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Designing and optimization of the microgrid with hybrid renewable energy model using ANN controller

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ABSTRACT: This paper presents the design and maintenance of green energy for a hybrid model consists of wind and solar based micro grid. The hybrid approach including MPPT for buck/boost converter gives fewer harmonic, which doesn't even need the filter. An Artificial Neural Network (ANN) controller is more suitable for the control of reactive power as well as to reduce the voltage fluctuation injected into the grid. The proposed system is developed in MATLAB Simulink and the results are presented for both PI controller and ANN controller. The fluctuation of voltage is minimized by 7% using a PI controller in the bus bar and 15% by ANN controller while varying different loads.

Keywords: Microgrid, Renewable Energy System, Hybrid

I. INTRODUCTION

The worldwide populace is expanding periodically. The present way of life with lots of appliances with a high need for electric power tends the researchers to analyze alternative ways to substitute common energy resources. By the common energy distribution networks like hydropower and thermal-based power, production can't able to reach these high demands in load by its available source capacities. Thus, the generating framework based on renewable energy was in an urgent need to balance the demand requirements [1-3]. In recent years, the uses of sustainable power resources such as solar and wind have demonstrated expanding production of energy. By expanding the usage of energy, it tends in quicker advancement technology for generating energy as well as developing general consciousness based on green energy sources as an alternative way to generate and distribute these energies. The different methods for controlling and managing the energies are used for developing a hybrid model comprising of a productive wind and solar framework in the usage of minimal capacity industries. Hence sustainable power source frameworks such as solar and wind individually can't able to satisfy the requirements of dynamic load demands. Due to the experience of instability in power as well as compensating the responding power was a developing requirement to an active stable framework. In the energy frameworks, the main necessity is the compensation of reactive power. Due to the issues in reactive power, it leads to major losses in power and various problems in the quality of the power. The capacitors with mechanically fixed switching and the condensers are presented [4, 5]. But these solutions face lots of demerits by larger in dimension, major level in loss and takes time to respond. To improve the stability of the framework and to maximize the transfer capacity of the power, the Flexible Alternating Current Transmission Systems (FACTS) components had introduced in the market [6 -8]. Both active and reactive powers are regulated based on the condition pattern using the conventional MPPT technique [9-10].

The proposed system consists of wind and solar-based renewable energy systems using ANN controller. This proposed controller aims to improve the stability and managing reactive power efficiently. By the usage of an ANN controller, numerous issues in the power systems are efficiently rectified. The major advantage of the ANN is to find the relationships within the data of input as well as the output for a given complicated task or unknown relations within the data. The PI controller was used as an existing framework in which its total performance efficiency is based on the load type of reactive power. The performance of the PI controller is not adaptable for the nonlinear loads, thus to improve the efficiency it needs frequent tuning. This research article concentrates on the ANN-based methodology with a broad characteristics range of the loads. In the MATLAB environment for simulation ANN toolbox with error-backpropagation training, technique was utilized. Finally, it demonstrates that stability provided by the ANN was better when compared with the PI controller.

This paper is organized as follows: Section 1 describes the introduction for the renewable energy system, hybrid model and types of controllers. Section 2 gives a brief methodology of the proposed model. Section 3 discusses the results obtained from the MATLAB Simulink model and finally, Section 4 presents the conclusion.

II. METHODOLOGY

Figure 1 shows the developed hybrid model. The proposed model consists of a 25 kilovolt with a 100 Megavolt Ampere distribution grid. In between the bus bars and the interconnected loads, it occupies 21 lines with 2 kilometers of length.

