170kW Solar Power Plant Microgrid in the Remote Island Indonesia: An overview

Andrianshah Priyadi[1]*, Toha Zaki[1] , Riza[1]
[1]National Laboratory for Energy Conversion Technology
[1]Agency for the assessment and application of technology
Jakarta, Indonesia
*Andrianshah.priyadi@bppt.go.id

***Abstract*— Indonesia is the largest archipelagic country in the world consisting of 17,508 islands including 9,638 unnamed islands and 6,000 uninhabited islands. The population which increases every year showing the results that there is the migration of people from the large islands to the remote islands and one of the problems of this condition is the optimal electricity supply. Electricity on the island is commonly carried out by diesel engines, so it needed combining the power plant system that reduced the working-load of diesel engines. One of the power plants is a solar power plant which needed to support the government's National Energy Policy (NEP) program in renewable energy. The paper has done by assessing one of the remote islands in Indonesia by identifying the whole power plant system design. The total number of solar power plant capacity installed is 170 kWp and 3 x 240 kW diesel engine. In the Future plan, the project will be made of a Solar Power Plant system that is reliable as a smart grid system and also there is optimizing in the load design. The paper will also identify all possibilities technical aspect that could improve the system becomes a smart grid system in the future.**

Keywords—Microgrid, Smartgrid, Solar Power Plant, Renewable Energy

I. INTRODUCTION

A. Geographical Condition

Indonesia is the largest archipelagic country in the world with a coastline of more than 81,000 km and a sea area of around 3.1 million km^2 as far as Indonesia's coastal and marine areas are known as the country with the most significant marine wealth and biodiversity in the world by having coastal ecosystems such as mangroves, coral reefs, and seagrass beds. The territory of Indonesia which stretches from 6° 08′ north to 11° 15′ South, and from 94° 45′ East to 141° 05′ East where is located in a very strategic geographical position, because it connects two oceans and two continents, the Indian Ocean with the Ocean Pacific, and the Continent of Asia with the Continent of Australia. The total area of Indonesia is 7.9 million km^2 consisting of 1.8 million km^2 of land, 3.2 million km^2 of the territorial sea and 2.9 million km^2 of EEZ territory. The territorial waters of 6.1 million km^2 are 77% of the total area of Indonesia, in other words, the area of Indonesian sea is three times the land area [1].

The project has been choosen one of the remote islands in Indonesia. The location can be accessed by sea transportation, and In addition to the cost of expensive boat operations, natural factors also become obstacles to mobility [2]. The road conditions in the rough area are in the form of white gravel sand and paving stone. The communication signal on this remote Island is quite reliable with 4G signal where there is the availability of Telkom Indonesia communication tower.

B. Summary of Solar Power Plant

The solar power plant in this this remote island was built in 2011 with the total capacity of 170 kWp, and it operated normally until 2013. Both of Solar Power Plant and diesel engine supply the energy to the 275 households and 12 public facilities whereas the solar power plant operated only 6 hours at midnight time.

The solar power plant components which are installed in this remote island, consist of:

- The photovoltaic modules use the EverExceed brand where the total number of photovoltaic is 1,728 units. The capacity of each photovoltaic is 100 Wp and using the monocrystalline type.
- The inverter uses the SMA brand with the Sunny Island SI 5048 type. The capacity of the inverter is 90 kW which divided into 18 x 5 kW, and the operating voltage is 48 VDC.
- There is a multicluster box which using SMA brand for synchronous inverters, and the multicluster box has a capacity of 300 kW.
- Batteries use the EverExceed brand which using oPzS type. The total number of batteries is 144 units, and each battery has a capacity of 2v 1500 AH
- Photovoltaic array support is made of Galvanized Iron.
- Protection system using surge protection, grounding, and breaker.
- The diameter cables used are four mm2 for connections between PV and PV, four mm2 for

connections between PV strings and Combiner Box, four mm2 for connections between PV strings.

- The diesel engine uses the Deutsch brand which a capacity of 3 x 240 kW and the operating voltage of 380 V.

II. SYSTEM DESIGN

The Installation of the solar power plant in this this remote island uses a manual hybrid pattern operation between the diesel engine which the capacity diesel is 240 kW and the solar power plant [3]. These two sources have been designed to serve around 250 kW of the total power load in 2011. The single Line diagram can be seen in figure 1 below.

