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Research paper

Investigation of ANFIS based grid integration of DFIG using matrix converter in wind energy conversion system

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Abstract

This paper offers a ANFIS control based grid integration of wind energy conversion system (WECS) through on a doubly fed induction generator (DFIG) with matrix converter. Instead of back to back converter matrix converter can be more suitable for connecting the DFIG rotor into the grid. The proposed system has been developed and simulated in MATLAB environment and analysis the system performance without rotor current controller. The DFIG and converter model has been used to calculate the performance of rotor current based on simulation results. ANFIS controller helps to reduce the error between rotor current and reference current for each of the valid states of the converter. The proposed controller has been developed a simulation in MATLAB and implemented to rotor current control for DFIG. The simulation results are analyzed and compared to with fuzzy controller. Finally, the simulation results are evaluated with IEEE 1547 standard for proving the effectiveness of the proposed system.

Keywords: *ANFIS; Doubly Fed Induction Generator; DC-Link; Rotor Current Control.*

1. Introduction

The recent electricity generation is fully reliant on the fossil fuels such as coal, petroleum and natural gas [1]. These fossil fuels took more ten centuries to form and the base resources for the fossil fuels were organic matter. A massive quantity of fossil fuels is already exhausted in the twentieth century [2]. If it continues in future become more dangerous for nature and expensive. The renewable energy resources are the only way by which the universal energy demand can be meet with affecting the climatic conditions [3] [4]. The wind energy sources are one of the important resources of renewable energy in the global [5]. The wind power generation classified two types such as fixed speed or variable speed turbines. The variable wind turbine system based on DFIG has become the highest popular configuration in wind energy conversion system. the DFIG system has more merits compare with fixed – speed induction generator such as variable speed constant frequency operation decoupled active and reactive power control, maximum power capture capability, reduced mechanical stress, low converter VA rating and reduced power loss [6 - 8]. The conventional PI, PD and PID controllers, in various combinations have been widely used for industrial processes due to their simplicity and effectiveness for linear systems, especially for first and second order systems. It has been well known that Proportional Integral Derivative (PID) controllers can be effectively used for linear systems, but usually cannot be used for higher order and nonlinear systems. So that, the non-linear system can be analyzed by this ANFIS controller is accurate as compared to other controllers. The biggest advantage of this controller over others is easy handling of non linear systems. The neural and ANFIS Controller are used for intelligent based Pressure control, Speed control, Current control, Acceleration control and Temperature water bath control in industries. In this paper, the modelling of matrix converter based DFIG and its operations are discussed in section II. Design of intelligent control for rotor current control has been presented in section III. The Proposed Model simulation and its results discussion are presented in section IV. Finally, section V has conclusion of proposed work.

2. DFIG using matrix converter

The DFIG is very widespread wind turbine system for generating electricity due to their merits such as high energy efficiency, low mechanical stress, less maintenance and low rating power electronics converter [9]. The power electronics devices are play very important role in energy conversion of wind power system [10] [11]. The conventional power electronic converters such as back-to-back two-level converters, matrix converter have some important benefits, such as sinusoidal input and output currents, absence of a Dc-link capacitor, fewer power electronics switches, simple and compact power circuit, operation with unity power factor for any load, and regeneration capability [12 - 14].
The proposed model matrix converter based DFIG has been presented in fig 1. The proposed matrix converter model has been simulated in MATLAB simulink environment as shown in fig 2. The three-phase matrix converter is developed in MATLAB and analyses their simulation results as shown in fig 4. In this proposed model has PI controller based DFIG rotor current controller has been designed and analysis the simulation results.

