Automatic Control of Turn on Position Control of Switched Reluctance Motor

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***Abstract**: This paper present a new approach to the automatic control of the turn-on angle used excite the switched reluctance motor (SRM). Switched reluctance motor output can be varied simply by controlling the switching angles. Such control flexibility however tends to increase considerably the magnitude of the motor design tuning process. In attempting to reduce the amount of design calculation, it is very desirable to be able to define before the design process is started the rated operating condition of a switched reluctance drive in terms of set of switching angles A closed form turn on angle equation based on linear SRM model is introduced. The control of SRM is implemented in Matlab. Simulation result is found to be is accordance to theory.*

Keywords – switched, reluctance motor, Matlab, performance analysis, switching angle, simulation, turn-on angle, inductance unaligned.

1. INTRODUCTION

A Switched Reluctance Motor (SRM) is a rotating electric machine where both stator and rotor have salient poles. The stator winding is comprised of a set of coils, each of which is wound on one pole. SRM motors differ in the number of phases wound on the stator. Each of them has a certain number of suitable combinations of stator and rotor poles.

The motor is excited by a sequence of current pulses applied at each phase. The individual phases are consequently excited, forcing the motor to rotate. The

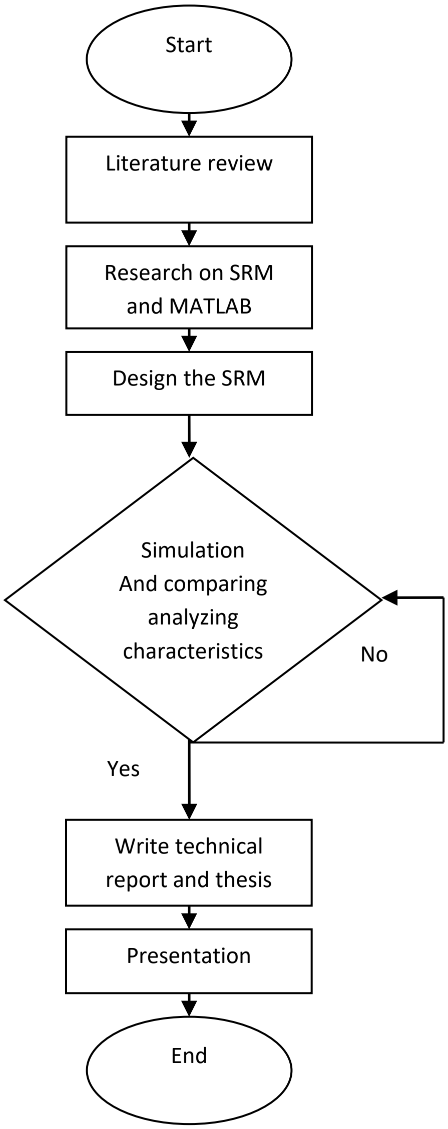
current pulses need to be applied to the respective phase at the exact rotor position relative to the excited phase. The inductance profile of SRM is triangular shaped, with maximum inductance when it is in an aligned position and minimum inductance when unaligned. When the voltage is applied to the stator phase, the motor creates torque in the direction of increasing inductance. When the phase is energized in its minimum inductance position; the rotor moves to the forthcoming position of maximal inductance. The profile of the phase current together with the magnetization characteristics defines the generated torque and thus the speed of the motor.

The SRM requires control electronic for its operation. Several power stage topologies are being implemented, according to the number of motor phases and the desired control algorithm. A power stage with two independent power switches per motor phase is the most used topology. This particular topology of SRM power stage is fault tolerant -- in contrast to power stages of AC induction motors -- because it eliminates the possibility of a rail-to-rail short circuit.

The SRM requires position feedback for motor phase commutation. In many cases, this requirement is addressed by using position sensors, like encoders, Hall sensors, etc. The result is that the implementation of mechanical sensors increases costs and decreases system reliability. Traditionally, developers of motion control products have attempted to lower system costs by reducing the number of sensors. A variety of algorithms for sensor less control have been developed, most of which involve evaluation of the variation of magnetic circuit parameters that are dependent on the rotor position.
In this project, the scope of work is to develop the switched reluctance motor using the Matlab simulation. The problems of starting with single phase machines can be overcome by stepping the air gap, or providing asymmetry in the rotor poles. This machine may be of the where the cost the winding connections are important.

