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Energy Management For Renewable Hybrid System Based On Artificial Neural Networks (ANN)

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Abstract: It has become necessary in recent years to use renewable energy sources, such as wind and solar energy, to meet the load demand. Because of their endless existence and environmentally friendly nature, they are useful for power generation. The management of energy in hybrid wind-solar power sources is the topic of this article. Using a common current source interface multiple-input DC-DC converter, the photovoltaic (PV) array, wind turbine, and battery storage are all connected. The power control between intermittent renewable energy generation, energy storage, and the grid is maintained by the artificial neural network (ANN) controller. For wind turbines to produce the most electricity, variable speed control can be used. For solar systems, the Maximum Power Point Tracking (MPPT) algorithm is used. By keeping the common DC voltage constant, the grid interface inverter sends the energy drawn from the PV array and wind turbine into the grid. Using MATLAB Simulink, the complete control strategy is subjected to a simulation study. The results of the simulation show the photovoltaic/wind hybrid system's dynamic behavior and control effectiveness.
Keywords: Renewable Energy, Solar energy, Photovoltaic array, Wind Energy, Hybrid system, Energy management, Artificial Neural Networks (ANN) Controller

I. INTRODUCTION

The energy that is obtained from resources that are found in nature, such as sunshine, wind, tides, waves, etc., is known as renewable energy. A hybrid generation system is used to provide enough electricity to fulfill the rising load demand. In a hybrid system, various renewable energy sources are integrated. The proposed system is a hybrid one that combines solar and wind power. Opportunities for using wind and solar resources for the creation of electric power have been made possible by advanced wind turbines and photovoltaic generating technology. They exhibit erratic, unpredictable conduct. Using both wind and solar energy effectively, the wind and solar integrated power supply system provides a fair source of energy.

Multiple control techniques are employed in a hybrid energy system for efficient and smooth power transfer. The type of converter used in the system, which is connected between the energy supply and the loads, determines the microgrid configuration. In order to regulate the energy among various resources, a control algorithm is needed [1]. It is applied in a setting with real-time control. The stand-alone hybrid system is employed to provide power to remote places connected to a flimsy grid. Depending on the weather, a hybrid energy-generating system is employed to satisfy the power requirement. The battery, which consists of lead-acid batteries linked in a series or parallel array, is used to store energy. The overuse of power compromises system dependability by causing an overvoltage on the DC bus. The adaptive control approach is utilized to mitigate reliability and over-voltage problems during excessive generating [2]. By keeping an eye on the battery's level of charge and the dc bus voltage, it is archived (SOC).

The processing and communication requirements are reduced by the energy management system-based multi-agent system (MAS). Middle-level and upper-level agents are its two agents [3]. The system is simple to maintain and regulate. The extraction of the load current and switching of the utility grid-side converter (UGC) is accomplished using an adaptive control technique based on least mean mixed norms (LMMN) [7]. It is used to lower the harmonic content of grid currents, enhancing the system's power quality.

In the hybrid system, various controller types are employed. PID controllers are the ones that are most frequently utilized. In fractional-order power generation and energy storage systems, frequency deviation is controlled using a fractional-order proportional-integral-derivative (FOPID) controller [4]. The output response oscillations are decreased, and the transient response is improved using a PID controller. The frequency deviation's settling time is shortened using a PID controller [11]. By using the wind turbine to drive the permanent magnet synchronous generator (PMSG), a gearbox setup that needs routine maintenance is avoided.

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A hysteresis controller is part of the hybrid wind-driven PMSG-PV system. It has excellent efficiency and a high-power factor. In order to get the most power out of both sources, PV and PSMG work together to create the current command [9].

Both the PV system and the wind energy conversion system employ artificial neural networks. It helps renewable energy sources perform as well as possible. The input layer, the hidden layer, and the output layer are all parts of an ANN's architecture [12]. The MPPT controller uses an RBFN-based Radial Basis Function Network (RBFN) to track maximum power from both solar and wind energy systems [5]. The two MPPT algorithms are combined to create a single RFBN-based MPPT controller that has been updated. As a result, the system became less complicated. Other neuro-fuzzy models can't match the speed of the adaptive neuro-fuzzy inference system (ANFIS). The three-phase inverter is subject to ANFIS-based regulation in order to manage the output power sent to the grid. It features two controllers: an active power controller and a reactive power controller [6].

Due to the resistance of time and place, it is exceedingly challenging to utilize solar and wind energy in all weather conditions alone through a solar system or a wind system. In order to address this need, a system based on renewable resources is also required, and wind/solar hybrid systems with battery storage can do so. This paper's main goal is to integrate hybrid solar and wind renewable sources to meet load power demand. The Luo Converter is used to increase efficiency and obtain significant voltage gains [8]. Low voltage ripple is provided by a Luo converter combined with great power density. The system's power is managed via an Artificial Neural Network. It is steady and dependable. By utilizing ANN, this system has low power and cost dissipation [10].

This paper is organized as follows. Section II introduces the proposed system Architecture and Modeling of Proposed architecture. In section III the artificial neural networks described. In section IV simulation and results Analysis of Proposed system. Finally, the summary of the proposed system is concluded in section V.

