Smart Controller Design of Solar Home System (SHS) for Load Management with Grid Connected

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Abstract: As one of the largest archipelagic countries in the world, Indonesia still faces electricity problems due to geographical reasons. One of the provinces which have a fairly low electrification ratio is the Province of East Nusa Tenggara (NTT). In terms of the potential of natural resources, especially renewable energy sources, NTT has great potential for the development of solar power plants. The ranges intensity of solar energy in NTT are 4.5 - 5 kWh/M^2. To take advantage of these renewable energy sources, this research offered the best solution to reduce community problems by providing electrical energy for residential homes, namely designing a smart controller by utilizing electricity from a solar power plant connected to the State Power Station electricity network. A specification of this system is the management of the use of electrical energy sources for loads. The test results show that the total consumption of electrical energy are 4678 watts/hour, while the total production of electrical energy from the solar power plant are 3622 watts/hour. With this load management system, the contribution of the solar power plant can save electricity consumption by 1056 watts/hour. With this system was known that the efficiency of the solar power plant are 77.4%.

1 INTRODUCTION

As one of the largest archipelagic countries in the world, Indonesia still faces electricity problems due to geographical reasons. One of the provinces that have a low electrification ratio is the Province of East Nusa Tenggara (NTT). Based on the Central Statistics Agency (BPS) in 2018, the electrification ratio of NTT under below the national electrification ratio, which are 68.82%. One of the problems faced by the government is the limited funding for electricity infrastructure development and the low interest in buying Public to meet basic needs and the geographical conditions of the hilly islands of NTT, making it difficult to provide access to new electricity networks.

Until now, there are still 11,944,675 out of 65,254,000 households in Indonesia that have not received a supply of Electrical Energy Channels (SEL) with an electrification ratio of 81.70%. Some provinces even have electrification ratios below 60% such as Jambi, West Sulawesi, West Papua, and East Nusa Tenggara (NTT) due to the accessibility of electricity infrastructure. PLN noted that there were 532,204 out of 1,104,500 households in Province NTT that had not received SEL supply with an electrification ratio of 51.81% (PLN, 2015). Meanwhile, from BPS data in 2015, there were 30,910 out of 78,011 households spread across 32 of 177 villages in Kupang Regency, NTT Province that had not yet received a supply of SEL (electrification ratio of 60%) (Sinaga, Tambunan, and Prastowo 1981).

The Government's efforts to increase the electrification ratio continue to be carried out with government programs. In Indonesia, the National Priority for Energy Sustainability includes two Priority Programs, namely: New and Renewable Energy (EBT) and Energy Conservation, as well as Meeting Energy Needs (Winanti et al. 2018). A follow-up to the government's efforts to utilize renewable energy such as solar radiation for the construction of solar power plants. It is proven that until now there have been additions and expansions of electricity networks to remote areas. However, the current problems are the low purchasing power of electricity from customers due to economic constraints and the increasing price of electrical energy. Other problems that are still felt by the community such as power outages that still often

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occur at peak load conditions and other external disturbances.

In 2018, NTT's electrification ratio increased to 68.82% but was still below the national average electrification ratio. The increase in the electrification ratio in 2018 shows the performance of PLN which continues to improve in a better direction, as evidenced by the expansion of new networks. When viewed from the natural potential, NTT is one of the provinces that have a source of electrical energy from renewable energy which is quite high, including electrical energy from the sun and electrical energy from wind power. The average intensity of solar radiation in NTT are 5 kWh/m2 with an average wind speed of 5.5-6.5 m/s (NASA 2017). If that the potential was utilized optimally, it will have an impact on increasing the electrification ratio and meeting the electricity needs of the NTT community. To take advantage of the natural potential that exists, this research will offer the best solution to overcome public problems associated with the provision of electrical energy for residential homes, namely by designing a smart controller by utilizing electricity from a Solar Power Plant that are connected to the PLN Grid. The existence of this system can meet the basic lighting needs of households as well as for other electrical needs. The results of this research will be recommended were systems are more efficient and effective to meet the needs of electrical loads with low cost and high reliability.