2. METHODOLOGY

This project consist software parts only and there're will be no hardware implementations. By the reason, this project includes the design and simulation the switched reluctance motor by using the Matlab simulation as simulink module. Below is the methodology during developing this project.



3. AUTOMATIC CONTROL OF THE TURN-ON ANGLE

The objectives of this project are best explained through consideration of the linear inductance profile for the SRM. In motoring operation, the turn-on angle is selected so that the phase current acquires its reference value on an angle, that the stator and rotor poles start to overlap and the inductance raises.

If one were to examine the static torque curve for a typical SRM as showed figure 1, it would be observed that the maximum torque for a given amount of current occurs as the rotor begins to move out of the minimum inductance position. This observation suggests that maximum torque per ampere is produced upon leaving the minimum inductance position.

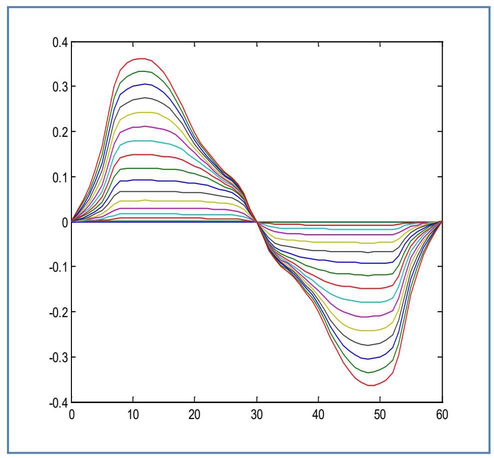


Figure 1: static torque versus position curves

In applications where average torque is of primary importance, it is important to make the most of the region near the unaligned position. Because it takes time to build the phase currents, we must anticipate the arrival of the torque production region. We must therefore turn on the phase windings before the angle marked θm in figure 2 so that the current is at reference current when the rotor reaches θm.

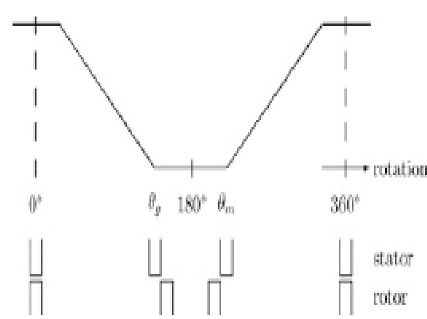


Figure2: Linear inductance profile of the SRM showing θg and θm

The turn-on advanced angle, α with reference to the unaligned axis using linear inductance profile can be derived as.

$$\alpha = \left(L_u \omega / V\right)\left(\mathrm{I_m}\right) - \left(\Omega_q / 2\right) \quad \text{...eqn (3.1)}$$

Where:

L_u is inductance at the unaligned position,
V is the dc supply voltage,
ω is the motor speed,
Ω_q is the constant inductance region around the unaligned rotor position
I_m is the reference current and the chopping level.

Equation (3.1) assumes that the inductance is constant during the region [θg, θm]. The inductance can be a function of the phase current, rotor position and temperature. At low speed, this method can give reasonable performance unless α becomes less than θg. For operation over a wide speed range, starts to break down as back emf voltage becomes more prominent. It is desired to have closed loop control that provides the turn-on angle making first peak of the phase current at um without the need of accurate motor parameters and measurement of the dc bus voltage. The proposed closed loop control algorithm continuously monitors the position of the first peak of the phase current (θp). The turn-on is advanced or retarded automatically according to the error between θp and θm. This piece of the controller successfully places up at θm. Above base speed, the peak current naturally tends to occur near θm. At these speeds, α has little impact on θp but significant impact on the magnitude of the current at θp.

4. RESULTS

To get the result, the automatic control of the turn-on angle of SRM programming has been design by the MATLAB module. From the programming of Matlab, the result of this project can be seen below. Figure 4 showed the constant mean torque have achieved when the operation of SRM under PWM current conditions.

