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Regular paper

Study and Experimental Comparative Analysis of Different Topologies in DC / DC converter under Shading Effect by Numerical Methods for Photovoltaic System.

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This paper we present a study simulation and validation experimental of shading effect on GPV connection with different DC/DC converter topologies for photovoltaic application and investigate different photovoltaic configurations and their effect on the PV array efficiency, the aims to assess the efficiency of three different PV/DC-DC converter topologies in order to optimize the performance of photovoltaic (PV) systems. Also, the study focuses on using the Maximum Power Point Tracking (MPPT) algorithm, especially the perturb and observe (P&O) method, to get the maximum energy possible from PV panels. The taking effect of irradiance into consideration, the output current and voltage characteristic of the photovoltaic system are simulated using the proposed by the different numerical methods in order to find the best method. It provides different improvements on the electrical architecture and evaluation of shading effect in fact, for this latter we use two configurations, the series and the parallel connection of a converter that involves a major power transfer capability. Obviously, these two topologies have some advantages. Each power converter can control the power conversion of each module individually, which results in increased overall energy conversion of the entire system. The MPPT control system in this case can react effectively to atmospheric variations and to study the influence of the effect of partial shading different values of solar radiation concerning performance of PV cells. We simulated and compared the different conversion configurations in order to find the best one in terms of efficiency and produced energy. This study provides valuable insights into how different PV configurations perform and highlights the importance of using MPPT algorithms to optimize energy production. By carrying out detailed experimental testing, The obtained results are very interesting; it allows the selection of the best PV topology and the best method evaluation of shading for a given application .The connection of a boost DC/DC converter in a photovoltaic facility to the panel output could be a good practice to improve performance.

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

1. Introduction

Renewable sources of energy acquire growing importance due to its enormous consumption and exhaustion of fossil fuel. Renewable energy is abundant, free, sustainable, and clean and can be harnessed from different sources in the form of wind, solar, tidal, hydro, and geothermal and biomass throughout the years, the increasing need for electricity has directly contributed to the fast reduction of fossil fuel shares. Consequently, this results in a direct impact on the environment by causing a rise in greenhouse gas emissions [1]. Nowadays renewable energy sources (RES) such as photovoltaic (PV) systems are considered essential sources for electricity generation, thanks to technological development and scientific contributions to improving electric energy efficiency[1]. PV systems

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have attracted significant interest since they dominate in distributed generation field and play a big part in smart grid development, thus PV systems distributed have experienced remarkable growth worldwide [2]. Solar energy is currently one of the most important sources of clean, free, inexhaustible and renewable energy with minimal environmental impact [3]. PV systems are among the most widely adopted clean energy sources ; in late 2020, the worldwide solar PV power installed capacity had reached 843 GW [3], Photovoltaic energy system has gained wide popularity in the past decade as one of the renewable energy sources due to the possibility of depletion of conventional energy sources and its high cost as well as its negative effects on the environment. Solar energy could be one of the significant sources as an alternative energy for the future [4]. Recently, one of the future projections is to reduce global carbon dioxide (CO2) emissions by 2050 to 75% of its 1985 level if we can improve and use the solar energy equipments such as the solar collectors [5].In regard to endless importance of solar energy, it is worth saying that photovoltaic energy is a best prospective solution for energy crisis [4]. The main reasons of this huge attention in the solar energy applications are due to the growing demand of energy, limited availability of fossil fuels and environmental problems associated with them such as carbon dioxide emissions [6]. So, the integration of a solar station in these solutions offers several advantages, including a significant reduction in operating costs thanks to the elimination of fossil fuels, simplified maintenance, and increased [8]. sustainability. Indeed, the development of renewable energy-based installations emerges as a promising solution to ensure a transition towards a cleaner and more sustainable energy future. [9].
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 [4]. The dominance of RES contributes to enhancing the microgrid power efficiency by minimizing the power losses in transmission, as well as running at a reasonable cost. [10].

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 [7]. The effect of the partial shadowing or mismatch between PV modules in the energy production will also depends on the type of the architecture. Nevertheless, the price and cost of the PV also depends on the choice of the architecture.

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

In this work, we perform study comparative between a series and parallels connection different arrangements of PV modules with their associated power converters have been developed to increase power production and reliability of the solar generators and the simulated partial shaded array with difference with the numerical methods Analyses, simulation and experimental validation 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. We present and discuss the obtained results via simulation using MATLAB. Moreover, 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.

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2. Notation

The notation used throughout the paper is stated below.

