MODULAR ON-GRID OFF-GRID SOLAR ENERGY SYSTEM MOCK–UP

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Abstract

The main purpose of this study was to innovate and assemble a Modular On-Grid Off-Grid Solar Energy System Mock-Up. Specifically, the study was conducted to provide student a simulation on solar setup particularly in Modular On-Grid Off-Grid Solar Energy System Mock-Up in order to prepare them in the actual field. The study was conducted at Bohol Island State University – Main Campus in the School Year 2021-2022. The researcher used experimental method of research in developing the gadget. There are four (4) experts as the respondents of this study. All of them are the electrical technology instructors from BISU main campus who witness and test the level of performance and effectiveness using On-Grid Off-Grid solar energy system Mock-up. The Modular On-Grid Off-Grid solar energy Mock-Up composed by Solar panel, Maximum power point tracking (MPPT), On-Grid inverter, Off-Grid inverter, Automatic transfer switch (ATS), Alternating current power monitor, Battery Management System (BMS), Batteries, Bulb and Switches. The researcher made an observation guide and conducted a trial and error to obtain necessary information to oversee the functionality of the device in terms of performance and effectiveness. The data collected on the performance of the Modular On-Grid Off-Grid Solar Energy System Mock-Up was analyzed and interpreted. The researcher concluded that Modular On-Grid Off-Grid Solar Energy System Mock-Up was found functional and very usefull that can be used by the students, instructors, and future researcher as an instructional apparatus. The researcher recommended and encouraged students of Electrical Technology to use the Modular On-Grid Off-Grid Solar Energy System Mock-Up as their instructional apparatus.

Keywords: Modular, On-grid, Off-grid, Mock-up.

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1. INTRODUCTION

Electricity is one of the most important things that science has given to mankind and use for the daily living of the entire humanity. It has also basic part of nature and one of the most widely used forms of energy. The electricity that use is a secondary energy source because it is produced by converting primary resources of energy such as coal, natural gas, nuclear energy, solar energy, wind energy, and hydro power, into electrical power.

On December 16, 2021, the entire province of Bohol was hit by Super Typhoon Odette. It brought violent winds and torrential rains which resulted to massive damage to buildings and other infrastructures. The special towers, located in Ubay did not escape the wrath of Typhoon Odette which led to power outage for a longer period of time. The aftermath of typhoon Odette was nightmarish and it severely affects people from all walks of life. The geothermal power plant in Leyte was the major source of electricity for Boholanos. It is a renewable energy source and most of all, it is cheaper. Tapping this kind of energy resource was an advantage for the province of Bohol. Sad to say, it has drawbacks since the Bohol - Leyte interconnection Project cannot withstand very harsh conditions. It was not the first time that Boholanos experienced long term power interruptions. The same scenario was also brought by Typhoon Yolanda December 16, 2021 . While the province has the so-called Bohol Diesel Plant, it cannot actually generate enough electricity to meet the demands of residential and business establishments. Not to mention the fact that it is costly. With these in mind , the researcher come up with an idea that it is high time to promote the use of solar power as a good alternative energy source for everyone. Harnessing radiant energy from the sun is a good choice. Calamities may strike again and again but this alternative energy source will surely sustain. It will continue to provide the much-needed energy that people need to live conveniently.

Renewable energy is the energy generated from natural processes that continuously replenished. Sunlight, geothermal heat, wind, tides, water and various form of biomass. This energy cannot be exhausted and is constantly renewed. To have a renewable energy is a good decision for an Alternative Energy. Alternative energy is a term used for an energy source that is alternative to using fossils fuel, low environment impact and doesn't harm the mother nature.

There are lots of renewable energy people are using now, however it lacks on information on how to install and operate it alone. Many people are hesitant to perform solar energy set up on their own, so the researcher created this device model to provide instructions on how properly up should be done. The solar energy system can lessen electricity bills, lessen carbon emission and increase value of energy efficiency. After the super typhoon Odette hits the Visayas area, Bohol was left devastated, experiencing total black out in the whole province. Few weeks after, electricity was slowly restored for some places with the help of the diesel power plant. But it's not enough to supply the whole province and turns to be a crisis. People are starting to use solar powered devices; solar energy was the only solution people saw at that time. The demands are highly urges and supplies became more aggressive. We are electrical student wants to educate everyone by using this device.

