cases will be removed from the NERC Library of Standardized Powerflow Parameters after the following steps:

1. Determination that the parameter is no longer suitable for use by the industry by one or more of the following:
    a. WECC SRWG
    b. ERAG MMWG
    c. Other Regional powerflow working groups
    d. Task Force with subject matter experts organized under auspices of MWG
    e. IEEE
    f. North American Transmission Forum
2. Approval by MWG of a decision to remove the parameter

Removals from NERC Library of Standardized Dynamics Models

Dynamics component models will be removed from the NERC Library of Standardized Dynamics Models after the following steps:

1. Determination that the model is no longer suitable for use in the industry by one or more of the following:
    a. WECC M&VWG
    b. Other Regional modeling working groups
    c. Task Force with subject matter experts organized under auspices of MWG
    d. IEEE

    e. North American Transmission Forum

2. Approval by MWG of a decision to remove the model

Industry Notification of New Version of NERC Libraries of Standardized Powerflow Parameters and Standardized Dynamics Models

After changes are made to either of these lists, the updated version of the lists will be posted on the MWG page of the NERC web site:

http://www.nerc.com/comm/PC/Pages/Model-Working-Group-(MWG)-2013.aspx

An announcement of the posting will be made.

Periodic Review of NERC Library of Standardized Dynamics Models

MWG will periodically review whether:

1. All models on the approved model lists for each Interconnection are included in the NERC Library of Standardized Dynamics Models (3 times per year)
2. All models in use in the Interconnection-wide dynamics cases for each Interconnection are included in the NERC Library of Standardized Dynamics Models (annual)

MWG will determine the reason for any discrepancy that is found and adjust the NERC Library Standardized Dynamics Models as appropriate. In a few cases, there may be legitimate reasons for discrepancies to exist.

Modeling Developments and Requirements for User-defined Models

MWG recognizes that the on-going development of new technologies for generation and load will require a corresponding on-going development of new dynamics component models. As the vetting of such models takes some time, ad hoc user-defined models will need to be used on an interim basis in some situations. The requirements for such models are already specified in both the Interconnection-specific requirements for dynamics cases and the recently approved MOD-032 standard. In particular, "black box" models without proper documentation, including block diagrams, are not allowed to be used in Interconnection-wide dynamics cases.

NERC LIBRARY OF STANDARDIZED POWERFLOW PARAMETERS

1. Case heading				
	a. Case title line 1	ID	first line of case title	String.
	b. Case title line 2	ID	second line of case title	String.
	c. System base (MVA)	ID	value of system base for transmission per unit quantities in MVA	Real.
2. Bus Data: 1 record for each bus				
	a. Bus number	ID	label identifying the particular bus represented by this data record	Integer, positive.
	b. Bus name	ID	short name for bus	String.
	c. Base voltage	EQ	base value in kV for bus voltage per unit quantities	Real.
	d. Bus Type	DEP	Powerflow constraints for this bus; 4 possible values: PQ bus (no generator, real and reactive power injection at bus fixed), PV bus (generator directly connected, real power injection at bus and bus voltage magnitude fixed), slack bus (bus voltage magnitude and angle fixed), bus out-of-service (not part of network solution)	Enumerated type
	e. Area number	ID	area to which bus is assigned	Integer, positive.
	f. Zone number	ID	zone to which bus is assigned	Integer, positive.
	g. Owner number	ID	Owner to which bus is assigned.	Integer.
	h. Voltage magnitude	DEP	value in per unit on bus base voltage (item 2c)	Real.
	i. Voltage angle	DEP	value in degrees	Real.
	j. Voltage regulation setpoint	OP	setpoint of all devices regulating the voltage of this bus, value in per unit	Real.
3. Load Data: 1 record for each load				
	a. Bus number	ID	number of bus in bus data (section 2) to which load is attached	Integer.
	b. Load identifier	ID	label identifying the particular load represented by this data record	String, maximum 2 characters*.
	c. Status	OP	0: load out-of-service, 1: load in-service	Integer, 0 or 1.
	d. Area Number	ID	number of the area in area data (section 9) to which load is assigned	Integer.
	e. Zone Number	ID	number of the zone in zone data (section 10) to which load is assigned	Integer.
	f. Owner Number	ID	number of the owner in owner data (section 11) to which load is assigned	Integer.
	g. P	OP	constant real power in MW drawn by load from bus	Real.
	h. Q	OP	constant reactive power in MVAR drawn by load from bus	Real.
	i. IP	OP	constant current real power in MW drawn by load from bus at 1.0 per unit voltage	Real.
	j. IQ	OP	constant current reactive power in MVAR drawn by load from bus at 1.0 per unit voltage	Real.
	k. YP	OP	constant impedance real power in MW drawn by load from bus at 1.0 per unit voltage	Real.
	l. YQ	OP	constant impedance reactive power in MVAR drawn by load from bus at 1.0 per unit voltage	Real.
	m. Load Type: Scalable/Non-conforming	EQ	2 possible values: load scalable, load non-conforming and should not be scaled	Enumerated type
4. Generating Units: 1 record for each generator				
	a. Bus number	ID	number of bus in bus data (section 2) to which generator is attached	Integer.
	b. Unit identifier	ID	label identifying the particular generator represented by this data record	String, maximum 2 characters*.
	c. P_{gen}	OP	real power in MW of generator injected into bus	Real.
	d. Q_{gen}	OP	reactive power in MW of generator injected into bus	Real.
	e. Maximum Reactive Power Limit (MVAR)	EQ	maximum continuous reactive power output in MVAR of unit (limit specified with item 4p)	Real.
	f. Minimum Reactive Power Limit (MVAR)	EQ	minimum continuous reactive power output in MVAR of unit (limit specified with item 4p)	Real.
	g. Regulated Bus Number	OP	number of bus in bus data (section 2) whose voltage this generator is regulating	Integer.
	h. Machine Base (MVA)	EQ	machine base value in MVA	Real.
	i. Status	OP	0: out-of-service, 1: in-service	Integer, 0 or 1.
	j. Regulated MVAR Percentage	OP	percentage or fraction of regulating reactive power provided by this generator	Real.
	k. Maximum Power Limit (MW)	EQ	maximum continuous real power output in MW of unit	Real.