II. PROPOSED SYSTEM ARCHITECTURE

Photovoltaic (PV) arrays, wind turbines, multiple input DC/DC converters, and PWM inverters make up the proposed Artificial Neural Network-based energy management for the hybrid renewable system. Fig. 1 depicts the block diagram of the proposed ANN-controlled PV/wind hybrid generating system. Electricity is produced from solar energy by photovoltaic cells. Higher voltages, currents, and power levels are produced by connecting photovoltaic cells in series or parallel. Direct current is the current generated by the PV system (DC). When solar panels are utilized to generate power, there are no emissions that result in the greenhouse effect. Solar-generated electricity is crucial for the transition to the generation of clean energy. To track the maximum power generated by the PV system, MPPT technology is employed.

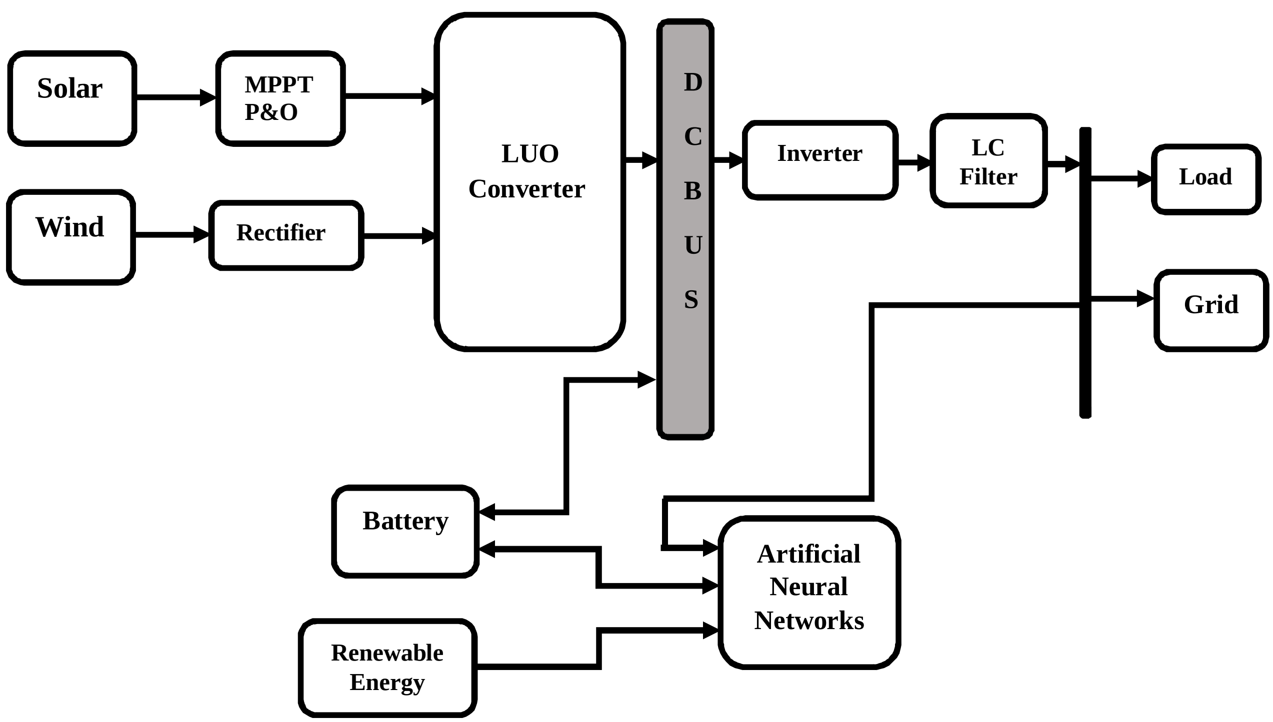

Fig. 1 Energy Management based on Artificial Neural Network (ANN)

The wind is utilized to produce current through the wind turbine generator (WTG). The kinetic energy is transformed into mechanical energy using a wind turbine. Electrical energy is created by a generator using mechanical energy. Wind turbines use alternating currents as their source of current. Wind turbine output is sent to a rectifier, which converts AC to DC.

The multi-input DC-DC converter is supplied with energy from the wind and solar panels as input. As a DC-DC converter, the Luo converter is employed here. On the output side, it is used to step up the voltage. To increase the system's efficiency and achieve high voltage gain, a Luo converter is employed. A pulse-width modulation (PWM) inverter is used to convert the DC output of the Luo converter to AC. The inverter's PWM approach produces a constant output voltage regardless of the load. Without any dissipation, it regulates the amount of power given to the load.

A. PV System Modelling

Fig. 2 depicts the PV cell's comparable circuit. A current source with a diode connected in parallel to it models a perfect solar cell. Nevertheless, no solar cell is perfect, so the model has series and shunt resistance incorporated, as seen in the picture. Rs is the very low value of the series resistance. The comparable shunt resistance, or Rp, has a very high value.

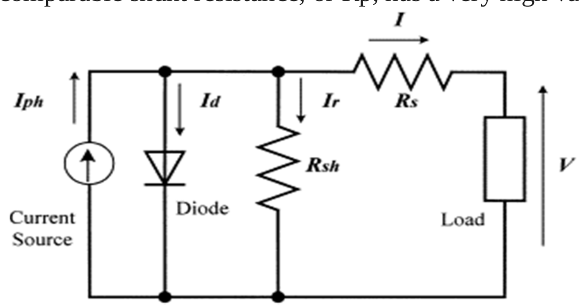

Fig. 2 Equivalent circuit of PV cell

Applying Kirchhoff's current law to the junction where I_{ph}, diode, R_{sh}, $and\ R_s$

$$I_{ph} = I_d + I_r + I \quad \text{......... (1)}$$

We get the following equation for the PV cell current

$$I = I_{ph} - (I_d + I_r) \quad \text{......... (2)}$$

Where,

I_{ph} is insolation current,

I is the cell current,

I_0 is the reverse saturation current,

V is the cell voltage,

R_s is the series resistance,

R_{sh} is the parallel resistance and

V_T is the thermal voltage.

