# Influencing factor analysis of the short circuit ratio on grid-connected photovoltaic systems

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Over the past few years, solar energy conversion technology is sharply developing. An important first step is to make this conversion system more effective and more reliable. The main objective of this paper is to study the influence of the power of the electricity network on the connection of the solar energy source. The photovoltaic source has been examined under the effect of the variation of the parameters of the networks such as the power of short-circuit and the frequency. The results obtained by the simulation have shown that the photovoltaic source has amazing performance if the power system is of high or medium power and with constant parameters.

*Keywords:* Photovoltaic (PV) systems; short circuit power; network impedance. the active power; the reactive power.

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## 1. Introduction

Renewable energies generate little or no waste or polluting emissions [1]. They contribute to the fight against the greenhouse effect and $CO_2$ emissions into the atmosphere, facilitate the reasoned management of local resources, and generate jobs. Solar (solar photovoltaic, solar, thermal), hydropower, wind power, biomass, geothermal energy are inexhaustible fluxes compared to “stock energies” from fossil fuel deposits in the process of becoming rarefied: oil, coal, lignite, natural gas [2]. Photovoltaic solar energy comes from the conversion of sunlight into electricity within semiconductor materials such as silicon or coated with a thin metal layer [3]. These photosensitive materials have the property of releasing their electrons under the influence of an external energy. This is the photovoltaic effect. Energy is provided by photons (components of light) that strike the electrons and release them, inducing an electric current. This continuous micro power current calculated in watt peak can be converted into alternating current thanks to an inverter. The electricity produced is available in the form of direct electricity or stored in batteries (decentralized electrical energy) or electricity injected into the grid. A photovoltaic solar generator is composed of photovoltaic modules themselves composed of photovoltaic cells connected together. In practice the photovoltaic generator is combined with a wind turbine and photovoltaic system, or both with energy storage accumulators. Such a system is a good choice for applications that require a continuous supply of relatively high power [4]. A Photovoltaic installation can be connected in parallel with the electricity network. The solar panels are connected in series to form “strings”, themselves connected to an inverter. The task of the inverter is to transform the DC current coming out of the panels into alternating current. Each inverter is chosen according to the power of the panels and can accommodate one or more strings. If the consumption is higher than the production of the Photovoltaic installation, the extra charge is provided by the network. Otherwise, energy is supplied to the public grid and is used to power consumers. In the past, distribution networks have behaved like passive elements in which power flows unidirectional from the source station to the end consumers. Due to the insertion of decentralized productions, power flows and voltages are impacted not only by the loads but also by the sources. As a result of these technical specificities the connection of Photovoltaic systems to electrical network can have significant impacts on its operation. The most significant influences of Photovoltaic systems on the distribution network are as follows [5]. The presence of Photovoltaic generators has an influence on the voltage plane and on the network control devices.The voltage varies according to the injections of active and reactive powers on the power system. Especially during a period of strong sunlight and low consumption, the voltage of certain nodes of the network may exceed the permissible threshold [6-9]. Our work presents a general overview of the photovoltaic system that is used with a three-phase source. We will highlight the influence of the short-circuit power of the network on the two electrical sources (photovoltaic and three-phase). We will also show the enormous influence of the variation of the variation of the network parameters as the power of short circuit.

## 2. Photovoltaic generator modeling

Due to very limited conversion efficiency, it is necessary to optimize all the conversion chain and specifically DC-DC converters by use to maximum power point tracking strategies (Fig. 1).

Photovoltaic generators consist usually of several modules interconnected in series and parallel for a given operating voltage an output power. Photovoltaic generators modeling can then be deduced from those of solar cells; many

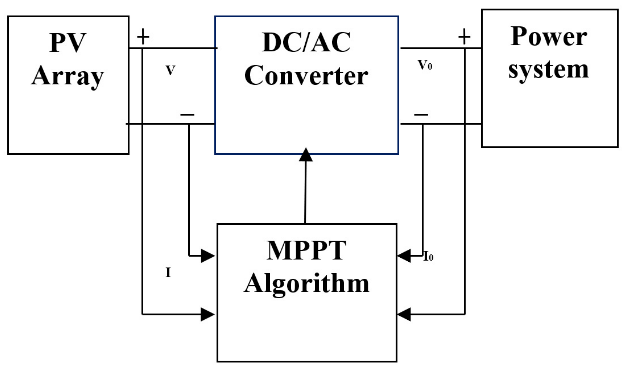


FIGURE 1. Block diagram of typical MPPT system.

