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Implementation of Solar Electricity and Water Filtration systems for a Smart House

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Abstract*: The use of fossil fuels as a source of energy is one of the problems faced by the government nowadays. These cause harmful effects not only on humans, but also on the environment. Another problem is the supply and sanitation of water. The supply is becoming limited especially in rural areas and the sanitation is not being assured. In this research paper, the uses of solar energy and water as alternative sources are discussed. This research implemented solar electricity and water filtration systems for home use. Through these systems, the user can save a minimum of 20% of specific electricity wattage and save a certain amount of filtered water depending on the amount of rainwater collected. The materials used are Solar Panel, AGM Battery, Grid-tie Inverter, Charge Controller, Reverse Osmosis System, LCD, gizDuino+, ATMEGA 324P, and various components like resistors, transistors, and wires that made up the monitoring system's circuit.

***Index Terms*: ATMEGA 324P, gizDuino+, Smart house, Solar panel, Reverse osmosis**

I. INTRODUCTION

Nowadays, the problems of electricity and water consumption are evident. To address these problems, the group decided to design a system which includes the use of solar energy and rainwater. The system that the group is going to design and implement makes use of solar panel which helps in reducing the use of and saving electricity and water filter which also helps in minimizing water consumption, saving water and purifying and filtering rainwater [1]. On one hand, the solar panel is becoming widely used in commercial infrastructures, schools, and even residential areas. With the use of solar panels, sunlight can be converted into electricity [2]. This approach is very efficient in energy conservation and at the same time, it is environment-friendly because no process of burning is involved [3]. According to studies, using solar energy could save about 15% - 20% of energy. This will not only reduce the expenses of the homeowner but also reduces the harm to the environment done by the steam powered generator. Unlike the source from current power supplies, the energy source from the sun is completely renewable. This system is called solar power system [4]. On the other hand, the usage of reverse osmosis filtration system is also becoming helpful because of its function which filters tap or rainwater. By installing the apparatus, rainwater can be filtered into clean water. This water filtration system helps in saving money for the homeowner and at the same time, it also helps in conserving water [5]. Combining the two aforementioned systems, a smart house will be developed. This smart house is a system aimed to help homeowners in conserving electricity and water. A monitoring system is used to monitor the overall functions of both systems. Its database can be in the pattern of this research [6].

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II. SOLAR POWER SYSTEM

The main objectives of this research is to implement a solar electricity and water filtration system for home use while the specific objectives are a) To design and assemble a water filtration system that will be able to filter rain water into utility water b) To use the Reverse Osmosis process for water treatment c) To create a monitoring system for the solar electricity and water filtration system to allow the user to track the level of water and the amount of charge stored in the battery. The solar power system comprises of the following: 100-watt solar panel, AGM and car batteries, grid-tie inverter, and MPPT charge controller. The solar panel is the one responsible for gathering solar energy from the sun and converting it to electricity. For optimization purposes, Spatial Processing, Rough Set Theory and Neural Network can be used [7,8,9,10]. The 100-watt solar panel is used in this project. The AGM battery is used and is the one responsible for storing the gathered energy. If the gathered energy will be used immediately, it will then be supplied to the appliances using a charge controller [11]. The grid-tie inverter converts the collected energy in DC into a clean and stable sinusoidal alternating current which then applied directly to commercial or local electrical grids. It usually supplies a stable sine wave current. The MPPT charge controller matches the output of the solar panel to the battery voltage level. It controls the output of the solar panels and protects the battery from damage due to overcharging [12].

The solar electricity system is fully automated. During the daytime, the solar panel will be responsible for supplying the house. The system aims to producing 20% of the required power of the listed appliances. In case that the system generates more power than expected, the excess power will be stored in the battery for night use. Once the battery is fully charged, all the power generated by the solar panel will be used in supplying the house.

