TO: WECC REMTF

FROM: POUYAN POURBEIK, PEACE®; PPOURBEIK@PEACE-PLLC.COM

SUBJECT: EXAMPLE FOR VERIFICATION OF THE PROPOSED IBFFR MODEL

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CC: ANISH GAIKWAD AND EVANGELOS FARANTATOS, EPRI

Recent efforts of the WECC REMTF have resulted in development of the now so-called second-generation generic renewable energy system (RES) models [1] and [2]. These models were first released in the major commercial software platforms in 2014, and adoption of the models in WECC, and some other regions, continues to increase.

In 2018, with several revisions and continued discussion in 2019, additional models have been specified [3] to further enhance these 2nd generation RES models. With funding from EPRI, PEACE® implemented some of these proposed new models as user-written model in GE PSLF™ to try the concepts [3].

One of these new proposed models is the auxiliary control feature that is available from many wind turbine manufacturers which is often called by various names, but the primary aim of the auxiliary control is to temporarily borrow kinetic-energy from the rotating turbine-generator assembly and to quickly inject this energy into the grid during an under-frequency event. Thus, one phrase that has been used to describe this control is inertial-based fast-frequency response (IBFFR)[1] control. It is outside of the scope of this document to describe this functionality and its many aspects and nuances in any detail. The simple user-written model that was developed [3] in GE PSLF™ we call here the WTGIBFFR_A model. It is shown in Figure 1. The model, the underlying assumptions behind it, and its functionality are explained in detail in [3], and so those details are not repeated here. Figure 2 shows how this auxiliary model would interface with the other core RES models for a wind turbine power plant.

The purpose of this memo is to show how this proposed model performs in comparison to the measured response of an actual wind power plant that has such controls installed in it. A wind turbine manufacturer, through a non-disclosure agreement, graciously provided to PEACE® the measured response, at the point-of-interconnection (POI), of a large transmission connected wind power plant (WPP) to field tests performed to demonstrate the emulated intertial-response control feature of their wind turbines. The vendor has asked to remain anonymous, and further more to not disclose any details about the plant in question. However, they have very kindly agreed to the release of these results to inform the industry. EPRI graciously funded this simulation work and the preparation of this memo.

The Tests and Simulation Results:

Three events were recorded, for three different operating conditions, for the same WPP. In each case the same test signal was applied to the WPP, which was the injection of a "synthetic" frequency signal into the plant level controls to emulate a sudden drop in system frequency, which is then latter restored. A simple model of a WPP connected at the POI to an infinite bus was developed in GE PSLF™ (see Figure 3), and then the playback feature was used in GE PSLF™ to play the exact same frequency signal played into the plant controller in the field into the model at the POI of the WPP. The parameters for the model are shown in Table 1. The results are shown in Figure 4.

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[1] The name IBFFR for this function/model is tentative, and the final naming convention will be discussed in future WECC meetings once this model starts to be implemented by the software vendors.

