Neural Network Based MPPT Controller for Solar PV System

T.Shanthi, S.U.Prabha

Abstract: Design of Maximum Power Point Tracking Controller with the application of Neural Network (NN) is discussed in this paper. The speed of the single phase induction motor is sensed by the controller and the controller is being fed from the solar panel. The necessity of Maximum power point tracking (MPPT) algorithm is increased in all photovoltaic (PV) system in order to achieve more efficiency of the system. The Incremental Conductance algorithm is used to extract maximum power from the solar panel which intern supplies an induction motor of 1HP. The voltage available from the solar panel is boosted using the dc – dc SEPIC (Single Ended Primary Inductor Converter). The main advantage of this converter is having non-inverted output. SEPIC converter acts as an interface between PV array and the motor. The entire proposed system is designed and modeled with MATLAB/Simulinksoftware.

Keywords: MPPT, Photovoltaic, SEPIC, Incremental conductance, Neural network controller.

I. INTRODUCTION

Amongst all renewable energy sources, solar energy provides excellent opportunity for the production of electricity and therefore this energy is widely used. Solar energy is a clean renewable resource with zero emission. Due to increase in power demand, the switch over to renewable energy sources which are eco-friendly and exist abundant in nature is extremely necessary. The efficiency of the PV system is improved by using the maximum power point tracking (MPPT) controller. Frequently used MPPT algorithms are Perturb & Observe (P&O) and Incremental Conductance (INC). In the incremental conductance algorithm, the gradient of the P-V curve is estimated [1], [2]. In this method , the peak power is being tracked even under the varying conditions of atmosphere. This is the main advantage of INC method. In this incremental conductance method, the relationship between dI/dV& -I/V is used to identify the direction of perturbation of the operating point [3]. A dc-dc step-up converter is required to raise the voltage obtained from the PV panel. The boost, buck, buck-boost, Cuk, single-ended primary inductance converter (SEPIC) converters are commonly used for this purpose [4]. Among these, the (SEPIC) gives a positively regulated output and non-inverted output. Eventhough the cost of buck-boost converters is less because of a single inductor and a capacitor, a more harmonics are generated. Therefore, a large capacitor or an LC filter are needed to eliminate these harmonics. Therefore it becomes inefficient or expensive, and also there is a complication in the usage of buck-boost converters. Cuk converters can eliminate these problems with the use of an extra inductor and capacitor [5]. But, buck-boost and Cuk converters generate greater amounts of electrical stress on the components during their operation, which results in overheating of device or device failure. The SEPIC converters will eliminate these drawbacks.

In this paper, the dc voltage available from the solar panel is regulated by the SEPIC converter and fed to the single phase inverter. The single phase Induction motor of the 1HP capacity is connected at the output of single phase inverter [6],[7]. The speed of the induction motor is used as a feedback signal. This is used to obtain the error voltage and change in error voltage. These are the inputs to the Neural Network controller. In [8-11], MPPT of solar PV using ANFIS and fuzzy logic have been reported. The generated pulses from the controller the pulses obtained from the Incremental Conductance Algorithm of a Solar panel are combined and fed to SEPIC converter and desired voltage output is generated [12-15].

II. PROPOSED SYSTEM

The block diagram of the proposed system is depicted in Figure 1.

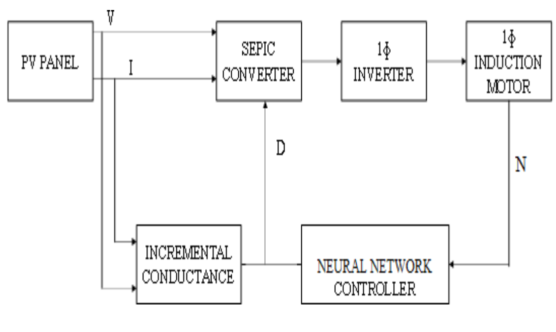

Figure 1.Block Diagram

A. Solar PV Module

Solar panel absorbs the the photon energy from the sun and converts it into electricity using the photovoltaic (PV) effect principle. Thin-film or silicon material are used in the manufacturing of of PV modules. This will provide approximately constant power at low cost and also it is pollution free. A general PV cell produces maximum of 3 watts with nearly 1/2V dc. Number of PV cells connected in series or parallel to make a PV module.