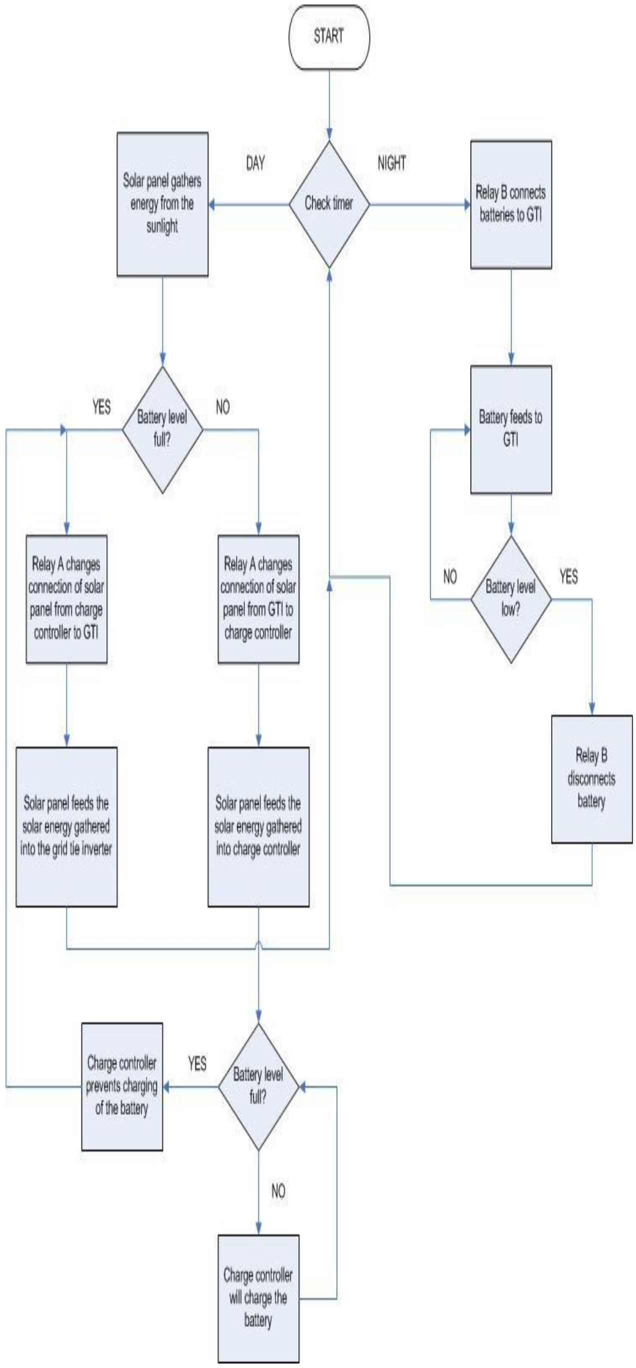

Fig. 1: Solar Panel Circuit Diagram

III. SOLAR PANEL

The total load of the appliances that will be used is 93 watts.

Table I: Solar Panel Computations

Appliances	Quantity	Wattage (W)
Desk Fan	1	40
16inches LED Television	1	20
Portable DVD Player	1	18
LED Light Bulb	1	10
Portable Stereo	1	5
Total	5	93

To compute for the Solar Panel wattage:

{Total Load x Number of Hrs. to be used x Desired Percentage to be contributed by the solar panel x 1.5 (Power Loss Factor)} / 3.5 (Insolation) = Solar Panel wattage (Wp)

Using the above formula, the required Wp is:

{93 W x 12 hrs. x 0.20 x 1.5} / 3.5 = 95.65 Wp ≈ **100Wp**

IV. BATTERY LIFE

In Solar Power Systems, AGM or Absorption Glass Mat battery is the most efficient type of battery to be considered due to its leak/spill-proof capability [13]. It is also the safest out of all the lead-acid types because it does not produce poisonous fumes and does not spill its chemical content due to it's enclosed or sealed casing. AGM is also considered to be the most effective because of its longer life span compared with the Gel and Flooded-type counterparts. The life span of a battery is measured in "cycles". One cycle pertains to one complete discharging and charging of a battery. It can also pertain to the times a battery can be used per day if a cycle is done per day. A life cycle can be observed in relation to DoD or the 'Depth of Discharge'. DoD is the percentage in which the battery is discharged and then charged out of its full capacity.

