Power Electronic Controller for A 8/6 Switched Reluctance Motor

BOLISHETTY NAVEEN[1], DR. HARI SHANKAR JAIN[2]

[1] *P.G Student, Dept of EEE, Vardhaman College of Engineering Hyderabad*

[2] *Professor, Dept of EEE, Vardhaman College of Engineering Hyderabad*

Abstract- In this paper, a power electronic controller for 8/6 switched reluctance motor (SRM) is described. The controller capacity is limited to SRMs operating at up to 30 V sinking maximum peak currents up to 2.0 A. The upper angular speed is chosen as 100 revolutions per minute (RPM), for this development. As the proposed system is designed for direct operations with 230/ 50 Hz AC a converter is also introduced in the design and discussed in this paper. The paper briefs on the concept and design of this controller its fabrication in the laboratory and assembly with a given SRM. A circuit design has been selected and developed for its energy efficient operations. The paper also includes testing procedure and test results. The findings are discussed and conclusions made in the conclusion section, on the basis of performance of the design and testing. The paper also suggests future work in this field

Indexed Terms- Switched Reluctance Motor, Power Electronic Converter, Electronic controller (Analogue /digital - microcontroller - Arduino based), DC / Switch Mode Power supply.

I. INTRODUCTION

SRM require power converters to control the conducting sequence of the stator winding. The stator has a winding, a set of coils. To minimize the eddy current losses rotor part is laminated. . The reluctance of the magnetic circuit is minimum when stator and rotor are aligning with each other. For attractive high-power density, low maintenance and high efficiency, high performance application SRMs are widely accepted industrial machine. SRM are used widely in applications like robotics, aerospace and industrial. A rotor position sensor is placed on the rotor shaft to detect the position of the rotor teeth alignment with stator. The position is communicated electrically/ electronically to the controller so as to help correct excitation and start of the machine. The major limitations of SRM include acoustic noise and strong torque effects.

Main/ basic components of a SRM drive system include:

1. Switched Reluctance Motor,
2. Power Electronic Converter,
3. Electronic controller (Analogue / digital - microcontroller - Arduino based),
4. DC /Switch Mode Power Supply and
5. Encoder.

- Block Diagram

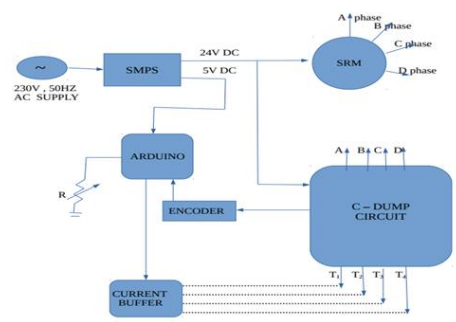

Fig 1: Block Diagram

- Circuit Diagram

The circuit diagram consists of four switches named as T_1, T_2, T_3 T_4 are along the phases ABCD.

Phase A ......T_1.......gate terminal 1 ....13 pin
Phase B......T_2........gate terminal 2 .....12 pin
Phase C .....T_3.......gate terminal 3 ......8 pin
Phase D ....T_4........gate terminal 4..... 7pin

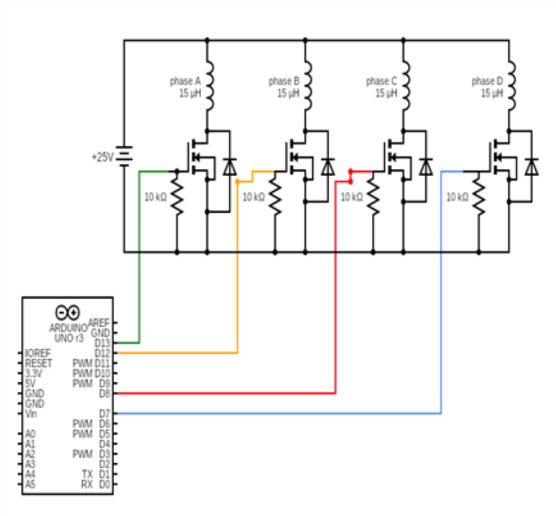

Fig 2: Circuit Diagram

Case 1: When switch T_1 is ON, the current passes through the phase A & A^1 and the coil will energized and the flux will release and it links to the rotor.

