PSIM

TUTORIAL
Electric Machine Modeling

April 2018

One can create electric machine models using the basic function blocks in PSIM. In this tutorial, we will illustrate how to create the model for a dc machine.

Creating the model involves the following steps:

- Derive the electrical and mechanical equations of the machine;
- Implement the electrical equivalent circuits of the equations in PSIM; and
- Package the circuit in the form of a subcircuit.

1. Deriving the Equations

The electrical and mechanical equations of a dc machine can be derived as follows:

$$v_t = E_a + i_a \cdot R_a + L_a \frac{di_a}{dt} \qquad (1)$$

$$v_f = i_f \cdot R_f + L_f \frac{di_f}{dt} \qquad (2)$$

$$E_a = k \cdot \phi \cdot \omega_m \qquad (3)$$

$$T_{em} = k \cdot \phi \cdot i_a \qquad (4)$$

$$J \frac{d\omega_m}{dt} = T_{em} - T_L \qquad (5)$$

where v_t, v_f, i_a, and i_f are the armature and field voltages and currents; R_a, L_a, R_f, and L_f are the armature and field winding resistances and inductances; E_a is the back emf; J is the moment of inertia, ω_m is the mechanical speed; ϕ is the field flux; and T_{em} and T_L are the developed torque and load torque, respectively. If the magnetic saturation is neglected, the back emf and the developed torque can also be expressed as:

$$E_a = L_{af} \cdot i_f \cdot \omega_m \qquad (6)$$

$$T_{em} = L_{af} \cdot i_f \cdot i_a \qquad (7)$$

where L_{af} is the mutual inductance between the armature and the field windings. It can be calculated based on the rated operating conditions as:

$$L_{af} = \frac{V_t - I_a \cdot R_a}{I_f \cdot \omega_m} \qquad (8)$$

2. Implementing the Equivalent Circuits

Once the equations are obtained, they can be represented and implemented in the form of equivalent circuits. For example, the armature winding equation (Eqn. (1)) can be represented by a resistor R_a, in series with an inductor L_a and a controlled voltage source E_a. The field winding equation can be represented in a similar way.

The mechanical equation, Eqn. (5), can be represented by either an inductor in series with two voltage sources, or a capacitor in parallel with two current sources. In PSIM, the capacitor

convention is used to implement mechanical equations. Eqn. (1), (2), and (5), therefore, can be represented by the equivalent circuits as shown below:

Eqn (1)

Eqn (5)

Eqn (2)
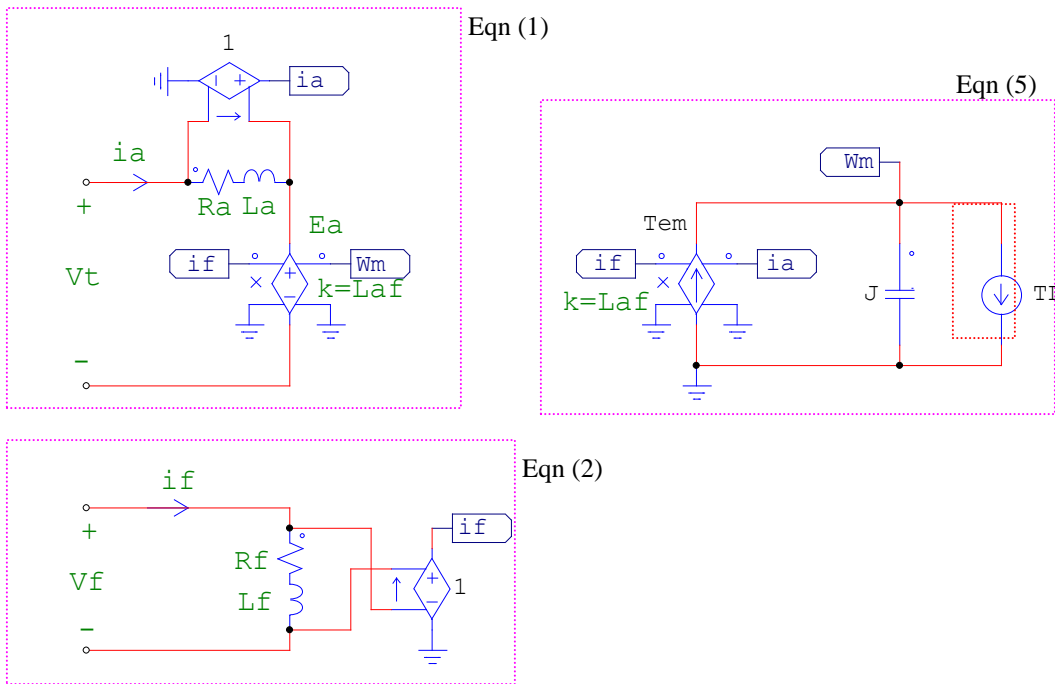
The equivalent circuit consists of three parts, with each part representing one of the equations. Current-controlled voltage sources are used to obtain the armature current i_a and the field current i_f. Nonlinear voltage sources with multiplication are used to represent the back emf E_a and the developed torque T_{em}. For the circuit representing Eqn. (5), torques are represented by currents, the mechanical speed is represented by the node-to-ground voltage, and the moment of inertia is represented by capacitance.

Labels are used instead of physical wires in the circuit for better layout.

Note that the load torque T_L, represented by a current source, comes from outside the machine, and is not part of the dc machine model itself.

