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STAND ALONE PHOTOVOLTAIC-WIND HYBRID SYSTEM FOR 100W MOTOR

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Abstract—**Hybrid system of Photovoltaic (PV) - Wind turbine (WT) generation has more advantages compared to PV or wind turbine system alone. The main objective of this paper is to study the characteristic of the hybrid system of PV-WT besides supplying 100W permanent-magnet dc motor with this type of sources. The aim is also to design a hybrid system of PV-WT for the source of 100W permanent-magnet dc motor. To achieve the objective, both of PV and WT are connected to converter in order to get the same source of DC supply. Then both source were combine or hybrid and straightly connected to 100W permanent magnet dc motor. All the works in this paper is only apply in circuit simulator of Matlab Simulink. The output source from each converter is expected to be suit to the motor specification. The value of the output source from each renewable energy system is as expected to be high as it can support the motor if one of them is breakdown.**

Keywords— **photovoltaic, wind, converter, motor.**

I. INTRODUCTION

The aim of this The World Energy Forum has predicted that natural sources such as oil, coal and gas reserves will be exhausted in less than another 10 decades. Petroleum account for over 79% of the primary energy consumed in the world, and 57.7% of that amount is used in the transport sector and are extremely reduced.

The exhaustion of natural resources and the increasing demand towards the conventional energy have forced planners and governor to look for alternative sources. Renewable energy is energy derived from resources that are regenerative, and do not deplete over time. Based on the development of such applications, renewable energies have been increased markedly in recent years. This is proven with the approach taken by each governor and education institute, where all the renewable energy is being study in order to implement the application for their future.

Nowadays, the natural resources are unlimitedly dissipated. This is because the demand towards these types of sources is become higher in each consecutive year. If this situation is last for many years ahead, our world will see the extreme decreasing in natural sources and leading to the problem for each governor to make their people life better. As a result, many new form of energy which is potentially renewable is extensively examined and developed. Then the newly form of energy such as solar system, wind turbine and diesel generator finally revealed and used. But another issue is come out which is the stand alone renewable energy has low reliability and flexibility such as the maintenance and the surrounding application. So by having hybrid system, the energy resources are become more flexible and reliable. For example the hybrid system of solar and wind turbine. This is because solar system is applicable during sunny day and the wind turbine greatly functions during a windy night. This eventually would make our life better as the natural sources could be greatly reserved.

II. PHOTOVOLTAIC SYSTEM

PV can be describe as a kind of technique or method of generating electrical power by transforming solar radiation into direct current electricity using semiconductor. Since solar energy is the most abundant energy source on the planet, PV system can be classified as a vital technology that needs to be explored extensively in order to preserve our planet. A PV cell is basically a semiconductor diode whose *p–n* junction is exposed to light [1].

Basically PV cell is made from several types of semiconductor such as monocrystalline and polycrystalline silicon cells. Silicon PV cells are composed of a thin layer of bulk Si or a thin Si film connected to electric terminals. One of the sides of the Si layer is doped to form the *p–n* junction. A thin metallic grid is placed on the Sun-facing surface of the semiconductor [2].

The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited [3]. Charges are generated when the energy of the incident photon is sufficient to detach the covalent electrons of the semiconductor. This phenomenon depends on the semiconductor material and on the wavelength of the incident light.

A simplified equivalent circuit of a solar cell consists of a diode and a current source which are connected in parallel. The photocurrent generated when the sunlight hits the solar cell can be represented with a current source and the P-N transition area of the solar cell can be represented with a diode. The shunt and series resistances represent the losses due to the body of the semiconductor and the contacts respectively [4-5]. Such an equivalent circuit of the solar cell is shown in Fig. 1[2].

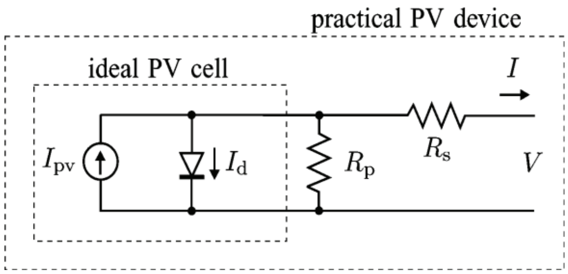

Figure 1. Solar cell equivalent circuit model.

