Speed Control of Switched Reluctance Motor

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Abstract – Recently Switched Reluctance Motors are suitable for replacing the other conventional motors like DC motor, Induction motor mainly because of low cost, improved efficiency of motor, and variable speeds. This paper uses MATLAB/SIMULINK to demonstrate the simulation of SRM speed control. MATLAB/SIMULINK is used to simulate the speed control of a 6/4 SRM. The 6 stator slots and 4 rotor poles are driven by an asymmetric bridge converter. Hardware implementation of SRM is performed for both open loop and closed loop condition.

Key Words: *Asymmetric bridge converter, Switched Reluctance Motor, PID controller.*

Fig.1. Construction of SRM [2]

1. INTRODUCTION

Switched Reluctance Motor (SRM) is being used from the year 1938. Limited utilization of SRM is mainly due to the absence of power electronic components in the earlier days. Development of power electronic components used to boost all the motor drives [1-2]. SRM is also known as variable reluctance motor. SRM is rugged, simple to construct, economical and exhibits fault tolerant capability as compared to induction motor and synchronous motor. High peak torque to inertia ratio is exhibited by SRM. The mechanical structure of the rotor is suitable for high-speed applications, electric vehicles and in various industries [3]. Due to the non-linear behavior of SRM, it is not that easy to control. SRM is highly suitable for application that involves very high-speed operation mainly due to its robust nature. The construction of SRM is as shown in Fig.1 [1,4].
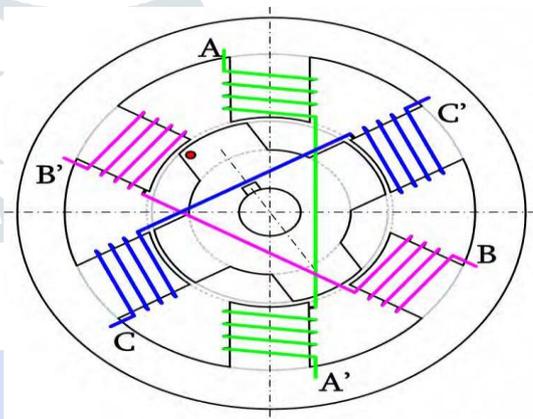
The salient poles with concentrated windings are present on rotor and stator poles. The feature that stands SRM apart from other motors is the absence of winding on rotor [5-7]. The block diagram of speed control of SRM is as shown in the Fig.2. The number of stator slots and number of rotor slots differs based on the applications. Normally used SRMs having number of stator slots and number of rotor poles are 6/4 or 8/6 or 10/8 or 12/10 respectively. The number of stator and rotor slots is not recommended to be same. Here, 6 stator slots and 4 rotor slots are used for simulation i.e, 6/4 SRM. An asymmetric bridge with 3 phase bridge rectifier is used to keep the output voltage regulated [8-10].
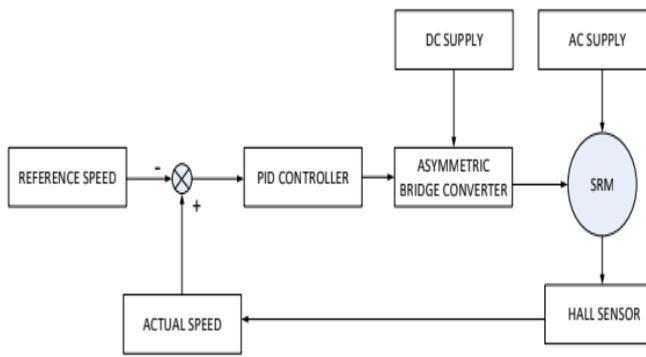
Fig.2. Block Diagram of Speed Control of SRM

