Journal of Newviews in Engineering and Technology (JNET)
Volume 4, Issue 3, December 2022
Available online at http://www.rsujnet.org/index.php/publications/2022-edition
e- ISSN: 2795-2215

Voltage Optimization of PV/Wind Hybrid Renewable Energy System using Adaptive Neuro-Fuzzy Logic Technique

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ABSTRACT

This research employs adaptive neuro-fuzzy inference system (ANFIS) technique to optimize the voltage of a PV-Wind hybrid renewable energy generating system with the aid of a Fuzzy Logic Charge controller. The controller increased the system's effectiveness and ensured that power is delivered as efficiently as possible irrespective of weather conditions. The controller is used to track the maximum power point of the PV panels and that of the wind turbine and helps to distribute power among the hybrid system and to manage the charge and discharge current flow for performance optimization. MATLAB/SIMULINK software is used to model a typical hybrid PV-wind turbine system. This software has a number of PV-wind turbines that generate 100 kW output power (KW). The findings demonstrate that the fuzzy logic controller is reliable, effective, and quick to react to oscillations and can monitor the system's peak power point at 0.25 seconds. From the simulation, the output voltages for phases A, B, and C are 874.407, 881.844, and 953.49 volts after optimization; and 794.91, 808.29, and 869.18 volts for phases A, B, and C before optimization. Similarly, significantly greater currents are produced by the optimized system than by the regular system. Phases A, B, and C of the optimized system has average current values of 82.74, 94.93, and 82.74 amperes each, whereas the phases A, B, and C of the conventional system has average current values of 81.93, 82.74, and 81.74 amperes each. System voltage is improved from an average value of 824.13V to 903.249V which shows a voltage gain of 79.12V. After optimization, the system's efficiency increased from 68.99% to 78.32%, a significant 8.33% increase in efficiency.

KEYWORDS: Adaptive Neuro-fuzzy Interface System, Hybrid System, Renewable Sources, Voltage Optimization.

Cite This Paper: Biragbara, P. B., Idoniboyeobu, D. C., Ahiakwo, C. O., Braide, S. L. & Amadi, H. N. (2022). Voltage Optimization of PV/Wind Hybrid Renewable Energy System using Adaptive Neuro-Fuzzy Logic Technique. *Journal of Newviews in Engineering and Technology*. 4(3), 77 – 84.

1. INTRODUCTION

Renewable sources are now accepted as an alternative sources of power supply both at commercial and residential levels in Nigeria and other countries of the world. Some Nigerian states, particularly the Federal Capital Territory (FCT), have adopted renewable energy sources in recent years (Oseni, 2011). To meet demand for electricity, the Federal Government of Nigeria has started implementing the use of renewable energy as a source of power supply in several states (Wang *et al.,* 2014). Insufficient power supply is a problem in Nigeria which is largely due to uncontrolled population growth. Poor infrastructures and their management are other factors that have contributed to the general setback in Nigerian power sector (Zou *et al.*, 2013). This is why alternate sources of power are now being sorted after especially, renewable energy. Renewable energy systems that transform energy into electricity include wind turbines, solar systems, biomass, micro-hydro, etc. (Wang *et al.*, 2015).

Renewable energy sources will solve the problem of power supply in Nigeria. It will reduce the high expense of running generators daily and spare the environment of carbon emissions (Uwho *et al*., 2022). Given the rising cost of fossil fuels and the importance of reducing carbon dioxide emissions into the atmosphere, it is crucial to consider the growing

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interest in renewable energy sources (Paterakis *et al.*, 2016). It becomes essential to diversify energy sources to renewable energy. Oseni (2011) revealed that Nigeria has a reasonable amount of renewable energy resource deposits which if taken advantage of, will improve the energy supply exponentially. Utilizing the necessary technologies for the optimization of renewable energy would be a solution to the inadequate power supply, and the system's overall environmental friendliness would in turn result in lower or reduced energy consumption (Oladeji, 2014).

