Disturbance Frequency 9 – 150 kHz Characteristics towards Total Demand Distortion on On-Grid Solar Panel System in the Electrical System of Kuningan Gas Station

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Abstract. To use solar energy into electricity, a solar panel system is needed which of course uses solar panels. As we know, a solar panel system has quite a lot of non-linear equipment, for example is an inverter. The use of this inverter will affect the power quality of the output of solar panels, one of which is disturbance. At a frequency range of 9 – 150 kHz, electrical equipment with an inverter will produce a disturbance in the system. So, in this paper, the study was conducted to observe the characteristics of the disturbance frequency of 9 – 150 kHz towards total demand distortion on on-grid solar system in the electrical system at the gas station so that it can be used as a guide for future disturbance and solar energy research.

1. Introduction
Energy is vital in human life. Energy cannot be created and destroyed and can be converted from one form to another [1]. Energy sources in the world are very abundant and distributed everywhere. Energy sources from petroleum, fossil fuels and natural gas are very widely used and utilized by humans while other energy sources such as leaves, wood, wind, air, sun, and tidal waves are rarely used [2].

In the present, many alternative energy sources have been applied in life to replace fossil energy sources [3]. One example of alternative energy is solar energy. Solar energy is an energy in the form of heat and light that emitted by the sun. Solar energy (sun) is one of the most important renewable energy sources [4]. Indonesia has abundant solar energy potential. But the abundance of solar energy sources in Indonesia has not been utilized optimally. Solar panels are needed to convert solar energy into electrical energy [5],[6].

The use of power electronics such as solar panels, batteries, or DC loads on electrical grid systems makes the electricity grid system more vulnerable to power quality problems and raises high-order harmonics [7],[8]. Inverters, as one of the important components in solar panel systems, have characteristics that are not linear, so they can cause distortion in the electrical system. Thus, the inverter has the potential to cause disturbances at a frequency of 9 kHz to 150 kHz. In the past, the number of researches on disturbances was still small because disturbances have not been found as much as now and number of devices that produce disturbances at frequencies of 9 kHz to 150 kHz are still small [9]. In the present, disturbances are important to study because emissions at high order frequencies have the potential to cause malfunctions in power line communication (PLC) [10]. Therefore, research on this disturbance is important for the present and the future.
Because the increasing use of inverters and solar panel system in electrical systems and the more frequent occurrence of this disturbance phenomenon in the electrical system [11],[12], we conducted research on the characteristics of the disturbance frequency of 9-150 kHz on-grid solar panel system against total demand distortion in the electrical system at the gas station as a preliminary study of the effects of disturbances on solar panel systems.

2. Research Methodology
This research is carried out using a computer connected to a Picoscope that is connected to the electrical system of the solar panel to see the disturbances that exist when the solar panel system works. Along with observing disturbances, measurement of system load power is also carried out using Power Quality Analyzer. The Picoscope is connected to the load which is the output of the inverter which aims to observe disturbances. Then, the measurement results and data are processed to be seen only from the voltage side so that the characteristics of the disturbance frequency of 9-150 kHz on-grid solar panel system to the total demand distortion in the electrical system at the gas station can be seen.

This research was conducted with a system configuration as below:
Figure 2. Measurement system configuration.

Figure 2 shows the research circuit used by us. This study uses 2 measuring devices namely Picoscope and Power Quality Analyzer. In the solar panel system at the gas station, there are two power reserves that are used when the solar panel system cannot supply the needs of the load at the gas station. When the solar panel system cannot supply the load, the PLN grid system will become a supply reserve for the system. Batteries and diesel generators are used when abnormalities occur in a system such as the PLN grid system that cannot deliver power to the system. This phenomenon can cause negative effect on the grid of PLN because the use of grid tie inverters and bi-directional inverters has non-linear characteristics so that it can cause abnormal waveforms.

In this study, Picoscope is used to sample the disturbance voltage on the bus from the inverter output in the electrical system through a high pass filter. High pass filter is used to remove low-frequency voltages so that disturbances at frequencies of 9 - 150 kHz can be observed and analyzed.

3. Result and Analysis
To see the effect of total harmonic distortion on the disturbances generated by the on-grid solar panel system in the gas station electrical system, it is necessary to process data to determine the total harmonic distortion. To get this data, large current data, large THD, and the largest amount of current in phase 1 are needed by using a Power Quality Analyzer (PQA) tool. The power sampling interval used is every 60 seconds. The measurement and data retrieval were carried out from March 6, 2019 at 17:11:51 to March 8, 2019 at 16:07:24. This data retrieval is done together with data retrieval disturbance on the Picoscope tool. The following is a graph of the TDD measurement results for time starting on March 6, 2019 17:11:51 to March 8, 2019 16:07:24.

Measurement of disturbance was carried out on the on-grid system of the gas station on the part of the gas station tenants. The solar panel system assisted by the National Electric Company supplies electricity to tenants. Tenant expenses depend on the use of tenants in the gas station tenant’s premises. Because the electricity system is an on-grid solar power plant, research is conducted to determine the effect of power quality, one of which can be seen from the TDD of the electrical system to the disturbances generated in the electricity system at the gas station in this tenant. Value of disturbance is taken from five data variations based on the percentage of TDD. In processing data, we took a sample of five large values of power, namely at the percentage of 0%-2%, 2%-4%, 4%-6%, and 6%-8%.
Figure 3. TDD on 6\textsuperscript{th}, 7\textsuperscript{th}, and 8\textsuperscript{th} of March 2019.

