ANN Control Strategy for THD Reduction in Microgrid.

Neethi M, M S Shashikala

Abstract: Micro-grid system is currently considered as alternate solution to fulfil the shortage of power today. It consists of several small Distributed generations integrated with storage systems to act as single entity. In a dc microgrid PWM inverter with conventional PI controller is incorporated to convert dc-ac. In this paper a microgrid is modelled with renewable energy generations such as Photo Voltaic, Wind Turbine and Fuel cell with Battery Energy Storage systems. A Neural Network control is implemented with ten-layer network to generate the pulses to control the voltage and current harmonics. The model is developed in MATLAB/Simulink and the results are compared with the conventional PI controller and analysis is made that the ANN controller improves the inverter performance.

Index terms- ANN, Distributed generations, Fuel cell, Photo Voltaic, Wind Turbine, THD.

1. INTRODUCTION

Distributed generation is one of the more focused area of research from the past few decades. Several authors have defined distributed generation in many ways based on the purpose, location, rating of distributed generation, technology, and environmental impact, mode of operation, ownership and penetration of distributed generation [1]. Availability of large land mass with highest solar irradiation and long coastline with high wind velocities, solar power and wind power are the leading energy sources.

Conventional power plants involve the production of electrical energy from coal, oil or natural gas. There are several disadvantages associated with these such as emission of greenhouse gases, deforestation, damaging the ecosystem, increased cost of generation etc. Due to the increased consumption, the fossil fuels are depleting and hence in order to get green energy, researchers are focused on to renewable sources for power generation, wherein several small distributed energy sources are integrated to form a microgrid with storage systems so as to act as an alternate supply to meet the energy demand.

Microgrid can be defined as the cluster of distributed generation, storage system, control systems and local loads which act as a single unit [2]. There are several advantages associated with microgrid such as low cost, reliability, ecofriendly etc. But there are some technical challenges associated with it in order to connect it to the main grid. It can operate in grid connected mode and in islanded mode, but before connecting or disconnecting from the grid challenges in operation, control and protection are being faced [3].

In this paper microgrid is modelled based on PV, Wind, Fuel cell along with battery energy storage system. Since all the power electronic converters inject harmonics, it is necessary to adopt control circuit in order to control the gate pulses there by improving the inverter performance by reducing the total harmonic distortion [4]. Conventional PI controller is employed to control the voltage and frequency deviation, but PI controller requires error free mathematical model of the system which is hard to get under fluctuating parameters and load changes. Hence this paper presents ANN control strategy for the PWM inverter to reduce the total harmonic distortion. The Artificial Neural Network is the robust controller with several advantages such as it accepts the varying inputs, multitasking, efficient in handling the tolerances created in the microgrid due to interfaces, effectively tuning the data etc. [6]

The paper is arranged as follows. Section 2 describes the modelling of Photovoltaic (PV), Wind Turbine (WT) system, Proton Exchange Membrane Fuel cell (PEMFC) and Battery Energy Storage Systems (BESS). Section 3 describes the Artificial Neural Network (ANN) and the developed ANN controller model for the microgrid. In Section 4 results are discussed and analyzed. Section 5 presents the conclusion of the paper.

2. MICROGRID MODELLING

As mentioned above the components for the microgrid system are modeled using MATLAB/SIMULINK software tool.

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2.1 PV Module

The mathematical model of the PV cell can be represented by an equivalent circuit with a photocurrent source, single diode, series and shunt resistance [7] as shown in figure 1 with the following equations:

$$I = I_{ph} - I_s\left(exp\frac{q(V+R_sI)}{aKTN_s} - 1\right) - \left(\frac{V+IR_s}{R_{sh}}\right) \quad (1)$$

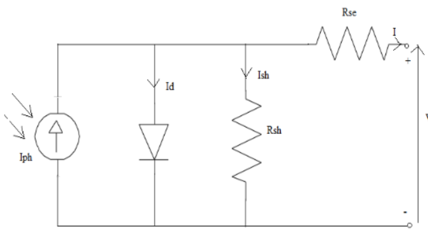

Figure 1. Equivalent circuit of PV panel.

$$I_{ph} = \left(I_{sc} + K_i(T - 298.15)\right)\frac{G}{1000} \quad (2)$$

$$I_s = \frac{I_{sc} + K_i(T - 298.15)}{\exp(q\left(\frac{V_{oc} + K_v(T - 298.15)}{aKTN_s}\right) - 1} \quad (3)$$

The PV model is built using the existing PV array in the Simulink library to illustrate the nonlinear I-V and P-V characteristics of the PV module as shown in the figure 2.

