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IMPACT OF GRID CONNECTED PHOTOVOLTAIC SYSTEM UNDER DIFFERENT WEATHER CONDITIONS AND LOAD TYPE

Rebai Asma[1]*, Zahzouh Zoubir[2], Boulahchiche Saliha[1]

[1] LGMM Laboratory, Faculty of Technology, 20 Août 1955 University, Skikda, Algeria
[2] Laboratory of Research on Electromechanical and Dependability, University of Souk Ahras, Algeria
* a.rebai@univ-skikda.dz

Electricity distribution managers are continuously under pressure to expand their grids to cope with load growth and properly supply their consumers. To achieve these objectives, it is necessary to provide an acceptable climate for the entry of solar resources and innovative operating practices. This work focuses on a study the impact of the insertion of photovoltaic energy into the low voltage distribution grid. We have shown the impact of weather conditions on the power injected into the grid, the impact of using a single-phase inverter with a TT-neutral regime, the flow of active and reactive bidirectional power to the point of common coupling PCC, and the impact of a grid connected photovoltaic system under different weather conditions and load types. This study was carried out using the Matlab Simulink environment for modeling and simulation of a single-phase system with a 3,5kW transformer inverter and the results show the impact of PV system integration on the overall and individual harmonic level of voltage and current considering several scenarios (variable solar irradiation, variable types of loads),the presence of filters such as the inductor and the capacitor in series or in parallel plays very important role on the improvement in the disturbance of the quality of the current and the tension.

Keywords: PV system, energy quality, PCC, LV network, harmonics

1 INTRODUCTION

Global consumption of electricity continues to increase in light of population growth and technology development. The majority of the electrical energy generated worldwide thus far has come from fossil fuels (gas, fuel oil, coal, and oil). However, the combustion of these materials emits greenhouse gases and severely pollutes the environment, which does not meet the requirements of sustainable development. Consequently, the excessive use of these raw materials leads to a reduction in the available reserves and compromises the chances of future generations. Today, 'Renewable Energy' (RE) technologies are considered not only as a means of ensuring energy security and combating climate change, but also as an investment that can guarantee direct and indirect economic benefits by reducing energy imports, air quality and safety, access to energy, economic development and job creation. The decline in the production costs of photovoltaic modules (PV) has also played an important role in the deployment of RE in recent years. Several renewable energy technologies are today competitive with conventional production technologies, without taking into consideration the environment and other aspects [1]. Among the renewable energies considered, solar power, an important renewable power, has been on the increase in most parts of the world in terms of installations [2]. Thus, solar modules are considered as an important building component of future power grids.

In this work, we discuss one of these types of energies: the photovoltaic solar energy, which is the energy produced by converting sunlight into electricity. In a solar PV system, a solar cell is used to convert energy in sunlight into a direct current power [3, 4]. The material used in this solar cell is silicon and semi-conductive in nature. The materials in use today for majority of solar cells are mono-crystalline, poly-crystalline and amorphous silicon [5, 6]. [7] This study scrutinizes the reliability and validity of existing analyses that focus on the impact of various environmental factors on a photovoltaic (PV) system's performance. A solar photovoltaic (PV) power system can operate in isolation or connected to a power grid [8]. This work deals with a grid connected PV system. Since PV production is intermittent, injecting it into the grid requires further study in the furor. The grid integration of the photovoltaic generator requires a power electronics inverter because it produces direct current (DC) energy in a natural way. This inverter causes power quality deterioration such as inrush current, over voltage, output power fluctuation, frequency fluctuation and harmonic injection [9, 10-12]. The effect of these drawbacks depends on the level of PV penetration into the integrated PV system, the grid construction, and the point of common coupling (PCC) between the grid and the PV system. Many researches deal with the challenges of photovoltaic grid integration from different points of view [11]. The magnitude of the harmonic content in a current (or) voltage signal is generally characterized by the THD factor. Harmonics can be dominant when the percentage of PV penetration connected to the inverter (compared to linear load and non-linear load) is high in the grid [11, 13]. Harmonic distortion is less when solar PV is integrated at the start of a feeder which has a high short-circuit level while harmonics can be dominant when the PV system is integrated at the feeder far from the grid with a low short-circuit level circuits [14].

In this context, a theoretical and experimental evaluation of the different possibilities of the harmonic distortion violants in PV systems connected to the low voltage grid caused by the integration of the PV system.

