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Indirect Position Estimation of Switched Reluctance Motor based on Flux Sensing Method

J.Uma[1], A.Jeevanandham[2]

Senior Assistant professor, Dept. of EIE, M.Kumarasamy College of Engineering, Karur, Tamilnadu, India[1]

Professor, Dept. of EEE, Bannari Amman Institute of Technology, Sathy, Tamilnadu, India[2]

ABSTRACT: Switched Reluctance Motor is one of the special machines with simple design, high startup torque and low inertia torque. Inspite of high torque ripple it has more merits on controller design flexibility. The sensorless operation need not require any extra hardware circuitry for position information and also it is easily reprogrammable as per the requirement of speed. The controllers of fuzzy logic estimation and Artificial Neuro Fuzzy Inference System estimation for predicting rotor position have been proposed. The simulated and performance characteristics of both controllers and its comparative study are presented in this paper.

KEYWORDS: Artificial Neuro Fuzzy Inference System estimation, Fuzzy Logic estimation, Flux sensing, Motional back emf, Rotor position, Switched Reluctance Motor.

I.INTRODUCTION

Switched Reluctance Motor (SRM) is an electric motor in which torque is produced by the tendency of its moveable part to move a position where the inductance of the excited winding is maximized. It is possible to operate in high temperatures. The SRM is a doubly salient, singly excited machine with independent windings of the stator. The configurations with higher number of stator/rotor pole combinations have less torque ripple. This paper presents the indirect rotor position of the drives with the help of pulse width modulation voltage control by detecting the change of the derivative of the phase current and this methodology holds good for medium and high speed applications like air moving and pump applications and even domestic appliances [1]. This paper proposes a practical sensorless rotor position exactly without any phase delay by proper compensation to achieve high performance drive [2]. In this paper speed control of Switched Reluctance Motor by self tuning fuzzy proportional integral controller with artificial neural network training is proposed. The dynamic model, flux-current-rotor position and torque-current-rotor position performance of the controller is compared with the performance of ANN, FL and FLPI controllers in MATLAB / Simulink.The [3]-[8].

This paper discusses robust control of SRM in robotic application by considering a mathematical model of SRM with unmodeled dynamics is proposed. Compared with normal controller, the proposed controller overcomes the influence of model uncertainties on system performance. [9]-[10]. This paper presents a speed control of SRG using ANN which is driven by variable speed wind turbine and it is connected to the grid through an asymmetric half bridge converter, DC link and DC-AC inverter system [11].This paper proposed to obtain the flux linkage characteristics of SRM to provide a good accuracy over the entire speed and torque range [12].In this paper a new soft switching driver with the auxiliary circuit is employed to reduce the electromagnetic interference [13].

The proposed work focuses on energy conversion by a SRG when two switch per phase converter circuit and discrete position sensors are employed [14]. In this paper a novel scheme of indirect rotor position estimation is described and it overcomes the drawback of previous sensorless scheme. The fuzzy based estimation is implemented by using DSP processor since it does not require any complex mathematical models and large look up table. The response speed is more and it works in all range of speeds (zero/low/high) and at different operating conditions (chopping/single pulse mode/steady state/transient response) [15].In this proposed paper the author implement the PI controller for four phase Switched Reluctance Motor Drive with rotor position sensor[17].The author analysed the vibration and acoustic noise

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occurance in the SRM drive under different load conditions with the help of sound level meter and Lab VIEW software and DAQ[18].

II.PRINCIPLE AND THEORY OF SWITCHED RELUCTANCE MOTOR

The movement of the rotor, the production of torque and power involving a switching of currents into stator windings when there is a variation of reluctance, this variable speed motor is referred to as Switched Reluctance Motor [16].

