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Solar MPPT Charge Controller with ANN Controller

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***Abstract*— Photovoltaic generation is the technique which uses photovoltaic cell to convert solar energy to electric energy. Nowadays, PV generation is developing increasingly fast as a renewable energy source. However, the disadvantage is that it has very low efficiency and PV generation is intermittent because it depends considerably on weather conditions. This paper proposes an intelligent control methods for the maximum power point tracking (MPPT) of a photovoltaic system under various conditions. In this paper, a simulation study of the maximum power point tracking (MPPT) for a photovoltaic system using an artificial neural network is presented. The system simulation is elaborated by combining the models established of solar PV module and a SEPIC or CUK converter. Finally the performance comparison between artificial neural network controller and Perturb and Observe method has been carried out which has shown the effectiveness of artificial neural networks controller to draw much energy and fast response against change in working conditions.**

Keywords*— *Solar Energy, Photovoltaic, MPPT, P&O,CUK Converter, Artificial Neural Network.

I. INTRODUCTION

Significant progress has been made over the last few years in the research and development of renewable energy systems such as wind, sea wave and solar energy systems. Among these resources, solar energy is considered nowadays as one of the most reliable, daily available, and environment friendly renewable energy source. However, solar energy systems generally suffer from their low efficiencies and high costs. In order to overcome these drawbacks, maximum power should be extracted from the PV panel using MPPT techniques to optimize the efficiency of overall PV system. MPPT is a real-time control scheme applied to the PV power converter in order to extract the maximum power possible from the PV panel. The MPPT working principle is based on the maximum power transfer theory. The power delivered from the source to the load is maximized when the input resistance seen by the source matches the source resistance. Therefore, in order to transfer maximum power from the panel to the load the internal resistance of the panel has to match the resistance seen by the PV panel. For a fixed load, the equivalent resistance seen by the panel can be adjusted by changing the power converter duty cycle .There are various MPPT techniques based on different topologies and with varying complexity, cost, and overall produced efficiency.

The Hill Climbing (HC) and the Perturb and Observe (P&O) are the most known and commercially used techniques. Other modified methods such as the incremental Conductance (INC) technique, the neural network (ANN) technique, and fuzzy logic controller technique, have been also reported to improve the performance of these techniques. In HC-MPPT technique, the duty cycle is directly incremented or decremented in fixed steps depending on the panel voltage and power values until the maximum power point (MPP) is reached. The P&O technique shares the same HC concept of operation, but with an additional PI control loop. In the P&O, the converter input reference voltage is the perturbed variable and the duty cycle is computed through an additional PI control loop. The additional control loop results in an increase in the P&O efficiency.

II. IMPORTANCE OF ANN CONTROLLER

The P&O method is commonly used because of its simplicity and ease of implementation. Furthermore, P&O (with a small step size) in nominal conditions can have MPPT efficiencies mostly the same like other complex techniques, and still easier implementation. However, the drawback of this technique is that the operating point of the PV array oscillates around the MPP. Therefore, the power loss may increase. Furthermore, when the sun insolation changes rapidly, the P&O method probably fails to track the MPP. Another possible disadvantage is that the MPPT may not be able to locate the MPP as the amount of sunlight decreases, because the PV curve flattens out. Recently intelligent control based control schemes MPPT have been introduced. In this paper, an intelligent control technique uses artificial neural network control is associated to an MPPT controller in order to improve energy conversion efficiency. The simulation can generate two different solutions for the control of converter system; one is P&O controller and the other one is ANN controller. The circuit diagram of the energy conversion system is shown in Fig.1.

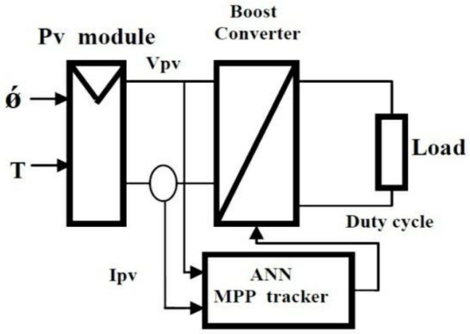

Fig.1. Schematic diagram of the proposed power conversion PV array.

