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# Power Quality Analysis of Integration Photovoltaic Generator to Three Phase Grid under Variable Solar Irradiance Level

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***Abstract***

*Objective of research is to analyze the influence of solar irradiance and integration of photovoltaic (PV) generator to power quality of three phase grid on the constant temperature and load, based on changes in some level of integration of PV generator. Power quality aspects studied are fluctuation or changing, and harmonics of voltage and current on eight scenarios PV generator connected to three-phase grid, using passive filter circuit model double band pass (double tuned). Research shows that voltage and current values on the PCC bus before use double tuned passive filter on the condition only connect single generator is still stable. However, if the PV generator connected to the three phase grid, amounted to more than one generation, voltage and current grid becomes unstable (fluctuation). At the level of solar radiation remains, the greater number of PV generators connected to the grid three-phase, then the values of voltage and current THD increases. At the level of solar irradiance increases, average THD of voltage and current grid also increased. Avarage THD of voltage and current grid is reduced after double tuned passive filter installed. Therefore, double tuned passive filter able to improve profile of voltage and current THD grid as a result of the integration of a number of PV power generators in three-phase grid according IEEE Standard 519-1992.*

***Keywords***: *Power Quality, Total Harmonic Distortion, Photovoltaic Generator, Grid, Irradiance*



## 1. Introduction

One important aspect of the integration of photovoltaic (PV) generator as part of distributed generation is the power quality generated from their operation for example voltage unbalance (fluctuation), voltage and current harmonics. A study to model and simulate residential grid connected solar photovoltaic system has been discussed. Mathematical modeling and simulation of PV generation systems has been conducted to determine the I-V, P-I, P-V characteristics [1]. Research of design and implementation of PV-based three phase four-wire series hybrid active power filter for power quality improvement have been conducted. This paper proposes a PV based three phase four wire series hybrid active power filter arranged by series active power filter and an LC shunt passive filter. The proposed model eliminates both the current and voltage harmonics and compensates reactive power, neutral current, and voltage interruption [2]. A study of power quality analysis of photovoltaic generation integrated in user grid. This paper analyzes impact of grid-connected photovoltaic power plant on harmonic in the power quality aspect of distribution network [3]. The weakness of three studies are number of PV generator used only a single PV generation and connected to single phase grid, so that current and voltage harmonics generated due to the presence of the inverter in PV generating system is not very significant.

Research to assess the impact of integration of a number of the PV generator to power quality at different solar irradiation level and daily load consumption based on changes in the level of PV integration is already done. The disadvantage is a PV generator that is used only

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to connect to single phase grid and harmonic analysis is only performed on the harmonic voltage [4]. Research on the effects of installation of PV generator to power quality in three phase industrial and residential distribution network has been discussed. However, PV generator which installed is still static which is based on level of solar irradiance, temperature, and current and voltage harmonic generated by PV generator with a fixed value [5]. Objective of research is to analyze the influence of solar irradiance and integration of PV generator to power quality of three phase grid on the constant temperature and load, based on changes in some level of integration of PV generator. Power quality aspects studied are fluctuation or changing, and harmonics of voltage and current on eight scenarios PV generator connected to three-phase grid. The rest of this paper is organized as follow. Section 2 shows proposed model of single and three PV generator system connected to three-phase grid, power quality and harmonic, photovoltaic system, mathematical model of PV cell and panel, and shunt passive filter. Section 3 describes influence of solar irradiance and integration of PV generator to voltage, current, voltage and current Total Harmonic Distortion (THD) of three phase grid on the constant temperature and load, based on changes in some level of integration of PV generator. In this section, example cases studied are presented and the results are verified with those of Matlab/Simulink. Finally, the paper in concluded in Section 4.

## 2. Proposed Model of PV Generator System Connected to Three Phase Grid

Figure 1 shows a model of a single PV power system connected three phase grid [6]. The series of DC/DC converter consists of a boost converter circuit that functions to raise the voltage of the DC output of the PV generator. DC output voltage of the boost converter circuit is then converted by the DC/AC inverter into a three-phase AC voltage to the three-phase grid. Single PV generator model is then used as a reference to create a model for many (multi) PV generators connected to the grid via a three-phase distribution transformer (Figure 1). The study used three groups of models of PV generators with the active power of 100 kW each. Besides connecting the three-phase grid, the PV generator is also connected to the three groups of three phase load with active power 20 kW respectively.

