

## Conference Paper

# Effect of Non-Linear Electricity Loads Against Harmonics in One Phase Inverters

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### Abstract

This study aims to obtain an overview of the effect of non-linear loads on harmonics on a single-phase inverter which can later use as one of the primary considerations on the quality of electricity on the harmonic side for AC load electricity use with power plants sourced from DC generators using inverters. This research conducted at the Jakarta Electrical Engineering Laboratory for 7 months from March to September 2018.

The research method uses an experimental method. The schematic of the experiment begins with setting the equipment. Then treated with non-linear load changes as an effect on harmonics. The results of the treatment analyzed so that conclusions can drawn.

The results showed that there an effect of changes in voltage harmonics, with the most significant increase in voltage THD caused by LED television load of 1,18%, and the lowest voltage THD caused by refrigerator load of 1,03%. However, when compared with IEEE 519 – 1992 standard, then all types of non-linear loads that get supplies from the inverter still within the safe limits for electronic devices. While the most significant current THD change caused by LED television of 39,57%, and the lowest current THD caused by refrigerator load of 6,76%. Change in current THD when compared to the IEEE 519 – 1992 standard with loads like compact fluorescent lamp  $\geq 40W$ , LED lamp  $\geq 32W$ , fluorescent tube lamp  $\geq 40W$  with electronic ballast, LED television, laptop, desktop, and printer that get supplies from the inverter not within the safe limits for electronic devices, because they are not in accordance with IEEE 519 – 1992 standard.

**Keywords:** Harmonics, voltage, current, nonlinear, one phase inverter

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## 1. Introduction

The number of non-linear load applications in the electric power system has made the system become distorted with a very high percentage of harmonic content. THD (Total Harmonic Distortion) is the ratio between the rms value of all harmonic components to the rms value of its fundamental value and usually calculated in percent. Generally, the distorted electric power system dominated by low-frequency odd order, that is, the fifth,

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seventh, eleven and so on harmonics, whose magnitude inversely proportional to the harmonic order.

The high percentage of total harmonic distortion (THD) in an electric power system can cause several harmonic severe problems in the system and its environment. Such as the occurrence of resonance in the system that damages the capacitor, makes the system power factor worse, creates interference with the telecommunications system, increases losses of the system, causing various kinds of damage to sensitive equipment, that all of which cause the use of electrical energy to be ineffective.

Hybrid power plants that combine solar cells power plant with wind power plant usually used for the supply of lower middle electricity such as the fulfillment of electrical energy of a house or building. This generator works with a battery charging system. Electricity produced by each power plant will charge the battery that prepared according to needs. Solar cells power plant will work in the morning to evening as long as there still sunlight, while the wind power plant will work according to the wind conditions in the region. However, electricity from each generator only produces DC inputs. Therefore, AC inverters will play an essential role in converting DC energy from solar cells power plant or wind power plant into AC electrical energy that we use a day.

However, inverter also tend to produce harmonics and the emergence of harmonics due to non-linear loads will also affect inverter performance. Based on this, the researcher will try to focus on analyzing how much Voltage Total Harmonic Distortion (V-THD) and Current Total Harmonic Distortion (I-THD) occurs in the inverter as a result of the many electrical non linear load.

## 2. Methods and Equipments

### 2.1. Methods

This research carried out using the experimental method by observing and measuring the initial conditions of harmonics. Then the inverter treated with non-linear load changes.

### 2.2. Equipment

The equipment that used in the research are PQA Hioki 3198 and electric loads such as compact fluorescent lamp, fluorescent tube lamp with electronic ballast, LED lamp, LED television, laptop, desktop, printer, and refrigerator.

### 3. Results

#### 3.1. Voltage total harmonic distortion

Before measuring each load, the author measures the inverter without using a load because as discussed in the previous chapter that the inverter itself produces harmonics. Here the results of voltage harmonics measurements on the inverter without load.

TABLE 1: The results of voltage harmonic measurements on the onverter without load.