B. MPPT

The MPPT algorithm is based on the computation of the PV power and the power change by sampling both the PV current and voltage in the Perturb and Observe (P&O) approach. The tracker works by regularly increasing or decreasing the voltage of the solar array. While using instantaneous PV array voltage and current, the technique functions as long as sampling takes place just once during each switching cycle.

Up until the MPP is reached, the procedure is periodically repeated. After that, the system oscillates about the MPP. By decreasing the perturbation step size, the oscillation can be decreased. The MPPT, however, is slower with a smaller perturbation size. The flowchart for the traditional P&O technique is shown in Fig. 3.

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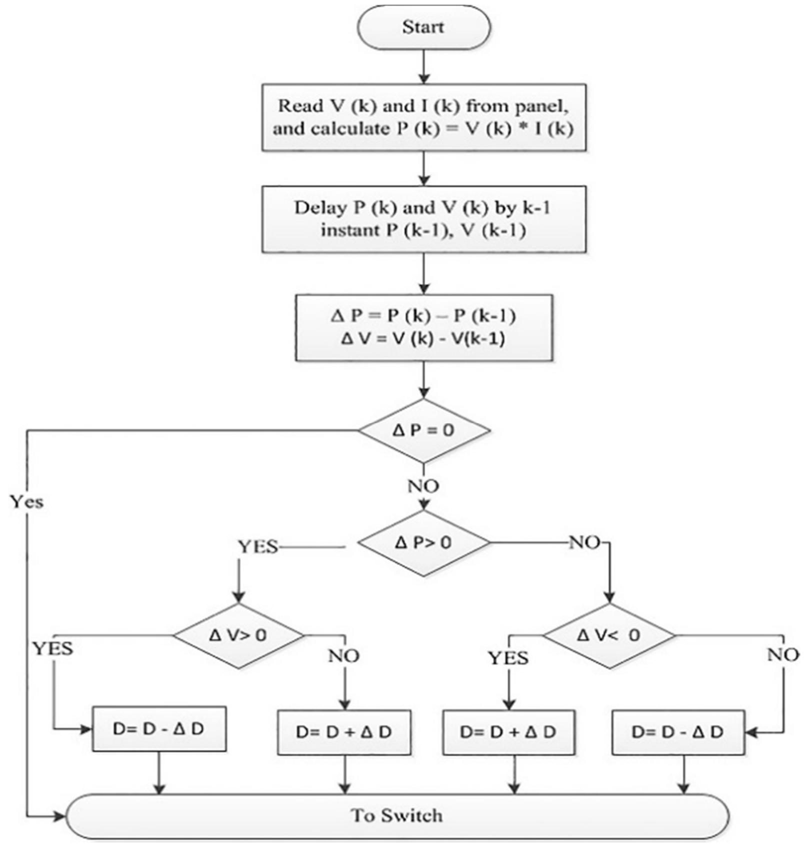

Fig.3 Flow chart of P&O Technique

C. Wind Modelling

To translate the wind's energy into mechanical torque, wind turbines are used. From the mechanical power at the turbine that is obtained from the wind power, the mechanical torque of the turbine may be determined. The steady-state power characteristics of the turbine provide the foundation for the wind turbine model. The following equation provides the turbine's output power.

$$P_m = \frac{1}{2} C_p(\lambda, \beta)\rho A V^3 \qquad \text{..........(3)}$$

Where,

Pm is the Mechanical output power of the turbine(W)

Cp is the performance coefficient of the turbine

ρ is Air density(kg/m3)

A is Turbine swept area(m2)

V is the wind speed(m/sec)

λ is tip speed ratio of the rotor blade tip speed of the wind speed

β is Blade pitch angle (deg)

The pitch angle, β, refers to the angle in which the turbine blades are aligned with respect to its longitudinal axis.

$$\lambda = R \;\omega b \;/V \text{ w} \qquad \text{......... (4)}$$

Where,

R is the turbine radius

ωb is the angular rotational speed.

The wind turbine, which gathers wind from the atmosphere and transforms it into mechanical energy, is the main component of the wind energy conversion system. This mechanical energy is used as input by the generator. This mechanical energy is transformed into electrical energy via the generator. The three-phase complete converter converts the three-phase AC produced by the generator into DC. After the DC bus, the inverter receives the DC.

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D. LUO Converter

Fig.4 depicts the schematic circuit for the Luo converter. S is the power switch, and D is the freewheeling diode in the circuit. This LUO Converter is a multiple-input DC-DC step-up converter.

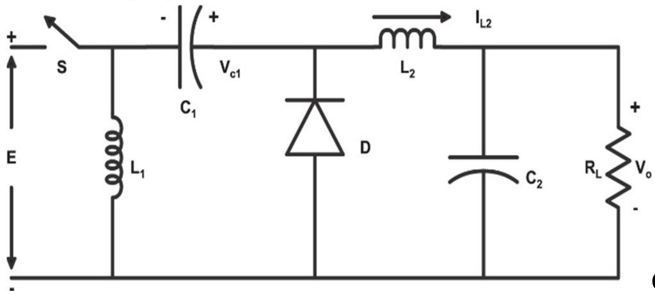

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Fig. 4 circuit diagram of LUO Converter

Inductors L1 and L2 and capacitors C1 and C2 are the passive energy storage components, and R is the load resistance. The circuit can be split into two modes in order to analyze how the Luo converter works.

