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SPWM BASED THREE PHASE STAND-ALONE PHOTOVOLTAIC (PV) SYSTEM

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ABSTRACT

Photovoltaic energy is a renewable energy with high potential, easy installation, simple maintenance, dependability and long life. Photovoltaic system output is non-linear and is affected by weather conditions, so maximum Power Point Tracker (MPPT) was implemented to draw out the maximum power from solar energy. In order to increase the efficiency of stand-alone photovoltaic (PV) system, it is most important an efficient Maximum Power Point Tracker (MPPT) is needed. This paper proposed a technique of tracking Maximum Power Point based on Incremental Conductance (INC) algorithm with Luo converter and three phase PWM Voltage Source Inverter (VSI) are implemented to measure the effectiveness of the Photovoltaic (PV) system and tracking mechanism.

Keywords: PV array, SPWM, DC-DC converter, incremental conductance algorithm, Three phase VSI, maximum power point tracker.

INTRODUCTION

The origin of PV energy conversion technology goes back in 1839, when becquerel first discovered the PV effect. PV energy conversion is the direct conversion of radiative energy, in form of sunlight, into electrical energy. In the past decades there was a huge development in the field of renewable-energy sources. Photovoltaic system (PV) is unrivalled of the sources of high cost and low conversion efficiency has limited to use such endless energy source. It is a clean energy technology and is anticipated to sustain a significant contribution to the world energy production towards the remnant of this nation. PV systems have particular features that offer some added value as a system of the output power of a PV system is nonlinear and it is affected by environmental conditions, such as irradiation and temperature.

So Maximum Power Point Tracking (MPPT) method was formulated to draw out the maximum power from each PV array [1]. In fact that the rise of PV as a formula to obtain electricity is one of the highest recorded in the area of renewable-energy. On the other hand, the cost and low conversion energy are thought to be a principal obstacle in the habit of this energy system. The process maximum power point has been tracking which is called max power point tracking (MMPT). Today, a large number of techniques are proposed for maximum power point tracking concept such as constant voltage tracking [2].

MAXIMUM POWER POINT TRACKING (MPPT)

Maximum Power Point Tracking, referred as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a way that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that “physically moves” the modules to make them point more directly at the sunlight. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum power. Additional power harvested from the modules is then formed as the increased battery charge current. MPPT can be utilized in concurrence with a mechanical tracking system, but the two systems are completely different.

Typical solar panel converts only 30 to 40 percent of the incident solar irradiation into electrical energy. According to Maximum Power Transfer theorem, the power output of a circuit is maximum when the Thevenin impedance of the circuit (source impedance) matches with the load impedance. Hence the problem of tracking the maximum power point reduces to an impedance matching problem [3].

On the source side used, a Luo converter (DC-DC) is connected to a solar panel in order to enhance the output voltage. By varying the duty cycle of the proposed Luo DC-DC converter appropriately to match the source impedance with load impedance. Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel. There are different techniques for MPPT such as Perturb and Observe, Incremental conductance, Fractional Short Circuit Current, Fractional Open Circuit Voltage, Fuzzy Control, Neural Network control and so on. Among all the methods Perturb and observe (P and O) and Incremental conductance methods are most commonly used because of their simple implementation, lesser time to cut through the MPP and several other economic reasons [3-4].

This paper looks at the case of Incremental Conductance algorithm [5]. The Incremental Conductance (INC) MPPT algorithm design based on the incremental and the instantaneous conductance value of the PV array has not the inclination to vary from the MPP due to rapidly changing the atmospheric conditions [6].

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PROPOSED PV SYSTEM DESCRIPTION

The Figure-1 shows the block diagram representation of PV system with MPPT tracking. The cost of the PV system is related to the total running efficiency of the system defined as follows [7],

$$\eta_{Total} = \eta_{PV} \cdot \eta_{MPPT} \cdot \eta_{Inverter} \quad (1)$$

$$= \frac{P_{PV}[W]}{G\left[\frac{W}{m^2}\right].A\left[m^2\right]} \cdot \frac{P_{MPPT}[W]}{P_{PV}[W]} \cdot \frac{P_{OUT}[W]}{P_{MPPT}[W]} \quad (2)$$

