Neuro Fuzzy based Peak Power Point Tracking for Solar Photo Voltaic System

Kalika S.
Research Scholar
Shri Venkateshwara University,
Gajraula/U.P./India

L. Rajaji
Professor, Department of EEE
P.B.College of Engineering
Chennai./India

Subhash Gupta
Shri Venkateshwara University
Gajraula/U.P./India

ABSTRACT

Photovoltaic systems are so versatile that it can supply any electric power need and are used for numerous applications. Recent advancements in efficiency and cost reduction have made photovoltaic systems economically competitive with traditional power sources. This paper presents an intelligent method of peak power point tracking for photovoltaic systems based on tracking the peak power point by measuring the voltage and current of the solar array to control a buck-boost DC to DC converter. Result analysis shows that the neuro-fuzzy controller can deal with different load and weather conditions and deliver more power from the photovoltaic systems. To increase the efficiency of PV panels, it must operate around the peak power point which is influenced by cell temperature and sun irradiation. A controller therefore is needed to find the peak power point and control PV output voltage according to peak power point voltage. The aim of the paper is to design and analyze neural fuzzy controller for controlling the PV system output voltage.

Keywords

Maximum Power Point, Neuro-fuzzy , Photovoltaic, PPPT, PV module.

I. INTRODUCTION

The use of new photovoltaic solar cells has emerged as an important solution in energy conservation and demand-side management during the last decades. Because of their initial high costs, photovoltaic solar cells have not yet been an attractive alternative for electricity users who are able to buy cheaper electrical energy from the utility grid. However, they have been used extensively for water pumping and air conditioning in remote and isolated areas where utility power is not available or is too expensive to transport. Although solar cell prices have decreased considerably during the last years due to new developments in the film technology and manufacturing process [1], PV arrays are still considered rather expensive compared with the utility fossil fuel generated electricity prices [6]. After building such an expensive renewable energy system, the user naturally wants to operate the PV array at its highest conversion efficiency by continuously utilizing the maximum available output power of the array. The electrical system powered by solar cells requires special design considerations because of the varying nature of the solar power generated resulting from unpredictable changes in weather conditions, which affect the solar radiation level as well as the cell operating temperature. To improve the efficiency of PV panels, it must operate around the peak power point [2]. Maximum power point (MPP) or peak power point (PPP) is influenced by the cell temperature and solar irradiation. Changes in temperature of the cells or irradiation will shift the point of working PV which will result in the efficiency of PV will be reduced, so that the necessary controls to adjust the point of working PV remains in MPP continuously, that is called Maximum Power Point Tracker [1][2].

Controlling of Point of work via MPPT can be done by regulating the duty cycle converter circuit that connects the PV with the load.

Several methods of control can be used, among others Incremental Conductance, paracitic capacitance and voltage constant, but these methods require a high cost and complex arrangement [4]. Compared with P&O method, the use of artificial intelligent MPPT also produce a better performance to changing environmental conditions [8]. Neural network with Multilayer Perceptron back propagation is used as an estimator to determine the MPP and the duty cycle of buck converter. With the use of neural fuzzy as MPPT, PV system is expected to work in the area MPP although there is a change in temperature and solar irradiation. Photovoltaic systems (PV) are a device that converts solar energy into electrical energy. it consists of several solar cells, each cell is associated with each other either in series or parallel to form a series of PV that is generally referred to as "PV modules". Energy conversion efficiency of solar cells depends on the maximum operating point (MPP) of PV systems [3].

In one day, solar insolation or solar irradiation is received can vary from 0.55kWh/m (2MJ/m) at cold area until 5.55kWh/m (20MJ/m) at tropic area [8]. In the sunny weather, the energy of sunlight scattering may be only 15-20% of the global irradiance and on cloudy weather will reach 100%.

2. PV Model

Characteristics of photovoltaic system is highly non linear which is influenced by external factor. Solar irradiation, ambient temperature and wind speed are the main environment factor affecting PV system. While the short circuit current (Isc), open circuit voltage (Voc), maximal voltage (Vmax) and MPP current is the main characteristics which show I-V and P-V curve [14] in figure 1 and figure 2 respectively , which work at one point that produces maximum output power that is influenced by solar irradiation and temperature of cell junctions for highly non-linear changes.