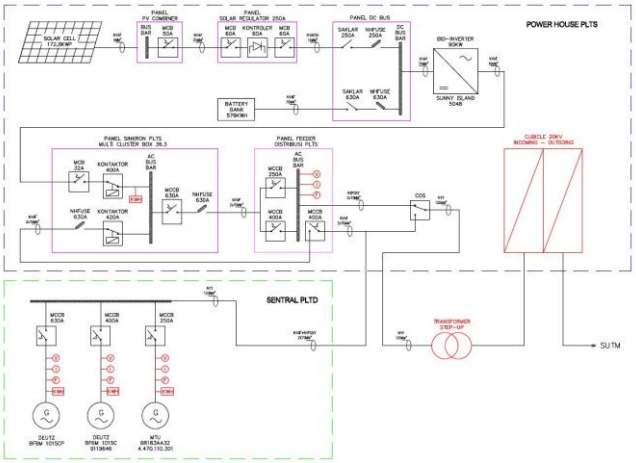

Fig 1. Single Line Diagram

In 2018, the number of installed expenses has increased as long as increasing in the number of households. The average number of loads also varies depending on the holiday season and weekend time. The average number load is around 375 kW and the highest peak number of the full load which has been measured around 450 kW. The author measures the amount of load on diesel engines that work 24/7 where the installed diesel engine is 3 x 240 kW and no supply energy from the solar power plant as shown in figure 2 below.

Fig 2. Daily Load Profile

The observation has been recorded to the fully load for every hour, and the load conditions also increased for each year. The data has been recorded where the minimum load is measured at 199.3 kW at 09.00 WITA, and the maximum load is measured at 299.8 kW at 19.00 WITA.

The main components of a solar power plant that installed in this remote Island will be described below:

- Photovoltaic

  Photovoltaic in This remote Island was installed using monocrystalline type. Monocrystalline is the most efficient solar cell, producing the highest electricity power unity. It has an efficiency of up to 15% [4]. The disadvantage of this type panel is that will no work as well in areas with less sunlight or shading; the efficiency will drop dramatically in cloudy weather. This type is popular, and it is usually used in large-scale solar power plants in Indonesia.

  The nominal specification parameter depends on the size photovoltaic module. Photovoltaic that installed in this remote Island has technical specification below;

  a. Power Max = 100 Wp
  b. Short-cut Current = 6.53 A
  c. Maximum Current = 5.56 A
  d. Open-Circuit Voltage = 22.4 VDC
  e. Maximum Voltage = 18 VDC
  f. Maximum system voltage = 1000 VDC

  The total number of photovoltaic is 1,728 units where divided into nine photovoltaic array module and each photovoltaic array support sustain 210 photovoltaic units. The photovoltaic and the array support can be shown in figure 3 below.

Fig 3. Photovoltaic design

- Inverter

  The inverter has a dual mode function which converts the DC voltage to AC voltage (VCVSI = Voltage control Voltage Source Inverter) and vice versa from the generator output to the DC voltage system to charge the battery (CCVSI = Charge Control Inverter Voltage Source) [5]. The Inverter showed in figure 4 below.

Fig 4. Inverter Design

In this system consist of 18 Inverters which divided into two parts, 15 inverter units as slave system (Battery Inverter) and three inverter units as the Main system (Grid Inverter). The Inverter works as a backup system that will not be able to operate with a diesel engine, and there is change over switch which can be used to switch the system operation between the solar power plant and diesel engine. The specification of the inverter will be described below;

a. Capacity = 5 kW
b. Nominal Voltage Input = 48 VDC
c. Nominal Voltage Output = 230 VAC
d. Maximum Current = 120 A
e. Frequency = 50 Hz

- Battery

The battery bank is used to store energy during the day from solar arrays, and the diesel engine can also charge the battery. The battery capacity of the bank can store the energy produced by photovoltaic modules which are not absorbed by the load and can be utilized optimally to supply the load when the solar radiation level is low, or there is no sunlight. The battery system which installed in this remote Island is used at night to reduce the operating time of the diesel engine [6].

The total number of batteries is 144 units that divided into six battery banks with the total number of capacity around 432 kWh as the total number of battery bank can be seen in figure 5 below. The battery banks also installed parallel with solar charge controller in the DC Coupling Bus before connected into Slave Inverter. The total number of battery bank can be seen in figure 5 below. The specification of the battery will be described below;

a. Capacity = 1500 Ah
b. Cell Battery = 2 VDC
c. Type of Battery = OPzS

Fig 5. The Configuration of Battery Bank

- Multicluster Box

The multicluster box is the ideal solution for the easy installation of off-grid systems, and the system voltage can be two to four three-phase clusters which can be connected in parallel. The multicluster Box is pre-wired for operation and equipped with the primary connection for Photovoltaic or other sources energy systems where the diesel engine is another one of the sources in this remote Island. The multicluster as shown in figure 6 below.

