Design of a hybrid system that uses low energy to power road lighting using PV and wind energy.

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Abstract

In this research, the photovoltaic cell and wind turbine acted as the primary power source, while the battery served as the secondary power source. The power flowing to the load was controlled using DC-DC boost converters with maximum power point tracking (MPPT). MATLAB was used to simulate the characteristics of the hybrid system between the photovoltaic cell and the wind turbine. The study concluded that the target maximum power output of the hybrid system was 79.3 W at 6 m/s and 1000 W/m^2. The photovoltaic cell could produce a maximum of 24.2 W at 1000 W/m^2, and the wind turbine could produce 55.08 W at 6 m/s. Furthermore, the study indicated that the highest efficiency of the hybrid system was 18.8% at 6 m/s and 400 W/m^2.

Keywords: Hybrid system, Wind turbine, Solar photovoltaic panel, DC-DC converter, MPPT control, Battery.

الملخص

في هذا البحث، عملت الخلية الكهروضوئية وتوربين الرياح كمصدر رئيسي للطاقة، بينما عملت البطارية كمصدر ثانوي للطاقة. تم التحكم في الطاقة المتدفقة إلى الحمل باستخدام محولات تعزيز DC-DC مع تتبع نقطة القدرة القصوى. (MPPT)تم استخدام MATLAB لمحاكاة خصائص النظام الهجين بين الخلية الكهروضوئية وتوربين الرياح. خلصت الدراسة إلى أن أقصى قدرة خرج مستهدفة للنظام الهجين كانت 79.3 واط عند 6 م/ث و 1000 واط/م^2. بلغ أقصى قدرة خرج من الخلية الكهروضوئية 24.2 واط عند 1000 واط/م^2، بينما ولّدت توربينة الرياح 55.08 واط عند 6 م/ث. علاوة على ذلك، أشارت الدراسة إلى أن أعلى كفاءة للنظام الهجين كانت 18.8% عند 6 م/ث و 400 واط/م^2.

الكلمات المفتاحية: نظام هجين، توربينات الرياح، الألواح الشمسية الكهروضوئية، محول تيار مستمر–تيار مستمر، التحكم في MPPT، البطارية.

1. **INTRODUCTION**

Energy has played a very fundamental role in human and economic development over the past years and is still indispensable in today's global economy and civilization. Since 2002, the total annual energy consumption has increased, while fossil fuels (i. e. coal, oil or natural gas) have provided three-quarters of the total [1]. Over the last decades, the significant and rapid depletion of fossil fuel resources worldwide have necessitated an urgent search for alternative energy sources to meet the present demand. In addition, energy resources, such as solar and wind, which are clean, inexhaustible, and environmentally friendly are potential resources for renewable energy. Renewable energy is energy generated from solar, wind, biomass, geo-thermal, hydro-power, and ocean resources. These types of energy sources provide cheaper and cleaner energy for consumed.

The advantage of PVs over other renewable energy sources is that they are not noisy and require practically no maintenance. The energy absorption properties of solar cells are governed by many factors, namely solar intensity, type of solar cells, weather and air temperatures. The most important factor is how the solar cell absorbs light and converts a photon's energy to electricity. For many decades, electricity generation by utilizing PV cells and wind turbine has increased rapidly, particularly, in the developed countries of Germany, the U.S., Norway, Denmark, Japan and Sweden.

Wind turbine produces electric by a generator, which is driven by a turbine according to aerodynamics in flowing air. Wind turbine is one of the fastest growing renewable energy technologies around the world. According to [2] PV module and wind turbine are widely used in developed countries to produce DC electric power in remote locations.

Wind energy is renewable and very flexible. It can be used for various purposes including generating power, lighting in residential buildings, and water pumping for irrigation. Wind energy can be used or constructed anywhere, both in the rural areas, mountains, and plateaus or even in the sea area. Unfortunately, most third world countries commonly lack of conventional energy resources and wind turbine, and it is difficult to provide the basic need of electricity, especially in rural areas where electricity lines are rare while the alternative for energy sources are expensive.

As stated above, Indonesia has an average wind speed of about 2-5.5 m/s [3], and it is occasionally cloudy at the same time. The country is potentially rich in solar energy. Wind energy can also be enhanced by the climate condition of a particular area.

As a result, it becomes necessary to study the PV and the wind turbine hybrid systems for stable power generation. The hybrid system is not a new concept; but it has gained more considerations in the last two decades by many researchers such as [4], who recommended an optimal design model for hybrid solar–wind system which employs battery banks.

Power system combining two or more sources such as solar, wind, diesel or gasoline can be referred to as hybrid. For small load, the most common hybrid system is PV-wind turbine [5]. The hybrid system of PV-wind turbine utilizes batteries to save energy. PV and wind is good match, because wind energy and solar energy can compensate each other. Furthermore, PV- wind hybrid system is good in remote locations [6].

Therefore, the focus of this study is to investigate the power characteristics of the PV-wind turbine hybrid system up to 50 W, in relation to the wind speeds and the solar intensities. The main problems formulated as research questions are:

1. How do wind velocity and light intensity influence the characteristics of power generation of the PV and wind turbine hybrid system?
2. How do wind velocity and light intensity influence the efficiency of the PV and wind turbine hybrid system? The objectives and benefits of this study are:

To determine the characteristics of hybrid system for small power generation between PV and wind turbine. To determine the efficiency of hybrid system for small power generation between PV and wind turbine. This research is limited to PV, wind turbine, controller and battery as specified as the following. The specification of PV: module ND-060p1, maximum power P (max) 60 W, open circuit voltage 22 V, short circuit current 3.9 A, voltage at point of max power 17.4 V, current at point of max power 3.45 A, max system voltage 60 V, over.

2. Basic Theory

2.1. Wind power

Normally the wind potential is given as the specific wind power and then the power per unit of area can be formed by:

$$P_{potential} = \frac{\rho V^3}{2} \quad (1)$$

The maximum power could be expressed as follows:

$$P_{max} = \frac{8}{27}\rho V^3 \quad (2)$$

Then the maximum efficiency of an ideal wind turbine will be as follows:

$$\eta_{max} = \frac{P_{potential}}{P_{max}} = \frac{16}{27} = 0.593 \quad (3)$$

The factor 16/27 = 0.593 is sometimes called Betz Coefficient or the Betz limit. It shows that an actual turbine cannot extract more than 59.3% of the power in an undisturbed tube of air of the same area. In practice, the fraction of power extracted will always be less because of mechanical imperfections. A good fraction is 35–40% of the power in the wind under optimum conditions, although fractions as high as 50% have been claimed [7]. A turbine which extracts 40% of the power in wind is extracting about two-thirds of the amount that would be extracted by an ideal turbine. This is very good, considering the aerodynamic problems caused by the constantly changing wind speed and direction, as well as the partial loss caused by the roughness of the blade surface. Figure 1 shows the characteristics of a typical wind turbine.