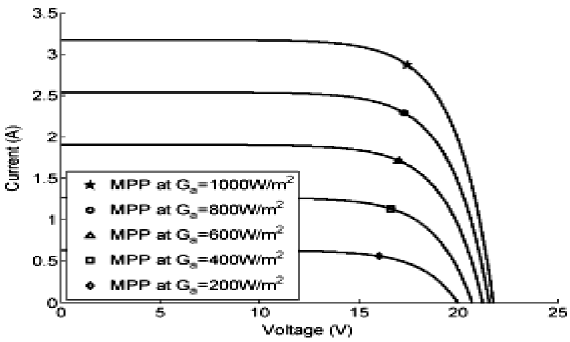


Figure 1: I-V curve of photovoltaic panel

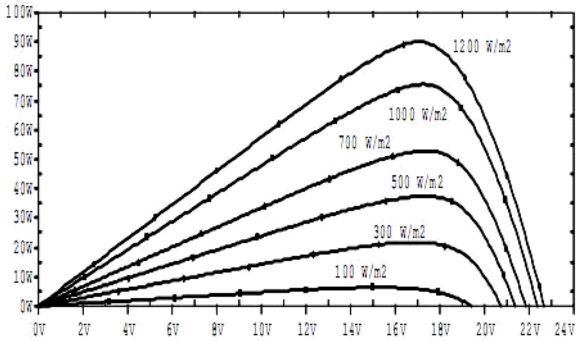


Figure 2: P-V curve of photovoltaic panel

Solar cell is a device which is non linear and can be expressed as a current source model as shown in Fig 3. A photovoltaic cell is basically a p–n semiconductor junction diode which converts solar light energy into electricity. Its equivalent circuit is shown by Fig. 3. A PVP is composed of np parallel modules each one including ns photovoltaic cell serial connected Fig. 4 shows the maximum power point tracker connecting the PVP module to the dc load[10] . The maximum power point tracker consists of boost dc–dc inverter with the output filter and the control system. The maximum power point tracking drives the operating point of the PVP to the Pmax detected by the control system.

The control unit switches the power transistor ON and OFF to carry out the Pmax from the PVP. When the transistor is switched ON, the current in the boost inductor increases linearly, so the diode is in the OFF stat[11] . However, when the transistor is switched off, the energy stored in the inductor is released through the diode to the load.

Figure.3. Equivalent circuit of a photovoltaic cell.

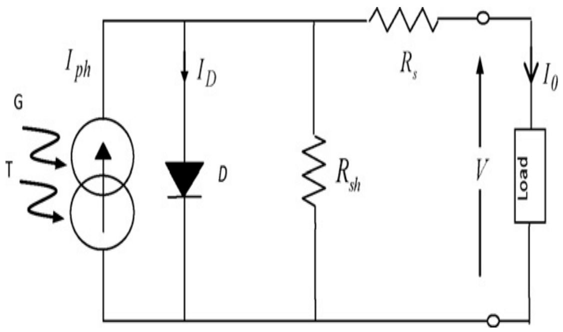
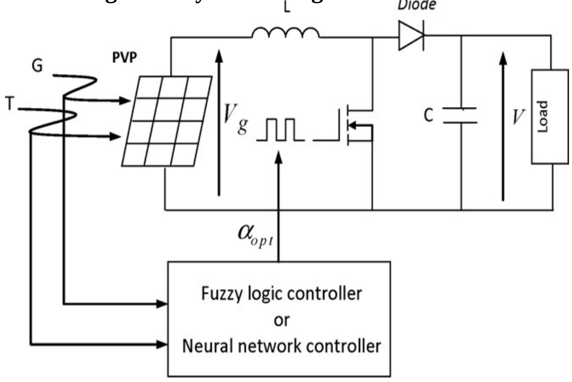


Figure.4. System configuration



The pulsating current produced by the switching action is smoothed by the capacitive filter and a dc voltage is provided to the load[27] .