	l. Minimum Power Limit (MW)	EQ	minimum continuous real power output in MW of unit	Real.
	m. Owners (provision for at least 4)	ID	One owner number (integer, positive) and one ownership fraction (real) for each owner or partial owner (from owner data, section 11). Ownership fractions must sum to one.	Integer. (4 values)
	n. Owner Fraction (provision for at least 4)	ID		Real. (4 values)
	o. Generator Type	EQ	Primary fuel type; possible values: hydro, nuclear, coal, natural gas, oil, diesel, wind, solar, pumped storage, other	Enumerated type
	p. Type of reactive limits	EQ	possible values: constant, number of reactive capability curve (section 13), constant power factor	Enumerated type
5. AC Transmission Line or Circuit (series capacitors and reactors shall be explicitly modeled as individual line segments): 1 record for each transmission line/circuit				
	a. From Bus Number	ID	number of bus in bus data (section 2) to which first end (“from end”) of line is attached	Integer.
	b. To Bus Number	ID	number of bus in bus data (section 2) to which second end (“to end”) of line is attached	Integer.
	c. Circuit Identifier	ID	label identifying the particular line represented by this data record	String, maximum 2 characters*.
	d. Resistance (R)	EQ	value of branch resistance in per unit on system base (item 1c) and “from bus” voltage base (item 2c)	Real.
	e. Reactance (X)	EQ	value of branch reactance in per unit on system base (item 1c) and “from bus” voltage base (item 2c)	Real.
	f. Susceptance (Charging) (B)	EQ	value of branch charging in per unit on system base (item 1c) and “from bus” voltage base (item 2c)	Real.
	g. Ratings (minimum 2)	EQ	normal and emergency ratings of branch in MVA	Real. (2 values)
	h. Line G (From)	EQ	value of line shunt conductance at “from end” in MW at 1.0 per unit voltage	Real.
	i. Line B (From)	EQ	value of line shunt susceptance at “from end” in MVAR at 1.0 per unit voltage	Real.
	j. Line G (To)	EQ	value of line shunt conductance at “to end” in MW at 1.0 per unit voltage	Real.
	k. Line B (To)	EQ	value of line shunt conductance at “to end” in MVAR at 1.0 per unit voltage	Real.
	l. Status	OP	0: out-of-service, 1: in-service	Integer, 0 or 1.
	m. Metered Bus	EQ	0: metered end is “from end”, 1: metered end is “to end”	Integer, 0 or 1.
	n. Owners (provision for at least 4)	ID	One owner number (integer, positive) and one ownership fraction (real) for each owner or partial owner (from owner data, section 11). Ownership fractions must sum to one.	Integer. (4 values)
	o. Owner Fraction (provision for at least 4)	ID		Real. (4 values)
6. Two Winding Transformer (voltage and phase-shifting) – 1 record for each two-winding transformer				
	a. From Bus Number	ID	number of bus in bus data (section 2) to which winding 1 is attached	Integer.
	b. To Bus Number	ID	number of bus in bus data (section 2) to which winding 2 is attached	Integer.
	c. Transformer Identifier	ID	label identifying the particular transformer represented by this data record	String, maximum 2 characters*.
	d. Magnetizing Conductance	EQ	magnetizing conductance (units specified in item 6ab)	Real.
	e. Magnetizing Susceptance	EQ	magnetizing susceptance (units specified in item 6ab)	Real.
	f. Metered Bus	EQ	0: metered end is “from end”, 1: metered end is “to end”	Integer, 0 or 1.
	g. Status	OP	0: transformer out-of-service, 1: transformer in-service	Integer, 0 or 1.
	h. Owners (provision for at least 4)	ID	One owner number (integer, positive) and one ownership fraction (real) for each owner or partial owner (from owner data, section 11). Ownership fractions must sum to one.	Integer. (4 values)
	i. Owner Fraction (provision for at least 4)	ID		Real. (4 values)
	j. Resistance (R)	EQ	value of transformer resistance (units specified in item 6aa)	Real.
	k. Reactance (X)	EQ	value of transformer reactance (units specified in item 6aa)	Real.
	l. Winding 1 Ratio	OP	turns ratio of winding 1 (units specified in item 6z)	Real.
	m. Winding 1 Angle	OP	angle of winding 1 in degrees	Real.
	n. Ratings (minimum 2)	EQ	normal and emergency ratings of transformer in MVA	Real. (2 values)
	o. Regulation Mode	EQ	3 possible values: fixed tap (no regulation), voltage regulating, MW regulating	Enumerated type
	p. Regulated Bus Number	OP	number of bus in bus data (section 2) whose voltage this transformer is regulating	Integer.
	q. Maximum Ratio or Angle	EQ	maximum tap ratio (units specified in item 6z)	Real.
	r. Minimum Ratio or Angle	EQ	minimum tap ratio (units specified in item 6z)	Real.
	s. Maximum Voltage	OP	upper limit in per unit of voltage regulation band	Real.
	t. Minimum Voltage	OP	lower limit in per unit of voltage regulation band	Real.
	u. Tap positions	EQ	number of tap positions (tap step = (<6q> - <6r>)/(<6u> - 1))	Integer.

	v. Impedance Table	EQ	number of impedance correction table (section 12) being applied, or 0 if not applicable	Integer.
	w. Transformer base	EQ	Transformer base in MVA	Real.
	x. Winding 1 nominal voltage (kV)	EQ	Nominal voltage of winding 1 in kV	Real.
	y. Winding 2 nominal voltage (kV)	EQ	Nominal voltage of winding 2 in kV	Real.
	z. Tap ratio units	EQ	3 possible values: per unit of winding bus voltage base (item 2c), voltage in kV, per unit of nominal winding voltage (item 6x)	Enumerated type
	aa. Impedance units	EQ	3 possible values: per unit on system base/winding bus voltage base (item 1c & 2c), per unit on transformer base/winding bus voltage base (items 6w & 2c), load loss in W & X in per unit on transformer base/winding bus voltage base (items 6w & 2c)	Enumerated type
	ab. Magnetizing units	EQ	2 possible values: per unit on system base/winding 1 bus voltage base (items 1c & 2c), no load loss in W & current per unit on transformer base/winding 1 base (items 6w & 6x)	Enumerated type
	ac. Winding 2 Ratio	OP	turns ratio of winding 2 (units specified in item 6z)	Real.
	ad. Winding 2 Angle	OP	angle of winding 2 in degrees	Real.
7. Three Winding Transformer – 1 record for each three-winding transformer				
	a. From (winding 1) Bus Number	ID	number of bus in bus data (section 2) to which winding 1 is attached	Integer.
	b. To (winding 2) Bus Number	ID	number of bus in bus data (section 2) to which winding 2 is attached	Integer.
	c. Last (winding 3) Bus Number	ID	number of bus in bus data (section 2) to which winding 3 is attached	Integer.
	d. Transformer Identifier	ID	label identifying the particular transformer represented by this data record	String, maximum 2 characters*.
	e. Resistance 1-2	EQ	value of transformer resistance between winding 1 and winding 2 (units specified in item 6bg)	Real.
	f. Reactance 1-2	EQ	value of transformer reactance between winding 1 and winding 2 (units specified in item 6bg)	Real.
	g. Resistance 2-3	EQ	value of transformer resistance between winding 1 and winding 2 (units specified in item 6bg)	Real.
	h. Reactance 2-3	EQ	value of transformer reactance between winding 1 and winding 2 (units specified in item 6bg)	Real.
	i. Resistance 3-1	EQ	value of transformer resistance between winding 1 and winding 2 (units specified in item 6bg)	Real.
	j. Reactance 3-1	EQ	value of transformer reactance between winding 1 and winding 2 (units specified in item 6bg)	Real.
	k. Star Bus Voltage	DEP	value in per unit on bus base voltage (item 2c)	Real.
	l. Star Bus Angle	DEP	value in degrees	Real.
	m. Magnetizing Conductance	EQ	magnetizing conductance (units specified in item 6bh)	Real.
	n. Magnetizing Susceptance	EQ	magnetizing susceptance (units specified in item 6bh)	Real.
	o. Status	OP	5 possible values: transformer out-of-service, transformer in-service (all windings), winding 2 only out-of-service, winding 3 only out-of-service, winding 1 only out-of-service	Enumerated type
	p. Non-metered Bus	EQ	designates non-metered winding	Integer, 1 to 3.
	q. Winding 1 Ratio	OP	turns ratio of winding 1 (units specified in item 6bf)	Real.
	r. Winding 1 Angle	OP	angle of winding 1 in degrees	Real.
	s. Winding 2 Ratio	OP	turns ratio of winding 2 (units specified in item 6bf)	Real.
	t. Winding 2 Angle	OP	angle of winding 2 in degrees	Real.
	u. Winding 3 Ratio	OP	turns ratio of winding 3 (units specified in item 6bf)	Real.
	v. Winding 3 Angle	OP	angle of winding 3 in degrees	Real.
	w. Winding 1 ratings (minimum 2)	EQ	normal and emergency ratings of transformer winding 1 in MVA	Real. (2 values)
	x. Winding 2 ratings (minimum 2)	EQ	normal and emergency ratings of transformer winding 2 in MVA	Real. (2 values)
	y. Winding 3 ratings (minimum 2)	EQ	normal and emergency ratings of transformer winding 3 in MVA	Real. (2 values)
	z. Regulation Mode 1	EQ	Winding 1 regulation; 3 possible values: fixed tap (no regulation), voltage regulating, MW regulating	Enumerated type
	aa. Regulated Bus Number 1	OP	number of bus in bus data (section 2) whose voltage this winding is regulating	Integer.
	ab. Maximum Ratio or Angle 1	EQ	maximum tap ratio of winding 1 (units specified in item 6bf)	Real.
	ac. Minimum Ratio or Angle 1	EQ	minimum tap ratio of winding 1 (units specified in item 6bf)	Real.
	ad. Maximum Voltage 1	OP	upper limit of voltage regulation band of winding 1	Real.

