Periodicals of Engineering and Natural Sciences ISSN 2303-4521
Vol. 9, No. 1, February 2021, pp.293-300

Performance monitoring of aircraft PMSM based on soft computing technique

Wathiq Abed[1], Qais Aish[2], Ahmmed Hamed[3]
[1,2,3] Electrical department, Institute of Technology, Middle Technical University
Baghdad, Iraq

ABSTRACT

Rigorous fault analysis (FA) referring to fault detection its level is important for maintenances to simplify as well as improves performance. The purpose of this study was to present a technique for the electronic diagnosis of switch defects in regular magnetic concurrent motors (PMSM) For Aircraft application. The performance level of the bridges of the thyristor and the device excitation diode is tracked in healthy and defective service processes. Extracted functionality in various procedures that use Decomposition of the Multi-Scale Wavelet (MSWD) to remove useful functionality. The functionalities of the MSWD are utilized to train the Autoregressive of the Nonlinear with Exogenous Model (NARX) that was Sequence of the method controlled to determine the level of the fault in an open circuit forming through a switch. Both models were evaluated and built based on simulated data, where the findings demonstrated a preferable efficacy in the diagnosis of different kinds of faults

Keywords: Soft Computing, Diagnosis of Fault, PMSM, Aircraft

Corresponding Author:

Qais Aish
Electrical Department,
Middle Technical University, Institute of Technology,
Baghdad, Iraq.
Email: qaisqais883@gmail.com

1. Introduction

Defects in electrical devices have been divided Into 2 categories: electrical and mechanical faults. Good monitoring of the condition is required to improve the efficiency of electrical machines. It also avoids the parts replacement with components and the significant losses of economics which are responsible for the cessation of production. As a result, this motivates the investigator to undertake the current study and to design current fault diagnostic process meanings [1]. Today, the PMSM drive has found easy usages in the industry. Usages like Computer gadgets drive electric vehicle propulsions and electromagnetic actuator systems. The device consists of a 3-level unit with an everlasting magnet rotor supported through the source of a DC source via a 3-level inverter bridge, filter capacitors, and choppers. The 2-quadrant hysteresis-kind circuit of Chopper is connected to the coil of choke for the magnitude of the current power.

