Neural Network MPPT control for Grid-Connected PV System

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***Abstract* - In this paper, the neural network (NN) based maximum power point tracking (MPPT) controller is presented for grid connected PV system. The grid connected PV system has its advantage of as it does not require storage system and provide efficient power utilization. The proposed system consists of PV array made from the combination of series parallel connected PV modules, boost converter on which MPPT is incorporated, three-phase voltage source inverter and the grid. Complete system is modeled and simulated using MATLAB/ Simulink and NN is trained using the neural network toolbox. To validate the performance of the proposed MPPT controller, comparative study is performed with conventional P&O MPPT controller. The study reveals that the proposed NN based MPPT controller shows better performance and produce satisfactory results.**

***Index Terms* - MPPT, ANN, Artificial intelligence, Solar Photovoltaic, P&O.**

I.INTRODUCTION

Now-a-days energy usage has been increasing at a comparably fast rate due to increase in population, urbanization, and industrialization. India is the fourth biggest energy consumer in the world after United States, China, and Russia. Renewable energy sources are substitute of our traditional energy sources which are limited and will expire [1].

In 1950, carbon emission in the worldwide due to fossil fuel combustion was 1.6 billion tones. By 1979, due to reduced fossil fuel consumption and improved emission control, the carbon emission reduced slightly. Energy resources can be classified into two categories and are renewable and non-renewable. Renewable energy is environment friendly and freely available energy source [2]. Nonrenewable energy sources produce pollution due to combustion of fuels and are harmful to the environment [3].

The power output of solar PV system changes, when there is a change in direction of sun, solar insolation level and temperature. Maximum power point tracker is used to extract the maximum power from solar PV system [4].

There are different methods for maximum power point tracking like Perturb and Observe (P&O) [5], Incremental Conductance (IC), Current Sweep, Fractional Open Circuit Voltage (FOCV), Fractional Short Circuit Current etc. [2], [6]– [8].

Artificial intelligence techniques have the potential for making better, quicker, and more practical decisions than any of the traditional methods. The advantage of the AI-based model is the fast-Maximum Power Point (MPP) approximation according to the parameters of the PV panel. The Artificial Neural Network (ANN) is the component of AI. The advantage of ANN based algorithm is this is that there is no need to solve the complex mathematical relation between output power, irradiance of solar PV system, temperature of solar PV system. The proposed ANN based MPPT system can search the MPP quickly and exactly in accordance with the change in environmental conditions [9]–[12]. The main objective is to achieve fast and stable response for the real power, controlled by an ANN based controller. The solar system uses ANN based technique to achieve effective maximum power point tracking. ANN provides better efficiency, accuracy and fast response making the system more effective.

It is also important for the AC utility system to produce high quality power at a fair cost. Via high frequency switching with PWM (Pulse width modulation) technologies of semiconductor chips, high power factor and low harmonic distortion. PV cell modelling, maximum power point tracking

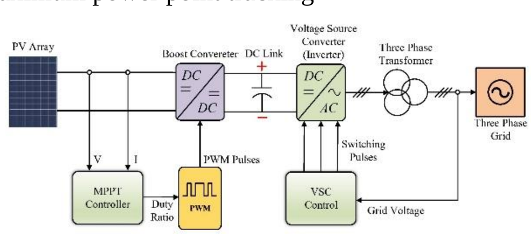

Fig. 1 Grid-Connected PV system with MPPT controller

(MPPT) algorithm, DC/DC converter and grid-connected DC/AC inverter are main technologies of a PV system.

In this article will present the ANN based MPPT control for grid connected PV system. configuration of proposed system. ANN model is trained using the PV voltage and current measurements and boost converter duty ratio is considered as target output.

II. SYSTEM CONFIGURATION

Configuration of the grid connected PV system with P&O MPPT is shown in Fig. 1. The proposed system consists of 50kW solar array directly tied to the DC-DC boost converter; this DC-DC converter connected to grid side inverter through DC link capacitor. This inverter power fed to the grid through step-down transformer. MPPT controller uses the PV voltage and current as an input and output the duty ration for the PWM controller which acting at 4kHz switching frequency. Parameters for the PV systems used is shown in table I.

