© 2005 - 2009 JATIT. All rights reserved.

PERFORMANCE ANALYSIS OF SRM DRIVE USING ANN BASED CONTROLLING OF 6/4 SWITCHED RELUCTANCE MOTOR

Vikas S. Wadnerkar * **Dr. G. Tulasi Ram Das **** **Dr. A.D.Rajkumar *****

ABSTRACT

This paper proposes and investigates the fast on-line training back propagation algorithm for feed-forward ANN. It presents an ANN based architecture suitable to identify the status of a Switched reluctance motor to minimize the torque ripple. A hardware implementation of this scheme is on the way to testify the results and implement the scheme to other SRM.

Note: Basics of ANN has not been included as no. of books and research papers are available.

Key Words: *SRM, Error analysis, estimation, ANN, modeling, nonlinear estimation, Switched Reluctance motor drives.*

INTRODUCTION

Now it has been proved that Switched Reluctance Motor Drive can be used widely in industries instead of conventional AC and DC drives because of its simple and rugged construction, easy control, low losses and high efficiency.

Various control strategies have been projected and implemented to control the speed of SRM. Where as Torque ripple and noise are always remain as a challenge. In classical control system knowledge of the controlled system is required in the form of a set of algebraic and differential equations, which analytically relate inputs and outputs. However these mathematical models are often complex, rely on many assumptions, may change significantly during operation, and sometimes such mathematical models cannot be determined. Furthermore, classical control theory suffers from some limitations due to the nature of the controlled system. To overcome these problems researchers have suggested various control techniques including Fuzzy Logic control and Artificial Neural network. These techniques can be used even when the analytical models are not known , and they can be less sensitive to parameter variation than classical systems. Everyone suggested that Fuzzy and neural can be implemented to minimize torque ripple and noise.

ANN architecture is most suitable to identify the online parameters required for the production of torque [1-3]. Schemes using associative memory neural networks to minimize torque ripples in SRM are also been implemented [3]. Various circuitry for constant velocity control and reference tracking are suggested [4]. To minimize the ripples and maximize the torque output one of the methods to estimate minimum and maximum inductance is necessary [5]. Finite element and neural network method get optimum results. The behavior of SRM is highly nonlinear. On line parameter measurement technique are also explained [7]. A approach based on feed forward ANN to account for mutual interactions between excited phases and nonlinearities in the system for the estimation for torque when simultaneously exciting two phases. The technique required a small measured data set and involves simple calculations [6].

Some of the advantages of using AI-based controllers and estimators are: Their design does not require a mathematical model of he plant, they can lead to improved performance, they can be designed exclusively on the basis of linguistic information available from experts or by using clustering or other technique, they may provide solutions to control problems which are intractable by conventional methods, they exhibit good noise rejection properties, they are inexpensive to implement, they are easy to extend and to modify [8].

Mr. Vikas S Wadnerkar is with Essar steel, Hazira, Surat as a Faculty Electrical Engineering and Dr. G. Tulasi Ram Das with JNTU College of Engineering , Hyderabad and Dr. Rajkumar are with College of Engineering, Osmania University, Hyderabad.

TORQUE IN SWITCHED RELUCTANCE MOTOR

In Switched Reluctance Motor the torque is developed because of the tendency of the magnetic circuit to adopt the configuration of minimum reluctance i.e. the rotor moves in line with the stator pole thus maximizing the inductance of the excited coil. The magnetic behavior of SRM is highly nonlinear. But by assuming an idealistic linear magnetic model, the behavior pattern of the SRM can be adjusted with ease of without serious loss of integrity from the actual behavior pattern.

The most general expression for the torque produced by one phase at any rotor position is,

$T = [\partial W`/ \partial \Theta]_{i = Const}$ ……………….. (1.1) Since W`=Co-energy = ½ F Φ = ½ N I Φ…1.2)

This equation shows that input electrical power goes partly to increase the stored magnetic energy ($½L*i^2$) and partly to provide mechanical output power ($i^2/2 \times dL/d\Theta \times \omega$), the latter being associated with the rotational e.m.f. in the stator circuit.

Neglecting saturation non-linearity

L = Inductance = NΦ/ I……………….. (1.3)

$T = ½ \, i^2 \, dL/d\Theta$……… ………. .(1.4)

This equation shows that the developed torque is independent of direction of current but only depends on magnitude of current & direction of dL/dΘ.