	ae. Minimum Voltage 1	OP	lower limit of voltage regulation band of winding 1	Real.
	af. Tap Positions 1	EQ	number of tap positions on winding 1	Integer.
	ag. Impedance Table 1	EQ	number of impedance correction table (section 12) being applied, or 0 if not applicable	Integer.
	ah. Regulation Mode 2	EQ	Winding 2 regulation; 3 possible values: fixed tap (no regulation), voltage regulating, MW regulating	Enumerated type
	ai. Regulated Bus Number 2	OP	number of bus in bus data (section 2) whose voltage this winding is regulating	Integer.
	aj. Maximum Ratio or Angle 2	EQ	maximum tap ratio of winding 2 (units specified in item 6bf)	Real.
	ak. Minimum Ratio or Angle 2	EQ	minimum tap ratio of winding 2 (units specified in item 6bf)	Real.
	al. Maximum Voltage 2	OP	upper limit of voltage regulation band of winding 2	Real.
	am. Minimum Voltage 2	OP	lower limit of voltage regulation band of winding 2	Real.
	an. Tap Positions 2	EQ	number of tap positions on winding 2	Integer.
	ao. Impedance Table 2	EQ	number of impedance correction table (section 12) being applied, or 0 if not applicable	Integer.
	ap. Regulation Mode 3	EQ	Winding 3 regulation; 3 possible values: fixed tap (no regulation), voltage regulating, MW regulating	Enumerated type
	aq. Regulated Bus Number 3	OP	number of bus in bus data (section 2) whose voltage this winding is regulating	Integer.
	ar. Maximum Ratio or Angle 3	EQ	maximum tap ratio of winding 3 (units specified in item 6bf)	Real.
	as. Minimum Ratio or Angle 3	EQ	minimum tap ratio of winding 3 (units specified in item 6bf)	Real.
	at. Maximum Voltage 3	OP	upper limit of voltage regulation band of winding 3	Real.
	au. Minimum Voltage 3	OP	lower limit of voltage regulation band of winding 3	Real.
	av. Impedance Table 3	EQ	number of impedance correction table (section 12) being applied, or 0 if not applicable	Integer.
	aw. Tap Positions 3	EQ	number of tap positions on winding 3	Integer.
	ax. Owners (provision for at least 4)	ID	One owner number (integer, positive) and one ownership fraction (real) for each owner or partial owner (from owner data, section 11). Ownership fractions must sum to one.	Integer. (4 values)
	ay. Owner Fraction (provision for at least 4)	ID		Real. (4 values)
	az. Transformer base (windings 1-2)	EQ	Transformer base for windings 1-2 in MVA	Real.
	ba. Transformer base (windings 2-3)	EQ	Transformer base for windings 2-3 in MVA	Real.
	bb. Transformer base (windings 3-1)	EQ	Transformer base for windings 3-1 in MVA	Real.
	bc. Winding 1 nominal voltage (kV)	EQ	Nominal voltage of winding 1 in kV	Real.
	bd. Winding 2 nominal voltage (kV)	EQ	Nominal voltage of winding 2 in kV	Real.
	be. Winding 3 nominal voltage (kV)	EQ	Nominal voltage of winding 3 in kV	Real.
	bf. Tap ratio units	EQ	3 possible values: per unit of winding bus voltage base (item 2c), voltage in kV, per unit of nominal winding voltage (item 7bc-be)	Enumerated type
	bg. Impedance units	EQ	3 possible values: per unit on system base/winding bus voltage base (item 1c & 2c), per unit on transformer base/winding bus voltage base (items 7az-bb & 2c), load loss in W & X in per unit on transformer base/winding bus voltage base (items 7az-bb & 2c)	Enumerated type
	bh. Magnetizing units	EQ	2 possible values: per unit on system base/winding 1 bus voltage base (items 1c & 2c), no load loss in W & current per unit on transformer base/winding 1 base (items 7az-bb & 7bc-be)	Enumerated type
8. Shunt compensation (shunt capacitors, reactors, SVC, STATCOM, etc.) – 1 record for each shunt				
	a. Bus number	ID	number of bus in bus data (section 2) to which shunt is attached	Integer.
	b. Shunt Identifier	ID	label identifying the particular shunt represented by this data record	String, maximum 2 characters*.
	c. Status	OP	0: shunt out-of-service, 1: shunt in-service	Integer, 0 or 1.
	d. Regulation Mode	EQ	3 possible values: fixed, discrete control, continuous control	Enumerated type
	e. Regulated Bus Number	OP	number of bus in bus data (section 2) whose voltage this shunt is regulating	Integer.
	f. Regulated MVAR Percentage	OP	percentage or fraction of regulating reactive power provided by this shunt	Real.
	g. Shunt Conductance (MW)	OP	value of shunt conductance in MW at 1.0 per unit voltage	Real.
	h. Shunt Susceptance (MVAR)	OP	value of shunt susceptance in MVAR at 1.0 per unit voltage	Real.