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The system consists of photovoltaic panel, a DC/DC CUK converter, a control unit and a resistive load. The first stage of the system is solar panel. The I-V characteristic of a panel depends on the temperature and solar irradiance. The three most important characteristics of PV panel are the short circuit current, open circuit voltage and the MPP which is a function of panel temperature and solar irradiance. The power stage is the CUK converter which duty cycle is regularly adjusted to track the maximum power point that can be delivered by the PV panel. The proposed MPP tracker, which is based on artificial neural networks control, has the objective to draw as much power as possible from the PV module by adjusting continuously the duty cycle of the DC/DC converter. This point corresponds to the maximum power point (MPP) on the PV curve. The main content of this paper is organized into several sections. Section two is dedicated to the study of the characteristics of solar panels. Section three is devoted to the study of the maximum power point tracking (MPPT) and section four discusses the modeling of DC/DC converters. Section five presents the different MPPT algorithms (P & O algorithm and ANN algorithm) to make a comparison between these two algorithms. Section six is dedicated to the simulation of the two methods (P & O and ANN). Finally, a general conclusion finished the paper.

III. BASIC IDEA OF PV CELL

Photovoltaic cell is the most basic generation part in PV system. Single-diode mathematic model is applicable to simulate silicon photovoltaic cells, which consists of a photocurrent source Iph, a nonlinear diode, internal resistances Rs and R_{sh}, as shown in Fig.2.

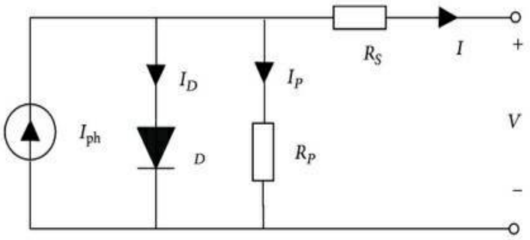

Fig. 2. Single-diode mathematic model of a PV cell

The mathematic relationship for the current and voltage in the single-diode equivalent circuit can be described as

q(V +IR_s) V +IR_s

I = I_{ph} -Is($_e$ Akt $_{-1)}$ - ^{R}sh (1)

where, Iph is photocurrent; Is is diode saturation current; q is coulomb constant (1.602e-19C); k is Boltzman‘s constant (1.381e-23 J/K); T is cell temperature (K); A is P-N junction ideality factor; Rs and Rsh are intrinsic series resistances. Photocurrent is the function of solar radiation and cell temperature described as

^{I}ph =(S / ^{S}re f)[^{I}ph,ref +^{C}T(T -^{T}ref)] (2)

where, S is the real solar radiation (W/m2); Sref , Tref Iph,ref is the solar radiation, cell absolute temperature, photocurrent in standard test conditions respectively; CT is the temperature coefficient (A/K).

The relationship of the voltage and current in PV array is:

I =$N_{ph}I_{ph}$ -NpIs($_e$ kT(q/A V/N$_s$ + IR$_s$/N$_p$) $_{-1)}$ -^{R}sh(Np/Ns V + IR_s/Np) (3)

Where, NS and NP are cell numbers of the series and parallel cells respectively.

Considering different temperatures and solar irradiations,the simulated output characteristics of the PV array are depicted in fig.3. and fig.4.

