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# THE POTENTIAL ECONOMIC ANALYSIS OF SOLAR HOME SYSTEM WITH SWITCHING METHOD ON HOUSEHOLD ELECTRICITY SCALE

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***Abstract***

This study aims to design a Solar Home System with an Arduino-based Smart Switching system so that the use of electrical energy generated by solar panels can be adjusted without adding power from other electricity sources, such as PLN. Calculation of Leveled Cost of Energy (LCOE) is used as the basis for the switching process that will be carried out to regulate the use of household appliances that are routinely used, regulate electricity consumption automatically, minimize usage, and calculate the effectiveness of electric power usage. The way SHS works is to collect electrical energy from sunlight, then convert DC voltage to AC so that it can be used to run household electronic equipment. To accommodate the adequacy of electrical power, an automatic adjustment is made for household appliances that are routinely used, namely house lights, which includes setting the lights on and off and the number of lights that can be activated. The advantage of this research is that the SHS system is integrated with the automatic setting of the lights installed in the house so that the number of lights on will adjust the availability of electrical energy in the battery. In addition, with the LCOE method, the level of usage can be calculated so that users can save electricity. From the results of usage testing, it is found that the application of this switching technology provides benefits for users because it is no longer dependent on PLN supply. From an economic point of view, based on the calculation of Leveled Cost of Energy (LCOE), there is a kWh value savings of Rp. 77, - for each kWh price or about 4.53% compared to purchasing electricity with prepaid mode.

***Keywords: Solar Home System, Arduino, Switching, Leveled Cost of Energy***

## INTRODUCTION

Solar Home System (SHS) technology has started to be developed in Indonesia since 1980, but until now its application is still limited to SHS as a government assistance program that is provided on a subsidized basis to people in areas not yet reached by the State Electricity Company (PLN). Based on data from research conducted by the Institute for Essential Services Reform (IESR) in 2019, the contribution of SHS to national installed electrical energy is still very small, namely until the end of 2018 the total installed capacity of SHS in Indonesia has only reached 95 Megawatt-peak (MWp), far from the potential SHS installed capacity, which is 93 to 116 Gigawatt-peaks (GWp) (Damayanti *et al.*, 2018).

One of the reasons for the slow development of solar power utilization as a source of electrical energy in the household sector, among others, is the top-down approach used so that it is still very dependent on government programs targeting people with low financial capacity and located in areas of Indonesia that are unreachable by PLN. In fact, according to the Technical Report on Residential Rooftop Solar Potential in 34 Provinces in Indonesia (IESR, 2019), 17.8 percent of the total number of households in 34 provinces in Indonesia has the potential to be developed into a Solar Home System. The potential households referred to are households that are financially able to finance the installation of the SHS equipment. If this potential is realized, the household sector can produce an installed solar power capacity of 13 to 116 GWp. Seeing this great potential, Indonesia should be able to meet 100 percent of electricity in the future from renewable energy. This shows that in the household sector, most of the potential market share has not been exploited (Damayanti *et al.*, 2018).

In this research, Arduino-based smart switching technology is proposed. The advantage of smart switching that is added to the SHS is that it can regulate the use of electrical energy so that the energy used adjusts the amount of electrical energy stored in the battery. The form of the planned arrangement is setting the lights with an automatic turn on and off scheme during the day and night, as well as reducing the number of lights that turn on automatically if the availability of electrical energy decreases. For other household appliances a minimum amount of electrical energy consumption will be set. This is intended to obtain a system that can reduce the use of electrical energy but can still work optimally.

Seeing the high potential of unexplored SHS, as well as the high cost of SHS, the research entitled Economic Analysis of the Solar Home System (SHS) with the Switching Method on a Household Electric Scale aims to design an SHS that will meet all the criteria for turning on household electrical appliances. at an affordable price. Then the SHS is implemented on a small scale, identification of input data, simulation and optimization is carried out using the Leveled Cost of Energy (LCOE) method and performs economic value analysis.

