The Effect of Solar Power Generating in Low Voltage Network on the Quality of Electricity to Costumers Side, A Case Study 4 kWp Photovoltaic at Salt Storage

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Abstract. Generating electricity using fossil fuels can increase global warming. To reduce the use of fossil fuels, the implementation of Renewable Energy becomes a choice. One example is a Photovoltaic (PV) installation connected to a grid. The addition of on-grid PV on the load side may provide an undesirable effect for low voltage distribution networks where there are a lot of customers. The most possible effect as PV grid supplies during full sunlight is increasing voltage. This condition may cause severe damage to electrical appliances. The purpose of this work is to analyze changes in power quality parameters, especially for the voltage that occurs as PV supplies full power when irradiation in the range of 90%–100%. A 4 kWp (kilo Watt peak) solar power generation is installed at the salt processing business in Pati Regency, Central Java. The behavior analysis of the low voltage network is proposed to be carried out by the ETAP 12.6 software. During the work, the presence of tapping of the nearest transformer is considered. The experimental results are expected to lead to the indication of the impact of PV on-grid supplies on the low-voltage network.

Keywords: Photovoltaic · Low Voltage · Power Quality

1 Introduction

Energy needs continue to increase along with the increase in population and community activities. One of them is by opening a business that cannot be separated from the use of electrical energy, such as factories or small-scale trading units. As we know the sources used in generating electrical energy are limited and are expected to run out in the near future if they continue to be used without any renewal, but over time, renewable energy such as solar and wind is growing rapidly in the world. According to British Petroleum (BP, 2021), based on data taken in 2020, the capacity of the two power plants grew to 238 GW compared to the previous year [1]. One of these generators is PLTS. The author describes the Solar Power Plant (PLTS) as a power plant that utilizes sunlight to generate electricity. This PLTS has an on-grid and off-grid system. The off-grid system

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is a system without a connection to the 20 kV network, usually these plants are built in remote areas, while the on-grid system is a system that is connected to the 20 kV network [2].

The use of PV is not only potential to generate economic benefits, but also advantages in electrical and environmental aspects. For example, distributed PV systems reduce power losses by generating energy directly at the load, this renewable energy also helps reduce CO_2 emissions from fossil fuels and meets the growing demand for electricity [3]. However, the quality of the power supply such as voltage beyond standard, overcurrent, reverse power flow, and miscoordination of network protection equipment can appear on the side of the medium network as well as the low voltage network. In previous studies the effect of PV has been carried out using a Medium Voltage Network voltage control strategy when PV penetration is high by using an On Load Tap Changer in the case of Overvoltage and Undervoltage [4]. Analyze the impact of harmonics on PV penetration of the network by considering the uncertainty of the load and solar radiation using MATLAB is also carried out considering that solar radiation can never be guessed [5].

From several studies that have been carried out, an idea emerged to analyze power quality, especially PV systems in low-voltage network systems. The survey that has been carried out shows that the location where the PV was established is a salt processing industry which has a capacity of 4kWp. This PV also implements an on-grid system, so when operating the power distribution is divided into 2 (two), which is used in the load for salt processing and distributed to the PLN network. In this article, we will discuss how the impact of adding PV on power quality in low voltage networks and observing the energy savings that occur through the output power of 50kVA distribution transformer that has never been discussed before [6]. The modeling of the PV network to the 20 kV network uses the ETAP 12.6 simulation, where the simulation provides a state of the picture that is in the field, starting from the selection of the PV on-grid components, cable selection, and rating in each component.

2 Methodology

This section aims to describe the design of PV with a capacity of 4kWp on grid for a 20 kV distribution network sourced from the Rembang 07 Substation. Figure 1. Shows a single line diagram of the Rembang Substation where the 4 kWp PV is connected as shown inside the red circle.

From the single line Rembang 07 data, it can be modeled using ETAP 12.6 software to see the load flow of all feeder if PV is connected.

