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Development and Analysis of ANN based MPPT and SL Z-Source Inverter for Photo-voltaic Systems

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Abstract : The artificial neural network is used as a maximum power point technique to transfer maximum power from a photovoltaic system to a three-phasestar connected R load. Switched inductor ZSI is used to increase the output DC voltage and also convert DC to AC voltage. The switched inductor ZSI eliminates the limitations of ZSI and by providing low voltage stress across components and employs a unique impedance. In the proposed system duty ratio control of switched inductor ZSI is developed to control the output voltage of photovoltaic system. The artificial neural network is trained with a hybrid back propagation track the maximum Voltage. The performance parameters are simulated in Matlab/Simulink environment.

Keywords : Artificial neural network [ANN], switched inductor ZSI, duty ratio control, back propagation.

1. INTRODUCTION

The rapid trend of industrialization of nations, increased interest in environmental issues led recently to explore the use of renewable forms such as solar energy. It also says that by 2022 renewable technologies will account for 175GW of new power generation capacity installing around the world, which includes 100GW solar and 60GW of wind energy. Solar energy which is available in most of the world has proven to be an economical source of energy. The solar energy has advantages no pollution, less maintenance, no noise emission. Some disadvantages of solar energy are low efficiency, a high cost of generation. Various types of power converters have been designed to interface solar resources for different applications. Output voltage is increased by connecting boost converter with inverter system in a two-stage conversion method. But single-stage conversion is becoming more popular in comparison to two stage conversion due to low cost, compactness, reliability, less voltage stress [1].Improving the performance of a ZSI switched inductor ZSI is implemented. Switched inductor Z-source inverter has some advantages by providing low voltage stress across the components and improving the modulation index.Different MPPT algorithms are available to track MPP from Photovoltaic system *i.e.* perturb and observe, incremental inductance, fuzzy logic controller(FLC), artificial neural network(ANN),etc. Fuzzy logic controllers have the advantage of relatively simple to design because they do not require knowledge of the exact model. The Main disadvantage of fuzzy logic control is complex algorithms which lead to a high cost of implementation. This paper presents human ANN based MPPT techniques are used to track the maximum voltage.

2. PROPOSED SYSTEM

In this proposed system, The ANN is trained with a set of input and output data. Artificial intelligence technique is used to track the maximum output voltage for the corresponding irradiance and temperature.

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PV panel output voltage is compared with the V_{mpp}. The error is given to PI controller it will reduce the steady state error. Output dc voltage of PV module is fed to Switched inductor ZSI and SLZSI converting the DC voltage to AC as well as boost up the voltage. The Output voltage of SLZSI is given to a three -phase star connected resistive load

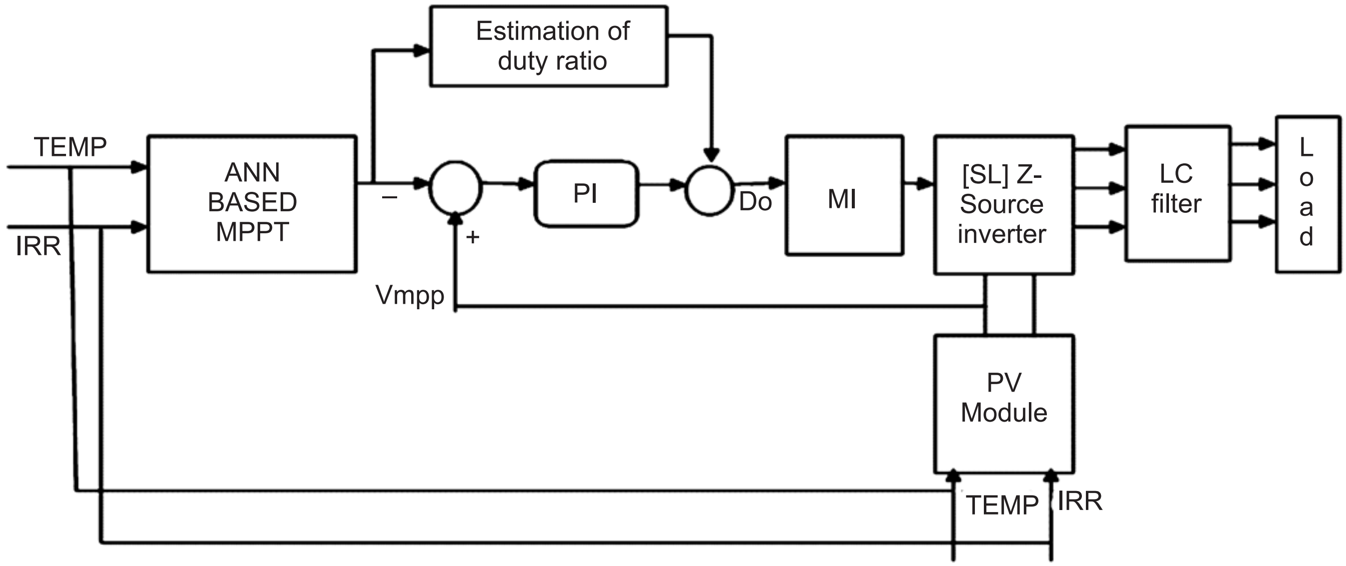

Figure 1: Block diagram of the proposed system

3. MODELLING OF PV MODULE

Photovoltaic cells which convert solar irradiance into electricity. this PV cells are made up of PN junction. Figure (2) represents the equivalent circuit of a PV cell.where I_d isdiode current. The type of diode determines the voltage and current characteristics of the cell. R_{sh} and R_s are shunt and series resistances, I_{sh} is shunt current, V is cell voltage, and I is output current of Photovoltaic cell [5].

