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Review of the Optimization of PV System to the Grid Network

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Abstract:** Among the potential renewable energies, photovoltaic (PV) has experienced enormous growth of generating electricity. In the modern power systems, the effectiveness of grid-tied PV systems has become a spotlight topic for researchers in this field. This paper presents a review on the optimization of PV system to the grid, considering the improvement that will be done to the grid network after connecting the PV system to the grid. A simulation under Matlab/Simulink have been carried out to prove the performance of the proposed power flow management. The objective is to show that the using of grid-connected PV will make a stabilization and increase the reliability to the network.
Keywords: Photovoltaic, Grid connected

I. INTRODUCTION

Renewable energy resources including among others solar, wind, hydro and geothermal. However, solar energy has gained much more attention due to its long life, inexhaustible nature, low maintenance, zero running costs, availability and pollution free [10]. Since the late 1990s, it has been considerable advancement in the field of renewable energy sources (RES) and the main driving force for boosting alternative energy sources has been global warming linked to CO 2 emission and other harmful gases generated from fossil fuels burning used in power plants. [6].

Solar photovoltaic (PV) industry is the dominant type of the renewable energy sources (RES) technology integrated to power grid systems. It has been achieving worldwide acceptance and it is playing a significant role in providing clean and sustainable energy. Moreover, it has obtained much attention from energy players, investors, government, and international organizations because of its several benefits including environmental and economic benefit. Therefore, PV power installation has experienced enormous growth over the last few years due to that the global PV cumulative installed capacity reached to 229.3 GWp, an addition of 50.909 GWp (an increase of 29%) in 2015 compared to that in 2014, as shown in Fig. 1[8]. The increased growth rate of these systems led to that the prices of PV modules has decreased of 7.5%, and the overall production of PV modules throughout the globe has ramped up by 18% per year [3].

There are different power system performance indicators are evaluated in terms of reduced emissions especially greenhouse gas (GHG) emissions, and global warming, reduced economic burden, improved the technical issues and improved system security by using renewable energy with connecting to the grid systems.

Furthermore, when the solar energy generation is higher than the load demand, the extra energy can be either stored in the battery or sold to the grid. At first the extra PV energy charges the battery, then it is exported to the connected grid. If the solar energy produced lower than the demand, the power will be imported to meet the unmet load demand.

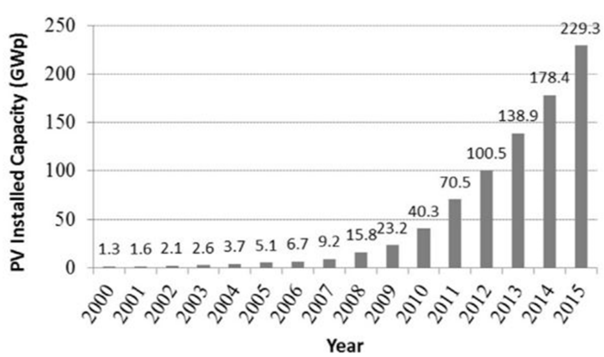

Fig.1: Global cumulative PV installed capacity.

II. MATERIAL & METHODOLOGY

The topology of the studied three-phase grid-connected PV system is illustrated in Figure 2. The scheme is based on a DC/DC boost converter which is in charge of both the MPP tracking of the PV generator and the generated power curtailment during grid voltage unbalances [2]. In addition, a 2-level three-phase dc/ac stage ensures the connection to the grid via a LCL filter. The inverter is in charge of controlling the dc-link voltage control and the injecting of the generated power into the grid. Otherwise, the LCL filter is exploited to decrease the attenuation of the harmonics caused by the switching [2].

