VIBRATION ESTIMATION, ASSESSMENT AND PROGNOSIS IN ELECTRICAL MACHINES

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Abstract

In recent reviews of vibrations in switched reluctance motors (SRMs) are processed to estimate the performances of the motors and limited with the acoustic noise and vibration. In this paper, the motor transient vibrations are predicted the response while sudden occurrences load changes or braking and sudden vibration. The model of the system is developed by the proposed EnAMDF (Enhanced Average Magnitude Difference Function) using GRNN and details of torque, normal force versus speed and flux. The accuracy of the system is tested and verified by artificial neural networks. An adaptive enhanced mechanism based on GRNN is proposed to tune the gain PI controller and find the vibration and load of torque. The estimation and reduction of the SRMs vibration is simulated the magnetic circuit using the MATLAB/SIMULINK Environment. The results reveal the forces of transient are abundant harmonics and improve the possibilities of proposed system from acoustic noise point of view and vibration.

Keywords: GRNN; Transient; SRMs; Electromagnetic force; Vibrations; PI Controller;

I. INTRODUCTION

Recently in various industrial fields they focus on existing drive system and suitable motor, but there is demand in low noise motor because of increasing the environmental concerns. The noise of the motors comes from the generated electromagnetic forces of motor vibration. Based on the behavior of motor vibration the machine frequency is influence and characteristics the nature of it. In order to reduce noise and vibration efficient counter measure is obtain between the relationship of frequencies and forces in electrical machines. The forces of electromagnetic are evaluated using the analysis methods and investigated the harmonics fluxes through FEM and coil search.

However, electromagnetic forces and vibration modes are not estimated at running conditions. As well as the correlation between the motor vibration, forces and frequencies are not defined clearly. Due to the forces the mechanical amplitude response are not characterize the theoretical calculation. The eccentricity of actual motors and imbalance of rotor causes noise and vibration in motor, but not provided with its calculation procedure. Fig [1] shows the induction motor with its elements.

The switched reluctance motor (SRM) provide lesser vibration and noise over the brushless dc motors and induction motor. It widely used to provide the results of acoustic noise and vibration when occurrences of stator resonance. The waveforms and the frequencies are coinciding with the natural frequencies and normal mode shapes. Also, essential to predict the SRM stator characteristics to quite the electrical machines operations and design. Generally, SRM stator ribs and poles is not treated as an extra mass; based on assumption the mass will provides better estimation of low order modes frequencies and hidden the shape of modes in it [4], [13]. Fig [2] shows the flow work of estimating the whole electromagnetic.

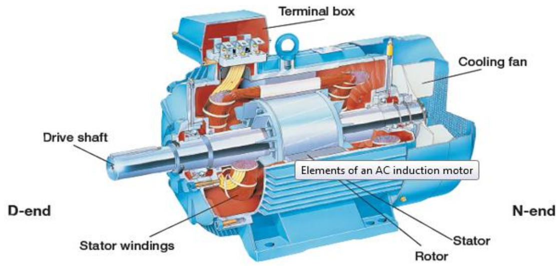

Fig.1: Induction Motor

The estimate of SRMs is performed with the vibrating test, analysis of model and frequency resonant. However the analysis and transient vibration are performances while braking, sudden load change and start up. In some circumstances, the steady state value is important to state the transient running time of SRMs with the application. It required encoding the rotor position and considering the torque ripple during the cause of acoustic noise and vibration [1]. Due to geometric design and control strategies the behavior of vibration is refers and associate with the forces to avoid noise. It predicts the function of the motors and estimated the function to run at different conditions [2], [6].

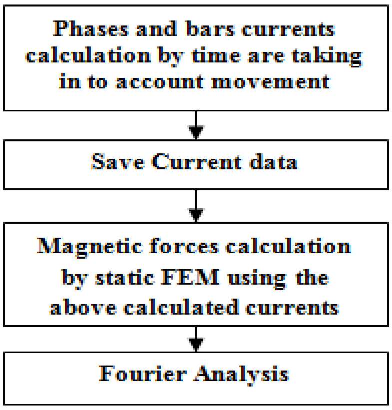

Fig.2: Flow work of electromagnetic calculation

The rest of the papers are organized in section wise. In section II the literature review of the SRMs and its related function and methods to avoid noise and to reduce vibration is discussed. In section III the explanation of proposed system EnAMDF (Enhanced Average Magnitude Difference Function) using GRNN and its implementation is presented. The simulation results and the analysis of proposed work with existing is presented in section IV and finally the conclusion of the proposed system analysis and the future work is in section V.