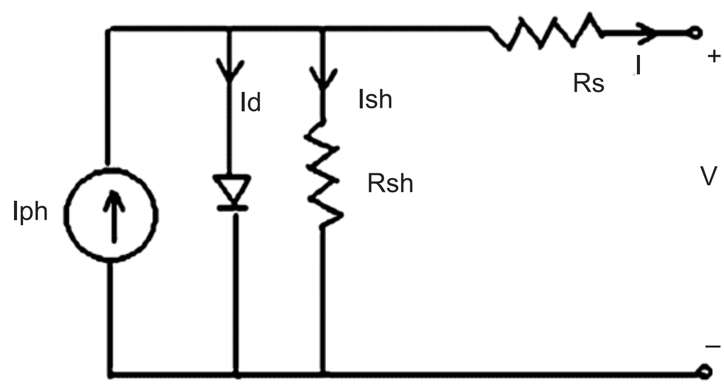

Figure 2: Equivalent circuit of Photovoltaic cell

From the PV equivalent circuit model, the current expression is obtained as

$$I = I_{ph} - I_s\left(\exp\frac{q(V + R_s I)}{NKT} - 1\right) - \left(V + \frac{R_s I}{R_{sh}}\right) \tag{1}$$

I_{ph} = Photovoltaic current
I_s = Reverse saturation current
I_{sh} = Shunt resistance current
R_s = Series resistance
R_{sh} = Shunt resistance

N = Diode quality factor

q = Electrical charge 1.6×10^{-19}C

T = Ambient temperature, in Kelvin

K = Boltzmann constant

The parameters (I_{ph}, R_s, R_{sh} and N) vary with temperature and irradiance. The PV cell photocurrent (I_{ph}) depends on the irradiation and the temperature. The output voltage obtained from the PV cell is very small. Some number of cells are connected in series and parallel to form PV module.

$$I = N_p I_{ph} - N_p I_s \left[\exp\left(\frac{q\left(\frac{V}{N_s} + \frac{INR_s}{N_p} \right)}{KNT} \right) - 1 \left(\frac{\frac{N_p V}{N_s}}{R_{sh}} \right) \right] \tag{2}$$

N_s is a total number of series cells and a N_p number of parallel connected cells.27 cells are connected in series and single cell connected in parallel. Photovoltaic module output voltage is 17V at temperature 25 °C and irradiance 750W/m^2

4. MAXIMUM POWER TRACKING

Maximum power tracking technique is used to increase the efficiency of the solar panel. Conventional based MPPT method has fixed step size and low efficiency because of the oscillations present around MPP. For improve the efficiency variable step sizing algorithms, *i.e.*, Artificial intelligent based techniques such a artificial neural network methods are applied [6] [8].

5. ARTIFICIAL NEURAL NETWORK

Artificial neural network as the name implies that the term neural network derive its origin from human brain or human nervous system. Which consist of massively parallel connection of a large number of neurons and that perform a different perceptual task, different reorganization task in an unceasingly small amount of time as compared to today high performing computer devices [4]. For training three-layer back propagation algorithm is used. Irradiance and temperature are considered as the input to the neural network and output of the neural network are maximum power point voltage. After learning the relation between MPP voltage and irradiance level and temperature the neural network can track the maximum power point voltage online[16-18]

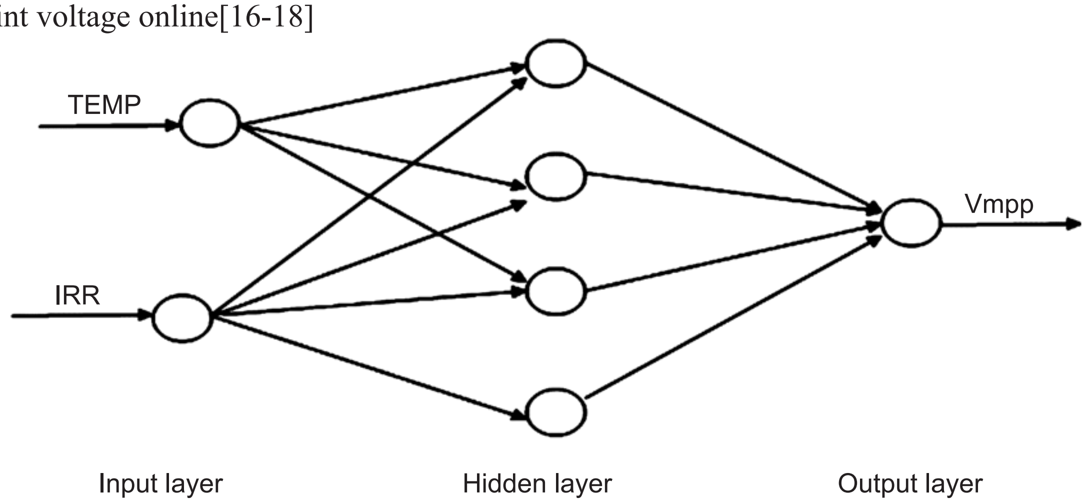

Figure 3: Neural network for Back propagation algorithm

A set of 220 training data are used for training the neural network by a specified learning algorithm. The learning algorithm used is a hybrid back propagation. In this irradiance range is 50 W/m^2 to 1000 W/m^2 in a step of 50 W/m^2 and temperature range is from 10°C to 70°C in a step of 6°C. When the performance function has the function of sum of squares, then the Hessian matrix can be approximated as

$$H = J^TJ \tag{3}$$

The gradient can be computed as $g = J^Te$ (4)

In Equation (3) and (4) J is the Jacobin matrix that contains first derivatives of the network errors with respect to the weights and biases, and *e* is a vector of network errors. Make sure that the approximated Hessian matrix J^TJ is invertible, Levenberg–Marquardt algorithm is another approximation to Hessian matrix.