	i. Maximum Continuous Susceptance (MVAR)	EQ	maximum value of continuous element of shunt (0 if no continuous element)	Real.
	j. Minimum Continuous Susceptance (MVAR)	EQ	minimum value of continuous element of shunt (0 if no continuous element)	Real.
	k. Maximum Voltage Regulation Setpoint	OP	upper limit of voltage regulation band	Real.
	l. Minimum Voltage Regulation Setpoint	OP	lower limit of voltage regulation band	Real.
	m. Block Steps (provision for at least 8)	EQ	number of discrete shunts (integer) in block and the size of each discrete shunt in MVAR (real) in that block	Integer. (8 values)
	n. Block Size (provision for at least 8)	EQ		Real. (8 values)
9. Area Interchange – 1 record for each area				
	a. Area number	ID	label identifying the particular area represented by this data record	Integer.
	b. Area name	ID	short name for area	String.
	c. Desired net interchange/Scheduled interchange	OP	desired interchange value in MW, positive indicates export, while negative indicates import	Real.
10. Zone Data – 1 record for each zone				
	a. Zone number	ID	label identifying the particular zone represented by this data record	Integer.
	b. Zone name	ID	short name for zone	String.
11. Owner Data – 1 record for each owner				
	a. Owner number	ID	label identifying the particular owner represented by this data record	Integer.
	b. Owner name	ID	short name for owner	String.
12. Transformer Impedance Correction Tables				
	a. Table number	EQ	label identifying the particular table represented by this data record	Integer.
	b. Winding ratio (provision for at least 11)	EQ	winding ratio (real) and the scaling factor to be applied to the transformer impedance at that winding ratio (real); scaling factor is linearly interpolated for other winding ratios	Real.
	c. Scaling factor (provision for at least 11)	EQ		Real.
13. Reactive Capability Curves				
	a. Table number	EQ	label identifying the particular reactive capability curve represented by this data record	Integer.
	b. Real power point (provision for at least 10)	EQ	Real power dispatch point	Real.
	c. Maximum reactive power (provision for at least 10)	EQ	Maximum reactive power at corresponding real power dispatch point.	Real.
	d. Minimum reactive power (provision for at least 10)	EQ	Minimum reactive power at corresponding real power dispatch point.	Real.
* - permitted characters: upper case letters, numbers, spaces				
		ID	Identifier: provided by PC/TP	
		EQ	Equipment characteristic: provided by equipment owner	
		OP	Operating state: reflects current state of the system	
			for past date/time (event reconstruction): filled with recorded data from TOP/GOP/RC	
			for day ahead/seasonal study: filled by TOP with values appropriate to scenario under study, taking into account known forced and scheduled outages of equipment	
			for near-term or long-term planning: filled by PC/TP with values appropriate to scenario under study	
		DEP	Dependent variable; value is a function of the other variables and is calculated by Powerflow solution	
NOTE: A Powerflow case for a particular interconnection may contain additional parameters not included on this list, including additional ratings and/or additional owners.				
NOTE: Some Interconnections may allow the use of additional values for enumerated type variables in addition to the ones given in this library. Enumerated type variables are typically represented by integers in conventional data formats.				

NERC LIBRARY OF STANDARDIZED DYNAMICS MODELS

				Siemens PTI (v. 33)		GE PSLF (v. 19)		PowerWorld (v. 19)		PowerTech DSATools (v. 15)		V&R Energy POM Suite (2015)	
								(PSSE)	(PSLF)	(PSSE)	(PSLF)	(PSSE)	(PSLF)
1.	Generator												
a) Synchronous machines:													
		IEEE Std 1110 §5.3.2 round-rotor (Model 2.2) - note A	[1]	GENROU		genrou	(1)	GENROU	genrou	GENROU	genrou	GENROU	genrou
		IEEE Std 1110 §5.3.1 salient-pole (Model 2.1) - note B	[1]	GENSAL		gensal	(1)	GENSAL	gensal	GENSAL	gensal	GENSAL	gensal
		IEEE Std 1110 §5.3.2 round-rotor (Model 2.2) - note C	[1]	GENROE		--		GENROE	--	GENROE	--	GENROE	--
		IEEE Std 1110 §5.3.1 salient-pole (Model 2.1) - note D	[1]	GENSAE		--		GENSAE	--	GENSAE	--	GENSAE	--
		Cross compound WECC Type F	[2]	--		gencc	(1)	--	gencc	--	gencc	--	gencc
		WECC Type F	[2]	--		gentpf	(1)	--	gentpf	--	gentpf	--	gentpf
		WECC Type J	[2]	GENTPJU1		gentpj	(1)	--	gentpj	GENTPJU1	gentpj	--	gentpj
		IEEE Std 1110 §5.4.2 classical	[1]	GENCLS		gencls	(1)	GENCLS	gencls	GENCLS	gencls	GENCLS	gencls
				CBEST		--		CBEST	--	--	--	CBEST	--
	Note A - Power-speed variations included; L_{f1d} = 0; single saturation increment consisting of quadratic function of ψ'' (added into $L_{ad} i_{fd}$)												
	Note B - Power-speed variations included; L_{f1d} = 0; single saturation increment consisting of quadratic function of ψ_{fd} (added into $L_{ad} i_{fd}$)												
	Note C - Power-speed variations included; L_{f1d} = 0; single saturation increment consisting of exponential function of ψ'' (added into $L_{ad} i_{fd}$)												
	Note D - Power-speed variations included; L_{f1d} = 0; single saturation increment consisting of exponential function of ψ_{fd} (added into $L_{ad} i_{fd}$)												
b) Other technologies, including, as appropriate to the model:													
		i. inertia constant											
		ii. damping coefficient											
		iii. saturation parameters											
		iv. direct and quadrature axes reactances and time constants											
	(1)	Model includes IEEE Std 421.5 current compensator (signs of impedance parameters are opposite of their specification in IEEE standard)											
2.	Excitation System												
		IEEE Std 421.5 Type AC1A	[3]	ESAC1A		esac1a	(1)	ESAC1A	esac1a	ESAC1A	esac1a	ESAC1A	esac1a
		IEEE Std 421.5 Type AC2A	[3]	ESAC2A		esac2a	(1)	ESAC2A	esac2a	ESAC2A	esac2a	ESAC2A	esac2a
		IEEE Std 421.5 Type AC3A	[3]	ESAC3A		esac3a	(1)	ESAC3A	esac3a	ESAC3A	esac3a	ESAC3A	esac3a
		IEEE Std 421.5 Type AC4A	[3]	ESAC4A		esac4a	(3)	ESAC4A	esac4a	ESAC4A	esac4a	ESAC4A	esac4a
		IEEE Std 421.5 Type AC5A	[3]	ESAC5A		esac5a		ESAC5A	esac5a	ESAC5A	esac5a	ESAC5A	esac5a
		IEEE Std 421.5 Type AC6A	[3]	ESAC6A		esac6a	(1)	ESAC6A	esac6a	ESAC6A	esac6a	ESAC6A	esac6a
		IEEE Std 421.5 Type AC7B*	[3]	AC7B		esac7b	(1)	AC7B	esac7b	AC7B	esac7b	AC7B	esac7b
		IEEE Std 421.5 Type AC8B	[3]	AC8B	(2)	esac8b	(1)	AC8B	esac8b_ge	AC8B	esac8b	AC8B	esac8b
		Modified IEEE Std 421.5 Type AC8B		ESAC8B		--		ESAC8B_PTI	--	ESAC8B	--	ESAC8B	--
		Modified IEEE Std 421.5 Type AC8B		--		exac8b		--	exac8b	--	exac8b	--	exac8b
		IEEE Std 421.5 Type DC1A	[3]	ESDC1A	(4),(5)	esdc1a	(1)	ESDC1A	esdc1a	ESDC1A	esdc1a	ESDC1A	esdc1a
		IEEE Std 421.5 Type DC2A	[3]	ESDC2A	(4),(5)	esdc2a	(1)	ESDC2A	esdc2a	ESDC2A	esdc2a	ESDC2A	esdc2a
		IEEE Std 421.5 Type DC3A	[3]	DC3A		esdc3a	(1)	DC3A	esdc3a	DC3A	esdc3a	DC3A	esdc3a
		IEEE Std 421.5 Type DC4B	[3]	DC4B		esdc4b	(1)	DC4B	esdc4b	DC4B	esdc4b	DC4B	esdc4b
		IEEE Std 421.5 Type ST1A	[3]	ESST1A		esst1a		ESST1A	esst1a	ESST1A	esst1a	ESST1A	esst1a
		IEEE Std 421.5 Type ST2A	[3]	ESST2A	(5)	esst2a	(6)	ESST2A	esst2a	ESST2A	esst2a	ESST2A	esst2a
		IEEE Std 421.5 Type ST3A	[3]	ESST3A		esst3a		ESST3A	esst3a	ESST3A	esst3a	ESST3A	esst3a