To achieve the best power flow under a variety of climatic conditions, it is crucial to assess the energy sources and their connections (Riva *et al.*, 2015). The application of optimal power flow has been of great significance to power system operations. Due to environmental factors, the Renewable Energy System required an optimal energy management system. It is important to disperse the load in the power system so that each generation unit can produce a steady supply (Nacer *et al.*, 2015).

One of the crucial areas of research that scholars and scientists should concentrate on is renewable energy systems, as doing so would make it easier to extract energy from these sources and utilise it by converting it into electrical energy. Among other sustainable energy sources, solar and wind power hold a special role (Caballero *et al.*, 2013). This is because wind and sunlight are present everywhere on earth. Therefore, these sources are the subject of more thorough research (Radjaia *et al.*, 2014). In addition to obtaining energy, the goal is to transform it into useful forms, control its presence in the national grid, and eliminate harmonics. Cost reduction and system performance optimization are considered while handling all of these (Mei *et al.*, 2011).

An energy source that can be replenished after usage is considered a renewable source of energy (Ahiakwo, 2011). A general definition of renewable energy would be a sort of energy that is obtained from resources that are replenishable throughout the course of a human lifetime, such as sunshine (solar), tides, wind, rain, geothermal heat, and waves (Meyer, 2014). These are the energy sources that can easily be created, renewed, or quickly refilled by natural processes (Ahiakwo, 2011). Their supply is unaffected by their rate of consumption; hence they cannot run out very soon. Even if human indiscriminate consumption has the potential to deplete most of these renewable resources, they may also be renewed, ensuring a constant supply. Later in this investigation, we'll talk about some of these readily accessible renewable energy sources that are pertinent to the Nigerian environment. Renewable energy supplies energy for certain crucial uses, including power generation, rural (off-grid) energy service, air and transportation, and water heating and cooling.

For thousands of years, people have harnessed wind energy to propel sails, run windmills, or create pressure for water pumps. Since the late 19th century, scientists have been studying how to use the wind to produce power. However, wind power has only recently become the focus of significant research and development due to significant attempts to find other sources of energy in the 20th century. Wind energy produces fluctuating power that varies significantly over shorter time periods but is relatively stable over the course of an entire year. As a result, it is combined with other electric power sources to provide a steady supply. Additionally, weather forecasting enables the preparation of the electricity network for the regular fluctuations in production that take place, (Idoniboyeobu *et al.*, 2017). As of 2015, At least 83 other nations use wind energy to power their electricity grids, and Denmark produces 40% of its electricity from the wind.

The tower maintains the whirling blades at a height where they can effectively capture wind power while supporting the wind turbine's main structure (Caballero *et al.*, 2013). The wind turbine rotor blades are turned counterclockwise by the mechanism they saw. The wind's kinetic energy is captured by the wind turbine's rotor, which has one or more blades. The gearbox

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converts the electrical generator side's greater rotational speeds from the wind turbine's slower rotational rates. When a wind turbine drives an electrical generator and its output is maintained in accordance with its requirements by using the proper management and supervision procedures, the electrical generator will produce energy (Caballero *et al.*, 2013). To safeguard the entire system, protection of equipment is frequently incorporated into the design of control systems.

Systems for generating electricity from the sun either use concentrated collectors or photovoltaic panels. The photovoltaics type is the most used. Ma *et al.* (2015) also highlighted that the concentrator cell's efficiency has increased over the past ten years from 30% to over 40%, with the potential to reach 50% in the years to come. Multi-junction III-V compound cells have efficiencies exceeding 45% (48% in the lab), while Si cells have efficiencies of only 26%. The outputs that PV modules produce are mostly influenced by the amount of incident radiation.

