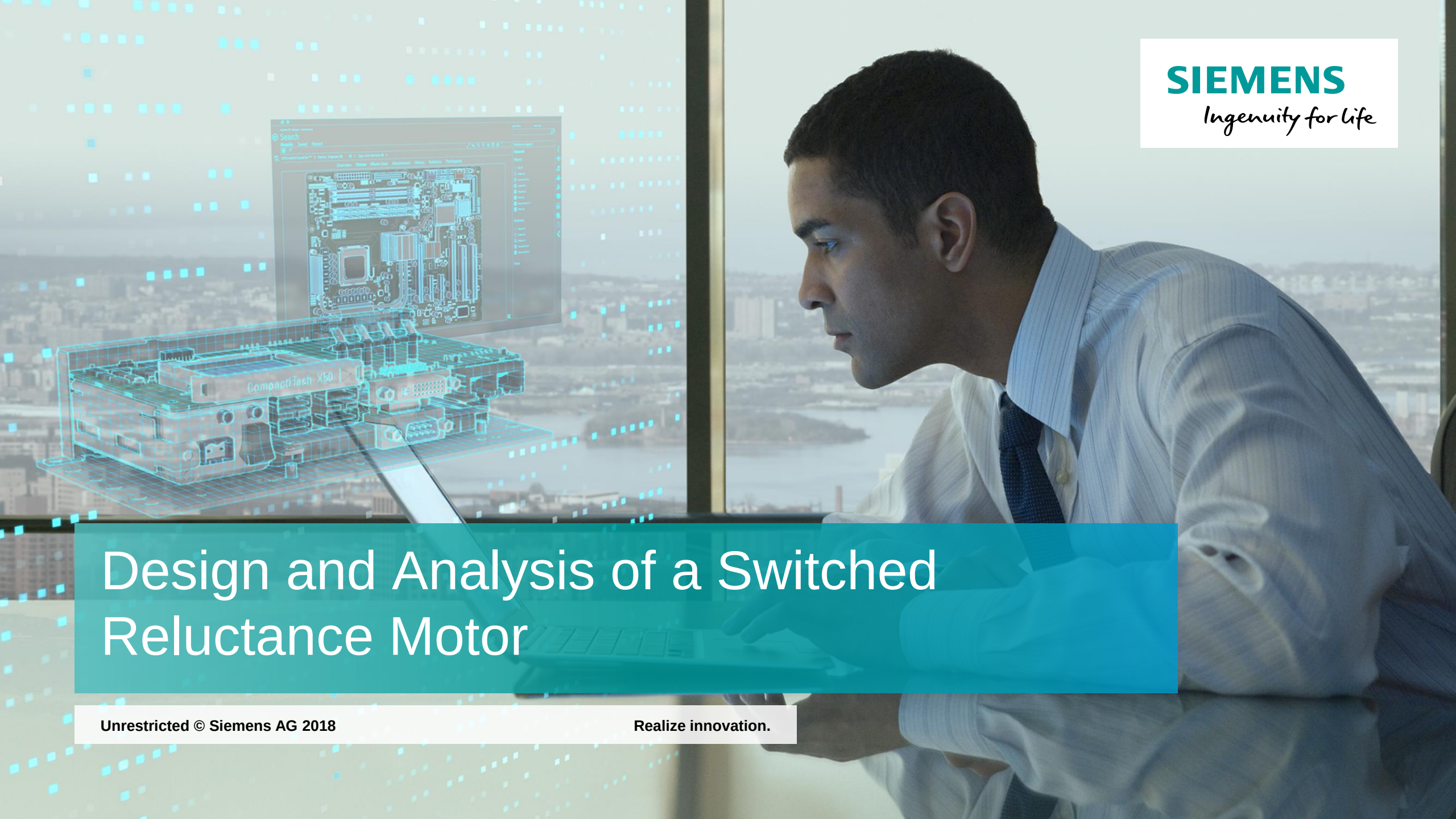

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Design and Analysis of a Switched Reluctance Motor

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Design and Analysis of a Switched Reluctance Motor

