PSS® E Wind and Solar Models

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PSS®E Wind Models

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Current View of PTI Web Site

http://www.pti-us.com/pti/software/psse/userarea/wind_farm_model_request_download_submit.cfm

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Wind Packages for PSS®E Versions 29 and Later</th>
<th>Package Download</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acciona AW15/30</td>
<td>pse_aw1530_w400.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Enercon ExF2</td>
<td>pse_EnerconExF2_w1.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Fuhrlaender FL2500</td>
<td>pse_fl2500_w403.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>GE 1.5/3.6/2.5 MW</td>
<td>pse_gewt_w510.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Generic WT3</td>
<td>pse_wt3_w402.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Mitsubishi MPS-1000A</td>
<td>pse_mps1000a_w5.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Mitsubishi IMWT-92/95/100/102</td>
<td>pse_mwt_w52.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Siemensa WT4</td>
<td>pse_siemensaWT4_w1.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Vestas V80/V47</td>
<td>pse_v8047_w410.exe</td>
<td>Click here to request to download the package.</td>
</tr>
<tr>
<td>Vestas V82</td>
<td>pse_v82_w41.exe</td>
<td>Click here to request to download the package.</td>
</tr>
</tbody>
</table>

Self-extracting files for most widely used vendor specific models are available for all PSS®E releases from 29 to 32. Models of Acciona, Enercon, GE wind turbines, and the WT3 and WT4 user written generic model can be directly downloaded, others will be provided upon manufacturer's authorization. All communications related to downloading the PSS®E wind models have to go via the PSS®E support.

Your request to download PSS®E Wind Farm models has been submitted. You will receive an email from PSS®E Support with further instructions.
Lately, we also developed PSS®E dynamic simulation models for:

- AMSC WindTec 1.5 MW 50Hz & 1.65 MW 60Hz
- Wind to Energy W93 and T93
- Northern Power NPS2.2-93
- Several Chinese manufacturers: Sinovel, Mingyang, Sany, United Power, Sewind.
Other Non-PTI PSS®E Models

- Siemens PTI is aware of several other PSS®E wind modeling packages **NOT** developed and therefore **NOT** supported by Siemens PTI, such as:
  - Vestas V52 850kW, V66 1.75MW, V80 2MW, V90 3MW, V90 1.8MW
  - DeWind D6 1.25MW and D8 2MW
  - Gamesa G5X 850kW and G8X 2MW
  - Clipper
  - Suzlon

- Some manufacturers recognize the importance of their models being supported by PTI and approached us with the request to review, modify, release and support their models. Acciona is a good example.
The latest wind turbine model infrastructure in PSS®E

- The user is responsible for aggregating the actual wind turbines into equivalent machines. For N lumped machines, the output of the equivalent machine cannot exceed N times the rated output of the individual units.

- The power factor correction shunt capacitors must be added (if available) and connected to the terminals of the equivalent machine by the user.
  - For example, for the original Vestas V80 machine, the total compensation available is 12 capacitors of 72 kVAR each. After compensation, the reactive power flow from the terminal bus to the system should be in the range of +40/-40 kVAR per machine.
The latest wind turbine model infrastructure in PSS®E

- The user prepares a dynamic input data file by following the example files included in the modeling package documentation.
- All vendor specific models are provided in the format of user’s written (defined) models.
- The dynamic simulation models implemented by Siemens PTI are self-initializing, as with all other PSS®E simulation models.
Wind Models Simulation Infrastructure in PSS®E
Application Features of PSS®E Software Packages

- In rev 31+, the new category of machine, namely wind machine, is introduced, along with new wind related common variables. This makes simulation more convenient and efficient.

- In the near future, a new name, like “Renewables”, might be needed to have solar and other inverter based generation fit in this category.

- All four generic models using a wind machine category, namely WT1, WT2, WT3, and WT4, are standard starting from rev 31.1.

- These generic models will not be available for rev. 29 and 30 – please upgrade to 32!

- The old user written WT3 generic model using the conventional machine in LF is available for rev 29+. Please note: this model is different from the standard generic WT3 model.

- Probably, at some point in foreseeable future we will “close” the option of treating the wind machine as a conventional machine.
The latest wind turbine model infrastructure in PSS®E – a reminder

Wind machines are specified on the existing generator record of the Power Flow Raw Data File.