The objectives of the paper were to:
i. model a PV-Wind network using Electrical Transient Analyser Program
ii. optimize the system's output voltage using Adaptive Neuro Fuzzy Inference System (ANFIS)

An energy management technique connected with AC load using Fuzzy Logic Controller was investigated by Altin and Ozdemir (2013). An algorithm was used to increase the power transfer capacity. The pitfall of the method is that Fuzzy controller alone could not produce the needed accurate result. Tang *et al.* (2013) evaluated the performance of a grid connected PV system using PID, Perturb and Observe; and Fuzzy Logic Controller. The drawback of the technique are lack of uncertainty and time complexity. Control strategy for Power management of hybrid power system based on Particle Swamp Optimization (PSO) was adopted by Wang *et al.* (2015) for the optimization of the output power of a hybrid system. It was found that the PSI controller could not harness optimal power under varying weather conditions. The present study employs adaptive neuro-fuzzy inference system (ANFIS) technique to optimize the voltage of a PV-Wind hybrid renewable energy generating system with the aid of a Fuzzy Logic Charge controller which increases the system's effectiveness and ensures that power is delivered as efficiently as possible irrespective of weather conditions. The deployment of Adaptive Neuro-Fuzzy Inference System (ANFIS) with Grey Wolf Optimization (ANFIS-GWO) enhances the performance of the entire Hybrid Renewable Energy System.

2. MATERIALS AND METHODS

2.1 Materials

The materials used in this research are solar PV arrays, wind turbine, wind/solar converter, a storage system (battery), inverter and connectors.

2.2 Solar PV Generator (array)

Suniva ART245-60 modules manufactured by Suniva®Inc. are used in this research. The modules were chosen because it is a high-efficient monocrystalline cell with rated output and a design ideally suited for high power application systems.

2.3 System Block Diagram

The figure below shows the schematic diagram of the hybrid system. Each power source is developed independently and integrated to satisfy the necessary reliability to forecast system performance.

2.4 Methods

The approach applied is to optimize the power flow of a hybrid renewable energy system using adaptive neuro-fuzzy logic. The system uses a hierarchical controller to enhance energy management amongst three energy sources which are: solar array, wind turbines, and battery storage. An FLC Controller is made at the third layer using the adaptive neuro-fuzzy logic inference system (ANIFS) to reach the wind turbine's MPP.

2.6 Thermal PV Model

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Determining a PV module's operating temperature is crucial to accurately forecast its performance. For ease of use, it is conceivable to assume that the solar cells' temperature is constant along the PV module's plane. Consequently, a PV cell or module thermal model is needed. A lumped thermal model for the PV module which expresses the temperature of a PV module as a function of the surrounding environment's temperature, irradiance, output current, and voltage is expressed mathematically as:

$$C_{PV}\frac{dT_C}{dt} = \tau\alpha G - \frac{U\times I}{A} - U_L(T_C - T_a) \qquad (1)$$

Where,
C_{PV} = overall heat capacity per unit area of the PV cell/module,
$\tau\alpha$ =transmittance–absorption product of PV cells,
Ta = overall heat loss coefficient

2.5 The Series Resistance

One crucial factor that influences a solar cell's efficiency is its series resistance (Rs). The temperature coefficient of open-circuit voltage (VOC) which is usually provided by PV manufacturers and can be used to calculate the series resistance is given in Equation (2) as:

$$V_{OC,Ref} = \frac{\gamma k T_C}{q}\left[ln\left(\frac{I_{SC,Ref}}{I_{0,Ref}}\right)\right]. \qquad (2)$$

The proper value of µVOC can be derived analytically as

$$\mu_{VOC} = \frac{\partial V_{OC,Ref}}{\partial T_{C,Ref}} \qquad (3)$$

$$\mu_{VOC} = \frac{\gamma k}{q}\left[ln\left(\frac{I_{SC,Ref}}{I_{O,Ref}}\right) + \frac{T_C\mu_{ISC}}{I_{SC,Ref}} - \left[3 + \frac{q\varepsilon_G}{AkT_{C,Ref}}\right]\right] \qquad (4)$$

