Design And Development Of Controller Circuit For Linear Switched Reluctance Motor

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ABSTRACT: This paper presents a novel and improved controller design and implementation method. An integrated approach has been considered as whole (Motor and Controller). The developed system is for linear operation as per the industrial requirement. A suitable and simple designed structure is proposed in this paper. The drivers are designed using high speed IGBT modules and the HPIGBT is controlled using software program.

IndexTerms: Switched Reluctance Motor, SR Drive, HPIGBT

1. INTRODUTION:

The most of the energy is utilized or consumed in mechanical, thermal or chemical form in Industrial area for different operations and mainly conveyer drives utilizes heavy electrical power due to conventional motors use. Recently, lot of research is going on for development of flexible drive with four quadrant operation and such one of the drive called as Switched Reluctance Motor (SRM) drive being used. Switched Reluctance Motor (SRM) drive can be digitally controlled offering significant advantages T.A. Lipo and Long Ya Xu [1]. The detailed analysis with experimentation is described in literature T.J.E. Miller [2] for construction, design and controlling and recent development for rotary type SR Motor for reduction in torque ripple, acoustic noise and cogging effect at the base speed at various load conditions elaborated in R.M. Autee [3]. The basic design and controlling software for analysis of variations in inductance profile is demonstrated in literature A.E. Fitzgerald and Charles Kingsley [4]. The mechanical as well as electrical modeling of 4 KW SR Motor is well experimented in the literature R.M. Autee [5]. The detailed modeling and simulation for all the types of SR Motor is well reported in R. Krishnan [6].

The Electro Mechanical Energy Conversion (EMEC) principle is explained in J. Nagrath and D.P.Kothari [7]. For analysis of Switched reluctance Motor with experimentation and validation is well reported in Semsudin masic et.al [8]. Installation, testing and dynamic simulation of SR Motor is demonstrated in R.M. Autee [9] as well as literature Sadeghi S.[10] for dynamic modeling and simulation for electric vehicles. Design of rotor holding system is given in literature [13] is modified for linear operation purpose in this project. The analysis is carried out for rotary SR Motor and very less attention is paid for linear and robotic operation of SR Motor and its drives. This paper describes design and development of linear operational SR Motor for various industrial operations

2. MATHEMATICAL MODEL OF THE SYSTEM:

For conventional SR Motor, the stator winding are mounted on salient poles and is able to handle the issues of electro-magnetic field. However, inductance of a phase is continuously changing from low value to medium and high value (in mH) at changing rotor positions. The entire operations is dependent of effective pole arc, however in this project, there is absence of effective pole arc, hence as per the equation described in [3],

$$L(\theta) = 2N_p^2 P_g + L_u = 2N_p^2 \frac{\mu_o r l_1 \theta}{g} + L \qquad (1)$$

Where, Pg is the permeance of air gap, N_p is the number of turns per phase, l_1 is the length of rotor, θ is the overlap angle of stator and rotor poles, μ_0 is the permeability of free space, L_u is the phase winding inductance when rotor inter-axis is aligned with stator poles. Hence, equation (1) is simplified as,

$$L(\theta) = 2N_{pL}^2 P_{gL} + L_{uL} = 2N_{pL}^2 \frac{\mu_o r_L l_1 H_L}{g_L} + L \qquad (2)$$

Further saturation indicates the nonlinearity of inductance is also changed as follows,

$$L(\theta) = 2N_{pL}^2 P_{gL} + L_{uL} = 2N_{pL}^2 \frac{\mu_o r_L l_1 H_L}{g_L} \qquad (3)$$

3. BLOCK DIAGRAM AND CIRCUIT FOR PROPOSED SYSTEM

Unlike the DC Motors and induction motors the switched reluctance motor cannot run directly from AC or DC supply. In the switched reluctance motor flux is not constant it is set up from zero after every working step. A suitable block diagram is developed for the proposed linear SR Drive system is as follows:

