

COMPARATIVE ANALYSIS OF INTELLIGENT CONTROLLER BASED MICROGRID INTEGRATION OF HYBRID PV/WIND POWER SYSTEM

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Abstract – In present years the consumer power demand has been increased day by day due to pollution growth and new industry establishments. The fossil fuel based power generation system unable to meet alone the consumer demand and environmental issues. In this paper, we have been investigating different renewable energy sources for generate the electricity and environmental safety. The hybrid renewable energy sources are very effective to generate the power even though the absence of any one source. The simulation model of hybrid PV, wind and battery power system developed using Matlab Simulink. The renewable energy system is operated with MPPT techniques based ANFIS controller for improving the system efficiency. The hybrid renewable energy system is presented as interconnected Microgrid system by using an intelligent controller. The proposed intelligent controller based phase loop locker show improvement in the system stability during Microgrid integration simulation. The proposed system analyzed with the different intelligent controller such as fuzzy, ANN and ANFIS using Matlab Simulink environment. The simulation results are evaluated and compared with the existing system. Finally recommends the proposed system for Microgrid integration of hybrid renewable energy system.

Keywords: Hybrid Renewable Energy, Photovoltaic (PV), Wind, Intelligent Control.

1. Introduction

In recent years the renewable power generations have an importance role to meet the consumer demand. The hybrid renewable energy sources are very effective to generate the power even though the absence of any one source [3]. In this paper, two renewable energy sources chosen, such as PV and Wind power system. The PV sources, generating the maximum power at during day time. The wind energy system has generated the maximum power at during night time. This paper has analyzed the operation of individual and hybrid PV/ Wind system. This research paper presents the technical contents lucidly in six sections as follows: Section II presents the MPPT operation and model of

PV system. Section III presents the operation and model of the wind system. Section IV presents the proposed system simulation model and results and discussion. Finally, the conclusion of proposed research work is presented in section V.

2. MPPT Controller

The renewable energy sources play a significant role to meet consumer power demand due to their ample obtainability and a smaller amount impact of environment. The main difficulty in PV energy expansion is the investment cost of the PV power system implementation. PV energy generation is not constant throughout the day due to the change of weather. The efficiency of power generation is very low (the range of efficiency is only 9-17% in low irradiation regions). Therefore, MPPT technologies have an important role in PV power generation to operate in the maximum power generation at various weather conditions. The various MPPT methods are established with respect to usage of equipment and cost [9].

2.1 ANFIS Based MPPT Controller

In this method, the ANFIS logic controller is designed for MPPT control of PV system (Vide Figure 1). This controller has two major parts such as ANN controller design and the input and output membership function of fuzzy logic controller and then forming the fuzzy IF-then rules. Finally, the fuzzy controller generates the duty cycle based on input data [18].

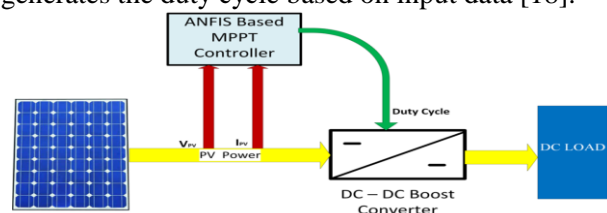


Fig 1: ANFIS Controller Based MPPT for PV System

Step 1: The ANFIS controller, network has been training using input data, such as PV parameters under various weather conditions and target data (duty Cycle) based on changing inputs. The above process has been developed using Neuro-Fuzzy training tools in MATLAB environment (Vide Figures 2 to 4).

Step 2: The trained data are validated and tested to provide best solution. The ANN controller network is developing fuzzy input and output membership functions and then fuzzy IF-Then rules after completing the processes of training, testing and validation.

Step 4: Finally, ANFIS controller is implemented for MPPT control of PV system. The ANN controller generates the duty cycle based on input data and then the signal is fed into a PWM generator to generate the pulse for DC-DC converter.