$$R_{S,Max} = \frac{1}{I_{MP,Ref}}\left[\frac{kT_{C,Ref}\gamma}{q}ln\left(1 - \frac{I_{MP,Ref}}{I_{SC,Ref}}\right) + V_{OC,Ref} - V_{MP,Ref}\right]. \qquad (5)$$

$$R_{S,Max} = \frac{1}{I_{MP,Ref}}\left[\frac{2V_{MP,Ref} - V_{OC,Ref}}{I_{SC,Ref}/(I_{SC,Ref} - I_{MP,Ref}) + ln\left(1 - \frac{I_{MP,Ref}}{I_{SC,Ref}}\right)}\right]ln\left(1 - \frac{I_{MP,Ref}}{I_{SC,Ref}}\right) + V_{OC,Ref} - V_{MP,Ref}. \qquad (6)$$

The upper and lower limits for RS are contrasted with the analytical estimate of VOC. By introducing fresh assumptions for RS, the limit technique RS is utilized to converge on the right value for VOC.

2.7 Wind Power

This is the rate of change of kinetic energy and is given by Equations (7) and (8).

$$P = \frac{d}{dt}(E) \qquad (7)$$

$$P = \frac{1}{2}\frac{dm}{dt}V_w^2 \qquad (8)$$

The mass flow rate is given by Equation (9)

$$\frac{dm}{dt} = \rho A V_w \qquad (9)$$

The wind power rate is now given as

$$P = \frac{1}{2}C_p\rho A V_w^3 \qquad (10)$$

Where:
m = mass of air
A = area through the wind
V_w = wind speed
ρ = density of air
C_p = coefficient of performance

3. RESULTS AND DISCUSSION

3.1 System Output Current

The system's output current is a strong indicator to check the effectiveness of the optimization. Figure 3.1 below shows the plot of the three-phase current of the hybrid system. It is evident from the result that the adaptive neuro-fuzzy inference system (ANFIS) technique enhanced the output current of the system irrespective of the erratic nature of weather conditions. This is made possible with the help of fuzzy logic controller.

Table 1 shows the output current of the Hybrid System when Adaptive Neuro-fuzzy Inference System has not been applied. The current in phase A, B and C are 81A, 93A and 81A respectively. Table 2 shows at a glance the output current of the hybrid system when Adaptive Neuro-fuzzy Inference System is applied. The current has been optimized as the current for each phase increased significantly when compared with the system without ANFIS from 81-82.74A, 93-94.93A and 81-82.74A. This improvement is made possible with the aid of ANFIS technology.

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3.2 System Output Voltage

The voltage level of any plant is a crucial parameter to determine the viability of such plant. Tables 3 and 4 show the output voltage of the hybrid system with and without the ANFIS. Comparing results of table 3 and 4, it is evident that the output voltages of the various phases of the hybrid system are optimized significantly from 794.91- 874.41V, 808.29 – 881.84V and 869.18 – 953.49V for phases A, B, and C respectively with an average voltage improvement of 79.12V, despite the erratic feature of sun and wind as the sources of fuel.

4. CONCLUSION

Renewable energy sources have come to stay as an alternative source of power supply. It is clean and reliable. An adaptive Neuro-fuzzy Inference System is employed in this research to optimize the output of pv/wind hybrid renewable energy system with the aid of a Fuzzy Logic Charge controller.

It can be deduced from the findings of the research that the objectives of the work are achieved as the output voltage and current of the hybrid system have been optimized for efficient power flow management, as the current for each phase has been increased from 81 to 82.74A, 93 to 94.93A and 81 to 82.74A and ; the voltage from 794.91 to 874.41V, 808.29 to 881.84V and 869.18 to 953.49V for phases A, B, and C respectively with a mean voltage improvement of 79.12V, despite the erratic feature of weather. Adaptive Neuro-Fuzzy Inference System (ANFIS) with Grey Wolf Optimization (ANFIS-GWO) is now seen as an efficient technique to improve the output power of a hybrid system under varying weather conditions.

