After the disastrous blackout of 2003 that affected a significant part of the Eastern Interconnection, the regulating authority in charge of reliability of the North-American power system (NERC) approved a set of standards to validate generating resources steady-state and dynamic models used in the planning and operations of the bulk electric system. The steady state models are used in load flow calculations while the dynamic models are used in power system stability analysis. The set of standards dealing with the validation of generating resource are the following:

- **MOD-024-1**: Verification of Generator Gross and Net Active Power Capability
- **MOD-025-1**: Verification of Generator Gross and Net and Reactive Power Capability
- **MOD-026-1**: Verification of Models and Data for Generator Excitation System or Plant Volt/Var Control Functions
- **MOD-027-1**: Verification of Models and Data for Turbine/Governor and Load Control or Active Power/Frequency Control Functions

Siemens PTI provides consulting services and assistance to generating resource owners to validate generating unit models in accordance with NERC’s MOD standards.

MOD-024-1 deals with the verification of generator gross and net real power capability. The active power capability is limited by the minimum and maximum power output of the prime mover for the case of synchronous in conventional fossil fueled and hydro power plants and induction generators and voltage source converters for renewable resources such as photovoltaic and energy storage devices. For example, temperature controls limiting the maximum power output and the NOx emission limiter establishing the threshold for the minimum power in gas turbines are seldom considered in the steady-state model of this type of generating resource. Also, the generating unit auxiliary load is an important data item required by the steady-state model to specify the net active power capability limits of the unit.

MOD-025-1, a required companion of the MOD-024 standard, focuses on the determination of the generating unit reactive limits at both overexcited and underexcited operating modes. When documenting the values of active and reactive power (P and Q) for different operational conditions, it is possible to obtain the Reactive Capability (D) curve that characterizes the thermal limits of the armature winding, field winding and core end of the generator unit. In most cases, this curve has an operative area that is considerably lower than that used in planning studies. This is because the interconnection studies usually do not consider the limits that are imposed by operative conditions, such as those imposed by over-excitation, under-excitation, field current, or V/Hz limiters that act directly on reactive power production. This is in essence the main objective of the MOD-025-1, providing transmission regional operators (TROs) and independent system operators (ISOs) with an updated model of the generating unit where the actual amount of reactive power under lagging and leading power factor operation is readily available.
Figure 1 shows a typical D-curve provided by an original equipment manufacturer (OEM), which is often used to specify the active and reactive capability operating limits of generating units, the PSS®E load flow model used in planning studies through the model parameters PMIN, PMAX, QMIN and QMAX, and the operational active and reactive power capability obtained as per standards MOD-024-1 and MOD-025-1. Quite often, the difference between what is considered as “available” in planning studies (D-curve) with what the unit is actually capable to generate.

MOD-026-1 requires the validation of the automatic voltage regulator (AVR), exciter, and power system stabilizer (PSS) models and data. The speed of the AVR response to reach ceiling voltage and the field forcing capability of the excitation system is of paramount importance when the stability of the power system may be at risk. The excitation system model validation and tuning is generally obtained with the unit rotating at synchronous speed and rated terminal voltage operating in open-circuit condition that is isolated from the network. However, it is also recommended to validate the excitation system with generating unit synchronized to grid and operating at rated power. Figure 2 shows the computer simulated and the field recorded terminal voltage when a 3% step change is applied to the voltage reference of the AVR. The left plot shows the comparison of the recorded terminal voltage signal and the computer simulated terminal voltage of an excitation system model using the dynamic data base of the TRO. It can be observed that the simulated response does not match the field recorded terminal voltage signal. After adjusting the appropriate gains and time constants in the model, the response closely matches the field records, as shown in the right plot. If the generating unit has a power system stabilizer (PSS) in service, the MOD-026-1 report must include the validation of the PSS model as it is shown in Figure 3.

MOD-027-1 is the NERC standard for the validation of the model and data of the turbine/governor and load controls of a generating unit. The validation can be performed using historical data of transient system frequency events or using test data obtained by injecting a frequency bias signal to the frequency loop of the unit’s speed governor. The importance of a good turbine/speed governor model is that it has direct impact on the accurate description of the frequency response of the unit and the aggregated power.
system frequency response. Figure 4 is an example of field record/simulation of a generating unit active power output when a frequency bias signal of -0.20 Hz is applied to the speed governor. Note the difference in active power output response between the original and updated turbine/governor model of the generating unit. The turbine/governor model validation includes verification of the steady state droop governor’s dead-band, gains and time constants.

To summarize, validation of a generating unit active and reactive capability and excitation system and turbine/governor controls dynamic models is vital to the operations, planning, security and reliability of power systems. Compliance to NERC standards MOD-024-1, MOD-025-1, MOD-026-1 and MOD-027-1 will help achieve an accurate representation of the steady state and dynamic response of generating units in simulations of power systems. Siemens PTI is here to assist you to solve this challenging task.

Figure 2 - Field Recorded/Computer Simulated Terminal Voltage with original AVR parameters (left) – Updated Model (right)

Figure 3 - Field Recorded/Computer Simulated Active Power with PSS off-line (left) – PSS on-line (right)
Figure 4 - Field Recorded/Computer Simulated Active Power with Speed Governor Original Parameters (left) – Updated Model Parameters (right)