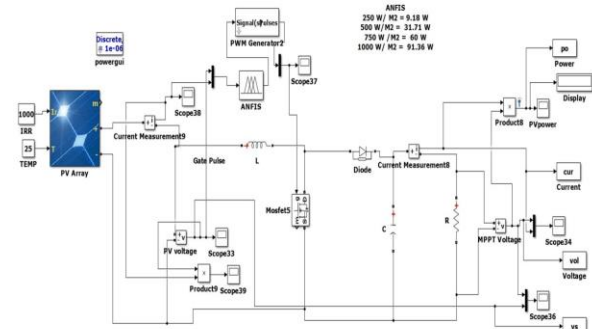


Fig 2: MATLAB Simulation model for ANFIS Controller Based MPPT for PV System

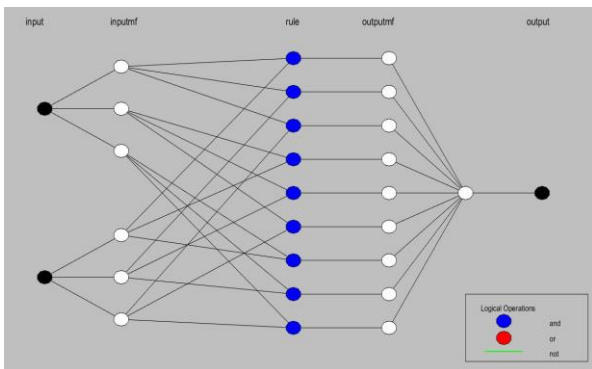


Fig 3 : ANFIS Controller network for MPPT of PV System



Fig 4: ANFIS training for MPPT of PV System

2.2 Results:

The ANFIS controller is implemented in MPPT simulation model and simulation at various weather conditions. The simulation results of PV power generation waveform are analyzed with different solar irradiation conditions such as 250 W/M^2 , 500 W/M^2 , 750 W/M^2 and 1000 W/M^2 as shown in Figure 5.

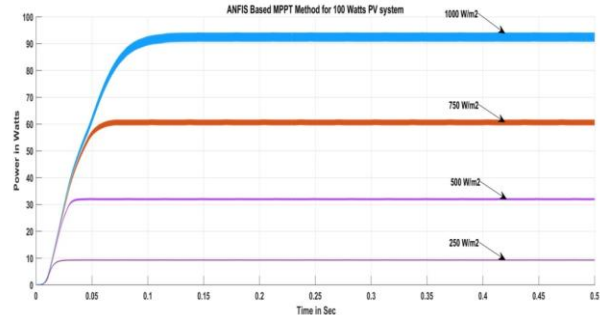


Fig 5 : ANFIS Based MPPT Power waveform for PV system under various weather

3. PMSG Design with & without MPPT Controller

A control method to control wind turbine rotor speed by controlling the generating controlling torque which is called MPPT (maximum Power Point Tracking) controller. The blade pitching drive produces a delay in response time with response to act accordingly with change in wind conditions, such as turbulent and gusty winds, which plays an influence role on the energy yield and causes subsequent mechanical stress on the wind turbine. Conversely, to maximize the electric power production, the generator rotor speed can be controlled electrically. MPPT based control techniques are been developed with a motive of achieving the maximum power coefficient [12]. The generator output power, in a variable speed wind energy system is efficiently controlled with the help of a power electronics based converters. In this paper, the author analyzed the ANFIS based MPPT of Wind power system.

The proposed PMSG design parameter as follows

1. Mechanical output power = 250 W
2. Maximum Voltage $V_{max} = 230 \text{ V}$
3. Maximum Current $I_{max} = 4 \text{ amp}$
4. Base Electrical generator power = 277.77 VA
5. Wind Speed - base = 12 m/s
6. Rotational speed - base = 1 p.u
7. At base wind speed, Maximum power = 0.8 p.u
8. Pitch angle = 0 deg

The proposed system has been simulated MATLAB Simulink environment at various weather conditions as shown in Fig.6. The turbine mechanical

power vs generation speed Characteristics are presented in Fig. 7.

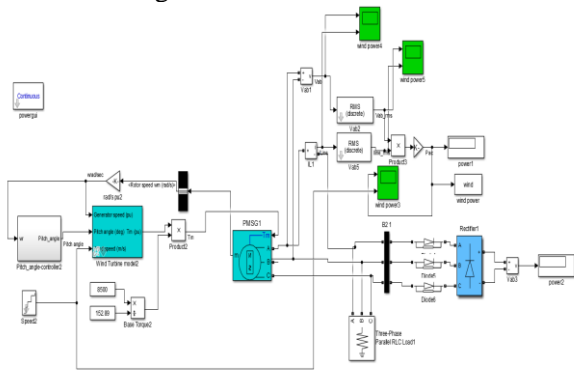


Fig 6: simulation model of PMSG based WES without MPPT controller

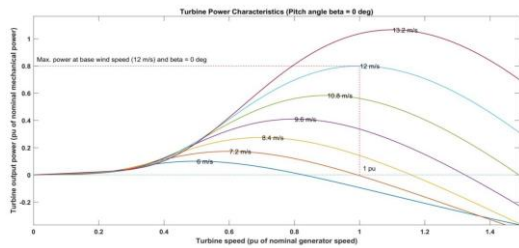


Fig. 7. Wind Turbine Characteristics

3.1 Modeling an ANFIS based MPPT

The estimation of the wind speed using the ANFIS concepts is presented here. The ANFIS is trained routinely by least-square inference and the back-propagation algorithm. Fig. 8 shows the structure of ANFIS with two inputs and one output. According to the designed model, the ANFIS network could make decision to estimate maximal wind speed to be achieved based on the inputs/outputs data used for training.

