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The Effect of Penetration Floating Photovoltaic On – Grid in Diponegoro Education Reservoir against Power Quality Distribution Network

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Abstract

Diponegoro University is one of the universities that support the research, development, and utilization of renewable energy in Indonesia. The Diponegoro educational reservoir is one of the facilities at Diponegoro University that can be developed as a floating photovoltaic. The potential of the Diponegoro educational reservoir as a floating photovoltaic on-grid is 1.846 kWp. Penetration of floating photovoltaic in the power grid can affect the power quality of the system. This paper discusses the effect of floating photovoltaic penetration in the education reservoir in Diponegoro on the 20 kV distribution network using ETAP software. In this study, the penetration of floating photovoltaic capacity connect to the distribution network is 0%, 10%, 20%, 30%, and 40%. Penetration of floating photovoltaic can cause a decrease in power factor and losses in the distribution system. The maximum penetration of floating photovoltaic in the education reservoir in Diponegoro in the 20 kV distribution system is 30% with the injected capacity of floating photovoltaic is 1.121,3 kWp and the power factor in of the network is 0,867. Penetration over 30% can cause the system power factor to be less than the allowable power factor standard.

Keywords

Floating photovoltaic, penetration, power factor, power quality

INTRODUCTION

Photovoltaic is an on of renewable energy that has the potential to be developed in Indonesia, which has a tropical climate and a relatively high level of solar radiation intensity. Floating photovoltaic is one of the technologies of photovoltaic that utilizes water reservoirs as an area for build photovoltaic to replace the land. Floating photovoltaic has several advantages compared to photovoltaic on the ground which has been discussed in the previous chapters. The advantage of floating photovoltaic is that water reservoirs can be used as an area to replace land to build photovoltaic on a large scale, and land can be used for other purposes such as for settlements, forests as well as industrial and business areas [1]. In addition, water can also be used for cooling systems for solar panels, with a lower temperature than above ground level, it is expected that the efficiency of solar panels will also be greater so that the output power produced by solar panels will also be greater [2][3]. Another advantage of floating solar panels is that solar panels can reduce evaporation in water storage areas.

The penetration of photovoltaic into the grid needs to consider several factors, including voltage and frequency system and the phase injected by photovoltaic suitable with the grid. Masoud Farhoodnea et al discuss the impact of large-scale photovoltaic on-grid penetration in the distribution power network system that can cause problems in terms of power quality in the electricity network, including voltage increases, voltage flicker, and power factor decreases [4]. The penetration of solar -rooftop photovoltaic in Thailand has also been discussed by Pongsatorn Kerdoum and Suttichai Premrudeepreechacharn [5], who explains that the maximum penetration that can be done in Chiang Mai Thailand is a maximum of 30% so as not to affect the quality of power in the distribution network system.

Diponegoro education reservoir is one of the facilities at Diponegoro University which has the potential to be used as a floating solar power plant. The potential of floating photovoltaic in the Diponegoro Education Reservoir at its standard conditions (radiation of 1,000 W/m2 and temperature of 25oC) is 1.846 kWp[6]. This study discusses the effect of penetration floating photovoltaic in the Diponegoro education reservoir with the power quality in the 20 kV distribution network.

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RELATED THEORY

The amount of active power and reactive power sent by the power plant to the power grid can be calculated using the following equation [7][8].

$$P = \frac{V_i V_s}{2\pi f L_c} \sin\delta = P_{MAX} \sin\delta \quad (1)$$

$$Q = \frac{V_i^2}{2\pi f L_C} - \frac{V_i V_s}{2\pi f L_C} \cos\delta \quad (2)$$

Where Vi is voltage of generator terminals, Vs is voltage of the grid, Lc is grid inductance, f is system frequency, and δ is the phase angle difference between Vs and Vi.

In a solar power plant, the amount of voltage sent by the generator is regulated by the inverter used. The power plant will transmit from the active power (P) to the power grid, which is influenced by the magnitude of the phase angle between the generator voltage and the grid voltage (δ). Active power will be sent by the generator if the generator voltage and power grid voltage are the same, but the phase angle of the generator voltage precedes the grid voltage or the phase angle is positive (positive δ). The generator will send reactive power (Q) to the power grid which is influenced by the magnitude of the generator voltage and the voltage of the power grid in one phase. If the generator voltage (Vi) is greater than the grid voltage (Vs) then the generator will send reactive power to the power grid.

PROCEDURE

In this study to determine the effect of the penetration of floating photovoltaic in the Diponegoro education reservoir on the power flow in the 20 kV distribution network will be analysed by using ETAP software. The floating photovoltaic is connected to one of the buses in the feeder which comes from a 3-phase transformer with a capacity of 60 MVA. The total load capacity connected to the PLTS bus is 200 kVA with a load power factor assumed to be 0,932. The modeling of the Floating photovoltaic in the Diponegoro education reservoir using ETAP can be seen in Fig.1 below.

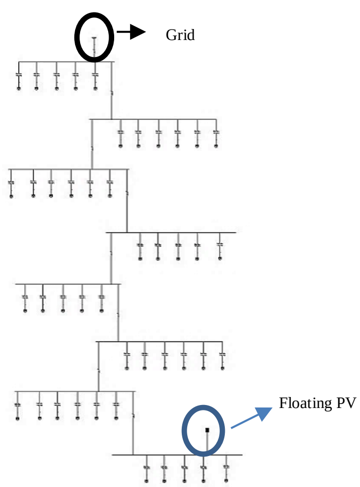

Figure 1. Single line modelling of floating photovoltaic

In this study, the penetration analysis of floating photovoltaic using standard conditions, where the radiation received by the floating solar power plant is 1000 W/m^2 and the ambient temperature and the photovoltaic is 25^{o}C. The effect of on-grid floating photovoltaic penetration on power quality in the 20 kV distribution system in this study discusses the effect of 10%, 20%, 30%, and 40% of the maximum potential of floating photovoltaic in the Diponegoro education reservoir on power on the grid, power factor on the grid, and losses in the 20 kV distribution system.

