Energy Efficiency Improvement of Photovoltaic Systems with Different Configurations of PV-Inverter Topology for Renewable Energy Systems.

MOUHOUB BIRANE[1]   CHERIF LARBES[2] ALI CHEKNANE[1]

[1] *Laboratory of Semiconductor and Functional Materials. University of Amar Telidji LAGHOUAT.Algeria.*
[2]*Laboratory of Communication Devices and Photovoltaic's Conversion*
Department of Electronics, National Polytechnic School
10, Avenue Hassen Badi El Harrach, 16200, Algiers, Algeria
É-mail: birane_mou2007@yahoo.fr

Abstract: In this paper we present the optimization of the efficiency of photovoltaic power conversion chain. The architecture of the power converter is important in a PV system. This structure determines the main characteristics of the photovoltaic installation, as the amount the PV modules need for the PV system and its type of connection. In this way, different type's improvements have been proposed of architecture in order to choose the correct PV architecture for each PV installation on the efficiency improvement in all power conversion level stages between PV cells and loads. In this context, this work presents the study comparative and simulation between the different photovoltaic management architectures. We compared the various possible management architectures in series or in parallel, A number of module can be connected in a series string to increase the voltage level or in parallel to increase the current level or in a combination of the two to form a PV module. Several modules are also connected in similar fashion to produce large PV power. Because of the partial shading different cells in a single PV module generate different power. The great interest of the series connection or parallel DC / DC converters with PV modules to reduce the impact of shading and maximize the energy produced under the same weather conditions, to find the most capable system to value the solar electricity production. We performed comparative between a to topologies connection of converter via an adaptation floor with Maximum Power Point Tracker (MPPT) control. For this reason, it is important to know different types of architecture in order to choose the correct PV architecture for each PV installation. Simulation results are used to demonstrate the proposed topologies to provide improvement in efficiency over existing traditional PV systems.

Keywords: Photovoltaic Generator, Maximum Power Point Tracker MPPT, performance, power, DC-DC Converters.

I. INTRODUCTION

Renewable sources of energy acquire growing importance due to its enormous consumption and exhaustion of fossil fuel. Solar energy could be one of the significant sources as an alternative energy for the future. In regard to endless importance of solar energy, it is worth saying that photovoltaic energy is a best prospective solution for energy crisis [1].

In the literature, different topologies for distributed power conversion for PV system have been studied.

The architecture of the power converter is important in a PV system. This structure determines the main characteristics of the photovoltaic installation, as the amount the PV modules need for the PV system and its type of connection. The effect of the partial shadowing or mismatch between PV modules in the energy production will also depend on the type of the architecture. Nevertheless, the price and cost of the PV also depends on the choice of the architecture, the choice will involve a bigger or smaller energy production and efficiency as well as an importance difference in the cost. For this reason, it is important to know different types of architecture in order to choose the correct PV architecture for each PV installation [2].

Upgradeable PV systems should be able to except additional modules, to increase the plant's power rating, and future module technologies without disrupting normal operation.

The upgradeability of topologies can be evaluated by detecting evolvable patterns, which they do not interfere with the overall operation. Furthermore, if modules need to be replaced during the plant's lifespan, an upgradeable installation must easily integrate new components without degrading its initial performance [3].

The competitive topologies must be ready to fulfill these requirements with minimal changes on the installation. The main architectures of the nowadays PV system will be analyzed, following their evolution and looking for the future tendency.

In the central inverter topology means that PV-panels are connected in one common array both series and parallel that is connected to one large inverter (implemented by MPPT system). The result of PV array is connected to a single DC/DC converter .This topology has the economical benefits as the number of the inverters is small, but the partial shadowing of the one panel will affect on the whole array

1

power output. The reduction of the generated power is caused by the characteristics of the PV-panels. The main advantages of the centralized inverter are the simplicity of the layout which leads to low cost, simple maintenance and monitoring of the plant leads to low cost, simple maintenance and monitoring of the plant [4].

In the String Inverter configuration, each string has its own inverter and all inverters operate in parallel to supply the load. The reliability of the system is enhanced. Moreover, the losses due to partial shading are reduced because each string operates at its maximum power point. Additional strings can be easily added to the system to increase its power rating, thus, increasing the flexibility in the design of the PV system. This system increases the system efficiency, but with additional cost due to the increase in the number of inverters [5].

