PROTOTYPE FOR OFFGRID SOLUTION USING SOLAR AND WIND

Nur Amalina Sakinah Ismail¹, Mohd Zamri Hasan¹, Khairul Nadiah Khalid¹, Ilham Shafini Ahmad Mahyudin¹

¹Department of Electrical Engineering Technology, Faculty of Engineering Technology, UniCITI Alam Campus, Universiti Malaysia Perlis, Sungai Chuchuh, Padang Besar, 02100 Perlis, Malaysia.

zamrihasan@unimap.edu.my, nadiahkhalid@unimap.edu.my

Abstract. This project is about the design and development of solar and wind turbine system for power generation that supply to the domestic household in the remote area, which is unable to connect to the grid. The construction of renewable resources as the power generation of a small house in a remote area occurs to save the cost installation. Renewable energy such as solar and wind that can prevent pollution occurs to nature. Wind turbines diversified by means of a standalone application, can be combined with a solar system to create a small network to act independently for supplying an electrical energy. This project was divided into two stages which are the software development and hardware development. In software development, this project has been simulated by Proteus Software by designing the charge controller for manufacturing the printed circuit boards (PCB). In hardware development, circuit power generation attached to 12 V battery as a storage. The prototype of the system has been using a piece of solar panel and a piece of a mini wind turbine. The solar and wind turbine must not exceed 10 kW and 12 VDC. Both resources are then converted into AC by using the inverter. In this project, the charge controller is needed to avoid battery exceed the energy. In the end, the power generation supplied to the small house. The microgrid system has been supplied from the 12 VDC solar and wind system. The system gave the output of 220 to 240 VAC to the small house. The basic requirement of an electric minimum load is determined in 2 kWh for the small house which is including the essential load demand such as lighting and householder appliances such as air conditioner, ceiling fan, water pump and socket outlet.

Keywords: offgrid, solar energy, wind energy

1. Introduction

Renewable energy is the energy that collected by the renewable resource, which recharges on a human timescale such as sun, wind, waves and geothermal heat. The solar energy directly for heating and lighting, generating electricity and a variety of commercial and industrial utilization. The wind energy also can generate electricity and can be combined with a solar energy to create an effective structure for local interconnection of distributed renewable generation, loads and storage [1].

Nowadays, small house location is far enough to get from the utility supply. In addition, the cost of installation of the supply connection is excessive. Therefore, this offgrid prototype project can generate power from the solar panel and wind turbine. The solar and wind energy also can prevent the
pollution occur to the environment as the sources are free from chemical processes. Since the source from solar and wind energy are varying and often inconsistent, [2] the battery bank as the storage is provided to overcome the problem and to provide power. Since the solar panel need to absorb sunlight as a source of energy, the solar system is operated in a sunny day here it can achieve the highest efficiencies. Meanwhile, wind energy system is capable of operating at night where there is no sun to be able to contribute to the system.

This project is about the design and development of solar and wind turbine system for power generation that supply to the domestic household in the remote area, where is unable to connect to the grid. The software part is about simulation and analyses the circuit of the charge controller. The hardware elements contain mechanical and electrical parts. Mechanical parts are about construction the body of the project such as the construction of the small house from plywood, polyvinyl chloride (PVC) modelling board and also used the PVC pipe for a stand of the wind turbine. The electrical part consists of circuit inverter, charge controller, battery, and load. Inverters are used to convert direct current (DC) into alternating currents (AC) in photovoltaic (PV) systems [3].

The power generating by solar and wind energy will develop according to the requirement of the load. In a power distribution system, linear loads such as heaters, incandescent light bulbs and air conditioners can affect the efficiency of the power distribution system. These linear loads commonly consume high energy and their sizes and weights are big and heavy. According to this difficulties, less energy consumption and small nonlinear devices such as induction heaters, light emitting diode (LED) bulbs and air conditioners with inverters are discovered [3].

2. Distribution System Calculation
Total connected load (TCL) divided by two types of load. For lighting system consists of a fluorescent lamp and for the motor load, consist air conditioner, ceiling fan and water pump. For the last category, socket contains a type of loads such as television, charger and spare socket. The TCL in watt and ampere can be calculated by using equation 1 and equation 2 respectively.

\[
TCL(W) = \text{Wattage} \times \text{Ballast Wattage} \times \text{Unit of lightning used}
\]

\[
TCL(A) = \frac{TCL(W)}{240V \times 0.9}
\]

In order to take the value of maintenance, Demand Factor (DF) must be considered to the type of load and type of premises. Maximum Demand (MD) can be calculated in watt or amperes using equation 3 and equation 4. The energy consumption for monthly depends on MD and how many hours that used per day. The value of TCL and MD for each load were obtained from following formulas.

\[
TCL(W) \times DF = MD(W)
\]

\[
TCL(A) \times DF = MD(A)
\]

The value obtained from the TCL and MD, are then used for determining the value of daily energy consumption for each load and monthly energy consumption as mentioned in Equation 5 and Equation 6 respectively.

\[
\frac{\text{Wattage} \times MD(W) \times \text{Hours used daily}}{1000} = \text{Daily kiloWatt – hour(kWh) consumption}
\]

\[
\text{Daily kWh} \times \text{ days per month} = \text{monthly energy consumption}
\]
3. Methodology
The flowchart explained on the flow of systematically taken as shown in Figure 1.

