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Enhancement of PV-Wind Plant Output Power via the Adaptive Neuro-Fuzzy Inference System

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***ABSTRACT**: This study looks at improvement of the output power of a Hybrid PV/Wind plant using the Adaptive Neuro-Fuzzy Inference System (ANFIS). MATLAB/SIMULINK is used in the simulation. The hybrid PV-wind turbine system used has a number of PV-wind turbines and a rated output of 100kW. The duration of Maximum Power Point Tracking (MPPT) under various environmental circumstances is simulated in the study. The findings demonstrates that the FLC is reliable, effective, and quick to react to oscillations. It is able to monitor the system's peak power point at 0.25 seconds. The optimized system's average power for phases A, B, and C are 72.35, 83.71 and 78.89MW while the output of the un-optimized system is 64.3882, 75.1710 and 70.4037MW respectively. Similarly, significantly greater currents are produced by the optimized system than by the un-optimized 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 un-optimized system gives average current values of 81, 93, and 81 amperes each. System improvements resulted in a power gain of 11.9%, from 69.9877 KW to 78.3179 MW. After optimization, the system's efficiency increased from 68.99% to 78.32%, a significant 8.33% increase in efficiency.*

***Keywords**: Improvement, Power, Adaptive Neuro-fuzzy Inference System, Hybrid, Plant.*

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I. INTRODUCTION

The demand to improve electricity generation and its efficiency is brought on by the growth of industries and the population [1]. Fossil fuels currently make up the majority of the primary energy sources used in the world. The enormous amount of electricity that may be generated at a single site using fossil fuels is one of their benefits. However, because fossil fuels are finite and will eventually run out, dependency on them has raised concerns about energy security. A non-renewable energy source that will eventually run out is fossil fuel. The main problem is the effects on the surrounding, called the greenhouse effect [2]. It becomes exigent for power system researchers to embark on research aimed at continuous improvement of renewable energy sources to enhance their efficiency. Renewable energy is more affordable, sustainable, and has very little to no environmental impact. Availability of Power has always been a big determinant and key indicator of a nation's development because it is essential in almost every part of the nation's development [3]. Renewable energies are alternate ways of producing energy that is cost-effective. Renewable energy sources are seen everywhere [5]. Nigeria, as a nation is experiencing a lot of setbacks in its effort for economic development due to irregular power supply [6]. Renewable energy has become a desirable energy source due to the rising energy demand, as well as other factors including rising energy prices, diminishing energy reserves, and environmental degradation [7]. These resources have an endless supply and do not harm the environment. They have recently undergone significant research.

1.1 Statement of the Problem

Reliable and affordable power supply has a problem in many developing countries such as Nigeria. An effective way of tapping and utilizing the output power of a renewable energy sources such as hybrid PV/Wind plant hitherto has been a source of concern to researchers due to changing nature of the output power. An intelligent energy management system that automatically modifies the power system control setting and addresses the Load Flow issue at the same time will be created using the ANFIS.

1.2 Aim of the Study

This research is aimed at improving the output power of a Hybrid PV/Wind plant whose output varies with time as a result of whether conditions thereby affecting the power flow of the system.

1.3 Objectives of the Study

The objectives are :

I. To model a PV/Wind plant using Matlab/Simulink
II. To install an adaptive neuro-fuzzy inference system in the network for power improvement
III. To simulate the system using Matlab/Simulink software.

II. LITERATURE REVIEW

2.1 Hydroelectricity

The phrase "hydroelectricity" is one that we should all be familiar with. It is alternative energy, commonly associated with the words "dam" and "waterfalls," which is produced by the kinetic energy present in moving water. Once more, the system comprises of a turbine whose rotation will produce electricity. When water falls from a great height, it quickly spins the turbine to generate power. The technique has been effective enough to justify the building of small-scale energy plants in remote locations and settlements [8]. Smaller areas may now be continuously and cleanly supplied with electricity thanks to these alternative energy sources. According to estimates, water energy could eventually help offset the shortfall and rising pollution. Hydroelectricity is a competitive source of renewable energy because of its affordable cost. In contrast to coal or gas plants, the hydro station uses no water. A hydroelectric facility with a capacity greater than 10 megawatts will typically cost 3 to 5 cents per kilowatt-hour to produce power [9].