## THEORITICAL REVIEW

### *1. Solar Home System (SHS)*

Solar Power Generation (PLTS) for household scale is generally called the Solar Home System, this system is connected to the electricity network and some are independent. Solar Home System is composed of main components such as solar panels, batteries, charge controllers, inverters (for AC loads), and the load itself [2].

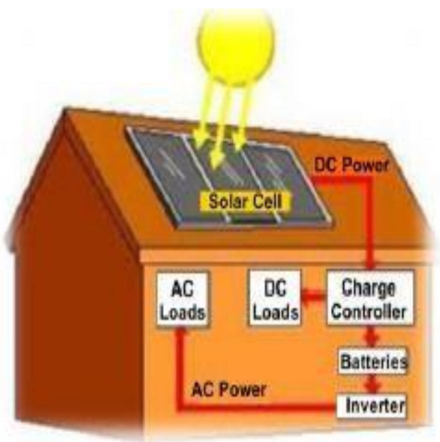


Figure 1. The Arrangement of *Solar Home System*

### *2. Fotovoltaik*

Photovoltaic is a process to convert light energy into electricity. When there are one or more photons that enter the solar cell which consists of a semiconductor layer, it will produce a free charge carrier in the form of electrons and holes. The incoming photons come from solar radiation. If the charge carrier can reach the area of the charge space before the recombination occurs, then the effect of the existing electric field will be separated and can move towards the contactor. If there is a connecting wire between contactors, current can be generated (Penick and Louk, 1998). This principle is applied to solar cells (Bachtiar, 2006).


Figure 2. Photovoltaic Modul

**3. Battery**

The battery is a storage medium for electrical energy. Storage of electrical energy is needed if the use of electrical energy is not at the same time as the time it is generated. Batteries commonly used for PV mini-grid are lead-acid, including wet cells, gels, and tube plates (Bachtiar, 2006).

Figure 3. Solar Panel Batteries

**4. *Battery Charge Regulator***

The power flow regulation in the system is carried out by the BCR (Battery Charge Regulator). This is useful for protecting batteries and other equipment from various causes of damage. The types of BCR on the market, namely series controllers, parallel controllers, and controllers using the MPP (Maximum Power Point) tracker (Asy'ari *et al.*, 2014).


Figure 4. *Battery Charge Regulator*

**5. *Inverter***

The inverter is a tool for converting DC voltage to AC, this is done in order to use the

AC load on the DC voltage generator system. There are three types of inverters in the market, namely sine wave inverters, modified sine wave inverters and square wave inverters (Bawah *et al.*, 2013).

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Figure 5. *Inverter*

***6. Net Present Cost (NPC)***

The NPC of a system is the Present Value (PV) of the total cost of installing and operating the system, minus the PV of the total revenue generated during the lifetime of the system. NPC can be calculated using the discounted cash flow method (Gall *et al.*, 2007).

***7. Leveled Cost of Energy (LCOE)***

LCOE is the average cost per kWh of useful electrical energy produced by the system. LCOE can be calculated by dividing the annual electricity production cost by the total electricity load served, using the following equation:

$$COE = \frac{C_{ann,tot}}{E_{served}}$$

The annual electricity production costs (Cann, tot) are calculated using the equation:

$$C_{ann,tot} = \mathrm{CRF}(i, R_{proj}) \cdot C_{NPC,tot}$$

Capital Recovery Factor (CRF) is the ratio used to calculate the PV of an annuity (a series of equal annual cash flows). The equation for calculating CRF is:

$$\mathrm{CRF}(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

## RESEARCH METHODS

This research was conducted using the Research and Development (R&D) method. This model was chosen because it can support this research as a link between basic research and applied research. R&D is often defined as a process or steps to develop a new product or improve an existing product. The R&D cycle briefly consists of studying research findings related to the product to be developed, developing the product, conducting testing, and revising it to correct deficiencies found.