2 MODELING AND SIMULATION OF PHOTOVOLTAIC SYSTEM CONNECTED TO THE GRID

2.1 Proposed model

The proposed PV system contains a photovoltaic generator, a boost converter, a "perturb and observe'' MPPT controller, the voltage inverter (DC-AC) controlled by PWM an RLC filter and the LV power grid (Fig.1).

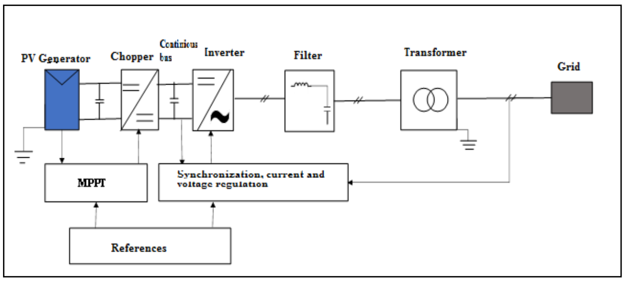

Fig. 1. Model of the proposed photovoltaic system

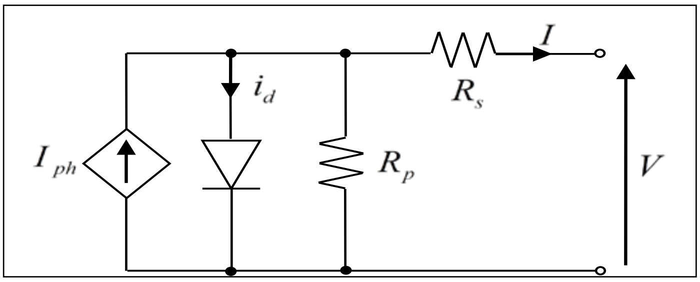

Fig. 2. Equivalent circuit of the PV cell with series and parallel resistance

2.2 Photovoltaic generator

There are several mathematical models of the photovoltaic module in the literature [15, 16]. In our work, we have chosen the five-parameter model with series and shunt resistor and a single diode, shown in Figure 2 [17]. The module is made up of following items:

- A current source, which represents the current generated by light.
- A diode shunted with a current source, which represents the p-n junction of the PV cell.
- A shunt resistor R_p and a series resistor R_s. The shunt resistance represents the current leakage due to the presence of impurities in the p-n junction. Series resistance represents the resistance of semiconductor and metal contacts.

The mathematical model is given by the following equation (1):

$$I = I_{ph} - I_0\left(\exp\left(\frac{V + R_s I}{N_s.AV_t}\right) - 1\right) - \frac{V + R_s I}{R_p} \tag{1}$$

Where:

I: Current at the terminals of the PV module (A).

V: PV current (A).

R_s: Equivalent series resistance (Ω).

I_o: Saturation current of the diode (A).

N_s: Number of cells connected in series.

$V_t = \frac{kq}{t}$: Thermal voltage of the diode

k: Boltzmann constant (1.3806503x10-23 J / K).

q: The charge of the electron (1.60217646x10-19 C).

T: Temperature (K°).

In our example, the photovoltaic generator consists of a chain of 14 modules Trina Solar TSM-250 connected in series. Under varying solar radiation and temperature conditions, the chain can produce 3,5kW.

Two small capacitors, connected to the + and - terminals of the photovoltaic generator with technical characteristics of STC (table 1), allow to model the stray capacity between the PV modules and the ground.

2.3 Single phase DC/AC inverter

The inverter is modeled using a single-phase full bridge IGBT module controlled by PWM (H-bridge). The topology of the line-side filter is the classic LCL configuration with inductors evenly distributed between the line and the neutral branches.

2.4 PWM control

Used the bipolar PWM modulation method to generate trigger signals to IGBTs.

Table 1. Technical characteristics of the generator (STC)

Symbol	Parameters	Value	Unit
N	Number of cells	47	
V	Rated voltage	31	V
Pmax	Max power	249.86	W
Isc.ref	Shorting current	8.55	A
Voc.ref	Open circuit voltage	21.6	V
Impp.ref	MPP current	8.06	A
Vmpp.ref	MPP voltage	31	V

3 RESULTS AND INTERPRETATION

3.1 Impact of metrological conditions

We performed the simulation of the PV system connected to the grid by varying illumination and temperature. We measured the following parameters at the input and output of the inverter (PCC): Current, voltage and power.