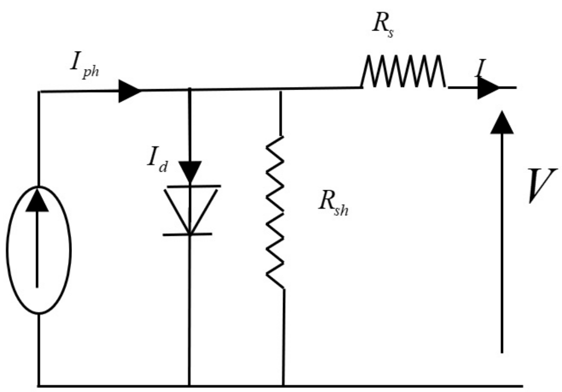


FIGURE 2. Conventional single diode model.

studies have been already proposed using one diode or more precise two diodes models. In this work we use the conventional single diode model presented on (Fig. 2).

$I_{ph}$ is the photo generated current related to the illumination level, $I_d$ the diode current, $R_{sh}$ and $R_s$ are respectively the shunt and series resistances. Based on (Fig. 3), the output voltage and current dependence can be written in the form:

$$I = I_{ph} - I_0\left(e^{(V+R_sI/V_t)} - 1\right) - \frac{V + R_sI}{R_{sh}} \qquad (1)$$

where $-V_t$ is the thermal voltage written as: $V_t = (A * K * T)/q$ where $A$ is the ideality factor, $K$ the Boltzmann constant, $T$ the temperature of the cell and $q$ the elementary charge.

$-I_0$ is the dark current. Compared to the measured photocurrent $I_{ph\_ref}$ at standard tests conditions (STC: $G_{ref} = 1000$ W/m$^2$, $T_{ref} = 25$°C), the photocurrent at another operating conditions can be expressed as:

$$I_{ph} = \frac{G}{G_{REF}}[I_{PH,REF} + \alpha(T - T_{REF})] \qquad (2)$$

$G$ is the solar irradiance, $\alpha$ is the short circuit current temperature coefficient. $I_{ph\_ref}$ can be taken to be the short current at STC ($I_{cc\_ref}$), $I_{cc\_ref}$ and $\alpha$ are generally given by solar module manufacturer. In the case where the cell temperature $T_{amb}$ not is determined directly by a temperature sensor, it can be deduced from the following relation:

$$T = T_{amb} + \left[\frac{N_{oct} - 20}{800}\right]G \qquad (3)$$

$T_{amb}$ is the ambient temperature, $N_{oct}$ is the normal operating cell temperature given in most cases by the manufacturer. For the dark current $I_0$ and we can write:

$$I_0 = I_{0,REF}\left(\frac{T}{T_{REF}}\right)^{3/A}\exp\left[\frac{qE_g}{AK}\left(\frac{1}{T_{REF}} - \frac{1}{T}\right)\right] \qquad (4)$$

$I_{0,ref}$ is the dark current at STC and $E_g$ is the forbidden band energy. In the single diode model, we assumed $R_{sh}$ to be infinite; the series resistance can be derived in the form [6]:

$$R_s = -\frac{dV}{dI_{(VOC)}} - \frac{AKT/q}{I_0\exp\left(\frac{qV_{OC}}{AKT}\right)} \qquad (5)$$

Equation (1) can be solved by numerical method like Newton Raphsons.

$$X_{n+1} = X_n - \frac{f(X_n)}{f'(X_n)}. \qquad (6)$$

The VSI is controlled in such a way that it can be used to inject sinusoidal current into the grid for energy extraction from the Photovoltaic cells.