$$H \approx J^TJ + \mu I \tag{5}$$

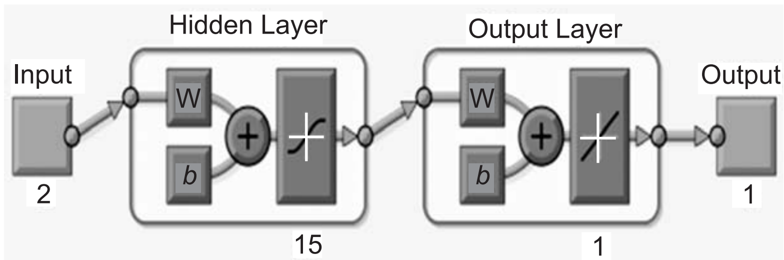

Figure 4: Neural network generated from Simulink

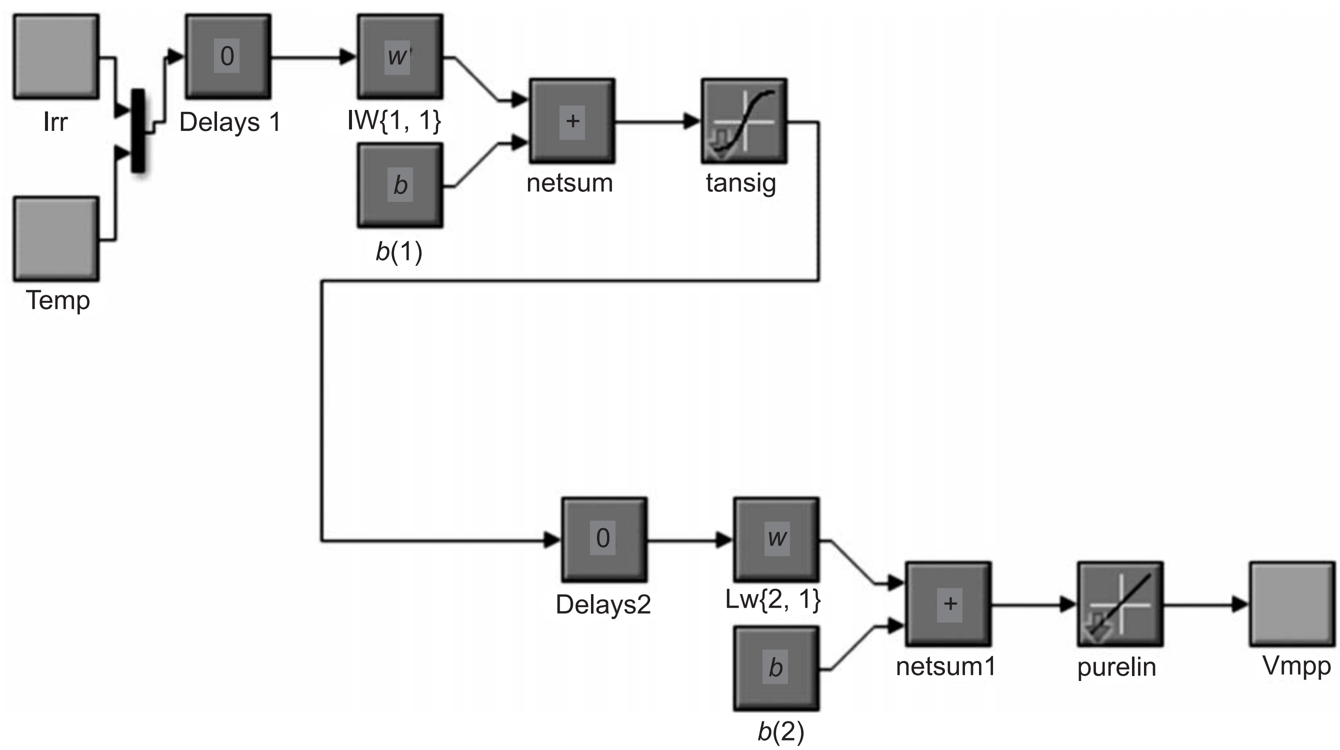

Figure 5: Matlab/Simulink model of ANN

The weights are adjusted in the training process [7][9]. A set of training data is required in training process and trained over a lengthy period of time so that we can obtain maximum voltage accurately.

6. SWITCHED INDUCTOR ZSI

The Switched inductor ZSI has been developed for application of photovoltaic system [20][22].To enhance voltage adjustability the three-phase SLZSI employs a unique impedance network to integrate the inverter actual circuit to the power source. Short shoot through time required in high voltage applications, which reduces the voltage stress across passive components [10].

The combination of L1-L2-D2-D3-D5 and the combination of L3-L4-D1-D4-D6 performs the function of the top& bottom switched inductor cells are used to store and transfer the energy from the capacitor to the DC bus [11-14].

