Open Loop Control of Switched Reluctance Motor Using Asymmetric Bridge Converter

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***Abstract*—Switched reluctance motor is popular for high speed industrial application environments. Its construction is rugged and robust and it is highly preferable than any other machines like induction motor, DC motor and any other conventional motor. To drive a switched reluctance motor we need a converter. Converter phase excitation is dependent on the position of rotor. Switched reluctance motor is popular for high speed industrial application environments. Its construction is rugged and robust. It is highly preferable than any other machines like induction motor, DC motor and any other conventional motor. To drive a switched reluctance motor we need a converter. Converter phase excitation is dependent on the position of rotor. The converter used in this paper is asymmetric bridge converter. The asymmetric bridge converter is one of the most popular converter. In this paper we see the comparative study of SRM using speed as a position sensor and theta as a position sensor. All work is done on MATLAB/Simulink software.**

***Index Terms*—Switched reluctance motor, Asymmetric bridge converter, Speed position sensing, Theta position sensing, Open loop control.**

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1. Introduction

Switched reluctance motor was discovered in the year 1838 by the scientist Davidson. It is a special electrical machine, neither AC nor DC machine, it is a special machine. It is doubly salient single excited machine. Number of phase of the motor decided by the number of stator poles on the machine [1]. The SRM has unique features compare to other motors such as induction motor, DC motor, etc. The advantages of SRM are as follows:-

1. Due to the absence of rotor winding and permanent magnets it is cheaper in cost.
2. It has simple construction.
3. It requires less number of power switches as bidirectional current not necessary.
4. As rotor winding is connected in series with converter switches; there is no shoot-through faults between the DC buses.
5. It is easier to cool.
6. Due to its higher self-inductance starting torque is very high.
7. It has higher efficiency.

The converter used to run the switched reluctance motor is asymmetric bridge converter. Asymmetric converter is the most popular and best performed converter. Each phase of this converter consists two switches and two diodes. Diodes in this circuit act as freewheel.

2. Switched Reluctance Motor

It is an electric motor that runs by reluctance torque. It doesn't contain any permanent magnets. The stator is similar to brushless dc motor hence rotor contain iron laminates. The iron rotor attracts towards the energized stator poles. Polarity of stator pole does not matter. Power is delivered to the windings in the stator rather than the rotor. Torque is produced as a result of attraction between electromagnet and rotor poles. Rotor form a magnetic circuit with energized stator pole. The reluctance of the magnetic circuit is similar to resistance in the electric circuit. Rotation of motor depends upon the reluctance torque produced in the circuitry. Reluctance of magnetic circuit decreases as rotor align with stator pole [2]. When rotor is in line with stator the gap between rotor and stator is very small. At this point reluctance is minimum. When reluctance is minimum; the magnitude of current in N turns also be minimum at constant flux and when reluctance is maximum the; magnitude of current in N turns also be maximum at constant flux. The switch reluctance motor is a singly excited motor in which both the rotor and stator have a salient poles. Only the stator poles carry windings and there is no winding on the rotor poles. Stator and rotor both are built up from stacks of steel laminations. One of the stator phase of the motor consist two series connected windings wound on diametrically opposite poles. The air gap between the stator and rotor is very small which makes the motor to operate in a saturated condition. The number of stator and rotor poles are selected in such a way that the motor can start and run in any direction. Figure 1 shows the 6/4 switched reluctance motor.

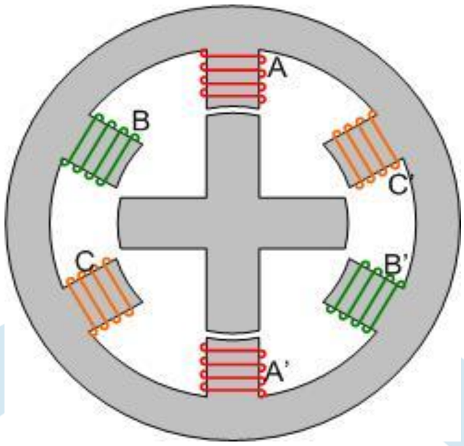

Fig. 1 Three phase 6/4 SRM

3. INDUCTANCE PROFILE

Inductance profile shows the turn-on and turn-off angle of the current. It has three region i.e., motoring region, constant region, generating region. When constant current flows through the phase winding, positive torque is generated and machine operates in increasing period that is motoring region. When inductance is decreasing, negative torque is generated and motor act as a generator. During constant region there is no inductance is generated because positive and negative torque is cancelled out and shaft torque become zero [3]. During this period rotor and stator are aligned to each other. Figure 2 shows the inductance profile.

