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ARTIFICIAL INTELLIGENCE TECHNIQUE BASED MPPT CONTROLLER FOR STANDALONE SOLAR ENERGY CONVERSION SYSTEM

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Abstract-This paper presents the development and performance analysis of Artificial Intelligence Technique based MPPT controller for a standalone solar energy conversion system. The proposed system consists of 2.5 kW PV array, DC to DC boost converter, inverter and different load. The DC to DC Converter connected to Inverter through DC link capacitor. The inverter power fed to the load through step down transformer. The standalone solar energy conversion system consists of MPPT controller. In this research Artificial Intelligence Technique based MPPT controller on Levenberg algorithm developed. For the proposed Artificial Intelligence Technique based MPPT takes two variables as PV voltage and PV current as an input and output the duty ratio for DC to DC boost converter. The Artificial Intelligence Technique based MPPT controller for standalone solar energy conversion system with various load is modeled and simulated in MATLAB/ Simulink environment. Performance of both the Artificial Intelligence Technique based MPPT controller compared with conventional incremental conductance MPPT. Simulation results show that for a wide range of input irradiance, Artificial Intelligence Technique based MPPT controller shows improved performance than the conventional incremental conductance MPPT with at various operating conditions.

1. INTRODUCTION

Many people today are concerned for the future of the planet. Over the last decade as world's population continues to grow, energy requirements are increasing [1-5]. Major source of energy comes from fossil fuels like oil, coal and natural gases. Increase in energy requirements leads to rise in production of these fossil fuels. Resources of fossil fuel are limited, as production rises, the supply of fossil fuel begin to diminish. The burning of fossil fuel causes increases in the release of carbon dioxide into the atmosphere [6,7& 8]. The excess of carbon dioxide in the atmosphere causes a dangerous effect on environment. Conversion of fossil fuel into energy leads to global warming it is the key reason to reduce our reliance on fossil fuel [9-12].

Renewable energy sources are the solution of these issues. Renewable energy sources cause less pollution as compared to fossil fuels. Solar energy, Wind energy, Geo-thermal energy, tidal energy etc. are the type of renewable energy sources [13&14].

Renewable energy sources play an important part in electric power generation; solar energy is a good choice of an electric power generation.

India is world's 3rd largest consumer of electricity and world's 3rd largest renewable energy producer with 38% (136 GW out of 373 GW) of total installed energy capacity in 2020 from renewable sources. Renewable Energy Country Attractiveness Index (RECAI) ranked India 3rd behind USA and China. Renewable Energy Sources includes Small Hydro Project (SHP), Biomass Gas (BG), Biomass Power (BP), Urban and Industrial Waste Power (U & I) and Wind Energy[15,16].

2. MATHEMATICAL MODELLING

2.1 Standalone Solar Energy Conversion System

In the proposed system 2.5kV standalone PV system is used. System interconnection is done through the inverter, which adjusts the DC power of Solar PV array into AC power and links the boost converter which attached to solar PV system to the load. The output voltage should be sinusoidal and in phase with the load voltage. A step-down transformer is used, which links boost converter to the load.This system consists of 2.5kW solar array directly tied to the DC-DC boost converter; this DC-DC converter connected to load side inverter through DC link capacitor. This inverter power fed to the load 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.

2.2 DC/AC Inverter

For converting DC into AC, single phase inverter is used for the proposed work the inverter is link to the boost converter. The load is connected to the inverter output terminals. Filters are connected between load and inverter to eliminates the harmonics using filter. PWM technique is used for the switching pulses of the inverter as shown in Fig. 2.1.

