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# Modeling Notification

## Modeling Pitch Controls in Stability Studies for Type 1 and Type 2 Wind Turbine Generators
## Initial Distribution: June 2019

This Modeling Notification provides Transmission Planners and Planning Coordinators with recommended modeling practices for representing pitch controls for legacy Type 1 (conventional induction generator) and Type 2 (wound-rotor induction generator with adjustable rotor resistance) wind turbine generators (WTGs). While these resources are being phased out for newer technologies, existing resources should be modeled with the most appropriate and accurate representation available. This guidance helps provide clarity and consistency in modeling practices for these resources.

### Primary Interest Groups

Transmission Planners (TPs), Planning Coordinators (PCs), Generator Owners (GOs), MOD-032 Designees

### Background

Presently,[1] all major WTG manufacturers have focused on inverter-based turbines, namely the doubly-fed (Type 3) and full-converter (Type 4) generators. For wind power plants (WPPs) connected to the bulk power system (BPS), these are the only technologies currently[2] being deployed for newly interconnecting facilities. Regardless, legacy Type 1 and Type 2 WTGs exist today and should be modeled correctly in interconnection-wide planning cases for stability studies.

Some Type 1 and Type 2 WTGs with active-stall pitch controls may employ supplemental controls that quickly ramp down mechanical power by pitching the blades when a nearby severe voltage dip (fault) is detected. Since 2010, it was identified that the *wt1p* model used to emulate these controls may exhibit overly optimistic and erroneous behavior. For that reason, the *wt1p* model should not be used. During the development of the 2nd generation renewable energy system models in the 2010–2014 timeframe, the *wt1p_b* model was developed to address these concerns, and was implemented in some of the major simulation software platforms. The *wt1p_b* model is the recommended model to emulate pitch controls.

This Modeling Notification is being developed to ensure clarity on how these models should be implemented to represent any existing Type 1 and Type 2 WTGs that use active-stall pitch controls. If sufficient information is available to replace any existing *wt1p* model with the *wt1p_b* model, this is the recommended approach. Otherwise, the *wt1p* model should be removed as a conservative modeling assumption.

[1] At least the past five years, or more.
[2] And for those resource deployed in the last decade or so.

## Modeling Notification

All recipients of this Modeling Notification should review the following, which describes recommended practices for modeling WTG pitch controls in stability studies for Type 1 and Type 2 wind power resources:

Therefore, at this point it is recommended that:

1. The *wt1p* and *wt2p* models should be removed from all applicable WPP models in the interconnection-wide base cases since they can exhibit erroneous behavior.
2. If data is available to populate the parameters of the *wt1p_b* model, and it is available in the planning software tool being used, then it should be used.
3. If insufficient data is available to populate the *wt1p_b* model, or if the *wt1p_b* model is not available in the software tool being used, then the *wt1p* (or *wt2p*) model should simply be removed, as this leads to a more conservative simulation result and does not exhibit the erroneous response from Type 1 or Type 2 WPPs.

If the Type 1 or Type 2 WTGs are of an active-stall control type (typically units that are greater than 1 MW), then by not modeling any pitch control, one will get a conservative result. That is, for nearby fault contingencies or other large disturbance simulations, the WTG may appear in simulations to be less transiently stable since the reduction in power provided by ramping down mechanical power is not modeled. However, the benefit is that the Type 1 or Type 2 WPP simulated response will not exhibit erroneous results such as unrealistic primary frequency response (as will occur when using the *wt1p* model).

*For more information or assistance, please contact the [NERC Advanced System Analytics and Modeling Department] (via email) or at (404) 446-2560.*

# Appendix A: Detailed Description of Modeling WTG Pitch Controls

For Type 1 WTGs, the *wt1g* and *wt1t* models are valid representations and should be used. These models represent the conventional induction generator electrical model and the mechanical drivetrain, respectively. For Type 2 WTGs, the *wt2g*, *wt2t*, and *wt2e* models are valid representations and should be used.[3] These models represent the electrical model of a wound rotor induction generator, the mechanical drivetrain, and the variable rotor resistance electrical control model, respectively. These models were part of the 1st generation generic WTG models [1], [7].