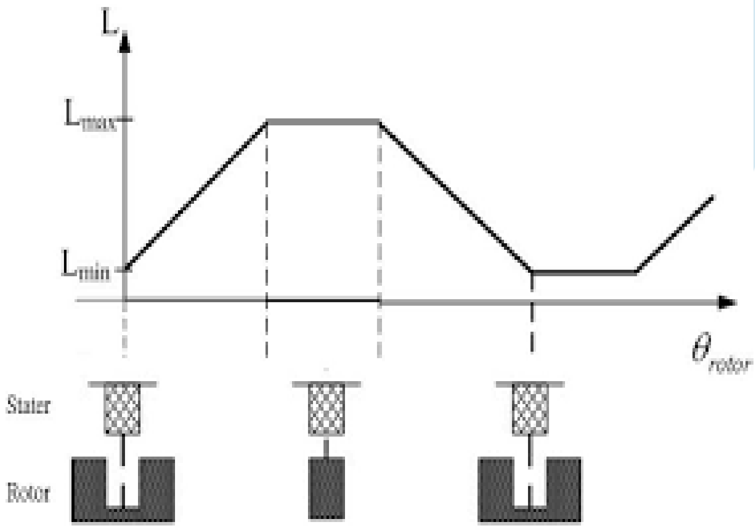

Fig.2 Inductance profile

4. CONVERTER CONFIGURATION

Switched reluctance drive have various advantages over conventional adjustable-speed ac and brushless dc drives. Firstly, shoot-through fault is impossible in converter because motor winding is always in series with each main power switching device. Secondly, independency between the phases. There is a little mutual inductance between the phases, but for practical purpose it is negligible. Due to the absence of mutual coupling each phase is electrically independent of other phase. This is very unique feature available only in this machine. Since the phases are independent therefore the fault in one phase doesn't effect on other phases.

For switched reluctance motor the converter topologies are not fixed till now, the research is going on. The various converter topologies are as:-

1. Asymmetric Converter
2. C-Dump Converter
3. R-Dump Converter

4. 3-level Converter
5. Miller Converter
6. Modified Miller Converter [4].

4.1 Asymmetric Bridge Converter

Asymmetric converter is the most popular and best performed converter. Each phase of this converter consists two switches and two diodes. Diodes in this circuit act as freewheel. Figure 3 shows the asymmetric bridge converter. During chopping period one main switch is turned on ant the other switch is turned off, the phase current will flow through the turn-on switch and freewheel diode. During commutation period the main switch is turned off and the current will flow through freewheel diode using stored magnetic energy in the motor [5].

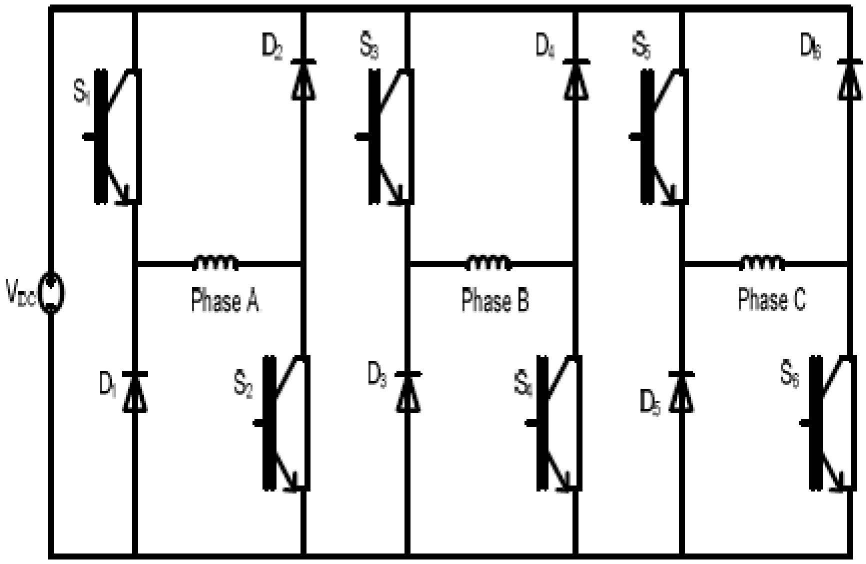

Fig.3 Asymmetric bridge converter

There are three modes of operation in asymmetric bridge converter:-

1. Magnetizing Mode.
2. Freewheeling Mode.
3. Demagnetization Mode.

Description of these modes of operation:-

1. Take one phase into consideration. When both the switches are turned on positive magnetizing voltage is applied and current rises rapidly in phase winding. This is magnetization mode. Figure 4 shows magnetizing mode.