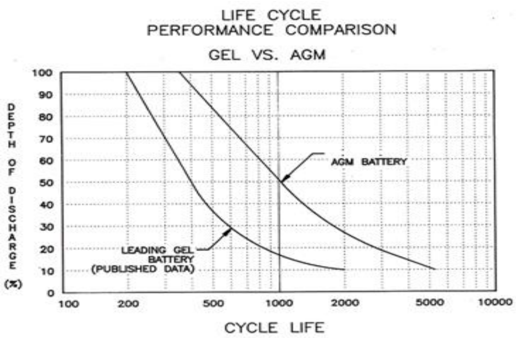

Fig. 2: Life Cycle Performance Comparison – GEL vs. AGM

In the figure above, the comparison between a Gel type and an AGM battery is shown. It can be seen that an AGM battery is a lot more efficient than the Gel type based on the ratio of the Cycle life with the DoD (Depth of Discharge). At 50% DoD, the AGM leads with 500 cycles more compared with the Gel which had only less than 500 cycles. This means that the Gel type can only be charged and discharged (one complete cycle) for 500 times at 50% DoD with its full 100% capacity.

Basing on the percentage of DoD, the Life Cycle or the times the battery can be charged and discharged (one cycle) can be observed. The higher the rate of discharge, the shorter the battery life becomes. If a cycle accounts for one day, then an AGM can be used for 1000 days hypothetically.

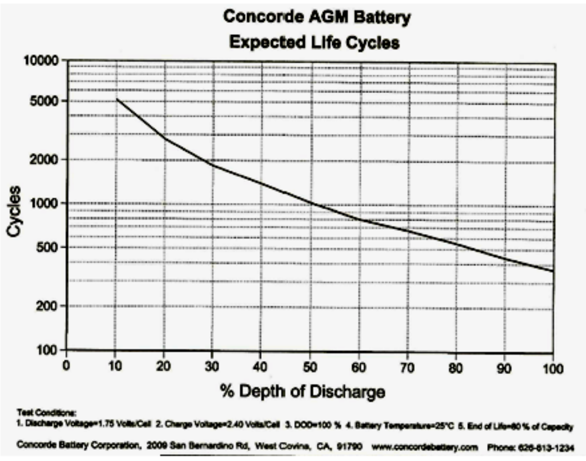

Fig. 3: Concorde AGM Battery Expected Life Cycles

The figure above is based on the life expectancy experiment on an AGM battery manufactured by Concorde.

The experiment which is conducted by the University of Colorado is based on different parameters and conditions such as the rate of charge and discharge both in volts, Depth of Discharge and Battery Temperature. The figure also states that the 'end of life' of the battery is 80% of its capacity (it can no more be charged at 100%).

In determining the Use Life of a battery (the number of hours the battery will last), the total load which can be in watts must be converted first into milliamperes which will then be divided into the total capacity of the battery. An allowance of 70% for external factors is usually allocated by professional engineers to approximate more accurate estimation. The equation is as follows:

$$\text{Battery Use Life} = \frac{\text{Battery Capacity in milliampere/hour}}{\text{Load Current in milliampere}} \times 70\%\ \text{external factors}$$

In the Solar Power System that we will be using, we computed for a total load of 93 watts at 12 volts regulation. Converting this into milliamperes results to:

$$\text{Ampere} = \frac{\text{Watt}}{\text{Volt}} = \frac{93\ \text{watts}}{12\ \text{volts}} \approx 7.75\text{A or } 7{,}750\text{mA}$$

Using it in the 'use life' equation, we can estimate our total battery use life in hours. Since we will be using a 100Ah battery, we get:

$$\frac{40{,}000\text{mAh}}{7{,}750\text{mA}} \times 0.7 \approx 4\ \text{Hours approximately}$$

Judging from the result, the batteries in our system can last up to 4 hours daily if the 93 watts load is consistent. In this approach, the 70% external loss can help produce a more real-life estimation since a battery discharge rate is not wholly reliant on the consuming load.