![Flowchart of overall project](image)

**Figure 1.** Flowchart of overall project

Figure 2 shows the block diagram of this project. The sources of this project are solar and wind energy. The solar panel and wind turbine generate the energy for supply to the load. The battery bank is energy storage and charge controller needed to prevent an overcharge the battery. Inverter is used for converting the DC to AC.

![Block diagram of microgrid using solar and wind turbine](image)

**Figure 2.** Block diagram of microgrid using solar and wind turbine

3.1. Distribution System
Before developing the power generation for the small house, the total load needs to be calculated. Table 1 shows the value of TCL for the small house using equation 1 to equation 6. The essential load included lighting and household appliance. For example, this small house has 4 units 18 W fluorescent (SH218PLD 18 W with open matt reflector), 1 unit of ceiling fan KDK R48SP, 1 unit for the water pump automatic 300L.H 12 V 70 W, 1 unit for 1.5 hp air conditioner (York R410A) and 2 units of the...
250 W socket outlet. Based on the calculation, 6.485 kWh is daily used and the monthly used is 194.44 kWh.

Table 1. Total connected load small house in remote area

| Type of load                  | Unit | TCL(W) | TCL(A) | DF  | MD(W) | MD(A) | Hour/day | Daily kWh | Monthly kWh |
|------------------------------|------|--------|--------|-----|-------|-------|----------|-----------|-------------|
| 1 Fluorescent 1 x 18 W      | 4    | 144    | 0.67   | 0.66| 95.04 | 0.44  | 7        | 0.67      | 19.96       |
| 2 Ceiling fan (60 W)        | 1    | 60     | 0.28   | 1.00| 60    | 0.28  | 10       | 0.60      | 18.00       |
| 3 Spare (250 W)             | 2    | 500    | 2.31   | 0.40| 20    | 0.93  | 3        | 0.60      | 18.00       |
| 4 Water pump                | 1    | 70     | 0.32   | 1.00| 70    | 0.32  | 2        | 0.14      | 4.20        |
| 5 1.5hp air conditioner     | 1    | 1119   | 5.18   | 1.00| 1119  | 5.18  | 4        | 4.48      | 134.28      |
|                              |      | 1893   | 8.76   |     |       |       |          |           | 194.44      |

Therefore, the small house in the remote area should be installed one a unit of a solar panel and wind turbine with capacity 1000 W, 12 V for supply the energy. It will supplied enough electricity for all appliances in the house. The both source of renewable energy need use the parallel circuit to produces largest output current. Since the ratio of the power generation is 1:100. For the prototype of a microgrid, the 10 W 12 VDC of solar and wind turbine was installed. The load must not exceed 100 W 230 VAC.

3.2. Simulation for Modelling Component in Proteus
The charge controller is designed and verified using the Proteus. Figure 3 shows the simulation of the charge controller circuit in Proteus. In additional, the inverter were needed as standalone equipment for applications such as for solar and wind power or to work as backup power supply from batteries which are charged separately.

![Figure 3. Charge controller in Proteus Software](image)

The measurement on the circuit recorded by attached the solar panel and wind turbines and the output is measured on the rechargeable battery. The charge controller circuit will be functional when the battery fully charged. The current flow to the battery stops and the zener diode get sufficient breakdown and it allows the current through it. The motor is successfully rotates up to 490 RPM.

3.3. Performance of Photovoltaic
The design of the power generation using solar and wind turbine are according to the load. The solar panel and wind turbine are 12 VDC, there was enough to supply to the AC loads such as a light bulb.

For the minimum, maximum, solar irradiance and temperature are captured at 7.00 am to 7.00 pm and the average value is 489.52 W/m² that designates it is suitable for the PV power generation [5]. The annual solar irradiance in Kolej Kediaman Unciti Alam (UniMAP), Perlis is 712.43 to 835.29 kWh/m². Figure 4 shows the connection of PV performance. The experimental will repeat with
variety of resistance. This experiment for the test of PV performance is using the spotlight and resistor (0 to 900 Ohm). The values output voltage and current can be obtained using a multimeter.

![Diagram of PV connection](image)

**Figure 4.** Connection for measure PV performance

The connection of the recharge battery, the solar is input and the battery is the output as simplified in Figure 5 and Figure 6. The voltage and current of the solar panel are input while the voltage and current of the battery is the output for this experiment.