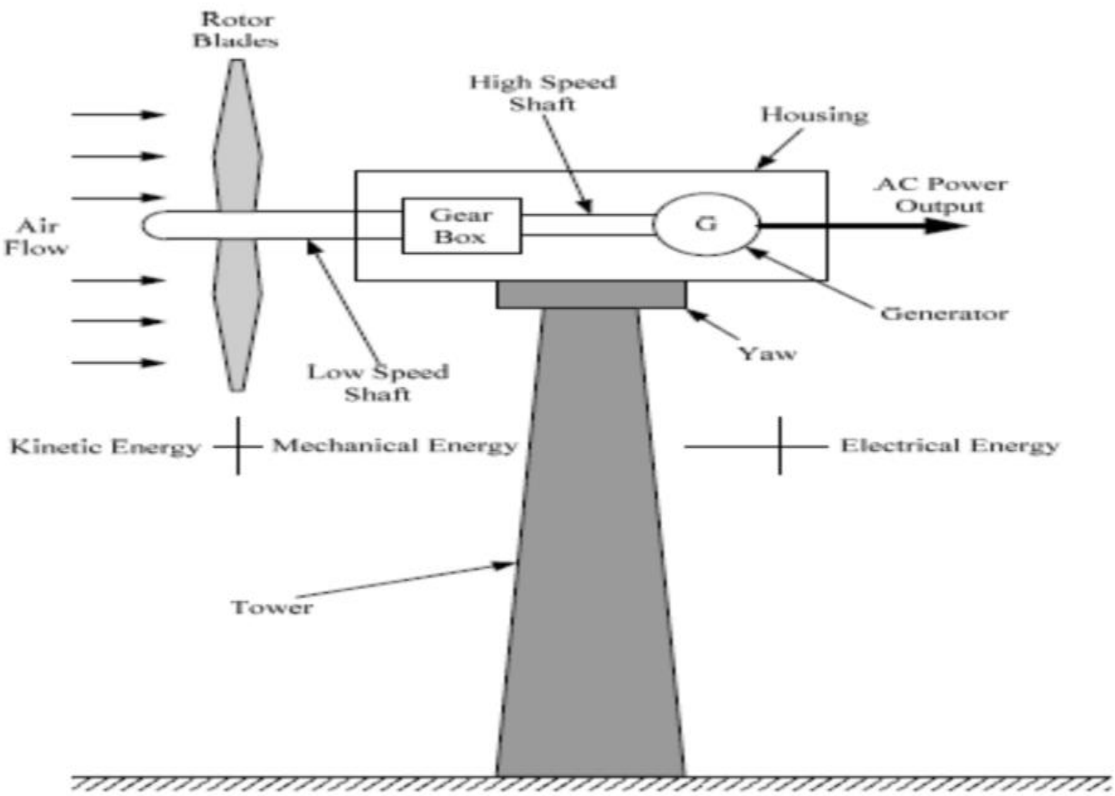

Figure 1: Design Diagram of Wind Plant

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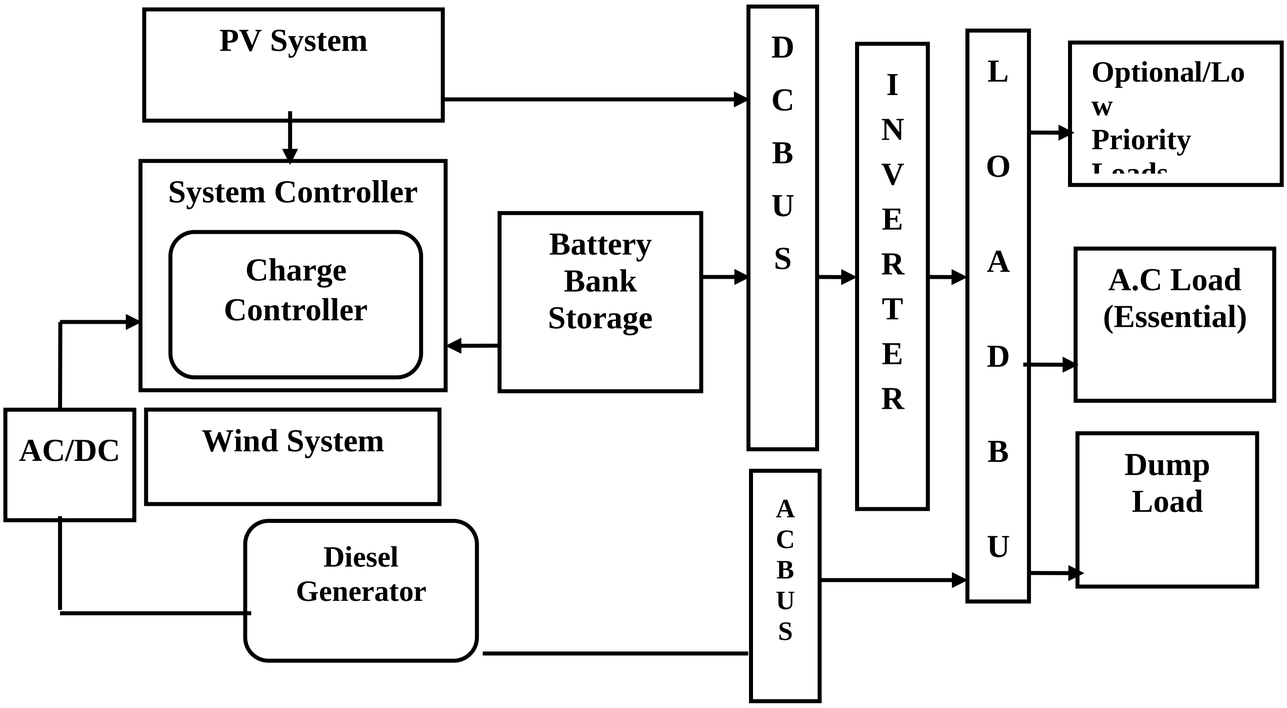