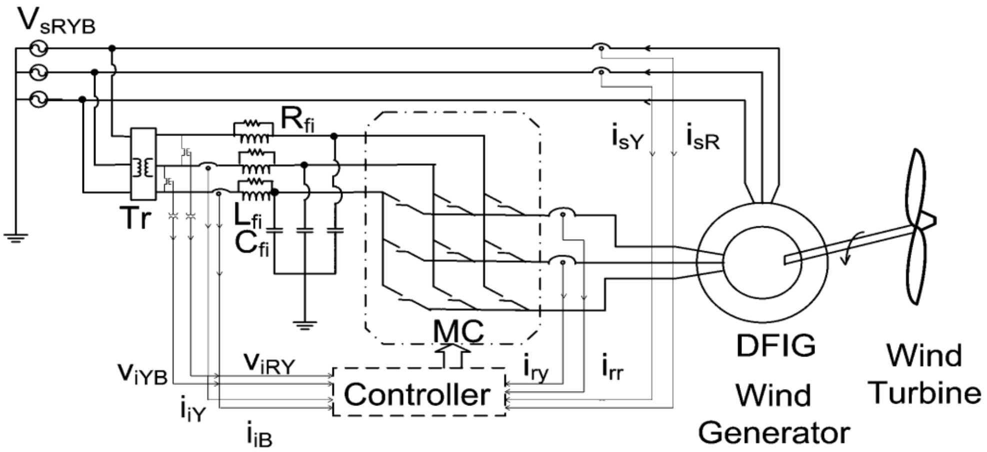

Fig. 1: Matrix Converter Based DFIG System.

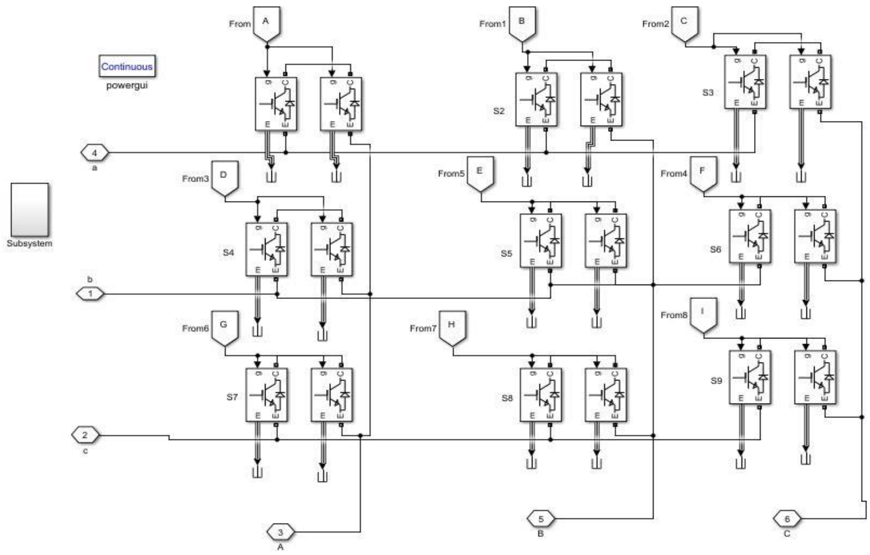

Fig. 2: MATLAB Simulation Model of Matrix Inverter.

3. ANFIS based rotor current control

The ANFIS controller has been designed for DFIG rotor current controller for improve the WES power quality [3]. The DFIG rotors currents are classified two types such as I_d and I_q for control the real and reactive power, therefore ANFIS controller has been regulate I_d and I_q. for better system performance under various condition [15]. The ANFIS controller two major parts such as ANN and Fuzzy, the ANN has been used for providing training for the network through back propagation algorithm as shown in fig 3. Initially collect the data of the I_d and I_q measure values under various conditions and its regulated I_d and I_q, the collected data are used to provide training and testing of ANN network as shown in fig 4. Finally, the ANN controller generates the fuzzy membership function based on training data as shown in fig 5. The fuzzy input and output membership function are developed by using trapezoidal function then the centre of gravity is used for defuzzification method [16] [17]. The I_d error value is fed into input of the ANFIS controller for I_d current regulator as shown in fig 7 as well as The I_q error value is fed into input of the ANFIS controller for I_q current regulator as shown in fig 7.The if then rules of both fuzzy controller (I_d and I_q) shown in fig 6. The design of park transformation of rotor current controller has been simulated in MATLAB environment as shown in fig 8. The real and reactive power controller has been developed in MATLAB is presented in fig 9.