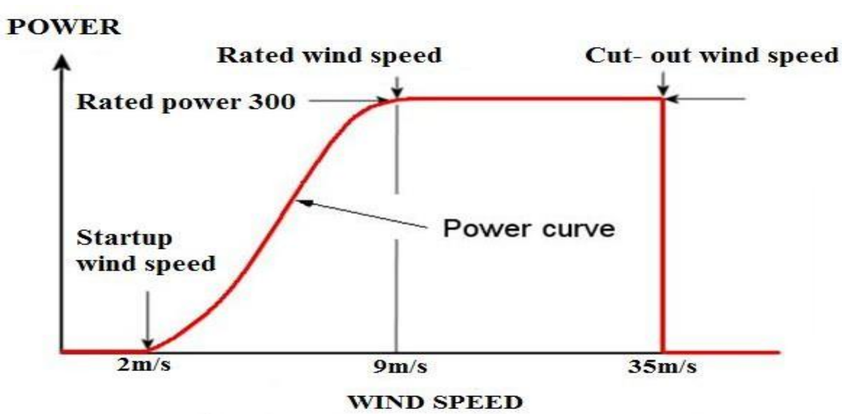

Figure 1: Shows typical characteristics of a wind turbine.

2.2. Solar cell power

The efficiency of a solar cell is dependent on both the irradiance and cell temperature. Both the open-circuit voltage and fill factor decrease substantially with temperature while the short-circuit current increases, slightly. The change in temperature will affect the power output from the cells. The voltage is highly dependent on the temperature and an increase in temperature will decrease the voltage. With decreasing temperature, PV current decrease slightly but PV voltage increase clearly then output power of photovoltaic module increase s with decreasing temperature [8].

The solar cell power conversion efficiency can be given as:

$$Eff_C = Eff_{Tref}\ [1 - \beta_{ref}\ * [T_a - T_{ref}\ + (T_{NOCT}\ - 20) * \frac{I_{rr1}}{Irr_{NOCT}} + \gamma \log 10 * Irr]\ 100 \text{ ---------------------------- } (4)$$

Where $EffTref\ is$ the module's electrical efficiency at the reference temperature and at solar radiation of 1000 W/m^2.

βref is the temperature coefficient.

Ta is the ambient temperature.

$Tref$ is the reference temperature.

$TNOCT$ is the Nominal Operating Cell Temperature (NOCT).

I_{rr} is solar radiation.

Irr_{NOCT} is the solar radiation at Nominal Operating Cell Temperature (NOCT).

γ is the solar radiation coefficient.

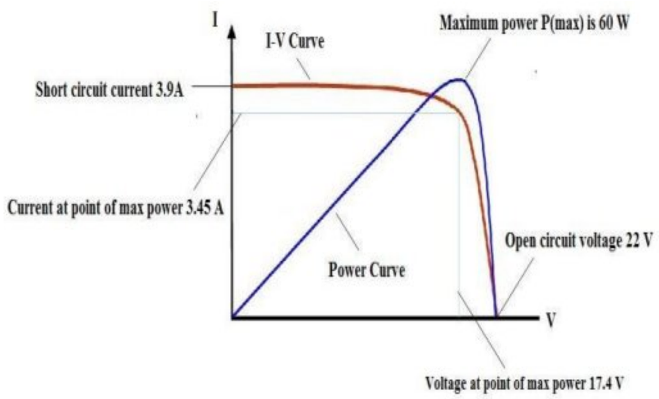

Figure 2: Shows the typical PV cell characteristics.

The output power (in Watts) for a photovoltaic PV panel at a given time can be expressed as

$$P = GHI.\,\eta_{pv} A_{pv} \text{ -- } (5)$$

Where GHI is the global horizontal irradiance [Wh/m^2] received on a horizontal surface, η_{pv} is the efficiency of the PV and A_{pv} is the total area of the PV panel [m^2]

For a battery storage, the maximum energy storage capacity used [9].

$$E_b = A_b V_b \qquad (6)$$

Where A_b is the current-hour (Ah) rating of the battery and V_b is the maximum voltage of the battery when it is fully charged (100% state of charge).

3. Research Methodology

3.1. Specification of PV cell design:

Module ND-060p1, Maximum power P(max) is 60 W, Open circuit voltage 22 V, Short circuit current 3.9A, Voltage at point of max power 17.4 V, Current at point of max power 3.45 A Max system voltage 60 V, Over current protection 7.5 A, Irradiation 1000 W/m^2.

3.2. Wind Turbine Specifications:

The most important specifications of this turbine are that it is an Oyad Angel 300 type. Rated power: 300 watts, rated voltage: 24 volts, rotor diameter: 1.44 meters, start-up wind speed: 2 meters/second, rated wind speed: 9 meters/second, break-in wind speed: 35 meters/second, and rotor rotation speed: 450 rpm.

Figure 3: Shows the PV cell.

Figure 4: Shows the wind turbine.

3.3. Controller for wind turbine and PV

Wind and solar hybrid controller OUYAD (brand), 300 W/24V. Fig: 3.3 Controller of wind turbine and PV.

3.4. Battery includes

1: GS premium 65D31R (N70). 2: GS premium 48D26R (N50), Figure 5 and 6 shows the battery.

Figure 5: Shows the controller of wind turbine and PV.

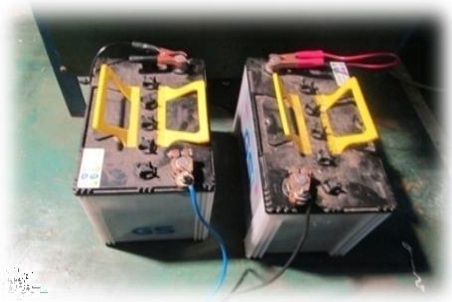

Figure 6: Shows the battery.

4. Methods and Scheme of Research

Describes an experiment to provide suitable wind speeds (3, 4, 5, and 6 m/s) using two fans to move the turbine blades, and to provide radiation intensities (400, 600, 800, and 1000 W/m²) using three powerful lamps to affect the solar panels. The air volume and the distance between the lamps and the panels were controlled, and the values were then measured at several points and averaged to determine the exact values for both wind speed and radiation intensity.

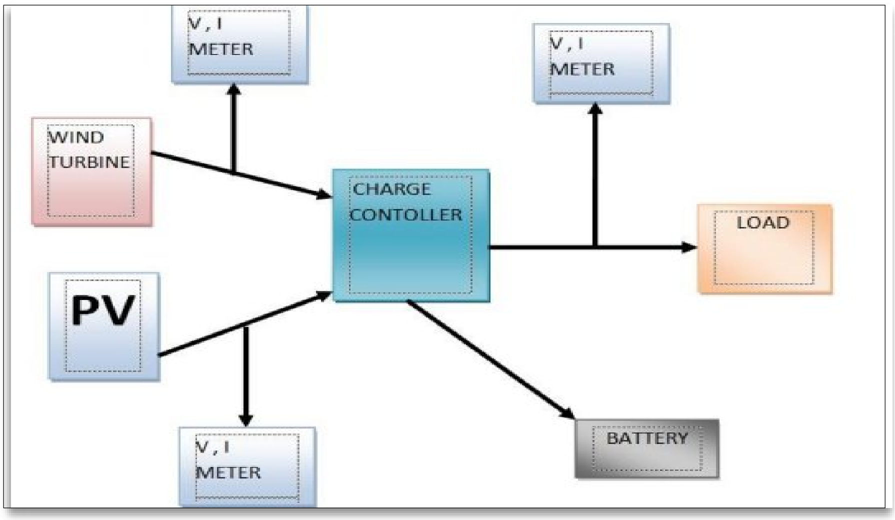

Figure 7: Shows the flow chart of the controller of wind turbine and PV.