3. NEURAL NETWORK PEAK POWER POINT TRACKING CONTROLLER

The peak power point tracking controller consists of two problems to be dealt with. One of these problems is to determine the peak power point for the current solar irradiation level and track it as the solar irradiation level changes[18]. For different solar irradiations, the PVA generates different peak power points to be determined and used as reference power values to be tracked. It should be noted that the peak power points are not fixed at a certain location. They can be anywhere on the P–V space depending on the light levels. Therefore, the first problem of the MPPT is to determine the locations of peak power points. Once the peak power point for the current solar irradiation level is determined, then the second part of the peak power point tracking problem starts[28]. The second part of the problem is more likely a control problem and the goal is to operate the PVA at the peak power point by managing loads. NN can generally be thought of as black box devices that accept inputs and produce outputs. The neural systems function as parallel distributed computing networks, the MPPT controller approach uses neural network are presented in the paper [4,5].The NN controller is used to estimate the optimum duty cycle which corresponds to Pmax at any given solar radiation and PV cell temperature .

Fuzzy controller is improved by developing artificial intelligent methods by using neural network . Neural networks have the ability to adapt so that it can handle [12] non- linearity, uncertainty and parameter variations that occur in a controlled plant. One example of non-linear feed forward networks is back propagation network and radial basis function network (RBF) [19]. These two networks have different, RBF network has only one hidden layer while back propagation network have one or more hidden layers. Hidden layer of RBF network is nonlinear while the output layer is linear. Back propagation training need time longer than the RBF. But it requires less information to obtain accurate modeling and maximum power point tracking [7].

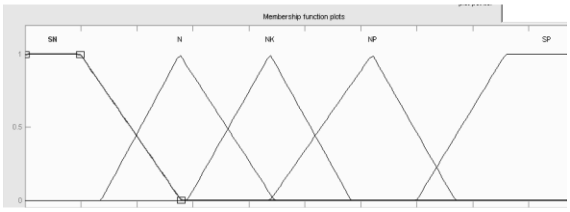
Neural network controller is used for control of duty cycle of boost converters so that the voltage of PV modules is proportional with MPP voltage at atmospheric conditions [26]. Using back propagation learning algorithm reference voltage at the MPP obtained through the learning offline. Neural network is used to obtain the maximum power voltage of the solar panels. Network has three layers consisting of input layer, hidden layer and output layer [17].

Neural network is used to determine the MPP, while fuzzy logic is used to set duty cycle of buck converter. Buck converters obtain input from PV output voltage and produce a smaller output voltage than the input voltage [13]. Fuzzy logic controller generating a control signal based on the voltage generated by the MPPT and the PV panels. The output of fuzzy controller to adjust the duty cycle of buck converter that generates a output voltage corresponding to Vmpp[16] .

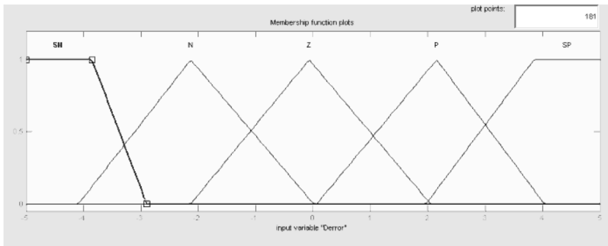
Neural networks have learning algorithms, data collected through observation of PV panels are used as training data to be used for updating neural parameters [15]. In this research, neural network algorithms are designed using Multilayer Perceptron Neural Network Error Back propagation type.

The output of the neural network is the maximum power point voltage of the reference for fuzzy logic in managing the duty cycle. According to back propagation algorithm [20] requires less information for accurate modeling and searching than the maximum power point using the method of radial basis function. Neural networks used three layers, consisting of input layer, hidden and output. Network has two layers are the input voltage from the PV panel and the current from the PV panel, a single layer in the form of output voltage at the MPP and one hidden layer [22] .

