

Effect of Turn-on Angle Variation on Performance of the Switched Reluctance Motor

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Abstract

Stepper motors, brushless DC motors and switch reluctance motors emerged in the last few decades and these motors are finding applications in the various fields depending upon the demand. Switched reluctance motors have 6-4, 8-6 and 10-8 stator pole-rotor pole construction available. These motors work on the principle of reluctance. In this paper, analysis is carried out for 6 stator pole, 4 rotor pole switched reluctance motor. The parameters like flux linkages, stator current, electromagnetic torque and rotor speed are compared for the two different cases of turn-on angle. Case 1 represents turn-on angle of 40° whereas, case 2 considers turn-on angle of 60° . Results of these two cases are compared and conclusions are derived. Complete test bench is simulated in MATLAB/SimulinkTM.

Keywords: Switched reluctance motor, torque, stepper motors, MATLAB, rotor speed.

INTRODUCTION

Switched reluctance motors (SRM) are gaining popularity mainly due to improved performance, reliability, improved motor drive efficiency and less system architecture cost. The basic principle behind these motors is a reluctance torque. In a DC motor, power is fed to the rotating part that is rotor whereas in a switched reluctance motor, power is fed to the stator winding. It is also known as a variable reluctance motor because depending upon the position of rotor pole with respect to a stator pole, the reluctance varies [1-2].

These motors use switching inverter that switch on and off power supply at a pre-defined interval. Thus, by controlling the switching instants, turn on and turn off angle can be controlled. In this paper an attempt is made to show the torque and speed variation with respect to variation of turn on angle. Turn on angle can directly be related to time of turning on power from a power supply to the stator. The rotor pole will try to align with the stator poles to come in a minimum reluctance position. Various stator and rotor pole configuration available are, 6 rotor poles and 4 rotor poles or 8 stator poles and 6 rotor poles or 10 stator poles and 8 rotor poles. Thus, in all these variations, number of rotor poles are 2 less than number of stator poles and hence, rotor poles when unaligned will give more reluctance and when aligned, will give less reluctance. These motors have much bigger steps in comparison to a stepper motor and they are used where power density is a major concern. These motors operate in a closed loop configuration. In comparison to stepper motors, SRMs produce more audible noise but can accelerate faster than stepper motors due to low inertia. These motors can withstand higher temperatures in comparison to stepper motors and they are having lower cost and a simple construction. The operating principle of these motors depends upon switching currents in the stator windings in response to changes in the magnetic circuit formed by the rotor and stator. Stator of these

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types of motor contains windings, like a brushless DC motor, but the rotor is simply made of steel that is shaped into salient poles, with no windings or magnets. SRMs have smaller air gap than the BLDC motors. SRMs are commercially available from 4 to 22 kW, and they can be used in vacuum cleaners, planers, pumps,

