International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Grid Connected PV Modules in Distributed Generation System during Irradiance and Temperature Variation

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Abstract: ***Now a days, photovoltaic (PV) system finds extreme interest as alternative source of energy and they are integrated with grids forming distributed generation (DG) systems. But, the output of PV system is dependent of irradiance and temperature. As these parameters changes location to location in a very unpredictable way due to weather and shading and also for some other reasons, it effects the overall performance of DG system. Here such three PV systems of each 255 KW was considered to be located in different locations. These PV systems feed power to the grid and acts like a DG system. But what if the insolation and temperature change in random behavior in these different locations and what will be their impact on the total system. The model was designed in PSCAD and the possible scenarios are considered and also the effect of it is analyzed. The comparison study is done with normal condition and varying condition. The study reveals the effect on PV, inverter and transformer output. The stability of overall system is affected and also harmonics are injected and also the differences in phase and amplitude are observed which degrades the system performance.***

Index Terms: ***Solar photovoltaic, irradiation, distributed generation, efficiency, PSCAD.***

I. INTRODUCTION

In general, most of the power plant is running by conventional energy resource such as coal, petroleum, natural gas, nuclear fuels etc. But these resources are limited in nature and it is going to be finished after few years.

So Distributed Generation (DG) such as solar energy, wind energy, geothermal energy etc. has received a huge illustriousness due to concern about the adverse effect of the conventional energy resource on the environment.

Manuscript published on 30 September 2019
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As a nonconventional energy resource solar photo voltaic (SPV) energy is most efficient and easy to access because it is available in anywhere. DG units can be used as standalone system or grid connected system. In case of standalone system power from the DG units is supplied to the local loads only [1] but in case of grid connected system the DG connected to the existing power distribution grid. Small scale PV system such as 0-10 Kw is generally connected to the power distribution grid [1][9].

The number of grid-connected SPV system is going to be increased because government launches so many concession schemes, provide incentives and reduction in the panel cost and cost of the electronic equipment. For injecting power into the grid need to maintain the power quality. Poor quality power could cause perturbation and various losses to user. As, the SPV system is connected with the power distribution grid so fluctuation in PV power may lead to voltage fluctuation in grid. The power from SPV system is fluctuating in nature, solar irradiance (G) and temperature (T) has a vast impact on it. As these two parameter changes accordingly solar power also changes, for such variation SPV power is feed to the grid through power electronic devices and controlling equipment. Shading is an essential factor for PV power generation, due to the shading effect there will be change in PV power generation and it also injected harmonics in the system. As power distribution grid is already running with non-linear loads, so there already harmonics is generated, due to this shading effect the total harmonics distortion (THD) will be more. So, in this paper we made a grid connected DG system where three independent PV systems of 255 KW each were considered to be connected in an array. Theses 3 PV systems were located in three different locations where the changes in G and T were also different and random in nature. With EMTDC blocks different values of G and T were fed to these PV systems with possible random values and the effect of this on the overall system was analyzed.

II. SIMULATION MODEL IN PSCAD WITH EMTDC

In PSCAD, a distributed generation system was designed with 3 PV systems each of 255 KW connected in an array. It was considered that 3 PV systems were installed in three different locations. A total765 KW power was generated from the PV systems.

Apart from the SPV modules, the system was consisted of DC link capacitor, a 3-phase inverter, AC filter, transformer and utility grid equivalent model. In real time the G and T changes randomly in different locations. As 3 PV systems were acting as distributed generators, the effect of varying irradiance and temperature in different locations was to be examined. So, 3 EMTDC blocks were used to control the G and T of the 3 PV modules with random possible values and the changes in different outputs and system characteristics were also examined accordingly.