2 PURPOSED TECHNOLOGY DESCRIPTION

A smart home system is a system that provides service, convenience, and comfort for consumers or residents. The smart home system provides optimal service and provides control over the use of electrical energy so that it has an impact on saving electrical energy costs. Previous research related to the management of electrical energy consumption, namely the management of voltage on the battery. Arduino acts as switching between local energy (PLTS) and main energy. When Arduino reads the voltage on the battery less than 11 volts, the system will prioritize the use of energy from the main energy. On the other hand, when the battery charging process reaches 13 volts, Arduino will prioritize the use of electrical energy from local energy (PLTS) (Mehdi et al. 2018).

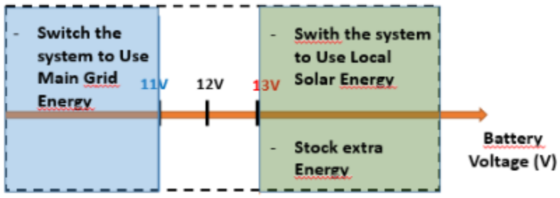

Figure 1: Smart Energy Management (Mehdi et al. 2018).

The research previously discussed above uses an on-grid system, namely local energy sourced from Solar Power Plants (PLTS) which are connected to the main grid (PLN). That system was equipped with a GSM SIM900 card to connect to an IoT-based smartphone for coordinated control and system interconnection via a mobile application. The results of this study indicate significant cost savings and more efficient management of electrical energy consumption compared to conventional systems (not using a management system for electricity consumption). The main disadvantage of an off-grid solar power plant is the durability of the battery life must be continuously replaced so that the customer or user has to replace the battery for about 5 to 6 years and it will cost 20% - 25% of the total normal project calculation (Jose and Itagi 2015). The solution to overcome their problems are to design the control system for the efficient performance of solar power plants, both off-grid systems, and on-grid systems. One such system design, such as the research conducted by Sam Jose and Dr. Raieshwari L Itagi in 2015 about "Smart solar power plant" as follows:

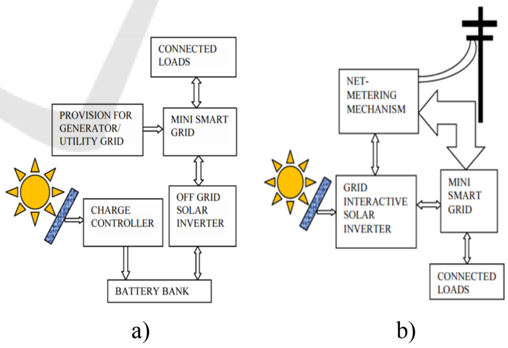

Figure 2: a) Off Grid System. b) Mini Smart Grid for Died Grid system (Jose and Itagi 2015).

The results show that a smart controller system was increased battery life, and the efficiency level of the off-grid and on-grid systems more than higher and the cost of the customer or user can be reduced. The Charger controller can also manage costs well. In addition, it can also provide overcharge protection for the battery to prevent over discharger in the battery.

Based on the literature study described above, the framework for designing a Solar Home System (SHS) with the Application of a Smart Grid Controller are shown in Figure 3.

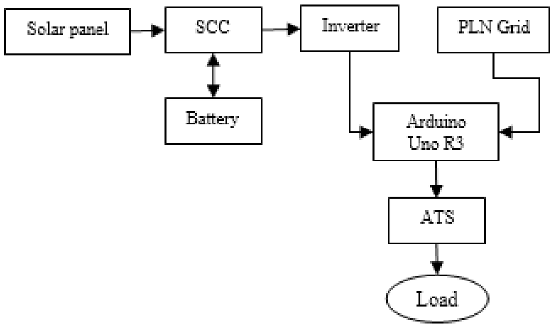

Figure 3: Blog Diagram Smart Solar Home System.