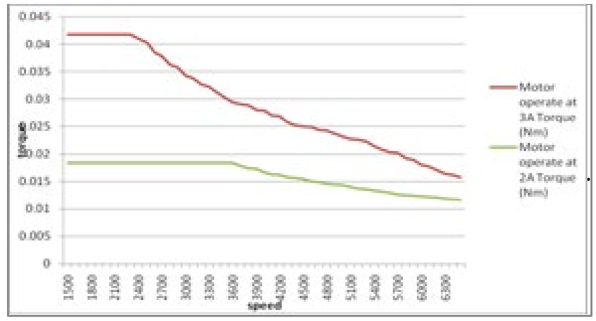


Figure 3: constant mean torque vs. speed

From the figure 3, showed the constant mean torque have achieved when the operation of SRM under PWM current conditions. The constant mean torque can be achieved during the rising inductance period. It can be seen, the constant mean torque can be maintained until reach a something value of speed and will decreased. When the SRM operated at 3 A, the torque will decrease when it reach at the speed 2300 rpm meanwhile the SRM operated at 2 A, the toque will decrease when reach at speed 3600 rpm.

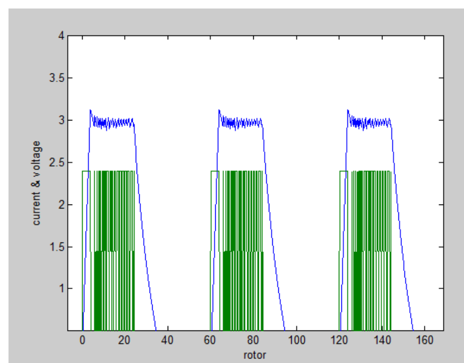


Figure 4: current and voltage at 1500 rpm and 3A

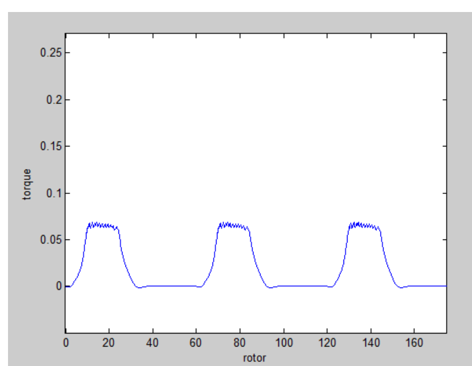


Figure 5: torque at 1500 rpm and 3A

From the figure 4 and 5, the automatic control turn on of the SRM are operated at 1500 rpm with rated current of 3A. At this speed, the peak current is 3.1195A and r.m.s current is 1.9231A. It also shows the value of average torque is 0.0418Nm and average power is 6.9968W can be achieved. The turn on angle for this condition is 2.1207°.

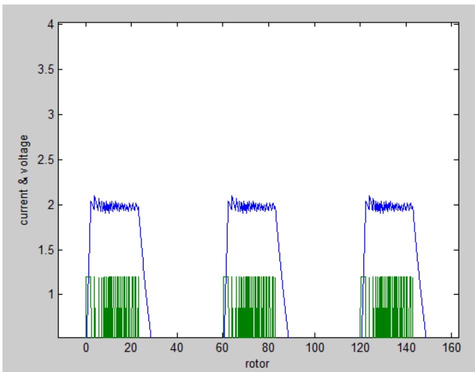


Figure 6: current and voltage at 1500 rpm and 2A

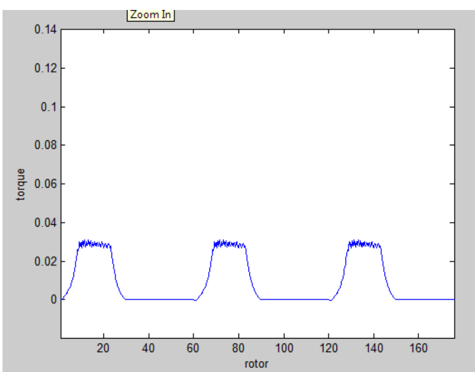


Figure 7: torque at 1500 rpm and 2A

From the figure 6 and 7, the automatic control turn on of the SRM are operated at 1500 rpm with rated current of 2A. At this speed, the peak current is 2.0887A and r.m.s current is 1.2464A. It also shows the value of average torque is 0.0184 Nm and average power is 2.8313 W can be achieved. The turn on angle for this condition is 1.0805°.