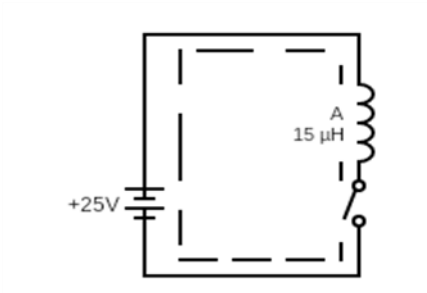

Fig 3: Phase A coil

Case 2: When switch T_2 is ON, the current passes through the phase B & B^1 and the coil will energize and the flux will release and it links to the rotor.

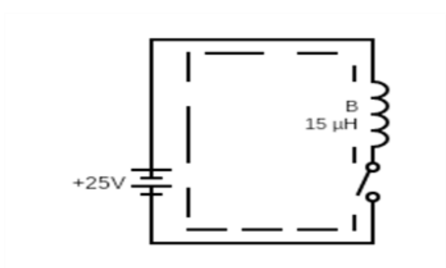

Fig 4: Phase B coil

Case 3: When switch T_3 is ON The current passes through the phase C & C^1 and the coil will energized and the flux will release and it links to the rotor.

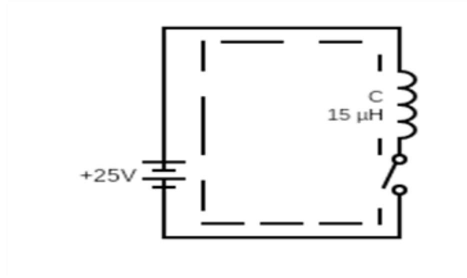

Fig 5: Phase C coil

Case 4: When switch T_4 is ON, the current passes through the phase D & D^1 and the coil will energized and the flux will release and it links to the rotor

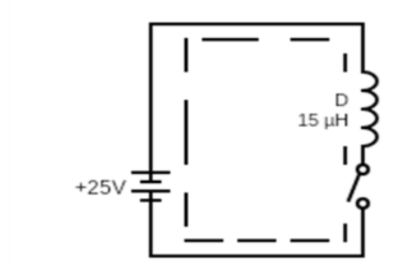

Fig 6: Phase D coil

Switched Reluctance Motor

I have used 8/6 Switched Reluctance Motor as a load. The rotor is made up of IRON material.

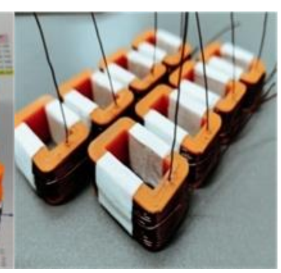

Fig 7 : SRM

Fig 8 : Stator coil

For Stator coil

$= 360 / 8$

$= 45^{o}$

For Rotor made coils

$= 360 / 6$

$= 60^{0}$

In stator we have eight coils so it has four phase named as A,B, C, D. I have demonstrate with help of 2A push button normally open and supply.

I have concluded that phase sequence of Switched reluctance motor is

A D C B .... Clock wise

A B C D .... counter Clock wise

Coil Resistance

DC resistance of a coil is the simplest parameter which can be measured approximately using a simple digital ohm meter or a DMM. For accurate measurement of low resistances however direct measurement is some time erroneous thus once shall.

verify this either by calculation using coil physical parameters (wire length, cross-sectional and resistivity) or by measurement of dc voltage drop across the coil for standard current (1, 10 or 100A) considering the capacity of the wire/ maximum rating of the coil.

We devised and used an indirect method for this measurement. The method is simple and effective as low coil resistances can be measured accurately using laboratory regulated power supplies RPS.

A current limiting resistance (R_1 = 1 KΩ) is used in series with the coil (Figure 9) so as to limit the current flow through RPS to safe limits. The dc voltage drop, across the coil, is recorded for different source voltages from 10-30V, in steps of 5Volts, refer Table 1. and R_2 is resistance of coil.

