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Design, Development, and Evaluation of a Microgrid for the Energy Management in a Small Poultry

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ABSTRACT

The Development of an Energy Management System for a Small Poultry is another solution to help the poultry raisers/farmers obtain a reasonable and renewable source of energy. A microgrid can be characterized by its integration of distributed energy resources and controllable loads. Such integration brings unique challenges to the microgrid management and control which can be significantly different from conventional power systems. The developed device is composed of the following major components: brooder, where the chicks are placed, and the electronic devices are installed; a relay which monitors and controls the power supply of the system; a solar panel and battery that captures and saves the energy from the sun; and an inverter that converts direct current to alternating current. The total power of the poultry is 33W and used 560W per day of the power source from the battery. Test results showed that the contribution of saving power consumption reached 83% and losses are 35.75%. The voltage of the battery in 100% reached to 12.4V down to 2% has 10.45V. The actual testing for amperes of the bulb is 2.5A, the counter has 0.6A, and the temperature has 0.25A. The actual wattage of bulb is 30W, and temperature has 3W. The performance of the prototype was evaluated by twenty (20) panel of evaluators composed of electronic technicians and engineers, agriculturists, and poultry farmers using the Technological University of the Philippines (TUP) Evaluation Instrument for Prototype Developed. The prototype got a grand mean of 4.72 with a descriptive rating of "Excellent" which proves that the project reduces the consumption of electricity from the commercial power distribution.

***Keywords* —** Energy management, microgrid, Small poultry, experimental, Manila, Philippines

INTRODUCTION

An energy management system is a systematic process for continually improving energy performance and maximizing energy savings. The principle of an energy management system is to engage and encourage staff at all levels of an organization to manage energy use on an on-going basis (Kahlenborn, Kabisch, Klein, Richter, & Schürmann, 2012). Energy efficiency means using less energy for the same or increased output. It is increasingly being recognized as one of the most important and cost-effective solutions for reducing greenhouse gas emissions produced as part of industrial processes (Bautista, Ong, Pineda, Urbano, Uy, & Dulay 2015).

Today, electricity is essential in daily life. Electricity is generated from various sources of energy and then distributed through the grids to consumers. For decades, most countries rely on large grids to fulfill electricity needs. However, with the rapid development of technology, there is a significant contribution from smaller grids all over the world in recent years, especially to fulfill the demands in remote areas. Based on geography, ASEAN Member States (AMS) have mountainous areas, forests, and islands (remote islands). This has brought the opportunity for AMS to develop microgrids or smart grids as part of the effort to increase the electrification ratio in remote area/islands. However, microgrids and smart grids are not only for the remote area as a stand-alone system (off-grid), but also could be integrated with the nearest national grid (or grid-connected) (Pranadi, 2016).

The Philippines' high electricity rates have not only hurt ordinary consumers but have also served as among the biggest barriers against investments in the country. What the country needs is a stronger state that can bust oligarchic collusion, and protect the interest of the consumers and productive sectors of the economy (The Energy Philippines, 2014).

The electricity is insufficient specifically in Mindanao – Region IX, Zamboanga Peninsula. The consumers have encountered a serious problem with the electricity supply in this region. This is usually occurring every start of summer and even during the rainy season and any time of the year. The water supply is decreasing because of the long summer where heat is strong, and rain is no longer evident. This would take two (2) to four (4) months brownout and the consumers are experiencing this every year. At present, the supply of energy in Zamboanga Peninsula area is insufficient.

On poultry population, as of January 1, 2014, the total chicken population was 167.67 million birds higher than last year's headcount of 166.39 million birds. The inventory of broilers and native/improved grew by 4.03 % and 1.19 %, respectively (Philippine Statistics Authority, 2015).