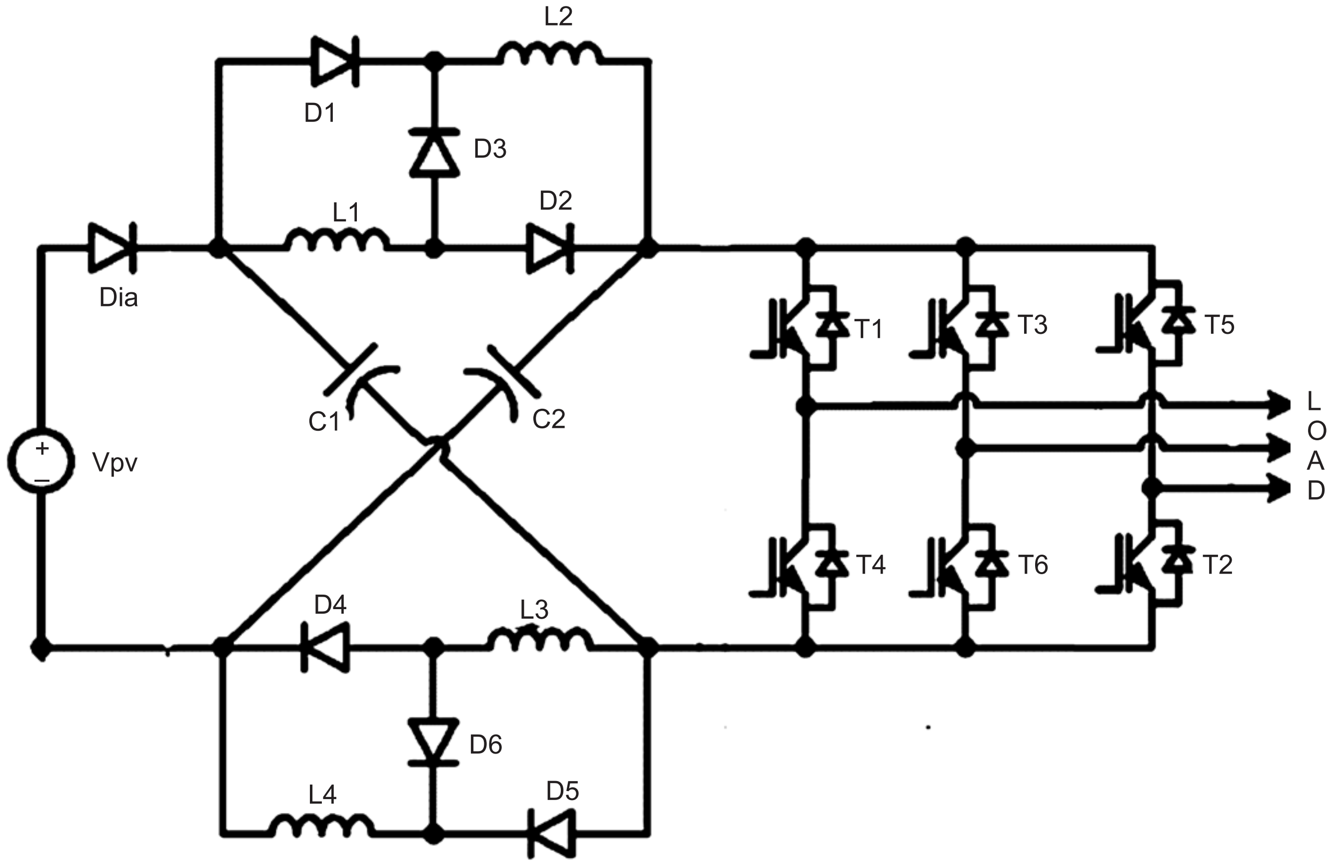

Figure 6: Equivalent circuit of [SL] ZSI

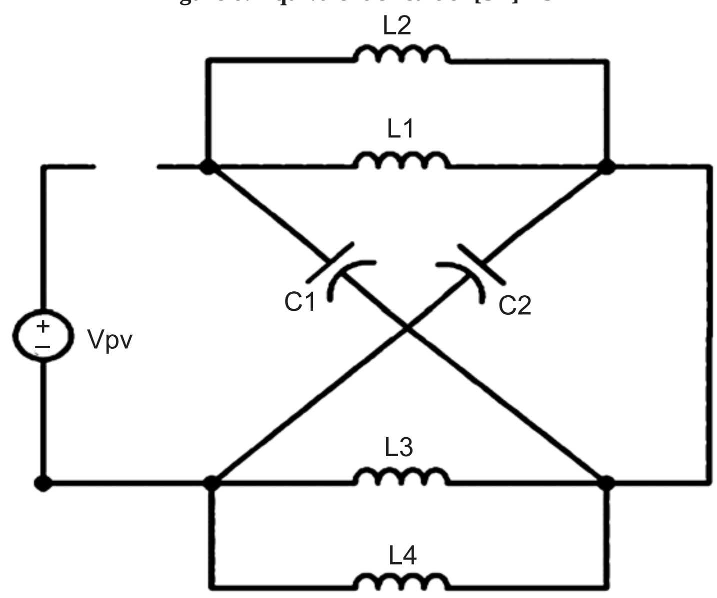

Figure 7: Equivalent circuit for shoot through state

The top switched inductor cell, D1 and D2 are ON and D3 is OFF, C1 charges L1 and L2 in parallel. For the SL bottom cell, D4 and D5 are ON and D6 is OFF, C2 charges L3 and L4 in parallel. Shoot through state provides additional zero states for improving the output voltage.

In non shoot through state the stored energy is transferred to active states and its equivalent circuit is shown in the figure (8). For the top SL cell D1 and D2 are OFF and D3 is ON, and L1 and L2 are connected in series, and the stored energy is transferred to the main circuit. For the SL bottom cell, D4 and D5 are OFF D6 is ON, L3 and L4 are connected in series,C1 is charged by V_{in} via SL bottom cell, V_{in} charges C2 via the top SL cell.

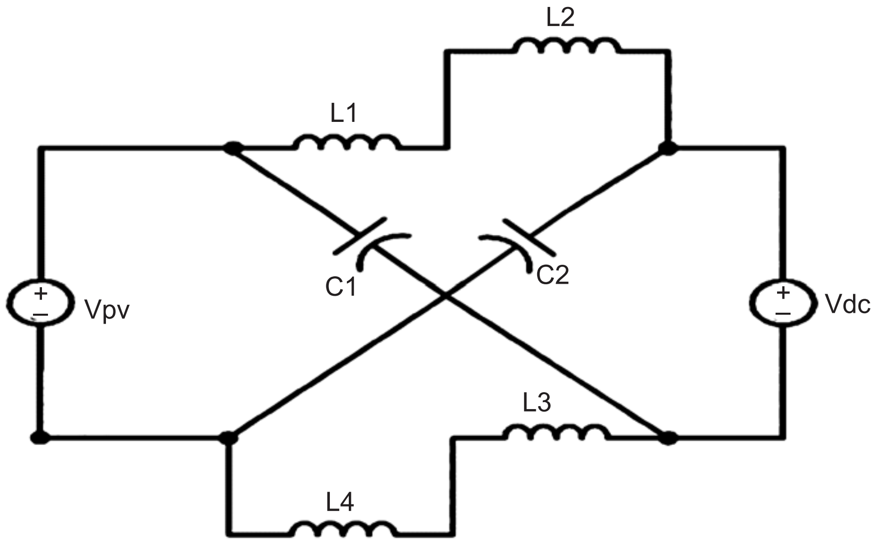

Figure 8: Equivalent circuit for Non shoot through state of SL-ZSI

Table 1
Design parameters for Switched inductor ZSI

Description	*Parameter*
Carrier frequency	*fc* = 10KHZ
Switching time	Tsw = 25 μsec
Inverter Impedances	(L1, L2, L3, L4) = 88.27 μH
Inverter capacitances	(C1 & C2) = 18.76 μF