## 3. Influence of the power system on the operation of photovoltaic installations

The characteristics, operation and disturbances of the distribution networks can influence the normal operation of Photovoltaic systems. This usually comes from either the intrinsic characteristics of the distribution networks, or the degraded quality of the voltage from other users of the network, or a combination of these two causes. These effects generally lead to unjustified decoupling of the inverters. The influences of the distribution network on the operation of photovoltaic installations can be summarized as follows.

### 3.1. Tension dips and holding of the systems

Voltage dips are therefore one of the main causes of triggering of PV systems. The disconnection of a large number of Photovoltaic systems could have local and global impacts on the operation of the network, especially on weak power system.

### 3.2. Presence of DC component and voltage harmonics

Inverters for photovoltaic systems chop the DC current from photovoltaic modules into pulse width modulation (PWM) to convert it to sinusoidal alternating current. The operation of transformer inverters can be affected by an asymmetry of power system voltages.

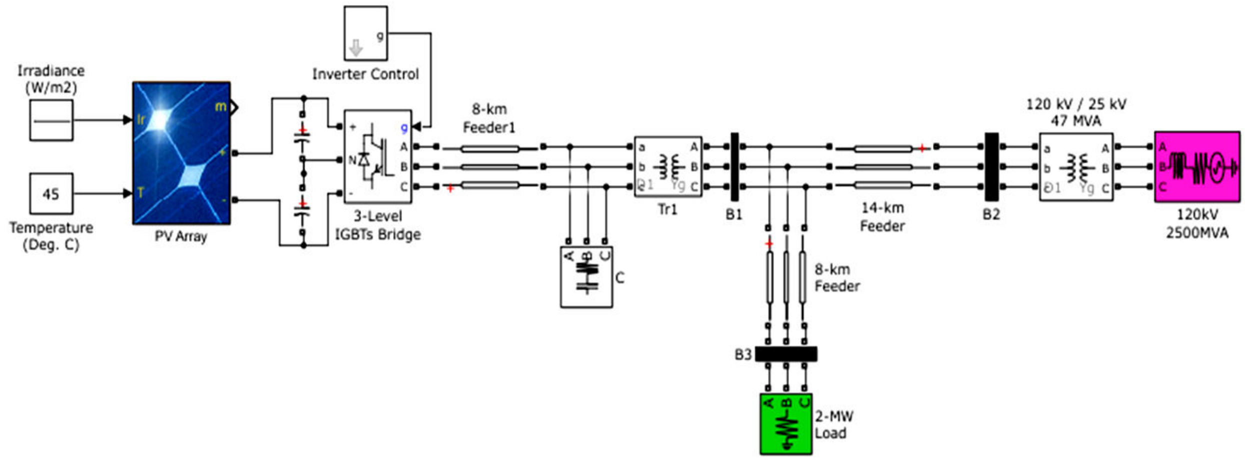


FIGURE 3. MATLAB/SIMULINK model for the studied system configuration.

TABLE I. System parameters.

| Grid | |
|---|---|
| Source | 2500 MVA/120 kV |
| Three-phase transformer | 47 MVA, 120 kV/25kV |
| Three-phase distributed line | 14 km |
| Photovoltaic source | |
| Nominal Power $P_T$ | 24 KW |
| cells Voltage $V_T$ | 850 V |
| Parallel strings, | 86*7 SPR-415E modules |
| Three-phase DC/AC Converter | 3-level IGBT bridge PWM-controlled |
| MPPT Controller | 'Perturb and Observe' technique |
| Inverter choke [R; L] | [0.37 mΩ; 99.35 mH] |
| Harmonics filter [Pc; Qc] | [0.5 kvar; 25 kvar] |
| Three-phase transformer | 250 kVA , 250 V/25 kV |
| MPPT Controller | 'Perturb and Observe' technique |
| PWM Generator | 1980 Hz |
| Load | |
| Load Power $P_L$ | 2 MW |
| Frequency $f_s$ | 60 Hz |
| Nominal voltage ph/ph | 25 kV |

## 4. Influence of the short-circuit power or the electricity grid of the three-phase source

The short circuit power of a power system is, a value whose order of magnitude is known to electricians, it makes it possible to know the level of the short-circuit current (symmetrical three-phase) of a power system,it gives an image of the sensitivity of a network to a disturbance (more it will be high, the more the network will be insensitive). In addition, its value, converted in the system p.u. is equivalent to the short-circuit current in the selected base, it is still the opposite of the reluctance by which the network can be replaced for a short-circuit study. It was used as a basis for sizing the circuit breakers, but in fact it was an error because for the latter the current constraints (breaking capacity) and voltage must be considered separately. Its definition is as follows:

$$S_{cc} = \sqrt{3}U_N I_{cc}. \tag{7}$$

This is a definition involving the nominal voltage and the short-circuit current, which cannot exist simultaneously, of course. There is no power factor, since in short-circuit mode, the current is out of phase by almost 90° with respect to the voltage.