- Wind machines are specified on the existing generator record of the Power Flow Raw Data File.

  | Bus # | Bus Name | Id | Code | Status | Pgen (MW) | Pmax (MW) | Pmin (MW) | Qmax (Mvar) | Qmin (Mvar) | Mbase (MVA) | XSource (pu) | Wind machine Control Mode | Wind machine PF |
  |-------|----------|----|------|--------|-----------|-----------|-----------|-------------|-------------|-------------|-------------|----------------|------------------------|--------------|
  | 1     | INFINITE| 1  | 3    | 1      | -49.618   | 9999      | -9999     | -9993       | 9999        | 100         | 0.2         | Not a wind machine     | 1            |
  | 5     | WT      | 1  | 2    | 1      | 50.25     | 105       | 0         | -3.17       | 3.4         | 111.69      | 0.8         | Standard QT, QB limits | 1            |

The following additional data items, appended to the end of the record, are specified for wind machines:

- 0 if this is not a wind machine (this is the default value).
- 1 if this is a wind machine which participates in voltage control, with the values of QT and QB on the data record specifying the machine's reactive power limits.
- 2 if this is a wind machine which participates in voltage control, with the specified power factor (see below) and the machine's active power setting (PG on the data record) used to set the machine's reactive power limits.
- 3 if this is a wind machine which operates at a fixed power, with the machine's reactive power output and reactive power upper and lower limits all equal, and set based on the specified power factor (see below) and the machine's active power setting (PG on the data record).

Power factor:

- Ignored if the wind control mode is 0
- Is used in setting the machine's reactive power limits when the wind control mode is 2 or 3
- Negative value may be specified when the wind control mode is 3, and is interpreted as a leading power factor (i.e., the wind machine produces active power and absorbs reactive power).
The latest wind turbine model infrastructure in PSS®E – a reminder

Any wind model may include one or several of the following wind modules:

<table>
<thead>
<tr>
<th>IC index</th>
<th>Wind module type</th>
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<tbody>
<tr>
<td>101</td>
<td>Generator</td>
</tr>
<tr>
<td>102</td>
<td>Electrical control</td>
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<td>103</td>
<td>Mechanical control</td>
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<td>105</td>
<td>Aerodynamics</td>
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<td>106</td>
<td>Wind Gust/Ramp</td>
</tr>
<tr>
<td>107</td>
<td>Auxiliary control</td>
</tr>
</tbody>
</table>

New variables of two categories have been added to support the wind models in PSS®E:
- Variables accessible for users, e.g., model outputs
- Variables not accessible for users: primarily for model developers.
To add the wind dynamic module as a user written model, the statement in the dynamic data file should be added as follows:

IBUS ‘USRMDL’ ID ‘ModelName’ IC IT NI NC NS NV parameters/

IT = 1 for IC = 101
IT = 0 for IC = 102 to 107
Simulating Manufacturer Specific PSS®E Wind Models using Python Module – pssewindpy

The idea is to allow for a quick and automatic model setup process for manufacturer specific wind generation models in order to help users in their familiarization with these models.
Module pssewindpy

- Provides Python functions to simulate PSS®E manufacturer specific wind models:
  - Acciona AW15/AW30,
  - Fuhrlander FL2500,
  - GE 1.5/2.5/3.6 MW,
  - Mitsubishi MWT 92/95/100,
  - Mitsubishi MPS1000A,
  - Vestas V47/V80/V82/NM72,
  - Generic WT3.

- Provides demo Python functions to simulate these models.

- Provides example Python scripts which can be edited/modified to select/specify desired wind model:
  - To add a WTG to any PSS®E load flow case
  - To create WTG model dyre records (.dyr file created).
Demo Simulation

- 5 bus demo test work

- Demo run python scripts:
  - Add selected WTG, its GSU and other components if required (like fixed shunt, switched shunt etc.)
  - Update the base case and base snapshot
  - Simulate WTG response to bus fault or complex wind input (if applicable)

Diagram:

- WTG
- 99971 BUSWTG
- 99972 COLLECTORBUS
- 99973 LVBUS
- 99974 HVBUS
- 99975 SWINGBUS
- 34.5 kV
- 138 kV

added by pssewindpy functions
**GE 1.5 MW WTG Demo Simulation**

- **Python Script to set up GE 1.5 MW demo:**
  ```python
  import pssewindpy
  psseversion = 32  # PSS(R)E Version
  wtg_mdl = 'ge15'
  wtg_units = 67  # Number of WTG Units
  pct_dispatch = 100.0  # % dispatch, e.g. 100.0 for 100%
  wtg_mass = 1  # Shaft Model, =1 for Single, =2 for Double mass
  freq = 60  # Network base freq in Hz
  pssewindpy.wtg_init(psseversion)
  cnvsavfile, snpfile = pssewindpy.wtg_demo_ge(wtg_mdl, wtg_units, pct_dispatch, wtg_mass, freq)
  ```