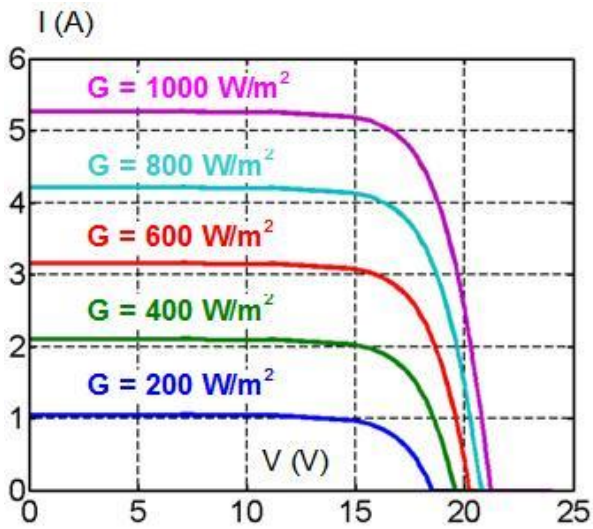

Fig.3.Characterstics curve of Solar PV module with different solar irradiations

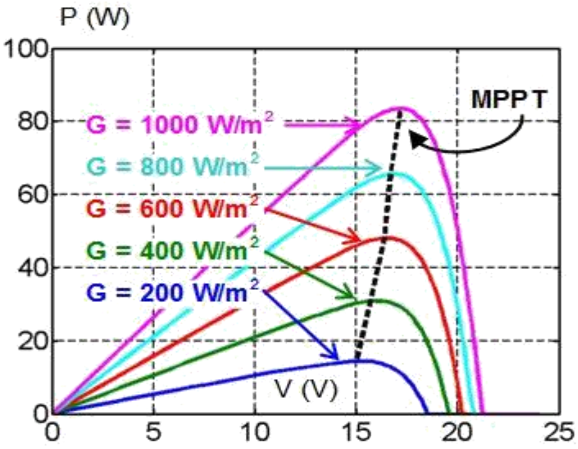

Fig.4.Characterstic curve of Solar PV module with different solar irradiations

A dynamic tracking method is necessary to extract the maximum power from the PV cells. Many researches has been developed concerning the different algorithms for the maximum power point tracking (MPPT) considering the variations of the system parameters and weather changes, such as perturb and observe method, open and short circuit method, incremental conductance algorithm,Tempreture method, Tempreture perametric method, fuzzy logic and artificial neural network. The block diagram in Fig.2 presents a PV generator with MPPT . The load or the battery can be charged from a PV panel using a MPPT circuit with a specific controller to track the peak power generated by the PV panel.

Other protection devices can be added. The control circuit takes voltage and current feedback from the battery, and generates the duty cycle D. This latter defines the output voltage of the Cuk converter. Many MPTT control techniques have been conceived for this purpose these last decades. They can be classified as:

Voltage feedback based methods which compare the PV operating voltage with a reference voltage in order to generate the PWM control signal of the DC/DC converter.

Current feedback based methods which use the PV

module short circuit current as a feedback in order to estimate the optimal current corresponding to the maximum power.

Power based methods which are based on iterative

algorithms to track continuously the MPP through the current and voltage measurement of the PV module. In this category, one of the most successful used method is perturbation and observation (P&O) technique.

IV. CUK CONVERTER WORKING

Fig.5 shows the electrical circuit of a Cuk converter.The power switch ‗S' is used to modulate the energy transfer from the input source to the load by varying the duty cycle D. The relationship between input and output voltages of Cuk converter operating at steady state condition is given by:

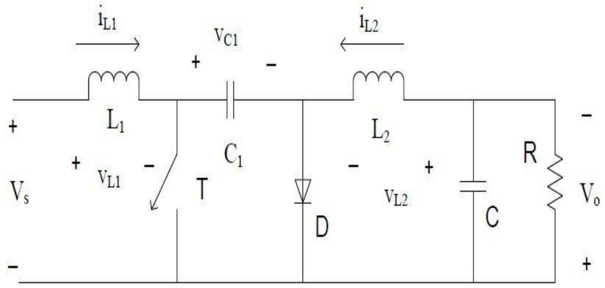

Fig.5. Basic circuit of DC/DC Cuk converter

The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change. When the switch is off, the inductor currents iL1 and iL2 flow through the diode. Capacitor C1 is charged through the diode. The circuit is shown in Figure: 4.8, Capacitor C1 is charged through the diode by energy from both the input and L1. Current iL1 decreases because VC1 is larger than Vs. Energy stored in feeds the output. Therefore iL2 also decreases.

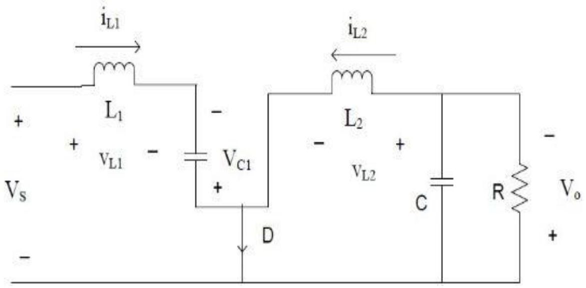

Fig.6 when switch S is OFF, Capacitor charging

When the switch is on, VC1 reverse biases the diode. The inductor currents iL1 and iL2 flow through the switch as shown in Figure: 4.9. Since VC1 >Vo, C1 discharges through the switch, transferring energy to the output and L2. Therefore iL2 increases the input feeds energy to L1 causing iL1 to increase.

