Boost Half Bridge Converter with ANN Based MPPT

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Abstract— This paper deals with the design and implementation of the boost half-bridge photovoltaic (PV) system with ANN based MPPT. In order to achieve low cost, easy control and high efficiency, a boost-half-bridge dc-dc converter is introduced to interface the low-voltage PV module. An ANN based maximum power point tracking (MPPT) generates the PV voltage reference. ANN is adopted such that fast tracking speed and high MPPT efficiency are obtained. It also improves the robustness of the MPPT system against temperature and irradiance. The performance of the system will be investigated with MATLAB/Simulink .

Index Terms—Artificial neural network (ANN) Boost half bridge converter (BHB), Maximum power point tracking (MPPT), **Photovoltaic (PV),**

I. INTRODUCTION

Conventional energy sources are unable to meet the increasing demand for energy worldwide. So, alternative energy sources like sunlight, wind and biomass come into picture. Among a variety of the renewable energy sources, photovoltaic (PV) sources have no supply limitations and are predicted to become the biggest contributors to electricity generation [1, 2]. The major advantages of using PV cells are: short lead time for designing and installing a new system, output power matching with peak load demands, static structure, no moving parts, longer life, no noise, inexhaustible and pollution free. For best utilization, the photovoltaic cells must be operated at their maximum power point (MPP). However, the MPP varies with illumination, temperature, radiation dose and other ageing effects [3]. To obtain the maximum power from a photovoltaic array, a maximum power point tracker (MPPT) is used. Commonly used MPPT techniques are perturb and observe (P&O) method, incremental conductance (IC) method, ripple correlation method, artificial neural network (ANN) based MPPT methods etc. Among the variety of MPPT methods

we use a neural network (NN) based MPPT system which is much faster than traditional ones and improves the robustness of the MPPT system against temperature and irradiance [4][5].

The isolated step-up dc–dc converter has been increasingly needed in high-power applications, such as fuel-cell systems, photovoltaic systems, hybrid electric vehicles, and uninterruptible power system (UPS), where high-step-up ratio and the use of high-frequency transformers for galvanic isolation and safety purpose are required. Among different topologies of dc-dc converter boost-half-bridge (BHB) converter has been presented. It demonstrates the following features: small input filter due to continuous input current, low electromagnetic interference (EMI) due to ZVS turn ON of all power switches, wide-input voltage range application due to wide-duty cycle range. The BHB converter with a voltage- doubler circuit at the secondary has further advantages such as no dc magnetizing current of the transformer, reduced voltage surge associated with diode reverse recovery, and no circulating current due to absence of output filter inductor [6].

II. MODELLING OF PVMODULE

Modeling is basic tool of the real system simulation. For modeling, it is necessary to analyze the influence of different factors on the photovoltaic cells and to take in consideration the characteristics given by the producers. The mathematical models for photovoltaic cells are based on the theoretical equations that describe the operation of the photovoltaic cells and can be developed using the equivalent circuit of the photovoltaic cells. The ideal equivalent circuit of a PV cell is a current source in parallel with a single diode. The configuration of the simulated ideal solar cell with single-diode is shown in figure 1
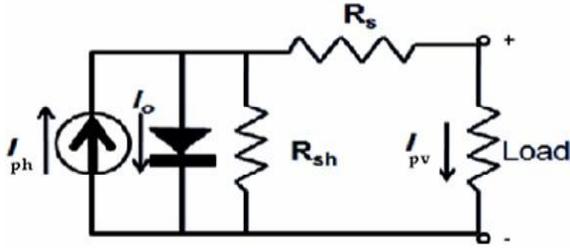
Figure 1.Single Diode Model of a Solar Cell

The current source generates the photo current I_{ph} which is directly proportional to the solar irradiance G [W/m²] and the ambient temperature T [°C]. The characteristic equation of the one diode model could be derived from Kirchhoff's current law:

$$I_{pv} = I_{ph} - I_0 - I_{rs}$$

where, I_{pv} is the output current of a PV module, I_{ph} represents the current generated by the incident light, I_0 is the diode current and I_{rs} is the reverse saturation current of the diode The photocurrent I_{ph} is given by the equation:

$$I_{ph} = [I_{scr} + K_i(T - T_r)](\lambda/100)$$

Where, I_{scr} is the short circuit current, T is the junction temperature, T_r is the reference temperature K_i is the temperature coefficient and λ is the PV module illumination. The diode current I_o can be calculated using:

$$I_0 = I_{rs}[\frac{T}{T_r}]^3 \exp\left(qE_{g0}\left(\frac{1}{T_r} - \frac{1}{T}\right)\right)$$