In our system, which uses the 100-watt Solar Panel as the source, it will be a dedicated charging of the battery. In order to calculate the charge time of our battery, the 100watt must be converted into milliampere first:

$$\frac{100\ \text{watts}}{12\ \text{volts}} \approx 8.33\text{A or } 8{,}333\text{mA}$$

The formula for the actual charging rate is:

$$\text{Time for Full Charge} = \frac{\text{Battery Capacity in mAh}}{\text{Charge rate current in mA}} = \frac{40{,}000\text{mAh}}{8{,}333\text{mA}} \approx 5\ \text{hours}$$

The result is 5 hours before the battery reaches its maximum charge supposing it is completely empty.

V. WATER FILTRATION SYSTEM

The water filtration system comprises of the following: rainwater tank, reverse osmosis system, load cell. Response Analysis can be done like in the Journals of Gustilo et. al. [14,15] The rainwater tank collects the rainwater from the gutter. The rainwater tank collects the water coming from the gutter. The rainwater gathered will then be filtered by the reverse osmosis system [16]. After passing thru the water filtration stages, the filtered water will then be stored in a clean, pressurized tank. The load cell is used for measuring the level of pressurized water in the filtered tank in terms of voltage. The load cell is a type of transducer which when a force is exerted on top, the weight will be converted into an electrical output. The type used in this project is the single point or off-center load cell. This type of load cell is mounted between an upper plate and a lower plate. When a load is applied anywhere on top of the upper plate, the signals produced will all be the same.

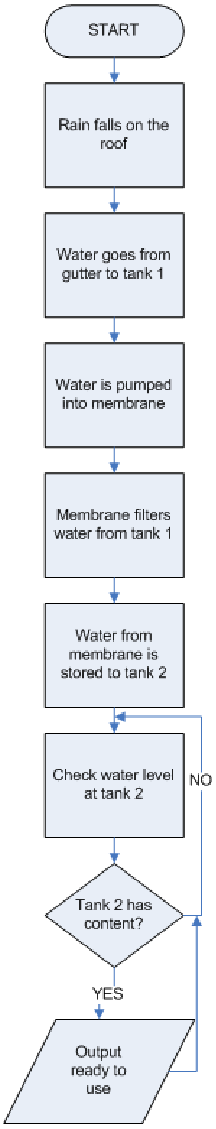

Fig. 4: Water Filtration System

There are three tests done in order to check the quality of the filtered water. These are total dissolved solids, pH test, and turbidity test. Total Dissolved Solids or TDS is associated with the clarity and purity of water and consists of inorganic salts and organic matter. pH stands for potential hydrogen and used as a unit of measurement for acidity, neutrality, and alkalinity and to what specific degree. The pH scale ranges from 0 to 14, 7 being neutral, below 7 being acidic and above 7 being alkaline. Turbidity is the degree of transparency of water due to the presence of suspended particulates.

VI. TOTAL DISSOLVED SOLIDS

Percent rejection rate is the percentage of the contaminants that have been excluded by the water filter.

To measure the percent rejection rate, first, test the TDS level of the tap water. Next, test the TDS level of the filtered water. Last, calculate the percent rejection rate. The formula for the percent rejection rate is:

$$\%\text{Rejection} = \frac{\text{Tap TDS} - \text{RO TDS}}{\text{Tap TDS}} \; x\; 100$$

The higher the percentage of the rejection rate, the better the performance of the water filter. This means that the water filter successfully filtered the tap water. However, the RO membrane should be changed if the percentage is less than 80%.

