

# Modeling and Simulation of an Intelligent Power Conversion System for Photovoltaic Generation

T. Hemanth Kumar, P. Swaminathan, M. Mohanraj

**Abstract**— This paper represents a simulation and design of two types of Maximum Power Point Tracking (MPPT) algorithm methods is proposed. Here the PV system is composed to a boost converter which can perform with those algorithm methods. In this the algorithm methods are Perturb and Observe (P&O) and Probability of Neural Network (PNN). The probability of neural network which can be deals with the neurons and can be included the neural based Maximum Power Point Tracking. By using these different MPPT techniques we can maximize the PV array output which can be track continuously from the solar panel's temperature and irradiation. These MPPT techniques can be explained by using the MATLAB.

**Key Words**— Solar Module, Maximum Power Point Tracking (MPPT), Perturb and Observe (P&O) and Probability of Neural Network (PNN).

## I. INTRODUCTION

In a Renewable Energy, Solar Energy is the regular use of energy within a less period of time without investing any materials for input. Because of this environmental eco-friendly in nature solar energy was gets populated. The main advantage of this Solar Energy is that it has store maximum energy, conserves energy for a long time, no need to fix any parts permanently [1]. Photo Voltaic can be used in many applications are like solar street lightning, water pumping for irrigation purpose, uses for Domestic Appliances, and grid connections. Because of increasing the usages of Fossil Fuels in worldwide increasing the Green House Gases. For this we are moving to the Renewable energy resources. Renewable sources can play a major role in replacing the fossil fuel. Solar energy gets populated because of it does not polluted the Earth's environment.

## II. MODELING OF PHOTOVOLTAIC CELL

Through the Sun's radiation Photovoltaic system converts sunlight into electric power. Photovoltaic system is having the basic device of a Photovoltaic cell. Combination of number of cells together forms a panel or a module. Similar to this number of solar cells are connected in series/ parallel together form an array [2]. All though initial stage of solar cells is very expensive but while using it regularly the cost will become minimizes. The design of a solar system can be designed to operate at maximum power output at different temperatures.

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The performance of a solar cell can be depending on the different materials that are designed on the system. Basically the Photovoltaic system is a p-n junction semiconductor diode. It is having the different types of materials for making the photovoltaic system i.e. polycrystalline and monocrystalline silicon materials. But these materials are having the high efficiency and good conductance which can be as shown in fig 1.

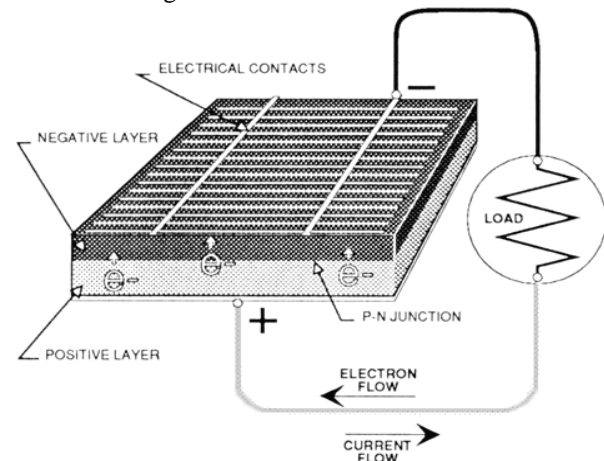


Fig. 1 Structure of PV cell

## III. MATHEMATICAL MODELING AND EQUIVALENT CIRCUIT OF PHOTOVOLTAIC CELL

Fig. 2 shows the equivalent circuit for a solar cell. It can be regarded as a non-linear current source. Mainly the performance can be depending on the cells, cell temperature and irradiation. The following equation can be mainly describes the V-I characteristics of a Photovoltaic cell.

$$I = I_{pv\ cell} - I_{o\ cell} \left[ \exp\left(\frac{qv}{AKT}\right) - 1 \right] \quad (1)$$