III. PVG MODELLING AND MPPT CONTROL

It is important to note that the modeling of the PVG was made by adopting the circuit with two diodes thanks to its accuracy compared to the mode with two diodes [2]. By neglecting the characteristic resistances, the generated current is expressed below:

$$I_{PV}(G,T) = \frac{G}{Gn}\left[I_{scn} + K_i(T - T_n)\right] - \frac{I_{scn}+K_i(T-T_n)}{\exp\left(\frac{V_{ocn}+I_{scn}(T-T_n)}{nN_SK_B\ T/q}\right)-1} \cdot \left[exp\left(\frac{V_{PV}}{nN_SK_B\ T/q}\right) - 1\right] \quad (1)$$

Where:
Ns: is the number of PV cells connected in series to form the PV panel.
T & G: are the ambient temperature and irradiation, respectively.
Tn & Gn: are the temperature and irradiation at standard test conditions (STC), respectively.
q: is the charge of an electron.
kB: is Boltzmann constant.
n: is the diode ideality factor.
Vocn & I scn: are the open circuit voltage (Voc) and the cell's short circuit current (I sc) at STC.
kv & ki: are the variation coefficients of the Voc and the Isc, respectively.

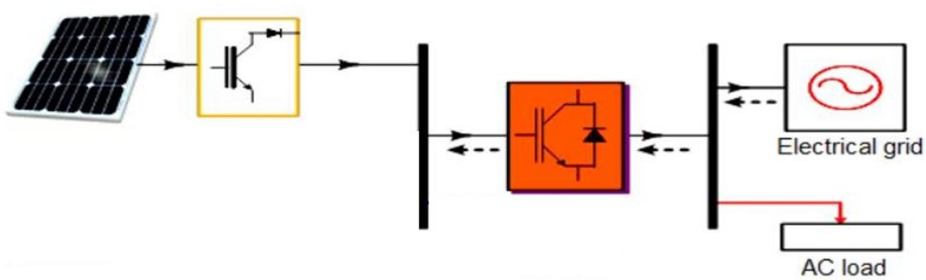

Fig.2: Grid-connected PV system.

For simulation the current and voltage and therefore the power of the PV generator containing
Nss: panels associated in series.
Np: panels connected in parallel.
Eq. (1) is rewritten as in Eq. (2) and the power as in Eq. (3)

$$I_{PV}(G,T) = \frac{G}{Gn}N_P\left[I_{scn} + K_i(T - T_n)\right] - \frac{(I_{scn}+K_i(T-T_n))N_P}{\exp\left(\frac{(V_{ocn}+I_{scn}(T-T_n))N_{SS}}{nN_SN_{SS}K_B\ T/q}\right)-1} \cdot \left[exp\left(\frac{V_{PV}}{nN_SN_{SS}K_B\ T/q}\right) - 1\right] \quad (2)$$

$$P_{PV}(G,T) = i_{PV}(G,T).v_{PV}(G,T) \quad (3)$$

To locate the MPP, it is essential to express the power derivative with respect to the generator voltage to obtain the below new characteristic function:

$$P_{PV}(G,T,v_{PV}) = \left\{\frac{G}{G_n}N_P\left[I_{scn} + K_i(T - T_n)\right] - \frac{(I_{scn}+K_i(T-T_n))N_P}{\exp\left(\frac{(V_{ocn}+I_{scn}(T-T_n))N_{SS}}{nN_SN_{SS}K_B\ T/q}\right)-1} \cdot \left[exp\left(\frac{V_{PV}}{nN_SN_{SS}K_B\ T/q}\right) - 1\right]\right\} \times v_{PV}(G,T) \quad (4)$$

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With a view to identify the combination of temperature and irradiance allowing to extract the maximum power point tracking (MPPT) due to incremental conductance (IC) MPPT technique, the power derivative is calculated. After determining the voltage value which corresponds to the maximum power, the duty cycle of the PVG side DC/DC chopper is adjusted [2].
The MPPT controller is designed to overcome the constraints generated by climatic conditions which are constantly in continuous and even rapid changes [2]. The performance of this controller depends essentially on the robustness of this controller in the face of sudden atmospheric changes and particularly on the speed of reaching the MPP and on the way of oscillating nearby it.

