Brief Summary of all 2nd Generation Generic Renewable Energy System Dynamic Models:

The Renewable Energy Modeling Working Group (REMWG)[1] of the WECC Modeling Validation Subcommittee[2] has been developing over the past ten years a series of modularized, standard and publicly available set of dynamic models for use in large system planning studies for the main forms of renewable energy systems (RES) [1], [2], [3], [4], [5]. These model structures, referred to as "generic" models, since they are not specific to any particular vendor can be parameterized to adequately emulate the dynamic behavior of many vendor's equipment. The efficacy of these models to represent various vendor equipment behavior for wind turbines, solar PV and battery energy storage has been shown in various publications and presentations are WECC REMWG meetings. A few such examples, both at the individual unit level and at the plant level are illustrated in [6]. These models do have limitations too, which are also discussed in [6].

The intent of this brief document is to list all of the current modules, as well as those in the process of being developed, and their intended use. In this document we refer to each of the models with their standard name. The actual name of the model in the various software platforms may be subtly different.

The modules fall into four (4) categories:

1. ***Renewable Energy Generator/Converter (REGC_*) models***: These modules are used to model the electrical generator and/or power converter interface between the generation unit and the grid. There are three (3) such modules:
    a. ***REGC_A*** – this is the original model developed many years ago. It is a current-source model. It is quite adequate for modeling the generator dynamic behavior of the generator/converter interface. It is not suitable for weak-grid connection points, where the short-circuit ratio (SCR) of the point of interconnection may be around 2 to 3 or less.
    b. ***REGC_B*** – this is a newly developed and approved voltage-source generator/converter interface model. It is better suited to weak-grid conditions, and if parameterized appropriately has been shown to behaved numerically down to SCRs close to 1.
    c. ***REGC_C*** – this is a new model yet to be fully implemented and approved by all the software vendors. It incorporates a generic representation of the phase-locked loop (PLL) and inner-current control loops, as well as being a voltage-source model. A user-written

[1] Previously called the Renewable Energy Modeling Task Force
[2] Previously called the Modeling and Validation Working Group

version developed by EPRI has shown the models efficacy at emulating the general dynamic behavior of the converter interface down to very low SCRs [7].

Presently REGC_A and REGC_B are both approved models on the WECC approved model list and both can be legitimately used for modeling the generator/converter interface of a RES. The choice of the model should be based on the location of the plant being modeled (weak connection point versus strong connection point) and the best data currently available for the plant being modeled. Also, it may be possible in some cases that the point-of-interconnection of the plant becomes weak over time (e.g. additional inverter based resources come into the network in the vicinity of the plant). In such cases there may be a need to transition from an REGC_A model to an REGC_B model.

2. ***Renewable Energy Electrical Controls (REEC_*) models***: These modules are used to model the electrical controls at the individual generating unit level, i.e. individual wind turbine generator, individual PV inverter, etc. There are three (3) such modules:

    a. ***REEC_A*** – this is the original model developed and can be used, if appropriately parameterized for wind and PV generators.

    b. ***RECC_C*** – this module was developed specifically for battery-energy storage systems (BESS) or can also be used to model hybrid PV-BESS systems, particularly when the BESS and PV and coupled on the dc-side of the inverter and share one common inverter.

    c. ***REEC_D*** – this is the latest electrical controls model developed [4], which contains main new features, such as extended voltage-dependent current limit tables. As such, when modeling new facilities this model may offer greater flexibility and features. IT can be used to model wind, PV and BESS.

Presently all three of the above REEC_* models are on the WECC approved model list and can be legitimately used for modeling the electrical controls of RES, as appropriate to the technology. IMPORTANT NOTE: the so-called REEC_B model is no longer approved, all existing REEC_B models must be converted per [3] to one of the other models above.