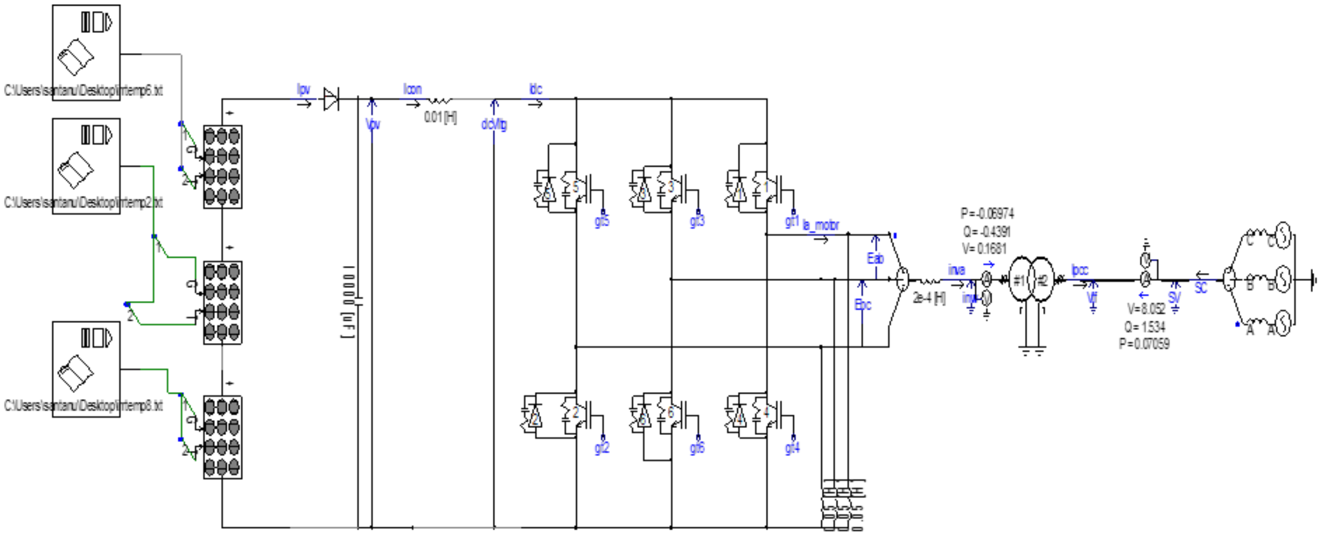

Fig. 1. PSCAD Model of grid connected distributed generation system

A. Distributed Generation (DG) system

A 765 KW DG system was designed connecting 3 independent PV systems each of 255KW in an array. These PV systems were considered to be installed in different locations where the G and T also varies independently and randomly. The open circuit voltage (Voc) and short circuit current (Isc) of the PV systems in total were 5 KV and .23KA respectively. The maximum power (Pmp) of 860 KW was achieved with Vmp= 4 KV and Imp= .21 KA in no shading condition.

B. DC link capacitor

As the ripples are present in output current of PV system, so to minimize these ripples a capacitor with higher value (1000μF) was connected in shunt to the system. It was assumed that this large DC link capacitor minimized the ripples.

C. EMTDC block

The EMTDC blocks, present in PSCAD, were used to feed the irradiance (G) and temperature (T) matrices with varying time. The EMTDC blocks were consisted of 3 columns time, irradiance and temperature respectively. The values of G and T were varied in accordance to the possible real time scenario in outer environment.

D. 3 phase inverter

To tie a PV system with the grid, the output of the DC-DC converter should be converted into three phase AC power. For this conversion a three-phase inverter is required. Here we use a 3-legged bridge inverter, total six IGBT switch is used. An inverter has to maintain a constant DC voltage across its input. 1 KV of constant DC voltage is maintained by a simple P & Q regulation circuit (Fig. 2). A firing pulse generation circuit (Fig. 5) is provided for creating switching signal (gt1, gt2, gt3, gt4, gt5, gt6) for six IGBT switches.