7. SIMULATION AND RESULTS

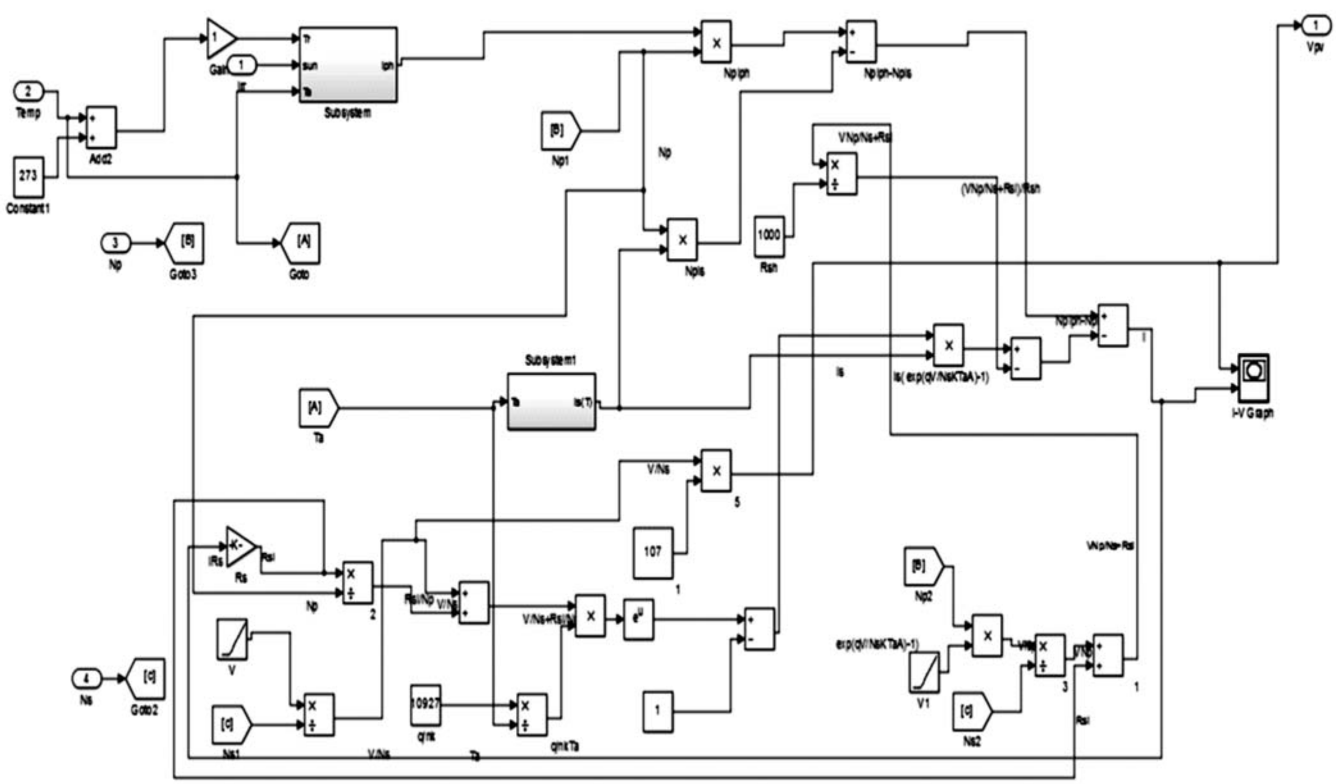

Figure 9: Simulation circuit of Photovoltaic system

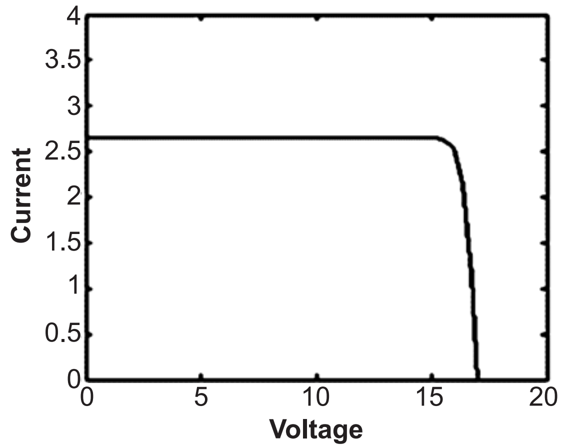

Figure 10: I-V curve for a PV cell

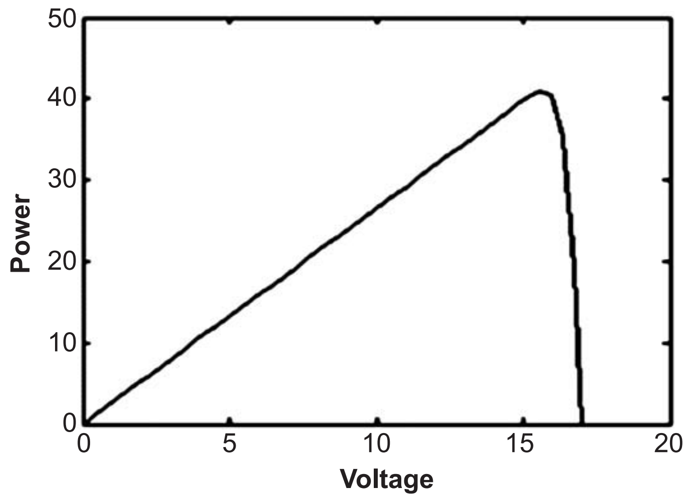

Figure 11: P-V curve for a PV cell

Photovoltaic voltage is 17*v* and photovoltaic current is 2.7amps.