II. RELATED WORK

In this section, the literature review related to the magnetic function of torque and flux and the electromagnetic forces of motor are discussed. The noises of the motor are increase nowadays by the consideration of environment. Mostly 4 and 6 pole of induction motor is a vibrations process of the electromagnetic and specified the node and magnetic flux. The forces are examined the response of the motor with its performances according to parameter. Finite element method (FEM) is estimate the motor flux density with the analysis of time and space domains. The forces are obtained by the FEM analysis and Maxwell stress method by the applied force using the analysis of structure. The mode of vibrations and the frequency are defining the mode of the system [14].

The source analysis of dynamic response are examined the response and forces of motor vibrations between the mode and magnetic flux. As per the domains of time and space the density of motor flux is analyzed over the radial direction of motor. Using FFT analysis of forces is obtained for the mechanical vibration. The behavior by electromagnetic force is simulated by FEM and the spectrum components are identified and influence the frequencies with its mechanical properties [7]. As shown in Fig [3] the electromagnetic FEM model. In switched reluctance motors (SRMs) the main issues is the noise and vibration which limit the applications. It estimates the accuracy of the prediction with the essential design of motor and operates the model with conditions. Electronic techniques are used to avoid noise according to the frequencies resonant. The stator vibration modal end bell and windings frequencies are reflect it and estimate the frequencies up to 20% even if end bells influence are ignored. The numerical computations validate the resonant and shape of mode [8].

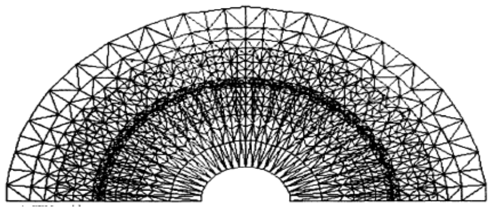
Fig.3: Electromagnetic FEM Model

The response of SRMs during the sudden changes of braking or load are estimated the performances and predict the developed vibrations in transient. Also the model is predict with the phase current versus normal force and using finite element the lookup table of rotor position is estimated. For better accuracy the model is tested during running motor. During transient the force are reveal the abundant harmonics and improves the design possibilities of model SRMs from the view of acoustic noise and vibration. Shaker and force hammer tests are used to measure the crucial parameters of vibrations like transfer function of damping ratio and modal frequency with accuracy [3], [11].

The applications are limited by the noise and vibration occurrences in SRMs. The determination of frequencies resonant and the stator shape mode are performed with less noise design. As per the theory of elasticity, finite method, frequencies and the modes of vibration are estimated and reflect in frames. Also the computation of numerical verifies the performances by the accelerometer [9]. The inductor motor vibratory behavior is analyzed by the numerical procedure. The rotational and model analyses are determine the structure of the mechanical motor. By the method of local force density the stator forces are evaluated. Finally the identification of spectrum vibrations is done [12]. Based on the magnetic equation the nonlinear model is developed and added by the profile with back EMF. The control technique of voltage and current is performed and analyzed the transform of frequency domain of electromagnetic torque with the dB magnitude and vibration frequencies [10].

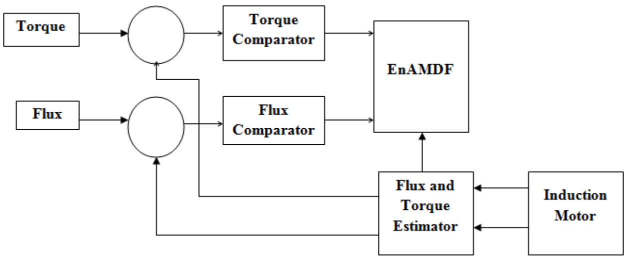

Fig.4: Block Diagram of Proposed system

III. PROPOSED WORK

In this section, the proposed EnAMDF (Enhanced Average Magnitude Difference Function) using GRNN is explained with its implementation. The switched reluctance motor (SRM) is used in the industrial application for robust and reliable process of working condition of motors for lifetime. The main issues are the ripple of torque and the acoustic noise occurrence in motor during the vibration, braking, sudden load change and frequency. The model of predicting vibration is based on the position of rotor and phase current and simulates the transient with various operating condition. The process of electromagnetic and mechanical process is performed by the equation as given below.

$$\frac{d\psi}{dt} = v - Ri \qquad (1)$$

$$T = T_1 + k_\omega \omega + m\frac{d\omega}{dt} \qquad (2)$$

$$\omega = \frac{d\theta}{dt} \qquad (3)$$

Where, the phase winding of linkage of flux is denoted as φ, Rand i are the winding resistance and current of the phase and the voltage terminal is denoted as t. T_1 is represent as electromagnetic torque, the coefficient of friction damping of load is denoted as k_ω, ω and m represent the rotor speed and the moment. The modeling of the SRM voltage phase is expressed as given below.