3.1.1 Impact of variation of solar irradiance

Figure 3 illustrates the profile of the illumination. We varied the illumination in the range 0.5 to 1 second from 1000W/m2 to 150W/m2 and kept the temperature constant at 25°C in order to observe the effect of the illumination on the current, voltage, and power of the photovoltaic generator.

3.1.2 Temperature Profile

Figure 4 illustrates the temperature profile. We varied the temperature in the 1.4 to 2.7 second range from 25°C to 60°C and kept the illumination constant at 1000W/m^2 to see the effect of the temperature on the current, voltage, and power of the GPV.

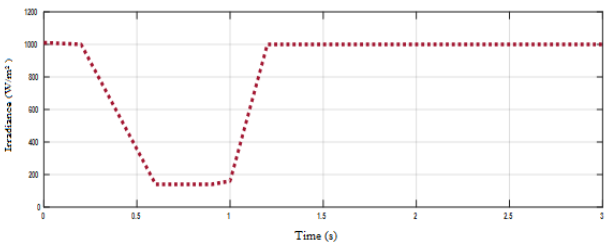

Fig. 3. Illumination profile in relation to time

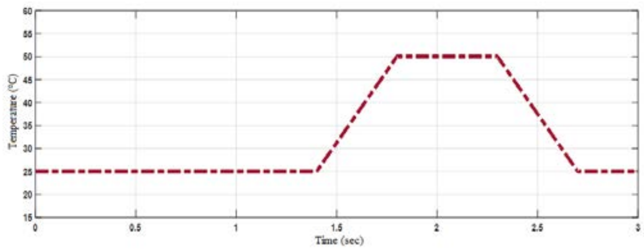

Fig. 4. Temperature versus time profile

3.1.3 Impact of irradiance and Temperature on Continuous Voltage Level

Figure 5 shows the impact of illumination and temperature on the voltage level at the input of the inverter; As can be seen, temperature has a significant impact in relation to illumination on the voltage decrease.

3.1.4 Impact of Irradiance and Temperature on power Level

Figure 6 shows the variations in the power injected into the grid, the impact of illumination and temperature on the power level at the common connection point. However, the illumination has a great influence on the product in relation to the temperature, which has less influence.

In this figure, we can notice the effect of the illumination and the temperature on the power at the input of the inverter, whose illumination we have shown is the most important factor on the production, because the PV system is a power generator.

3.2 Results without adding a load in PCC

To see the impact of integrating a grid-connected photovoltaic system into the grid without the impact of integrating loads into the PCC, we presented the performance of the PV system (electrical parameter, THD level and leakage current capacitive) at the PCC takes in consideration the type of the single-phase inverter without transformer use.

3.2.1 Impact of metrological on the voltage at PCC

Figure 7 shows the effective voltage difference (RMS) as the grid voltage is 240 V at PCC due the effect of irradiance and temperature on the voltage level at the connection point with the grid. From this figure, they show that irradiance plays a major role in voltage changes compared temperature.

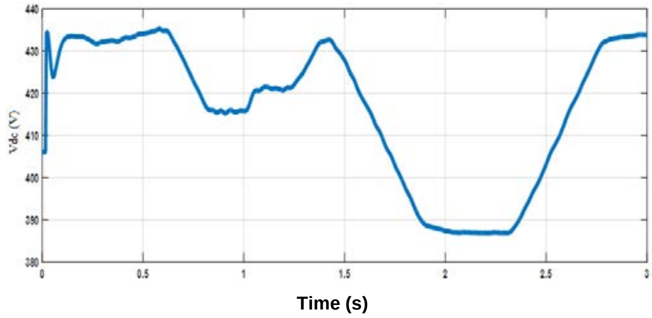

Fig. 5. Impact of temperature and irradiation on DC voltage

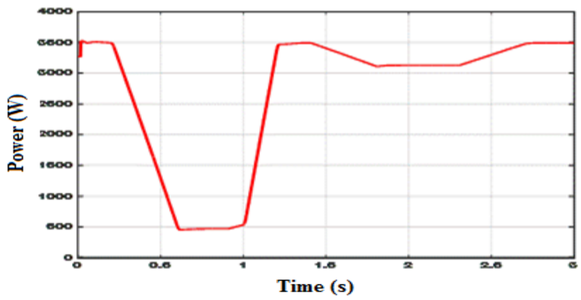

Fig. 6. Impact of temperature and irradiation on the power delivered at the PCC

3.2.2 Effective current at PCC

Figure 8 shows the changes in alternative current at the PCC, and the effect of irradiance and temperature on the current level at the common connection point with the grid. From this figure, we see that the amount of irradiance has a significant effect on the output current in relation to the temperature, which has a lower impact.