III. WIND TURBINE SYSTEM

Wind turbines are used to generate electricity from the kinetic power of the wind. Historically they were more frequently used as a mechanical device to turn machinery [6]. In other words wind turbine is a device that changes kinetic energy from the wind source to generate mechanical energy. In windmills, wind energy is used to turn mechanical machinery to do physical work, such as crushing grain or pumping water.

Wind power is used in large scale wind farms for national electrical grids as well as in small individual turbines for providing electricity to rural residences or grid isolated locations. Wind energy is plentiful, renewable, widely distributed, cleans, and reduces toxic atmospheric and greenhouse gas emissions if used to replace fossil-fuel derived electricity.

In this paper the WT system model is developed using the functional block that already provided in Matlab Simulink library. Matlab Simulink is an environment for multidomain simulation and Model-Based Design for dynamic and embedded systems. Fig. 2 shows the general design of the WT system [7].

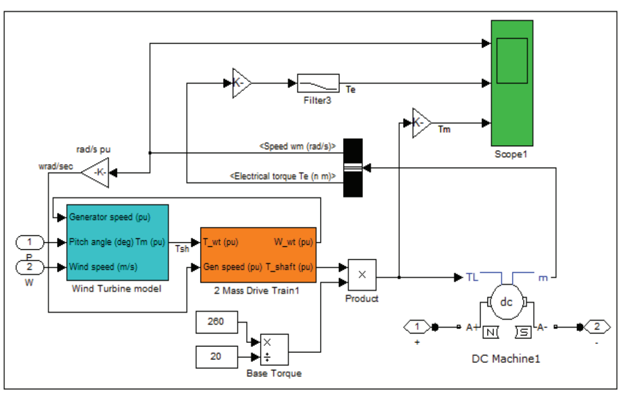

Figure 2. The general design of the WT system

But the design of the drive train is different from the rest of the WT system since the wind turbine and dc machine blocks can be used from the Simulink library. The drive train is modeled using these equations.

$$2H_t \frac{d\omega_t}{dt} = T_m - T_{sh} \quad (1)$$

$$\frac{1}{\omega_{elb}} \frac{d\theta_{t\omega}}{dt} = \omega_t - \omega_r \quad (2)$$

$$2Hg \frac{d\omega_r}{dt} = T_{sh} - T_g \quad (3)$$

where is the inertia constant of the turbine, is the inertia constant of the generator, is the shaft twist angle, is the angular speed of the wind turbine in p.u., is the rotor speed of the generator in p.u., is the electrical base speed, and the shaft torque is calculated by using the equation below.

$$T_{sh} = K_{sh}\theta_{t\omega} + D_t \frac{d\theta_{t\omega}}{dt} \quad (4)$$

where is the shaft stiffness and is the damping coefficient. Fig. 3 shows the two-mass drive train component [7] that used in this study.

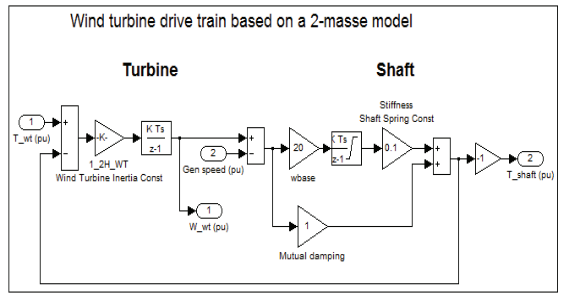

Figure 3. Two-mass drive train component

IV. HYBRID PV-WT SYSTEM

All components or system which developed in Matlab Simulink are PV system, WT, permanent magnet DC motor and the buck converter. Fig. 4 shows general system design with three points of analysis which are marked with oval shape.

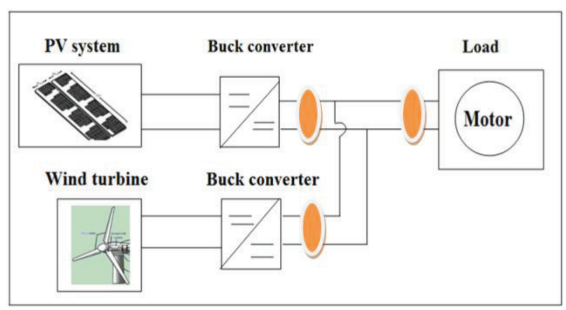

Figure 4. Hybrid system of PV-WT

V. SIMULATION RESULTS

The simulation results are divided into three parts which is the PV alone, WT alone and hybrid system performance. Fig. 5 shows the block diagram for overall system for hybrid pv-wind system connected to 100 W motor. Both sources PV and WT were connected to Buck converter to ensure the voltage level at common point were at the same value. Buck vonverter were designed in such a way the output voltage of the converter is 12 V.