## 5. Simulation results and discussion

In order to determine the short-circuit power of the network, appropriate to the fixed load value suppliedby System PV,

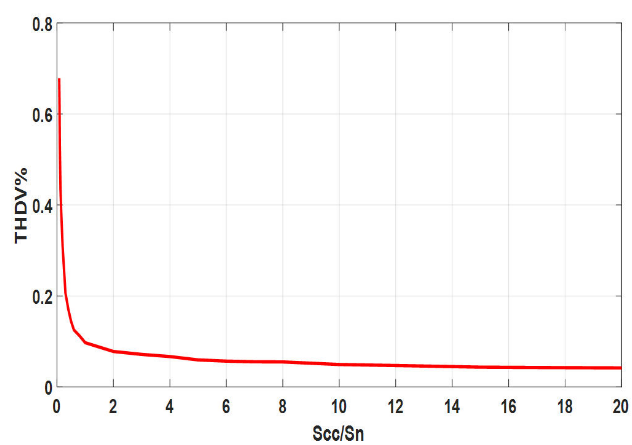


FIGURE 4. Varition of THDV according to the ratio $S_{cc}/S_n$, load side $B_3$.

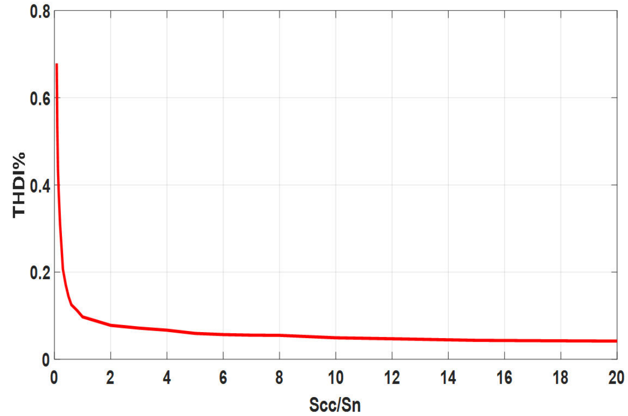


FIGURE 5. Varition of THDI according to the ratio $S_{cc}/S_n$, load side $B_3$.

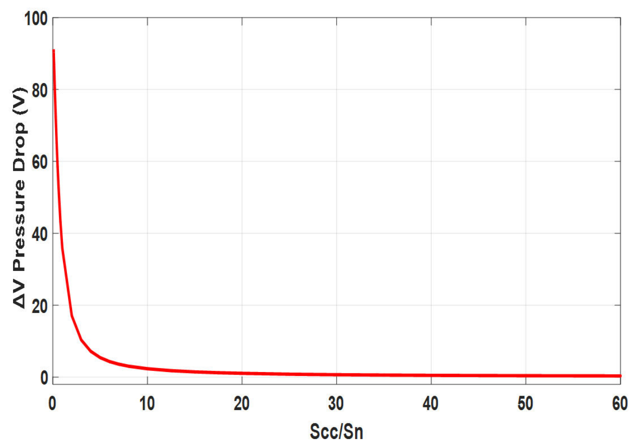


FIGURE 6. Varition of Voltage drop according to the ratio $S_{cc}/S_n$, load side $B_3$.

