The impact of electric disturbance at frequencies 2-150 kHz on analogue kilowatt-hour meter

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Abstract. Along with the times and technology, more often we find housing or offices that use a smart home system or smart building that integrates electrical appliances at home and offices into a single system, for example, lighting, air conditioning, security systems, etc. The use of electrical equipment that uses a system with an inverter technology can trigger disturbances related to the frequency switching used. The disturbance may affect the energy measured by energy meter. The study observes the impact of electric disturbances at frequencies range of 9-150 kHz on kWh meter. The disturbances are generated manually using Personal Computer and injected to the system through coupling network device. The disturbance generated has single and multifrequency disturbance in the range of 9-150 kHz. The result shows that there are inaccurate measurements on the analogue kWh meter when exposed to disturbances with an average percentage error of 2.91%. What can be done in the future is to install filters to reduce disturbances at these frequencies so as not to interfere with the performance of these devices.

1. Introduction
Today, technology is growing, and more and more household appliances are using power electronics device. The use of household appliances that use power electronics device can certainly cause disturbances. Disturbances can be caused by electromagnetic interference EMI. Disturbances that emerge radiatively emanate from communication equipment and conductively from non-communication equipment [1]. The use of power electronics such as solar panels, batteries, or DC loads on the electricity grid system makes the electrical grid system more vulnerable to power quality problems and raises harmonics at high order [2],[3]. Therefore, it is important to study disturbances and know the impact that occurs on household appliances.

According to the Deutsche Commission's EFD, electromagnetic disturbances affect to household appliances that use electricity. For example, the radio produces sound noise up to 20 kHz. For notebooks, the cursor position changes at a frequency of 37 kHz [4].

In the past, research on disturbances was still small because disturbances have not been found as much now and devices that produce disturbances at frequencies from 9 kHz to 150 kHz are still few [5]. At present, this is important to study because emissions at high order frequencies have the potential to create malfunctions in power line communication (PLC) [3],[6]. The most common effects of superharmonics on equipment are additional heating, audible noise, malfunction of equipment, and
malfunction of PLC [7]. Therefore, research on these disturbances important for the present and future [8].

Table 1. Permissible Error Limit of kWh Meter [9].

| Class | Permissible Error Limits |
|-------|--------------------------|
| 0,5   | ± 0,5%                   |
| 1     | ± 1%                     |
| 2     | ± 2%                     |

KWh (KiloWatts per Hour) meter is the electronic equipment used to read power usage in households and industries. Power used by electricity consumers will be recorded by kWh meter per hour. Generally, residential consumers use a single-phase kWh meter while industrial consumers use three-phase kWh meter. The kWh meter is designed to measure the power used with inputs in the form of currents and voltages with pure sinusoidal waveforms.

Measurement errors by the kWh meter can cause losses both on the customer side and from the utility company. As an illustration, in Indonesia consists of millions of electricity customers who use kWh meter as gauges for electrical energy transactions. This can illustrate how much loss must be experienced if there is a measurement error by the kWh meter, and this can be caused by disturbances [10].

Based on the Decree of the Director-General of Domestic Trade of Indonesia, the allowable error limit of analogue kWh meter is in Table 1. If the disturbance can lead to more measurement errors than is permitted, then the disturbance must, of course, be taken more seriously because of its adverse effects.[9]

2. Research Methodology
This test requires a process that makes testing structured and systematic. This flow diagram will be the basis for the author in conducting testing so that the testing process runs smoothly. The following is a test flow chart of this research:

![Figure 1. Research flowchart.](image-url)
Figure 2 is the test configurations in this research, namely for testing the impact of disturbances on kWh meter. For testing the impact of disturbances on kWh meter, the disturbances are generated by PC using MATLAB software. Then, the output from the PC is inserted into the amplifier. This amplifier is used to amplify the output signal from the PC. From this amplifier and then connected to the CDN or Coupling-Decoupling Network. Couplings function to inject disturbances to the load through the power grid and the decoupling circuit is used to ensure that the disturbances do not affect the electrical network outside the test circuit. And then, there is a kWh meter and a PQA to measure the number of kWh used by the load. The load used is a resistor which according to theoretical calculations uses 1045 W. The purpose of this test is to expect an impact on the measurement of the kWh meter due to the disturbances given to the kWh meter. Tests carried out three times with each test carried out for one hour. In this study, the analogue kWh meter used was class 2.