B. Solar Panel Specifications

For the generation of power of 1KW, four number of 250W panels are series connected. In this connection, the voltage is added and the current remains the same.

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S.No	Parameters	Range
1	Number of solar cells	72
2	Voltage- Open circuit (V_{OC})	44 V
3	Current - Short circuit (I_{SC})	7.58 A
4	MPP Voltage (V_{MP})	35.55 V
5	MPP Current (I_{MP})	7.04 A

Table.1 Solar Panel Ratings

C. Maximum Power Point Tracking

If MPPT method is employed in wind turbines and PV solar panels, the extraction of maximum power is possible under all conditions. PV solar system has many different configurations. A typical solar panel efficiency is about 30-40 (%). Application of MPPT increases the efficiency of the solar panel rapidly. If the operating point is maintained at MPP even for the rapid environmental changes then the solar panel supplies maximum power to the load. Among many number of MPPT methods available, the most suitable techniques for medium and large-size photovoltaic applications are P&O and INC [16-18]. These MPPT techniques are easy to implement.

D. Incremental Conductance Algorithm

Among all the available MPPT algorithms, the Incremental Conductance Algorithm shows better performance. The incremental Conductance method is having high tracking speed, better efficiency and it is easily adaptable for the varying atmospheric conditions and hence the efficiency of the PV system is increased. It is most suitable for the changing environmental conditions. The efficiency of (P&O) is 95% and the INC method is 98% [2].

In this method, the current output and voltage output of the PV array are sensed using sensors. The P&O method fails to track the maximum power during the rapidly varying atmospheric conditions whereas in INC method this drawback is eliminated. The incremental conductance value is calculated to find the MPPT and if the MPP is reached it stops perturbing the operating point[19].

$$\left(\frac{dP}{dV}\right)_{MPP} = 0.$$

$$\left(\frac{d(VI)}{dV}\right) = 0.$$

$$I\left(\frac{dV}{dV}\right) + V\left(\frac{dI}{dV}\right) = 0.$$

$$I + V\left(\frac{dI}{dV}\right)_{MPP} = 0.$$

$$\left(\frac{dI}{dV}\right)_{MPP} = -\frac{I}{V}.$$

The term –I/V and (dI/dV) represents the instantaneous conductance and the incremental conductance of the PV panel respectively.

The principle of this method is that the P-V curve has zero slope at the MPP. For the decrease in slope MPP lies on the right side and for the increase in slope MPP lies on the left side. This can be given by,

$$\left(\frac{dP}{dV}\right) = 0 \text{ at MPP.}$$

$$\left(\frac{dP}{dV}\right) > 0 \text{ at left of MPP.}$$

$$\left(\frac{dP}{dV}\right) < 0 \text{ at right of MPP}$$

Perturbation continues until the MPP is reached. Until the current changes, the operating point is maintained at this point.