5. Flow Chart of the Research Methodology

The flow chart of this research showed in figure 3 and 6

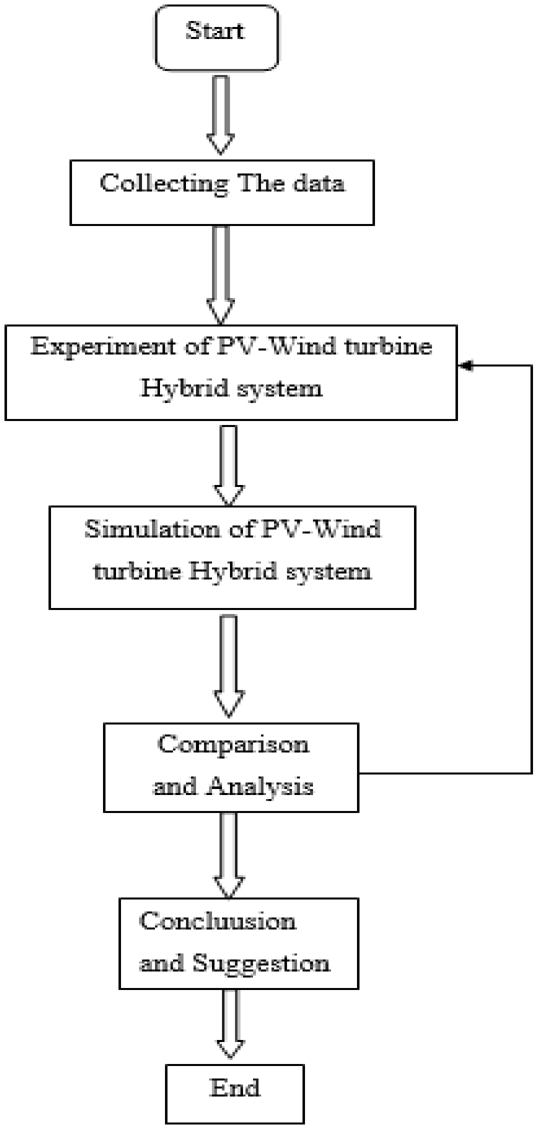

Figure 8: Shows the flow chart of the research methodology.

5.1. Model and MATLAB Simulink of PV Cell

a. Abbreviation

PPCE is PV Power Conversion Efficiency

TNOCT is Normal Operating Cell temperature

b. Symbols

Where the: Shunt Resistance = R_{sh}, Shunt-leakage Current = I_{sh}, Series Resistance = R_S, Current = I Cell, Current Load = I_L, Current source = I_{ph}, and the model PV cell can be shown in Figure 3.7

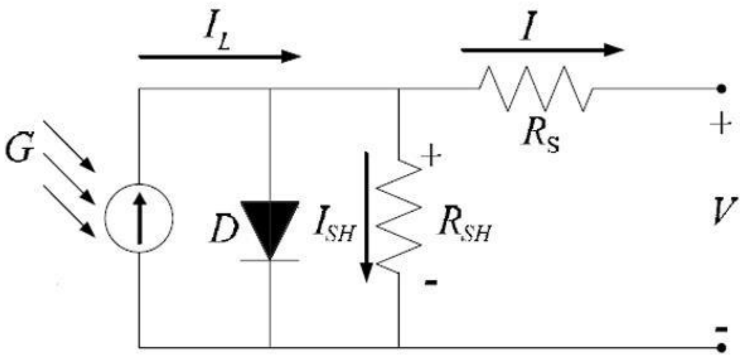

Figure 9: Shows the model of PV cell.

Scientifically, the physical appearance of a PV cell is similar to a classical diode with a PV junction; when the junction absorbs light, it transfers the energy of absorbed protons to the electron-proton system of the material. Technically, due to its non-ideal structure in nature, there are some losses which occur in real PV cells. Therefore, these losses are expressed by using resistances in equivalent circuits. The behavior model of the proposed PV model is based on this equivalent electrical circuit model. Current source, I_{ph}, which is an absolute current produced by the photons, is constant at a fixed value of radiation and temperature.

It can be seen that the shunt resistance, R_{sh}, is used to represent the shunt-leakage current, I_{sh}. The series resistance, R_s, is used to represent the voltage drop at the output. PV power conversion efficiency (PPCE) is sensitive to small changes at R_S. *PPCE* is not sensitive to changes of R_{sh}. Therefore, the small increase in R_S significantly reduces the output of the PV module. In the equivalent circuit, the current I_{Cell}, delivered to the external load equals the current I_L and the voltage over the load equals the voltage of PV cell, V_{cell}. Current and voltage of PV panel depend on load value and presents nonlinear, power-limited electrical characteristics. It can be seen that the Equation 3.1 describing output current of the non-ideal PV cell is derived using Kirchhoff's current law as follows:

$$I_{cell} = I_{ph} - I_d - I_{sh} \quad (7)$$

Where, $I_{ph}$is the photo current or the current generated by sunlight imposed on the PV cell

. I_d is the diode current. I_{sh} is the current through the shunt resistance

$$I_{ph} = \left(\frac{I_{sc.stc} \cdot S}{1000}\right) + \left[\left(T - T_r\right) K_i\right] \quad (8)$$

Where the $I_{sc.stc}$ is the short circuit current of the PV cell at standard test conditions: (S=1000W/m^2, T=25^{o}C). *Ki* is the temperature coefficient for ISC. Tr is the reference temperature.

T is the ambient temperature. S is the solar irradiance in W/m^2.

The diode current:

$$I_d = I_0 \left[\exp\left(\frac{q}{AKT(V+IR_S)}\right) - 1\right] \quad (9)$$

$$\text{And, } \frac{AKT}{q} = V_t \quad (10)$$

Where *Io* is the Reverse saturation current of the diode; *q* is the charge of electron (1.6× 10^{-19}C). *K* is the Boltzmann constant (1.38 x10^{-23}J/K). A is the quality factor (lies between 1.2-1.6 for crystalline silicon). V_T is the thermal voltage of diode. V is the terminal voltage of the PV cell. Io can be expressed by:

$$I_o = I_{rr}\left(T/T_r\right)^3 \exp\left[\frac{qEg}{AK}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right] \quad (11)$$

Where *Eg* is the band gap energy (1.12 ev for crystalline silicon). *Irr* is the I at standard test condition (STC) and the shunt current is:

$$I_{sh} = \frac{(V+IR_S)}{R_{sh}} \quad (12)$$

Then combining the equations 3.2 to 3.6 and putting them in equation 3.1 we will get the total output current source. The PV cell temperature depends on the ambient temperature and the solar insulation in this way:

$$T_{cell} = T_{ambient} + (T_{NOCT} - 25)\frac{S}{1000} \quad (13)$$

Where T_{NOCT} is the cell temperature at 23°C and 1000 W/m^2. PV cell is modeled in MATLAB/SIMULINK environment shown in figure 3.8 where 1000W/m^2 and 25^{o}C are the standard test conditions of in isolation and temperature [10].