- **Python Script to run Simulation:**
  ```python
  outfile1 = pssewindpy.wtg_demo_run_collect_bus_flt(cnvsavfile, snpfile)
  outfile2 = pssewindpy.wtg_demo_simulate_complex_wind(cnvsavfile, snpfile)
  ```
Adding WTG model to PSS®E Case

- **Python function to add any manufacturer specific WTG model to any PSS®E Case**

  ```python
  chngpyfile, dyrfile = wtg_create_chng_dyr_files(wtg_mdl, 
  bus_collect, bus_wtg, wtg_units, pct_dispatch=100, aw_extqctrl=True, 
  aw_cnvmvar=True, # AW1530
  gewt_mass=1, # GE 1.5/3.6/2.5 MW
  ge15_old=False, # GE 1.5
  mwt_crowbar=0, mwt_ndh=0, # mwt92/mwt95
  v8047_shaft=1, # v80/v47 (enable/disable shaft model)
  v82nm72_qctrl='pf', v82nm72_svctype='local', # V82/NM72
  v82nm72_bus_wtg2=None,
  v82nm72_gridsvc_kvar=None, v82nm72_svc_bus=None # V82/NM72 grid SVC
  v82nm72_svc_wtgside_bus=None, v82nm72_svc_gridside_bus=None,
  v82nm72_pf=0.95, # V82/NM72 when qctrl=pf
  v82nm72_kvar=0.0, # V82/NM72 when qctrl=var
  wt3_data={}, wt3_mass=1) # generic WT3
  ```
Adding WTG model to PSS®E Case (continued)

Python function to create converted case and snapshot

- From base snapshot:
  - cnvsavfile, snpfile =
    - `pssewindpy.wtg_create_cnvsav_snp_files(chngpyfile, dyrfile, basesnpfile=bassnpfile, convertpyfile=None)`

- From base DYR file:
  - cnvsavfile, snpfile =
    - `pssewindpy.wtg_create_cnvsav_snp_files(chngpyfile, dyrfile, basedyrfile=basdyrfile, convertpyfile=None)`
Adding WTG model to PSS®E Case (continued)

