



PLECS

*DEMO MODEL*

## Configurable Switched Reluctance Machine

**Current-controlled switched reluctance machine with a configurable number of rotor and stator poles**

Last updated in PLECS 4.5.5

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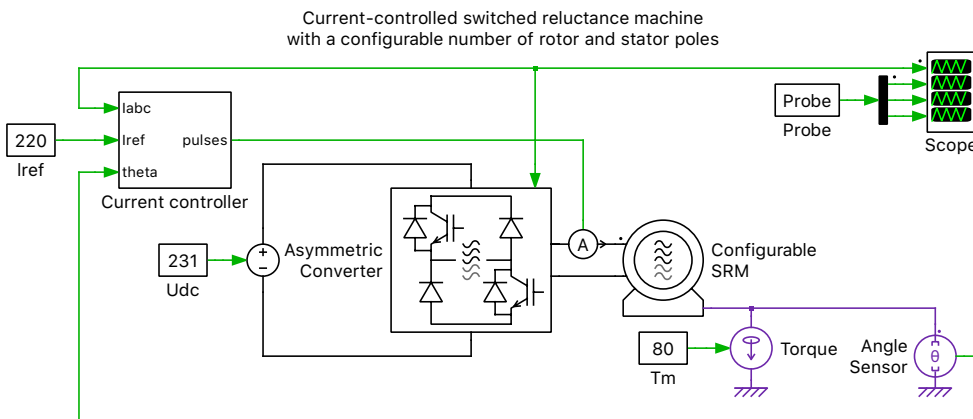
# 1 Overview

This example shows an inverter-fed, current-controlled switched reluctance machine (SRM) that can be configured as a 3, 4, and 5 phase machine. The machine has either 4 and 6, 6 and 8, or 8 and 10 rotor and stator poles, respectively. The drive comprises a DC voltage source feeding an asymmetric converter that can be operated in magnetization, freewheeling, and demagnetization modes.

**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: Switched reluctance machine circuit**

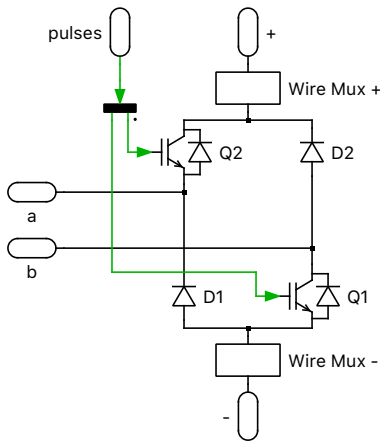
## 2 Model

An ideal 231 V<sub>DC</sub> source and a 2-level inverter with a configurable number of phases are used to drive a configurable-phase SRM. Selecting the machine type will automatically update the inverter dimensioning. The machine itself is implemented underneath a Configurable Subsystem, with one configuration each containing the library component for the three different types (3, 4, 5 phase).

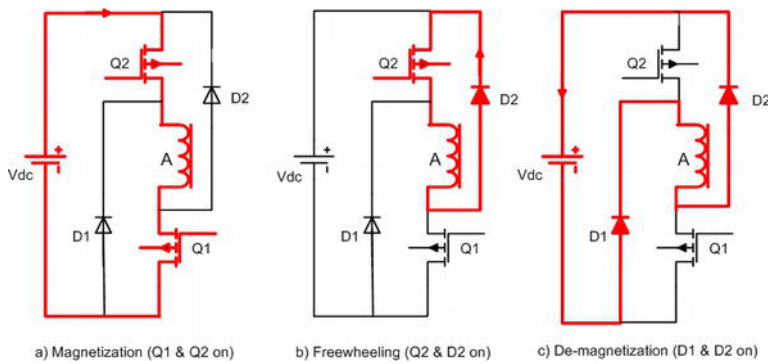
The drive electronics are based on a unipolar bridge converter, as shown in Fig. 2. With this topology, each phase is comprised of two asymmetric legs, each with one IGBT and integrated anti-parallel diode, and one freewheeling diode. The two diagonally-orthogonal IGBTs are modulated in a complementary fashion to actuate a given phase. This topology is used rather than having a total of four fully-controllable switches as the torque developed in the machine is independent of the current flow direction, and therefore cost savings can be made with fewer switch components for unipolar operation.

For each phase of the machine there are three modes of operation for the power stage, as shown in Fig. 3. First, during the magnetization period, both switches are turned on and energy is transferred from the DC-link to the phase winding. A second optional mode called freewheeling has only one of the switches turned on where the phase winding is more slowly magnetized or demagnetized. The third mode, demagnetization, occurs when both switches are off and decaying current flows from the winding through both diodes.

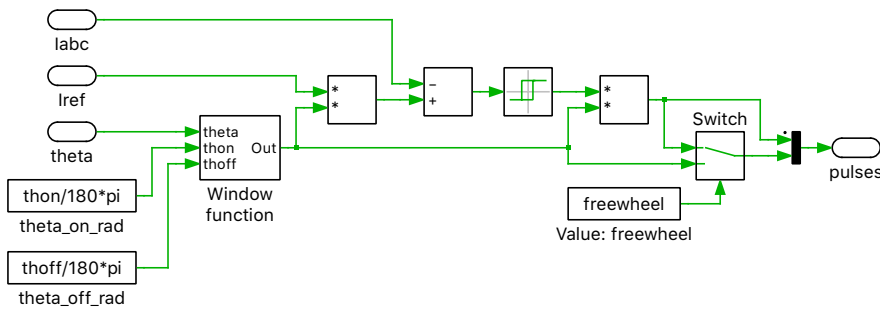
A reference current of 220 A is fed to the controller and a constant torque of 80 Nm is applied to the rotor.



**Figure 2: Switched reluctance machine circuit**



**Figure 3: Asymmetric drive operation [1]**



**Figure 4: Current controller**

### 3 Control

The rotor position of the SRM is measured using an ideal Angle Sensor and fed to a Window function to determine turn-on and turn-off timing of the machine's stator windings via the power switches. Additionally, a multiphase ammeter is used to measure the stator phase currents of the machine, which are compared to a reference current magnitude. The resulting error is then fed into a hysteresis controller (Relay block) with an error band of  $\pm 50$  A that then generates the switching signal for the IGBTs. The modulation signals are provided as simple sequential signals to each phase such that only one coil is energized at a time, and the average switching frequency is quite low, specifically on the order of hundreds of hertz.

While initially the current set point may be met at low speeds, current regulation is not possible at high speeds with this converter as the freewheeling diodes are uncontrolled. The controller could be extended

with an additional, outer speed loop to adjust the current setpoint. With the current design, the speed is mainly influenced in steady state by the DC voltage magnitude.

## 4 Simulation

Run the simulation with the model as provided to view the steady-state waveforms. The SRM machine is initially at standstill but speeds up to a steady-state speed of 300 rad/s in the case of the 6/4 machine, and slower speeds for the 8/6 and 10/8 versions. The typical traits for this machine and drive of high torque ripple and low switching speeds can be observed. The machine type can be toggled in the initialization commands. You can also set whether the control allows for freewheeling mode, though this will have negligible impact during steady state operation.

## References

- [1] Sandeep Narla (June 21st 2017), Four-Quadrant Control of Switched Reluctance Machine, Switched Reluctance Motor - Concept, Control and Applications, Ahmed Tahour and Abdel Ghani Aissaoui, IntechOpen, DOI: 10.5772/intechopen.69228. Available from: <https://www.intechopen.com/books/switched-reluctance-motor-concept-control-and-applications/four-quadrant-control-of-switched-reluctance-machine>.

## Revision History:

PLECS 4.5.5      First release

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