ICREN-01/2013 February 16-17, 2013 Constantine, Algeria
First International Conference on Renewable Energies and Nanotechnology impact on Medicine and Ecology

A Neural Network MPPT For Photovoltaic Grid Connected System

Keddar Mohamed[a], Della Krachai Mohamed[a] and Midoun Abdelhamid[a]

[a] *Faculty of Electrical Engineering, Department of Electronics, University of Science and Technology USTO-MB, BP 1505 El Menaouar USTO 31000 Oran- Algeria.*

Abstract

A photovoltaic (PV) output power depends nonlinearly on the climatic changes such au solar irradiation and temperature, there exists a unique maximum power point (MPP). Thus, a maximum power point tracking (MPPT) controller is needed to continuously extract the highest possible power the PV panel to increase the efficiency of such as systems. Many papers have presented different techniques to track the MPP, Base on the conventional methods, as perturb and observe (P&O) and incremental conductance (INC), or artificial intelligence (AI) techniques which they are becoming useful as alternate approaches to conventional techniques and they can be integrated easily in such as systems. In this paper an artificial intelligence technique is presented based on a feed forward neural network. The inputs of the MPP tracker are the sort circuit current and the open circuit voltage of the photovoltaic panel, however the output is the optimum current. This output is taken as a reference by the control algorithm of the grid connected inverter, to inject an optimal sinusoidal wave form into the utility. It is proved through experimentally results that the algorithm has a good performances and very fast response to climatic changes. Simulation and experimental results are presented to prove the efficiency of the proposed technique.

Keywords: Photovoltaic, MPPT. Nnet, Fuzzy, Inverter

1. Introduction

In the recent year, the world demands for conventional energy sources like coal, natural gas and oil is increasing rapidly, on the other hand, these recourses are responsible for global warming and environment pollution. This fact drives societies towards the research and development of alternate energy sources to reduce dependency on conventional sources. Many renewable energy resources have been developed like solar, wind energy, fuel cell etc… [1].

Photovoltaic energy (PV) is now well developed, cost effective and is being widely used, while some others like fuel cells are in their advanced developmental stage. PV energy could be a good answer to that need. It is being used in space and terrestrial applications where it is economically competitive with alternative sources.

Grid-connected systems are used to supply the electric grid in order to reduce the electrical energy imported from the electric network. In such as system the dc output current from the PV array is converted into ac current and injected into the grid through an inverter. The very expensive part in such as system are the PV panels, so due to their high cost and the inherent non-linear current voltage (I–V) relationship, a maximum power point tracking (MPPT) algorithm is commonly used to maximize the power drown from PV modules under varying atmospheric conditions.

Many techniques have been proposed for tracking the maximum power point of PV arrays. The techniques vary in complexity, sensors requirements, convergence speed, cost, range of effectiveness, implementation hardware and popularity. For example the perturb and observe (P&O) method needs to calculate dP/dV to determine the maximum power point (MPP). Though it is relatively simple to implement, it cannot track the MPP when the irradiance changes rapidly; and it oscillates around the MPP instead of directly tracking it.

The incremental conductance method can track MPP rapidly but increases the complexity of the algorithm, which employs the calculation of dI/dV [2]. The constant voltage method which uses 76% open circuit voltage as the MPP voltage, and the short-circuit current method are simple, but they do not always accurately track MPP. Fuzzy logic control and neural networks have been applied as a soft computing techniques [3,4]. These techniques have the advantage to be robust and relatively simple to design as they do not require the knowledge of the exact model. They do require on the other hand the complete knowledge of the operation of the PV system by the designer [5].

Neural networks have been extensively used in optimization problems, they are used to perform MPP tracking and this optimizing the operation of the whole system.

In this paper a **Feed forward Neural Networks** are presented.

2. System overview

The main configuration of the system is shown in figure 01, it can be divided into two parts, the DC side the AC side. In the DC side we have the PVG and the MPPT calculator, in the AC side we have the inverter, the grid and the control algorithms.

