ERCOT User Defined Model Submittal Guideline



*Please provide this Guideline to your manufacturer when requesting PSSE/TSAT dynamic stability model for your plant. This information will help your manufacturer provide functional models.*

# Introduction

To adequately simulate dynamic and transient events in the ERCOT System, it is necessary to establish and maintain dynamics data and simulation-ready study cases representing the dynamic capability and frequency characteristics of machines and equipment connected to the ERCOT System. ERCOT Dynamics Working Group (DWG) uses the PSS/E and TSAT software programs. Standard library models, including the so called “WECC Generic Models” are preferred provided the model accuracy is good, as these models are simpler to use and maintain. Often, however, generators especially IRRs and batteries will require use of User-Defined Models (UDM). UDM models utilize compiled model code provided by the manufacturer (.dll file) to expand the capability of the simulation program. To improve compatibility, ERCOT requests that all UDM models adhere to these guidelines.

# UDM Guidance

Some UDMs lack features or have certain limitations that have been observed to create challenges in preparing DWG simulation-ready study cases and are often difficult or impossible to use in large scale grid studies. The following list of items provides discussion and recommendations regarding UDM characteristics based on user experience.

* **Detailed Model Manual shall be provided:**  
  The model manual should contain all the information needed to set up the dynamic model and understand its overall behavior. In particular,
  + Manual should describe how the poweflow generator model should be set up, including values for Rsource, Xsource, MBase, Qmin, Qmax, and whether the model is considered a “Wind Machine” in PSSE.
  + Manual should list and describe the major tunable control parameters.
  + Manual should provide a high level control block diagram illustrating major control functions and how the tunable control parameters are utilized.
* **Inter-Model Communication:**
* Documentation should be included on how the model exchanges data (e.g., real and reactive power setpoint or other data exchange) with other downstream or upstream models.
* If submitting a site-specific model, this interfacing between specific upstream/downstream models should be verified, e.g., data exchange between power plant controller (PPC), wind turbine generator (WTG) and STATCOM user-defined models.
* **Parameter Error Checking:**
* Error and warning messages should be provided to users as appropriate.
* The model should be setup with correct parameter conditions such as min/max values if applicable to allow the software tool to catch and report on issues when running simulation.
* **Multiple Module Dependencies:**

When multiple modular user-defined models are used to represent a plant, there is a possibility that the end user may exclude required modules (intentionally or unintentionally). Module dependencies should be verified when a UDM is developed, and an error thrown when dependencies are not present. Failure to perform this dependency/error handling has the potential to cause the simulation software to crash.

* **Multiple Instances:**

In one ERCOT case, a given user defined model file (.dll or .tudm) may be used at different sites. The UDM should be verified to operate properly in this situation.

* **Access of External Files:**
* With default parameters, the UDM code should not write to files.
* Error messages should be sent using the appropriate APIs. Diagnostic messages should also be suppressed with default model parameters.
* Accessing/reading from a file is OK, but note that other instances of model may be accessing at the same time.
* **Operating Points:**
* Model should be simulated, and behavior validated at a variety of operating points that are expected to be encountered in a powerflow. At minimum, all MQT tests should be performed at 100% dispatch and additional LVRT test should be performed at 50% and 10% dispatches.
* **Compatible TSAT model shall be provided:**
  + The same UDM shall be supplied for TSAT software. Typically, this requires submitting compatible .dll and .tudm (template UDM) files.
  + In addition to ERCOT’s general guideline for UDMs (applicable to both TSAT and PSS/E models), there are some guidelines specific to TSAT:
    - **Instantiation Compatibility:**   
      The UDM model for TSAT should be compatible with the PSS/E dyr file format, thus one should be able to use the same site-specific parameter list in both software platforms.
    - **Equipment Name Support and Validation:**The model should operate with dynamic data files in “bus number” format (similar to PSS/E) and in “equipment name” format.   
      Equipment name format is specific to TSAT and allows a unique 32-character identified to be used for mapping dynamic (or other auxiliary data).

UDM authors should also verify that model works with equipment names that include space characters.   
It should also be verified that the TSAT case operates equivalently in both bus-number and equipment name format by running equivalent test scenarios.

* + - **Transfer Analysis:**The model should be verified to operate as expected in a “transfer” scenario, that is, utilizing TSAT’s transfer analysis feature to automatically re-dispatch the unit other test (or other units in the system). Here, testing of all model functionality should be performed at multiple transfer “points”.   
      Any model features which are intended to interact directly with TSAT generator (re)dispatch should be verified.
    - **Numerical Integration Methods:**

Model should operate consistently when using different numerical integration methods, e.g., Modified Euler (ME), RK2, RK3, or RK4.

