Switched Reluctance Motor for Electrical Vehicle Application

Swinal Shende[1] Samiksha Kagdalwar[2] Sneha Shambharkar[3] Dipti Mankar[4] Pranaali Bodhe[5]
[1,2,3,4,5]Student
[1,2,3,4,5]Department of Electrical Engineering
[1,2,3,4,5]Government College of engineering Chandrapur, Maharashtra, India

Abstract— Today Current scenario, use brushless DC motors (BLDCs) and DC motors for many electrical applications. However, recently, replacement of traditional motors switched reluctance motors (SRMs) have become the best option will be available and BLDC are due to is an advance precision forging tech enabling high performance, uniformity and superior quality high efficiency, fault tolerance, minimized cost. Switching reluctance (SRMs) have neither windings nor permanent magnets in the rotor. Vital play the role around the world applications such as the drive motor for EV (Electric Vehicle) and HEV (Hybrid electric vehicle) Torque pulsations are inherent in SRMs because of its sequential excitation and doubly salient structure of the machine, have great torque. It lacks windings on the side of the rotor. The switch reluctance whose construction is simple, control flexibility, simple structure, lower cost and high efficiency. In first phase shows the characteristics and structure parameters of performance analysis of S.R.M. now we proposed in this paper sub system model, power subsystem and simulation model and its result.

Keywords: Switched Reluctance Motor, Switched Reluctance Motor Drive, Speed Control, MATLAB Simulation

I. Introduction

The Switched Reluctance Motor (S.R.M) very advantages as they are simple and easy to maintain and available at low cost with the heightened fault tolerance and capability of handling different loads [4].The equivalent circuit of Switched Reluctance Motor is shown in fig.2In this paper we used an eight/six switched reluctance motor (S.R.M) for analysis the working of SRM drive. In this paper at starting it discuss the characteristics and parameters of switch Reluctance Motor. The result of this motor is electromagnetic torque is periodic. Due to its special characteristics shown in this paper modelling of S.R.M (switch reluctance motor) is different from other electrical motor.

The simple construction and good efficiency are key factors of attraction and attention towards this motor. The non-linear magnetic behaviour and magnetic saturation of the motor are caused by its doubly-salient pole structure. Due to the nonlinear behaviour of the motor, handling of the data in form of look-up data tables is well deliberated in (Corda et al., 1993). The Simulink based modelling is reported in (Cornea et al., 2008) and (Hao et al., 2000). The fundamentals and essential investigation of the machine form its construction, working and design point of view is highlighted in (Lawrenson et al., 1980). The rotation in switched reluctance motor is produced by virtue of magnetic pull of its stator poles on the rotor poles to align when the former is energized where reluctance is minimum (Miller, 2001). The stator and rotor poles in a switched reluctance motor are of salient type with difference that laminated rotor carries no windings; whereas stator carries windings only (Memon, 2012).Also that the number of stator and rotor poles are not same. The windings which are in series with power semiconductor switches form a phase of the machine. Usually the SR machine is available in multi-phase arrangement (Memon, 2012). The motor phases are excited by a sequence of voltage pulses which are obtained from the power electronic converter. The pulses are synchronised with signals obtained from position detector which is located on the shaft of the motor (Memon, 2012).

II. Inductance Profile of Switched Reluctance Motor

The torque in the motor is produced when its' stator winding is energized, in result the stator pole pulls the nearest rotor pole to align in the region where reluctance is minimum and inductance is maximum (Miller, 2001). The inductance starts increasing with relative approach of rotor poles to energized stator poles. Different rotor position and inductance profile of the motor is indicated in (Fig.1) (Memon, 2012).

