**ECHAHID HAMMA LAKHDAR UNIVERSITY - EL-OUED**
**Under the Supervision of the DGRSDT and in collaboration with the CRTI**
**International Pluridisciplinary PhD Meeting (IPPM'20)**
**23-26, 2020 1st Edition, February**
**Theme: Modern Technology and Fineness Life**

**4 à 5 pages**

# Gain-Adaptive PID-fuzzy MPPT for PV System

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**Abstract**

In this paper, in this paper, new improved maximum power point tracking based on Gain-Adaptive PID has been designed and studied using PID-fuzzy approach. PID controller is the most widely adopted method in industry due to many reason (simplicity, low cost), however, it's not perfect suitable for systems, fuzzy logic is used to enhance PID controller by adapting the PID parameters. This paper present PID-fuzzy as maximum power point tracking (MPPT) for photovoltaic system to maximize photovoltaic outputs (voltage, power and current).

***Keywords*** — fuzzy, PID, PID-fuzzy, MPPt, Dc-Dc boost.

## 1. Introduction

Since the last century, energy consumption has increased significantly. But our resources in oil, coal or gas are not eternal and it is also better not to burn them more so as not to aggravate the pollution. The solution is the use of renewable energies such as hydro, wind or solar power. Use of this type of energy has increased by 12.5% since 1990 [1].

Solar energy is one of the most important renewable energy sources. As opposed to conventional unrenewable resources such as gasoline, coal, etc..., solar energy is clean, inexhaustible and free. The main applications of photovoltaic (PV) systems are in either stand-alone (water pumping, domestic and street lighting, electric vehicles, military and space applications) [2-3] or grid-connected configurations (hybrid systems, power plants) .

Photovoltaic cells convert solar radiation directly into DC electrical energy. The basic material for almost all the photovoltaic cells existing in the market, which is high purified silicon (Si), is obtained from sand or quartz. Basically, three types of technology are used in the production of photovoltaic cells. Mono crystalline, polycrystalline and amorphous silicon.

Photovoltaic cell is a device convert the sun light into electrical energy and are considered to be one of the major ways of producing clean, however this devices does not always maximum efficiency due to the nonlinearity of their output current –voltage characteristic which is affected by the panel temperature and irradiance, Hence, the addition of a high performance maximum-power-point tracking, MPPT, power converter interface is the key to keeping the PV system operating at the optimum power point which then gives maximum efficiency[5-6]. We chose the photovoltaic module BP SX 150 BP Solar. The SX series BP Solar provides a cost effective photovoltaic power for a general purpose direct operating expenses direct current or current loads Alternating on UPS systems equipped. The module consists of 72 solar cells multi crystalline silicon connected in series to produce a maximum power of 150W in 25c and 1000 w/m2.

In industrial applications, the PID command by its simplicity of design is the most used command. The synthesis of a PID command consists in determining three parameters, namely: the proportional gain Kp, the integration gain Ki and the bypass gain Kd. For linear systems, the Ziegler-Nichols method [7] is the most used method to determine the gains Kp, Ki and Kd. On the other hand, for nonlinear systems there are no systematic methods to find these three gains. For this class of systems, the current trend is towards adaptive PID control, [8], and robust PID control [9], especially for the case of uncertain or disturbed nonlinear systems[10-13].