E. P & Q regulation circuit

Here two PI controller is used, one is for maintaining a constant DC voltage between inverter and DC-DC converter. Here we set the voltage at 1 KV fixed. The output signal from the PI controller which is named "Ang" is used as an input in the firing pulse generation circuit, it is discussed next. Another PI controller is used for operating the inverter at unity power factor. So, inverter will produce sinusoidal webform and voltage and current will be remain in same phase that's why we set the reactive power (Q) of grid at zero value. It's output signal which is named "Mag" is the input of the firing pulse generation circuit.

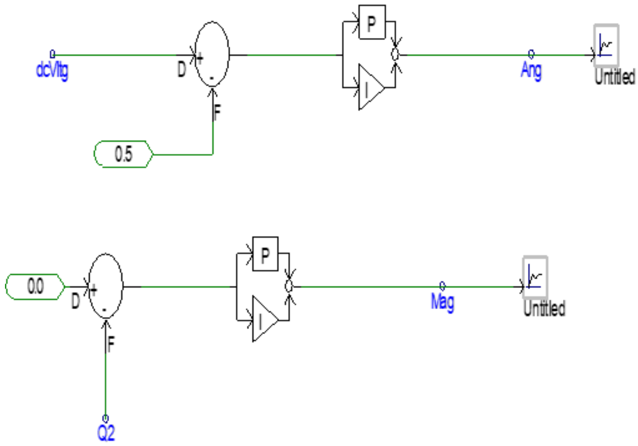

Fig.2. P&Q regulation module

F. Firing Pulse Generation Circuit

The switching signal of the six IGBT switch of the inverter is generate by firing pulse generation circuit using Sinusoidal Pulse Width Modulation (SPWM) technique.

Here three input is required, one is frequency (50 KHz) signal, a phase shift signal which is equal to the output of the previous PI controller output (Ang) with an additional phase shift of -120 and 120 degrees, another one is "Mag" signal from the previous controller.

Using these three inputs 3 sinusoidal modulating waves is generated. Then these three waves are compared with a triangular career wave which has range between -1 to +1. The output of the comparator was set to 1 to generate the switching signals gt1, gt3, gt5 and another three switching signals gt4, gt6, gt2 are created by inverting the above three signals. These signals are used to switch the six IGBT switch of the inverter.

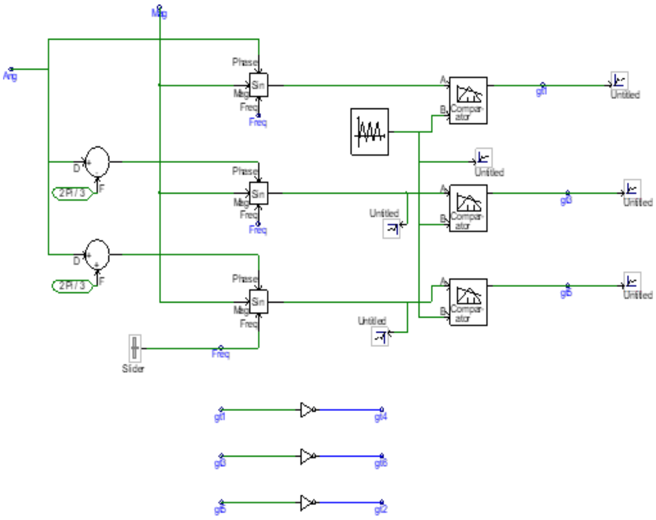

Fig.3. Firing pulse generation circuit

G. AC filter

Distortion is involved in the inverter output voltage. So, an AC filtering action is required for further smoothen the output. In this model using an inductor (Fig. 1) a AC filtering action is provide. This inductor improves the shape of the inverter output voltage wave to an almost sinusoidal wave.

H. Transformer

Transformer is very essential for grid connected PV system, it is used for galvanic isolation and for voltage adjustment. A conventional, step up (400 V/33KV), wye-wye, three phase transformer is used which is operate on 50 Hz.