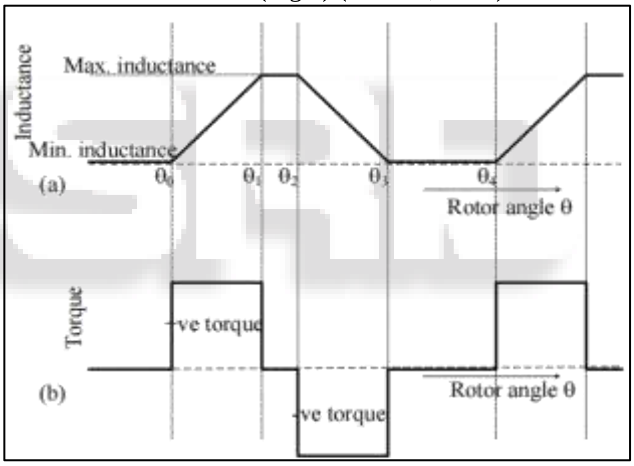

Fig. 1: Variation of inductance as function of rotor position

- At position θ1 where the poles are fully aligned inductance is maximum i.e. L_{max} (Lawrenson et al., 1980), the inductance gradient dL/dθ > 0, therefore torque produced is positive.
- At position θ1 to θ2 inductance remains constant, the inductance gradient dL/dθ = 0, therefore torque produced is zero. This region is known as 'dead zone' (Lawrenson et al., 1980).
- During θ2 to θ3, inductance decreases, the inductance gradient dL/dθ<0, therefore torque produced is negative.
- For position θ3 to θ4 inductance remains constant at minimum level, the inductance gradient dL/dθ= 0, and therefore torque is not produced. Fig.2 shows) inductance profile of an existing motor for range of the current from 1A to 14 A.

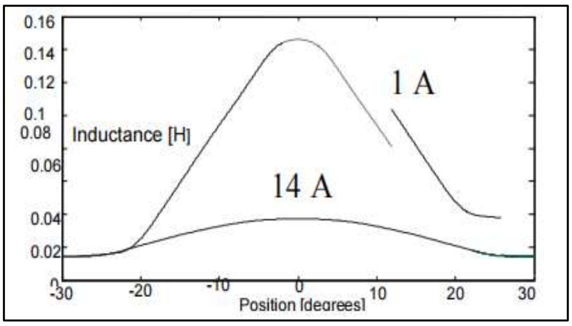

Fig.2. Actual variation of inductance versus position

Variation of phase torque as function of rotor position.

Voltage Equation for Stator Current

The voltage equation for stator current of the motor is given by

$$v = Ri + \frac{d\psi}{dt} \quad (1)$$

Where v is the instantaneous applied voltage across the windings of the motor, R is the winding resistance and dψ/dt is the rate of change of flux linkage.

Since ψ = Li, therefore eq. 1 can be written as:

$$v = Ri + L\frac{di}{dt} + i\frac{dL}{dt} \quad (2)$$

$$v = Ri + L\frac{di}{dt} + i\frac{dL}{d\theta} \times \frac{d\theta}{dt} \quad (3)$$

$$v = Ri + L\frac{di}{dt} + i\frac{dL}{d\theta} \times \omega \quad (4)$$

where three terms on right hand side in eq.4 represents resistive voltage drop, transformational emf (inductive voltage drop) provided inductance remains constant and motional emf (back emf) respectively. While (omega) is the rotational speed in rad / sec.

The rate of flow of the energy is given by

$$v = Ri^2 + \frac{d}{dt}\left(\frac{Li^2}{2}\right) + \frac{i^2}{2} \times \frac{dL}{d\theta} \times \omega \quad (5)$$

where the first term in the eq.5 on right hand side is the power loss in coil due to its resistance, second term is rate of increase of stored magnetic energy and the last term is the power converted from electrical energy to mechanical output power. Torque equation neglecting magnetic non-linearity

(Lawrenson et al., 1980) is given by

$$\tau = \frac{i^2}{2} \times \frac{dL}{d\theta} \quad (6)$$

Current, Flux and Torque Waveforms Voltage pulses at correct sequence with respect to rotor position are applied to the switching devices to excite the phases of the machine. Many converter topologies have been documented in the literature among which the asymmetrical converter topology is regarded as a most common topology. (Fig.3) shows one phase of the 8/6 pole SR machine.

In this particular arrangement of the converter for switched reluctance motor the winding see positive voltage when switched T_1andT_2 are closed. The energy flows from source into the winding of the motor. The energy which is supplied by the source is converted into mechanical output and part of it is stored magnetically (Lawrenson et al., 1980).Similarly, when switches are opened, negative voltage is impressed and the stored magnetic energy is partly converted to mechanical output and partly transferred to source (Lawrenson et al., 1980).In third case, motor winding see zero voltage when either switch T_1 or T_2 is opened, energy is neither transferred from source to motor winding nor returned to source.