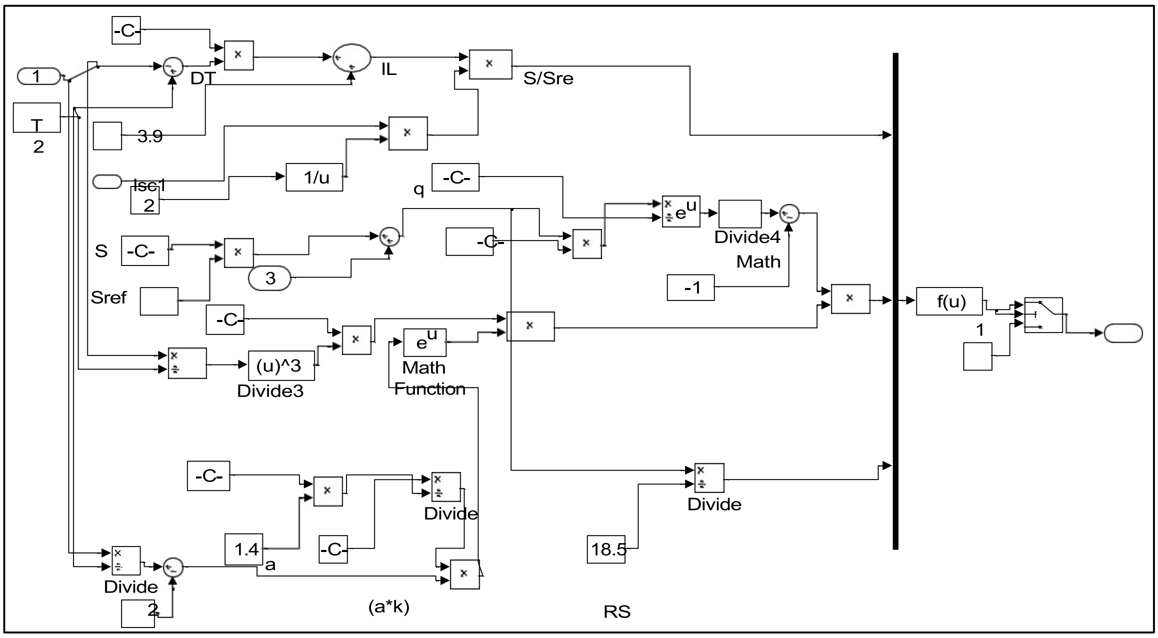

Fig 10: Shows the PV cell in MATLAB/SIMULINK.

6. Wind Turbine Model in Simulink MATLAB

The power extracted from the wind by a wind turbine is given:

$$P_T = \frac{1}{2} C_P A \rho V^3 \qquad (14)$$

Where:

P_T is the power produced by the wind turbine. C_P is the power coefficient of the rotor and varies between 0.2 and 0.5.

ρ is the density of air, approximately 1.225 kg/m^3, and V is the wind speed m/s A is the swept area perpendicular to the wind velocity m^2:

$$A = \pi R^2 \qquad (15)$$

Where R is the rotor radius (m).

The power available in the wind is given by:

$$P_W = \frac{1}{2} A \rho V^3 \qquad (16)$$

The rotor torque is given by:

$$T = \frac{1}{2} A \rho V^2 R C_T \qquad (17)$$

The relation between C_P and C_T is:

$$\frac{C_P}{C_T} = \square \qquad (18)$$

Where (□ is tip-speed ratio which means how many times the speed of the tip of the turbine blade is bigger than the wind speed:

□ = Ω x R / V ....(19)

Where Ω is the angular velocity of the wind turbine in rad/s [11]. The model of wind turbine in Simulink /MATLAB can be shown in figure 11 and 12.

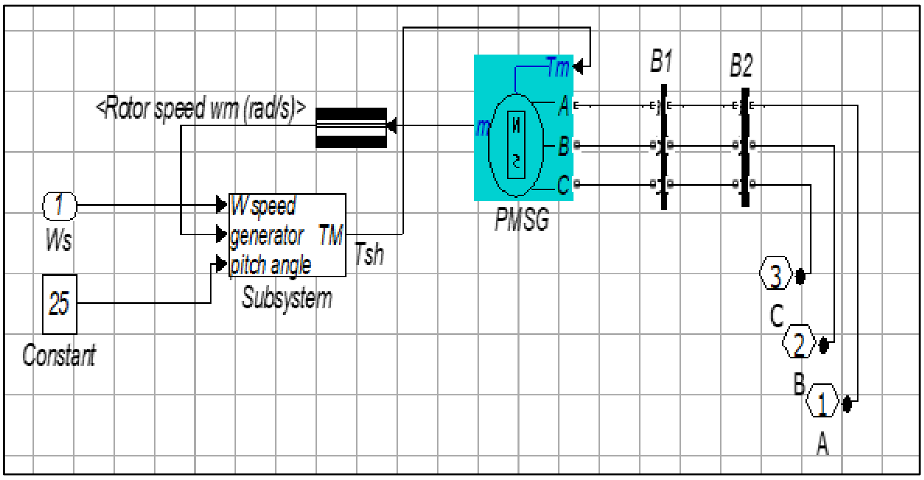

Figure 11: Shows the wind turbine in MATLAB/SIMULINK.

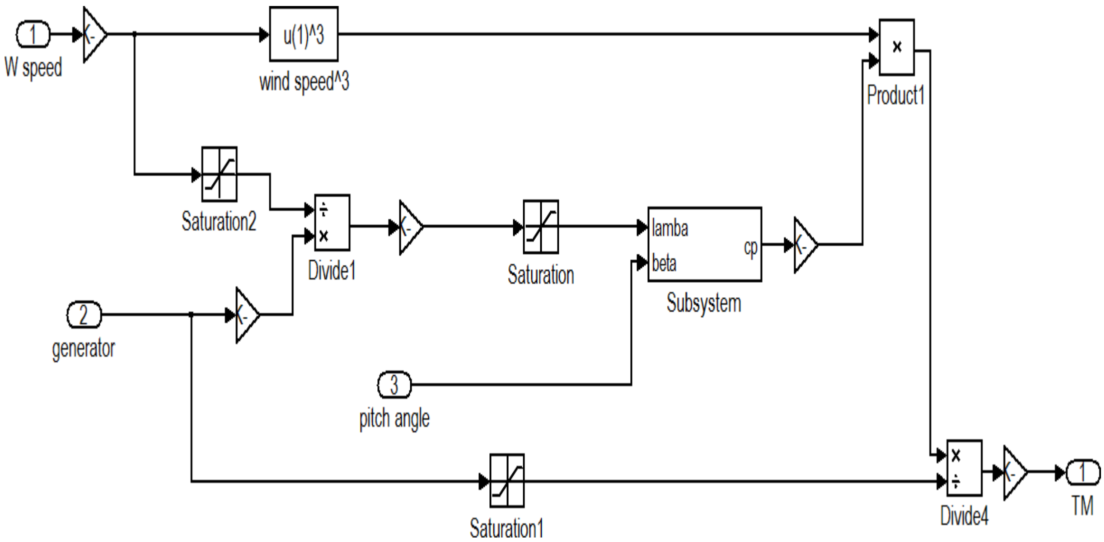

Figure 12: Shows the wind turbine in MATLAB/SIMULINK.

7. DC-DC Converter

In scientific method, to convert the irregular DC voltage into regular DC output voltage, the switch mode regulators used is the DC-DC converter system. The commonly used switch device is BJT, MOSFET or IGBT. [12,13]. It is clear that the input voltage can be levelled up and down as required by the output voltage by the DC-DC buck-boost converter at the load end. The voltage of energy sources like relatively low voltage solar photovoltaic and wind energy systems can be increased by this converter as it can also be fed by individually or simultaneously two similar inputs and low voltage energy sources, like solar or wind, on energy source availability or requirement basis [14,15], The model of DC-DC boost converter showed in figure 13.