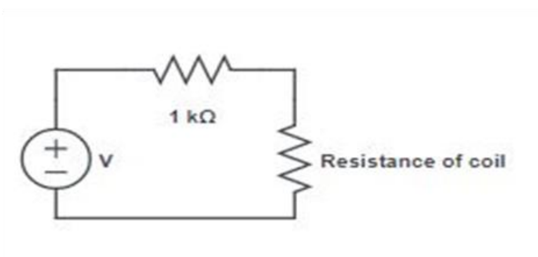

Fig 9: Measurement of coil resistance

By passing unknown (but permissible) current (I) through the circuit

$V = IR_1 + IR_2$ 1

By using the DM Meter, measure voltage drop across the coil.

IR_1 = voltage drop of the coil 2

supply voltage - voltage drop across coil and divide by resistor will give the current passing through the circuit by using above current in equation-2, we compute the resistance of coil (R_1)

Supply voltage (V)	Voltage drop across coil (mV)	Current (m A)	Resistance of coil R_1 (Ω)
10	0.009	9.991	0.9
15	0.014	14.986	0.934
20	0.018	19.982	0.9
25	0.023	24.977	0.92
30	0.029	29.971	0.967

Table 1: Voltage Drop measurements.

To minimize measurement error, we will take the average resistance

coil resistance = 0.924 Ω

Coil Inductance

Inductance of a coil is the indirect parameter which can be measured approximately using a simple digital meter.

A current limiting resistance (R = KΩ) is used in series with the coil so as to limit the current flow through RPS to safe limits. The dc voltage drop, across the coil, is recorded for different source voltages from 10-30V, in steps of 5Volts, refer Table 2 and R_2 = 0.92 Ω is resistance of coil and L be inductance of coil. Here we consider a ac voltage.

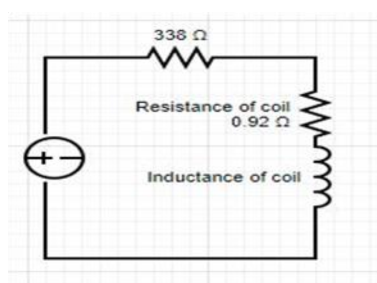

Fig 10: Measurement of coil Inductance

By considering the 60W lamp in lab

V = A.C Voltage source = 230
L = Inductance of coil
R = Resistance of coil = 0.92 Ω

Supply Voltage (V)	Current I (m A)	Voltage drop across coil (v)	Impedance Z	Reactance XL (Ω)	Inductance L (m H)
10	8	0.133	16.625	16.6	52.8
15	12	0.188	15.66	15.6	49.6
20	16	0.288	18	17.99	57.3
25	20	0.373	18.65	18.63	59.3
30	24	0.468	19.5	19.48	62.0

As we know that

$P = V^2/R$ 3

60 = 230 * 230 / R

R = 881 Ω

R = 881.66 is at the room temperature so according to ohms law should find at constant temperature.
considering equation
The resistance R of an object also varies with temperature

$R=R0(1+\alpha\Delta T)$....................4

where
R_0 the original resistance,
R is the resistance after the temperature change.
α is temperature coefficient

ΔT change in temperature
Therefore we consider
$\alpha = 0.00104$, $\Delta T= 400^oC$
R = 1250 Ω

From the above circuit
$Z = R_2 + j X_L$.........................5

By applying KVL to the circuit

$V = V_R + V_Z$ 6

for a maximum passing current in the circuit we will consider $V_Z = 0$

$V = V_R = IR$

V = I x 1250 I = V/1250

Then we will take voltage drop across coil ($Z = R_e + j X_L$) by using the Multi meter
voltage drop = I Z
$Z = R_2 + j X_L$
$R_2 = 0.92$ Ω
By using R_2 and Z we can find the X_L value then
$X_L = \omega L$
$= 2 \pi f L$ 7
From the above equation 7 we can find value of Inductance (L)

Table 2 : *Voltage Drop measurements*

To minimize measurement error, we will take the average Inductance

Inductance of coil = 56.2 m H

Speed Control

The speed control of Switched Reluctance Motor is mainly depends on the delay given by Arduino.

As we know that as delay decreases then speed increases. The delay can be changed by the help of potentiometer.

I have used a potentiometer 22 K Ω to demonstrate the speed of motor at different voltages and 100 ms time.