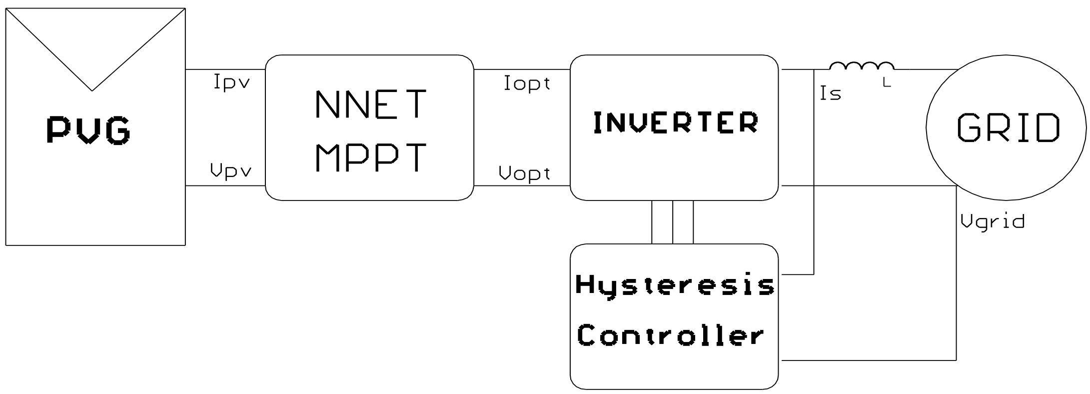

Fig. 1. System Overview.

2.1. Maximum power point tracker

Due to the high cost of the PVG and in order to extract the maximum power from them to increase the performance of the system we should use a MPPT controller. It is an algorithm frequently associated with a DC-DC converter (Buck, boost…). The main function of this block is to track the maximum power generated by the PVG and to force the system to operate in this optimal point.

The equivalent circuit shown in Figure 02 and described by Equation 01 represents a photovoltaic cell [6].

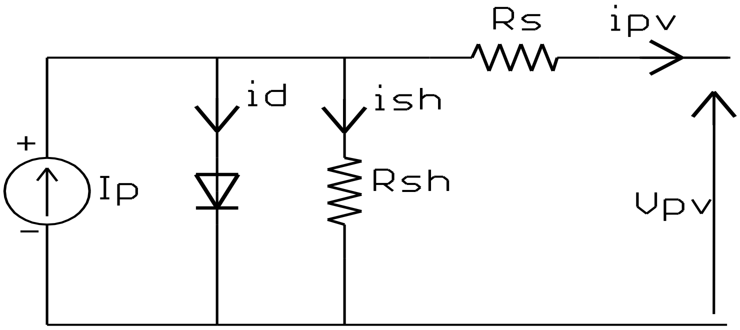

Fig. 2. PV cell equivalent circuit.

$I_{pv} = I_p - I_D - I_{sh}$

$$I_{pv} = I_p - I_0\,(\mathrm{Exp}(q(V_{pv} + R_s\,I_{pv})/NkT)-1)(Vpv+ R_s\,I_{pv})/\,R_{sh} \quad (1)$$

Where: I_p = Photocurrent [A].
V_{pv} = Terminal voltage of the cell [V].
I_D = Diode current [A].
I_0 = Saturation current [A].
I_{sh} = Shunt current [A].
N = Ideality factor.
q = Electron charge [C].
k = Boltzmann's constant.
T = Junction temperature [K].
R_s = Series resistance [Ω].
R_{sh} = Shunt resistance [Ω].

Figure 03 shows the Ipv Vpv characteristic of a PV cell where Voc is the open circuit voltage, Isc is the short circuit current and Mpp is the maximum power point. The system operating point moves along the Ipv-Vpv or Ppv-Vpv characteristics curves of the PV cell, it can be in the MPP, far from it or near it.