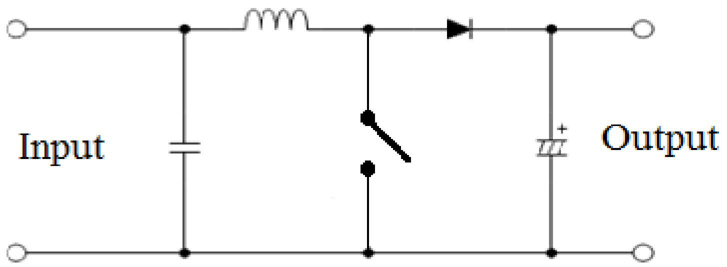

Figure 13: Shows the model of DC–DC boost converter.

7.1. Design of the Boost Converter

According to the IEC harmonics standard, CRP should be bounded within 30%.

$\frac{\Delta I_1}{I_1} = 30\%$ --(20)

Voltage Ripple Factor (VRF)

$\frac{\Delta v_0}{v_0} = 5\%$ --(21)

Switching frequency (fs)

Fs= 100 khz -- (22)

7.2. Permanent Magnet Synchronous Generator Model

Permanent Magnet Synchronous Generator gives an optimal solution for varying-speed wind turbines, MATLAB library already included function block of permanent magnet generator as below in figure 14 Permanent Magnet Synchronous Generator provides an optimal solution variable for-speed wind turbines three phase output, generates about 300 W.

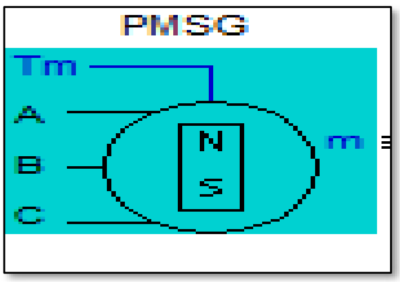

Figure 14: Shows the model of permanent magnet synchronous generator.

7.3. Rectifier Model

A three-phase diode bridge rectifier converts the AC generated output voltage, which will be varying in magnitude and also in frequency, into DC [16]. The average output voltage of the three-phase diode rectifier is obtained as follows:

$$V_{dc}= (3*V_m) /\pi \quad (23)$$

$$I_{dc}= V_{dc}/ R_L \quad (24)$$

$$Imax=V_{rms}/R_L \quad (25)$$

7.4. MPPT Controller

A MPPT, or maximum power point tracker is an electronic DC to DC converter that optimizes the input from the sources (PV panels and wind turbine), to enough output that can charge the battery. However, photovoltaic generation and wind generation use Maximum Power Point Tracker MPPT and hence maximum power is extracted from the wind turbine and the photo voltaic array.

7.5. Model of Hybrid Power System Wind Turbine and PV

According to renewable energy science, a hybrid energy conversion system combining photovoltaic and wind turbine, as a small-scale alternative source of electrical energy where conventional generation is not practical. Technically, the hybrid system consists of photovoltaic panels, wind turbines and storage batteries. The wind and PV are used as main energy sources, while the battery is used as back-up energy source. Two individual DC-DC boost converters are used to control the power flow to the load. A simple and cost-effective control with DC-DC converter is used for maximum power point tracking. Wind turbine and photovoltaic array are the sources from which the MPPT and maximum power are obtained. The wind-solar complementary power supply system is a reasonable power supply which makes good use of wind and solar energy. Wind and solar energy are converted into electricity and then sent to loads or stored in battery bank. The topology of hybrid energy system consisting of variable speed WT coupled to a permanent magnet generator PMG and PV array. The output of the hybrid generating system goes to the DC bus line to feed the isolating DC load or to the inverter, which converts the dc into AC. A battery charger is used to keep the battery fully charged at a constant DC bus line voltage. When the output of the system is not available then the battery powers the DC load or discharged to the inverter to power AC loads [17]. The actual simulation of the hybrid wind and PV system is shown in figure 15, that was done in a totally MATLAB/SIMULINK environment. The main blocks in the above Simulink diagram are Wind turbine block, PV model block, MPPT block, DC/DC converter block, battery block.

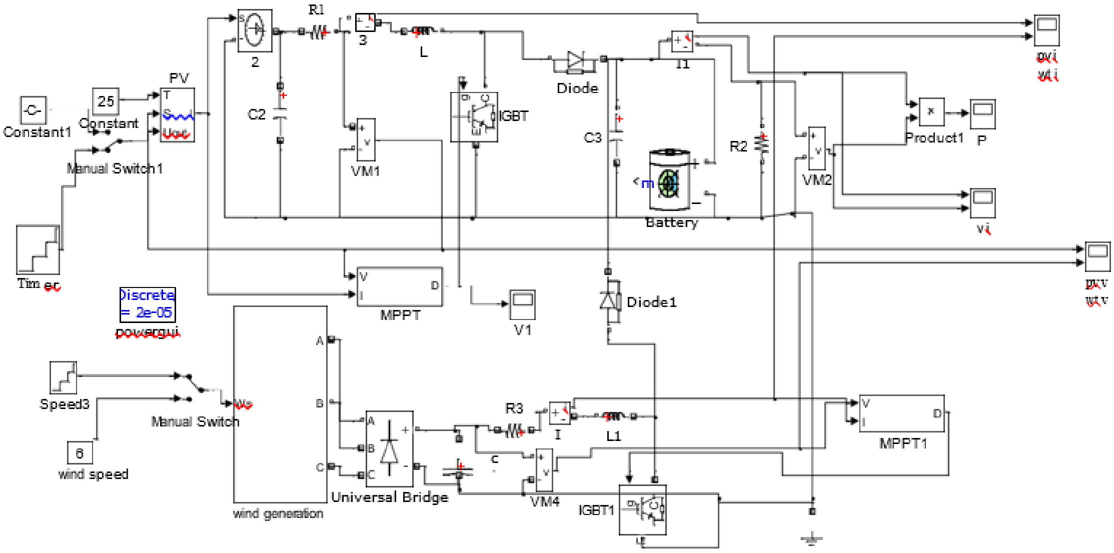

Figure 15: Shows the model of hybrid system in MATLAB/SIMULINK

8. Proposed Hybrid Energy System

The configuration of household hybrid wind and PV system is shown figure in. The wind and solar energy are converted into electricity and then sent to loads or stored in battery bank. Variable speed WT found in hybrid energy system topology is coupled to a permanent magnet generator PMG and PV array. The two energy sources are connected in parallel to a common DC bus line through their individual DC-DC converter.

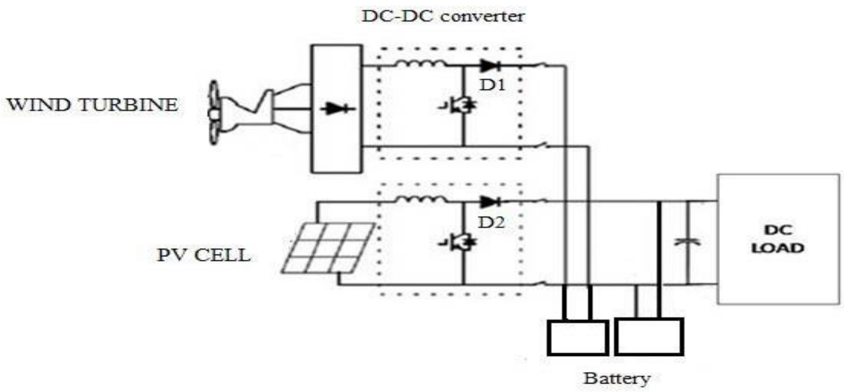

Figure 16: Shows the circuit of hybrid model.