Incremental machine energy, $\Delta\omega_m = T_e\Delta\theta$ (1)

Where T_e – Electromagnetic Torque and $\Delta\theta$ –change in rotor position

For the case of constant excitation (ie., when the mmf is constant) then,

$\Delta\omega_m = \Delta\omega'_f$ (change in magnetic co energy) (2)

By the theory of electromagnetic field,if no magnetic saturation exists,the coenergy at any position in the motor can be expressed as

$$\Delta\omega'_f = \frac{1}{2} L(\theta,i)\, i^2 \quad (3)$$

where $L(\theta,i)$ is stator inductance at a particular position and I is the stator phase current.

$$Te = \frac{\Delta\omega m}{\Delta\theta} = \frac{\Delta\omega' f}{\Delta\theta} = \frac{\partial L(\theta,i)}{\partial\theta}\frac{i^2}{2} \quad (4)$$

At any position, the co energy and the stored magnetic energy are equal, which are given by

$$\Delta\omega'_f = \omega' = \frac{1}{2} L\, i^2 \quad (5)$$

Instantaneous torque, $T = \frac{1}{2} i^2 \frac{dL}{d\theta}$ (6)

$$P_{in} = i_{ph}^2 R_s + \frac{d}{dt}\left(\frac{1}{2} L_{ph} i_{ph}^2\right) + \frac{1}{2} i_{ph}^2 \frac{dL_{ph}}{d\theta}\omega \quad (7)$$

- First term gives the stator winding loss
- Second term gives the rate of change of magnetic stored energy
- Third term gives the mechanical output power

The most effective use of the energy supplied is to maintain phase current constant during the positive slope in that case the second term is equal to zero.

III.OVERALL BLOCK DIAGRAM EXPLANATION

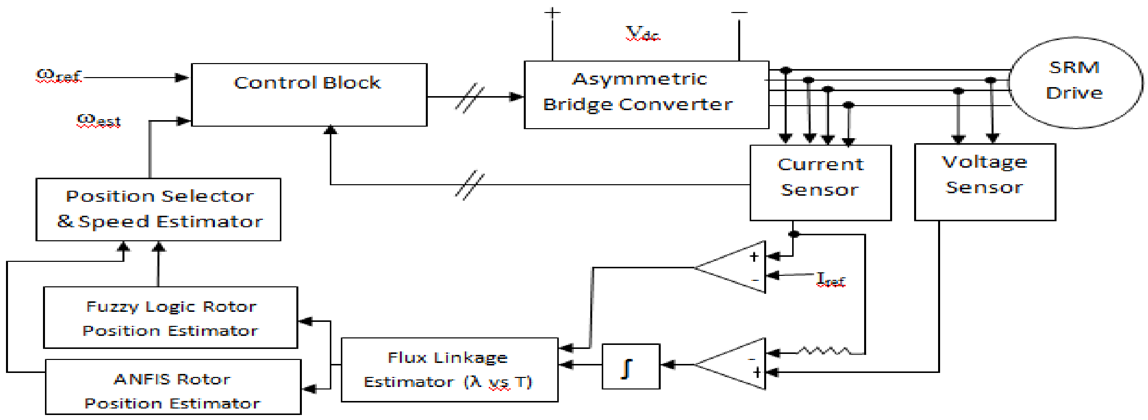

Fig.1.Overall Drive Controller Block Diagram

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The usage of these algorithms reduces the complexity of equation model. The proper selection of training data and the membership function gives the precise positioning of rotor with negligible error. According to the reference speed value the estimated position is selected as the input data for the production of control signal. The current signal at every instant of time also given as the input for the control block.

IV.FUZZY LOGIC AND ANFIS BLOCK DIAGRAM EXPLANATION

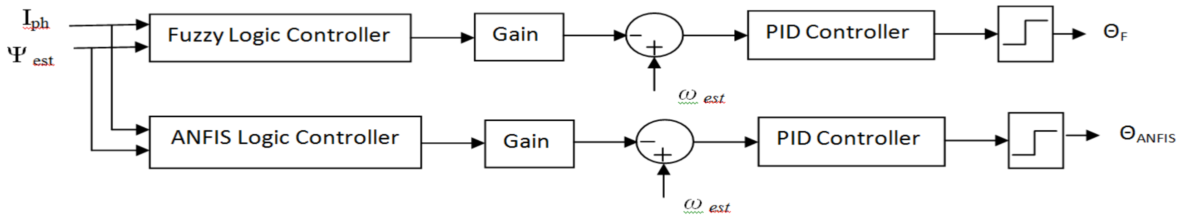

Fig.2.Fuzzy Logic and ANFIS Controller Block Diagram

The proposed sensorless scheme of SRM uses current sensor and voltage sensor to calculate flux linkage characteristics. From that data and current signal, the rotor position is estimated with the help of Fuzzy Logic and Artificial Neuro Fuzzy Inference System (ANFIS) algorithm.