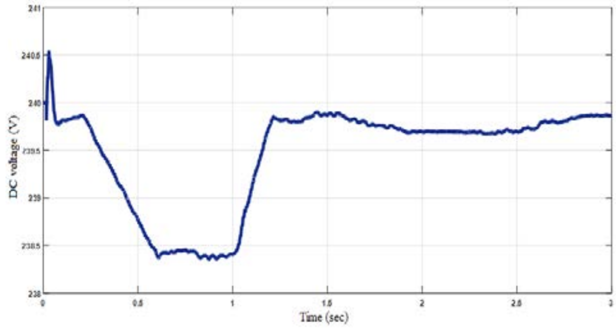

Fig. 7. Impact of temperature and irradiation on voltage at PCC

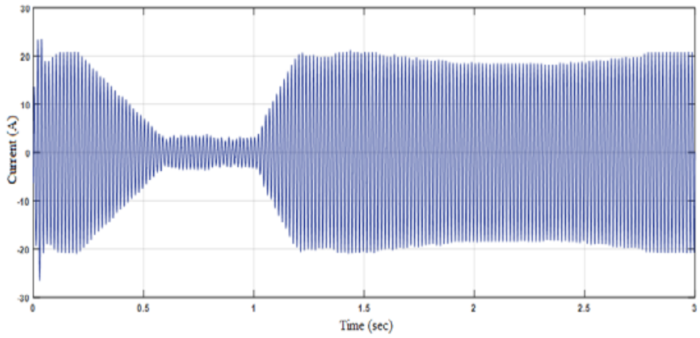

Fig. 8. Impact of temperature and irradiation on current at PCC

3.2.3 Flow of active and reactive power at point of common coupling

Solar energy is a generator of direct current, while the transformer is considered a source of actual and reactive energy, depending on its type. Figure 9 shows the effect of lighting and temperature on active and reactive energy. In the case of an inverter with a transformer and no loads, its active power depends on the power produced by the photovoltaic system, while the reactive power is almost non-existent due to the type of inverter used.

3.2.4 Capacitive leakage current

Transformers less inverters are more attractive to the grounded photovoltaic system because of their higher level of efficiency, minimal cost, and weight. Unfortunately, the absence of galvanic isolation creates ground faults caused by the passage of capacitive leakage current. Figure 10 shows the characteristics of the capacitive leakage current of which we have found the alternating characteristics of the current, since the leakage current increases to a value of 250mA and decreases to a value of 0mA due to an end of the PV generator parasitic electrons.

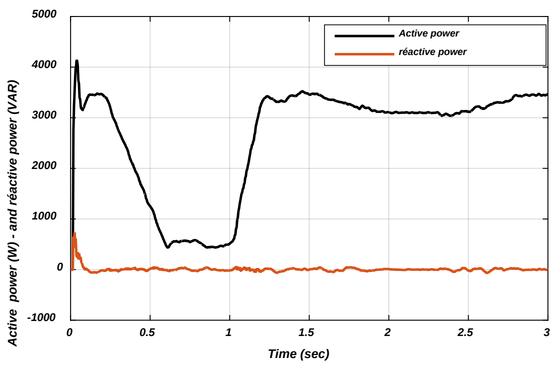

Fig. 9. Impact of metrological conditions on the active and reactive power produced at the PCC

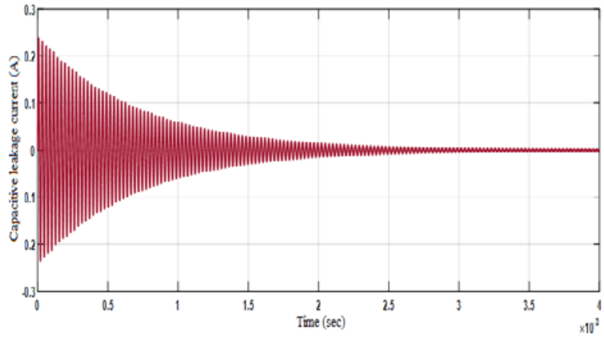

Fig. 10. Impact of the presence of a transformer less inverter on the presence of the capacitive leakage current

3.2.5 Analyzes of harmonic distortion without adding a load at PCC

Based on the results obtained illustrated in Figure 11, it can be observed that the harmonic current distortion is within the acceptable limits declared on international standards (< 5%) due to the filtering effect at the PWM ,RL filter and the absence of a load connected to the PCC.