$$V_{ph} = r_{ph}.i_{ph} + L_{ph}\frac{di}{dt} \qquad (4)$$

$$L_{ph}\frac{di}{dt} = \frac{\delta_{ph}\left(i_{ph} \cdot \varphi_{ph}\right)}{\delta i_{ph}} \cdot \frac{di_{ph}}{dt} + \frac{d_{ph}\left(i_{ph} \cdot \theta_{ph}\right)}{\delta\theta_{ph}} . \varpi \qquad (5)$$

Where, the self-inductances voltage is represented as $L_{ph}\frac{di}{dt}$ and defined by the linkage of the magnetic flux φ_{ph}. θ_{ph} as the position of rotor and the speed of the torque motor is denoted as ω.

In the proposed method the vibration estimation is performed by using the PI controllers with Artificial Intelligence Technique (AI). For the measurement of motors vibration the gain of PI controller is used to tune by the proposed Enhanced AMDF technique using Generalized Regression Neural Network (GRNN) with generalization process and learning capability. Generally to understand the motor model lot of training is required and the functions of nonlinear are complicated in this process.

GRNN is used to connect the corresponding nodes and each node input signal is multiplied with the constant weight. The results are maps the functions to transfer the output. In enhanced GRNN, the layer functions of hidden, input and output layer is generalized the functions and perform the variation in weight till the error desired between the vector target. It enhanced the process of the vibration in network through the layers.

Enhanced GRNN used to tune up the PI controller gain and optimized the process for each stage of rotor vibration condition with the trained data. The input layer represents the rotor vibration and the gain internal controller and proportional are represented by the output layer. The linear function of activation and hyperbolic tangent sigmoid of output layer is representing in hidden layer. The learning of the proposed system is performed and simulated with the error and epochs. Fig [4] shows the block diagram of the proposed system.

The Enhanced Average Magnitude Difference Function using GRNN is used to find the load torque changes which applied to the motor. It compared the functions of the motor with the conventional fixed PI vibration controller. By apply of enhanced GRNN in PI speed controller to tune the gain of controller is specified as PI-GRNN controller. The occurrences of nonlinearities in motor are occur by the variations in parameters and it is find by the PI controller gain for motor control. The nonlinear and linear functions are mapping the dynamic process of the system and the controller tune the motor by adaptive mechanism based on GRNN.

GRNN:

%% Generating Vibration Datas

[x, xtrain, ytrain, fig] = Input Vibration Signals ();

%% Creating Neural Network for Vibration Measurement in Motors

net = newgrnn(xtrain, ytrain)

%% To Simulate Vibration Datas in Neural Network

y = net(x);

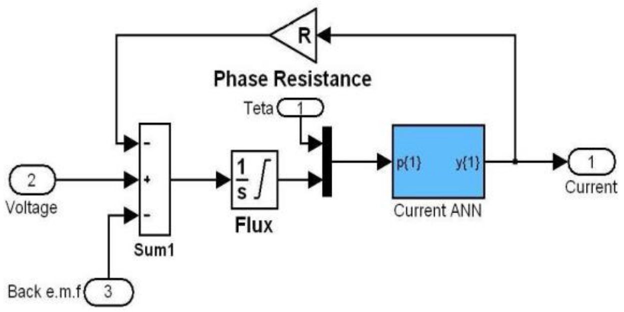

Fig.5: Current Block

In electrical machines, the stator resistance is performed with variation of vibrations and operating condition of motor because of voltage drop. The function of vibration in resistance is a function flowing current through winding and motor shaft speed and it is a nonlinear function. So compensating of vibrations effects are essential in the stator resistance. Fig [5] shows the current block of the SRM. Fig [6] and Fig [7] shows the position block of rotor and the block of inductance.