Where

η_{Total} = Total efficiency of the PV system

η_{MPPT} = Efficiency of the MPPT algorithm

$\eta_{Inverter}$ = Efficiency of the PV inverter

η_{PV} = Efficiency of the PV array

P_{PV} = Maximum power from the PV array

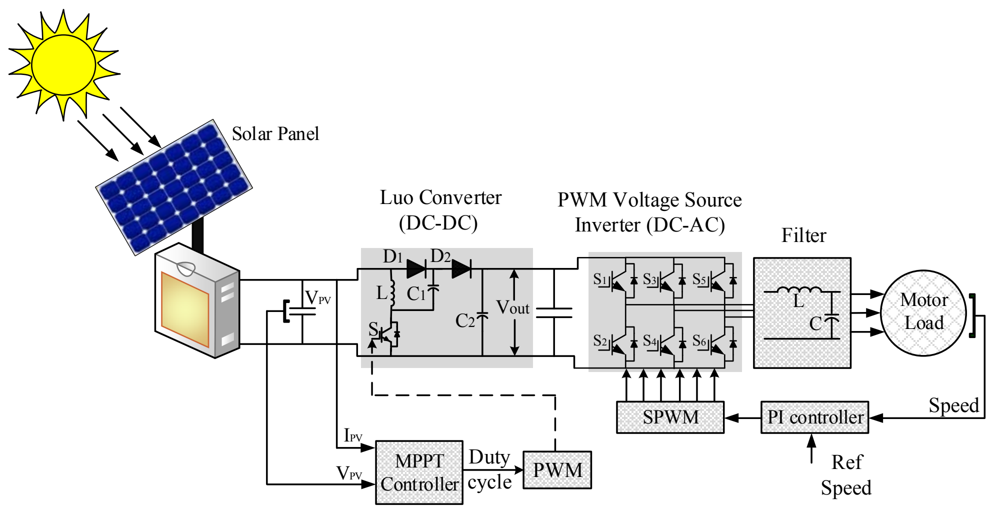

Figure-1. Block diagram representation of PV system with INC MPPT tracking.

Solar panel (DC source)

A sun power 305-WHT panel is modeled for proposed system, which consists of 96 cells, and has the capacity of 100kW at 1000 W/m^2, 25°C.

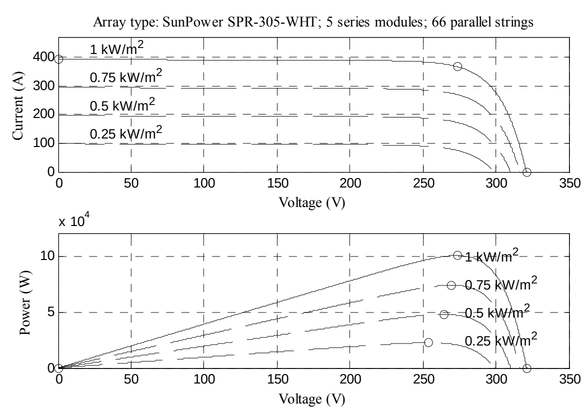

Figure-2. (a) V-I characteristics (b) P-V characteristics for four different irradiation levels.

P_{MPPT} = PV power tracked by MPPT

P_{OUT} = Output power to the utility grid

G = Solar irradiance

A = PV array area.

Figure-1 consists of three divisions such as, DC source, DC-DC converter and DC-AC converter. A DC power source (PV panel) connected in series with the luo converter. Luo converter (DC/DC) which regulates the output voltage of PV panel and helps to attain the maximum power. PWM Voltage Source Inverter (DC-AC) converting DC to AC to be connected to either grid or AC load.

Figure-2 shows the V-I and P-V characteristics of the proposed PV panel at different temperature conditions. Panel parameters are given in Table-1. Solar panel shown in the have the maximum power point of 100kW with an irradiance of 1000 W/m^2 and 25°C temperature, at 200 W/m^2 irradiance with 25°C temperature have the maximum power of 22kW and 82kW of maximum power at 1000W/m^2 with 75°C.

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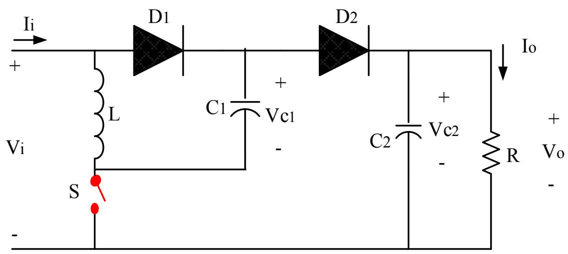
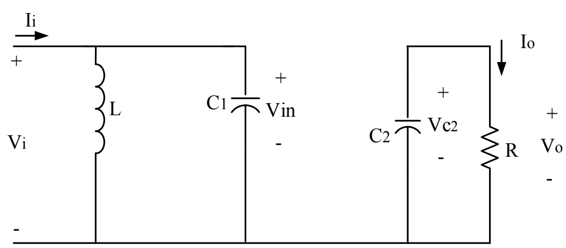
Luo converter (DC-DC converter)

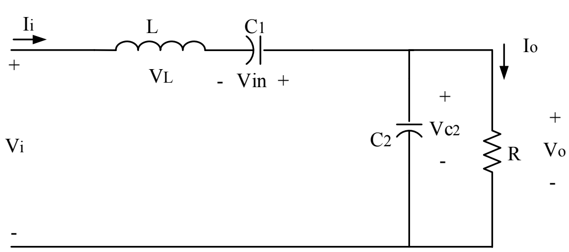
Maximum power point algorithm (incremental conductance) is implemented here to control the duty ratio of luo converter (Luo F L and Ye H, 2004). Based on the rate of change of voltage and current, either the duty ratio is increased or decreased to attain maximum power with a DC output voltage in the acceptable limit. A PI controller is used to regulate the duty ratio of incremental algorithm. System parameters are given in Table-2. The elementary circuit and its equivalent circuits during switch-on and off are shown in Figure-3. The voltage across capacitor C_1 is charged to V_{in}.