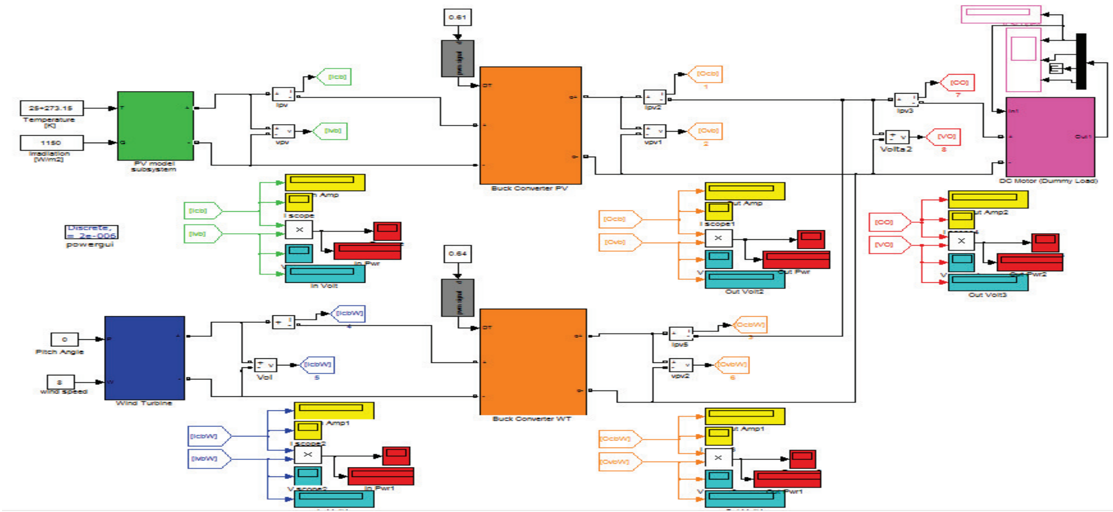

Figure 5. Block diagram for overall system for hybrid pv-wind system connected to a 100 W motor.

A. PV system performance

Firstly the PV system were analyzed based on the changes in the ratio value of number of cells series, N_{ss} and number of cells parallel, N_{pp} which were set to be 1:1, 1:4 and 4:1. Then the PV system was analyzed by changing the value of temperature while the irradiant value was constant and vice versa. Those results are shown in the Fig. 6, 7 and 8.