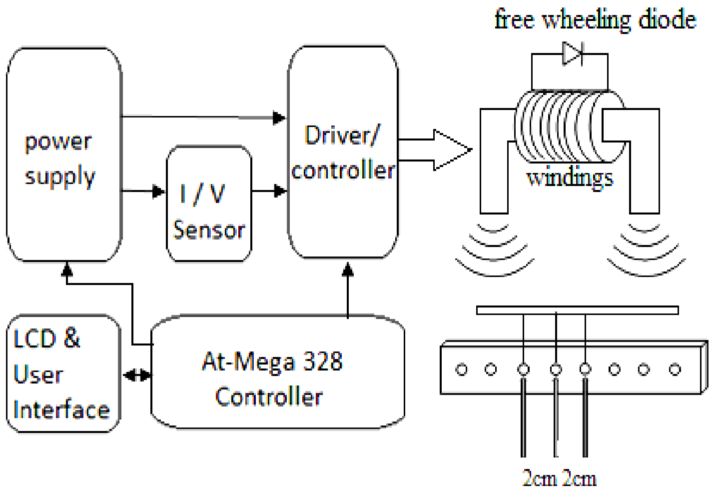


Figure (1): Block diagram of the proposed system

The switched reluctance motor work on constant switching for rotation such as switching achieved using IGBT speed of the motor is dependent upon IGBT switching frequency. Such fast switching done using micro-controller controlled firing circuit. Usually the IGBT takes 10KV for firing so regular micro-controller which work on 3.3V-5V are unable to fire IGBT such case firing circuit is made of M57982. Supply for our prototype, we have used two transformers for two independent supply. One transformer regulate voltage into 15V, 9V, 5V, -5V, -9V, -15V and ground that is zero using 78xx and 79xx series of the regulators for micro-controller, IGBT firing circuit while another supply rectified voltage of 18V and 35V for coil driven by IGBT using rectifier diode and filter capacitor. The micro-controller is interfaced with 16x2 LCD and three variable resistor pots. LCD shows values for firing pin such as voltage, time delay between pulse and number of pulse it going to fire where pot let user adjust these values these each pot of 5KΩ value in program. In this prototype, the divided resistance assigned value for each part which act as selection options. This configuration gives full control over winding which going to be part of switched reluctance motor.
The firing circuit is the crucial part of prototype, this circuit should work at lightning speed to control IGBT. As micro-controller provide pulse its time delay between acquiring pulse and firing IGBT should be less as possible this way time delay between first pulse and second pulse is constant less so the circuit is efficient. In the solenoid winding, winding is just nichrome wire winded over metal bar of 10mm diameter and 150 turns in the three layers of 0.75mm gauge wire. In the voltage and current sensor, the voltage sensor is nothing but the voltage divider bias circuit for stepping down 0V-40V to 0V-5V. the current sensor is hall sensor which measures flux emitted by the copper wire more flux current so it measure current depending flux produced in wire. The schematic for firing circuit and power supply is as follows,