Overall, the Solar Home System (SHS) Design System with the Implementation of the Smart Grid Controller consists of three main parts. The first part is the source of power generation, namely PLTS which are connected to the PLN network. The second part is load power management. In this section, current and voltage measurements will be carried out using current and voltage sensors. The results of the measurements will be processed by Arduino to determine which power plant source will supply the electrical load. Switching between PLTS and PLN Grid was automatically controlled using an automatic transfer switch (ATS). The PLN grid will back up the PLTS system to supplying the load when the load capacity has exceeded the PLTS capacity. When the capacity of PLTS produces electrical energy more than the load capacity, the main energy source used comes from PLTS. The third part are the electrical loads. Electrical loads in the form of electronic equipment and other electrical equipment. Meanwhile, the PLN grid power was adjusted to the 900 Watt kWh meter electric power.

3 DESCRIPTION OF THE TECHNOLOGY

The first step in this research are the design of Solar Power Plant (PLTS). The PLTS system design consists of several components, namely solar panels, solar charge controllers, batteries and inverters. The next step are the design of the ATS system. The ATS system was designed using 3 contactors that will work based on current and voltage sensors. The next stage is the design of the load management system. Load management system using Arduino. The current sensor will provide an input signal for the Arduino and the Arduino will turn on which contactor will work.

The way system works in the management of electrical energy consumption was shown in Figure 4. The sensor will measure the current and voltage at the load by prioritizing the main source of the PLTS. The maximum power was set from Arduino for PLTS are 400 Watts. When the load was less than 400 watt, PLTS will take over the load. If the load more than 400 Watts. For example, 500 watts, the PLTS will still supply 400 watts of power and the remaining 100 watt will be taken from the PLN grid.

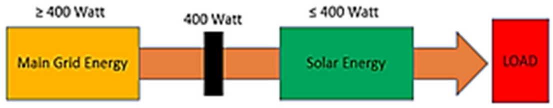

Figure 4: The Working Principle of Energy Management Solar Home System.

3.1 Load Profile

Based on the measurement results of the load data was known that the total power requirement for one day are 11,709 Watt with a total consumption of electrical energy of 11.27 kWh/day. The measurement results were known that the peak and load are 890 Watt which occurs from 18.00 to 19.00. This is because all electronic and lighting equipment starts operating. While the lowest power requirement of the load are 114 Watt from 07.00 until 09.00. In this state, some lighting loads have been turned off and some electronic equipment has not been operating.

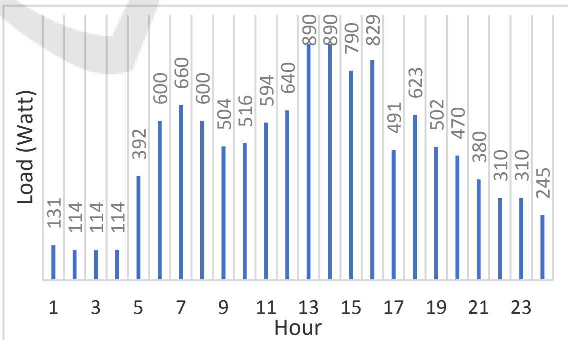

Figure 5: Daily Load Profile.

3.2 Determination of Solar Power Plant

To calculate the capacity of solar panels, it is necessary to know the total electrical load that will be supplied by the PLTS. In addition to the load capacity, it is necessary to calculate the peak solar radiation that occurs in one day. Another parameter to determine the capacity of solar panels are the efficiency of the system. Efficiency can be calculated based on solar panel losses, battery losses, inverter losses, and cable losses. To maintain stability in producing electrical energy, the total system losses are 30% so that the system efficiency are 70% (Sreewirote and Leelajindakrairerk 2016). To calculate the power of solar panels can use the equation:

$$P_{pv} = E_{load} / (PSH \times n_{system}) \quad (1)$$

When:

Ppv = PV panel nominal peak power (W)
E_{load} = Total energy demand for a day (Wh)
PSH = Peak sun hour (hr)
n_{system} = overall system efficiency

With a total load power of 400 watts and an assumed operating time of 2.5 hours, the total energy required by the load are 1 kWh. While the peak solar radiation (PSH) for the NTT area is an average of 5 hours starting from 09.00-14.00 (NASA 2017). From the calculation results, it is known that the solar panel power should not be less than 286 Wp so that in this design a solar panel with a capacity of 310 Wp is used.

To determine the battery capacity, it can be calculated using equation 2 (Sreewirote and Leelajindakrairerk 2016) (Duan et al. 2018).

$$BC = (P_{load} \times h) / (V_{batt} \times n_{system} \times DOD) \quad (2)$$

When:

BC = Battery capacity (Ah)
P_{load} = Demand power (W)
V_{batt} = Battery voltage (v)
h = Discharge times (h)
n_{system} = Battery efficiency
DOD = Dead of Discharge

From the results of calculations with a battery voltage capacity of 12 volts and battery efficiency of 80%, it is known that the battery capacity that must be used should not be less than 100 Ah. Thus, in this study, the battery used was 100 Ah.

The type of inverter used is a Grid Tie inverter which was connected to the PLN electricity network. Inverter capacity is adjusted to the capacity of PLTS, so this study using an inverter with a capacity of 600 Watt. While the Solar Charge Controller used in this design is MPPT type with a capacity of 12/24 V 30 Ampere.

3.3 PV and Main Grid Switching System

The switching system between the PLTS and the PLN Grid to supply electrical energy to the load will be taken over by the Automatic Transfer Switch (ATS) system. The ATS circuit was equipped with sensors and relays that will be ordered by Arduino based on current and voltage sensors on the load. In this design, 2 relays are used namely relay one for PLTS and relay two for the PLN grid. Both relays will work based on current and load voltage sensors. The value of current, voltage, and electric power generated from the load will be displayed on the LCD. Power is set in this design process are when the load is greater than 400 watts, PLN will help supply excess electrical energy to the load. When the load is less than 400 watts, PLTS will take over the load.

ATS circuits are equipped with 3 contactors and a timer. In this design, the system only uses two contactors, namely a contactor for PLTS and a contactor for PLN. While the third contactor is planned for the use of a generator set. The timer functions as a delay time setting when switching between PLTS and PLN sources.

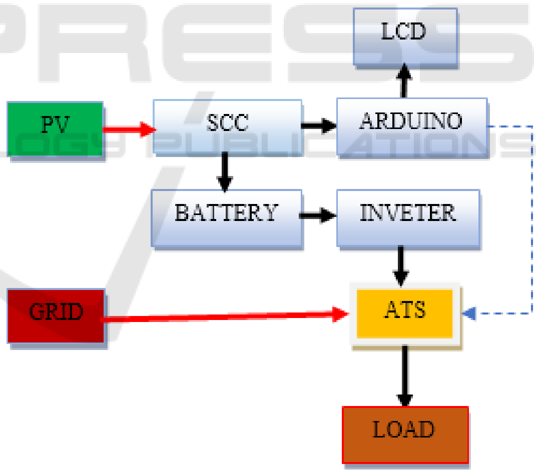

Figure 6: PLTS and PLN Grid Switching.

For electrical power to the load, the two relays are connected with 2 different conditions. PLTS is prioritized as the main source of electrical energy so that the PLTS relay was installed in the Normally Closed (NC) position while the PLN relay was in the Normally Open (NO) state. The PLTS relay will be directly connected to the load through the PLTS contactor, while the PLN relay will work when there input signal from Arduino when the load is more than 400 watts. Relay installation in this system are shown in Figure 7.

