Power electronic systems such as variable-speed electrical drives are complex systems having components of different nature: power converters built from linear and nonlinear electric elements and power semiconductors switches, electrical machines, and control systems containing linear and nonlinear elements. Effective modeling and simulation of such systems require a software tool that can handle all these functions in an integrated environment.

Available simulation software for electronic circuits or dynamic systems can be classified into two main categories: circuit simulation programs (such as EMTP, SPICE-based simulation programs,...) and equation solver programs (such as SIMNON, MATLAB/Simulink,...). These programs are not designed specifically for power electronic systems so that the users have to develop their own models to fulfill their needs. For example, SPICE users have to develop models for electrical machines and control components because SPICE is an electronic circuit simulation program. On the other hand, MATLAB/Simulink users have to develop models for power electronics and electrical machines. This approach can give good results but requires considerable effort.

In this tutorial, a unified method for modeling and simulation of electrical drives using state-space formulation in MATLAB/Simulink is presented.

State-space representation is a convenient and effective method to modeling linear circuits in time domain. However, it is not directly applicable to circuits containing nonlinear elements such as power electronic circuits because these elements cannot be described by differential equations. It is possible to use the state-space approach to model power electronic circuits by separating the nonlinear elements and power switches from the system to form two distinct parts: linear and nonlinear parts. The linear part is represented by its state-space model characterized by its ABCD matrices. The nonlinear part (including nonlinear components, electrical machines, and power switches) is represented by nonlinear models which are transfer characteristics relating their output currents to the input voltages. The system is thus modeled as a feedback system with the linear part in the direct path and the nonlinear part in the feedback path.

The proposed method has been successfully implemented in a simulation package called “Power System Blockset” (PSB) for use in MATLAB/Simulink environment. The PSB uses the Simulink graphical interface to represent common electric components and electric machines found in power electronic systems. The PSB consists of libraries of electric blocks and analysis tools which are used to convert electric diagrams into Simulink state-space diagrams. The simulation of complete electrical drives can be done with sufficient details in both power electronic circuits and control systems. This is useful for waveforms analysis and also for control parameters tuning.

The application of the Power System Blockset to the modeling of two variable-speed drives is considered in details: a brushless dc motor drive and a Direct Torque Control (DTC) induction motor drive. Simulation results obtained with the PSB are presented to illustrate its capabilities in drive studies.