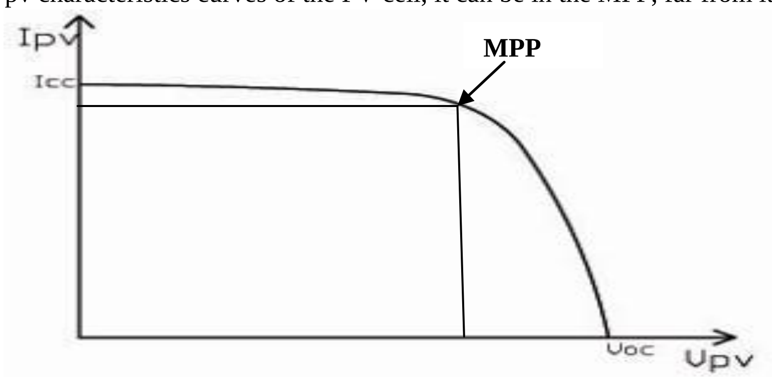

Fig. 3. Ipv-Vpv Characteristic of PV cell

These two characteristics are sensitive to the weather changes, especially to the irradiation and temperature changes. Increasing irradiation give a proportional increase in maximal power Figure 4.b. However, increasing temperature give a lower power Figure 4.a. This means that the Mpp changes due to weather changes and the operation point of the system. For that many MPP tracking (MPPT) methods have been developed and implemented [7]. Some methods are based on soft computing techniques as fuzzy logic, neural networks, Genetic algorithms or a combination between theme. In this paper the application of Feed forward Neural Networks is investigated through simulation and prototype realization.

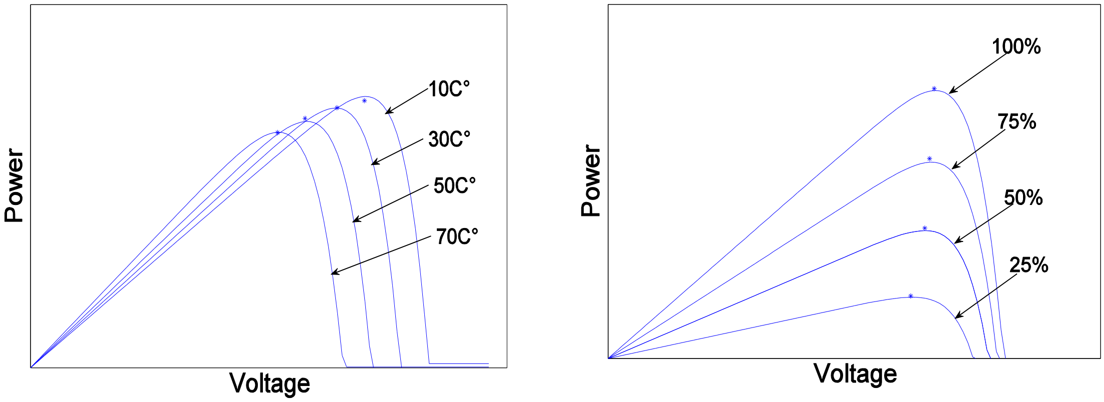

Fig. 4. Effects of temperature(a) and irradiation (b) on the PV cell.

2.2. Artificial neural networks

Artificial neural networks (ANN) have been successfully employed in solving complex problems in various fields of applications including pattern recognition, identification, classification, speech, vision, prediction and control systems. Today ANNs can be trained to solve problems that are difficult for conventional computers or human beings. ANNs, overcome the limitations of the conventional approaches by extracting the desired information directly from the experimental (measured) data.

The artificial neural network employed in this paper is shown in Figure 05. The number of nodes in each layer varies and is user dependent. The input variables can be all PV array parameters like open circuit voltage (Voc), temperature, irradiance, short circuit current (Isc) etc..., or any combination of these. The output is usually one or several reference signal(s) like a duty cycle signal used to drive the power converter to operate at or close to the MPP, the optimum current, the optimum voltage etc... In our case we have used three layers, input layer which contain two inputs the open circuit voltage (Voc) and the short circuit current (Isc) , the output layer that contain the optimum current (Iopt) and , hidden layer that contain tree nodes.

A simplified procedure for the learning process of an ANN is as follows:

-Provide the network with training data consisting of patterns of input variables and target outputs.

-Assess how closely the network output matches the target outputs. Adapt the connection strength (i.e., weights) of the various neurons.

-Continue the process of adjusting the weights until the desired accuracy level is achieved.

Usually a back propagation-learning algorithm is used.