I. Grid connection

Transformer output is fed to a utility grid. This is a functional model of 33 KV utility grid which is operating at 50 Hz source behind the system inductive impedance. The model of 33 KV grid designed in PSCAD is considered to be medium range grid.

III. RESULTS AND DISCUSSION

The V_{oc} and I_{sc} of the 3 PV systems were measured as 5 KV and .23 KA respectively. The maximum power (P_{mp}) of 860 KW was calculated where V_{mp}= 4 KV and I_{mp}= .21 KA in no shading condition were observed. In variable irradiance and temperature conditions the P_{mp} was measured as 798 KW where V_{mp}= 3.97 KV and I_{mp}= .20 KA. If the irradiance (G) increases the output voltage and current also get increased. After 25˚ C of the module temperature the output current decreases with rising temperature resulting a drop in overall efficiency at a rate of 0.5% with each 1 ˚ C. Photo current of a PV module is defined by,

$$I_{ph} = I_{ph,ref}\left(\frac{G}{G_{ref}}\right)[1+\propto_T (T - T_{ref})]$$

Where,

I_{ph} = photo current of PV module at certain irradiance

$I_{ph,ref}$ = photo current of PV module at irradiance (G_{ref})= 1000 W/m^2

G =certain irradiance at which photo current is to be calculated

$\propto_T$ = relative temperature co-efficient of short circuit current

T = Ambient temperature

T_{ref} = 25˚ C

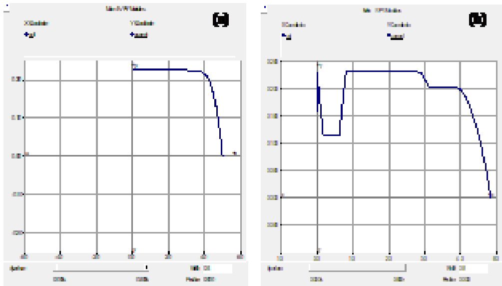

Fig. 4. Current(I)-Voltage(V) characteristics of the grid connected PV system under (a) STC condition (G=1000 W/m^2 and T=25˚ C) (b) different G and T condition

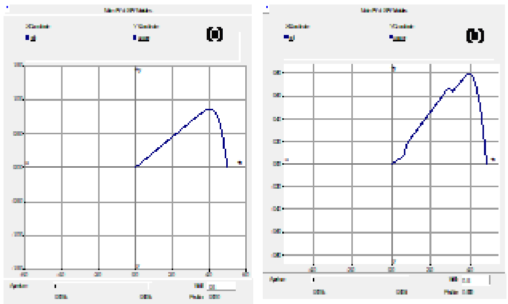

Fig. 5. Power (P)-Voltage (V) curve of the grid connected PV system under (a) STC condition (G=1000 W/m^2 and T=25˚ C) (b) different G and T condition

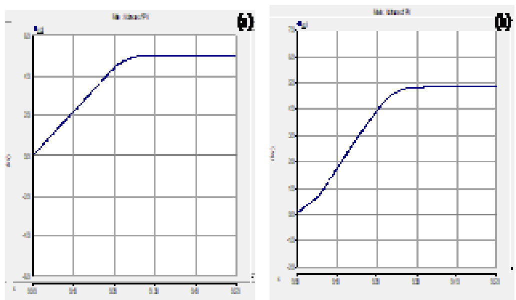

Fig. 6. Output Voltage(V) of the PV modules under (a) STC condition (G=1000 W/m^2 and T=25˚ C) (b) different G and T condition