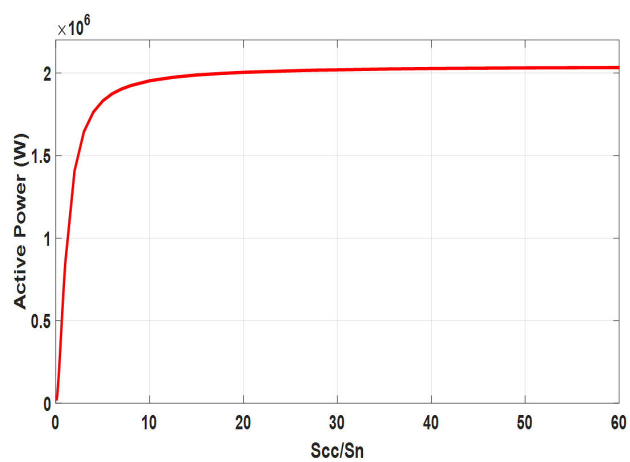


FIGURE 7. Varition of Activepower according to the ratio$S_{cc}/S_n$, load side $B_3$.

this study shows the short circuit power influence on the load and PV characteristics.

So as to show the validity of the concepts discussed previously a simulation using MATLAB/SIMULINK environment is done as it is shown in Fig. 3. A 250 kW PV array connected

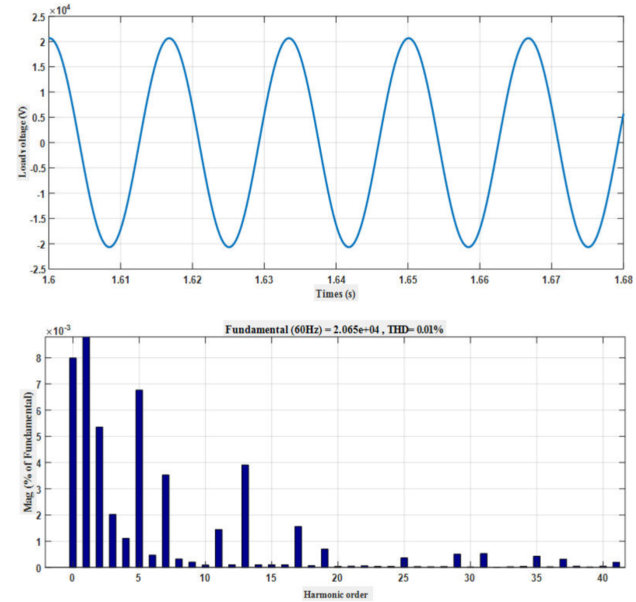


FIGURE 8. Load voltage and their spectral decomposition in the case $Scc/Sn = 100$.

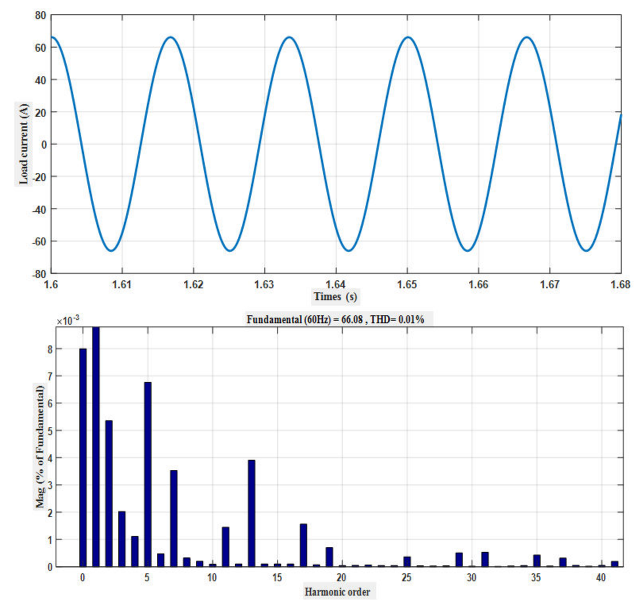


FIGURE 9. Load current and their spectral decomposition in the case $Scc/Sn = 100$.

$S_{CC}$: short circuit power of the electrical network at the point of connection (PCC). $S_n$: nominal power of the load ($S_n = 2$ MVA). The system parameters are shown in Table I.

It can be clearly seen that according to Figs. 8-11, the $S_{cc}$/SN ratio has a great influence on THDv and THDi. So, it is absurd not to consider this ratio to define the harmonic injection limits in the power system. This remark has been taken into account by the IEEE 519-1992 standard. For this reason, the latter has defined 5 intervals for which it has imposed harmonic current limits injected into the electrical network.

