# Design Fabrication And Control Of Switched Reluctance Motor

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*Abstract: In switched reluctance motors magnetic field is produced by only one member, i.e. either stator or rotor. The rotor tends to move to minimum reluctance position for the flux of this magnetic field. Minimum reluctance is achieved when iron comes into contact with the magnet. By sensing the rotor position of SRM is used to switch on and switch off phase windings. In SRM inductance of phase winding varies with rotor position. For a unidirectional torque, current must be present in the coil only when the rate of change of coil inductance with rotor position is positive. Two rotor laminations are kept on the unused portion of shaft to sense the rotor position by using opto sensors as gap detectors. When rotor rotates and comes under influence of gap detectors and generates a pulse. Apparently three pulses generate in every rotation. These pulses act as input to the Arduino mega 2560. These outputs act as triggers for six gates in converter circuit. Converter circuit is connected to SRM. Once supply is applied, current flows through the winding and speed can be measured.*

## 1 Introduction

Electrical machines can be classified into two categories on the basis of how torque is developed in them: electromagnetically or through variation of reluctance. In the first category, motion is produced by the interaction of two magnetic fields, one generated by the stator and the other by the rotor. Two magnetic fields, mutually coupled, produce an electromagnetic torque tending to bring the fields into alignment. The same phenomenon causes opposite poles of bar magnets to attract and like poles to repel. The vast majority of motors in commercial use today operate on this principle.

In the second category, motion is produced as a result of the variable reluctance in the air gap between the rotor and the stator. When a stator winding is energized, producing a single magnetic field, reluctance torque is produced by the tendency of the rotor to move to its minimum reluctance position. This phenomenon is analogous to the force that attracts iron or steel to permanent magnets. In those cases, reluctance is minimized when the magnet and metal come into physical contact. Switched reluctance motor falls into this class of machines.

In Switched reluctance motor, switching of supply from one stator to the next causes minimum reluctance position of the rotor to change continuously thus producing rotation. By controlling the switching strategy, and the current flowing through the stator coils, we can control the torque and the speed of the motor. Because of their simple mechanical construction switched reluctance motors are of low cost. This has motivated a large amount of research on these motors in the last decade.

The mechanical simplicity of the device, however, comes with some limitations. Like the brushless dc motor, switched reluctance motors cannot run directly from a dc bus or an ac bus, but must always be electronically commutated. Also, the saliency of the stator and rotor, necessary for the machine to produce reluctance torque, causes strong non-linear magnetic characteristics, complicating the analysis and control of the Switched Reluctance Motor.

# 2 Modelling of Switched Reluctance Motor

The design specifications for the SRM comprise of the required power output Po in Watts. Speed N in rpm, allowable peak phase current ip in Amps, and available dc supply voltage Vdc in volts for the system. Knowing the speed and power output will automatically fix the torque to be developed by the machine as power divided by speed in rps. Torque developed by the machine is 0.76N.m

## 2.1 Frame Size Selection

The preliminary selection of frame size automatically fixes the outer diameter of the stator.

Practically, the outer diameter of the Stator is fixed as follows:

$$Do = (FrameSize - 3) * 2$$

where the Frame Size is given according to the IEC recommendations. Frame Size is 21 mm and then outer diameter(Ro) of the Stator is 36mm

## 2.2 Pole Selection

Normally, the designer fixes the number of stator poles Ns and the number of rotor poles Nr and deviates from this fixed value only for very special applications because then converter configurations and feedback devices can be standardized. There are many possible combinations for the number of poles. This paper primarily focuses on the popular combination of 6 stator and 4 rotor poles, also commonly known as the 6/4 machine. This machine has the advantage of lesser switching losses than the other common combination of 8 stator and 6 rotor poles (8/6 machine).

## 2.3 Stator and Rotor Pole Angle Selection

The stator and rotor pole angle selection form a crucial part of the design process. There are many guidelines to be followed during the selection process. The standard design normally has the Stator pole arc angle βs smaller than the Rotor pole angle βr. In this paper Stator pole arc is 280 and Rotor pole arc is 320.