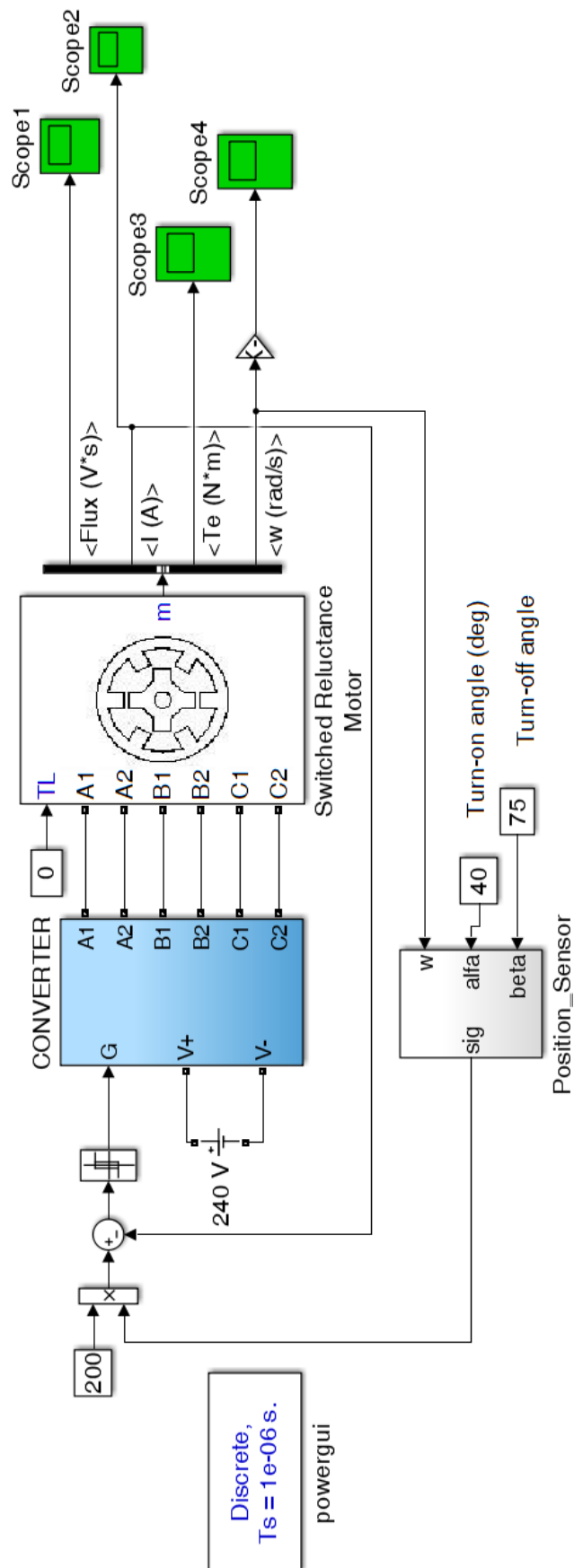


Figure 1. MATLAB/Simulink® Model of SRM.

compressors, lifts, food mixing machineries, conveyers, metal rolling applications, paper mills, extrusion machines, screw presses, coal crushers and even in electric vehicles and solar PV applications [3-12].

MODEL OF SWITCHED RELUCTANCE MOTOR

Figure 1 shows a model of a switched reluctance motor simulated in MATLAB/Simulink™. Stator voltage is V . There are four quantities to be measured viz. Flux linkages $V*s$, Stator Current I (A), Electromagnetic Torque T_e (N*m) and Rotor Speed ω (rad/s). There is a position sensor that takes feedback of Rotor Speed ω (rad/s) and adjusts the same according to the defined turn-on and turn-off angles. This motor is having 6 stator and 4 rotor poles. Parameters like stator resistance, inertia, initial position, unaligned inductance, aligned inductance, saturated aligned inductance, maximum current and maximum flux linkages can be varied depending upon requirements and a design. Table 1 shows motor parameters used in the simulation carried out.

Table 1. Motor Parameters used in Simulation.

Parameter	Value
Stator resistance	0.01 Ohm
Inertia,	0.0082 kg*m ²
Initial position,	0.01 N*m*s
Unaligned inductance	0.67*10 ⁻³ H
Aligned inductance	23.60*10 ⁻³ H
Saturated aligned inductance	0.15*10 ⁻³ H
Maximum current	450 A
Maximum flux linkages	0.486 V*s

RESULTS AND DISCUSSION

There are two cases considered. Case (1) Turn-on angle 40° and Turn-off angle 75°. Case (2) Turn-on angle 60° and Turn-off angle 75°. The parameters Flux linkages $V*s$, Stator Current I (A), Electromagnetic Torque T_e (N*m) and Rotor Speed ω (rad/s) are measured for these two cases and a comparison is made based on results obtained. The results obtained are shown in Figures 2 (a) to 2(d) for case 1 and Figure 3(a) to 3 (d) for case 2. Comparing Figures from 2(a) to 3(d) with the respective parameters, it can be noted that the variation of turn-on angle slightly changes value of flux linkages having maximum value around 0.4 ($V*s$) in both the cases, stator current having maximum value around 210 (A) in both the cases and electromagnetic torque around 150 (N*m) in both the case are identical. But there is a very large gap in the rotor speed ω (rad/s). In case 1, when turn-on angle was kept at 40°, maximum rotor speed was about 4500 (rad/s) and for case 2 of 60° turn-on angle, it is approximately 1600 (rad/s). Thus, turn-on angle has a major role to play in the speed of the switched reluctance motors. Rotor speed reduces drastically with increase in the turn-on angle.