Indexes:

I_0	*Saturation current (A);*
I_d	*Diode current (A);*
Iph	*Light-generated current or photocurrent (A);*
Isc	*short-circuit current (A);*
k	*Boltzmann constant (1.38 × 10^{-23} J/K);*
q	*Electron charge (1.602 × 10^{-19}C);*
Rs	*Series resistance of cell (Ω);*
Rp	*parallel resistance of cell (Ω);*
Vd	*Diode voltage (Volt);*
V_{OC}	*Open-circuit voltage (Volt);*
Vt	*Thermal junction voltage (mV);*
n	*Ideality factor ;*
Np	*number of cells connected in parallel;*
Ns	*number of cells connected in series;*
GPV	*Photovoltaic generator;*
MPP	*maximum power point;*
MPPT	*maximum power point tracking;*
Pmax	*maximum power;*
P&O	*perturb and observe;*
VDC	*direct current bus voltage;*
AC	*Alternative Current;*
DC	*Direct Current;*
IGBT	*Insulated Gate Bipolar Transistor;*
MOSFET	*Metal Oxide Semiconductor Field Effect Transistor;*
MATLAB	*Matrix Laboratory;*

3. System Modeling

The PV system is initially modelled. As exposed in Fig. 1, the designed SECS involves of PV panels, DC/DC boost converter, plus P&O-based MPPT controller. When sunlight strikes PV panels' solar cells, electricity production commences. The following equations represent the association between the PV cell's output current [7]. The single diode PV model is the preferred choice in this study due to its simplicity, characterized by a reduced number of equations and parameters [12]:

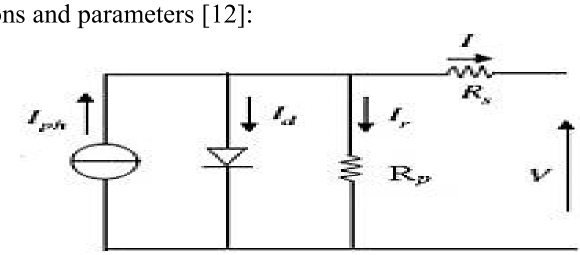

Figure. 1: General model of PV cell in a single diode model

$$I = I_{ph} - I_d - \frac{V + I R_S}{R_P} \qquad (1)$$

$$I = I_{ph} - I_0\left[e^{\frac{q(V+IR_S)}{nKT}} - 1\right] - \frac{V + I R_S}{R_P} \qquad (2)$$

$$I_{ph} = I_{SC} \frac{\phi}{1000} \tag{3}$$

The produced photo-current, the diode's reverse saturation current, the diode ideality factor, the series resistance (Rs) and the parallel resistance (Rp), and the absolute temperature (T) are all variables in this equation. Also included in the equation are the Boltzmann constant k ($1{,}380.10^{-23}$ J/K) and the elementary charge constant q ($1{,}602.10^{-19}$C).

A solar panel's fundamental component is a solar cell. The connection of several solar cells in both series (Ns) and parallel (Np) forms a PV module. Eq.4 gives the available output power from the PV generator.

$$Ppv = Ns * Vpv * Np * Ipv \tag{4}$$

Eq.4 gives the relationship between the output current and voltage, where Np is the number of cells linked in parallel and Ns is the number of cells connected in series. Eq.9 also determines the current characteristic [4].

$$I_{ph\ final} = N_P \ I_{ph} \tag{5}$$

$$I_{0\ final} = N_P \ I_0 \tag{6}$$

$$n_{final} = N_S \ n \tag{7}$$

$$R_{S\ final} = \frac{N_S}{N_P} R_S \tag{8}$$

$$I = N_P I_{ph} - N_P I_0 \left[e^{\frac{q\left(\frac{V}{N_S} + \frac{IR_S}{N_P}\right)}{nKT}} - 1 \right] - \frac{N_P}{R_P}\left(\frac{V}{N_S} + \frac{IR_S}{N_P}\right) \tag{9}$$

The P-V and I-V characteristics of PV module were measured under various irradiance levels and 25°C, as illustrated in Fig. 2.