IV. RESULTS

It is important to recall that many criteria have been taken into consideration to maximize the efficiency of the studied PV system connected to the grid.

At first, a great attention was paid on extracting the maximum power available from the GPV side. Indeed, in the simulated scenario, the considered sunshine and temperature profiles are those presented in figure 3 (a) and (b). So, the optimum power generated by the PVG is depicted in figure 3 (c)

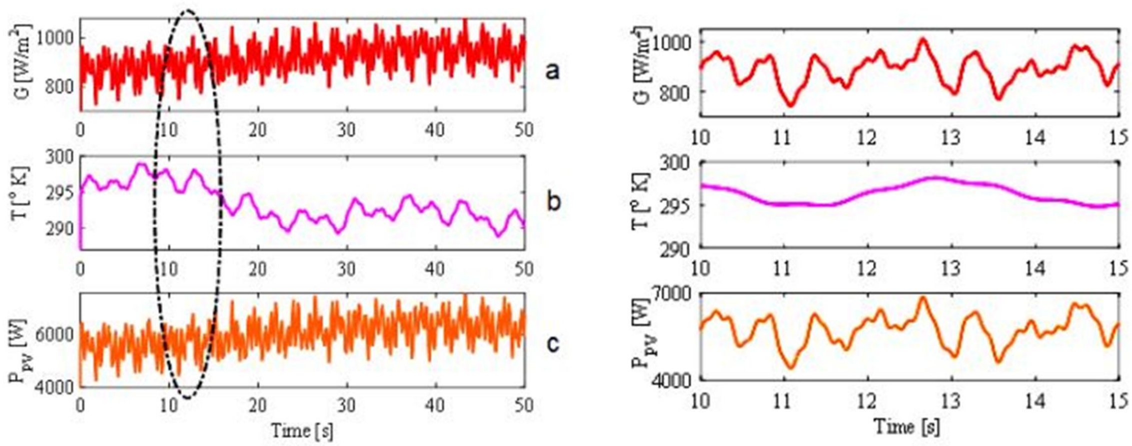


Fig.3: Weather conditions and PVG power and it is zoomed version.

In this case, all of the PVG power is injected into the point of common coupling (PCC) without the contribution of the storage system. The power PPV generated by the PVG is transmitted completely to the grid (Pg) and keeping the DC bus voltage constant. This is very clear in Figure 4(a) showing the shape of the power (Pg) transmitted to the PCC and the gap between the power PPV and Pg which does not exceed 15 W reflecting the losses.