Table I: PARAMETERS OF PV SYSTEM USED IN SIMULATION

Total capacity of the PV array system	50kW
Module maximum power of PV module(W)	390.01
Module voltage at maximum power point(V)	72.9
Module current at maximum power point(A)	5.35
Module open circuit voltage(V)	85.3
Module short circuit current(A)	5.72

III. MATHEMETICAL MODELING

PV module is composed of solar cells. Individual solar cells are connected in series and parallel and mounted on a single panel. Single diode model of PV cell is most widely used model. Output power can be calculated using current voltage relationship. This current voltage relationship is based on electrical characteristics of the model. An equivalent circuit of a single diode model is shown in the Fig. 2.

The voltage-current relationship can be written as:

$$I = I_{ph} - I_d = I_{ph} - I_0 \left\{ e \frac{q(V+Rs)}{AKT} - 1 \right\} - \frac{V + IR_s}{R_{sh}}$$

(1)

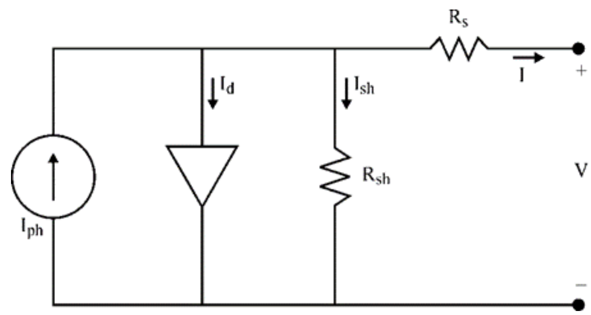

Fig. 2 Equivalent circuit of PV Cell

Where, I_{ph} is light Current, I_d is Diode Current, I_0 is Saturation Current, V is Output voltage, R_s is Series Resistance, q is Electron Charge, A is Curve Fitting Factor, K is Boltzmann Constant and R_{sh} is Shunt Resistance.

The DC-DC boost converter can regulate the voltage at output when sudden changes occurs at input and output conditions. Modeling and analysis of DC-DC boost converter is studied in this section.

The circuit diagram of the DC-DC boost converter is shown in the Fig.3. To control the voltage at output V_{out}, duty cycle of the switch is controlled.

When the switch S_w is in ON condition, the energy is stored by the inductor in the circuit and when the switch S_w is turned OFF, the energy is released by the inductor in the circuit.

Under the continuous conduction mode (CCM) operation, the value of L and C can be calculated using following equation.

$$L = \frac{D \times V_i}{\Delta i_L \times f_s} \quad (2)$$

$$C = \frac{D}{(\Delta V_{out} / V_{out}) \times R \times f_s} \quad (3)$$

Where D is Duty Cycle, fs is switching frequency.

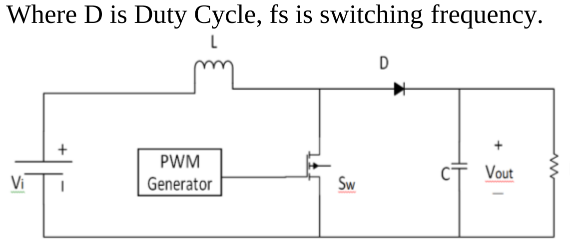

Fig. 3 Boost converter circuit

For converting DC into AC, a three-phase 6-pulse pulse width modulation (PWM) voltage source inverter (VSI) is used. Fig 4. shows the circuit diagram of a 3 phase PWM voltage source inverter.

Fig. 5 shows the Simulink Model for grid connected Solar PV system with MPPT Controller.

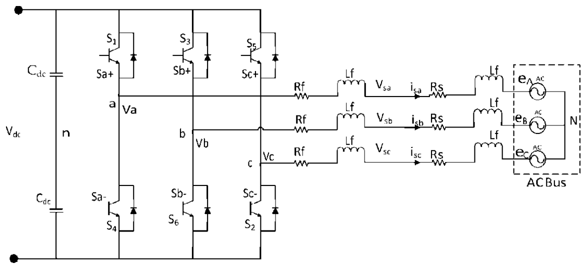

Fig. 4 Three-phase voltage source inverter for grid connection

IV. MPPT CONTROLLER

In order to improve the performance of maximum power point tracking of solar PV system, an effective MPPT controller is developed and compared with the conventional P&O.