In this work, we perform study comparative between a central and distribution connection different arrangements of PV modules with their associated power converters have been developed to increase power production and reliability of the solar generators. The following system topologies will be presented beginning with the centralized layouts and ending with the distributed ones.

The goal of the research presented in this paper is structured around three main parts.

Firstly, we present different topologies in details and discussing different proposed PV topologies such as Adaptive PV central-inverter configuration, and the Adaptive PV string-inverter configuration including some illustrations of different operational conditions and the controller logic.

Secondly, we describe and analyze this characteristic curve by using DC-DC converters. The switching power converter DC-DC are widely used in photovoltaic systems to transform DC power between a voltage and another, and are also used in maximum power point tracker (MPPT) an adaptive photovoltaic (PV) system is proposed adaptive configuration is analyzed form different possible topologies.

Finlay is organized as follows. Analyses and simulation of the performance of the different configurations are presented tools are used to demonstrate that the proposed topologies provide improvement in efficiency over existing traditional PV systems. Furthermore, a prototype has been designed and developed we present and discuss the obtained results via simulation using a co-simulation MATLAB and PSIM software. Furthermore, results of both systems are analyzed and compared.

In the conclusion, the key show your results presented a potential research idea for future work in this field is proposed

1. II. CONNECTION TOPOLOGIES OF PV SYSTEMS

The utility interactive system, the simplest system in terms of its number of components, can be configured with added components to serve its intended purpose and improve efficiency.

These configurations can be classified into; central converter topology, string converter topology,

A. Centralized converter topology

The simplest configuration is the central inverter system, shown in Fig. (1), where PV modules are connected to form strings. In the central inverter topology, strings consisting of series connected PV panels are connected in parallel to obtain the desired power. The resulting PV array is connected to a single DC/DC converter.

This configuration is usually used for large PV systems up to several megawatts. The main advantage of the central inverter topology is the low cost as compared to other topologies as well as the ease of maintenance of the inverter. However, this topology has low reliability as the failure of the inverter will stop the PV system from operating. Moreover, there is significant power loss in the cases of mismatch between the modules and partial shading, due to the use of one inverter for tracking the maximum power point. This configuration cannot correctly track the maximum power point (MPP) for the whole array [6] . This is because each string has its own MPP according to the operational conditions and shadowing effect.
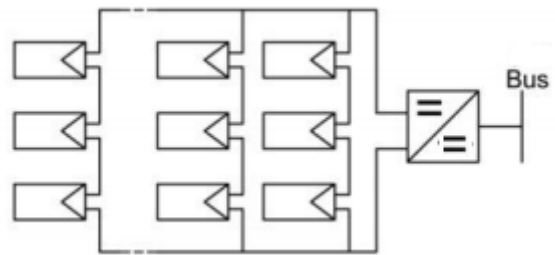

Fig. 1.Central converter configuration

B. String converter topology

In the String converter configuration, shown in Figure (2), each string has its own converter and all inverters operate in parallel or series to supply the load. In this configuration all PV strings are connecting across the same voltage, which may not be the desired voltage required to obtain MPPT for all panels. Consequently with this configuration not all the panels are utilized effectively.

The reduction of the generated power is caused by the characteristics of the PV-panels. The current of the series string in this case is limited by the most shadowed panel the problems of the partial shadowing of array each of the PV-modules gets equipped by parallel diode, that by passes the module in case if module is shadowed or damaged. Some of the modules get`s produced with built in diodes for several cells of PV-panel. This system increases the system efficiency, but with additional cost due to the increase in the number of converter [5].
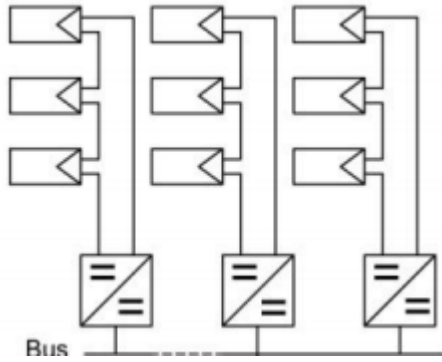
Fig. 2.String converter configuration