The computation of phase instantaneous current and torque is done by numerical integration of non-linear differential equation

$$\frac{d\psi(\theta, i)}{dt} = v - Ri \quad (7)$$

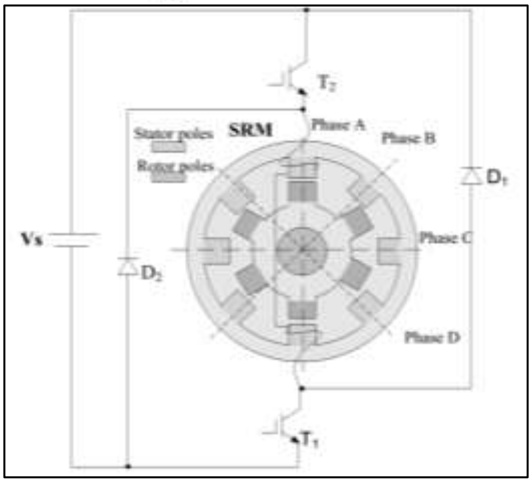

Fig. 3: One phase of four– phase 8/6 SR motor with two switches per phase

In other words, the control method based on torque, speed, and current. Control based on speed utilizing an asymmetric bridge converter topology is followed.

III. SRM DRIVE SPEED CONTROL

Steady-state errors are eliminated by the P and I terms, a Combination of proportional and integral, which also improves response speed. The performance of a PI controller can be improved by providing feedback to the converter, which can also be controlled by overcoming disturbances. Steady state errors can be removed by the PI controller during the operation of each of the P controller and ON-OFF controller.

The integration mode has a negative effect on the speed response and stability of the system. You can detect this problem by using derivatives mode. Differential mode allows you to predict errors and reduce controller response time. PI controllers are typically used when speed control is not the switch reluctance motor drive, when a sudden abnormal condition occurs, the motor runs at the rated speed, the motor slows down and does not operate at the rated speed, the error is minimized and the feedback via the controller, This improved feedback motor starts running again at normal speed. Therefore, it is possible to analyze the speed control of switch reluctance motor drive by P.I controller.

IV. PROPOSED WORK

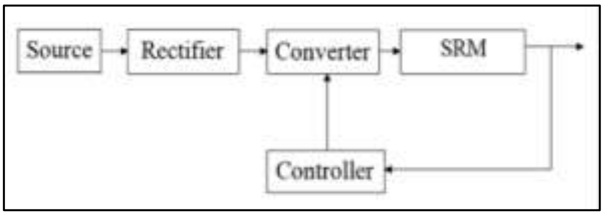

Fig 4. Block diagram of Switched Reluctance Motor Drive

The motor is comprised with rectifier, controller, switch reluctance motor and converter. In the converter, an asymmetric bridge converter was used to transfer the energy generated by controlling the motor winding current switch. Fig () shows a single-phase asymmetric bridge converter. Similarly, the same converter was used for the remaining phases. When transistors (T1) and (T2) are turned on, current circulates in the A phase of the switched reluctance motor. When the current exceeds the command value, transistors T1and T2 are turned off. The energy stored in the A phase of the switched reluctance motor keeps the current in the same direction until the current is exhausted because D1 and D2 become forward biased. As a result, the current decreases and falls below the command value [1].

The SRM's configuration for 8/6 pole is shown in the figure.4. Here, we used a PI controller, a proportional integral. PI controllers are used to minimize steady-state errors without affecting system stability. PI controllers are also used to improve attenuation, while PI controllers reduce bandwidth and increase rise time. This means that the transient response will be slow and the PI controller will also elude the frequency noise [5].

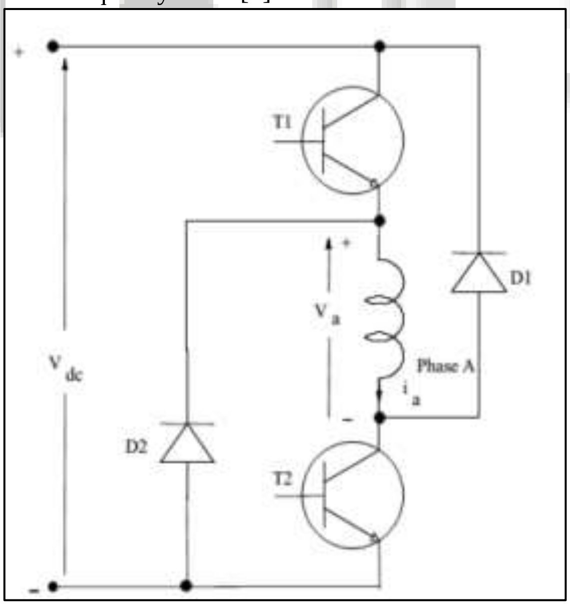

Fig. 5: Single Phase Asymmetric Converter

There are various ways to analyze the performance of a switched reluctance motor (S.R.M) drive.