Figure 2: Shows a Block Diagram of Hybrid PV-Wind Renewable Energy System

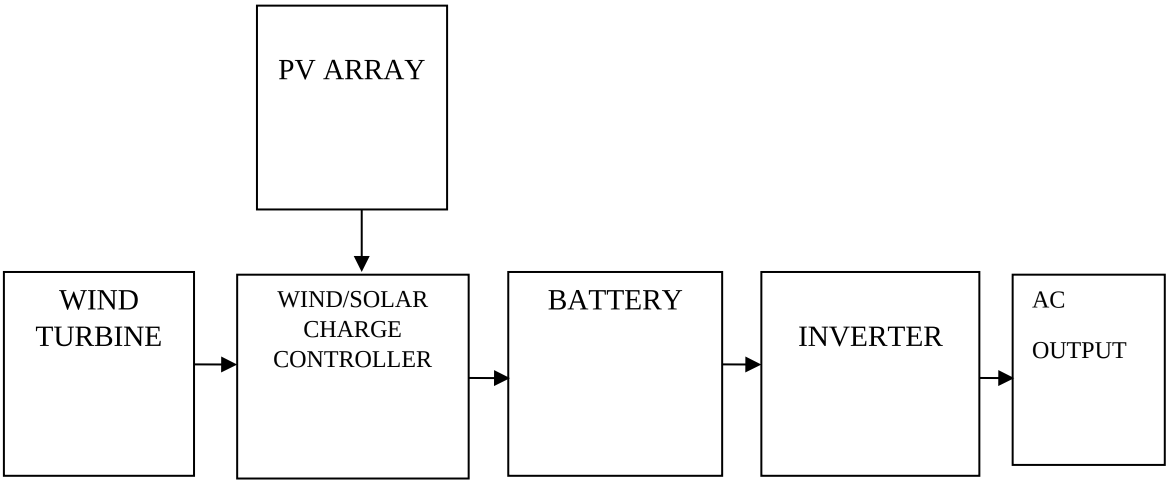

Figure 3: Block Diagram representing the Structure of PV/Wind Hybrid Renewable Energy System