VII. PH LEVEL

Litmus paper will be used to test the pH level of rainwater and filtered water [17]. It will be dipped in the collection of rainwater and will be observed for changes in its color. The scale of pH is shown below:

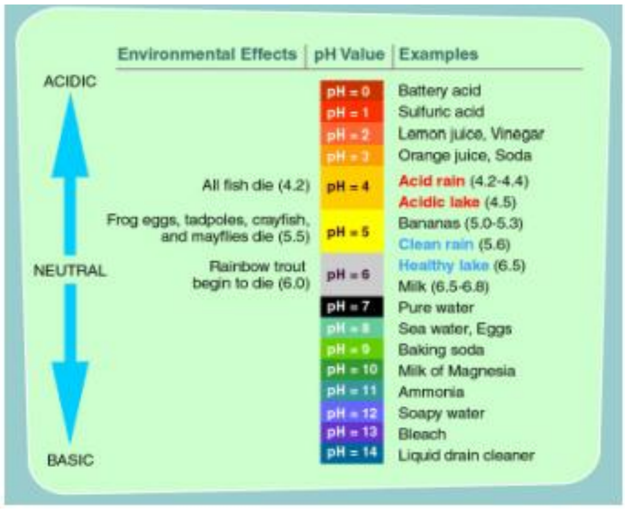

Fig. 5: pH Scale

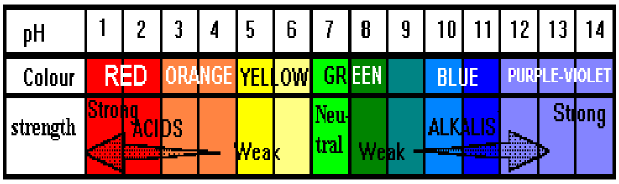

Fig. 6: pH Indicator using Litmus Paper

VIII. MONITORING SYSTEM

A monitoring system is built in order to track the levels of the amount of charge in the batteries and water in the pressurized tank. gizDuino+ board and Atmega324P microprocessor are the main parts of the monitoring system. gizDuino+ is a type of board which is compatible with Arduino IDE and inspired by Sanguino. gizDuino+ offers an additional 12 I/Os compared to the standard gizDuino. It has also an additional hardware UART port and another SPI channel. It's Atmega microprocessor [18] which includes three variants: the ATMEGA644P, ATMEGA324P, and ATMEGA164P. The three ATMEGA microprocessors' only difference is memory capacity wherein it has 64K, 32K, and 16K respectively.

The group selected the ATMEGA324P gizDuino+ since 32K memory would be sufficient for both the battery and water level monitoring systems.

In order to operate or control the modes of operation of the solar electricity system, C language is to be used. The instructions are written or being programmed into the microcontroller after compilation will be able to let the system respond to the inputs from the user, perform logical operations, and output the corresponding result of the system into a display module. Database monitoring is also important [19,20] This research follows the database configurations in the studies of: [21,22,23].

A monitoring box is created for the user to monitor the battery charge and water levels. There are times when the system will have vague values for this Neural Network can be used [24,25,26,27]. It has an LCD display where the levels can be seen. There are also buttons representing the eight functions which the user can select in order to interact with the monitoring system. These eight functions are the following: View Battery Level, View Water Level, Set Time, Increment Hour, Increment Minute, Enter, Manual/Auto, Activate/Deactivate Relay. Computer Vision can be used to further improve the monitoring of the system [28, 29, 30].