1) *Modes of Operations*

a) *Mode 1:* When the switch is ON, the supply voltage E charges the inductor L1. Both the capacitor C1 and the inductor L2 simultaneously absorb energy from the source. The capacitor C2 supplies power to the load.

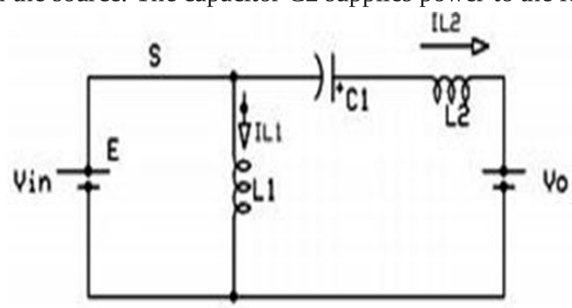

Fig. 5 When Switch is ON

The Inductor L1's voltage is,

$$V_{L1} = V_{in} \qquad \text{......... (5)}$$

The Inductor L2's voltage is,

$$V_{L2} = V_{C1} + V_{L1} - V_0 \qquad \text{......... (6)}$$

b) *Mode 2:* The current taken from the source is zero in this mode since the switch is in the Off position, as indicated in (b). The freewheeling diode receives current iL1 in order to charge the capacitor C1. In order to maintain continuous operation, current iL2 passes via the C2-R circuit and the freewheeling diode D.

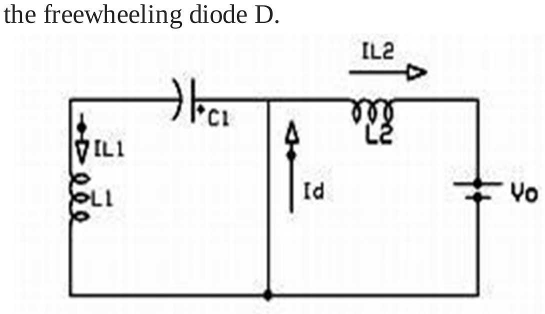

Fig. 6 When Switch is OFF

The Inductor L1's voltage is,

$$V_{L1} = V_{C1} \qquad \text{......... (7)}$$

The Inductor L2's voltage is,

$$V_{L2} = V_0 \quad \text{......... (8)}$$

This is the output voltage of the Luo converter:

$$V_0 = \frac{\alpha}{1-\alpha} V_{in} \quad \text{........ (9)}$$

Where α is the duty cycle.

E. Sinusoidal Pulse Width Modulation (SPWM)

The SPWM method for single-phase PWM inverters is shown in Fig. 7. The reference waveform and the carrier waveform are the two types of waveforms used in the SPWM method. The carrier waveform is a triangle waveform with a high frequency, while the reference waveform is a sinusoidal waveform with a fundamental frequency [13]. The switching frequency of the inverter is determined by the frequency of the carrier waveform. The switching frequency rises along with the carrier wave frequency as it gets stronger. The inverter output frequency is set by the frequency of the reference waveform. The carrier waveform and the reference waveform are compared to create the output frequency. The modulation index can be used to control the output voltage's fundamental frequency component.

$$M_a = \frac{V_m}{V_{cr}} \quad \text{......... (10)}$$

Where V_m and V_{cr} are the peak value of modulating waveform and carrier waveform. The peak amplitude controls the modulation index, which in turn regulates the rms output voltage of the inverter.

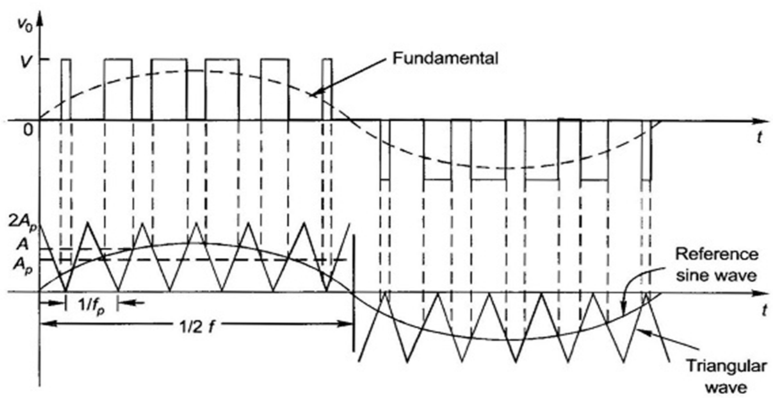

Fig. 7 Sinusoidal Pulse with Modulation (SPWM)

F. Three-Phase Spwm Inverter

Fig. 8 represents the three-phase voltage source inverter. High-power applications usually employ three-phase inverters. To form a three-phase voltage source inverter, the three single-phase half-bridge inverters must be linked in parallel [14]. The inverter comprises three phase legs, and each one consists of two switches and a body diode and is supplied by a constant DC voltage. In the SPWM control, the inverter switches are regulated by contrasting a triangular carrier signal with a sinusoidal modulating signal. The triangular carrier signal determines the inverter's switching frequency, while the sinusoidal modulating signal selects the required fundamental frequency of the inverter output. The modulation frequency ratio is the ratio of the triangular carrier signal to the sinusoidal modulating signal.