2.2 Biomass

Biomass is among the means of energy is used by many [10]. Biomass is grouped into three namely solid biofuels, liquid biofuels and biogas [11].

2.2.1 Biofuels

There are several sources of alternative energy that come from plants. These are referred to as biogas and biofuels. Ethanol, a component of biofuels, is produced through the fermentation of sugar. It is added to petroleum as a fuel additive because it burns cleaner and emits less greenhouse emissions. On the other hand, biogas develops naturally when organic waste such as biomass breaks down without oxygen [1]. When burned, the resulting mixture of gases produces clean energy. It serves as the foundation for compressed natural gas, which is widely used in the transportation industry. Biofuels are made from living things or metabolic waste (organic or food waste products). A fuel must include more than 80% renewable resources in order to be categorized as a biofuel. It is frequently referred to as a solar energy source because it was originally obtained through the photosynthesis process.

2.3 Ocean Energy

Given that water covers around 70% of the earth's surface, ocean energy has enormous potential. This is the reason why the energy generated by this type of energy is far more versatile than energy from other sources. Tidal energy, wave energy, and ocean thermal energy conversion (OTEC) are three methods for utilizing ocean energy. The kinetic energy of the tides is converted to electrical energy by tidal energy generators using the rise and fall of the tides [2]. Oceans are the largest solar collectors in the world because they make up more than 70% of the Earth's surface. Thermal energy is produced as a result of the sun's heat warming surface water much more than deep ocean water.

2.4 Nuclear Energy

Any harm to a person, including death, illness, or disease; harm to the environment, including loss of property; and nuclear damage are all considered to fall under this category; or damage resulting from handling radioactive materials, a nuclear installation, a nuclear vessel, or exposure to ionizing radiation.

2.5 Artificial Intelligence

The area of computer science known as artificial intelligence (AI) investigates and creates intelligent hardware and software. The definition of artificial intelligence (AI) is "the capacity to hold two separate thoughts simultaneously while retaining the capacity to operate." However, AI must have experience-based learning, rational decision-making, strong inference, and speedy response. Time is not independent from AI definition. It provides an assessment of any system while considering time.

AI has four components :

I. Expert System
II. Heuristic problem solving
III. Natural language processing
IV. Vision

Neuro-Fuzzy-Based Model Grid-Connected Predictive Energy Management Microgrids shows rising levels of technology use and population growth, resulting to increase in the need for electrical energy. Growing power production from fossil fuels has detrimental effects on the environment [1]. As a result, interest in renewable resources has increased as a result of their environmental friendliness and potential for long-term cost savings. The intermittent nature of renewable energy sources, however, is a significant drawback. In order to gain their benefits and lessen their negative effects, it is crucial to integrate them with the rest of the grid. This article suggests an energy management algorithm for a grid-connected microgrid with loads, a PV system, and a battery to make the most effective use of energy. Utilizing estimates of PV output and consumption derived from measurements of the same area's temperature and daylight solar irradiation, an energy management strategy influenced by model predictive control is devised. A rule-based control technique is contrasted with the suggested system. The proposed control algorithm assures that the microgrid is supplied with dependable energy while maximizing the usage of renewable energy, according to results.

III. MATERIALS AND METHOD

3.1 Materials

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

3.2 Method

The method used is modelling of a PV/Wind plant using Matlab/Simulink aided by adaptive neuro-fuzzy logic inference system. The system is then simulated to check for effectiveness in the power flow. An FLC Controller is made at the third layer using the adaptive neuro-fuzzy logic inference system (ANIFS) in order to reach the wind turbine's MPP.

Table 3.1: Wind Turbine Parameters

Parameters	Value
Rated power	1.6
Rated Voltage	69
Rated Frequency	50
Number of poles	4
Rotor diameter d(m)	100
Stator resistance Rs(pU)	0.00706
Rotor resistance, Rr(pU)	0.005
Stator leakage inductance Xs (pU)	0.171
Rotor leakage, Xr (pU)	0.310
Magnetizing inductance, Xm (pU)	2.0
Gear ratio	1.91

