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The Concept of Sustainable Development: The Case of Photovoltaic Energy Generation using Fractional MPPT Algorithms

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Abstract:- This paper deals with the notion of sustainable development: the case of electricity production from the solar energy. This amounts to studying the different dimensions of sustainable development in relation to energy and the two main approaches of this development. For this purpose we will develop and process the different characteristics of the PV cell by integrating the maximum power point tracking (MPPT) command of the photovoltaic panel that is focus on the fractional open-circuit voltage (FOV) and Fractional short circuit current (FSC) algorithms in order to have a better sustainable development and to reduce the cost of electrical installations in different fields. The results of a simulation are discussed to check the performance or quality and to prove the efficiency of the proposed MPPT commands for tracking the maximum power point of the PV panel.

Keywords:- *Energy, Sustainable Development, Society, Environment, Economy, Photovoltaic (PV), MPPT Algorithm, FOV, FSC, DC-DC Boost Converter.*

I. INTRODUCTION

All human activities, especially those that contribute to economic and social development, use energy. Indeed, the development of a society is reflected in the increasing satisfaction of a certain number of needs: food, education, housing, leisure, health, transport... The most of activities require, the varying degrees, the use of energy in different types. Thus, the use of new energy services is essential for economic development.

However, the strengths of the use of energy in economic domain are necessary and manifold, it is the damage done by the consuming of energy by companies which deserves our attention. Indeed, the global consumption energy is overpowered by fossil energy (coal, natural gas and oil) by around 78.3% in 2013.

As a result, the demand of energy is primarily covered through the use of fossil fuels, which are the principal origins of greenhouse gases (GHG) [17].

The observed increase in concentrations of these GHG is the principal reason of global warming. The latter presents the mostly major environmental problem attached the using of energy [18,19].

So we are faced with a dilemma, on the one hand we must reduce the consumption of fossil gases which are the essential source of GHG and on the other side we must satisfy the rapid development of the world economy which requires a continuous growth of energy consumption [14-15,17].

Thus, the main important goal for many countries is to apply a less carbon efficient energy without impeding of the development economic.

Monitoring the path of sustainable development therefore requires a transition to renewable energies, since fossil fuels do not answer of the sustainable development [14].

The main sources of renewable energies are: hydraulics, biomass, solar, wind and geothermal energy.

However, almost all of them are derived from solar radiation in a direct or indirect way. Their exploitation is increasing in parallel with the progress of science especially photovoltaic energy and wind energy which are the most widespread today. Indeed, they are totally clean sources that do not dissipate greenhouse gases or waste, ensuring conversion to electricity from a free source, unlimited and accessible anywhere in the world.

In this case, photovoltaic system is one of the main sources of renewable energy that has a solution to our energy production problems. This energy is defined by the transformation of sunlight into electrical energy.

Besides, this energy appear to be the most promising and no-polluting. However, energy solar production is no linear and rely on climatic changes: temperature and irradiation.

To ensure a good sustainable development of this type of energy; the functional point of the PV panel must coincide with the optimum power point. Then the used of a mechanism make the study and tracking of the MPPT so that the optimal power is producted continuously [1,5-6].

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Thus, a DC-DC converter must be inserted between the PV panel and the load to provid the maximum power transfer to the load [10].

Thus, many studies have interested on PV systems. They develop an algorithms to extract the maximum energy provided by the panel which allows maximum operation of the photovoltaic panel. Several algorithms focus on the following commands such as: Perturb & Observer (P&O) and Increment of Conductance (INC). Other controls have been studied alike measuring an open circuit voltage fraction (FOV) or measuring a short circuit current fraction (FSC) [7-8].

This paper is described as follows. In section 2, the concept of sustainable development and the contribution of renewable energies to the social, economic and environmental dimensions of this development is presented. In section 3, we recall the different approaches of sustainable development. In section 4, we introduce the process of the PV power system. In section 5, we present the MPPT techniques using traditional algorithms; Fractional Open-Circuit Voltage algorithm (FOV) and Fractional Short-Circuit Current algorithm (FSC). To show the control performance, the results of simulation of PV system are presented and discussed in section 6. Finally, conclusions are presented in the final section.