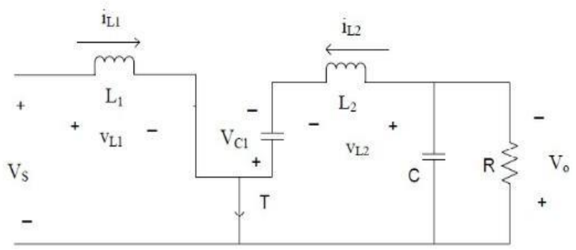

Fig.7 when Switch S is ON

The inductor currents iL1 and iL2 are assumed to be continuous. The voltage and the current expressions in steady state can be obtained in two different ways. If we assume the capacitor voltage VC1 to be constant, then equating the integral of the voltages across L1 and L2 over one time period to zero yields.

The output voltage can be derived by:

If D=0.5 the output is the same as the input.

$$\frac{V_o}{V_s} = \frac{D}{D-1}$$

If 0.5<D<1 the output is larger than the input.

V. DIFFERENT ALGORITHM MPPT

It is necessary to constantly track the MPP of a solar panel. For the past years, research has focused on various MPP control algorithms to draw the maximum power of the solar array. In this section, the effectiveness of two different control algorithms are thoroughly investigated using a numerical simulation.

A. P&O controller method:

Its relationship to the duty cycle(D) is:

If 0<D<0.5 the output is smaller than the input.

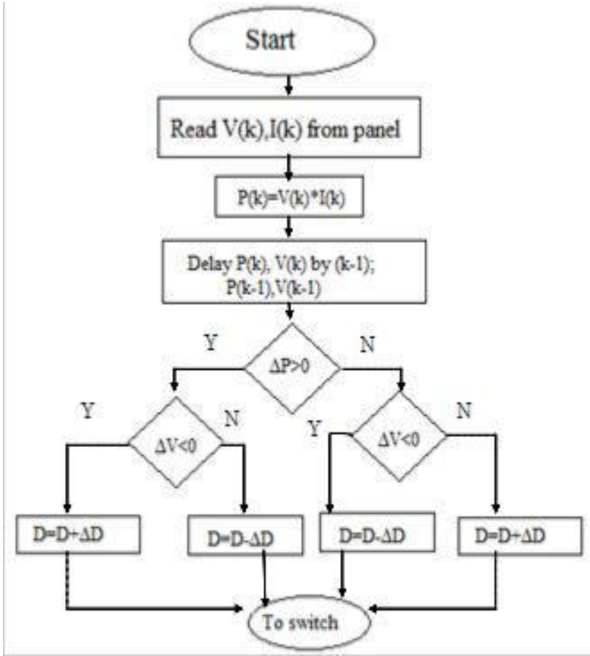

Fig.8. flow chart P&O method.

The P&O algorithm is the most commonly used in PV systems applications due to its ease of implementation and simplicity. It is an iterative method for obtaining the MPP. Whereas, it measures a PV module current and voltage, then perturbs the operating point of a PV module to determine the change direction. Fig.8 shows the flow chart of the classical P&O algorithm. The P&O algorithm has been broadly used because of its practical implementation. The MPP tracker operates by periodically incrementing or decrementing the solar panel voltage, current or the duty cycle comparing to the PV output power with that of the previous perturbation cycle. If a given perturbation leads to increase (or decrease) the output power of the PV, the successive perturbation is generated in the same (or opposite) direction, on Fig.10. We consider that the maximum power point MPP. If the operating point C is on the left of MPP, the duty cycle must be decreased until the MPP is reached. If the operating point is on the right of the MPP, the duty cycle is increased to reach the MPP. The results for different tests using the P&O algorithm are presented and compared to those obtained with the artificial neural network (ANN) MPPT controller in sect.

B. ARTIFICIAL NEURAL NETWORK CONTROLLER METHOD

The MPPT strategy proposed here consists of a combination of an artificial neural network and the MPPT technique in order to implement of the duty cycle regulator. When solar irradiation changes slowly, the system controls the DC-DC converter using the P&O, and the neural network learns simultaneously the MPP found by the P&O. However if the solar radiation varies too rapidly, the neural network controller tracks the MPP rapidly and adjusts the duty cycle of the DC-DC converter. Neural networks usually require independent and identically distributed samples to ensure successful on-line learning. Here, however, similar training samples are used by the artificial neural network.