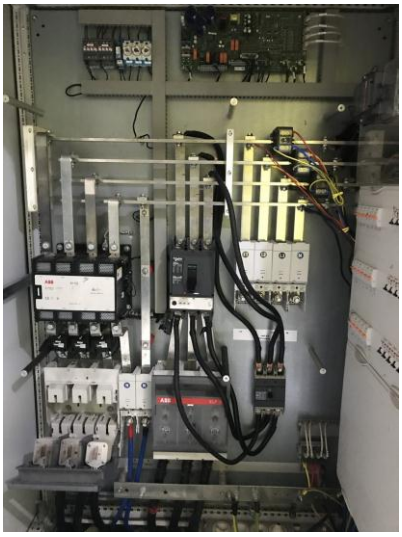

Fig 6. 300 kW Multicluster Box

- Diesel Generator

An equipment machine that has the ability to produce energy from fuel to electricity on a standalone system. The diesel generator as shown in figure 7 below. The diesel engine has been combined with the solar power plant where the diesel engine could charge the energy to the battery through the inverter system. The system works separately with the solar power plant, and there is change over switch in AC coupling [7]. If the diesel engine supplies energy to the load, it also can charge the battery, but the solar power plant could not equally discharge the energy to the load with the diesel engine. The specification of the diesel generator will be described below;

a. Base Rating Power = 240 kW / 300 kVA
b. Base Rating Current = 455.8 A

c. RPM = 1500
d. Phase = 3
e. Power Factor = 0.8

Fig 7. The Design of Diesel generators

III. ANALYSIS SYSTEM

The electrical system in This remote Island which is currently expected to be supplied by solar energy sources using a photovoltaic module where the capacity of the solar power plant is 170 kWp and also the size of the battery is 432 kWh that currently, the system is not operating. The capacity of the solar power plant can still increase potential energy, especially for photovoltaic modules that there is still free land around the north and west of the solar power plant.

The assessment activity has been done to identify the current condition of the solar power plant that any possibilities technical could improve the system and any recommendation maintenance the system if there is a problem since 2013. The analysis from the assessment activity has been classified only for the main component of a solar power plant, and the result will be described below;

- Photovoltaic
  The author has been checked the photovoltaic array and also measured the performance of single unit photovoltaic output power. The analysis shows that there are problems for the photovoltaic module and the photovoltaic array that as shown in the figure below;

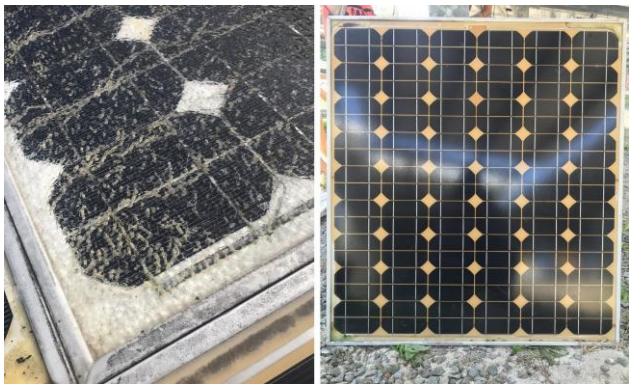

Fig 8. The condition of the photovoltaic module

Water enters the photovoltaic module glass through from the underside of the solar panel which is cracked because the adhesive on the solar module layer is leaking causing oxidation from high temperature in the sheet and changing the color of the inside layer. There is also cracked solar module glass which caused by unstable of soil conditions that effect sliding on the photovoltaic array support [8].

The condition of the sea also gives the salt the effect to the photovoltaic array support [9]. The structure of array support can be the corrosion along the steel structure, and if this condition happened in a long-term period, it could make the strength of the structure brittle as we can see in the figure below;

Fig 9. Photovoltaic Array Support

- Inverter
  Measurements are performed for a total of 18 inverters where divided into three Inverter as master system and 15 Inverter as slaves system. The inverter condition is active, but the system could not be ascertained to operate and delivering energy to the load. The analysis obtained that there is no synchronization of the slave inverter to the master inverter so that the capacity power of inverter is reduced and there is an unnatural sound when the inverter works

- Battery
  Measurements have been done for all battery cell voltages where the total of the battery is 144 battery cells and consisting of 6 battery banks for 24 batteries that connected in series. The result of measurement shows that there are six damaged of cell batteries which marked with a result of 0 VDC voltage which the nominal voltage of the battery cell is 2VDC as shown in the figure below. In addition, the level of the chemical water shows at the minimum level that indicated no maintenance during operating.

