Effect of Connected Non-Linear Household Appliances on the Disturbance at Frequency Range of 9-150 kHz in the On-Grid Photovoltaic System

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Abstract. Nowadays, the usage of power electronic circuit which is called inverter is increasing especially in household appliances. This inverter technology is the technology that can convert alternating current (AC) to direct current (DC), and this technology may produce disturbance at frequency range 9-150 kHz. In the residential area, a house can be built one of on-grid photovoltaic (PV) system, and the usage of household appliances inside the house system can be connected together at same time and operated simultaneously. This research is focused on investigating the effect of connected household appliances, such as induction cooker. The result shows that the connected two types of induction cooker in same system may either increase or decrease the disturbance value in the system. The connected appliances affect the disturbance through by the power consumption.

1. Introduction

Power electronic is an electronic circuit that can control a power converter with aim to produce alternating current (AC) or direct current (DC) which can be designed for the differences load. And because of the main target power electronic system is to transfer power efficiently and the size of the device should be smaller, power electronic circuit that called by inverter technology is using inside the photovoltaic (PV) system, such as PV inverter [1]. In this inverter technology, it has some switching devices that switching in the frequency range 9-150 kHz, it means this PV inverter produced distortion in that frequency range 9-150 kHz [2]-[3]. Furthermore, renewable energy is widely used in PV system, not only in industrial building, also installed at residential areas, such as rooftop PV system and this system usually using grid-connected inverter. Nowadays, caused of power electronic circuit is using inside all electronic equipment, especially household appliances. It may influence the PV system including other equipment of household appliances that connected or used inside the PV system which installed in the house [4]-[5].

Some of researcher reported that the power electronic devices generated distortion in waveform of voltage and current in some frequencies. In international standardization distortion that generated below 2 kHz called harmonics, and the distortion that generated above 2 kHz until 150 kHz is called disturbance. However, the standardization of this frequency range 9-150 kHz is still not covered, so the...
research to find the standard of disturbance and to limit this disturbance in order to improve power quality [6]-[7].

In residential area or PV system that installed in the house, there must be some of loads connected in the same time inside the system, these connected loads are not only generates disturbance, also influenced the PV system, and may be influenced the other appliances [8]. The household appliances also have some of power electronic circuit inside the equipment, because the appliances operated in differences voltage level and power consumption. Some of researcher also recognized and reported that the non-linear household appliances, especially induction cooker, were generated harmonic [9]-[10]. This study will observe the effect of connected household appliances in the on-grid PV system, in this case is two types of induction cooker.

2. Methodology

This measurement is aimed to find the influence of disturbances at frequency 9-150 kHz while non-linear household appliances loads, such as two types of induction cooker are connected in the same system. The system that used is on-grid PV system which the system is system generated by PV and also connected to utility grid.

The first part of the measurement was observed characteristic of each induction cooker which is using two types of induction cooker, brand C and brand P. After that, for the next part, these two brands of induction cooker connected to the system at the same time and find the changes and the differences disturbances between the first part of measurement and the second measurement.

The data taken using PicoScope which used for measured the disturbance in frequency 9-150kHz, and the data processed using Matlab. So that, the data of disturbance may be known.

Based on Figure 1, it can be seen output of load measurement point was connected with high pass filter and connected to PicoScope.

3. Result and Discussion

3.1. Disturbance Characteristics of each Induction Cooker

This measurement is using two types of induction cooker. For each induction cooker had disturbance characteristics and this study aimed to look at the disturbance characteristics of each induction cooker before connecting these two types of induction cooker to the system and measuring its, so the differences and changes of disturbance can be compared between of each induction cooker and two types of
induction cooker that connected together in same system. The disturbance characteristics of each induction cooker shown in figures below

**Figure 2.** Disturbance of Induction Cooker Brand C

**Figure 3.** Disturbance of Induction Cooker Brand P

Figure 2 and 3 shows each of disturbances characteristics of two types induction cooker, which brand C disturbance at power 100 W is 3699.09 mV; power 200 W is 3868.42 mV; power 300 W is 3965.14 mV; power 400 W is 4158.87 mV; power 500 W is 5691.53; power 550 W is 7991.61 mV; power 600 W is 11037.38 mV; and 800 W is 9536.96 mV. And for brand P disturbance at power 100 W is 1608.58 mV; power 400 W is 1644.56 mV; power 1000 W is 1845.10 mV; power 1400 W is 5361.03 mV; power 1800 W is 12009.20 mV; and power 2100 W is 14122.20 mV.
3.2. The Effect of Connected Appliance to the Disturbance