3. Result and Analysis
In testing the impact of disturbance on the analogue kWh meter, observed the total energy consumption of the load in units of kWh at the time before and being given disturbances compared with measurements from the power quality analyzer (PQA). Then a large percentage of errors from analogue kWh meter measurements are compared with the results of kWh measurements with PQA. Then see if given the distribution will increase the measurement error of the analogue kWh meter tested. To calculate the percentage error of the kWh meter, the following formula is used:

\[
\% \text{error} = \frac{E_{kWh} - E_{PQA}}{E_{PQA}} \times 100\%
\]

Where:
- \(E_{kWh}\) = Energy measurement by analogue kWh meter
- \(E_{PQA}\) = Energy measurement by Power Quality Analyzer
Based on the Figure 3, it can be ascertained that the measurement of energy when an analogue kWh meter is injected with frequency disturbances of 2-80 kHz at single or multi-frequency has a greater error percentage than when measuring energy with an analogue kWh meter when no injection is injected. This concludes that the frequency distribution of 2-80 kHz has an impact on the analogue kWh meter. It can also be seen that the greater the frequency, the greater the relative error percentage of the analogue kWh meter which concludes that this is following the existing theory. Based on the graph above, the largest percentage of errors is when injected with a single frequency at a frequency of 30 kHz with a large percentage of errors of 3.94%. For multi-frequency injection, the largest percentage of errors is when injected with a frequency of 60-80 kHz with a large percentage of errors of 3.85%. The average percentage error in measurement of kWh meter when injected with frequency disturbances of 2-80 kHz is 2.91%. This result proves that the disturbance makes the percentage of measurement error from the kWh meter exceed the provisions based on the Decree of the Directorate General of Domestic Trade is +/- 2%.

Then, based on Table 2, it can be observed that the average difference between energy measurements with kWh meter compared with energy measurements with PQA is positive which indicates that energy measurements with analogue kWh meter are greater than they should be so it can be concluded that under these conditions disadvantaged is from the consumer side.
Table 2. The difference in energy measurement between analogue kWh Meter and Power Quality Analyzer for each type of disturbance.

| Type of Disturbance | Deviation [kWh Meter – PQA] (kWh) | 1st Experiment | 2nd Experiment | 3rd Experiment |
|---------------------|-----------------------------------|----------------|----------------|---------------|
| 0.01352             |                                   |                |                |               |
| 0.01804             |                                   |                |                |               |
| 0.00684             |                                   |                |                |               |
| 0.03823             |                                   | 0.01295        | 0.01488        |               |
| 0.01753             |                                   |                |                |               |
| 0.02363             |                                   |                |                |               |
| 0.01899             |                                   | 0.01942        | 0.01598        |               |
| 0.01871             |                                   |                |                | 0.01660       |
| 0.03151             |                                   |                |                | 0.01887       |
| 0.01799             |                                   | 0.01759        | 0.01349        |               |
| 0.02923             |                                   | 0.02712        | 0.02641        |               |
| 0.02179             |                                   |                | 0.04260        |               |
| 0.03800             |                                   | 0.03800        | 0.02511        |               |
| 0.02814             |                                   |                | 0.03267        |               |
| 0.01307             |                                   | 0.02100        | 0.01249        |               |
| 0.02154             |                                   | 0.03853        | 0.02744        |               |
| 0.02998             |                                   | 0.02550        | 0.02887        |               |
| 0.03216             |                                   | 0.03260        | 0.02512        |               |
| 0.02136             |                                   | 0.03314        | 0.02616        |               |
| 0.01780             |                                   | 0.03651        | -0.00080       |               |
| 0.02052             |                                   | 0.01498        | 0.01536        |               |
| 0.01776             |                                   | 0.01678        | 0.01389        |               |
| 0.02655             |                                   | 0.05036        | -0.01665       |               |

From testing the impact of 2-80 kHz frequency disturbances on this kWh meter, it can be observed that this 2-80 kHz frequency disturbances have a bad impact on the accuracy of the kWh meter and are financially detrimental, especially from the consumer side. To anticipate this loss, filters can be installed in the future to reduce disturbances at these 2-80 kHz frequencies to reduce energy measurement errors by the kWh meter and reduce financial losses that will occur.

4. Conclusion
Based on the results of measurements and analysis of the impact of disturbances on kWh meter, conclusions can be drawn namely: the results of energy measurements using analogue kWh meter are affected by disturbances of 2-80 kHz, which is becoming more inaccurate, and the greater the frequency, the greater the relative percentage of analogue kWh meter error. Then, the average percentage error of measurement of kWh meter when injected with frequency disturbances from 2-150 kHz at a single frequency and multi-frequency is 2.91%, so the disturbances make the percentage of measurement error from the kWh meter exceed the provisions based on the Decree of the Directorate General of Domestic Trade is +/- 2%. Next, the largest average percentage of error in energy measurement with a analogue kWh meter occurs when injected with a single frequency disturbance that is at a frequency of 30 kHz is 3.94%. Furthermore, the largest average percentage of error in energy measurements with analogue kWh meter, when injected with multi-frequency disturbances, is when injected with 60-80 kHz frequency disturbances is 3.85%. Finally, to anticipate this loss, filters
can be installed in the future to reduce disturbances at the frequency of 2-150 kHz to reduce energy measurement errors by the kWh meter and reduce financial losses that will occur.

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Acknowledgment

This research was supported by Universitas Indonesia (UI) through PUTI grant 2020 (International Indexed Publication) launched by DRPM UI.