The supply of the electric power in the poultry industry is vital to give the consistent heat to sustain needed heat of the bodies of the newly hatched chicks. In this study, one piece of the 25-watt bulb will be connected to the microgrid that will serve as the source of heat for a group of 25 chicks. This heat would maintain the appropriate temperature during brooding for a period of more or less 21 days. This is the time where chicks require a constant supply of heat while feathers begin to grow and develop but still unable to protect their body from the external environment. This is why provision of artificial heat becomes a very necessary process for birds to cope up from temperature stress and survive normally. There are several sources of artificial heat for the chicks during brooding.

The most common source is electricity supplied by Zamboanga City Electric Corporation (ZAMCELCO) an electric cooperative operating in Zamboanga City, however, it is costly, irregular, and insufficient. The author has thought of studying the possibility of using an alternative renewable, cheap and environment-friendly source that would supply energy to the chicks using microgrid, hence this study. The microgrid is one way to solve the problem of the power crisis in Zamboanga city where brownouts occur for more than six hours a day. It is noted that the use of a generator to supply electricity during brooding is very costly. Hence, the installation of a microgrid is an answer to this dilemma. This can help poultry farmers in the area which cannot afford generator set or use of electricity for raising poultry. This equipment will be easy to use and convenient because it is simple to operate and requires less monitoring work since it is programmable. It could be automatically switched on and off both the solar panel from the heat of the sun and the supply from the utility grid.

Therefore, the development of microgrid is facilitated by switching on the supply of power from the battery that comes from the heat of the sun.

The existence of this equipment can really support the chicks' temperature requirement during the brooding in the poultry house. The adoption of this technology is the ultimate solution for the farmers who can now obtain a cheap and renewable source of energy from the sun. The Solar Panel is huge that could contribute to the non- stop source of electricity that is essential to effect a more efficient and effective poultry production system. This is of great help to the reduction of electricity consumption cost and at the same time easy to install, portable and most especially an environment-friendly technology.

Conceptual Model of the Study

On the basis of the foregoing concepts, theories, and findings of related literature, studies presented, and insights taken from them, a conceptual model is developed as shown below.

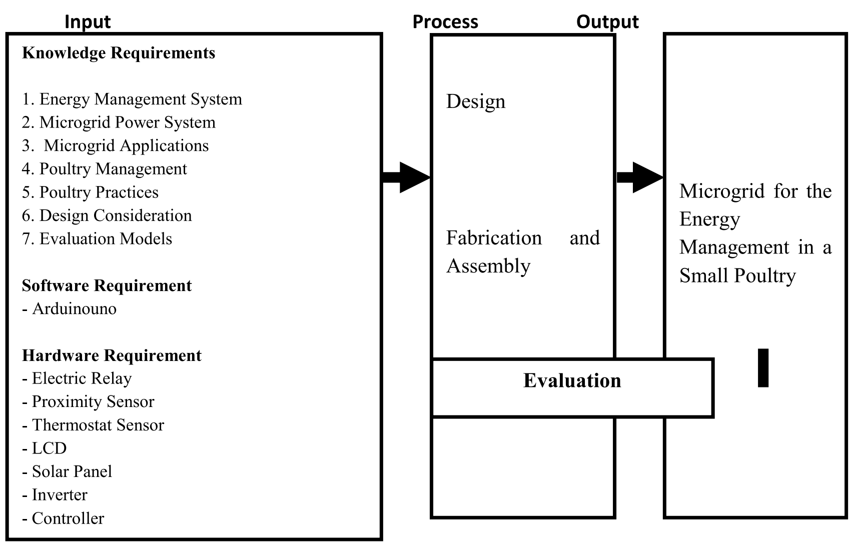

Figure 1. Conceptual Model of the Study

Figure 1 shows the conceptual model of the study of the different stages of the process involved in order to achieve the objectives of the study. The input stage consists of the knowledge requirements needed in the design and development of the microgrid for energy management in small poultry. The knowledge requirement includes the topics for the energy management, microgrid management, and poultry management system. Hardware requirements consist of the important part of the electric study relay, proximity sensor, thermostat sensor with LCD display, solar panel, counter with LCD display, inverter, and solar charge controller. The software is Arduino Uno for the coding. The process block is composed of the system design, fabrication and assembly, and the testing of the prototype. The fabrication has two (2) phases: the circuit and casing fabrication. Finally, an evaluation on the performance of the system is done a panel of evaluators. The output of the study is the microgrid for energy management in small poultry.