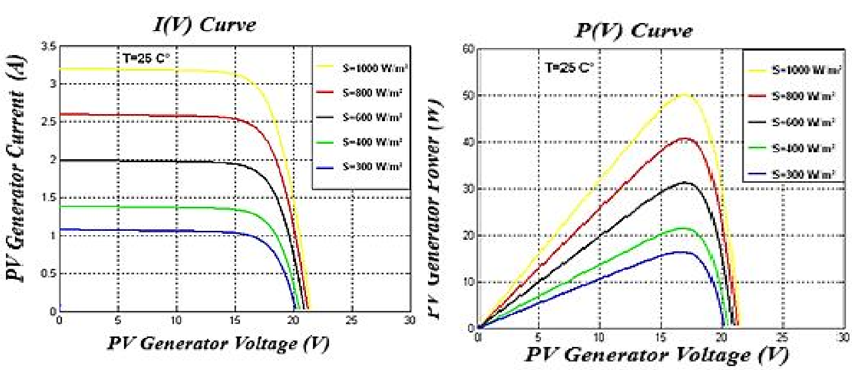

Figure .2: Simulation results for the I(V) and P(V) characteristics of a PV module as a function of different irradiances at T=25°C.

4. DC-DC boost converter

In this study, a boost converter, which is a widely used and easy-to-implement classical DC-DC converter in such MPPT applications, has been employed. The electrical circuit of the boost converter is reminded in the Fig.3. The converter circuit, which has a step-up configuration, increases the DC voltage applied at its input based on the duty cycle of the PWM signal applied to the power switch.

To facilitate the study of the system's dynamic response to perturbations. The load is represented by the R, the solar array voltage and current are represented by Vi and $\hat{I}_i$ through its terminals. According to [12], the system's output voltage Vi is determined by taking the transfer function between the input duty cycle α and disregarding the battery load.

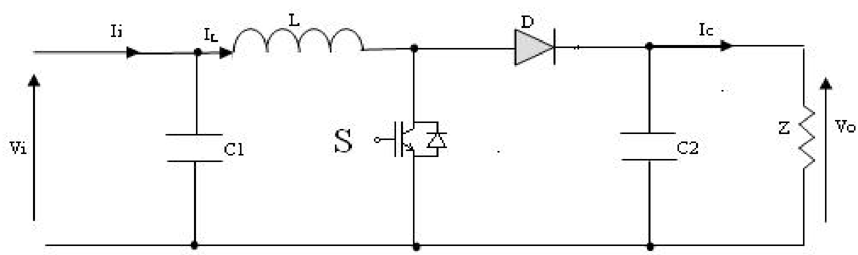

Figure.3: Electrical circuit of boost converter [7]

Similar to the inverter average model, the boost converter's electrical switch utilizes a duty cycle α. Here, nevertheless, the duty cycle is always positive within the interval [0,1]. The standard relationship between the output voltage, the input signal, and the duty ratio was utilized in the design.

$$V_o = \frac{1}{1-\alpha}\ V_i \tag{10}$$

In this context, α represents the duty cycle of the S switch, V_i stands for the voltage given to the converter's input, V_o for the voltage obtained from the converter's output, and so on. In order to get the most juice out of the PV array, the DC-DC converter's control strategy figures out what the best input voltage reference is. An MPPT method is used to achieve the best possible voltage reference by continually monitoring the PV array's power production.

Solar photovoltaic (PV) systems use maximum power point tracking (MPPT) to boost efficiency and output power. Temperature, shade, and sunshine intensity are a few of the variables that might affect the MPP. In order to maximize power extraction, maximum power point tracking algorithms keep a close eye on the MPP and make adjustments to the solar panel's operational voltage and current. [13].

The use of DC optimizers for maximizing photovoltaic energy extraction is becoming increasingly common. These devices are installed next to the PV modules, allowing for the efficient extraction of maximum energy in a distributed manner according to studies forecasting photovoltaic usage [14].

The latest approach to optimizing power transfer is to use a matching stage DC-DC controller with MPPT. This setup works in a modular way, with each section having its own adaptation stage to make the most of the power available from the PV modules. By placing the control closer to the source of power generation, the goal is to produce as much power as possible. Figure 4 shows how this power control works.

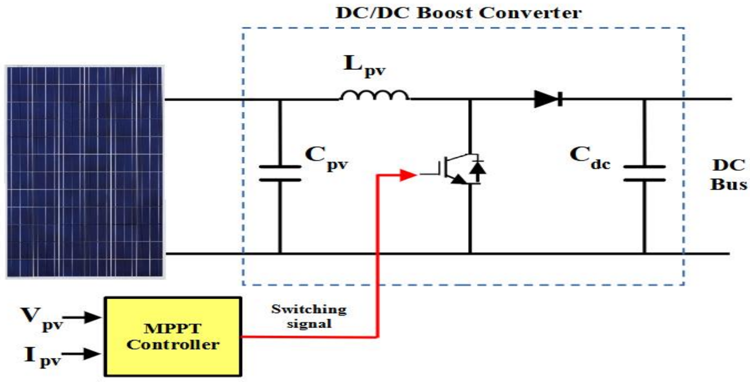

Figure. 4: Solar energy conversion system with P&O MPPT.