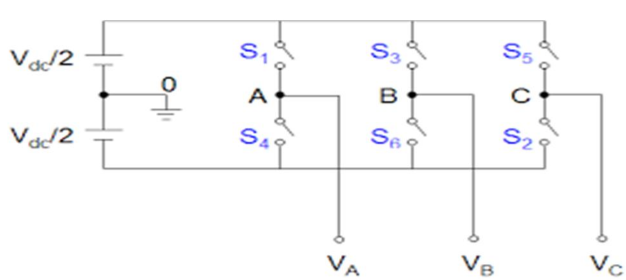

Fig. 8 Three-phase SPWM Inverter

The intention of the three-phase inverters is to drive three-phase devices. Three sinusoidal signals 0 deg, 120 deg, and 240 deg are incorporated into the three-phase design at distinct phase angles. To produce positive and negative PWM pulses for the inverter, which should be fed to the switching devices, these three sinusoidal waveforms are compared with a positive and a negative carrier waveform [15]. The three legs of the switching devices should acquire the three distinct positive and negative pulses that make up the three phases. A scope is employed to monitor the switching pulses of all the switching device legs. Each switch is offered alternate switching of a positive and a negative signal at periodic intervals thanks to the organization of all the switching signals.

III. ARTIFICIAL NEURON NETWORK (ANN)

A. Artificial Neuron

ANNs are composed of artificial neurons which are conceptually derived from biological neurons. Each artificial neuron has inputs and produces a single output which can be sent to multiple other neurons. The inputs can be the feature values of a sample of external data, such as images or documents, or they can be the outputs of other neurons. The outputs of the final output neurons of the neural net accomplish the task, such as recognizing an object in an image. To find the output of the neuron we take the weighted sum of all the inputs, weighted by the weights of the connections from the inputs to the neuron. We add a bias term to this sum. This weighted sum is sometimes called activation. This weighted sum is then passed through a (usually nonlinear) activation function to produce the output. The initial inputs are external data, such as images and documents. The ultimate outputs accomplish the task, such as recognizing an object in an image.

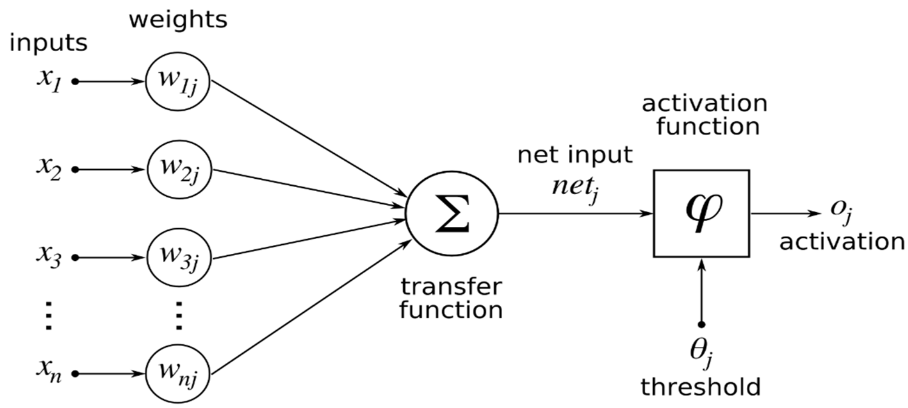

Fig. 9 Representation of Artificial Neuron

B. Multilayer Neural Network

Artificial neural networks (ANNs), also known as neural networks (NNs) or neural nets, are computer architectures that draw inspiration from the organic neural networks found in animal minds. Artificial neurons, which are a set of interconnected units or nodes that vaguely resemble the neurons in a real brain, are the foundation of an ANN. Like the synapses in a biological brain, each link has the ability to send communication to neighboring neurons. An artificial neuron can signal neurons that are linked to it after processing impulses that are sent to it [16]. The output of each neuron is calculated by some non-linear function of the total of its inputs, and the "signal" at a connection is a real integer. Edges refer to the links.

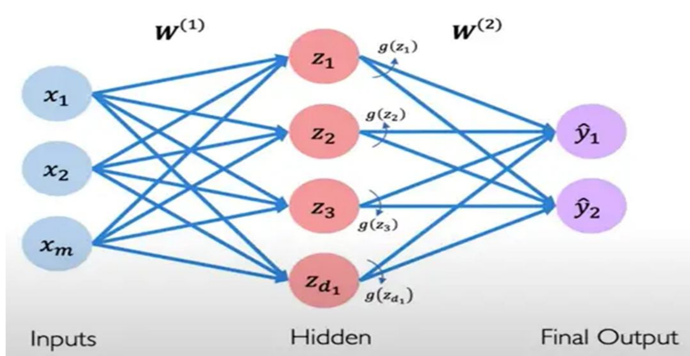

Fig. 10 Multilayer Neuron Network

The weight of neurons and edges usually changes as learning progresses. The weight alters a connection's transmission power by increasing or decreasing it. Neurons may have a cutoff and only send a signal if the combined signal passes it. Neurons may have a cutoff and only send a signal if the combined signal passes. Neurons frequently group together into layers. Different layers may alter their sources in distinct ways. Signals move through the levels, potentially more than once, from the first layer (the input layer) to the last layer (the output layer).

IV. SIMULATION

MATLAB/Simulink software is used to investigate the circuit behavior of the proposed Artificial Neural Network controlled solar-wind hybrid system. The simulation model of the hybrid system with Artificial Neural Networks is depicted in Figure 11.