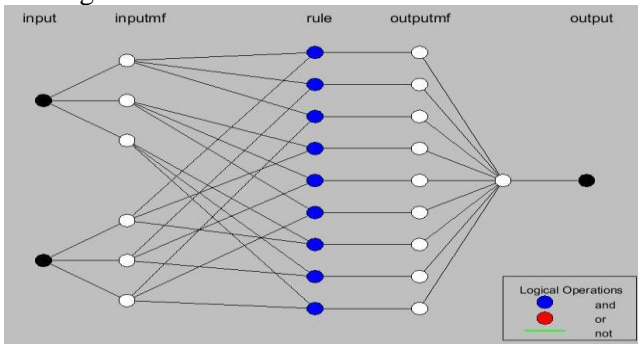


Fig. 8 Structure of ANFIS controller

The ANFIS controller has been designed for MPPT controller for Wind Energy system as presented in fig 8. The proposed ANFIS MPPT controller has two input triangle membership function such as input one WES voltage and second input current. The output of fuzzy control is triangle membership function such

as duty cycle. ANFIS based MPPT controller reference model is developed using ANFIS editor of MATLAB/Simulink software package.

ANFIS Control Based MPPT Techniques for 250 Watts Wind Power System

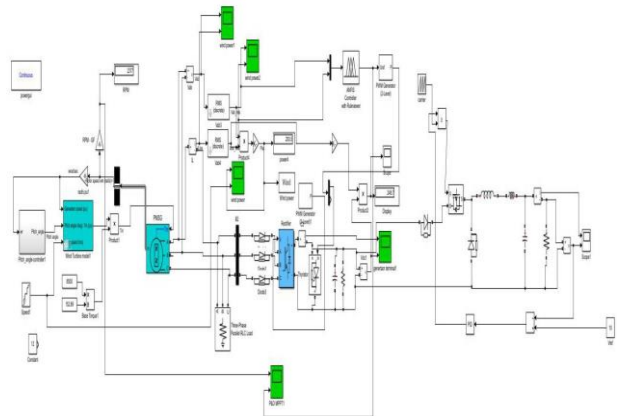


Fig 9: ANFIS Based MPPT controller for WES with buck converter

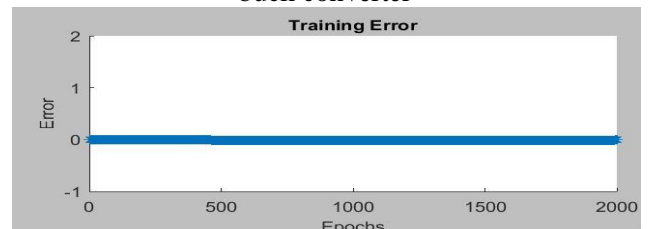


Fig 10 : ANFIS control system training

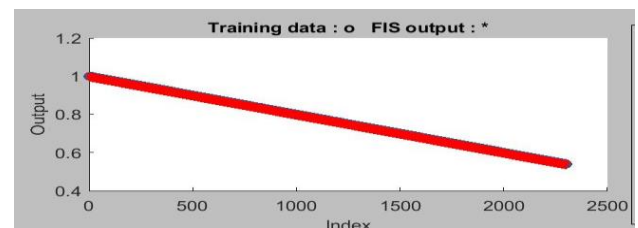


Fig 11 : ANFIS control system output

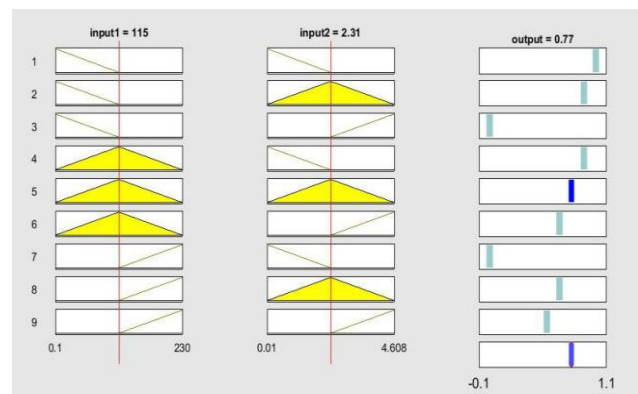


Fig 12 : ANFIS control system rules

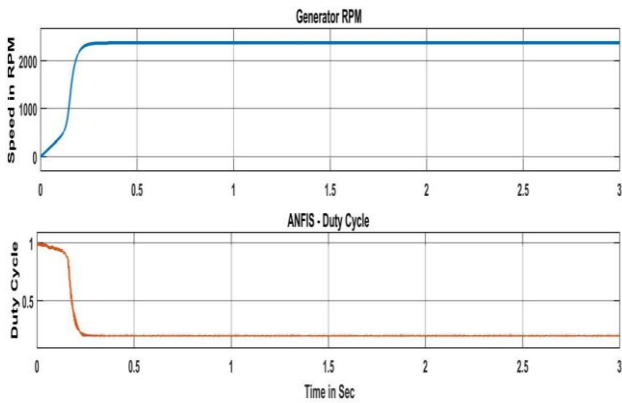


Fig 13: Speed and duty cycle wind power system under standard Wind 12 m/s

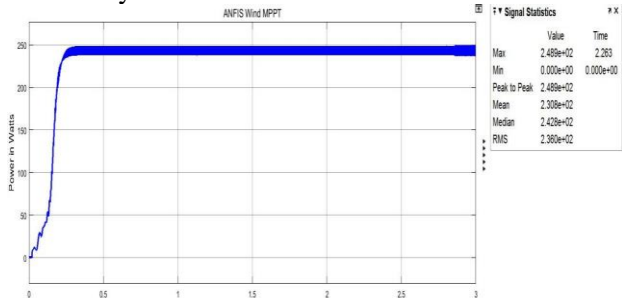