C. Photovoltaic arrays

In order to implement the cell into real application, a combination of cells forms different sizes where a module consists of connected PV cells in one frame, and an array is a complete PV unit consisting of connected modules with structural support [7].
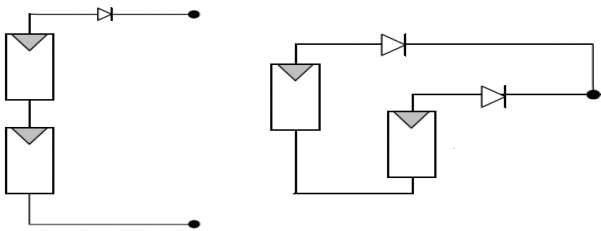

Fig. 3. The connection of PV module

Each PV array is comprised of parallel connected strings. Each string consists of multiple series connection of PV modules that provide the required voltage of the array. These structures can be used to supply power to scalable applications known as photovoltaic plants, which may be stand-alone systems or grid-connected systems [8].
Modules can be connected in different ways to form PV array. This is done for the sake of voltage/current requirement of the power conditioning units of the PV system. In order to do that, a series and parallel connections of PV modules are needed.

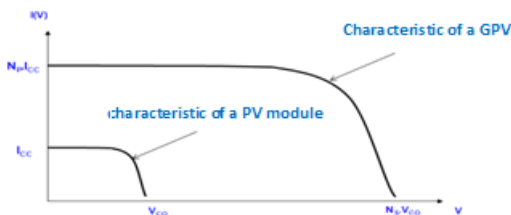Fig. 3. The typical electric protections in a PV module: DBP the by-pass diodes.

Fig. 4.The association of PV module

D. Shading of PV system

Shading and mismatch losses of PV system are considered very critical problems in the PV systems. Significant reduction in generated power from solar PV arrays occurs when the shading falls across some PV modules, leading to extra losses [9]. PV modules are very sensitive to shading. Shading of a single cell within a PV-module, which contains a number of modules connected in series, leads to a reverse bias operation of the cell, which may result in hot-spots and potential breakdown of the shaded cell. The hot spot in the shaded module is capable of sustaining permanent damage at the cell level. When a small portion of a cell/module/array is shaded, while the remainder is in sunlight, the output falls dramatically. Soft shading sources, a tree branch, roof vent, or chimney, significantly reduce the amount of light reaching the cell(s) of a module. Hard sources are defined as those that stop light from reaching the cell(s), such as a blanket, tree branch, bird dropping or the like, sitting directly on top of the glass. When one full cell is hard shaded by structure that stops light from reaching the cell(s), the voltage of that module will drop to half of its non shaded value in order to protect itself as shown in Fig. (5), if enough cells are hard shaded, the module will not convert any energy and will in fact beco
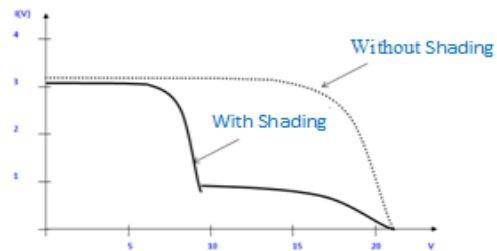

Fig. 5. Shading affects me a tiny drain of energy on the entire system.

E. Maximum Power Point Tracking (MPPT)

The main goal of a MPPT control is to automatically find at each time the V_{OPT} and I_{OPT} of a PV array and then to allow it to operate at its PMPP under given temperature and irradiance. Best MPPT control algorithms have to be fast, stable, robust, and efficient. MPPT methods, commonly used in widespread applications, are currently reported in the literature [10].
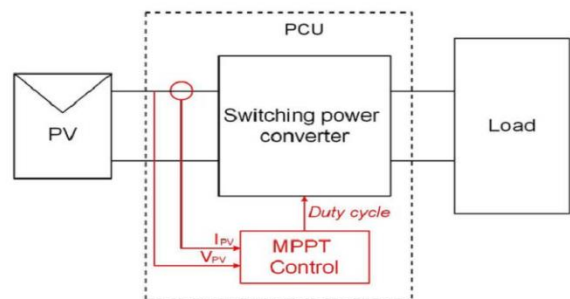

Fig.6.Simplest electrical scheme block of a typical power conversion chain.