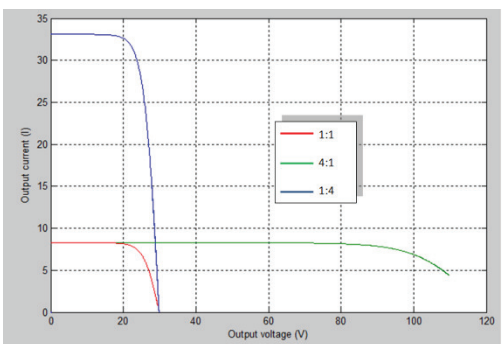

Figure 6. Plot of current vs. voltage for different ratio of N_{ss}:N_{pp}

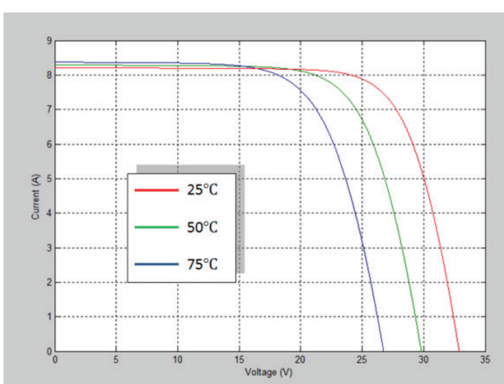

Figure 7. Plot of current vs. voltage for different temperature value

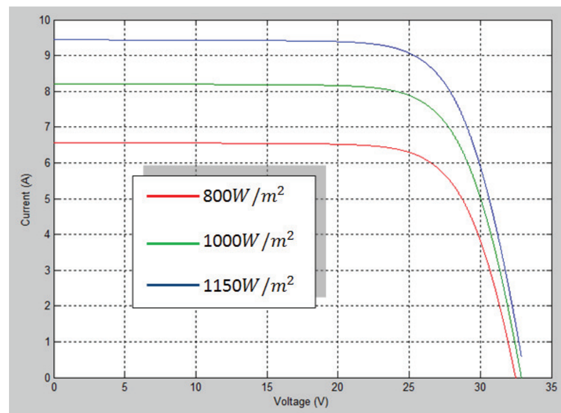

Figure 8. Plot of current vs. voltage for different irradiant value

Fig. 6 shows that the ratio of N_{ss}:N_{pp} is one of the factor that determine the output performance of PV system. Parameter of N_{ss} represents the total connection of PV in series formation while N_{pp} represent the total connection of the system in parallel connection. Loads that connected in series would increase the output voltage while loads connect in parallel increase the output current and same goes to PV system which constructed in array formation.

Fig. 7 shows that the temperature is one of the factors that determine the output performance of PV system. The higher the temperature value, the lower output voltage and power obtained. This proved that temperature is the factor that would make the PV system less efficient and the higher temperature value, the lower efficiency of the PV system.

Fig. 8 shows that the irradiant is one of the factors that determine the output performance of PV system. The higher the irradiant value, the higher output current and power obtained. This proved that irradiant is the factor that would make the PV system operates more efficient which is the higher irradiant value, the higher efficiency of the PV system.

B. WT system performance

The WT system were analyzed based on the changes in the pitch angle which were set to be , and as shown in Fig. 9 and Fig. 10 while the speed is constant at 12 m/s. Then the WT system was analyzed by the assumption that the base turbine output power ( ) and base generator speed ( ) are 260W and 20 rad/s.

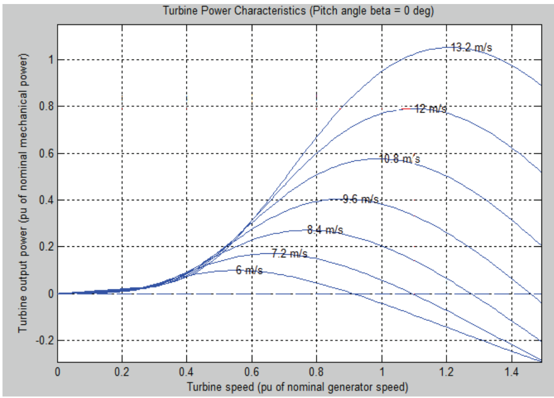

Figure 9. Plot of power vs. speed at different wind speed for pitch angle.

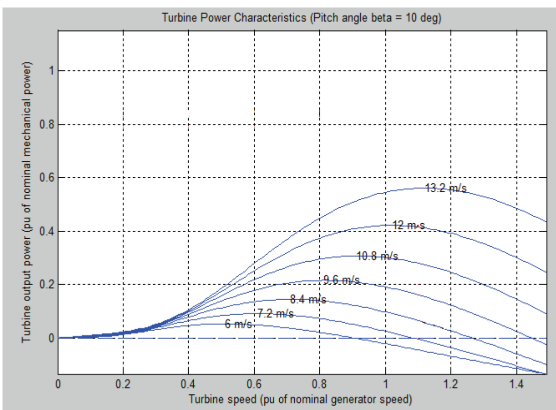

Figure 10. Plot of power vs. speed at different wind speed for pitch angle.

Based from the plots, the turbine output power and the turbine speed were decrease as the pitch angle was decrease. These results show that the pitch angle is one of the factors that determine the output performance of the WT beside of the wind speed itself.

C. Hybrid system performance at load

As been stated before, there are three points in this project that would be analysed in this paper. Two of the points were located at the output of each converter while the last point was located at the coupling point or at the input of the DC motor. This is because the performance at these points would determine the ability of the hybrid system to operate the DC motor. Table 1, 2 and 3 shows the performance of the hybrid system in term of voltage, current and power. While Fig. 11, 12 and 13 shows the input voltage, current and power of the load.

Based on the results above the input voltage of the DC motor was same to the both output voltage of the buck converters. These results shows that the coupling or hybrid process had succeed since both of the supplies were connected in parallel formation.