Fig 10. The measurement of the battery

- Diesel Generator
  Measurement of diesel generators is also done to examine the condition of the diesel generator.

Measurements were taken in the order of measurements of Total Harmonic Distortion (THD) current and Total Harmonic Distortion voltage on the output side of the diesel generator [10]. Measurements are presented to recognize the harmonic current also voltage and the quality of electrical energy to the load. The result of measurements results show that Total Harmonic Distortion Voltage is 2.75% and Total Harmonic Distortion current is 5.49% respectively where the recommended value is around 5% for voltage and current as can be shown the result below;

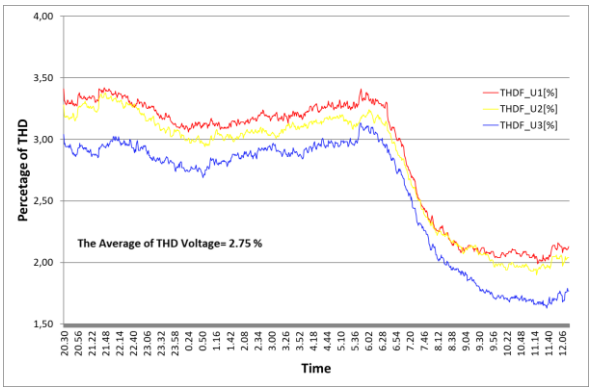

Fig. 11. Total Harmonic Distortion Current

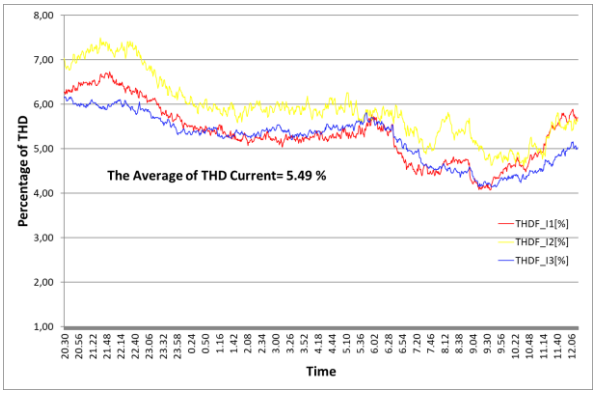

Fig 12. Total Harmonic Distortion Voltage

- Grounding system
  Grounding is a system of safety in the system against equipment that affected electricity as a power source, power surges, and lightning. The primary purpose of the grounding system is to create a low-impedance path to the earth's surface for electrical waves and transient voltage. Lighting, electric current, circuit switching, and electrostatic discharge are common causes of electrical shocks or transient voltage. Grounding an effective grounding system will minimize these effects [11]. The solar power plant in this remote Island has an unnormal ground value on the side of the inverter (6.42 Ω) and the side of the generator show the value (10.15 Ω) as we can see in figure below. The existing grounding system needed to add ground rods to improve the value of the grounding system to get a value below 5 Ω which the nominal standard value of grounding system should show below 5 Ω [11].

Fig 13. The measurement of the grounding system

IV. RECOMMENDATION

The solar power plant in operates from 2011 to 2013 to serve customers or electric power loads on this remote Island. The pattern of operating the solar power plant when it first operated that substituted with the 240 kW diesel generator. The solar power plant will not be able to work in parallel with the diesel generator, because the type of SI5048 inverter could not charge or discharge the energy parallel with the diesel generator to the grid. Therefore, the solar power plant could operate as backup energy (Backup mode).

The solar power plant has a capacity of 170 kWp serves the load for during the time 6 hours at night and the daytime was charged from the photovoltaic module. The improvement of the system is necessary by adding 4 x 25 kWP a grid-tie inverter to optimize the amount of energy that produced from the solar module and also could directly be used to supply the load to reduce the work-load of the diesel generator. However, by adding of a 120 kVA AC combiner box with AC Coupling system is the best solution to reduce un-synchronous the AC frequency and voltage.

Photovoltaic, battery and Inverter are essential issues in this assessment. The existing condition of those components needed changing with the new components. The existing condition could reduce the performance of the solar power plant mainly, and life cycle of those components have derating of the specification.