## 2.4 Preliminary Design Process

Once the outer diameter, pole numbers and preliminary pole arcs are fixed, the preliminary design of the bore diameter D and the stack length L form the next step in the design. The stack length can be initially chosen to be equal to the distance between the mounting holes in a foot mounted machine. With the selection of preliminary values of Do, L, D, βs and βr, the design process is continued. Only Do is fixed and can change only with the change of the entire frame size. At this point the shaft diameter Dsh can also be selected from standard tables based on the required torque of the machine.

In this paper, outer diameter taken as 36mm, 6 Stator poles, 4 Rotor poles and preliminary pole arcs are 28 and 32 degrees respectively. Each lamination of Stator is 0.5mm so total stack length is 40mm and shaft diameter is 5mm.airgap is 0.3 to 0.6mm for small machines. Shaft diameter is selected based on strength required. For this machine 0.5mm is taken. Initially Rotor outer radius is assumed as 9mm and then Stator inner radius is 9.25mm by adding air gap to the outer radius of the Rotor. With reference to the specified pole arcs of Stator and Rotor pole arcs, outer radius of the Stator is 15mm.

Cross sectional area of the 35SWG wire is 0.3108mm2 and wire diameter is 0.629mm by using this parameters calculated value of number turns are 122.Stator has 6 poles and each pole containing 122 turns per phase so resistance per phase is 2.2 ohm, Inductance per phase aligned is 7.4mH and Inductance per phase unaligned is 5.56mH.Weight of the copper is 250gm.

# 3 Design of Switched Reluctance Motor using AutoCAD

3.1 Stator Design

Stator is made of Non Grain Oriented Steel material. Stator lamination of dimensions 40 X 40X30 mm is used and is shown in figure 3.1. Outer radius of stator is 15.3mm and inner radius is 9.2 mm. It has 6 poles and carries winding made of 36 SWG copper. Stator pole arc is 28 degrees.

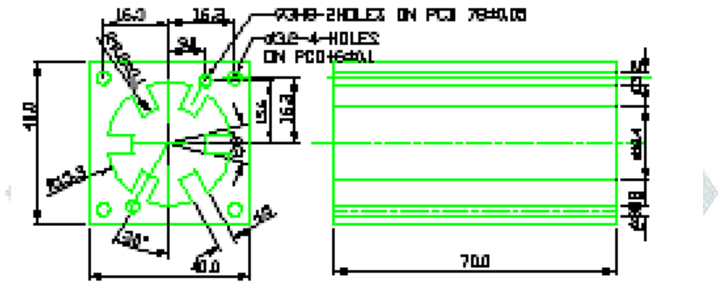

Figure 3.1 Design daigram of stator using Auto CAD

3.2 Rotor Design

Rotor is made of Non Grain Oriented Steel material. Rotor lamination of dimensions 40 X 40X30 mm is used and is shown in figure 3.2. Outer radius of Rotor is 9 mm while inner radius is 6 mm. It has 4 poles and carries no winding. Rotor pole arc is 32 degrees.

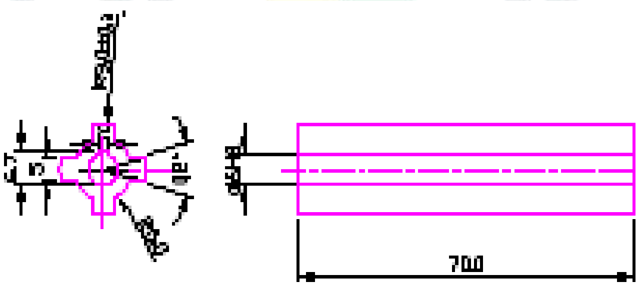

Figure 3.2 Design diagram of Rotor

3.3 Shaft, End Plates and Key Way Design

Shaft Design and Key Way Design

Shaft is made of mild Steel material of dimensions 70mm length of which 40 mm has diameter of 6 mm while rest (30mm) has diameter of 8mm. Underlying key pin of size 2X2 put across 30mm length of stator. Key way used is of size 5X2X30mm and is shown in figure 3.3.