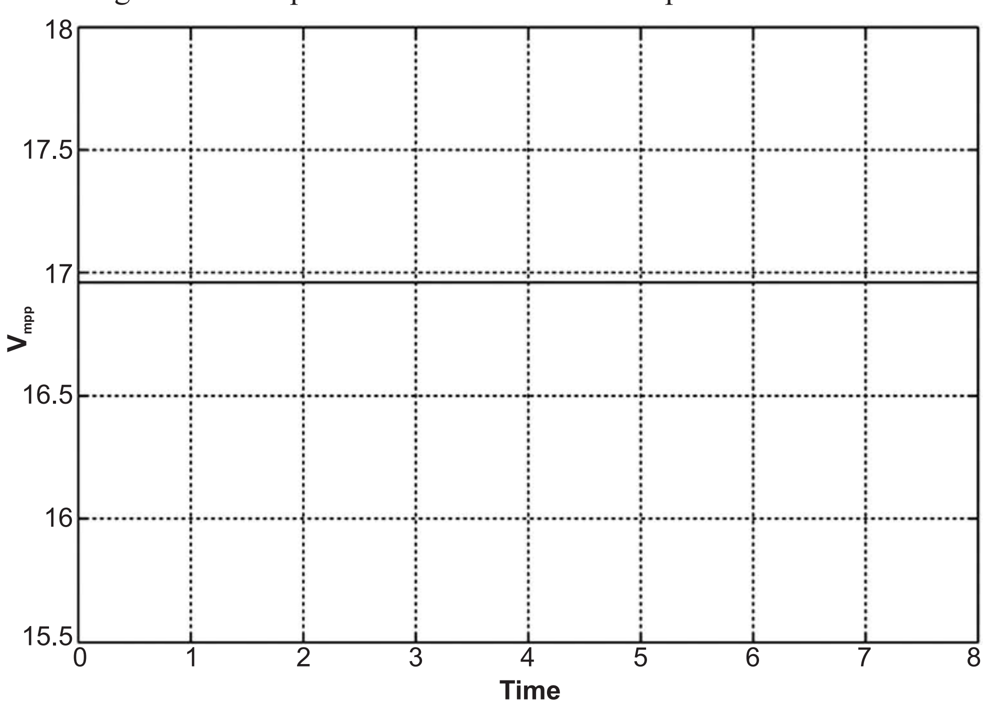

Figure 12: V_{mpp} from Simulink diagram of neural network for stand-alone system

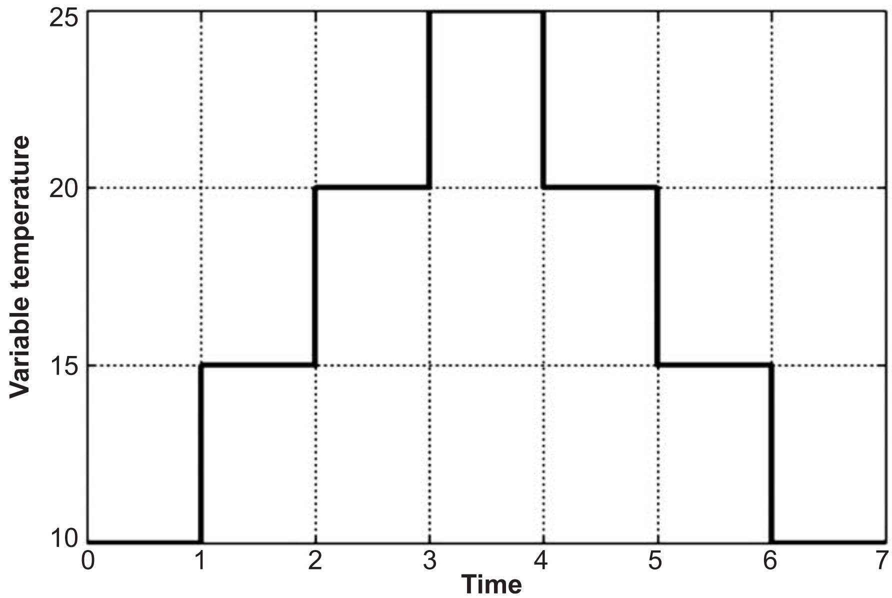

Figure 13: Variations of V_{mpp} with respect on temperature for proposed system

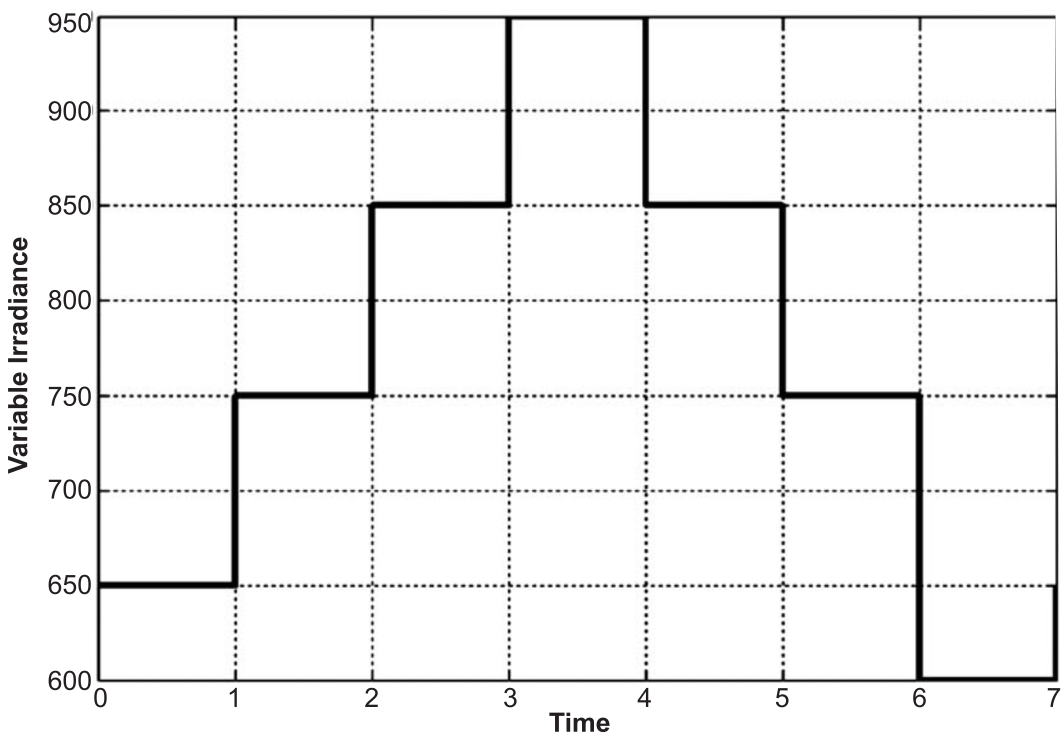

Figure 14: Variations of V_{mpp} with respect on temperatureand temperature for proposed system

