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Design and Installation of A 20.1 kWp Photovoltaic-Wind Power System

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Abstract

This paper discusses the detailed design, description and performance of a 20.1 kWp PV-wind hybrid renewable energy systems installed at the roof top of the LRC Building of Mindanao University of Science and Technology. This system supplies the lightings, convenient outlets, and 2 units of inverter type air-condition at the 3rd and 4th floor of LRC building. The power generated is measured and monitored through the measuring device called TED (The Energy Detective). TED records production and consumption detail, as well as showing net energy generated by the two system supplied to the load. The system started its operation on the second week of October 2013 and it was observed that an average of 55 kWh is generated per day. Hence, it is projected that the average energy production will be 20,075 kWh per year. Based on its performance, it is projected that this PV power system will save approximately P130,487.5 in utilities per year, and increase electrical reliability for a portion of the buildings in the quad. The avoided pollutants are approximately 10,579.5 kg of CO_2, 79.3 kg of SO_2 and 31.7 kg of Knox per year released to the region.

Keywords: photovoltaic, wind turbine, inverter, solar charge controller, renewable energy

1. Introduction

Energy has been playing a significant role in human, environment and economic development. It is because the world energy demand keeps on growing due to the rise in population and more urbanization while fossil fuels become more expensive as supplies diminish. With this scenario, it could not sustain the demand of energy in the near future thus, creating problem in our country. Aside from that, increasing use of fossil fuels to have electricity has done big damaged to our environment (The Energy Problem).

In order to solve these issues, let us consider the manner in which we produce and consume energy for sustainable development (Subrahmanyam *et al.,* 2012). We must look for alternatives and additional sources of energy. As such, a renewable energy resource is not a perfect answer to our electricity needs, but it is a valuable part of the solution (The National Energy Education Development Project, 2012). Renewable Energy such as energy generated from solar, wind, biomass, hydropower, geothermal and ocean resources, could increased the diversity of energy supplies and offer us clean energy beyond all doubt (Boyle, 2004).

In this study, photovoltaic and wind energy are integrated in buildings to help generate clean energy. The systems are integrated and installed at the roof top of Learning Resource Center (LRC) Building of Mindanao University of Science and Technology to supply electricity in the said building. Integrated Photovoltaics and wind turbines in the building can make a unique contribution towards a better environment (Cultura and Salameh, 2006).

Integrating the wind and solar energy is a challenge since these resources are intermittent which means sun is not always shining and wind is not always blowing (Nikolakakis and Fthenakis, 2011). However, these two energy sources can complement each other because solar has the ability to generate power all day while wind can generate power when strong wind blows especially at night time. The combination of these two resources will ensure that the level of energy fed into the grid is more stable than that of the photovoltaic and wind power plants alone (Ludwig, 2012). With this, the power system can help to reduce the energy consumption of the building from the utility grid by utilizing the available resources in the vicinity.

2. Methodology

The system is composed of a solar arrays, wind turbines, pv combiner, solar charge controllers, batteries and inverters. Solar arrays and wind turbines are responsible for gathering the energy from the sun and wind which are then converted into electricity. The gathered energy is transported to the pv combiner to merge all the collected electrical energy from pv arrays and wind turbine which then transported to solar charge controller. Solar charge controller is used to manage the battery charging and with all kinds of protection such as over charge and overdischarge protection. It is also used to monitor the battery voltage, charge current, discharge current and indicating failure. The battery stores the electrical energy produced by the panel that is not immediately utilize by the load. This energy stored is in the form of chemical energy and can be used during periods of low irradiation. On the other hand, inverters adapt the stored energy to match the requirements of the load. It is used to convert the DC current from the pv panel arrays and the batteries into AC to match the required energy by the load. Lastly, the load refers to any device that requires electrical power and is the sum of the consumption of all electrical equipment connected to the system. All of these components are integrated as shown in Figure 1 to provide the complete photovoltaic/wind hybrid systems.

