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Comparative Analysis of Various MPPT Techniques for Photovoltaic System with SEPIC Converter

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Abstract-- This paper analyzes a Radial Basis Function Network (RBFN) based Maximum Power Point Tracking (MPPT) algorithm for photovoltaic (PV) system with Single Ended Primary Inductor Converter (SEPIC).The proposed methodology uses RBFN for MPPT and the results are compared with conventional Perturb and Observe (P&O), Incremental Conductance (INC). To improve the voltage rating a SEPIC is proposed and the results are compared with Boost converter. In conventional methods having drawbacks of high oscillations due to changing the solar irradiation and temperature which leads to low efficiency. In order to overcome this problem RBFN based MPPT technique is used. It is high efficient with low settling time and less time taken to track MPPT than other techniques.

Keywords-- *Maximum Power Point Tracking (MPPT), Radial Basis Function Network (RBFN), Photovoltaic (PV), Single Ended Primary Inductor Converter (SEPIC).*

I. INTRODUCTION

In recent years, the renewable energy becoming more popular and energy sources such as PV were used because of reduction of fossil fuels, global warming and availability energy where a PV cell's voltage varies with respect to temperature and irradiation. In order to improve the efficiency of the system, Maximum Power Point Tracking (MPPT) algorithms were used. It is used to track the maximum operating point from the PV array. Various conventional MPPT techniques such as P&O, INC were used. It has some drawbacks like slow time response, high oscillations and low efficiency during a change in irradiation and temperature.

In this paper, artificial intelligence RBFN based technique is designed and compared under various solar irradiations. It is high efficient with low settling time, and less time is taken to track MPPT than other techniques. The operating voltage of PV system is very less and it is not applicable for high voltage applications. In order to overcome this problem, DC-DC converter topology is used. DC-DC converter topologies namely boost converter, buck converter, SEPIC etc. Boost converters are commonly used for the PV power generation system. The switching voltage was high for the boost converter during conversion periods. To avoid this problem SEPIC converter is used. By using MPPT techniques, to track the maximum operating point the PV cell's voltage and current is given as the input and it generates the duty cycle of the converters.

II. PV CELL MODELLING

PV cell is a current source have inverted diode,shunt resistance to minimize the leakage current and series resistance as shown in Fig.1.

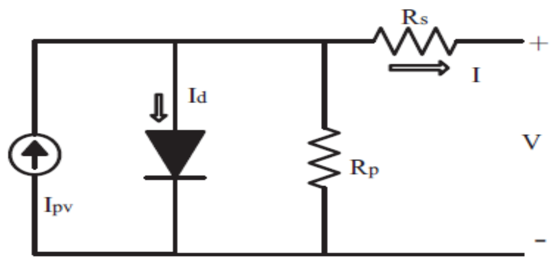


Figure 1: Equivalent circuit of a single diode solar cell

The relationship of voltage-current of PV system is given by,

$$i = I_{ph-} I_{s(T)} (\exp\{q(V_{in} + i.R_s) / KTA\} - 1 \qquad (1)$$

where I is the PV panel output current; I_{ph} is photocurrent; $I_s(T)$ is the reverse saturation current; q (= 1.6×10^{-19}) is an electron charge; V_{in} is the terminal voltage of the PV panel; R_{SH} is the PV panel series resistance; A is the ideal factor of the PN junction of the PV diode, which varies in the range of [1, 2]; and k(= 1.38×10^{-23} J/K) is the Boltzmann constant. The photocurrent is then found using equation 2.

$$I_{ph} = [I_{sc} + K_i (T - T_{ref})].\lambda \qquad (2)$$

Where I_{sc} is the short circuit current provided by the PV panel at a reference temperature and an irradiance of 1kW/m²; K_i (= 3mA/°C) is the temperature coefficient, λ is the solar irradiance in kW/m²; T and T_{ref} are measured temperature and reference temperature, respectively. The output current is then

$$I_{st}(T) = I_s(T_{ref}) \exp\{K_s (T - T_{ref})\} \qquad (3)$$

Where $i_s(T_{ref})$ is the reverse saturation current (T_{ref} = 295K) and K_s (≈ 0.072/°C) is the temperature coefficient of the PV panel.

III. MPPT TECHNIQUES

The MPPT techniques are used to track the maximum operating point from the PV system as shown in Fig.3. The MPPT techniques have been described below;

A. Perturbation and Observation method

P&O method is a simple and easy method to applicable in real time. It is used to measure the output power variation (ΔP) which follows each perturbation from PV system. If ΔP is positive, then operating point moves in a positive direction at each stage. If ΔP is negative, then the point is moved away from the MPPT and perturbation change in reverse direction. Then the process is repeated again and again until to select the maximum operating point from PV array. If the size of perturbation is large, then the oscillations become less. The major drawback of this method is high oscillations, low tracking efficiency under a change in irradiance conditions.