II. SUSTAINABLE DEVELOPMENT

The sustainable development of renewable energies is at the heart of the concerns of governments around the world. The main challenges today are to preserve the planet and its resources, while ensuring sufficient energy production to meet the needs of each, since the intensive use of fossil energy has had negative consequences for the environment and the global consequence is the phenomenon of climate [16]. Indeed, the major consumed energy in the world is based on fossil fuels that mimic greenhouse gases. These gases are among the main causes of global warming. The phenomenon has attracted most attention with the coming methods of the concept of sustainable development since 1980s. It is easy to perceive that the change of climate and its catastrophic consequences are an obstacle to achieving development. sustainable [12,19].

A. Definition of Sustainable Development

Sustainable development is a process that encompasses both economic development, environmental preservation and respect for equality between present and future generations within the same generation. Therefore there is a powerful link between the different form of energy, the environment and sustainable development. To ensure the goals of sustainable development, the use of renewable energy is necessary because they didn't have a negative impacts on the environment [14,16].

B. Different Dimensions of Sustainable Development

Sustainable development is not just an awareness of environmental protection, but rather aims to achieve the best possible equality between the different dimensions of sustainable development : economic, social and environmental.

Figure 1 presents the different dimensions of sustainable development.

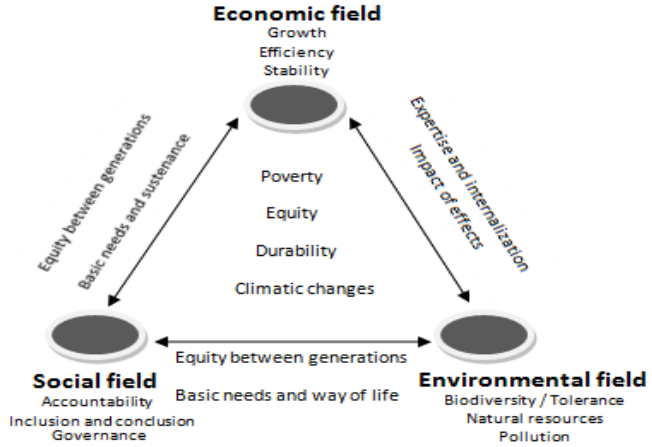

Fig 1:- Key elements of sustainable development and their interactions

➢ *Energy and Society*

At all times, energy has been considered as an essential social need for man. It is crucial for social progress and economic development, for health, transport, communications...

The last century has seen the gradual emergence of a series of principles that reflect the essential social need of energy:

- Continuity, because there is a social or strategic need to satisfy, implying that the supply is regular and continuous.
- Equality, which requires that users be placed in an equal position, without discrimination or special advantages, which leads to equalization of tariffs in the context of the area covered.
- The search for the least cost [19].

➢ *Energy and Environment*

The exploitation and consumption of energy causes significant environmental damage at the local and global level.

Any energy sector is a source of nuisances that disturb the natural environment and, through it, the man. Nevertheless, the type and depth of this damage varies depending on the type of energy used.

The different environmental impacts of traditional energies have shifted interest towards RE. They have major advantages: they are less risky to burn, have little or no fuel cost, are at least certain, better distributed geographically, are often well suited to areas with low

population densities and have less impact on the environment [17].

➢ *Energy and Economy*

Energy is at the same time an economic sector which groups together the activities of production, transport, distribution and marketing of the various forms of energy (oil, gas, electricity...) and at the same time is a key factor of production which conditions the functioning of all other sectors of the economy.

Energy also accounts for a significant share of external accounts in many countries, either on the export side or the import side.

Energy can be a significant part of revenue and/or tax expenditures [15,19].

III. DIFFERENT APPROACHES OF SUSTAINABLE DEVELOPMENT

Sustainable development is treated according to two main approaches which are: strong sustainability and low sustainability. The principal difference between these two methods is relative to substitutability between natural resources and man-made capital [13,18].

A. Low Durability

The drawback of sustainability, is defined by neoclassical economists, In fact, by the neoclassical economists, sustainability is presented by the maintenance major time of the level of most well-being in company. Thus, the stock should remain intact from one generation to the next in sequence to maintain a well-being for next generations that must lose equal to that of the present generations.