In Fig. 2 starting from a power grid with a capacity of 60 MVA, then heading to a 60 kVA step-down power transformer from a voltage of 150 kV to 20 kV. The distribution network cable is adjusted according to its type, namely ACCC (All Aluminum Conductor). On the 20 kV network there is a load symbolized by Lumped load and can be adjusted according to the load data taken during the survey. This network has protection systems such as Recloser, LBS (Load Break Switch) and Fuse Cut Out for overcurrent protection due to faults. For low-voltage network configuration, a 50 kVA step-down transformer is provided to lower the voltage from 20 kV to 200/380 V. Then the PLTS On Grid scheme is given by compiling a circuit starting from a PV Array,

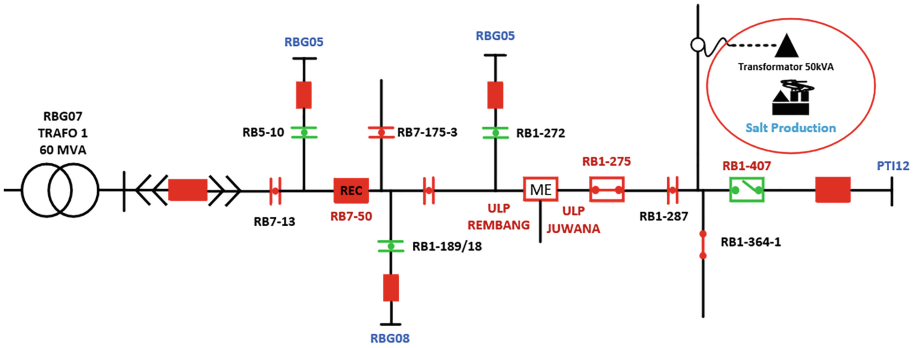


Fig. 1. Single line Rembang 07 distribution network

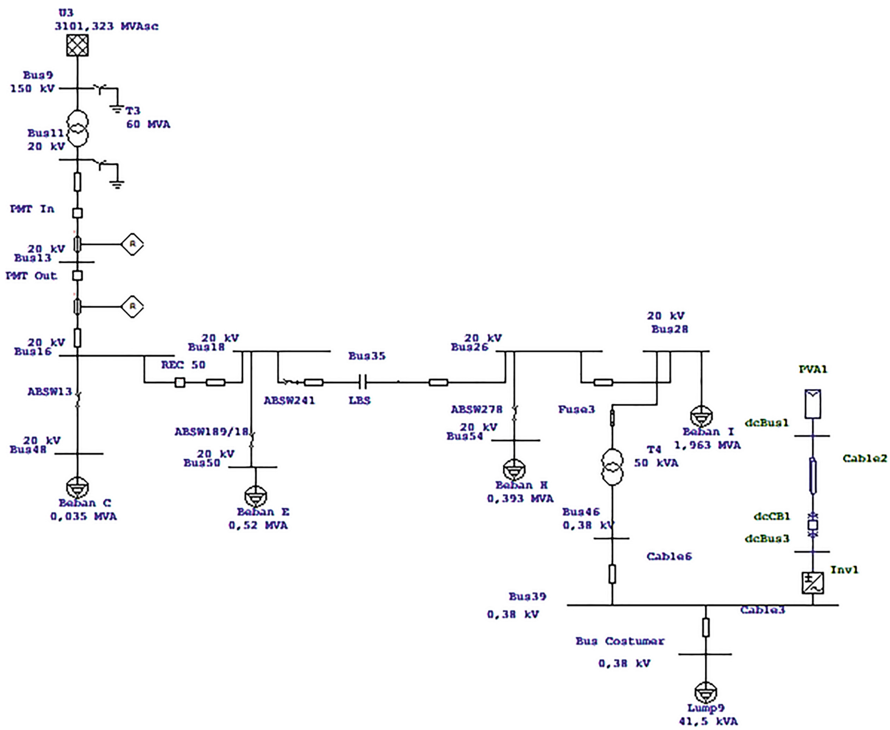


Fig. 2. PV on-grid 4 kWp to Rembang distribution network

DC cable, DC Circuit Breaker and an adjusted inverter. The power flow simulation was chosen to determine the power quality of the salt processing industry affected by the PV installation.

3 Result and Discussion

This experiment has 3 experiments to see the effect of adding PLTS to power quality, especially on the voltage received by the customer. Case 1, measuring the voltage on the side of the transformer 50 kVA before loading. Case 2 the settings for Power Simulation are set at the peak load time and Case 3, when the load conditions are outside the peak load. The configuration of PLTS in both methods is the same, namely providing lighting intensity according to the measurement time from morning to evening. This causes variations in the power output of the PV. For the nominal load variations are also carried out according to the operating hours of the salt processing plant. Later it will be observed on the output voltage side of the 50 kVA transformer with normal tapping and the receiving side symbolized by "Bus Customer".