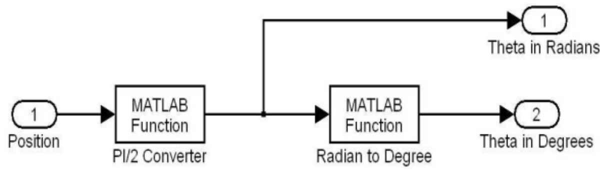

Fig.6: Rotor position Block

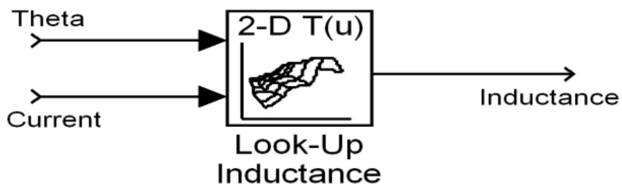

Fig.7: Inductance Block

By the suitable vector voltage selection the control of electromagnetic torque and stator flux are done independently and directly. The selection of vector is based on the flux hysteresis comparators, torque and position of stator flux. The gain of PI controller using the proposed system block diagram is shown in Fig [8]. Fig [9] and Fig [10] shows the torque block and controller of the current. So the error occurrences of flux and torque limited the approval of hysteresis bands. The optimum switching-voltage vectors are required and chosen by using proposed EnAMDF. So it obtained the simple considerations of stator flux and torque with its position. Due to the nonlinear operation the desired performances control is not performed but conventional PI controller is ready to tune up the gain and perform in continuous condition changing with better performances. The tuning up process of PI controller gain by adaptive enhanced mechanism based on GRNN. It maps the nonlinear system and linear system of dynamic process and by the speed of torque and induction motor the load torque is performed.

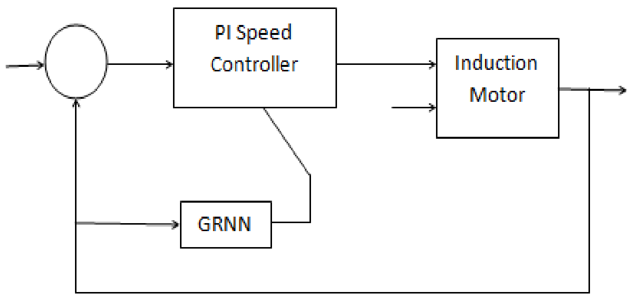

Fig.8: Block diagram of proposed controller system

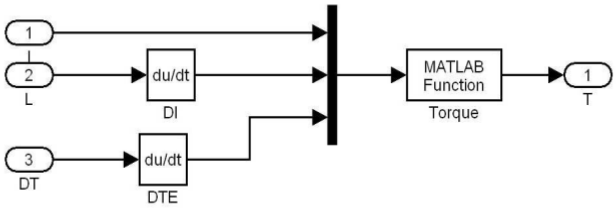

Fig.9: Block of Torque

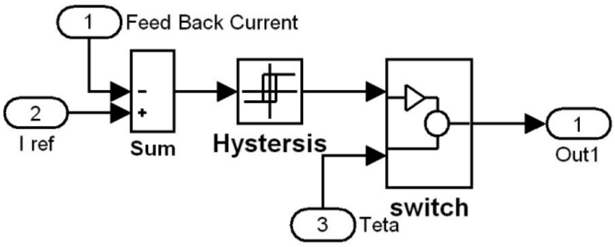

Fig.10: Controller of current

The adaptive enhanced GRNN interconnected the neurons to compute nodes and perform the network weight till the error in the network. Through layer by layer the vibrations processed in neural network. The proposed method strategies are operating in three conditions for decelerating, starting and accelerating. The performances is start from starting condition, in that vibration motor are starts and change from zero. In accelerating condition, the vibration is changes gradually and the condition is start from one. In decelerating condition, the motor vibrations are decreases and the condition starts from two. The changes of vibrations in each condition cause the changes in the load torque. During the operation of control in induction motor performs the gains of PI-GRNN controllers and occur changes according to the controller.

IV. SIMULATION RESULT

In this section, simulations of the proposed method performances have been analyzed with the existing method to show better performances. The non linear model is developed by the profile of inductance in MATLAB/SIMULINK environment. SRM dynamic characteristic is simulated and verified the performances of the result. The torque is analyzed by the tool to find the magnitude and frequencies of the operating condition.

The analysis of the proposed system than the existing are illustrated. Fig [11] shows the simulation results of estimated flux speed and the torque estimation is shown in Fig [12]. The operating conditions of the three stages are simulated by the proposed method strategy.

