

# Frequency Control of Distributed Generators in Microgrid with ANFIS Controller

K. Hema<sup>1</sup>, P. Maruthupandi<sup>2</sup>

<sup>1</sup>M.E II year, Department of EEE, Government College Technology, Coimbatore, India

<sup>2</sup>Assistant Professor, Department of EEE, Government College Technology, Coimbatore, India

\*\*\*

**Abstract** - Frequency deviation is the major problem in microgrid due to the varying power output from the renewable energy sources. In this paper, solar and wind are taken as prime source of power. Since the renewables lack inertia diesel-generator is used to provide inertia to the system and energy storage devices are used. The proposed controller has less settling time compared to the conventional controllers. Artificial neuro-fuzzy inference system (ANFIS) controller combines the features of fuzzy and neural and has improved performance where the fuzzy rules modify the network according to the power output. The results are obtained using MATLAB/Simulink model.

**Key Words:** renewables, frequency deviation, settling time, fuzzy, ANFIS.

## 1. INTRODUCTION

A hybrid energy system might consist of various renewable energy conversion component like wind turbine, PV array and hydro turbines as well as conventional non-renewable generators like diesel generators, and storage devices. To overcome the incredible power crisis in the country, the best way is to make use of renewable energy sources. It is inexhaustible and non-polluting. It has the advantages of low running and maintenance cost and also noiseless operation.

The voltage power characteristic of a photovoltaic (PV) array is nonlinear and time varying because of the changes caused by the atmospheric conditions [1]. When the solar radiation and temperature varies, the output power of the PV module is also getting changed. But to get the maximum efficiency of the PV module it must be operated at maximum point, so it is necessary to operate the PV module at its maximum power point for all irradiance and temperature conditions [2]. To obtain maximum power from photovoltaic array, photovoltaic power system usually requires maximum power point tracking controller (MPPT).

Block diagram of the microgrid is shown in fig.1. Here Solar, wind, diesel are used as prime source of power production and energy storage devices such as battery and fuel cell are used. The power produced from PV array is varying according to irradiance and temperature hence a zeta converter is used to boost the voltage level. Inverter is

used before connecting to the load. Similarly wind, battery and fuel cell are simulated in the same fashion as earlier.

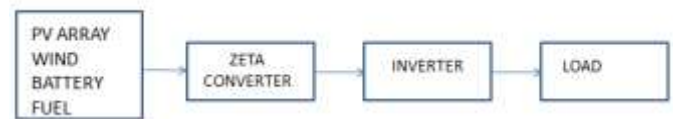


Fig -1: Block diagram of test system

Paper is as follows. In introduction an overview is given. Solar panel is simulated along with converter and inverter. Wind energy conversion system is modelled followed by diesel engine generator and energy storage units such as battery and fuel energy storage systems. Initially PI controller is used to attain stability and the proposed controller is implemented which shows improved performance which are discussed in the results section.

## 2. MODELLING COMPONENTS

### 2.1. PV ARRAY

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building blocks of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.

The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25°C (77°F), and incident solar irradiance level of 1000 W/m<sup>2</sup> and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating.

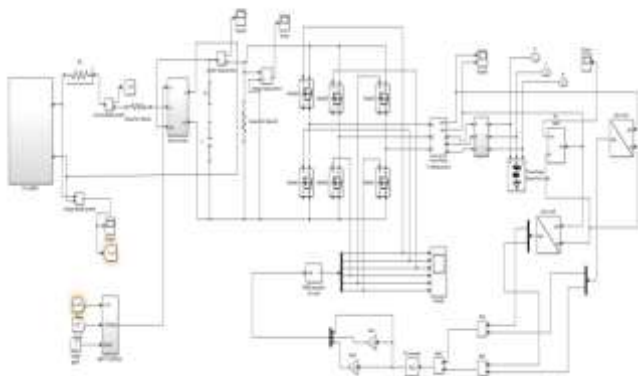


Fig -2: Simulink diagram of solar system

As the amount of sunlight varies, the load characteristic that gives the highest power transfer efficiency changes, so that the efficiency of the system is optimized when the load characteristic changes to keep the power transfer at highest efficiency. This load characteristic is called the maximum power point (MPP) and MPPT is the process of finding this point and keeping the load characteristic there. Electrical circuits can be designed to present arbitrary loads to the photovoltaic cells and then convert the voltage, current, or frequency to suit other devices or systems, and MPPT solves the problem of choosing the best load to be presented to the cells in order to get the most usable power out.