The existing multicluster box has the capacity only 300 kW which is not suitable to handle the current load conditions. The capacity of the load is 350kW-450kW in 2018 and will increase for every year so should have improvement of the multicluster box by changing with larger the capacity of the multicluster box.

The capacity of the solar power plant can still be increased, especially for photovoltaic modules and the battery. There is still unoccupied land in the west area which closed to the solar power plant area, and the potential for renewable energy can also be added by using

wind energy or biogass resources. The optimal design of those recommendations can be seen in the figure below.

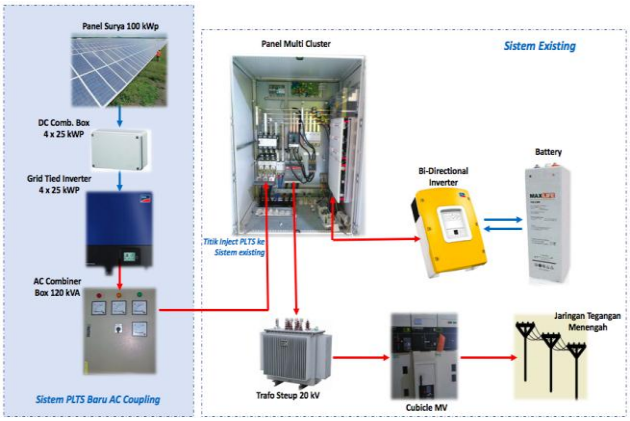

Fig. 14. The recommendation design

V. CONCLUSION

The point of this paper is how to make the system better than the previous design that was built in 2011. The new design is hopefully could automatically operate the system which does not need change over system. The smart grid system is the best option to improve this system where the existing load will always be in excellent condition and each of the components synchronous continuously. The design of the solar power plant can also be chosen as the green energy power plant which implemented in the remote island and also be affected to decrease the total generating cost of the diesel generator.

ACKNOWLEDGMENT

This project has been funded through Non-Tax State Revenue. The author also wished to thank National Laboratory for Energy Conversion Technology for the support.

REFERENCES

[1] "Indonesia." *Wikipedia*, Wikimedia Foundation, 30 Oct. 2018, id.wikipedia.org/wiki/Indonesia.

[2] Singal, S. K., Varun, & Singh, R. P. (2007). Rural electrification of this remote island by renewable energy sources. *Renewable Energy*. https://doi.org/10.1016/j.renene.2006.12.013

[3] Dimeas, A. L., & Hatziargyriou, N. D. (2005). Operation of a multiagent system for microgrid control. *IEEE Transactions on Power Systems*. https://doi.org/10.1109/TPWRS.2005.852060

[4] Zhao, J., Wang, A., Green, M. A., Ferrazza, F., Zhao, J., Wang, A., … Ferrazza, F. (1991). Monocrystalline silicon solar cells. *Appl. Phys. Lett.* https://doi.org/10.1063/1.122345

[5] Heredero-Peris, D., Chillón-Antón, C., Pagès-Giménez, M., Gross, G., & Montesinos-Miracle, D. (2013). Grid-connected to/from off-grid transference for micro-grid inverters. In *PCIM Europe Conference Proceedings*. https://doi.org/10.1109/IECON.2013.6699243

[6] Zsiborács, H., Baranyai, N. H. usné, Vincze, A., Háber, I., & Pintér, G. (2018). Economic and Technical Aspects of Flexible Storage Photovoltaic Systems in Europe. *Energies*. https://doi.org/10.3390/en11061445

[7] Bortolini, M., Gamberi, M., Graziani, A., & Pilati, F. (2015). Economic and environmental bi-objective design of an off-grid photovoltaic-battery-diesel generator hybrid energy system. *Energy Conversion and Management*. https://doi.org/10.1016/j.enconman.2015.10.051

[8] Carlson, D. E., Romero, R., Willing, F., Meakin, D., Gonzalez, L., Murphy, R., … Al-Jassim, M. (2003). Corrosion Effects in Thin-Film Photovoltaic Modules. *Progress in Photovoltaics: Research and Applications*. https://doi.org/10.1002/pip.500

[9] Autengruber, R., Luckeneder, G., & Hassel, A. W. (2012). Corrosion of press-hardened galvanized steel. *Corrosion Science*. https://doi.org/10.1016/j.corsci.2012.04.048

[10] Associated Power Technologies. (2011). 3.Total Harmonic Distortion and effects in Electrical Power Systems. *Associated Power Technologies*. https://doi.org/10.15713/ins.mmj.3

[11] IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System. (n.d.). doi:10.1109/ieeestd.2012.6392181