The objective of research is to analyze the influence of solar irradiance and integration of photovoltaic (PV) generator to power quality of three phase grid on the constant temperature and load, based on changes in some level of integration of PV generator. Power quality aspects studied is the fluctuation, and harmonics of voltage and current on eight scenarios PV generator connected to three phase grid (a) before and (b) after double tuned passive filter installed as follow four conditions respectively: (i) irradiance 400 W/m$^2$, (ii) irradiance 600 W/m$^2$, (iii) irradiance 800 W/m$^2$, and (iv) irradiance 1000 W/m$^2$ on the condition 1, 2, and 3 of model PV generator connected to three phase grid. The model of passive filter circuit is a double band pass (double tuned). The circuit model simulations conducted to determine the voltage and current curves of three phase grid. There are two scenarios simulations done that before and after the double tuned passive filter installed. Wherein each consisting of four scenarios for a total of eight scenarios integration of PV generators. The next stage is to determine the value of voltage and current THD on each scenario grid. The final step is to compare the value of voltage, current, voltage and current THD grid on point common coupling (PCC) bus refers to the IEEE Standard 519-1992. This standart is the basis for determining level of power quality at the eight scenarios radiation levels and integration of grid connected PV generator model three phase. Simulation and analysis of this research use Matlab/Simulink.

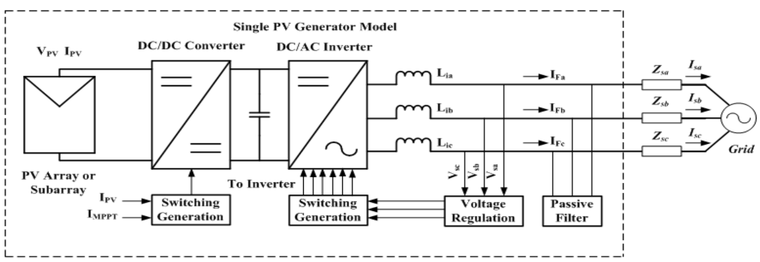



Figure 1. Model of single PV generator system connected to three phase grid

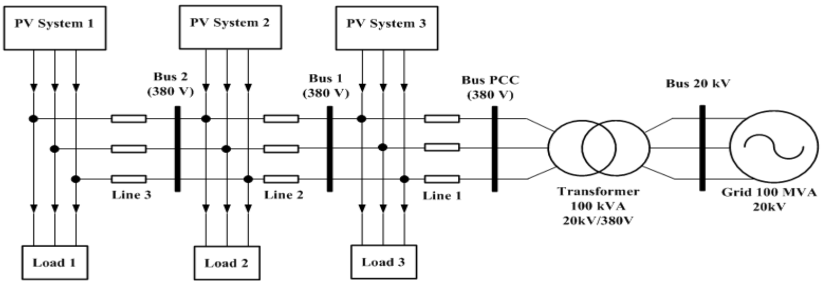
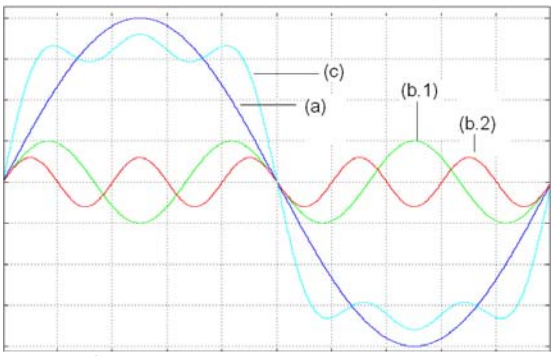



Figure 2. Proposed model of three PV generator system connected to three phase grid

### 2.1. Power Quality and Harmonic

Power quality means the quality of voltage and current. Voltage and current quality is determined based on the value or the tolerance limit of the equipment used. In general, current and voltage wave form of the pure sinusoidal waveform. One problem that arises is the wave of current and voltage is not sinusoidal or defects caused by the emergence of harmonics generated by the power system [7]. The term used to describe deviations harmonics sinusoidal wave associated with the current and voltage of different amplitude and frequency. Changes in current and voltage waveforms caused by harmonics will disrupt the electrical distribution system and lower the quality of the system power. Figure 1 shows the signal waveform distortion due to harmonics. Harmonic distortion explained through several key parameters to describe the effects of harmonics on power system components. The first parameter is Total Harmonic Distortion (THD). THD is the ratio of the rms value of harmonic components to the rms value of the fundamental component and is commonly expressed in percent (%). This index is used to measure deviations periodic waveforms containing harmonics of a perfect sine wave [7]. On a perfect sine wave THD value is zero percent. $THD_V$ value is expressed in Equation 1.