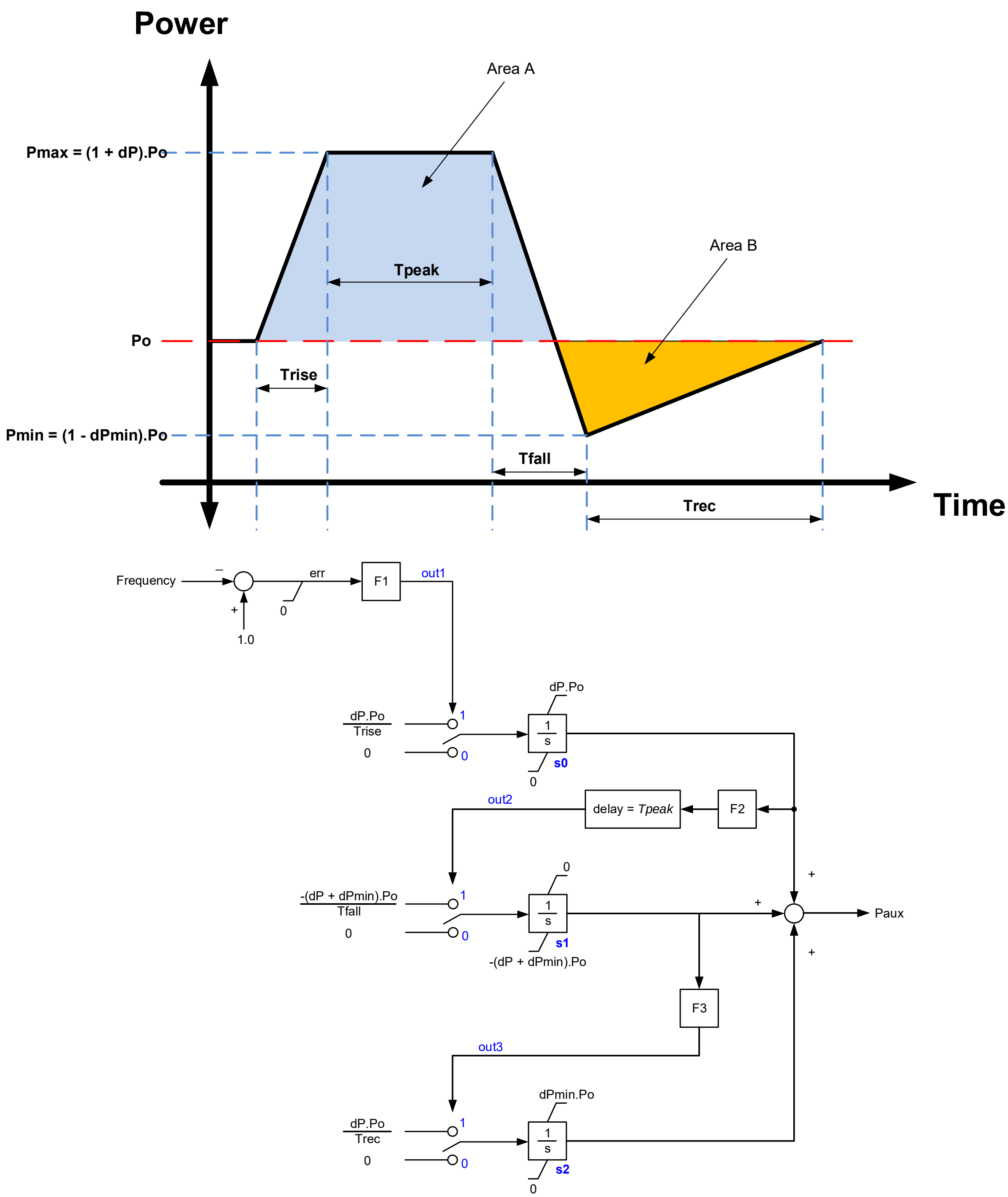

Figure 1: Block-diagram of the implemented WTGIBFFR_A model. Please refer to the model specification document [3] for a detailed account of this model.

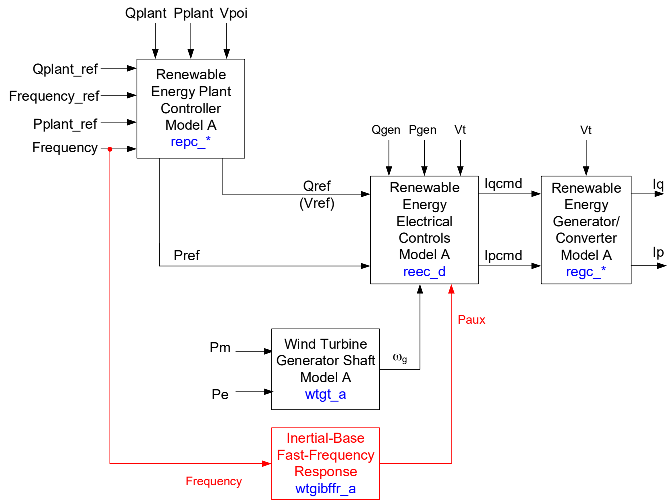

Figure 2: High-level block-diagram showing, as an example for a type 4 WTG, how WTGIBFFR_A fits into the RES models. For a type 3 WTG, it would work the same.