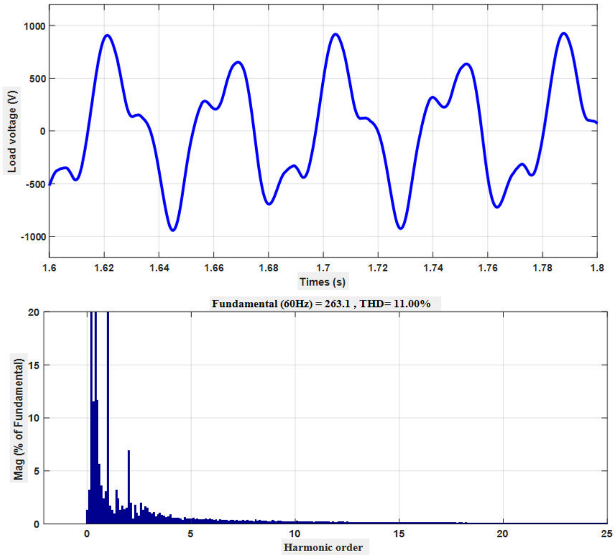


FIGURE 10. Load voltage and their spectral decomposition in the case $Scc/Sn = 6 \times 10^{-3}$.

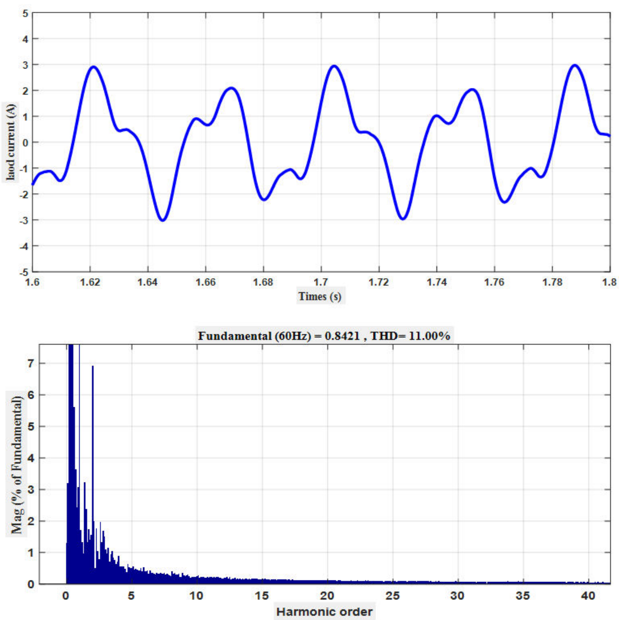


FIGURE 11. Load current and their spectral decomposition in the case $Scc/Sn = 6 \times 10^{-3}$.

Figures 4 and 5 show an improvement in $\text{THD}_v$ and $\text{THD}_i$ with increasing $S_{cc}/S_n$ ratio. At $S_{CC}/S_n = 10$ the $\text{THD}_v$ and $\text{THD}_i$ can be considered equal to 0.04. From Fig. 7 it can be seen that the active power of the load increases with the increase of the SCC/SN ratio. It can be said that the short circuit power of the electrical network is large enough. This increase in active power is related to the diminution of the voltage drop caused by the $S_{cc}/S_n$ ratio, see Fig. 6.

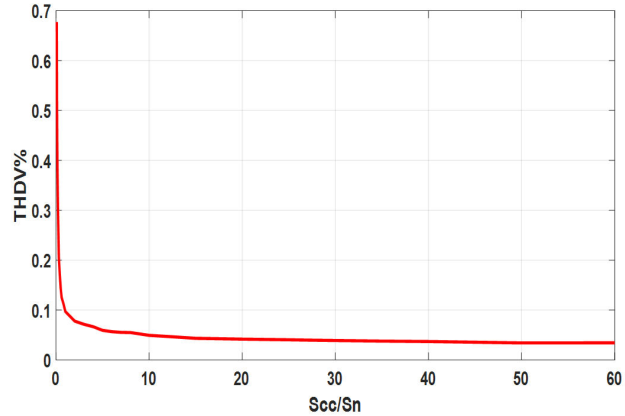


FIGURE 12. Varition of THDv according to the ratio $Scc/Sn$, PV side $\text{B}_1$.