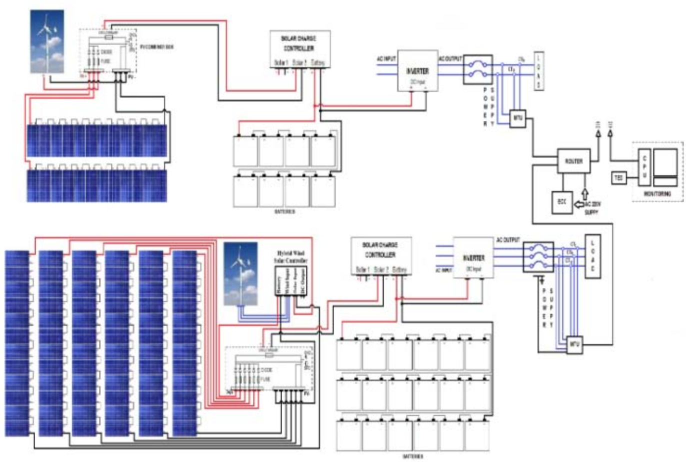

Figure 1. Schematic diagram of 20.1 kWp Photovoltaic and Wind Energy System

The 20.1kWp photovoltaic and wind power system is divided into two independently integrated 5.1kWp and 15 kWp as shown in Figure 2 and Figure 3 respectively. The 5.1 kWp power system is a single-phase design which consists of 24 photovoltaic modules (200 watts each), 300 watts dc wind turbine, PV array combiner box, 60A solar charge controller, 8 batteries and 5kW inverter. On the other hand, the 15 kWp is the three-phase design which consists of 72 photovoltaic modules (200 watts each), 600 watts ac wind turbine, hybrid wind-solar controller, PV array combiner box, 80-A solar charge controller, 18 batteries and 15kW inverter.

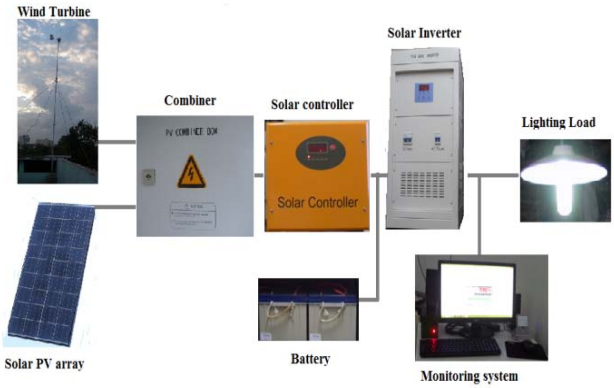

Figure 2. Picture diagram of 5.1 kWp Photovoltaic and Wind Energy System

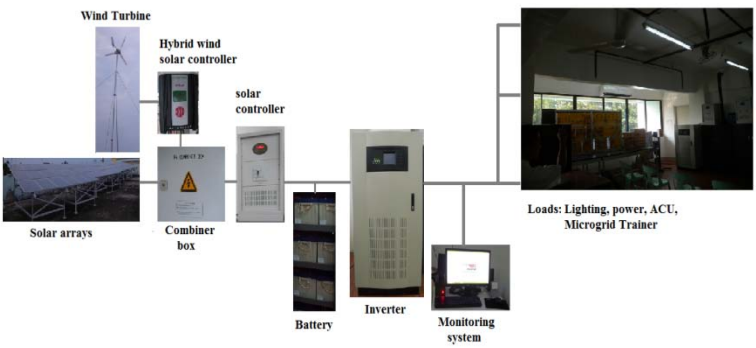

Figure 3. Picture diagram of 15 kWp Photovoltaic and Wind Energy System

2.1 The 20.1 kW pv-wind system components

2.1.1 Photovoltaic arrays and wind turbine

There are 96 modules and 2 wind (300 watts and 600 watts) turbines that were installed on the rooftop of the LRC building (shown in Figure 4). Each module has a peak power of 200 watts, maximum current of 7.4 A, maximum voltage of 27 V and with the temperature of 25°C. Modules are wired in series string, where the positive leads of one module are connected to the negative leads of the next module. In this design, there are 12 modules connected in series string which results in cumulative voltage output, with constant current. Similar to pv arrays, the 2 wind turbines (300 watts and 600 watts) are also connected to the pv array combiner box (See Figure 5).

Figure 4. PV Arrays and wind turbine

On the other hand, there are two (2) wind turbines (300 watts and 600 watts) that were installed on the rooftop of LRC Building. These two wind turbines are incorporated with the photovoltaic panels in order to help generate electricity especially during night time where there is no solar energy. The 300 watts wind turbine is a single-phase design which produces a DC voltage while the 600 watts wind turbine is a three phase design produces AC voltage. Because of the AC voltage generated by 600 watts wind turbine, it is connected first to the wind and solar hybrid controller as shown in figure 4 in order to convert AC voltage to DC voltage then finally connected to the pv array combiner box.

Figure 5. Wind and Solar Hybrid Controller

2.1.2 Combiner box

The power produced from pv and wind turbines are coupled in the combiner box as shown in Figure 6, which contain terminals for combining the inputs. Each terminal is connected with the fuse and blocking diode to ensure all the circuit protections are in placed. PV arrays combiner box also contains a current counter-attack, an overcurrent protection device, overvoltage protection, lightning protection, and a series of perfect protection function.