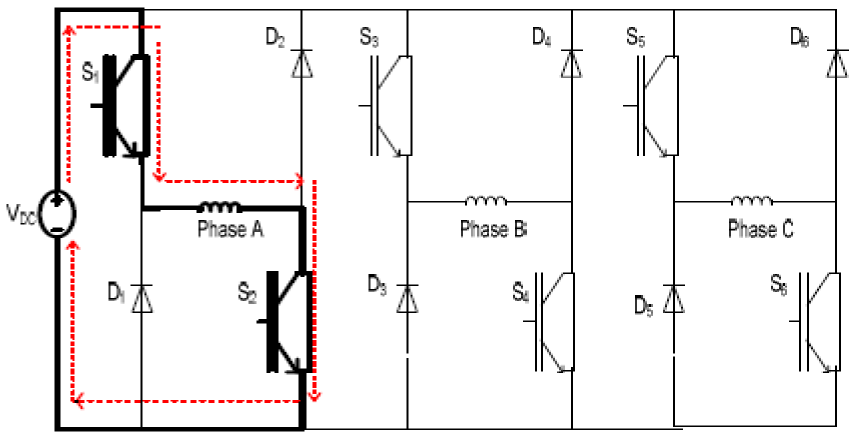

Fig.4 Magnetizing mode

2. If under low speed operation phase current will exceed its demanded value fast. During this period one switch is turned off and current circulates through the other switch and one diode. There is no energy transfer between phase winding and DC source. This operation is called freewheeling mode, which applies a low demagnetizing voltage to the phase winding. Figure 5 shows freewheeling mode.

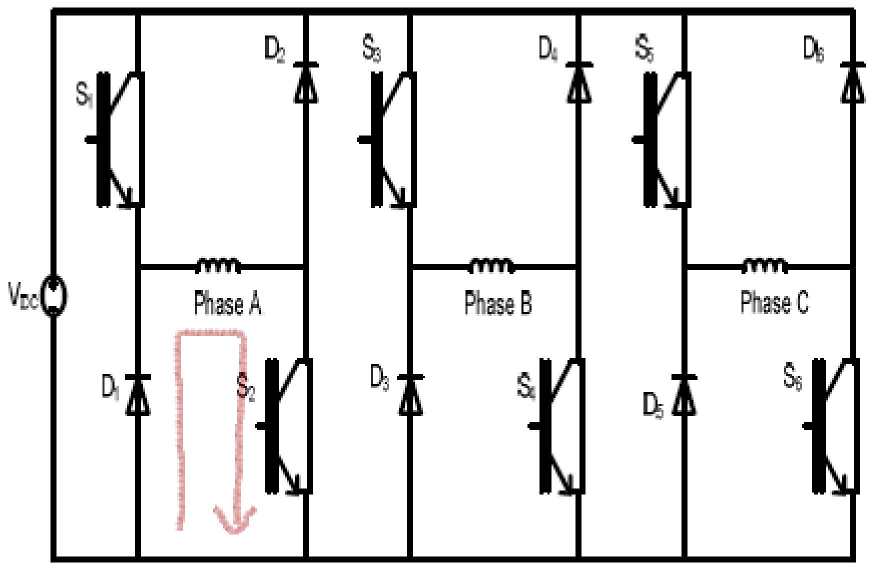

Fig.5 Freewheeling mode

3. When both the switches are turned off, winding current circulates through two diodes and recharge the capacitor. This is demagnetization mode. This mode is much faster than freewheeling mode. Figure 6 shows demagnetizing mode [6].

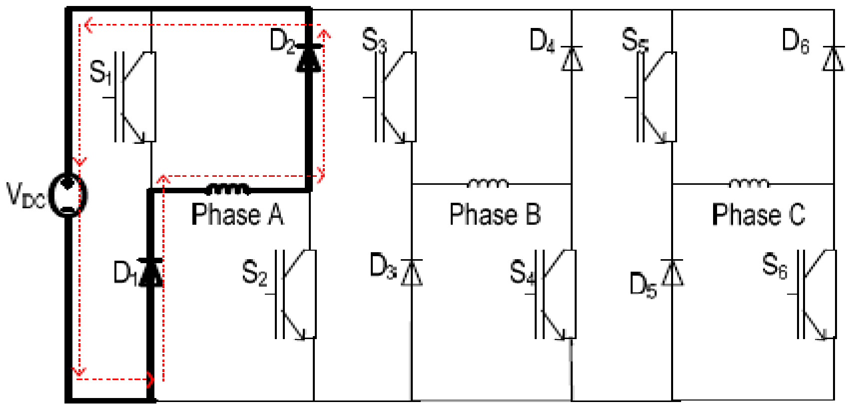

Fig.6 Demagnetizing mode

4.2 Merits and Demerits

Merits

1. It is ideal for high performance current and torque control.
2. Has great flexibility in controlling machine current.
3. Has very good performance.
4. Controlling is simple.
5. Capable of positive, negative and zero voltage control.
6. Phase impedance is complete.
7. There is no need of external circuitry for completing its performance.
8. Higher efficiency.

Demerits

1. High switching losses.
2. Larger heat sinks.
3. Not suitable for high performance applications.
4. Device rating is lower [6].

5. PHASE ACTIVATION THROUGH THETA AND SPEED SENSING POSITION SENSOR

Fig 7 shows the position sensor block using theta sensing. The output of the theta is continously increasing with time. The theta is first converted from rad to degree. Then this signal is modulus with angle which is reset from 0 to 360 degree, and divide with 360^0. Again the signal is divided by 90^0 with the phase shift of 0^0, -30^0, -60^0. It is divided by 90^0 because for compliting one cycle rotor has to shift by 90^0. Then this signal goes to modulus operator where theta is compare with turn-on and turn-off angle. If theta equals to turn-on angle then switch Q1 and Q2 turns on. If theta equals to turn-off angle then switch Q1 and Q2 turns off i.e, $-V_s$. This output goes to AND operator then the ouput of the gate pulse trigger the switch [7].