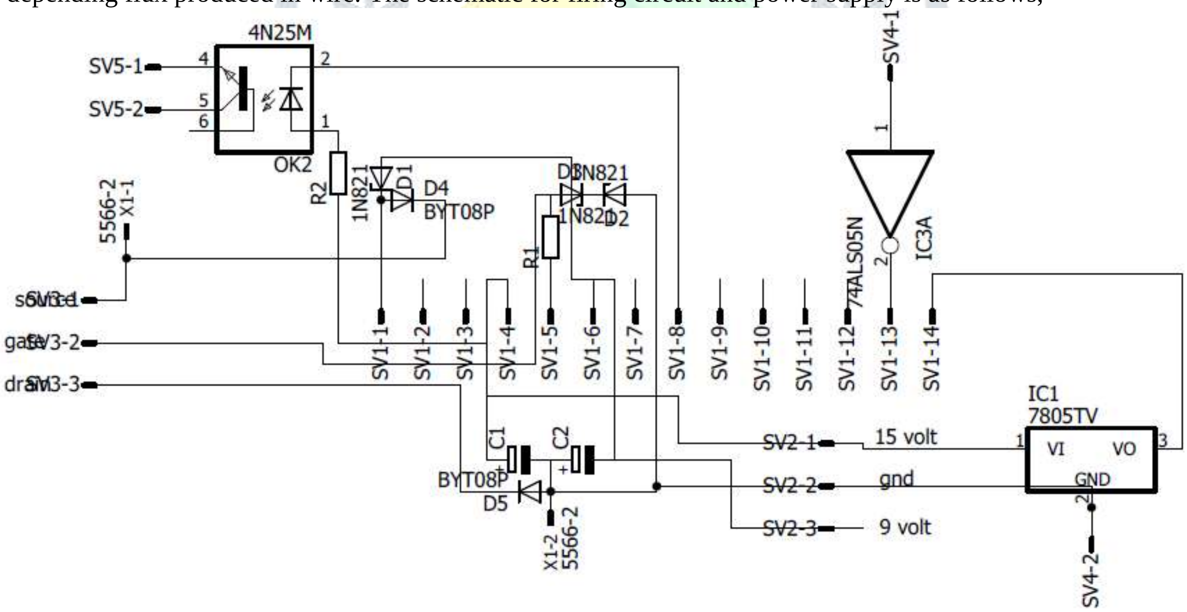


Figure (2): Schematic for firing circuit

There are two types of supply this IC need +15V, -9V which is connected to pin no 4 and 6, ground common. The supply pin no 5 is driving output with the low value resistor for protection pin no 1 is for fault detection diode and zener is connected in order to reverse and over voltage protection pin no 8 is for fault and short circuit indication for micro-controller. There is two zener's connected cathode to cathode for protection against short circuit from damaged IGBT. Pin number 14is connected to +5V vcc pulse is given by inverter for inverting 5volt to ground which accepts as pulse fires output.