3. ***Renewable Energy Plant Controller (REPC_*) models:*** These modules are used to model the plant level controls that monitor the point of common coupling (PCC), or point of interconnection (POI), of a plant and issues real and reactive power commands to all the individual generating units in the plant to control the real and reactive power at the PCC (or POI). The are three (3) such models:

    a. ***REPC_A*** – this is the original simple plant level controller. It allows for volt/var control and active power control. It does not include power factor control.

b. ***REPC_B*** – this is a complex-plant controller to be used primarily for hybrid-plants which include multiple technologies, e.g. a combination of two different wind turbine technologies, or wind and PV, etc. It does also allow for power factor control at the PCC (POI).

c. ***REPC_C*** – this model is under development [4] and has been released as a beta in some tools but not yet finalized and approved. It presents significant additional features and flexibility including, power factor control at the PCC (POI), ability to have coordinated and automatically switched shunt devices at the PCC (POI), and extra features for active power control.

Presently REPC_A and REPC_B are both approved models on the WECC approved model list and both can be legitimately used for modeling the plant controller, as appropriate.

4. ***Mechanical Element Models for Wind Turbine Generators:*** specifically for wind turbine generators (WTGs) there are a series of mechanical side models. Presently, for type 4 WTGs the only mechanical model used is an emulation of the drive-train dynamics [8]. All the other models are used only for type 3 WTGs. The models are:

   a. ***WTGT_A*** – this is a two-mass model of the WTG drive-train.

   b. ***WTGA_A*** – this is a very simple aero-dynamic model for the type 3 WTG based on [9].

   c. ***WTGP_A*** – this is a simple model of the pitch control system.

   d. ***WTGQ_A*** – this is a simple model of the torque control system.

   e. ***WTGT_B*** – this is a new two-mass model to be used for type 4 WTGs when it becomes available [4]. The model incorporates a small modification to mitigate a problem seen in the WTGT_A model when used with type 4 WTGs – see [4] for more details.

   f. ***WTGP_B*** – this is a new refined pitch-controller model, which provides added flexibility in the limits of the pitch controller.

   WTGT_A, WTGA_A, WTGP_A and WTGQ_A are all currently approved models in WECC and should be used when modeling a type 3 WTG. When modeling a type 4 WTG, due to the full-converter interface, for stability simulations it has been shown that none of these models are necessary. In some cases where one may desire to emulated the torsional ripple seen in the electrical power of the WTG following a close in fault, the WTGT_A model may be used. However, when WTGT_B becomes available, that is the recommended model in these cases with a type 4 WTG. WTGT_B should NOT be used for type 3 WTGs.

5. ***Auxiliary Controllers:*** These are new modules being developed and yet to be fully benchmark tested and approved by WECC. Yet they have already been tested as user-written models (see [4]).

a. ***WTGWGO_A*** – this is an auxiliary controller model, used primarily on type 4 WTGs, for improving the post-fault recovery of type 4 wind power plants for PCC (POI) connection points that have low SCR. The WGO stands for weak-grid option.

b. ***WTGIBFFR*** – This is another auxiliary control module that is available from many wind turbine manufacturers and is the so-called inertial-based fast-frequency response (IBFFR)[3] controls.

These two models are not yet fully benchmark tested and approved, but should hopefully be available soon.

Summary Tables:

RES	Model Combination
Type 3 WTG	regc_a(or _b), reec_a (or _d), repc_a, wtgt_a, wtga_a, wtgp_a, wtgq_a
Type 4 WTG	regc_a (or _b), reec_a (or _d), repc_a (optional: wtgt_a; preferred wtgt_b when available)
PV plant	regc_a (or _b), reec_a (or _d), repc_a
BESS	regc_a (or _b), reec_c (or _d), repc_a

Note: in some cases the more appropriate plant controller model to use may be *repc_b*, for example, for hybrid-plants, plants that have two or more aggregated inverter-based generating units, where plant level power factor control is used, etc.