a = wave at the fundamental frequency, b.1 = 3rd harmonic wave, b.2 = wave harmonics 5th, c. = Distorted Wave

Figure 3. Distorted Wave resulted by Harmonics.

$$THD_V = \frac{\sqrt{\sum_{n=2}^{k} U_n^2}}{U_1} \times 100\ \% \tag{1}$$

Description: $U_n$ = harmonic component; $U_1$ = the fundamental component; K = maximum harmonic components.

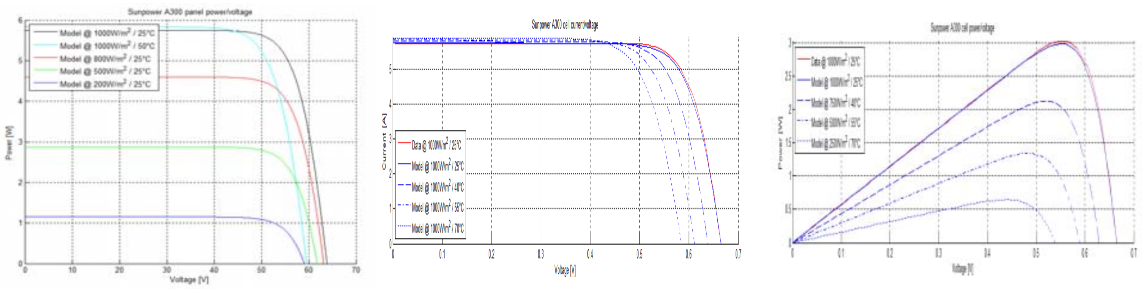
The second parameter is the Individual Harmonic Distortion (IHD) is the ratio of rms value of individual harmonics to rms value of the fundamental component. The third parameter is the Total Demand Distortion (TDD) or $THD_I$ is amount of current harmonic distortion and defined in the following equation [7]:

$$THD_I = \frac{\sqrt{\sum_{n=2}^{k} I_n^2}}{I_L} \times 100\ \% \quad (2)$$

Where $I_L$ is the maximum load current (for 15 or 30 minutes) at the fundamental frequency at the PCC, calculated from the average current of the maximum load of 12 months earlier. THD value of the maximum allowable for each country is different depending on the standard used. THD standards most often used in electric power system is the IEEE Standard 519-1992 [8]. There are two criteria that are used in the analysis of harmonic distortion that limits voltage distortion and current distortion limits.

### 2.2. Photovoltaic System

The working principle of PV panel is when sunlight reaches the surface of the solar panel, then the photons with a certain energy level will be absorbed, thus freeing electrons from their atomic bonds and the flow of electric current. The solar panels generate the current that varies depending on the voltage of it. Current-voltage characteristics show the relationship. When the voltage of the solar panel is equal to zero, short circuit current ($I_{SC}$), which is proportional to the amount of solar radiation on the solar panel can be measured. $I_{SC}$ value rises with increasing temperature, although the standard temperature recorded for the short circuit current is $25^0$ C. If the current solar panel is equal to zero, the solar panel is described as an open circuit. The voltage on open circuit or open-circuit voltage ($V_{OC}$), depending on the amount of solar radiation. This dependence is logarithmic, and decline more rapidly with increased temperatures exceeding the speed increase in $I_{sc}$. The maximum power of solar panels and solar panel efficiency will decrease with increasing temperature. Solar panels, increasing the temperature of $25^0$C resulted in a decrease of about 10% power. Figure 4 shows the curve of the PV panel karakteristisk [9].




(a) I-V Curve on fixed temperature and irradiance change

(b) I-V curve on fixed irradiance and temperature change

(c) P-V curve on temperature change

Figure 4. Characteristic Curve of Panel PV (Tipe MSX-60)

### 2.3. Mathematical Model of PV Cell and Panel

PV cell equivalent circuit shown in Figure 5 [6] consists of a power supply and a diode. Current photo ($I_{ph}$) depending on solar radiation (G), and temperature (T) environment.