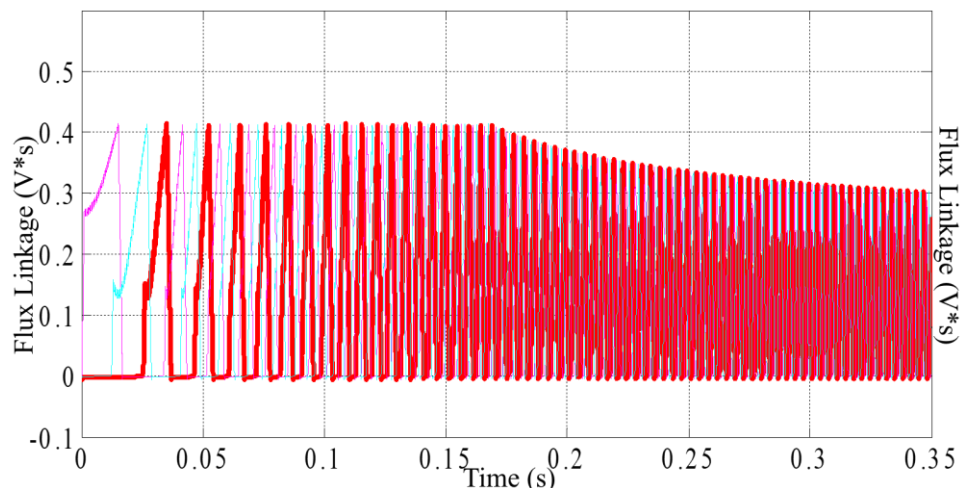


Figure 2. (a). Case 1: Flux Linkages ($V*s$)

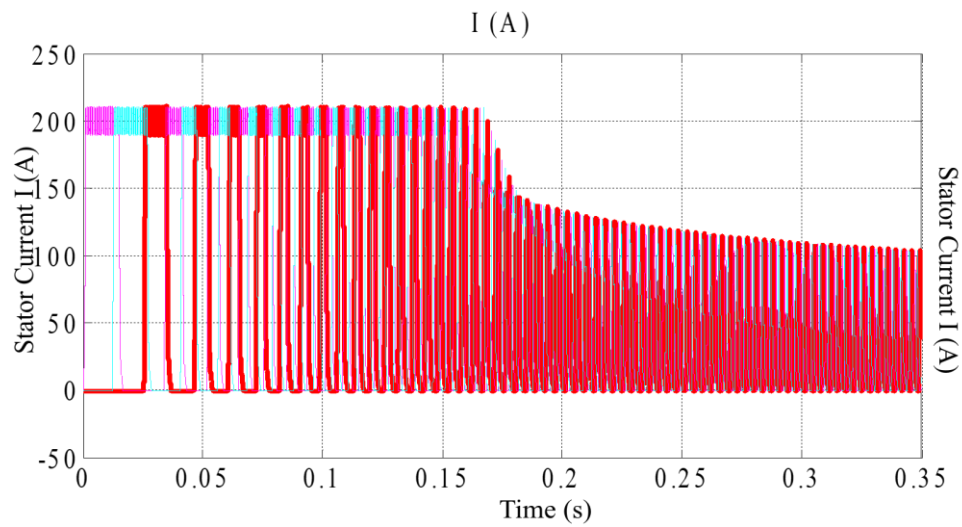


Figure 2 (b) Case 1: Stator Current I (A)

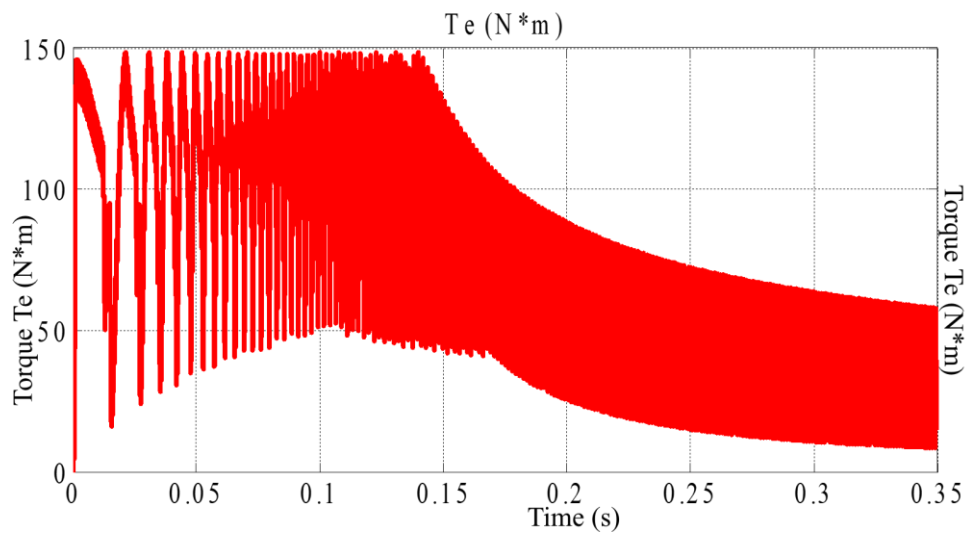


Figure 2. (c). Case 1: Electromagnetic Torque T_e (N*m)