IX. ATA AND RESULTS

Table II: Trials in Load Consumption with Solar Panel as Source

Trial	Load	Voltage	Current	Inst Power	Power Supplied	% Supplied	Ave power	Time (PM)
1	63.4	14.5/229.4	3.18	23.1	39.5	62.1	0.012	2:25
2	63.4	14.5/229.2	2.91	25.3	37.8	59.33	0.0091	2:30
3	63.4	14.6/228.3	2.85	20.3	40.9	64.3	0.0052	2:35
4	63.4	14.5/231.4	1.51	29.8	32.5	51.09	0.0043	2:40
5	63.4	15.1/231.4	2.02	24	38.2	60.01	0.0087	2:45
6	63.4	15.3/230.8	1.68	26.4	34.8	54.47	0.0077	2:50
7	63.4	14.4/231.6	1.81	23.2	39.2	61.23	0.0045	2:55
8	63.4	14.5/231.0	1.82	22.1	39.7	62.21	0.0053	3:00
9	63.4	15.0/228.8	1.75	25.8	36.5	57.42	0.0067	3:05
10	63.4	14.9/228.7	2.94	21.3	40.6	64.03	0.0089	3:10
11	63.4	14.8/229.5	2.67	20.1	41.4	65.18	0.0054	3:15
12	63.4	15.2/228.6	1.86	22.3	39.2	61.52	0.0059	3:20
13	63.4	14.7/229.4	1.69	26.6	35.2	55.28	0.0069	3:25
14	63.4	15.1/228.8	2.23	24.9	37.4	58.14	0.0083	3:30
15	63.4	15.1/230.2	3.1	24.5	36.9	58.2	0.0072	3:35
16	63.4	15.0/228.9	2.75	20.4	42.3	66.41	0.0087	3:40
17	63.4	14.9/229.2	2.9	24.8	38.1	60.12	0.0054	3:45
18	63.4	14.6/230.1	3.19	27.4	35.1	55.04	0.0089	3:50
19	63.4	15.2/228.3	2.44	29.1	33.9	53.4	0.0064	3:55
20	63.4	14.4/231.7	3.09	25.2	37.8	59.65	0.0083	4:00

$$Average\ of\ Power\ Supplied = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3 \ldots + Trial\ 20}{20}$$

$$= \frac{757}{20}$$

$$= 37.85$$

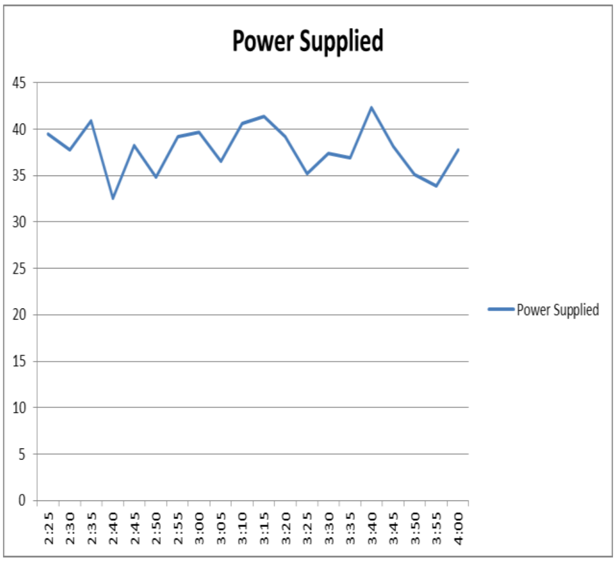

Fig. 7: Power Supplied by the Solar Panel

For this graph, the solar panel supplies at least 20% of the total load.