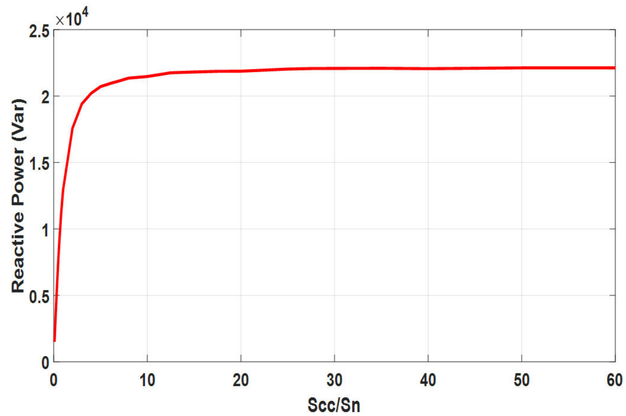


FIGURE 13. Varition of Reactive according to the ratio $Scc/Sn$, PV side $\text{B}_1$.

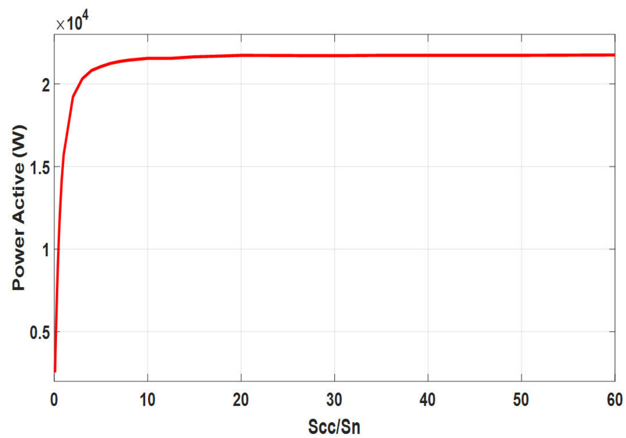


FIGURE 14. varition of Active power according to the ratio $Scc/Sn$, PV side $\text{B}_1$.

All the variation of THD and active power according to $S_{cc}/S_n$ are the same as rated load (see Figs. 12 and 15), except there is a variation of the reactive power according to $S_{cc}/S_n$, (see Fig. 13) and which stabilizes almost 22 kvar. This power is the cause of the decrease of the power factor next to the source PV (see Fig. 13). This reactive power is

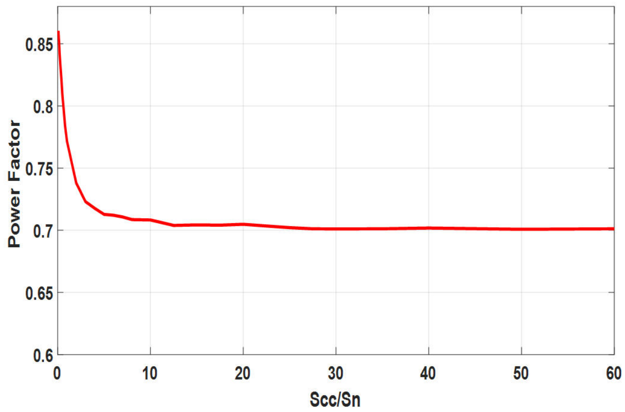


FIGURE 15. Varition of Power factor according to the ratio $Scc/Sn$, PV side $B_1$.

consumed by the PV inverter and the inductive elements of the line. The $S_{cc}/S_n$ ratio has a great influence on the design of passive PV filters.

## 6. Conclusion

A general overview of photovoltaic source has been presented and is used for renewable energy generation. Emphasis was placed on the influence of the short-circuit power of the network on the connection of photovoltaic source to the power grid. Photovoltaic source performance in low power networks has been justified. The results obtained give very good reasons to say that the photovoltaic source is practically usable in connection with large or medium power short-circuit networks and with network parameters that remain almost constant during the operation of this device.


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