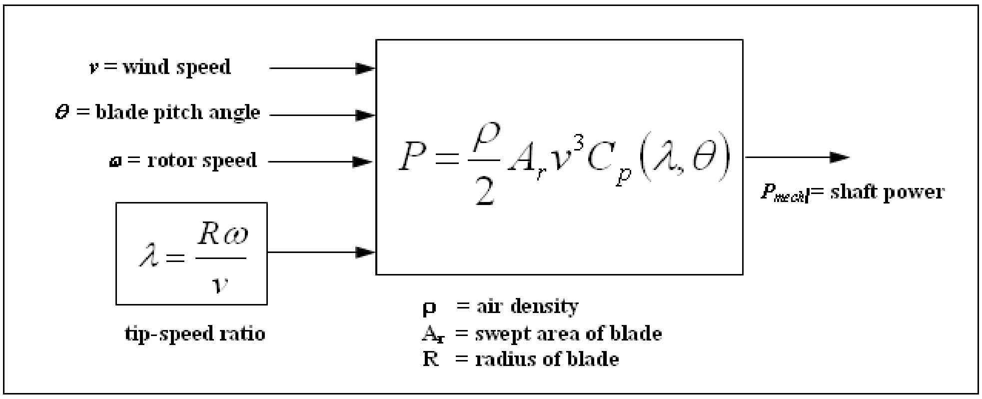

Figure: 3.1 Block Diagram of Wind Turbine Modsyste

Table 3.2 Parameter Settings of the Algorithm

Algorithm	Parameter values
GWO	a=[2,0]
GA	Pc=0.8,y=0.2,pm=0.3 $\beta = 8$
PSO	$w=1, w_{Damp}=0.99, c_1=1, c_2=2$
GOA	$C_{max}=1$ $c_{min}=0.0004$
SCA	a=2
WOA	a=[0,2],b=1,l=[-1,1]
Flower	Proximity probability=0.8
ANFIS	Error goal=0 ,initial step size =0.01

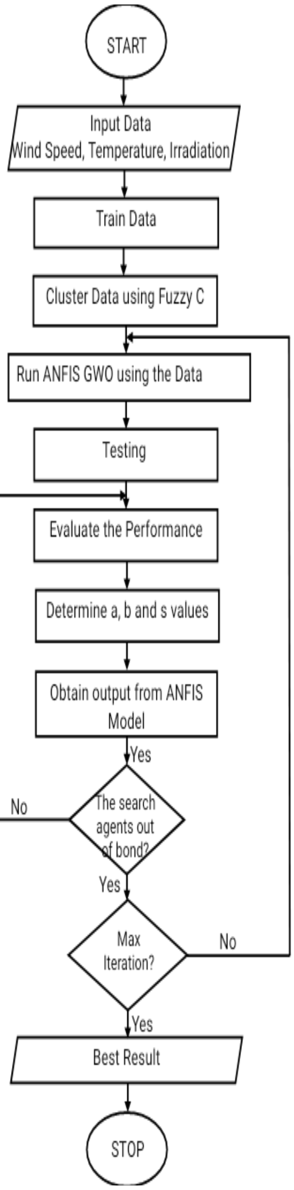

Figure 3.2 : Flow Chart for the ANFIS-GWO Algorithm

3.3 Maximum Power Point of Wind Turbine can be determined by

$K.E = \frac{1}{2}mV_N^2$ (3.38)

$P_{out}\, m = \rho_A V_m$ (3.39)

$K.E = \frac{1}{2}(\rho AV)V^2$ (3.40)

$K.E = \frac{1}{2}(\rho AV^3)$ (3.41)

$P_{out} = \frac{1}{2}mV_1^2 - \frac{1}{2}mV_N^2$ (3.42)

$= \frac{1}{2}m(V_1^2)$ -V_2^2 (3.43)

But $V = \frac{V_1+V_2}{2}$ (3.44)

Also; $m = VA\rho$ (3.45)

$= \left(\frac{V_1+V_2}{2}\right)A\rho$ (3.46)

$P_{out} = \frac{1}{2}\left(\frac{V_1+V_2}{2}\right)A\rho$ (3.47)