The current and voltage measurements are important parts in the MPPT controls, since they affect in the accuracy and the efficiency of the controls. The place of each sensor can be done at the input and/or output ports of the power converter stage associated with the PVG.

III. ANALYSIS OF DC / DC CONVERTER

In this paper we describe and analyze a new way to measure characteristic curve by using DC-DC converters. The switching power converter DC-DC are widely used in photovoltaic systems to transform DC power between a voltage and another, and are also used in maximum power point tracker (MPPT)
.The goal of the DC optimizer is to extract the maximum power possible from the PVG, placing the MPPT in a distributed way.

The DC-DC converters concerned in this study are step-up voltage converters known as Boost converters. The electrical schema of the boost converter is reminded in the fig. (7). The boost converter is one of the simplest DC-DC converters. In a DC transformer the relationship of transformation can be controlled electronically by changing the duty cycle of the converter in the range [0, 1].
The relationships used for the design are the conventional relationship between the output voltage, the input signal and the duty ratio [11]:

$$V_{OUT} = \frac{1}{1-\alpha} V_{in}$$

Nowadays, there are two widespread and cost-effective technologies suitable for the implementation of the proposed converter switches: MOSFET and IGBTs because both technologies are available for the intended operation voltage, current and frequency .
In this study concerned of Si-IGBT (Insulated Gate Bipolar Transistor) switched mode converter able to produce a dc output voltage that is greater in magnitude than the dc input voltage [12].

Losses of IGBT

For high power IGBT modules it is necessary to provide a suitable heat sink, otherwise, it may go into the thermal runaway. IGBTs works in two states and produce losses in those States; conduction losses and switching losses.
Conduction losses mainly depend on the duty cycle, load current and junction temperature, whereas, switching losses depends on the load current, dc link voltage, junction temperature and switching frequency [12]. If the switching frequency is higher, then the losses will be higher.The total average power of the IGBT is the sum of the conduction loss, turn on and turn off losses as shown in Eqn.(1).

$$P_{avg\,IGBT} = P_{cond} + P_{on} + P_{off} \tag{1}$$

When the IGBT turns on, collector current increases rapidly and the voltage across the collector to emitter decreases. During this switching it takes time for the current to go from zero to its rated level, also current overshoot can be seen. This overshoot is the mirror image of diode added current and the voltage drops to the saturation level. This transition of voltage and current produce losses called turn on power loss. For turn off condition the device behaves in vice versa [12].

Conduction losses are the losses that occur while the IGBT or freewheeling diode is on and conducting current, the total power dissipation during conduction is computed by multiplying the on-state voltage (Vce sat) and the on-state current (Ic) .
Conduction loss is the on-state loss or steady state loss. The average power dissipated by the IGBT is given by Eqn.2.

$$P_{avg\,cond} = \frac{1}{T}\int_0^T [V_{ce}(t) \times I_{ce}(t)]\,dt \tag{2}$$

Time period 'T' is inversely proportional to frequency 'f'

$$T = \frac{1}{f} \qquad P_{avg\,cond} = f\int_0^T [P(t)]\,dt \tag{3}$$

The total average power loss incurred in the IGBT can be obtained by integrating all the values of power losses over a period of time. The total average power loss for the IGBT can be split into three phases;
1) Turning on the device,
2) Conducting period,
3) Turning off the device.

$$P_{avg\,IGBT} = P_{cond} + P_{on} + P_{off} \tag{4}$$

The conduction losses are independent of the switching frequency but dependant on the duty cycle, whereas the switching losses are dependant of the switching frequency and therefore they are directly proportional to each other. The values for the energy loss Eon and Eoff are given in the Dynex datasheet; therefore there is no need to calculate these values [12]. The switching energies are then simply multiplied by the switching frequency to give the power loss for on and off time as shown in Eqn. (5).