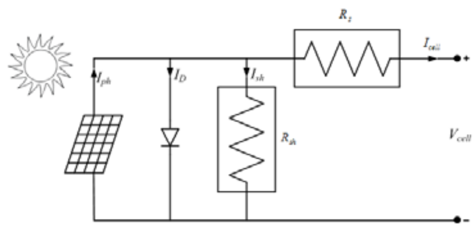



Figure 5. Equivalent Circuit of PV Cell

The conditions described in the Equation 3. $I_{ph}$ (Tref) is the photo stream at a nominal temperature $T_{ref}$. On the other hand, Equation 4 gives the formula of photo current at a nominal temperature $K_0$ is a constant that is expressed in Equation 5. $G_{ref}$ and $I_{sc}$ respectively nominal radiation provided by the factory short-circuit current. This equation refers to Figure 2 for a single PV cell [6].

$$I_{ph} = I_{ph}(T_{ref}) \times \left(1 + K_0(T - T_{ref})\right) \tag{3}$$

$$I_{ph}(T_{ref}) = \frac{G}{G_{ref}} \times I_{sc}(T_{ref}) \tag{4}$$

$$K_0 = \frac{I_{sc}(T) - I_{sc}(T_{ref})}{T - T_{ref}} \tag{5}$$

Taking into account that the environment temperature is set at a certain nominal value, then the next PV flow only depends on solar irradiace expressed in Equation 6.

$$I_{ph} = I_{ph}(T_{ref}) = \frac{G}{G_{ref}} \times I_{sc}(T_{ref}) \tag{6}$$

Characteristics of diode current ($I_D$) is expressed in Equation 7, where the value of saturation current $I_O$ is a diode, where $V_T$ represents the thermal voltage.

$$I_D = \left( I_o e^{V_D/V_T} - 1 \right) \tag{7}$$

Where; $V_D = V_{cell} + (I_{cell} \times R_s)$

Furthermore, by using the Kirchoff Law, shunt current $I_{sh}$ is defined in the following equation:

$$I_{sh} = \frac{V_D}{R_{sh}} \tag{8}$$

By calculating Equation 3 and 8, and applying current Kirchoff's Law, I-V characteristics PV shown in Equation 9.

$$I_{cell} = I_{ph} - I_D - I_{sh}$$
$$I_{cell} = I_{ph} - \left( I_o e^{V_D/V_T} - 1 \right) - \left( \frac{V_D}{R_{sh}} \right) \tag{9}$$

### 2.4. Shunt Passive Filter

Passive filter consists of passive elements such as resistors, capacitors and inductors. This filter is permanent and once installed they become part of the network and need to be redesigned to obtain different filter frequencies. Passive filter is still considered the best in the network system of three-phase four-wire. The majority of them are low-pass filter that is tuned to the desired frequency. Shunt filter using passive components and offer better harmonics reduction, especially in the harmonic 3, 5, and 7. Some models include a passive filter are band pass filter (single atau double tuned), high pass filters (first, second, third-order or C-type), and composite filter [10]. Figure 6 shows models of filter [11].

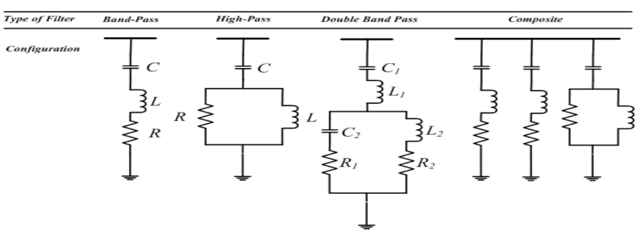



Figure 6. Models of Passive Filter

## 3. Result dan Discussion

Table 1 shows the simulation parameters of the three models of PV generators connected to the three phase grid. Table 2 and 3 respectively shows the nominal of phase and average $THD_V$ grid as well as phase and average $THD_I$ grid on three models of integration of PV generators and four different levels of irradiance connected to grid.