$P_{out} = \frac{1}{4}aP(V_1+V_2)(V_1^2+V_2^2)$ (3.48)

$$\frac{1}{4}aP(V_1^3 - V_1V_2^2 + V_2V_1^2 - V_2^3) \quad (3.49)$$

$$P_{out} = \frac{1}{4}APV_1^3\left[1 - \frac{V_1V_2^2}{V_1^3} + \frac{V_2V_1^2}{V_1^3} - \frac{V_2^3}{V_1^3}\right] \quad (3.50)$$

$$\frac{1}{4}APV_1^3\left(1 - \left(\frac{V_2}{V_1}\right)^2 + \left(\frac{V_2}{V_1}\right) - \left(\frac{V_2}{1}\right)\right) \quad (3.51)$$

$$P_{out} = \frac{P_w}{2}(1 - x - x^1 - x^3) \quad (3.52)$$

$$\frac{df(x)}{2dx} = 0 \Rightarrow \quad (3.53)$$

$$\frac{dP_{out}}{dx} = 0 \Rightarrow \frac{P_w}{2}(1 - 2x - 3x^2) = 0 \quad (3.54)$$

$$(1 - 2x - 3x^2) = 0 \quad (3.55)$$

$$3x^2 - 2x - 1 = 0 \quad (3.56)$$

$$x = -\frac{1}{3} \quad (3.57)$$

$$P_{out} = \frac{P_w}{2}\left(1 + \frac{1}{3} - \left(\frac{1}{3}\right)^2 - \left(\frac{1}{3}\right)^3\right) \quad (3.58)$$

$$= \frac{16}{27}P_w = 0.593P_w \quad (3.59)$$

Normal system $0.4 \approx 0.5$**Root System**

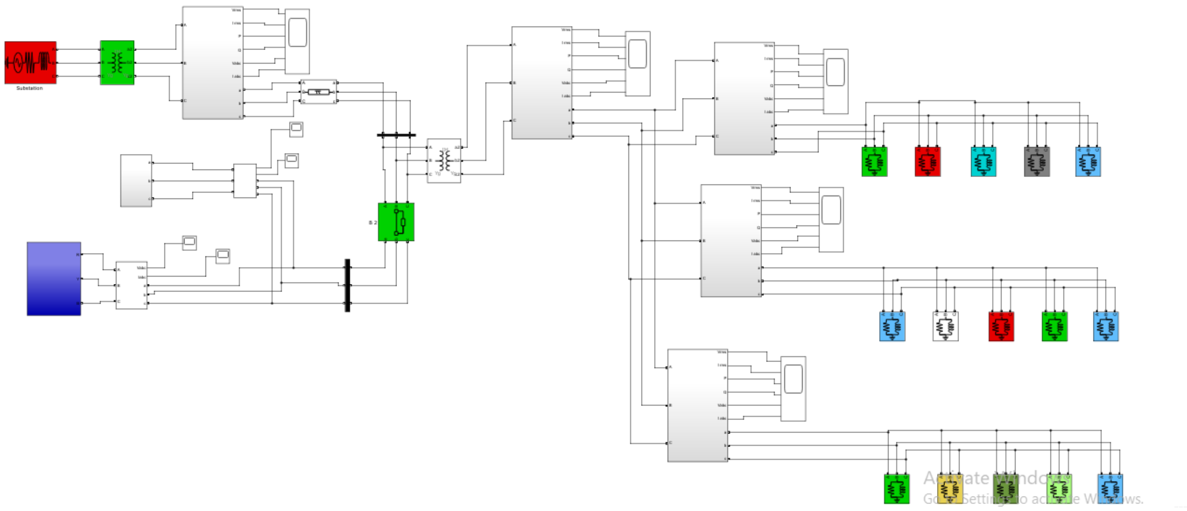

Figure 3.3 : ANFIS optimized PV-Wind Hybrid Simulation Model

IV. RESULTS AND DISCUSSION

4.1: System Output Power

The system's output power is a veritable tool to check for the performance of the optimization. Figure 4.1 below shows the plot of the three-phase power of the hybrid system.