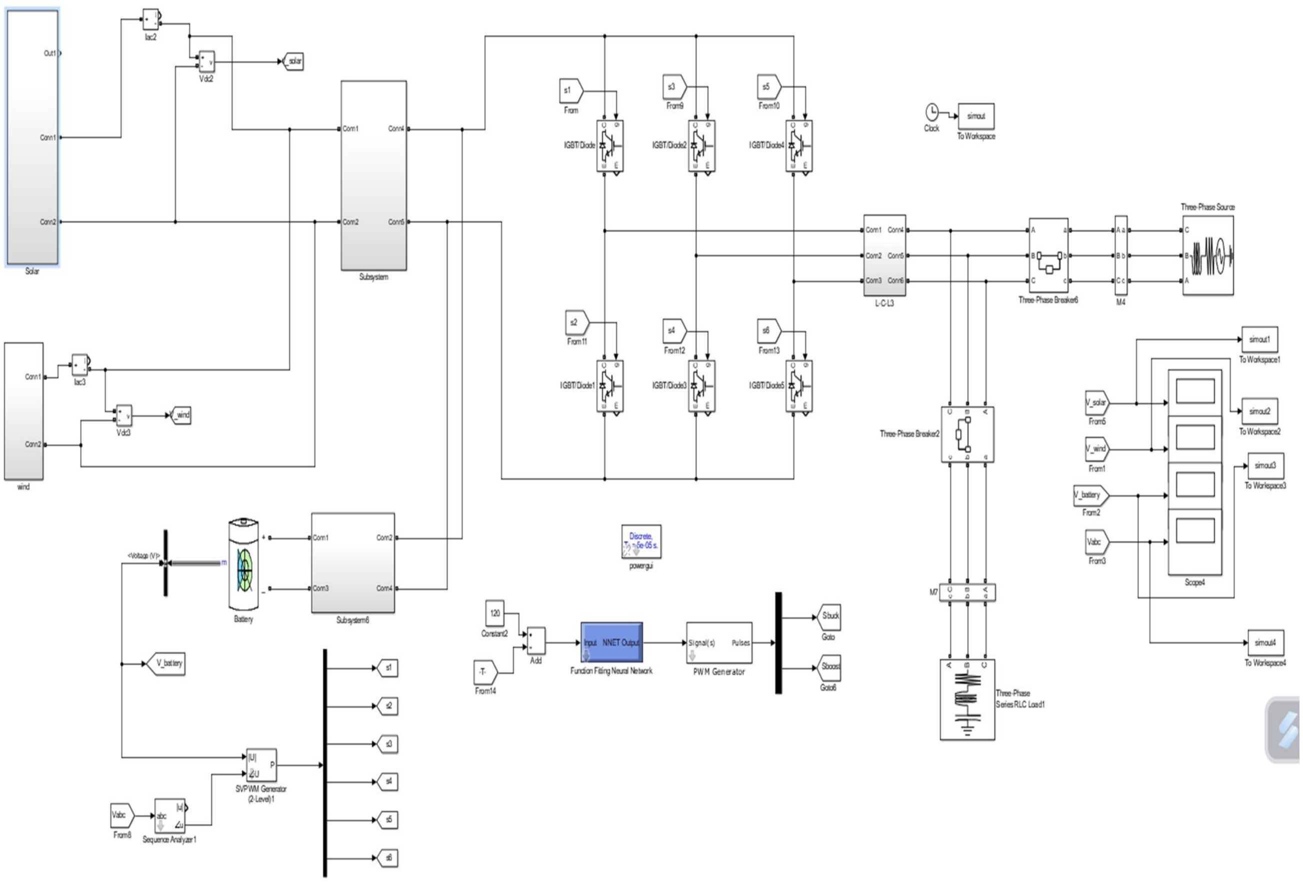

Fig. 11 Simulation of Energy Management based on Artificial Neural Network (ANN)

The suggested system's simulation model is made up of a PV module, a wind module, a battery, a Luo converter, and an Artificial Neural Network. The photovoltaic system produces a DC current. PV may produce its most electricity when the MPPT technology is used. The wind turbine's output is in the form of AC. AC-to-DC conversion takes place in a rectifier. The DC-DC Luo converter receives energy from PV and wind as input. Currently, the Luo converter produces DC, which a PWM inverter converts to AC. The LC filter reduces the output signal's ripples and harmonics. The electric grid or AC loads are fed with the output.

The power management between renewable energy generation, energy storage, and grid is integrated by ANN Controller. In the ANN having inputs, hidden layers and outputs. The renewable energies and load are the input of ANN and the output of the ANN is Battery. The error (e) is used to adjust the neural network parameters. NN training involves supplying different inputs to the plant and teaching the network to map the corresponding outputs back to the plant inputs. The first stage of model predictive control is to train a NN to represent the forward dynamics of the plant. The prediction error between the plant output and the NN output is used as the NN training signal. The neural network plant model uses previous inputs and previous plant outputs to predict future values of the plant output.

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A DC voltage of 75 volts is supplied by the solar module. Wind turbines provide an output voltage of 110 volts. When power is produced, the battery gets a 120-volt charge. The Luo converter combines the voltages from the sun and the wind. In order to convert DC to AC, the Luo converted the DC voltage and fed it to the inverter. The suggested ANN-controlled hybrid system produces 230 volts of final AC power. Figures 12, 13, 14, and 15 demonstrate the simulation results for the suggested ANN controlled solar/wind hybrid system.