The MPPT controller takes Voc and Isc as inputs to detect the maximum power point and generates Impp, to track the maximum power point during the operation of our system, the optimum current is taken as a reference and multiplied by a sinusoidal wave to generate a sinusoidal optimum current reference Figure 06.

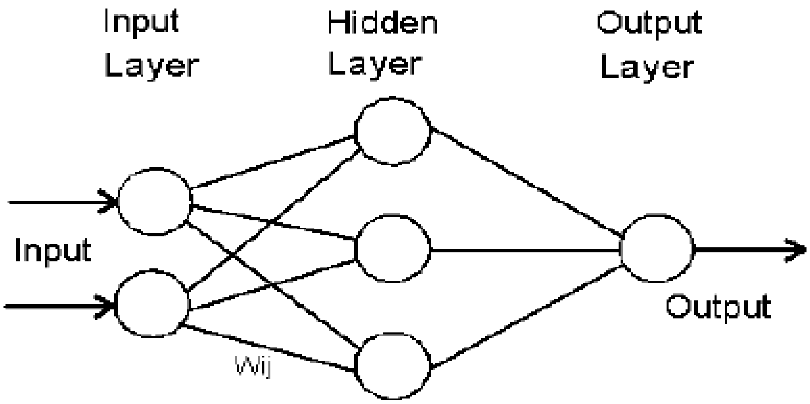

Fig. 5 The proposed Nnet architecture

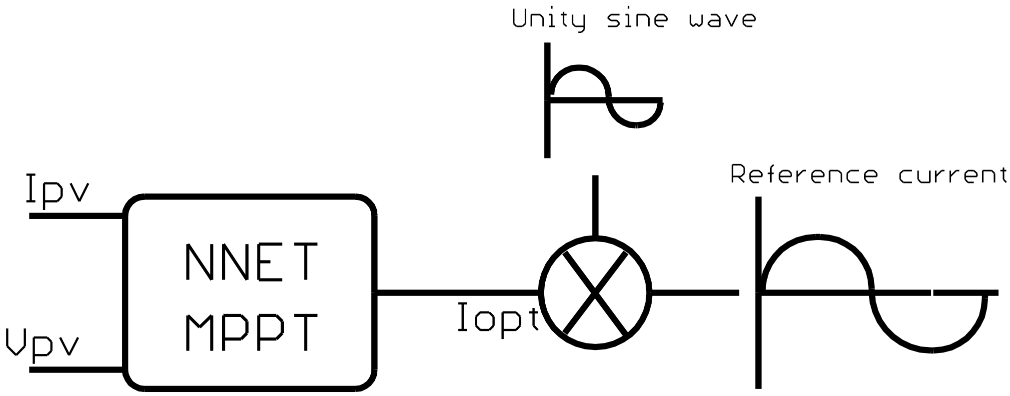

Fig.6 Generation of the reference current

Then, this sinusoidal optimum current is taken as reference by the hysteresis current control algorithm to generate the driving signals if the inverter power switches.

2.3. Inverter

A single phase H-bridge PWM inverter shown in Figure 07 was simply designed to show whether the proposed system operate at the maximum power point. There were four power switches (IRFP260) with internal anti-parallel diodes. Two switches in each leg are complementary to prevent a short circuit in the PVG, so we have introduced a delay in the switching angles between each two switches. The power switches they were driven by two driver circuits which were electrically isolated from the power circuit using the optocouplers (HCPL). The driver circuits were controlled by a Microchip (PIC) (18F458).