3. Packaging the Model in a Subcircuit

The circuit that represents the dc machine can be packaged in the form of a subcircuit for easy use and parameter specification. This involves the following steps:

- Define the subcircuit size;

- Place the interface ports; and

- Create and edit the subcircuit image, if necessary.

The subcircuit size is the size of the subcircuit block as it appears in the main circuit. It is set by selecting **Subcircuit** -> **Set Size** in PSIM. The size should be large enough to allow the proper placement of the interface ports. In this circuit, we set the subcircuit size with the width of 6 and the height of 16.

Once the subcircuit size is set, the next step is to place the interface ports. Interface ports are ports that interface with external circuits. In this example, there will be two interface ports for armature winding terminals, two interface ports for field winding terminals, and one interface port for the mechanical shaft. To place an interface port, go to **Subcircuit** -> **Place Bi-directional Port** in PSIM.

In PSIM, the mechanical shaft of an electrical machine only connects to another mechanical shaft or other mechanical elements. In order to connect the mechanical equivalent circuit of the model to other mechanical shafts or elements, an Electrical-Mechanical Interface block needs to be connected to the speed node, with the electrical side of the interface block connected to the speed node and the mechanical side of the interface block connected to an interface port. The circuit looks like the following after the ports are placed.
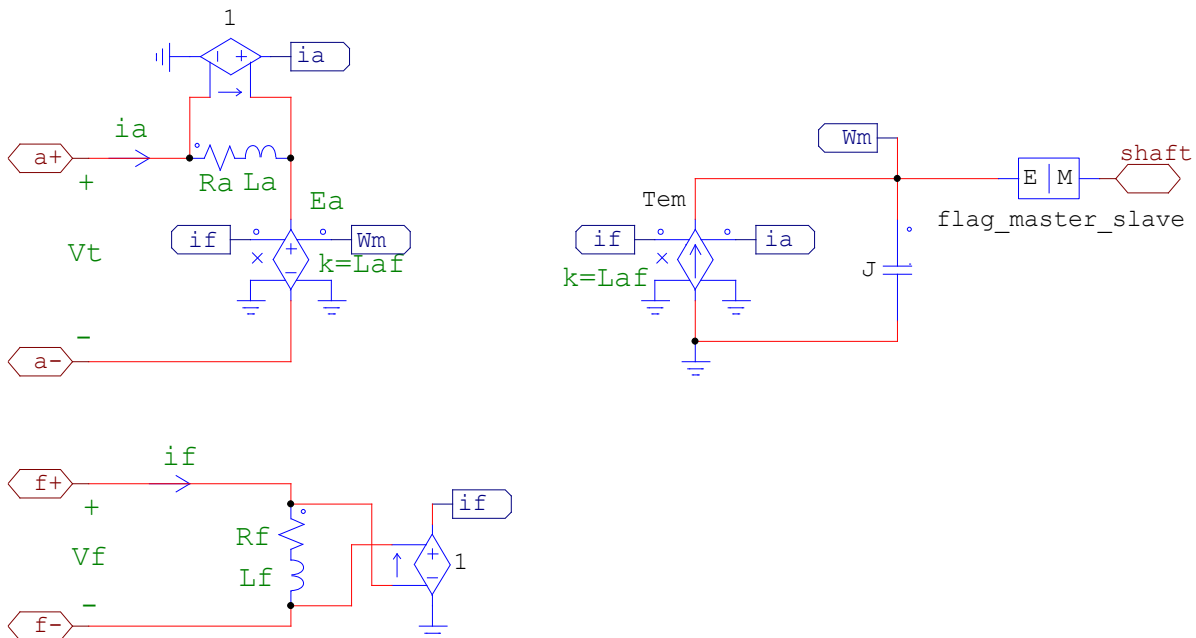
Furthermore, the parameters in the model will be defined as variables and will be specified at the main circuit level. In the circuit, define the armature/field winding resistances and inductances as Ra, La, Rf, and Lf, the capacitance representing the moment of inertia as J, and the gain of the sources for E_a and T_{em} as Laf. Then, in PSIM, go to **Subcircuit** -> **Edit Default Variable List**, and add the variables and the default values to the list. The dialog window of the default variable list is shown below after the variables are added:
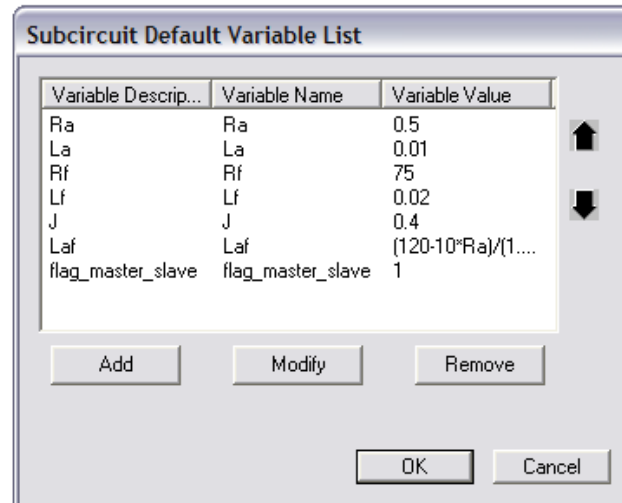
Finally, the subcircuit image can be modified or edited by going to **Subcircuit** -> **Edit Image**. Use the utility tools to create the desired image. The figure below shows an image created for the dc machine model.