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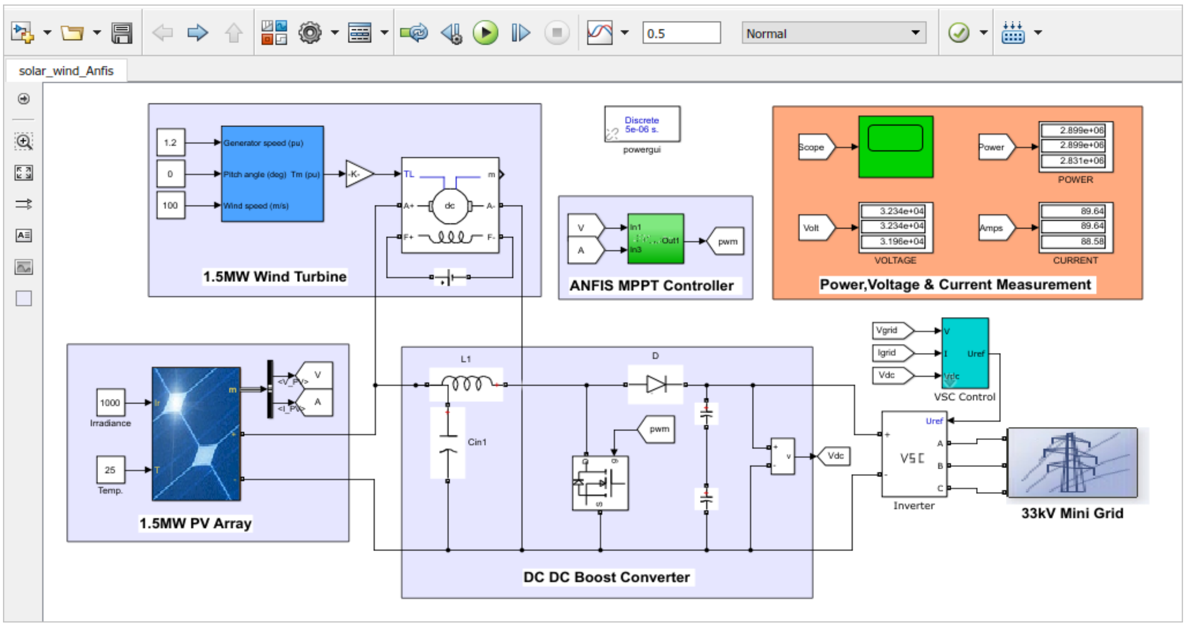

Figure 4: Hybrid/Wind Model showing voltage, current and power measurement.

Table 1: Three-phase Output Current of the Hybrid System Without ANFIS

Phase	Phase A	Phase B	Phase C
Mean Current (Amperes)	81	93	81

Table 2: Three-phase Output Current of the Hybrid System With ANFIS

Phase	Phase A	Phase B	Phase C
Mean Current (Amperes)	82.74	94.93	82.74

Table 3: Three-phase Output Voltage of the Hybrid System Without ANFIS

Phase	Phase A	Phase B	Phase C
Mean Voltage (Volts)	**794.91**	**808.29**	**869.18**

Table 4: Three-phase Output Voltage of the Hybrid System With ANFIS

Phase	Phase A	Phase B	Phase C
Mean Voltage (Volts)	**874.41**	**881.84**	**953.49**

REFERENCES

Ahiakwo, C.O. (2011). Renewable Energy for Rural Electrification to Ameliorate Climate change. *International Journal of Engineering Science and Technology*,2(1), 10-19.

Altin, N. & Ozdemir, S. (2013). Three-phase three-level grid interactive inverter with fuzzy logic based maximum power point tracking controller. *Solar Energy*, 69(2), 17–26.