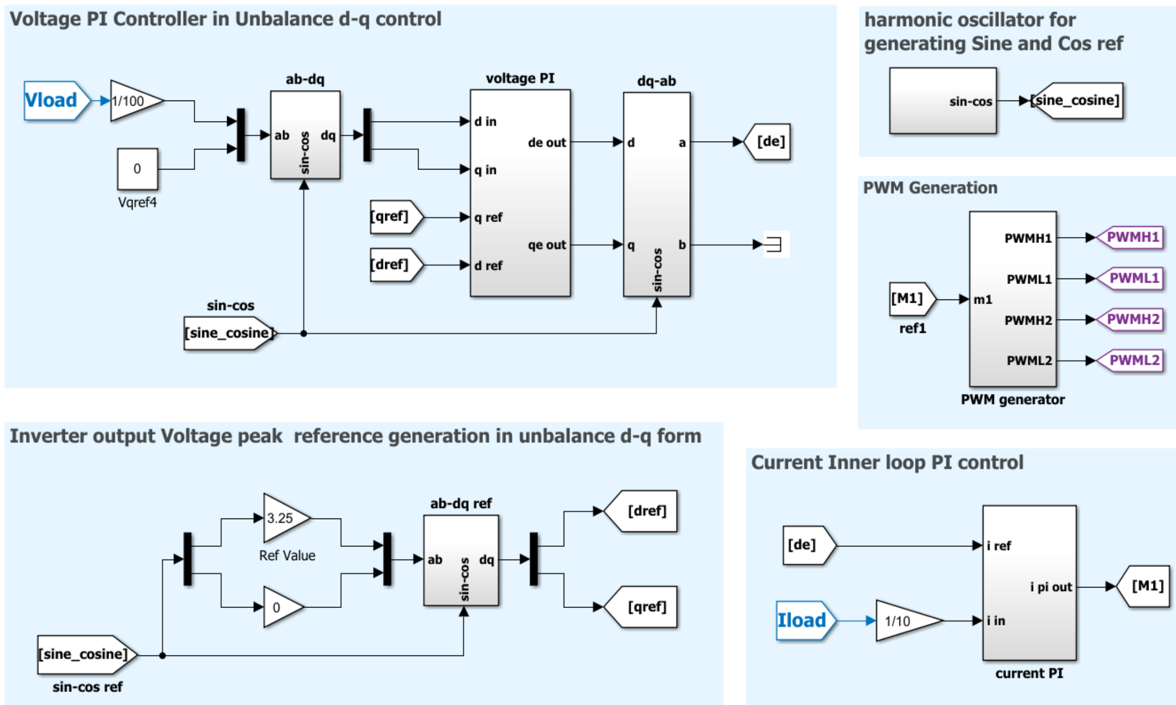

Fig. 2.1 DC-AC Inverter

3. MPPT TECHNIQUES

3.1 Incremental Conductance MATLAB Code

Incremental conductance MPPT controller is able to track the MPP under varying physical conditions, which is the major drawback of perturb and observe algorithm. If the PV array impedance matches with the effective impedance of the converter reflected across the array terminals, then the MPP is tracked.
MPPT controller based on the Variable Step size Incremental Conductance (VSSIC) implemented in proposed system using the above coding and represented shown in Fig. 3.1

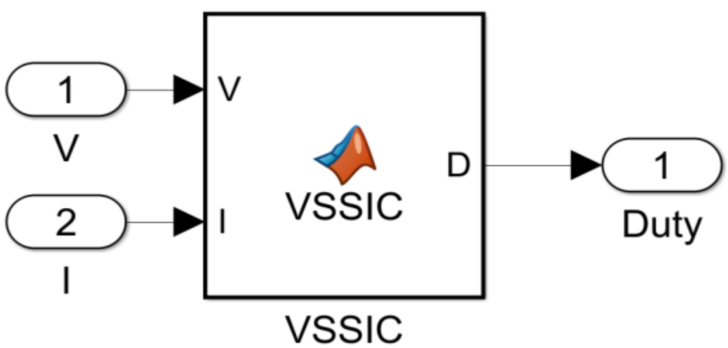

Fig. 3.1 MATLAB SIMULINK Model of VSSIC Technique

3.2 Artificial Neural Network (ANN)

The concept of ANN is inspired by the working of human brains. The functioning of ANN revolves around the processing elements called neurons interconnected by links and having some adjustable weights assigned to them. The ANN is trained with a set of data and has the ability of comprehension. The major advantage of ANN is its self-learning and self-organized nature. By self-organized it is meant that ANN represents the information which it receives during learning time. ANN is used in the applications that require pattern recognition or data classification. Any artificial neural network basically consists of three layers, i.e. input layer, hidden layer and output layer. The input layer receives the information or data from some file or directly from the sensors in case of real-time application. This data is now processed based on the weight associated with a link between input layer and hidden layer. Similarly, weight is also assigned between hidden and the output layer. These weights are adjustable and affect the output.