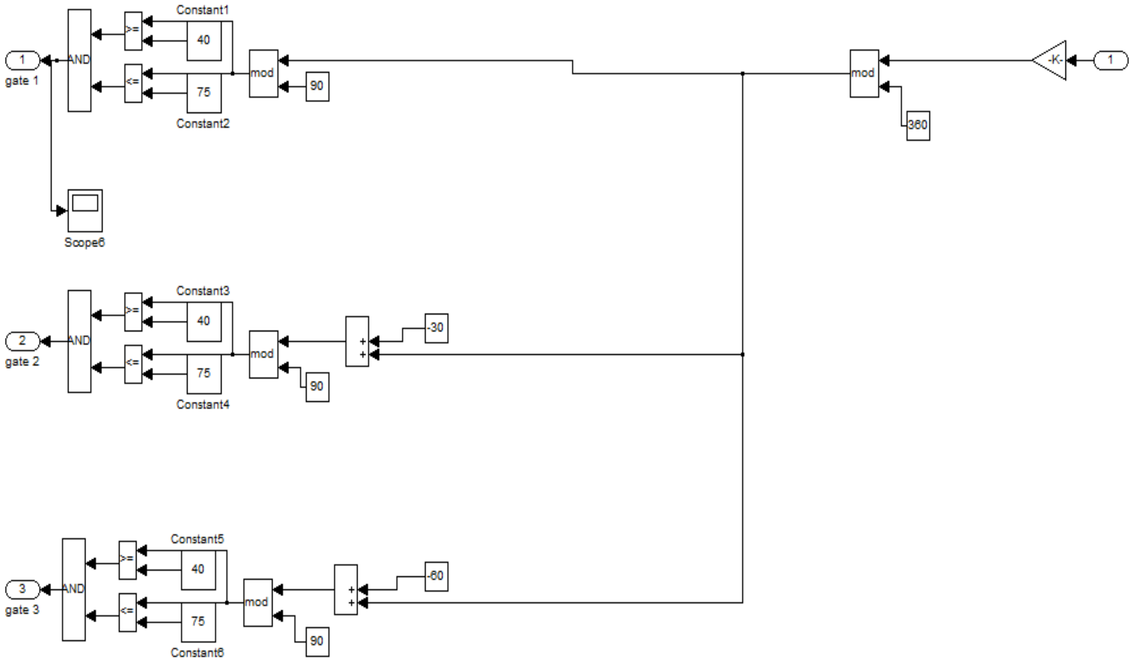

Fig.7 Position sensor using theta sensing

Figure 8 shows the postion sensor using speed sensing. The output of the speed is continously incresing with time. Speed is first converted from radian/sec to rpm. In this position sensor in place of using various blocks we are using discrete time integrator to minimize the subsytem [9]. The use of discrete time integrator helps to avoid the the blocks of phase shifting. Discrete time integrator in matlab is shown in figure 9.

