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Materials Today: Proceedings XX (2016) XXX–XXX

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PMME 2016

Hybrid Artificial Intelligence based Fault Diagnosis of SVPWM Voltage Source Inverters for Induction Motor

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Abstract

Induction motors are widely used in various industries for production processes due to their inherent characteristics like high reliability, robustness, low cost and ease of construction and operation. However, while in operation they face harsh and severe conditions imposed on them by the electrical, mechanical, thermal and environmental stresses which give rise to abnormalities in machine parameters such as voltages and currents. If the motor drive is allowed to continue to run under such situations, it will lead to catastrophic failure of the motor disrupting the production process and huge loss of revenue. Hence, an intelligent drive control method based on Hybrid Artificial Intelligence (AI) technique of Neuro-Genetic Algorithm is proposed in this paper for condition monitoring, fault diagnosis and evaluation of induction motor without any additional information. The hybrid architecture of Back Propagation Neural Network (BPN) to get the desired output fast and with Genetic Algorithm to overcome the computational complexity and time consuming process involved in BPN.

Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

Keywords: Voltage Source Inverter; Fault Diagnosis;Hybrid Artificial Intelligence; Back Propagation Neural Networks; Genetic Algorithm;

1. Introduction

Most of the industrial production processes are driven by the induction motors as prime movers over those of other electric (AC/DC) motors. This is because AC induction motors are simple in construction when compared to DC and other AC motors. Induction motors are extensively used as industrial drives in various industries and act as

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Selection and Peer-review under responsibility of International Conference on Processing of Materials, Minerals and Energy (July 29th – 30th) 2016, Ongole, Andhra Pradesh, India.

prime movers to run pumps, blowers, fans, compressors, transportation etc., It is reported that in an industrialized nation, induction motor drives consume power as much as 40 % to 50 % of the total generated electrical power of that country [1]. Hence, utmost care should be exercised in the selection of most appropriate type of controller scheme for each application, so that the motor would provide the optimum desired performance with high reliability. Faults such as vibration, circulating currents, loss of coolants, earth fault, turn to turn faults due to cracking of insulation, fretting of insulation and displacement of conductors do occur inside the machine as it faces electrical, mechanical, thermal and environmental stresses while in operation and these will also give rise to over voltages and injection of current harmonics and distortion of air gap flux [2]. Further, manufacturing defects and installation issues in industrial applications also cause faults inside the motor.

All the above faults, if unchecked, will lead to the catastrophic failure of the motor, thereby disrupting the industrial processes causing huge loss of revenue and enormous increase in the maintenance and repair costs. The timely detection and diagnosis of various faults not only avoids the expensive failures of the motor drive but also will increase the time interval between planned shutdowns for standard maintenance, thereby realizing reduction in maintenance and operational costs. The conventional protective systems against such faults are, in general, passive devices such as fuses, over load relays and circuit breakers which will disconnect the power sources from the inverter systems on occurrence of fault either external or internal to the motor drive, thereby stopping the industrial processes and therefore such protection schemes do not serve any purpose to avoid unscheduled downtimes and huge loss of revenues; moreover they are sluggish and might lead to catastrophic failures of induction motor[3-5]. Hybrid Artificial Intelligence (AI) techniques such as the Genetic Algorithm (GA) and Artificial Neural Network (ANN) are being used now a days to find an optimal solution for complex problems like fault diagnosis and control of induction motor drive [6-7]. Hence, the hybrid AI system is tested on an Induction motor for fault diagnosis, to reduce the learning time and to obtain an efficient solution for the machine design [8]. Due to the increasing complexity of machine design and production, there is a constant requirement for efficient methods like artificial intelligence technique for fault diagnosis [9].