As part of the development of the 1st generation generic WTG models, the *wt1p* model (shown in Figure 1) and the *wt2p* model were developed to emulate the pitch controller on Type 1 and Type 2 WTGs.[4] It was identified in the Western Electricity Coordinating Council (WECC) stakeholder groups as early as 2010 that the *wt1p* model is prone to exhibiting unrealistic behavior if not properly parameterized. For example, use of the model can lead to WTGs exhibiting primary frequency response, which is not realistic for these turbine types. Thus, during the 2nd generation WTG model development work from 2010–2014, the new *wt1p_b* pitch controller model (shown in Figure 2) was created to replace the *wt1p* model [2], [3], [4]. The *wt1p_b* model was developed as a simple and generic emulation of the general behavior of the pitch control functionality used in Type 1 and Type 2 WTGs with active-stall control [5].

Therefore, it is recommended that, when possible and applicable, the newer *wt1p_b* model should be used to represent pitch controls for Type 1 and Type 2 WTGs. If data does not exist to complete the *wt1p_b* model parameters, it is recommended that the *wt1p* model be removed and no pitch control be modeled. If the WTGs are stall-regulated turbines (the blades are fixed to the rotor), then this is the correct modeling approach since there is no pitch controller [5]. However, if the WTGs do have active-stall controls, then not modeling any pitch controller may lead to a more conservative[5] response of the WPP for simulated faults near the plant. While the slightly less stable response may not be desirable, the modeling approach may be preferred to keeping the *wt1p* model and having the plant exhibit unrealistic response (i.e., providing primary frequency response).

Presently, the *wt1p_b* model is available in at least two of the commercial software platforms, but may not be available in all software platforms.

## Detailed Description of Models

Figure 1 shows the block diagram of the old *wt1p* model (referred to as a pseudo-governor model). The model changes mechanical power based on changes in speed from the system reference frequency, and the machine electrical power from the initial power reference. This means that:

- For simulations where system frequency changes, subsequent changes in slip-speed of the unit due to system frequency variations can result in a governor-type action from the model. This is not a realistic response since Type 1 and Type 2 WTGs do not generally provide primary frequency response.

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[3] See the user manual of any major stability simulation software platform for more details on these models.

[4] For Type 2 WTGs, the *wt2p* 1st generation generic model is identical to the wt1p model. Therefore, all comments here equally apply to that model.

[5] Slightly less stable response, which is a conservative assumption when insufficient data is available.

- For relatively larger[6] Type 1 WTGs, many of the turbine manufacturers provided active-stall pitch control regulation of the turbine [5]. This offers the ability to incorporate further supplemental controls that quickly ramps down mechanical power by pitching the blades when a nearby severe voltage dip (fault) is detected. This assists in low voltage ride-through capability (see [5], Figure 2-12). This control is not represented by the *wt1p* model. Although, for a simulated fault, the *wt1p* model can result in a momentary reduction in mechanical power, which is generally the correct behavior but it is not a ramp down and back up. Therefore, this response can be optimistic.

In contrast, the *wt1p_b* model (see Figure 2) overcomes these concerns.

- First, it does not exhibit the undesired primary frequency response behavior.
- Secondly, it provides for a simple emulation of the mechanical power ramp-down for nearby faults [2], [6]. The *wt1p_b* model emulates this behavior by looking at filtered terminal voltage (filter time constant *Tr*), and if the voltage falls below specified set-points (see [3] for details), then *Flag1* is changed by the model from 0 to 1. The change in the flag then initiates the ramping down of the mechanical power at a rate of *rmin* to a minimum power level ($P_{min}$). This occurs for a given amount of time determined by the look-up table *F(Vt)*[7]. Once the given time has lapsed, *Flag1* switches back to position 0 and the mechanical power ramps back up to the initial value *Po*, at a rate of *rmax*.