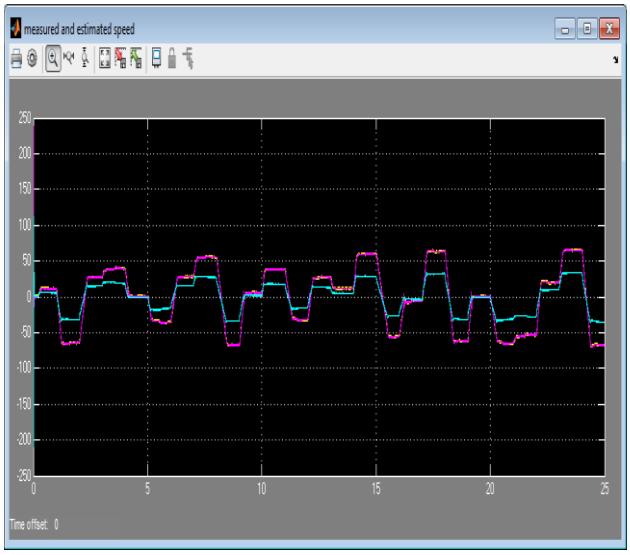

Fig.11: Simulation results of Flux speed

The training set of model speed, load and the estimated speed is shown in Fig [11]. Table [1] illustrates the results of proposed work analysis of vibrations from rotor with existing model. Performances Analysis of Electro Magnetic Torque of Induction Motor is plotted in Table [2]. Finally the Analysis of Stator Current of Induction Motor is in Table [3].

The results are simulated and compare with existing system to show the performances of proposed system provide better performances, reduce the vibrations and improved the method. The error rate is less than the existing method.

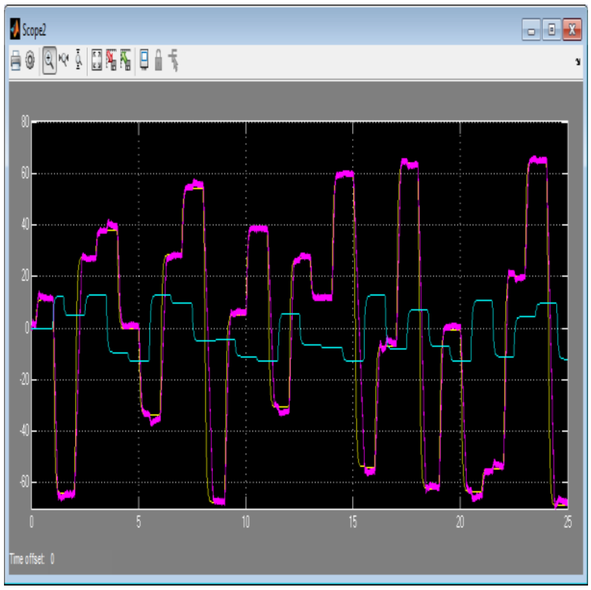

Fig.12: Simulation results of Torque speed

Table 1: Analysis of Error rate in vibrations from Rotor

Vibrations From Rotor	PI-FFNN	PI-GRNN
0-60	3.09	3.05
60	2.76	2.64
60-100	3.53	3.41
100	3.02	2.99
100-80	2.65	2.60
80	2.84	2.80

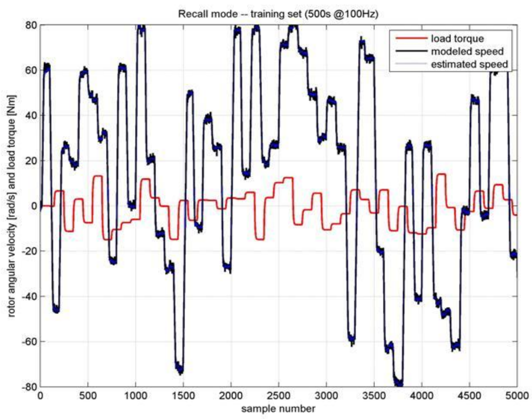

Fig.13: Training set of recall mode

Table 2: Performances Analysis of Electro Magnetic Torque of Induction Motor

ROTOR SPEED	PI-FFNN	PI-GRNN
60	0.5	0.1
100	1.5	0.6
80	0.2	0.1

Table 3: Performances Analysis of Stator Current of Induction Motor

ROTOR SPEED	PI-FFNN	PI-GRNN
0-60	5.32	5.24
60	1.57	1.44
60-100	8.12	8.09
100	4.37	4.33
100-80	0.99	0.77
80	2.8	1.95

V. CONCLUSION

In this paper, the performances analyses of the proposed EnAMDF (Enhanced Average Magnitude Difference Function) using GRNN is enhanced and design to provide better performances than the existing by avoiding noise and resonant modes with less vibration. The simulation results of proposed system are obtained by simulating the model using matlab/simulink. The system function of the motor is enhanced the technique to find the magnitude differences of the model of flux and torque. In order to provide better performances in speed, reduction of error rate from rotor, performances of induction motor stator and torque and to avoid noise the proposed enhanced technique is implemented and tested to verify the performance. Future work, improve the efficiency of the system by implementing a new technique and also design the system with less noise.

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