Table 1. Voltage performance

Component	Voltage (V)
Output PVs buck converter	19.18
Output WTs buck converter	19.18
Input DC motor	19.18

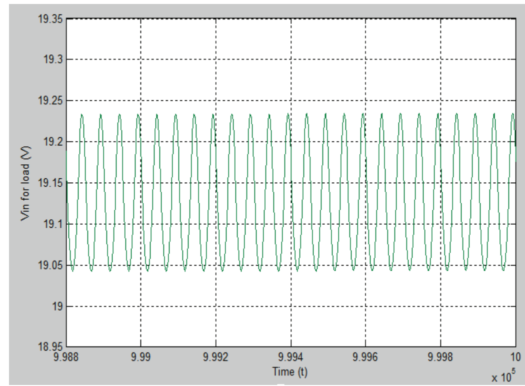

Figure 11. Input voltage of load vs. time.

Table 2. Current performance

Component	Current (A)
Output PVs buck converter	2.022
Output WTs buck converter	3.031
Input DC motor	5.053

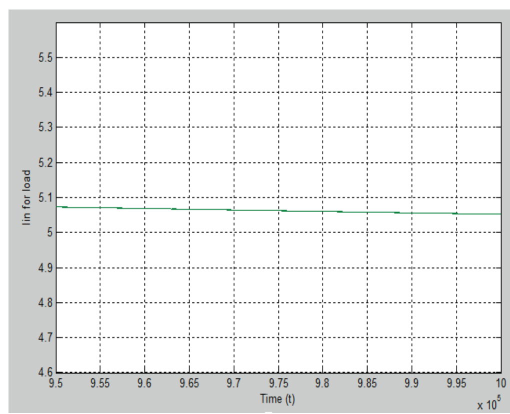

Figure 12. Input current of load vs. time

Result in Fig. 12 shows that the coupling or hybrid process had succeed since total summation of both output converters current was same as the input current of the DC motor. In other words, both sources of PV system and WT system were working together very well in order to operate the DC motor. This is because the possibility of input current from one of the buck converters to become negative polarity is high. If one of the input current from the buck converters has negative polarity, it proves that the converter which produce the negative polarity has change to become a load that receive a supply from the converter that produce positive polarity of input current.

Table 3 Power performance

Component	Power (W)
Output PVs buck converter	38.76
Output WTs buck converter	58.12
Input DC motor	96.88

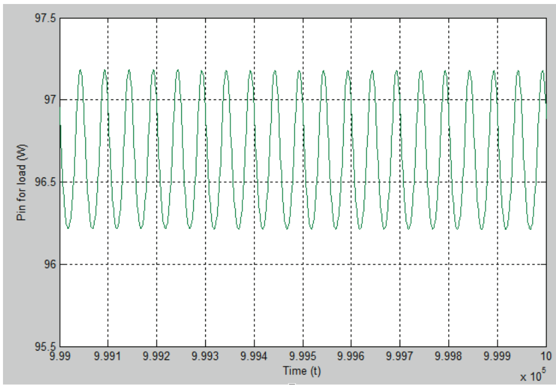

Figure 13. Input power of load vs. time.

Results in Fig. 13 shows that the coupling or hybrid process had succeed since total summation of both converters output power was same as the input power of the DC motor. In other words, both sources of PV system and WT system were working together very well in order to operate the DC motor. Since the DC motor specification is only 100W, supplying an input power with the value of 96.88W could be considered as the ideal value for operating the DC motor. This is because supplying an input value which is above the specification or overrated might result in damaging the motor.

VI. Conclusions

PV and WT system which had been modeled in this project is the main factor that determines the ability of DC permanent magnet motor to operate. The output of PV system, which depend on the N_{ss}:N_{pp} ratio, irradiant and temperature are the key of PV system performance and same thing goes to wind turbine model where wind speed and pitch angle plays an important role for WT performance.

Meanwhile the designed buck converters that mainly functions to step down the input supply besides supplying a DC source is the element that can make the motor supply suitable for the motor specification. Since the characteristic of PV and WT had been designed and analyzed, the objectives were successfully achieved. Finally, hybrid system of PV-WT had produce such a promising result that able to operate a load like DC permanent magnet motor very well by using only the natural resources compared to the stand-alone resource.

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