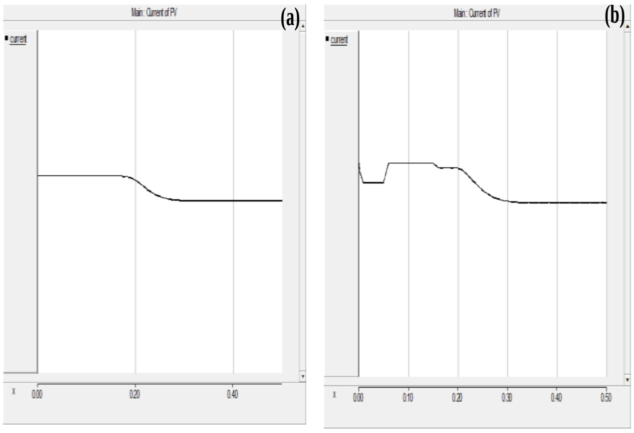

Fig. 7. Output Current(I) graph of the PV modules under (a) STC condition (G=1000 W/m^2 and T=25° C) (b) different G and T condition

So, from the equation it's determined that the photo current of solar cells changes depending on the values of irradiance and temperature. When there is a shading or rise in temperature it affects the system and the overall efficiency is decreased. The PSCAD model was designed with 3 PV systems in 3 different locations in a DG system and the performances and the different output characteristics were measured and compared for Standard Testing Condition (STC) and for different irradiance or shading or change in temperatures. Fig 4. (a) and (b) depicts I-V characteristics for STC and different G and T conditions respectively. For STC condition a smooth I-V graph was observed but whereas in case of other condition the graph was abnormal and very unpredictable in nature due to random change s in G and T. So, it effected V_{oc} and I_{sc} too. The P-V graphs (Fig 5(a) and(b)) was also shown remarkable changes due to the variation. Fig.6(a) and (b) show the voltage profiles for 2 cases and Fig.7(a) and (b) show the change in current profiles.

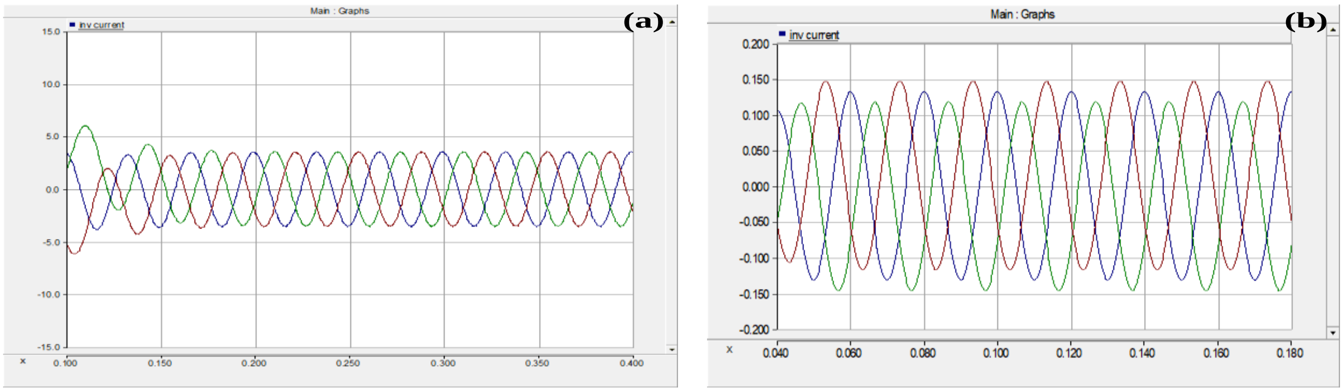

Fig. 8. Inverter output current under (a) STC condition (G=1000 W/m^2 and T=25° C) (b) different G and T condition