Where, q is the electron charge, Ego is the band gap for silicon and I_{rs} is the diode reverse saturation current and is given by the equation

$$I_{rs} = \frac{I_{scr}}{\left[exp\left(\frac{qV_{oc}}{N_s kAT}\right) - 1\right]}$$

V_{oc} is the open circuit voltage, A is the ideality factor, Ns is the number of cells connected in series and k is the Boltzman constant. The PV current can be calculated using the equation

$$I_{pv} = N_p I_{ph} - N_p I_o \left[e^{\left(q\left(\frac{I_{pv} + I_p R_S}{N_s kAT}\right)\right)} - 1\right]$$

Here N_p is the number of cells connected in parallel and Rs is the series resistance.

III. MPPTALGORITHMS

The output characteristics of photovoltaic arrays ie, the power verses voltage and the current verses voltage characteristics are nonlinear and change with the modules temperature and solar irradiance. For a given conditions there is a unique point in which the array produces maximum output power. This point is called maximum power point (MPP) which varies depending of cell temperature and present irradiation level. To obtain the maximum power from a photovoltaic array, a maximum power point tracker (MPPT) is used. The Perturbation and observation is one of the most commonly used MPPT methods for its simplicity and ease of implementation. The P& O works well when the irradiance change slowly but it presents drawbacks such as slow response speed, oscillation around the MPP in steady state, and even tracking in wrong way under rapidly changing atmospheric conditions.

In literature, the simplest models of MPPTs are based on the technique where PV-array voltage or current is compared with a reference voltage or current at which the solar PV delivers its maximum power. The error signal is then used to drive a power conditioner such as dc-dc converter with a PI controlled PWM. This method has a major disadvantage that the reference voltage or current changes with change of weather (temperature and solar irradiance). Thus the method is unable to deliver MPP for all weather conditions. This method can be improved byre-calculation of reference current or voltage. The Artificial Neural Network was used to model the PV and to calculate the reference value precisely for any weather condition.

A. ARTIFICIAL NEURAL NETWORK (ANN)

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems.

Artificial neural networks are the electrical analogues of the biological neural systems, called neurons, receives signals from the neighboring neurons or receptors through dendrites, process the received

electrical pulses at the cell body and transmit signal through nerve fibers called an axon. In a similar way the electrical model of a typical biological neuron consist of a linear activator followed by a non linear inhibiting function. The linear activation function yields the sum of the weighted input excitation, while the non linear inhibiting function attempt to capture the signal levels of the sum. The resulting signal produced by the electrical neuron gives the typical structure of a feed forward neural network.
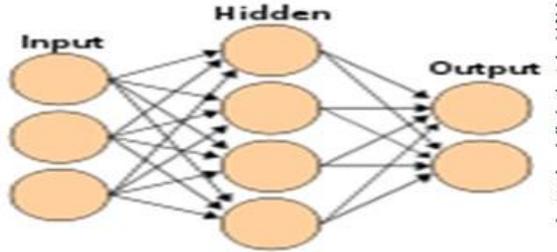
Figure 2.Basic structure of an ANN

The common type of artificial neural network consists of three groups, or layers, of units: a layer of input units is connected to a layer of hidden units, which is connected to a layer of output units. The basic structure of the neural network is shown in figure 2.

IV. BOOST-HALF-BRIDGE DC-DC CONVERTER

The boost converter converts an input voltage to a higher output voltage. The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. DC/DC converter helps to reduce the undesired effects on the output PV power and draw its maximum power. A boost half-bridge (BHB) dc-dc converter integrates the boost converter and the dual-half-bridge converter together by using minimal number of devices. It is composed of two decoupled power processing stages. Topology of the boost-half-bridge converter is shown in figure 3. The circuit consists of a boost inductor L_{in} and the input capacitor C_{in} respectively. In the front-end dc-dc converter, a conventional boost converter is modified by splitting the output dc capacitor into two separate ones. These half-bridges are placed on each side of the main transformer. The transformer is used to provide isolation and voltage matching. The leakage inductance of the transformer is utilized as an interface and energy transfer element between the two

