



# Permanent Magnet Synchronous Machine

## PMSM – IPM - BLDC- SPM

The automotive and transportation industries comprise the core markets for PMSMs. This machine type is known for its power density (power per unit of size/weight), and its higher speed capacity. OPAL-RT's solutions provide resolver and encoder I/O interfaces and communications protocols to exchange time-accurate information and position sensor responses—crucial for the successful testing and simulation of this motor type.

**Table 1: Overview of PMSM model implementation available in eFPGASIM:**

**Variable D-Q model — VDQ:**

2-phase equivalent circuit model with a d-q rotating reference frame and variable inductance table according to the operating point

**Pros:** Fast execution: ~ 100 ns, Low resource, Variable  $L_d - L_q$ , good for most operating condition

**Cons:** No simulation of cogging torque and current harmonics

**Spatial Harmonics model — SH:**

3-phase detailed model with 3D table for flux, torque and inductance.

**Pros:** Simulation of cogging torque and spatial/current harmonics, FEA based models, mechanical model on FPGA

**Cons:** Slower execution: ~ 500 ns, High FPGA resource usage



Table 2 describes the main specifications of the FPGA-Based PMSM machine models for applications requiring very fast simulation and accurate results. OPAL-RT offers two main versions of the PMSM model on FPGA: SH and VDQ.

**Table 2: PMSM model comparison table\***

	PMSM SH	PMSM VDQ
<b>Machine topology</b>	3-phase wye connected	
<b>Maximum machine speed</b>	300 kRPM	
<b>Maximum current / voltage / power / torque</b>	Not limited	
<b>Minimum time step</b>	500 ns	100 ns
<b>Calculation precision</b>	Single Floating Point	
<b>Compatibility with JSOL's JMAG</b>	From JMAG v10.5	No
<b>Compatibility with ANSYS Maxwell</b>	Yes	No
<b>Compatibility with Infolytica's MotorSolve</b>	Yes	No
<b>Electrical machine parameters</b>	3D tables for phase inductance, magnet flux and torque tables $L_d$ , $L_q$ and $\theta$ are dependent	Constant $L_d$ , $L_q$ and magnet flux or 2D tables for $L_d$ , $L_q$ and magnet flux $L_d$ and $L_q$ are dependent
<b>Fixed <math>L_d</math>, <math>L_q</math> mode (basic)</b>	No	Yes
<b>Mechanical model</b>	Basic inertia and friction mechanical model provided on CPU or FPGA. The user can define their own model on CPU or FPGA	Basic inertia and friction mechanical model provided on CPU. The user can define their own model on CPU or FPGA
<b>Inductance / torque / flux table size</b>	Up to 32x32x32 for 2 machines or 64x32x32 for 1 machine	128x128 for 2 machines
<b>Cogging torque / current harmonics</b>	Yes	No
<b>Saturation vs current amplitude</b>	Yes	
<b>Flux dependence on speed or temperature</b>	Not supported	
<b>Copper losses</b>	Not supported	
<b>Audience / Application</b>	Engineers with access or who build the machine design. For tests that require a model that reproduces the right current harmonics and cogging torque. Or for engineers with access to the machine design who want to export this directly from Finite Element Analysis software to the real time simulation.	Engineers with access to the basic machine parameters from manufacturer. For tests that don't require higher fidelity regarding the current and torque harmonics.
<b>Recommended platform</b>	OP4510 OP560x OP5707	OP560x OP4510 OP5707 OP4200

\*Table 2 describes the main specifications of the FPGA-Based PMSM Machine model available on eFPGASIM. This model is typically used for an application requiring very fast simulation and accurate results. OPAL-RT also offers CPU-based models for slower applications and consultancy services to develop specific machine models.

**ABOUT OPAL-RT TECHNOLOGIES**

OPAL-RT is the world leader in the development of PC/FPGA Based Real-Time Digital Simulator, Hardware-In-the-Loop (HIL) testing equipment and Rapid Control Prototyping (RCP) systems to design, test and optimize control and protection systems used in power grids, power electronics, motor drives, automotive industry, trains, aircraft and various industries, as well as R&D centers and universities.