2. PROPOSED CONFIGURATION

The asymmetric bridge converter is used to provide fast excitation current. So, high switching voltage is therefore necessary. Fig.3 shows the circuit diagram of asymmetric bridge converter for 3-phase drive of SRM [4]. Strategy of unipolar switching is incorporated in the converter. For each phase or leg of the converter, there are two power switches and two diodes. The upper switch is used to switch control of PWM in each phase or leg, and the bottom switches are used to charge commutation. So, every phase is controlled independently. Magnetization, freewheeling, and demagnetization modes of operation are the various operating conditions. The inner current control loop of the drive system uses the unipolar switching method to reduce current ripple and improve frequency response. Table 1 represents the parameters considered for simulation of speed control of SRM [1].
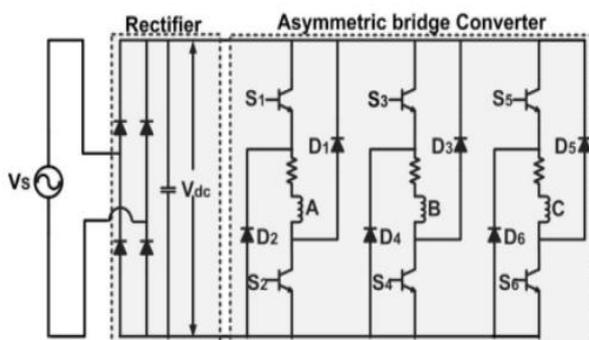

Fig.3. Asymmetric bridge converter

Table 1: Parameters considered for simulation of speed control of SRM

Motor parameters	Values
Rated Power	60kW
Number of phases	3
Number of stator poles	6
Number of rotor poles	4
Aligned phase inductance	23.6mH
Unaligned phase inductance	0.67mH
Inertia	0.05kg.m
Stator resistance	0.05Ω
DC Voltage supply	240 V
Inductor	1mH

4. SIMULATION RESULTS

The simulation of speed control of SRM is performed using MATLAB/SIMULINK software. The supply voltage that is applied to the circuit is 240VDC. The turn-on angle and turn-off angle supplied to the converter is 45º and 75º respectively. The specifications for speed control of SRM are as shown in the Table 1. The reference speed is considered as 1500rpm. The converter used for simulation is an asymmetric bridge converter. Position sensor is mainly used to gather all the physical data from the motor and converts them into electrical input signals to the system. They measure the distance of object or body from a particular position from the reference point.

Speed control using P controller:

Proportional controller is a type of control system that operates in the direction of a line or linear and acts as a correction element between the measured value and the reference value. An error is generated by the comparison of actual and the reference value [5]. The error input supplied to the circuit is

$$u = K_P * e(t)$$

For the steady state error to be improved, a large gain is necessary. A proportional controller is therefore employed. The value of K_p is used by tuning method. The value of K_p used in the simulation circuit is 50.

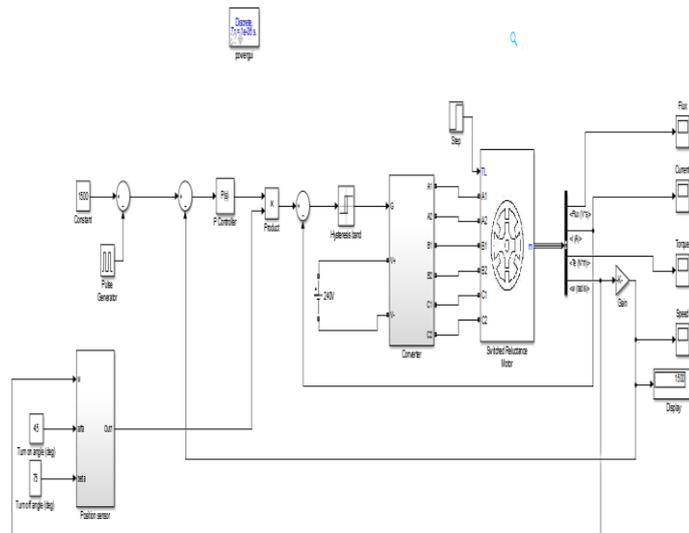Simulation of speed control of SRM for P controller is as depicted in Fig 4.

Fig.4 Speed Control of SRM using P Controller

Speed control using PI controller:

Proportional integral controllers are also known as proportional in conjunction with integral control. Proportional integral is used to reduce error between the measured value and the reference value by varying the value of input supplied to the circuit. PI controller is a combination of both proportional control and the integral control. Speed control of SRM using PI controller is simple, implementation is easier, low cost, less error in the steady state condition and highly robust [5].