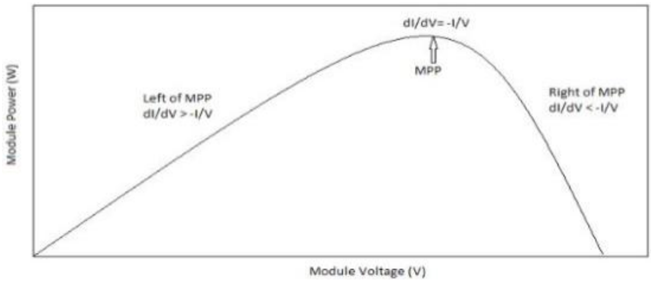

Figure 2. The concept of INC on a P-V curve

E. Flow Diagram

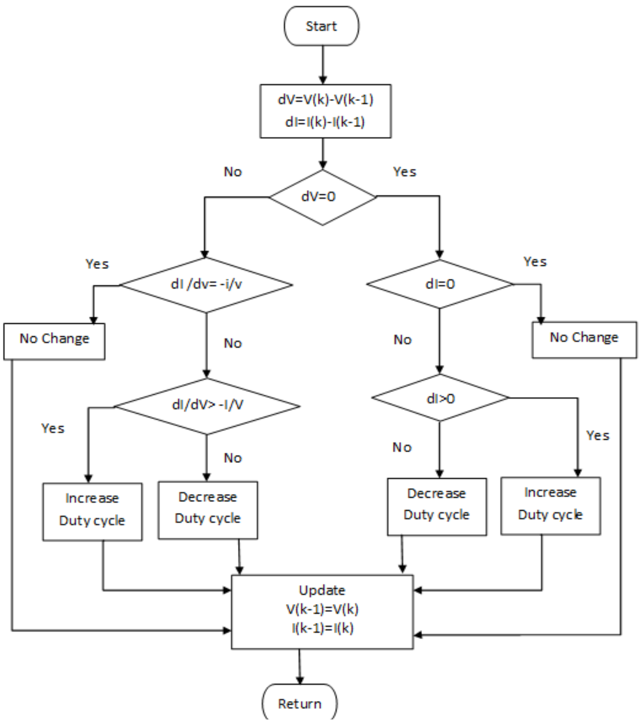

Figure 3. INC algorithm Flow chart

F. Sepic Converter

The circuit diagram of the SEPIC converter is shown in Fig. 4. A SEPIC is a DC-DC converter which has a boost stage and a buck stage. SEPIC converter has the capability of producing a non-inverted output. Its output voltage may be higher than or less than or equal to the input voltage.

The output voltage control is done by varying the converter switch duty ratio. The switch is generally a MOSFET. This device offers a greater input impedance,

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minimum voltage drop and reduced losses. This converter has two inductors and two capacitors which transfers energy to load. Both the inductor L1 and the MOSFET switch performs a boost operation. The inductor L2 performs a buck-boost operation.

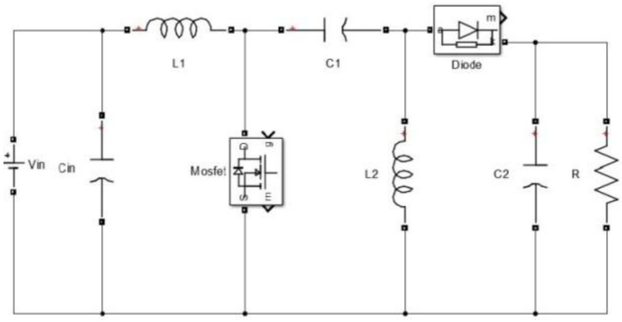

Figure 4. SEPIC converter circuit

G. Neural Networks

A neural network is inspired by biological neural networks as like a brain. Human brain learns from experience and informations are stored as patterns. The information storage process interms of patterns has a new computing field. This computing uses a massive networks and are trained to solve a specific problem [20].

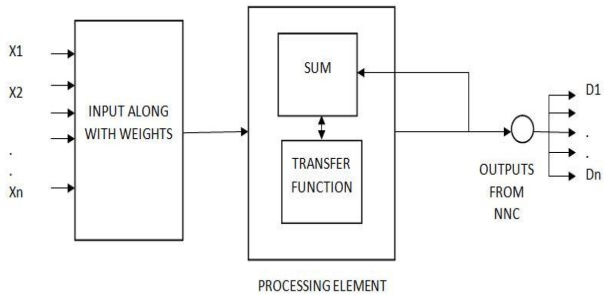

Figure 5. Artificial Neural Network Layout

A set of artificial neurons have been interconnected to form the neural network, and it processes the information using a connectivity approach for computation.

All artificial neural networks exhibit the same structure. In this, some neurons interfere to receive input, other neurons interfere with the network output and rest of the neuron has a role but will not be displayed. Basically, the neural network has input layer, output layer and the hidden layer. The existence of hidden layer depends on the application. This neural network for induction motor speed control has two layers, namely input layer and output layer.

H. Training and Artificial Neural Network

After framing the network for a particular application the next step is training the artificial neural network. This process involves the random assumption of initial weights. Artificial neural network training can be approached in two ways namely supervised and unsupervised.

The output is known in supervised training and therfore input is given as per the required output. This process involves the comparison of resulting output and desired output so that error value would be generated. The error value so obtained is propagating back and weights are adjusted and this process continues until desired output is obtained. The set of data which enable this whole process is called "training set". On other unsupervised training will be preceded by the random input as desired output is not predictable. So this process is also called as self-organization [21].