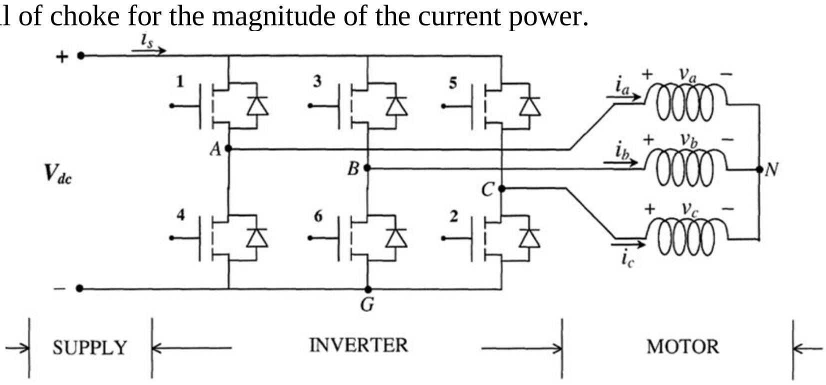


Figure 1. The schematic diagram of the integrated drive system

Various types of identification methods for electrical devices have been used for fault detection and condition control, such as signal analysis, highest accuracy artificial intelligence (AI) instruments, hybrid approaches as well as modeling dependent is now employed in fault detection and condition tracking. There are some difficulties to construct an accurate statistical model. AI goal is to generate simple, classifying expressions that people can easily understand [2]. AI comprises approaches according to genetic algorithms (GAs), fuzzy logic (FL), and neural networks (NNs) [4], with fuzzy logic, fusion algorithm is capable of minimizing fuzzy data [3]. In comparison, fuzzy models help to adjust their shape and variables over period [5,4]. NNs known as global approaches will also represent high non-linearity rates that exist directly within the data as FL through the utilize of lagging training characteristics. The increased number of laws, for instance, depending on the increment of variables in the fugzing sets or the quantities of variables. This is challenging to identify complete model based only on expert knowledge [6]. In this regard, the FL model relies on explosion of the law. The SVM is, by comparison, an important way to identify motor faults on the basis of statistic learning [7] based on its ability to carry out efficacious analysis. Using binary categorization problems, the normal support vector machine determines the linear boundary between these two kinds through minimizing nearest data area to their boundary for each class. However, the help vector machine asks for the kernel parameters to be rigorously tuned and maximized produces a large amount of estimation. Moreover, the support vector machine requires a wide data range and includes a significant complexity, the standard support vector machine is not used for dynamic information [8]. NN was a completely useful instrument for motor fault identification. There is no mathematical model required for such techniques. Moreover, NNs are capable of identifying patterns considering the high noise levels [9]. Previous analysis has used static NNs, through a literature review, to classify flaws, whereas many business systems are nonlinear and complex by nature. Thus the experiments used techniques to show the device dynamics when the fault was detected. Thanks to its capability to produce nonlinear dynamic systems, NARX has gained significant interest. The studies considered NARX to be the most effective diagnostic defect technique in electrical machinery [2]. NARX increases the performance of the system state monitoring error, which is treated as having an additional impact than static NN. In addition, DRNNs can learn the dynamics of complicated non-linear structures and are more flexible than traditional static NNs have shown not to have this capability kind [10]. The purpose of this analysis is to diagnose the inverter bridge switch open-circuit failure during advanced driving, as a typical model of operation was established. In the case of the MOSFET short circuit, the provide short circuit shall take place. On the other hand, this flaw should be the normality of the switching pattern. The switches can be switched on and off as broadcast, because of the conceptual signals of the three Hall sensors rotor position. Switching takes place in a way that increases the torque through magnetic contact between the stator fields and rotor [13].

2. Fault diagnosis process

Three major stages, as seen in Figure 1, provide protocols for the proposed diagnosis used in this current study. In the first step, the physical current compilation occurred and then MSWD was used for the time-specific elimination of frequency areas and benefits. The final move is to evaluate the defect by the NARX application.

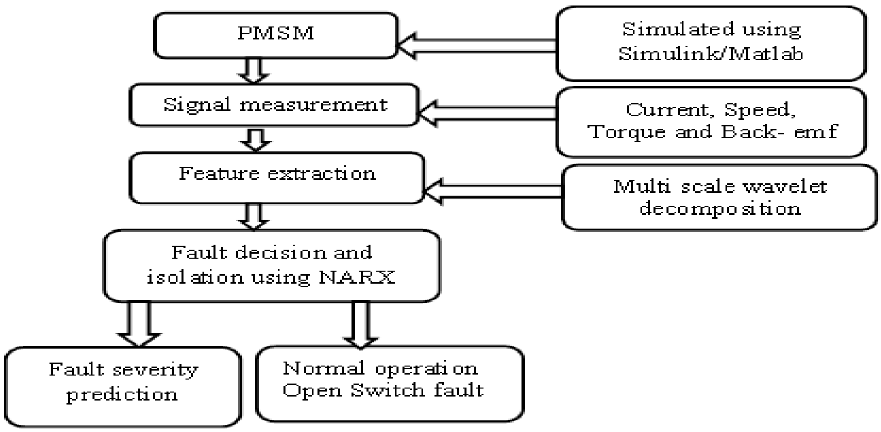


Figure 2. Fault Diagnosis Process

3. Simulink model of PMSM

This article suggests that model consistency and computational complexity will be affected. In the present study, the flexible paradigm are bad and stable states of the PMSM. During the model creation process [13], the authors conducted those assumptions:

- Ignore the engine torque cogging.
- Because of statisor harmonic fields, induced harmonic on the rotor is neglected
- The lack of iron and stray is overlooked
- The ignored saturation
- The decrease in voltage through the electronic control device is insignificant