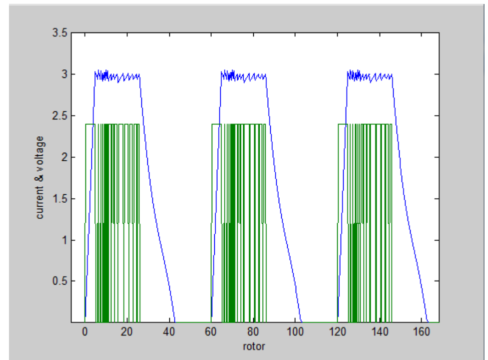


Figure 8: current and voltage at 2000 rpm and 3A

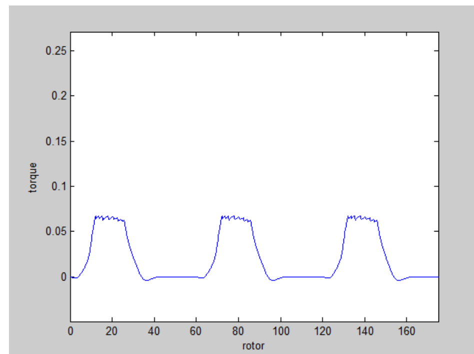


Figure 9: torque at 2000 rpm and 3A

From the figure 8 and 9, the operation of automatic control turn on angle of the SRM at 2000 rpm with rated current of 3A. At this speed, the peak current is 3.0551A and r.m.s current is 1.9839A. It also shows the value of average torque is 0.0418 Nm and average is 10.5786 W can be achieved. The turn on angle for this condition is 3.161°.

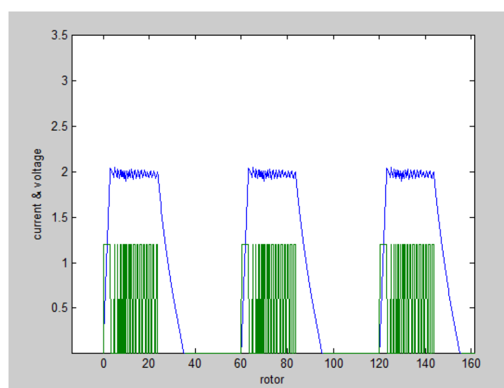


Figure 10: current and voltage at 2000 rpm and 2A

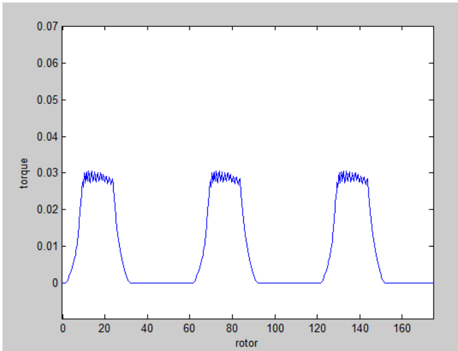


Figure 11: torque at 2000 rpm and 2A

From the figure 10 and 11, the operation of automatic control turn on angle of the SRM at 2000 rpm with rated current of 2A. At this speed, the peak current is 2.0343A and r.m.s current is 1.2652A. It also shows the value of average torque is 0.0184 Nm and average is 3.8492 W can be achieved. The turn on angle for this condition is 1.774°.

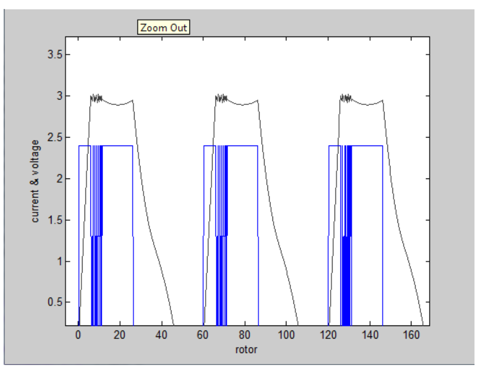


Figure 12: current and voltage at 2500 rpm and 3A

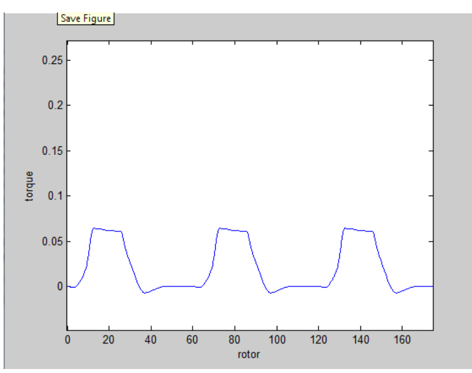


Figure 13: torque at 2500 rpm and 3A

From the figure 12 and 13, the operation of automatic control turn on angle of the SRM at 2500 rpm with rated current of 3A. At this speed, the peak current is 3.0368A and r.m.s current is 1.9054A. It also shows the value of average torque is 0.0404 Nm and average is 10.687 W can be achieved. The turn on angle for this condition is 4.2013°.