Orde	(V)	Orde	(V)	Orde	(V)	Orde	(V)
0	0,35	16	0,02	32	0,01	48	0
1	225,17	17	0,45	33	0,1	49	0,02
2	0,06	18	0,03	34	0,01	50	0
3	1,64	19	0,57	35	0,08		
4	0,03	20	0,04	36	0,01		
5	0,72	21	0,85	37	0,06		
6	0,01	22	0,06	38	0		
7	0,53	23	0,85	39	0,04		
8	0,02	24	0,05	40	0		
9	0,44	25	0,54	41	0,03		
10	0,01	26	0,04	42	0		
11	0,4	27	0,34	43	0,02		
12	0,02	28	0,02	44	0		
13	0,38	29	0,21	45	0,03		
14	0,02	30	0,01	46	0		
15	0,39	31	0,11	47	0,03		

$$V\text{-THD}_0 = \frac{\sqrt{V_{h2}^2 + V_{h3}^2 + V_{h4}^2 + V_{h5}^2 + \dots + V_{hn}^2}}{V_{h1}} \times 100\% = \frac{\sqrt{6,6172}}{225,17} \times 100\%$$

$$V\text{-THD}_0 = \frac{2,572392}{225,17} \times 100\% = 1,14\%$$

From the results of the calculations above, voltage total harmonic distortion (V-THD) without load was 1.14%.

The following the value of voltage total harmonic distortion (V-THD) measurements for each nonlinear loads that supplied by a single phase inverter:

Based on the table above, the highest voltage THD increase caused by the LED television load of 1.18%, while the lowest voltage THD caused by the refrigerator load of 1.03%. To facilitate the depiction of table data, it can described in the graph as follows

TABLE 2: The value of V- THD measurements that supplied by a single phase inverter.

No.	Load	Power (W)	V-THD (%)
1	Compact Fluorescent Lamp 5	5	1,18
2	Compact Fluorescent Lamp 10	10	1,23
3	Compact Fluorescent Lamp 15	15	1,30
4	Compact Fluorescent Lamp 20	20	1,33
5	Compact Fluorescent Lamp 25	25	1,37
6	Compact Fluorescent Lamp 30	30	1,41
7	Compact Fluorescent Lamp 35	35	1,48
8	Compact Fluorescent Lamp 40	40	1,52
9	LED Lamp 8	8	1,20
10	LED Lamp 16	16	1,29
11	LED Lamp 24	24	1,37
12	LED Lamp 32	32	1,45
13	LED Lamp 40	40	1,53
14	Fluorescent Tube Lamp with Electronic Ballast	40	1,51
15	LED Television	75	1,81
16	Laptop	44	1,61
17	Desktop	77	1,48
18	Printer	329	1,62
19	Refrigerator	106	1,03

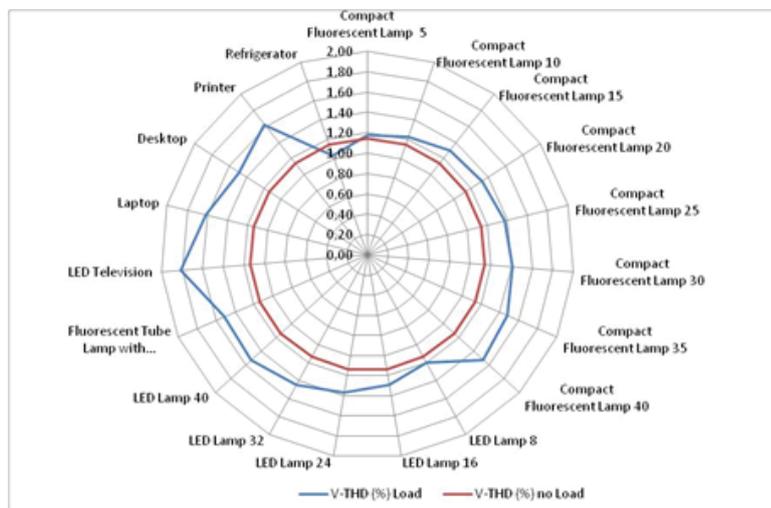


Figure 1: The graph of Voltage THD no load and with load.

In the Figure 1 above shows that farther from the center point, greater of Voltage Total Harmonic Distortion. The farthest point is LED television load, and the closest point is the refrigerator load.

### 3.2. Current total harmonic distortion

The following the value of current total harmonic distortion (I-THD) measurements for each nonlinear loads that supplied by a single phase inverter:

TABLE 3: The value of I- THD measurements that supplied by a single phase inverter.