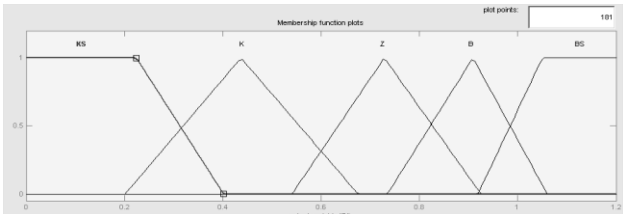
Activation function used for input and hidden layers are sigmoid logarithmic while for output neurons use linear activation functions.



(a) Error membership function.



(b) Delta error membership function.



(c) Output membership function

Figure 5: Membership functions of fuzzy

Fuzzy controller consists of two variable inputs and one output variable. Input variables consists of the error and change of error that have 5 membership functions. The output of fuzzy logic in the form of duty cycle is connected to input of buck converter circuit. Membership functions of input and output of fuzzy controller is shown on Fig.4 Error input variables will be negative if the value of the PV output voltage is above maximum power point voltage value of the resulting neural network. Fuzzy rules are used as shown in Table 1 [25] .

Table 1: Fuzzy Rules

e Δe	SN	N	NK	NP	SP
SN	B	BS	BS	BS	BS
N	Z	B	BS	BS	BS
Z	Z	B	B	BS	BS
P	K	K	B	B	BS
SP	KS	KS	B	B	BS

4. SIMULATION RESULT

Simulation of neural fuzzy algorithm as MPPT on PV system is done by providing interference in the form of solar irradiation and temperature changes because these two variables affect PV output voltage and current. Fig 6 shows the simulation results of the PV system with a PV voltage of 18V without disturbance at irradiation of 400W/m2 and temperature of 25oC. In this simulation the neural network can recognize a change in solar irradiation to produce change in Vmpp [23].

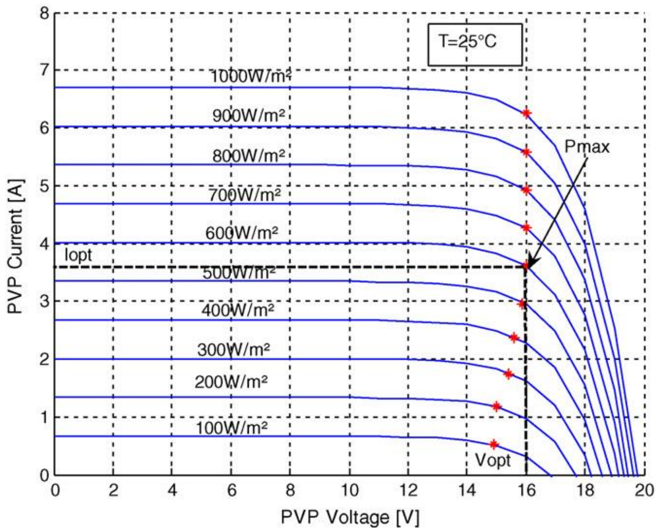


Fig 6: P/V characteristics at constant temp T =25 C.

Using the derivative procedure of each PVP power curve, a new maximum power characteristic is extracted to indicate the optimal functioning points for the PVP (Iopt, Vopt) for different solar radiation and ambient temperature. Figs. 6 and 7 plot P = f(V) and I = f(V) curves respectively for different solar radiation G and with constant temperature T =25 C.
Figs. 8 and 9 present the same parameters curves for different temperature T but with constant solar radiation G = 100 W/m2. As it is shown in Figs. 6 and 7, the current, due to the cutoff circuit is positively varying with solar radiation. However, the voltage in the open circuit remains quasi constant.