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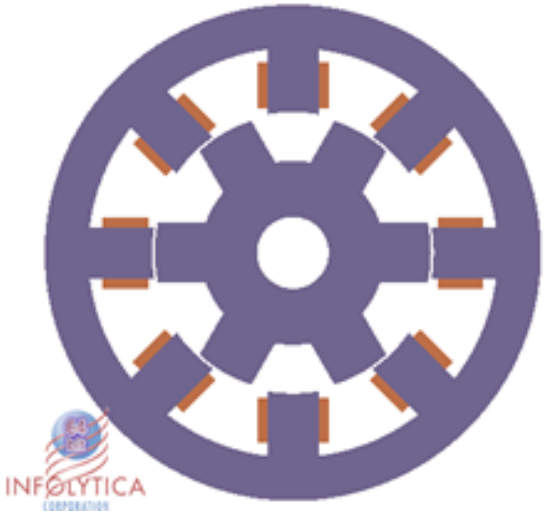
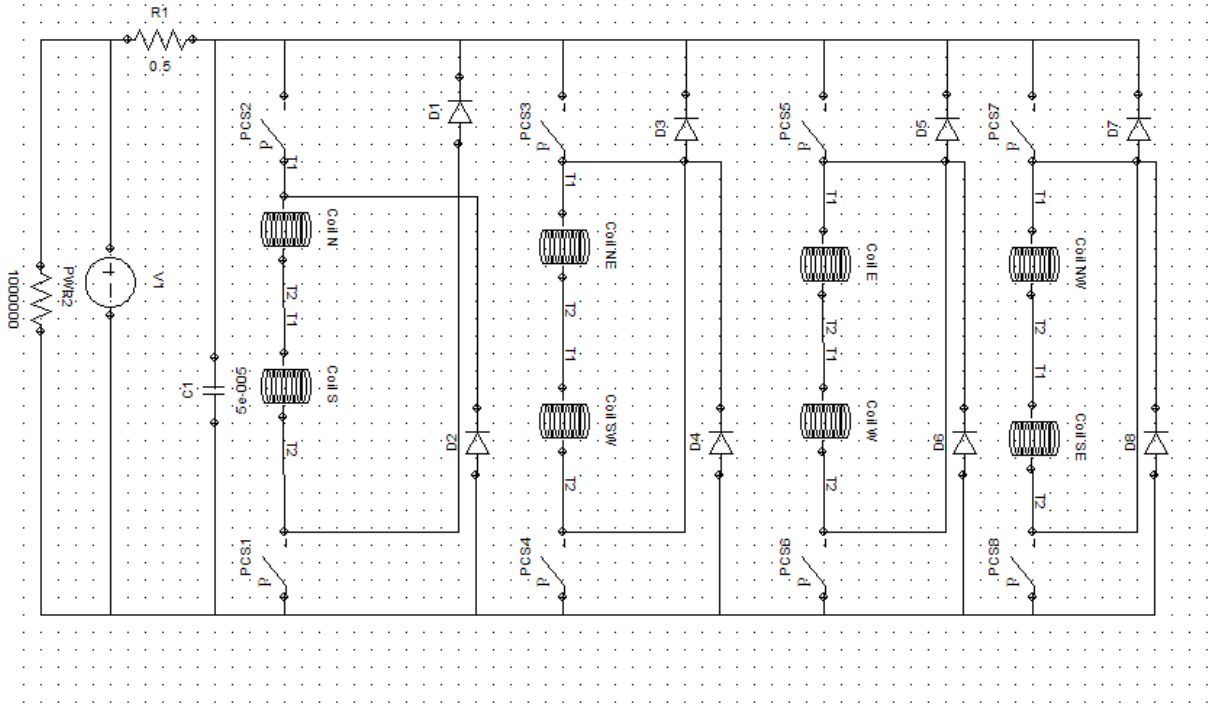


Switched reluctance motors (SRM) are often considered to be economical alternatives to induction motors, and the design of such motors usually begin with some of the dimensions from an equivalent induction motor. In general, most design algorithms of SRMs combine analytic approximations, FEM based verification and numerical iterations (using the CAD software Simcenter MAGNET) that 'optimize' the dimensions of the motor.