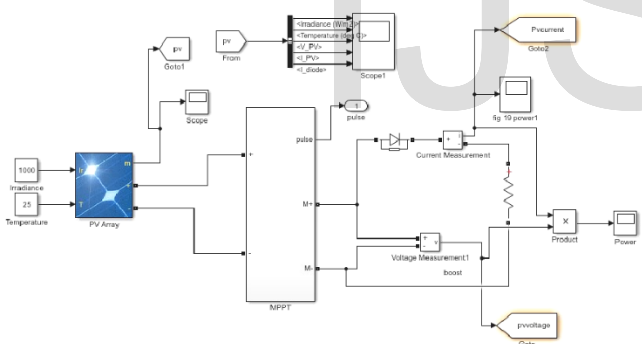

Figure 2. Simulink Model of PV array with MPPT.

2.2 Wind Turbine Module

Wind turbine is used to generate the electricity from the Kinetic energy of the wind. It works on the principle of aerodynamics and is composed of rotor, generator, blades and a drive train. The generator output varies due to the fluctuating wind speed and hence the output power is controlled by adjusting the pitch angle. The mechanical torque and the power developed by the wind turbine is given by [8]. The Simulink model of wind turbine and its subsystem in shown in figure 3 and 4.

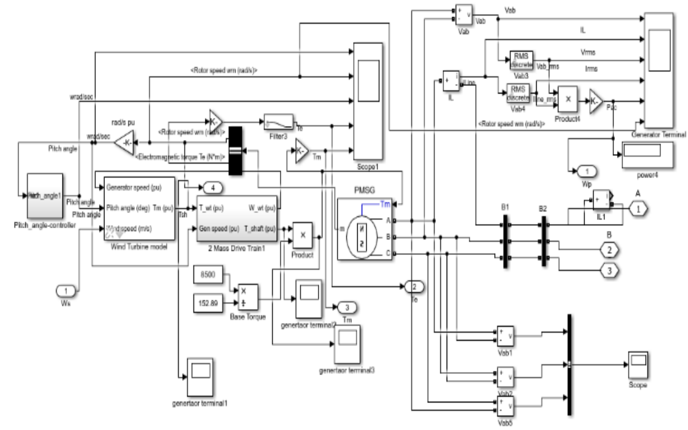

Figure 3. Simulink Model of wind energy system with MPPT

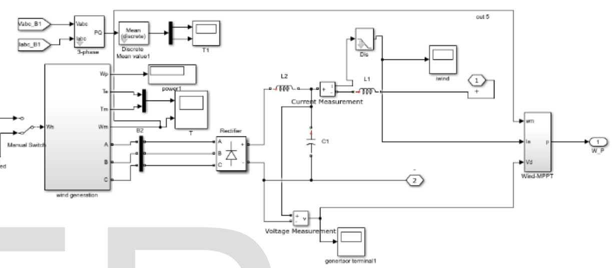

Figure 4. Subsystem of wind generation

2.3 Fuel cell module

Fuel cell stack is designed by considering the preset model of proton exchange membrane fuel cell in the Simulink library. It generates the electricity based on the oxidation and reduction chemical reaction taking place at the respective electrodes with the supply of hydrogen and oxygen through solid membrane. The chemical reactions and the voltage generated by fuel cell is given by [9]. The Simulink model of fuel cell is shown in figure 5.