Tabel 1. Simulation Parameter

| Equipment | Parameters | Value |
|---|---|---|
| PV Generator | Power | 100 kW |
| 1, 2, and 3 | Temperature | $40^0$ C |
| | Irradiance | 400, 600, 800, dan 1000 W/$m^2$ |
| Three phase grid | MVA short-circuit | 100 MVA |
| | Voltage (phase-phase) | 380 volt |
| | Frequency | 50 Hz |
| Load 1, 2, 3 | Active Power | 20 kW |
| | Voltage | 380 Volt |
| | Frequency | 50 Hz |
| Low voltage line | Resistance | R = 0,1273 Ohm/km |
| 1,2, dan 3 | Induktance | L = 93,37 mH/km |
| | Capasitance | C = 1,274 µF/km |
| Length of Low Voltage Distribution Line | Line 1, 2, and 3 | 1 km |
| DC Link Kapasitor | Capacitor | 2000 µF |
| PWM Generator | Frequency | 4 kHz |
| For each PV Generator | Sampling time | 5 x $10^{-6}$ detik |
| Double Tuned Filter | Reactive Power | 50 MVAR |
| Passive | Voltage (phase-phase) | 380 V |
| | Sistem frequency | 50 Hz |
| | Tuning frequency | $f_1$ = 11 x 50 Hz, $f_2$ = 13 x 50 Hz |
| | Quality Factor (Q) | 16 |

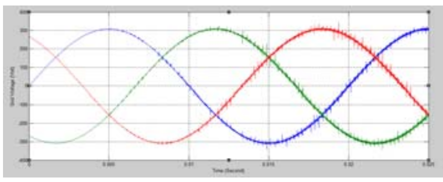
Table 2. Nominal of phase and average voltage harmonic ($THD_V$) grid

| No. | Irradiance (W/$m^2$) | PV Integration | Phase Voltage (V) A | B | C | $THD_V$ A | B | C | $THD_V$ Avarage (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | Before using Double Tuned Passive Fiter | | | | | | | |
| 1 | 400 | $PV_1$ | 220 | 220 | 220 | 0.54 | 0.51 | 0.49 | 0.52 |
| | | $PV_1 + PV_2$ | 212 | 212 | 212 | 0.91 | 0.88 | 0.98 | 0.93 |
| | | $PV_1 + PV_2 + PV_3$ | 212 | 212 | 212 | 2.68 | 2.58 | 2.63 | 2.62 |
| 2 | 600 | $PV_1$ | 220 | 220 | 220 | 0.78 | 0.73 | 0.65 | 0.72 |
| | | $PV_1 + PV_2$ | 212 | 212 | 212 | 1.13 | 1.22 | 1.39 | 1.25 |
| | | $PV_1 + PV_2 + PV_3$ | 212 | 212 | 212 | 3.71 | 3.62 | 3.54 | 3.62 |
| 3 | 800 | $PV_1$ | 220 | 220 | 220 | 0.91 | 0.86 | 0.85 | 0.88 |
| | | $PV_1 + PV_2$ | 212 | 212 | 212 | 1.46 | 1.54 | 1.48 | 1.49 |
| | | $PV_1 + PV_2 + PV_3$ | 212 | 212 | 212 | 4.11 | 4.17 | 4.05 | 4.11 |
| 4 | 1000 | $PV_1$ | 220 | 220 | 220 | 0.87 | 0.83 | 0.78 | 0.83 |
| | | $PV_1 + PV_2$ | 212 | 212 | 212 | 1.46 | 1.54 | 1.59 | 1.53 |
| | | $PV_1 + PV_2 + PV_3$ | 212 | 212 | 212 | 3.95 | 3.92 | 3.84 | 3.91 |
| | | After using Double Tuned Passive Fiter | | | | | | | |
| 1 | 400 | $PV_1$ | 220 | 220 | 220 | 0.04 | 0.03 | 0.03 | 0.03 |
| | | $PV_1 + PV_2$ | 220 | 220 | 220 | 0.03 | 0.03 | 0.05 | 0.04 |
| | | $PV_1 + PV_2 + PV_3$ | 220 | 220 | 220 | 0.09 | 0.10 | 0.09 | 0.09 |
| 2 | 600 | $PV_1$ | 220 | 220 | 220 | 0.05 | 0.04 | 0.04 | 0.04 |
| | | $PV_1 + PV_2$ | 220 | 220 | 220 | 0.05 | 0.05 | 0.08 | 0.06 |
| | | $PV_1 + PV_2 + PV_3$ | 220 | 220 | 220 | 0.19 | 0.11 | 0.14 | 0.15 |
| 3 | 800 | $PV_1$ | 220 | 220 | 220 | 0.06 | 0.05 | 0.06 | 0.06 |
| | | $PV_1 + PV_2$ | 220 | 220 | 220 | 0.06 | 0.06 | 0.10 | 0.08 |
| | | $PV_1 + PV_2 + PV_3$ | 220 | 220 | 220 | 0.23 | 0.14 | 0.18 | 0.19 |
| 4 | 1000 | $PV_1$ | 220 | 220 | 220 | 0.05 | 0.05 | 0.07 | 0.06 |
| | | $PV_1 + PV_2$ | 220 | 220 | 220 | 0.06 | 0.06 | 0.09 | 0.07 |
| | | $PV_1 + PV_2 + PV_3$ | 220 | 220 | 220 | 0.22 | 0.13 | 0.18 | 0.18 |