Table 2

Final result for ANN

Input Data		*Target Data*	*Trained value*	*Error*
Irradiance	*Temp*	$V_{pv}(A)$	$V_{pv}(B)$	*(|A-B|A)*100*
960	25	17	17.07	0.41
840	36	24	24.12	0.5
600	35.9	23.7	23.58	0.5
100	31.4	20	19.93	0.35
160	31.4	20.2	20.22	0.09

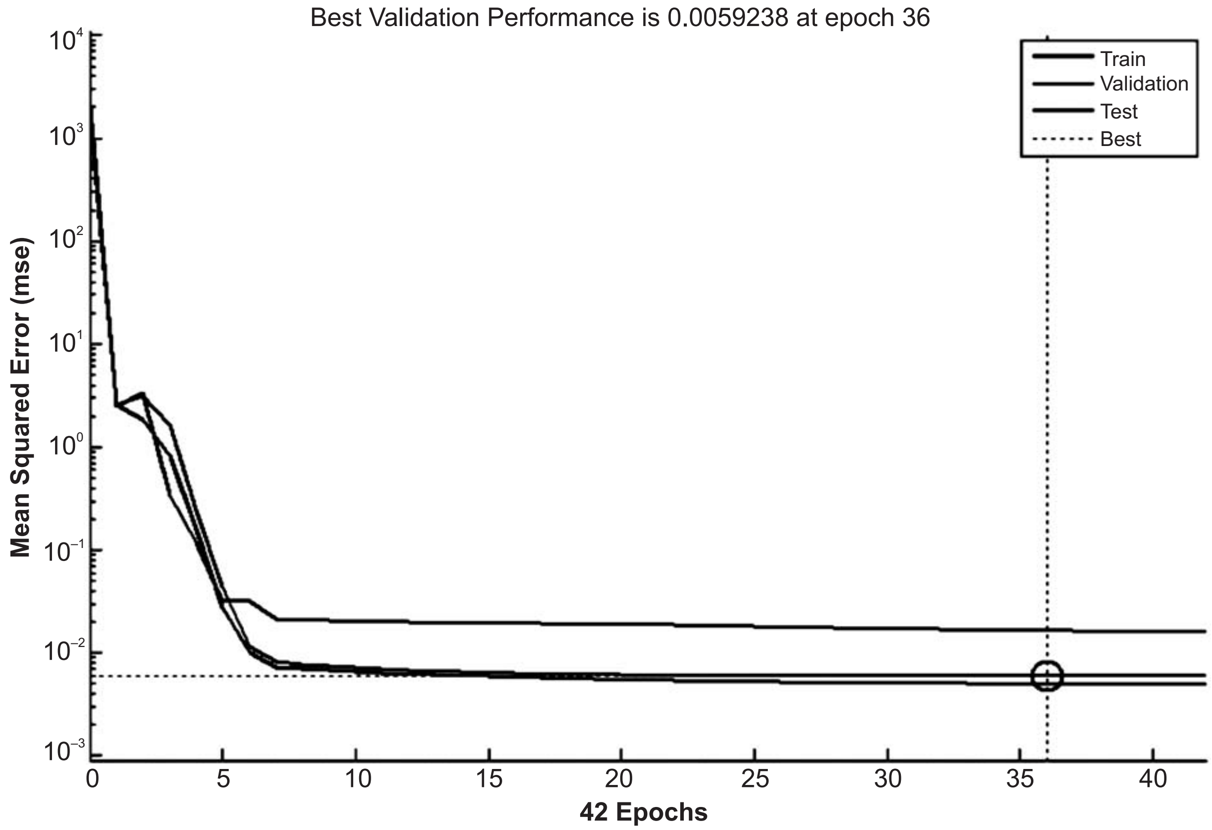

Figure 15: Root mean square error *vs* Epchos

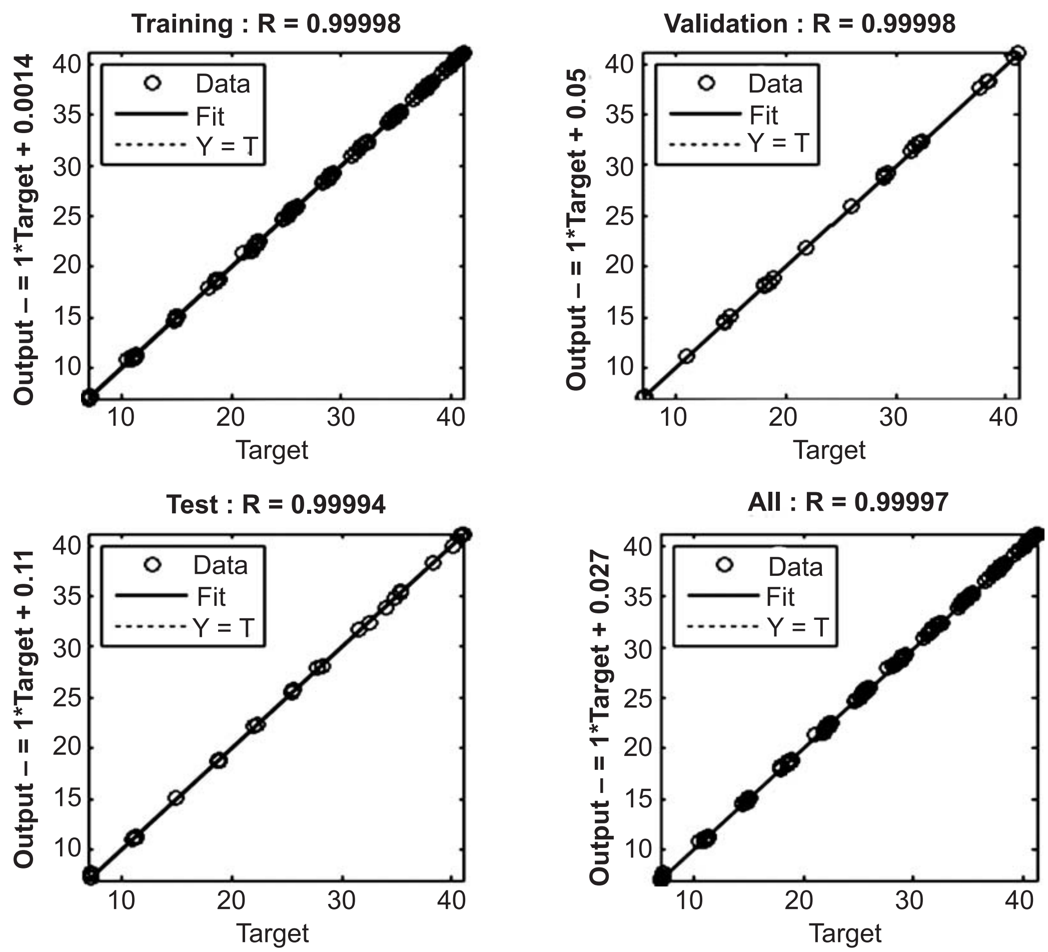

Figure 16: Regression plot for training data sets

The figure16 shows the regression plot for 220 training datasets. Regression values measure the correlation between outputs and targets. A Regression(R) value of one means a close relationship; zero means a random relationship.

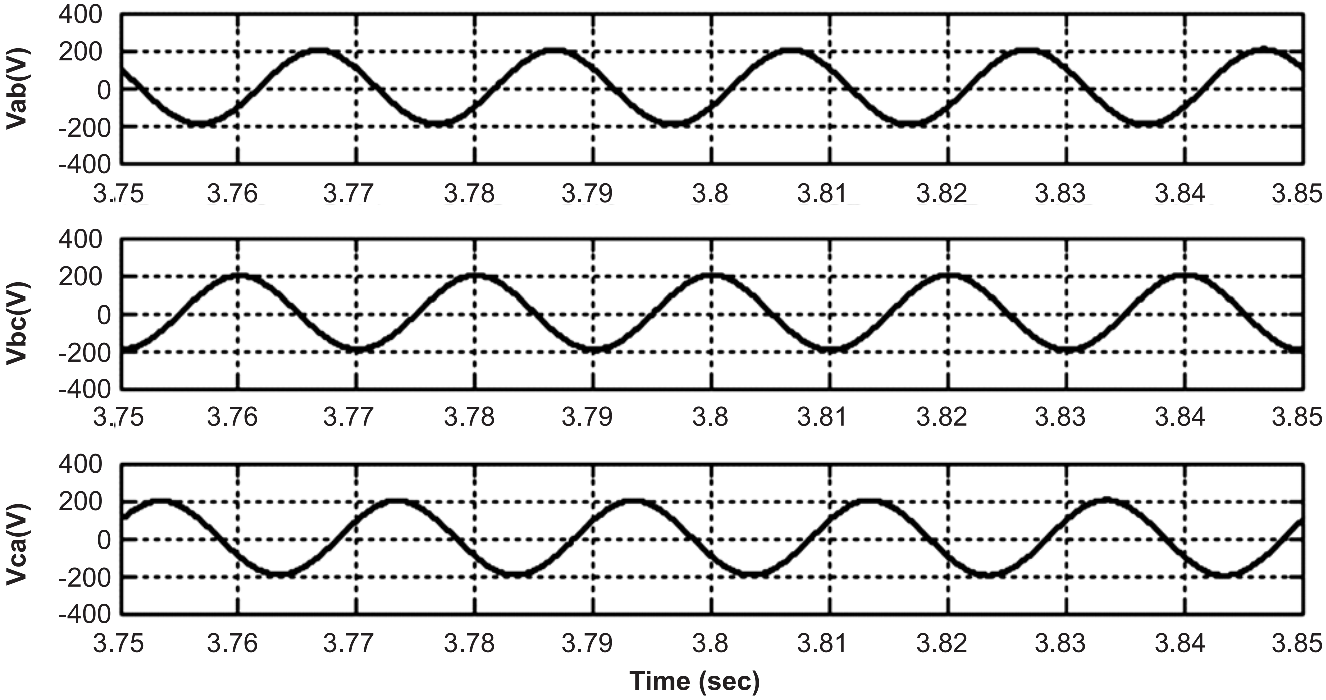

Figure 17: SL-ZSI output voltage with resistive load

Table 3
Performance parameters of proposed system

Description	*ANN based MPPT*
Maximum power point voltage[Vmpp]	16.9V
Modulation index	0.86
Duty cycle	0.14
Boost factor	2.38
Output voltage of SLZSI	210V
Efficiency	94.17%
RMSE	0.02
% of Error	0.12%
Total Harmonic Distortion	0.98%

8. CONCLUSION

The ANN is trained offline for some set of data and the performance of the ANN based MPPT is verified by test data consist of various irradiance and temperature. Switched inductor Z-Source inverter, which reduces the voltage stress across components and providing high modulation index. The ANN is verified, the percentage error lies between 0.05% to 4.46%.The duty ratio of Switched inductor Z-Source inverter is controlled using maximum output voltage obtained from ANN based MPPT. The output of the SL-ZSI is connected to the three phase resistive load.

9. REFERENCES

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