Figure 4. Disturbance in TDD at percentage of 0\%-2\%, 2\%-4\%, 4\%-6\%, and 6\%-8\%. 
We averaged the five data for each percentage TDD to see the trend. We chose the frequency of 10 kHz to be observed because disturbances at this frequency always appear on the five data and are frequencies with the most dominant disturbances. Then we also chose the 30 kHz frequency as a comparison. The following is the result of the average disturbance at each percentage of TDD at frequencies of 10 kHz and 30 kHz:

![Figure 5](image)

**Figure 5.** Average disturbance at each percentage of TDD at frequencies of 10 kHz and 30 kHz.

Figure 5 shows that at frequency of 10 kHz, the greatest disturbance is at the TDD percentage of 0% - 2% with the value of 258.51 mV and the smallest disturbance at the TDD percentage of 4% - 6% with 223.9 mV. The disturbance graph at 30 kHz frequency is also included as a comparison. The relationship of voltage disturbances at frequencies of 10 kHz and 30 kHz can be said to be relatively constant.

We reviewed the Disturbance Voltage on the dominant frequency of the on-grid solar panel electricity system at the gas station at the time of sun irradiation at the 18 kHz frequency and review the 10 kHz frequency which is dominant at times other than the sun exposure period and frequency used in data analysis in the previous analysis as a comparison. The analysis was carried out on March 7, 2019 from 6:00:00 WIB to 17:59:59 WIB. In this analysis all values are converted into percentages compared to the largest values at each disturbance and TDD to simplify the analysis.

![Figure 6](image)

(a) ![Figure 6](image)

(b) ![Figure 6](image)

**Figure 6.** Disturbance graph for time at 18 kHz and 10 kHz frequency compared to TDD.

In (a), disturbance voltage at the 18 kHz frequency is similar with the TDD curve, where when the TDD value rises, the voltage disturbance tends to increase and vice versa. In (b), namely disturbance voltage at 10 kHz frequency, it is seen that disturbance voltage does not significantly affect TDD at this frequency. This is because the disturbance at this frequency can be concluded depending on the amount of load connected.
4. Conclusion
Based on the results of measurements and analysis carried out on the characteristics of the disturbance percentage of TDD in the on-grid solar panel system of the gas stations, some conclusions can be drawn:

1. In the TDD percentage of the disturbances that are generated in the gas station solar panel system, frequency with the most disturbance voltage and always appears in the five data is 10 kHz frequency, with an average TDD of 0% - 2% at 258.51 mV, on TDD 2% - 4% at 239.63 mV, on TDD 4% - 6% at 223.92 mV, and on TDD 6% - 8% at 235.25 mV.
2. The value of disturbance voltage at frequencies of 10 kHz and 30 kHz compared to the increase in TDD is relatively constant.
3. The voltage disturbance at the 18 kHz frequency is similar with the TDD curve, that is, when the TDD value increases the disturbance voltage value also increases and vice versa.
4. The voltage disturbance at 10 kHz frequency is not too affected by TDD, because the disturbance at this frequency is more affected by the load.

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References
[1] Kanna I V and Pinky D 2018 Solar research – a review and recommendations for the most important supplier of energy for the earth with solar systems Int. J. Ambient Energy 1 1–7
[2] Zhang D, Wang J, Lin Y, Si Y, Huang C, Yang J, Huang B and Li W 2017 Present situation and future prospect of renewable energy in China Renew. Sustain. Energy Rev. 76 865–71
[3] Cheng J J 2017 Biomass to Renewable Energy Processes, Second Edition (CRC Press)
[4] Kannan N and Vakeesan D 2016 Solar energy for future world: - A review Renew. Sustain. Energy Rev. 62 1092–105
[5] Tiandho Y, Dinata I, Sunanda W, Gusa F and Novitasari D 2019 Solar energy potential in Bangka Belitung Islands, Indonesia IOP Conference Series: Earth and Environmental Sciences 257 012022
[6] Handayani T P, Hulukati S A, Jaya R, Tiandho Y, Abdullah R 2019 The prototype of solar-powered building lighting IoT IOP Conference Series: Materials Science and Engineering 486 012079
[7] Rönnberg S 2015 Primary emission and Secondary Emission 23rd International Conference on Electricity Distribution Lyon 15-18 June 2015 1621 PV 15–8
[8] Amaripadath D, Roche R, Joseph-Auguste L, Istrate D, Fortune D, Braun J P and Gao F 2018 Measurement of Supraharmonic Emissions (2-150 kHz) in Real Grid Scenarios CPEM 2018 - Conf. Precis. Electromagn. Meas. 1–2
[9] Larsson E O A and Bollen M H J 2009 Emission and immunity of equipment in the frequency range 2 to 150 kHz 2009 IEEE Bucharest PowerTech Innov. Ideas Towar. Electr. Grid Futur. 1–5
[10] Rönnberg S and Bollen M 2016 Power quality issues in the electric power system of the future Electr. J. 29 49–61
[11] Sudiarto B 2017 The Properties and Behavior of Disturbances in the Frequency Range 9 kHz to 150 kHz Produced by Household Appliances in a Residential Network Environment (Germany: Universitat Duisburg Essen).
[12] Klatt M, Meyer J, Scheugner P and Lakenbrink C 2016 Characterization of supraharmonic emission caused by small photovoltaic inverters Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion (MedPower 2016) 6 78