

Paux Controller WTGIBFFR_A

Wind Turbine Inertial-Based Fast-Frequency Response WTGIBFFR_A

Represents a generic inertial-based fast frequency response of a wind turbine. Output (Paux) of this model will feed into the various Paux inputs on governor or exciter (electrical control) models such as REEC_D.

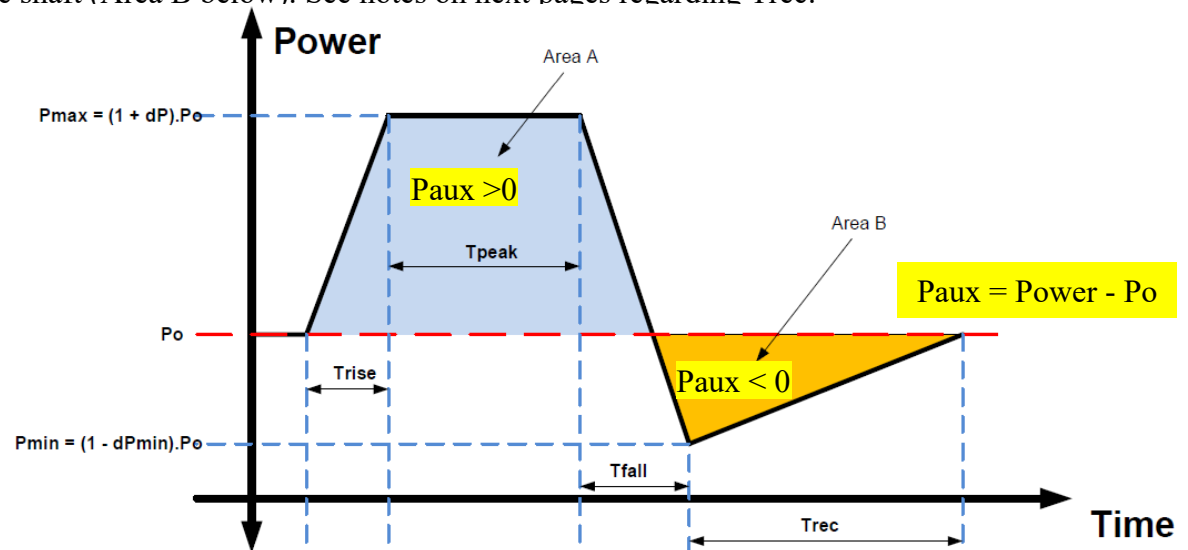
User may specify a bus at which the per unit frequency is measured. If a bus is not specified the terminal bus is used. This bus frequency is also run through a Tflt time constant delay block. A frequency deadband (db) is also specified. When the per unit frequency drops below a value of $(1.0 - \text{db})$ per unit then a pre-programmed Paux response will occur. This response is divided into four regions, as shown in the figure below defined by the input parameters **Trise**, **Tpeak**, **Tfall**, **Trec**, **dP**, and **dPmin**.

1. **Trise** – which is the time it takes for the power of the unit to rise from its initial power to the peak value during the IBFFR.
2. **Tpeak** – which is the time (duration) that the WTG remains at the peak value of the IBFFR, with the peak of response being a percentage of the initial power, i.e. $\text{Peak} = P_o \times (1 + \text{dP})$
3. **Tfall** – which is the time it takes for the power to fall back down, and typically (when the incident wind energy is below rated wind power) the turbine will fall below its initial power output. It will fall to a level that is a percentage of the initial power, i.e. $P_{\min} = P_o \times (1 - \text{dPmin})$.
4. **Trec** – which is the time it takes for the power to recover back to its initial value; this is the time during which energy is given back to the rotor to bring it back to its initial speed. It is expected that this value will normally be given as 0.0 in which case the software will automatically calculate a value of Trec ensuring that the energy taken out of the shaft (Area A below) is equal to the energy returned to the shaft (Area B below). See notes on next pages regarding Trec.

