Harmonisa in defibrillator equipment (DC Shock) using simulink Matlab

P Harahap* and B Oktrialdi
Departement of Electrical Engineering, Faculty of Engineering, Universitas Muhammadiyah Sumatera Utara, Medan, Indonesia

*Email: partaonanharahap@umsu.ac.id

Abstract. The quality of electric power is a combination of voltage quality and current quality. Voltage disturbances often occur from the electricity network which can affect end users. Whereas, current interruption originates from end users which will affect the network. Electrical power quality problems in hospitals often occur due to non-linear loads, harmonic injection, and interaction between medical devices. Because the electrical power quality problem is cumulative, the detected minor event must be taken seriously. The nonlinear load distorts the current waveform and creates a harmonic current to the current system. After the simulation, it can be concluded that DC Shock/Defibrillator equipment has Total Harmonic Current Distortion (THDi) equal to 76.1% and Total Harmonic Voltage (THDv) 3.5% with 330Watt power.

1. Introduction
Electric power quality is a combination of voltage quality and current quality. Voltage disturbances often occur from electrical networks that can affect end users. Meanwhile, current interference comes from end users that will affect the network. The problem of electric power quality in hospitals often occurs due to non-linear loads, harmonic injection, and interactions between medical devices. Because the problem of electric power quality is cumulative, small incidents detected must be taken seriously. Non-linear loads distort current waveforms and create harmonic currents to the current system. For example, from electric lighting. In Indonesia, the lamp must be tested by a medical electric laboratory before being used by the hospital.

Defibrillator (DC Shock) is a tool to provide electrical energy therapy with a certain dose to the patient's heart through an electrode (pedal) placed on the surface of the patient's chest wall. Besides the rapid development of technology from a country, the development is almost comprehensive in all fields, especially in the field of electricity. Since the development of electronic power technology, the device has become the main expectation in almost all electric utilities. But the problems of system power quality caused by the increase in electronic power users by electricity consumers. Basically good electricity quality is electricity which has a stable voltage and frequency. For in Indonesia, electricity sourced from PLN is with a voltage of 220 volts and a frequency of 50 Hz.

There are many aspects that can affect the reduction in electricity quality. One of these aspects is the emergence of harmonics in electric waves rather than the intended equipment is Defibrillator (DC Shock).
A defibrillator is a fibrillation removal device or resets the heart to restore regularity to the heart beat. The defibrillator method/method is shocked/electric shock (shock counter) on the heart with a frequency of 60 Hz, and current of 6 A, in 0.25 - 1 second. In this study the author describes previous researchers who are relevant to the problems to be studied about Harmonics in Defibrillator (DC Shock) equipment are anticipated:

- Ariadi Hazmi (2015), in the title Reducing harmonics on Mobile 100ma X-Ray equipment by using a passive filter (Single Tuned And Double Tuned Passive Filter) test results using Single-Tuned Filter Passive Filter and Double-Tuned Passive Filter and merging Single filters -Tuned Passive Filter and Double-Tuned Passive Filter on X-rays can reduce 3rd order harmonics to 39th order with each Total Distortion Harmonics (THDi) and Total Voltage Distortion Harmonics (THDv), namely: 57.77 % and 2.79%, 58.48% and 2.75%, 1.74% and 2.77%
- Faisal Irsan Pasaribu (2014), with the title Reducing harmonics on ceragem medical devices with a single tuned passive filter, it can be seen that the result filter designed to function properly, from testing to ceragem loads at 6 C there is a harmonic reduction namely from 133.8% to 17%.

As a result of this harmonics causes current and voltage waves to be deformed and not sinusoidal can be seen, measured, calculated, and analyzed which is expected to cause harmonics by first doing measurements of THDv, THDi, IHDV and IHDI. To answer the approximate harmonics contained in the equipment, the researchers measured THDv, THDi, and IHDI on Defibrillator (DC Shock) equipment [1-3].