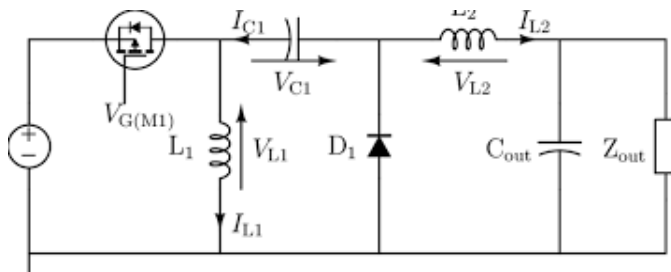


Fig -3: Schematic diagram of Zeta converter

Zeta, or 'inverse sepic', is a dc-dc converters, like Cuk and Sepic, that have a capacitor in series with the power path. Both zeta and Sepic have the same transfer function,

$$V_{out} = V_{in} \times D / (1-D) \text{ -----(1)}$$

Zeta has many advantages, such as input to output DC insulation, buck-boost capability and continuous output current, but it is difficult to control, according to Microchip in its AN1467.

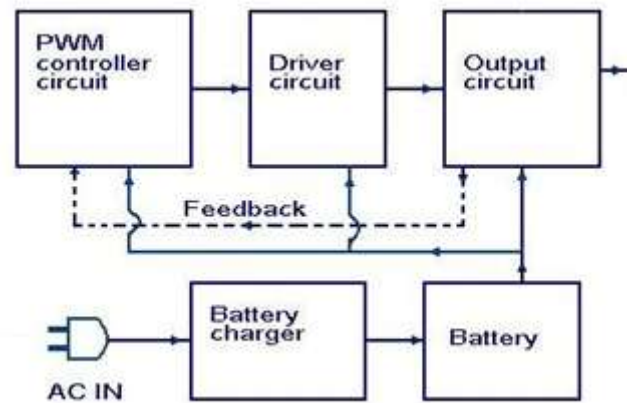


Fig -4: Block diagram of PWM inverter

Pulse Width Modulation or PWM technology is used in Inverters to give a steady output voltage of 230 or 110 V AC irrespective of the load. The Inverters based on the PWM technology are more superior to the conventional inverters. The use of MOSFETs in the output stage and the PWM technology makes these inverters ideal for all types of loads. In addition to the pulse width modulation, the PWM Inverters have additional circuits for protection and voltage control. The quality of the output wave form from the inverter determines its efficiency. The quality of the inverter output wave form is expressed using Fourier analysis data to calculate the Total Harmonic Distortion (THD). THD is the square root of the sum of the squares of the harmonic voltage divided by the fundamental voltage.

$$THD = \sqrt{V_2^2 + V_3^2 + V_4^2 + \dots + V_n^2} / V_1 \text{ -----(2)}$$

Based on the output waveforms, there are three types of Inverters. These are Sine wave, Modified Sine wave or Quasi sine wave and Square wave inverters.

## 2.2. WIND ENERGY CONVERSION SYSTEM

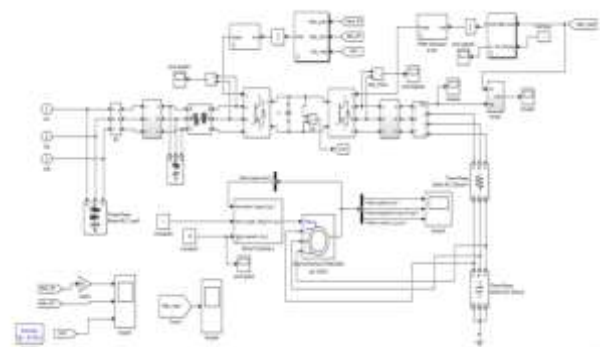


Fig -5: Simulink diagram of wind system

Wind farms generally inject active power into the power system based on two different types including inertia control and primary frequency control. In inertia approach, the existing kinetic energy of rotational masses is utilised in frequency control and primary frequency

control exploits the injected power to provide an appropriate frequency response using pitch angle controller as shown in fig.5