Present and lack of hysteresis are missed.

$$V_{abc} = I_{abc} ++ R_{abc} + \frac{dh_{abc}}{dt} + e_{abc} \tag{1}$$

$$h_{abc} = L_{abc} + I_{abc} \tag{2}$$

$$L_a = L_a = L_c \tag{3}$$

$$L_s = L_m = L \tag{4}$$

The voltage of stator phases will be determined according:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} R_a & 0 & 0 \\ 0 & R_a & 0 \\ 0 & 0 & R_a \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} - \begin{bmatrix} L_s & L_m & L_m \\ L_m & L_s & L_m \\ L_m & L_m & L_s \end{bmatrix} p \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} - \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \tag{5}$$

$$T_{em} = J \ \frac{d_{wr}}{dt} + \beta w_r + T_l$$

The engine speed is proportional to and determined by the position of the rotor:

$$\frac{d\theta}{dt} = w_r \tag{7}$$

Where T_l is the torque of load, and e_{abc} is the back–emf, γ_{abc} is the flux relation, R_{abc} is the resistance to stature, L_s is auto-inductance, V_{abc} is the voltage of three stages, I_{abc} is the current of three stages of the stator, w_r the speed of the rotor, e, L_M is a reciprocal inductance, L is the inductance, the electro-mechanical torque is represented by Tem. SunPower's Framework Matlab/Simulink setting simulates PMSM equations. The full block diagram of the PMSM drive is illustrated in Figure 3.

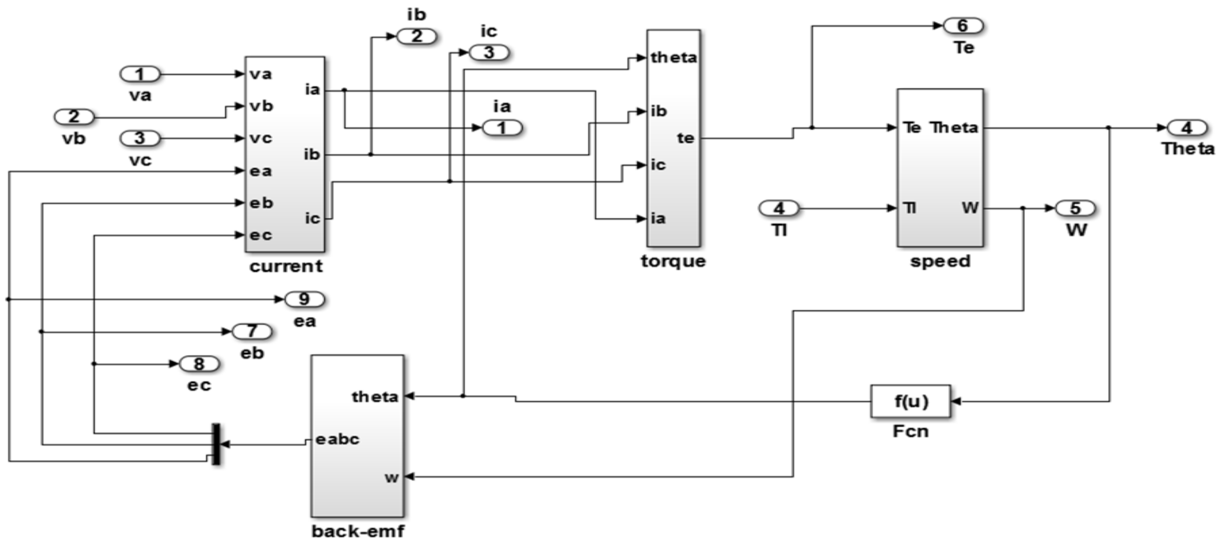
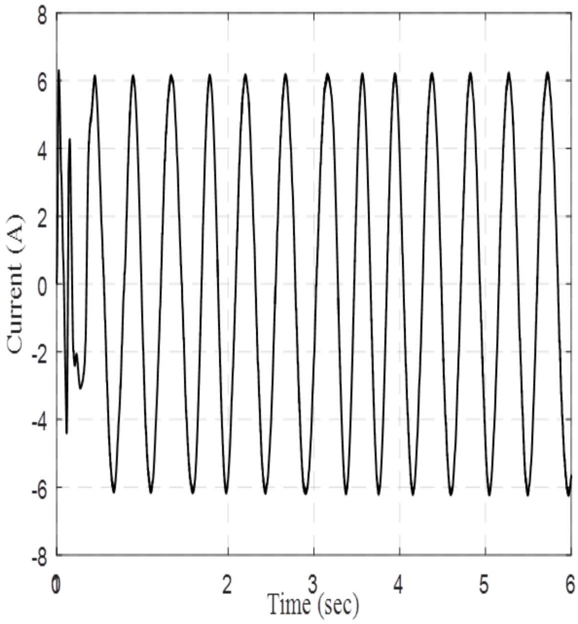