2. Preliminary

Harmonics are periodically distorted waves that occur in waves of voltage, current, or power consisting of sine waves whose frequency is a round multiple of the source/fundamental frequency, so that the shape is not sinusoidal. The relationship between harmonic and fundamental frequencies can be written as follows:

$$f_h = n \times f_i$$  \hspace{1cm} (1)

With $f_h$ is the harmonic frequency, $n$ is a multiple of waves (integers), and $f_i$ is the fundamental frequency. This harmonic wave will hitch in the fundamental wave so that a distorted wave will form. This is due to the summing effect of harmonic waves with their fundamental waves.

The role of harmonics in the electric power system is quite large, especially in the tools contained in the power system. Harmonics will cause several effects such as overheating in some devices such as generators and transformers because the tendency for harmonics to flow to places with lower impedances. Some other impacts will be explained in this article. The magnitude parameters of harmonics are stated in Total Harmonic Distortion (THD) which can be written as:

$$THD_V = \sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2} \over V_1$$  \hspace{1cm} (2)

For voltage,

$$THD_I = \sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2} \over I_1$$  \hspace{1cm} (3)

Based on an agreement agreed upon internationally, the THD received is if it is worth under 5% of its fundamental voltage or current. If above this limit, the electronic device must not be used. The harmonic effect cannot be completely eliminated, but can be reduced. There are several methods commonly used in reducing harmonics, namely by using passive filters such as installing capacitors, adding phase quantities, and compensating or injecting negative harmonics.
As is generally known, harmonic currents arise due to non-linear loads. To eliminate harmonic currents, harmonic filters are commonly used. Harmonic filters can be composed of active or passive circuits. While the combination of the two is commonly called a hybrid filter. Based on the installation on the nets, these filters can be divided into two types: parallel and series. The filter functions to hold the harmonic current and pass the fundamental current I_s. The harmonic current is marked with a cross to describe the current that cannot flow because of a series filter.

Passive harmonic filters can be arranged from a series of combinations of inductors, capacitors and resistors. Because it consists of passive components, this type of filter performance is affected by grid impedance. Therefore, the installation of passive filters needs to consider net impedance. Passive filters also inject reactive power because it consists of inductor and capacitor components.

The power electronic circuit is an electrical circuit that can change the electrical power source of certain waveforms such as sinusoidal waveforms into electrical resources with other non-sinusoidal waveforms by using a power semi-conductor device. Power semi-conductors have an important role in power electronic circuits. In harmonic analysis, several indices of Equations (1) and (2) are used to describe the effect of harmonics on electrical power system components.

\[ THD \text{ the voltage: } THD_V = \sqrt{\frac{\sum_{k=2}^{\infty} V_k^2}{V_1^2}} \times 100\% \]  
\[ THD \text{ current: } THD_i = \sqrt{\frac{\sum_{k=2}^{\infty} I_k^2}{I_1^2}} \times 100\% \]  

Equations (4) and (5) are defined as the ratio of the rms value of the harmonic component to the basic component in (%). This index is used to measure deviation deviations from one period waveforms containing harmonics on one perfect sine wave. For one perfect sine wave at the basic frequency THD is zero. Likewise the measurement of individual harmonic distortion for voltage and current order h is defined as \( V_h/V_1 \) and \( I_h/I_1 \).

This transformation can decipher a waveform into DC components, cosines and or sines with several different frequencies. The DC component is represented (ao/ 2) and n is the harmonic to n. Therefore, there is a harmonic term of 3, 5 and so on which shows the frequency of multiples of 3, 5 and so on of the fundamental frequency. The figure below shows how a square wave can be decomposed into several sine waves with several frequencies, namely n = 3.5 and 7. If harmonics are present in an electric power system, the fundamental frequency is the frequency of the system e.g. 50Hz or 60Hz. Harmonics in electric power systems can be in the form of harmonic voltages or harmonic currents [4].