voltage-source half bridge converters: low voltage side (LVS) and high voltage side (HVS) half bridges. The center taps of the two MOSFETs (S_1 and S_2) and the two output capacitors (C_1 and C_2) are connected to
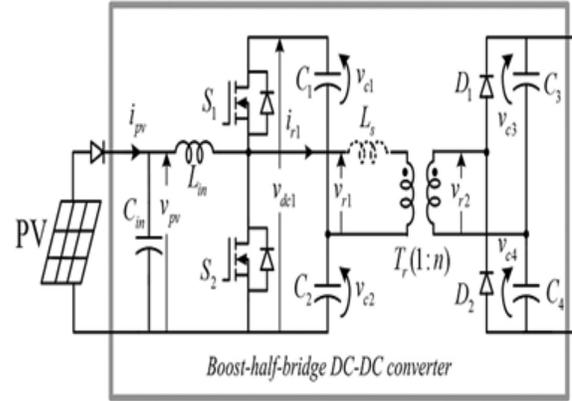

Figure 3.Topology of the boost-half-bridge converter.

the primary terminals of the isolation transformer T_r. The transformer leakage inductance reflected to the primary is represented by L_s and the transformer turns ratio is 1: n. A voltage doubler circuit composed of two diodes and two capacitors (C_3 and C_4) is incorporated to rectify the transformer secondary voltage to the inverter dc link.

The PV current and voltage are represented by I_{PV} and V_{PV}, respectively. The voltages across C_1, C_2, C_3, and C_4 are denoted by V_{c1}, V_{c2}, V_{c3}, and V_{c4}, respectively. The transformer primary voltage, secondary voltage, and primary current are denoted as v_{r1}, v_{r2}, and i_{r1}, i_{r2} respectively. The low-voltage side (LVS) dc-link voltage is v_{dc1} and the high-voltage side (HVS) dc-link voltage is v_{dc2}. The boost-half-bridge converter is controlled by S_1 and S_2 with complementary duty cycles. When S_1 is ON and S_2 is OFF, v_{r1} equals to V_{c1}. When S1 is OFF and S2 is ON, v_{r1} equals to V_{c2}. The two voltage-source half bridge converters: LVS and HVS half bridges, each generates a square-wave voltage applied to the primary and secondary of the transformer, respectively.

V. MATLAB/ SIMULINK SIMULATION MODEL

The simulation studies are performed in MATLAB/Simulink software. The figure 4 shows the model of simulink model of the PV cell. 210W solar

panel is modelled based on the following values given in the table 1.

TABLE 1. Parameters of the PV cell

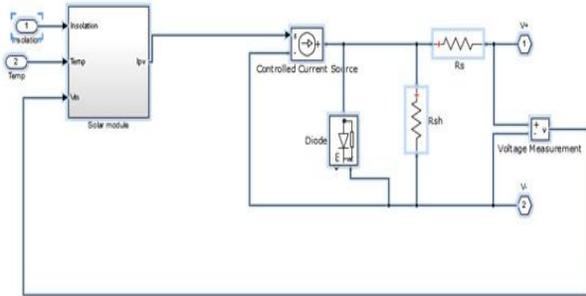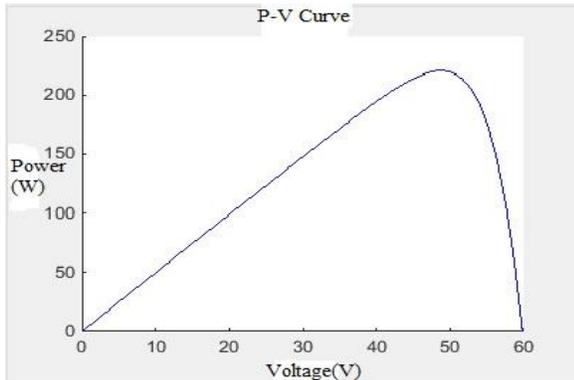| Maximum Power Pmax	210W
Voltage at Pmax	50V
Current at Pmax	4.2A
Open circuit voltage	60
Short circuit current	4.54A
Ns	100
Np	1

Fig.4 Simulink model of the PV module

Fig.5 PV curve

The figure 5 shows the PV characteristics of the PV module. From the PV curve it is clear that the maximum output power is 210W and the voltage at P_{max} is 50V. Figure 6 shows the simulink model of the ANN based MPPT.
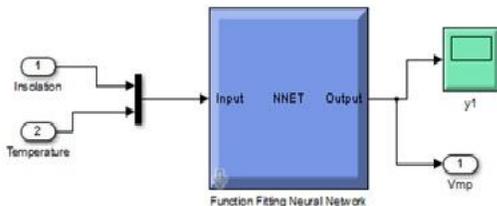

Fig 6 the Simulink model of the ANN based MPPT.