Figure 3. Simulink diagram of a process

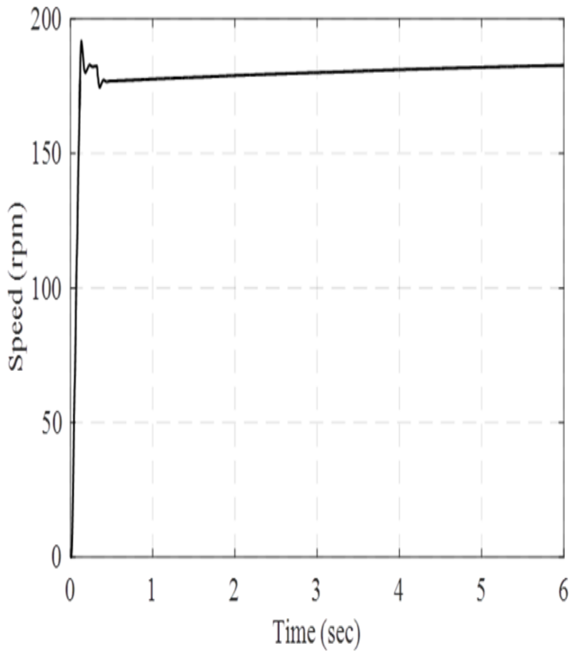
The feature blocks PMSM, the power control, inverters, control, and referrals are split into separate functional blocks. The current signal and the location signal (del) are the latest reference block inputs. For control, the motor speed can be used in a closed-loop by measuring the actual rotor speed and comparing it to the reference speed. The new reference block induces reference current for the current block, such that the torque changes based on the current magnitude of the reference block. The current control unit compares the three-phase current to the reference current signal and passes it to the driver block, which contains the three-phase inverter and conversion circuit centered on MOSFET. There are two aspects of PMSM: one is an electrical component that defines the electromagnetic torque (Tem) and the other is the mechanical part that generates the engine's movement. PMSM block inputs provide phase end friction and load torque [15].

4. PMSM regular and irregular operation switching efficiency

In the usual operation of the stable speed method, consistency waveforms were observed. This procedure was followed by imperfect interactions and ideal situations such as noisy operations. When the change between switching states shows the desired rotor location, the electronic switching of the inverter bridge becomes fine. This state was listed as the most prevalent working condition. The photo. Photo. 4 to 5 indicates the normal working state of the signature waveforms at 200 RPM.