8.1. DATA AND ANALYSIS

This chapter showed the characteristics of the PV- wind turbine hybrid system. In addition to comparison between the experimental results and simulation results Concerning the hybrid system and PV cell and Wind turbine.

8.2. Experimental Results:

The experimental results showed in table 1.

Table 1: Explains the experimental results of PV- wind turbine hybrid system

Wind Speed (m/s)	Radiation Intensity (W/m²)	PV Voltage (V)	PV Current (A)	PV Power (W)	Wind Turbine Voltage (V)	Wind Turbine Current (A)	Wind Turbine Power (W)	Total Power of Hybrid (W)
6.05	1000	31.8	0.76	24.168	54.0	1.02	55.08	79.248
5.08	800	23.3	0.58	13.514	40.3	0.72	29.016	42.53
4.02	600	22.9	0.42	9.618	8.8	0.2	1.76	11.378
2.97	400	18.2	0.34	6.188	2.5	0.05	0.125	6.313

The experiment recorded the intensity of radiation of 400, 600, 800, and 1000 W/m^2 by putting three active and strong lamps as source to create suitable intensity of radiation needed to influence the PV panel. Through the table 4.1, it can be observed that, the increase in the radiation will be accompanied by increasing in the power, voltage and the current. At 400 W/m^2 producing a voltage of 18.2 V and current of 0.34 A at 600 W/m^2 a voltage of 22.9 V producing a current of 0.42 A and a voltage of 23.3 V at 800W/m^2 producing current of 0.58 A.

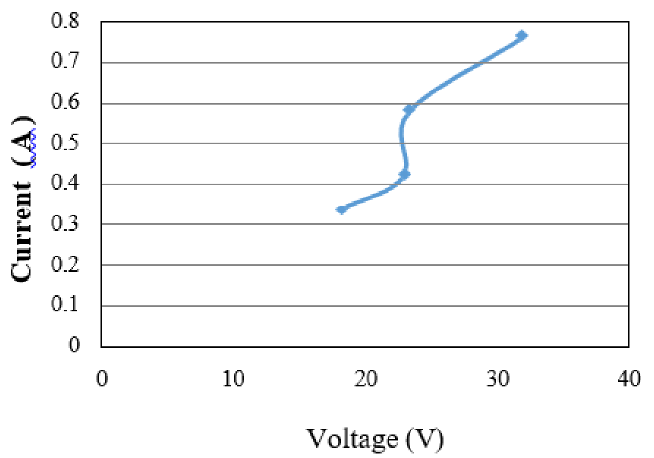

Figure 17: Shows the output Voltage and current of PV cell.

The wind speeds required in the experiment were 3, 4, 5, and 6 m/s, two fans have used as sources to create relatively strong and suitable wind speeds as needed to move the blades of wind turbine. In order to get appropriate wind speeds, the amount of air must be controlled. Afterward, the wind speed was measured by an anemometer device to measure the wind speed at several points. Finally, the average of these points was taken to determine the value of wind speed. From the points at 3 m/s a voltage of 2.5 V producing a current of 0.05 A, at 4 m/s producing a voltage of 8.8 V and current of 0.2 A, at 5 m/s producing a voltage of 40.3 V and current of 0.72 A. This study indicates the increase in the wind speed will be accompanied by increasing in the voltage and the current.

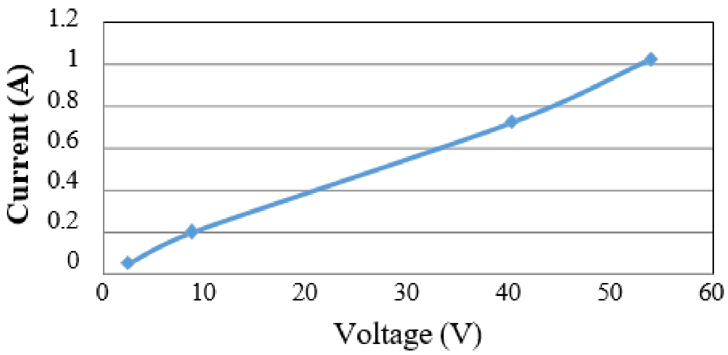

Figure 18: Shows the output voltage and current of wind turbine.

8.3. Efficiency of PV Cell.

Table 2: Explains the efficiency of PV Cell at different radiation

Radiation *Io* (W/m^2)	Input Power (W)	Output Power (W)	Efficiency of PV Cell
1000	**435.20**	**24.168**	**5.6 %**
800	**348.16**	**13.514**	**3.88 %**
600	**261.12**	**9.618**	**3.68%**
400	**174.08**	**6.188**	**3.55%**

Table 4.2 was presented the efficiency of PV cell at different radiation of 400, 600, 800, and 1000 W/m^2, and it showed the relationship between the irradiance and efficiency of PV cell, that was where the efficiency of PV cell was increasing with the increase of the irradiance. The efficiency was ratio between the output power and input power to percentage. The formula below explained the power input for a photovoltaic PV panel:

$$P_{In} = I_o \times A_{pv} \quad \text{------------------------------} (26)$$

$P_{In} = I_o \times A_{pv}$ --(26)

I_o: the radiation intensity (W/m² received on a horizontal surface)

A_{pv}: the total area of the PV panel (m²) = 0.4352 m²

The efficiency of PV was described by applying:

$(Pout/Pin)_{PV}$ --(27)

$(Pout/Pin)_{PV}$ --(28)

The efficiency of PV was described in figure 19 below:

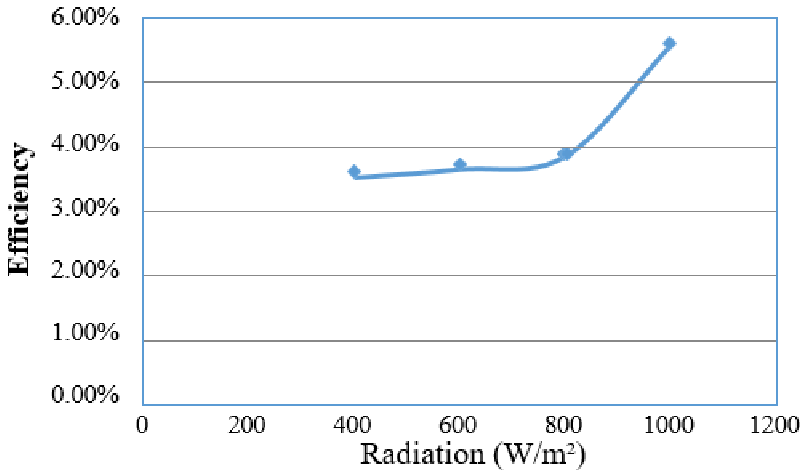

Figure 19: Shows the efficiency and radiation

8.4. Power Coefficient of Wind Turbine (Cp).

Table 3: Explains the coefficient power of wind turbine at different winds peeds

Wind Speed (m/s)	Input Power (W)	Output Power (W)	Power Coefficient (Cp)
6.05	216	55.08	0.26
5.08	125	29.016	0,23
4.02	64	1.76	0,028
2.97	27	0.125	0,005