A. Conventional P&O MPPT Algorithm

The Perturb & Observe algorithm states that if the operating voltage of the PV panel is changed by a small increment, if the resulting shift in power P is positive, then we are going in the direction of the MPP, and we're going in the same direction. If P is negative, we are heading away from the path of MPP, and the sign of change given has to be changed. Flow chart of conventional P&O is shown in Fig. 6.

B. Artificial Neural Network MPPT Controller

“Artificial Neural Networks (ANN) are massively parallel interconnected networks of simple organizations (processing elements) which are intended to interact with the objects of real world in the same way as the biological neural system do.”

These parallel distributed models are potentially capable of performing non-linear modeling and adaptation without any assumptions about the model. In very broad terms, the ANN may be defined as an attempt to capture the human brains capabilities for solving complex problem.

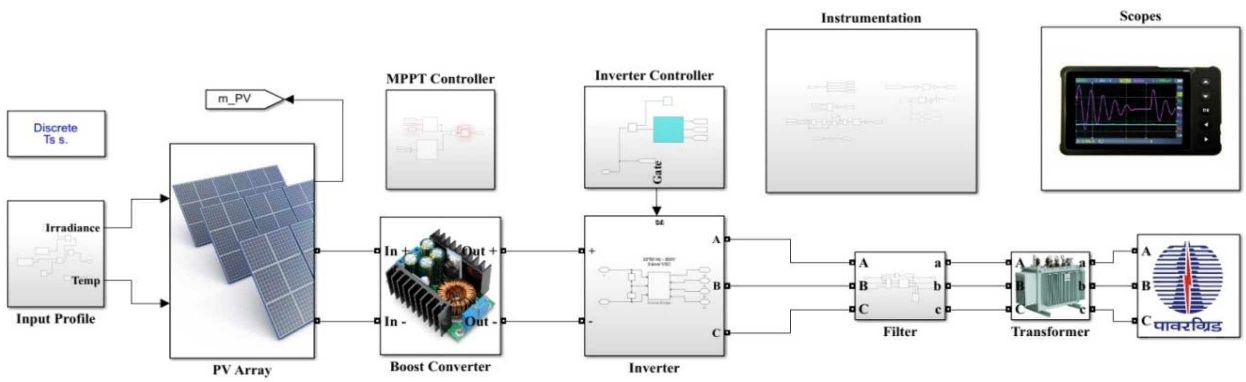

Fig. 5 Simulink model of proposed system

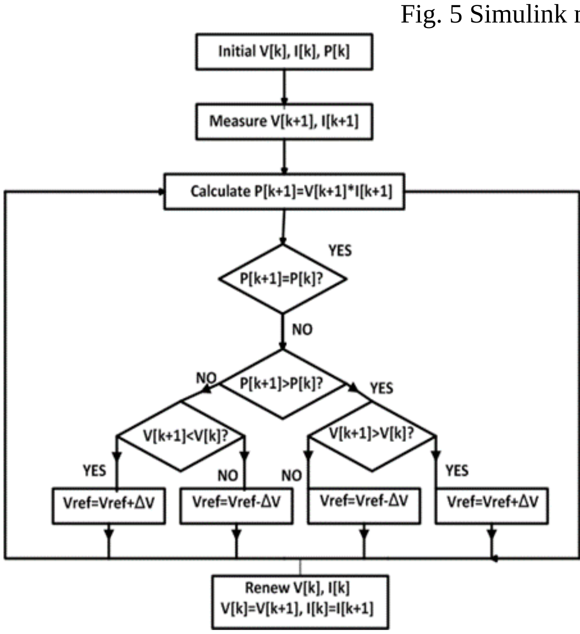

Fig. 6 P&O MPPT controller flow chart

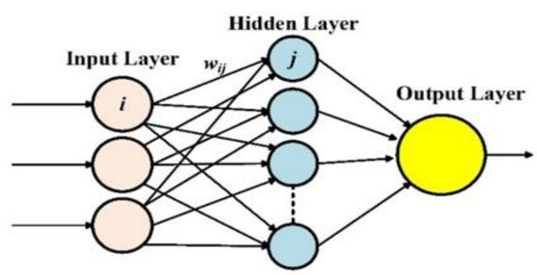

Fig. 7 Basic Architecture of artificial neural network

The ANN consists of several artificial neurons that are connected through variable weights connections. Basic Architecture of the ANN consists of three layers as an input layer, hidden layer and output layer which is shown in Fig. 7.