OBJECTIVES OF THE STUDY

Generally, it aims to develop a Microgrid for Energy Management in a Small Poultry. Specifically, it aimed to answer the following (1) Design a micro-grid system with the following features to; (a) manage the power supply inside the brooder, (b) include a monitoring and control panel for the system, (c) monitor and controls the temperature of the brooder, (d) compute the area of the solar panel based on the assumptions of the number of chicks, (e) determine the total power of the brooder, (f) also determine the losses in each of the parts of the electrical system, (2) to construct the prototype, as designed; (3) to test and improve the developed prototype; and (4) to evaluate the performance of the developed prototype.

METHODOLOGY

Research Design

Microgrid for the Energy Management in small poultry is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that act as a single controllable entity with respect to the grid. It consists the two (2) way automatic switching responsible for the energy distribution from the Solar and utility grid as shown in Figure 2. The loads for the distribution of power supply are the monitoring device installed on top of the brooder and the 25W bulb inside the brooder.

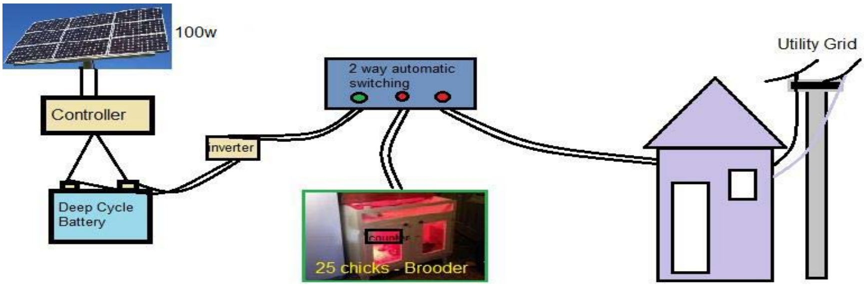

Figure 2. Block Diagram of the Study

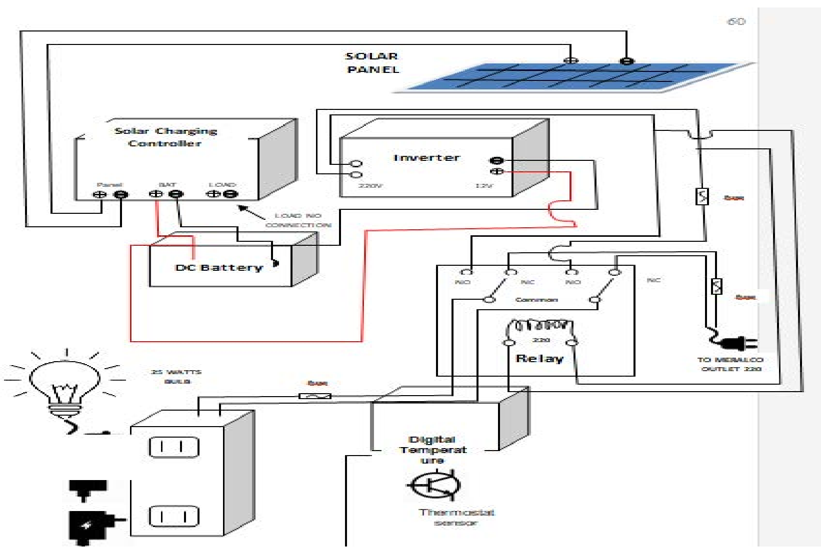

Figure 3. Circuit Diagram of Microgrid
in a Small Poultry with Temperature

Figure 3 shows the circuit diagram of the microgrid. This consists of the utility grid connected to the island mode which is the controller. On the other, another alternative source of energy is coming from the Solar which is coming from the sun. The solar panel contains 100W is also connected to the island mode. The two-way automatic microcontroller is responsible for managing the energy distribution in the brooder cage. The 25W bulb is responsible for giving the heat for the chicks in order for them to live and grow their feathers for 21 days period.