		IEEE Std 421.5 Type ST4B	[3]	ESST4B		esst4b	(7)	ESST4B	esst4b	ESST4B	esst4b	ESST4B	esst4b
		IEEE Std 421.5 Type ST5B**	[3]	ST5B	(8)	esst5b	(8)	ST5B	esst5b	ST5B	esst5b	ST5B	esst5b
		IEEE Std 421.5 Type ST6B	[3]	ST6B	(9)	esst6b	(10)	ST6B	esst6b	ST6B	esst6b	ST6B	esst6b
		IEEE Std 421.5 Type ST7B	[3]	ST7B	(11)	esst7b	(10),(11)	ST7B	esst7b	ST7B	esst7b	ST7B	esst7b
		1968 IEEE Type 1	[4]	IEEET1	(12)	ieeet1	(12),(14)	IEEET1	ieeet1	IEEET1	ieeet1	IEEET1	ieeet1
		Modified 1968 IEEE Type 1		IEET1A		--		IEET1A	--	IEET1A	--	IEET1A	--
		1968 IEEE Type 2	[4]	IEEET2	(12)	--		IEEET2	--	IEEET2	--	IEEET2	--
		1968 IEEE Type 3	[4]	IEEET3	(12)	--		IEEET3	--	IEEET3	--	IEEET3	--
		1968 IEEE Type 4	[4]	IEEET4	(13)	exdc4		IEEET4	exdc4	IEEET4	exdc4	IEEET4	--
		Modified 1968 IEEE Type 4		IEEET5		--		IEEET5	--	IEEET5	--	IEEET5	--
		1981 IEEE Type AC1	[5]	EXAC1		exac1	(14),(15)	EXAC1	exac1	EXAC1	exac1	EXAC1	exac1
		Modified 1981 IEEE Type AC1		EXAC1A		exac1a		EXAC1A	exac1a	EXAC1A	exac1a	EXAC1A	exac1a
		1981 IEEE Type AC2	[5]	EXAC2		exac2	(14)	EXAC2	exac2	EXAC2	exac2	EXAC2	exac2
		1981 IEEE Type AC3	[5]	EXAC3		exac3	(14),(16)	EXAC3	exac3	EXAC3	exac3	EXAC3	--
		Modified 1981 IEEE Type AC3		--		exac3a		--	exac3a	--	exac3a	--	exac3a
		1981 IEEE Type AC4	[5]	EXAC4		exac4		EXAC4	exac4	EXAC4	exac4	EXAC4	exac4
		1981 IEEE Type DC1	[5]	IEEEX1		exdc1	(14)	IEEEX1	exdc1	IEEEX1	exdc1	IEEEX1	exdc1
		Modified 1981 IEEE Type DC1		IEEEX2		--		IEEEX2	--	IEEEX2	--	IEEEX2	--
		Modified 1981 IEEE Type DC1		IEEX2A		--		IEEX2A	--	IEEX2A	--	IEEX2A	--
		1981 IEEE Type DC2	[5]	EXDC2		exdc2a	(14)	EXDC2_PTI	exdc2a	EXDC2	exdc2a	EXDC2	exdc2a
		Modified 1981 IEEE Type DC2		--		exdc2		--	exdc2_ge	--	exdc2	--	exdc2
		1981 IEEE Type DC3	[5]	IEEEX4		exdc4		IEEEX4	exdc4	IEEEX4	exdc4	IEEEX4	exdc4
		1981 IEEE Type ST1	[5]	EXST1		exst1	(17)	EXST1_PTI	exst1_ge	EXST1	exst1	EXST1	exst1
		1981 IEEE Type ST2	[5]	EXST2		exst2	(18)	EXST2	exst2	EXST2	exst2	EXST2	exst2
		Modified 1981 IEEE Type ST2		EXST2A		exst2a		EXST2A	exst2a	EXST2A	exst2a	EXST2A	exst2a
		Modified 1981 IEEE Type ST2		IEEEX3		--		IEEEX3	--	IEEEX3	--	IEEEX3	--
		1981 IEEE Type ST3	[5]	EXST3		exst3	(14)	EXST3	exst3	EXST3	exst3	EXST3	exst3
		Modified 1981 IEEE Type ST3		--		exst3a		--	exst3a	--	exst3a	--	exst3a
		Brown-Boveri static		BBSEX1		exbbc		BBSEX1	exbbc	BBSEX1	exbbc	BBSEX1	exbbc
		Static PI transformer fed		EXELI		exeli		EXELI	exeli	EXELI	exeli	EXELI	exeli
				--		exst4b		--	exst4b	--	exst4b	--	exst4b
		General purpose rotating		REXSYS		rexs		REXSYS	rexs	REXSYS	rexs	REXSYS	rexs
				REXSY1		--		REXSY1	--	REXSY1	--	REXSY1	--
		SCR Bridge		SCRX		scrx		SCRX	scrx	SCRX	scrx	SCRX	scrx
		Simplified excitation system		SEXS		sexs		SEXS_PTI	sexs_ge	SEXS	sexs	SEXS	sexs
		IVO excitation system		IVOEX		exivo		IVOEX	exivo	IVOEX	--	IVOEX	exivo
				EXPIC1		expic1		EXPIC1	expic1	EXPIC1	expic1	EXPIC1	expic1
		Basler static voltage regulator feeding dc or ac rotating exciter		EXBAS		--		EXBAS	--	EXBAS	--	EXBAS	--
		GE EX2000 excitation system		EX2000		--		EX2000	--	EX2000	--	EX2000	--
		AEP Rockport excitation system		EMAC1T		--		EMAC1T	--	EMAC1	--	EMAC1T	--
		Proposed IEEE Type ST5B		URST5T		--		URST5T	--	URST5T	--	URST5T	--
				CELIN		--		--	--	CELIN	--	CELIN	--
				USAC6AU		--		--	--	--	--	--	--
				--		texs		--	texs	--	texs	--	texs
	a) Current Compensation												
				COMP		--		COMP	--	COMP	--	COMP	--
		IEEE Std 421.5 current compensator	[3]	IEEEVC		†		IEEEVC	†	IEEEVC	†	IEEEVC	†
				REMCMP		--		REMCMP	--	REMCMP	--	REMCMP	--
				COMPCC		ccomp		COMPCC	--	--	--	COMPCC	--