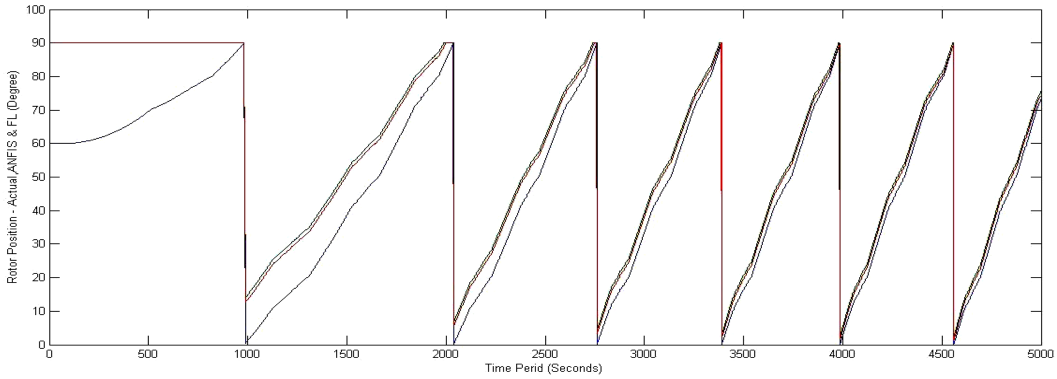

Fig.3.Rotor Position –Actual, Fuzzy Logic and ANFIS in degree Vs Time Period in seconds

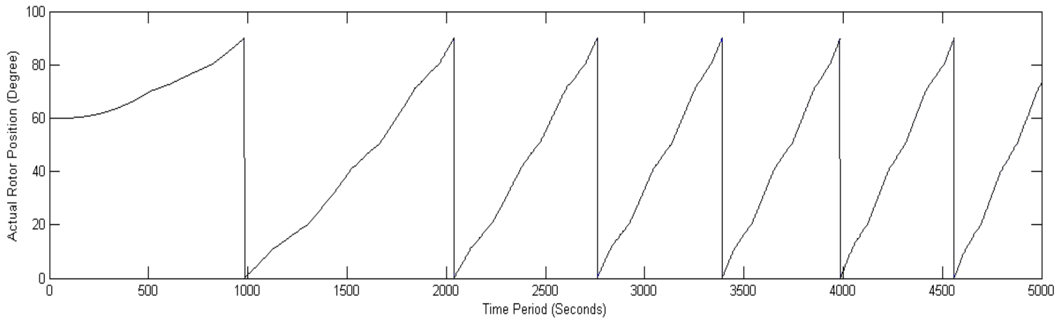

Fig.4.Actual Rotor Position in degree Vs Time Period in seconds

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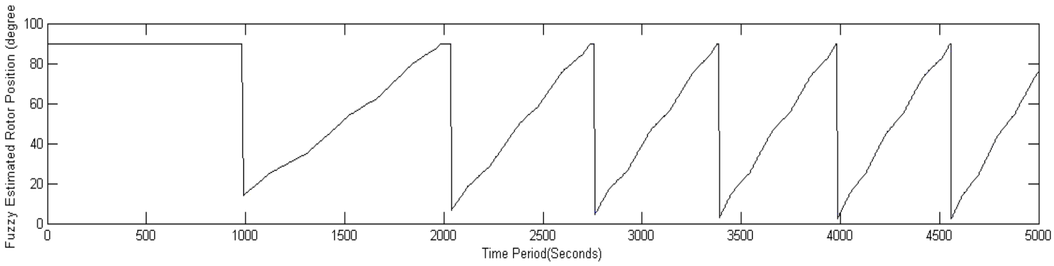

Fig.5.Fuzzy Estimated Rotor Position in degree Vs Time Period in seconds

Benefits of both ANN and FIS in a single model, so the ANFIS shows characteristics of fast and accurate learning, the ability of using both linguistic information and data information [4].