$$P_{sw\,IGBT} = (E_{on} + E_{off}) \times f_{sw} \tag{5}$$

Total Losses:

$$P_{avg\,.IGBT} = P_{cond.IGBT} + P_{sw\,.IGBT} \tag{6}$$

The average total power losses in diode is given by Eqn. (7)

$$P_{avg\,.diode} = P_{cond.diode} + P_{rec.diode} \tag{7}$$

Reverse Recovery Time:
When switching from the conduction to the blocking state, a diode or rectifier has stored charge that must be discharged first before the diode blocks reverse voltage. This discharge takes a finite amount of time known as the Reverse Recovery Time, or trr. During this time, diode current may flow in the reverse direction [12].
When the device turns off it generates losses called recovery loss and the time required to recover is called the reverse recovery time.Change of forward voltage and forward current can give the R_D resistance value.

$$V_f = V_{D0} + R_D \times I_C \tag{8}$$

The average power losses in diode are when operated under PWM sine wave switching is given by Eqn.(9).

$$P_{rec.diode} = E_{rec} \times f_{sw} \qquad (9)$$

IV. SIMULATION RESULTANTS AND DISCUSSION

The simulations were done using MATLAB Simulink and toolbox, used for simulation of PV- generator and PSIM software for simulation electrical circuits BOOST converter while modeling BOOST converter is provided by PSIM.
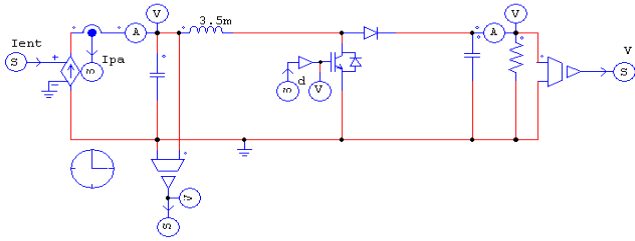

Fig.7. Electric structure of the boost power converter

The parameters have been used throughout the simulations, these are listed below:

L = 3.5 mH. $C_1 = C_2 = 5.6$ mF.

The switching frequency: fsw = 5 kHz.

A. Simulation of a string converter:

1 / The converters are connected in series:
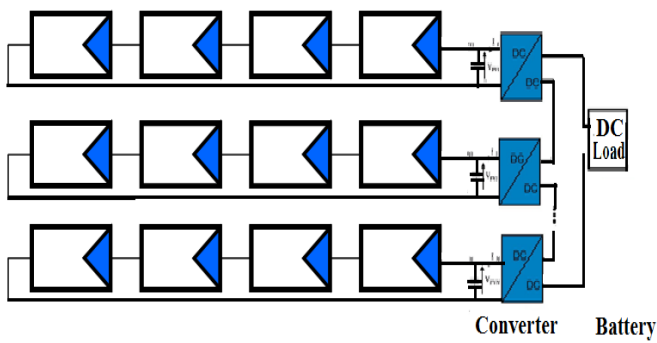
Fig.8. Series connection of a string converter

The model of each converter is the same as each string converter, the two converters connected in series.
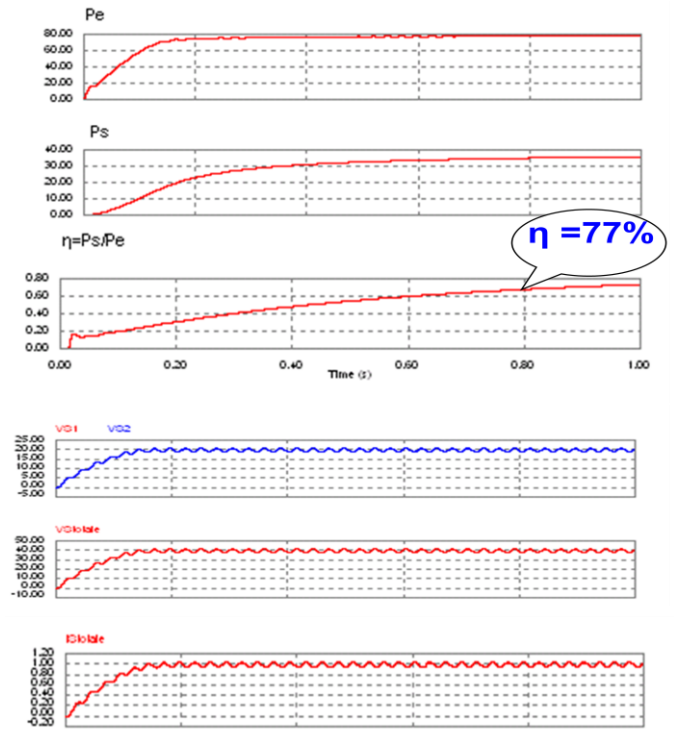

Fig.9. Simulation results of the string converter connected in series.