Table III: Trials in Load Consumption with Batteries as Source

Trial	Load	Voltage	Current	Inst Power	Power Supplied	% Supplied	Ave power	Time (PM)
1	63.4	12.5/232.8	0.81	51.2	12	18.9	0.0024	6:00
2	63.4	12.45/231.7	1.53	50.7	12.6	19.84	0.0038	6:05
3	63.4	12.45/232	1.53	52.7	10.5	16.5	0.003	6:10
4	63.4	12.45/236.2	0.6	53.2	10	15.7	0.0058	6:15
5	63.4	12.48/235.4	0.61	56	7.2	11.25	0.0037	6:20
6	63.4	12.46/234.8	1.32	55.4	7.8	12.23	0.0032	6:25
7	63.4	12.30/238.2	1.63	42.7	20.5	32.3	0.0028	6:30
8	63.4	12.30/237.7	1.57	44.2	19	29.77	0.0037	6:35
9	63.4	12.32/234.3	1.2	47.6	15.6	24.5	0.0039	6:40
10	63.4	12.34/230.0	1.35	45.3	18	28.21	0.0038	6:45
11	63.4	12.40/238.2	1.5	45	18.2	28.54	0.0035	6:50
12	63.4	12.37/233.4	1.04	44.1	19	29.87	0.0027	6:55
13	63.4	12.42/234.5	1.24	47.9	15.2	23.8	0.0043	7:00
14	63.4	12.39/235.6	0.98	50.2	13.1	20.5	0.0035	7:05
15	63.4	12.48/230.6	0.95	53.4	9.7	15.19	0.0053	7:10
16	63.4	12.37/234.9	1.17	50.3	12.9	20.2	0.0062	7:15
17	63.4	12.30/235.5	0.79	47.6	15.3	24.02	0.0052	7:20
18	63.4	12.42/236	1.01	45.2	18	28.15	0.0085	7:25
19	63.4	12.45/232.7	0.88	49.3	13.7	21.45	0.0076	7:30
20	63.4	12.49/236.5	0.71	44.1	19	29.84	0.0083	7:35

$$Average\ of\ Power\ Supplied = \frac{Trial\ 1 + Trial\ 2 + Trial\ 3 \ldots + Trial\ 20}{20}$$

$$= 287.3/20$$

$$= 14.37$$

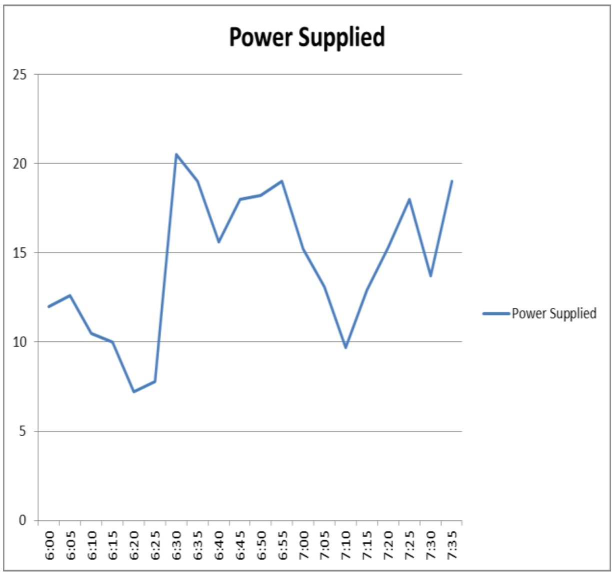

Fig. 8: Power Supplied by the Batteries

The chart shows that the power supplied by the batteries is fluctuating. There are trials wherein the 20% is reached and there are some that did not reach 20%. This is due to the temperature, depth of discharge and maintenance of the batteries. Tables 2 and 3 summarize the twenty trials done while the five appliances are being operated with the solar panel and AGM battery as the sources. The tables consist of five parameters namely load, voltage, current, instantaneous power, average power, and time. As an alternative PLC and FPGA can be used for the system. The load is the total wattage consumed by the five appliances which are measured by the watt meter. To distribute the signal wireless technology can be used [31]. The voltage measurement is obtained from the wattmeter. Just like what is done in the researches of [32, 33]. Current is the result of dividing the instantaneous power by the voltage. Instantaneous power is the power consumed by the load minus the power supplied by the solar panel. This is also obtained through the watt meter. Power supplied is the power contributed by solar panel or batteries [34]. This is obtained through the reading of the wattmeter when no load is plugged. Multipath clustering can also be performed to improve the performance [35]. Average power is the power obtained in a certain period of time and expressed in terms of a kilowatt-hour. The time of each trial is also recorded. The total load recorded based on the watt meter is 63.4 watts and 20% of this is 12.68 watts. This means that at least 12.68 watts should be contributed by the solar panel and batteries. For the solar panel, the maximum contribution of the solar panel without any load connected is 63.3 watts. The time when this measurement was taken was at 2:00 in the afternoon. These data can be send through a wireless system or transmitterless systems just like in the studies of [36, 37]. There are five levels assigned to the filtered water tank/pressurized tank. These levels are Full, High, Medium, Low and Empty. Each of the water level's corresponding volume and weight are shown in the table below. These are obtained through the use of a weighing scale. The load cell's output is expressed in volts. The motor will turn on only from empty to high.