![Block diagram of recharge battery](image)

**Figure 5.** Block diagram of recharge battery

![Experimental during charging battery using solar](image)

**Figure 6.** Experimental during charging battery using solar

### 3.4. Wind Turbine Design

The wind exists in 24 hours for earth’s ecosystem [6]. Wind is the constant movement of atmospheric air masses and is determined by its speed and orientation. A wind turbine with huge blades which are attached to the rotor of the generator to produce electrical energy moving by the wind. Wind turbine is a mechanical system which generates electricity from renewable wind energy source.

The generator that used in this project is 12 VDC and can rotate until 5000 RPM. The rotor of the generator joined the propeller as shown in Figure 7 so that the rotation of the wind turbine can produce an efficiency of maximum power. The rotational speed of wind turbine is measured by a tachometer.
and the current and voltage measured by multimeter. This project is used an artificial wind for the propeller to be rotate at maximum rotation.

![Propeller attach with generator](image)

**Figure 7.** Propeller attach with generator

4. Result and Analysis

The result and analysis in this paper are based on PV performance on IV and PV curve, the efficiency of the proposed wind turbine, the performance of the recharging battery and the design of the off-grid system.

4.1. PV Performance

This experiment for the test of PV performance is using the spotlight and resistor (0 to 900 Ohm). The values in Table 2 were recorded by using a variety of resistance (0 – 90Ω) in the PV circuit, which is straightly affects the voltage and current in the circuit. The voltage and current of the circuit were obtained using multimeter.

| Resistor Value | Voltage (V) | Current (A) | Power (W) |
|----------------|-------------|-------------|-----------|
| 0              | 0.00        | 0.0361      | 0.000     |
| 100            | 3.14        | 0.0358      | 0.112     |
| 200            | 5.44        | 0.0342      | 0.186     |
| 300            | 8.25        | 0.0329      | 0.271     |
| 400            | 11.01       | 0.0326      | 0.359     |
| 500            | 12.39       | 0.0319      | 0.395     |
| 600            | 12.56       | 0.0299      | 0.376     |
| 700            | 12.64       | 0.0275      | 0.348     |
| 800            | 12.70       | 0.0254      | 0.323     |
| 900            | 13.02       | 0.0000      | 0.000     |

The varying resistance affects the total power output of the panel. In this experiment, the short circuit current, $I_{sc} = 0.0361$ A (or current when $V = 0$), and open circuit voltage, $V_{oc} = 13.02$ V (or voltage when $I = 0$). The MPP can also be found as the point at which the product of the current and voltage equal the greatest value [8,9]. The power calculation shows that the MPP has a voltage of $V_{MPP} = 12.39$, a current of $I_{MPP} = 0.0319$ A, with the power, $P = 0.395$ W.

These data can be illustrated more clearly in a graph shown in Figure 8. Graphing the current and voltage creates a curve that is referred to as an I-V curve while the curve of power and voltage is referred to as a P-V curve.
Figure 8. I–V and P–V of pv performance

The green line in the Figure 8 graph is an I-V curve. The current is plotted in amps (A) on the left y-axis. The voltage is plotted in volts (V) on the x-axis. On the same graph, the power for each current-voltage combination is plotted in yellow line. The power is plotted in watts (W) on the right y-axis. The maximum point of the I-V curve clearly shows the MPP.

4.2. Performance of Wind Turbine

Efficiency of the wind turbine will be evaluated by recorded the voltage and current while the output power is the product of voltage and current. The totational speed of the turbine is then measured by the tachometer and shown in Table 3.

Table 3. Measurement data of wind turbine

| Wind Speed of Industrial Fan (km/h) | Voltage (V) | Current (A) | Power (W) | Rotational Speed (RPM) |
|------------------------------------|-------------|-------------|-----------|------------------------|
| 17.3                               | 2.35        | 0.12        | 0.282     | 1799                   |
| 18.7                               | 2.67        | 0.12        | 0.320     | 1820                   |
| 21.9                               | 3.59        | 0.12        | 0.431     | 2681                   |
| 22.3                               | 4.52        | 0.13        | 0.588     | 2987                   |
| 23.7                               | 5.23        | 0.16        | 0.837     | 3719                   |
| 24.4                               | 5.83        | 0.17        | 0.991     | 4040                   |

Based on the table, the propeller can rotate up until 4040 rpm during the experiment. The range of wind speed by the artificial wind is between 17.3 km/h to 24.4 km/h and the maximum voltage that produced by the generator is 5.83 V.