The figures show a simulation of the variables: Pe (input power), Ps (output power), η (efficiency), VE (input voltage), VS (output voltage), IS (output currant),

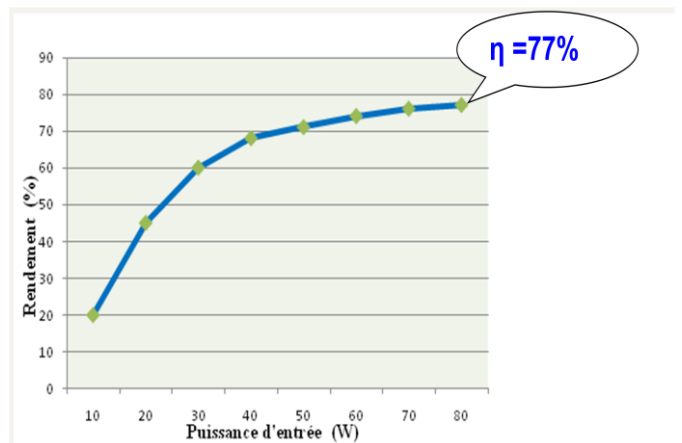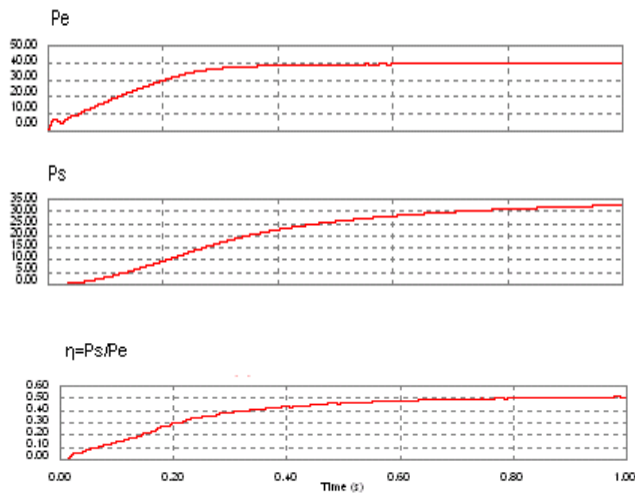The fig. (10) show a variation of efficiency simulation of a power converter in relation with input power.

Fig.10.Efficiency simulation of a power converter in relation with input power.

5

That the efficiency η increases rapidly with the power to reach a maximum yield of 75% -80 %.

Damage on a single converter

The efficiency is low because the effect of damage a single converter.

If damage a single converter, the efficiency η is low rapidly.
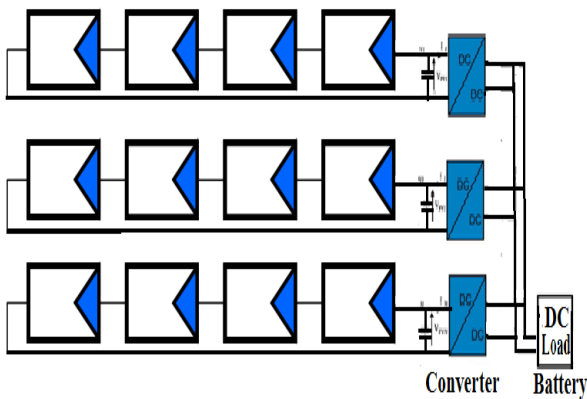
2/ The converters are connected in parallels