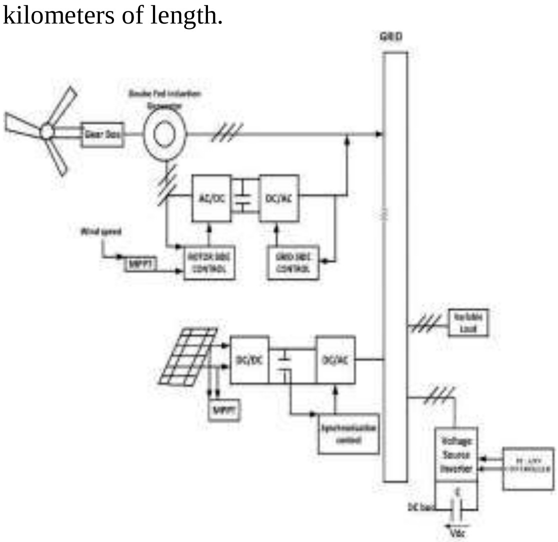

Figure 1: Solar-Wind Hybrid System including PI and ANN

The DFIG based wind turbine was developed with both grid and rotor side controls. Based on the optimal torque and the speed of wind the MPPT had been used indirectly. The solar array with 0.4 Megawatt was designed as well as it performs the synchronize control using PLL. In the bus bar terminal, the fluctuation in voltage was reduced and compensating the reactive power by adding the controller part in Point of Common Coupling (PCC). In the bus bar terminal side, the values of the voltage, reactive power and the current are analyzed by the PI controller initially following by the ANN controller. In the line's terminal, the load was attached which was varies within 1 Megavolt Ampere and 5.2 Megavolt Ampere. Where 1 power unit was maintained as a reference voltage by programming the framework with 1.077 power unit. To maintain the stability of the voltage for the PI controller the time domain characteristics in the control circuit were evaluated. The framework leads to instability and causes to failure when the tuning of the controller in the control section acquires irrelevant values without proper constant. To overcome the drawbacks of this PI controller, ANN was utilized to deliver efficient parameter adjustment and opting better tuning with constant values. The entire system maintains its stability and efficiency by using the ANN controller.

2.1 WIND POWER SYSTEM MODELLING

One of the majorly using generators at the present era for wind is the Doubly Fed Induction Generator (DFIG). This generator encompassed with 3phase fixed frequency networks consists of stator windings with direct connection and in rotor windings; it consists of converters based on voltage back to back. Doubly fed was termed by its operation as the power converter is used to induce the rotor voltage and through the main, the stator voltage is derived. It was capable to permit huge operations with the restricted speed in variables. The frequencies of the electrical, as well as mechanical, are altered by the transducers through injecting the current in the rotor with various frequencies. The behavior of the generator was handled by the controllers else the power converters during the system's operation condition are in normal or in fault mode. Converters with voltage induced successively were composed in the DFIG system. The converters were organized in direct connection to the grid with 3phase fixed frequency as well as connected in windings of the rotor side bidirectionally. The regulation of reactive and active powers is achieved by controlling the rectifier's current components in the rotor side are the significant aim of this system. The voltages on the DC link are controlled by the grid area inverter. It consists of many merits like control the power ability of the reactive and active through the rotor current. Also, it consists of dual converters successively one on the grid side and another on the rotor side.

2.2 PHOTOVOLTAIC POWER SYSTEM MODELLING

The photovoltaic boards guarantee the Direct Current (DC) power generation through the conversion of the energy rays from the sun. To

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expand the output efficiency of the power, numerous PV boards were organized in the structure of serially or parallelly that was placed on the surface level sequentially which was termed as solar array module. The circuit of one diode equivalent was used to model the solar cells. Moreover, in the solar energy framework, it contains the maximum power point tracking (MPPT) module. The maximum level of power is achieved from the solar array by using this MPPT controller. It operates in the manner of acquiring the inputs of Solar's current and voltage and alters the boost converters duty cycle, this was achieved by tracking the maximal power point based on the input it took. The prediction of the effects that happened by the voltage change is achieved by this technique by analyzing the level of subsequent changes occurs in the solar module voltage and current. Through accompanying the controller this was able to identify maximal power continuously with higher proficiency while rapid changes occur during irradiance. Thus, the maximal PowerPoint was determined with a strong maximal value without any oscillation.

2.3 BATTERY MODELING

For the applications with the higher power, the battery Li-ion is the best option to choose. In our microgrid model, we use this battery because of its series-parallel connectivity which gives an efficient powerful battery network.

2.4 CONTROLLERS:

2.4.1 PI CONTROLLER:

In each sampling time (T) second the PI controller evaluates and transmits the controller's output signal to the last control appliances. The work of the PI was similar to P control. The output which is evaluated by the PI is compromised by fine-tuning limits of the controller as well as controller error e(t). The structure of the PI controller was shown in figure 2.

The DC offsets are eliminated by the PI methods with its inbuilt operations and capable of eliminating the steady state error. In many industries based on power systems, the PI is very much adaptable due to its solving abilities, reducing the complex structure and providing a good level of integrity. These benefits of the PI are achieved by its high-class sinusoidal waveforms. Following equation is the standard for PI controller:

$$y(t) = y_{bias} + K_C e(t) + \frac{K_C}{\tau}\int_0^t e(t)dt. \quad (1)$$

The output value of the controller was y(t) which was inputted in the grid as calculated alterable inputs. The regulator's tunable attributes are integral time constant τ and controller gain (KC). In both the integral term and the proportional error, the controller's value is the gain multiplier. The reply of the controller to the errors is more aggressive by its upper-value marks from the defined point (DP). The expected value and the processing variable is the DP, in which it might be varied by the actual value.