Fig 14: ANFIS based MPPT of Wind power system under standard Wind 12 m/s

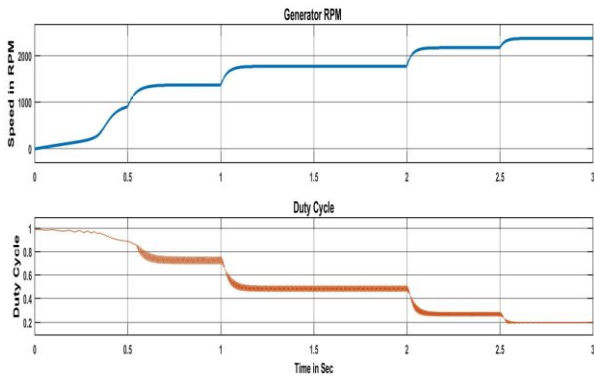


Fig 15: Speed and duty cycle wind power system under various Wind speed

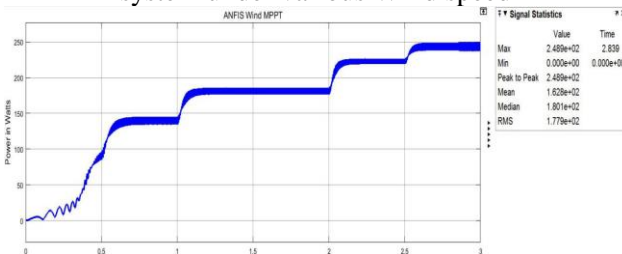


Fig 16: ANFIS based MPPT of Wind power system under various Wind

4. Microgrid integration of Hybrid PV /Wind Power system

4.1 Block diagram:

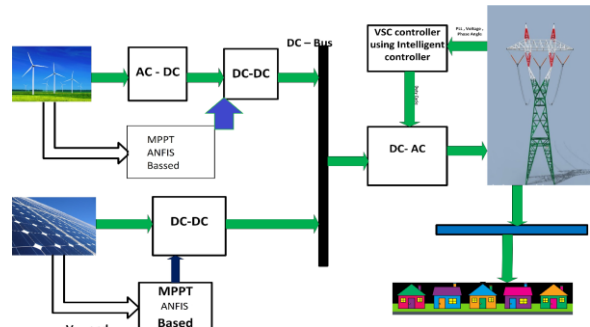


Fig 17: Proposed Microgrid integration of hybrid PV/ Wind power system

The proposed Microgrid power system model is presented in fig 17. The proposed model has been simulated in Matlab environment. The simulation has been developed hybrid PV/Wind power and design intelligent controller for voltage source converter [7]. The control of voltage source converter has phased locked loop, Voltage regulator and current regulator as shown in fig 19. The current regulator has been operated with intelligent controller and analysis their operation with different intelligent controller such as Fuzzy and ANN [1]. Finally compare the simulation results and its performance are evaluated then choose best controller for Microgrid [2].