B. Strong Durability

As for the proponents of the ecological economy, they rather support the idea of this type of sustainability. The paradigm of this sustainability owes is discussed by Daly (1992, 1996). This improved method which is based on the assumption of complementarity between natural capital and man-made capital. Therefore, it is essential to maintain, over time, a stock of "critical natural capital" that is essential for the well-being of next generations. In fact, some components of the environment provide services that can not be replaced by human-made capital.

Noting that climatic changes is mainly due to CO_2 emissions that is emitted by conventional energy. By United Nations Department of Economic Affairs and Social, the energy is important for economic development and renewable energy. Thus, a magic conversion of fossil fuel use to renewable energy is short choice but an urgent issue for achieving the stability of the climate. Indeed, there is a consensus among researches that the use of renewable energy is needed to mitigate climate change [15,17].

In our case, we are interested in solar energy as a type of renewable energy.

Thus, we will study the different characteristics of the photovoltaic panel and some types of MPPT controls in order to have a better sustainable development and to reduce the cost of electrical installations in different fields.

IV. PV SYSTEM CHARACTERISTICS

A PV system consists of four blocks as shown in Figure 2. The first block represents PV panel, the second block is a DC-DC converter, the third block represents the load and the fourth block represents the command system.

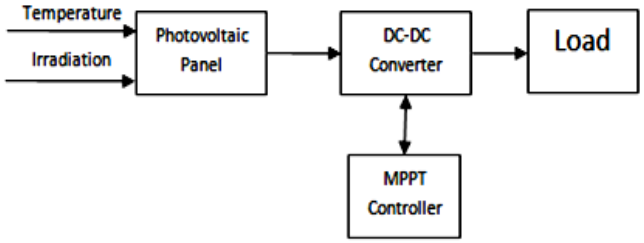

Fig 2:- Configuration of the PV system.

A. Photovoltaic Array

The PV cell rely on climatic parameters such as solar irradiation (G) and temperature (T). It consists of a current generator I_{ph}, in parallel with a diode, and connected to a series and internal parallel resistor, namely, respectively, R_s and R_p [3,11].

A schematic overview of the PV cell is presented in Figure 3.

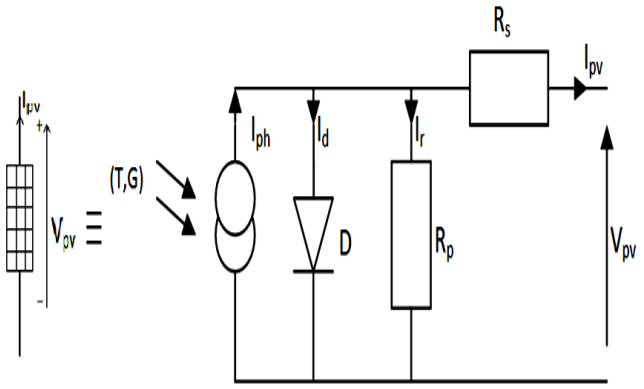

Fig 3:- The circuit of photovoltaic cell

PV panel is modeled by the following equations:

$$I = n_p(I_{ph} - I_{rs}(e^{\frac{qV}{pKTn_s}} - 1)) \quad (1)$$

$$I_{ph} = (I_{cc} + K_I(T - T_r))\frac{G}{100} \quad (2)$$

$$I_{rs} = I_{rr}(\frac{T}{T_r})^3 \exp(qE_g(\frac{1}{T_r} - \frac{1}{T}))/\ pK \quad (3)$$

where n_s and n_p are the number of the series and parallel cells, with p is an ideal factor, T is the cell temperature, K=1.38 10^{-23}JK^{-1} is the Boltzmann's constant, q=1.6 10^{-19}C is the electronic charge, E_g=1.1 is the band gab energy, K_I=0.00171A/°C is the controller gain, I_{ph} and I_{rs} are respectively the photocurrent and reverse saturation current.

Figures 4 and 5 show the I-V and P-V characteristics of the PV cell under 25°C and 1000 W/m².