No	Load	Power (W)	I-THD (%)
1	Compact Fluorescent Lamp 5	5	4,70
2	Compact Fluorescent Lamp 10	10	6,42
3	Compact Fluorescent Lamp 15	15	8,58
4	Compact Fluorescent Lamp 20	20	10,86
5	Compact Fluorescent Lamp 25	25	13,29
6	Compact Fluorescent Lamp 30	30	15,76
7	Compact Fluorescent Lamp 35	35	18,52
8	Compact Fluorescent Lamp 40	40	20,97
9	LED Lamp 8	8	6,83
10	LED Lamp 16	16	11,45
11	LED Lamp 24	24	16,48
12	LED Lamp 32	32	21,84
13	LED Lamp 40	40	26,97
14	Fluorescent Tube Lamp with Electronic Ballast	40	20,53
15	LED Television	75	39,57
16	Laptop	44	23,63
17	Desktop	77	29,27
18	Printer	329	32,65
19	Refrigerator	106	6,76

Based on the table above, the highest current THD increase caused by the LED television load of 39.57%, while the lowest current THD caused by refrigerator load of 6.76%. To facilitate the depiction of table data, it can described in the graph as follows

In the Figure 2 above shows that farther from the center point, greater of Current Total Harmonic Distortion. The farthest point is LED television load, and the closest point is the refrigerator load

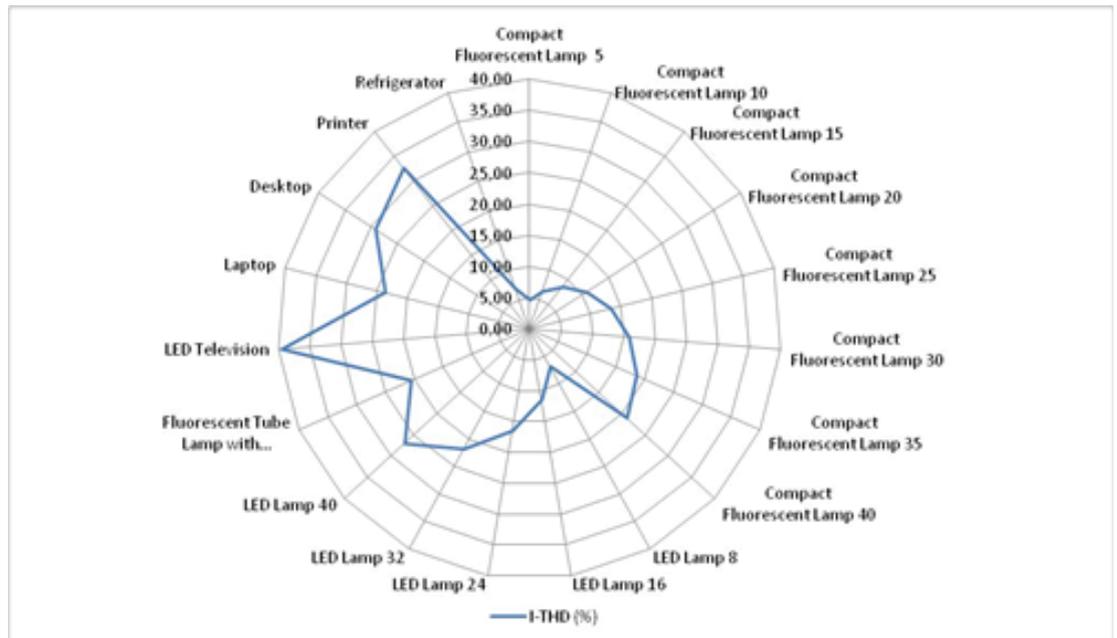


Figure 2: The graph of Current THD with load.

#### 4. Discussion

In further analyzing the amount of voltage THD due to non-linear loads that supplied by a one-phase inverter refer to the IEEE 519 - 1992 standard where the maximum harmonic voltage limit for voltages below 69 kV is 5%. The following the voltage THD analysis tabulation according the IEEE 519 - 1992 standard

From the table above, when compared with the IEEE 519 – 1992 standard, then all types of non-linear loads that get supplies from the inverter still within the safe limits for electronic devices.