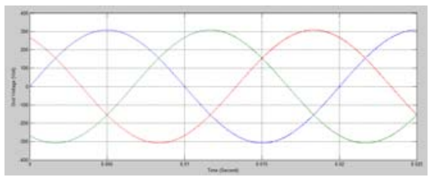
Table 3. Nominal of phase and average current harmonic ($THD_I$) grid on three models of integration of PV generators connected to the three phase grid

| No. | Irradiance ($W/m^2$) | PV Integration | Phase Current (A) | | | $THD_I$ | | | $THD_I$ Avarage (%) |
|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | A | B | C | |
| | | Before using Passive *Double Tuned* | | | | | | | |
| 1 | 400 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.07 | 0.08 | 0.06 | 0.07 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.24 | 0.24 | 0.35 | 0.28 |
| | | $PV_1 + PV_2 + PV_3$ | 6.8 | 8.6 | 6.8 | 2.10 | 1.27 | 1.69 | 1.69 |
| 2 | 600 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.10 | 0.12 | 0.10 | 0.11 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.35 | 0.24 | 0.39 | 0.33 |
| | | $PV_1 + PV_2 + PV_3$ | 7.1 | 9.2 | 7.1 | 2.24 | 1.48 | 1.83 | 1.86 |
| 3 | 800 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.13 | 0.13 | 0.13 | 0.13 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.44 | 0.30 | 0.40 | 0.38 |
| | | $PV_1 + PV_2 + PV_3$ | 7.1 | 9.2 | 7.1 | 2.28 | 1.56 | 1.93 | 1.93 |
| 4 | 1000 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.12 | 0.13 | 0.14 | 0.13 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.39 | 0.32 | 0.41 | 0.38 |
| | | $PV_1 + PV_2 + PV_3$ | 7.1 | 9.2 | 7.1 | 2.31 | 1.61 | 1.85 | 1.93 |
| | | After Using Filter Pasif *Double Tuned* | | | | | | | |
| 1 | 400 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.00 | 0.00 | 0.00 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | $PV_1 + PV_2 + PV_3$ | 7.5 | 7.5 | 7.5 | 0.03 | 0.02 | 0.03 | 0.03 |
| 2 | 600 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | $PV_1 + PV_2 + PV_3$ | 7.5 | 7.5 | 7.5 | 0.04 | 0.03 | 0.04 | 0.04 |
| 3 | 800 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.02 | 0.02 | 0.02 |
| | | $PV_1 + PV_2 + PV_3$ | 7.5 | 7.5 | 7.5 | 0.05 | 0.04 | 0.06 | 0.05 |
| 4 | 1000 | $PV_1$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.01 | 0.01 | 0.01 |
| | | $PV_1 + PV_2$ | 6.8 | 6.8 | 6.8 | 0.01 | 0.02 | 0.02 | 0.02 |
| | | $PV_1 + PV_2 + PV_3$ | 7.5 | 7.5 | 7.5 | 0.07 | 0.04 | 0.05 | 0.05 |

Figure 7 shows the curve of grid voltage on two models of integration of PV generators connected to the grid three-phase (solar radiation of 1000 W / m2) on the PCC bus.