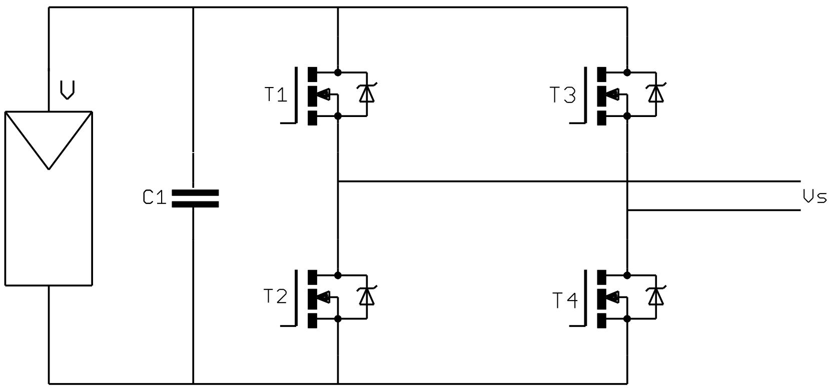

Fig .7 H bridge inverter

2.4. Control algorithm

A real time control algorithm based on interrupts has been used in order to grantee the calculation of the optimum current and generate the power switching signals.
The flowchart of the control algorithm is shown in figure 08.

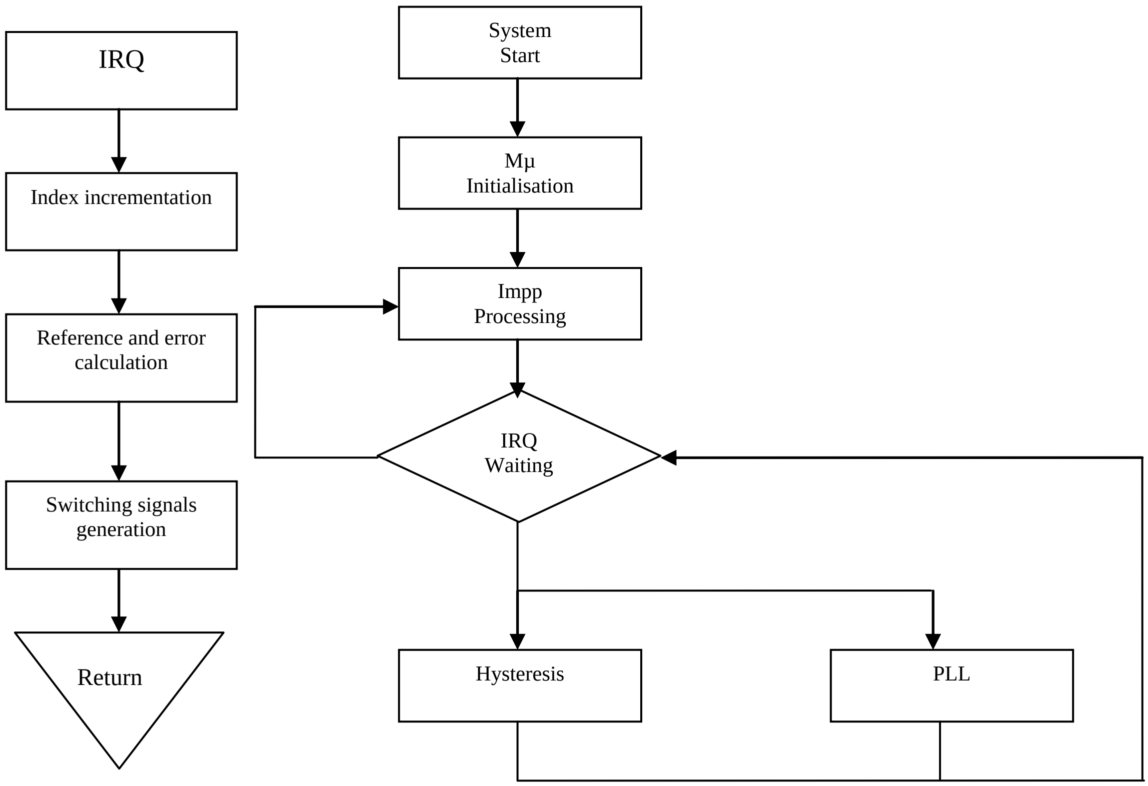

Figure 08 Control algorithm flowchart.

3. Algorithm implementation

To implement this algorithm in the microcontroller we used two interrupt routines with priority. The first interrupt is a hardware one and it detects the zero crossing of the grid sine wave form to synchronize the injected current with the grid. This interrupt has the highest priority.

The second one generates the switching states for the inverter power switches and it is a software interrupt generated by an overflow of a timer.