In further analyzing the amount of current THD due to non-linear loads that applied by a one-phase inverter refer to the IEEE 519 - 1992 standard where the maximum harmonic current limit for  $I_{sc} / I_L > 1000$  is 20%. The following the current THD analysis tabulation according the IEEE 519 – 1992 standard.

From the table above, when compared with the IEEE 519 – 1992 standard, nonlinear loads such as compact fluorescent lamp  $\geq 40W$ , LED lamp  $\geq 32W$ , fluorescent tube lamp  $\geq 40W$  with electronic ballast, LED television, laptop, desktop, and printer that get supplies from the inverter not within the safe limits for electronic devices.

TABLE 4: The analysis of Voltage THD measurements according the IEEE 519 - 1992 standard.

No	Load	V-THD (%) Load	IEEE 519-1992 (max.5%)
1	Compact Fluorescent Lamp 5	1,18	Still According to standard
2	Compact Fluorescent Lamp 10	1,23	Still According to standard
3	Compact Fluorescent Lamp 15	1,30	Still According to standard
4	Compact Fluorescent Lamp 20	1,33	Still According to standard
5	Compact Fluorescent Lamp 25	1,37	Still According to standard
6	Compact Fluorescent Lamp 30	1,41	Still According to standard
7	Compact Fluorescent Lamp 35	1,48	Still According to standard
8	Compact Fluorescent Lamp 40	1,52	Still According to standard
9	LED Lamp 8	1,20	Still According to standard
10	LED Lamp 16	1,29	Still According to standard
11	LED Lamp 24	1,37	Still According to standard
12	LED Lamp 32	1,45	Still According to standard
13	LED Lamp 40	1,53	Still According to standard
14	Fluorescent Tube Lamp with Electronic	1,37	Still According to standard
15	LED Television	1,81	Still According to standard
16	Laptop	1,61	Still According to standard
17	Desktop	1,48	Still According to standard
18	Printer	1,62	Still According to standard
19	Refrigerator	1,03	Still According to standard

## 5. Conclusion

The results showed that there an effect of changes in voltage harmonics, with the most significant increase in voltage THD caused by LED television load of 1,18%, and the lowest voltage THD caused by refrigerator load of 1,03%. However, when compared with IEEE 519 – 1992 standard, then all types of non-linear loads that get supplies from the inverter still within the safe limits for electronic devices. While the most significant current THD change caused by LED television of 39,57%, and the lowest current THD caused by refrigerator load of 6,76%. Change in current THD when compared to the IEEE 519 – 1992 standard with loads like compact fluorescent lamp  $\geq 40W$ , LED lamp  $\geq 32W$ , fluorescent tube lamp  $\geq 40W$  with electronic ballast, LED television, laptop, desktop, and printer that get supplies from the inverter not within the safe limits for electronic devices, because they are not in accordance with IEEE 519 – 1992 standard.

TABLE 5: The analysis of Current THD measurements according the IEEE 519 - 1992 standard.

No	Load	I-THD (%)	IEEE 519-1992 (max.20%)
1	Compact Fluorescent Lamp 5	4,70	Still According to standard
2	Compact Fluorescent Lamp 10	6,42	Still According to standard
3	Compact Fluorescent Lamp 15	8,58	Still According to standard
4	Compact Fluorescent Lamp 20	10,86	Still According to standard
5	Compact Fluorescent Lamp 25	13,29	Still According to standard
6	Compact Fluorescent Lamp 30	15,76	Still According to standard
7	Compact Fluorescent Lamp 35	18,52	Still According to standard
8	Compact Fluorescent Lamp 40	20,97	Not According to standard
9	LED Lamp 8	6,83	Still According to standard
10	LED Lamp 16	11,45	Still According to standard
11	LED Lamp 24	16,48	Still According to standard
12	LED Lamp 32	21,84	Not According to standard
13	LED Lamp 40	26,97	Not According to standard
14	Fluorescent Tube Lamp with Electronic	20,53	Not According to standard
15	LED Television	39,57	Not According to standard
16	Laptop	23,63	Not According to standard
17	Desktop	29,27	Not According to standard
18	Printer	32,65	Not According to standard
19	Refrigerator	6,76	Still According to standard

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