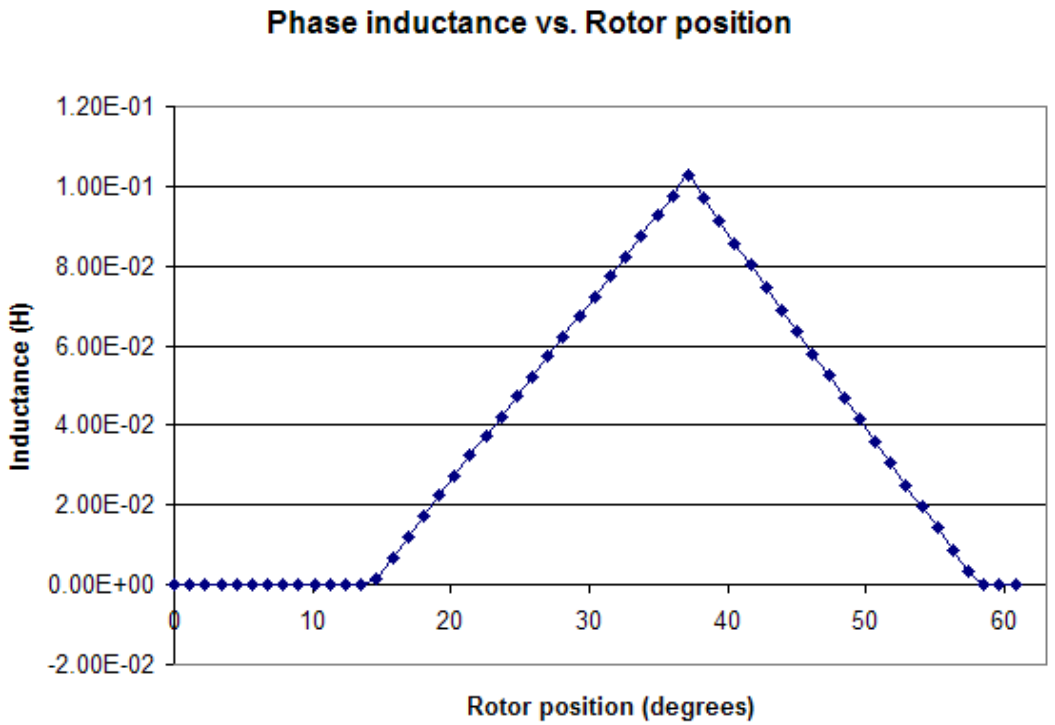
Using MAGNET, an 8/6 SRM is simulated. Presented below are a series of results that are integral to the design and analysis of any SRM. The results presented here are for such a machine operating at 1500 RPM. Some other specifications of this motor are; rated current and voltage: 7 A, 300 V.

DRIVER CIRCUIT FOR SRM



Driver circuits for SRMs are based on motor type and geometry, power, cost and resource constraints etc. For the 8/6 machine considered here, the driver used is an eight switch asymmetric inverter shown on the figure to the right. The firing angles of the position controlled switches are determined from the initial position of the rotor and the phase inductance as a function of the rotor positions at peak current. This is discussed further below.