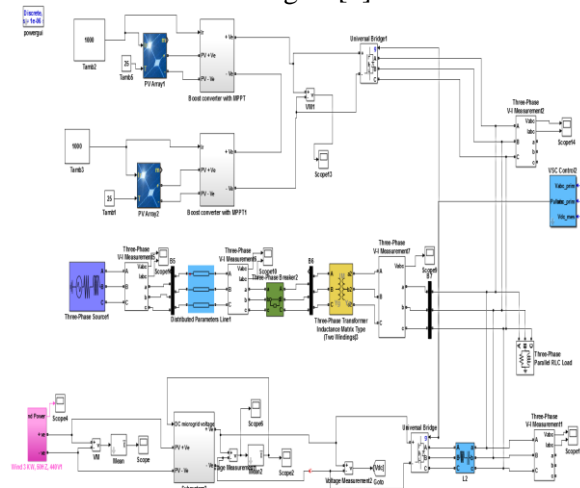


Fig 18: Hybrid PV / Wind Power system with Battery Management System

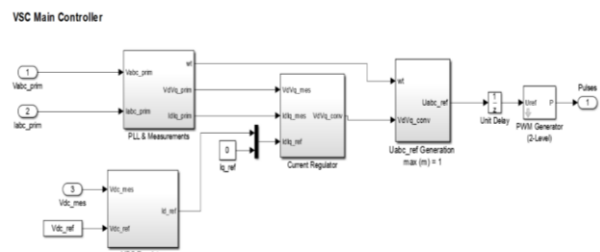


Fig 19: Voltage Source Converter (VSC) controller

4.2 Fuzzy controller for VSC

The fuzzy logic controller has been designed for current regulator for VSC. The fuzzy controller has two input signals and two output signals such as input (direct axis and quadrature axis current) output (regulated direct axis and quadrature axis current) shown in fig 20. The direct axis current value is positive converter deliver the active power to Microgrid and quadrature axis current value is negative converter observe the reactive power from Microgrid [10 -14]. The proposed fuzzy control has been applied hybrid PV /Wind with Microgrid and its voltage source converter as shown in fig 21. The Matlab simulation results are presented such three-phase voltage waveform and three phase THD value as shown in fig 22 to fig 25 respectively.

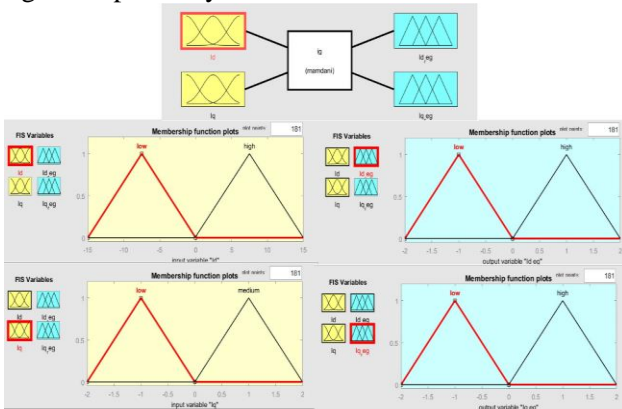


Fig 20. Fuzzy controller membership function and its rules for current regulator of VSC.

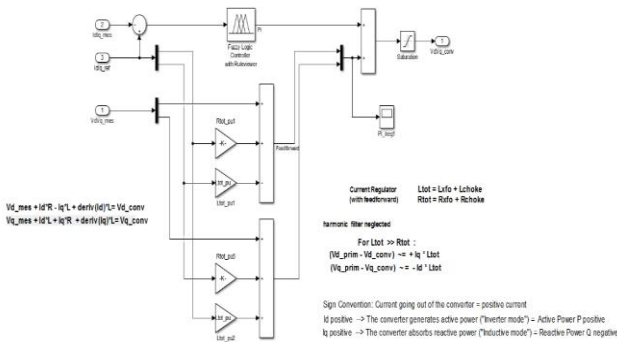


Fig 21 .Fuzzy based Current regulator

4.3 Fuzzy based results

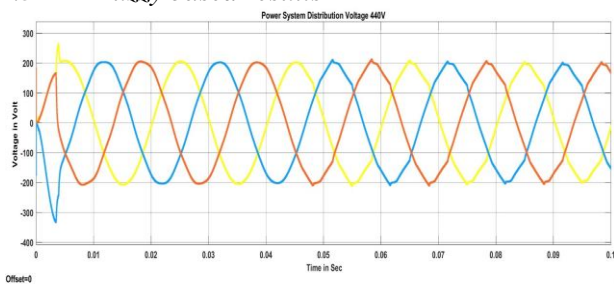


Fig 22. Microgrid integration of hybrid PV and Wind

power system voltage waveform

Fig 23. Voltage at Phase R – THD level

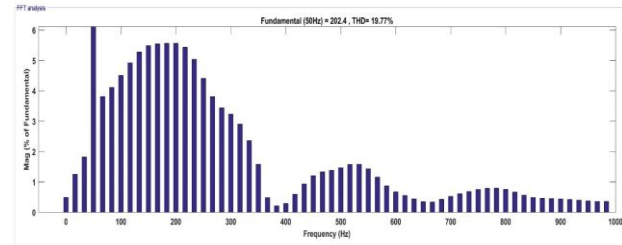
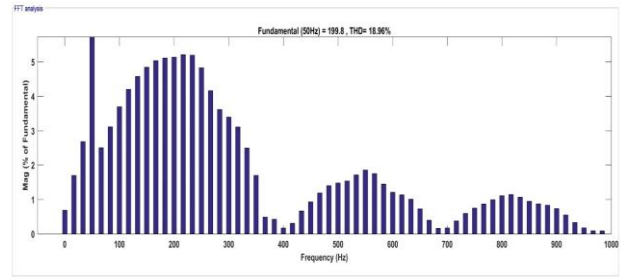