This solar photovoltaic generator contains two types of solar power system set-up, the on-grid solar photovoltaic system and the off-grid solar photovoltaic system. It has been discussed during our first year of college (S.Y 2019-2020) but we have not seen an actual device and no one did perform personally. All researcher came up with this study to create an instructional device to let other students observe and perform actual connection and also instructors can show the actual demonstration to the future electrical students. This device will have a big contribution of our next future researcher of Electrical base works and all Electrical students since this device is the first mock-up in all BISU-Campus that involve on-grid and off-grid solar energy system. Solar Energy system mock-up is a device that is very applicable or useful to many electrical students to enhance their knowledge and skills in connecting, controlling, and installing electronic devices.

2. RESEARCH METHODOLOGY

Research Design

The study used the experimental design method in assembling and designing the device to make it Modular On-Grid Off-Grid Solar Energy System Mock-up. Experimental research is a kind of research that tests and establishes the effects of the different variables under investigation.

Environment and Participants

This study was conducted particularly at Bohol Island State University Main Campus, Tagbilaran City. The institution was chosen as it offers technical programs like electrical technology, electronics technology, mechanical technology, and engineering. Furthermore, the institution will also utilize teaching materials that involved practical hands-on programming, interfacing, troubleshooting, and wiring installation of the Modular On-Grid Off-Grid Solar Energy System Mock-up.

There are experts as respondents who was a BS Electrical student purposively chosen to test and validate the level of performance and functionality of the device. They were composed of electrical technology and engineering instructors from BISU Main Campus. These experts were chosen because of their expertise in the field of electrical and wiring installation who can give reliable remarks and ideas regarding the performance of the modular on-grid and off-grid solar energy system.

Instruments

The researcher produced an observation guide in order to gather data in relation to the device's performance and functionality of the Modular On-Grid Off-Grid Solar Energy System Mock-up.

Table 1 The Efficiency of Modular On-Grid Off-Grid Solar Energy System Mock-up in terms of standard rating:

Device	Unit	Standard Rating	One week							Remarks
			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	
Charge Controller	DC V	14.4V	14.4V	14.4V	14.4V	14.4V	14.4V	14.4V	14.4V	Functional
	Vmp 17-75V	41V	41.3V	39.34 V	38.83 V	40.26 V	38.37	41V	39.1V	Functional
Sant Inverter	AC output	220V	224V	223V	224V	224V	224V	223V	224V	Functional
	DC Input	12V	12.8V	12.8V	12.8V	12.8V	12.8V	12.8V	12.8V	Functional
	AC Input	230V	237V	238V	237V	238V	237V	236V	237V	Functional
Grid-Tie Inverter	DC Input	10.8-30 DC	12.8V	12.8V	12.8V	12.8V	12.8V	12.8V	12.8V	Functional
	Ac Output	Total watts per day	**1676.2 W**	**1676.2 W**	**1649.8 W**	**1656.3 W**	**1676.2 W**	**1636.2 W**	**1631.2 W**	Functional

Table 1 shows the functionality of On-Grid and Off-Grid Solar Energy System Mock-up in terms of standard range. The charge controller can receive Output from solar panel with the range of 17-75V and can read the current up to 40A. A fully charged battery is 14.4V. The Snat inverter can receive 12DCV as input and 220ACV as output, it can also receive 220ACV to charge the battery from grid. The Grid-Tie inverter receive 10.8-30DCV as input and accurately match the voltage, frequency and

phase of the grid sinewave AC waveform with an output of 1-200 wattage. Therefore, the standard range of all devices are functional.

Table 2 Performance of Modular On-Grid Off-Grid Solar Energy System Mock-up in terms of Battery capacity in sustaining the loads.

The table 2 showing the 12V 200Ah Lifepo4 Battery capacity in sustaining the loads.