- **Python function to add Voltage or Frequency protection model**

  ```python
  pssewindpy.add_protection_relay(dyrfile, relaymdl, bus_mon, bus_gen, gen_id, threshold, t_pickup, t_breaker=0.08)
  ``

- **For Voltage protection, model names are**: 'vtgdca', 'vtgtpa'

- **For Frequency protection, model names are**: 'frqdca', 'frqtpa'
  - 'vtgdca' -> Under Voltage / Over Voltage Bus Disconnection Relay
  - 'vtgtpa' -> Under Voltage / Over Voltage Generator Disconnection Relay
  - 'frqdca' -> Under Frequency / Over Frequency Bus Disconnection Relay
  - 'frqtpa' -> Under Frequency / Over Frequency Generator Disconnection Relay

- `bus_mon` = Bus number where voltage or frequency is monitored
- `bus_gen` = Bus number of generator bus where relay is located
- `gen_id` = Generator ID
- `threshold` = Voltage (pu) or Frequency (Hz) threshold (upper or lower threshold)
- `t_pickup` = Relay pickup time (sec)
- `t_breaker` = Breaker contact parting time (sec), default = 0.08 sec.
Generic Wind Generation Models in PSS®E
The model structure:

WT1G model is a modification of the standard induction machine model.
Type 2 Wind Turbine
The first generic model developed was of Type 3.

The model includes 4 modules responsible for:
- WT3G1, WT3G2, doubly-fed induction generator which is mostly an algebraic model to calculate the current injection to the grid based on commands from controls, with or without the PLL control.
- WT3E1, electrical control including the torque control and a voltage control.
- WT3T1, the turbine model including a two-mass shaft mechanical system and a simplified method of aerodynamic conversion, namely \( \Delta P = K_{\text{aero}} \cdot \theta \cdot \Delta \theta \) where \( P \) is mechanical power, \( \theta \) is a pitch angle; this method was validated against results obtained when using the \( C_p \) matrix.
- WT3P1, the pitch control.
The machine is decoupled from the grid by a power converter: no angular stability problem, the power conversion is controlled by converters on the machine and grid sides; the latter is also capable to control voltage, MVAr flow, or power factor.
The WT4 generic model includes the special entry for Siemens 2.3 MW wind turbine. It was carefully parameterized jointly by Siemens PTI and Siemens Wind Power. We are planning to separate the Siemens wind turbine model as a separate standard model.

Per SWP’s request we have converted the WT4 generic model to earlier PSSE releases as a user written model.

This is the example of “parameterization” of the WT4 generic model to match the response of the vendor specific model of the Siemens 2.3 MW wind turbine.

Oscillations in Pel from the vendor specific model cannot be replicated by the WT4 model because it does not take the machine dynamics into account.
Generic wind models as a basis for manufacturer specific models

- Some manufacturers approached us with the request to
  - Try to parameterize the generic model in order to match their benchmark - **Availability of the benchmark is a must!**
  - If testing with the adjusted parameters shows a significant mismatch add new features to the generic model and make a new vendor specific model

- **Example:** for the Fuhrlaender 2.5 MW wind turbine model the active power up-ramping was added to the WT3
PSS®E 33.0 – Dynamics Engine Enhancements
Implication to PSS®E users:

- No Requirement for generating model calls in CONEC and CONET subroutines

- Models currently being called in CONEC/CONET will be called internally within PSS®E
Elimination of Need for CONEC & CONET
Benefits to users:

- No need to compile conec.flx & conet.flx
- Problems involved with “Cut and Paste” when doing DYRE, ADD of CONEC/CONET called models are gone
- Model edits become greatly simplified – edits done via spreadsheet
- Only use PSS®E supplied models? No need for doing compile and link
- Users that don’t write models don’t need to compile and link
- Wind manufacturers can supply dll’s instead of supplying “obj” and “lib” files
Models have been converted from the old CONEC-CONEC form into a new table-driven form.

<table>
<thead>
<tr>
<th>Old Model Name</th>
<th>New Model Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCTC1</td>
<td>DCTC1T</td>
</tr>
<tr>
<td>LOEXR1</td>
<td>LOEXR1T</td>
</tr>
<tr>
<td>VTGDCA / VTGTPA</td>
<td>VTGDCAT /</td>
</tr>
<tr>
<td>FRQDCA / FRQTPA</td>
<td>FRQDRA / FRQTPA</td>
</tr>
<tr>
<td>SWCAP</td>
<td>SWCAP</td>
</tr>
<tr>
<td>SAT2</td>
<td>SAT2T</td>
</tr>
<tr>
<td>OLTC1 / OLPS1</td>
<td>OLTC1T / OLPS1T</td>
</tr>
<tr>
<td>OLTC3 / OLPS3</td>
<td>OLTC3T / OLPS3T</td>
</tr>
<tr>
<td>CRANI</td>
<td>CRANIT</td>
</tr>
<tr>
<td>RUNBK</td>
<td>RUNBKT</td>
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<tr>
<td>CHIGAT</td>
<td>CHIGATT</td>
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<tr>
<td>CEELRI</td>
<td>CEELRIT</td>
</tr>
<tr>
<td>CMDWAS</td>
<td>CMDWAST</td>
</tr>
<tr>
<td>CMDWS2</td>
<td>CMDWS2T</td>
</tr>
<tr>
<td>CMFORD</td>
<td>CMFORDT</td>
</tr>
</tbody>
</table>
Can PSS®E users still use the CONEC and CONET subroutines?

**Answer is ... YES**
“Hot” issues
Fictitious Frequency Spikes

- Prevent abrupt change in bus voltage angle during and after the fault to prevent fictitious frequency spikes.
- Problem is very acute in weak systems.
- Causes false frequency relay trips.
- Temporary Solution: Disabling Frequency Relay.