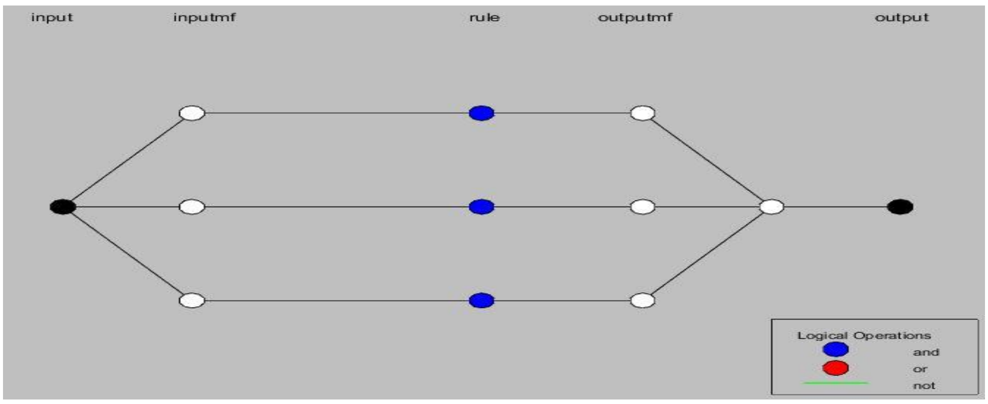

Fig. 3: ANFIS Network Design for Rotor Current Control.

Fig. 4: ANFIS Training for Rotor Current Control.

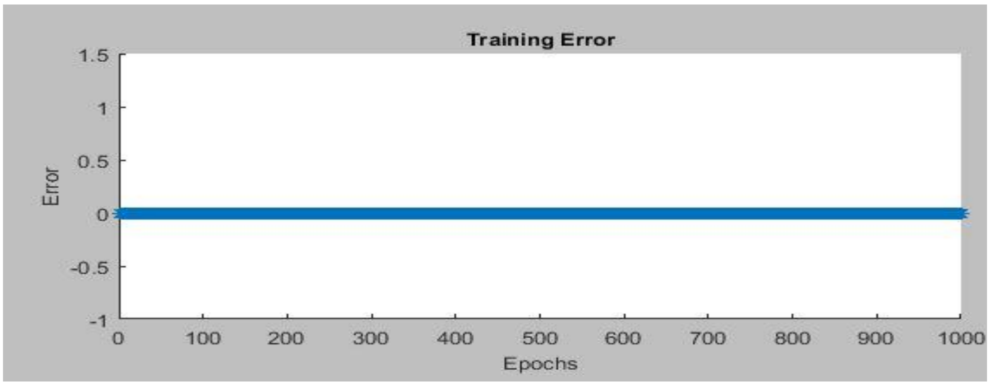

Fig. 5: ANFIS Training Error for Rotor Current Control.

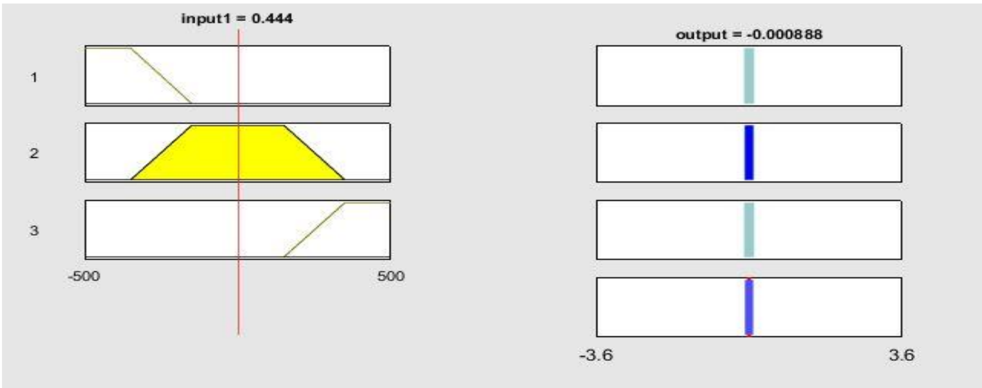

Fig. 6: ANFIS Rules for Rotor Current Control.