3.1 Case 1

In the first experiment, running simulations were carried out using the "Adaptive Newton-Raphson" method which can be selected in the "Load Flow Study Case" column in ETAP 12.6. The source voltage of the 50 kVA transformer before it is connected to the load loading. In a 50 kVA distribution transformer before loading, the voltage on the secondary side has a value of 380,7 V. This value is obtained by setting the transformer tap on the primary side under normal conditions. This nominal is in accordance with the applicable low voltage standard. We can see in the Fig. 3:

For the according to the procedure, the results are shown in Table 1 below:

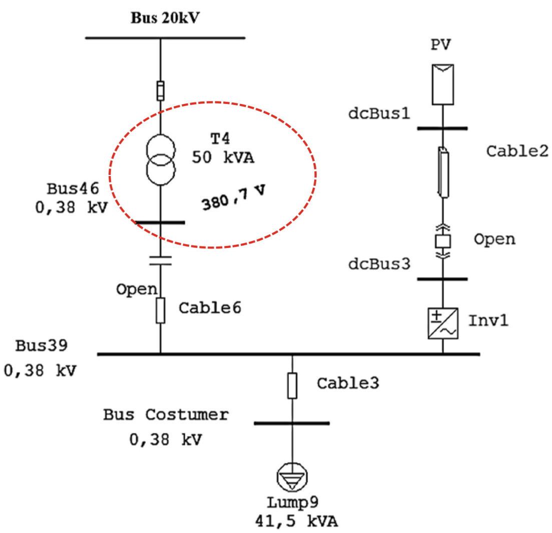


Fig. 3. Transformer output voltage before it is connected to the load

Table 1. Peak load time simulation result.

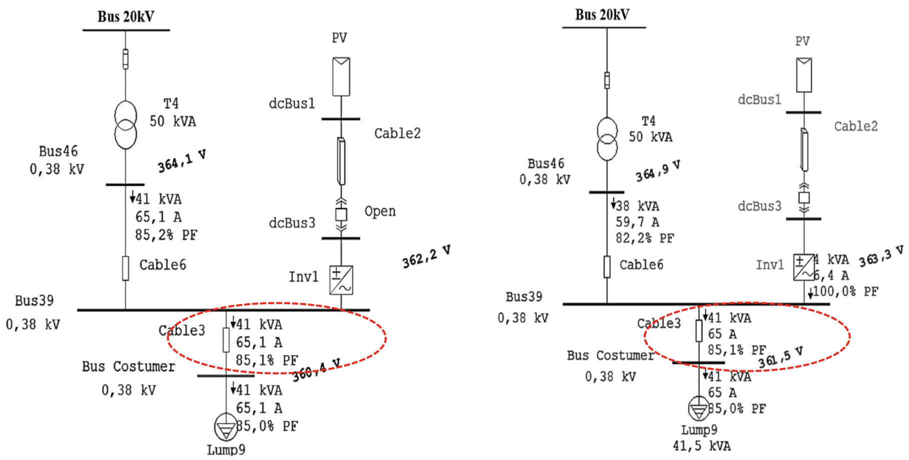
Time	Light Intensity W/m^2	Temperature PV (Default ETAP)	Percentage load in Salt Processing % (kVA)	Percentage load in Salt Processing (kW)	PV Output Power (kW)	Voltage after inject PV (V)	Voltage after Inject PV (V)
7 am	55	25	10% (4,15)	3,57	0,17	376	376
8 am	86	25	75% (31,125)	26,43	0,29	364,8	364,9
9 am to 11 am	905	25	100% (41,5)	35,27	3,98	360	361
12 pm to 1 pm	1000	25	50% (20,75)	17,68	4	369	370,2
2 pm to 3 pm	837	25	100% (41,5)	35,27	3,6	360,4	361
4 pm	400	25	50% (20,75)	17,68	2	369,2	369,6
5 pm	57	25	10% (4,15)	3,57	0,18	376	376

3.2 Case 2

Table 1 shows the effect of the nominal voltage that fluctuates with changes in the load on the salt production house connected by PV. For example, at 7 am when the intensity of sunlight is 55 W/m^2 and the PV outputs active power through the inverter of 0.17 kW, the normal voltage when the salt processing is not fully operational is 376 V, this nominal voltage is the same when the power from the PV is injected. This can happen because the power from the PV is of small value so that the effect of voltage changes on the network is small.

Changes in voltage begin to occur at 9 am to 4 pm, when the salt processing has started to operate and the nominal load begins to rise, the working voltage obtained by the customer is reduced. This is evidenced by a change in the color of the simulation circuit which detects a voltage drop approaching 10% on the low voltage side between 9 am and 11 am.