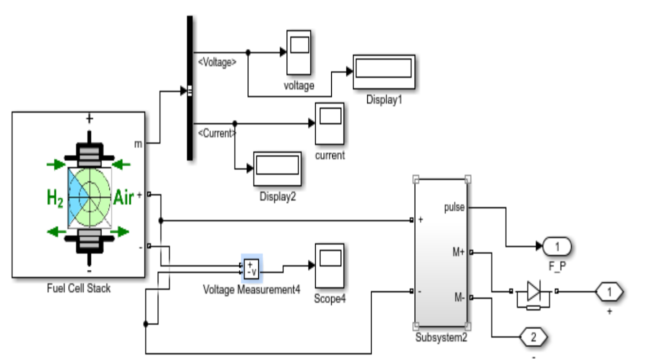

Figure 5. Simulink model of PEMFC stack

2.4 Battery Energy storage system model

Battery energy storage systems plays a vital role in integrating the distributed generation in microgrid. It is incorporated to balance the power and the peak load demand in grid connected mode of operation and to supply when the generation is intermittent. Several approaches have been proposed to model battery, in this case a Nickel metal hydride battery of 6.5Ah capacity with controller to control the state of charge has been modelled as shown in figure 6.

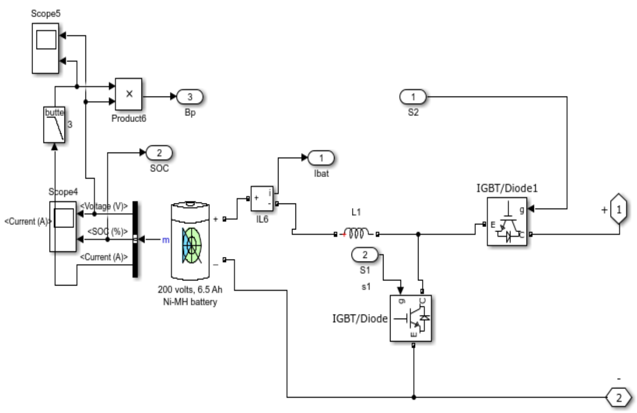

Figure 6. Simulink model of Ni-MH battery

3. ARTIFICIAL NEURAL NETWORK

ANN consists of number of connected nodes called as artificial neurons. These artificial neurons consist of inputs, weights, activation function and output. In ANN each of the neurons receives the number of inputs, these inputs are multiplied with the weights and when the activation function is applied it resets the output value of the neuron [10]. The basic ANN architecture consists of three layers input layer, hidden layer and the output layer. The model of ANN is as shown in figure 7 and its output equation follows as:

$$y = f(x_1w_1 + x_2w_2 + x_3w_3 + b) = f(\sum x_1w_1 + b) \quad (4)$$

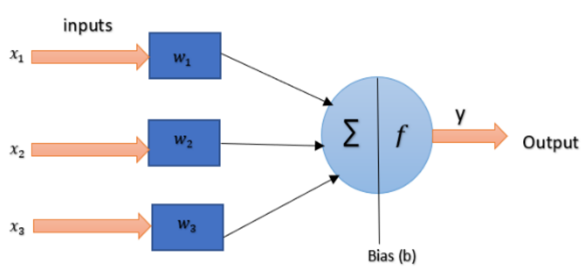

Figure 7. Model of ANN

3.1 ANN Controller for Microgrid

In order to improve the performance of the inverter a multi-layer back propagation type artificial neural network controller is used. Back propagation algorithm performs parallel training of the multilayer network thereby improving the efficiency of network. There are other two algorithms that have been developed for training the network such as gradient decent algorithm and Gauss newton algorithm. The drawback of Gradient method is slow convergence, this is improved by the Gauss-Newton algorithm. It finds proper step sizes for each direction and converge very fast, but this can be achieved only if the quadratic approximation of error function is reasonable otherwise this method would be mostly divergent. The Levenberg- Marquart algorithm is the second order optimization, it is fast and stable convergence.