To generate a sinusoidal optimum reference current, a unity sinusoidal wave form was discredited into 256 values and stored in the EEPROM, when the maximum power point tracker algorithm calculate the Iopt, this Iopt is multiplied by the unity sinusoidal wave form to have a sinusoidal reference current.

When an interruption occurs, the algorithm tests witch interrupt occurs, if it is the timer one we call the hysteresis function to generate the switching states, after that an index is increment to the next value of the unity sinusoidal wave form.

If the second interrupt occurs we reset the index variable to synchronize the inverter output with the grid utility and we call the hysteresis function.

In the hysteresis function the Iopt is multiplied by the indexed value of the unity sinusoidal wave form, then, this reference is compared to the measured inverter output current. The difference between them (the error) is compared with the hysteresis band to generate the switching states.

4. Experimental results

In this section, experimental tests are provided based on the concept previously exposed in order to verify the efficiency of the developed system. The test bench is composed of PV panel, the MPPT tracker based on a 18F458 Microchip microcontroller and the H bridge inverter.

Figures 09 and 10 show the test in a sunny day, we can see that the optimum current follows the short circuit current. This verifies the efficiency of the developed algorithm.

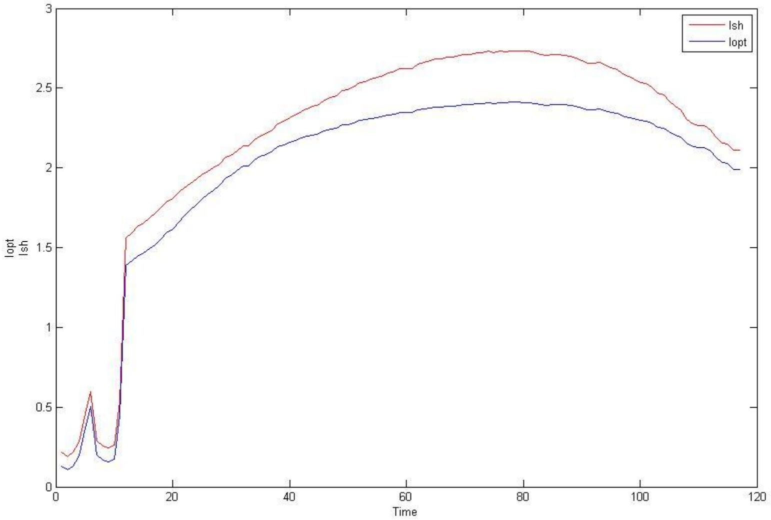

Fig.09 Experimental test of the MPPT in a sunny day

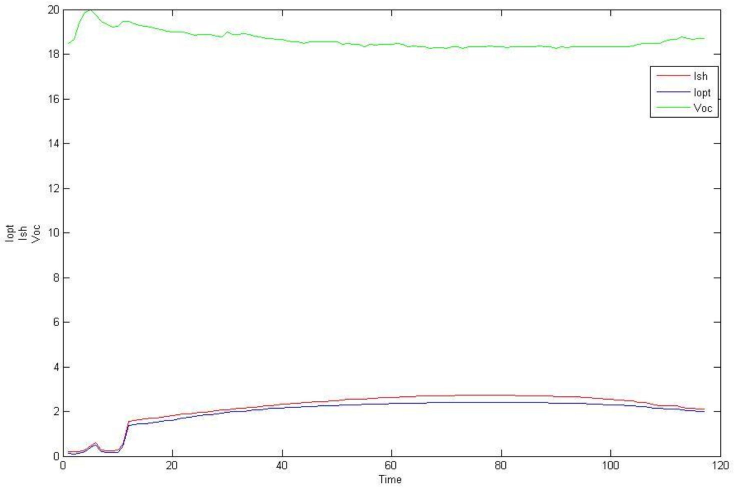

Fig.10 Experimental test of the MPPT in a sunny day

Another test was performed to verify the robustness of the algorithm, it is shown in figure 11 and 12 ,the optimum current increase when the short circuit current increase and vice versa. This confirms the robustness of the developed algorithm under climatic changes.