Before entering the power from the PV Fig. (a), at full load, the nominal voltage received by the customer is 360 V. But after the PV box and the load are turned off, the PV provides energy to the customer. So that there is an increase in voltage of 1 V. This nominal voltage is still within the safe limits indicated in Fig. (b) where the bus returns to normal. This phenomenon is caused because the Rembang 07 feeder is in peak load time



(a) (b)

Fig. 4. Simulation of power flow in case 2 before (a) and after (b) PV energize power to low voltage network

and the location of the salt processing at the end of the network so that the possibility of undervoltage in the 20 kV network is large enough to affect the low voltage side.

3.3 Case 3

In the third case, another phenomenon occurs in the voltage profile on the customer side, the circuit is simulated in the Rembang 07 feeder condition outside the peak load time and variations in sunlight as well to see the effect of voltage changes that occur on the customer side. The results of various experiments are listed in Table 2 as follows,

In Table 2 shows the voltage profile on the customer side ranging from 363 V to 379 V which is better than experiment 2. This is caused by the load on the 20 kV network in the off-peak load time so that the nominal voltage at the end of the network increases even though the transformer tapping from substation inside normal position. In this condition when the salt processing operation is in full load, the role of PV is not only to increase the voltage profile but also to reduce the active power used by customers from substation sources but partly supplied from the PV. This phenomenon can be seen in Fig. 5.

When the PV conditions have not sent energy to the load, the voltage conditions received by the customer are quite good and close to the standard with a nominal 363.5 V by absorbing power from the transformer of 41 kVA (Fig. 1). But after PV sends energy to the load, the nominal voltage increases to 364.5 V and reduces the transformer loading by 4 kVA (Fig. 2). This phenomenon is the same as in the second experiment, but in the third experiment, PV plays more of a role in saving electricity consumption when PV reaches its maximum output power.

Table 2. Peak load time off simulation results

Time	Light Intensity W/m^2	Temperature PV (Default ETAP)	Percentage load in Salt Processing % (kVA)	Percentage load in Salt Processing (kW)	PV Output Power (kW)	Voltage after inject PV (V)	Voltage after inject PV (V)
7 am	55	25	10% (4,15)	3,57	0,17	379	379
8 am	86	25	75% (31,125)	26,43	0,29	367,9	368
9 am to 11 am	905	25	100% (41,5)	35,27	3,98	363,5	364,5
12 pm to 1 pm	1000	25	50% (20,75)	17,68	4	372,2	373,2
2 pm to 3 pm	837	25	100% (41,5)	35,27	3,6	363,5	364,5
4 pm	400	25	50% (20,75)	17,68	2	372,2	372,7
5 pm	57	25	10% (4,15)	3,57	0,18	379	379

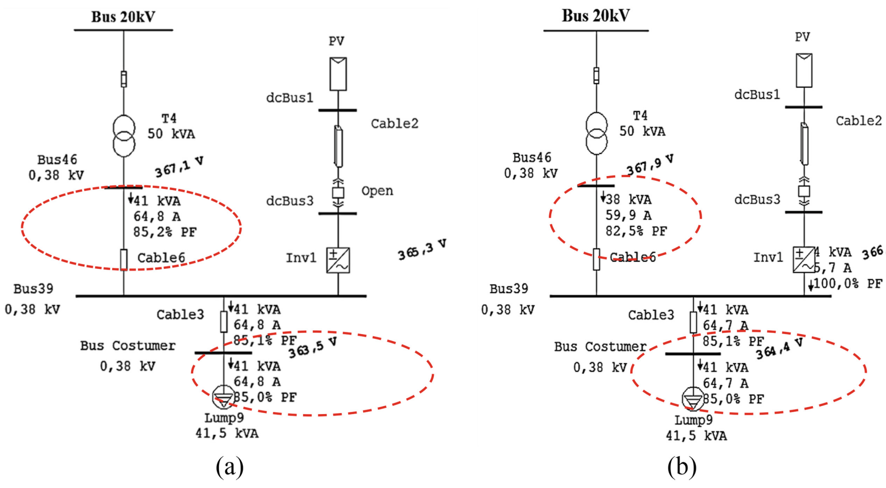


Fig. 5. Simulation of power flow in case 3 before (a) and after (b) PV energize power to low voltage network

4 Conclusion

The effect of adding PV 4kWp in salt processing plant as a second source of electrical energy on the customer has a significant impact in terms of power quality and long-term energy savings. Base on simulate in ETAP form 360 V becomes 361 V. It is proven that when the voltage value drops at the end of the network, the power output from this PV can division power supply and increase the nominal voltage so that the nominal is still within the specified standard limits. The distribution transformer tapping adjustment does not need to be adjusted to get better voltage because of power supply division. Energy savings can also be made when PV gets optimal absorption of sunlight which affects the PV power output.

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