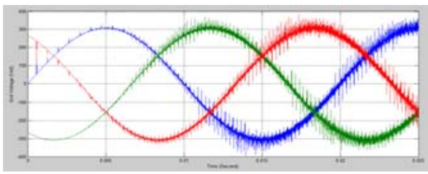


(i) Before Using Filter Passive *Double Tuned*

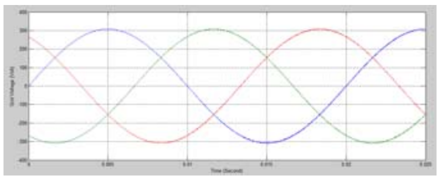


(ii) After Using Filter Passive *Double Tuned*

(a) PV1+PV2+PV3



(i) Before Using Filter Passive *Double Tuned*

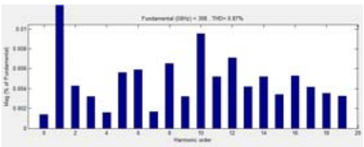


(ii) After Using Filter Passive *Double Tuned*

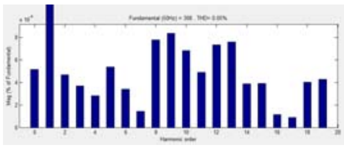
Figure 7. Simulation results grid voltage on integration of two models of three-phase grid connected PV under solar irradiance level of 1000 W/m2

Figure 8 shows the spectrum of $THD_V$ grid at phase A in two models of integration of PV generator connected to grid under solar irradiance level of 1000 W/m2 on the PCC bus.

(a)PV1

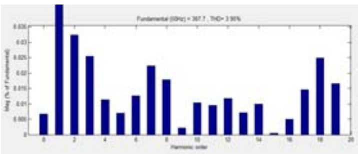


(i) Before Filter Passive *Double Tuned*

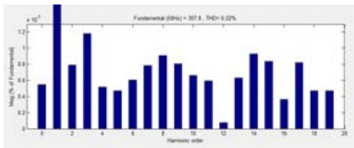


(ii) After Using Filter Passive *Double Tuned*

(b)PV1+PV2+PV3



(i) Before Filter Passive *Double Tuned*



(ii ) After Using Filter Passive *Double Tuned*

Figure 8. Harmonic spectrum of phase A grid voltage on two models of integration of PV connected grid under solar irradiation of 1000 W/m2

Figure 9 shows curve of average $THD_V$ on three models of integration of generation PV and four levels of solar irradiance connected to the three-phase grid on PCC bus.

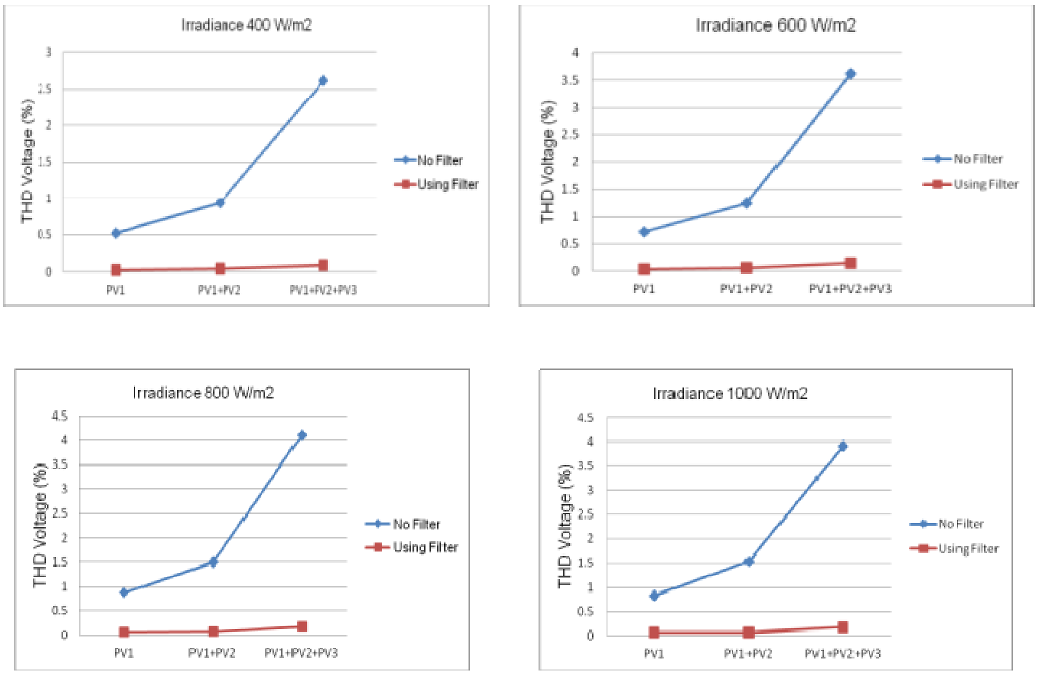



Figure 9. Avarage harmonic of voltage grid in three models of integration PV connected to three phase grid under solar irradiance level of 400 to 1000 W/m2