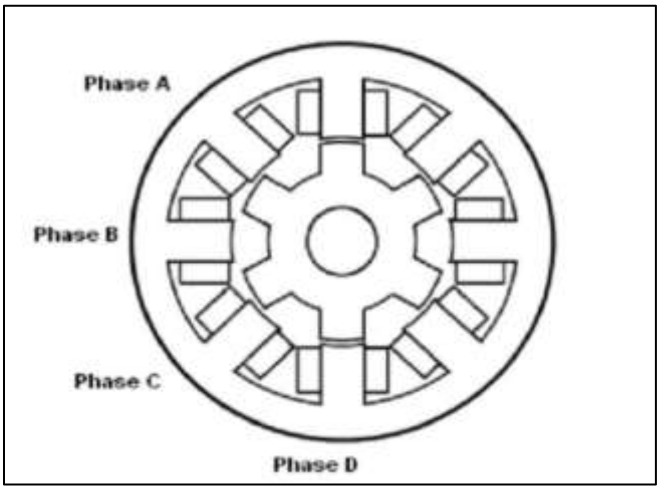

Fig. 6: 8/6 pole SRM

In other words, the control method based on torque, speed, and current. Control based on speed utilizing an asymmetric bridge converter topology is followed.

V. SRM DRIVE SPEED CONTROL

Steady-state errors are eliminated by the P and I terms, a combination of proportional and integral, which also improves response speed. The performance of a PI controller can be improved by providing feedback to the converter, which can also be controlled by overcoming disturbances. Steady state errors can be removed by the PI controller during the operation of each of the P controller and ON-OFF controller. The integration mode has a negative effect on the speed response and stability of the system. You can detect this problem by using derivatives mode. Differential mode allows you to predict errors and reduce controller response time. PI controllers are typically used when speed control is not the norm. In a switch reluctance motor drive, when a sudden abnormal condition occurs, the motor runs at the rated speed, the motor slows down and does not operate at the rated speed, the error is minimized and the feedback via the controller, this improved feedback motor starts running again at normal speed. Therefore, it is possible to analyze the speed control of switch reluctance motor drive by P.I controller.

VI. SIMULATION RESULT

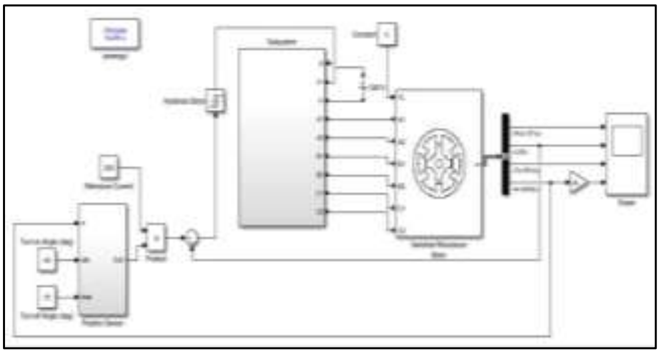

Fig. 7: 6/4switched reluctance motor simulation diagram

The results of a simulation structure for speed control of a (S.R.M) switched reluctance motor drive using a P.I controller are as follows: The phase (φ) is also turned off and continues for the remaining phase (φ) of the (S.R.M). Figure (7) shows the 6/4switched reluctance motor simulation diagram, Figure (8) shows the power converter subsystem, Figure (9) shows the positional sensor, Figure (10) shows the SRM drives torque output waveform Figure (11) shows the switch reluctance motor using a PI controller with a reference speed(N) set at 3000 r.p.m. Indicates the speed can achieve almost 2970-2980.

