Study of Battery Sizing for Solar Power Plant

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Abstract. Photovoltaic is one of the products of renewable energy-based electrical energy generation technology, without using fossil fuels, even without mechanical movements in the energy conversion process. Photovoltaic depends only on photons from solar rays. The sensitivity is relatively high against the sun's irradiance, so because of that, both the output voltage and current become unstable. However, the instability of photovoltaic in producing electricity needs to be fixed by adding power storage component, such as batteries. The purpose of this paper is to design an optimal system to measure the size of the battery in Solar Power Plant. The best sizing battery is 80MW with 194 cells.

1. Introduction
Energy is one of the main needs in human life. Increase can be used as an indicator of human prosperity, but at the same time it will cause problems in its supply business. Most people still rely on fossil energy to meet energy needs [1]. So that the longer the fossil energy will be depleted. Excessive consumption of fossil fuels as the main energy source has contributed to various environmental problems, which ultimately accelerate the process of climate change globally. For this reason we need technology which is can supply the energy using the new and renewable energy. New and renewable energy consists of several plants such as Geothermal Power Plant, Hydroelectric Power Plant, Micro Hydro Power Plant, Biomass Power Plant, Wind Turbine Power Plant, Solar Power Plant, etc. However, using the new and renewable energy is very minimal. Based on RUPTL PLN 2016-2025 application from the new and renewable energy just 20% from total system needed.

Solar power is the use of the solar energy either directly as thermal energy (heat) or through the use of photovoltaic cells in solar panels and transparent photovoltaic glass to generate electricity [2]. It is planned to develop a potential solar power plant until 5.000 MW [3]. However, this is difficult to realize because solar power is unstable. Therefore, we need a component that can be help to storage the energy which is to ensure the continuity of electricity supply to grid, even when the generator is not operating. The component is battery or energy storage system (ESS). Battery or energy storage system have two types, that is Lead Acid and Lithium Ion [3-6].

This paper an analysis of battery capacity that is suitable for use in Indonesia will be carried out by having a irradiance of 701 kWh/m²/day and solar power plant capacity is 7 MWp. It is also used the diesel generation as a power support in this system. Which will be simulated by using ETAP.
2. Methodology and material

2.1 Photovoltaic

PV power plant in this study is located in one of major systems in Indonesia. In this simulation the PV capacity is 7 MWp (5 MWac), which has the characteristics of a nominal max power of 320 watts with an optimum operating voltage of 37.4 volts, an optimum operating current of 8.56 amps and a short current circuit of 9.05 amps. With PV installation of 20 modules in series and three modules in parallel. Temperature coefficient alpha (Isc) PV 0.06 and temperature coefficient beta (Voc) -0.03

![Figure 1. PV Power Plant Output](image)

PV has an inverter with 97% efficiency which can be categorized quite well for existing inverter standards. In the results of Fig. 1 it can be seen that the maximum output power of PV is sat 12.00 AM.

| Scenario | Time  | Total Load (MW) | PV Output(MW) |
|----------|-------|----------------|---------------|
| 1        | 01.00 | 8.68           | 0             |
| 2        | 12.00 | 8.73           | 4.5           |
| 3        | 14.30 | 12.19          | 1.25          |
| 4        | 18.00 | 9.17           | 0             |

We will use four scenarios for analysis and result, for 01.00 AM is to see the minimum load, for 12.00 AM is to see the maximum PV output in that day, for 14:30 PM is to see the highest load for evening and 18:00 PM is to see the highest load for night. In table 1, there are four scenarios to identify the best and worst conditions when charging and discharging.

2.2 Energy Storage System

With an inverter, it can convert DC power to energy storage into AC power. In its operation, energy storage has two conditions: charging and discharging [4-9]. When charging, the energy storage system will get power from the rest of the system power minus the load power and when discharging, the energy storage system will provide power to the grid.

As we can know have many type of battery for example is Lead Acid, Lithium Ion, NiCd, and NiMh. Battery Lead Acid or commonly called accu have two types are the starting battery and deep cycle of the battery. The advantages from this battery is equivalent to 800 cycles (2 years of use) and maintenance and can replacement by fill the electrolyte fluid. But this battery contains harmful ingredients [10-13].