The characteristics of wind energy are shown in Figure 9 and Figure 10. The graph of voltage and current against the rotational speed is clear indicates that the values are proportional to the speed of the wind blades. The reading of the voltage output is increasing whenever the speed of the blade rotation is high. Same goes to the current value.
Figure 9. Graph of voltage and current against rotational speed

Figure 10 illustrates the power delivered against rotational speed. The graph shows the relationship between the power and speed of the blade is linear. Based on Table 3 the values also showed that the speed of the wind will also affect the rotational speed of the blades. Therefore, this experiment can indicate that the wind energy is potentially fully used in the area where it can capture a lot of speed wind.

Figure 10 Graph of power against rotational speed

Figure 11 shows graph the output voltage and current against the wind speed of artificial wind. The power of wind turbine is calculated by using equation (7) [10].
Figure 1. Output voltage and current against wind speed (artificial wind)

\[ Efficiciency \% = \frac{power\ output}{power\ blades} \] (7)

The air density in Perlis is 1.165 kg/m³ and the diameter of the propeller is 0.12 m and the velocity is 4 m/s. The result of the calculation is 0.706 kW and the maximum rotor efficiency is 4.88 \%.

4.3. Recharging Battery

The temperature while tested the circuit is between 24 °C to 26 °C where the time taken start from 7.45 am until 10.00 am. The data were recorded every 15 minutes and the measurement of recharging battery using solar panel is shown in Table 4.

| Time   | Voltage (V) | Current (A) | Power (W) | Battery Voltage (V) |
|--------|-------------|-------------|-----------|--------------------|
| 7:45 am| 11.68       | 0.03        | 0.35      | 7.71               |
| 8:00 am| 13.57       | 0.22        | 2.99      | 8.23               |
| 8:15 am| 13.40       | 0.33        | 4.42      | 9.89               |
| 8:30 am| 13.46       | 0.27        | 3.63      | 10.33              |
| 8:45 am| 12.86       | 0.12        | 1.54      | 10.12              |
| 9:00 am| 13.43       | 0.38        | 5.10      | 10.38              |
| 9:15 am| 13.04       | 0.22        | 2.87      | 10.20              |
| 9:30 am| 13.50       | 0.53        | 7.16      | 10.40              |
| 9:45 am| 13.82       | 0.55        | 7.60      | 10.41              |
| 10:00 am| 13.11      | 0.38        | 4.98      | 10.47              |

Based on the data, the highest voltage that achieved from solar irradiance is at 9.45 am. The time taken for charging the battery is rapidly increase from 7.45 am to 8.00 am as the power of solar increased from 0.35 W to 2.99 W. Basically the performance of charging battery from the solar panel can be viewed by a graph represented by Figure 12. However, the PV performance is affected by the shading effect due to trees, passing of clouds, neighboring buildings and any other means.
Figure 12. Recharging battery characteristic

Figure 13 shows the charge controller circuit on PCB. The NPN transistor and zener diode act as the cut-off switch when the batteries fully charge. When the battery achieves 12.69 V, the current flow to the battery stops and the zener diode get sufficient breakdown and it allows the current through it. When the system cut off happened, the LED is turning ON.

Figure 13. Charge controller on PCB

4.4. Prototype of Offgrid System
A mechanical part is about the dimension of the body of small house. The house was built using the PVC modelling board and the generators are put at the top of the model. The solar panel will be capturing more solar irradiance and the wind generator will be situated at the highest place of the model. The socket outlet for plug is put outside as Figure 14 for exhibition. As expected, the solar and wind energy can supply electricity to the prototype of the offgrid system. The AC load in this project is the lamps turn on after connecting with power generations. As expected, the solar and wind energy can supply electricity to the prototype of the offgrid.
5. Discussion

An offgrid system is currently popular throughout the nation especially when the usage is not connected to the national grid. The system reliable to the remote area from far away in the jungle to the fishermen catching fish in the deep ocean. This project is the prototype for implementing the usage of hybrid renewable energy such as solar and wind energy. In order to implement the solar panel, TCL and MD need to be determined for a small house with some basic electrical appliances. The sources of solar and wind energy is then being stored in a battery bank before converting into AC by an inverter. The charge controller is a circuit for controlling the current supply to the battery becomes overcharge. The charge controller circuit is functional when the battery achieves 12.69 V, the current flow to the battery stops and the zener diode get sufficient breakdown and it allows the current through it.

Based on the result obtained, it shows the solar panel is suitable for this project because the output voltage achieved 12 VDC. Besides of that, the one other source is the wind turbine in considering running this project because the highest output voltage is just 5.83 VDC, this means the generator is very low to provide more voltage and current. During the experiment, the efficiency of the wind turbine is 4.88 %. Between the solar and wind turbine, the solar is better being power generation because the output voltage is highest than the wind turbine. The prototype of the offgrid system using solar and wind turbine implemented in the small house. The solar panel and wind turbine was installed at the top of the small house. There was saving the space for the complete prototype. The socket outlet for plug the home appliances. The home appliance is the AC load such as the lamp and fan.

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