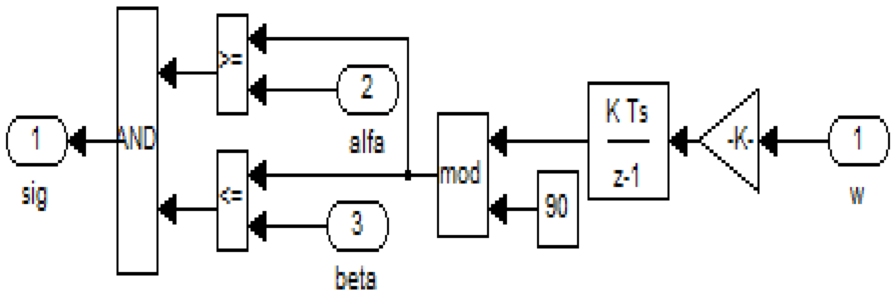

Fig.8 Positon sensor using speed sensing

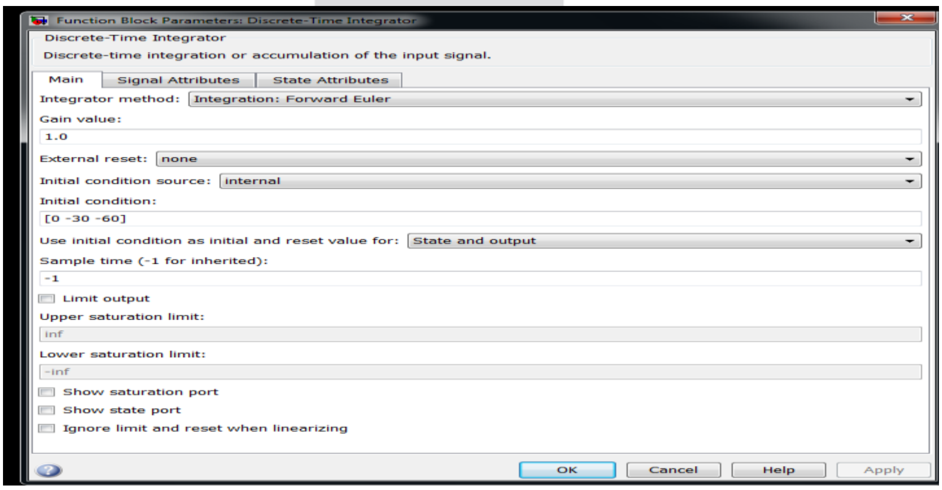

Fig. 9 Discrete time integrator

6. SIMULATION MODEL

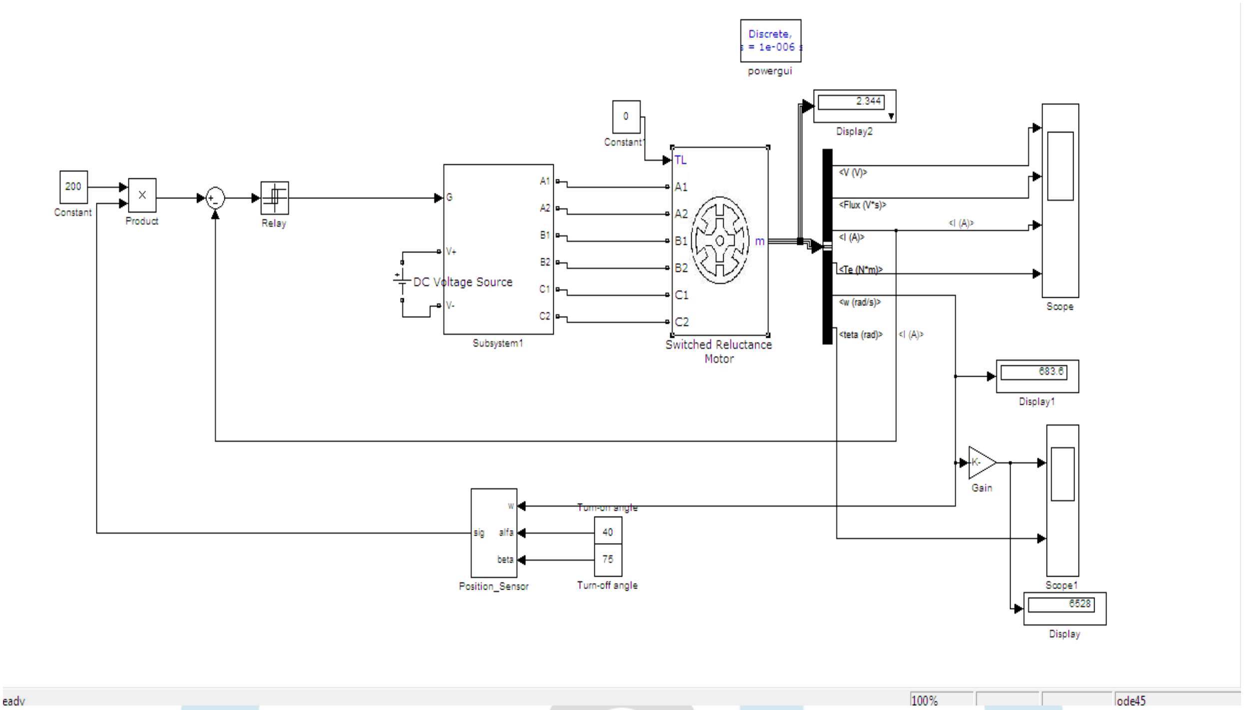

Fig. 10 Simulation model using speed as a position sensor

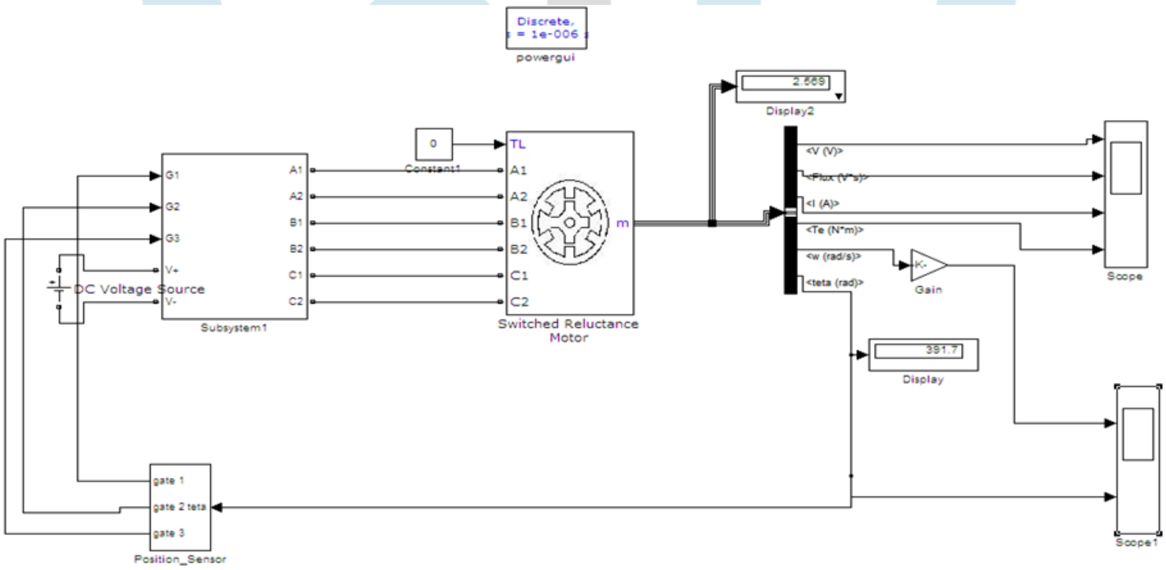

Fig. 11 Simulation model using theta as a position sensor

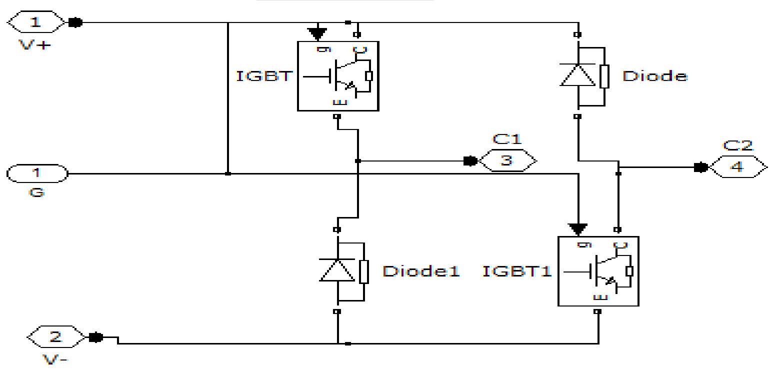

Fig. 12 Subsystem of converter

7. SPECIFICATION OF MODEL

PARAMETERS	VALUES	UNITS
Supply	240	Volts
No. of stator poles	6	Nos
No. of rotor poles	4	Nos
Phases	3	Nos
Moment of inertia	0.05	Kg.m.m
Stator resistance	0.05	Ohm
Friction	0.02	N.m.s
Unaligned inductance	0.67e-3	H
Aligned inductance	23.6e-3	H
Saturated aligned inductance	0.15e-3	H
Max. current	450	A
Max. flux linkage	0.486	Vs