The research flow was carried out by following the model of Borg and Gall (2007: 775) as follows:


Figure 6. Research Flow

However, the research is limited to the initial product trial stage or the trial is limited due to limited time and cost. The following is the composition of the team and the division of tasks in this study.

### 1. *Data Collection*

At this stage a field study is carried out or in other words as a measurement of needs and research on a small scale (Sukmadinata: 2005). In developing a product, it should be based on a need assessment. One of the data extracted at this stage is the electricity needs for households as well as technical data on hardware and software requirements

### 2. *Work Planning*

Based on the preliminary studies that have been conducted, a product design is made which includes: a) the purpose of using the product; b) who is the user of the product; c) a description of the product components and their use. At this stage the input data will be used to make designs, simulations and optimizations using HOMER. Then also made the design of the system hardware components and the system installation plan.

### 3. *Initial Product Development*

The initial product is developed by researchers in collaboration with experts and / or practitioners in accordance with their field of expertise. This stage is often called the expert validation stage. Experts' trials or evaluations are approximate or judgmental, based on the analysis and logical considerations of the researchers and experts. At this stage the design will be validated by experts or practitioners to assess the feasibility of the system design so that it can be realized into a functional system. Then designs that pass expert validation will be realized by building at least one Solar Home System with Arduino-based Smart Switching

### 4. *Initial product trial / Limited trial*

After the initial product has been developed, field trials are carried out on a small scale or in the laboratory. According to Borg and Gall (2007), initial product field trials are recommended to be carried out in 1 to 3 houses. At this stage, SHS hardware and software will be installed with Arduino-based Smart Switching in at least one house. During the implementation of this field trial, the researcher made intensive observations and recorded important things that would be used as evaluation material for the improvement of the initial product.

### *5. System Design*

The description of the application of the Solar Home System in the household is as follows:

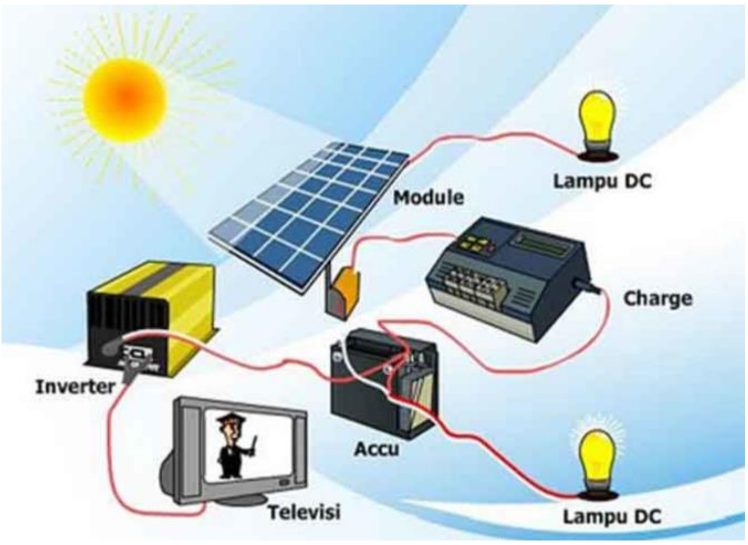


Figure 7. Household Solar Home System (SHS)

## RESULTS AND DISCUSSION

This study aims to design an SHS with Arduino-based Smart Switching that will meet all the criteria for powering electrical equipment at an affordable price, calculating the Leveled Cost of Energy (LCOE) as a basis for determining prices and analyzing business feasibility. Smart switching is implemented to regulate the use of household appliances that are routinely used, regulate the consumption of electric power automatically, minimize usage, and take into account the effectiveness of the use of electrical power generated by the SHS. In this research, the SHS design is carried out as a provider of standard simple home electrical energy consisting of solar panel components, batteries, converters and relays as household appliances switches and two watt meters installed on solar panels and batteries. The way SHS works is to collect electrical energy from sunlight, then convert DC voltage to AC so that it can be used to run household electronic equipment. To accommodate the adequacy of electrical power, an automatic adjustment is made for household appliances that are routinely used, namely house lights, which includes setting the lights on and off and the number of lights that can be activated.