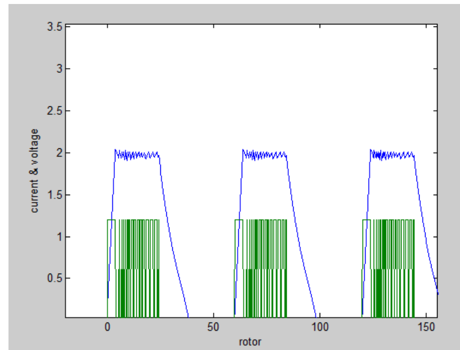


Figure 14: current and voltage at 2500 rpm and 2A

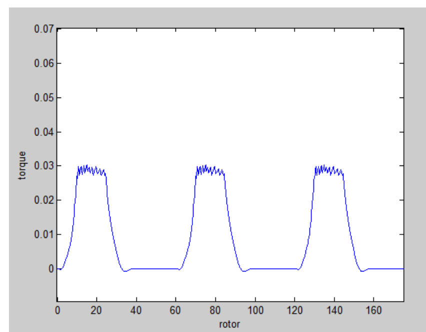


Figure 15: torque at 2500 rpm and 2A

From the figure 14 and 15, the operation of automatic control turn on angle of the SRM at 2500 rpm with rated current of 2A. At this speed, the peak current is 2.0304A and r.m.s current is 1.2877A. It also shows the value of average torque is 0.0184 Nm and average is 4.8768 W can be achieved. The turn on angle for this condition is 2.4675°.

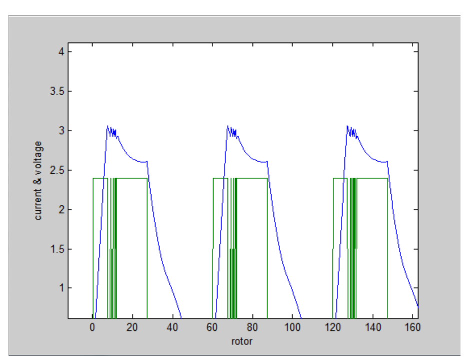


Figure 16: current and voltage at 3000 rpm and 3A

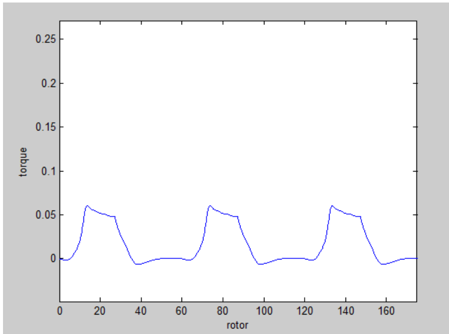


Figure 17: torque at 3000 rpm and 3A

From the figure 16 and 17, the operation of automatic control turn on angle of the SRM at 3000 rpm with rated current of 3A. At this speed, the peak current is 3.0536A and r.m.s current is 1.8808A. It also shows the value of average torque is 0.0343 Nm and average is 10.7879 W can be achieved. The turn on angle for this condition is 5.2415°.

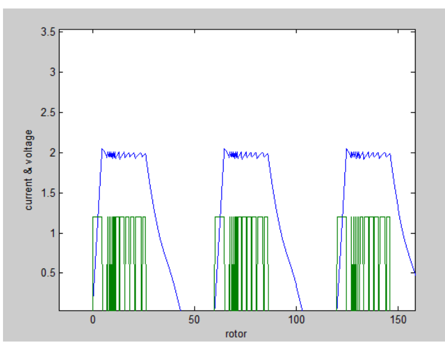


Figure 18: current and voltage at 3000 rpm and 2A

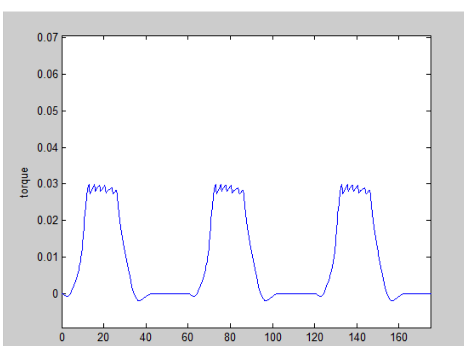


Figure 19: torque at 3000 rpm and 2A

From the figure 18 and 19, the operation of automatic control turn on angle of the SRM at 3000 rpm with rated current of 2A. At this speed, the peak current is 2.0069A and r.m.s current is 1.3335A. It also shows the value of average torque is 0.0184 Nm and average is 5.8431 W can be achieved. The turn on angle for this condition is 3.161°.