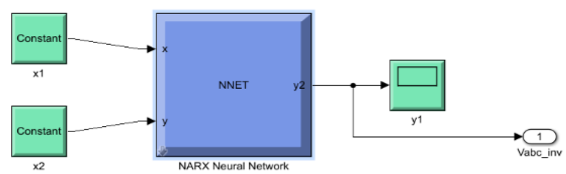

Figure 8. NARX neural network model

The Nonlinear autoregressive with external input neural network is developed using neural network time series tool in MATLAB/Simulink software as shown in figure 8.

A nonlinear regressive problem is chosen, the input time series x(t) and the target time series defining the desired output are 3x27336 matrices representing the dynamic data: 27336-time steps of 3 elements which is the output of the inverter. Out of 27336-time steps 70% for training, 15% for validation and remaining 15% for testing is considered. The ANN architecture is developed by considering 10 neurons with 2 delays by employing Levenberg- Marquart algorithm as shown in figure 9. It is specifically designed to minimize sum-of-square error functions. This algorithm requires more memory but less computation time and the training automatically stop when the optimization stops improving. In this case the computation time taken is 38 seconds in which 180 iterations are performed which achieved regression of 99%.

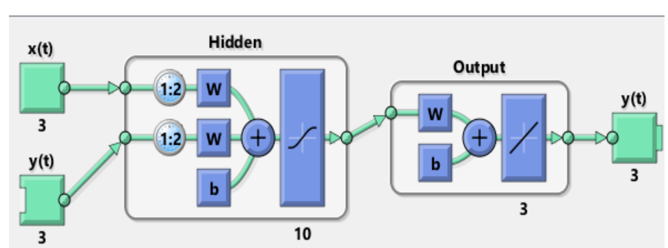

Figure 9. Layers of NARX neural network model

4. RESULTS AND ANALYSIS

Microgrid with ANN control topology connected to standard IEEE 14 bus system. The PV model, wind fuel cell and Battery energy storage system are integrated to form dc microgrid and then connected at 8th bus of IEEE standard 14 bus system through PWM inverter as shown in figure 10.

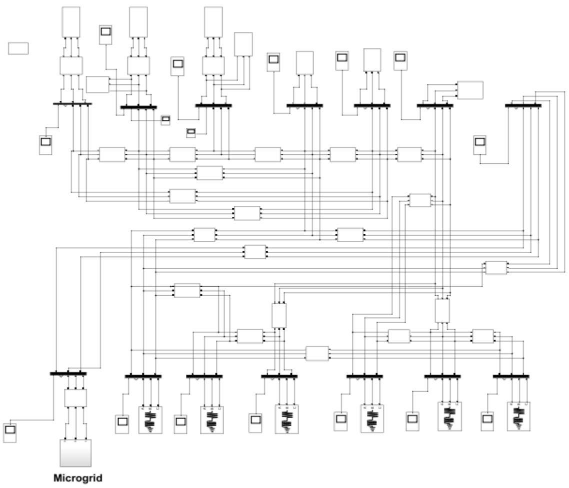

Figure 10. Microgrid with ANN controller

FFT analysis is performed to study the behavior of microgrid when connected to IEEE14 bus system. The voltage at all the buses before connecting microgrid were pure sinusoidal waveforms but when Microgrid is integrated at 8th bus the voltage waveforms are distorted due to the injection of harmonics. The total harmonic distortion before connecting the microgrid was 0% and after connecting the microgrid it is observed that the total harmonic distortion is 27.02%. The distorted voltage waveform and the percentage of THD is as shown in figure 11(a) and 11(b).