Awogbemi, O. & Komolafe, A.C. (2011). Potential for Sustainable Renewable Energy Development in Nigeria. *Pacific Journal of Science and Technology*, 12(1), 161-169.

Caballero, F., Sauma, E. & Yanine, F. (2013). Business Optimal Design of a Grid-Connected Hybrid Photovoltaic-wind energy system. *Journal of Energy*, 6(1), 248-261.

Idoniboyeobu, D.C., Orike, S., & Biragbara, B.P. (2017). Optimization of a Grid Connected Photovoltaic System Using Fuzzy Logic Control. *European Journal of Electrical and Computer Engineering*, *1*(2), 1-13.

Ma, T., Yang, H., Lu, L & Peng, J. (2015). Optimal design of an autonomous solar-wind-pumped storage power supply system. *Applied Energy*, 160, 728–736.

Mei, Q., Shan, M.W., Liu, L.Y. & Guerrero, J.M. (2011). A Novel Improved Variable Step-Size Incremental-Resistance Maximum Power Point Tracking. Method for Photovoltaic Systems. *Solar Energy*, 58(4), 2427–2434.

Meyer, N.I. (2014). Renewable energy policy in Denmark, *Energy for Sustainable Development*,8(1),25–35.

Nacer, T., Hamidat, A. & Nadjemi, O. (2015). Techno-Economic Impacts Analysis of a Hybrid Grid Connected Energy System Applied for a Cattle Farm. *Article in Energy procedia*, 964-968. Retrieved on 23 April, 2019 from https://www.researchgate.net/publication/28283107

Oladeji, J.T. (2014). Renewable Energy as a sure Solution to Nigeria's Perennial Energy Problems- an Overview. 6(6), 45-50. Retrieved on 13 July, 2017 from http://www.sciencepub,net/research.

Oseni, M. (2011). An analysis of the power sector performance in Nigeria. *The Journal of Electrical and Computer Engineering*, 9(3) 8-15.

Paterakis, N.G., Erdinc, O., Pappi, I. N., Bakirtzis, A.G. & Catalao, J. P. (2016). Coordinated Operation of a Neighborhood of Smart Households Comprising Electric Vehicles, Energy Storage and Distributed Generation. *IEEE Transactions on Smart Grid*, *7*(6), 2736–2747.

Radjaia, T., Rahmania, L., Mekhilefb, S. & Gaubertc, J. P. (2014). Implementation of a Modified Incremental Conductance Maximum Power Point Tracking Algorithm with direct control based on a fuzzy duty cycle change estimator using Dpace. *Solar Energy*, 110(7), 325–337.

Riva Sanseverino, E., Nguyen, N., Quang, M. L. Silvestre, J. Guerrero, M., & Li, C. (2015). Optimal power flow in three-phase islanded microgrids with inverter interfaced units. *Electric Power Systems Research*, 123, 48–56.

Tang, X., Tsang, K. & Chan, W. (2013). Power Conditioning System for Grid-Connected Photovoltaic System. Solar Energy, 9(7), 187-193.

Uwho, K. O., Idoniboyeobu, D. C. & Amadi, H. N. (2022). Design and Simulation 500kW Grid Connected PV System for Faculty of Engineering, Rivers State University Using PVsyst Software, *Iconic Research and Engineering Journal*,5(8), 221-229.

Wang, G., Ciobotaru, M. & Agelidis, V.G. (2015). Optimal capacity design for hybrid energy storage system supporting dispatch of large-scale photovoltaic power plant," *Journal of Energy Storage*, 3, 25–35.

Wang, C., Liu, Y., Zhang, X. & Yang, X. (2014). Simulation Design and Benefit Analysis of Grid-Connected Photovoltaic System. *Journal of Energy*, 6(4), 169-172.

Zou, X., Bian, L. & Zhai, Y. (2013). Design of Online Monitoring System for Grid-Connected Photovoltaic Power Plants. *Nigerian Journal of Solar Energy*, 3(6), 431-434.