(a) Circuit diagram



(b) Equivalent circuit during switching-on



(c) Equivalent circuit during switching-off

Figure-3. Positive output super-lift Luo (DC-DC) converter.

The current i_L flowing through inductor L increases with voltage Vin during switch-on period kT and decreases with voltage - (V_O - $2V_{in}$) during switch off period (1-k)T. Therefore, the ripple of the inductor current i_L is

$$\Delta i_{L1} = \frac{V_{in}}{L} kT = \frac{V_o - 2V_{in}}{L}(1-k)T \qquad (3)$$

$$V_o = \frac{2-k}{1-k} V_{in} \qquad (4)$$

The voltage transfer gain is,

$$G = \frac{V_o}{V_{in}} = \frac{2-k}{1-k} \qquad (5)$$

The input current i_{in} is equal to (i_L + i_{C1}) during switch-on, and only equal to i_L during switch-off. Capacitor current i_{C1} is equal to i_L during switch off. In steady–state, the average charge across capacitor C_1 should not change. The following relations are held:

$$\begin{aligned} i_{in-off} &= i_{L-off} = i_{C1-off} \\ i_{in-on} &= i_{L-on} = i_{C1-on} \\ kTi_{C1-on} &= (1-k)Ti_{C1-off} \end{aligned} \qquad (6)$$

If inductance L is large enough, i_L is nearly equal to its average current I_L.
So,

$$\begin{aligned} i_{in-off} &= i_{C1-off} = I_L \\ i_{in-on} &= I_L + \frac{1-k}{k} I_L = \frac{I_L}{k} \\ i_{C1-on} &= \frac{1-k}{k} I_L \end{aligned} \qquad (7)$$

Measure the average input current from the supply

$$i_{in} = ki_{in-on} + (1-k)i_{in-off} = I_L = (2-k)I_L \qquad (8)$$

Considering

$$\frac{V_{in}}{I_{in}} = \left(\frac{1-k}{2-k}\right)^2 \frac{V_o}{I_o} = \left(\frac{1-k}{2-k}\right)^2 R \qquad (9)$$

The fluctuation of the current I_L through inductor L is,

$$\xi = \frac{\Delta i_L / 2}{I_L} = \frac{k(2-k)TV_{in}}{2LI_{in}} = \frac{k(1-k)^2}{2(2-k)} \frac{R}{fL} \qquad (10)$$

Usually ξ is small; it means this converter normally works in the continuous mode.
The ripple voltage of output voltage v_o is

$$\Delta v_o = \frac{\Delta Q}{C_2} = \frac{I_o(1-k)T}{C_2} = \frac{1-k}{fC_2} \frac{V_o}{R} \qquad (11)$$

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Thus, the variation ratio of output voltage v_o is [8],

$$\varepsilon = \frac{\Delta v_o / 2}{V_o} = \frac{1-k}{2RfC_2} \tag{12}$$

Voltage source inverter

DC/DC Luo converter output is connected to the voltage source converter. DC link voltage for VSI is 500V. The output of VSI is controlled by SPWM technique using voltage regulator.

INCREMENTAL CONDUCTANCE ALGORITHM

The Incremental conductance algorithm is an advanced version of P and O algorithm. The Incremental Conductance (IC) method had taken in order to overcome the drawbacks of the PO algorithm when subjected to fast changing environmental conditions. With the help of voltage and current measurements, the conductance I/V and incremental conductance di/dv are determined so that the decision can be made to increase or decrease the operating voltage according to the operating point on the left or the right of the MPP respectively.