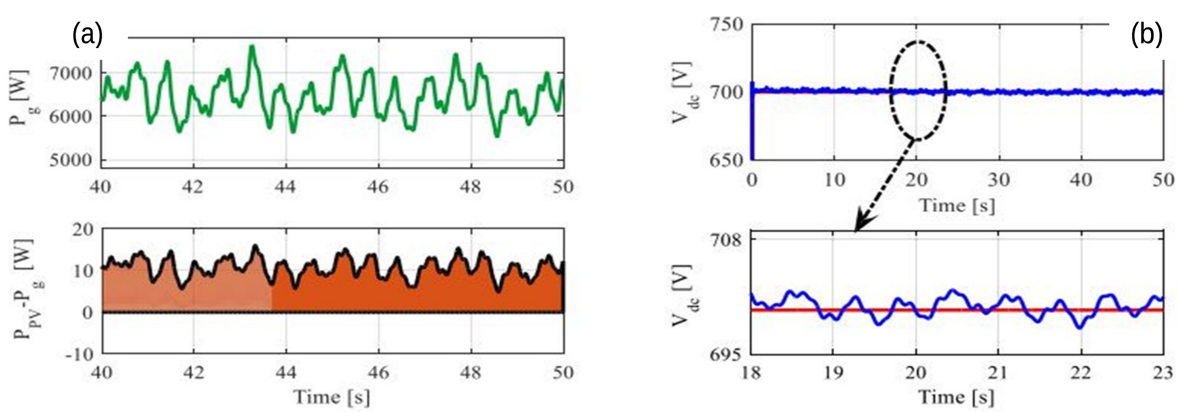
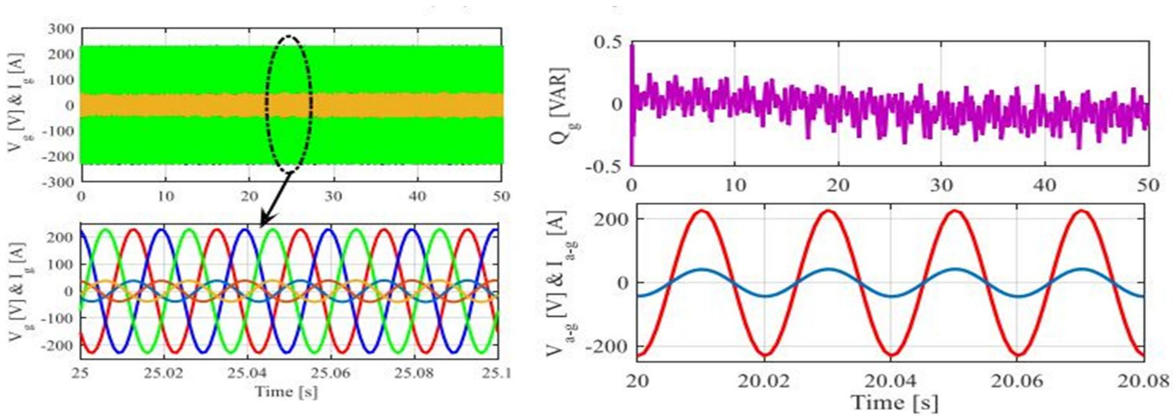


Fig.4: (a)Active power exchanged with the grid and power losses. (b) DC bus voltage and its reference value.

Under the same situations, the waveform of the voltage at the DC bus level is depicted in Figure 4(b). It is clear that the technique of controlling the voltage of the DC bus manages to keep its value close to its reference value as depicted in the zoomed Figure 4(b).

With regard to the electrical quantities exchanged with the electrical network, great importance has been given to the nature of the currents injected at the PCC point and that of the voltages at the same point. The following figure (Fig. 5(a)) shows that both the voltages are sinusoidal. Otherwise, the currents are also sinusoidal albeit their amplitude is fluctuating because it depends on the fluctuating PV generator power PPV which confirms that the proposed control system is effective [2].

(a)



(b)

Fig.5: (a) Grid voltages and currents. (b) Reactive power and phase shift between voltages and currents at the PCC point.

Moreover, the grid reactive power is simulated in figure 5(b). Depending on the Pg power transmitted due to the DC bus to the power grid, the reactive power is zero although negligible fluctuations are registered. In this same context, the nullity of reactive power is clearly shown by the fact that the voltage and the current of the same phase are perfectly in phase which is mean a controlling of reactive power in the grid lead to more stability to the network as shown in the same figure 5(b)[2].

V. CONCLUSION

This paper aimed to show a review of the grid-connected PV system and it is optimization to the grid network. It has been observed that the objective functions have shifted mainly from minimization of system costs (investment, operation, maintenance costs) and pollutant emissions to maximizing system's reliability, minimizing expected customer interruption cost as well. Simulations were conducted for the case mentioned using MATLAB software and it shows a controlling of reactive power which is result to more stability to the grid. Moreover, adding a battery storage system (BSS) will enhance the system efficiency and the net savings for the customer and this subject to be treated for next studies.

