Characteristics of disturbance in frequency 9 -150 kHz of Rasuna Said gas station’s solar panel system

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Abstract. Dependence on the usage of fossil fuel energy sources as a source of electrical energy to overcome the increase in electrical energy needs. The high demand for electricity encourages the development of the use of non-fossil energy sources. One of the new and renewable energy sources producing electricity is solar energy from the sun. Solar panels produce DC electricity which can be converted into AC electricity using an inverter so that it can be connected to an AC load. The switching process and the use of power electronic components in the inverter can generate electrical wave distortion such as disturbance with 9 – 150 kHz frequency in the solar panel system. In this study, the characteristics of the disturbance frequency 9-150 kHz reviewed and their effects on solar irradiation. Furthermore, it shows that the solar panels system-generated disturbance and increased by 1.5 – 12.6% per 100 W/m2

1. Introduction
Dependence on the usage of fossil fuel energy sources as a source of electrical energy to overcome the increase in electrical energy needs. Based on Statistical of World Energy 2018 BP data, Indonesia in 2017 has the availability of fossil fuel sources equivalent to 3.2 million barrels of oil with an annual decline of 2% in the last 10 years. While the consumption of fossil fuel source based on Statistical of World Energy BP 2018 data, Indonesia has increased consumption each year with an average of 0.74% in the last 11 years with the largest consumption occurring in 2017 which is equivalent to 77, 3 million tons of oil [1].

The high demand for electricity encourages the development of the use of non-fossil energy sources. One of the new and renewable energy sources producing electricity is solar energy from the sun [2,3]. The use of solar energy is converted into electrical energy to be applied using solar panels in the Solar Power Plant. Solar panels can be used in small-scale or large-scale electricity networks by utilizing off-grid and on-grid systems [4]. Solar panels produce DC electricity which can then be converted into AC electricity using an inverter so that it can be connected to an AC load [5]. The switching process and the use of power electronic components in the inverter can generate electrical wave distortion in the solar panel system.

Inverters are electronic devices that have non-linear characteristics, namely devices that have a comparison of voltage and current that are not comparable, this is due to the inverter switching process in converting dc electricity into ac electricity. Switching inverters is in the frequency range of 9 - 150 kHz [6]. Therefore, this inverter causes a disturbance in that frequency range. Disturbances at these frequencies are still not standardized so that efforts to limit or eliminate disturbances at these
frequencies are still very few [7,8]. However, due to the increasing use of inverters in the usage of solar power plants, there is a need for excessive handling of disturbances at these frequencies [9,10]. In this study, the characteristics of the disturbance frequency of 9-150 kHz reviewed and their relationship with solar irradiation.

2. Measurement Methodology
The study used a PicoScope. The PicoScope was connected to the output side of the inverter via a high pass filter to obtain observations of high-frequency disturbances. At the same time, the measurements of solar irradiation were carried out using a solar power meter. After the results were obtained, the data was processed by Fourier transformation using a fast Fourier transform method in Matlab [11], so that the response of the frequency could be seen from the disturbance results. Then the result of disturbance was compared with the value of solar irradiation. Figure 1 provides a process flow diagram of this study.

In this study, the system reviewed is a system that has been running, namely the solar panel system in the gas station. This system is a hybrid type on-grid solar panel system, namely a solar panel system connected to electricity network of the State Electricity Company and has a backup system in the form of a battery. Figure 2 is a scheme of the solar panel system of the gas station. In this study variation of solar irradiation was carried out in 6 types of solar irradiation. The analysis of this study focuses on the dominant frequency between 9-150 kHz since it has more contribution to the whole system disturbance. In addition, the effect of volatile solar energy is also investigated on this dominant frequency.

![Methodology flow diagram](image_url)

Figure 1. Methodology flow diagram
Figure 2 shows the research configuration. This study uses 2 measuring devices namely Picoscope and Solar Power Meter (SPM). Picoscope is used to sample the disturbance voltage on bus with inverter output through a high pass filter. High pass filter is used to remove low-frequency voltages so disturbances at high-frequency can be observed and analyzed. Picoscope being used to sample 20ms electric waveform in one second. SPM is used to sample the solar irradiance. It is used only for comparing the relationship between disturbances and solar irradiance.

3. Result of Measurement

3.1. Solar Irradiance
Measurement of solar irradiation was carried out by Solar Power Meter (SPM). The data collected using SPM every 1 second where the SPM was installed on the roof of the gas station next to the solar panel. The study was conducted on February 15, 2019 (11:30 to 18:00), February 16, 2019 (06:00 to 18:00), and February 17 (6:00 to 10:30).

On 15, 16 and 17 February 2019 Solar panels were exposed to maximum irradiation in the amount of 1104, 1114, and 1019 W/m² with the average irradiation values on the day period were 300.95, 297.97 and 229.91 W/m². This solar irradiation fluctuation used as a comparison to the disturbance of the solar panel system which was examined to determine the sun irradiation value to the disturbance of this system.
3.2. Disturbance Characteristics

This measurement was carried out by comparing disturbances arising from solar panel inverters when exposed to solar irradiation. The measurement of this disturbance was carried out in the solar panel system of the gas station. This measurement was carried out with a measurement interval of 1 second. The spectrum of frequency disturbances generated on solar panel systems in the frequency range 9 kHz - 150 kHz is shown in the Fig.4.

Based on the curve above, it can be seen that disturbances occur at several frequencies, namely 10500 Hz, 17500 Hz - 20500 Hz, 30500 Hz, and so disturbances continue to appear periodically which are multiplied by 10kHz. From data processing, there is a dominant disturbance voltage that always appears at certain frequencies, namely the frequency of 18500 Hz, 60500 Hz, and 80500 Hz.

According to the graph, the biggest disturbance occurs in solar irradiation of 900 W/m² with a value of 434 mV and the smallest disturbance occurs in solar irradiation of 400 W/m² with a value of 284.8 mV. From the data, it can be seen that the disturbance at the frequency of 18.5 kHz has increased by 29.84 mV or 7.97% per increase of 100 W/m² of solar irradiation. The disturbances included at frequencies 60.5 and 80.5 kHz as a comparison. While the disturbance at frequencies 60.5 and 80.5 kHz does not experience significant changes and tends to be constant.

The average value of the disturbance is plotted for each solar irradiane level to see their correlation with each other, such as presented by Fig.5.

Figure 3. Solar Irradiation: (a) 15, (b) 16, (c) 17 February 2019.
Figure 4. Disturbance in system solar irradiation: (a) 400, (b) 500, (c) 600, (d) 700, (e) 800, (f) 900 W/m².

Figure 5. Disturbance in Solar Panel System
4. Conclusions
Based on the results of measurements of disturbances at the frequency of 9-150 kHz in the solar panel system of the gas station, the following conclusions were obtained:

- Solar Panel System has a Disturbance Voltage which is dominated by a frequency of 18500 Hz.
- Solar Panel System in Gas Station has a Disturbance Voltage Average at Frequency 18500 Hz of 284.8 mV, when Solar Irradiation is 400 W / m², 297.9 mV, when Solar Irradiation is 500 W / m², 340.9 mV, and when Solar Irradiation is 600 W / m², 374.4 mV during Solar Irradiation of 700 W / m², 380 mV during Solar Irradiation of 800 W / m², and 340.9 mV during Solar Irradiation of 900 W / m².
- When solar irradiation increases, the disturbance voltage also increases. In this study, the disturbance voltage increased around 1.5% - 12.6% for each irradiation increase of 100 W / m².
- The disturbance by the solar panel system is likely to affect the other electronic devices that connected in the same electric system as solar panel systems such as malfunction or derating.

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