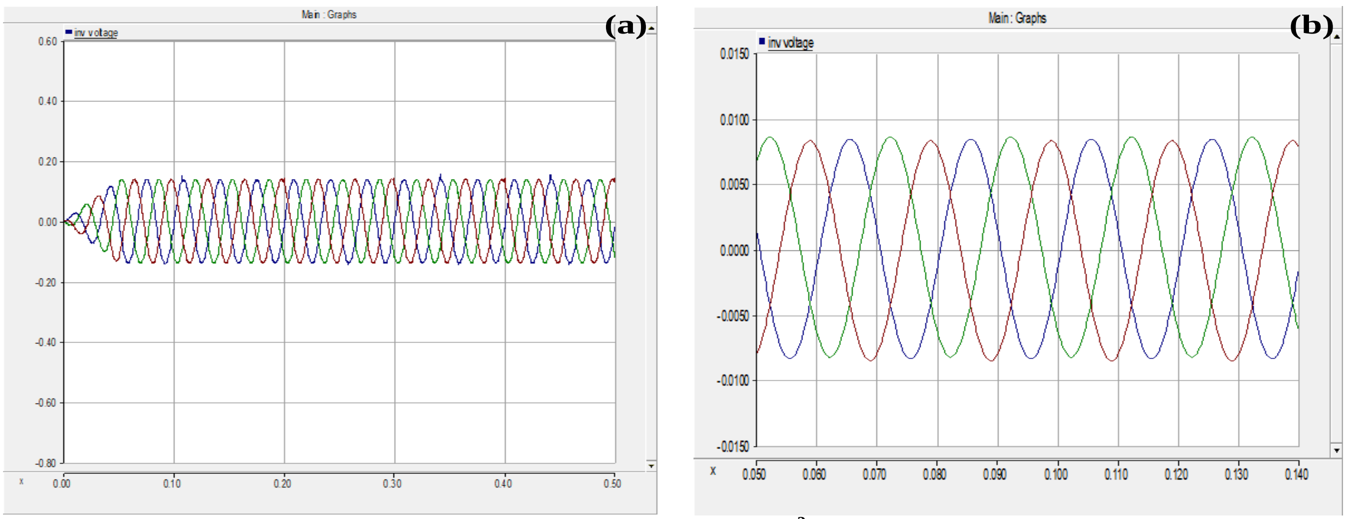

Fig. 9. Inverter output voltage under (a) STC condition (G=1000 W/m^2 and T=25° C) (b) different G and T condition

The variations in G and T in different PV systems installed in different locations also effected the inverter and transformer outputs. Fig.8 and Fig.9 depicts the inverter output current and voltage respectively. Fig.10 and Fig. 11 shows the transformer current and voltage characteristics respectively. In both the outputs harmonics injection can be clearly seen due to the variation. The 3 phase outputs also have phase variation and amplitude mismatch. Due to this the overall stability of the system was also disturbed and the performance was degraded and hence creating uncertainty which is not desirable.

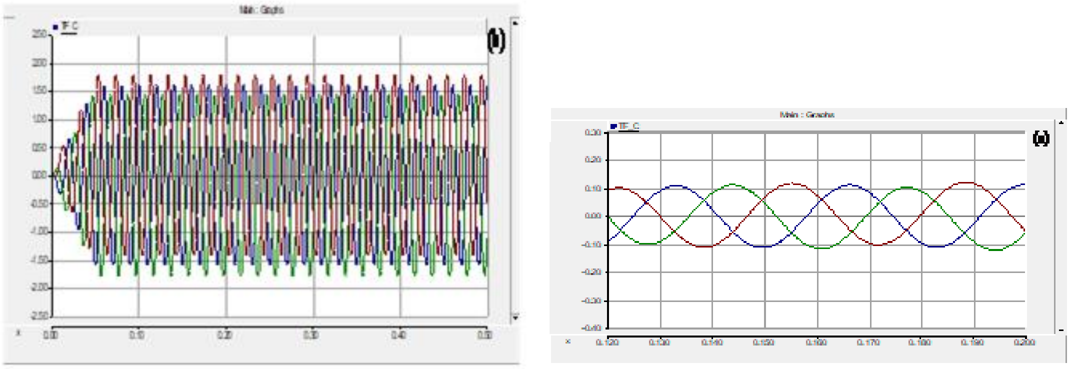

Fig. 10. Transformer output current under (a) STC condition (G=1000 W/m^2 and T=25° C) (b) different G and T condition