This will be operated by two operation modes: the grid-connected mode and the island mode. In the grid-connected mode, a microgrid is connected to a power system, especially a distributed system in the utility grid. On the other hand, the island mode means isolated operation mode energy is coming from the solar sun's energy.

This device has a small power system composed of one or more distributed generation units that can be operated independently or connected to the utility. The microgrid is a small scale flexible reliable source of electricity. This is connected to both local generating system units and utility grid to prevent outages. The green color as indicated above is represented that the energy is coming from the utility grid. On the other hand, the deep cycle is already empty.

Project Development

The preparation and installation of the various components of the project, Microgrid for Energy Management in a Small Poultry, used the following procedures:

1. The needed materials and devices were prepared such as, solar panel, deep cycle (DC) battery, solar charge controller, power inverter, relay responsible for the energy management coming from both utility grid and Sun's energy, wooden brooder for the chicks, temperature with LCD display and the 25W bulb.
2. The 100W Solar Panel was set up connected to the solar charge controller to DC battery, DC to a power inverter in its proper place.
3. The relay was set up on its proper place.
4. The brooder cage was prepared and the 25 heads of chicks' were purchased as subjects for observation good for 14 days.
5. The 25w bulb was fixed inside the brooder;
6. The temperature control panel with LCD display was placed on top in the brooder.
7. The software was prepared for installation ready to monitor the heating temperature inside the brooder.
8. Finally, all the devices were tested for their functional operations.

Brooder

1. All the materials for constructing the brooder were prepared, such as, lumber, nails, plywood, bolts, and the plastic screen.
2. The plywood was cut into 36 inches and 42.5 inches.

3. The lumber was cut at least 4 by 27 inches.
4. Eight holes were drilled for the bolts to fasten.
5. The plastic mesh was cut into size 18 x 42.5 inches.
6. Then, all four sides were assembled by inserting the bolts on all 8 holes.

Temperature Panel

1. The gizDuino was inserted onto the LCD.
2. Wires on positive and negative adaptor were connected on the LCD.
3. The LM34 inserted into the thermostat sensor.

Operation and Testing Procedure

Operation Procedure

The following steps were done to maintain the normal operations of the project.

1. First, the solar panel was exposed in the sun for 12 hours.
2. Connect the relay to 220V from the utility grid.
3. Connect the solar panel to solar charge controller to the deep cycle battery.
4. Connect the power inverter to 220V to DC battery.
5. Plug the 9V temperature with LCD display to 220V.
6. Plug the 25W bulb to 220V.

Testing Procedure

Three (3) tests were performed for pilot testing of the developed prototype, namely: reliability test, quick response test, and functionality test.

A. Reliability Test

1. Test the relay for proper switching and energy distribution.
2. Test the solar charge controller for battery charging consumption.

B. Quick Response Test

1. Monitor switching speed of the relay.
2. Check temperature monitoring inside the brooder.
3. Monitor the time of solar battery charging.

C. Functionality Test

1. List down the charging time of the solar charge controller to DC battery.
2. List down the time consumption of the DC battery to load per day.
3. List down the number of seconds of switching relay.

Table 1. Testing for DC Power Supply

Time	Battery (voltage)	Bulb (A)	Temperature (A)
6:00 am	12V	3A	1A
7:00 am	12V	3A	1A
8:00 am	12V	3A	1A
9:00 am	12V	3A	1A
10:00 am	12V	3A	1A
11:00 am	12V	3A	1A
12:00 pm	12V	3A	1A
1:00 pm	12V	3A	1A
2:00 pm	12V	3A	1A
3:00 pm	12V	3A	1A
4:00 pm	12V	3A	1A
5:00 pm	12V	3A	1A
6:00 pm	12V	3A	1A

Table 1 shows the assumption of the testing DC power supply for voltage and ammeter of DC battery, the incandescent bulb, and temperature with LCD. This is to test and determine the actual voltage and ammeter of the power supply distributed by the DC battery.