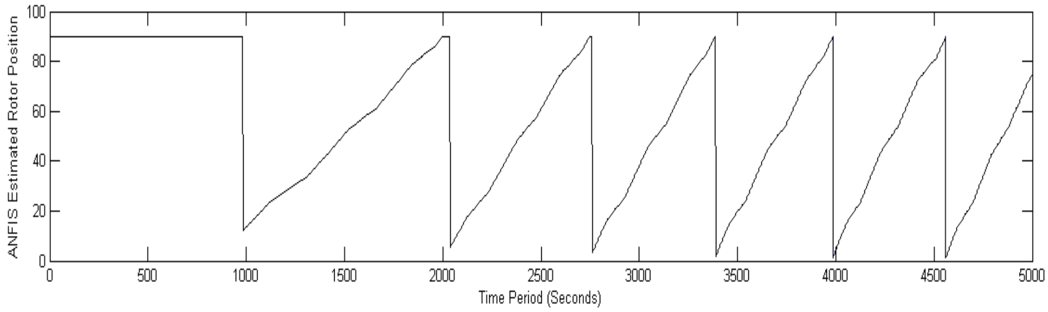

Fig.6.ANFIS Estimated Rotor Position in degree Vs Time Period in seconds

The winding excitation depends upon the gate signal of the bridge inverter. The gate signal for one winding excitation makes the next winding also to initiate excitation. The method of exciting next winding before the end of previous winding is referred as motional back emf method.

TABLE I

Time Period (seconds)	Actual Position (degree)	Fuzzy Logic Position (degree)	ANFIS Position (degree)
500	70º	90 º	90 º
1500	40 º	60 º	57 º
2500	60 º	65 º	63 º
3500	10 º	12 º	12 º
4500	70 º	71 º	72 º

REPRESENTATION OF POSITION IN DEGREES BY DIFFERENT CONTROLLERS

From the measured phase current and flux, the rotor position is estimated with the help of two types of controller algorithm. Depending upon the requirement the gain value is introduced. Then the comparator block compare the flux estimated with the measured flux .The PID controller is introduced for fine tuning the signal .Finally with the help of training both inputs with reference signal the rotor position is estimated separately by two controllers. From the simulated results (see Fig.3-6) the rotor position predicted with the help of ANFIS is very closer to actual position when compared to fuzzy logic. The difference of the position is around 10% from the actual position at the time of initial period. After certain period of time all the controller position and actual position gets merged.

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V. RESULT AND DISCUSSION

From the results of flux induced versus time period(see Fig.7), the initial period of time the flux envelope is wider in nature .When the time period gets increased the flux envelope becomes narrow and also ripples gets reduced due to feedback controller.

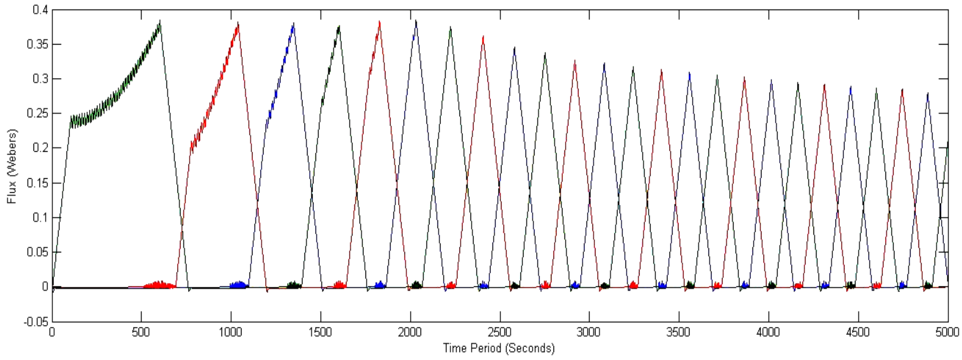

Fig.7.Estimated Flux in Weber Vs Time Period in seconds

The amount of error (see Fig.8) occurred when the flux is estimated by the controller.