Fig 24. Voltage at Phase Y – THD level

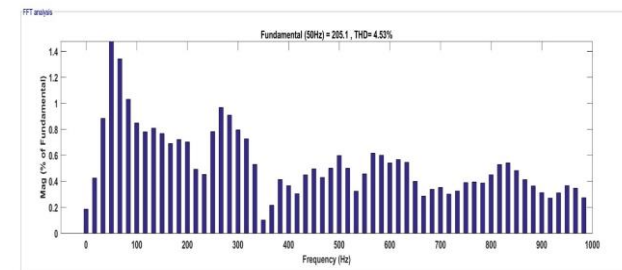


Fig 25. Voltage at Phase B – THD level

4.4 ANN controller for VSC

The ANN controller has been developed for current regulator of VSC as shown in fig 26. The ANN controller has been trained by back propagation method and provides the 70% data for training, 15 % data for testing and 15% data for validation as shown in fig 27. The error of ANN training data as shown in fig 28. After ANN training the network has been analysed overall results as shown in fig 29 and finally ANN network has been developed after successful training for Current regulation for VSC as shown in fig 30. The proposed ANN controller is applied for VSC of hybrid PV/Wind based Microgrid system [15 - 17]. The simulation results are presented such as three phase voltage waveforms and three phase voltage THD as shown in fig 31 to 34 respectively.

Finally, the different intelligent controller results are compared as shown in table 1 and the results are evaluated with IEEE 1547.

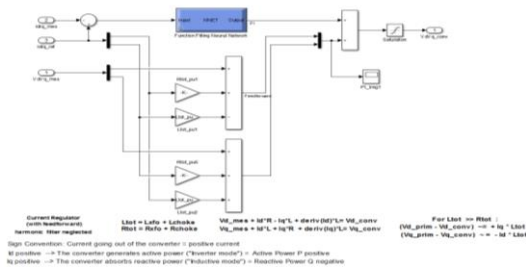


Fig 26. ANN based current regulator

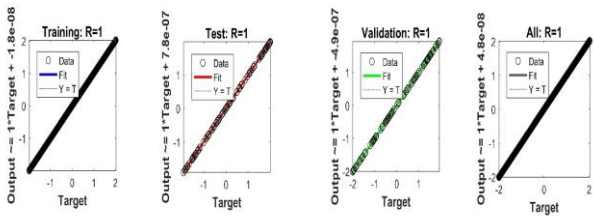


Fig 27. ANN training, Testing, validation and over all performance.