3.3 Results with adding a load in PCC

To see the impact of integrating a photovoltaic system connected to the grid with the addition of different types of loads, we presented the performance of the system to the PCC with the influence of different types of loads on the THD level.

3.3.1 Integration of a serial RLC load into the PCC

In our case, we integrated a RLC load into the PCC. Figure 12 shows the variations in current over time. We have shown the impact of the load on the variation of the current as a function of the need for the load, which is, defined as a stable intake, the consumption of which depends on the production of the GPV and the demand for the load.

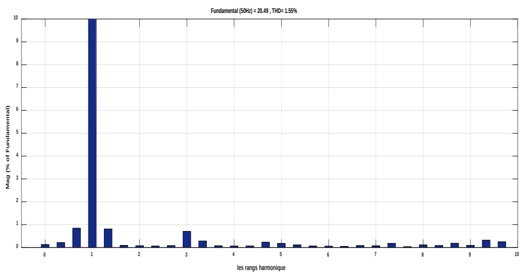

Fig. 11. Spectral presentation of harmonic rows without PCC loading

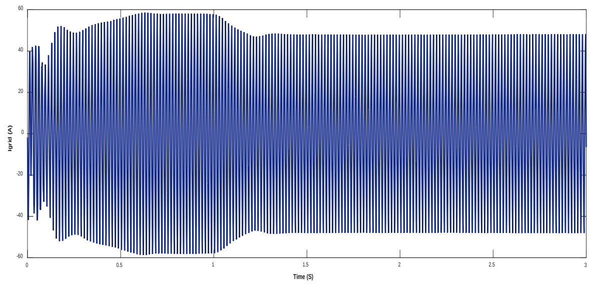

Fig. 12. Impact of the load on the current at the PCC

3.3.2 Flow of active and reactive power in the presence of an RLC load

In the case of a load connected to the PCC connection point, the consumption of the latter depends on the presence of inductive and capacitive components which affect the active and reactive power consumed. Figure 13 illustrates the two-dimensional flow of the active power and the reactive power at the PCC between the PV system and the network the load taking in consideration the inductive and capacitive characteristics of the RLC load in series.

3.3.3 Harmonic Analysis at PCC

– ***Integration of a serial RLC load***

Figure 14 illustrates the current waveform and the spectral presentation of the harmonics. According to Figure,: we have noted the impact of the integration of the RLC load in series on the level of harmonic distortion of the current including THDi = 18.09% and THDv = 0.93% (see table), due to the connection of an inductor in series and the positive reactive power consumed by the load, which plays a role in improving or disturbing the wave quality of the current.

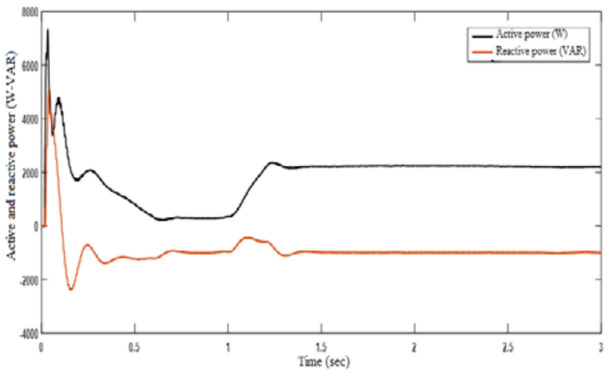

Fig. 13. Flow of active and reactive power according to PCC load consumption

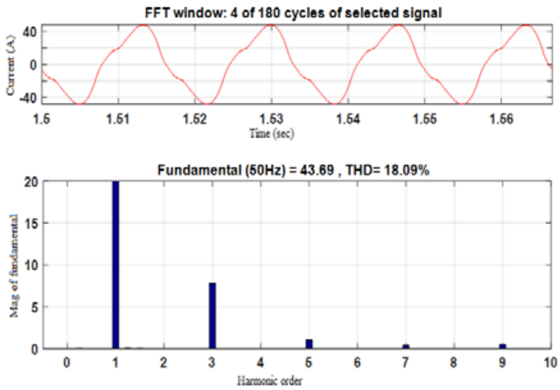

Fig. 14. Impact Spectral presentation of harmonic rows and waveform with integration of a RLC load in series at the PCC

– ***Integration of a parallel RLC load***

Figure 15 illustrates the current waveform and the spectral presentation of the harmonics. We have noted, according to the figure, the impact of the integration of the RLC load in parallel on the level of harmonic distortion of the current and voltage whose THDi = 14.13% and THDv = 6.14% (see table) that the connection of the capacity is in parallel with a negative reactive power according to the consumption of the load. We have shown that the connection of the capacity in parallel impacts on the improvement or the disturbance of the quality of voltage wave.