4.1 Perturb and Observe method

This MPPT technique involves a small disturbance being introduced to the solar module's power, leading to continuous fluctuations. When the power increases due to the perturbation, it continues in the same direction until the maximum power point is reached. At this point, the power at the next instant decreases, and the perturbation is reversed. The algorithm oscillates around the peak point until it reaches a steady state. To prevent large power variations, the perturbation size is kept very small [15]. The flowchart shown in Figure 5 provides an easy-to-understand visualization of the algorithm.

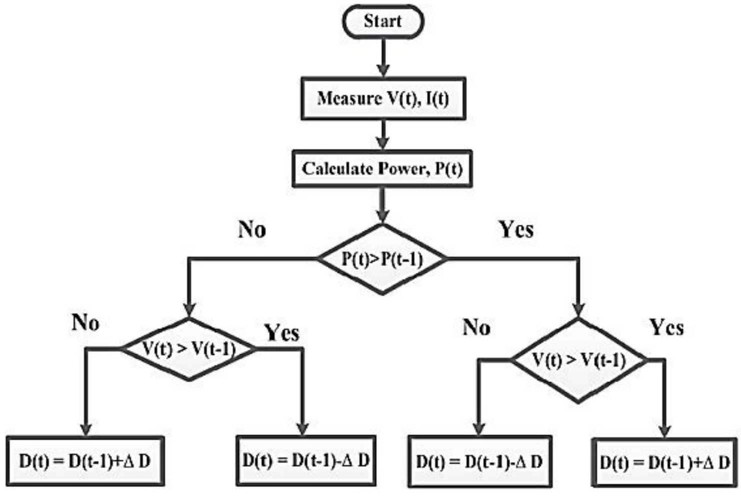

Figure. 5: Flowchart for P&O Method [6]

The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module.

5. The Designed Topologies

The most basic system in terms of components is the interactive utility system, but it can be improved and made more efficient with the inclusion of other components. Changing the wiring between the inverters, DC-DC converters, and modules is a common method for this. A photovoltaic array can be set up in one way by connecting it to an inverter or DC-DC converter. Another allows for a fixed number of DC-DC converters or inverters to be linked to numerous strings [12]. Alterations to the electrical connections between DC-DC converters and PV modules are also possible using other techniques.

5.1 Central converter topology

In the most basic setup, as illustrated in Figure 6, PV modules are linked together to create strings, which is then connected to the central inverter system. To accomplish the required power output, this architecture involves connecting strings of PV panels that are series-connected in parallel. One DC-DC converter is subsequently linked to the generated PV array.

Large PV systems, capable of generating many megawatts, usually employ this layout. Compared to other topologies, the central inverter topology is more cost-effective, and inverters are easier to maintain, which are its key advantages. The PV system as a whole will come to a standstill in the event of an inverter failure, making this topology unreliable. Since just one inverter is accountable for monitoring the MPP, substantial power loss might also happen as a result of module mismatches or partial shadowing. Consequently, it's possible that the MPP won't be tracked efficiently for the full array using this setup [13]. The reason behind this restriction is that the MPP differs for every string; these differences are affected by operational conditions and the effects of shading. Here, PV panels are arrayed in both series and parallel connections to form a single big inverter that may be attached to the grid or an MPPT converter. The inverter has an MPPT system. This topology has a financial benefit since it uses fewer inverters, which means it's cheaper. But even a little shade on one panel can have a major impact on the array's total power output. Reduced output power is a result of the most darkened panel limiting the series string current. Two kinds of connections are included in this topology: total cross-tied and series-parallel [16].

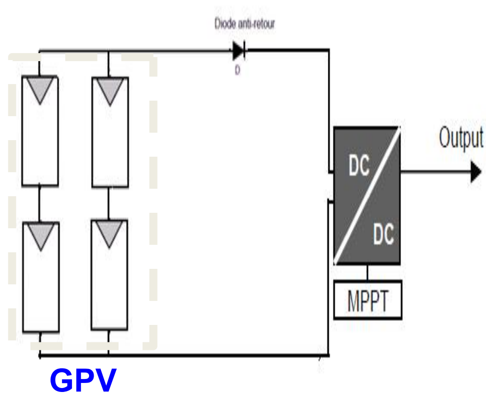

Figure.6 : Central converter configuration.