RESULT

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Photovoltaic on – grid-connected to the distribution network can be used as a distributed generation that can reduce losses in the distribution network system because the location of the generator is close to the load, but the large capacity of on-grid PLTS connected to the electricity network must be considered, especially in the power quality system. In the standard conditions, the potential output power generated by the floating photovoltaic in the Diponegoro education reservoir is 1.846 kWp. The following are the results of the research on the effect of the penetration of the floating photovoltaic capacity to the grid with the power generated by the grid, power factor of the grid, and losses in the distribution system.

TABLE I
Effect of penetration floating photovoltaic on grid with output power, power factor and losses in the grid

No	PV Penetration	Power grid (kW)	Pf grid	System losses (kW)
1	0%	1.698,0	0,932	61,3
2	10%	1.516,6	0,918	55,9
3	20%	1.316,1	0,897	51,2
4	30%	1.121,3	0,867	47,8
5	40%	942,8	0,826	45,8

Based on the results from Table I, it can be seen that the penetration of the floating photovoltaic capacity will affect the amount of power supplied by the grid to the load, the power factor generated by the grid, and losses that occur in the distribution systems. According to Table I, it can be seen that the larger the floating photovoltaic capacity that is injected into the grid, the less power will be generated by the grid. This is because floating photovoltaic also function as a distribution generator to supply power to the load. The effect of floating photovoltaic capacity injection on the power generated by the grid can be seen in the figure below.

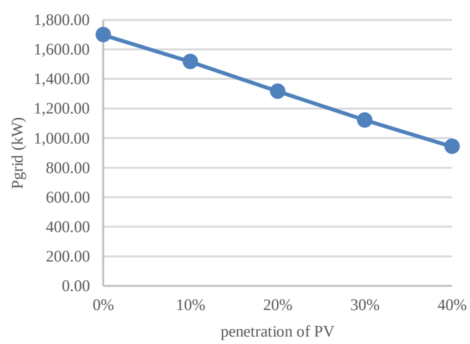

Figure 2. The effect of injection floating photovoltaic on grid power output

Photovoltaic can only send active power to the grid, so the installation of photovoltaic on-grid on the electricity network can cause the power factor in the electricity network to decrease. This can be seen in Table I where the increase of injection of floating photovoltaic on-grid injected into the electricity network can make the power factor in the electricity network decreases. According to PLN standards, the power factor allowed in the electricity network is 0,85. The injection of floating photovoltaic on-grid injection also needs to follow this standard. Based on Table I, the maximum allowed on-grid PLTS capacity injection is 30%. This is because the injection of photovoltaic more than 30% can make the power factor on the grid is 0,826. This value is not suitable with the PLN standards, where the minimum power factor allowed in the electricity network is 0,85. The effect of floating photovoltaic on-grid injection with the power factor on the grid can be seen in the following graphic.

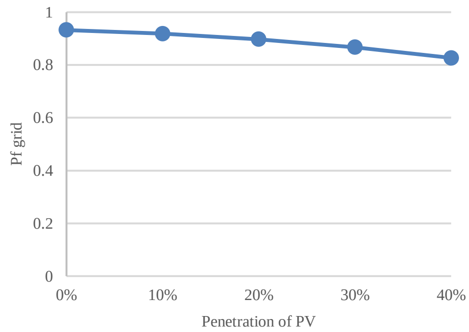

Figure 3. The effect of injection floating photovoltaic with the power factor on grid

The effect of injection floating photovoltaic on-grid also affects the losses that occur in the electric power system. The graphic of the effect of injection floating photovoltaic on-grid on losses in the power grid system can be seen in Figure 3.

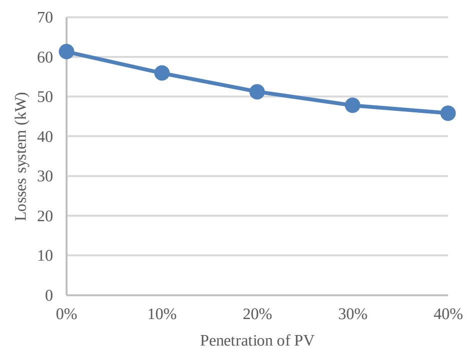

Figure 4. The effect of injection floating photovoltaic with the losses in system

The effect of injection of floating photovoltaic on-grid affects the losses that occur in the electric power system. In Figure 3 it can be seen that the larger the capacity of injected floating photovoltaic into the grid, the smaller the losses in the grid. This is because the floating photovoltaic on-grid as a distributed generator that is located close to the load and it can reduce losses due to the length of the power line.

CONCLUSION

The Diponegoro Educational Reservoir is one of the facilities at Diponegoro University which has the potential as a floating photovoltaic is 1.846 kWp. This photovoltaic can be connected to the grid. The capacity of floating photovoltaic on-grid injection needs to be considered to comply with the applicable electricity network standards so it cant affect the power quality in the grid. Injection of floating photovoltaic on-grid can affect the decrease of output power, power factor, and losses in the grid. In this study, the maximum injection of floating photovoltaic on-grid in the Diponegoro Education Reservoir which is allowed is 30%. This is due to the 40% capacity injection of floating photovoltaic can cause a decrease in the power factor of the grid until 0,826 and this power factor is not suitable with the power factor standard limits allowed by PLN standards.

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