Table 4.3 was presented the coefficient power of wind turbine at different winds speeds of 3, 4, 5, and 6 m/s, and shows the relationship between the wind speed and the coefficient power of wind turbine. The coefficient power of wind turbine was increasing by the increase of wind speed. The coefficient power is ratio between the output power and input power. The following formula could be used to produce input power

$P_{IN} = \frac{1}{2} \rho \pi R^2 V^3$ --(29)

Where is R = 0.72 m

The coefficient power of wind turbine was described by applying

$(Pout/Pin)_{wind}$ -- (30)

The coefficient power of wind turbine was described in figure 20 below:

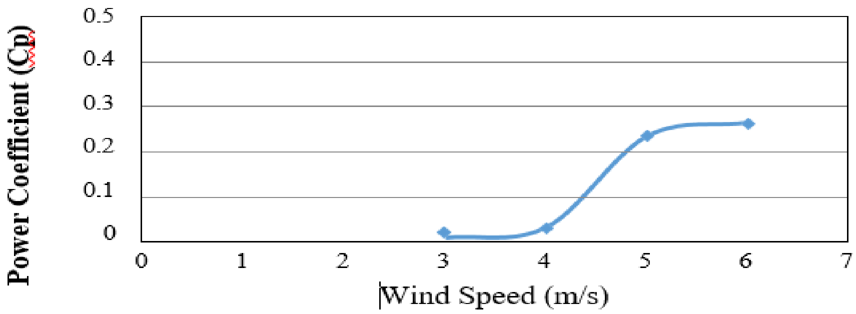

Figure 20: Shows the efficiency and wind speed.

8.5. Simulation Results.

Table 4: Explains the simulation results of PV- wind turbine hybrid system.

Wind Speed (m/s)	Radiation Intensity (W/m^2)	PV Voltage (V)	PV Currant (A)	PV power (W)	Wind Turbine Voltage (V)	Wind Turbine Currant (A)	Wind Turbine power (W)	Total Power or Hybrid (W)
6	**1000**	**23**	**1.57**	**36.11**	**27**	**1.615**	**43.605**	**79.71 5**
5	**800**	**17**	**1.4**	**23.8**	**25**	**0.69**	**17.25**	**41.05**
4	**600**	**14.5**	**1**	**14.5**	**24**	**0.1**	**2.4**	**16.9**
3	**400**	**10**	**0.54**	**5.4**	**7**	**0.05**	**0.35**	**5.75**

In this test, which was conducted by software Simulation, and from the points, starting at 400 W/m^2 producing a voltage of 10V and current of 0.54 A at 600 W/m^2a voltage of 14.5V producing a current of 1 A and a voltage of 17 V at 800W/m^2 producing current of 1.4 A this can therefore be concluded that the increase in the radiation will be accompanied by increasing in the voltage and the current.

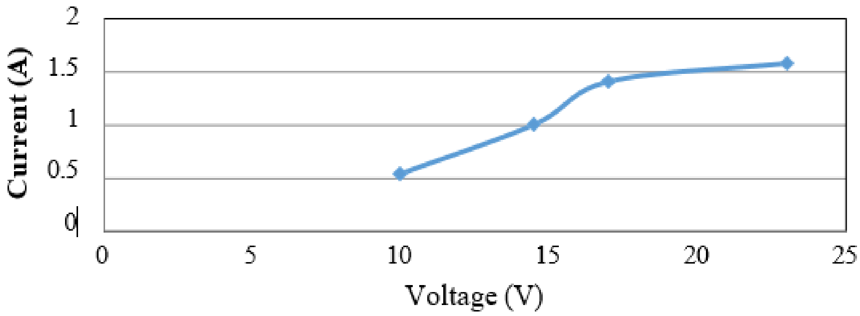

Figure 21: Shows the output voltage and current of PV cell.

The wind turbine produced voltage of 7 V at 3 m/s with current of 0.05 A, at 4m/s producing a voltage of 24 V and current of 0.1 A at 5 m/s a voltage of 25 V produced a current of 0.69 A. So, this is clear described that the increase in the wind speed will be accompanied by increasing in the voltage and the current.

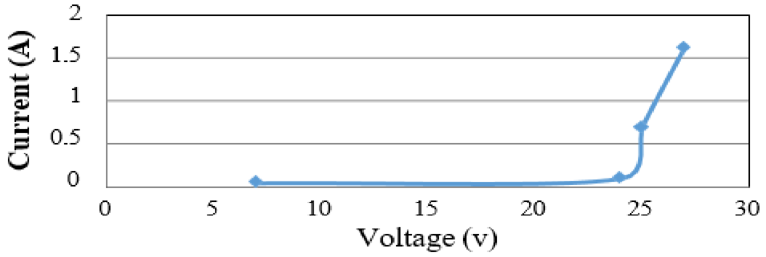

Figure 22: Shows the output voltage and current of wind turbine.

8.6. Comparison Between Experimental Result and Simulation Result

Table 5: Explains the experiment Result and Simulation Result for Total Power of PV-Wind Turbine Hybrid System/

Radiation	Wind Speed	Experiment Results of Total Power	Simulation Results of Total Power
W/m^2	**m/s**	**W**	**W**
1000	**6**	**79,248**	**79,715**
800	**5**	**42,53**	**41,05**
600	**4**	**11,378**	**16,9**
400	**3**	**6,313**	**5,75**

From the table 4.5 it was showed the experiment result and simulation result of total power, and it was appeared there is no difference between the experiment result and simulation result. The Comparison was described in figure 23.

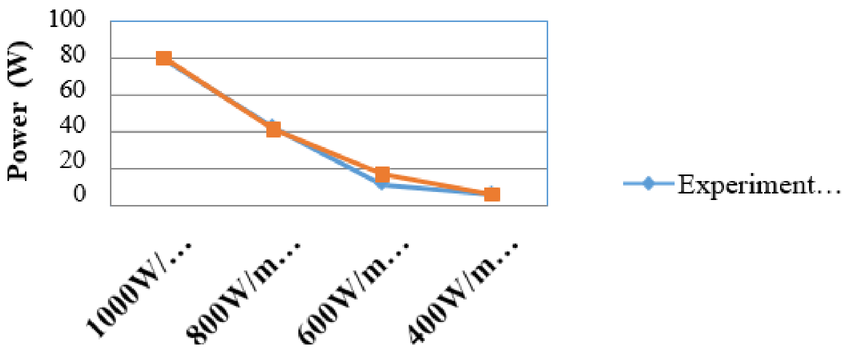

Figure 23: Shows the experimental result and simulation result.