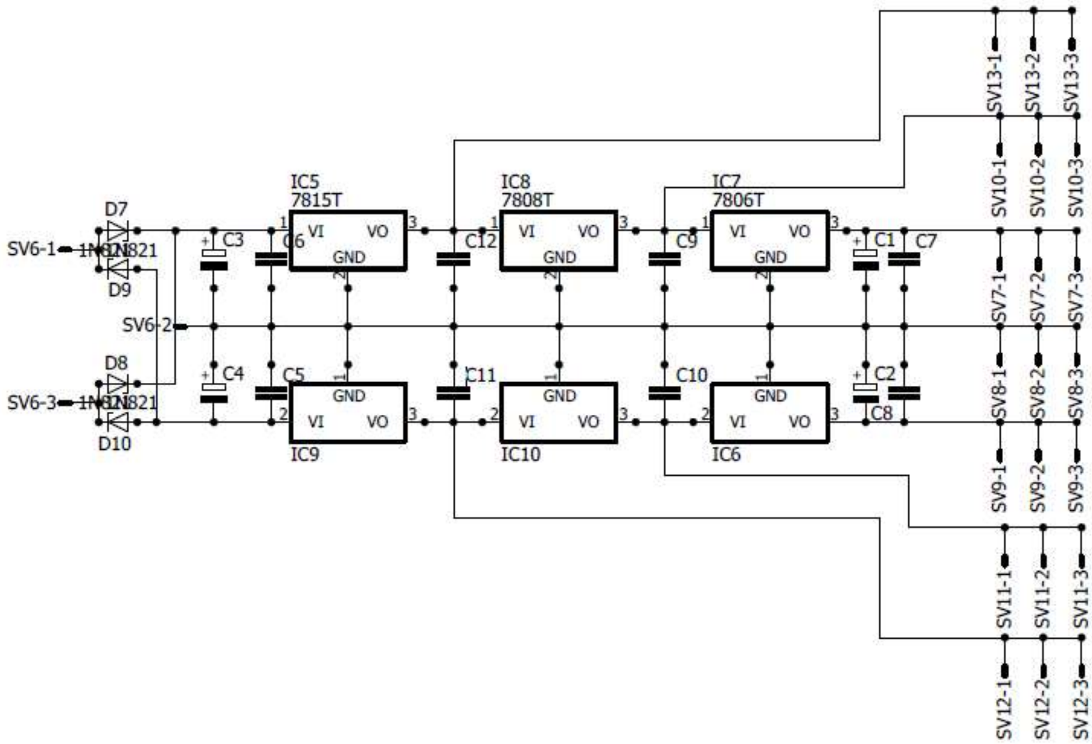


Figure (3): Schematic for power supply

For power supply module 18-0-18 transformer is used. Bridge rectifier four diode 1N4007 is used with capacitors 1000uF 50V as filter. LM7815, LM7809, LM7805 are used for positive regulation pin no one of LM78XX is input voltage, second pin of ground and third pin is of ground. LM7915, LM7909, LM7905 are used for negative regulation pin no is input voltage second pin is output and third pin is ground. After rectifier supply of positive, ground and negative positive and ground is first given to LM7815 then regulated supply is past down to LM7809 then LM7805. Similarly, negative and ground supply is connected to LM7915 which will pass down regulated supply to LM7909 and LM7905.Adjusted PWM is fires through toggle switch connected to micro-controller. This PWM pulse goes to inverter IC which inverts its output for IGBT firing IC. Depending upon pulses voltage and duration IGBT firing IC give out firing voltage means if pulse voltage is 2.5 volt then firing IC give out 7.5volt same goes for duration. This fired output voltage given to gate of IGBT. IGBT is connected to another power supply which is only for winding.

4. EXPERIMENTAL RESULTS

In the electrical network if node or branch is added or excluded then short circuit is observed due to its parameters changes. Because of this circuit behavior changes from one steady state to another steady state. The experimentation is carried out on linear SR Motor for measurement of different parameters such as acting torque which is shown in figure (4). As rotor moves the current present in stator circuit are switched ON and OFF. Due to this simplest form of control the SR motor creates the torque characteristics.

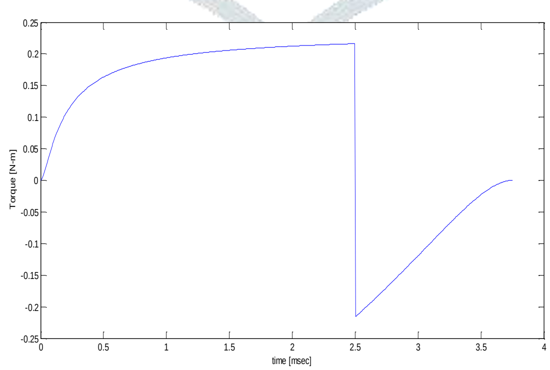


Figure (4) : Torque characteristics

When the rotor position matches the turn-off position, phase switches are turns off. So power source will stop to the input energy. The magnetic field needs to be released then phase current start to feedback energy to power source. At that time, magnetic field energy converted into the mechanical work and loss. The magnetic co-energy characteristics graph shown below.

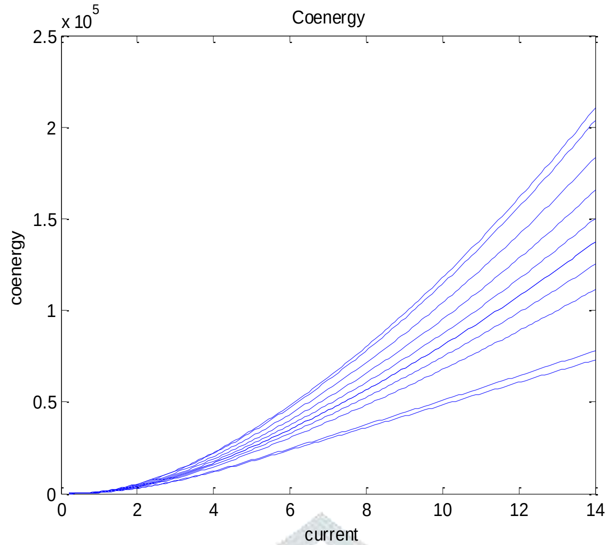


Figure (5): Magnetic Co-energy Characteristics

Rotor angle position is essential for the stator phase commutation and advanced angle control. When current passed through the phase winding the rotor tends to align with stator pole and produce torque that tends to move rotor to a minimum reluctance position. The rising and falling inductance can be seen in the figure (6) which is the function of rotor position