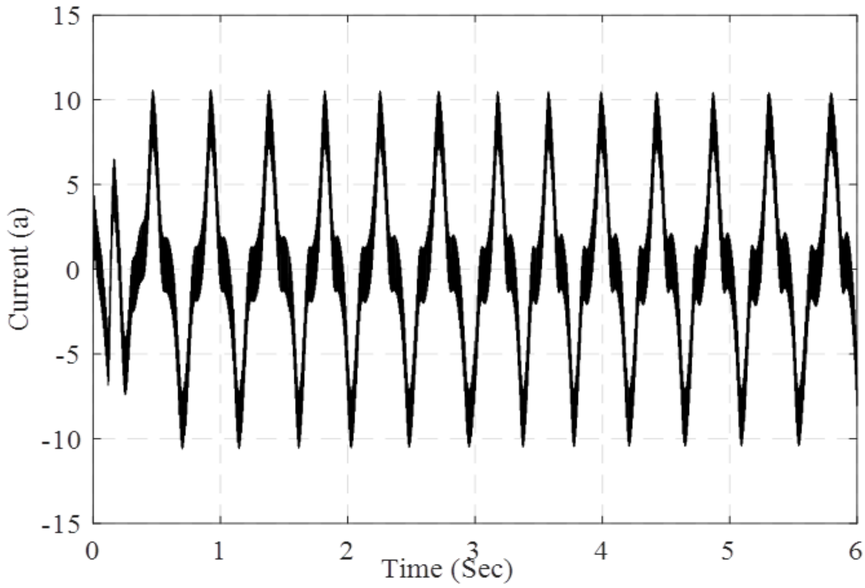
(a)



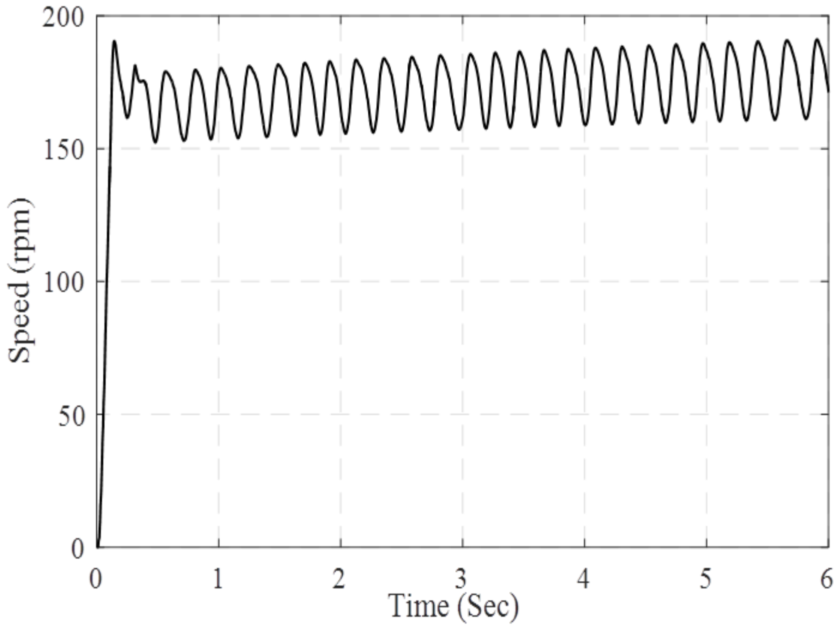
(b)

Figure 4. Motor operating under normal conditions (a) motor current, (b) motor speed

The design represented increasing electronic switch drive mechanism has a non-linear resistor, the non-linear resistors have a really low value. when the current switch is plugged ON, on the other side, if it is plugged OFF, the value is quite significant. At the regular pattern of switching, the short circuit of every switch refers to the short circuit supply. This can be tripped through an overcurrent defensive relay. Through evaluating the non-linear resistors quite significant values that the faulty switch is modeled by the researcher. In 2 consecutive states, Successful MOSFET may be allowed, meaning "one 3rd, of the entire electrical cycle. The efficiencies for all MOSFET switches were found: one at a time in the open circuit faults. Ses properties were compared with standard surgical waveforms to acquire a range of diagnostic markers. Fig 5 demonstrates the motor DC relation current followed by open-circuit errors on switches 1, so stage A has no positive current at all, on switch 1 there is not a positive current under the open circuit loss except in the remaining stages throughout switches 1 and 6 respectively [15,16] (see Figure 6).