NEURAL NETWORK ALGORITHM

Neural networks with the abilities of real-time learning, parallel computation, and self organizing make pattern classification more suitable to handle complex classification problems through their learning and generalization abilities. An artificial neural-network (ANN)-based predictor was used along with a state predictor to greatly improve the performance of the rectifier regulator and shows a typical result where the impact of the Prediction schemes on the dc-bus voltage ripple is obvious. The feed-forward ANN was trained on line using standard back-propagation (BP) as opposed to most of the applications of the feed-forward neural networks where training is performed off line using pre-stored data.

In general, each on-line training epoch consists of propagating the ANN input vector to compute its output, comparing this output with some reference to compute the training error, and finally modifying the ANN weights in such a way as to reduce the magnitude of this error to obtain the optimum value. Similar training is done with all the patterns so that matching occurs for all the functions.

This paper proposes and investigates the fast on-line training back propagation algorithm for feed-forward ANN.

BACK PROPAGATION:

Back propagation which is the most popular training method for a multi-layer feed forward network is shown in Fig. below. The ANN with back propagation algorithm is trained with fifty thousand data for both voltage controller. The topology is trained with one input layer, five hidden layers and one output layer with standard purelin, tansigmoid activation function.

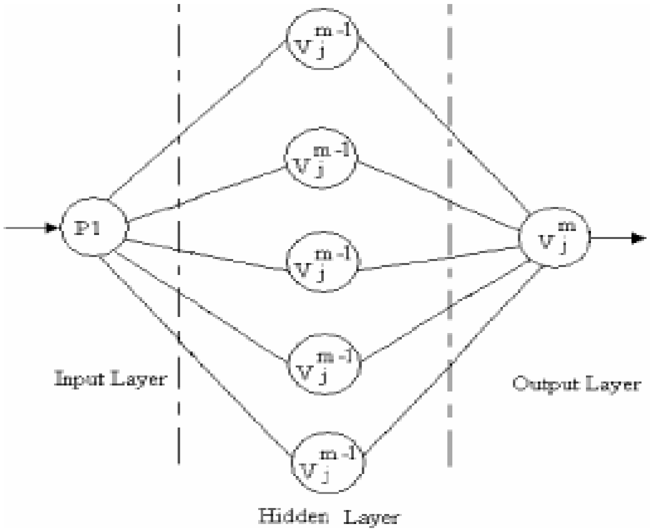

Fig. 1. ANN ARCHITECTURE FOR TUNING THE D-Q CONTROLLER

BACK PROPAGATION ALGORITHM:

The input to the ANN is the error and the output is the desired proportional gain Kp and integral gain Ki. The training data for the neural controllers are derived from the appropriate PI controller gain values for a typical load condition. The following steps are utilized for tuning controller using BP algorithm.

1. Set all weights to small random values.
2. Present an input vector I and a desired output O apply I to the input layer (m=0) so that $V^{O}=1$.
3. For other layer, namely m=1…….M, perform forward computation:

$V_i^{(m)} = f\,[\square_{\square} W_{ij}^{\,m} V_{ij}^{\,m-1}]$

where $W_{ij}^{\,m} V_{ij}^{\,m-1}$ represent the connection weight from $V_j^{\,m-1}$ to $V_i^{\,m}$.

.

4. Compute the error for the output layer

$\delta_i^{(m)} = V_i^m(1 - V_i^m)(Oi - V_i^m)$

5. Compute the back propagation errors for the preceding layers M-1…….1;

$\delta_i^{(m-1)} = V_i^{m-1}(1 - V_i^{m-1})\,[\square_j W_{ji}^{\,m}\,\delta^{\,m}]$

6. Adjust all weights:

$W_{ij}^{(m)}(t+1) = W_{ij}^{(m)}(t) + n\delta_i^{(m)} V_j^{m-1}$

where n is a gain parameter.

Thresholds are adjusted in a way similar to weight.

7. Repeat and go to step 2 until the desired epoch is achieved.

MODELLING OF SRM

- Linear Model of SRM (Fig 2)

From Above equations of SRM the model for simulation is developed. Fig: 2.