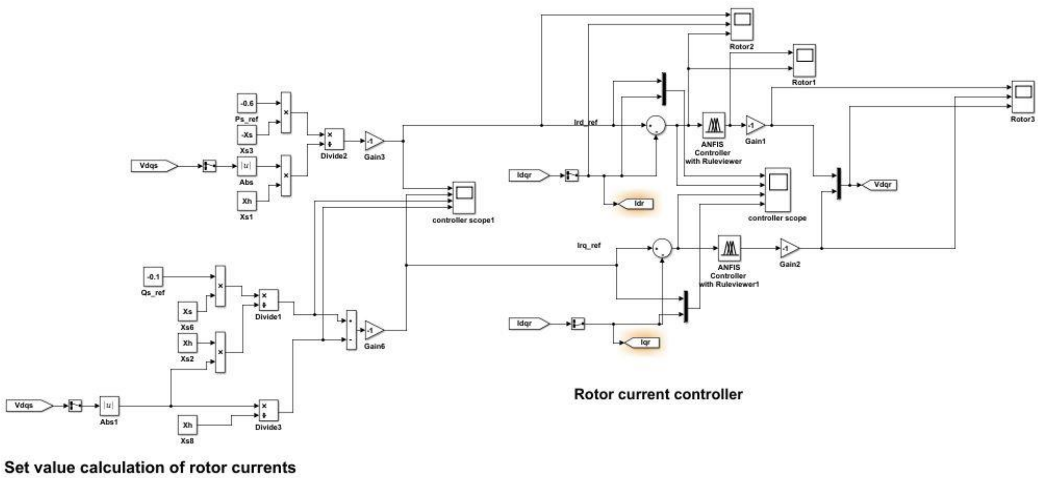

Fig. 7: ANFIS Simulation Design for Rotor Current Control.

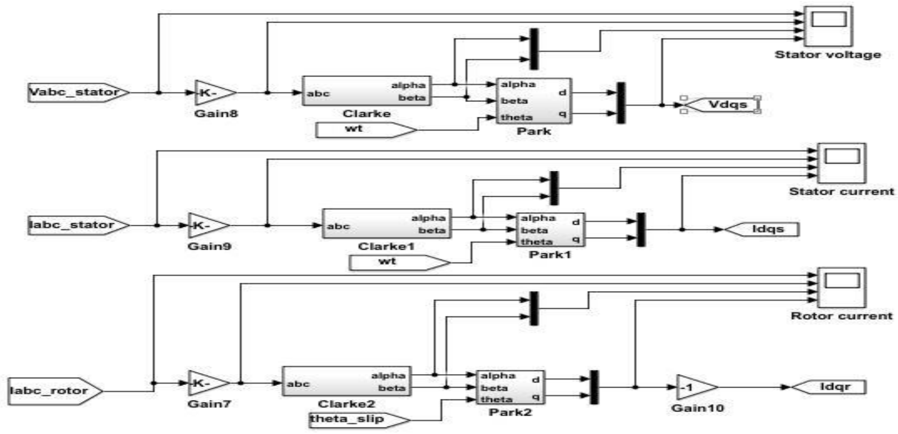

Fig. 8: ANFIS Simulation Design of Parks Transformation for Rotor Current Control.

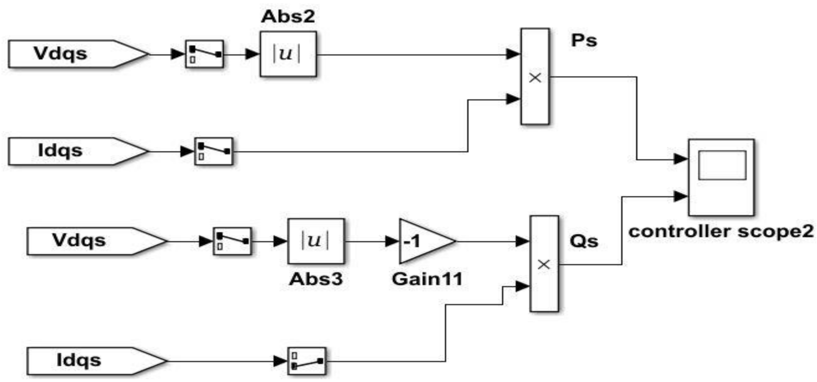

Fig. 9: Active and Reactive Power Control.