Table IV: Water Level and corresponding volume, weight and motor status

Water Level	Water Volume (Liters)	Weight (Kilos)	Motor State
Full	9	9	OFF
High	7	7	ON
Medium	5	5	ON
Low	3	3	ON
Empty	0	0	ON

X. CONCLUSION

The research group is able to implement a solar electricity system that saves at least 20% of the electricity wattage consumed. The solar electricity system was also connected in parallel with the main power grid. When the solar panel is connected to the grid-tie inverter, the solar panel helps in saving at least 20% of the total wattage consumed. The batteries, which are connected in parallel, are also connected to the grid-tie inverter. These also lessen the consumption of electricity. The water filtration system was implemented by designing our own structure and by using a reverse osmosis system. This water filtration system was able to filter rainwater into utility water. The water filtration system is designed to collect a certain amount of rainwater flowing from the gutter to the rainwater tank and using a reverse osmosis system to treat and filter the rainwater collected. The filtered water is then stored in the pressurized tank and can be used already as utility water. The voltage levels of the batteries and water levels in the pressurized tank were monitored through the use of our own monitoring system. The levels are displayed on the LCD. For the water filtration system, a load cell is used to measure the level of water inside the pressurized tank. The output of this is expressed in voltage. Gizduino+ and Atmega324P are used in storing the main program of the monitoring system. Comparative analysis can also be used in terms of cost and design parameters. The Total Dissolved Solids (TDS) and pH levels of the rainwater and filtered water are tested for comparison. It is proven that the filtered water can be used as utility water because its TDS level is 4 ppm which is within the ideal range of TDS (0-50 ppm) and the pH level is neutral. The project can be further improved by adding functions to the monitoring system such as designing a module that will be able to take control of the usage of each appliance at home. To be more specific, the module will be able to set the on and off time of an appliance. A GUI will be designed for the monitoring system and an application consist of the same functions will be designed and made compatible with mobile phones, tablets, and personal computers. By doing this, the user will be able to take control of the monitoring system even outside the house. Another improvement would be to increase the number of panels and batteries to be used. So far, the current system can only supply for low power appliances.

By increasing the power generated and power storage, the system would be able to sustain the consumption of high-power appliances like refrigerators or air conditioning units.

Since the thesis already focuses on solar energy, another improvement would be to create a module that would allow movement for the solar panels. The module would be containing a sun intensity monitor/sensor which tells the system where the panel will be moving depending on the behavior of the sun through rotational or slope movement. While it would require additional resources, it could improve the efficiency of solar energy harvesting.

Using off-grid inverters would further maximize the usage of batteries because off-grid inverters draw current from the battery only when there are appliances connected to it. Otherwise, the battery will not be drained. Unlike using grid-tie inverters, it will continuously drain the battery even if no appliance is connected to it. Using off-grid inverters will also prolong the life of the battery because it does not deeply drain the battery below its usable level.

The usage of a car battery is chosen when a high current is wanted. But it will be used only for a short period of time, while the usage of the deep cycle is preferred when the battery will be used for a long time.

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