

Pattern Recognition and Diagnosis of Open Circuit Faults Inverter in DTC- SVM with PI Controller of Induction Motor Drive Using Neural Networks

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Abstract - the operation and control induction motor and inverter drives under faulty condition is a big challenging task in the present day. For that reason, these electrical systems must have well considering to establish a good diagnostic of these elements. Consequently, detecting defects early will be very important, to determine strategies that will allow us to control the operation and take preventative measures to avoid frequent failures. Using neural networks, this study provides a pattern identification technique for open circuit switch failures in inverter. With a simple feature extractor technique to make detection and diagnosis faults possible and straight forward with a neural network. . We also attempted to reconfigure the inverter system to prevent faults from occurring. Simulation results and classification performances improved by using a neural network for fault detection, recognition and reconfigure.

Keywords - Space Vector Modulated–Direct torque control; faults diagnosis; induction motor; neural network control, open circuit switches; inverter reconfiguration.

I. INTRODUCTION

A novel control approach known as Direct Torque Control - Space Vector Modulated (DTC-SVM) has recently been created from the traditional DTC methods. The disadvantages of the traditional DTC are eliminated in this new approach. DTC-SVM strategies are essentially techniques that use a constant switching frequency [1].

The DTC-SVM technique that is being presented has a straightforward structure, has dynamic behavior, and significantly improves parameters during steady state operation [1].

Papers [2-3] have discussed the modelling of inverters and induction motors.

Several intelligence algorithms were developed to control induction motors. Fuzzy logic control (FLC) [4-6], adaptive neuro-fuzzy interference system (ANFIS) [7], artificial neural networks (ANN) [8] and deep learning [9] are examples of such systems.

Artificial Neural Networks (ANN) are machine learning and artificial intelligence algorithms inspired by a human brain's functioning. It's composed of an abstracted model of interconnected neurons whose unique layout and connections can be used to resolve computer-based application challenges in a variety of industries. A neural network requires training before it can handle issues. [10-11].

Many faults occur in different elements in the AC drive, such as stator winding faults [12-14], cut of an inverter arm fault [15], switching device, DC bus faults, Machine failures (rotor, stator), drive chain faults (mating flaw, sensors), and power supply failures (imbalance in power supply, power electronics converter fault). [16], as well as a fault tolerance control [15]. Given this, switching devices in the study are likely to be damaged by faults due to their frailty [12,17-18]. Various electrical power system defaults have already been invented and published [19-22].

The purpose of this project is to use a feature extraction method to investigate the possibilities of employing neural networks to discover faults. To allow for the detection, localization and reconfiguration of defects in the PWM inverter, a defect classification based on artificial neural networks will be built up.

II. BASIC DTC-SVM

As seen in fig. 1, two loops correspond to the torque and flux stator magnitudes. When reference values (T_e^*, Φ_s^*) compared with actual values (Φ_s, T_e) errors ($\varepsilon T, \varepsilon F$) occurs. These errors feed into two PI controllers of flux and torque to obtain the reference voltages (U^*_{ds}, U^*_{qs}). These components are then transformed into the stationary frame ($\alpha-\beta$), then will be injected into the SVM vector modulation block which generates the inverter control orders [1] [19,23-25].

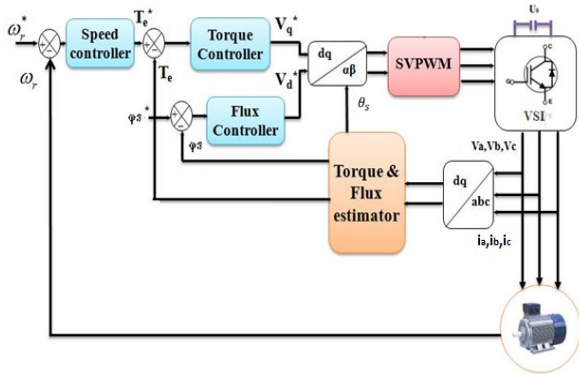


Fig. 1. Block diagram of DTC-SVM with PI Controller.

$$V_\alpha = V_d^* \cos(\theta) - V_q^* \sin(\theta) \quad (1)$$

$$V_\beta = V_d^* \sin(\theta) + V_q^* \cos(\theta) \quad (2)$$

$$V_s = \sqrt{V_\alpha^2 + V_\beta^2} \quad (3)$$

U_0 : is alimentation of inverter
The flux stator is determined by:

$$\begin{cases} \varphi_{sd} = \int_0^t (V_{sd} - R_s I_{sd}) dt \\ \varphi_{sq} = \int_0^t (V_{sq} - R_s I_{sq}) dt \end{cases} \quad (4)$$