Evaluation Procedure

The evaluation is one way to determine the efficiency, accuracy, functionality and acceptability as designed to assess the energy management in small poultry. People were selected as respondents and were asked to rate the performance of the device. These respondents composed of twenty (20) professionals in different fields related to electronics such as engineers, technicians, instructors and poultry farmers. Prior to the actual demonstration and evaluation of the device, the researcher had explained the function of the device as well as specification of the prototype. Furthermore, the researcher also discussed the contents of the evaluation sheet before this was given to each respondent.

The instrument used for evaluation of the device comes from the Technological University of the Philippines. This instrument had the following criteria: functionality, aesthetics, workability, durability, economic value, safety, and salability are part of the instrument. One portion of the evaluation was the "Comments and suggestions from the evaluators". This was intended for additional improvements on the device for its system of energy distribution on poultry.

The evaluation was accomplished and the results were organized, tabulated and computed statistically to find the mean of every criterion as well as the overall mean.

Table 2. Likert Scale of Rating

Numerical Rating	Equivalent Meaning
4.51 - 5.00	Excellent
3.51 - 4.50	Very Good
2.51 - 3.50	Good
1.51 - 2.50	Fair
1.0 - 1.50	Poor

Table 2 shows the Likert scale of rating that the result of the evaluation will be based on the tabulated and computed mean score. This will be graded on the numerical rating and will be interpreted on the equivalent meaning.

RESULTS AND DISCUSSION

Project Description

The project is about the development of a microgrid design for energy management in small poultry. The system has two energy sources, the utility grid which is 220V and the DC battery that contains the energy captured from the heat of the sun using the solar panel. The relay is responsible for energy distribution; it will automatically switch on and off.

The temperature sensor with LCD display monitors the temperature inside the brooder. The 25W incandescent bulb is the source of heat inside the brooder so the chicks can sustain their internal body temperature from coldness. The temperature for the first week is 32.2^0C – 35^0C, the second week is 29.4^0C – 32.2^0C, the third week is 29.4^0C – 26.7^0C, and for the fourth weeks is 23^0C.

Project Structure

The project is composed of two parts, the hardware and the software. The hardware parts are the following: solar panel, solar charge controller, DC battery, inverter, relay, and the 25W incandescent bulb. The software is built-in using Arduino Uno on temperature and chicks both with LCD display.

Project Capabilities and Limitations

The project prototype has the following capabilities: (1) can monitor the temperature inside the brooder, (2) can automatically switch on and off the energy supply from utility grid and DC battery, (3) can decrease the bill from the utility grid, (4) Low current, and (5) can switch on and off the relay for 2 seconds both from utility grid and DC battery.

However, the project has the following limitations, (1) the energy consumption from DC battery last for 14 hours, and (2) the proximity collision sensor is sensitive and can detect up to 25 cm.

The following details show the different computations regarding the design, implementation and testing conducted on the prototype.

Area of Solar Panel based on the Number of Chicks
1watt per chick X 10,000 chicks = **10,000watts**
Area of 100 watt Solar Panel
A = L X W
A = 48 in X 21.5 in
A = **1,032 sq. inches**

Table 3. Result of DC Testing for Ammeter

Time	Battery	Voltage (V)	Bulb (A)	Temperature (A)
6:00 am	100%	12.6	2.5	0.25
7:00 am	93%	12.5	2.5	0.25
8:00 am	86%	12.42	2.5	0.25
9:00 am	79%	12.38	2.5	0.25
10:00 am	72%	12.35	2.5	0.25
11:00 am	65%	12.27	2.5	0.25
12:00 pm	58%	12.15	2.5	0.25
1:00 pm	51%	12.02	2.5	0.25