Table 2 shows that the value of the grid voltage before use double tuned passive filter on the condition only connect one generator (PV1) remained stable (220 Volt). However, if the PV generator connected to the grid three-phase, amounted to more than one generation (PV1+PV2 and PV1+PV2+PV3), grid voltage at PCC bus decrease to 212 Volt or 3.36%. After using double tuned passive filter, grid voltage of PV generator integration at all levels (PV1, PV2 + PV1, and PV1+PV2+PV3) value becomes stable (220 Volt). Without double tuned passive filter, the largest THD average of grid voltage is generated on the condition of all PV generators connected to the three phase grid (PV1 + PV2 + PV3) and the irradiance level of 800 W/m2 at 4.11%. The smallest value of average grid voltage THD is produced on the condition of only single PV generators connected to the grid three-phase (PV1) and the radiation level of 400 W/m2 at 0.52%. On the condition of using double tuned passive filter, the largest THD average of grid voltage is generated on the condition of all PV generators connected to the three phase grid (PV1 + PV2 + PV3) and the irradiance level of 800 W/m2 at 0.19%. The smallest average of grid voltage THD produced on the condition of the PV generators connected to the grid three-phase (PV1) and the radiation level of 400 W / m2 of 0.03%. Figure 7 and 8 shows that at the level of solar irradiance remains, the greater number of PV generators connected to three-phase grid, then the greater the value of the voltage THD. Figure 9 also shows that the level of solar irradiace increases, THD average of voltage grid will also increase. THD average of grid voltage is reduced after double tuned passive filter installed.

Table 3 shows that the current value of grid before use double tuned passive filter on the condition only connect one and two generators (PV1 and PV1+PV1) was stable (6.8 Volt). However, if the PV generator connected to the three phase grid is three generators (PV1+PV2+PV3), the current grid in Bus PCC appears unbalanced currents between 6.8 up to 9.2 Ampere. After using double tuned passive filter, grid current value on the condition only connect one and two generators (PV1 and PV1+ PV2 ) was stable (6.8 Ampere). However, if all PV generators connected to the three phase grid (PV1 + PV2 + PV3), the current grid PCC bus increase to 7.5 Ampere or 10.29%. Without double tuned passive filter, the largest average THD current grid is generated by the condition of three PV generators connected to the grid three-phase (PV1+PV2+PV3) and the irradiance level of 800 W/m2 at 1.93%. The smallest THD avarage of grid current is produced by only single PV generators connected to three phase grid (PV1) and irradiance level of 400 W/m2 at 0.07%. On the condition of using double tuned passive filter, the largest of THD average grid voltage is generated of all PV generators connected to three phase grid (PV1 + PV2 + PV3) and irradiance level of 800 W/m2 of 0.05%. The smallest average THD of grid current is produced on the condition of the PV generators connected to the grid three-phase (PV1) and the radiation level of 400 W/m2 at 0.00%.

## 4. Conclusion

The nominal of voltage and current on the PCC bus of three phase grid before use double tuned passive filter on the condition only connect single generator (PV1) is still stable. However, if the PV generator connected to the three phase grid, amounted to more than one generation (PV1+PV2 and PV1+PV2+ PV3), voltage and current grid becomes unstable (fluctuation). At the level of solar radiation remains, the greater number of PV generators connected to the three phase grid, then the nominal of voltage and current THD also increase. At the level of solar irradiance increases, average THD of voltage and current grid also increased. Avarage THD of voltage and current grid is reduced after double tuned passive filter installed in three phase grid. Therefore double tuned passive filter able to improve profile of voltage and current THD grid, as a result of the integration of a number of PV power generators in three-phase grid according with IEEE Standard 519-1992.

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