8. SIMULATION RESULT

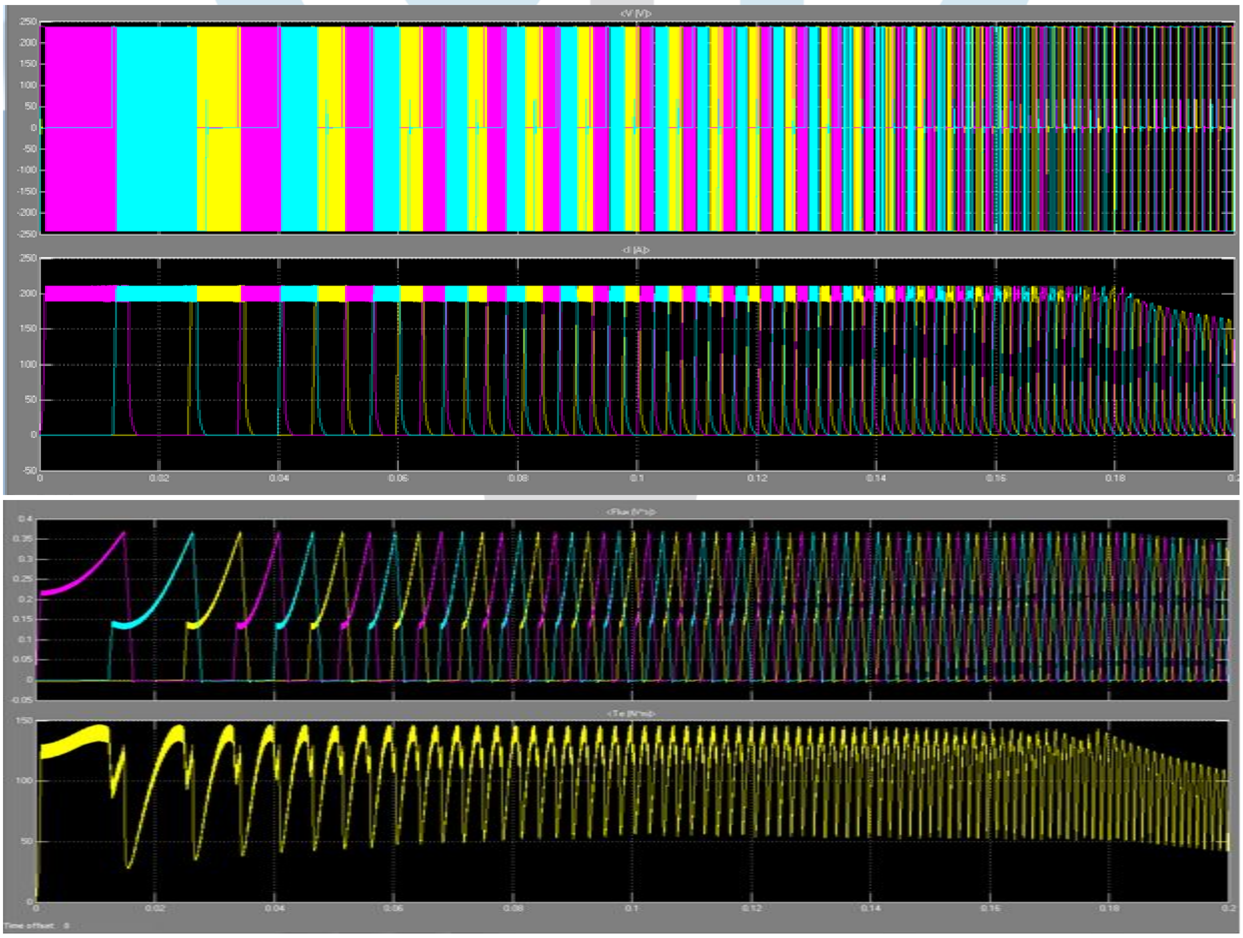

Fig. 13 Voltage, Current, Flux and Torque waveform using speed as position sensor