The neural network for a PV system consists of two input variables: voltage and current. Hidden layer consists of 15 neurons.

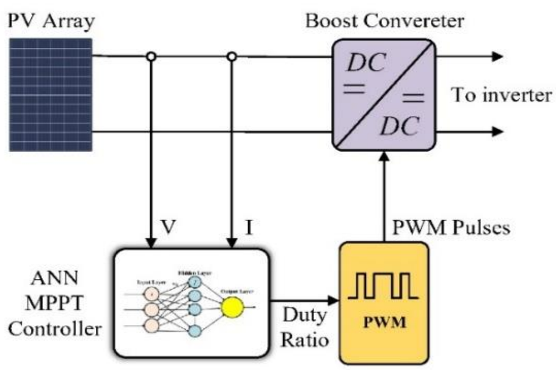

Fig 8 Proposed MPPT Controller

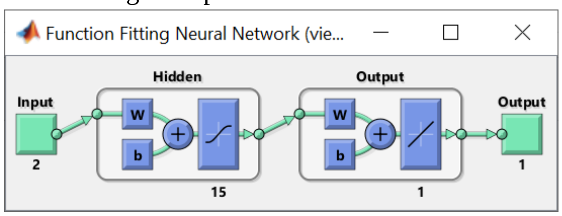

Fig. 9 Architecture of Levenberg- Marquardt and Bayesian- regularization ANN

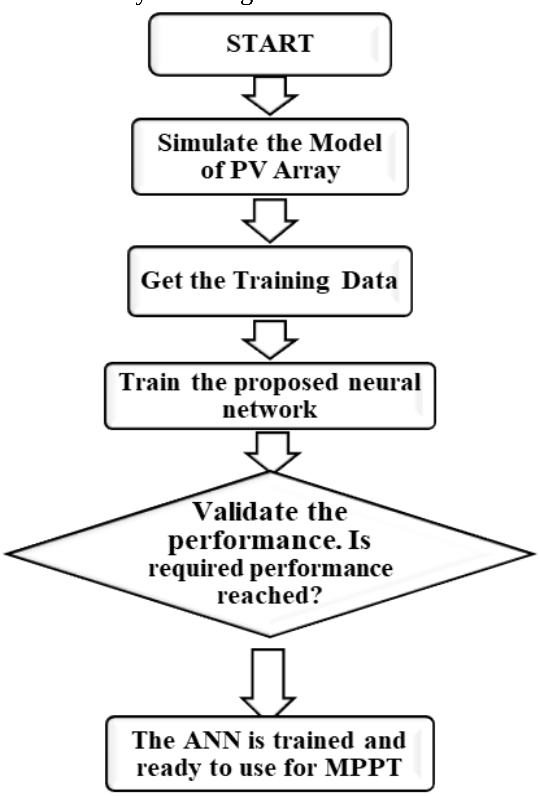

Fig. 10 Flow chart of ANN MPPT algorithm

Levenberg-Marquardt and Bayesian regularization algorithm is used for the training of the neural network for the MPPTs. Proposed MPPT scheme is shown in Fig. 8. Fig. 9 shows the architecture of the Levenberg-Marquardt and Bayesian- regularization ANN. Flow chart of ANN MPPT is shown in Fig. 10.

V. SIMULATION RESULTS AND DISCUSSION

The proposed PV system is simulated for 3.2 sec in MATLAB/Simulink. Irradiance profile is stepped manner. The irradiance and temperature profile for the input of PV array, Performance of voltage, power, current for both ANN and P&O algorithm is shown in Fig. 11 and Fig. 12 efficiency, THD, frequency for both ANN.