Other Notes

- This response will only occur for an under-frequency event. In addition it will only occur once during a simulation. After the response below is completed the model will be made inactive for the remainder of the simulation.
- This model is not intended for use a combination of fault and frequency events.
- P_o is in per unit on the mvab

Model supported by PowerWorld



Input Parameters

Parameters	Description	Typical Range
Rem Bus	The bus at which the frequency measurement is made. If not specified then the terminal bus of the generator is used.	N/A
Mvab	MVABase of the model on which the input parameter Po and the output Paux is expressed.	N/A
db	frequency deadband in per unit.	0.0008 – 0.0017
p1, p2, ..., p6	Initial power values used to lookup the values of dP, dPmin, Trise, Tpeak, Tfall, and Trec	N/A
dP1, dP2, ..., dP6	6 values of dP which are determined based p1...p6 based on initial Po	0.05 – 0.10
dPmin1, dPmin2, ..., dPmin6	6 values of dPmin which are determined based p1...p6 based on initial Po	0.00 – 0.08
Trise1, Trise2, ..., Trise6	6 values of Trise which are determined based p1...p6 based on initial Po	0.10 – 0.20
Tpeak1, Tpeak2, ..., Tpeak6	6 values of TPeak which are determined based p1...p6 based on initial Po	1.00 – 2.00
Tfall1, Tfall2, ..., Tfall6	6 values of Tfall which are determined based p1...p6 based on initial Po	0.20 – 0.50
Trec1, Trec2, ..., Trec6	6 values of Trec which are determined based p1...p6 based on initial Po	0

Determining which Parameters to use

For input parameters for this model, we provide 6 different set of values for **Trise**, **Tpeak**, **Tfall**, **Trec**, **dP**, and **dPmin**. These values are associated with size different power levels p1, p2, p3, p4, p5 and p6. The actual amount of IBFFR available from a WTG is dependent of the incident wind energy (wind speed) and the rotation speed of the shaft. However, for the generic RES models wind speed is not an available input and the shaft speed is not available for some of the type 4 WTGs. Thus, we have made the assumption that the power output of the WTG (in per unit of the rated output) at the moment that the IBFFR is initiated is a reasonable indicator of both these variables (i.e. incident wind speed and rotor speed). Thus, this matrix of 6×6 values works in the following way:

```

if      Po ≥ p6) then dP = dP6; dPmin = dPmin6; Trise = Trise6; Tpeak = Tpeak6; Tfall = Tfall6; Trec = Trec6;
elseif (Po ≥ p5) then dP = dP5; dPmin = dPmin5; Trise = Trise5; Tpeak = Tpeak5; Tfall = Tfall5; Trec = Trec5;
elseif (Po ≥ p4) then dP = dP4; dPmin = dPmin4; Trise = Trise4; Tpeak = Tpeak4; Tfall = Tfall4; Trec = Trec4;
elseif (Po ≥ p3) then dP = dP3; dPmin = dPmin3; Trise = Trise3; Tpeak = Tpeak3; Tfall = Tfall3; Trec = Trec3;
elseif (Po ≥ p2) then dP = dP2; dPmin = dPmin2; Trise = Trise2; Tpeak = Tpeak2; Tfall = Tfall2; Trec = Trec2;
elseif (Po ≥ p1) then dP = dP1; dPmin = dPmin1; Trise = Trise1; Tpeak = Tpeak1; Tfall = Tfall1; Trec = Trec1;
else      dP = 0;    dPmin = 0;    Trise = 0;    Tpeak = 0;    Tfall = 0;    Trec = 0;

```

After the Trec timer has expired, the model will wait a time of Tlapse seconds before another round of IBFFR is activated.

Special Considerations for Trec

The six Trec values in the model should typically be set to zero. By doing so, the model internally calculates the value of Trec using Equation 1. However, if the user wishes to define a Trec that is greater than the calculated value using Equation 1, for each of the designated six power levels, then the user may populate the Trec parameters. This may be done in scenarios where Area B is actually larger than Area A due to losses during the period of power injection as the turbine speed significantly declines from its optimal point of efficiency. In doing so, it must be noted that since positive sequence models do not represent such losses, by making Area B larger, the speed of the machine in simulation may end up artificially higher at the end of the simulation. Furthermore, if the user defined a value for Trec that is less than the value calculated by Equation 1, then the model will ignore the user defined value and use that calculated by Equation 1. This is because, except under operation when the incident wind speed is greater than the rated wind speed, in all other cases Area B must always be either equal to or greater than Area A.

$$Trec = \frac{2dP}{dPmin} \left[\frac{Trise}{2} + Tpeak + \left(\frac{dP}{dP + dPmin} \right) \frac{Tfall}{2} \right] - Tfall \left[1 - \frac{dP}{dP + dPmin} \right]$$