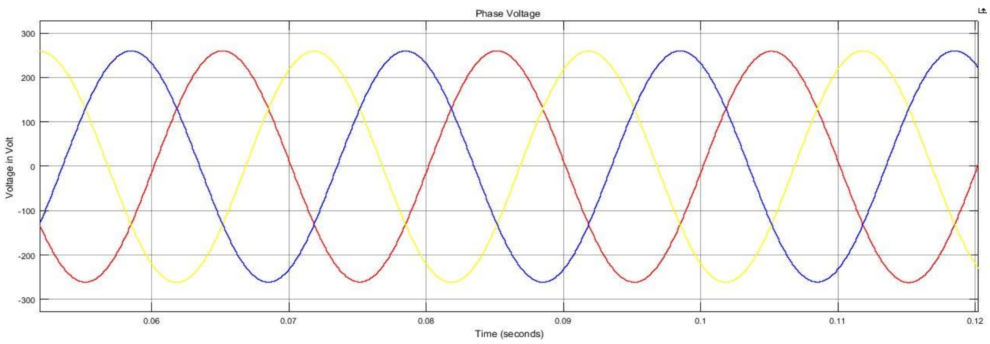

Fig. 10: Grid Voltage Waveform under DFIG.

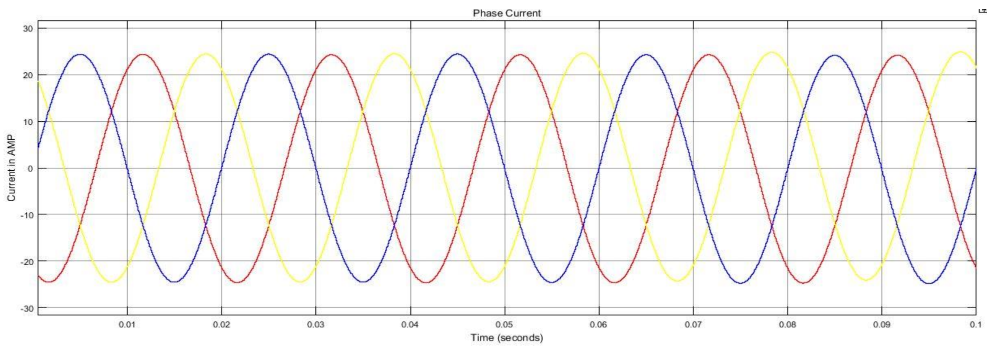

Fig. 11: Grid Current Waveform under DFIG.

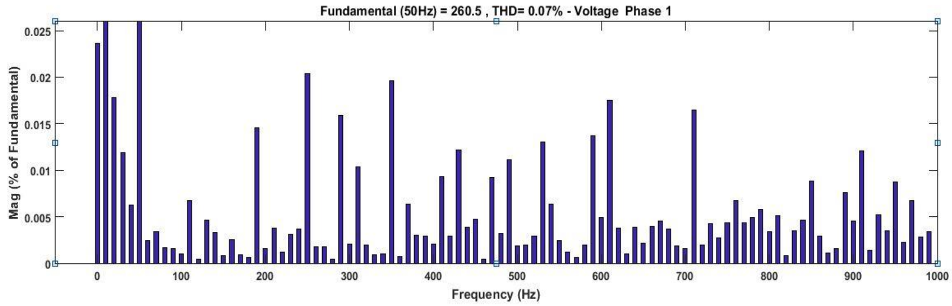

Fig. 12: The DFIG Voltage THD Percentage for R – Phase.

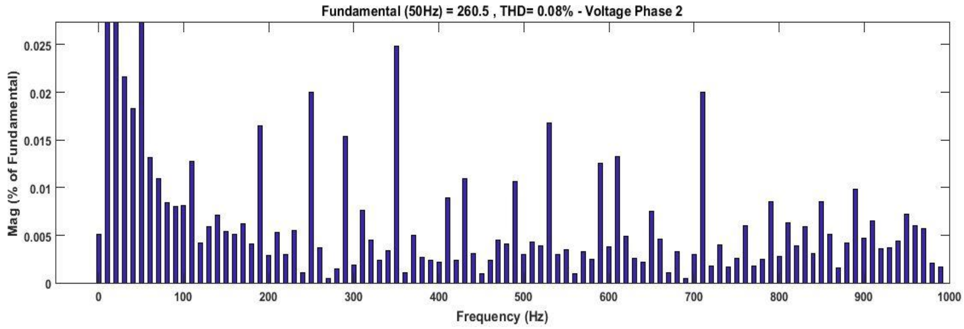

Fig. 13: The DFIG Voltage THD Percentage for Y – Phase.