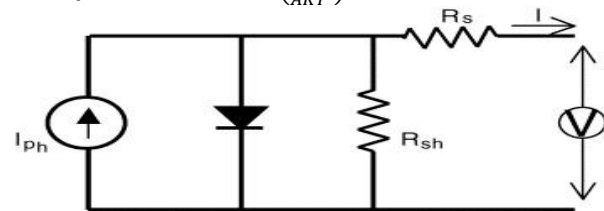


Fig. 2 Equivalent electric circuit of photovoltaic cell

In the above equation (1) the terms can be referred as follows:

$I_{o\ cell}$  is the reverse saturation or leakage current of the diode,  $I_{pv\ cell}$  is the current generated by the incident light (it is directly proportional to the Sun irradiation),



$I_d$  is the Shockley diode equation,  
 $q$  is the Shockley diode equation,  
 $k$  is the Boltzmann constant ( $1.3806503 \times 10^{-23}$  J/K),  
 $T$  (in Kelvin) is the temperature of the  $p-n$  junction,  
 $A$  is the diode ideality constant,  
 $e$  is the electron charge ( $1.602 \times 10^{-19}$  C),  
 $T$  is reference cell operating temperature ( $20^\circ\text{C}$ ),  
 $v$  is the cell output voltage,

**CIRCUIT & SIMULATION RESULTS:**

The mathematical model of the generated current in the photovoltaic system can be represented by the following equations:

$$I = I_{ph} - I_0(e^{q(V + IR_s)/nkT} - 1) \tag{2}$$

$$I_{ph} = I_{ph}(T_1)(1 + K_0(T - T_1)) \tag{3}$$

$$I_{ph}(T_1) = G * ISC(T_1;nom)/G(nom) \tag{4}$$

$$K_0 = (ISC(T_2) - ISC(T_1))/(T_2 - T_1) \tag{5}$$

$$I_0 = I_0(T_1) * (T/T_1)^{3/n} * e^{-qV_g/nk*(1/T-1/T_1)} \tag{6}$$

$$I_0(T_1) = ISC(T_1) / (e^{qV_{oc}(T_1)/nkT_1} - 1) \tag{7}$$

$$R_s = -dV/dI_{Voc} - 1/XV \tag{8}$$

$$XV = I_0(T_1) * q/nkT_1 * e^{qV_{oc}(T_1)/nkT_1} \tag{9}$$

In the fig. 3 it has shown the modeling of photovoltaic model in matlab simulation. It is a polycrystalline silicon solar cell of 60w maximum power. The model of pv cell was implemented in matlab program. The cell includes the open circuit voltage ( $V_{oc}$ ), short circuit current ( $I_{sc}$ ), Temperature ( $T$ ) and Irradiation ( $G$ ) [4].

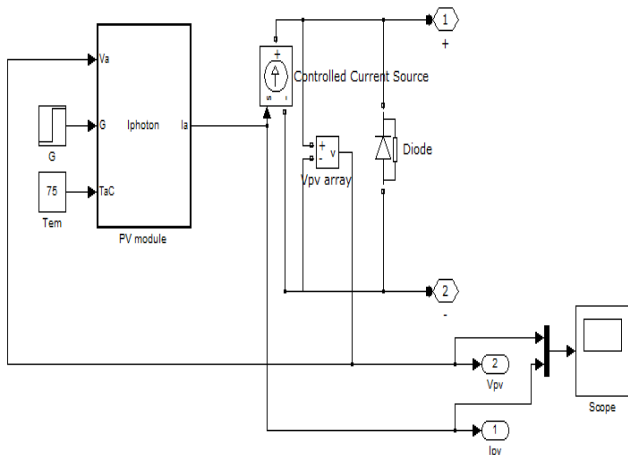


Fig. 3 modeling of a PV panel

The characteristics of P-I & V-I of a photovoltaic cell can be explained as follows:

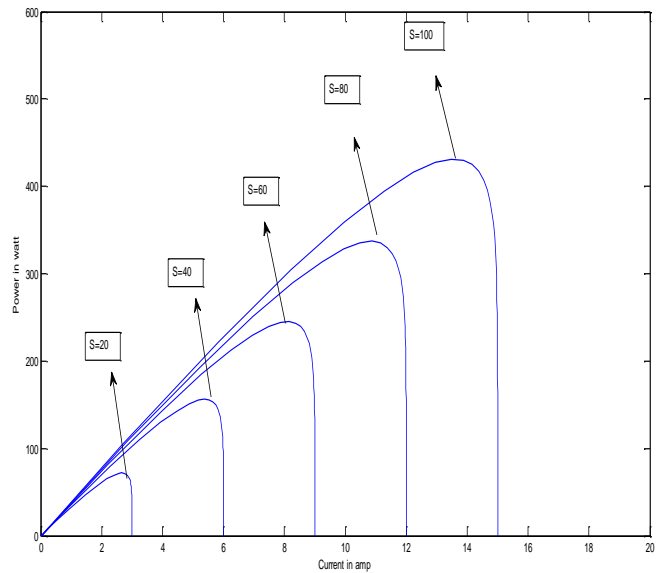


Fig. 4 P-I characteristics of photovoltaic cell

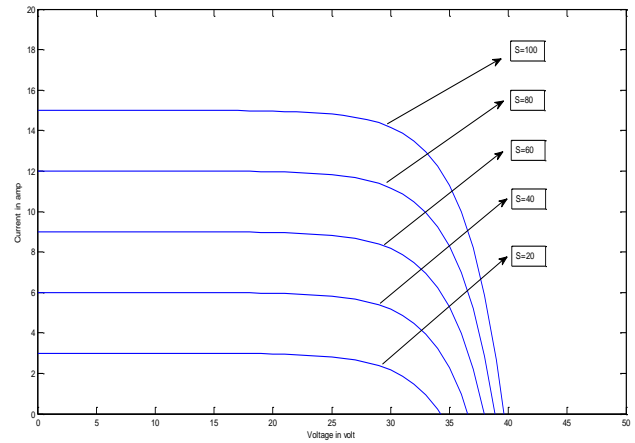


Fig. 5 V-I characteristics of photovoltaic cell

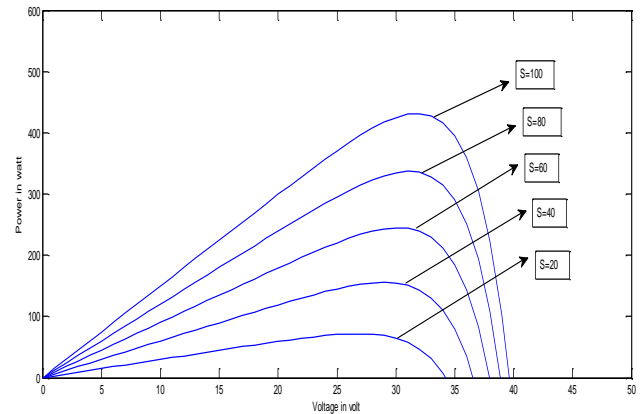


Fig. 6 P-V characteristics of photovoltaic cell

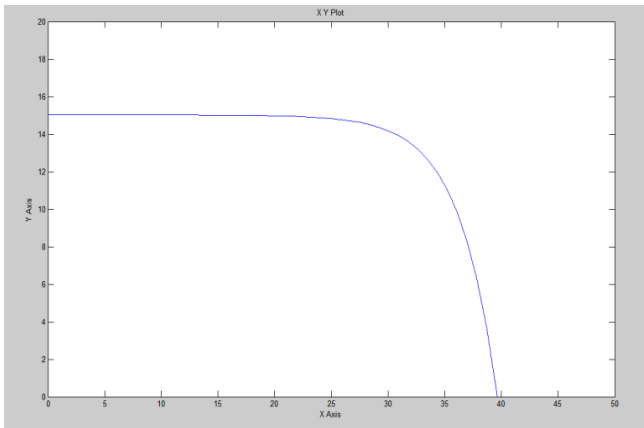


Fig. 7 Simulated output of a photovoltaic cell

IV. PERTURB & OBSERVE MPPT ALGORITHM (P&O):

In a photovoltaic application the MPPT methods are necessary because of the variation of irradiation and temperatures using the different MPPT methods require tracking the maximum power from the solar array. Earlier it was having many methods to find the maximum Power from the solar array. But these techniques can differ in many ways such as cost, sensors, complexity, tracking correctly when it is in irradiation or change in temperature [4]. Among all these the P&O and incremental conductance are populated. P&O method is also known as “Hill-Climbing” method. These are having the advantages and easy implementation in real time and also having some of the drawbacks.

Some of the other techniques based on the different methods such as fuzzy logic control, neural network, fractional open circuit voltage or short circuit current, current sweep, etc.