The average power increase by levenberg and Bayesian is 3.43% and 3.08 % respectively. The artificial intelligence based Levenberg and Bayesian based MPPT controller gives nearly ideal performance as seen from the Fig. 10 and Fig. 11.

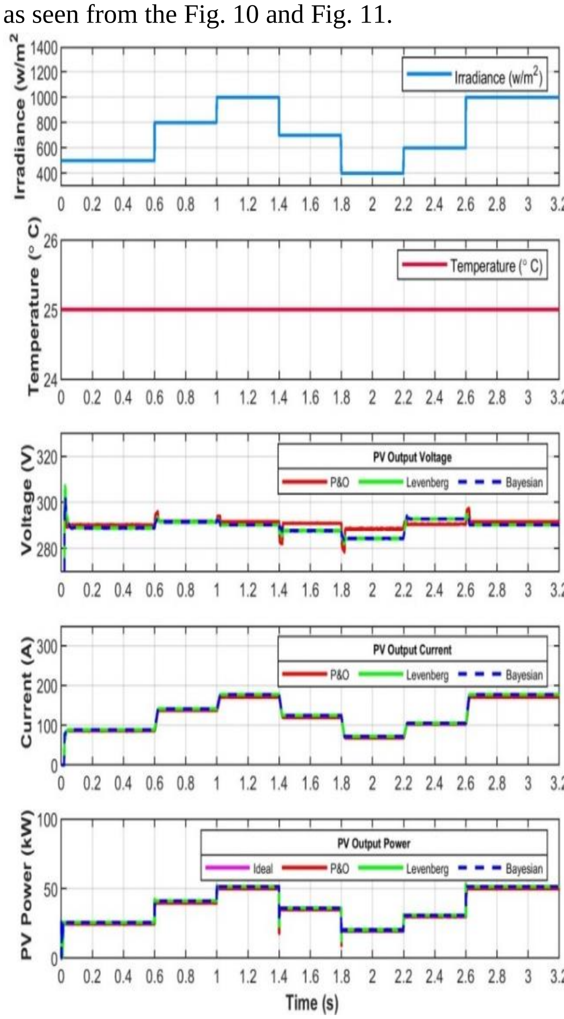

Fig. 11 Comparative results of ANN MPPT algorithm with conventional MPPT algorithm for grid connected solar PV system.

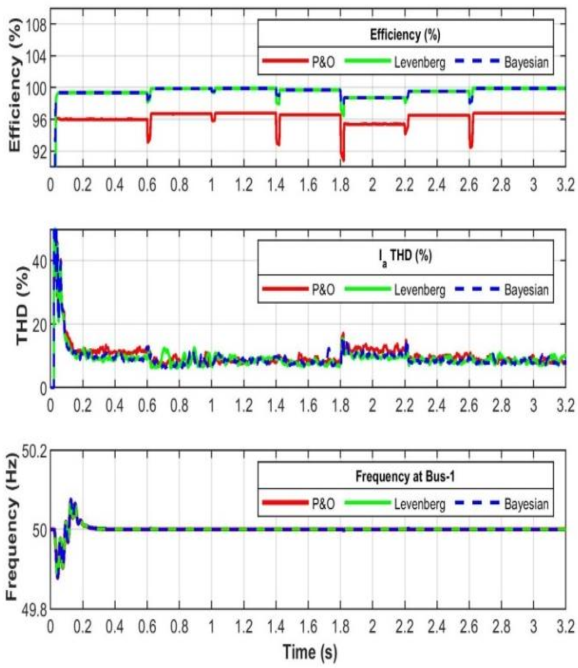

Fig. 12 Performance in terms of efficiency, THD and frequency

VI. CONCLUSION

The results show that the grid connected solar PV system consists of ANN MPPT algorithms gives improved performance than the conventional P&O MPPT algorithm. The overall efficiency ANN MPPT algorithms for grid connected PV system is 99.57 % and overall efficiency of conventional P&O is 96.39% Total Harmonic Distortion of ANN based MPPT controller is less as compared to P&O.

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