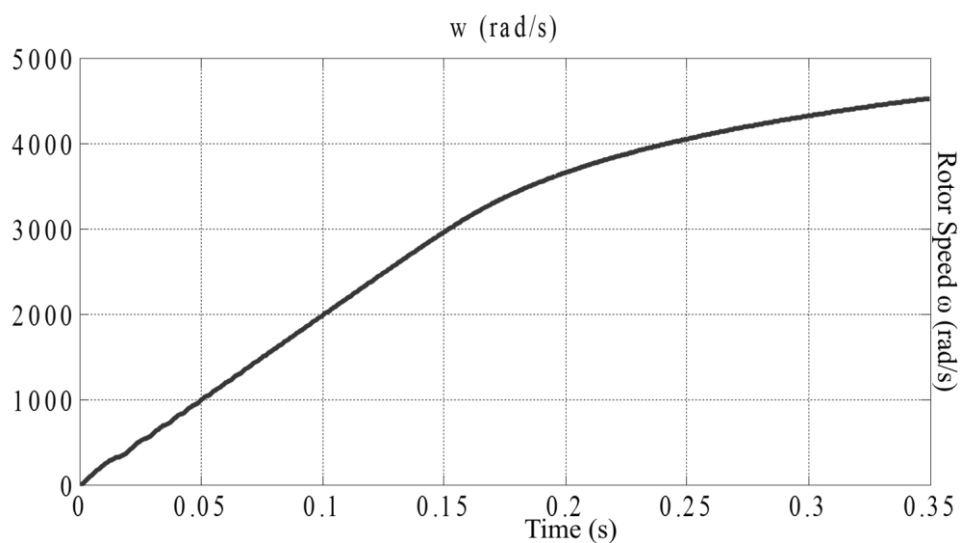


Figure 2. (d). Case 1: Rotor Speed ω (rad/s)

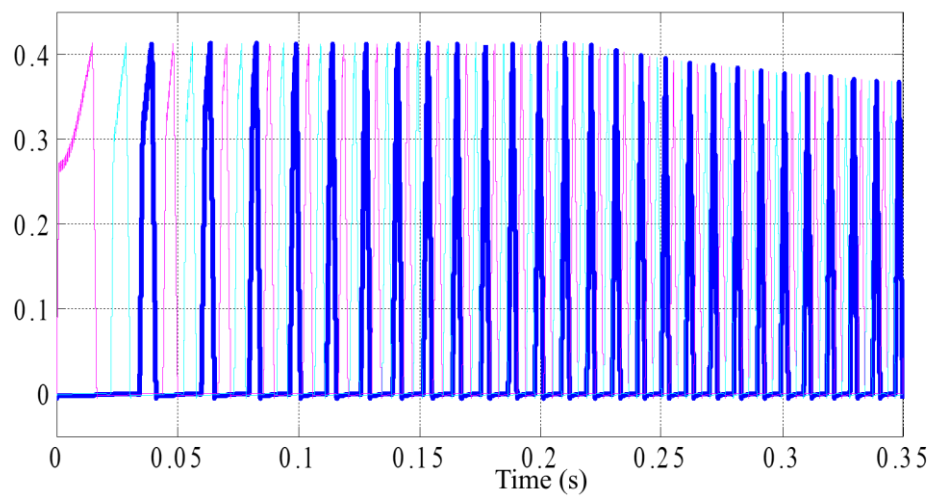


Figure 3. (a). Case 2: Flux Linkages (V*s)

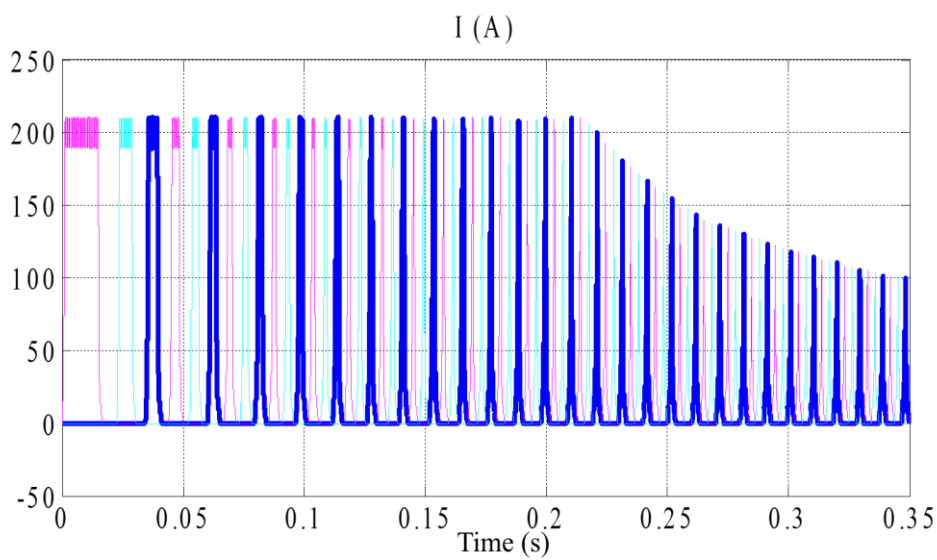


Figure 3. (b). Case 2: Stator Current I (A)