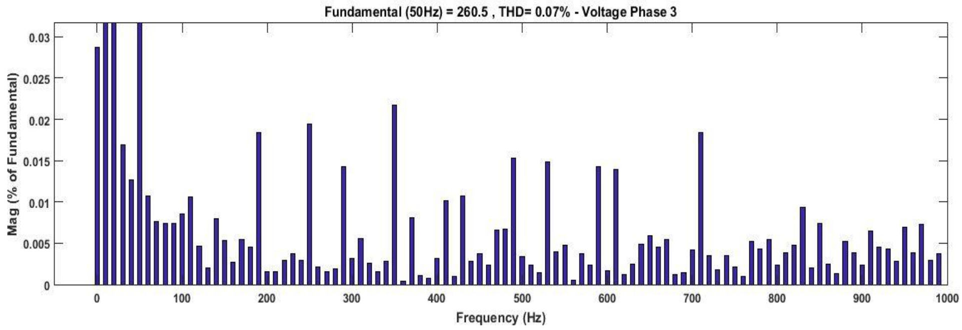

Fig. 14: The DFIG Voltage THD Percentage for B – Phase.

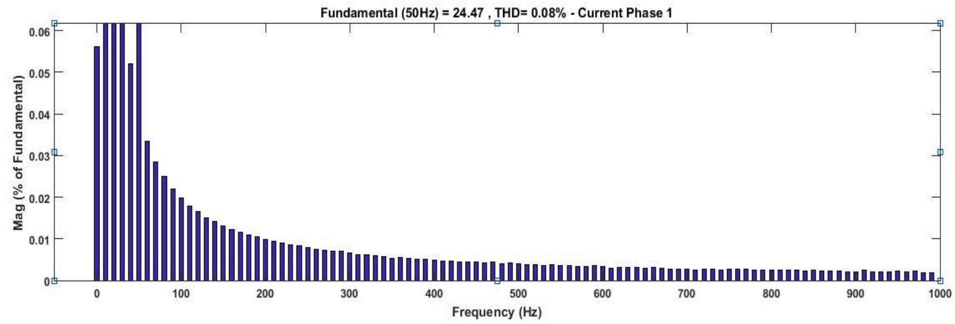

Fig. 15: The DFIG Current THD Percentage for R – Phase.

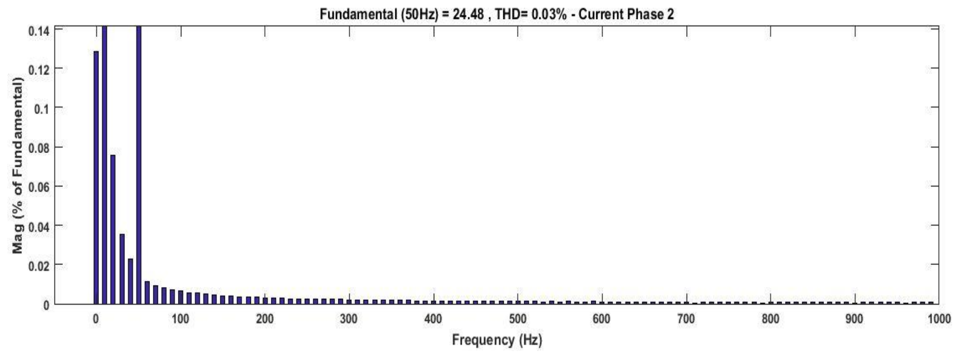

Fig. 16: The DFIG Current THD Percentage for Y – Phase.