5.2 String converter topology

Each string in the string converter system (Figure 7–8) has its own converter, and the load is supplied by inverters that operate either in series or parallel. This configuration has all PV strings linked across a single voltage, which might not be the best way to ensure that all panels reach maximum power point tracking (MPPT). Consequently, this arrangement does not make optimal use of all panels. Because of the nature of the PV panels, which confine the current in a series string to the panel that is shaded the greatest, the power generated is reduced.

To address the issues caused by partial shading, each PV module can be equipped with a bypass diode. This diode allows current to bypass the shaded or damaged module, preventing it from limiting the current of the entire string. Some PV modules are even manufactured with built-in diodes for several cells within the panel. While this system increases overall efficiency, it also adds cost due to the increased number of converters required [15]. The topologies discussed in study [16], similar to the DC-DC cascaded converter topology with a high level of integration, are capable of providing the highest energy generation in scenarios with partial shading. The study includes simulations of energy output for different topologies in a rooftop PV system, considering both non-shaded and shaded conditions caused by structures like chimneys and other buildings. According to the graphs, the best performance is achieved by systems where each panel is equipped with its own MPPT converter, such as the cascaded DC-DC converter topology. Additionally, the study [15] proposes a current diverter. While the panels are unshaded, the current diverters remain inactive, but when the irradiation of a PV panel changes, the additional circuitry adjusts the current in the converter string to optimize performance.

Finding the optimal topology to extract the most power at the lowest cost is the primary goal of this research. The many topologies that resulted from experimenting with various converter and PV array configurations are a direct result of this. Figure 7 shows the first topology, which consists of two sets of PV panels linked in series and then in parallel with one another. Each set of panels uses a single converter that is managed by an MPPT controller. The second topology involves connecting the converters in series. The two converters are linked in series, as illustrated in Figure 7, and they are both modeled similarly to string converters.

In third topology, the converters are connected in parallel. The model of each converter is the same as each string converter and the two converters are connected in parallel as shown in Figure 8.

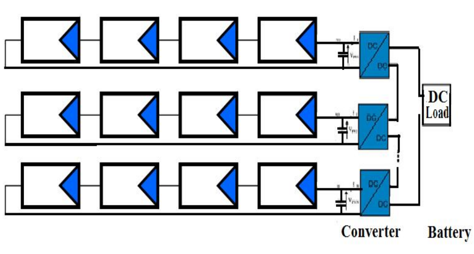

Figure .7: Series connection of a string converter

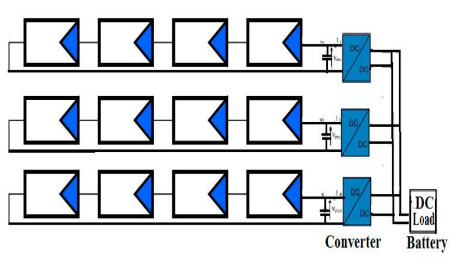

Figure.8: Parallel connection of a string converter

Simulation resultants and discussion

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

A. The converters are connected in series

In the series topology of converter we have used two PV panels and two converters connected in series and controlled with an MPPT controller. The model of each converter is the same as each string converter for this case of simulation.
The simulation resultants of Vs (output voltage), I_S (output currant), and η (efficiency) are shown in the following figures.

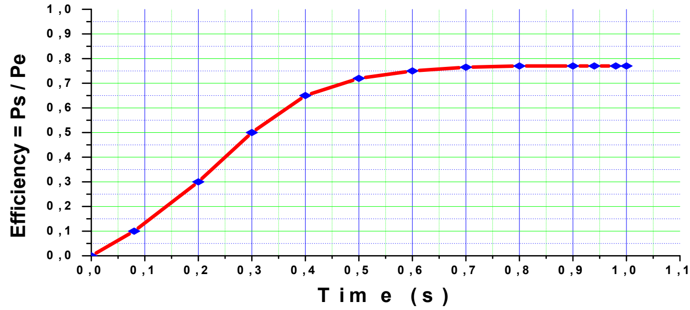

Figure.9: Simulation results of the string converter connected in series.

That means that the efficiency η increases rapidly with the power to reach a maximum yield of 77% -78 %.

Damage on a single converter

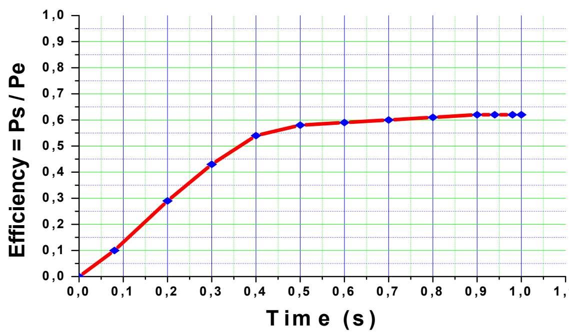

Figure.10. The yield effect in case of single converter damage.