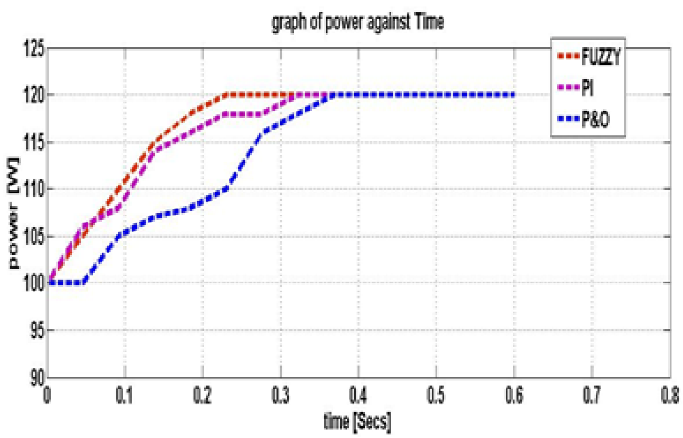

Figure 4.1: Graph of Power against Time for Various Controllers

Figure 4.1: shows the time taken to arrive at maximum power for various controllers under varying irradiance it shows that the fastest is that of the Fuzzy Logic Controller (FLC) which takes 0.25 seconds and showed high stability when the maximum power is attained. This shows that the maximum power point using fuzzy logic performs better than other controllers such as the perturb and observe method and using normal controllers such as the proportional-integral controllers.

Table 4.1: Output Power of the Hybrid PV-Wind System without ANFIS

	Phase A	Phase B	Phase C
Mean Power (MW)	64.3882	75.1710	70.4037

Table 4.2: Output Power the Hybrid PV-Wind System with ANFIS

	Phase A	Phase B	Phase C
Mean Power (MW)	72.35	83.71	78.89

From tables 4.1 and 4.2, it is obvious that the output power of the system has improved tremendously from a mean value of 69.99MW to 78.32MW. This is made possible with the installation of fuzzy logic controller (FLC).

4.2 System Output Current

This is another important factor that determines the viability of the system. Figure 4.2 below shows the graph of the output current of the system with ANFIS.

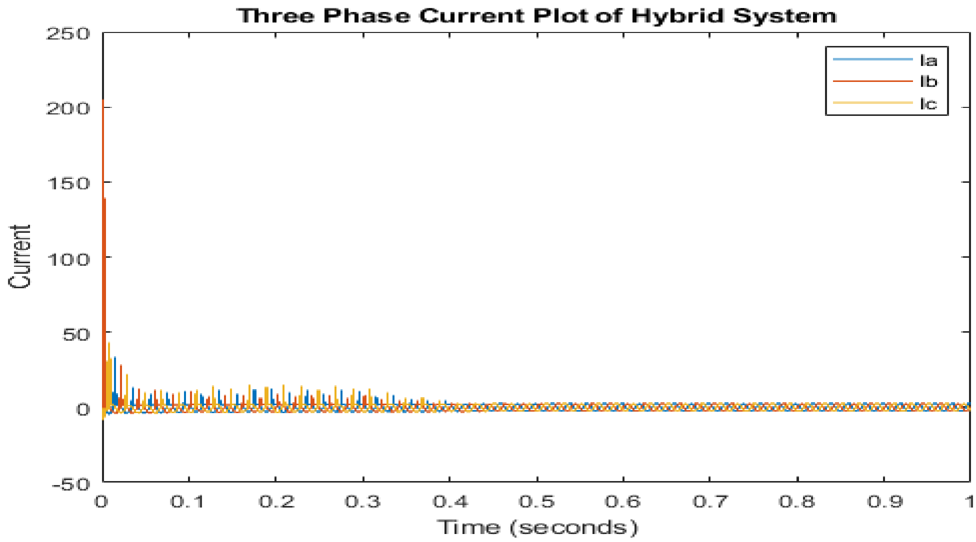

Figure 4.2: Plot of Output currents of the Hybrid PV-Wind System

Table 4.3 : Three-phase Output Current of the Hybrid System Without ANFIS

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

Table 4.4 : Three-phase Output Current of the Hybrid System With ANFIS

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

Looking at tables 4.3and 4.4, it shows at a glance that the output current of the hybrid system has been optimized as the current for each phase increased significantly from 81-82.74A, 93-94.93A and 81-82.74A. This improvement is made possible with the aid of ANFIS technology.

V. CONCLUSION

Renewable energy sources especially PV/Wind plant is now a means of power generation. It is clean and reliable because it is inexhaustible.From this research, the output power of the hybrid system has been improved for efficient power flow management. The power for each phase increased drastically from 64.39MW – 72.35MW, 75.17MW – 83.71MW and from 70.40MW – 78.89MW while the current increased significantly from 81-82.74A, 93-94.93A and 81-82.74A for phases A, B, and C respectively with a mean power improvement of 78.25MW despite the varying feature of the environmental condition.

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