2. Materials and Methods

Fault detection using analytical methods is also not possible as it requires a perfect knowledge of the motor model [10]. Therefore operators of drive systems are under continual pressure to prevent unscheduled downtimes and keep down the maintenance costs. Therefore the strategy to be adopted should be such that early detection of the abnormalities arising out of fault occurrence is made possible or in other words online condition monitoring and diagnosis are the necessities [11-12]. Condition monitoring can be defined as the process of monitoring the operating characteristics of a machine so that changes and the trends of monitored signals can be made use of to predict the need for maintenance before a breakdown or serious deterioration occurs in the motor drive [13]. Moreover as the modern production processes are sophisticated and complex, it is always very much essential to ensure the required reliability and condition based maintenance strategies to avoid the unexpected total failures of the drive systems and downtimes [14].

The induction motor is fed by a Voltage Source Inverter (VSI). The block diagram of the AI based fault diagnosis of induction motor drive is shown in Figure 1. The IGBT inverter is used for inverting the supply voltage from DC (Direct Current) to AC (Alternating Current). IGBT inverters have low acoustic noise due to high switching frequency. The inverter topology consists of 3 legs, each carrying two switches S1,S2, S3,S4 and S5,S6. The fourth leg carries switches S7 and S8. Three Triacs T1,T2 and T3 are used to configurate the inverter circuit after fault occurrence and its isolation. Supposing misfiring in power switch Sn occurs, fault diagnosis block detects this fault and isolates the corresponding faulty leg by interrupting the gate signals to the corresponding switches Sn. Variations if any in voltage, current and speed will be sensed immediately by flux and signal estimation block and the signals will be transferred to the AI block for fault identification. Flux and Signal estimation block receives as its input signals corresponding to terminal voltages and currents of the induction motor after getting themselves converted into d-axis and q-axis components and speed of the motor, which are processed and estimated and converted into output signals representing torque and flux. These signals fed in to the AI block, the output of which are input signals to SVPWM block which processes and generate the appropriate pulses to be provided to Binary logic block. If any variation or fault is identified in any of the switches from S1 to S7, immediately the faulty legs are disconnected and spare leg will be replaced. This process will improve the overall running performance of the motor.