The stator flow modulus is calculated using the following equation:

$$\Phi_s = \sqrt{\varphi_{sd}^2 + \varphi_{sq}^2} \quad (5)$$

The angle θ_s is set by:

$$\theta_s = \tan^{-1} \frac{\varphi_{sq}}{\varphi_{sd}} \quad (6)$$

The calculated currents (I_{sq}, I_{sd}) and the estimated flux magnitudes ($\varphi_{sd}, \varphi_{sq}$) are used to evaluate the electromagnetic torque given by:

$$T_e = \frac{3}{2} p (I_{sq} \varphi_{sd} - I_{sd} \varphi_{sq}) \quad (7)$$

p Poles number.

III. SYSTEM OF FAULT DIAGNOSIS

Figure 2 depicts the proposed fault open and short switch in the diagnosis system. A malfunctioning switch in a PWM voltage source inverter will show the usual current and voltage patterns.

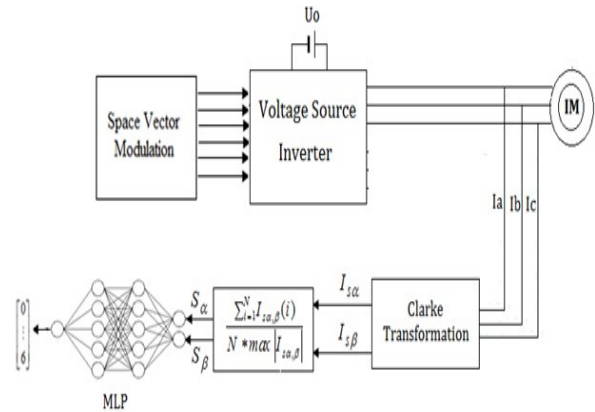


Fig. 2. Proposed fault diagnosis system.

The line currents of the three phases with respect to the neutral are represented in the $\alpha\beta$ -reference frame by a simple vector addition of these three-phase variables. these two new vectors are obtained by applying the Clarke-Concordia transformation. Therefore, the measured currents (I_{sa}, I_{sb}, I_{sc}) are transformed into two dimension ($I_{s\alpha}, I_{s\beta}$) by :

$$\begin{cases} I_{s\alpha} = \frac{2}{3} I_{sa} - \frac{1}{3} I_{sb} - \frac{1}{3} I_{sc} \\ I_{s\beta} = \frac{1}{\sqrt{3}} (I_{sb} - I_{sc}) \end{cases} \quad (8)$$

IV. FEATURE EXTRACTION

Feature extraction is critical for developing an efficient problem detection and diagnosis system from the output three-phase current signal. It was used to extract data and train a neural network to detect faults. Normalized functions should be universal for different reference speeds [18].

We employ the extracted feature as an input to a neural network, which aids in recognizing and identifying defects. It provides the opportunity to make a system more precise in fault patterns.

In this project, we will use a method based on surface calculation. Currents measured ($I_{s\alpha}, I_{s\beta}, I_{sc}$) transformed into two dimensions ($I_{s\alpha}, I_{s\beta}$) by equation (8) are calculated their surfaces ($S\alpha, S\beta$) using a feature extraction mathematical model defined in a single equation (9) [19], [22]:

$$\begin{cases} S_{\alpha} = \frac{\sum_{i=1}^N I_{s\alpha}(i)}{\text{length}(I_{s\alpha}) * \max(\text{abs}(I_{s\alpha}))} \\ S_{\beta} = \frac{\sum_{i=1}^N I_{s\beta}(i)}{\text{length}(I_{s\beta}) * \max(\text{abs}(I_{s\beta}))} \end{cases} \quad (9)$$

Where N represents the size of samples in $I_s(\alpha, \beta)$. Selection of N is determined by the time it takes to make a diagnostic determination.

Feature extraction is the best method to organizing and preparing data to be classified.

In open circuit choosing surface calculation as feature extraction because it gives three symmetric levels (negative, zero, positive) to present lower switch default, healthy switch, and upper switch default. The data are well organized and the fault classification will be simple and easy.

To obtain distinct feature modes, faults produce manually. Based on the data acquired and shown in Fig.3, we construct a dataset that will be used to train the neural network.