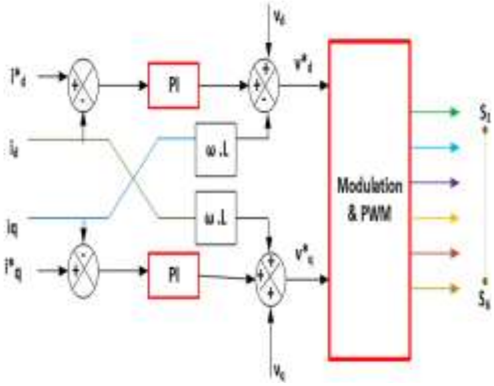

FIGURE 2: STRUCTURE OF PI

2.4.2 ARTIFICIAL NEURAL NETWORK

The ANNs work for competing for the machines near the human cerebrum's capacity by emulating unmistakable aspects of information handling in the brain by proficiently. A neural system has interrelated arrangements of artificial neurons that reproduce natural brain behavioral framework. ANN was a versatile system and differs its design by its learning phase. It has opted while contact among impacts and reactions are confusable. It was better to use in the current controller's procedure in light of their increasing robust nature. Its self-learning ability makes any type of design simply and possibly in the energy grid environment. The structure of the ANN was shown in figure 3. The major advantages of the ANN with advance robustness while comparing it with traditional controllers it was possible to eliminate the sensors and major equipment for controlling the line voltage and current in the grid. It can assess elective capacity planning. Grid networks face the complex structure and lack of computation this can be overcome by using ANN. By using a low voltage ride process (LVRT) for the powers of both active and reactive control it was able to balance the power during any type of fault condition that occurs in the grid unit. The stabilization of the output voltage is mandatory in the grid system based on a hybrid model with solar

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and wind by its non-linear nature. The ANN handles the Dc-Dc converter's duty cycle for controlling the voltages of both the solar and wind energy modules.

For structuring ANN, it was mandatory to coordinate some or large neurons in various layers as well as connection in various ways. An architectural of the ANN is determine through arrangements of the neurons, to overcome difficult issues in various fields. Using feedback format, the connections within the network can be accomplished. Here the ANN architecture consists of two layers which are hidden with both the solar and wind system. It includes the layers of hidden, input and output by the transfer functions and its accordance weight values. Through this, the controller could achieve the desired results by adjusting the weighted coefficients. For each hidden node, the values of the inputs and weights are summed up and it was compared with the determined threshold value. While the output value is higher than the threshold it picks the activated value. If not, it picks the deactivated one. The back-propagation method was used here to train the model. The MATLAB tool was utilized here for training the model.

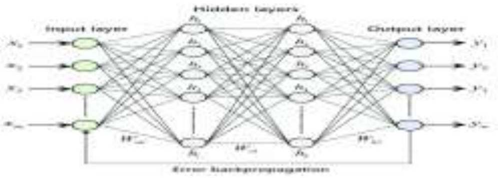

FIGURE 3: STRUCTURE OF ANN

III. RESULTS AND DISCUSSIONS

The ANN structures for the proposed hybrid wind and the solar system as shown in figure 4. For both wind and solar systems, the first ANN structure includes just one neuron and one sigmoid activation function. In the first hidden layer, as well as one single neuron and one linear activation function in the second hidden layer. In the second analyzed ANN structure, the number of neurons of the first layers is increased and linear activation functions are used in the second layers for both wind and solar systems. The third ANN structure contains three hidden layers and one neuron for both wind and solar systems. Also, sigmoid activation functions are used in both first layers and linear activation functions are used in the third one in both wind and solar systems. The architecture in the fourth and fifth analyzed ANN structures are the same as used in the third one, and the number of neurons of the first layers is raised.