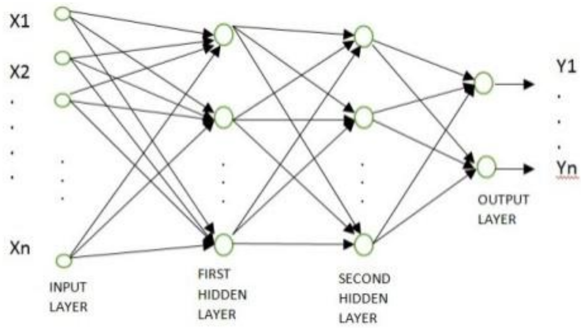

Figure 6. The layout of typical Neural Network

I. Components of Artificial Neural Network

There are seven major components involved in the artificial neural network. These components are important whether the neuron is used in input, output or hidden layer [22-23].

1. Determination of weight
2. Summation function
3. Transfer function
4. Scaling and limiting
5. Output function
6. Error function and back propagated value
7. Learning function

J. Steps Involved in Framing ANN

Step1: Input to the Artificial Neural Network

The error voltage from the motor is given at input of the artificial neural network.

Step2: Processing of Input

From multiple inputs, a single input is chosen and assumed minimum value is subtracted and multiplied by the gain which is the ratio of output range to input range, and in some situation, additional bias is given to the input. This forms the first layer of an artificial neural network.

Step 3: Output Processing

The layer 1 output is given as an input to this layer 2 and the output would be a two-dimensional element. This element is made dot products with weights assumed and then given to the transfer function and the process of step 2 is done in a reverse manner

III. SIMULATION MODELING

A. MPPT Modeling Using Neural Network Controller

Fig. 7 shows the modeling circuit of Neural Network Controller method and its subsystem with incremental conductance algorithm. It shows that the 1kW solar panel connected to the SEPIC converter along with a

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single phase induction motor (1HP) as a load. The speed of the single-phase induction motor is measured and the error & change in error are given to the controller. The controller generates pulses which are combined with the pulses obtained from the Incremental Conductance Algorithm of a Solar panel and fed to SEPIC converter and desired voltage output is produced [24-25].

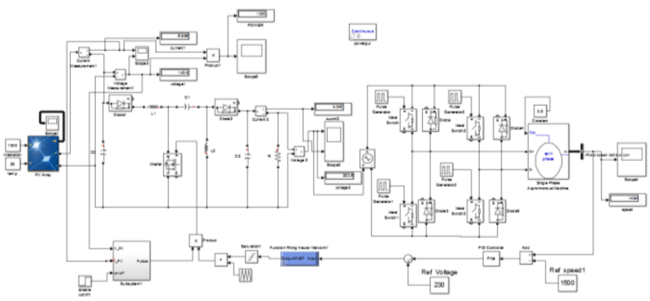

Figure 7. Simulink Model for Neural Network Controller

B. Modeling of Neural Network Controller Subsystem

MATLAB Simulink subsystem model for neural network is shown in Fig. 8. Comparison of the reference value with the output voltage is done. Based on the error values, the output voltage is generated from trained neural networks.

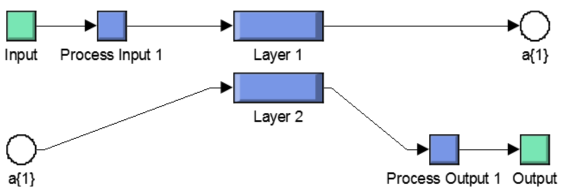

Figure 8. Neural Network Subsystem

IV. SIMULATION RESULTS

A. Output Current & Voltage from solar panel

Fig. 9 shows the simulation output of voltage and current of the photovoltaic system. Simulation results show that the output voltage obtained is of 143.8V and output current obtained is of 6.9A.