That is the efficiency η increases rapidly with the power to reach a maximum yield of 61% -62 %.

B. The converters are connected in parallels.

The model of each converter is the same as each string converter, the two converters connected in parallel. The simulation resultants of Vs (output voltage), I_S (output currant), and η (efficiency) are shown in the following figures:

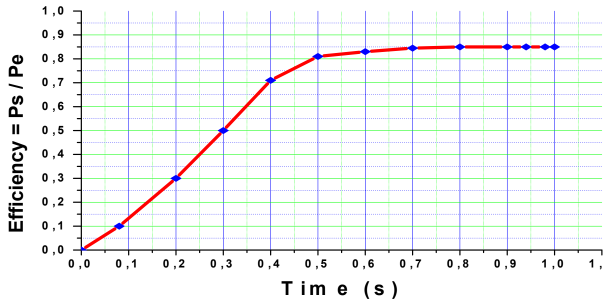

Figure.11: Simulation results of the string converter connected in parallels.

In the case of damage on a single converter, it is noticed that the efficiency η increases rapidly with the power to reach a maximum yield of 85% -86 %.

Damage on a single converter

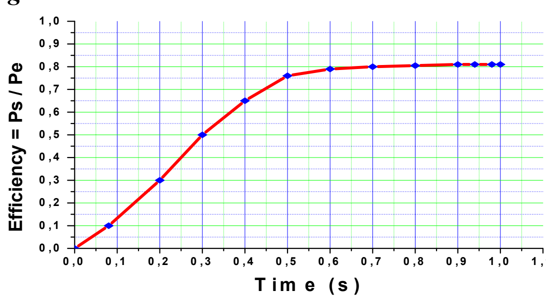

Fig.12 : The yield effect in case of single converter damage.

In the case of damage on a single converter, it is noticed that the efficiency η increases rapidly with the power to reach a maximum yield of 80% -82 %.

C. Simulation and Evaluation of Shading Effect on GPV Connection of Two Converters by Numerical Methods

The Converters are connected in Series

The following characteristics (I-V) represent the association of two BOOST in series with a variation of sunshine by different values (1000-950-900-850-800W/m^2). This curve is obtained by an enhancement of fart defined by different numerical methods uses (Analytical, B.Shapmine, Euler, P. Domand). Consequently the result obtained by the methods of Euler and B. shapmine represents the best improvement methods between poor times compared to other method.

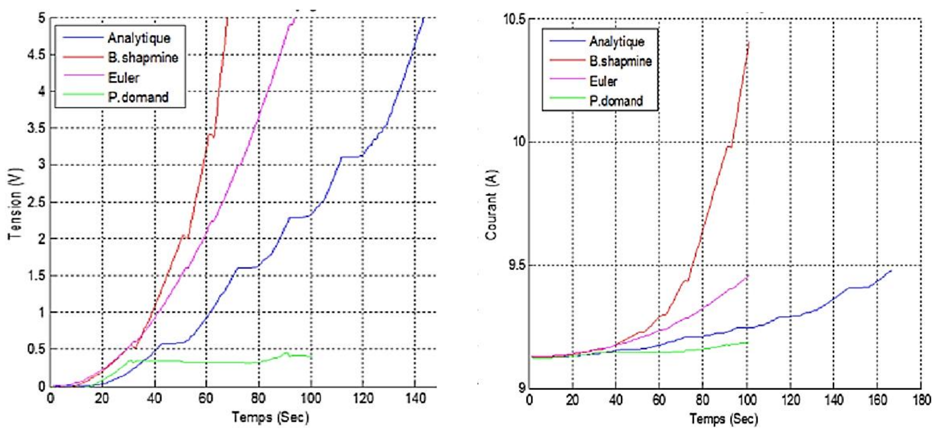

Figure.13: The characteristics of (I and V) for two BOOST in series with the evaluation of the shading effect by the different numerical methods.

The converters are connected in parallels.