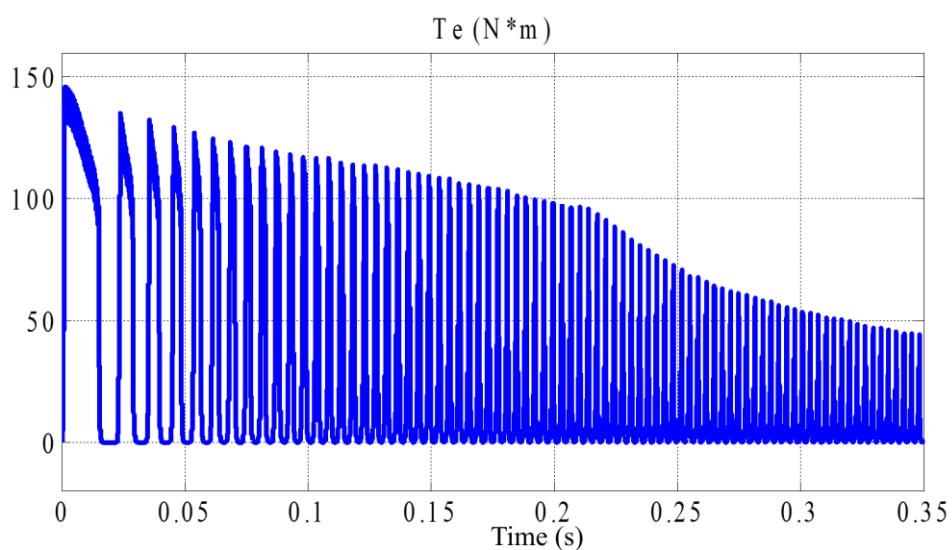


Figure 3. (c). Case 2: Electromagnetic Torque TE (N*m)

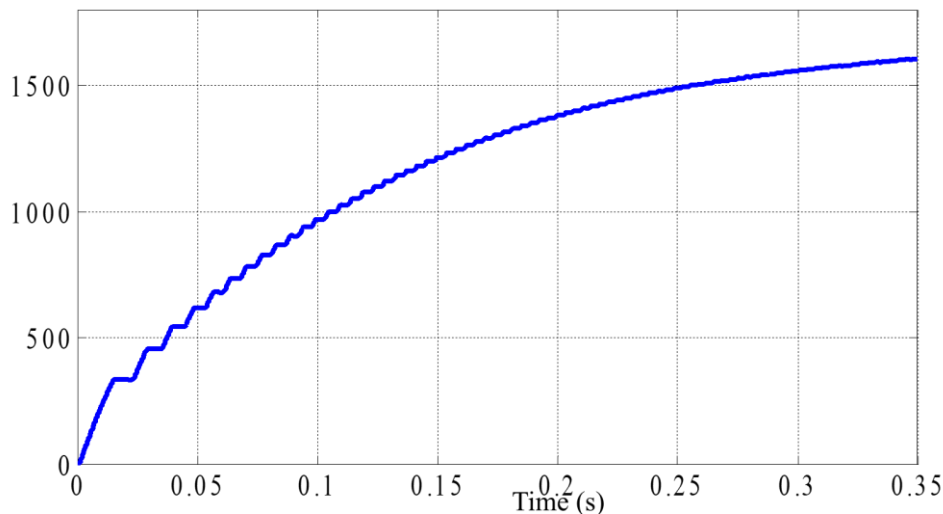


Figure 3. (d). Case 2: Rotor Speed ω (rad/s)

CONCLUSION

The test system was simulated in MATLAB/Simulink® to evaluate and compare the performance parameters of the switched reluctance motor. Two cases of turn-on angles 40° and 60° were considered for a comparison of flux linkages, stator current, electromagnetic torque, and rotor speed. From the comparison of parameters, it is concluded that in both the cases, flux linkages, stator current and electromagnetic torque remains almost constant whereas, rotor speed reduces drastically with increase in the turn-on angle.

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