PLECS

DEMO MODEL

Induction Machine Drive Controlled with DTC

Last updated in PLECS 4.4.2

1 Overview

This example demonstrates an Induction Motor (IM) drive with an outer Speed Controller and an inner Direct Torque Controller. Additionally, a Brake Chopper controller is implemented to clamp the voltage of the DC-link capacitor of the back-to-back converter. An overview of the system is given in Fig. 1.

Note This model contains model initialization commands that are accessible from:
PLECS Standalone: The menu **Simulation + Simulation Parameters... + Initializations**
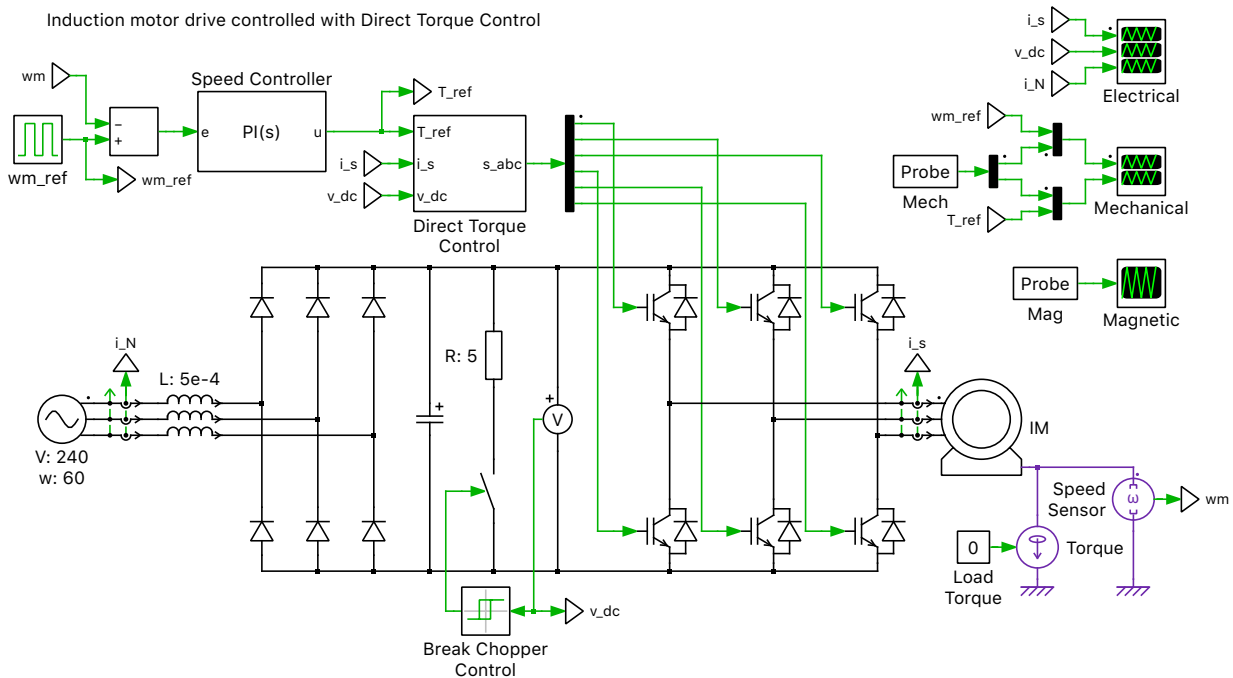*PLECS Blockset:* Right click in the **Simulink model window + Model Properties + Callbacks + InitFcn***

Figure 1: Induction machine drive controlled with DTC circuit

2 Model

An IM is an electric machine where the magnetic field generated by windings on the stator induces AC currents in the rotor. Here a squirrel-cage IM (shorted rotor windings) with no load and zero friction has been modeled. A more detailed description about the IM can be found here.

The IM is supplied by a stiff three-phase AC source through a back-to-back converter. The inverter side of the back-to-back converter consists of six IGBTs with anti-parallel diodes to allow for bidirectional power flow. The rectifier side of the converter consists of a three-phase diode bridge rectifier. During regenerative operation of the IM, the energy flows from the machine into the back-to-back converter. Due to the uni-directional nature of the diode bridge rectifier, this energy is stored in the DC-link capacitor leading to an increase in capacitor voltage. A brake chopper and resistor are connected to the DC bus capacitor to maintain the capacitor voltage within a desired range by dissipating the excess energy.

3 Control

The speed of the IM is regulated by an outer speed loop using a PI controller with an anti-windup mechanism. The output of the PI controller consists of a torque set point (`T_ref`) for the electric machine. The output of the outer speed controller, the DC bus voltage, and the stator phase currents are fed into a Direct Torque Controller (DTC). Additionally, the DC bus voltage is clamped below a desired level using a Brake Chopper Controller.

The DTC regulates both the stator flux and rotor torque using hysteric controllers. The measured DC-link capacitor voltage and the switching state of the inverter are used to determine the phase voltages. These phase voltages and the measured stator currents are both transformed into the stationary reference frame to determine the stator flux and rotor torque. Both the stator flux and rotor torque are compared with their reference values and the generated errors are fed into their respective hysteric controllers. Additionally, the stator flux values are used to determine the position of the synchronous frame.

The outputs of the Torque and Flux controllers along with the position of the synchronous frame are fed into an optimum pulse selector that generates the switching signals for the inverter.

4 Simulation

Run the simulation with the model as provided to view the behavior of the machine following a step change in the reference speed. The IM is initially spinning at 180 rads/s. In the first $60\,\mathrm{ms}$, the speed of the IM is maintained at $180\,\mathrm{rad/s}$. During this time the stator flux is ramped up from $30\,\%$ of its desired flux amplitude to the desired value. The direct and quadrature flux values can be observed in the Magnetic scope.

At $60\,\mathrm{ms}$, a step change occurs in the reference speed from $180\,\mathrm{rad/s}$ to $181.5\,\mathrm{rad/s}$. The PI controller saturates and applies maximum machine torque to achieve the desired rotor reference speed. As the speed approaches the new reference point the applied torque is slowly reduced.

At $120\,\mathrm{ms}$, the reference speed is stepped back down to $180\,\mathrm{rad/s}$. A negative machine torque is applied to reduce the speed back to the desired speed. This causes the IM to operate in generator mode and the energy is fed back into the DC bus capacitor through the inverter, that now acts as a three-phase active rectifier. The voltage of the DC bus increases quickly as the power is fed back into the back-to-back converter. The brake chopper controller dissipates the energy stored in the DC capacitor to maintain the DC bus voltage below $425\,\mathrm{V}$.

Revision History:

PLECS 4.3.1	First release
PLECS 4.4.2	Update PI controller component

How to Contact Plexim:

PLECS Demo Model

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