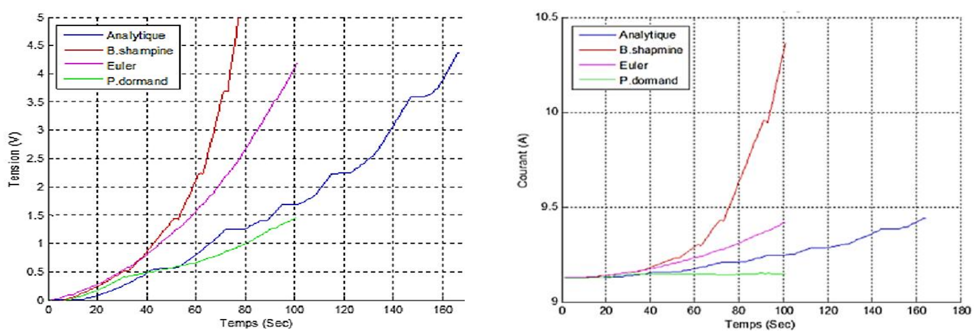

Figure.14: The characteristics of (I and V) of two BOOST in parallels with the evaluation of the shading effect by the different numerical methods.

The following characteristics (I-V) represent by the association of two BOOST in parallels with a variation of sunshine by different values (1000-950-900-850-800W/m^2).This curve is obtained by an enhancement of fart defined by different numerical methods uses (Analytical, B.Shapmine, Euler, P. Domand). Consequently the result obtained by the methods of Euler and B. shapmine which represents the best improvement methods between poor times compared to other method.

Experimental results and discussions

Using an I-V curve tracer, the first experimental approach involves evaluating the I-V characteristics of the entire array and each module individually.

Here are some details about the LMOPS equipment that was installed at IUT Thionville-Yutza: - The initial BP solar panel is a 50W polycrystalline. An additional 40W monocrystalline BP Solar panel is in the works.

The equipment used in these experimental measurements is LMOPS PV panels. The 50 W polycrystalline and 40 W monocrystalline options are available from BP Solar.

In this study, LMOPS PV panels are utilized in the experimental measurements. The 50 W polycrystalline and 40 W monocrystalline options are available from BP Solar

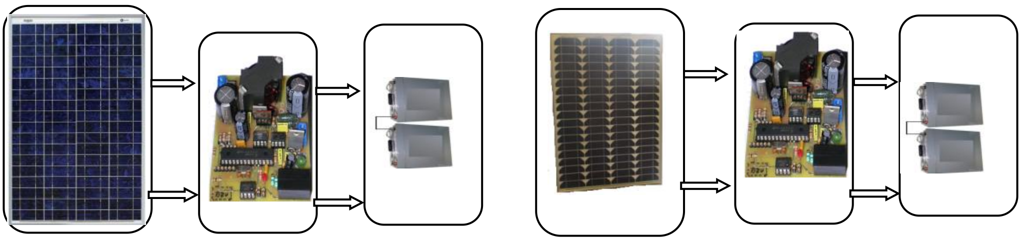

Figure.15: BP Solar photovoltaic panels (a) 50 W (Poly crystalline) and (b) 40 W (Mono crystalline).

One bypass diode panel protector is all that's included in this panel. A 4kW halogen bench light illuminates the panel. This is accomplished by connecting a rheostat to the panel; this lets you adjust the load resistance value and measures both current and voltage at the same time from the same location. Throughout these tests, the panel is illuminated with a constant maximum amplitude using lights with a rated voltage of 4 kW. Nevertheless, a ventilation system was incorporated to maintain a temperature that was near the panel room temperature. Moreover, the performance of different balancer structures under different scenarios of Shading. In figure 15 the output of the converter is connected to a two battery 12V connects in series. The MPPT control determines the voltage reference. The measuring system can simultaneously and independently measure for each elementary chain:

-The voltage and current across the PV generator (V_{PV}, I_{PV})

-The voltage and current output of the elementary DC / DC converter (V_{OUT}, I_{OUT}).

An experimental, using the laboratory prototype of equipment to LMOPS Was performed on wafer with the parameters indicated:

- The control MOSFET being performed by a BF generator
- 12 V power supply for the converter attacked
- 5V supply for the current regulator.

C. Simulation and Evaluation of Shading Effect on GPV Connection of Two Converters by Numerical Methods

The results of the experimental tests according to the type of association that we studied and described in this part correspond to series architecture of converters illustrated in Figure 16.In addition to this architecture and in order to continue the study of the usefulness of distributed management, we carried out comparative tests under the same operating conditions with separate management of the two panels.

