PSS®E Models for Dynamic Simulation of Composite Load

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Loads are traditionally represented in dynamic simulation by a combination of constant current and constant impedance models. The use of these load models results in a fast voltage recovery following fault clearance. However, in the real world, actual voltage recovery is delayed and is widely affected by the load composition. The IEEE Task Force on Load Representation for Dynamic Performance recommended the structure of multiple load types connected to a load bus [1]. The WECC Load Modeling Task Force further improved upon this structure and recommended the inclusion of air conditioner motor loads in the composite load model as these loads in the system are seen to be having a major impact on the fault induced delayed voltage recovery [2].

To meet the needs for modeling of these complex loads, PSS®E now has two dynamic simulation models. In addition to the standard library model CLODBL, there is now also user-written composite load model CMLDBL.

Complex Load Model CLODBL

The complex load model CLODBL represents a mix of induction motors, lighting and other types of equipment such as would be fed from many typical substations (see Figure 1). This standard library model is intended for use in situations where it is desirable to represent loads at the dynamic level, but where detailed dynamics data is not available. This model allows the user to specify a minimum amount of data representing the general character of the composite load. The model uses this data internally to establish the relative sizes of motors modeled in dynamic detail and to establish typical values for detailed parameter lists.

Composite Load Model CMLDBL

A new user-written model of a composite load, CMLDBL, has been developed for use in PSS®E to represent the dynamic behavior of an aggregate of three-phase motors, a single-phase air conditioner motor, electronic loads and static loads connected to a low-voltage load bus. The dynamic response is reflected at the high-voltage system bus. In addition to representing the mix of loads at the low-voltage

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a The present name of this model is CMLDBL. When this model is included as a standard library model in PSS®E, it may be under a different name.
bus, this model also includes an equivalent of distribution transformer, substation compensation, distribution feeder equivalent and feeder compensation. Refer to Figure 2 for the structure of the new composite load model CMLDBL.

The main components of the composite load model CMLDBL are:

- Substation transformer with load tap changer (LTC) control
- Substation shunt
- Distribution feeder equivalent
- Feeder compensation
- Motor loads (up to four)
  - Up to three different types of three-phase induction motors with built-in protection
  - Single-phase air conditioner compressor motor with built-in protection (These motors stall when voltage drops below a set value and a portion of these motors restart when voltage recovers.)
- Electronic loads
  - Power factor
  - Voltage drop out values, Vd1 and Vd2
  - Constant P, Q down to V=Vd1
  - P, Q reduces to zero linearly between Vd1 and Vd2
- Static load
  - Power factor
  - Voltage sensitivity
  - Frequency sensitivity
- Load shedding
  - Number of stages
  - Undervoltage-based load shedding
  - Underfrequency-based load shedding
Model Validation
Composite load model CMLDBL has been validated and benchmarked by comparing its dynamic response with that of the explicit representation of its various components. These benchmarking tests have been performed on a simple test system for a large variety of disturbances. These tests included voltage step, voltage ramp, voltage sag, voltage oscillation, frequency ramp, voltage sag with ramp recovery, motor protection, load shedding and LTC operation. For the sake of brevity, only the results of voltage sag tests are given in this article.

Test System
The one-line diagram for a simple test system is shown in Figure 3. The test system includes a voltage source whose voltage and frequency can be adjusted to simulate different types of perturbations on the composite load model. Loads of identical magnitude are connected at buses 11 and 22; the composite load model CMLDBL is connected at bus 11, and the explicit representation of individual load components is connected at bus 22.

The results of the voltage sag test for source voltage dropping to 50% for 30 cycles, followed by recovery to 100%, are shown in Figure 4 through Figure 6. The voltages of load buses 11 and 22 are compared in Figure 4. The bus voltage recovers to the nominal value about 8 seconds after the fault. The active and reactive components of the loads at buses 11 and 22 are compared in Figures 5 and 6, respectively.
Figure 4 - Dynamic Response Comparison of Composite Load Model CMLDBL and Explicit Load Representation (LOAD BUS VOLTAGE)
Figure 5 - Dynamic Response Comparison of Composite Load Model CMLDBL and Explicit Load Representation (PLOAD)
There is no visible difference in the dynamic response of the composite load model CMLDBL and that of the explicit representation of individual load components, for the voltage sag tests. Results of the other tests performed were similarly positive. These tests show that the composite load model CMLDBL in PSS®E is able to reproduce the fault induced delayed voltage recovery phenomenon in a power system.

**Beta Version**

The beta version of user-written composite load model CMLDBL is available upon request from PSS®E support at [http://www.pti-us.com/pti/software/support/support.cfm](http://www.pti-us.com/pti/software/support/support.cfm). This new composite load model will be included as a standard library model in a forthcoming release of PSS®E.

**References**