		Cross-current compensation	[14]	--		ccomp4		--	ccomp4	--	--	--	--
	* - In standard, V_E output comes from 1/(1+sT_E) block; this appears to be a typographical error (should be 1/sT_E).												
	** - In standard, V_REF is missing.												
	† - Current compensator is part of the generator model												
	(1)	Software model includes additional option to multiply field voltage output by speed.											
	(2)	In software model, non-windup integrator limits are applied to PID output. Software model also explicitly shows V_UEL and V_OEL.											
	(3)	Software model uses windup limits for E_FD.											
	(4)	In software model, minimum for E_FD is set to 0.											
	(5)	In software model, V_UEL may only be injected at HV gate.											
	(6)	Software model has additional lead-lag block between summing junction and HV gate.											
	(7)	Software model has additional maximum value limiter on V_G = K_G E_FD											
	(8)	In software model, non-windup limits are applied to each individual lead-lag block (6 total).											
	(9)	Software model uses a PID voltage regulator instead of a PI voltage regulator.											
	(10)	In software model, field voltage passes through additional lag with time constant T_S											
	(11)	Software model only has provision for input from one overexcitation limiter, not two.											
	(12)	In software model, V_R has non-windup limits.											
	(13)	In software model, deadband K_R is explicitly specified.											
	(14)	In software model, field voltage signal is multiplied by speed.											
	(15)	Software model has two sets of limits applied to V_R.											
	(16)	Software model also has maximum non-windup limit for V_E.											
	(17)	In software model, there are two lead-lag compensators instead of one, and I_FD affects field voltage through additional logic.											
	(18)	Software model has additional lead-lag block between summing junction and V_R output block.											
3. Turbine-governor													
		WECC double derivative hydro		WSHYDD		g2wscc		WSHYDD	g2wscc	WSHYDD	g2wscc	WSHYDD	g2wscc
				URGS3T		gast		URGS3T	gast_ge	URGS3T	gast	URGS3T	gast
		General purpose thermal (Ver. 1)	[13]	GGOV1	(1)	--		GGOV1	--	GGOV1	--	GGOV1	--
		General purpose thermal (Ver. 2)	[7]	--		ggov1		--	ggov1	--	ggov1	--	ggov1
				--		ggov3		--	ggov3	--	ggov3	--	ggov3
				WSHYGP		gpwscc		WSHYGP	gpwscc	WSHYGP	gpwscc	WSHYGP	gpwscc
				--		hyg3		--	hyg3	--	hyg3	--	hyg3
		Hydro turbine-governor		HYGOV		hygov		HYGOV	hygov	HYGOV	hygov	HYGOV	hygov
		Hydro turbine-governor		HYGOV2		--		HYGOV2	--	HYGOV2	--	HYGOV2	--
				--		hygov4		--	hygov4	--	hygov4	--	hygov4
				--		hygovr		--	hygovr	--	hygovr	--	hygovr
		1973 IEEE General Steam Turbine System (fig. 4 (A) & 8)	[6]	IEEEG1		--		IEEEG1	--	IEEEG1	--	IEEEG1	--
		1973 IEEE General Approx. Linear Ideal Hydro (fig. 4 (B) & 10 (B))	[6]	IEEEG2		--		IEEEG2	--	IEEEG2	--	IEEEG2	--
		1973 IEEE General Mechanical-Hydraulic (fig. 9 (B) & 10 (A))	[6]	IEEEG3		ieeeg3	(2)	IEEEG3_PTI	ieeeg3_ge	IEEEG3	ieeeg3	IEEEG3	ieeeg3
		1973 IEEE General Steam Turbine System (fig. 4 (A) & 8) w/ speed deadband	[7]	WSIEG1		ieeeg1		WSIEG1	ieeeg1_ge	WSIEG1	ieeeg1	WSIEG1	--
		Hydro turbine and governor		PIDGOV		pidgov		PIDGOV	pidgov	PIDGOV	pidgov	PIDGOV	pidgov
		Steam turbine-governor	[7]	TGOV1		tgov1		TGOV1	tgov1	TGOV1	tgov1	TGOV1	tgov1
		Steam turbine-governor w/ fast valving		TGOV2		--		TGOV2	--	TGOV2 (DSA1)	--	TGOV2	--
		1973 IEEE General w/ fast valving		TGOV3		tgov3		TGOV3	tgov3	TGOV3 (DSA1)	tgov3 (DSA1)	TGOV3	tgov3
				TGOV5		--		TGOV5	--	--	--	TGOV5	--