The error input supplied to the circuit is

$$u = K_P * e(t) + K_i * \int e(t)\, dt$$

The tuning procedure is used to determine Kp and Ki values. The simulation circuit uses Kp and Ki values of 50 and 0.1, respectively. Fig. 5 depicts the

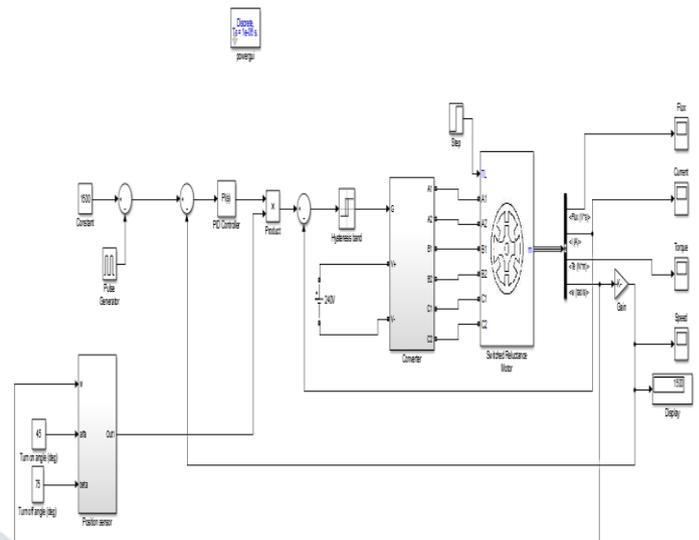simulation of SRM speed control for PI controller.

Fig.5 Speed Control of SRM using PI Controller

Speed control using PID controller:

Proportional Integral Differential Controller is a closed loop system that is commonly used in most of the industrial and other applications. The error that is generated is reduced in spite of increase in gain [5]. The error input supplied to the circuit is

$$u = K_P * e(t) + K_i * \int e(t)\, dt + K_d * \frac{de(t)}{dt}$$

The tuning procedure is used to determine the values of K_p, K_i, and K_d. The simulated circuit uses K_p, K_i, and K_d values of 20, 0.1, and 0.05, respectively. Fig. 6 depicts the simulation of SRM speed control for PID controller. The tuning method is often used to get the values of Kp, Ki, and Kd. Kp, Ki, and Kd values are

Proportional controller, $K_P = 50$

Proportional Integral controller, $K_P = 50$, $K_i = 0.1$

Proportional Integral Differential controller, $K_P = 20$, $K_i = 0.1$, $K_d = 0.05$
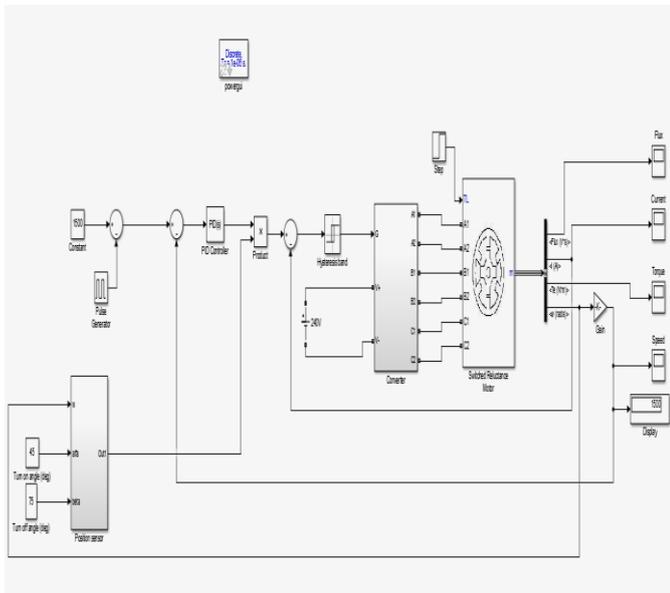
Fig.6 Speed Control of SRM using PID Controller