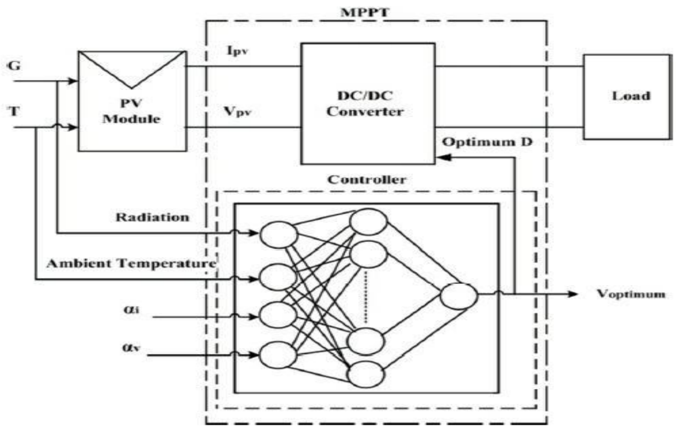

Fig.9. Proposed MPPT system with ANN controller

To deal with these training samples, we have used an MLP in order to ensure fast and correct learning. The main idea is that the neural network learns each sample online because it is difficult to store all learning samples in small devices. In Fig. 11, the ANN learning technique is a memory-based one and allows estimating at any instant the required optimal duty cycle_D'. Even with sparse data in a multidimensional measurement space, the algorithm provides smooth transitions from one estimated value of D to another. The ANN consists of an input layer (Ppv), a pattern layer, a summation layer an output layer. The output of the ANN is the duty cycle D(x) as follow:

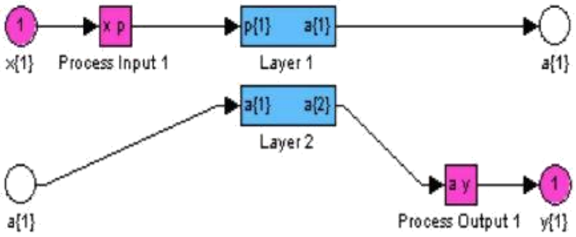

Fig.10.MPPT with ANN controller Modeling in MATLAB

The MPPT technique proposed differs from other techniques in that the duty cycle of the switching of the DC/DC boost converter is optimally calculated on-line. The algorithm of the three-point weights comparison is run periodically by perturbing the solar array terminal voltage and comparing the PV output power on three points of the P-V curve. The three points are the current operation point (A), a point B, perturbed from point A, and a point C, with doubly perturbed in the opposite direction from point B. Fig.13 depicts the three possible cases. In these cases, for the points A and B, if the power corresponding to the point B is greater than or equal to that of point A, the status is assigned a positive weighting. Otherwise, the status is assigned a negative weighting. Amongst the three measured points, if two are positively weighted, the duty cycle of the converter should be increased. On the contrary, when two are negatively weighted, the duty cycle of the converter should be decreased. In the other cases with one positive and one negative weighting, the MPP is reached or the solar radiation has changed rapidly and the duty cycle must not be changed. Fig.13 shows the idea of the MPP detection algorithm. By monitoring voltage V and current I, the P&O algorithm determines whether generated power has increased. If so, the next change in voltage should be the same as the last V. If not, the next change in voltage should be negative P&O achieves the function of an MPPT easily,

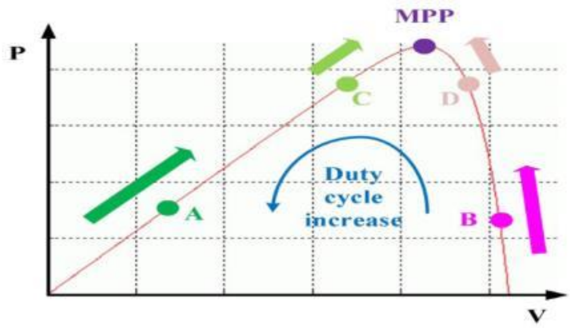

Fig.11. Characterstic curve with the working of P&O method

but it cannot track MPP rapidly when solar radiation changes quickly. In order to eliminate this drawback, our MPP technique utilizes an ANN to achieve learning and maximum power point tracking. The MPP tracker operates by periodically incrementing or decrementing the estimated solar panel voltage Vpv. If a perturbation occurs on the PV output, then the subsequent perturbation is generated in the opposite direction. The weights of the neurons are changed subsequently to the presence and severity of a perturbation. They are maintained constants in stable working condition.

VI. CONCLUSION

This paper discusse Artificial neural network-based MPPT, Under variation in atmospheric conditions. By using artificial neural network, point of maximum power is specified fast and precisely. Another advantage of the artificial neural network in PV maximum power-point tracking is its better dynamic performance in comparison with any the other methods. Also the maximum power point is tracked by dc-dc cuk converter. So the maximum power solar energy and the best efficiency are obtained.

VII. ACKNOWLEDGEMENT

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