### 2.3 Diesel engine generator

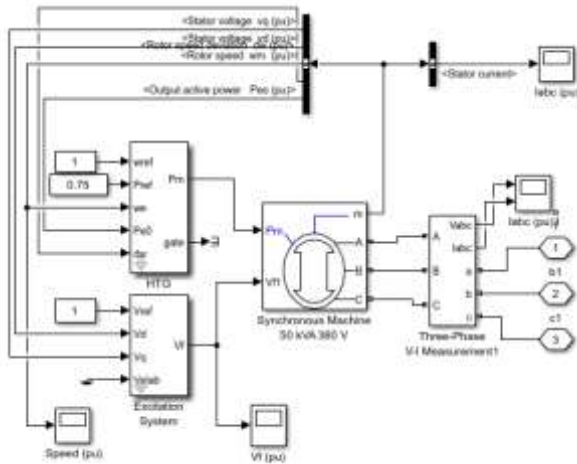


Fig-6: Simulink diagram of diesel engine generator

A diesel generator is the blend of a diesel motor with an electric generator (regularly an alternator) to produce electrical energy. This is a particular instance of motor generator. A diesel pressure start motor frequently is intended to keep running on fuel oil, yet a few sorts are adjusted for other liquid fuels or natural gas. Diesel generating sets are utilized as a part of spots without connection with a power grid, or as emergency powersupply if the grid fails, and also for more complex applications, for example, peak-lopping, grid support and fare to the power grid.

### 2.4 Battery energy storage system

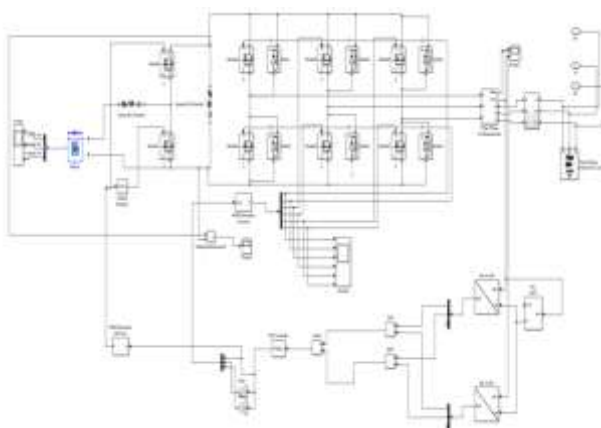


Fig-7: Simulink diagram of battery energy storage system.

Battery system comprises of cells which have a qualities working voltage and most extreme current potential. Dominant part of battery energy storages system have

control power system that handle electricity from the battery and makes it suitable for AC loads. This including changing the current and voltages to maximize the power output, coordinating the changed over AC power to AC electrical system and goes to the end current flow out of the system into grid during outages. The change from DC to AC power in power conditioning system is finished by an inverter.

### 2.5 Fuel energy storage system

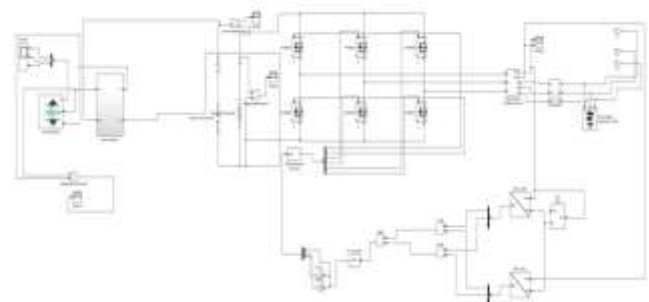


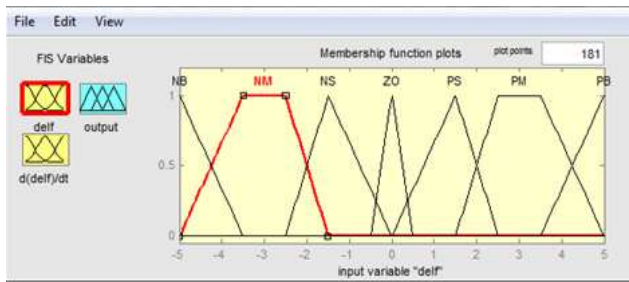
Fig-8: Simulink diagram of fuel energy storage system

Hydrogen fuel cell (HFC) fascinates academics and industrialists because it is suitable for emission-free electricity generation and can be applicable in distributed generation to the automobile industry. When burned, HFC releases water vapor only into the environment. HFC burns faster and contains considerable chemical energy per mass (142 MJ) compared with other hydrocarbon fuels. HFC has high energy density by weight and low energy density by volume. The environmental impact of hydrogen storage is desirable, which leads governments across the globe to enhance the prospects of the hydrogen economy.