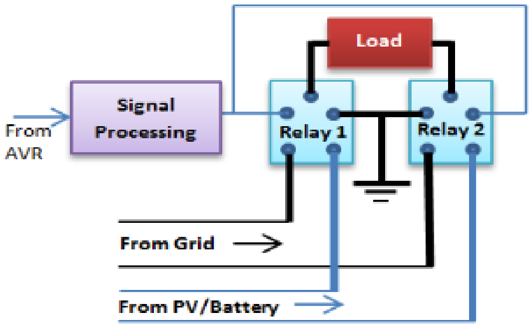

Figure 7: Relay installation.

Overall, the electrical installation of a smart solar Home system for electrical load management with a grid-connected system are shown in Figure 8.

Figure 8: System Electricity Smart Controller SHS for Load Management.

4 PERFORMANCE OF THE SYSTEM

The test results show a significant contribution to saving electricity consumption. However, in this test, the inverter did not work optimally. The 600-watt inverter capacity was only capable of producing a maximum output power of 319 watts. Thus, the inverter efficiency can be calculated by 53%. Because the maximum output power of the inverter is below 400 watts, the Arduino algorithm for the load power priority switching system was reduced to 300 watts. The test results are shown in Figure 9.

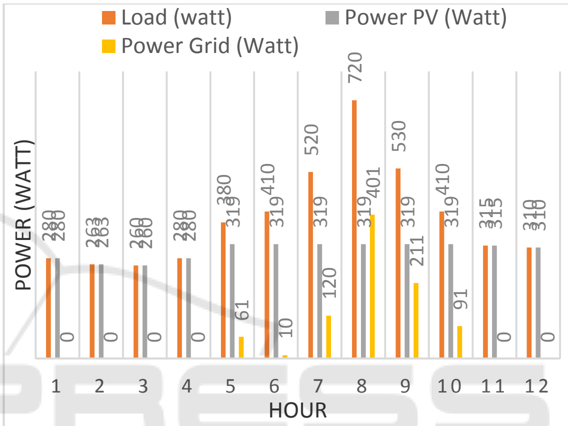

Figure 9: System Test Results.

The test results show that the total consumption of electrical energy are 4678 watts/hour, while the total production of electrical energy from the solar power plant are 3622 watts/hour. Thus, with this load management system, the contribution of the solar power plant can save electricity consumption by 1056 watts/hour. Thus, are known that the efficiency of the solar power plant was 77.4%.

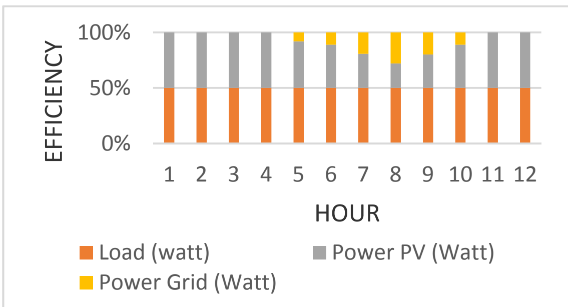

Figure 10: System Efficiency.

The total efficiency of the system is highest when the total electrical energy of the load can be taken over by the solar power plant. While the lowest efficiency occurs at peak load, namely the consumption of electric power of 720 watts. At this peak load, the total purchase of electrical energy from the PLN Grid are 401 watts while the contribution from the solar power plant are 319 watts.

5 CONCLUSION

The Smart Controller Design of Solar Home System (SHS) for Load Management With Grid Connected has a performance efficiency of 77%. By saving electricity consumption of 1.5 kWh of the total electrical energy consumption of 4,678 kWh. The highest electricity consumption from the PLN Grid are 720 watts while the total electricity production from the solar power plant are 319 watts. One of the obstacles that occur in this design is the performance of the inverter not optimal. In addition, the lack of sensitivity of current and voltage readings from the sensor so that the need for a proper calibration system. The above constraints can be an open problem for further system development.

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