* + - **Compatibility with Distributed Computation:**  
      Model should be tested for compatibility with TSAT’s distributed computation feature, where multiple TSAT server instances are processing multiple scenarios which all utilize the UDM.  
      Model instructions should include details of which supporting files are required to be accessible by TSAT server instances, i.e., in addition to the DLL/TUDM.
    - **Model Quality Testing:**

All ERCOT model-quality testing guidelines should be followed, testing the TSAT site-specific model in both **equipment name** and bus-number format.

* + - **Critical Clearing Time (CCT) –** TSAT has a special mode of operation which allows for determination of the critical clearing time for a given contingency list. As the execution sequence for CCT mode differs from basecase or transfer analysis, it is recommended that model authors ensure that this mode of operation does not cause issues with the developed user defined model by including a CCT scan as part of testing.
    - **Multi-Threaded capability –** As of V23.0.0, TSAT has the capability to perform simulations using a multi-threaded process which can speed up simulation run-time considerably. At present, user-defined DLLs (DLBs) are restricted to a single thread so there are no additional considerations for DLB authors, however it is suggested that the model be tested with TSAT operating in both single- and multi-threaded mode to ensure compatibility with this feature. In future, if support is expanded to allow vendor DLBs to operate across multiple threads, additional testing may be necessary.
    - **Small Signal Stability Analysis (SSAT) –** The DSATools SSAT module makes use of linearized eigenvalue analysis to study power system oscillatory behavior. In order for a dynamic model to be incorporated in that analysis, a Jacobian matrix for that device must be defined. This can either be defined explicitly in a DLL (DLB), accounting for initial conditions and all modes of operation. As an alternative, a simplified variant of the model may be prepared in the DSATools UDM standard format, model benchmarked against non-linear time-domain model.
    - **Trapezoidal Integration –** In order for trapezoidal integration to be used in a TSAT simulation, the Jacobian matrix (as noted with SSAT above) as well as dynamic step size support must be verified in the model (see above regarding variable time steps).
    - **Performance Impact Testing –** TSAT is commonly used in operation applications (control center environments) where simulation performance is critical. In addition, TSAT-RTDS co-simulation and PMU data streaming (ePMU module) require simulations to run in real-time, and the ability to do so may be impacted by execution of user-defined models. Model developers are therefore recommended to verify and report any significant impact their model may have on simulation performance (and, if applicable, other factors which may impact ability to simulate in real-time), especially when a model may be instantiated many times in a given simulation (i.e., used across multiple plants).
* **Black-box model with limited control and model information**:

Most UDM user manuals focus on how to incorporate model properly in the simulation tool. Many features are described very briefly without detailed control block diagrams and design logic included in the document. This basic information may allow a user to include the model in the study tool but is not sufficient to fully understand the response and perform further investigation for observed responses.

* **Avoid Multiple library files and specific set up**:

UDMs generally should avoid utilizing multiple linked library files or parameter files or a specific folder structure unless this method provides a clear benefit, such as providing greater fidelity in model response.

* **.DLL Files only:**  
  For PSSE software, ERCOT no longer accepts models that require linking and/or compiling. Thus ERCOT no longer accepts .OBJ and .LIB model files in PSSE.
* **Time Step Flexibility**:  
  Models should be capable of running at a range of time steps commonly used in dynamic simulation (e.g. half cycle or lower).
* **Limited Number of Key Parameters and Settings**:

Manufacturers should strive to limit the number of parameters to those that are typically tuned or adjusted.

* **Diagnostic Messaging:**

The best UDMs provide informative messages during initialization to help debug issues.

* **Immune to numerical noise / transients**:

During/after faults, bus frequency, which is a calculated value in PSSE, may be subject to numerical deviations. Protection models should avoid using instantaneous protection (zero pickup time) and consider whether additional filtering and associated time delay is necessary.

* **Gracefully Handle Islanding**:

Models should not crash when islanded but instead should trip.

* **Gracefully Handle GNETing or out-of-service**:

The GNET function in PSSE is a useful debugging tool to discount certain plant dynamics. Some UDMs also require removal of the dynamic model itself in order to GNET properly, which makes the debugging process cumbersome.

* **Good Memory Management**:

UDMs require designated memory location to write the response. Poor memory management can write to the memory address that is out of the bound of the allocated space by PSS/E and affect other models in the system.

* **Protocol-Required Capability**:

Except where otherwise allowed, all generating plants must have dynamic reactive power and automatic voltage regulation capability (NP 3.15 and NOG 2.2.5), Voltage Ride Through capability (NOG 2.9), and Frequency Response (NOG 2.2.7), among others. This required capability should be reflected in provided models.

* + In addition, control strategies should consider the need to provide system support while coordinating with nearby resources. Voltage regulation with droop capability and dynamic reactive capability during voltage ride through are examples of such response.
* **Fully Support PSS/E UDM Implementation:**

Models should avoid requiring a specific unit ID to be utilized such as “1” or “W” or “G1”. Models should avoid requiring Qmin and Qmax limits to be set artificially in power flow, such as Qmin=Qmax or Qmin=Qmax=0.