The stages of this research include designing and installing hardware which includes the installation of solar panels which are used as an energy source, then a converter as a converter of heat energy into electrical energy, and a battery which functions to store the energy that has been converted by the converter.

The design of the Solar Home System system with automatic switching based on Arduino is shown in the block diagram below.

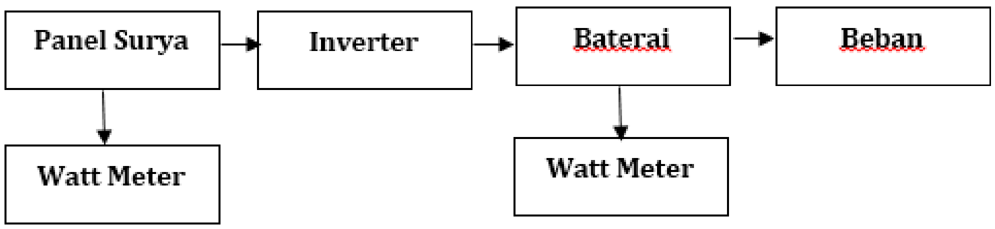


Figure 8. Diagram Block

From the system block diagram above, it can be explained as follows:

1. The solar panel is activated during the day, the results of the power obtained every day can be read on a measuring instrument (watt meter)
2. Inverters are used to convert DC voltage to AC, this is done in order to use the AC load on the DC voltage generator system.
3. Regulating the flow of power to the system is carried out by the BCR (Battery Charge Regulator). This is useful for protecting batteries and other equipment from various causes of damage.
4. Block diagram of loads, in this study used as a simulation is the load of 4 lamps which are activated for 12 hours

The following is for a load circuit that is installed using switching technology:

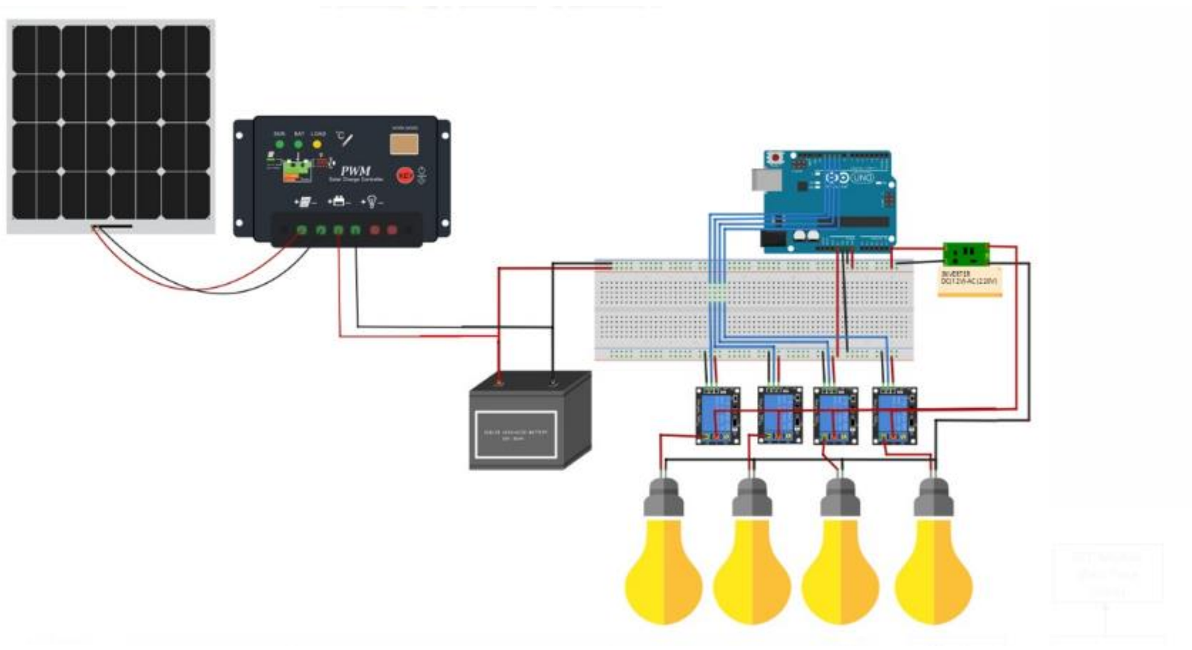

Figure 9. Circuit System

The arrangement of the circuit components required in the automatic lamp switching process is as follows:

1. 12V DC power supply x1
2. Arduino Uno R3 x1

3. Relay Module x4
4. DC lamp x4
5. Solar Panel x1
6. Converter x1
7. Battery x1

The 12V DC power supply is used to supply power to the relay components, the Arduino Uno R3 is used to control the on and off light settings in order to optimize the power received from the solar panel. The power stored in the battery is used to turn on the lamp, if it is insufficient to activate the four lamps then the automatic switching will only activate 3 or 2 lights provided that not all the lights are turned off because they run out of power. In this system, there is no use of back-up electricity from PLN

Relay is used as an automatic switch that will turn on and off the DC lamp. Each relay will read the value of the power stored in the battery, if it is insufficient to activate 4 lights for 12 hours then the number of active lights will be reduced until the availability of power in the battery is again fulfilled.

The results of the lamp use test are as follows:

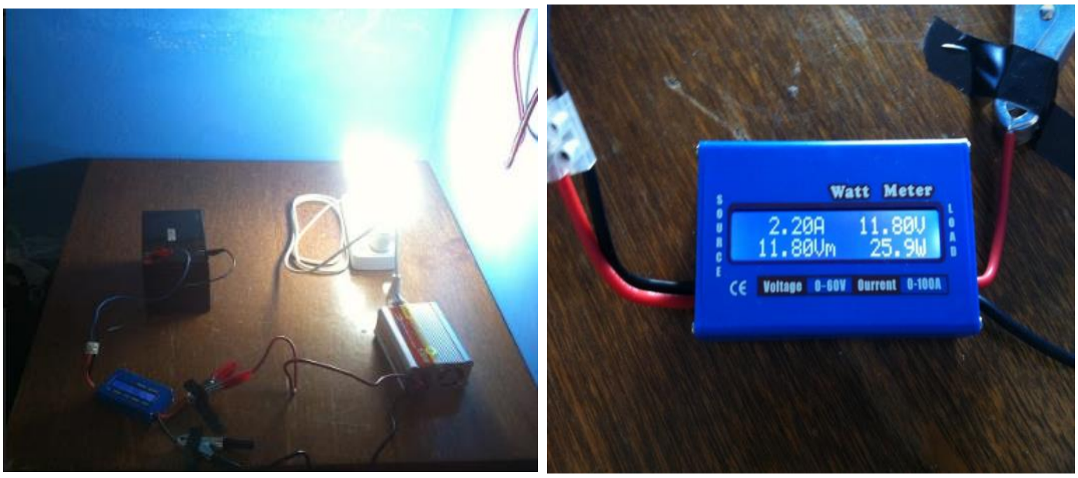


Figure 10. System Testing

In calculating the load requirements at home that will use power from solar panels. From the electricity bill, you can see the consumption rate in terms of kWh (kilowatt per hour) every month, for example. Next, identify how many kWh are needed each day, for example 100 watts and a 100 watt load time will be activated by solar panels for a certain time. From the test results obtained results that are more profitable if the load using solar panels is activated at night. Thus, the use of batteries is relatively light and the number of batteries used can be reduced in number, because the electricity supplied is not only by batteries but sunlight still providing supply.