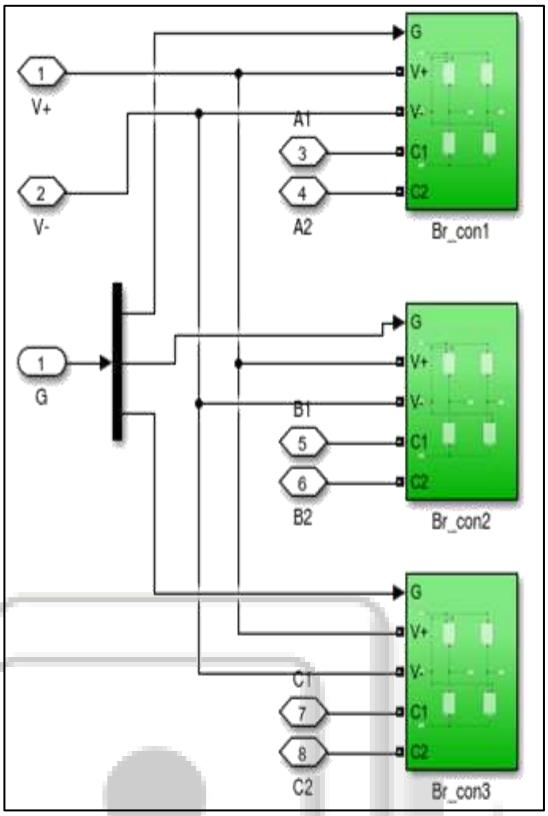

Fig .8: Power converter subsystem

While using S.R.M it having some advantages like it reduces the cost, increase the efficiency, consolidation of supply chain, etc.

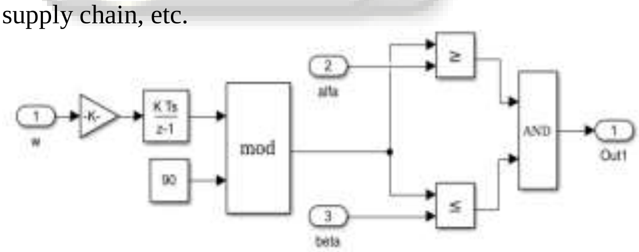

Fig. 9: positional sensor

Switch reluctance motor having more scope in industrial application such as a wind energy and electrical vehicles due to its construction, high temperature, and its insensitivity.

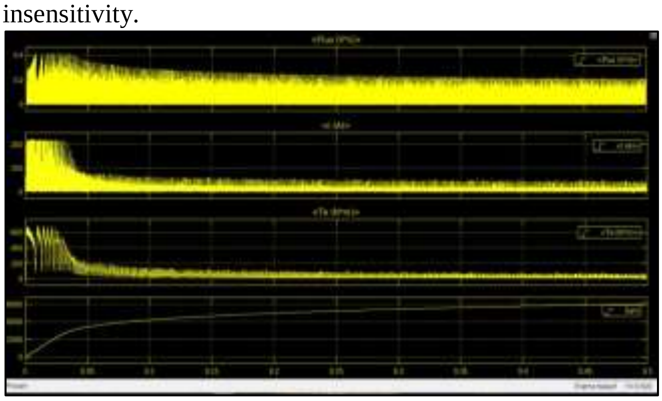

Fig .10: SRM drives torque output waveform

Appliances for Smart Home. Wearable sensors to monitor the physiological parameters of home occupants such as heart rate, blood pressure, etc were included in a smart home device ecosystem.

In response to the growing interest of customers about smart home, Apple and Google, which are the leaders in mobile OS platform, recently introduced smart home platform. This smart home platform will allow customer easily to control various connected products using devices that run on their mobile OS platform.

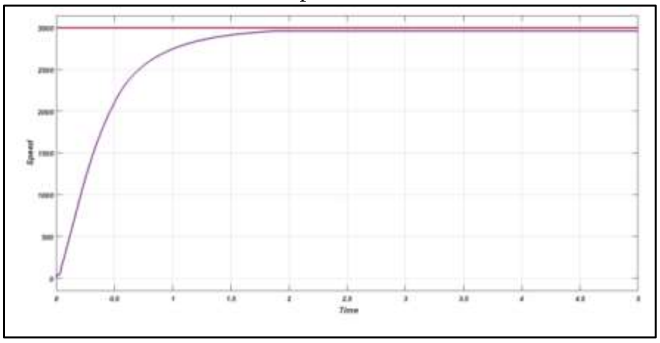

Fig. 11: Speed of switched reluctance motor

VII. Conclusion

Switched Reluctance Motors (S.R.M), for industrial and consumer electronics are the most reliable motors Because of switching reluctance and also various advantages over traditional motors. In this paper, By using switching reluctance (S.R.M) drive functioning controlling speed of a motor with under the normal and the undesirable conditions is observed by using MATLAB / Simulink design a simulation model . This paper has shown modeling and simulation tools for implementation of SRM speed controlled, increased performance, high motor-drive efficiency.

References

[1] El-Shahat, Adel, Austin Hunter, Mosfequr Rahman, and Yan Wu. "Ultra-High Speed Switched Reluctance Motor-Generator for Turbocharger Applications." Energy Procedia 162 (2019): 359-368.