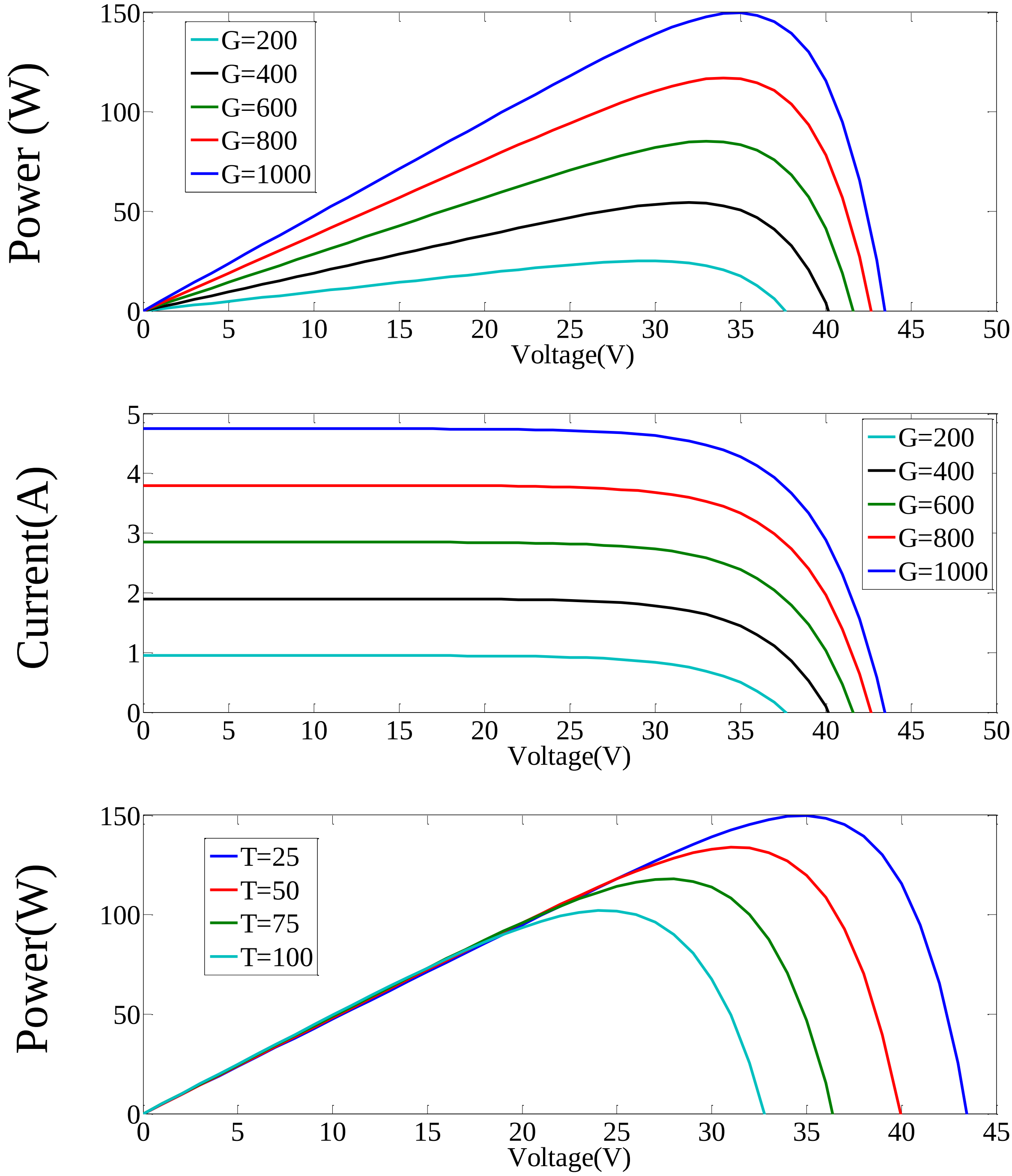
To improve the disadvantages of conventional PID such as peak and response time, an adaptive gain PID controller will be used to best approach the unknown ideal command. The three gains of this PID controller, i.e., the gain Kp, Ki and Kd will be considered here as the adjustable parameters. To do this, comparative study between PID classical and PID-fuzzy is presented as maximum power point tracking, the parameters of PID controller will be adapted with fuzzy controller in order to ameliorate the PID inconvenient and control the error between the photovoltaic output voltage and the reference voltage.

## 2. PV system modeling

The PV array current can be written by following equation [16]:

$$I_{PV} = N_p I_{ph} - N_p I_{rs}\left[e^{\frac{q(V+R_s I_{PV})}{AkTN_s}} - 1\right] - N_p \frac{q(V+R_s I_{PV})}{N_s R_{sh}} \qquad (1)$$

In order to study the effects of the irradiation and temperature to the BP SX 150(P-V, I-V characteristic), Fig 2 shows the effect of irradiation with fixed temperature and the effect of the temperature with fixed irradiation.