**Calculation of kWh Meter in Solar Power Systems**

Calculation of the kWh meter for the solar power system starts from calculating the power capacity required for the load used at home. In the use of solar power systems, it will be more advantageous if the load is activated at night. Thus, the use of batteries is relatively light and allows the use of the number of batteries to be reduced because the electricity supplied is not only carried out by the battery but also by sunlight. The use of an effective solar panel system every day is at 09.00 15.00.

If the average daily power consumption is 1,200 watts, it is necessary to add 20% of the additional power used by devices other than solar panels, such as inverters to convert DC to AC currents, because in general household appliances use AC current. In addition, the controller as a current regulator also requires power to close the current to the battery if the voltage is excessive in the battery and stops the absorption of current from the battery if the battery is almost empty. With an additional 20% of power, the total power required is 1,440 watts.

Of the 1,440 watts provided, divided by the battery voltage of 12, the current required is 120 Ampere. If the battery used has a working capacity of 120 Ah 12 V, then we need 1 battery (120 x 12 x 1 = 1,440 watts).

From the required power value of 1,440 watts, a calculation of the number of panels needed will be obtained, including the amount of power from the solar panels, which is 50 wP (watt peak). In a day this solar panel will produce a supply of about 50 wp x 6 (hours) = 300 watts. If 1 50 wp panel is able to provide 300 watts of electricity, it takes 1,440 watts / 300 watts = 5 panels. The estimated purchase price for a solar panel set in Table 2 is Rp. 8,415,000, - with an average life time of 10 years.

The use of the smart switching method is used as an alternative in conserving the use of electrical energy from solar panels, preventing energy exhaustion if the energy stored in the battery is running low, so there is no need for backup from PLN. The application of this automatic switching is carried out only on the lamp component, this is because the lamp is the most flexible component to turn on and off without a large risk of damage to the components compared to other equipment such as magicom, refrigerator and iron. The switching process is carried out by calculating the power stored in the battery. If the power stored in a battery with a voltage of 12V 120Ah is met, then 1 battery is charged as much as 1,440 Watt.

The 1,440 Watt power from charging this solar panel is not fully used, but only 80% so that there is still remaining power stored in the battery. The power that can be used is 1,152 Watt, the switching process is based on a decrease in the available electrical power. If the available electric power is still half of the total battery capacity then the lights will be switched off automatically by 1 piece, if the battery power is still 2/3, then the lights will be switched off as many as 2 pieces and if the battery availability is left 1/3 then the lights will be switched off 3 pieces. This is to maintain usage in order to still be able to use solar panel sources. When the battery has increased power, the use of lights will return to normal.

This economical calculation of the use of solar electricity is carried out with the Leveled Cost of Energy (LCoE), the LCoE analysis considers costs distributed over the lifetime, providing a very accurate financial picture rather than the simple cost per watt calculation often used in industry. LCOE calculates actual costs, measured in cost / kWh of energy produced. While it may seem difficult to weigh upfront investments against future benefits, the returns are enormous. For example in this study the cost of installing a solar panel system required is IDR 8,415,000, while the energy that can be stored in 25 years of life is 5,184,000 Watts or 5,184 kWh, so the LCoE value is IDR 1,623 / kWh. This value is smaller than the pre-paid electricity price which reached Rp. 1,700, - / kWh, from here the savings are obtained of 4.53%.

## CONCLUSION

This research produces a solar panel-based electricity provider system, Solar Home System (SHS) which is equipped with automatic switching on certain household appliances in order to meet the needs of electrical energy without backing up from PLN. Based on the results of testing to users, the results show that the application of this switching technology provides benefits for users because it is no longer dependent on PLN supply. From an economic point of view, based on the calculation of Leveled Cost of Energy (LCOE), there is a kWh value savings of Rp. 77, - for each kWh price or about 4.53% compared to purchasing electricity with prepaid mode. Besides that, another advantage is the security of electrical energy because there is never a blackout.

## ACKNOWLEGMENT

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