B. Incremental Conductance method

INC technique using the slope from PV array power curve to obtain the sign of the derivative of power and voltage. The slope is zero at MPP,positive when the maximum operating point is left to the MPP, and negative when the maximum operating point is right to the MPP. The maximum point is achieved by differentiating the power with respect to voltage and equal to zero. Once it reaches MPP, the PV array operates, to maintain that point, until a change in current occurs. It provides the arrangement between oscillations and convergence speed. The major advantage of INC is able to track the MPP during changing environmental conditions, but it requires complex control circuit.

C. Radial Basis Function network

It is a feed forward neural network (NN) model. The activation function of the hidden layer is determined by the distance between input layer and prototype layer. To train RBFN can be done by two steps. In the first step, the basis functions are determined by unsupervised methods and the second step the final layer unit weights are determined. RBFN is used to design the controller from PV array. RBFN contains an input layer, hidden layer and output layer as shown in Fig.2. PV voltage and current as input for input layer and obtain the duty cycle as output in the output layer. The input layer has two neurons to transmit the net input and output data to the next layer.

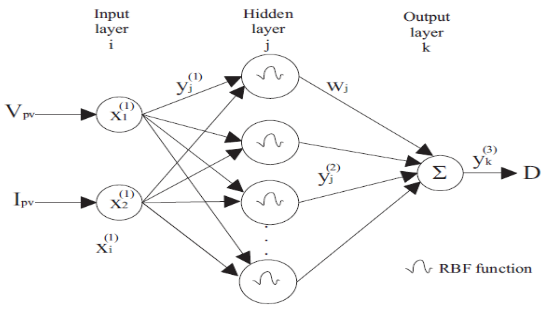


Figure 2: Structure of RBFN

$$x_i^{(1)}(n) = net_i^{(1)} \quad (4)$$

$$y_i^{(1)}(n) = f_i^{(1)}[net_i^{(1)}(n)] = net_i^{(1)}(n), \text{ i=1, 2...} \quad (5)$$

Where $x_i^{(1)}(n)$is the input layer,$net_i^{(1)}$ is the sum of the input layer and $y_i^{(1)}(n)$is the hidden layer with node i.

$$net_j^{(2)}(n)\text{=-} \left(x - M_j\right)^T \textstyle\sum_j \left(x - M_j\right) \quad (6)$$

$$y_j^{(2)}(n) = f_j^{(2)}[net_j^{(2)}(n)]\exp[net_j^{(2)}(n)], \text{ j=1,2...} \quad (7)$$

The output layer has single neuron with the node,y_k generates the control signal D with a linear activation function as shown in Fig. 4.5.1. The output signal was computed by making a summation of incoming signals.

$$net_k^{(3)} = \textstyle\sum_j w_j y_j^{(2)}(n) \quad (8)$$

$$y_k^{(3)}(n) = f_k^{(3)}[net_k^{(3)}(n)] = net_k^{(3)}(n) \quad (9)$$

Where$w_j$is the weights which connect between the hidden and the output layers.

IV. CONVERTER TOPOLOGIES

It is used to convert the low voltage to high voltage .It is an important role of any PV power generation. The main aim of the converter is to regulate the generated PV cell's power in order to meet the load conditions. Details of the conventional boost, SEPIC converters are explained below,

A. Boost Converter

The converter consists of an inductor, capacitor, a switch and a diode as shown in Fig.3. When the switch is turned ON, the diode acts as a reverse biased and hence the current flowing through the inductor and switch. When the switch is turned OFF, the diode gets forward biased all the energy is dissipated from inductor when the current flowing through the inductor and capacitor. The major drawback of this converter is high inrush current and switches stress.

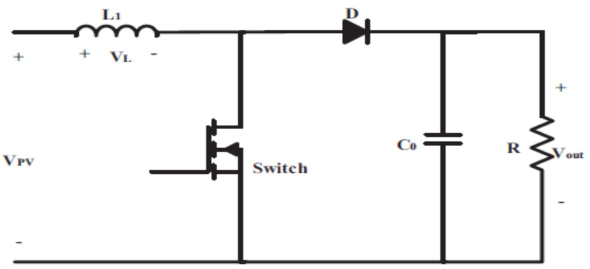


Figure 3: Boost converter circuit

B. SEPIC converter

It is a combination of both step-up and step-down mode of operation. It can generate the output voltage with high or lower than the input voltage. This converter contains two inductors, two capacitors, diode and a switch as shown in Fig.4. When the switch is turned ON the diode is reverse biased. The energy stored in inductor L. The current in capacitors Cs flows through the inductor L2 and capacitor C0. When the switch is turned OFF, the diode is forward biased. The capacitor Cs gets charged from the inductor L1. The major drawback of this converter is high switching stress due to high static gain.