INDUCTIVE LOAD	RESISTIVE LOAD	No. of Loads	No. of Hours used (Hrs)	Total Consump-tion (watts)	Current (A)	State of Discharge (80%)
Electric Fan(140w)		1	6	840	0.65	43.75%
	Led Bulb 15 watts	1	4	60	0.11	3.13%
	Laptop Charger (45w)	1	2	90	0.30	4.68%
2 loads at the same time used.						
Electric Fan(140w)	Led Bulb 15 watts	2	6	930	0.72	48.44%
2 loads while charging using PV						
Electric Fan(140w)	Led Bulb 15 watts	2	4	580	0.72	2%

Table 2 shows the power consumption of the given loads and how long can the battery sustain the given loads. The researcher computed and measured the actual consumption of the device, using the ac monitor instrumentation. The load of the device depends on the number of hours it was used. Operation was computed in watts. Total power consumption in one load was divided to the total battery output which is 2400 watts, that generate the percentage of the total consumption in one load and compared it into the standard which a consumption will not go beyond 80% of the battery capacity. The power consumption of the device was interpreted as functional since it was not going beyond 80% limit of consumption. If two loads are placed, still it will be dependent on the number of hours used. The same method of computation was employed. If a solar panel is used, while adding loads on the off-grid system, only a very minimal battery percentage will be used up since the voltage will just pass by.

The table 3 showing the performance of Grid Tie in terms Output Watts per hour

DAY 1 observation			
Time	**Voltage of solar panel**	**Current**	**Grid-Tie inverter Watts**
7am-8am	38.6V	9.95A	186.9w
8am-9am	40.3V	10.38A	164.7w
9am-10am	41.8V	9.8A	160.0w
10am-11am	40.1V	12.2A	174.5w
11am-12am	45.1V	11.2A	178.5w
12am-1pm	43.2V	10.0A	164.1w
1pm-2pm	42.4V	13.2A	159.8w
2pm-3pm	45.2V	12.4A	180.1w
3pm-4pm	43.6V	7.9A	159.1w
4pm-5pm	28.7V	3.03	148.5w
Total			**1676.2W**
DAY 2 observation			

Time	Voltage of solar panel	Current	**Grid-Tie inverter Watts**
7am-8am	37.6V	8.8A	190.8w
8am-9am	38.6V	10.8A	184.2w
9am-10am	38.4V	12.9A	169.9w
10am-11am	40.5V	10.9A	164.3w
11am-12am	37.4V	13.5A	154.6w
12am-1pm	32.2V	12.8A	168.1w
1pm-2pm	36.8V	10.9A	161.7w
2pm-3pm	44.0V	11.2A	157.5w
3pm-4pm	45.2V	8.1A	150.2w
4pm-5pm	39.7V	5.1A	148.5w
Total			**1649.8W**
DAY 3 observation			
Time	Voltage of solar panel	Current	**Grid-Tie inverter Watts**
7am-8am	39V	9.8A	180.2w
8am-9am	36.3V	10.8A	179.5w
9am-10am	407.2V	12.9A	166.8w
10am-11am	39.9V	11.9A	177.4w
11am-12am	41.8V	12.5A	174.4w
12am-1pm	42.8V	13.8A	165.6w
1pm-2pm	40.8V	11.9A	154.8w
2pm-3pm	41.9V	10.2A	159.5w
3pm-4pm	44.0V	8.1A	152.2w
4pm-5pm	34.2V	6.1A	146.2w
Total			**1656.3W**

The table 3 show that the performance of Grid Tie inverter shows the total watts by each day, Day 1 (**1676.2w**) Day 2 (**1649.8w**) Day 3 (**1656.3w**) The total output of the Grid tie inverter in 3days is **4982.2w.** Grid-tie system store energy in the power grid. During the day, solar power will run through a switchboard.

The table 4 showing the performance of solar panel (450watts) in terms Sunny weather of charging.

DAYS	**Weather Condition**	**Time**	**Voltage of solar panel**	**Current**	**Temp**	**Battery Voltage**	**State of Charge**
1	**Sunny**	7:40am-8:40am	38.6V	10.7A	39.0ºC	12.9V	20%
		8:40am-9:40am	40.3V	19.63A	45.0ºC	13.0V	30%
		9:40am-10:40am	41.8V	9.11A	45.0ºC	13.1V	40%
		10:40am-11:40am	40.1V	18.61A	42.0ºC	13.2V	70%
		11:40am-12:40am	45.1V	4.6A	43.0ºC	13.2V	70%
		12:40am-1:40pm	43.2V	1.63A	40.0ºC	13.3V	90%
		1:40pm-2:40pm	45.4V	1.16A	40.0ºC	13.4V	96%
		2:40pm-3:40pm	45.2V	1.17A	38.0ºC	14.3V	99%
		3:40pm-4:40pm	44.6V	1.15A	38.0ºC	14.3V	99%
		4:40pm-5:40pm	28.7V	0.61A	34.0ºC	14.4V	**100%**
2	**Sunny**	7:15am-8:15am	37.6V	9.85A	37.0ºC	12.9V	20%
		8:15am-9:15am	38.6V	15.83A	41.0ºC	13.0V	30%
		9:15am-10:15am	38.4V	12.6A	43.0ºC	13.1V	40%
		10:15am-11:15am	40.5V	19.88A	47.0ºC	13.2V	70%
		11:15am-12:15am	37.4V	17.18A	45.0ºC	13.2V	70%