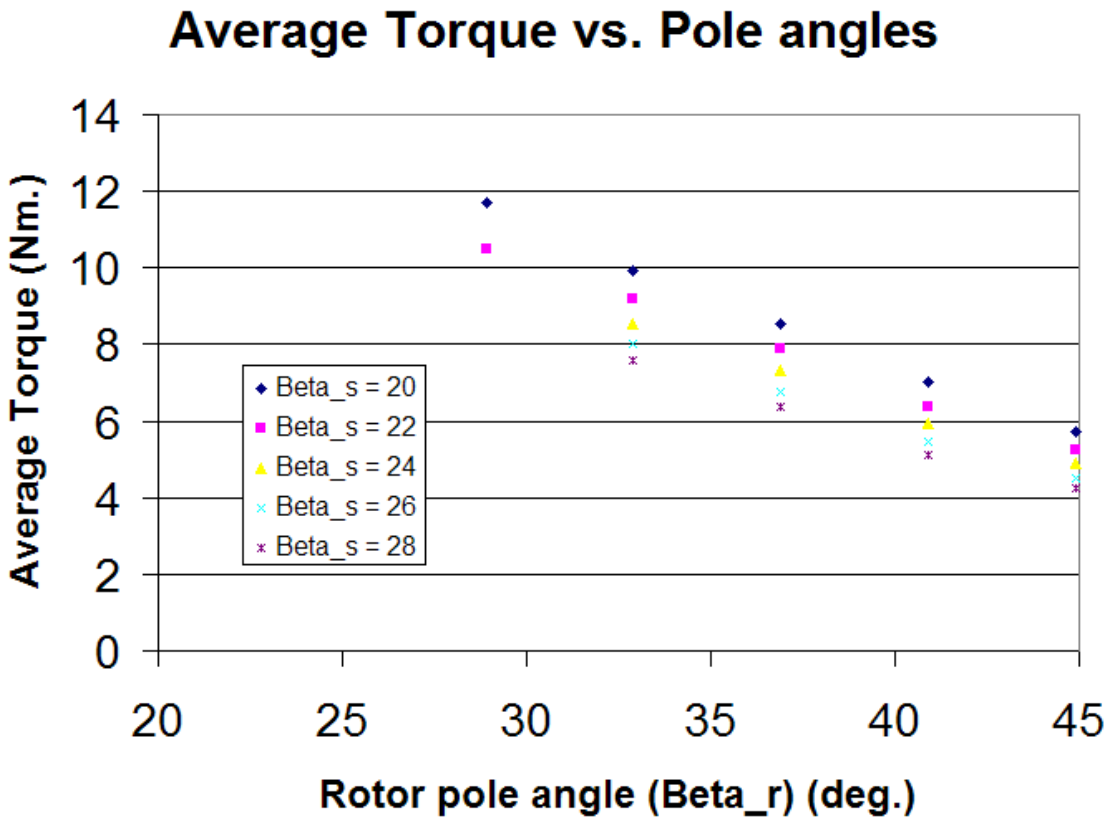
INDUCTANCE PROFILE OF THE PHASES



One of the most important aspects of simulating SRMs is to determine the firing angles of the phase switches. These are based on the inductance profile of the phases as a function of position. Such inductance plots can be generated readily in Simcenter MAGNET an example of which is shown here. In this example, the phase switches are turned on at 15 degrees and turned off at about 35 degrees.

AVERAGE TORQUE AS A FUNCTION OF THE POLE ANGLES

Another important aspect of designing a SRM is determining the rotor and stator pole angles. These angles significantly affect the smooth operations of SRMs. For a given set of motor specifications, it can be shown analytically that many valid pole angle combinations exist that satisfy the power or operational torque criterion. However, restrictions from stability, clearance, torque per iron volume, cost and other considerations can help reduce the phase space of possibilities. An example of a plot of the average torque as a function the pole angles is shown here. Using Simcenter MAGNET and it's powerful parameterization capabilities and array of solvers, accurate results of such plots can be generated readily.