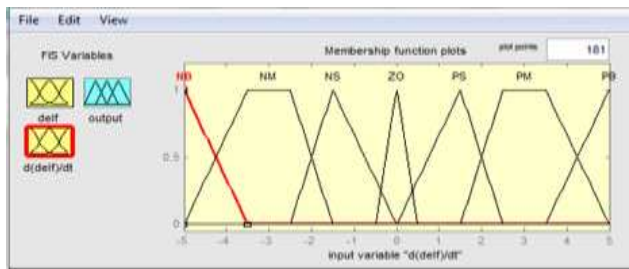
### 3. Proposed Controller

First Fuzzy logic controller based on Mamdani inference system is designed for given power system problem. The input and output data so obtained is utilized as training and testing data. Later adaptive neuro fuzzy system is designed. ANFSEdit toolbox is used to generate ANFIS.fis file in MATLAB software. Training and testing data is utilized to train and test the adaptive neuro fuzzy system. Detail steps of designing of ANFIS can be found in literature [3]. Briefly, the first layer in ANFIS structure performs fuzzy formation and second layer performs fuzzy AND and fuzzy rules. The third layer performs the normalization of the membership functions and the fourth layer is the conclusive part of fuzzy rules and finally, the last layer calculates the network output. According to these, it is obvious that the first and fourth layers in ANFIS structure are adaptive layers in which  $C_i$  and  $\sigma_i$  in layer 1 are known as premise parameters that are related to membership function of fuzzy input. In layer 4  $r_i$ ,  $q_i$  and  $p_i$

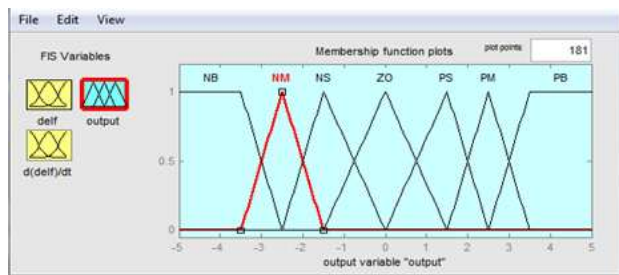
are adaptive parameters of the layer and are called consequent parameters.



(a)



(b)



(c)

Fig-9: Membership function of Fuzzy controller, (a)&(b) represents the input function and (c) represents output function

#### 4. Simulation and Results

The simulink models which are modeled separately are given to load through a common bus as shown in fig.10. The frequency is measured at the loading unit by PLL. The frequency deviation and the derivative of frequency deviation are given as the input to the fuzzy and the error signal is given as the input to the neural network. The fuzzy rules are designed as shown in fig.9.