Fig.11. Parallel connection of a string converter

The model of each converter is the same as each string converter, the two converters connected in parallel.
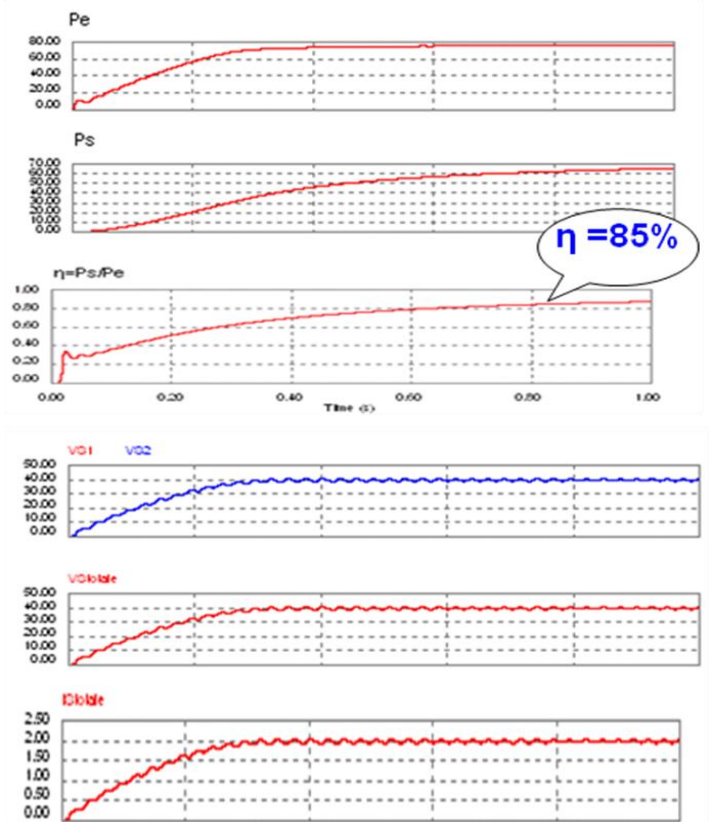

Fig.12. Simulation results of the string converter connected in parallels.

The figures show a simulation of the variables: Pe (input power), Ps (output power), η (efficiency), VE (input voltage), VS (output voltage), IS (output currant),

The fig. (13) show a variation of efficiency simulation of a power converter in relation with input power.
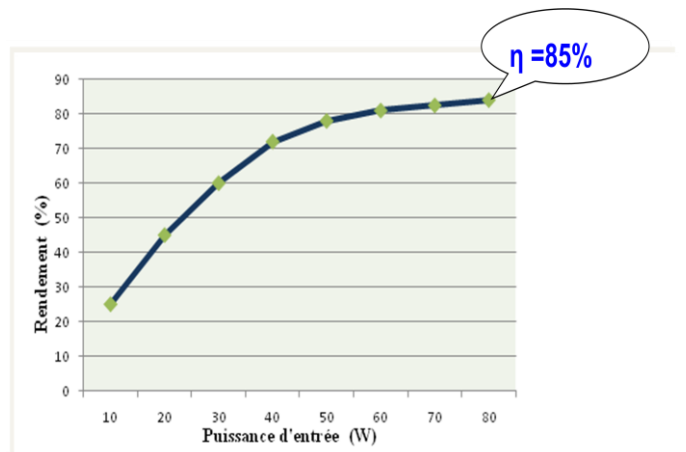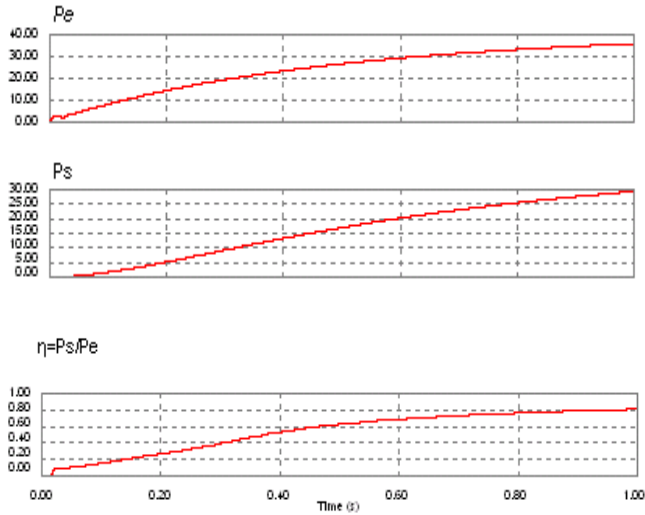

Fig.13.Efficiency simulation of a power converter in relation with input power.