2.1. IEC harmonics distortion standard

In this case the standard used as a harmonic limitation is issued by the International Electrotechnical Commission (IEC) which regulates harmonic limits on single phase or three phase small load loads whose current values are smaller than 16 amperes of perfume. For load loads, IEC 61000-3-2 standard is generally used. This is due to the absence of standard standards produced by IEEE. In the IEC 61000-3-2 standard [5, 6] the small load is classified in classes A, B, C, and D, where each class has different harmonic limits which are explained as follows:

Class D includes all types of equipment whose power is below 600 Watt specifically for personal computers, monitors, TVs [7, 8]. The current limits are expressed in the form of mA/ W and are limited to absolute prices whose values are shown in Table 1.
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Table 1. Harmonic current limits for class D equipment

| Harmonic Order (n) | Maximum Harmonic Flow permitted (mA/W) | Maximum Harmonic Flow permitted (A) |
|------------------|--------------------------------------|-------------------------------------|
|                  | 75 < P < 600 W                       | P > 600 W                           |
| 3                | 3.4                                  | 2.3                                 |
| 5                | 1.9                                  | 1.14                                |
| 7                | 1                                    | 0.77                                |
| 9                | 0.5                                  | 0.4                                 |
| 11               | 0.35                                 | 0.33                                |
| 13               | 0.296                                | 0.21                                |
| 15 ≤ n ≤ 39      | 3.85/n                               | 2.25/n                              |

2.2. DC Shock/defibrillator

The Maximum Harmonic Flow that is defibrillated can provide controlled electric shock to the liver that has a life-threatening rhythm, such as ventricular fibrillation (VF). In VF, chaotic activity of the heart prevents blood from pumping to the body and brain. The voltage is stored by a defibrillator conducting an electric current (shock) through the chest by means of electrodes or pads placed on the chest. This short pulse stops the activity when it is chaotic, giving the heart the opportunity to restart normalization rhythm (A) (Figure 1).

External defibrillators can offer a variety of energy choices. So-called "low energy" defibrillators are those that limit their energy choices to 200J or less. Increased energy defibrillators offer a variety of energies, starting with low energy levels with the option to increase energy levels for the next surprise [9, 10].

Many people are confused at this time and energy. This distinction is important in defibrillation, because defibrillators are often explained in terms of energy (for example, 200J) but they are currently - not energy - that defibrillates. Successful defibrillation requires that now enough is sent to the heart muscle during shock.

Defibrillation requires a true middle-of-the-road approach. You must have enough of this time to reach the heart to defibrillate the heart (stop the deadly rhythm), but not so many peak currents that you risk damaging the heart. In fact, the low energy shocks of some defibrillators provide higher current peaks than higher energy shocks than other types of defibrillators. Impedance is the body's resistance to current flow. Some people naturally have a higher impedance than others.

![Figure 1. DC Shock/defibrillator](image)

Effects of Harmonics on Electric Power Systems can cause the appearance of voltage harmonics in the electric power system. This is because the harmonic current flows through the impedance of the system. Impedance can come from channels, transformers etc. [11] Negative effects of the presence of harmonic currents include:

1. Interference with analogue kWh meter.
2. Increased losses and abnormal heating on the transformer.
3. Increased losses and abnormal heating on the motor
4. Possible burst of bank capacitors

Even so this effect does not always appear and occur if there are other conditions that support. Therefore, the presence of harmonic currents is not always accompanied by the interference [12, 13].

3. Research methodology

The method used in this study is a simulation method that starts from data collection and then performs harmonic measurements, and filter modelling calculations. Measurements are made on Defibrillator equipment as shown in Figure 2. The measurement results are in the form of voltage harmonics (IHDv) and current harmonics (IHDi). Measurements on Defibrillator equipment to find out the magnitude of the harmonic value contained therein. Measurement and data retrieval was carried out in Medan. Measurement using a Fluke 43B Power Quality Analyzer. Measurement data is displayed in the form of lists and graphs directly, and the data can be stored on the computer.