MAGNETIZATION CURVES

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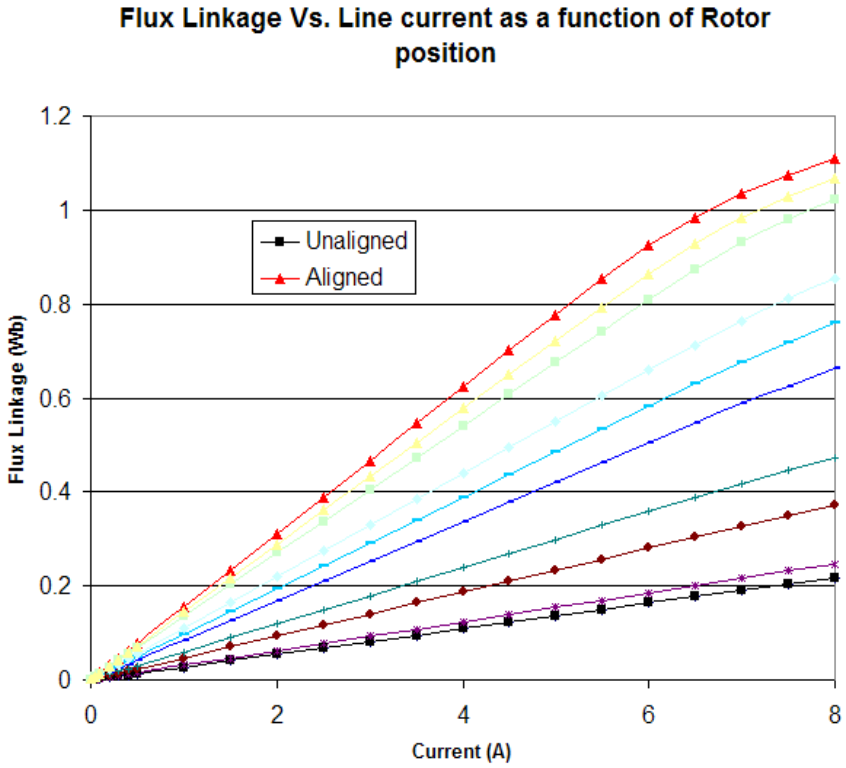
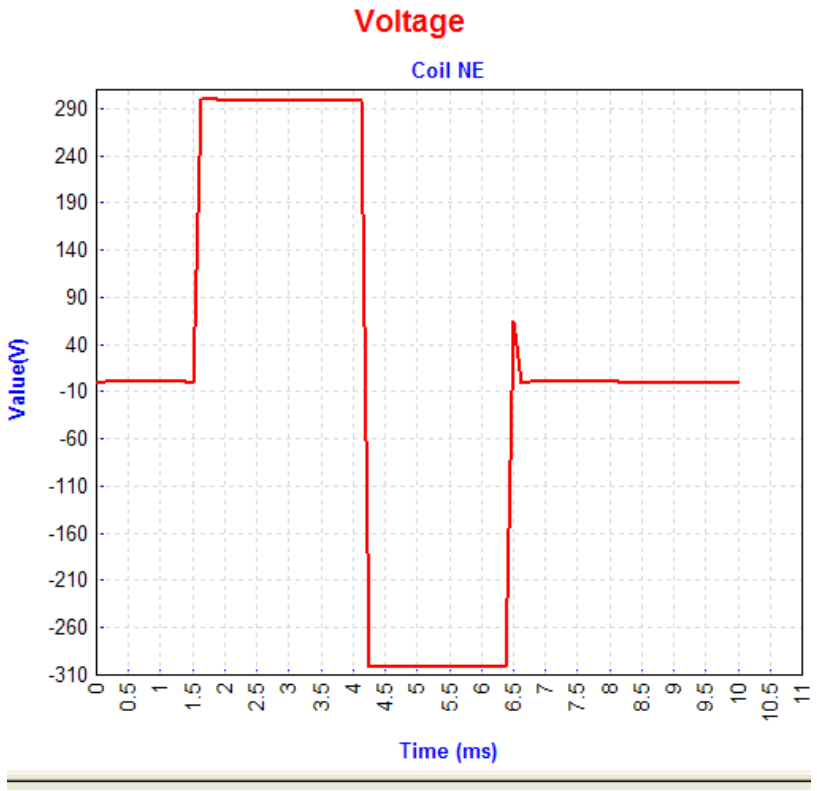
An integral component of any SRM design is the use of magnetization curves. These are curves that plot the flux linkage of a phase as a function of current and rotor position from the unaligned to the aligned position. They are required when implementing design algorithms that integrate the system magnetic and mechanical equations for analysis of a particular design. Usually, such curves are obtained from experiments or from FEM analysis. In Simcenter MAGNET, this can be done with ease. A significant aspect of using MAGNET to generate such curves is it's ability to handle non-linear (saturation) regions of such plots as shown here in the example. Note that this example is for a 2D analysis.