S No	Delay reference in volts	Time taken for 1 RPM sec
1	0.1	4
2	2.5	27
3	5	47

Table 3: Speed Measurement

Torque

In SRM, torque is produced by the variation of reluctance or permeance of air gap

$T = 1/2\ i^2\ dL(\Theta)/d\Theta$
where,

i = current passes through circuit
T = torque produced in machine
L= inductance value.

$dL(\Theta)/d\Theta$ = consider slope of the graph

L = 56.2 m H

dL = 56.2 + 56.2 = 112.4 m H

i = 2 A Θ = 12.5° or 0.2180 radian

Torque = 18 m N m

Switching Frequency

It is defined as the number of cycles or pulses per second.
To rotate a motor one RPM we are switch on and off 16 times.
For four phase For one phase

8....... switch ON 2........... switch ON 8......... switch OFF 2............switch OFF

we will switch ON 2 times then

Switching frequency of each switch is 2 Hz

Duty cycle

It is defined as the ratio of turn on time (T_{ON}) to total time (T).

Duty cycle = T_{ON} / T

For our switching device there are four phases
Let us consider each phase has 1 T_{ON} and 1 T_{OFF}
for 4 phase we have 4 T_{ON} and 4 T_{OFF}

Total time T = 4 T_{ON} + 4 T_{OFF}
when A phase ON after that 3 T_{ON} + 4 T_{OFF} only the A phase will ON .

% duty cycle = T_{ON} / T

= 1/ 8 * 100

= 12.5 %

Fabrication , Assembly & Testing

For a Switched Reluctance Motor I have calculated the values of Inductance and Admittance with help of high frequency LCR meter for different phase of coils

Fig 11: LCR Frequency meter

Table 4: Inductance and Admittance by LCR Frequency meter

S.No	Inductance mH	Admittance mS	Description
1	3.849	38.47	A phase coil
2	4.0	37.273	B phase coil
3	3.88	38.06	C phase coil
4	3.9263	37.547	D phase coil

Table: 5 Absolute maximum rating at 25° C

Voltage	24 V
Power	40.833 W
Air gap	2 mm
Rotor angle	24.5 deg
Rotor pole width	9.3 mm
Stator diameter	100 mm
Stator pole width	11.5 mm
Stack length	24.68 mm
Rotor diameter	60 mm
Number of turns per phase	100
Number of phases	4
Slot depth	10 mm
Flux density	0.4 Wb/m^2
Stator poles /Rotor poles	8/6

Table: 6 Electrical characteristics

Symbol	Parameter	Value	Unit
V_{DS}	Drain source voltage	55	V
V_{GS}	Gate source voltage	±20	V
I_D	Drain current	49	A
P_D	Power dissipation at 25^0C	94	W

T able 7: 8/6 SRM

Symbol	Parameter	Value	Unit
V_{DS}	Drain source voltage	55	V
V_{GS}	Gate source voltage	±20	V
I_D	Drain current	49	A
P_D	Power dissipation at 25^0C	94	W

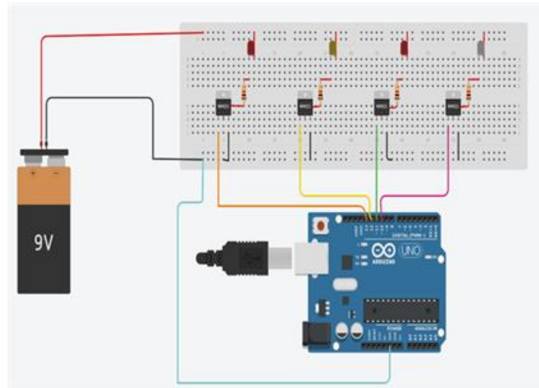

Fig 12: Demonstrate of circuit diagram

IRFZ44N type MOSFET is used as switching device

II. RESULTS

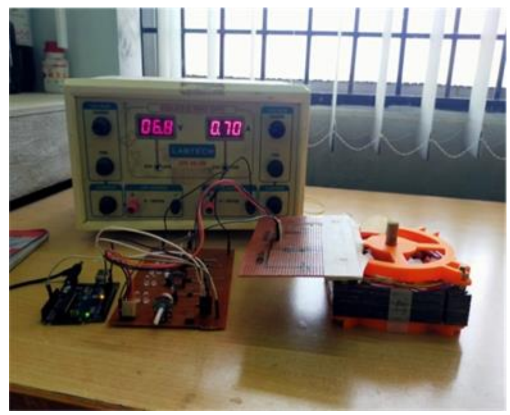
Fig 13: Demonstrated circuit diagram


Fig 14: load current vs time

The graph is observed from oscilloscope i.e current passes through switched reluctance motor . The above curve is because of freewheeling diode and below curve denotes the load current

CONCLUSION

I have design a power electronic controller to control the speed of Switched Reluctance Motor. The speed of the motor will depend upon the delay given by Arduino If we increase supply it makes noise which is main disadvantage to us.