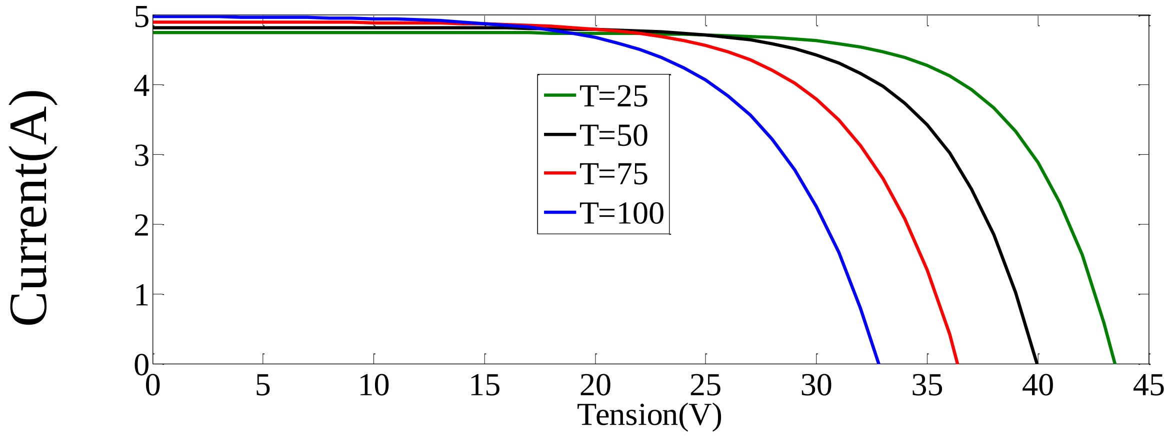



**Fig .01. P-V, I-V characteristic with irradiation changes and temperature changes.**

It's clearly that the power and current depend directly by the change of irradiation which means that they have proportional relation with irradiation. However, the effect to the voltage is lowly against the temperature which has inverse proportional relation to the power and voltage and it has little effect to the current.

## 3. Maximum power point tracking.

PID regulators meet more than 90% of industrial needs and the number of regulators installed in a petroleum plant, for example, is in the thousands. Unfortunately, despite the experience acquired over the years, the values chosen for the parameters P, I and D are not always satisfactory, nor adapted to the process to be regulated.

Conventional PID controllers are generally insufficient to control processes with additional complexities such as time delays, significant oscillatory behavior, therefore, one of the research directions in advancing the existing PID controllers is to combine fuzzy logic control technology with the conventional PID controller to obtain behavior better than that of a regular PID controller. Fig 3