The simulation results for the simulation of speed control of SRM for P controller is as shown in Fig 7 and the waveform is same for PI and PID controller.
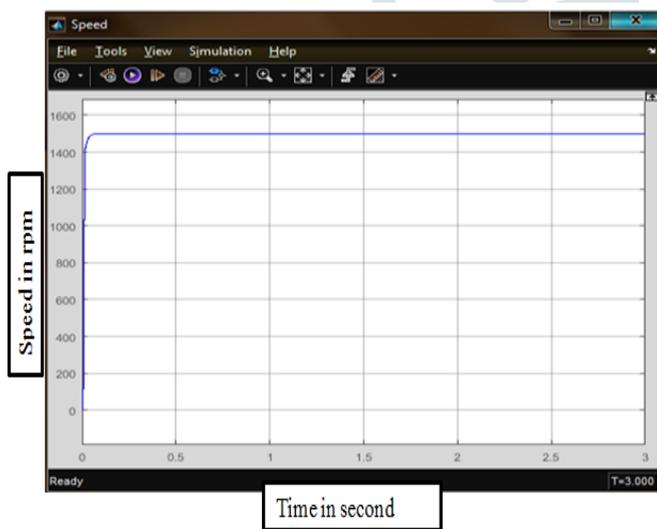

Fig.7 A plot of Speed using P controller with $K_P = 50$ and reference speed = 1500rpm

Simulation results for speed control of SRM using PID controller is as shown in Table 2.

Table2 Simulation results for speed control of SRM using PID controller

		Reference speed in rpm	Actual speed in rpm
P controller	$K_p = 50$	1500	1500
	$K_p = 40$	1500	1500
	$K_p = 30$	1500	1500
PI controller	$K_p = 50$, $K_i = 0.01$	1500	1500
	$K_p = 40$, $K_i = 0.01$	1500	1500
	$K_p = 30$, $K_i = 0.2$	1500	1500
PID controller	$K_p = 20$, $K_i = 0.1$, $K_d = 0.05$	1500	1500
	$K_p = 30$, $K_i = 0.01$, $K_d = 0.5$	1500	1500
	$K_p = 40$, $K_i = 0.2$, $K_d = 0.04$	1500	1500

The hardware for speed control of SRM is performed for 8/6 SRM with 8 stator poles and 6 rotor poles for 1 kW motor. The hardware is implemented for both open loop and closed loop condition. For open loop condition the reference speed is maintained at 1500 rpm and the measured value is 1428rpm at 200VAC. Under closed loop condition, here also the reference speed is maintained at 1500rpm and the measured speed is 1460rpm for 210VAC. Since it is under closed loop condition the PID controller provides 1460rpm as the output speed under both no-load and full load conditions. Hardware results for speed control of SRM is as shown in Table 3.

Table 3: Hardware results for speed control of SRM

AC voltage (V)	Reference speed (rpm)	Simulation result of speed in rpm	Measured speed (rpm) Open loop	Measures speed (rpm) Closed loop
31	1500	1500	186.1	1417
50	1500	1500	256.8	1423
70	1500	1500	402.5	1446
90	1500	1500	754	1442
110	1500	1500	987.5	1452
130	1500	1500	1287.6	1454
150	1500	1500	1428	1460

5. CONCLUSION

MATLAB/SIMULINK is used to simulate the speed control SRM. An asymmetric bridge converter powers the 4 rotor poles and 6 stator slots. So, the construction is simple and speed control is easy. Based on the PID values the output speed that is obtained is same as the reference speed. Hardware implementation of SRM is performed for both open loop and closed loop condition and the measured

speed is almost same as the reference speed. The future scope of the project is

- The issues related to SRM can be solved to provide solutions with reasonable cost and performance since the cost of SRM is very high.

- Design of the motor with speed – torque performance for applications with higher efficiency and less size.

- Controller design of SRM is more complex as compared to other motors due to the dependency of torque developed on the rotor angle.

- Elimination of mechanical position sensor that reduces size of motor and cost so the reliability of system can be improved.

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