Disturbance Characteristics of Uninterruptible Power Supply System in the Frequency Range 9 – 150 kHz with Capacitive Load Level Variations

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Abstract. Nowadays the use of Uninterruptible Power Supply (UPS) is common because UPS is able to provide a backup electrical power when the main source is disconnected or interrupted. With the use of a UPS, the supply of electrical power to the system will not be interrupted. When the UPS operates, the voltage go through dual conversion process, from AC to DC by the rectifier and from DC to AC by the inverter. The DC voltage in the UPS is used to supply the battery charger and the AC voltage is used to supply the load system. The switching process of the inverter can produce disturbances at high frequency. In this study, a 1 KVA UPS is connected to a capacitive load 3.6 μF, 7.2 μF, 14.4 μF and 28.8 μF which generate the highest disturbances voltage of 309.53 mV at a frequency of 9.8 kHz at a load of 28.8 μF and the lowest of 1.33 mV at a frequency of 110.6 kHz at a load of 3.6 μF. The disturbances voltage occur at three dominant frequencies of 19-24 kHz, 35-44 kHz and 105- 114 kHz and increases as the increase of capacitive load level.

1. Introduction
The need for backup of electric power sources as a source that is able to supply electricity temporarily when electricity from the main source is interrupted or disrupted make the use of Uninterruptible Power Supply (UPS) devices increasing. Also in recent years the use of UPS increase as the development of power infrastructure needed to support IT [1]. Because the use of UPS devices ensures that all equipment connected to a UPS device will not interrupted for even a second [2]. The UPS is compatible to use for sensitive applications and it can adjust the input voltage so the output of the UPS suit with the load input ranges voltage [3]. In standard operation the UPS has three modes namely bypass mode, battery mode and normal mode [4]. Bypass mode is used when the UPS device is in the process of maintenance or under certain conditions it can automatically switch to bypass mode when the load carried by the UPS device exceeds its nominal capacity [5]. Battery mode or emergency mode occurs when the main power source is disconnected so the UPS device automatically switches to use a battery to supply voltage to the load without power cut [6]. In this mode, the direct current bus supplied by the battery [7]. Stored electric power will be distributed to electronic equipment when themain power source is lost. The process of supplying the battery will continue until the battery voltage drops. And the last is the normal mode, this mode is used when the UPS works in normal conditions. The alternating current from the main source enters the UPS device which is then converted into direct current by the rectifier.
Direct current is used to supply to the battery charger for charging the battery and the output from it is converted again into alternating current by the inverter to supply voltage to the load. High switching frequency of inverters can reduce the low order harmonic distortion, but it shifts emissions into higher frequencies which is more than 2 kHz [8]. With the use of an inverter, the UPS device becomes one of the devices that can cause disturbances on the output voltage that connected to the load [9]. The characteristic of an inverter is nonlinear, thus potentially causing disturbances voltage in the electrical system [10].

2. Research Methodology

This study uses a picoscope to record the data. Picoscope is a portable oscilloscope that is used by connecting to a computer so that it gets power through a USB connection from the computer. All measurement data files recorded by the oscilloscope are then stored in the computer. Data recorded by the oscilloscope is still in the time domain signal, so it needs to be converted into the frequency domain signal using fourier transforms. In order to facilitate the data processing, changing data from the time domain signal to the frequency domain signal using fourier transforms is done using the matlab application. To filter the measured frequency only in the range of 9 kHz to 150 kHz, this study uses a high pass filter that connects the output voltage of the UPS to the oscilloscope so that the recorded data is only the disturbances voltage that generated at frequencies from 9 kHz to 150 kHz. In result of this research can be seen the characteristics of the disturbances voltage produced when the UPS uses normal mode with capacitive loads in the frequency range of 9 kHz to 150 kHz. The research flowchart presented in Figure 1.

![Figure 1. Research Flowchart](image-url)
This research was conducted with a system configuration as Figure 2.

As in Figure 2, in this study the disturbances voltage generated from the output side of the UPS with a maximum capacity of 1 KVA are recorded continuously using an oscilloscope. Before carrying out data measurements, the UPS is first set to operate in normal mode so that the voltage supplied to the system comes from the output of an inverter. The dc voltage that comes from the rectifier is then converted to ac voltage using an inverter so that the voltage supplied to the system is in the form of an ac voltage with a voltage range of 200 volts to 240 volts. When the UPS operates in normal mode, alternately the capacitive load connected to the UPS is turned on so that the capacitive load connected to the UPS varies from 3.6 μF, 7.2 μF, 14.4 μF and 28.8 μF. Thus the data recorded by the oscilloscope has each characteristics according to the connected load level.