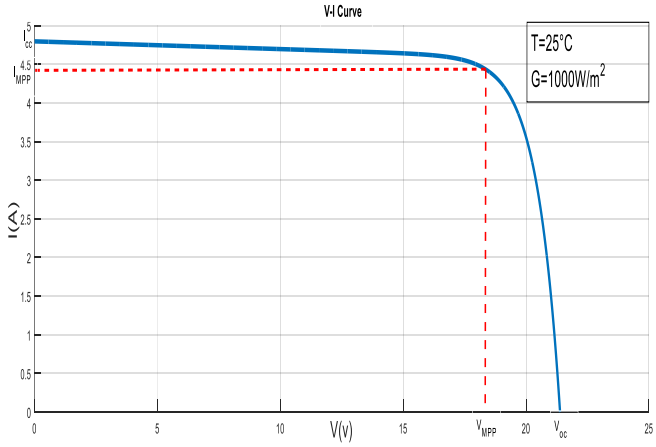

Fig 4:- I-V performance of the PV panel

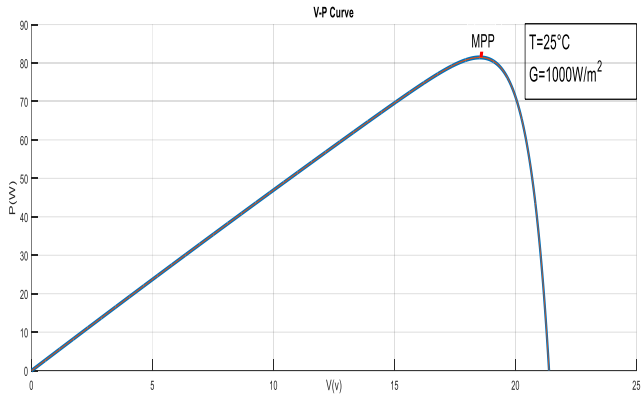

Fig 5:- P-V pperformance of the PV panel

The I-V characteristic is a no-linear performance with a single optimum point where the power is optimal (MPP). The corresponding maximum voltage and current are I_{MPP} and V_{MPP}.

B. DC-DC Boost Converter

The several role of the DC-DC converter is to make an impedance matching so that the PV panel delivers the optimum energy.

There exist many kind of DC-DC converter such as Buck, Buck-Boost and Boost [2,10]. For instance, we utilize a boost converter as the required DC-DC power one.

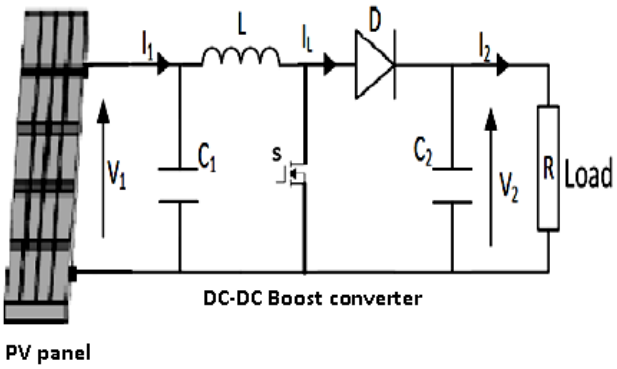

Fig 6:- Configuration of the PV energy system

This converter is defined by the following equations:

$$V_2 = \frac{1}{1-\mu} V_1 \quad (4)$$

$$I_1 = \frac{1}{1-\mu} I_2 \quad (5)$$

$$I_L = I_1 - C_1 \frac{dV_1}{dt} \quad (6)$$

$$I_2 = (1-\mu) I_L - C_2 \frac{dV_2}{dt} \quad (7)$$

$$V_1 = (1-\mu) V_2 + R_L I_L + L \frac{dI_L}{dt} \quad (8)$$

where I_L is the current on the inductance L and μ is the duty cycle of the Boost converter.

V. FRACTIONAL MPPT ALGORITHMS

The MPPT command regardless of the input parameters uses certain algorithms to "up" the PV generator operating point along the P-V performance until it reaches the MPP [1-2,9].

In this type of methods, we can use the two algorithms: Fractional Open-Circuit Voltage (FOV) and Fractional Short-Circuit Current (FSC) algorithms.

A. Fractional Open-Circuit Voltage Algorithm

This approach is based on the use of the proportionality relationship between the open circuit voltage V_{oc} and the optimal one V_{MPP} [5].