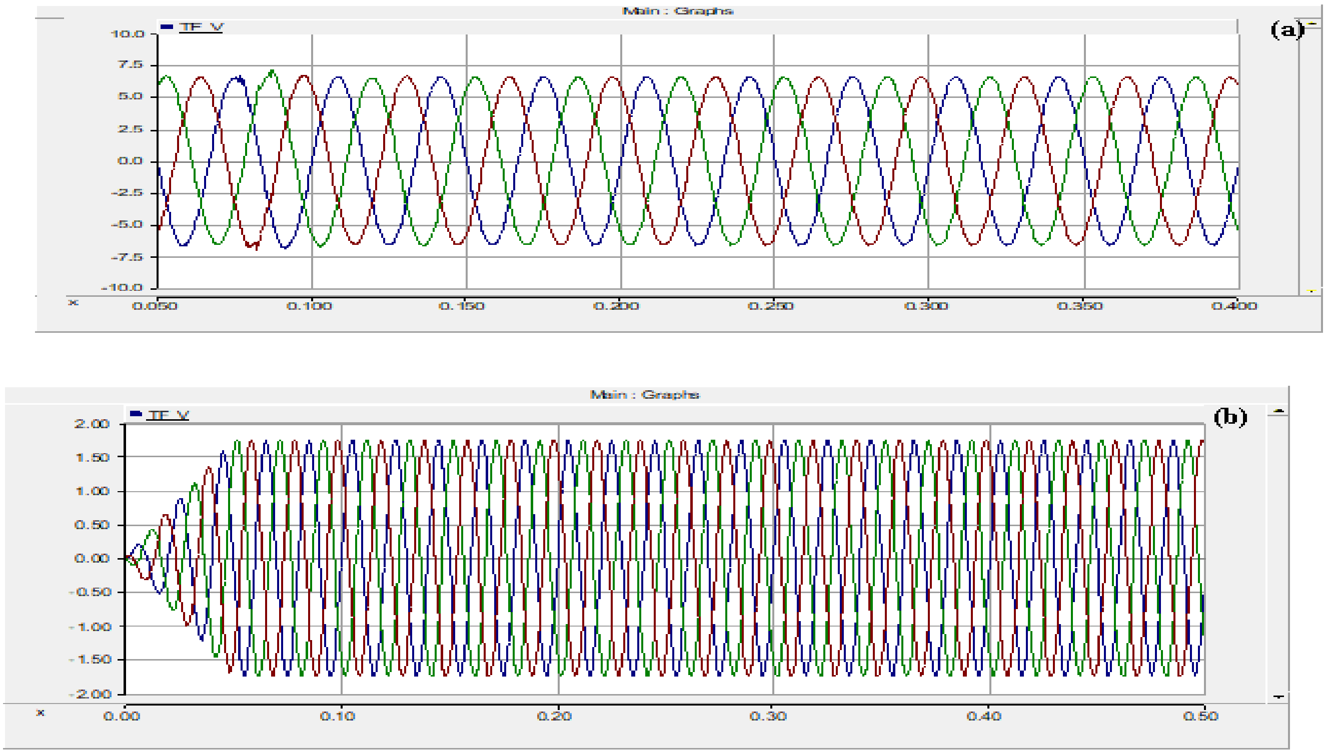

Fig. 11. Transformer output voltage under (a) STC condition (G=1000 W/m^2 and T=25° C) (b) different G and T condition

IV. CONCLUSION

In this paper a grid connected DG system was designed in PSCAD. The DG consisted of 3 PV systems located in three different locations. As the output of PV systems has irradiance temperature dependency so the outcome of variation of G and T were analysed. We have tried to consider the situation when there are changes in G and T due to shading or any other climate changes and overall these changes are no equal from all the PV systems located in different locations. The impact of these in grid connected DG systems were examined and compared with STC condition. From the above discussed results, it's very prominent that how the consideration effected the normal operation and degraded the overall performance.

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