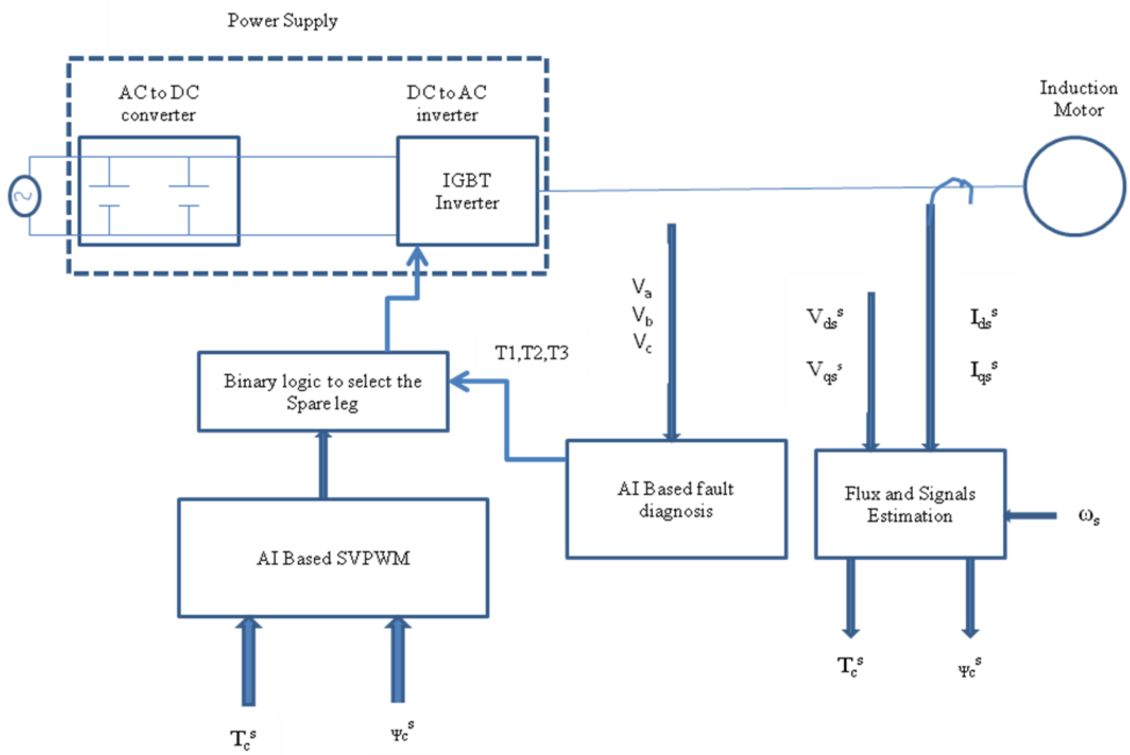


Fig. 1. Block diagram of AI based fault diagnosis of induction motor drive

2.1. Neuro-Genetic Technique

Neuro-Genetic combined operation is used to generate new populations iteratively. The fault controller unit is designed by using the Genetic Algorithm (GA) for the optimum selection of switching pulses in SVPWM to the supply input of IGBT (Insulated Gate Bipolar Transistor) inverter. In the Neuro-Genetic Implementation, Back Propagation Neural Network (BPN) is used to get the desired output fast and the Genetic Algorithm to overcome the computational complexity and time consuming process involved in ANN. The proposed design technique is modeled and verified by using Matlab Simulink as one of the effective design for fault diagnosis of induction motor drive. The GA process should concentrate on the convergence time; else it fails to get the optimum result in real time applications. Many researchers have proposed and applied the SVPWM technique for pulse generation, the most successful technique in motor control. But if the searching time of the control unit is increased, the fast responses of the switch may not be achieved. The MATLB simulink model of neuro-genetic technique for fault diagnosis of induction motor drive is shown in Figure 2.Wherever fault occurs, fast response to the selection of legs when the fault occurs is important for continuous running of the motor. Hence, this process is successfully achieved by using the optimized control unit.