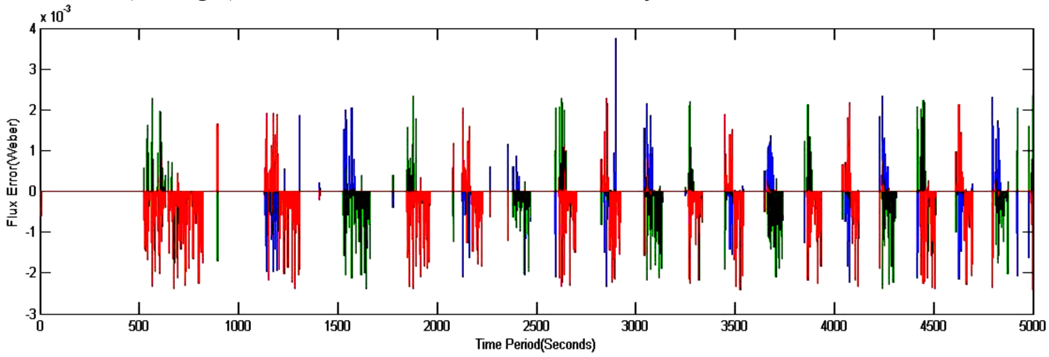

Fig.8.Flux Error in Weber Vs Time Period in seconds

The current waveform of all the phases(see Fig.9) are present in one characteristics curve, depending upon the training and learning algorithm the ripple content of current value gets reduced.

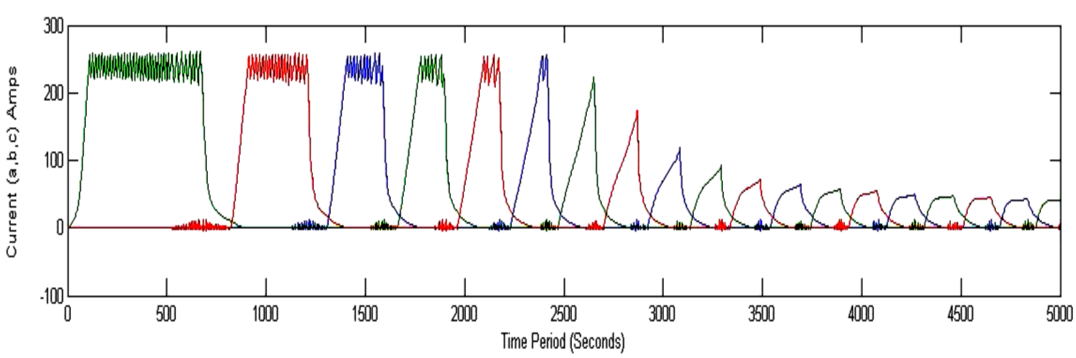

Fig.9.Phasor Current (a,b,c) in Amperes Vs Time Period in seconds

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The speed curve (see Fig.11) increases linearly as the time increases at the initial part. The torque (see Fig.10) and current magnitude increases at the initial period to makes the drives to reach the rated speed of 3000 rpm.