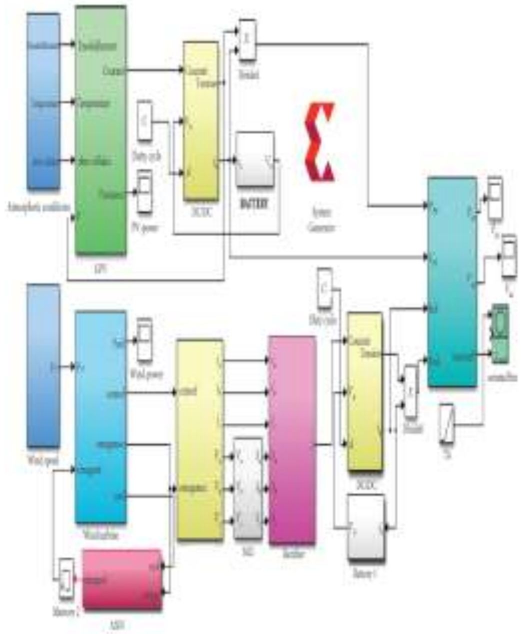

FIGURE 4: ANN BASED HYBRID MODEL

The ANN controller structures are modeled using MATLAB/Simulink. This obtains the power curves of the simulated hybrid system. These ANN structures give good power values that can satisfy the continuous supply of the hybrid system. The curves reach their MPP at different values of the time. The quickest ones are considered. The power output of controllers will be compared by focusing on the MPPT achieving time. The current and voltage output waveform for the proposed model was shown in figure 5 using the PI controller and figure 6 using the ANN controller. The output shows the difference between the settling time of both controllers, in which ANN provides better while comparing with the PI controller.

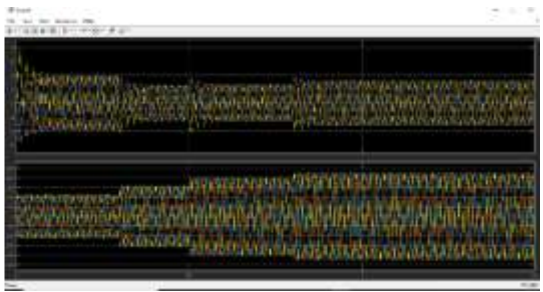

FIGURE 5: CURRENTAND VOLTAGE FOR PI BASED MODEL

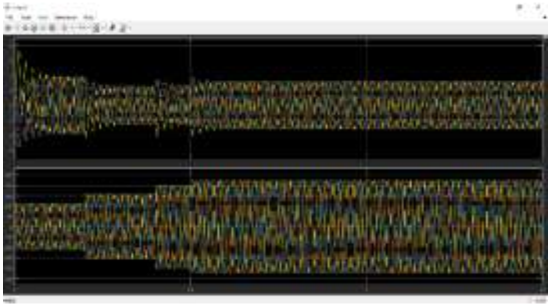

FIGURE 6:CURRENT AND VOLTAGE FOR ANN BASED MODEL

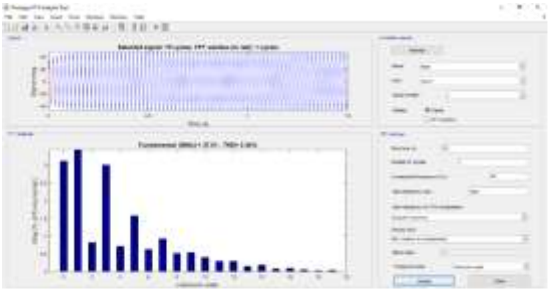

FIGURE 7: THD OF PI BASED MODEL

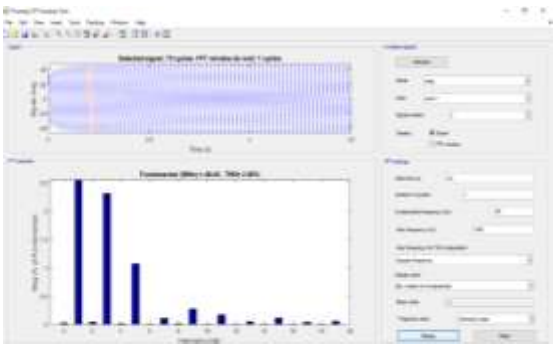

FIGURE 8: THD OF ANN BASED MODEL

The total harmonic distortion (THD) for the proposed model was shown in figure 7 using the PI controller and figure 8 using the ANN controller. The output shows the difference between the percentages of both controllers, in which ANN provides 2.58% while comparing it with 3.84% by PI controller.

IV. CONCLUSION

The micro-level hybrid system is developed using the green energies which were optimal for remotely located areas with a smaller number of populaces. The MPPT was used in the solar side directly and in the wind side indirectly to track the maximal power point. The hybrid micro grid system is modeled a using MATLAB simulation tool with respective with a wind turbine, solar panel and battery unit. The system was analyzed using the traditional PI controller and ANN controller. The reduction of voltage fluctuation, responding time and reduction in harmonics distortion are better with the ANN controller while comparing with the PI controller.

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