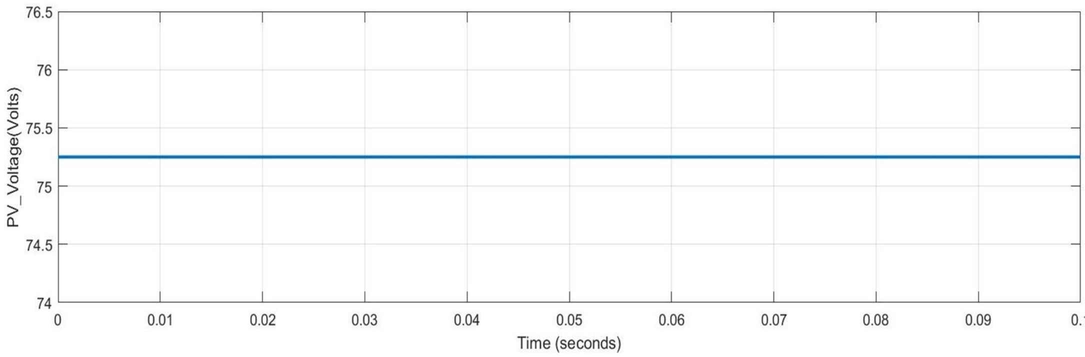

Fig. 12 Solar PV Output Voltage

The output waveform of the solar PV system is shown above Fig. 12. Each solar cell is produce 0.7volt. The output of solar PV panel is 75 volts

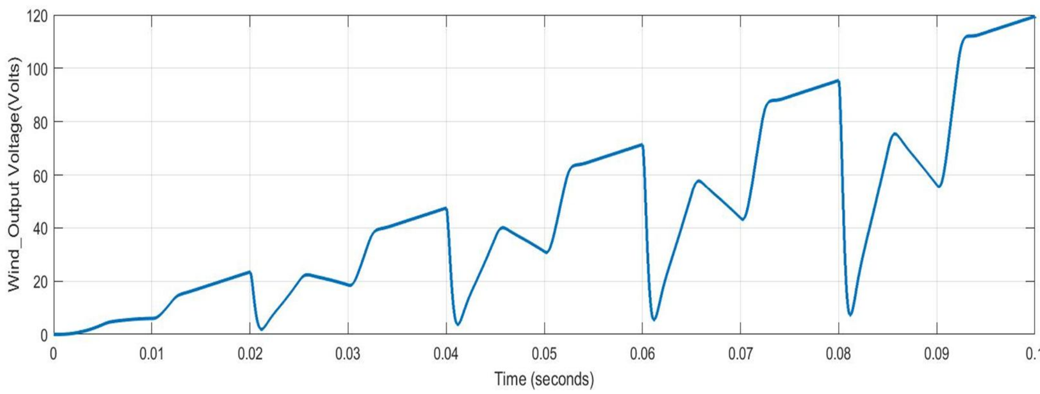

Fig. 13 Wind Output Voltage

The output waveform of the wind system is shown above Fig. 13. The output of the wind system is generated 110 volts.

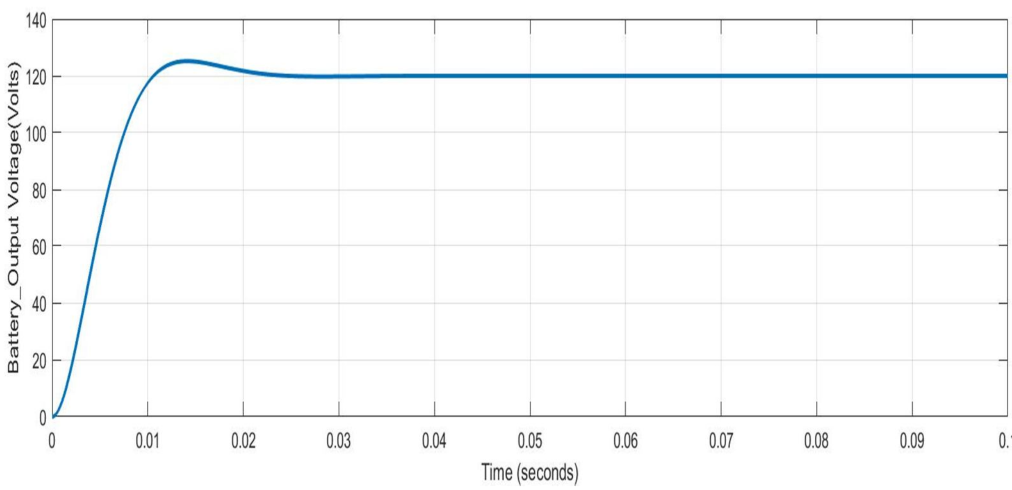

Fig. 14 Battery Voltage

The waveform of the battery voltage is shown above Fig. 14. The maximum capacity of the battery is 120 volts.