In this work N equal 450 of sampling from current $I_{s\alpha}$ than, calculus sum of 450 sampling from current $I_{s\alpha}$ a result is divided in size of sampling (N) also is divided in Absolut maximum of current than we obtain surface $S\alpha$. The same thing to obtain $S\beta$.

In figure 3 we present curve on $S\alpha$ and $S\beta$ separate you can see in healthy state $S\alpha$ and $S\beta$ equal zero whereas in deferent faults you can see curve varied between zero, positive and negative each fault is deferent from another, you can see also fault in switch T1 is opposite to switch T4 that means are in the same leg also between (T2 and T5), (T3 and T6)

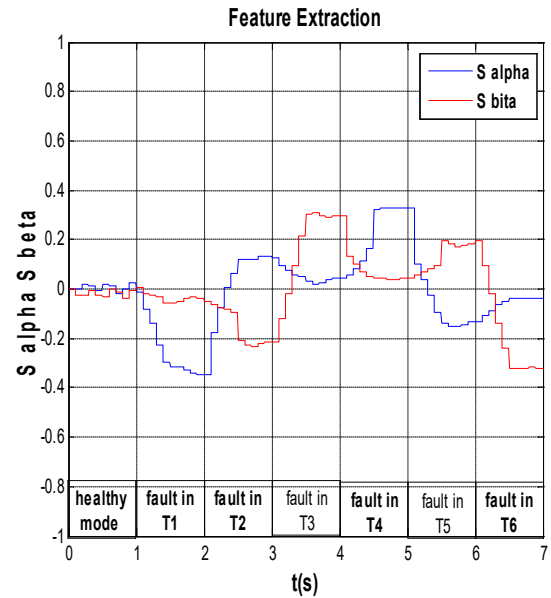


Fig. 3. Feature extraction under open circuit switch fault occurrence

Faults are manually generated to obtain different features in normal and faulty mode. This method is repeated many times for each potential variant of data at many different speeds. As well, for good neural network training, the neural network is then trained with this group of database sets for training.

V. ANN FAULT CLASSIFICATION

A) Structure of ANN

The proposed Structure for classification is a Multilayer Perceptron (MLP) neural network [26].

The network has two input nodes corresponding to the normalized algebraic sum of ($S\alpha, S\beta$), and an output node defining the three legs state of the PWM inverter. This architecture is illustrated in Fig.4.

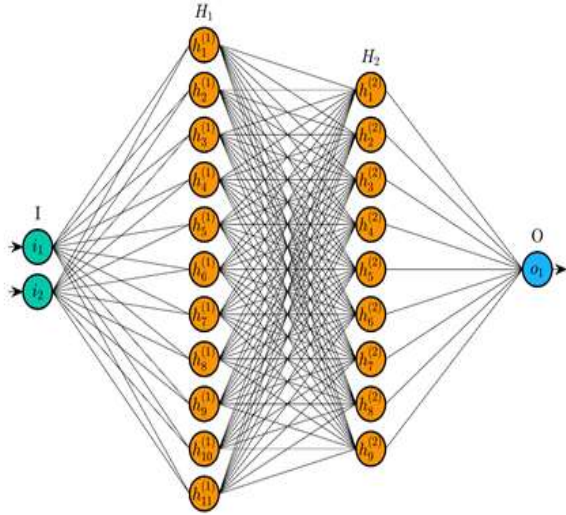


Fig. 4. Proposed multilayer network architecture.

B) ANN Training

We used Levenberg Marquardt training paradigm to train the neural network [27]. A network will be trained with different faulty modes. The input matrix data is two rows length. $(S\alpha, S\beta)$ Each pattern input has a total of 40000 columns. This gives a healthy pattern a score of 40000. And $40000*6=24000$ for fault occurrence. That gives a 280000 data base for neural network training. The output target categorization is represented for various speed references. The 5% in both misclassification and input data error rate are selected to determine a sum of square error, SSE. Training process finished when the 0.01 SSE goal is get [12]

$$SSE = \sum_{k=1}^N (y_k - d_k)^2 \quad (10)$$

y_k is a target output value d_k is data train output, N is a number data training.

C) Neural Network Testing

Simulation tests with various speed references were used to produce the training data set. In our work, we use 50% of the total input/output data for training, 25% for validation, and 25% for testing. When the selected SSE is gotten, the training phase will end. As illustrate in equation (12). Fig. 9 illustrates off-line train epochs, to achieve a 0.001 error is 614 epochs.