The figure 7 shows the simulink model of the PV module with boost half bridge converter. The nominal power of the converter is 210W and input voltage is 50V. The BHB converter boosts the input voltage to a higher value. Table 2 gives the simulation parameters.

TABLE 2. Parameters of the BHB converter

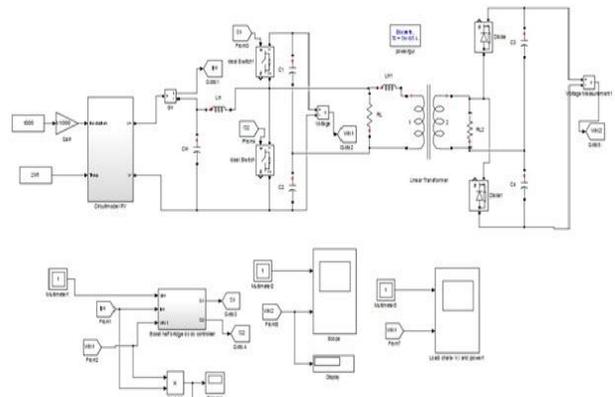| Nominal PV power	210W
Input Voltage	50V
Switching frequency	21.6kHz
Transformer turns ratio	1:6
Input inductor	200H
Capacitor	489F

Fig 7 Simulink model of the Boost Half Bridge Converter

Figure 8 shows the output voltage of the PV and the boost half bridge converter and figure 9 shows the transformer input voltage
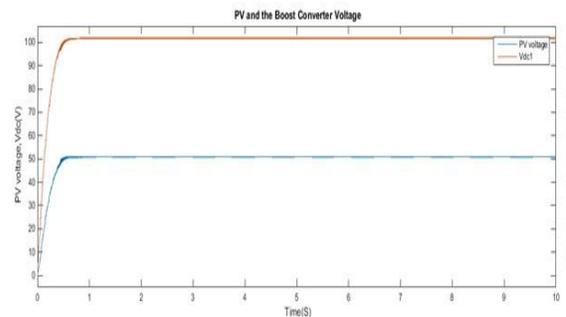

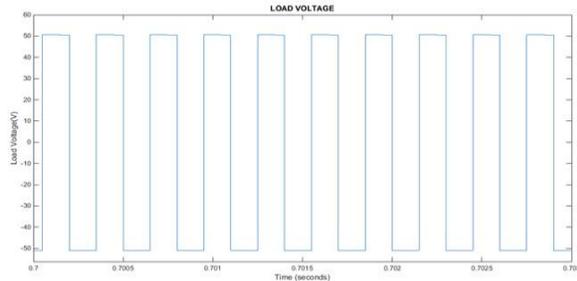Fig 8 Output voltage of the PV and the boost half bridge converter
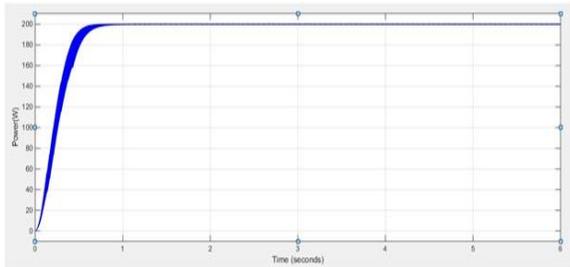
Fig 9. Transformer input voltage

Fig 10 Output power of the boost half bridge converter

VI. CONCLUSION

The proposed Boost half Bridge converter with ANN (Artificial Neural Network) based MPPT improves the stability of the MPPT system against temperature and irradiance. In our proposed method, we replace the traditional MPPT block with neural network based model which can directly predicts the right signal for PWM required for the MPP .This algorithm determines when the MPPT has reached the MPP (Maximum Power Point), where as P & O oscillates around the MPP. This is clearly an advantage over P & O. The boost-half-bridge PV possesses promising features of low cost and high reliability.

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