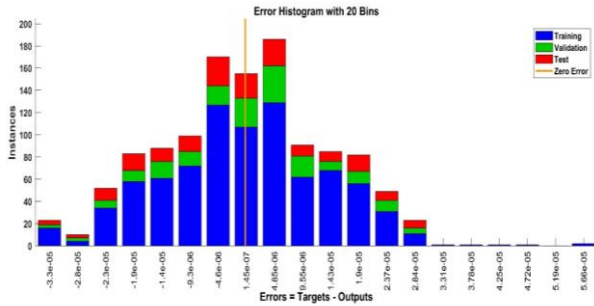


Fig 28. ANN training performane

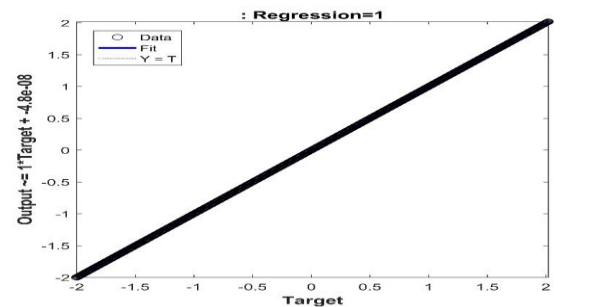


Fig 29. Over all performance of ANN network

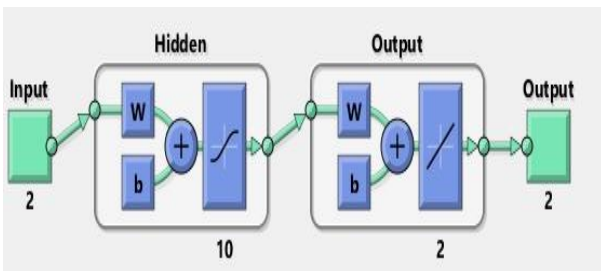


Fig 30 : proposed ANN controller for VSC

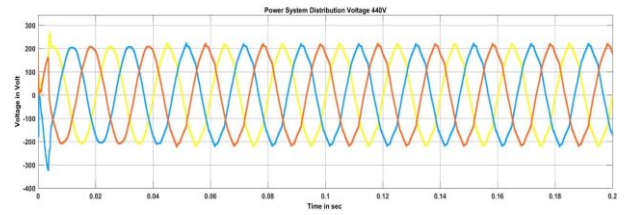


Fig 31: Microgrid integration of hybrid PV and Wind power system voltage waveform

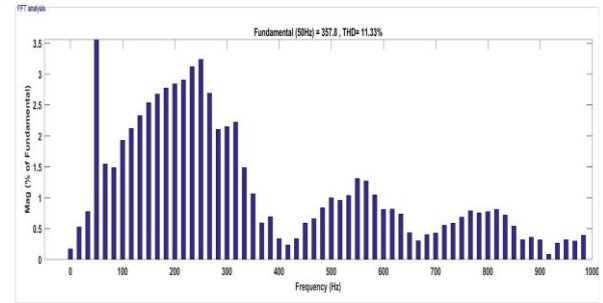


Fig 32. Voltage at Phase R – THD level

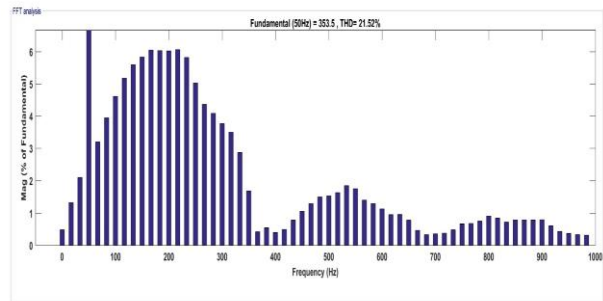


Fig 33. Voltage at Phase Y – THD level

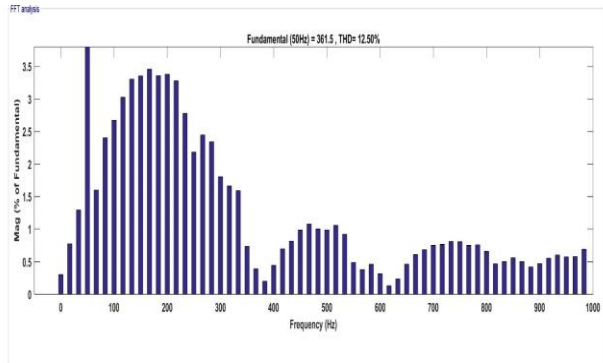


Fig 34. Voltage at Phase B – THD level

4.5 ANFIS controller for VSC

The ANFIS controller has been developed in MATLAB Simulink environment for current regulator. This controller has been designed with two inputs and two outputs namely, error value of I_d and I_q and regulated I_d and I_q respectively (Vide figure 36).

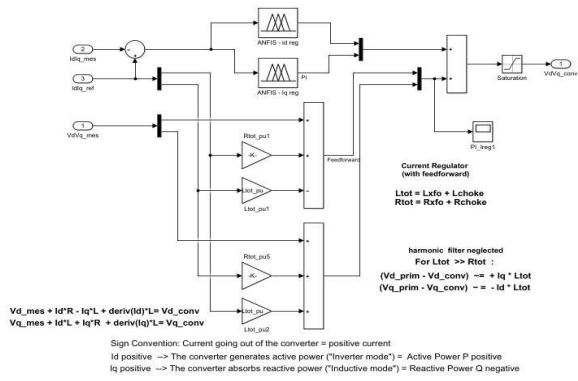


Fig 36: ANFIS Controller Model for Current Regulator.

The error value of I_d and I_q can be calculated by the difference between I_d, I_q reference generated by voltage regulator and I_d, I_q measured. Based on training of ANN network fuzzy input, output membership function and fuzzy rules are generated by controller (Vide figures 37 and 38).