		12:15pm-1:15pm	34.2V	16.98A	44.0ºC	13.4V	96%
		1:15pm-2:15pm	36.8V	17.8A	46.0ºC	14.3V	99%
		2:15pm-3:15pm	44.0V	3.25A	43.0ºC	14.3V	99%
		3:15pm-4:15pm	45.2V	1.35A	38.0ºC	14.3V	99%
		4:15pm-5:15pm	42.7V	1.14A	37.0ºC	14.4V	**100%**

Table 4 shows the performance of a 450W solar panel, during a two day of observation. The output voltage of the solar panel is between 34V-45.1V. The rate of charging depends on the daily weather conditions. The researcher observed that on a sunny day, Charging is fast.

The Table 5 showing the performance of solar panel (450watts) in terms Cloudy weather of charging.

DAYS	Weather Condition	Time	Voltage of solar panel	Current	Temp	Battery Voltage	State of Charge
1	Cloudy	7:00am-8:00am	39V	11.64A	35.0ºC	12.8V	10%
		8:00am-9:00am	36.3V	10.20A	40.0ºC	12.9V	20%
		9:00am-10:00am	37.2V	9.16A	38.0ºC	13.0V	30%
		10:00am-11:00am	39.9V	17.30A	43.0ºC	13.1V	40%
		11:00am-12:00am	41.8V	16.27A	43.0ºC	13.2V	70%
		12:00am-1:00pm	38.8V	15.22A	39.0ºC	13.2V	70%
		1:00pm-2:00pm	35.8V	16.25A	40.0ºC	13.3V	90%
		2:00pm-3:00pm	41.9V	10.43A	38.0ºC	13.4V	99%
		3:00pm-4:00pm	42.0V	3.13A	35.0ºC	14.3V	99%
		4:00pm-5:00pm	34.2V	0.23A	34.0ºC	14.4V	100%
2	Cloudy	7:00am-8:00am	38.8V	9.66A	33.0ºC	12.8V	10%
		8:00am-9:00am	37.4V	10.45A	38.0ºC	12.9V	20%
		9:00am-10:00am	37.5V	10.74A	38.0ºC	13.0V	30%
		10:00am-11:00am	37.6V	17.58A	40.0ºC	13.0V	30%
		11:00am-12:00am	37.1V	14.45A	41.0ºC	13.1V	40%
		12:00am-1:00pm	40.0V	16.07A	40.0ºC	13.2V	70%
		1:00pm-2:00pm	36.7V	15.55A	42.0ºC	13.3V	90%
		2:00pm-3:00pm	39.4V	8.25A	38.0ºC	13.4V	99%
		3:00pm-4:00pm	37.4V	5.50A	37.0ºC	14.3V	99%
		4:00pm-5:00pm	34.7V	1.14A	35.0ºC	14.4V	100%

Table 5 shows the performance of a 450w solar panel, during a two-day observation. The average output voltage of the solar panel is in between 34.2v-41.2v. Still, it depends on the daily weather conditions. The researcher observed that on a cloudy day, charging is slow. This implied that the rate of charging depends on the weather condition. On a cloudy day, when the sun is covered with thick clouds, charging time is a bit slow when the sun is not shining brightly.

3. CONCLUSION

From all the data gathered and analyzed, the researcher concluded that the Modular on-grid off-grid solar system mock-up operates on its performance, and functions very efficiently based on the data gathered.

Recommendations

Based on the findings, the following recommendation are given:

1. The Electrical Technology students my adopt the newly – designed Modular on-grid off-grid solar energy system mock-up which is useful and advantageous to their field.
2. The researcher and instructors will introduce the device to other institutions in order to help students observe and perform actual connection and also instructors can

show the actual demonstration to the future electrical students.

3. For the future researcher, this will give them ideas and they may conduct related studies innovating the design of the device.

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