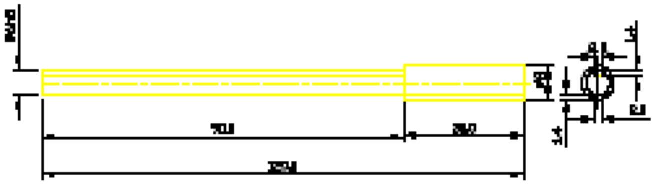

Figure 3.3 Design diagram of Shaft

Left End Plate Design

Left End plate is made of mild steel of dimensions 40X40X10 mm and PCD of 36mm. Possess holes of diameter 3mm at four corners of end plate. Bearing used of size 15X5mm. From the centre point of end plate, 5 mm to the left and 5 mm to the right taken as groove of which 7mm is used for fixing the bearing and rest 3mm is open for wires and is shown in figure 3.4.

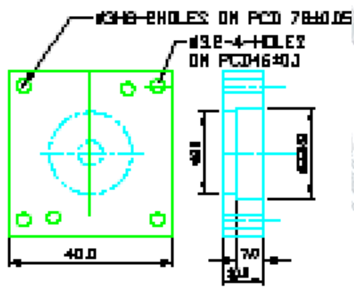

Figure 3.4 Design diagram of Right End plate

Right End Plate Design

Right end plate is made of mild steel of dimensions 40X40X10 mm and PCD of 36mm. Possess holes of diameter 3mm at four corners of end plate. Bearing used of size 18X5mm. From the centre point of end plate, 5 mm to the left and 5 mm to the right taken as groove. of which 7mm is used for fixing the bearing and rest 3mm is open for wires and which are shown in figure 3.5

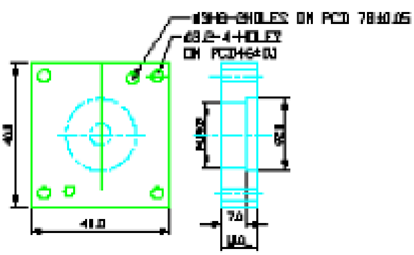

Figure 3.5 Design diagram of Left end plate

Stator, Rotor, key way and shaft are shown in figure 3.6

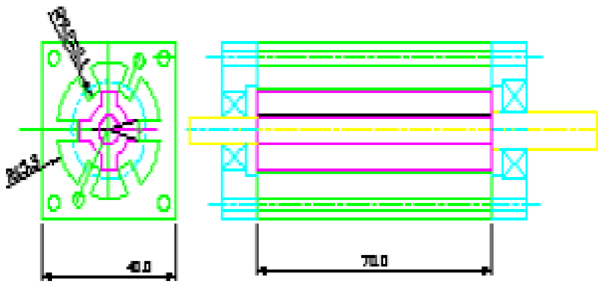


Figure 3.6 complete design diagram

The parameters of the DC motor used as the movement execution element are: rated voltage 24 V, rated current 3 A, maximum speed 3000 rpm,gear box with a speed reduction ratio of 1: 20.