The following equation describes the relation between V_{OC} and V_{MPP}:

$$V_{MPP} = K_v * V_{oc} \quad (9)$$

where K_v is a gain factor which $0{,}73 \leq K_v \leq 0{,}8$.

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The FOV algorithm is given by the Flowchart in Figure 7.

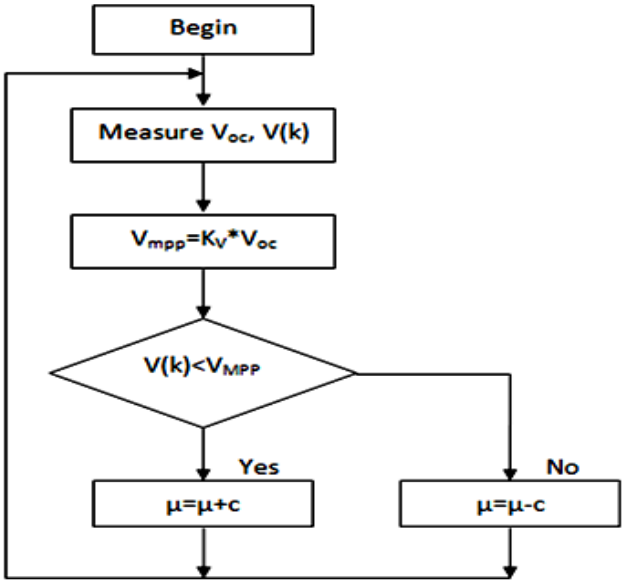

Fig 7:- Flowchart of the FOV algorithm

B. Fractional Short-Circuit Current Algorithm

The FSC algorithm is defined by a linear relationship between the short-circuit current I_{cc} and the optimal current I_{MPP} [4].

The fundamental relationship is presented as follows:

$$I_{MPP} = K_i * I_{cc} \qquad (10)$$

where K_i is a gain factor which $0{,}85 \leq K_i \leq 0{,}92$.

A Flowchart, which describes the FSC algorithm, is:

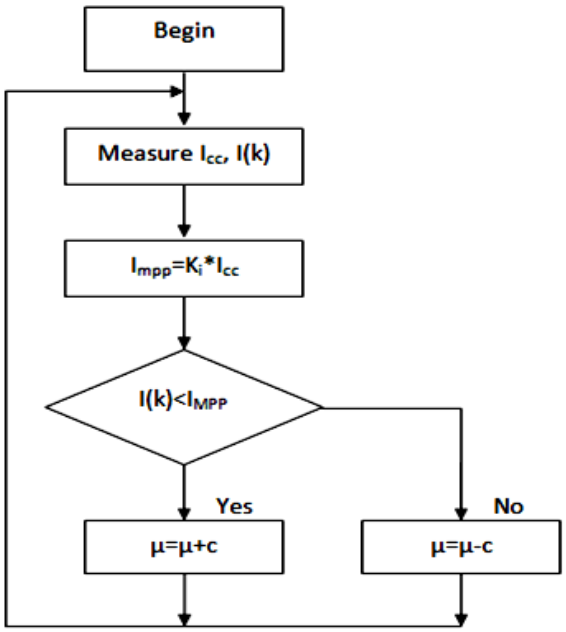

Fig 8:- Flowchart of the FSC algorithm

VI. SIMULATION RESULTS

This section developed the different results that evaluate the proposed MPPT algorithms. The photovoltaic system was simulated with Matlab/Simulink program.

The following Table present the characteristics of the PV panel under 25°C and 1000 W/m².

Parameters	Values
Maximum power P_{max}	81,5 W
Voltage at P_{max}	18,4 V
Current at P_{max}	4,42 A
Short Circuit Current I_{cc}	4,8 A
Open Circuit Voltage V_{oc}	21,38 V
Series-Parralel cells	(36,1)

Table 1:- PV Array Parameters

To explain the characteristic of the MPPT used, we apply a sudden change in temperature and irradiation .The temperature starts from 30°C, then decreases to 25°C, after that increases to 35°C and finally, increases to 40°C, while the solar radiation level starts from 700 W/m², then decreases to 600 W/m², after that increases to 1000 W/m² and finally, decreases to 900 W/m². The evolution of the varying temperature and solar irradiation are given, respectively, by the following Figures 9 and 10.