(a)



(b)

Figure 5. PMSM faulty condition results (a) current, (b) speed

The new Multi wavelet chapter has recently been applied to the wavelet theory. As in the case of Wavelet, vector-valued wavelets are assumed to satisfy requirements, since matrices instead of scalars are present. It will be a positive since it can create a multi-wavelet foundation that concurrently has multiple possessions.

For instance, orthogonal and symmetry, a high amount of disappearance, and short support periods. Starting with the scalar case N, the multiresolution analysis principle can be maximized into a general dimension. A valuable vector function $[\emptyset_1, \emptyset_2 \ldots\ldots \emptyset_2]^T$ belongs to $L^2(R^r)$ and N is a multi-scaling function if the closed spaces sequence [17, 18].

$$V_j = \{span\, 2^{\frac{j}{2}} \emptyset_i\left(2^j - k\right) : 1 \leq i \leq r, k \in Z\} \quad (8)$$

The x(t) of complete multiple wavelet signal decomposition can be achieved by the following iterative filtering coefficient of scaling:

$$V_{jk} = \sum G_m - 2kV_{j-1,m} \quad (9)$$

$$W_{jk} = \sum H_m - 2kV_{j-1,m} \quad (10)$$

Where V_{jk}, W_{jk} *are* $r\times 1$ are column vector

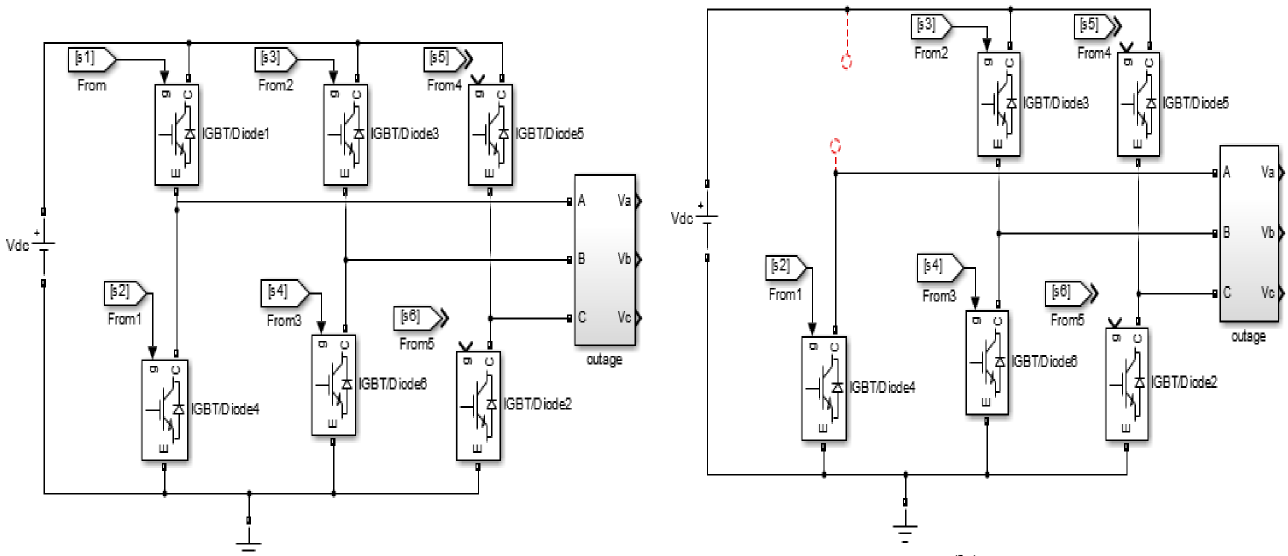
NARX is an exogenous paradigm of nonlinear self-administrative. This implies that the current time series meaning is related to:

- Identical sequence preceding values.
- Previous and pre-existing exogenous (driving) sequence values that are externally defined and influence the interest spectrum.

This is related to the fact that understanding the rest of the words does not offer the ability to forecast the existing values in a timely manner. This model could have been written algebraically. U is the variable quite evaluated; y is the variable of interest. Thus, based on this eq., data about y may be predicted through the data of u, as do previous values of y itself.