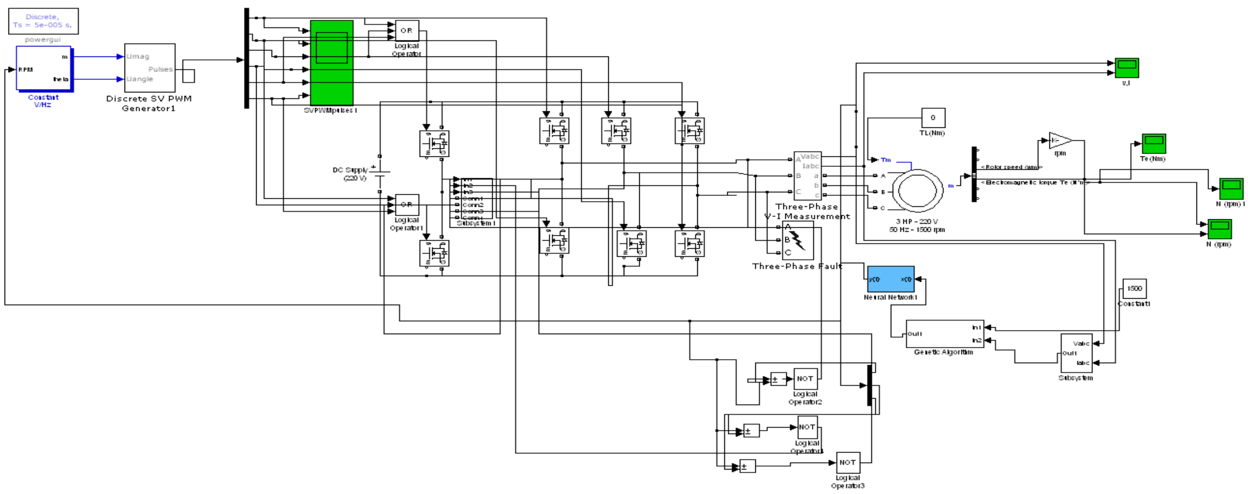
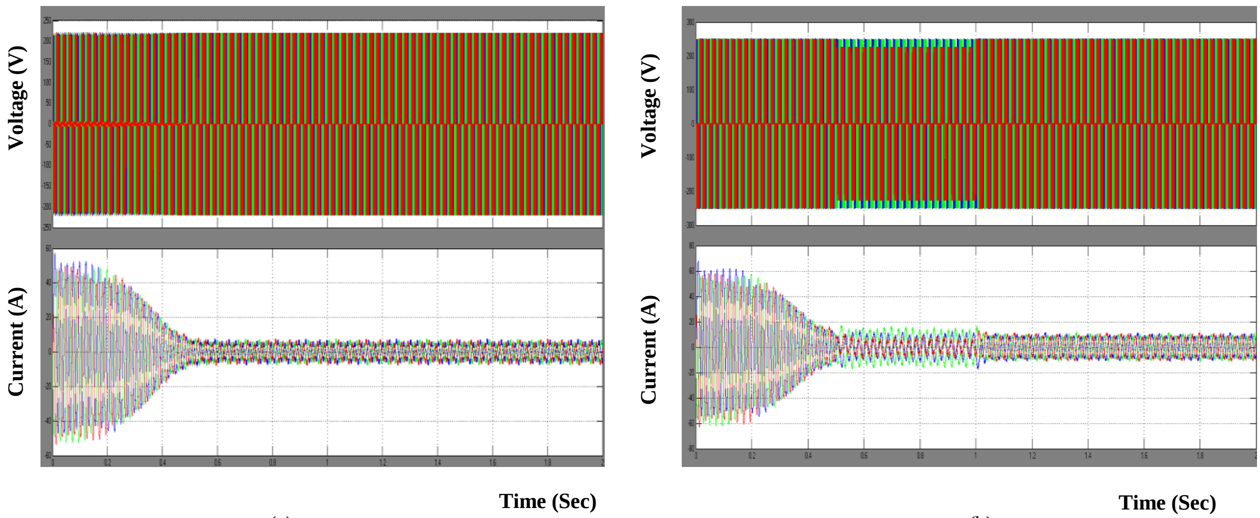


Fig. 2. MATLAB Simulink model of Neuro-Genetic based fault diagnosis of induction motor

3. Results

In real time applications, the efficiency and reliability of the induction motor depends on fault free operation. In order to diagnose the fault, Neuro-Genetic (BPN with Genetic Algorithm) are used for condition monitoring, drives control and evaluation of induction motor. The input voltage, current, electromagnetic torques is observed under normal and faulty conditions. The observed outputs are given in Figure 3. The fault legs identification and variation in SVPWM is given in Figure 4. The speed of the induction motor almost reached the no load speed 1490 in 0.55 sec after the fault recovery is shown in Figure 5.



(a) (b)

Fig. 3. Input voltage and current waveforms under (a) normal and (b) faulty condition