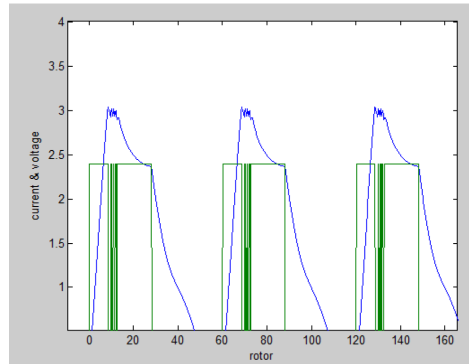


Figure 20: current and voltage at 3500 rpm and 3A

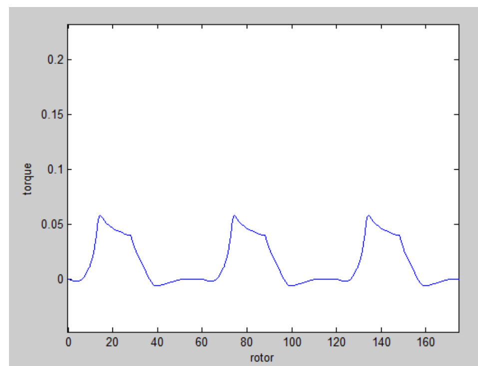


Figure 21: torque at 3500 rpm and 3A

From the figure 20 and 21, the operation of automatic control turn on angle of the SRM at 3500 rpm with rated current of 3A. At this speed, the peak current is 3.0335A and r.m.s current is 1.8133A. It also shows the value of average torque is 0.0303 Nm and average is 11.0928 W can be achieved. The turn on angle for this condition is 6.2817°.

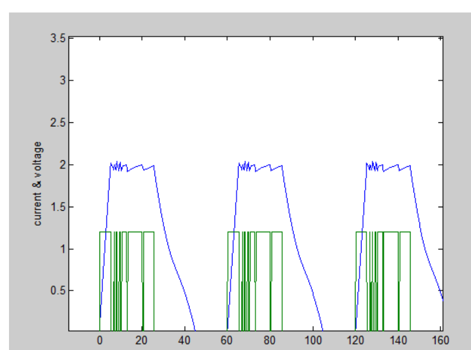


Figure 22: current and voltage at 3500 rpm and 2A

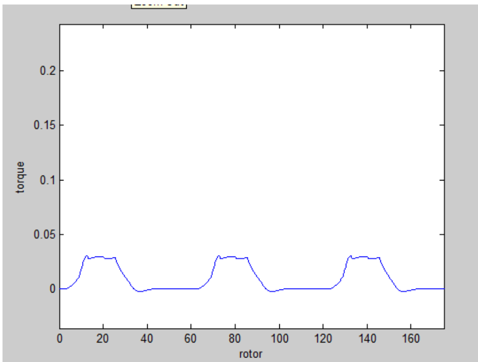


Figure 23: torque at 3500 rpm and 2A

From the figure 22 and 23, the operation of automatic control turn on angle of the SRM at 2500 rpm with rated current of 2A. At this speed, the peak current is 2.0442A and r.m.s current is 1.3192A. It also shows the value of average torque is 0.0184 Nm and average is 6.5667 W can be achieved. The turn on angle for this condition is 3.8545°.

6. CONCLUSION

This project presented the use of MATLAB simulation in reforming the switching turn-on advance angle for SRM has been developed. A closed form turn on angle equation was proposed for SRM validated by simulation using Matlab. Constant torque with minimum r.m.s current was achieved in the SRM variable speed operating from zero speed to the rated speed

7. FUTURE RECOMMENDATION

After got the result from this project, the performance of this project can be increase or improved with make some additional to a system as it future development. This project can be adapted to improve the quality and performance of SRM. Another controller such as fuzzy logic controller can be utilized to simulate performance of SRM.

8. REFERENCE

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