Lithium Ion batteries is the highest durability than other and the lowest power losses. This battery has the advantage of being environmentally friendly which is often used on smartphones, laptops and...
various other portable electronic devices [1] Ni-Cd (Nickel-Cadmium) batteries made of Nickel Oxide Hydroxide and Metallic Cadmium electrolytes. It has the advantage of being one of the strongest batteries for the type of rechargeable. But it has disadvantage very fast running, so it must be the charger frequently and contain poisons that can harm humans [3]. NiMh battery (Nickel-Metal Hydride) is a battery has higher capacity than NiCd and other advantages NiMh does not contain toxins in it. But NiMh has more power loss than NiCd.

| Table 2. Battery Characteristic |
|--------------------------------|
| Specification                  |
|                                 |
| Specific Energy (Wh/kg)         |
| Lead Acid                      |
| 30 until 50                    |
| Lithium Ion                    |
| 90 until 250                   |
| NiCd                           |
| 45 until 80                    |
| NiMh                           |
| 60 until 120                   |
| Cycle Life (80% DoD)           |
| Lead Acid                      |
| 200 until 300                  |
| Lithium Ion                    |
| 500 until 2000                 |
| NiCd                           |
| 1000                            |
| NiMh                           |
| 300 until 500                  |
| Cost (per 1 Wh)                |
| Lead Acid                      |
| Low                             |
| Lithium Ion                    |
| High                            |
| NiCd                            |
| Moderate                        |
| NiMh                            |
| Moderate                        |

It can be identified from the table that the highest battery capacity is Lithium Ion. For the best lifetime is Lithium Ion but Lithium Ion has an expensive price than the other three batteries. But seen from its use the most suitable battery to use is Lithium Ion. This simulation was carried out in ETAP 12.6.0 software, where in Fig. 2 is a battery simulation on a 20 kV AC bus will be reduced to 0.4 kV DC via a DC-DC Converter

3. Results and analysis

Figure 2. Single Line Diagram System Power Plant
Basically, it is impossible for a diesel power plant to work 100% for 24 hours, so this simulation is try to see the situation when the diesel power plant works only 80%. It can be identified from Fig. 3 that if the system only gets supplies from the diesel power plant then blackouts will occur in some time. And if the system only gets supplies from the solar power plant, it does not have sufficient capability to support the existing load requirements. As seen from Fig. 3, the graph of the solar power plant never passes the graph load. Therefore, two plants are needed to work together to supply power. From Fig. 3 when a diesel power plant and solar power plant are combined the graph shows that the average output is increased so that the load can be covered and there will be residual output from the solar power plant so that when the solar power plant doesn't work anymore, from 18:00 to 06:30, there will be a component that can help the diesel power plant to supply power to the grid. And the use of diesel can be reduced too. It shown in Table 3 that the result of surplus power which obtained from subtractions between load power and generation (diesel power plant and solar power plant).

| Time  | Load   | Diesel Power Plant 80% | Surplus |
|-------|--------|------------------------|---------|
| 01.00 | 8.688  | 10.18                  | 1.491   |
| 12.00 | 12.897 | 14.711                 | 1.814   |
| 14.30 | 12.192 | 13.810                 | 1.618   |
| 18.00 | 9.171  | 10.18                  | 1.009   |

And from the result we can see that the power have surplus more than 1 MW. From the simulation results of ETAP 12.6.0, the results show that the battery energy storage system that is good for use in the Paokmotong area is shown in Table 4.

| Battery energy storage system characteristic | Value | Unit   |
|---------------------------------------------|-------|--------|
| Total capacity                              | 200   | AH     |
| Rated Voc                                   | 400   | Volt   |
| Cell of battery                             | 194   |        |
| Temperature maximal                         | 30    | Celcius|
| Temperature minimal                         | 15    | Celcius|
Table 5. Result of charging and discharging energy storage system

| Scenario Hour | Storage Condition | PV Pout (MW) | Integration Bus Voltage (kV) | GI Paokmotong System Voltage (kV) | Load Power (MW) | Pout Power Flow (MW) |
|---------------|-------------------|--------------|------------------------------|-----------------------------------|-----------------|---------------------|
| 01.00         | Night Discharging | 0            | 0                            | 19.761                            | 8.573           | 9.783               |
|               | Charging          | 0            | 19.515                       | 19.705                            | 8.564           | 10.5                |
| 12.00         | Day Discharging   | 4.519        | 20.123                       | 19.713                            | 12.775          | 8.247               |
|               | Charging          | 4.519        | 19.887                       | 19.656                            | 9.985           | 2.5                 |
| 14.30         | Day Discharging   | 3.63         | 20.01                        | 19.68                             | 12.331          | 8.761               |
|               | Charging          | Not charging |                              |                                   |                 |                     |
| 18.00         | Evening Discharging | 0           | 19.755                       | 19.755                            | 9.153           | 9.153               |
|               | Charging          | Not charging |                              |                                   |                 |                     |

4. Conclusion

The combination of a diesel and solar power plant can help the system to cover the existing load demand from scenario 1 when 1:00 am having a surplus of 1.499 MW; at 12:00 pm has a surplus of 1.814 MW at 2:30 pm has a surplus 1.618 MW; at 18:00 pm has a surplus 1.009 MW. So that the combined diesel power plant and solar power plant are steps that can be taken to overcoming the blackout problem that occurs due to a single diesel power plant system. Solar power plant that is arranged can use a battery whose characteristics can be taken from ETAP 12.6.0 which is 0.4kV and 400 Ah with the total cell of 194 units. The total power capacity that is right for major area is 80 MW.

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