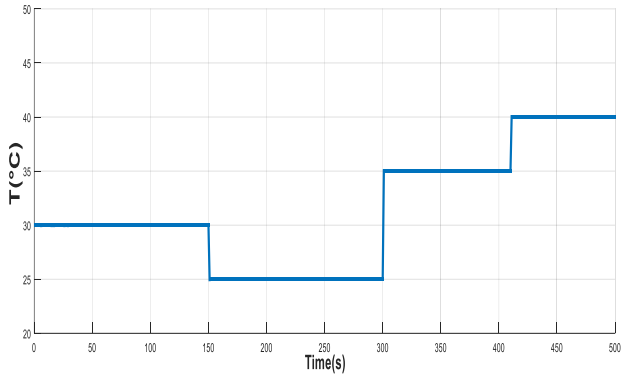

Fig 9 :- Temperature levels

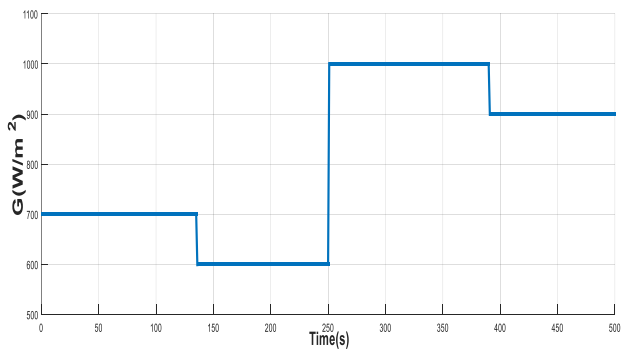

Fig 10:- Solar irradiation levels

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To check the performance of the photovoltaic panel, we can used the FOV and FSC, MPPT algorithms.

The Figures 11, 12, 13 and 14 illustrate, respectively, the evolution of PV voltage, the error of PV voltage, the evolution of PV current and the error of PV current according to the MPPT algorithms used.