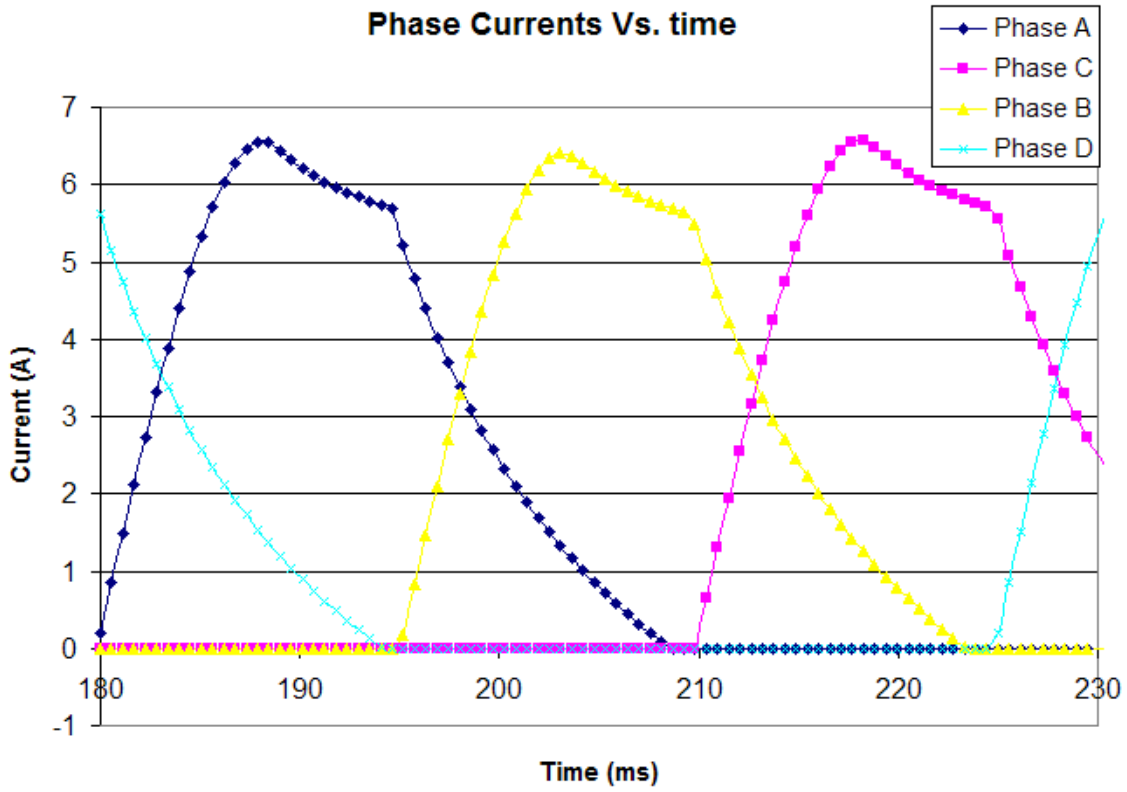
Another important aspect of SRM design and analysis is to compute the average and instantaneous torques. In Simcenter MAGNET, the instantaneous torque is reported during any transient analysis which eliminates the need for analytic approximations, as is done in many algorithms. Also, the average torque can be computed using the instantaneous values with minimal post-processing using a standard spreadsheet such as Excel. Examples of some torque profiles from transient analysis are shown below.

VOLTAGE VARIATION IN ONE PHASE



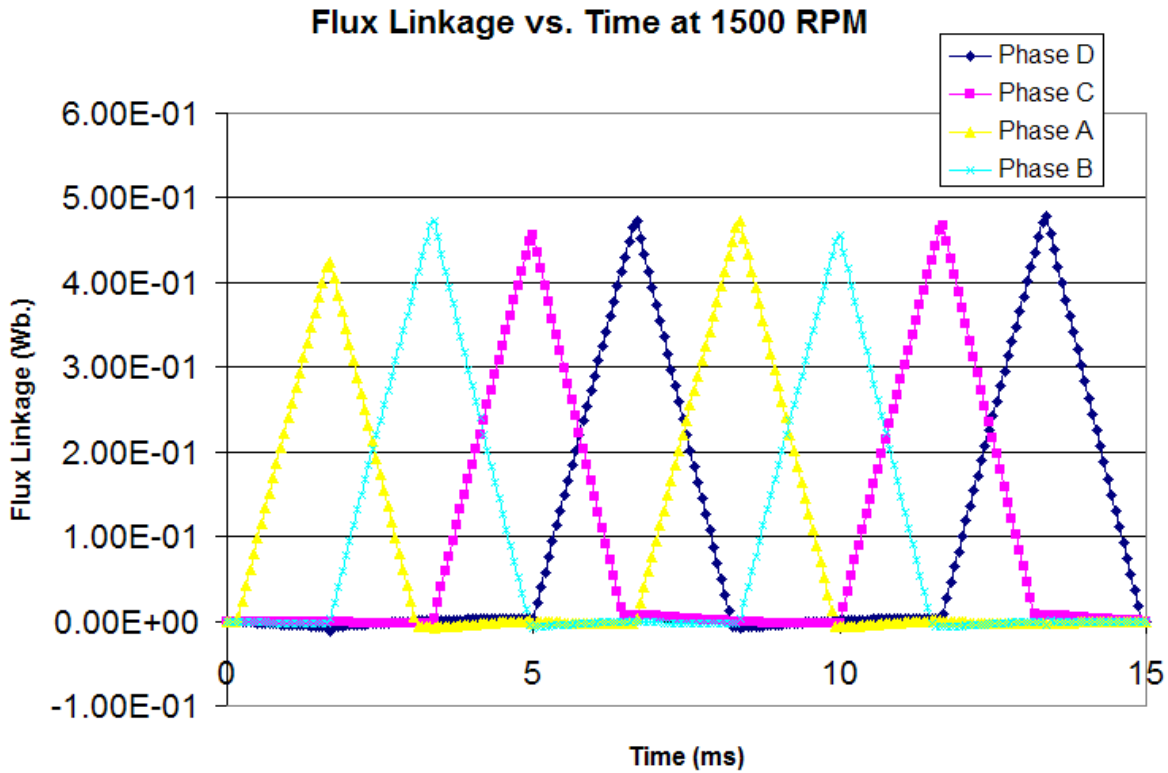
Presented here are some transient simulation data. First, the current and voltage profiles as a function of time when the motor is operating at 1500 RPM are shown. The driver for these results was presented above. First a snapshot of the voltage variations in one of the phases is shown.