2:00 pm	44%	11.9	2.5	0.25
3:00 pm	37%	11.5	2.5	0.25
4:00 pm	30%	11.08	2.5	0.25
5:00 pm	23%	10.89	2.5	0.25
6:00 pm	16%	10.65	2.5	0.25
7:00 pm	9%	10.57	2.5	0.25
8:00 pm	2%	10.45	2.5	0.25

Table 3 shows the result of DC testing for the ammeter. The voltage that is coming from the DC battery changes from 100% is in full charge and it has 12.6V. The level of DC battery becomes lower; the voltage also is going low where 2% is at the lowest level where the voltage is 10.45V. The bulb ampere has 2.5A, and the temperature has 0.25A.

Table 4. Result of DC Testing for Wattage

Time	Battery	Bulb (W)	Temperature (W)	Total
6:00 am	100%	30	3	40
7:00 am	93%	30	3	40
8:00 am	86%	30	3	40
9:00 am	79%	30	3	40
10:00 am	72%	30	3	40
11:00 am	65%	30	3	40
12:00 pm	58%	30	3	40
1:00 pm	51%	30	3	40
2:00 pm	44%	30	3	40
3:00 pm	37%	30	3	40
4:00 pm	30%	30	3	40
5:00 pm	23%	30	3	40
6:00 pm	16%	30	3	40
700pm	9%	30	3	40
8:00 pm	2%	30	3	40
			Grand Total	560

Table 4 shows the result of DC testing for wattage. The monitoring is 14 hours to get the accurate data from a 100% level of DC battery down to 2%. The incandescent bulb is 25W but the actual is 30W, and the temperature is 5W and the actual is 3W. The total power wattage of all the supplies are 30W and the grand total is 560W per day.

Table 5. Results of Solar Charging

	Solar Charging			
Number of Days	Time in (Charging)	Time out (Charging)	Percent of charging	Total Number of Hours
Day 1	7:00 am	6:00 pm	90%	11 hrs
Day 2	7:00 am	6:00 pm	40%	11 hrs
Day 3	7:00 am	6:00 pm	40%	11 hrs
Day 4	7:00 am	4:00 pm	100%	9hrs
Day 5	7:00 am	6:00 pm	40%	11 hrs
Day 6	7:00 am	4:00 pm	100%	9 hrs
Day 7	7:00 am	4:00 pm	100%	9 hrs

The table 5 shows the results of solar panel captured the heat of the sun and charge to DC battery controlled by a solar charge controller. This is the actual result of the total hours per day. The full charge of the DC battery is 9 hours in high humidity and good weather. The minimum charge is 40% in 11 hours in cloudy weather.

Table 6. Results of Battery Used

	Solar Discharging			
Number of Days	Time in (Charging)	Time out (Charging)	Total Number of Hours	Battery Used
Day 1	6:00 pm	6:00 am	12 hrs	90%
Day 2	6:00 pm	1:00 am	7 hrs	40%
Day 3	6:00 pm	1:00 am	7 hrs	40%
Day 4	6:00 pm	8:00 am	14 hrs	100%
Day 5	6:00 pm	1:00 am	7 hrs	40%
Day 6	6:00 pm	8:00 am	14 hrs	100%
Day 7	6:00 pm	8:00 am	14 hrs	100%

Table 6 shows the results of the battery used. The supply loads of battery are the 25W incandescent bulb, and 3.5W temperature with LCD. The average hours that the battery can supply is 14 hours in a full charge and the shortest hours is 7 hours in 40%.

Project Evaluation

The project was set-up and evaluated in Technological University of the Philippines - Manila as seen in Figures 20 and 21 and assessed the performance in terms of its Functionality, Aesthetics, Workability, Durability, Economy, Safety and Saleability. Table 8 shows a summary of the evaluation results of the performance of the project.