FUTURE SCOPE

1. The power electronic controller can be made with the help of 8 switches which will give you more speed and low noise of the motor.
2. In my controller i have used then channel MOSFET it gives me some inaccurate result so by using a advanced switches we can improve performance of load.
3. I have made a rotor wit a iron material we can improve a motor performance by designing a rotor with CRGO ,Silicon material.
4. In future we use this total demonstrate in Electrical vechiles based system

REFERENCES

[1] Souvik Ganguli, "Analysis of C dump converter for Switched Reluctance Motor drive using Pspice", Trans of International Journal of Advanced Engineering Technology, vol-2, pp 331-335 , October 2011.

[2] Yong-Ho Yoon, Yuen-Chung Kim, Sang-Hoon Song, Chung-Yuen Won, "Control of C-dump converter fed from Switched Reluctance Motor on an Automotive Application ", Trans of Journal of Power Electronics,vol-5, pp 2, April 2005.

[3] Samia M.Mahmoud, Mohsen Z El-Sherif ," Studying Different Types of Power Converters Fed Switched Reluctance Motor", International Journal of Electronics and Electrical Engineering ,vol 1, pp 4 ,December 2013.

[4] Manikanta Swamy, Polamraju V S Sobhan, "Design and Implementation of C- dump converter for 8/6 Switched Reluctance Motor", Journal of Advanced Research in Dynamic and Control system, vol 9, pp 16, 2017.

[5] Jin-Woo Ahn, Jianing Liang, Dong-Hee Lee, " Classification and Analysis of Switched Reluctance Converters", Journal of Electrical Engineering and Technology , vol 5, pp 571-579 , 2010.

[6] Ayhan Ozdemir, Zekiye Erdem, Irfan Yanzici, "Study about SMPS Design and Reduction of Common Mode Noises", Trans of Journal vol 1 January 2009.

[7] Sinsu Kyoung, Eun Sik Jung, Ey Goo Kang, " A Study on Characteristic Improvement of IGBT with P-floating Layer", Journal of Electrical Engineering and Technology ,March 2014.

[8] Mahato G.C, Niranjan, Waquar Aarif Abu, "Analysis of IGBT Developments", International Journal of Engineering Research and Technology, vol 4 , 2016.

[9] Kuldeep Singh Kaswan, Santar Pal Singh, Shrddha Sagar, "Role of Arduino in Real World Application", International Journal of Scientific and Technology, vol 9 January 2010.

[10] T. J. E Miller, "Switched Reluctance Motors and Their Control," Oxford University press, 1993.

[11] R. Krishnan and P.N. Materu , "Design of a single –switch per phase converter for switched reluctance motor drives". Industrial electronics, IEEE transactions Volume: 37, pp. 469 – 476, 1990.

[12] Insulated Gate Bipolar Transistor (IGBT) Basics Abdus Sattar, IXYS Corporation 1 IXAN0063.

[13] R. Krishnan, "Switched Reluctance MotorDrives: Modeling, Simulation, Analysis, Design and Applications". Industrial Electronics Series, CRC Press, 2001.

[14] B. J. Baliga, "Power semiconductor devices", PWS Publishing Company, 1996.

[15] F. Faradjizadeh, R. Tavakoli, "Accumulator Capacitor Converter for Switched Reluctance Generator," vol.12,pp 1-9, Issue: 99, 2017.

[16] T. Wichert, "Design and construction modifications of switched reluctance machines," Ph.D. thesis, Warsaw University of Technology, 2008.

[17] T. J. E Miller, "Switched Reluctance Motors and Their Control," Oxford University press, 1993.