The effect of connected two types of induction cooker to the disturbance appeared in this on-grid PV system. In this measurement, used two methods of measurement, the first one is giving randomly changes of power level the two induction cookers and the next method is raising the power level step by step from the lowest power level to the highest power level. The disturbance for this measurement can be obtained as shown in Table 1. and Table 2.

| Power (W) | Disturbance Brand P (mV) | Power (W) | Disturbance Brand C (mV) | Power (W) | Brand P and C (mV) |
|-----------|--------------------------|-----------|--------------------------|-----------|-------------------|
| 100       | 1495.00                  | 100       | 3495.99                  | 100       | 2477.80           |
| 400       | 1595.42                  | 200       | 3253.72                  | 400       | 2418.01           |
| 400       | 1595.42                  | 400       | 3877.24                  | 400       | 2928.68           |
| 1000      | 1633.76                  | 800       | 8594.55                  | 1000      | 8471.73           |
| 2100      | 13385.08                 | 400       | 3877.24                  | 2100      | 5900.99           |
| 1000      | 1633.764                 | 400       | 3877.24                  | 1000      | 2809.05           |
| 2100      | 13385.07                 | 800       | 8594.55                  | 2100      | 8664.99           |

According to the Table 1 and 2, there are some changes and influence of connected the two types of induction cooker. Even the measurement used random variation of power usage or rising the power level step by step.

Table 3 has relation with the two table before, table 1 and 2. In this table 3 can be seen that there are some changes in disturbance. In 2nd, 4th, and 6th column shown the disturbance change of each power level by percentage. 3rd and 5th column shown the disturbance change of connected two induction cooker and before connected the induction cooker by percentage. Also, there is the difference definition of negative mark on the table 3. In 2nd, 4th, and 6th column, the negative sign means the changes of the disturbance caused by power consumption is decreasing the disturbance value, and in 3rd and 5th column, the negative sign means the changes that caused by connected appliances is increasing the value. For the graphic of the table before can be seen in Figure 4.

Figure 5 and 6 which are showing the graph of disturbance changes by two methods and the figures has a relation with the table above. It can be seen there are some changes on disturbances value even the measurement used any method. And even the other load absorbs the disturbance, the disturbance value should be got the attention.
Table 3. Percentage changes of disturbance value

| Power (W)  | Disturbance Change (%) | Disturbance Change (%) | Disturbance Change (%) | Disturbance Change (%) | Disturbance Change (%) |
|------------|------------------------|------------------------|------------------------|------------------------|------------------------|
| 100/100    | -133.85%               |                        |                        |                        | 25.20%                 |
| 400/200    | 6.29%                  | -103.94%               | -7.45%                 | 23.25%                 | -4.72%                 |
| 1000/400   | 2.35%                  | -137.32%               | 16.08%                 | 19.85%                 | 19.65%                 |
| 2100/800   | 87.79%                 | 35.79%                 | 54.89%                 | -8.60%                 | 66.70%                 |

Figure 4. Disturbance Changes by Power Usage Variation

Figure 5. Disturbance Changes by Power Level
4. Conclusion

The connected household appliances, in this case connected two types of induction cooker affect the disturbance through power consumption. The power consumption of connected appliances may cause changes the disturbance generated by appliances in the system. The disturbance generated by the appliances could be higher or lower depended on the disturbance behaviour generated by the appliance responding to the system.

In this study, connected appliance caused the disturbance in the system either decrease or increase. For the method of raising power consumption, each induction cooker has different changes. Disturbance changes brand P from 100 W to 400 W is 6.29%; from 400 W to 1000 W is 2.35%; from 1000 W to 2100 W is 87.79%. Disturbance changes brand C from 100 W to 200 W is -7.45%; from 200 W to 400 W is 16.08%; from 400 W to 800 W is 54.89%. The effect of connected two types of induction cooker is only for equipment used in this measurement. Because every appliance has unique disturbance behaviour and component, the effect of connected other appliances may get the difference results.

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