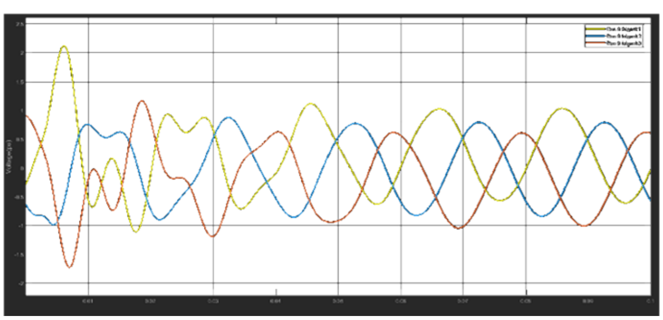

Figure 11 (a) Voltage waveform without ANN controller

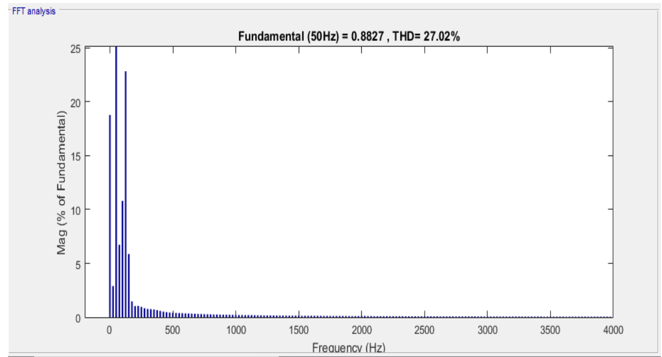

Figure 11 (b) THD without ANN controller

After implementing ANN control for the PWM inverter it is observed that the voltage distortion is reduced as shown in figure 12(a) and the total harmonic distortion has reduced to 13.69% as shown in figure 12(b)

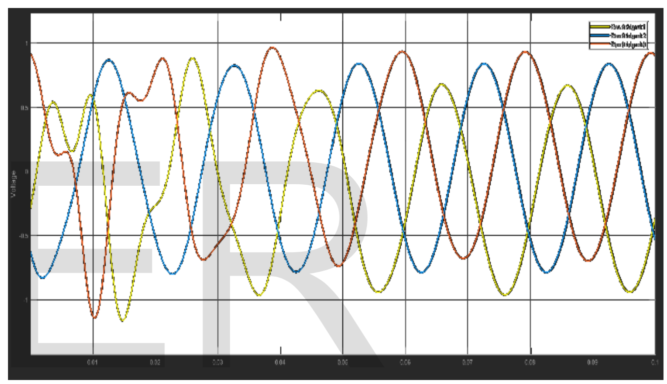

Figure 12 (a) Improved voltage waveform with ANN controller

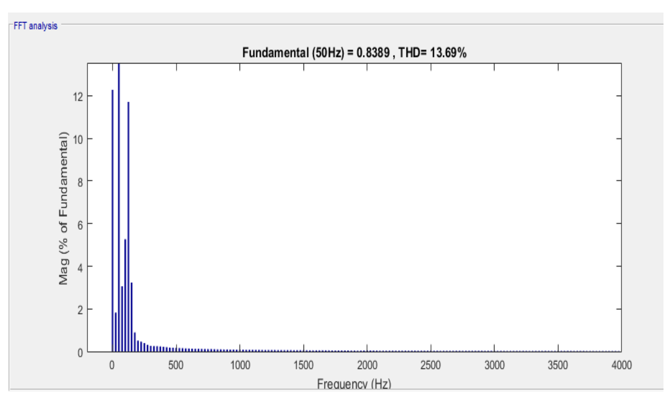

Figure 12(b) THD with ANN controller

Table 1: Comparison of THD with PI and ANN controller

Controller	Total harmonic distortion (%)		
	Signal 1	Signal 2	Signal3
PI controller	27.02	8.97	24.13
ANN controller	13.69	1.88	13.25

By using PI and ANN controller FFT analysis is made for inverter output. When we compare the PI and ANN values, the ANN controller values are relatively better than PI controller values as shown in Table 1.

5. Conclusion

The paper presents the simulation model of renewable energy generation such as PV, Wind, Fuel cell with BESS integrated to IEEE14 bus system. The microgrid integration is tested with conventional PI controller and ANN controller implemented to PWM inverter. It is observed that the total harmonic distortion has significantly reduced with ANN controller when compared to the conventional PI controller referring from Table 1. From the simulation results it observed that ANN controller will remove the error from the reference signal and improve the voltage deviation. Thus, THD can be reduced further more by incorporating ANN controller.

6. References

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