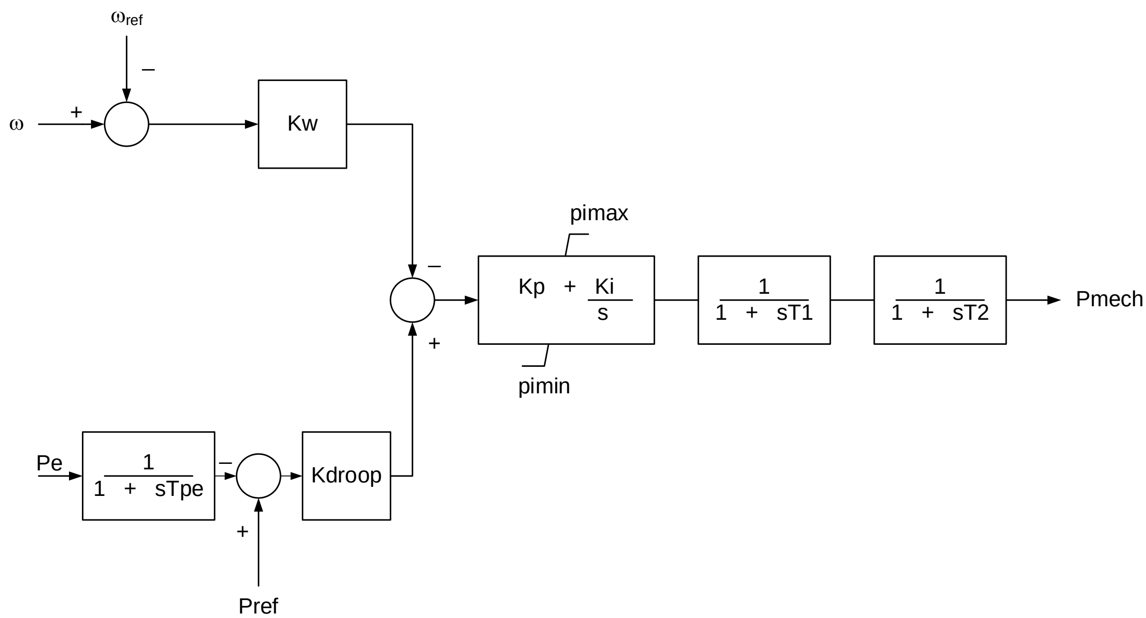


**Figure 1: *wt1p* 1st Generation Generic WTG Model (no longer recommended for use)**

6 Typically for units greater than around 1 MW.
7 Briefly, the look-up table consists of four (4) voltage levels (v1, v2, v3, v4) and four-time settings (t1, t2, t3 and t4). If Vt falls below v1, then the time is set to t1. If it is below v2 and above v1, it is set to t2, and so on.