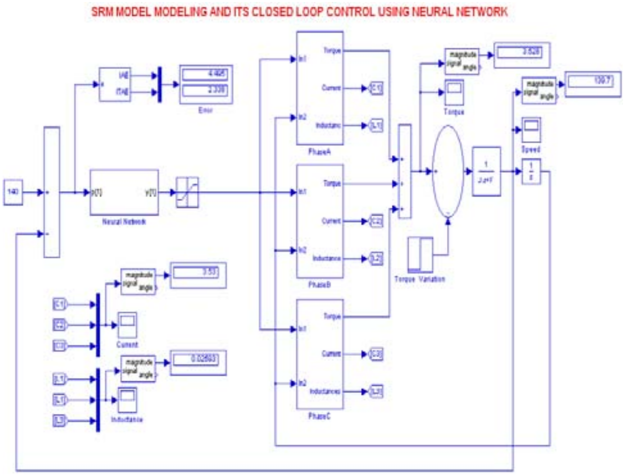

Fig 2: SRM MODEL MODELING AND ITS CLOSED LOOP CONTROL USING ANN

FIG: 3 EXPANSION OF ONE OF THE PHASE

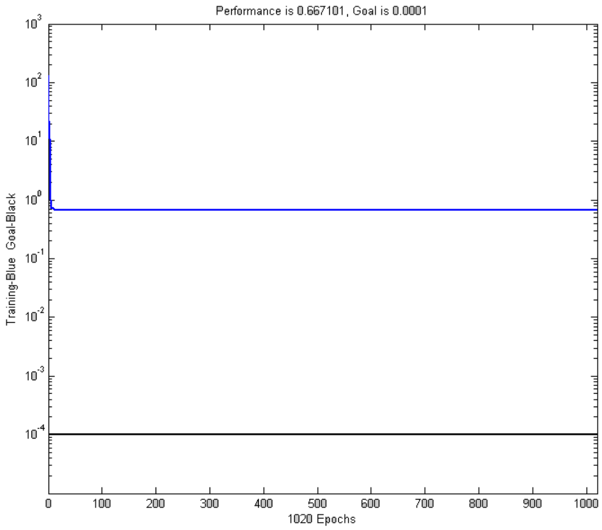

FIG 4: GOAL

SIMULATION RESULTS FROM ANN MODEL OF SRM

The various simulation results obtained are shown below which shows the superiority of fuzzy logic.