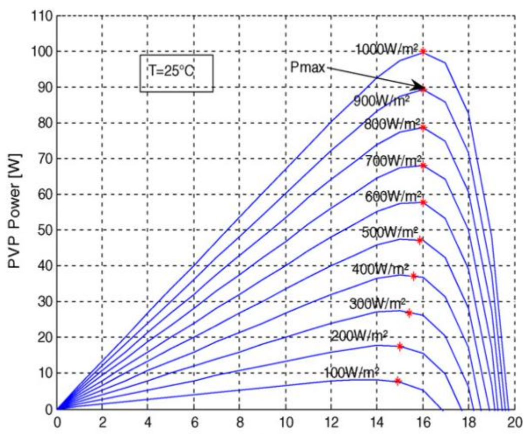


Fig 7: I/V characteristics at constant temp T =25 °C.

Furthermore, maximum power points are situated around a critical value of 16 V. The charge regulator, the MPPT, will not be perturbed enough by the solar radiation when searching the maximum power points. Figs. 9 and 10 shows that the affect of temperature is slightly significant and it needs important choice in panel and systems conception[24] .

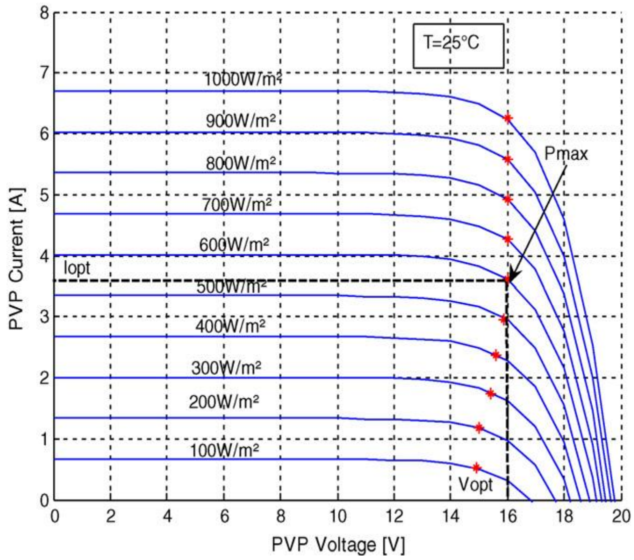


Fig 8: I/V characteristics at constant temperature T =25°C

The temperature has a negligible effect on the cutoff circuit current. However, the open circuit voltage decays rapidly as the temperature increases.

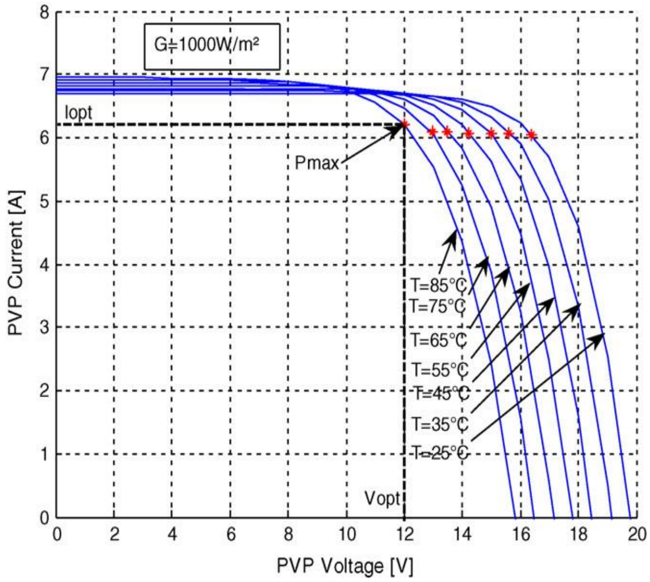


Fig 9. I /V characteristics at constant solar radiation 1000 W/m^2.

5. CONCLUSION

This paper has presented neural fuzzy for controlling PV system output voltage to operate at maximum power point although happened temperature and irradiation changes. The system was analyzed and designed and performance was studied by simulation. PV system can operate at maximum power point although occurrence of temperature and sun irradiation change can shift maximum power point. This method is fully dynamic in nature which can model dynamical complex systems that change with time following non-linear laws. These proposed algorithms command a boost dc–dc inverter to obtain the MPPT directly from the climate data solar radiation and PV cell temperature. In addition this technique gives a simplified system and low cost to implement it.

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