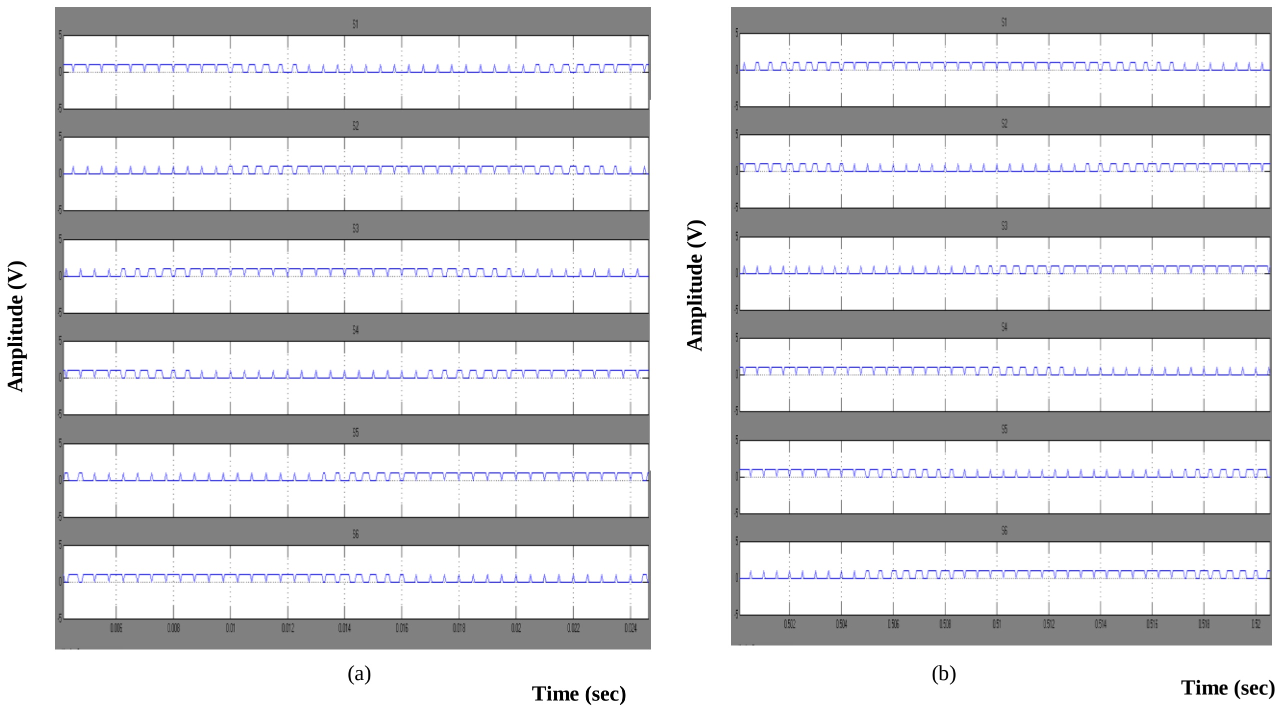


Fig.4. SVPWM waveforms under (a) normal and (b) faulty condition

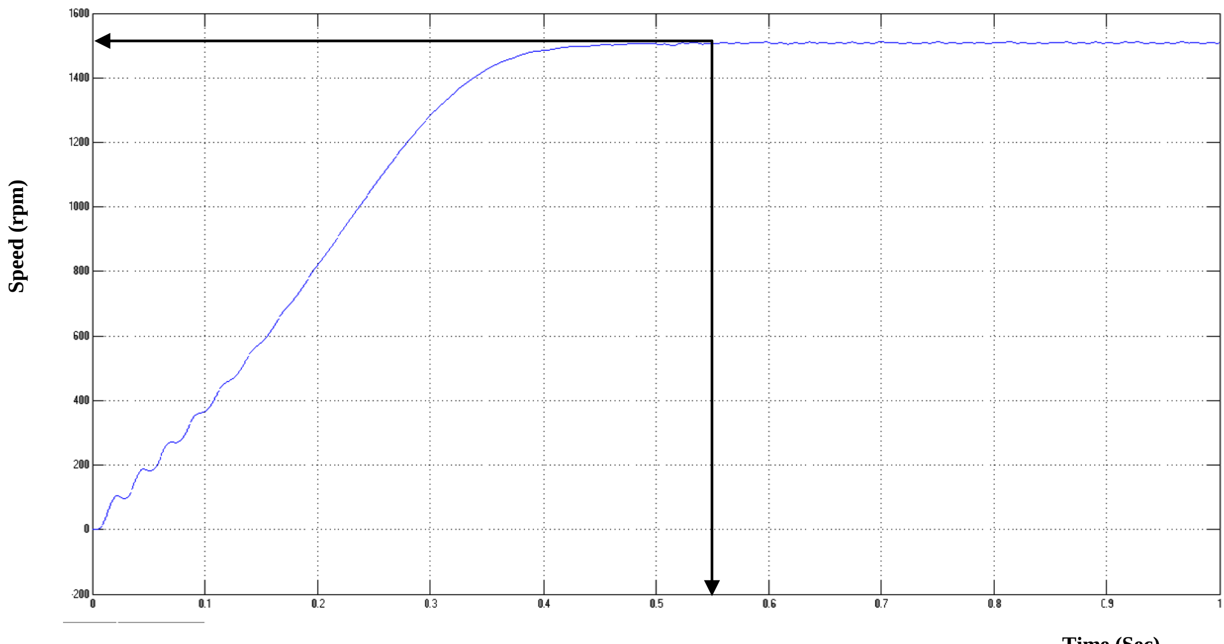


Fig. 5. Observed Speed variation of induction motor

4. Discussions

To assess the capabilities in diagnosing the fault, Neuro-Genetic technique that have been applied by using MATLAB Simulink tool to diagnose the fault occurring in VSI of the induction motor drive.The Neuro-Genetic technique which is developed in this paper is applied using MATLAB Simulink tool for the fault diagnosis and results obtained. For testing purpose three phase fault block has been added in the Simulink model to initiate the fault (short circuit) between any phase and ground with a time period from 0.5sec to 1sec in the simulation. In this simulation, Phase C is considered as the faulty phase. The obtained results are presented in faulty and normal conditions of the induction motor under no load conditions. When compared with all other methods, Neuro-Genetic approach gives fast response time as shown in Table 1 and Figure 6.