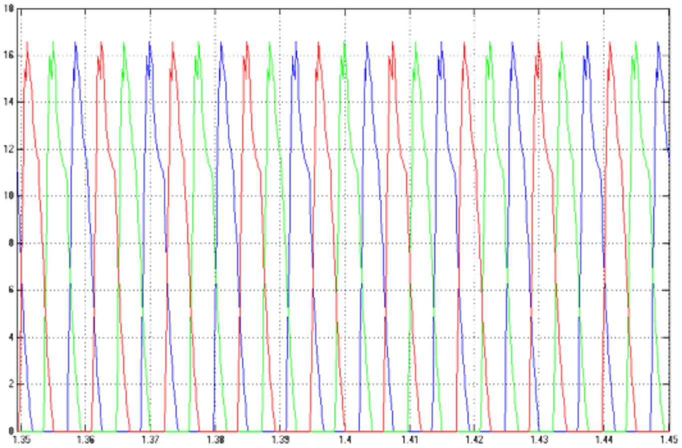

Fig: 5 Current under full load

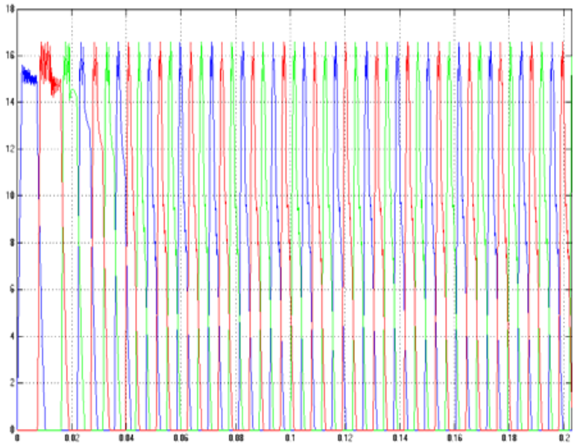

Fig: 6 Current under no load

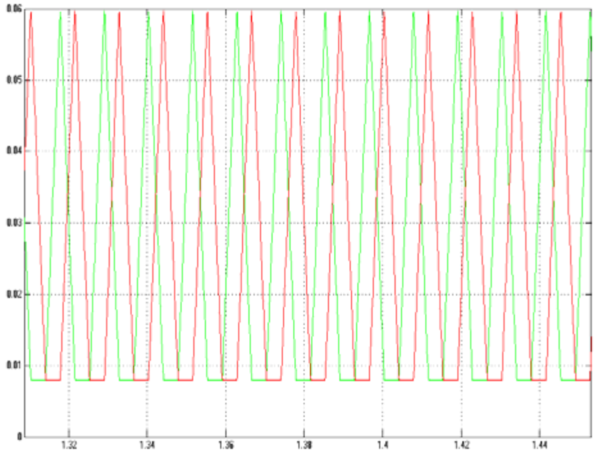

Fig 7: Inductance Profile

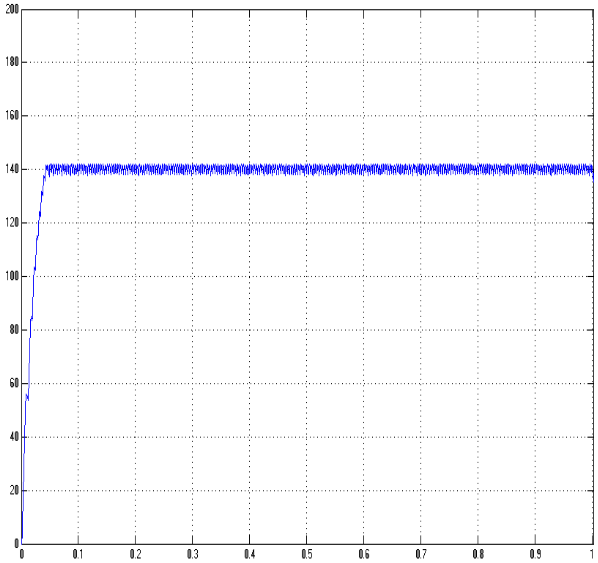

Fig 8: Speed of SRM

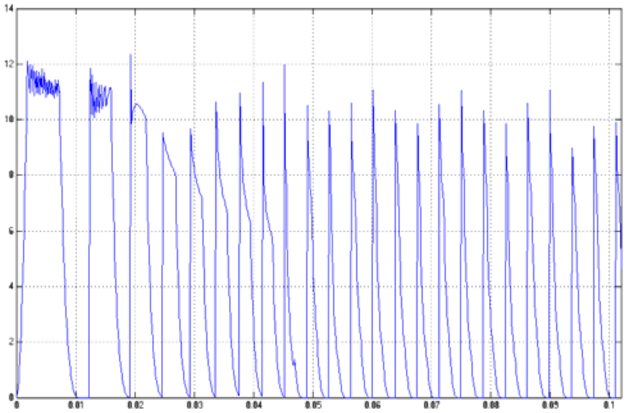

Fig 9: Torque

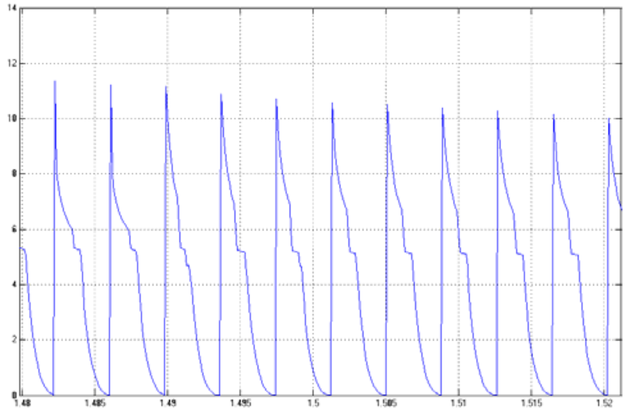

Fig 10: Torque under loading Condition

CONCLUSION

The application specific activation function gave the ANN`s an added advantage in terms of convergence speed and quality. It can be concluded that ANN`s are feasible structures to identify the states of a SRM.

It should be noted that the ANN`s without application specific layers did well but not as well as the ANN`s with application specific layers.