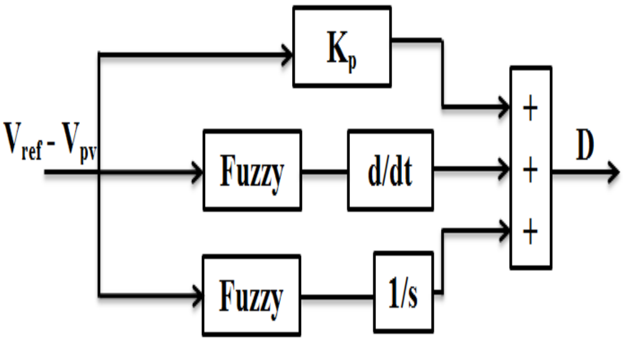


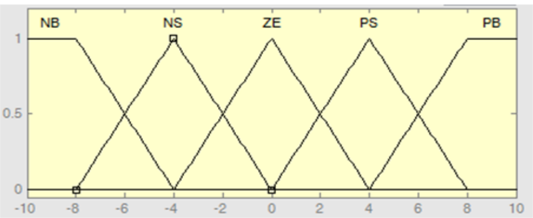

**Fig .02. Fuzzy PID controller.**

## 4. fuzzy-PID strategy.

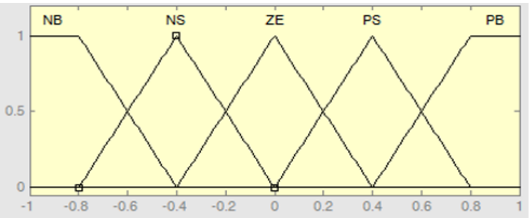
A fuzzy logic control (F-L-C) can be applied to nonlinear system it does not require accurate system parameters or complex mathematics models to achieve superior control performance, The four parts of FLC, fuzzification in the first than rule-base, inference and at last defuzzification [13-17], in this work the input of FLC is the change of PV array power and voltage and in the output is duty cycle, To compute the duty cycle the defuzzification used the center of gravity and the fuzzy inference is carried out by using Madani's method [17-18], Table 1 shows the corresponding input and output membership functions with E is the error and ΔE the derivate of error. The membership functions for the variable are shown in Fig 4 with five fuzzy subsets, which are denoted by NB (negative big), N (negative), ZE (zero), P (positive), and PB (positive big).

Table 01.fuzzy MPPT rules table.

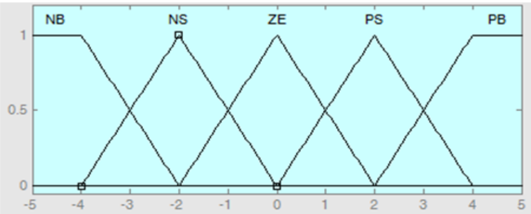
| | | $\Delta$E(k) | | | | |
|---|---|---|---|---|---|---|
| | | **NB** | **N** | **ZE** | **P** | **PB** |
| | **NB** | **NB** | **NB** | **NB** | **N** | **ZE** |
| | **N** | **NB** | **NB** | **N** | **ZE** | **P** |
| E(k) | **ZE** | **NB** | **N** | **ZE** | **P** | **PB** |
| | **P** | **N** | **ZE** | **P** | **PB** | **PB** |
| | **PB** | **ZE** | **P** | **PB** | **PB** | **PB** |




a : Membership Functions of the first Input Variable




b : Membership Functions of the second Input Variable




c : Membership Functions of the second Input Variable

**Fig .03. Membership Function for input and output of fuzzy MPPT controller**

## 5. Simulation results

The simulation results is presented using PV module, boost converter, MPPT (comparative between PID and PID-fuzzy), and resistive load as is shown in Fig 5, the fuzzy controller is used to adapt the ki and kd regulators as is shown in figs 9 and 10

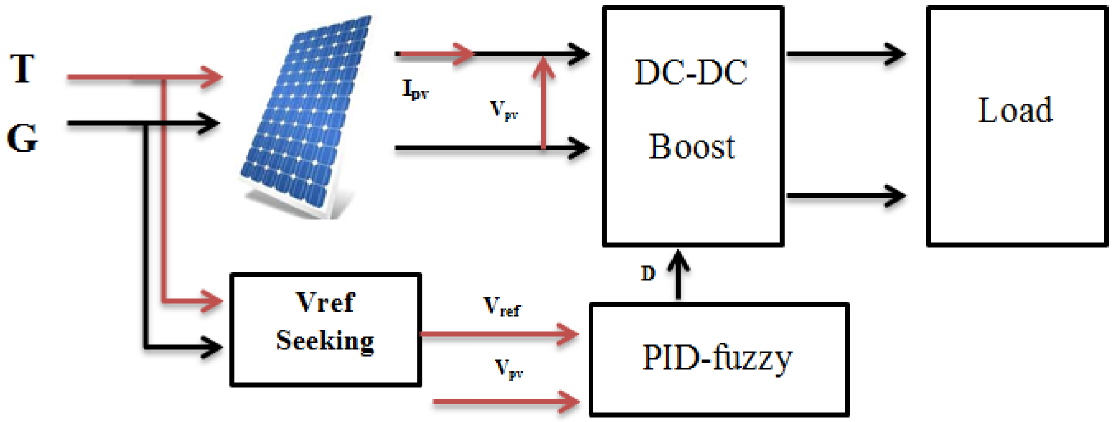



**Fig .04. PV system with PID-fuzzy MPPT.**

The reference voltage is calculated by the following equation:

$$V_{ref} = S_e \left( \frac{N_s AKT}{q} \log\left(\frac{I_{ph} - I_{ref} + I_0}{I_0}\right) \right) \tag{2}$$

With Se the number of series cellule.