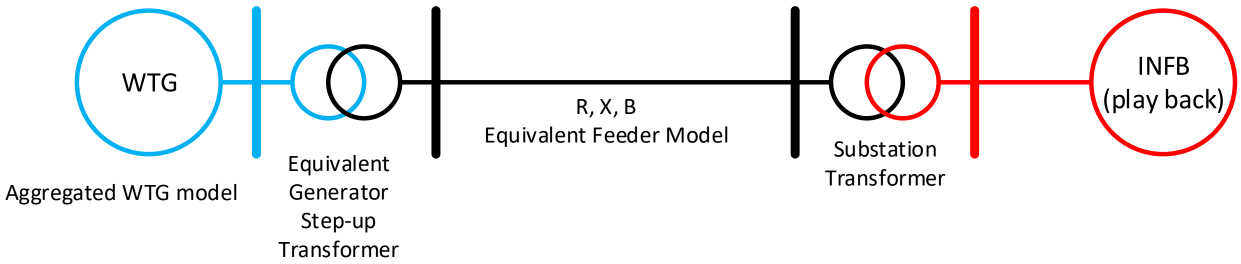

Figure 3: Simple WPP model.

Table 1: Parameter List for WTGIBFFR_A model.

Parameter	**Description**	**Typical Range/Value**
dbd	Deadband below which IBFFR is initiated, that is when (1 – frequency) ≥ *dbd*, then the IBFFR is initiated [pu]	0.0017
[p1, p2, p3, p4, p5, p6]	Six (6) power points corresponding to the six sets of parameters [pu]	{0.3, 0.5, 0.6, 0.7, 0.8, 0.9}
[dP1 to dP6]	Six *dP* values (see Figure 1) [pu]	{0.06, 0.06, 0.06, 0.06, 0.06, 0.06}
[dPmin1 to dPmin6]	Six *dPmin* values (see Figure 1) [pu]	{0.05, 0.05, 0.04, 0.02, 0.02, 0.02}
[Trise1 to Trise6]	Six *Trise* values (see Figure 1) [s]	{1.5, 1.5, 1.5, 1.5, 1.5, 1.5}
[Tpeak1 to Tpeak6]	Six *Tpeak* values (see Figure 1) [s]	{9, 9, 9, 9, 9, 9}
[Tfall1 to Tfall6]	Six *Tfall* values (see Figure 1) [s]	{1.5, 1.5, 1.5, 1.5, 1.5, 1.5}

