The Motor Control Design Suite provides a total solution for motor drive system design. From system specifications, the Motor Control Design Suite will design all the controllers automatically, and will generate a system that is ready to simulate.

The Motor Control Design Suite provides a very quick solution to an otherwise complicated motor controller design task, and helps to speed up the development process significantly.

Three design templates are provided in the Motor Control Design Suite:

- PMSM Drive: PMSM drive system with maximum-torque-per-ampere and field weakening control
- PMSM Drive (nonlinear): PMSM drive system, with nonlinear motor, with maximum-torque-per-ampere and field weakening control
- Induction Motor Drive: Induction motor drive system with vector and field weakening control

A motor drive system consists of a dc bus, 3-phase voltage source inverter, motor, motor controller, and mechanical load. The design template interface for induction motor drive, for example, is shown below:

After parameters are entered for each block, one can generate the circuit with all controller parameters designed based on the operating conditions, and the circuit is ready for simulation.

This tutorial describes how to use the Motor Control Design Suite. We will use the following motor as an example to illustrate the process.

Induction motor: 100 HP, 460V, 60 Hz, 4 poles, 1756 rpm, 400 N*m
Parameters: stator resistance: 0.0426 Ohm; stator leakage inductance: 75.3 uH
             rotor resistance: 0.0568 Ohm; rotor leakage inductance: 75.3 uH
             Magnetizing inductance: 15 mH
             Moment of inertia: 0.1 kg*m^2
Based on the motor, we will set the dc bus voltage at 650V, and the inverter switching frequency at 10kHz. The control sampling frequency will be set at 20kHz. The current loop bandwidth will be set at 1500 Hz, and the speed loop bandwidth will be set at 200 Hz.

Running the Motor Control Design Suite involves two steps: defining system parameters, and generating the circuit.

1. Defining System Parameters

To run the Induction Motor Drive template, follow the steps below:

- In PSIM, go to Design Suites >> Motor Control Design Suite, and select Induction Motor Drive. An interface as shown in the figure in Page 2 will appear.

- Move the cursor into the interface Window and certain areas will be highlighted. These areas can be double clicked for parameter input. Double click on top of each area, and enter the following parameters:

  For DC Bus:
  - Minimum DC Bus Voltage (Vdc_min): 575.
  - Operating DC Bus Voltage (Vdc): 650.

  For Inverter:
  - Switching Frequency (fsw): 10k

  For Motor:
  - Stator Resistance (Rs): 0.0426
  - Stator Leakage Inductance (Lls): 753e-6
  - Rotor Resistance (Rr): 0.0568
  - Rotor Leakage Inductance (Llr): 753.e-6
  - Magnetizing Inductance (Lm): 15.e-3
  - Number of Poles (P): 4
  - Rated Speed (rpm) (nm_rated): 1756
  - AC Source Frequency (f): 60
  - AC Voltage (line-line rms): 460

  For Load:
  - Load Torque (T_load): 200.
  - Load Moment of Inertia (J_load): 0.01

  For Motor Controller:
  - PWM Gain (Gpwm): 100.
  - Current Loop Crossover Frequency (fcr_i): 1500
  - Speed Loop Crossover Frequency (fcr_w): 200.

The variables in the brackets are the parameter names used in the circuit.

The PWM Gain of the inverter is defined as the ratio between the dc bus voltage $V_{dc}$ and the peak-to-peak carrier voltage. If the carrier wave peak voltage is $V_{carr}$ (the signal is from $-V_{carr}$ to $+V_{carr}$), the PWM gain is defined as $V_{dc}/(2*V_{carr})$. The PWM gain is also the gain between the inverter peak phase voltage $V_{an}$ and the modulation wave $V_{ma}$, i.e. PWM Gain = $V_{an}/V_{ma}$. 
2. Generating the Circuit

After system parameters are defined, go to **Design Suites >> Generate Circuit** to generate the circuit. The figure below shows the generated circuit.

The control scheme is in the dq frame, and the control circuit consists of d-axis and q-axis current loops and a speed loop. A slip calculator calculates the motor slip frequency. Based on the dc bus voltage and the stator frequency, a field weakening control block calculates the d-axis reference to achieve the maximum power output. This reference is used when the stator frequency is over than the base frequency $We_{\text{base}}$. When the stator frequency is less than the base frequency, the calculated reference $Ids$ is used to achieve the maximum torque output.

One big advantage of the Motor Control Design Suite is that the motor maximum current $I_{\text{sm}}$, the d-axis reference $Ids$ (for maximum torque output) and the base stator frequency $We_{\text{base}}$ are calculated automatically with no user effort, ensuring the optimum operation of the system.

The figure below shows the simulation waveforms of 3-phase current $I_{sa}$, $I_{sb}$, and $I_{sc}$, the motor speed $nm$ and the reference speed $nm_{\text{ref}}$, and the motor developed torque $Tem_{IM1}$.
3. PMSM Drive Template

The PMSM Drive design template consists of a motor drive system, with a linear PMSM, with maximum-torque-per-ampere control and field weakening control. The template circuit is shown below.

![PMSM Drive System](image)

The control scheme is in dq frame. It consists of the d-axis and q-axis current loops and a speed loop. The speed loop establishes the torque reference. Based on the torque reference and other operating conditions, the Dynamic Torque Limit Control block determines if the system is to operate in the field weakening region, and adjust the torque reference.

The torque reference is then converted to the current reference and is sent to the Maximum-Torque-Per-Ampere Control (MTPA) block and the Field Weakening Control block. If the motor speed is below the base speed $n_{mb}$ (calculated by the Dynamic Torque Limit Control block), the system operates in the maximum torque region and the MTPA outputs are used as the current loop references. Otherwise, the system operates in the field weakening region and the Field Weakening Control block outputs are used as the references.

All the controller parameters are calculated automatically by the Design Suite.

4. PMSM Drive (Nonlinear) Template

The PMSM Drive (nonlinear) design template consists of a motor drive system, with a nonlinear PMSM, with maximum-torque-per-ampere control and field weakening control. The template circuit is shown below.

![PMSM Drive (Nonlinear) System](image)

Similar to the PMSM Drive template, the control scheme is in dq frame. It consists of the d-axis and q-axis current loops and a speed loop. The speed loop establishes the torque reference. Based on the torque reference and other operating conditions, the Dynamic Torque Limit Control block determines if the system is to operate in the field weakening region, and adjust the torque reference.
The torque reference is then converted to the current reference and is sent to the Maximum-Torque-Per-Ampere Control (MTPA) block and the Field Weakening Control block. If the motor speed is below the base speed $n_{mb}$ (calculated by the Dynamic Torque Limit Control block), the system operates in the maximum torque region and the MTPA outputs are used as the current loop references. Otherwise, the system operates in the field weakening region and the Field Weakening Control block outputs are used as the references.

Unlike in the linear PMSM drive system, however, PMSM in this system is nonlinear, and d-axis and q-axis inductances and back EMF constant are a function of the motor currents $I_d$ and $I_q$. Through 2-dimensional lookup tables, the inductances $L_d$ and $L_q$ and the stator flux linkage Lambda are obtained and are fed back to various control blocks.

All the controller parameters are calculated automatically by the Design Suite with the proper stability margin. Controller design involving the nonlinearity of a machine is often a difficult and complicated task, and this is made considerably easier with the Design Suite.