In this paper an improved ANN based sensor less rotor position estimation scheme with high accuracy is used to control the speed for 6/4 Switched Reluctance Motor. An optimized ANN based motor model with back propagation is used to calculate the rotor position from the current and flux waveforms. Various results are tested and studied. An ANN based optimal phase selector and a predictive filter are implemented to improve the estimation accuracy. The ANN model proved to be reasonably accurate. The advantage is that no

© 2005 - 2009 JATIT. All rights reserved.

prior knowledge is required, reduced complexity and faster operation after training.

A hardware implementation of this scheme is on the way to testify the results and implement the scheme to other SRM.

Appendix:

- No of Stator / Rotor Pole 6/4
- Supply Voltage 150 ± 50 v
- Current 5 Amp, R=1.30 ohms/phase
- L_{min} = 8mH, L_{max} = 60mH
- J=0.0013 kg m^2

REFERENCES

[1]. *Garside, J.J.; Brown, R.H.; Arkadan, A.A.;* Identification of switched reluctance motor states using application specific artificial neural networks, Industrial Electronics, Control, and Instrumentation, 1995., Proceedings of the 1995 IEEE IECON 21st International Conference on , Volume: 2 , 6-10 Nov. 1995 Pages:1446 - 1451 vol.2

[2]. *Elmas, C.; Sagiroglu, S.; Colak, I.; Bal, G.;* Modelling of a nonlinear switched reluctance drive based on artificial neural networks Power Electronics and Variable-Speed Drives, 1994. Fifth International Conference on , 26-28 Oct 1994 Pages:7 – 12

[3]. *Reay, D.S.; Green, T.C.; Williams, B.W.;* Minimisation of torque ripple in a switched reluctance motor using a neural network
Reay, D.S.; Green, T.C.; Williams, B.W.; Artificial Neural Networks, 1993., Third International Conference on , 25-27 May 1993 Pages:224 – 228

[4]. *Garside, J.J.; Brown, R.H.; Arkadan, A.A.;* Switched reluctance motor control with artificial neural networks Electric Machines and Drives Conference Record, 1997, IEEE International , 18-21 May 1997 Pages:TB1/2.1 - TB1/2.3

[5]. *Yilmaz, K.; Mese, E.; Cengiz, A.;* Minimum inductance estimation in switched reluctance motors by using artificial neural networks Electro technical Conference, 2002. MELECON 2002. 11th Mediterranean , 7-9 May 2002 Pages:152 – 156

[6]. *Ramamurthy, S.S.; Schupbach, R.M.; Balda, J.C.;* Artificial neural networks based models for the multiply excited switched reluctance motor Applied Power Electronics Conference and Exposition, 2001. APEC 2001. Sixteenth Annual IEEE , Volume: 2 , 4-8 March 2001 Pages:1109 - 1115 vol.2

[7]. *Ramamurthy, S.S.; Balda, J.C.;* Intelligent and adaptive on-line direct electromagnetic torque estimator for switched reluctance motors based on artificial neural networks Electric Machines and Drives Conference, 2001. IEMDC 2001. IEEE International , 2001
Pages:826 – 830

[8]. M.H. RASHID, POWER ELECTRONICS HANDBOOK, ACADEMIC PRESS, 2004, CHAPTER 29, PAGE NO 769-778.

Authors:

Vikas S Wadnerkar received the B.E. degree from Nagpur University, India in 1997, The ME degree from S G SITS, Indore under R G P V Bhopal, India and is currently pursuing the Ph D degree in Electrical Engineering at Jawaharlal Nehru Technological University, Hyderabad, India. His areas of Interest include Power Electronics control of Electrical Machines, Advances in Power Electronics.

Dr. G Tulasi Ram Das has specialised in Power Electronics and Drives. His research interests include Simulation studies on drives for PMSMs. He has 17 years of experience. He delivered invited lectures in institutes such as Anna University, Chennai; IEEE Hyderabad Chapter, BHEL R&D. He is conducting a research project funded by AICTE. He has a few publications of national and international level. He has guided 3 Ph.D. candidates and presently guiding 4 Ph.D. candidates.

Dr. A. D. Rajkumar, is a Professor in the EED of college of Engineering, Osmania University Hyderabad, Andhra Pradesh, India. His specialization is in Power Electronics and Microprocessor. He published a no of research papers in national and international journals and a member of various Technical committees.