Table. 1 have illustrated the NARX parameters applied at the time of the training phase.

Using tiny neurons in hidden layers helps in the identification of Complex data set signals. On the other side, it overfits when the use of a lot no of neurons in the network has hidden layers. This is more ideal if the NN can train the whole number of neurons in the shrouded layers if the information loop is not sufficiently high in the training range. In addition, a too huge number of network neurons in hidden layers will raise the time acquired to operate, error steps, and several tests were used to maximize the secret neurons number needed.



(a) (b)

Figure 6. Motor circuit of control at (a) normal and (b) abnormal conditions

Table 1. Neural network training factors

Learning rate (α)	Regularization parameter(λ)	*FB* ratio	No of Delay	No of iteration	No of Hidden unit
0.1	0.001	0.7	6	3000	25

The findings reveal that the precision of classification means 97 percent of the procedure used shows that it is remarkably greater than the conventional methods of classification. A significant number of previous studies only use one indication to display the abnormality that limits the accuracy of classification of the faults (see Figure 7).

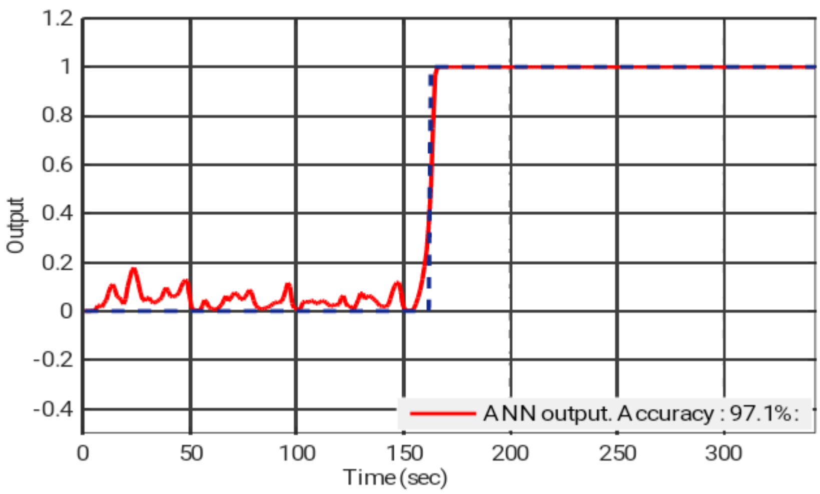


Fig 7. NARX performance

5. Conclusion

This research has established an Exogenous (NARX) non-linear autoregressive to diagnose the PMSM inverter bridge open-switch fault. By a distinct time-lumped parameter-network model, the output characteristics of the device are either dysfunctional or secure. The analysis extracted diagnostic indices from the current DC-link signal after MSWD is processed to enhance the time in addition to frequency domain signal resolution. An intelligent paradigm, NARX has practiced under various operating conditions based on MSWD parameters for the classification of defects. And the results have shown that classification accuracy has been increased.

Acknowledgements

This work was supported by the Middle Technical University Institute of Technology Electrical.