VI. ACKNOWLEDGMENT

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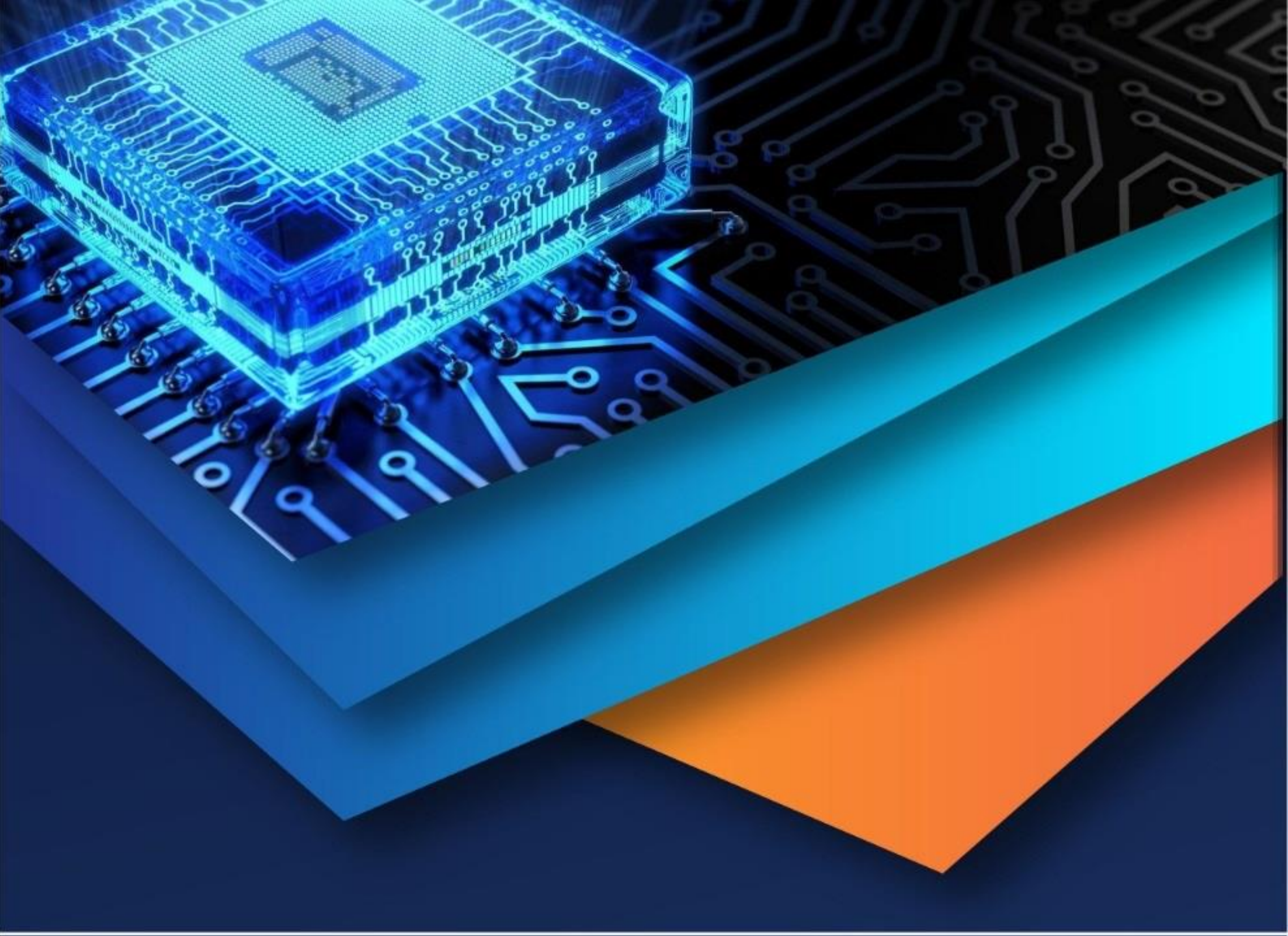

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