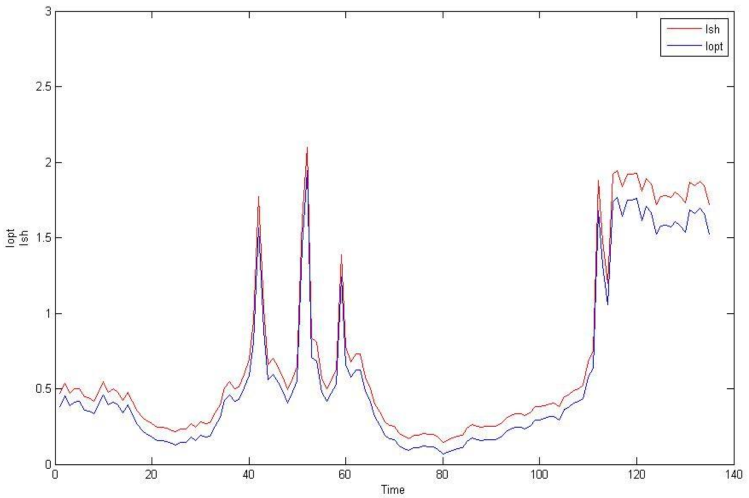

Fig.11 Experimental test of the MPPT in a cloudy day

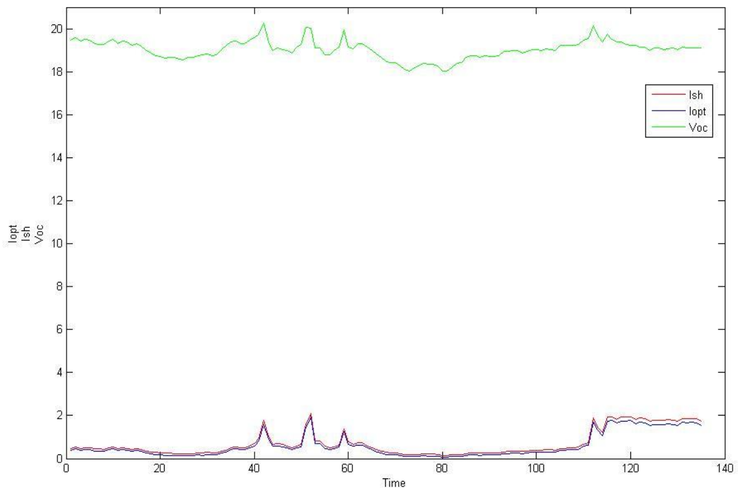

Fig.11 Experimental test of the MPPT in a cloudy day

5. Conclusion

A neural maximum power point tracker was presented in this paper. This tracker was used to generate the PV optimum current under solar insulation and ambient temperature changes, this current has been taken as a reference by the grid current inverter. The performed tests demonstrate the effectiveness and robustness of the developed algorithm.

References

[1] Nabil A. Ahmeda, Masafumi Miyatake , A novel maximum power point tracking for photovoltaic applications under partially shaded insolation conditions.

[2] N. Ammasai Gounden*, Sabitha Ann Peter, Himaja Nallandula, S. Krithiga, Fuzzy logic controller with MPPT using line-commutated inverter for three-phase grid-connected photovoltaic systems .

[3]Mohamed DELLA KRACHAI, Abdelhamid MIDOUN, High efficiency maximum power point tracking control in photovoltaic-grid connected plants. ISSN 1335-8243 ©, Faculty of Electrical Engineering and Informatics, Technical University of Košice, Slovak Republic, 2007.

[4]Adel Mellit , Soteris A. Kalogirou, ANFIS-based modelling for photovoltaic power supply system: A case study. Renewable Energy 36 (2011) 250e258, 2010.

[5]F.Bouchafaal, D.Beriberl, M.S.Boucherit2, Modeling and simulation of a gird connected PV generation system With MPPT fuzzy logic control.

[6]Keddar Mohamed, Della Krachai Mohamed and Midoun Abdelhamid, A Multilevel Inverter for Photovoltaic Grid Connected System. First International Symposium on Environment Friendly Energies in Electrical Applications (EFEEA2010). 02-04 November 2010. Algeria.

[7]Trishan Esram, Patrick, Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques. 2005.