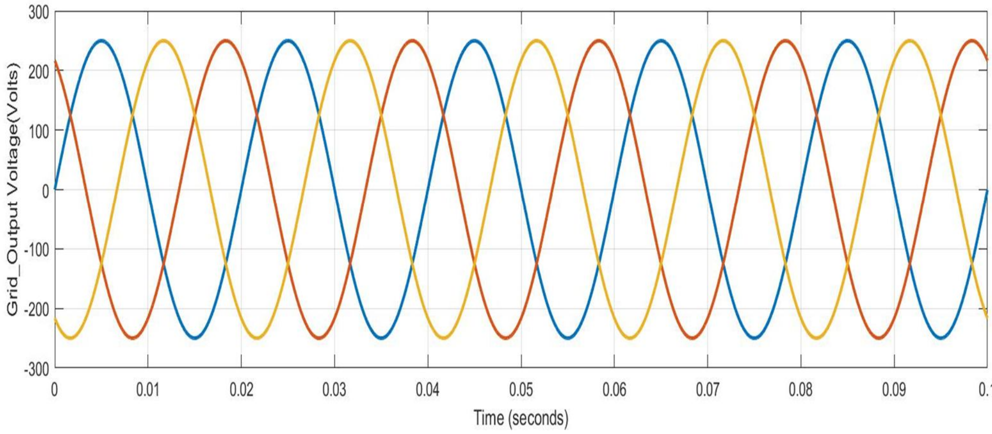

Fig. 15 Grid Output voltage

The output waveform of the grid voltage is shown in above Fig. 15. The output of the system is generated by 230 volts per phase.

V. CONCLUSION

In this Paper, an artificial neural network (ANN) controller-based hybrid solar/wind system is suggested for energy management. In the suggested hybrid system, the MPPT algorithm's efficiency is evaluated. The Luo converter is employed to maintain and adjust the DC link voltage. The high-frequency current harmonics in the wind generator could be reduced using the Luo converter. Power density and voltage gain are increased. The hybrid system's utilization of an artificial neural network (ANN) controller gives it reduces harmonics distraction and improved energy management. As a result, the overall performance of the hybrid system enhances operational effectiveness, quality, and system availability for power generation. According to simulation findings from MATLAB/Simulink, the suggested hybrid system is a realistic option for producing continuous electrical energy, particularly in rural locations.

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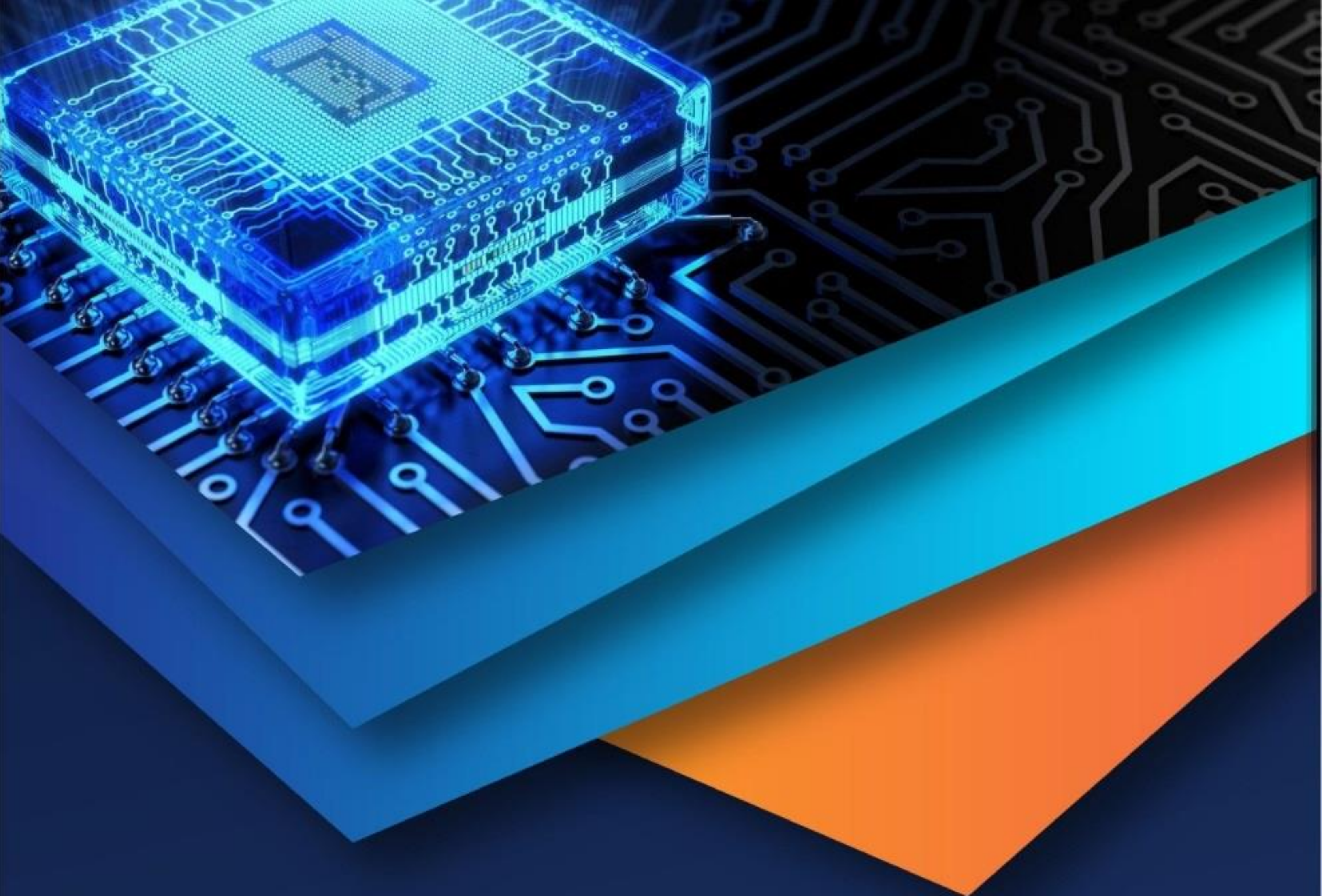

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