The P&O and incremental conductance are based on the “Hill- Climbing” principle. It can be moves to the operating point of the solar array in which the power increases. These methods are gets populated because of the tracking the power and easy to implement. The advantageous thing is that it is having the simplicity and needs low computational power. Oscillations around the MPP tracking or tracking wrong losing some power. All these drawbacks are explained later modifying with some other techniques.

This method is having two names such as P&O and Hill-Climbing, but when implementing in real time it depends on same algorithm. Hill-climbing involves a perturbation on the duty cycle of the power converter and P&O a perturbation in the operating voltage of the DC link between the PV array and the power converter. From the left of the MPP incrementing the voltage increases the power whereas on the right decrementing the voltage increases the power.

If there is an increment in the power, the perturbation should be kept in the same direction and if the power decreases, then the next perturbation should be in the opposite direction. The process shall be continuing which can be reach upto the maximum level. Depend on these this algorithm fig. 8 was implemented.

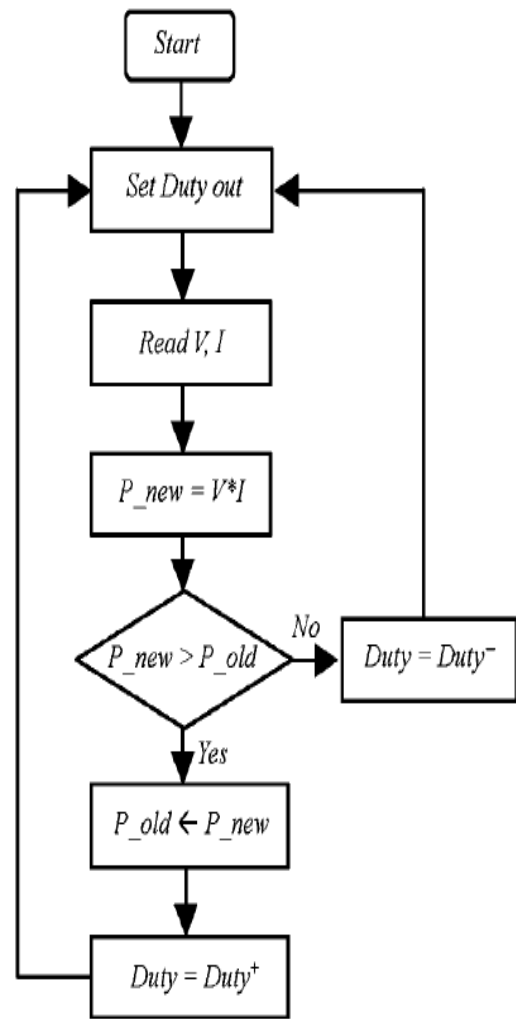


Fig. 8 flowchart of the P&O Algorithm  
The circuit diagram fig. 9 and characteristics fig. 10 of P&O method are as follows:

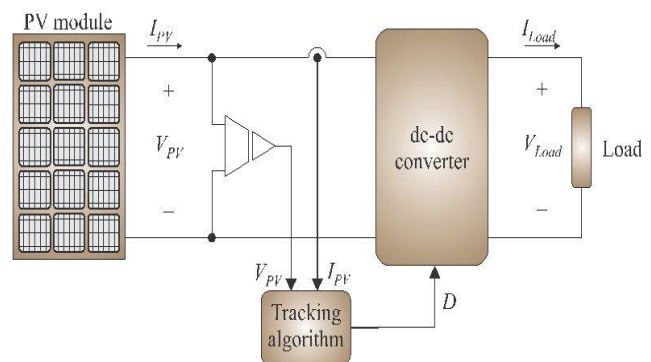


Fig. 9 Circuit of Perturb & Observe method

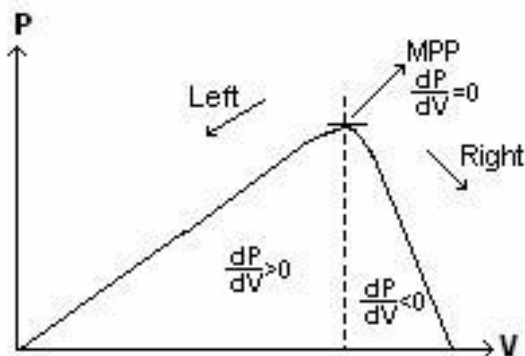


Fig. 10 P-V characteristics of P&O method

SIMULATION RESULTS OF P&O METHOD:

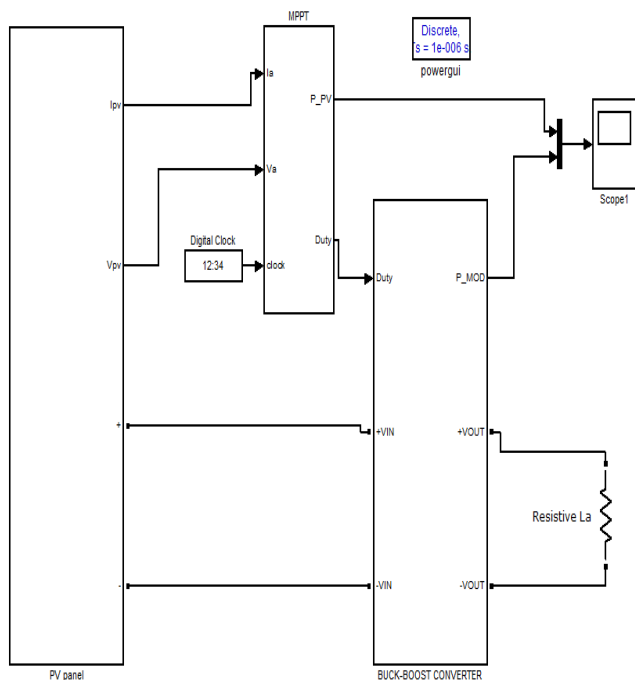


Fig. 11 Circuit diagram of P&O method

In the above circuit diagram fig. 11 the solar pv panel can be connected to the Maximum Power Point Tracking (MPPT) with that it can be connected to the boost converter. From there a load was connected. In the MPPT block the algorithm of the P&O method can be written for tracking the maximum power at a particular radiation. The simulated output of a P&O algorithm as shown in fig. 12:

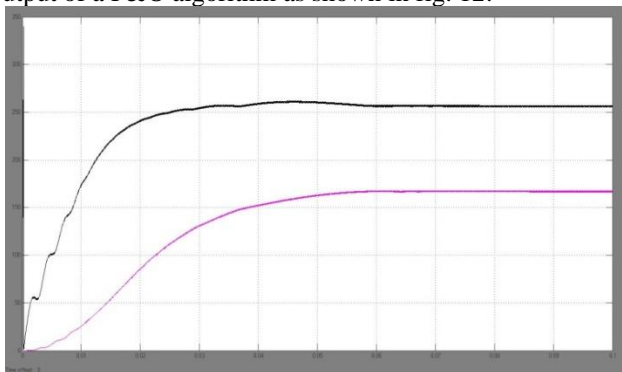


Fig. 12 Simulated output of P&O algorithm

The drawbacks of this technique are after reaching the particular position or a maximum power it cannot be stable; it always oscillates at a maximum point or a position. At that time it can loss some amount of energy. But in incremental Conductance after reaching the particular position it can be stable. To overcome these drawbacks some of the improved methods can be implemented named as “dP-P&O” which can perform additional measurement without perturbation in current and voltage.

IV. PROBABILISTIC NEURAL NETWORK (PNN)

Another MPPT method well adapted to microcontrollers is Neural Networks. They came along with Fuzzy Logic and both are part of the so called “Soft Computing”. The simplest example of a Neural Network (NN) has three layers called the input layer, hidden layer and output layer. More complicated NN’s are built adding more hidden layers. The number of layers and the number of nodes in each layer as well as the function used in each layer vary and depend on the user knowledge. The input variables can be parameters of the PV array such as Voc and Isc, atmospheric data as irradiation and temperature or a combination of these. The output is usually one or more reference signals like the duty cycle or the DC-link reference voltage.

The performance of the neural network can be depending by using the hidden layers and the well trained of neural network [6]. The links between the nodes are weights which can be denoted as Wij. The weights can be trained in the training process. To execute this training process, data of the patterns between inputs and outputs of the neural network are recorded over a lengthy period of time, so that the MPP can be tracked accurately. The neural network can be as shown in the fig. 13

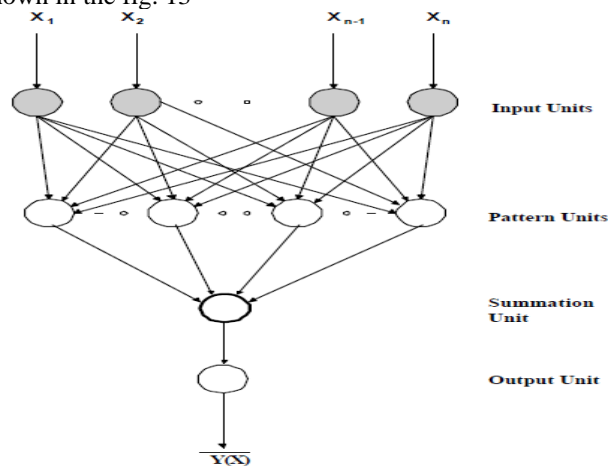


Fig. 13 Neural Network

A probabilistic neural network (PNN) is a feed forward neural network, which was derived from the Bayesian network and a statistical algorithm called Kernel Fisher discriminate analysis [6]. The operations are organized into a multilayered feed forward network with four layers which can be named as:

- Input layer
- Hidden layer
- Pattern layer/Summation layer
- Output layer

Each neuron in the input layer represents a predictor variable. The input neurons feed the values to each of the neurons in the hidden layer. The pattern layer contains one neuron for each case in the training data set. It stores the values of the predictor variables for the case along with the target value [6]. The output layer compares the weighted votes for each target category accumulated in the pattern layer and uses the largest vote to predict the target category.

**ALGORITHM OF PROBABILISTIC NETWORK**

We are given the exemplar feature vectors that make up the training set. For each one we know the class to which it belongs. The following sets up the PNN.

- Ste 1. Read in the file of exemplar vectors and class numbers
- Step2. Sort these into the K sets where each set contains one class of vectors
- Step3. For each k define a Gaussian function centered on each exemplar vector in set k define the summed Gaussian output function Once the PNN is defined, then we can feed vectors into it and classify them as follows.
- Step1. Read input vector and feed it to each Gaussian function in each class
- Step2. For each group of hidden nodes, compute all Gaussian functional values at the hidden nodes
- Step3. For each group of hidden nodes, feed all its Gaussian functional values to the single output node for that group
- Step4. At each class output node, sum all of the inputs and multiply by constant
- Step5. Find maximum value of all summed functional values at the output nodes.