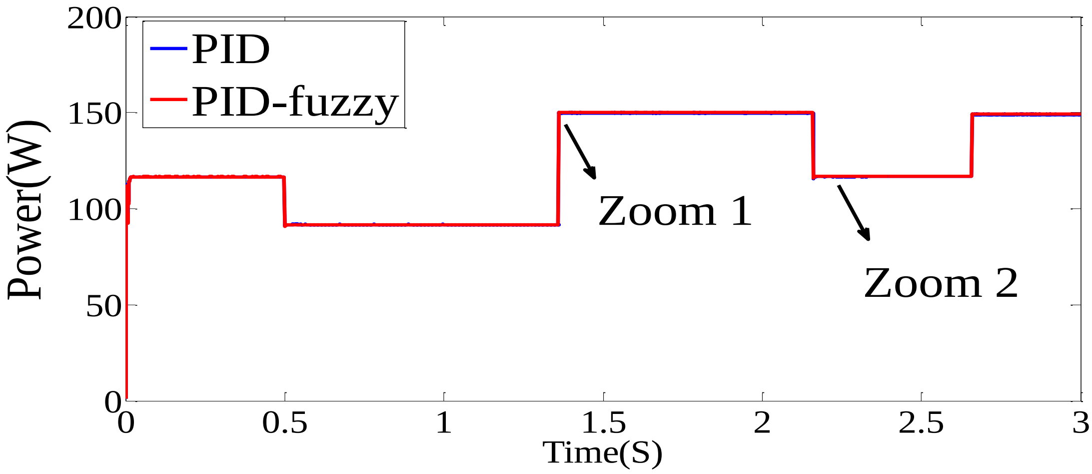



**Fig .05. PV output power with PID-fuzzy and PID classic MPPT**

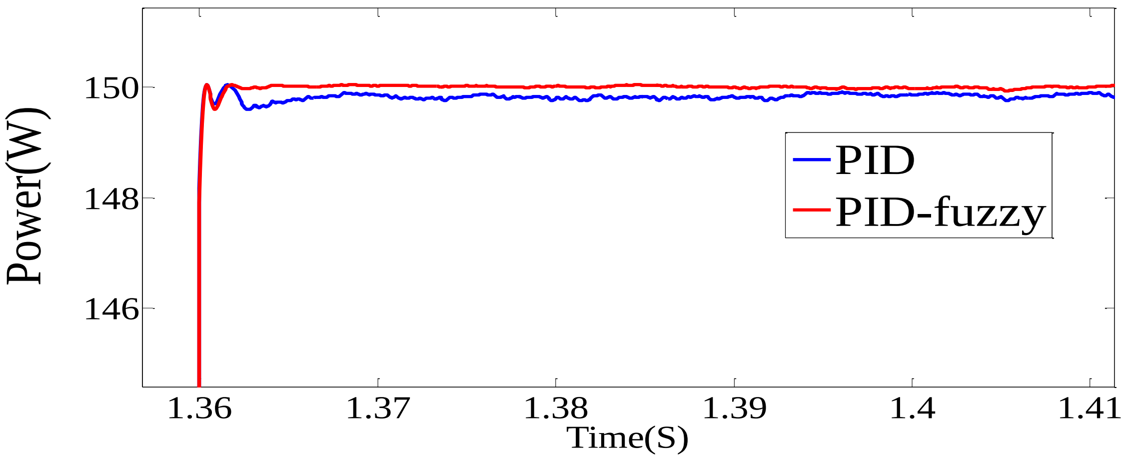



**Fig .06. PV output power with PID-fuzzy and PID classic MPPT In Zoom 1.**

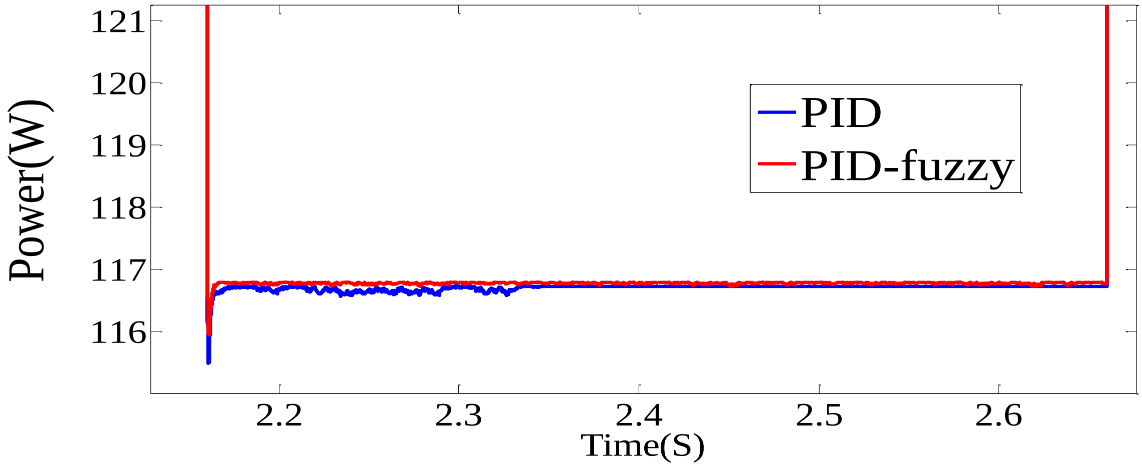


**Fig .07. PV output power with PID-fuzzy and PID classic MPPT In Zoom 2.**

As can be seen from Figs 5, 6 and 7, PID classic and PID-fuzzy follow succefully the maximum power point (MPP) for each irradiation changes and control the error between the reference voltage which is calculated by equation 