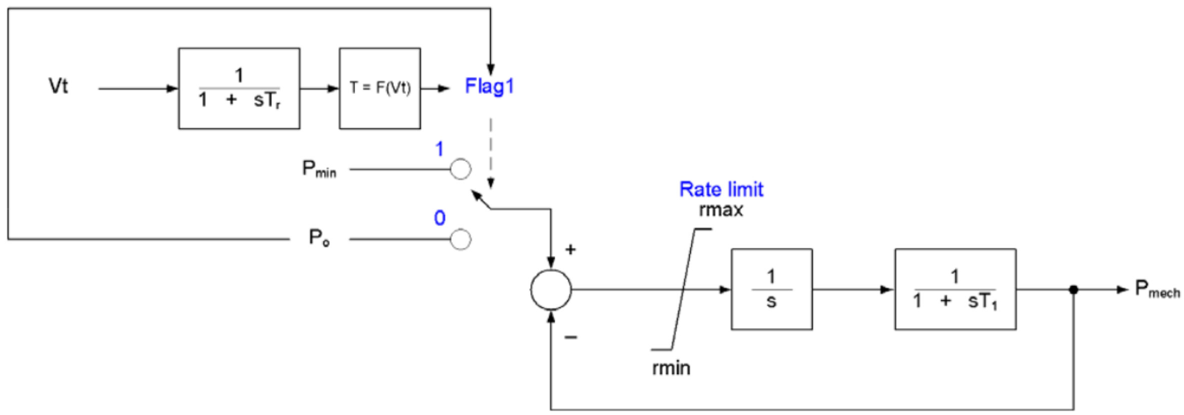


**Figure 2: New Pitch Controller Model for Type 1 and Type 2 WTGs, *wt1p_b* (recommended model)**

### Illustrative Simulations of *wt1p* and *wt1p_b* Response

Figure 3 and Figure 4 show simulation examples that illustrate the issues presented above. Figure 3 shows an illustration[8] of the difference in response for a close-in fault disturbance between:

- Using the wt1p model (blue)
- Using the wt1p_b model (red)
- Using no pitch controller for the case of a close-in fault (magenta)

The simulation in Figure 3 shows that the change in mechanical power using the *wt1p* model is somewhat unrealistic and larger than expected. The *wt1p_b* model exhibits a behavior closer to the actual turbine behavior of ramping mechanical power down and then back up due to the fault. Not modeling the pitch controller at all simply means that mechanical power remains constant, which is the most conservative assumption.

Figure 4 shows an illustration[9] of the difference in response for an underfrequency disturbance between:

- Using the wt1p model (blue)
- Using the wt1p_b model (red)
- Using no pitch controller for the case of a close-in fault (magenta)

The simulation in Figure 4 shows that the *wt1p* model gives an unrealistic response showing (blue) that the WPP is capable of providing primary frequency response. The other two cases, using the *wtp1_b* model (red) or using no pitch controller model (magenta), show the expected response. That is, an initial inertia response[10] occurs from the WTGs and thereafter the turbine power remains constant.  Note that these two plots are exactly the same (magenta curve overlays the red curve); hence, why only the magenta curve is seen in Figure 4.

[8] This is simulated on a small test system, and not necessarily representative of any single plant. However, the model parameters are realistic and show the general issues explained.

[9] Again, this is also simulated on a small test system, and not necessarily representative of any single plant. However, the model parameters are realistic and show the general issues explained.

[10] Type 1 and Type 2 WTGs are directly-connected generators with no power electronic interface. Therefore, they exhibit inertial response.