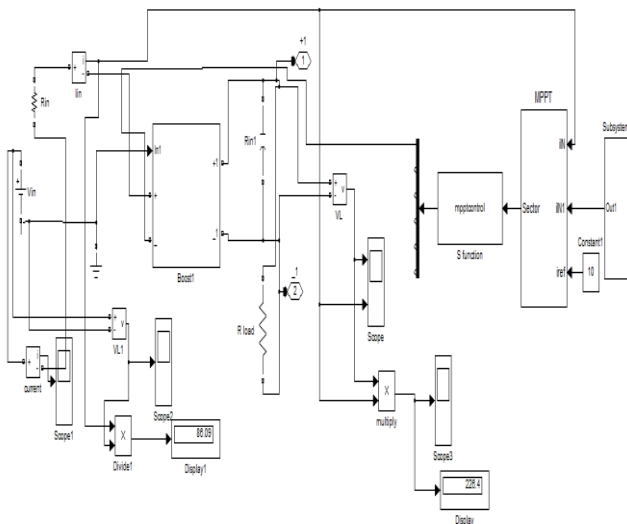


FIG. 14 Circuit Diagram of PNN

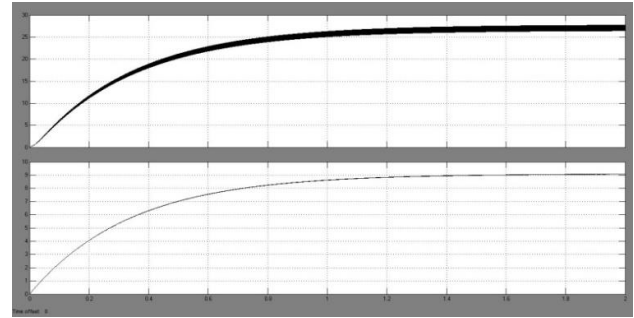


Fig. 15 V-I curve of PNN

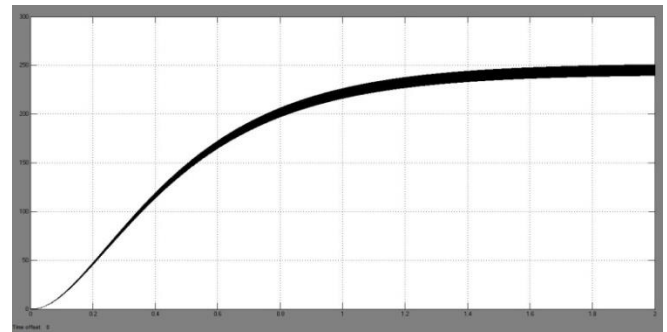


Fig. 16 Current curve of PNN

**COMPARISON OF DISADVANTAGES & ADVANTAGES OF P&O AND PNN METHODS:**

In the P&O method after tracking the maximum power at a steady state position it cannot be stable, it will oscillates the tracking the power. In that some amount of energy was losing. But in the PNN method it should not be oscillate. It does not have any local minima issues [8]. It is an inherently parallel structure with a fast training process. It is more accurate than multilayer perceptron network. It requires large memory and a slow execution process are the disadvantages of PNN [8].

**V. CONCLUSION**

An intelligent management of a grid-connected PV system characterized by the following software features: a DC/DC boost converter performing the MPPT on the basis of the online estimation of the solar irradiance by the probabilistic neural network As far as the tracking of the maximum power is concerned, a comparison between the proposed approach and a classical P&O technique has been done on a real irradiance profile on a daily scale, showing the capability of the proposed MPPT to generate more energy in the amount of 13%.

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