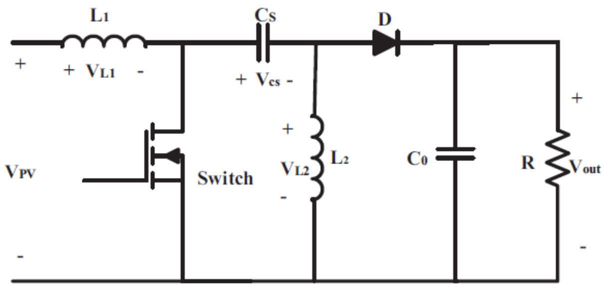


Figure 4: SEPIC converter

By using the expressions, the parameters are calculated and used for conversion of the PV low voltage to the high step-up voltage with high static gain for required applications.

V. SIMULATION RESULTS AND DISCUSSION

In this section, P&O, INC, RBFN based MPPT techniques have been designed and simulated using MATLAB/Simulink software. The specification of the PV panel under standard test condition (STC) used in this system is listed in Table1. The boost and SEPIC were designed using parameters listed in Table2. The performance of the three MPPT techniques based on the converters was designed and compared under constant temperature and various irradiation.

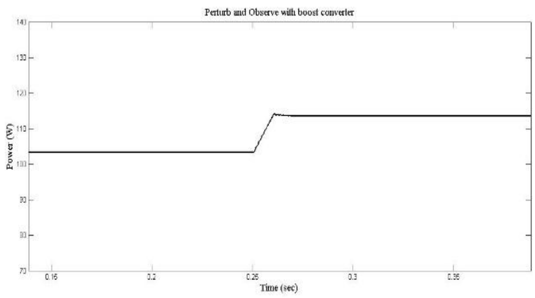
Table 1: PV Panel Specification

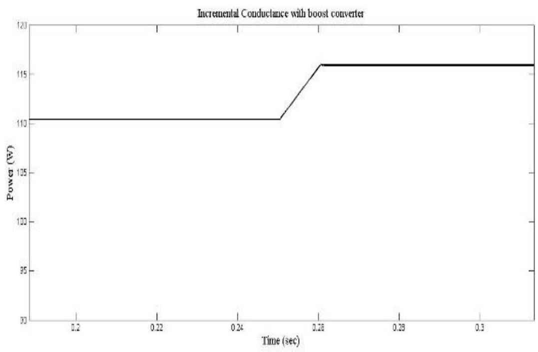
Parameter	Value took for simulation
Maximum power(W)	150
Cells per module	72
Open circuit voltage(V)	34.5
Short circuit current(A)	4.35
Voltage at maximum power point(V)	43.5
Current at maximum power point(A)	4.75

Table 2: Converter Parameters

Parameters	Boost converter	SEPIC converter
Switching frequency(f_{sw})	20 KHz	20 KHz
L_1	500 µH	356µH
L_2	-	356µH
C_0	10 µF	122µF
C_s	-	10 µF
C_m	-	1µF
R	170Ω	170Ω

The power output of the boost converter based PV system is shown in Fig.5 with P&O, INC and RBFN based MPPT techniques for various irradiation conditions (600 $W/m^2$and $1000W/m^2$) and constant temperature at25°C . Among the various MPPT methods, RBFN based algorithm performs better than the other two algorithms by providing high power output.