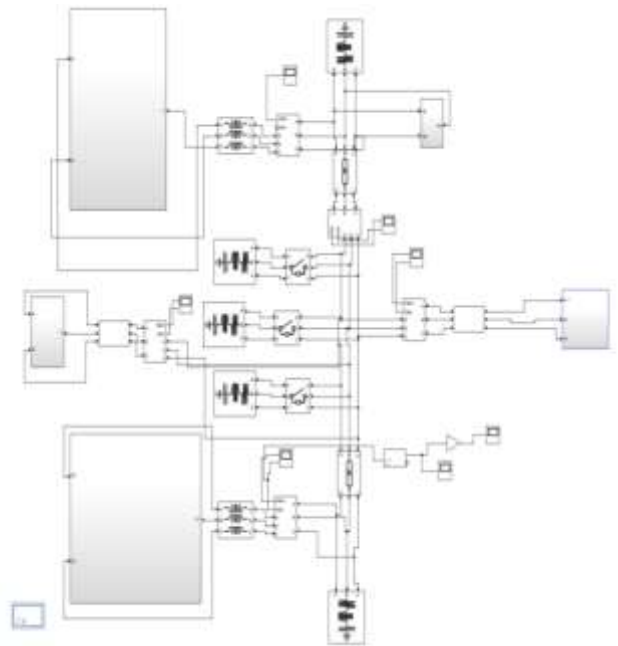


Fig-10: Simulink diagram of standalone microgrid

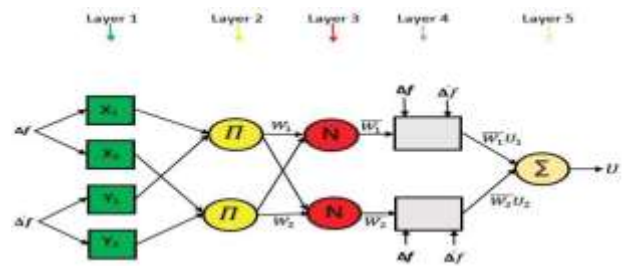


Fig-11: Architecture of ANFIS

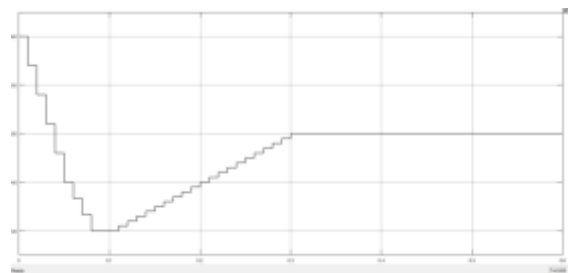


Fig-12: Frequency plot of PI controller without DG

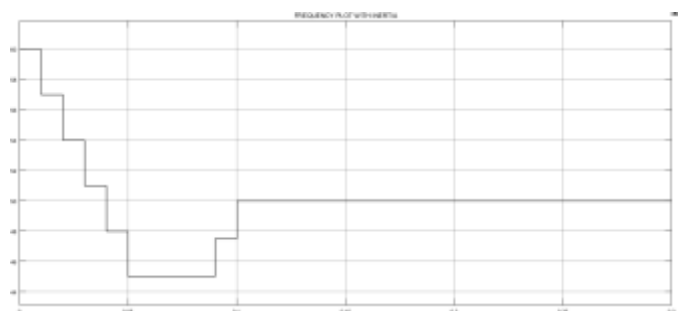
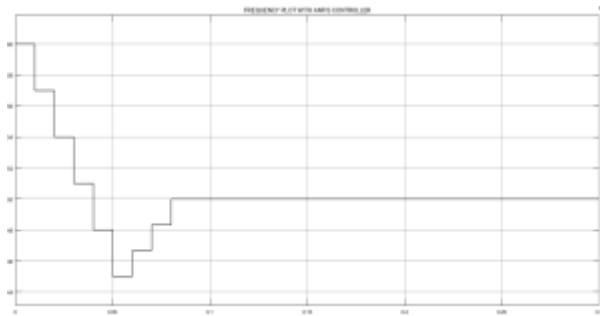


Fig-13: Frequency plot of PI controller with DG



**Fig-14:** Frequency plot using ANFIS controller

## 5. Conclusion

The results are obtained using MATLAB/Simulation. Initially only the sources are connected without any external inertia .PI controller has higher settling time (0.3S) as shown in fig12. Then diesel engine generator is added to the system and shows settling time comparatively less (0.1S). Finally the proposed ANFIS controller is used and frequency stability is achieved at 0.08S and it is superior to other controllers as shown in fig14. The work undertaken is for standalone microgrid and further it may be modified as an islanded microgrid or grid connected microgrid.

## REFERENCES

- [1] Ansari, S. Chaterjee, and A. Iqbal, "Fuzzy logic control scheme for solar photo voltaic system for maximum power point tracker," *Int. J Sustain. Energy*, vol. 29, no. 4, pp. 245–255, Apr. 2010.
- [2] E. Kremers, P. Viejo, O. Barambones and J. G. d. Durana, "A Complex Systems Modelling Approach for Decentralised Simulation of Electrical Microgrids," *2010 15th IEEE International Conference on Engineering of Complex Computer Systems*, Oxford, 2010, pp. 302-311.
- [3] Bevrani, H., Daneshmand, P.R.: 'Fuzzy logic-based load frequency control concerning high penetration of wind turbine', *IEEE Syst. J.*, 2012, 6, (1), pp.173–180.
- [4] Cam, E.: 'Application of fuzzy logic for load frequency control of hydro electrical power plants', *Energy Convers. Manage.*, 2007, 48, pp. 1281–1288.
- [5] T. L. Kottas, Y. S. Boutalis, and A. D. Karlis, "New maximum power tracker for PV arrays using fuzzy controller in close cooperation with fuzzy cognitive networks," *IEEE Trans. Energy Convers.*, vol. 21.
- [6] Hassan Bevrani, Fuzzy Logic-Based Load-Frequency Control Concerning High Penetration

of Wind Turbines, *IEEE SYSTEMS JOURNAL*, Vol. 6, no. 1, March 2012.

- [7] A.A. Salarn, A. Moharned, and M. A. Hannan, " Technical challenges on Microgrids," *Asian Research Publishing Network (ARPN)*, vol. 3, no. 6, pp. 64-69, Dec. 2008.
- [8] M. S. Mahmoud, M. Saif Ur Rahman and F. M. A. L. - Sunni, "Review of microgrid architectures – a system of systems perspective," in *IET Renewable Power Generation*, vol. 9, no. 8, pp. 1064-1078, 11 2015.
- [9] Ngamroo I, "Robust frequency control of wind-diesel hybrid power system using superconducting magnetic energy storage". *Int J Emerg Electr Power Syst* 2009;10(2).
- [10] I.Serban and C. Marinescu, "Aggregate load-frequency control of a wind-hydro autonomous microgrid," *Renew. Energy*, vol. 36, no. 12, pp. 3345–3354, 2011.
- [11] H. Bevrani, "Robust load frequency controller in a deregulated environment: A mu;-synthesis approach," in *Proc. IEEE Int. Conf. Control Appl.*, 1999, vol. 1, pp. 616–621.