2 and the output voltage of PV module, however, Figs 8 and 9 show that the PID-fuzzy minimize the oscillation and error of PID classic succefully for all insolation changes.

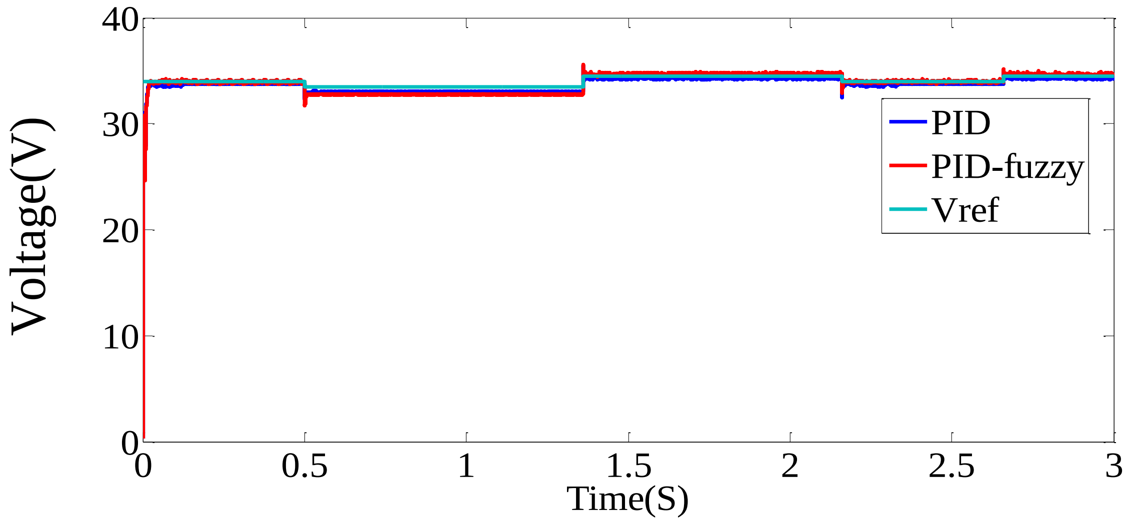


**Fig .08. PV output voltage with PID-fuzzy, PID classic MPPT and reference voltage.**

From fig 8, PID and PID- fuzzy follow the reference voltage for all irradiation steps with fast response time and little error, the equation 2 provides the reference voltage with high performance precision and zero oscillation, which is necessary for the control.