# 4 Simulation of Switched Reluctance Motor

## 4.1 Motor Drive System

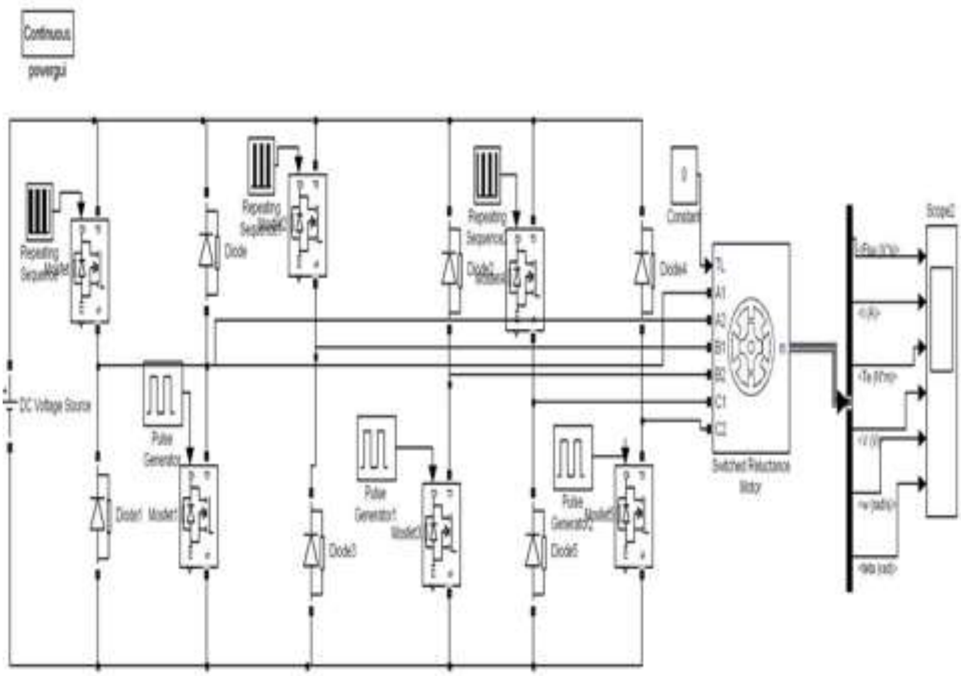


Figure 4.1 Simulation Circuit Diagram of SRM

This topology has six MOSFETs, six Diodes. A set consists of two MOSFET's and two Diodes in each phase connected to the Switched Reluctance Motor terminals as shown in figure. Likewise all three phases namely A, B and C are connected. Two types of pulses are considered for upper and lower MOSFET's. Repeating Sequence is used for upper leg while pulse generator for lower leg.

Consider phase-A, the voltage used to the phase winding is +12V when the switches Q1 with repeating sequence and Q2 with pulse generator applied are on (+Vs-Q1-phase A-Q2- -Vs). Phase current then increases through both the switches. If Q1 is off while the Q2 is still on, the winding voltage will be zero. Phase current cannot be zero because of inductance in Phase A.Then phase current slowly decreases by freewheeling through Q1 and Diode D1.When Q1 and Q2 are off, the phase winding will experience -12V voltage. Phase current then quickly decreases through both diodes (-Vs-D2-phase A-D1-+Vs). Once the current reaches to zero switches Q1 and Q2 can be switched on, when operation requires. By appropriately coordinating the above three switching states, phase current of the Switched Reluctance Motor is controlled. Output quantities of SRM are Flux, Current and Voltage and they can be seen through the scope and are shown in below Figure 4.1.