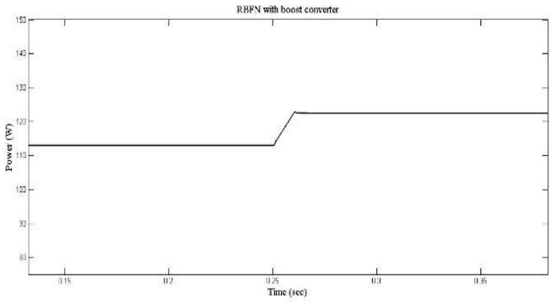
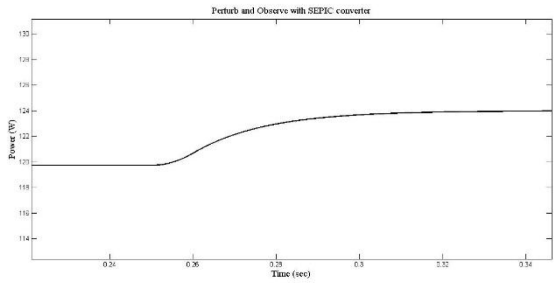
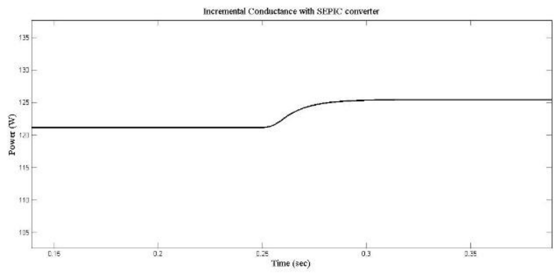


Figure 5: Output power waveforms for P&O, INC, RBFN with Boost converter

The power output of the SEPIC converter based PV system is shown in Fig.6with P&O, INC and RBFN based MPPT techniques for various irradiation conditions (600 $W/m^2$and $1000W/m^2$) and constant temperature at25°C. Among the various MPPT methods, RBFN based algorithm performs better than the other two algorithms by providing high power output.





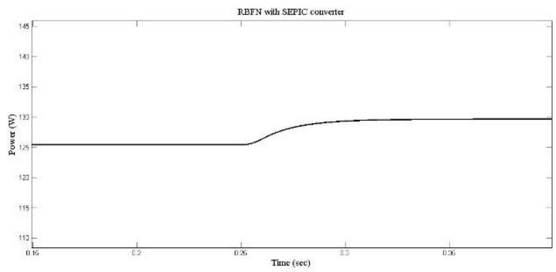
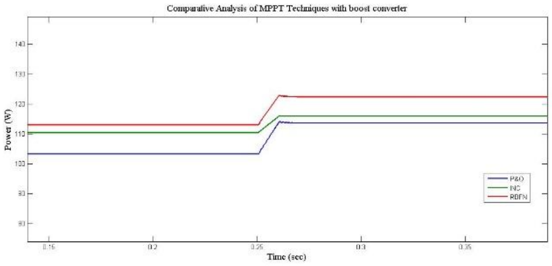
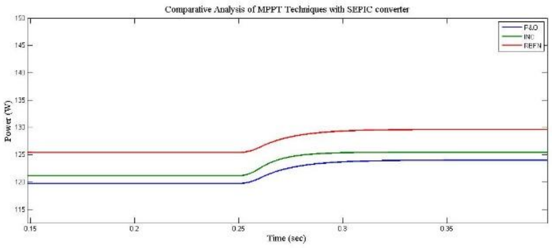


Figure 6: Output power waveforms for P&O, INC, RBFN with SEPIC converter

The comparative analysis was performed for various irradiation and constant temperature with both boost and SEPIC converter is shown in Fig.7.The output power of SEPIC converter performed by RBFN can produce up to 125.4 W and 129.6 W for 600 $W/m^2$and 1000 W/m^2 respectively and boost converter produces 113 W and 122.4 W for 600 $W/m^2$and 1000 W/m^2 respectively. Hence it is concluded that the combination of RBFN based MPPT and SEPIC converter for PV system generates better power output compared with boost converter system.



(a)



(b)

Figure 7: Comparative Analysis on MPPT Techniques (a) Boost Converter (b) SEPIC converter

Table 3 Comparison of Maximum Power on MPPT techniques with Boost Converter

	$600W/m^2$	$800W/m^2$	$1000W/m^2$
P&O	103.3	109.6	113.6
INC	110.4	113.8	115.9
RBFN	113	118.6	122.4

Table 4 Comparison of Maximum Power on MPPT techniques with SEPIC Converter

	$600\ W/m^2$	$800W/m^2$	$1000W/m^2$
P&O	119.8	122.3	124
INC	121.2	123.7	125.4
RBFN	125.4	127.9	129.6

Table 3 and 4 illustrates the maximum output power generated from PV system using three MPPT methods for different conditions. Compared to the boost converter, the SEPIC operates well for different irradiation conditions and constant temperatureat 25℃ can generate maximum power.

CONCLUSION

In this paper, various MPPT techniques such as P&O, INC, RBFN with converter topologies boost and SEPIC were designed for a PV system. These methods are analyzed and the results were obtained. The results show that the RBFNbased MPPT algorithm performs better than the P&O and INC methods.

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