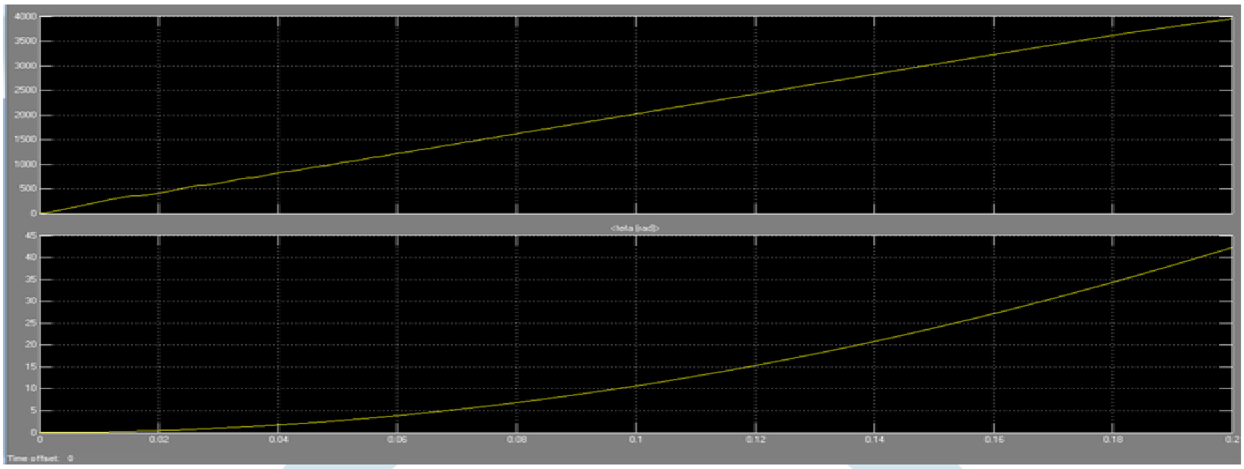

Fig. 14 Speed and theta waveform using speed as a waveform

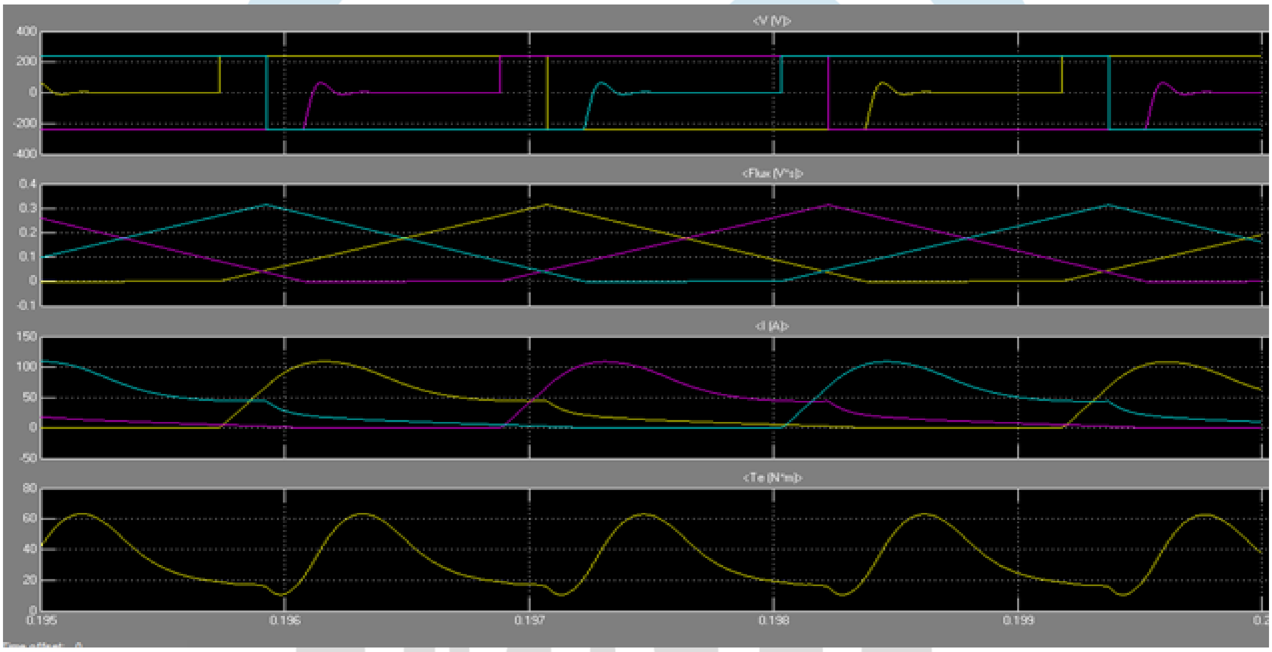

Fig. 15 Voltage, Current, Flux and Torque waveform using theta as position sensor

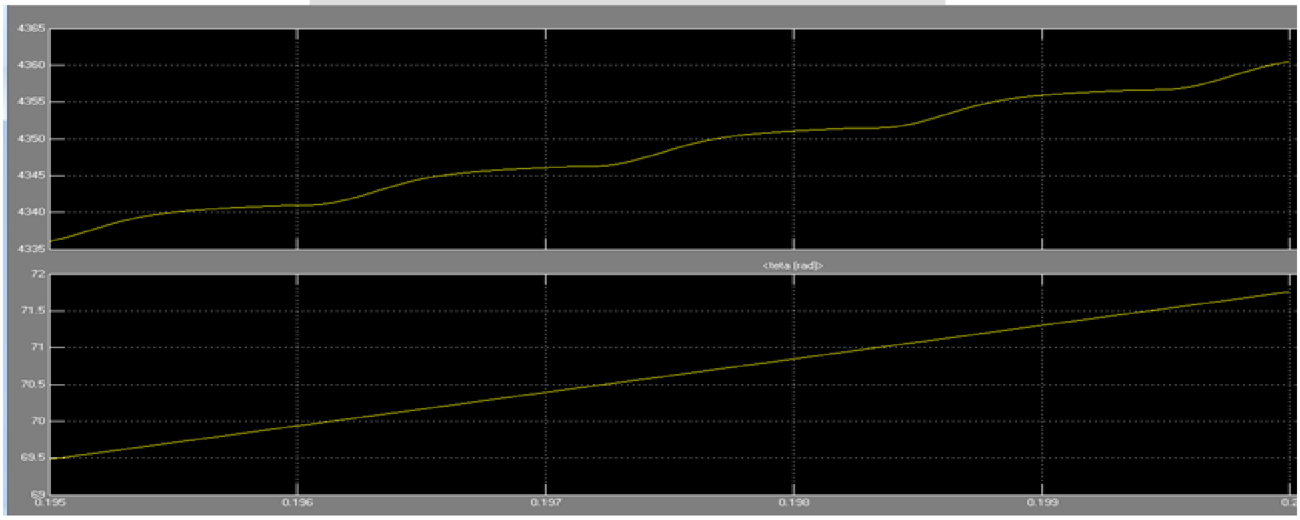

Fig. 16 Speed and Theta waveform using theta as a position sensor

9. CONCLUSION

The performance of new topology asymmetric bridge converter has been explained in this paper. The switched reluctance motor use this topology to run a motor. As we know switched reluctance motor always need a converter to run a motor. In this paper we are comparing the open loop control of switched reluctance motor using speed as a gate pulse and theta as a gate pulse. From the output waveform of the speed as a gate pulse and theta as a gate pulse we conclude that, speed as a gate pulse is more preferable than the theta as gate pulse. The fluctuation that we have seen in the speed waveform of theta as a gate pulse is overcome in speed as a gate pulse. Repletion of the torque is also overcome in speed as a gate pulse. The comparative table of the speed as gate pulse and theta as a gate pulse is shown below:

S. No.	Parameters	Speed as a gate pulse	Theta as a gate pulse
1.	Speed	4000 rpm	4361 rpm
2.	Theta	42.5 rad	71.55 rad
3.	Max. Voltage	200 V	210 V
4.	Max. Current	200 A	105 A
5.	Max. Flux	0.35 Vs	0.31 Vs
6.	Max. Torque	150 Nm	62 Nm

10. REFERENCES

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