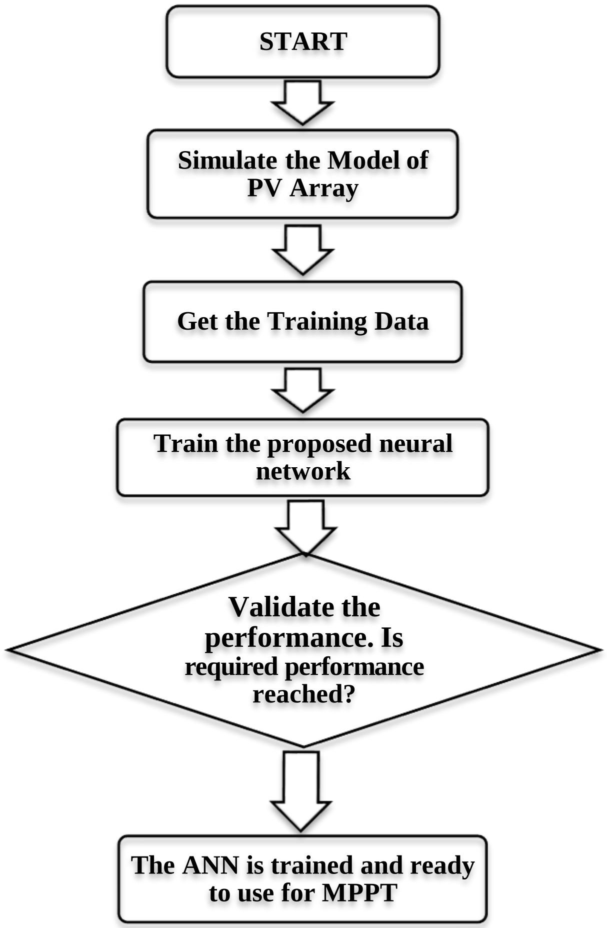

Fig. 3.2 Flow chart for Training Procedure of ANN based MPPT for Solar PV System

Depending upon the number of hidden layers used, the structure is named as single layer or multilayer. The working of ANN follows either of the two topologies. These are feedforward and feedbackward approach. In feedforward approach, the signal travels in one direction from input to output. The feedback concept is not used. This type of approach is also called top-down or bottom-up approach. However, in feedbackward network, signals can travel in both the directions, and the output of one layer forms a loop by connecting to the previous layer. These networks are powerful and possess memory. ANNs are used in MPPT system as it can provide accurate and fast response for different environmental conditions. To train the neural network for MPPT of solar PV system Levenberg-Marquardt algorithm is used. The training data used for learning the ANN for MPPT are gained from PV module. A flow chart of training procedure of ANN based MPPT for solar PV system has shown in Fig. 3

To extract the maximum power from grid connected solar PV system, artificial neural network based MPPT is proposed. The basic architecture of ANN consists of three layers as an input layer, hidden layer and output layer. The basic architecture of ANN is shown in Fig. 3.

4. SIMULATION RESULT

Simulation Result of Incremental Conductance MPPT Controller at Irradiance Step Decrease from 100W/m^2 to 600 W/m^2 with Resistive Load. This simulation study shows the proposed system performance with incremental conductance MPPT controller at step increase irradiance from 600 W/m^2 to 1000 W/m^2 with resistive load of 2.5 kW. In this case, model is simulated for 4sec. Simulation results at different stages are shown in following subsections.

4.1 PV Array Results

Fig. 4 (a) shows the input irradiance at t = 0 is 1000 W/m^2 and it is step change to 600 W/m^2 at t=2 sec, constant to at t=4 sec. with temperature is kept constant at 25°C shown in Fig. 4 (b).

Output voltage of the PV system is nearly 170 V during the total simulation time and slightly change at the time t=2 sec when step is changed as shown in Fig. 4 (c). Figure 4.5(d) shows the PV system output current that is change from 15 A to 9 A during t=2 to t=4 sec. Fig. 4 (f) shows the output power of the PV system when irradiance is 1000 W/m^2 then output power is 2500W. When step change from 1000 W/m^2 to 600 W/m^2 at t=2 sec then PV output power reach at 1550W.