Frequencies that are below 9 kHz will be cut by a high pass filter so that the data recorded for analysis will only display disturbances voltage in the frequency range of 9 kHz to 150 kHz.

3. Result and Discussion

From the results of this study it was found that the disturbances voltage from 1 KVA UPS in the frequency range of 9 kHz to 150 kHz have different characteristics at each load level variation. The peak disturbances voltage generated in this study increase as the increase of capacitive load level and the result of disturbances voltage with capacitive load level variation accumulate with the disturbances voltage that generated from the switching frequency process from an inverter in UPS. The disturbances voltage that generated in this study are occur at three dominant frequencies of 15 kHz - 24 kHz, 35 kHz - 44 kHz and 105 kHz - 114 kHz as presented in Table 1.

| Capacitive Load | Load Level | Description | Frequency Range (kHz) |
|-----------------|------------|-------------|-----------------------|
| 3.6 μF          | 10%        | Frequency (kHz) | 19.6 39.4 110.6 |
|                 |            | Voltage Peak (mV) | 195.07 71.07 1.33 |
| 7.2 μF          | 20%        | Frequency (kHz) | 19.6 39.4 110.4 |
|                 |            | Voltage Peak (mV) | 243.85 214.20 61.47 |
| 14.4 μF         | 40%        | Frequency (kHz) | 19.8 39.6 110.4 |
|                 |            | Voltage Peak (mV) | 288.53 274.59 66.91 |
| 28.8 μF         | 80%        | Frequency (kHz) | 19.8 39.6 110.4 |
|                 |            | Voltage Peak (mV) | 309.53 291.94 83.60 |
As in Figure 3, it shown when the UPS is connected to a capacitive load of 3.6 µF. The highest disturbance voltage that generated is 195.07 mV at a frequency of 19.6 kHz then the next disturbance voltage peak is 71.07 mV at a frequency of 39.4 kHz and 1.33 mV at a frequency of 110.6 mV.

![Figure 3. Disturbance Voltage at Load of 3.6 µF](image)

As in Figure 4, it shown when the UPS is connected to a capacitive load of 7.2 µF. The highest disturbance voltage that generated is 243.85 mV at a frequency of 19.6 kHz then the next disturbance voltage peak is 214.20 mV at a frequency of 39.4 kHz and 61.47 mV at a frequency of 110.4 mV.

![Figure 4. Disturbance Voltage at Load of 7.2 µF](image)

As in Figure 5, it shown when the UPS is connected to a capacitive load of 14.4 µF. The highest disturbance voltage that generated is 288.53 mV at a frequency of 19.8 kHz then the next disturbance voltage peak is 274.59 mV at a frequency of 39.6 kHz and 66.91 mV at a frequency of 110.4 mV.

![Figure 5. Disturbance Voltage at Load of 14.4 µF](image)
As in Figure 6, it shown when the UPS is connected to a capacitive load of 28.8 µF. The highest disturbance voltage that generated is 309.53 mV at a frequency of 19.8 kHz then the next disturbance voltage peak is 291.94 mV at a frequency of 39.6 kHz and 83.6 mV at a frequency of 110.4 mV.

Figure 6. Disturbance Voltage at Load of 28.8 µF

4. Conclusion

Based on the results of measurements of disturbances voltage at the frequency of 9 kHz to 150 kHz in UPS system with capacitive load level variations, the following conclusions were obtained:

- UPS system has disturbances voltage peak which are dominated by frequency ranges of 15 – 24 kHz, 35 – 44 kHz and 105 – 114 kHz
- Disturbances voltage peak which are generated in UPS system that connected to capacitive load has the highest voltage peak at 19.8 kHz and 19.6 kHz.
- As the capacitive load level increases, the disturbances voltage also increase. When the load level is 10% or when load connected is 3.6 µF the disturbance voltage is 195.07 mV at frequency of 19.8 kHz and when the load level increase to 80% or when load connected is 28.8 µF the disturbance voltage increase to 309.53 mV at frequency of 19.8 kHz.
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