[2] Azadru, Allahverdi, Siamak Masoudi, Reza Ghanizadeh, and Payam Alemi. "New adaptive fuzzy sliding mode scheme for speed control of linear switched reluctance motor." IET Electric Power Applications 13, no. 8 (2019): 1141-1149.

[3] Thakare, Shubham Rajendra, and S. V. Patil. "Speed Control Strategy of Switched Reluctance Motor Drive Using Asymmetric Bridge Converter Topology." In 2019 4th International Conference on Recent Trends on Electronics, Information, Communication & Technology (RTEICT), pp. 313-317. IEEE, 2019.

[4] Qiao, Dong-kai, and Mei-qing Cai. "The Design of BP Neural Network Modeling for Switched Reluctance Motor." In 2nd International Conference on Electrical and Electronic Engineering (EEE 2019). Atlantis Press, 2019.

[5] Valencia, Diego F., Silvio Rotilli Filho, Alan Dorneles Callegaro, Matthias Preindl, and Ali Emadi. "Virtual-

Flux Finite Control Set Model Predictive Control of Switched Reluctance Motor Drives." In IECON 2019-45th Annual Conference of the IEEE Industrial. Electronics Society, vol. 1, pp. 1465-1470. IEEE, 2019.
[6] Manikandan, R., and S. Smys. "Controller based performance measures of speed control of electrical motor for industrial applications." In 2017 nternational Conference on Inventive Systems and Control (ICISC), pp. 1-5. IEEE, 2017.
[7] Pierre, Aguemon Dourodjayé, Agbokpanzo Richard Gilles, Houngan Kokou Théophile, and Vianou Antoine. "Torque ripple minimization in Switch Reluctance Motor using Model Predictive Control for water pumping application." Current Journal of Applied Science and Technology (2019): 1-9.
[8] Torkaman, H., H. Khanbabaei, M. S. Toulabi, and A. Keyhani."Two-level current reference method for speed control of switched reluctance motors." EPE Journal 30, no. 1 (2020): 13-23.
[9] Aaditya P. Agarkar ,Dr. S. B Mohod, “Supervise and Administration of Individual Load using Hyper Terminals” VYWS Prof Ram Meghe College of Engineering and Management, Badnera, Amravati Maharashtra,India, E-ISSN No : 2454-9916 | Volume : 3 | Issue : 5 | May 2017
[10] Omac, Zeki. "Fuzzy-logic-based robust speed control of switched reluctance motor for low and high speeds." Turkish Journal of Electrical Engineering & Computer Sciences 27, no. 1 (2019): 316-329.
[11] Divandari, Mohammad, Behrooz Rezaie, and Abolfazl Ranjbar Noei. "Speed control of switched reluctance motor via fuzzy fast terminal sliding-mode control." Computers & Electrical Engineering 80 (2019): 106472.
[12] Ferková, Želmíra, Ľuboš Suchý, and Peter Bober. "Comparison of 6/4 and 12/8 switched reluctance motor models using direct torque control with torque lookup table." Electrical Engineering (2019): 1-
[13] Makwana, Jignesh A., Pramod Agarwal, and Satya P. Srivastava. "Novel Physical Modeling Technique for Switched Reluctance Motor." In 2019 Innovations in Power and Advanced Computing Technologies (i-PACT), vol. 1, pp. 1-7. IEEE, 2019.
[14] Corda, J., S. Masic, and J. M. Stephenson, (1993) “Computation and experimental determination of running torque waveforms in switched-reluctance motors". Electric Power Applications, IEE Proceedings B [see also IEE Proceedings-Electric Power Applications], 140 (6): 387-392.
[15] Cornea. O., V. Popovici. and D. Argeseanu. (2008) "A switched reluctance motor drive model using standard simulink library components". Optimization of Electrical and Electronic Equipment, OPTIM 2008. 11th International Conference, 69-74, 22-24.
[16] Chen H., J. Jianguo, S. Suli, and Z. Dong, (2000) "Dynamic simulation models of switched reluctance motor drivers". Intelligent Control and Automation, Proceedings of the 3rd World Congress, Vol. (3): 2111-2115. (2000)
[17] Rodrigues. M.G., W.I. Suemitsu P. Branco J.A. Dente L.G.B. Rolim (1997) "Fuzzy logic control of a switched reluctance motor", Industrial Electronics, ISIE, Proceedings of the IEEE International Symposium , Vol. (2): 527-531. 1997.