		1973 IEEE General Steam Non-reheat (fig. 4 (B) & 7 (B))	[6]	IEESGO		--		IEESGO	--	IEESGOV	--	IEESGO	--
		Cross compound turbine-governor		CRCMGV		crcmgv		CRCMGV	crcmgv	CRCMGV	crcmgv	CRCMGV	crcmgv
		Gas turbine-governor		GAST		--		GAST_PTI	--	GAST	--	GAST	--
		Heavy duty gas turbine	[12]	GAST2A	(3)	--		GAST2A	--	GAST2A	--	GAST2A	--
		Gas turbine-governor		GASTWD		--		GASTWD	--	GASTWD	--	GASTWD	--
		Woodward P.I.D. hydro		WPIDHY		--		WPIDHY	--	WPIDHY	--	WPIDHY	--
				WESGOV		--		WESGOV	--	WESGOV	--	WESGOV	--
				WEHGOV		--		WEHGOV	--	WEHGOV	--	WEHGOV	--
		Woodward diesel governor		DEGOV		--		DEGOV	--	--	--	DEGOV	--
		Woodward diesel governor		DEGOV1		degov1		DEGOV1	--	DEGOV1	--	DEGOV1	--
		Brown-Boveri turbine-governor		BBGOV1		--		--	--	--	--	BBGOV1	--
				TURCZT		--		--	--	--	--	--	--
				--		h6b		--	--	--	--	--	--
				--		ccbt1		--	ccbt1	--	--	--	ccbt1
				--		w2301		--	w2301	--	w2301	--	w2301
	a) Load controller												
			[7]	LCFB1		lcfb1	(4)	LCFB1_PTI	lcfb1	LCFB1	lcfb1	LCFB1	lcfb1
	(1)	Software model has additional lead-lag block in temperature limit control loop, and temperature feedback signal has upper limit of 1.0.											
	(2)	Software model uses windup limits for gate position, has two additional deadband blocks, includes a piecewise linear power-gate position characteristic (up to 6 points), and different parameters in Pmech output block.											
	(3)	Software model has non-windup limits on speed governor and temperature control outputs instead of windup limits. Software model lacks acceleration control. Software model has additional block for fuel control delay.											
	(4)	Software model has additional gain block following windup limits of PI controller.											
4.	Power System Stabilizer												
				ST2CUT		wsccst		ST2CUT	wsccst	ST2CUT	wsccst	ST2CUT	wsccst
				PSS2A		pss2a		PSS2A	pss2a	PSS2A	pss2a	PSS2A	pss2a
		1981 IEEE Power System Stabilizer	[5]	IEEEST	(1)	ieeest	(4)	IEEEST	ieeest	IEEEST	ieeest	IEEEST	ieeest
				--		psssb		--	psssb	--	psssb	--	psssb
		IEEE Std 421.5 PSS1A	[3]	(PSS1A)	(2)	pss1a		PSS1A	pss1a	--	pss1a	--	pss1a
		IEEE Std 421.5 PSS2B	[3]	PSS2B		pss2b	(5)	PSS2B	pss2b	PSS2B	pss2b	PSS2B	pss2b
		IEEE Std 421.5 PSS3B	[3]	PSS3B		pss3b		--	pss3b	--	pss3b	PSS3B	pss3b
		IEEE Std 421.5 PSS4B	[3]	PSS4B	(3)	--		--	--	--	--	--	--
				STAB1		--		STAB1	--	STAB1	--	STAB1	--
				STAB3		--		STAB3	--	STAB3	--	STAB3	--
				STAB4		--		STAB4	--	STAB4	--	STAB4	--
				IEE2ST		--		IEE2ST	--	IEE2ST	--	IEE2ST	--
				PTIST1		--		--	--	PTIST1	--	PTIST1	--
				PTIST3		--		--	--	PTIST3	--	PTIST3	--
				STBSVC		--		STBSVC	--	STBSVC	--	STBSVC	--
	(1)	Software model has extra output block											
	(2)	PSS1A "model" is actually a template for placing PSS1A parameters into IEEEST model											
	(3)	Software model has option for quadratic term in numerator of frequency digital transducer transfer function and allows choice of coefficients of transducer transfer functions.											
	(4)	Software model has additional time delay and output limiter blocks.											
	(5)	Software model has additional lead-lag block.											
5.	Demand (consistent with system load representation (composite load model) and components as a function of frequency and voltage)												
				IEEL__		_lwscc		IEEL	--	IEELxx	xLWSCC	IEEL__	--

				LDFR__		--		LDFR	--	LDFRxx	--	LDFR__	--
		WECC Composite Load Model	[8]	CMLDBLU1		cmpldw		--	cmpldw	CMLDBLU1	cmpldw	CMLDBLU1	cmpldw
				ACMTBLU1		ld1pac		--	ld1pac	--	--	--	--
				CIMTR1		--		CIMTR1	--	CIMTR1	--	CIMTR1	--
				CIMTR2		--		CIMTR2	--	CIMTR2	--	CIMTR2	--
				CIMTR3		--		CIMTR3	--	CIMTR3	--	CIMTR3	--
				CIMTR4		motor1		CIMTR4	motor1	CIMTR4	motor1	CIMTR4	motor1
				CIMTR5		--		--	--	--	--	--	--
				CIMWBL		motorw		--	motorw	CIMWBL	motorw	CIMWBL	motorw
				CLOD__		--		CLOD	--	CLODxx	--	CLOD__	--
		area		__=AR		__=a							
		bus		__=BL		__=b							
		zone		__=ZN		__=z							
		all		__=AL		__=w							
6.	Wind Machine and Photovoltaic Data												
		Generator for WECC WT1 Generic Wind Model (Fixed-speed induction generator)	[9]	WT1G1		wt1g		WT1G1	wt1g	WT1G1	wt1g	WT1G1	wt1g
		Generator for WECC WT2 Generic Wind Model (Variable slip induction generator with variable rotor resistance)	[9]	WT2G1		wt2g		WT2G1	wt2g	WT2G1	wt2g	WT2G1	wt2g
		Generator/converter for WECC WT3 Generic Wind Model, PSSE (Doubly-fed induction generator)	[9]	WT3G1		--		WT3G1	--	WT3G1	--	WT3G1	--
		Generator/converter for WECC WT3 Generic Wind Model, PSLF (Doubly-fed induction generator)	[9]	WT3G2		wt3g		WT3G2	wt3g	WT3G2	wt3g	WT3G2	wt3g
		Generator/converter for WECC WT4 Generic Wind Model, PSSE (Variable speed generator with full converter)	[9]	WT4G1		--		WT4G1	--	WT4G1	--	WT4G1	--
		Generator/converter for WECC WT4 Generic Wind Model, PSLF (Variable speed generator with full converter)	[9]	WT4G2		wt4g		--	wt4g	--	wt4g	WT4G2	wt4g
		Renewable energy generator/converter	[10]	REGCAU1		regc_a		--	regc_a	REGCAU1	regc_a	--	--
		Rotor resistance control for WECC WT2 Generic Wind Model	[9]	WT2E1		wt2e		WT2E1	wt2e	WT2E1	wt2e	WT2E1	wt2e
		Electrical control for WECC WT3 Generic Wind Model	[9]	WT3E1		wt3e		WT3E1	wt3e	WT3E1	wt3e	WT3E1	wt3e
		Electrical control for WECC WT4 Generic Wind Model, PSSE	[9]	WT4E1		--		WT4E1	--	WT4E1	--	WT4E1	--
		Electrical control for WECC WT4 Generic Wind Model, PSLF	[9]	WT4E2		wt4e		--	wt4e	--	wt4e	WT4E2	wt4e
		Renewable energy electrical controls	[10]	REECAU1		reec_a		--	reec_a	REECAU1	reec_a	REECAU1	reec_a
		PV electrical controls	[10]	REECBU1		reec_b		--	reec_b	REECBU1	reec_b	REECBU1	reec_b
		Energy storage electrical controls	[15]	--		reec_c		--	--	--	--	--	--
		Two mass turbine model for WECC WT1 Generic Wind Model	[9]	WT12T1		wt1t		WT12T1	wt1t	WT12T1	wt1t	WT12T1	wt1t
		Two mass turbine model for WECC WT2 Generic Wind Model	[9]	WT12T1		wt2t		WT12T1	wt2t	WT12T1	wt2t	WT12T1	wt2t