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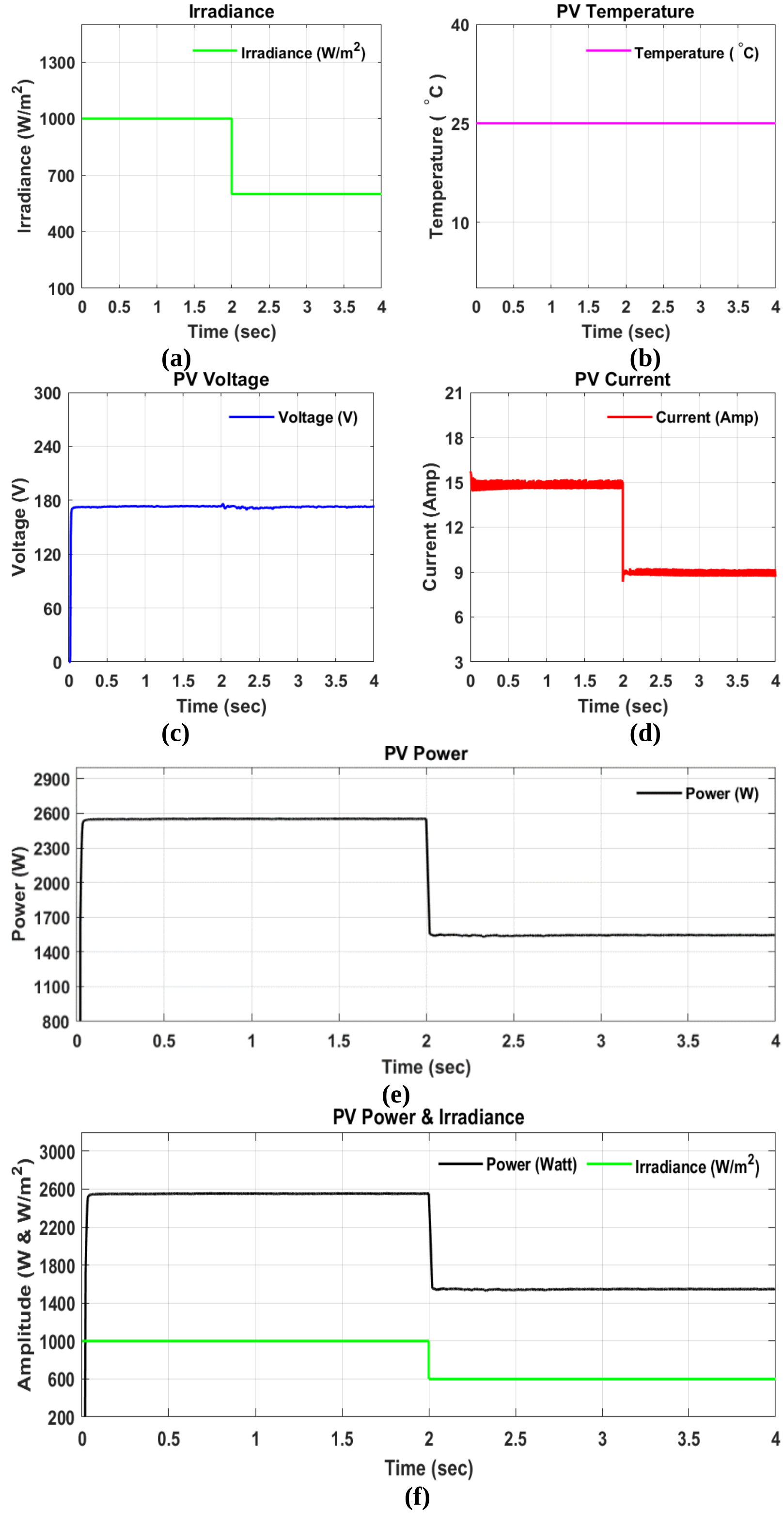
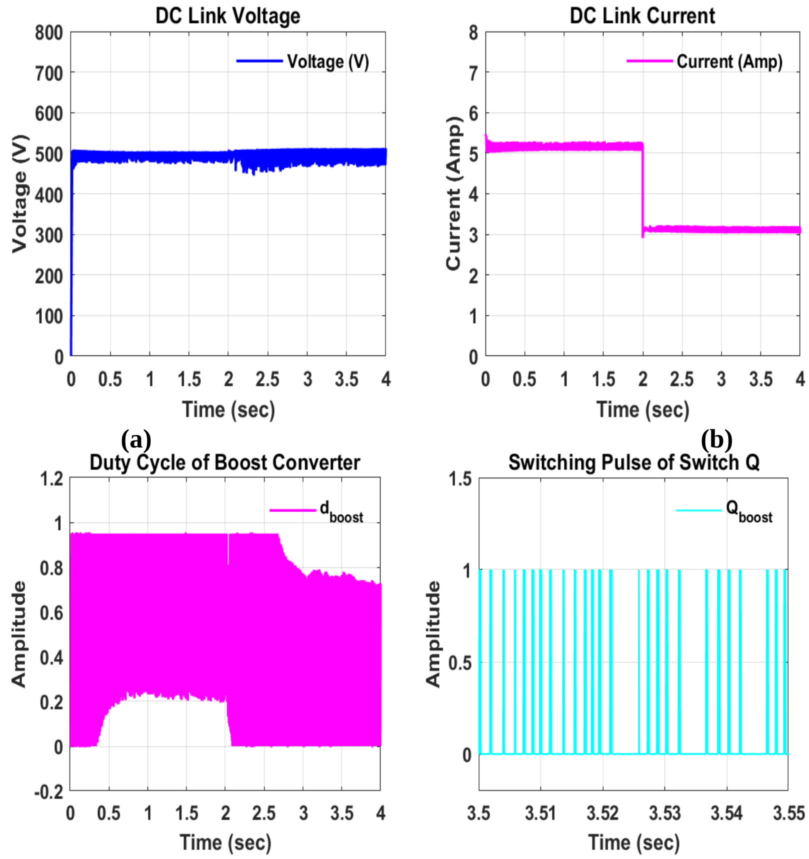