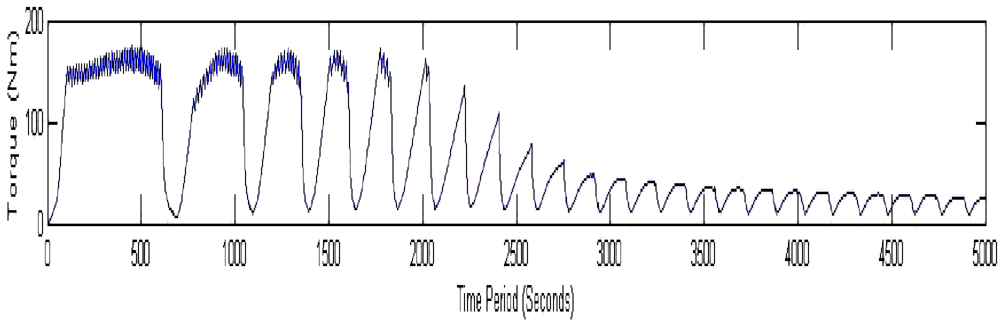

Fig.10.Torque in Newton-meter Vs Time Period in seconds

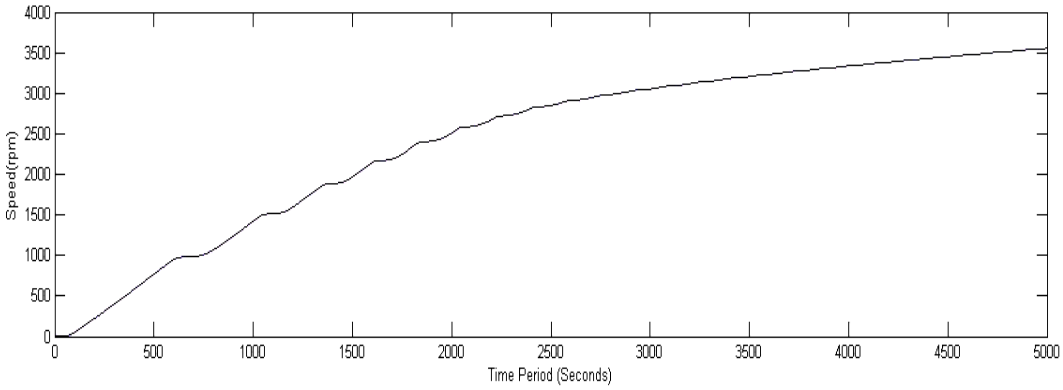

Fig.11.Speed in rpm Vs Time Period in seconds

Once it reached a maximum rated speed the magnitude of current and torque gets reduced. The voltage induced in windings (see Fig.12) shows that even before the completion of voltage induced in one winding the next winding gets energized to induce a flux continuously and also rotor rotates without any distortion with the help of control signal.

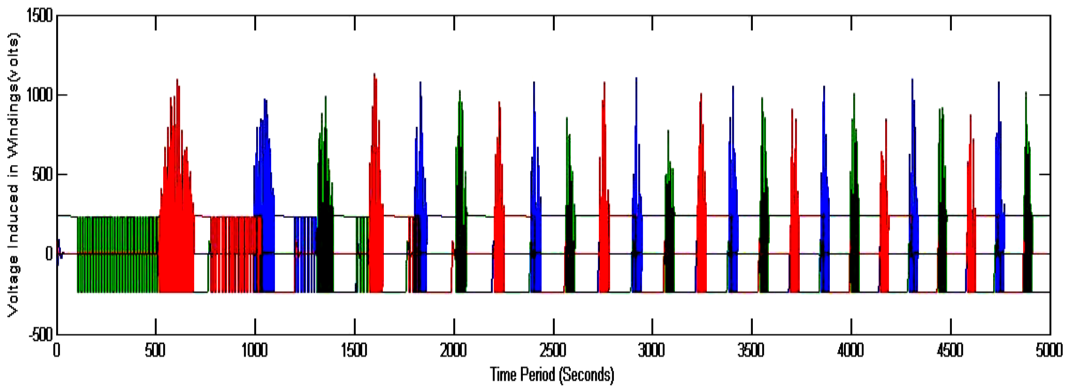

Fig.12.Voltage Induced in windings volts Vs Time Period in seconds

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VI.CONCLUSION

The proposed method uses the phasor current and flux linkage characteristics of the SRM to predict the position of the rotor without any external sensor makes the drive to be cost effective. The training data and linguistic information of ANFIS and Fuzzy Logic algorithm makes the prediction of position nearer to actual position with minimal error. The torque ripple is the major drawback of this drive is reduced with the help of effective sampling of data at every instant. The predicted position is given as exciting pulse of particular switches with the help of gate signal without any propagation delay and also it uses motional back emf method. The above said algorithm can be implemented in the hardware with the help of processor is the future scope of this paper

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BIOGRAPHY

Uma J, Tamil Nadu pursuing research in Power Electronics and Drives, completed post graduate in Power Electronics and Drives,from Annai Mathammal Sheela Engineering Collge - Anna University Chennai and under graduate in Electrical and Electronics Engineering from Bannari Amman Institute of Technology,Bharathiyar University.She published paper in Refereed Journal -2, National Conference-5 and International Conference -1 with IEEE conference proceedings. Major Fields of interest are Power Electronics and Drives and Electrical Machines. She is currently working as a Senior Assistant Professor in M.Kumarasamy College of Engineering, Karur- Tamil Nadu.

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Jeevanandham Arumugam, Tamil Nadu completed his Under graduation in Electrical and Electronics Engineering from Coimbatore Institute of Technology, Coimbatore and Post-graduation in Power Systems Engineering from Government College of Technology, Coimbatore. He obtained Ph.D in the field of Application of Artificial Intelligence to Power System from Anna University, Chennai. He awarded with PDF in the field of Power System Dynamics from San Diego State University, San Diego, California, USA and PDF in the field of High Solar Penetration from The University of Texas at San Antonio, San Antonio, Texas, USA. He published 18 papers in Refereed Journals, 7 papers in International Conferences and 45 papers in National Conferences. At present, he isworking as a Professor in the department of Electrical and Electronics Engineering,Bannari Amman Institute of Technology,Sathyamangalam, India.