– ***Adding of a rectifier with an RL load in series***

Figure 16 and Figure 17 show the waveform and spectral presentation of current and voltage harmonics respectively. In this case we chose a rectifier load with a serial RL load of L = 50 *10-3 to see the impact on the harmonic distortion level of the current and voltage, according to the simulation results obtained the THDi = 39.13% and the THDv = 15.88%, these results give the global harmonic distortion rates of rectifier with the integrated load.

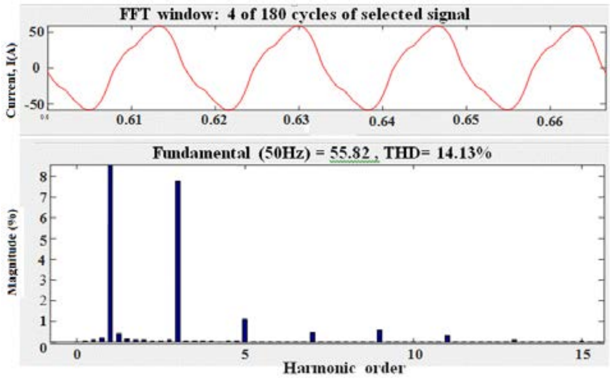

Fig. 15. Spectral presentation of harmonic rows and waveform with RLC loading in parallel with the PCC

Table 2. Impact of Inductance on Current and Voltage

R (ohms)	L (H)	THD_V(%)	THDi (%)
1	L = 50 *10^{-3}	15,88	35,87
1	L = 100 *10^{-3}	15,79	39,44
1	L = 200 *10^{-3}	15,25	40,52

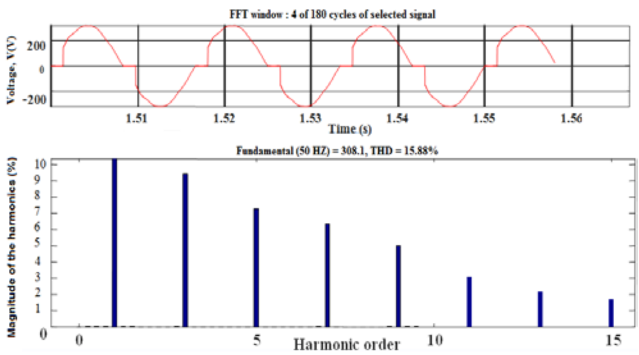

Fig. 16. Spectral presentation of harmonic rows and voltage waveform with rectifier integration with serial RL load at the PCC

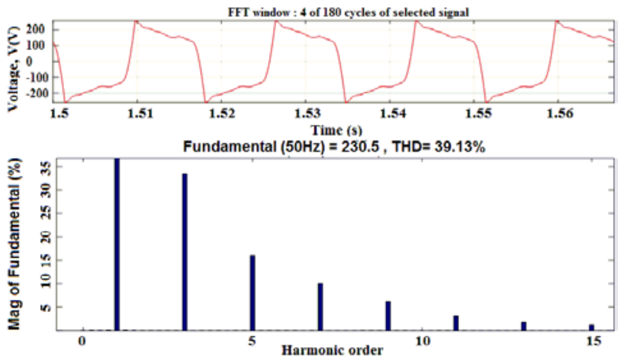

Fig. 17. Spectral presentation of harmonic rows and current waveform with rectifier integration with serial RL load at the PCC

We repeated the experiment again with this load and varied the inductance value L. The overall harmonic distortion rates of current and voltage recorded in Table 2. The results have shown that the connection of the inductor in series plays a very important role in improving or disturbing the wave quality of the current.