8.7. Characteristics of PV-Wind Turbine Hybrid System by Simulation

Table 6: Explains the characteristics of PV-wind turbine hybrid at fixed wind speed and different radiation

Wind Speed (m/s)	Radiation Intensity (W/m^2)	PV Voltage (V)	PV Currant (A)	PV Power (W)	Wind Turbine Voltage (V)	Wind Turbine Current (A)	Wind Turbine Power (W)	Total Power for hybrid (W)
6	1000	23	1,57	36,11	27	1,615	43,605	79,715
	800	17	1,4	23,8	27	1,615	43,605	67,405
	600	14,5	1	14,5	27	1,615	43,605	58,105
	400	10	0,54	5,4	27	1,615	43,605	49,005
5	1000	23	1,57	36,11	25	0,69	17,25	53,36
	800	17	1,4	23,8	25	0,69	17,25	41,05
	600	14,5	1	14,5	25	0,69	17,25	31,75
	400	10	0,54	5,4	25	0,69	17,25	22,65
4	1000	23	1,57	36,11	24	0,1	2,4	38,51
	800	17	1,4	23,8	24	0,1	2,4	26,2
	600	14,5	1	14,5	24	0,1	2,4	16,9
	400	10	0,54	5,4	24	0,1	2,4	7,8
3	1000	23	1,57	36,11	7	0,05	0,35	36,46
	800	17	1,4	23,8	7	0,05	0,35	24,15
	600	14,5	1	14,5	7	0,05	0,35	14,85
	400	10	0,54	5,4	7	0,05	0,35	5,75

This table was conducted by using simulation, as it shown that the fixed wind speed was used in each test with different intensity of radiation, when the maximum wind speed 6 m/s was used with 400, 600, 800 and 1000 W/m^2 .It is noted that at 6 m/s ,1000 W/m^2 the PV cell producing a power of 36 W with 43,6 W is produced from the wind turbine so the total power of hybrid was 79,7W. The PV is produced 23,8 W and 43,6 W was produced from wind turbine with total power of 67,4 W at 6 m/s, 800 W/m^2. At 6 m/s, 600 W/m^{2}the output power of PV was 14,5 and the output of wind turbine was 43,6 W with total power of hybrid 58,1W. The last point at first testing the total power of hybrid was 49 W at 6 m/s, 400 W/m^2 with power of PV was 5,4 W and power of wind turbine was 43,6 W. In this testing at 6 m/s with 1000, 800, 600, and 400 W/m^2 showed that the power of PV is increasing as the radiation increase and the output power of wind turbine was fixed as the wind speed was fixed. In addition, the table 4.6 was represented the maximum power of PV-wind turbine hybrid system. The maximum power point of PV- wind turbine hybrid system was at 6 m/s, 1000 W/m^2.the maximum power was described in figure 24.

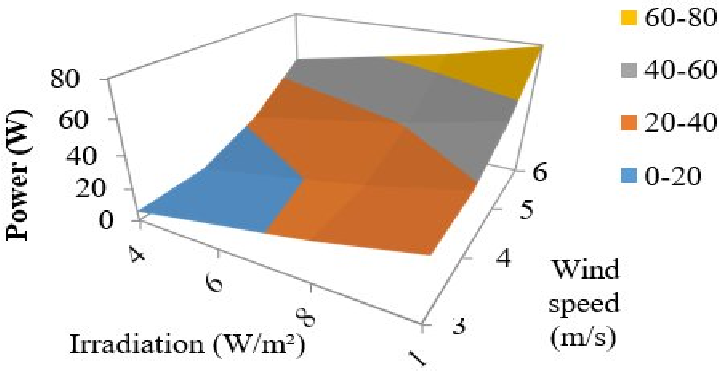

Figure 24: Shows the hybrid Power with wind speed and radiation.

8.8. Efficiency of PV-Wind Turbine Hybrid System

Table 7: Explains the efficiency of PV-Wind Turbine Hybrid at Fixed Wind Speed and different radiation.

Wind Speed (m/s)	Radiation Intensity (W/m^2)	Input Ppower (W)	Output Ppower (W)	Efficiency of Hybrid %
6	1000	521.70	79.715	15.3 %
	800	434.66	67.405	15.5 %
	600	347.62	58.105	16.7 %
	400	260.58	49.005	18.8 %
5	1000	485.2	53.36	10.9 %
	800	398.16	41.05	10.3 %
	600	311.12	31.75	10.2 %
	400	224.08	22.65	10.1 %
4	1000	460.80	38.51	8.3 %
	800	373.76	26.2	7 %
	600	286.72	16.9	5.9 %
	400	199.68	7.8	3.9 %
3	1000	446.20	36.46	8 %
	800	359.16	24.15	6.7 %
	600	272.12	14.85	5.45 %
	400	185.08	5.75	3 %

In table 4.7, it is elaborated efficiency of PV-wind turbine hybrid system, the fixed wind speed was used in each test with different intensity of radiation. As shown by the results the best efficiency obtained was 18.8 % at 6 m/s, 400 W/m^2. The formula that explained the power input for a photovoltaic PV panel and wind turbine hybrid system is:

$$P_{In} = (\frac{1}{2}\rho \pi R^2 V^3) + (Irr * Apv) \quad (31)$$

Where is R = 0.72 m and A =

0.4352 m^2

So, the Efficiency of PV- wind turbine hybrid system was:

$$\eta_{Hybrid} = (Pout/Pin)_{Hybrid} x\ 100 \quad (32)$$

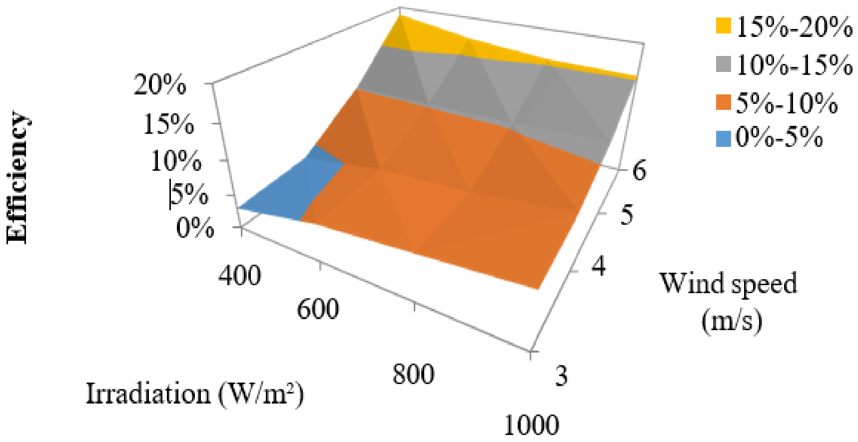

Figure 25: Shows the efficiency of PV- wind turbine hybrid system.

9. Conclusions

This research described renewable energy of the PV and wind turbine hybrid system with battery storage. The wind turbine and PV were used as main energy sources, while the battery was the back-up energy source. The characteristic of the PV-wind turbine hybrid system set forth, the maximum power was 79,248W at maximum wind speed of 6 m/s and maximum radiation of 1000 W/m² with fixed load 50W. Otherwise, the characteristic of the PV cell indicate that the maximum output voltage and current of PV cell were 0.76 A and 31.8 V at 1000 W/m², and the maximum output voltage and current of wind turbine were 1.02 A and 54.0 V at 6 m/s. Which pointed out that the power, voltage, and current were increasing with the raise of wind speeds and radiation. The use of hybrid system which included two energy sources solar and wind, provided a stable power supply and the storage system delivered constant power. The power flow was controlled by using DC-DC boost converter with maximum power point tracking MPPT. From the results obtained, it showed that the efficiency of wind turbine increased with the raising of the wind speed. And the efficiency of wind turbine at maximum wind speed 6 m/s was 25.5

%, also the results indicated that the efficiency of PV cell increased with higher light intensity. And the efficiency of PV cell at maximum radiation of 1000 W/m^2 was 5.6 %. For hybrid system, the results indicated that the maximum efficiency of the PV-wind turbine hybrid system was 15.3 % at wind speed of 6 m/s and radiation 400 W/m^2. Also, in this study showed us that the efficiency of the PV and wind turbine hybrid system is less than of standalone in comparison with each other.

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