Table 1. Comparison results of different Models

Parameters	Fuzzy Logic	BPN	Neuro-Fuzzy	Neuro-Genetic
Fault Recovery time (Sec)	0.9	0.7	0.7	0.55

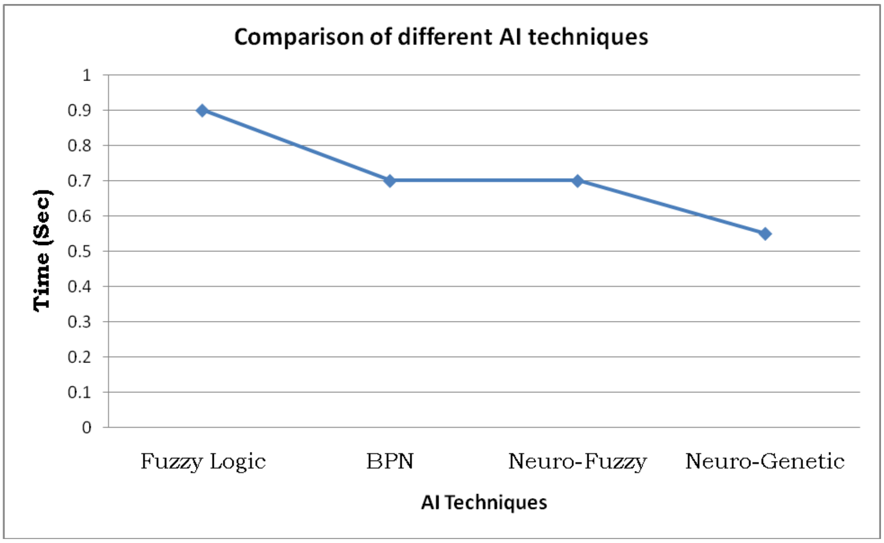


Fig. 6. . Fault recovery time comparison of different AI techniques

5. Conclusion

To assess the capabilities in diagnosing the faults in VSI of the induction motor drive hybrid Artificial Intelligence technique such as Neuro-Genetic Algorithm is applied. A comparison of the results shows clearly that the Neuro-Genetic methodology developed in this paper offers the best results. The results are extremely important for fault detection monitoring of the induction motor and for the development of a low-cost digital controller IC for control of induction motors in future.

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