![Measurement results](image)

**Figure 2.** Measurement of defibrillator equipment can result in THDi measurement of 76.1%.

4. Results and discussion

The following is the data that will be taken from the Defibrillator Measurement measured through the Fluke 43B Power Quality Analyzer. The data is attached to appendix B as in Table 2.

| Parameter          | Unit | Measurement results |
|--------------------|------|---------------------|
| U (Phase Voltage)  | Volt | 205.2               |
| I (Phase Current)  | Ampere | 0.79               |
| S (Apparent Power) | KVA   | 0.59                |
| P (Active Power)   | KW    | 0.33                |
| Q (Reaktive Power) | KVAR  | 0.49                |
| PF (Power Factor)  |       | 0.56                |
| Frekuensi          | Hz    | 50.2                |
| THDv               | %     | 3.5                 |
| THDi               | %     | 76.1                |
| IHDi 1             | (mA)  | 2510                |
| IHDi 3             | (mA)  | 2149                |
| IHDi 5             | (mA)  | 1514                |
| IHDi 7             | (mA)  | 931                 |
| IHDi 9             | (mA)  | 515                 |
| IHDi 11            | (mA)  | 361                 |
| IHDi 13            | (mA)  | 306                 |
| IHDi 15            | (mA)  | 241                 |
| IHDi 17            | (mA)  | 264                 |
| IHDi 19            | (mA)  | 241                 |
| IHDi 21            | (mA)  | 241                 |
In Table 1, we can see the results of individual measurements of current harmonic distortion (IHDi) of each harmonic sequence. The harmonic sequence shown is the harmonic sequence from first to 39th with different values for each harmonic. To make a simulation circuit, measurement and calculation results are used in the form of voltage, harmonic current value (IHDi), capacitance, inductance, and filter resistance (Figure 3).

| Parameter | Unit | Measurement results |
|-----------|------|---------------------|
| IHDi 23   | (mA) | 218                 |
| IHDi 25   | (mA) | 186                 |
| IHDi 27   | (mA) | 143                 |
| IHDi 29   | (mA) | 98                  |
| IHDi 31   | (mA) | 55                  |
| IHDi 33   | (mA) | 65                  |
| IHDi 35   | (mA) | 43                  |

**Figure 3.** Graph of defibrillator measurement results

Current and voltage waveforms are obtained from the Power GUI Block section of Fast Fourier Transform (FFT) Analysis. (Figure 4 and 5).

**Figure 4.** Voltage graphs before installation of filters

**Figure 5.** Flow chart before installation of filters
Classification of Harmonics Flow on DC Shock / Defibrillator equipment based on IEC61000-3-2 Class D.

Standard measurement results obtained from DC Shock/ Defibrillator equipment are indicated harmonic order which is not in accordance with the International Electro technical Standards Commission (IEC) 61000-3-2 Class D from order 3 to 39th order. In Classification of harmonic currents before filter installation is IEC 61000-3-2 Class D Standard. In simulations for DC Shock/ Defibrillation circuit loads with simulation data adjusted for measurement data (Figure 6). Harmonic currents in DC Shock / Defibrillator equipment prior to the use of filters are known to not meet the IEC 61000-3-2 Class D standard. For this reason, it is necessary to install a single tuned or double tuned filter.

![Figure 6. Chart harmonic current on the DC Shock/defibrillator equipment](image)

5. Conclusion

The problem of electric power quality in hospitals often occurs due to non-linear loads, harmonic injection, and interactions between medical devices. Because the problem of electric power quality is cumulative, small incidents detected must be taken seriously. Non-linear loads distort current waveforms and create harmonic currents to the current system. After the simulation, the conclusion is that the DC Shock/ Defibrillator equipment has a Total Harmonic Current Distortion (THDi) of 76.1% and Total Voltage Harmonics (THDv) 3.5% with a power of 330Watt. The measurement of harmonic current in the DC Shock / Defibrillator equipment before the use of filters is known not to meet the standard IEC 61000-3-2 Class D. For this reason, further research is needed in harmonic reduction in DC Shock / Defibrillator devices by using tuned and double tune filter types to reduce harmonics in DC Shock/ Defibrillator equipment in accordance with standard harmonic limits International Electronical Commission (IEC) 61000-3-2 Class D.

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