There are two combiner boxes used for the two independent (5.1kWp and 15 kWp pv / wind) power system. Two (2) strings of photovoltaics and 300 watts wind turbines are coupled to the first combiner box. On the other hand, four (4) strings of photovoltaics and 600 watts are coupled in the second combiner box.

Figure 6. PV Combiner Box

2.1.3 Solar charge controller

The TS96S60P and TS220S80P solar charge controller as shown in Figure 7 were used to regulate the voltage and current from 5kw and 15kw solar panel respectively. The series solar controllers used microcomputer chip control for battery charging, and with all kinds of protection such as overcharge protection and over discharge protection. Also, the controller can monitor the battery voltage, solar voltage, charge current, discharge current, chassis temperature and indicating failure. The TS96S60P and TS220S80P solar charge controllers as shown in Figure 7 have a rated current of 60 ampere and 80 ampere, rate voltage of 96 volts and 220 volts correspondingly. It will operate with the range of 88 volts to 98 volts and 198 volts to 270 volts respectively. Below or higher that voltage range, the controller will indicate that the battery is either under voltage or over voltage thus preventing over charging and over discharging.

Figure 7. Solar ChargeController (left –TS96S60P& right –TS220S80P)

2.1.4 Batteries

Batteries are essential for storing the excess generated energy for later used especially in the absence of sunlight or wind. The 5.1 kWp and 15 kWp used eight (8) and eighteen (18) batteries respectively. These are deep cycled solar batteries with 24V, 250Ah rating each which are connected in series as shown in Figure 8.

Figure 8. Batteries

2.1.5 Inverters

Two units of different type of inverters were installed in the system that supply electrical load independently. These are two solar power inventers (TI965KNB and TI22015KN3P model) as shown in Figure 9 equipped with ac by-pass which used to convert the DC power from solar panel and wind into AC power used by the electrical and electronic equipment in the building.

The TI965KNB solar power inverter and ac by-pass is a single-phase design with a rated power of 5 kw, DC input rated voltage of 96 volts and AC output rated current of 22.7 A. When the DC input is 88 volts, the inverter will alarm indicating under voltage. On the other hand, the inverter will alarm indicating high voltage when the DC input reached 140 volts. The AC output is 220 VAC, 60 HZ which is connected to the identified electrical loads. This additional inverter is used in the 5.1 kWp pv/wind power system.

Figure 9. Charge controller, inverters, batteries and monitoring system

Conversely, TI22015KN3P solar power inverter with ac by-pass is the three-phase design with a rated power of 15 kw and a DC voltage of 220VDC. During the installation, the researcher found out that the inverter has rated output voltage of 330 volts with a rated frequency of 60 Hz. Because of this

330 VAC rated voltage, there is a problem in the inverter since the load requires 110 or 220 VAC for the equipment to operate. In order to fix the problem, the researcher decided to install a transformer to step down the 330 VAC to 220 VAC.

3. Results and Discussions

PV systems produce power in proportion to the intensity of sunlight striking the solar array surface. The intensity of light on a surface varies throughout a day, as well as day to day, so the actual output of a solar power system can vary significantly. The authors monitor the performance and the energy production of the entire system.

Data from the pv arrays and wind turbines are also recorded using the arduino data logger to store data in real time. Computer is interfaced in the system through arduino data logger to monitor the power generated of two power systems. Since 5.1 kWp (single-phase) and 15kWp (three-phase) power systems are independently operated, then the actual energy was recorded separately. As a result, it was observed that an average of 55 kWh is generated per day in a sunny weather. Hence, it is projected that the average energy production will be 20,075 kWh per year. Based on its performance, it is projected that this PV power system will save approximately Php130,487.5 in utilities per year, and increase electrical reliability for a portion of the buildings in the quad. With that, it would help saving the energy consumption of the building from utility grid by using the generated energy from these renewable resources.

4. Conclusion

Utilizing renewable energy resources is not only highly beneficial from an energetic perspective but also from ecological and economic perspective. It is because these resources produce no pollution and therefore helps to combat climate change caused by fossil fuel usage. The energy generated in this pv and wind power system is used for supplying the electricity in the building. With this technology, the energy consumption of the building from utility grid is decreasing. Based on its performance, the average generated energy is 20,075kWhr per year. Thus, it is projected that this PV power system will save approximately P 130,487.5 in utilities per year, and increase electrical reliability for a portion of the buildings in the quad. The avoided pollutants are approximately 10,579.5 kg of CO_2, 79.3 kg of SO_2 and 31.7 kg of Knox per year released to the region.

5. Acknowledgements

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