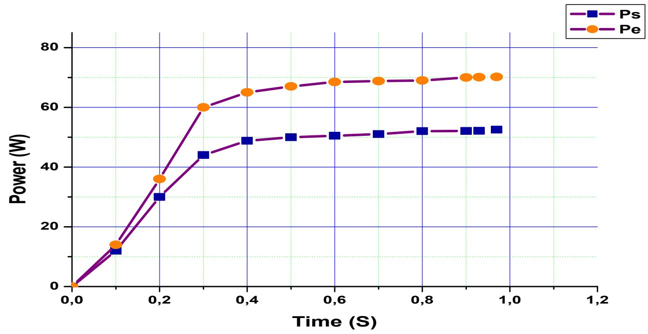

Figure .16 : Power of the string converter connected in series.

In Figure 16, we have superimposed the input power (Pe = 75.5 W) and the output power (Ps = 51 W), the conversion efficiency (η) and the output current of this structure. A first analysis shows that the adaptation stage for distributed management has a conversion behavior identical to the previous case, i.e. a conversion efficiency close to 68-69% when the power delivered by the PV is greater than 75 W. Thus, we can notice that in this example of comparative calculations, the power of the GPV is available at the input of the PV adaptation stage Simulated with the boost stage because the internal extreme MPPT control makes the operating point oscillate around the maximum power point.

Simulation and Evaluation of Shading Effect on GPV Connection of Two Converters by Numerical Methods

The converters are connected in parallels.

The results of the experimental tests according to the type of association that we studied and described in this part correspond to a parallel architecture of converters illustrated in Figure.17.In addition to this architecture and in order to continue the study of the usefulness of distributed management, we carried out comparative tests under the same operating conditions with separate management of the two panels.

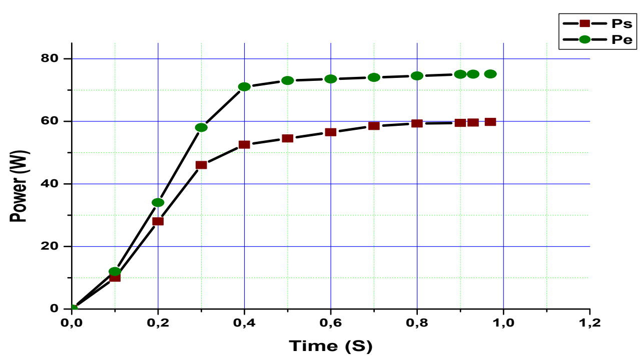

Figure .17: Power of the string converter connected in parallel.

In this case observing these results, for this new test, we deliberately chose a slightly higher voltage in order to show the influence of the load on the photovoltaic conversion chains, the input power (Pe = 77 W) and the output power (Ps = 60 W), and the output current of this structure. The overall efficiencies of the conversion chains show that, in this configuration of 78-79%. The discretization of the power management is the most appropriate in this case thanks to the production gain generated by the MPPT efficiency. In Figure 17, we can observe the powers transmitted by the GPVs of this structure. Distributed management has therefore proven that it could be an interesting and enriching architecture as soon as the electrical characteristics of the load differ from the optimal characteristics of the solar modules.

Conclusion

This paper presents the results of an experimental investigation that tries to evaluate the efficiency of three distinct PV/DC-DC converter topologies in this paper investigation that tries to evaluate the efficiency of three distinct PV/DC-DC converter topologies. Compare two different photovoltaic system architectures. An experimental research comparing central and distributed PV system topologies provided the basis for the methodology used in this work. A PV array linked to a single DC-DC converter constitutes the central topology, in contrast to the several strings that make up the distributed design. Compare two different photovoltaic system architectures. The strings can be strung in either a series or parallel configuration. A substantial capacity for power transfer is included in these string connections, which can be either series or parallel. To raise the voltage, one uses a series connection, and to raise the current, one uses a parallel connection. Each string or PV module in a dispersed setup has its own DC-DC converter. These two topologies series and the parallel connection of a converter that involves a major power transfer capability can be connected in series and/or parallel. However, these structures are instable and request for complex control system. Whereas the parallel connected are the more popular and used structures. Indeed, these structures allow the improvement of efficiency and are normally and taking the effect of irradiance into consideration, the output current and voltage characteristic of the photovoltaic system are simulated using the proposed by the different numerical methods in order to find the best method. Avoiding the problems due to the mismatching of them. As a result, the PV power generation is enhanced and the energy production remains unaffected in the event of a string failure. In order to improve sustainable energy solutions, it is crucial to perform tests to verify the efficacy and reliability of photovoltaic (PV) systems, as this study experimentally shows. In order to select the best PV architecture for every PV installation, it is crucial to study various types of architecture. the series connections are used to increase the voltage. This was the motivation behind this work. As future work it is important to compare these simulation results to experimental ones for the different PV arrays architectures.

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