– ***Integration of a rectifier with a parallel RC load***

Figure 18 and Figure 19 illustrate the waveform and spectral presentation of current and voltage harmonics, respectively. In this case we have chosen a rectifier load with a series RC load of C = 100 * e-6 to see the impact of the capacitive components in parallel and the absence of inductive component on the level of harmonic distortion of the current and voltage, according to the simulation results obtained THDi = 44.86% and THDv = 5.76%, these results confirm that the presence of a capacitive component to the loads improves the level of voltage THD and on the other hand the absence of inductance at the loads increased by current THD.

We repeated the study on this load with the change of the capacity value C by different values. The overall harmonic distortion rates of current and voltage recorded in Table 3. The results have shown that the connection of a capacitor in parallel plays a very important role in improving or disturbing the quality of the voltage waves which influence the quality of the current.

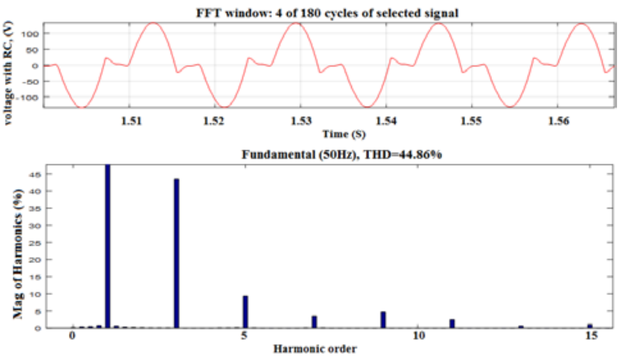

Fig. 18. Spectral presentation of harmonic rows and voltage waveform with RC load integration in parallel with the PCC

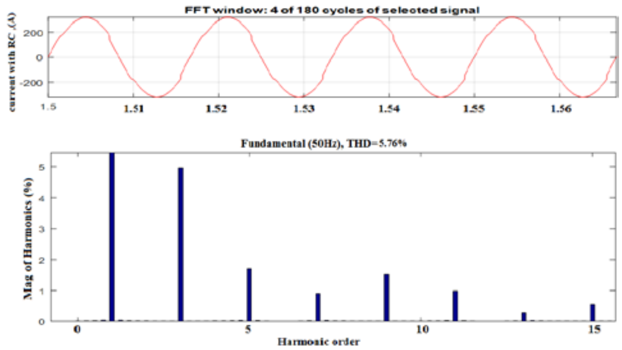

Fig. 19. Spectral presentation of harmonic rows and current waveform with RC load integration in parallel with PCC

Table 3. Impact of Inductance on Current and Voltage

R (ohms)	C(F)	THDi (%)	THDv (%)
1	$C = 1*10^{-6}$	16,74	5.54
1	$C = 4*10^{-6}$	5,03	2.98
1	$C = 8*10^{-6}$	3,37	1.98

Table 4. Impact of Inductance on Current and Voltage

R (ohms)	C (F)	THDi (%)	THDv (%)
1	$C = 1*10^{-6}$	44.86	5.76
1	$C = 4*10^{-6}$	24.80	5.89
1	$C = 8*10^{-6}$	89.20	4.31

– ***Integration of a rectifier with a serial RC load***

To see the impact of the absence of inductance to the converter we have integrated a rectifier with RC in series for different values the table 4 gives the results of THDi and THDv:

– ***Integration of a rectifier with a parallel LC load***

To see the impact of passive components L and C we have integrated a charge with LC with L = 200*10-3 H et C =100*10-6F the results give that THDi = 3.23% and THDv = 5.74%.

4 CONCLUSION

In this work we have studied a photovoltaic system connected to the low voltage grid with a type of inverter, the system model was implemented in Matlab/Simulink and the simulations are carried out. The results are satisfactory and conform to the permissible limits in accordance to IEEE norms. Regarding the scenarios presented, we can conclude that the operation of the PV system is related to the changes in weather conditions and the types of loads and connection method to the PCC.

This work monitors the quality of electrical energy in the low voltage distribution network by considering the influence of the total harmonics distortion THD of current and voltage in the different scenarios : Analyzes of harmonic distortion without adding a loads at PCC and Analyzes of harmonic distortion with adding a different types loads at PCC (serial RLC, parallel RLC,RL load in series and RC parallel load), we conclude that the THD increases with the addition of non-linear loads, and as the total harmonic distortion of current and voltage vary for the different types of loads. In order to solve the harmonic issue in distributed generation, filters are commonly used. Conventionally, series inductors and capacitor or in parallel a very important role on the improvement or the disturbance of the quality of the current and the tension.

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