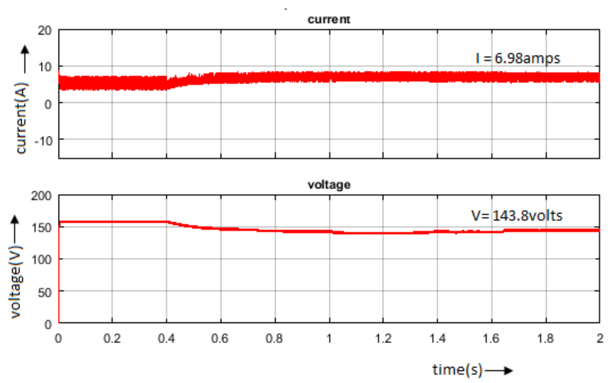

Figure 9. PV Output Voltage & Current with NNC

B. Output Power of PV panel

Fig. 10 shows the simulation result of PV output power. Output power obtained from the simulation is of 1000W.

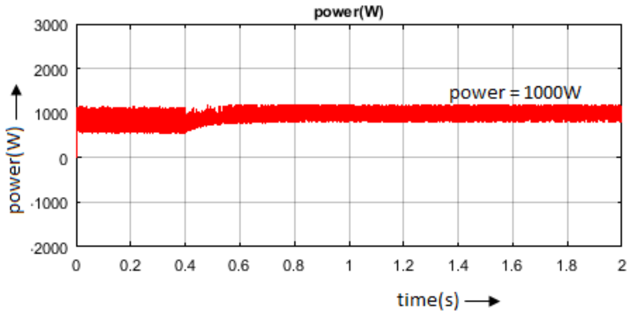

Figure 10. PV Output Power with NNC

C. Output Current & Voltage of SEPIC converter

Voltage and current output from solar panel is boosted up to 230.6V & 4.06A using SEPIC converter. Fig. 11 gives the simulation result of the voltage output and the current output from the SEPIC converter.

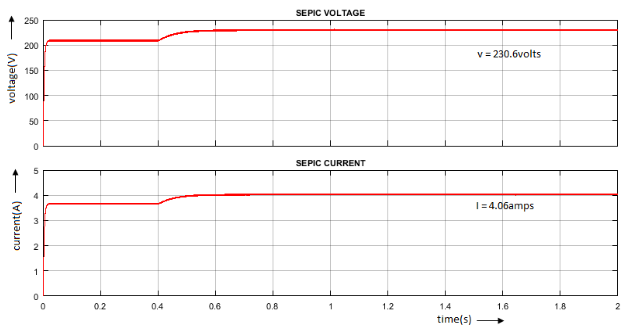

Figure 11. Output Voltage & Current Of SEPIC Converter With NNC

D. Output Speed of the Motor

The following Fig. 12 show the simulation result of output speed of the single phase induction motor. By applying the obtained SEPIC voltage to the Induction motor, its speed gradually increases to 1000 RPM and after t=0.5 seconds the speed of the motor reaches to the steady state value of 1494RPM.

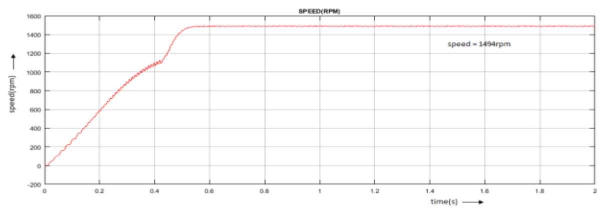

Figure. 12 Motor Speed with NNC

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V. RESULTS

Output voltage of the SEPIC converter	Output current of SEPIC converter	Speed of the motor
230.6 V	4.05 A	1494 rpm

Table.2: Voltage, Current and Speed

Using NNC, the voltage and current from the solar panel is obtained as 143.8V and 6.98A and output power as 1000W. The obtained voltage and current is boosted to 230.6V and 4.05A using SEPIC converter. The inverted voltage is applied to the induction motor at no-load condition which runs at 1494rpm.

VI. CONCLUSION

Design of the neural network controller for the single phase induction motor (1 HP) speed control, driven by the solar energy system has been highlighted in this paper. The peak power from the solar panel is extracted using Incremental Conductance method. Solar panel output voltage and current are regulated by SEPIC converter which feeds the single phase inverter and that drives the induction motor. The pulses from the respective controller and Incremental Conductance algorithm based MPPT Controller is combined then given to the SEPIC converter to increase the voltage obtained from the solar panel. The Induction Motor speed is given as feedback to the controller. The simulation for the neural network controller has been carried out. Simulation results obtained shows that Neural Network controller performs better for speed control of induction motor.

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