CURRENT VARIATIONS IN FOUR PHASES



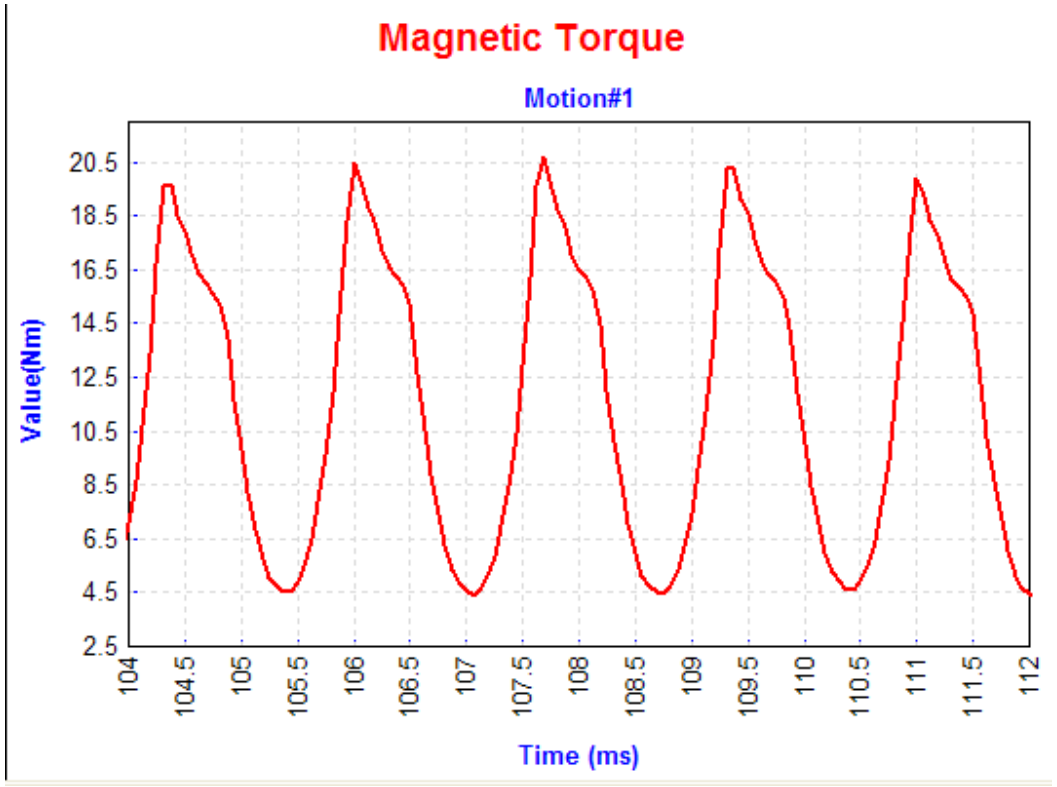
The resulting current variations in all four phases are shown here.

FLUX VARIATIONS



The flux variations as a function of time are shown here.

MECHANICAL TORQUE



The mechanical torque delivered to the rotor as a function of time are shown here.

ADVANCED METHODS

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Designing a motor is a complicated and multi-step process with significant variations in approaches and algorithms. Once the motor geometry is selected, driver design, control simulations, thermal analysis need to be done to optimize the design parameters. Here, only the most basic aspects of designing a SRM have been presented. Using a number of other Infolytica packages such as OptiNet and ThermNet it is possible to carry out both optimization and thermal analysis for a complete motor design solution. Also, Simcenter MAGNET's compatibility with Simulink and other co-simulation packages can also be used to design the appropriate driver and control systems.