That the efficiency η increases rapidly with the power to reach a maximum yield of 80% -85% .

6

Damage on a single converter

The efficiency is low because the effect of damage a single converter.

If damage a single converter, the efficiency η is low rapidly.

V. CONCLUSION

In conclusion to this work, we have studied different topologies in details of photovoltaic system between series or in parallel distribution and discuss different proposed PV topologies.

The approach proposed in this paper a comparison study by simulation of these two approaches. Every panel has its own converter; the series and parallel connection of converter involve a major power transfer capability. The series connections increase the voltage. The parallel connections are used to increase the current. But these converters are dc–dc converters, and the panels with their associated converters are still placed in series who follows the maximum power point (MPP) is that each panel can give the maximum available power The parallelization of power converters is one of the simplest forms of connecting power structures. The parallel connected power converters add robustness, redundancy and power capability of the systems. In the topologies, string benefits of the MPPT control and the maximum power point tracking is carried out in more distributed way than the centralized architecture. Thus, a failure in one of the string does not affect to the energy production of other strings and the PV power production is improved. Nevertheless, the price and cost of the PV also depends on the choice of the architecture. For this reason, it is important to know different types of architecture in order to choose the correct PV architecture for each PV installation.

The conclusion of the paper is presented a potential research idea for future work. This work was motivated by these issues and hopes to have contributed to their progression. The future work will be simulate and experimental data of the different architecture with series connection or in parallel DC / DC and compare this result with experimental typical configurations.

REFERENCES

[1] Mboumboue, E.and Donatien N. "Mathematical Modeling and Digital Simulation of PV Solar Panel using MATLAB Software " International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 9, September 2013).

[2] Alona, B.A "New Optimized Electrical Architectures of Photovoltaic Generators with High Conversion Efficiency" Doctoral Thesis, University of Toulouse3 Paul Sabatier (UT3PaulSabatier), France 2013.

[3] D. Picault, B. Raison, S. Bacha"Reducing mismatch losses in grid-connected residential BIPV arrays using active power conversion components"EUPVSEC'10 Conf. Proceedings, pp.5141-5144.EUPVSEC'10 Valencia, Spain September 6-9, 2010.

[4] Chaaban, M. Amer. "adaptive photovoltaic configurations for decreasing the electrical mismatching losses"(2011). architectural engineering - dissertations and student research. paper 10.

[5] B. Burger et al., Extreme High Efficiency PV-Power Converters. European conference EPE'09 (2009) pp. 1-13 .

[6] Rashid MH. Power electronics handbook. San Diego, CA: Academic Press; 2007.

[7] Dunlop JP, National Joint Apprenticeship and Training Committee for the Electrical Industry. Photovoltaic systems. Orland Park, Ill.: American Technical Publishers, Inc.; 2010.

[8] Tiwari GN, Dubey S. Fundamentals of photovoltaic modules and their applications. Cambridge: Royal Society of Chemistry; 2010.

[9] Dzung N, Lehman B. An adaptive solar photovoltaic array using model-based reconfiguration algorithm. Industrial Electronics, IEEE Transactions on. 2008; 55(7):2644-54.

[10] P. Assis Sobreira, M.Gradella Villalva, P.Gomes Barbosa, H.A. Carvalho, J.R. Gazoli, E. Ruppert, A.A. Ferreira; "Comparative analysis of current a nd maximum voltage- controlled photovoltaic Maximum Power Point trac king"; Power Electronics Conference, COBEP, Brazil, 2011.

[11] Birane.M, Larbes C, cheknane A "Topologies modeling efficiency of DC / DC converter for CCM and DCM mode for applications of renewable energy systems". International Conférence on Renewable Energy ICRE 2012 15/16 avril 2012 - Université A. Mira - Bejaia.

[12] Noman. Rao, Dinesh. Chamund "Calculating power losses in an IGBT Module" AN6156-1 September 2014 LN31943