Table 7. The Mean Scores and Results on the Evaluation of the Project

Criteria	Mean Scores	Equivalent Meaning
Functionality	4.67	Excellent
Aesthetics	4.42	Very Good
Workability	4.82	Excellent
Durability	4.78	Excellent
Economy	4.82	Excellent
Safety	4.65	Excellent
Saleability	4.85	Excellent
Overall Mean	4.72	Excellent

Table 7 shows the mean scores and descriptive equivalents of respondents' results on the evaluation of the project.

The Functionality of the machine got an average mean of 4.67 which has a descriptive rating of "Excellent". It signifies that the project functioned as designed, easy to operate, convenient and user-friendly.

The Aesthetics of the project had a mean rating of 4.42 which is described to be "Very Good". This implies that the size of the project depends on the number of chicks and the design is appealing to the eyes of the evaluators.

The Workability of the project was "Excellent" with an average mean of 4.82. This shows that the materials used are locally available, the technical expertise needed to make the project work as well as the tools, machines and devices were all readily available.

The criteria of Durability gained an average mean of 4.78 which is described to be "Excellent". This indicates the quality of the materials used, its design and workmanship.

In terms of Economy in relation to the materials needed, time and labor spent and machines required, the evaluators gave an average mean of 4.82 which has a descriptive meaning of "Excellent".

The Safety of the device was given a mean of 4.65 which denotes to be "Excellent". It indicates that there was an absence of sharp edges, along with the provision for the protection of devices and the resulting design is safe from electric shock.

The Saleability of the overall project was given a mean of 4.85 which denotes to be "Excellent". It indicates that there was a necessity on demand for the poultry raisers specifically on areas experiencing brown out every day.

Results of the evaluation revealed that the respondents are satisfied with the outcome of the project and gave an overall mean score of 4.72 with a descriptive meaning of "Excellent".

CONCLUSIONS

In consideration of the objectives of the study and the results of the project evaluation, the following conclusions are derived (1) The Design of the prototype has the following features: (a) the project installed a relay device for immediate managing the power supply inside the brooder, the energy has two sources, one is from the utility grid and the other one is from the solar panel charge on DC battery; (b) the 100W solar panel can charge the 50Ah DC battery for 9 hours in 100% and 11 hours in 40% during cloudy weather, the usage of 100% reached up to 14 hours and 9 hours for 40%. (c) the brooder has a temperature with an LCD display that monitors the temperature inside the brooder for the first week is 32^0C, the second week is 29^0C and third week is 26^0C. (d) The total area of the solar panel is 1,032W; (e) the brooder has a total power of 33W and 560W consumption of the load from the DC battery per day; (f) the losses of the electrical system is 0.1kwh and 35.75%. (2) The designed prototype is based on the evaluation of the respondents' that the prototype has a mean rating of 4.42 which is described to be "Very Good". This implies that the size of the project depends on the number of chicks and the design is appealing to the eyes of the evaluators. (3) The result in testing, the actual wattage of the supplies in the brooder such as the bulb has 30W, and the temperature sensor is 3W. (4) The performance of the prototype and the electrical system of the brooder in terms of energy management has an overall mean score of 4.72 in the descriptive rating of "Excellent". It is evident that the prototype is working well.

TRANSLATIONAL RESEARCH
USER MANUAL

1. The project has following major components: brooder, where the chicks are placed, electronic devices are installed, relay, which monitors and controls the power supply of the system, solar panel and battery, that captures and saves the energy from the sun, inverter, that converts direct current to alternating current.
2. Micro-grid is island mode means isolated operation mode energy is coming from the solar sun's energy. This is connected to both local generating system units and utility grid to prevent outages. The green color is represented that the energy is coming from the utility grid. On the other hand, the deep cycle battery is already empty.
3. The two (2) ways automatic switching responsible for the energy distribution from the Solar and utility grid. The loads for the distribution of power supply are the monitoring device installed on top of the brooder and the 25W bulb inside the brooder.

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