		Turbine model for WECC WT3 Generic Wind Model	[9]	WT3T1		wt3t		WT3T1	wt3t	WT3T1	wt3t	WT3T1	wt3t
		Power converter model for WECC WT4 Generic Wind Model	[9]	--		wt4t		--	wt4t	--	wt4t	--	wt4t
		Pitch control model for Type 1 and 2 wind generators	[9]	WT12A1		wt1p		WT12A1	wt1p	WT12A1	wt1p	WT12A1	wt1p
		Pitch control model for Type 3 wind generator	[9]	WT3P1		wt3p		WT3P1	wt3p	WT3P1	wt3p	WT3P1	wt3p
		Pitch control model for Type 4 wind generator	[9]	--		wt4p		--	--	--	wt4p	--	wt4p
		Pitch control model for Type 1 and 2 wind generators	[10]	--		wt1p_b		--	wt1p_b	--	--	--	--
		Drive train model for Type 3 and 4 wind generators	[10]	WTDTAU1		wtgt_a		--	wtgt_a	WTDTAU1	wtgt_a	WTDTAU1	wtgt_a
		Aerodynamics model for Type 3 and 4 wind generators	[10]	WTARAU1		wtga_a		--	wtgar_a	WTARAU1	wtgar_a	WTARAU1	wtga_a
		Pitch control model for Type 3 and 4 wind generators	[10]	WTPTAU1		wtgp_a		--	wtgpt_a	WTPTAU1	wtgpt_a	WTPTAU1	wtgpt_a
		Torque control model for Type 3 and 4 wind generators	[10]	WTTQAU1		wtgq_a		--	wtgtrq_a	WTTQAU1	wtgtrq_a	WTTQAU1	wtgtrq_a
		Renewable energy plant controller	[10]	REPCAU1		repc_a		--	repc_a	REPCAU1	repc_a	REPCAU1	repc_a
		Distributed photovoltaic system	[10]	--		pvd1		--	pvd1	--	--	--	--
7.	Static Var Systems and FACTS												
			[11]	SVSMO1U2		svsmo1		--	svsmo1	Template UDM	svsmo1	--	svsmo1
			[11]	SVSMO2U2		svsmo2		--	svsmo2	Template UDM	svsmo2	--	svsmo2
			[11]	SVSMO3U2		svsmo3		--	svsmo3	Template UDM	svsmo3	--	svsmo3
				CSVGN1		--		CSVGN1	--	CSVGN1	--	CSVGN1	--
				CSVGN3		--		CSVGN3	--	CSVGN3	--	CSVGN3	--
				CSVGN4		--		CSVGN4	--	CSVGN4	--	CSVGN4	--
				CSVGN5		vwscc		CSVGN5	vwscc	CSVGN5	vwscc	CSVGN5	vwscc
				SWSHNT		msc1		SWSHNT	msc1	SWSHNT	--	--	--
				CDSMS1		--		--	--	--	--	--	--
				CSTATT		--		CSTATT	--	CSTATT	--	CSTATT	--
				CSTCNT		--		--	--	CSTCNT	--	--	--
				ABBSVC1		--		--	--	--	--	--	--
				CHSVCT		--		--	--	CHSVCT	--	CHSVCT	--
				CSSCST		--		CSSCST	--	CSSCST	--	CSSCST	--

deprecated model; use of this model is not recommended
interim model; replacement recommended

NOTE: Some of the models in this list may not be acceptable for use in all Interconnections. The modeling requirements for each Interconnection supercede this list and should be consulted directly. The Western Interconnection in particular has a library of dynamics models [W1] that are approved for use in Western Interconnection base cases.

References

[1] "IEEE Guide for Synchronous Generator Modeling Practices and Applications in Power System Stability Analyses," IEEE Std 1110-2002.

[2] Undrill, J., "The gentpj model," November 19, 2007 (updated June 19, 2012). http://www.wecc.biz/

[3] "IEEE Recommended Practice for Excitation System Models for Power System Stability Studies," IEEE Std 421.5-2005.

[4] “Computer Representation of Excitation Systems," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-87, No. 6, pp. 1460-1468, 1968 (Committee Report).

[5] "Excitation System Models for Power System Stability Studies," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 2, pp. 494-509, 1981 (Committee Report).

[6] IEEE Task Force on Overall Plant Response, “Dynamic Models for Steam and Hydro Turbines in Power System Studies”, IEEE Trans. on PAS, Vol PAS-92, Nov-Dec 1973, pp. 1904-1915.

[7] Task Force on Turbine-Governor Modeling, "Dynamic Models for Turbine-Governors in Power System Studies," IEEE Technical Report, PES-TR1, Jan. 2013.

[8] WECC M&VWG, "Composite Load Model for Dynamic Simulations" Ver 1.0, June 12, 2012.
[9] WECC M&VWG, "WECC Wind Power Plant Dynamic Modeling Guide," November 2010.
[10] EPRI, "Specification of the Second Generation Generic Models for Wind Turbine Generators," September 20, 2013.
and WECC M&VWG, "Generic Solar Photovoltaic System Dynamic Simulation Model Specification," September 2012.
[11] WECC, "Generic Static Var System Models for the Western Electricity Coordinating Council" April 18, 2011.

[12] W. I. Rowen, “Simplified Mathematical Representations of Heavy Duty Gas Turbines”, ASME Paper 83-GT-63 and ASME Journal of Engineering for Power, October 1983, pages 865-869. [GAST2A reference]

[13] Periera, L. et al, "A New Thermal Governing Approach in the WECC," IEEE Transaction on Power System, Vol. 18, No. 2, pp. 819-829, May 2003.
[14] WECC M&VWG, "Cross-current Compensation Model Specification," August 2015.
[15] EPRI, "Simple Model Specification for Battery Energy Storage System," March 6, 2015.

[W1] WECC Approved Dynamic Model Library. http://www.wecc.biz/

Additional Reading
WECC M&VWG, "WECC Wind Power Plant Dynamic Modeling Guide," April 2014.
WECC M&VWG, "WECC PV Power Plant Dynamic Modeling Guide," April 2014.
EPRI, "Proposed Changes to the WECC WT3 Generic Model for Type 3 Wind Turbine Generators," September 27, 2013.
EPRI, "Proposed Changes to the WECC WT4 Generic Model for Type 4 Wind Turbine Generators," January 23, 2013.