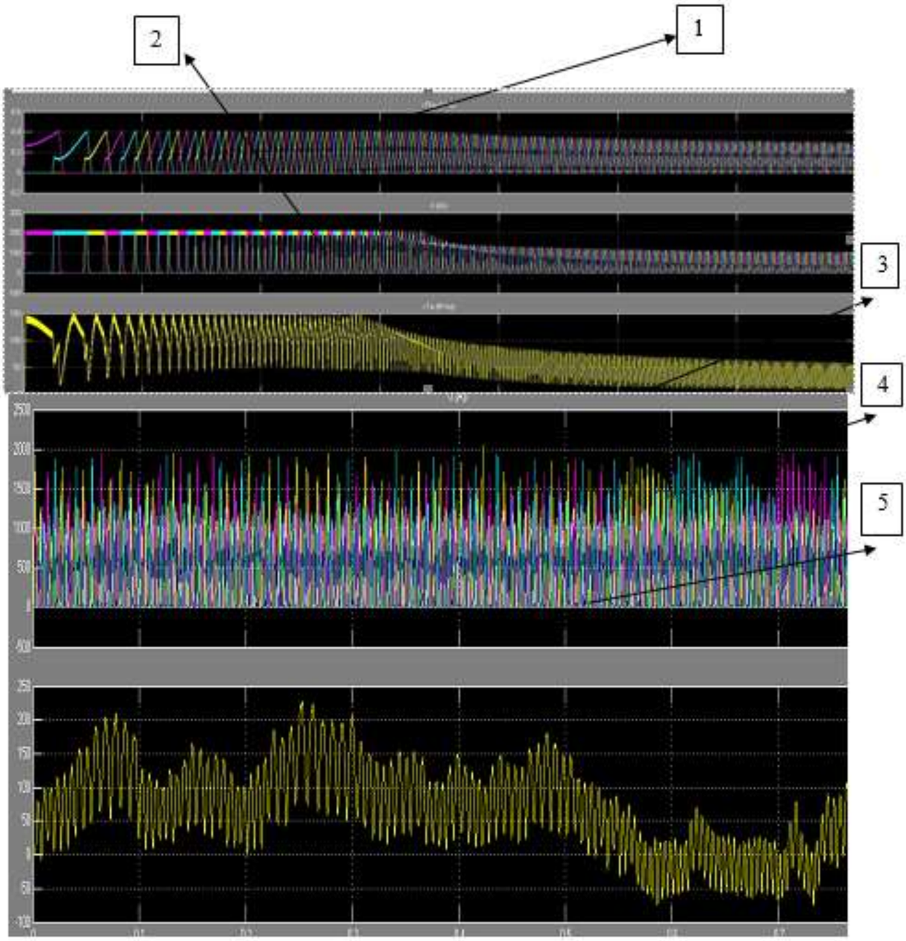


Figure 5.8 Waveforms of Flux, Three Phase Current, Torque, Voltage and Speed

## 5 Hardware Design of Switched Reluctance Motor

Assembled Switched Reluctance Motor has Shaft with a length 70mm, Left and Right End Plates with 10mm width, 40mm width of Stator and Rotor stack, and all these parts are fitted with bolts and nuts. Finally H12A gap detector is used for detecting Rotor position which is input to the Arduino Mega. Power Converter Circuit consists of six MOSFET's as lower and upper legs of the circuit, six Transistors which are used for amplifying the switching signal came from arduino and it has six Opto Isolators which isolated the Arduino and Power converter. Total arrangement is shown in Figure 5.1.

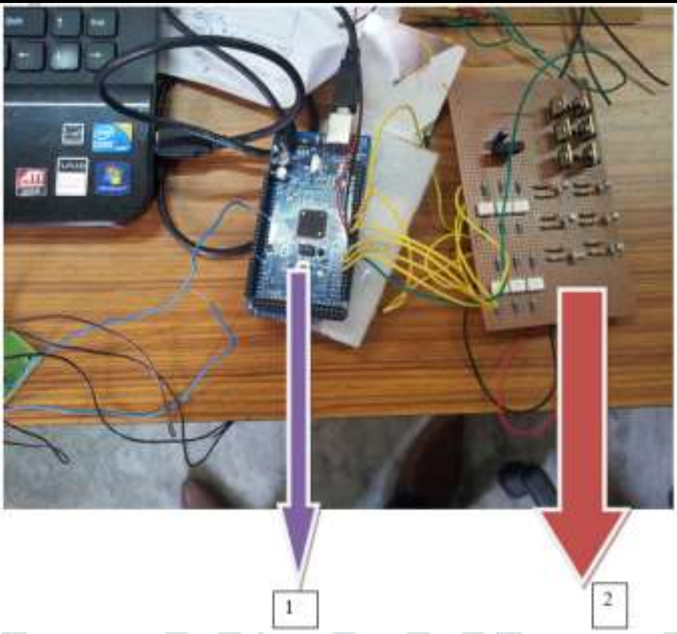


Figure 5.1 Interfacing of power converter and Arduino mega

# 6 Conclusion

Switched Reluctance Motor speed characteristics are studied. Design and Fabrication of SRM is done. Coding and compiling of a Arduino program is verified. Hardware implementation by connecting Schematic is done successfully. The hardware kit is tested successfully by embedding the Arduino mega. Switched Reluctance Motor is cost effective and it has a potential to replace all conventional motors. An economical, highly effective Switched Reluctance Motor design can be worked at industry. There by resulting in lot of power saving and environmental benefits.

**References**

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