References

[1] L. Frosini, "Monitoring and Diagnostics of Electrical Machines and Drives: a State of the Art," IEEE Workshop on Electrical Machines Design, Control and Diagnosis (WEMDCD), Athens, Greece, 2019, pp. 169-176, doi: 10.1109/WEMDCD.2019.8887815.
[2] G. CMontanari, R. Hebner, P. Morshuis and P. Seri, "An Approach to Insulation Condition Monitoring and Life Assessment in Emerging Electrical Environments," in IEEE Transactions on Power Delivery, vol. 34, no. 4, pp. 1357-1364, Aug. 2019, doi: 10.1109/TPWRD.2019.2897905.
[3] X. Tian, H. Guo, J. Xu and L. Liu, "Online Inverter Open-circuit Fault Diagnosis for Fault Tolerant Permanent Magnet Synchronous Motor System under multi-fault condition," 22nd International Conference on Electrical Machines and Systems (ICEMS), Harbin, China, 2019, pp. 1-5, doi: 10.1109/ICEMS.2019.8921897.
[4] I. Jlassi, J. Estima, S. Khojet , N. Mrabet , A. Cardoso, "Multiple open-circuit faults diagnosis in back-to-back converters of PMSG drives for wind turbine systems", *IEEE Trans. Power Electron.*, vol. 30, no. 5, pp. 2689-2702, May 2015.
[5] W. Zhang , Hu X et al (2020) 'A hybrid information model based on long short-term memory network for tool condition monitoring'. Journal of Intelligent Manufacturing, https://doi.org/10.1007/s10845-019-01526-4.
[6] A. Labak, "New design of switched reluctance motor using finite element analysis for hybrid electric vehicle applications" . Electronic Theses and Dissertations, 2009.
[7] G.Tian, Y.Jing, J.Shou and Y.Cheng "A novel fault diagnostic method for analog circuits using frequency response features" AIP Review of Scientific Instruments, vol. 90,2019

[8] H.Hamed , H.Ian , S.Silvio .(2019) ' Reliability improvement of wind turbine power generation using model-based fault detection and fault tolerant control: A review' Renewable Energy, v 135, pp. 877-896, 2019, https://doi.org/10.1016/j.renene.2018.12.066.

[9] L.Liu, "Robust Fault Detection and Diagnosis for Permanent Magnet Synchronous Motors" Florida State University Libraries ,Florida State University Libraries,2006.

[10] A.Vijay, F. Kamatchi , V. Adaptive "ELM neural computing framework with fuzzy PI controller for speed regulation in permanent magnet synchronous motors", *Soft Comput*ing, vol.14, 2010 https://doi.org/10.1007/s00500-020-04994-6.

[11] S.Piotr and K "Application of artificial neural networks for transistor open-circuit fault diagnosis in three-phase rectifiers" , IET Power Electronics v 12, pp. 2189 – 2200, 2019, doi: 10.1049/iet-pel.2018.5330.

[12] H. Yuan, X. Zhao and D. Fu, "Intelligent Adaptive Jerk Control With Dynamic Compensation Gain for Permanent Magnet Linear Synchronous Motor Servo System," in IEEE Access, vol. 8, pp. 138456-138469, 2020, doi: 10.1109/ACCESS.2020.3012088.

[13] H. Zhang, C. da Sun, Z.-X. Li, J. Liu, H.-Y. Cao and X. Zhang, "Voltage vector error fault diagnosis for open-circuit faults of three-phase four-wire active power filters", *IEEE Trans. Power Electron.*, vol. 32, no. 3, pp. 2215-2226, Mar. 2017.

[14]. S. Khojet , I. Jlassi, A. J. Marques , J. Estima and N. Mrabet, "Diagnosis of Open-Switch and Current Sensor Faults in PMSM Drives Through Stator Current Analysis," in *IEEE Transactions on Industry Applications*, vol. 55, no. 6, pp. 5925-5937, 2019, doi: 10.1109/TIA.2019.2930592.

[15] X. Xu, X. Qiao , N. Zhang, J. Feng and X. Wang "Review of intelligent fault diagnosis for permanent magnet synchronous motors in electric vehicles", *Advances in Mechanical Engineering*. vol.12, pp.1-14,2020. doi:10.1177/1687814020944323.

[16]. M. Shao, G. Yang, G. Sun and J. Su, "A Method of Open Circuit Fault Diagnosis for Five-phase Permanent Magnet Synchronous Motor Based on Wavelet Analysis," 22nd International Conference on Electrical Machines and Systems (ICEMS), Harbin, China, pp. 1-6,2019, doi: 10.1109/ICEMS.2019.8921763.

[17]. S. Balambigai, R. Asokan and R. Kamalakannan. "Performance Comparison of Wavelet and Multiwavelet Denoising Methods for an Electrocardiogram Signal", Journal of Applied Mathematics, vol.2014, pp.1-8, 2014doi.org/10.1155/2014/24154