Fig. 4.1 PV Array Results at Step Decrease in Irradiance from 1000 W/m^2 to 600 W/m^2 with Resistive Load: (a) Irradiance, (b) Temperature, (c) PV Voltage, (d) PV Current, (e) PV Actual Output Power, and (f) PV Output Power with Irradiance

4.2 Boost Converter Results

In this section, boost converter results are displayed at step decrease in Irradiance from 1000 W/m^2 to 600 W/m^2 with Resistive load. Fig. 5 (a) and Fig. 5 (b) shows the voltage output of the boost converter which is kept constant at 500V and current generated by the incremental conductance MPPT controller at step decrease in irradiance from 1000 W/m^2 to 600 W/m^2 with resistive load of 2.5 kW.



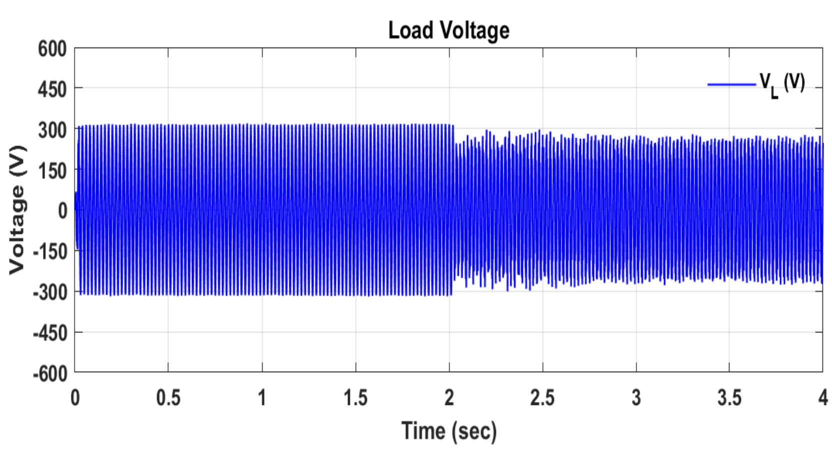
(c) (d)

Fig. 4.2 Boost Converter Results at Step Increase in Irradiance from 1000 W/m^2 to 600 W/m^2 with Resistive Load: (a) DC Link Voltage, (b) DC Link Current, (c) Duty Cycle of Boost Converter, (d) Switching Pulse of Switch Q

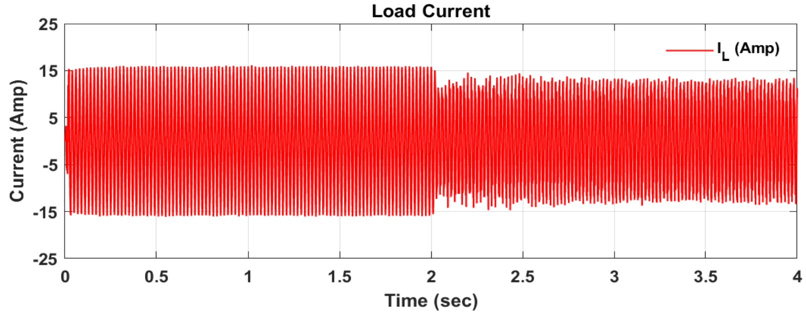
Fig. 4.2 (c) and Fig. 5 (d) shows the duty cycle and switching pulse of boost converter this duty ratio is input to the pulse generator which generates PWM pulses of switching frequency 5 kHz.