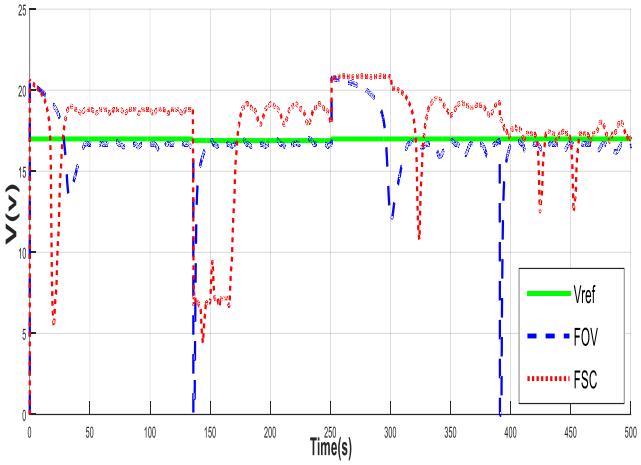

Fig 11:- Evolution of PV voltage based on MPPT algorithms

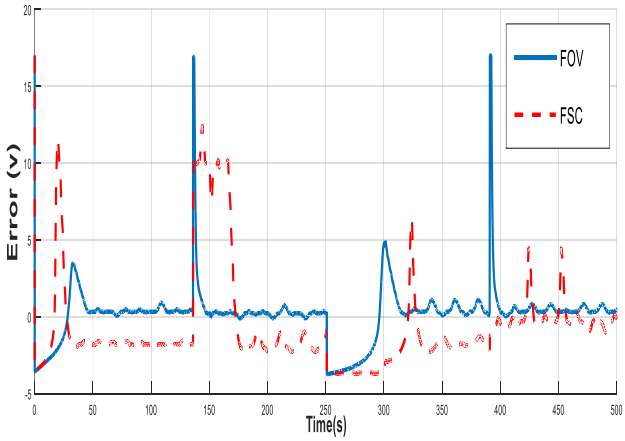

Fig 12:- Evolution of the error PV voltage

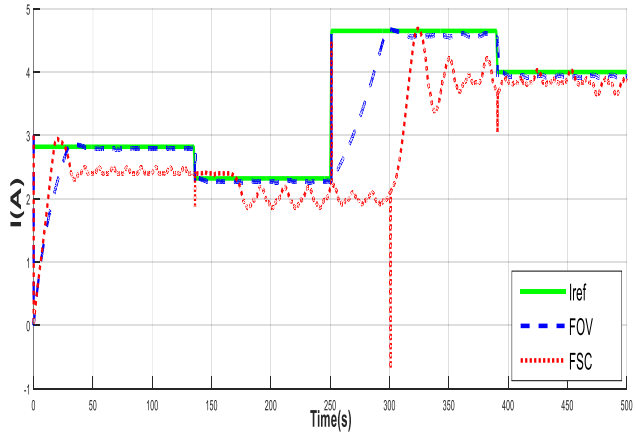

Fig 13:- Evolution of PV current based on MPPT algorithms

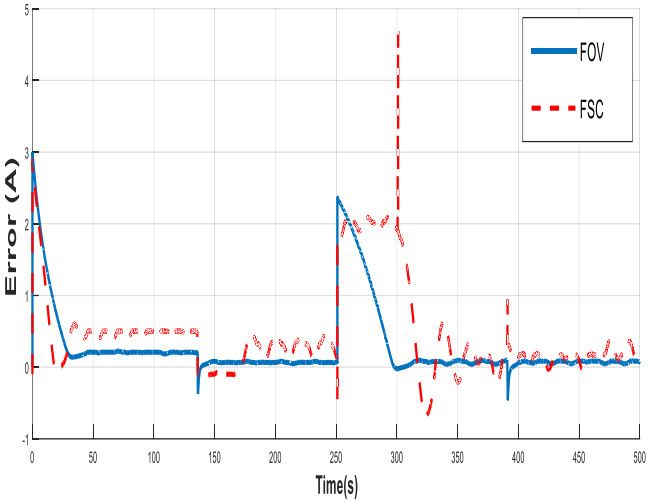

Fig 14:- Evolution of the error PV current.

In Figures 11 and 13, we can observe momentary peaks, which are resulted from sudden change in temperature and solar irradiation.

It can be seen in Figures 12 and 14 that the method FSC results in important oscillations. Contrariwise, the FOV method present less oscillations and the errors tend towards zero.

The power regulation response generated by using the FOV and FSC, MPPT algorithms are illustrated in Figure 15.

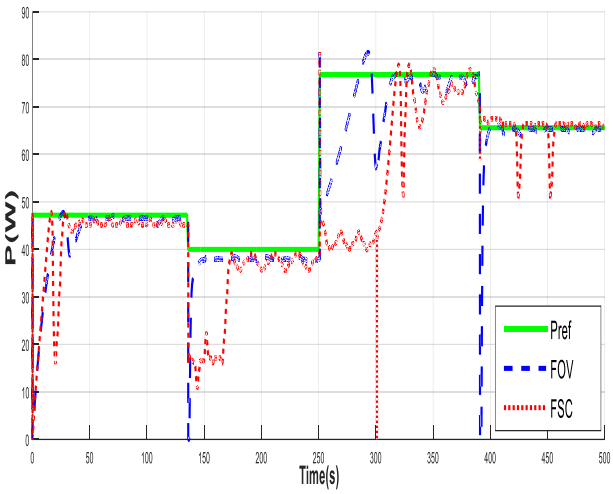

Fig 15:- Evolution of PV power based on MPPT algorithms

From Figure 15, we can notice that the MPPT algorithms track the MPP, but the FOV command gives a better performance than the FSC command.

VII. CONCLUSION

This paper presented the strategy of sustainable development and these different dimensions to take into consideration: society, environment and economy, by defining their approaches: strong sustainability and low sustainability.

Two Fractional MPPT Algorithms with FOV and FSC controllers have been presented for the MPPT of a PV process in order to have a better sustainable development and to reduce the cost of electrical installations in different fields industrial, domestic.

To track the maximum power generation, a DC-DC Boost converter has been connected to the photovoltaic panel.

The results of simulation illustrate the characteristic of the proposed MPPT commands for tracking the maximum operating point despite of the temperature and the solar irradiation abrupt variations.

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