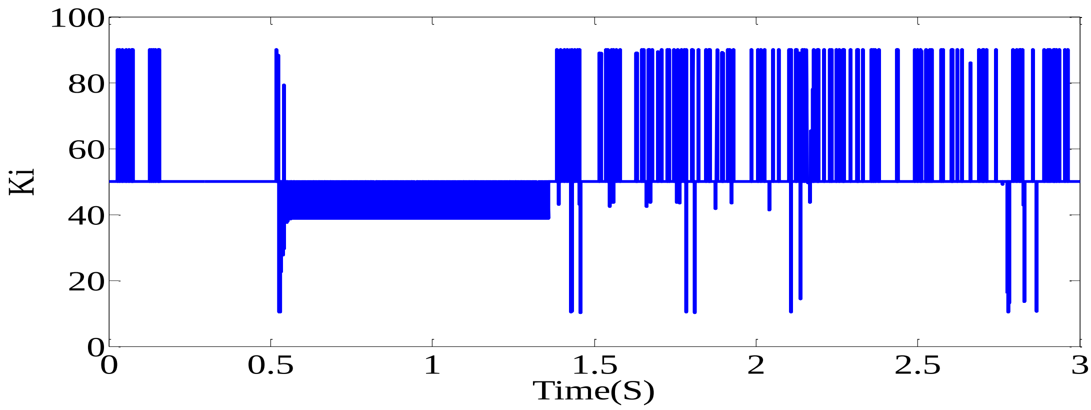


**Fig .10. $K_i$ adapted with fuzzy controller**

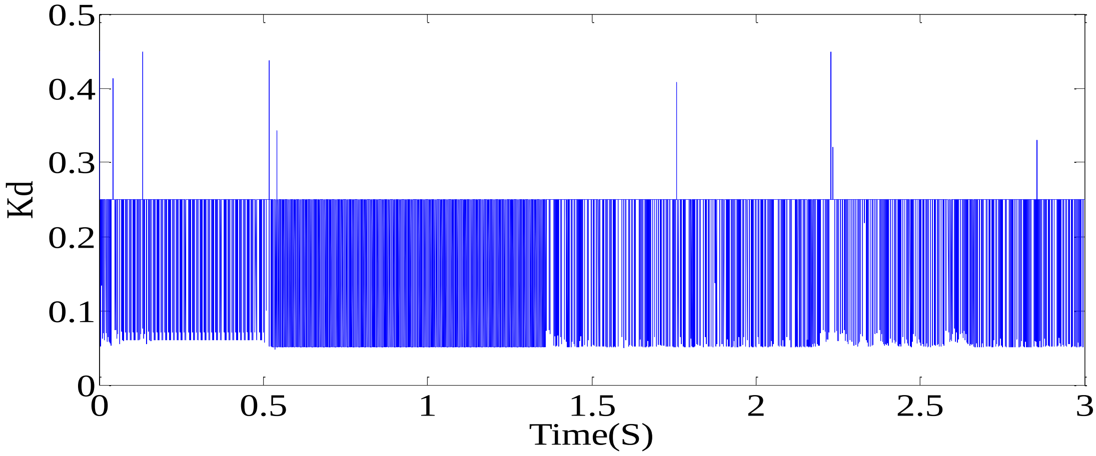



**Fig .11. $K_d$ adapted with fuzzy controller**

Figs 10 and 11 show the adaptation of the PID parameters (Ki and Kd) for all irradiation changes, this adaption enhance the PID classic performance in stability, error and also oscillation.

**6. conclusion**

In this paper, new MPPT controller combining neural-PID fuzzy techniques has been presented. The investigated PV system is based on BP SX 150 solar panel connected to DC-DC boost converter. Simulation results have established under several atmospheric conditions, in which many indexes performances have studied. The obtained results showed the high performance of the proposed method compared to PID classical methods especially in term of low ripple and low overshoot. Hence, the proposed MPPT controller can be selected as one of the most suitable MPPT for PV systems operating under variable conditions

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