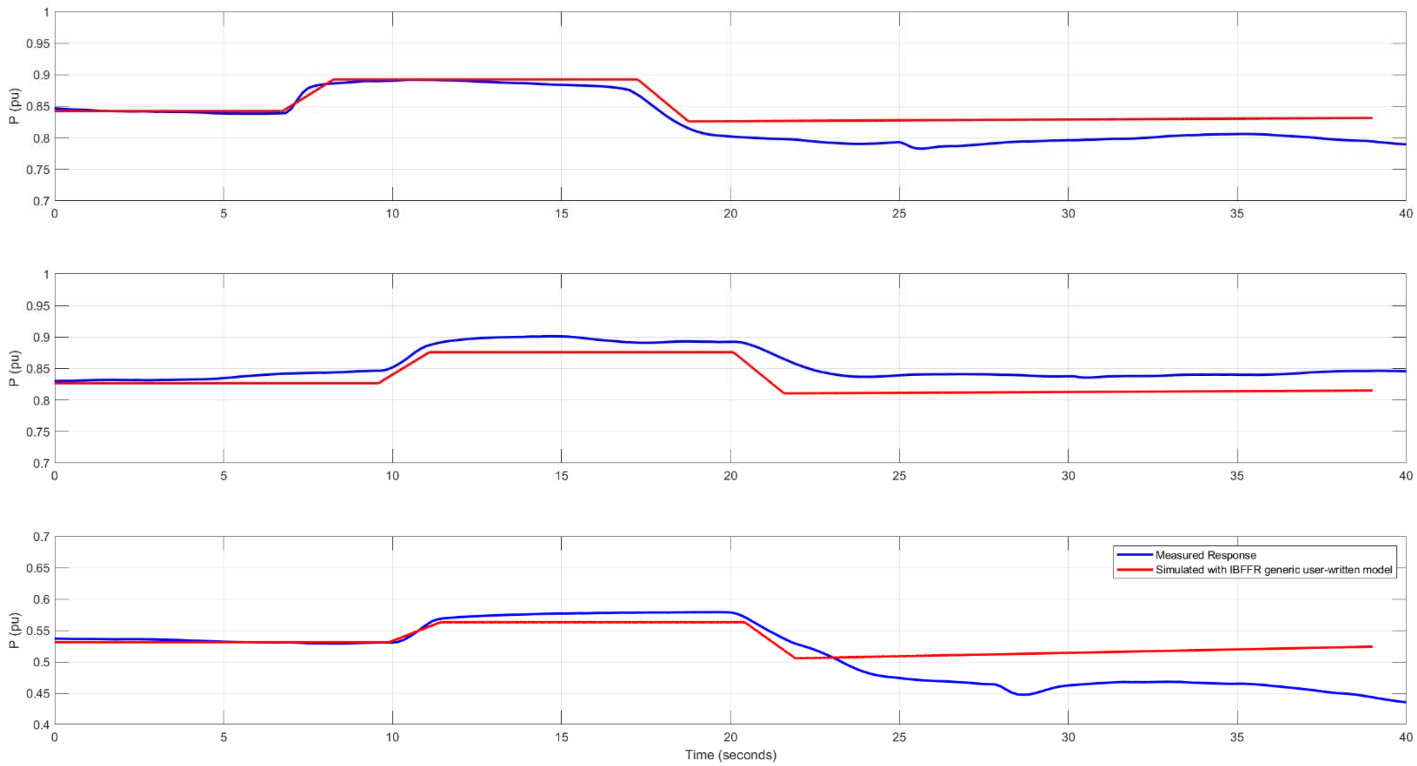

Figure 4: Simulation results as compared to actual measured response of a large WPP related to the emulated inertial response.

Observations and Conclusions:

A perusal of the simulation and measurement results in Figure 4 lead to the following observations:

- The results are actually quite good. Certainly, the match between simulation and measurement is not perfect but it is quite reasonable given the extreme simplicity of the model.
- It should be noted, that the assumptions for parametrization of the simple model (Table 1) for power levels below 0.5 pu are not necessarily valid, since there were no field measured results to compare with below 0.5 pu plant output. Also, at a certain power level, here we are assuming 0.3 pu (parameter *p1* in Table 1) power, the IBFFR function is longer available. Here the value in our simple model is an assumption, and is NOT the limit for this or any vendor. Nevertheless, there is always some lower limit of power below which IBFFR is no longer available. Also, this limit applies on a turbine by turbine basis, which is hard to capture faithfully with an aggregated model since in real life within a power plant, at any given time, due to the spatial variations in wind speed across the power plant, some turbines may be below this limit, while others may be above.

Based on these results it may be concluded that the simple generic IBFFR model is reasonable for use in planning studies, with an understanding of the following, that the actual IBFFR that is supplied by each individual turbine in a wind power plant is dependent on many factors, such as (i) the incident wind energy (wind speed) on a turbine, and (ii) the initial speed of the rotor of the turbine. When performing large scale stability studies, whether using a generic model such as that discussed here, or detailed user-written vendor specific models, one thing is for certain and that is we cannot predict with much accuracy what the wind-speed and rotor-speed of each wind turbine in a wind power plant (WPP) is going to be for a future scenario. Furthermore, the accepted practice for modeling WPPs in large scale stability studies is by using an aggregated WTG model with a simple feeder model. Thus, it is not feasible to model such details even if such data were available. In short, the simple IBFFR model applied on an aggregated WPP model cannot be made to emulate exactly what actual field response will be due to the stochastic nature of the resource. As such, we are in need of a simplifying assumption to make the model usable. Although clearly not representative of what would happen in the field, the most conducive assumption is to assume that all the WTGs in the WPP are at the same power level and experiencing the same wind speed. That is how things were modeled here, and as seen the results are reasonable, but not perfect, as expected.

Acknowledgements:

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References:

[1] WECC Second Generation Wind Turbine Models, 2014 https://www.wecc.biz/Reliability/WECC-Second-Generation-Wind-Turbine-Models-012314.pdf

[2] 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/

[3] P. Pourbeik, "Proposal for New Features for the Renewable Energy System Generic Models", Issued to WECC REMTF and EPRI on 07/23/18 (revised 8/3/18; 11/14/18; 11/18/18; 12/13/18; 1/20/19; 2/7/19; 3/5/19; 6/24/19; 6/27/19).