Figure 37: ANFIS Controller training for Current Regulator

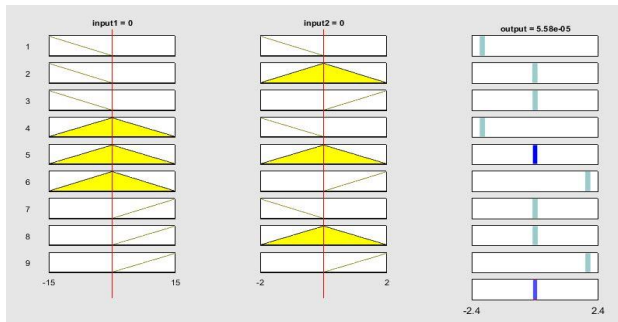


Figure 38: ANFIS Controller Rules for Current Regulator

The ANFIS output signal is fed into feed forward current regulator of converter. Figure 39 presents Voltage and Current Waveform of ANFIS controller based grid integration of Hybrid PV-FC Power system. Its total harmonics distortions values are presented in figures 40 and 42 respectively.

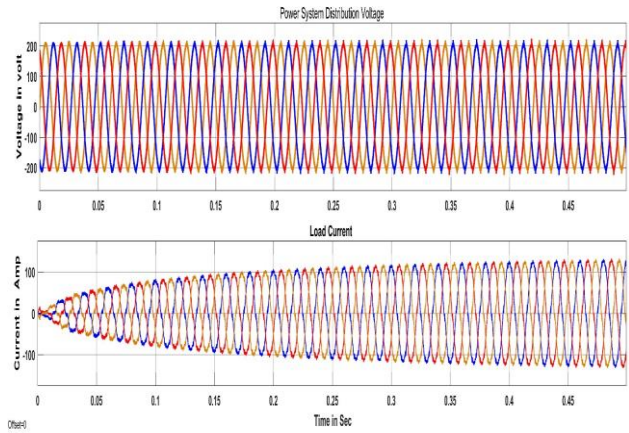


Figure 39: Voltage and Current Waveform ANFIS controller based grid integration hybrid PV-FC Power system

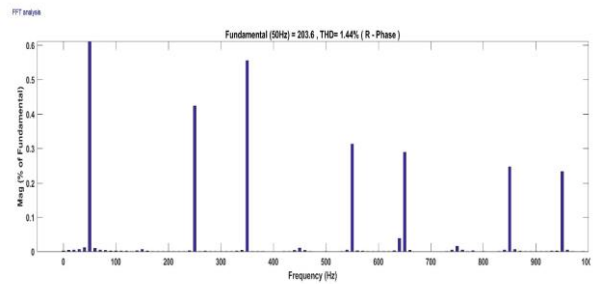


Fig 40: Voltage at Phase R – THD level

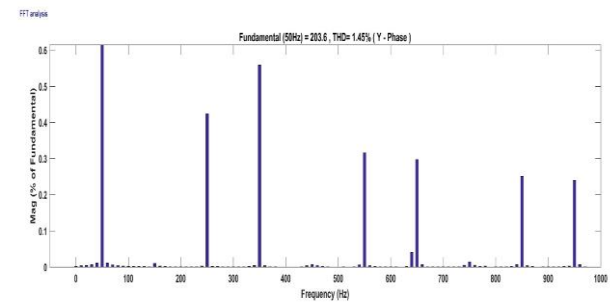


Fig 41: Voltage at Phase Y – THD level

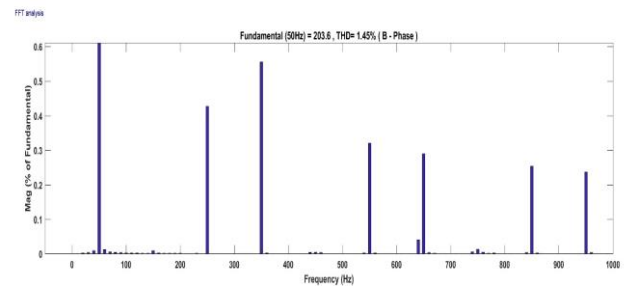


Fig 42: Voltage at Phase B – THD level

Table 1: Comparison THD of proposed system for Fuzzy and ANN

Phase	THD		
	R	Y	B
Fuzzy	18.96%	19.77%	4.53%
ANN	11.33%	21.52%	12.50%
ANFIS	1.44 %	1.45 %	1.45 %

5. Conclusion:

The renewable energy based Microgrid power system has been modeled and simulated in Matlab Simulink software. The PV and Wind system has been simulated and controlled by ANFIS controller then analyzed simulation results under weather condition. The hybrid PV/ Wind power system is modeled and integrated with Microgrid power system by using ANFIS controller. The proposed system analyzed with various intelligent control such as Fuzzy, ANN and ANFIS. The simulation results are evaluated and compared with dissimilar intelligent controller performance. The table 1 presented simulation results of ANFIS controller based VSC has minimum level THD observed compared with fuzzy and ANN based VSC and improve the power system stability as well as quality in all three phases. Finally based on simulation results performance the ANFIS controller has been recommended to hybrid PV/Wind based Microgrid power system.

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