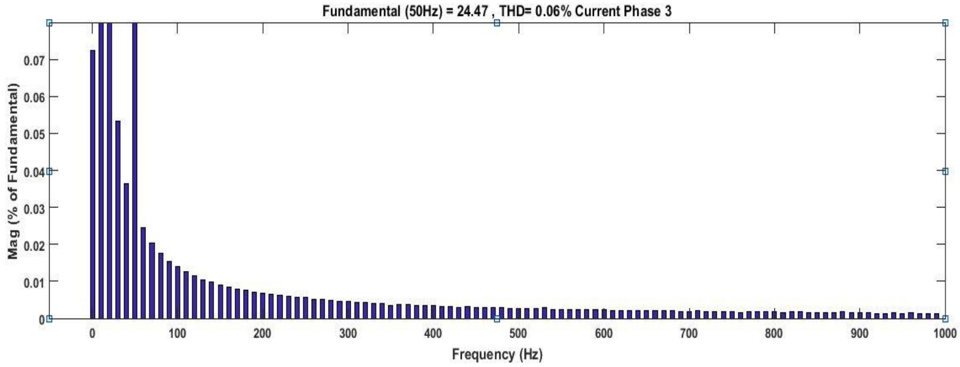

Fig. 17: The DFIG Current THD Percentage for B – Phase.

Fig. 12, 13 and 14 shows the percentage of THD in DFIG output voltages of phase R, Y and B. Similarly, Fig. 15, 16 and 17 shows the percentage of THD in DFIG output currents of phase R, Y and B. The magnitudes of the harmonic components can be computed from the equivalent phasor circuits. The sequence components of the rotor voltages and currents are listed in Table 1. A comparison of the analysis results from the circuit in Fig. 2 and simulation results shows that the rotor voltage and current THD components from the analysis agree with the simulation results in Table 2.

Table 1: Voltage and Current THD Values under ANFIS Controller

	ANFIS – Voltage THD	ANFIS – Current THD
Phase 1	0.07 %	0.08 %
Phase 2	0.08 %	0.03 %
Phase 3	0.07 %	0.06 %

4. Discussion of results

The proposed ANFIS control has been modeled and implemented in matrix converter based DIFG rotor current regulator. The ANFIS controller provide proper control signal for synchronizing gird phase angle, voltage and DIFG voltage, Phase angle. The DFIG generated voltage and current waveform are presented in fig 10 and fig 11. The simulation results are analysed and evaluate the performance of each phase voltage and current waveform. The total harmonics distortion has analyzed in each phase voltages under proposed ANFIS logic control such as the R –Phase voltage THD value is 0.07% as shown in fig 12. The Y- Phase Voltage THD value is 0.08% as shown in fig 13. The B-Phase Voltage THD value is 0.07% as shown in fig 14. The R - Phase Current THD value is 0.08% as shown in fig 15. The Y- Phase Current THD value is 0.03% as shown in fig 16. The B- Phase Current THD value is 0.06% as shown in fig17 .The ANFIS simulation results are presented in table 1. The comparisons of ANFIS and Fuzzy control results are presented in table 2. Based on the simulation results and best performance the fuzzy logic controller has been recommended for matrix converter based DIFG power system.

Table 2: Comparative Analysis of ANFIS and Fuzzy Results

	Fuzzy		ANFIS	
	Voltage	Current	Voltage	Current
Phase 1	0.32 %	0.48 %	0.07 %	0.08 %
Phase 2	0.17 %	1.05 %	0.08 %	0.03 %
Phase 3	0.17 %	1.52 %	0.07 %	0.06 %

5. Conclusion

This research paper focused on the operation and analysis of intelligent controller based grid integration of DFIG system using three phase matrix converters. The proposed system has been developed as a simulation model in mat lab simulink environment and analyzed with fuzzy controller. The Fuzzy controller does not meet the expectation, so the ANFIS intelligent system has been designed for DFIG rotor current controller and simulated in mat lab environment. The simulation results are analyzed and evaluate with IEEE 1547 standard. Finally, the ANFIS and Fuzzy Intelligence simulation results and performance are compared and based on best performance the ANFIS intelligence has been recommended for grid integration of DFIG system using three phase matrix converters. This ANFIS controller is widely used for controlling the non-linear systems. As this is the best controller as compared to conventional PID controller and other controllers.

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