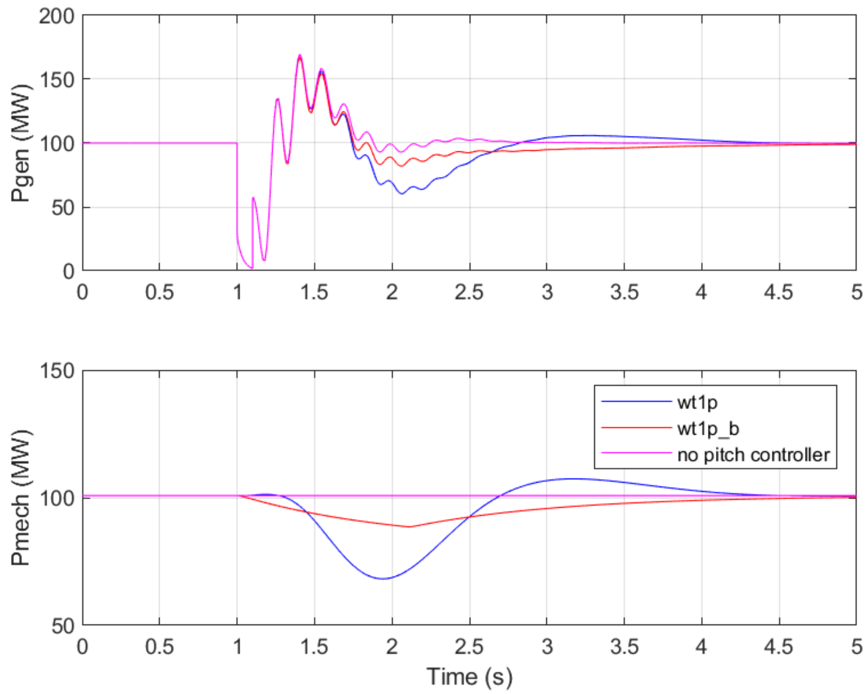


**Figure 3: Illustration of Response for Using wt1p Model, wt1p_b Model, and No Pitch Controls Modeled for Close-In Fault Disturbance**

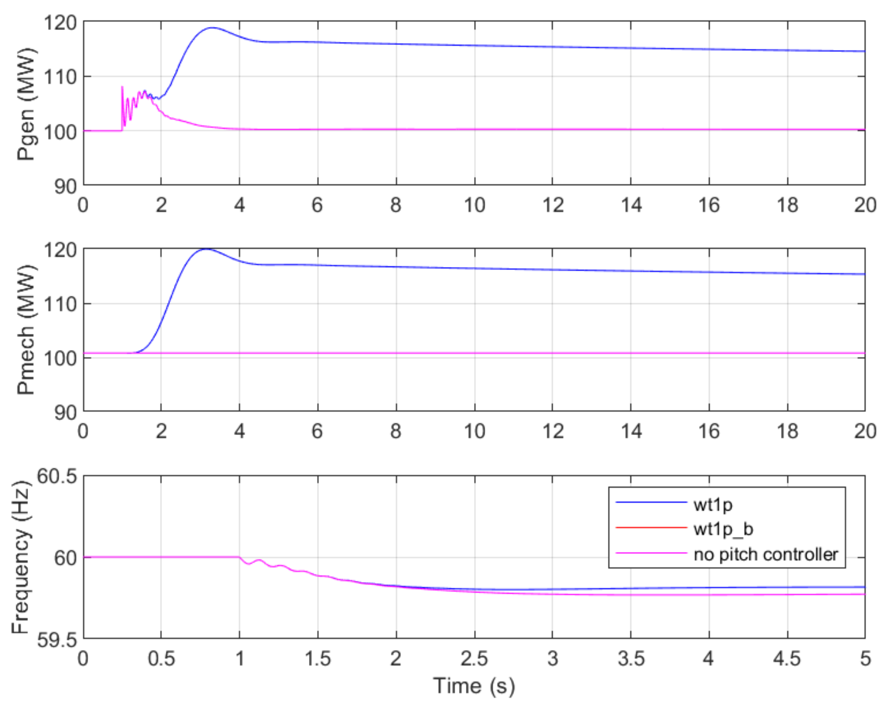


**Figure 4: Illustration of Response for Using wt1p Model, wt1p_b Model, and No Pitch Controls Modeled for Underfrequency Disturbance**

## Appendix B: References


[1] P-K. Keung, Y. Kazachkov and J. Senthil, "Generic models of wind turbines for power system stability studies", *8th International Conference on Advances in Power System Control, Operation and Management (APSCOM 2009)* https://ieeexplore.ieee.org/document/5528306

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

[5] CIGRE Technical Brochure 328, *Modeling and Dynamic Behavior of Wind Generation as it Relates to Power System Control and Dynamic Performance*, August 2007 (http://www.e-cigre.org/Search/download.asp?ID=328.pdf)

[6] P. Pourbeik, "Proposed Changes to the WECC WT1 Generic Model for Type 1 Wind Turbine Generators", Prepared under Subcontract No. NFT-1-11342-01 with NREL, Issued: 1/21/13

[7] A. Ellis, Y. Kazachkov, E. Muljadi, P. Pourbeik, J.J. Sanchez-Gasca, "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.

# Appendix C: Acknowledgments

NERC would like to acknowledge the Electric Power Research Institute (EPRI) for their funding support and PEACE® for the technical leadership in developing this notification.