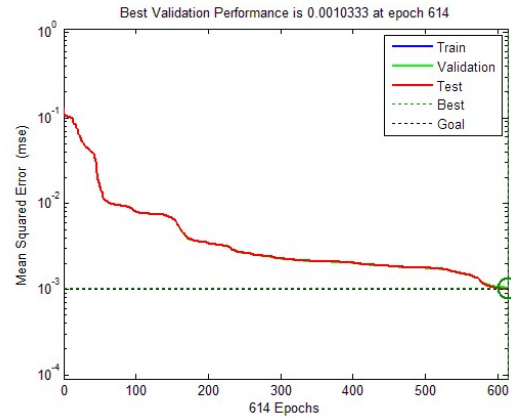


Fig. 5. Diagnosis errors in training, testing, and validation (open switch).

VI. SUBMITTING RESULTS

The simulation is done as follow:

- Speed reference is 60 (rad/s), stator flux is 0.8 (wb).
- We made (0.54s) for healthy mode, after we did fault in switch T4. Detection, localization and reconfiguration is done in (0.78s), the same in switch T5, fault in (1.2s) reconfiguration in (1.3s). Also in switch T3 fault in (1.7s) reconfiguration in (1.9s) Total time for simulation is (2.4s).

We select three fault switch for reconfiguration T3, T4 and T5 a maximum time for reconfiguration is (0.24s).

VII. CONCLUSION

A paper proposes a fault finding and identification technique for a PWM inverter with an induction motor drive controlled by an artificial neural network direct torque control based in Space Vector Modulated (DTC-SVM_ANN).

In DTC-SVM ANN, there is a simple and effective approach to regulate an induction motor drive. Giving a viable solution to problems with robustness.

We used artificial intelligence to model the different forms of defects in order to study the detection and diagnosis of open inverter switch failures. We looked also at how to reconfigure

the inverter to detect and diagnose open inverter switching faults in DTC-SVM.

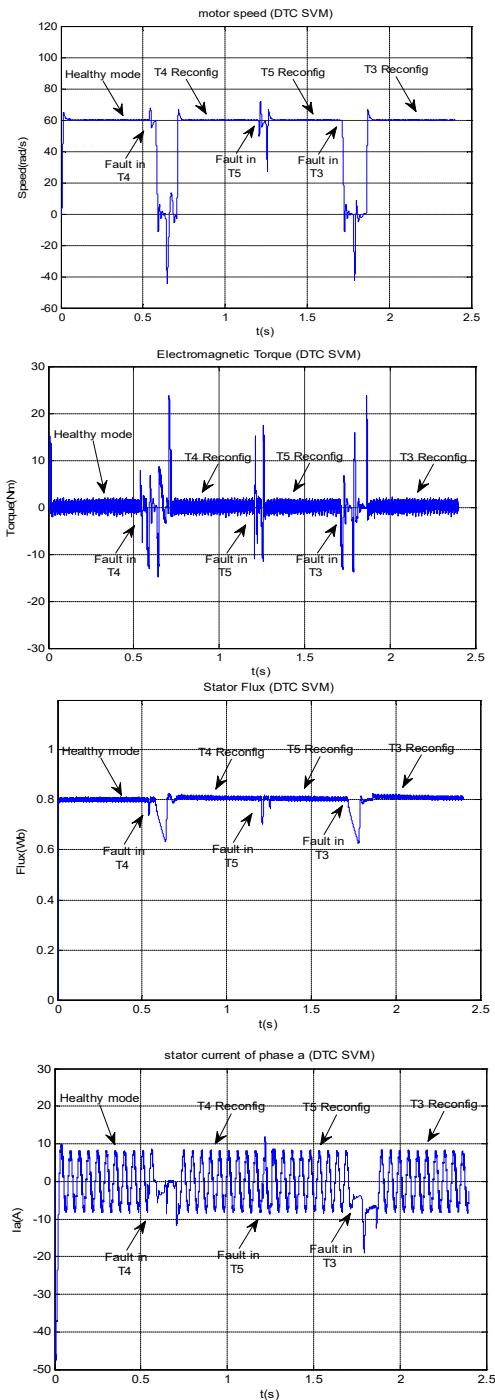


Fig. 6. Patterns curreant fault in faulty and healthy Mode in ANN_DTC-SVM (open witch).

VIII. ACKNOWLEDGMENTS

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