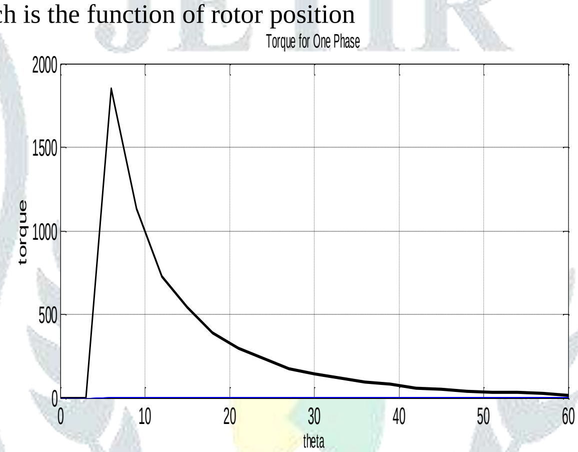
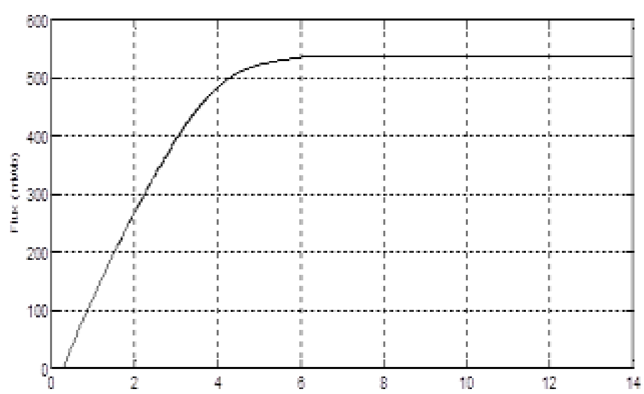
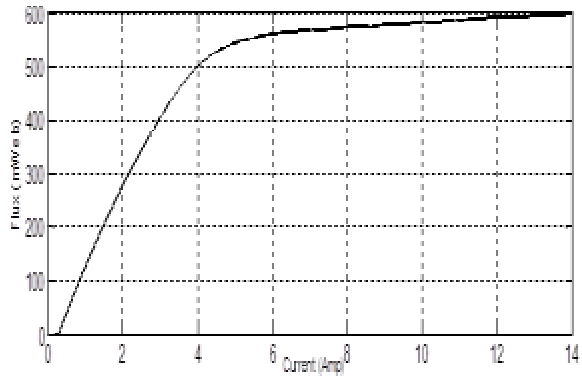


Figure (6) : Torque Characteristics Vs Rotor Angle

The flux linkage of SR Motor is a function of both current and rotor position. Flux linkage torque created by the SR Motor is dependent on change of flux linkage and rotor position. Due to nonlinear behavior of SR Motor estimation of flux linkage occur. Flux linkage characteristics at 0^0 and 3^0 shown below



Figure(7)Flux-Linkage Characteristics of 4KW SR Motor at 0^0



Figure(8)Flux-Linkage Characteristics of 4KW SR Motor at 3^0

The running condition of motor as a speed of the rotor and this speed voltage indicates that the motor starts from 0^{th} position to steady state position at 1500 rpm.

5. CONCLUSION

The analysis is carried out for simple and suitable design of the switched reluctance motor. Necessity in development of successful switched reluctance motor is combination of electronic, mechanical and electromagnetic design. The development of linear SR Motor, for application in general purpose industrial drives, in manufacturing area, mass rapid transit system are evident in this recent technological trend. The paper presented design and development of linear operational switches reluctance motor for various industrial application and experimentation has been carried out at different speed and load to validate the work by experimentation of Switched Reluctance Motor.

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