- Mid-Term Solution: External Intelligent Frequency Relay with smoothen frequency measurement.
Network Non Convergence

- Prevent network non-convergence during 3-phase faults

- Terminal bus voltage angle is uncertain because the reference frame is lost: no machine flux dynamics for WT3 or PLL for WT4

- Many planners use PSSE setups that include the so called “Shut down” model: it calculates a number of “Network not converged” (NNC) events and stops the simulation if it exceeds the given threshold, e.g. 6 NNCs.
Network Non Convergence

The existing model for GE WTs of 1.5 MW, 1.6, 3.6 MW (Type 3) and 2.5 MW (Type 4): two NNCs were observed when testing the 1.5 MW and 2.5 MW WTs, with 3-phase bolted fault applied to the POI bus 2—one at the fault inception, another at the instant of fault clearing.

The upcoming model for GE WTs of 1.5 MW, 1.6 MW (Type 3) and 2.5 MW, 2.75 MW, 4.0 MW (Type 4) – no NNCs with SCR as low as 3.

Note: we can run these tests if time allows.
Frequency Events
Modeling frequency events

- Can generic models be used and trusted for simulating frequency events: loss of generation or loads?
- This question first should be addressed to vendor specific models that provide a benchmark for generic models.
- Collecting information from field tests or tests using the detailed equipment level models (PSCAD/EMTDC, MatLab/Simulink) is of urgent importance.
- Below are some examples illustrating some concerns. The main question is: does the wind turbine respond to frequency events, as provided by vendor specific or generic models, seem realistic?
Test System

- Bus 15 - wind turbine 100 MW unit
- Bus 19 - Hydro 1000 MW unit
- Bus 19 - GT 100 MW unit

- 100 MW Load
- 1000 MW load
No governors: drop the WT unit

- Under-frequency event: only conventional units
- Accelerating power (PMECH-PELEC) is negative
- Loads are intact. To compensate for the lost generation, outputs of on-line machines increase at the expense of the rotor kinetic energy: inertial response!
- New reduced frequency is such that there is a balance between generation, loads, and losses
- For on-line units, rotor speed and system frequency are the same
- Under sudden low frequency conditions, when load demand exceeds the generation, increase of the machine active power output by means of converting the rotor kinetic energy into the electrical energy is a sound response.

- For a conventional generation unit, the under-speed protection may shut it down.
Hydro Governor Impact: drop the WT unit

- Accelerating power (PMECH-PELEC) restores to ~0
- New steady state frequency depends on the governor droop
The GEWT (DFIG) vendor specific model: drop the GT unit, no Hydro governor

After the GT was dropped off, all the lost power was picked up by a Hydro. WT’s power does not change.

Great difference between the WT rotor speed and the system frequency.

Note: the initial WT rotor speed is about 1.2 pu (72 Hz). For conventional machines, rotor speed follows the frequency. For DFIG it stays constant.
The GEWT (DFIG) vendor specific model: drop the GT unit, no Hydro governor; WindInertia enabled

WindInertia increased WTG Pelec by 4% at the expense of the rotor deceleration - very different physics.
MPS-1000 versus WT1; drop GT unit; hydro governor

- Similar response
- Trustworthy: the full order machine model for both models
- WT rotor speed and the system frequency have a similar pattern
V80 60 Hz (VRCC) versus WT2; drop GT unit; hydro governor

- Similar response
- Trustworthy: the full order machine model for both models
- WT rotor speed and the system frequency have different patterns
Replace vendor specific GEWT (DFIG) model by generic WT3 model; drop GT unit; no hydro governor

WT3 and GEWT provide identical response
- For under-frequency events, the system response shown by generic models is very close to one shown by vendor specific models.
- For under-frequency events, the system response shown by both models seems realistic.
- Results from the field and from full order models are badly needed to verify the stability model performance.
Generic Solar Photovoltaic Model in PSS®E
PSS/E Implementation

Irradiance Model  PV Panel Model  Converter Model  Rest of System

IrradU1  PANELU1  PVGU1, PVEU1

Siemens Energy, Inc., Siemens Power Technologies International
**Irradiance Model**

- **Standard Model** that allows user to vary the amount of solar irradiance.
- **User** enters up to ~10 data points (time(s), irradiance(W/m\(^2\))) as cons
- **Initializes** based on steady state P/Pmax
- **For each time step**, outputs linearized irradiance level
PV Panel Model

- **Standard Model for a PV panel’s I-V curves**
- **PV panel’s output varies with Irradiance, temperature, terminal voltage (set by MPPT)**
- **User enters maximum Pdc (per unitized) for different irradiance levels as cons**
- **For each time step, reads irradiance level, outputs linearized power order**
Converter Model – use slightly modified WT4 full converter model

- Largely ignores dynamics from DC side.
- Different reactive control modes: Voltage control, PF control, Q control
- For each time step, outputs linearized irradiance level
Converter Model

Converter GE PVG Model
For GE PV Converters
SolarVAR Emulator in Electrical Control GEPVE Model
For GE PV ineters
Electrical Control - 2

Siemens Energy, Inc., Siemens Power Technologies International