Name in this Document	Model Name in GE PSLF™	Model Name in Siemens PTI PSS®E	Model Name in PowerWorld Simulator	PowerTech Labs TSAT™
REGC_A	regc_a	REGCAU1 (V33); REGCA1 (V34 & V35)	REGC_A	REGC_A
REGC_B	regc_b	REGCBU1 (V34 & V35)	REGC_B	REGC_B (V21)
REEC_A	reec_a	REECAU1 (V33); REECA1 (V34 & V35)	REEC_A	REEC_A
REEC_C	reec_c	REECCU1 (V33 & V34); REEC1 (V35)	REEC_C	supported*
REEC_D	reec_d	REECDU1 (V34 & V35)	REEC_D	REEC_D (V21)
REPC_A	repc_a	REPCTAU1 & REPCAU1 (V33); REPCTA1 & REPCA1 (V34 & V35)	REPC_A	REPC_A
REPC_B	repc_b	PLNTBU1 (V33, V34 & V35)	REPC_B	supported*
WTGT_A	wtgt_a	WTDTAU1 (V33); WTDTA1 (V34 & V35)	WTGT_A	WTGT_A
WTGA_A	wtga_a	WTARAU1 (V33); WTARA1 (V34 & V35)	WTGA_A	WTGA_A
WTGP_A	wtgp_a	WTPTAU1 (V33); WTPTA1 (V34 & V35)	WTGP_A	WTGP_A
WTGQ_A	wtgq_a	WTTQAU1 (V33); WTTQA1 (V34 & V35)	WTGTRQ_A	WTGQ_A
Protection Relay Models				
LHVRT	lhvrt	VTGTPAT (trips machine), VTGDCAT (disconnects bus)	LHVRT	supported*
LHFRT	lhfrt	FRQTPAT (trips machine), FRQDCAT (disconnects bus)	LHFRT	supported*
*supports PSS®E and PSLF formats				

[3] The name IBFFR was chosen in WECC meeting discussions. This feature is sometimes also called synthetic inertia, or emulated inertia, etc.

References:

[1] https://www.wecc.org/Reliability/WECC-Second-Generation-Wind-Turbine-Models-012314.pdf

[2] https://www.wecc.org/Administrative/WECC%20White%20Paper%20on%20Modeling%20Hybrid%20Power%20Plant.pdf

[3] https://www.wecc.org/Reliability/WECC%20White%20Paper%20on%20Converting%20REEC%20rev202008.pdf

[4] https://www.wecc.org/Administrative/Memo_RES_Modeling_Updates_083120_Rev17_Clean.pdf

[5] EPRI Report, Model User Guide for Generic Renewable Energy System Models, Product Id: 3002014083, Date Published: July 13, 2018 https://www.epri.com/#/pages/product/3002014083/

[6] P. Pourbeik, J. Sanchez-Gasca, J. Senthil, J. Weber, P. Zadehkhost, Y. Kazachkov, S. Tacke and J. Wen, "Generic Dynamic Models for Modeling Wind Power Plants and other Renewable Technologies in Large Scale Power System Studies", *IEEE Trans. on Energy Conversion*, September 2017

[7] D. Ramasubramanian, W. Wang, P. Pourbeik, E. Farantatos, A. Gaikwad, S. Soni and V. Chadliev, "A Positive Sequence Voltage Source Converter Mathematical Model for Use in Low Short Circuit Systems", IET Generation, Transmission & Distribution, January 2020.

[8] https://www.wecc.org/Reliability/WECC-Type-4-Wind-Turbine-Generator-Model-Phase-II-012313.pdf

[9] W. W. Price, J.J. Sanchez-Gasca, "Simplified Wind Turbine Generator Aerodynamic Models for Transient Stability Studies", *Proc. IEEE PES 2006 Power Systems Conference and Exposition (PSCE)*, Oct. 29-Nov. 1, 2006, Atlanta, GA, pp. 986-992.