4.3 Load Side Results

In this section load side simulation result is discussed at step decrease in irradiance from 1000W/m^2 to 600 W/m^2 with Resistive load. Fig. 6(1) and Fig. 6(b) shows the output voltage and output current waveform of the load is change according irradiance. Fig.6 (c) shows the power at load side is changed from 180V to 230V respectively change in irradiance from 1000 W/m^{2}to 600 W/m^2. Fig. 6 (e) shows the PV power and load power change 2400W at 1000 W/m^{2}and 1400W at 600 W/m^2.We can see in Fig. (e) PV output voltage and Load voltage nearly equal so we can say system is well regulated.



(a)



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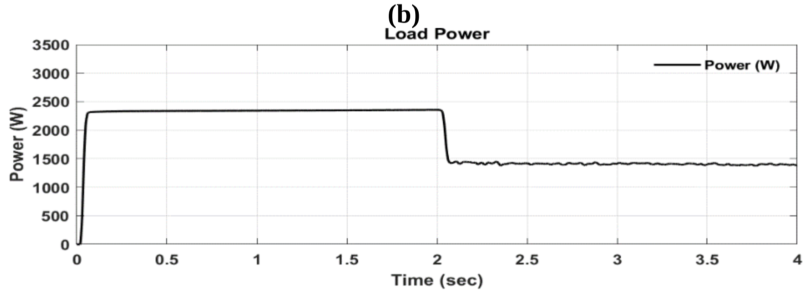
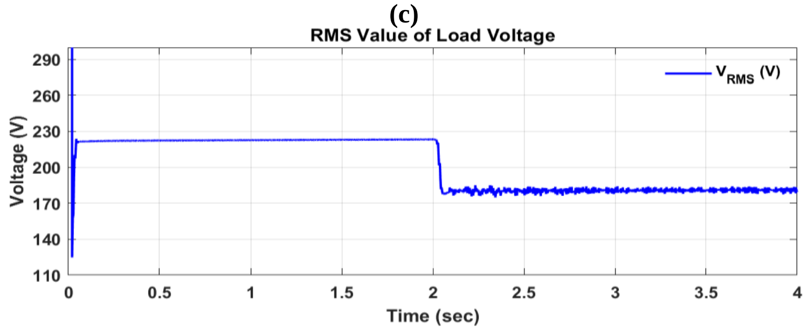
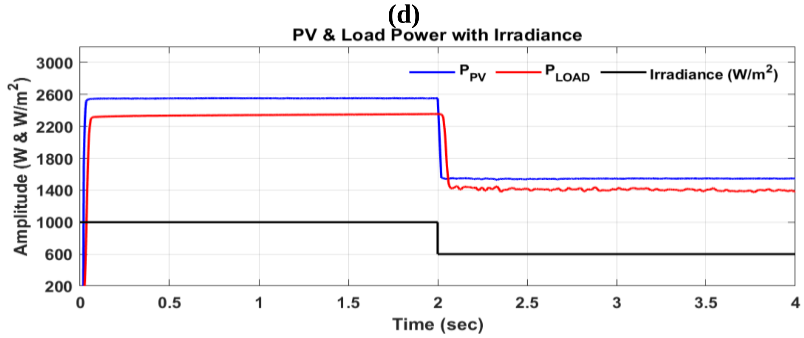


(c)



(d)



(e)

Fig. 4.4 Load Side Results at Step Decrease in Irradiance from 1000 W/m^2 to 600 W/m^2 with Resistive Load: (a) Load Voltage, (b) Load Current, (c) Load Power, (d) RMS Value of Load Voltage and (e) PV and Load Power with Irradiance

CONCLUSION

Artificial Intelligence Technique based Levenberg algorithm for MPPT with conventional incremental conductance based MPPT for PV system is compared. The model has been tested for different input and output conditions. Simulation results and real time applications show that for wide range of input irradiance Artificial Intelligence Technique based MPPT controller shows better performance than the conventional controller. Proposed Levenberg based MPPT controller shows 1.84% improvement in PV power output compare to conventional incremental conductance method. The average efficiency of Proposed Levenberg based MPPT system is 99.57% and average efficiency of conventional incremental conductance is 97.73%. From the simulation results of the system, it is clear that Artificial Intelligence Technique based MPPT algorithms is for MPPT shows effective results as compared to conventional incremental conductance based MPPT controllers.

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