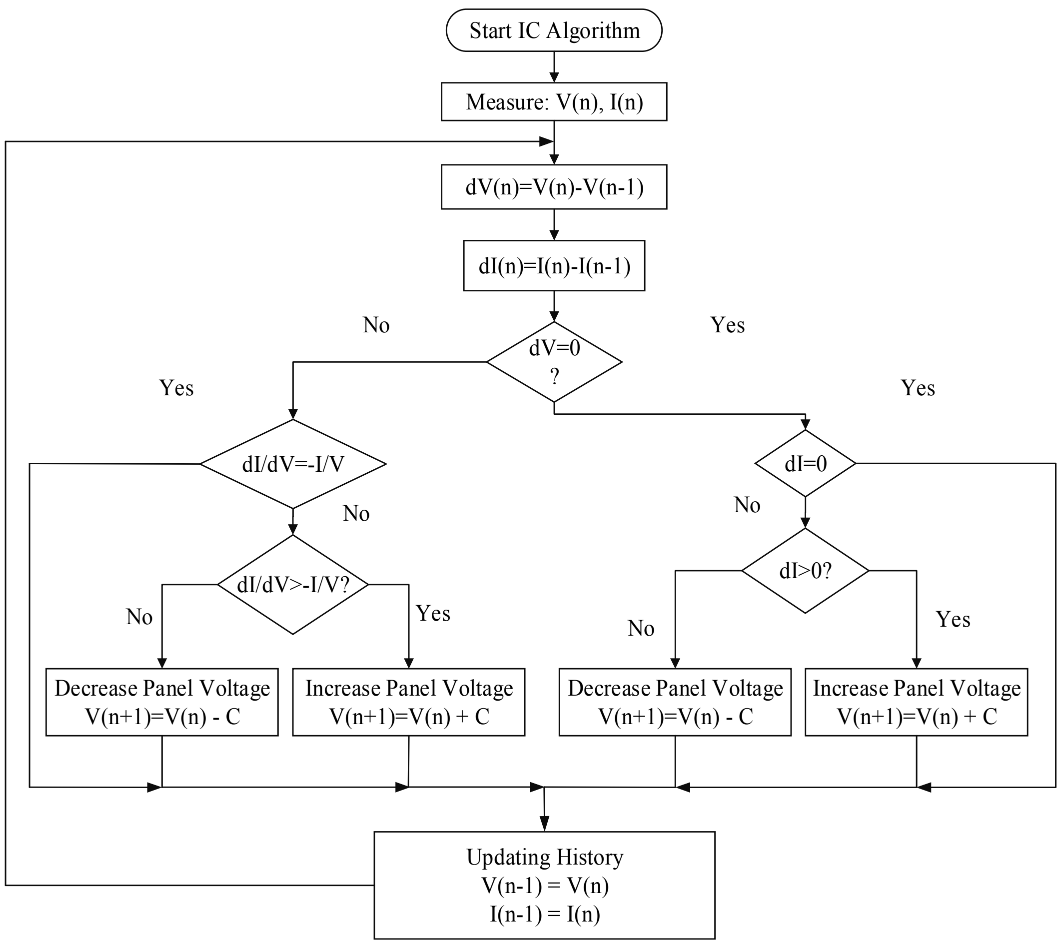

Figure-4. Flow chart of incremental conductance algorithm.

Operating principle

The operating principle of the IC method relies on the fact that the gradient of the PV panel power curve is negative on the right of the MPP, zero at the MPP and positive on the left of the MPP as follows:

$$\frac{dP}{dV} > 0 \text{ left of MPP } (V<V_{MPP})$$

$$\frac{dP}{dV} = 0 \text{ at MPP } (V=V_{MPP})$$

$$\frac{dP}{dV} < 0 \text{ right of MPP } (V>V_{MPP}) \tag{13}$$

Since P=VI, the gradient of power curve at MPP as follows,

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$$\frac{dP}{dV} = I\frac{dV}{dV} + V\frac{dI}{dV} = I + V\frac{dI}{dV} = 0 \tag{14}$$

Equation 13, can be written as,

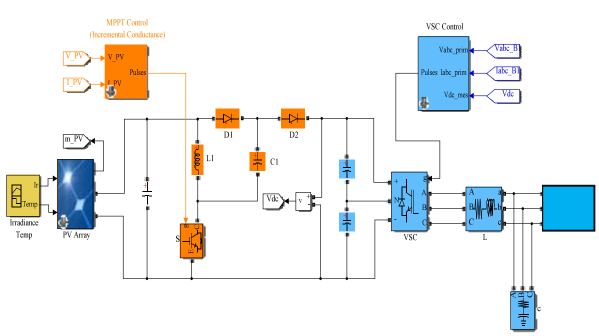
$$\begin{aligned} \frac{dI}{dV} &< -\frac{I}{V} \text{ right of MPP} \\ \frac{dI}{dV} &= -\frac{I}{V} \text{ at MPP} \\ \frac{dI}{dV} &> -\frac{I}{V} \text{ left of MPP} \end{aligned} \tag{15}$$

According to equation 15, the incremental conductance (IC) algorithm provides enough data to locate the MPP. This is made possible by the respective measurement and comparison of, dI/dV and I/V. V_{MPP} is the set point reference voltage corresponding to the MPP at which the PV module is required to operate. The detailed operating principle of the IC algorithm can be seen by the accompanying flow chart [4], [9].

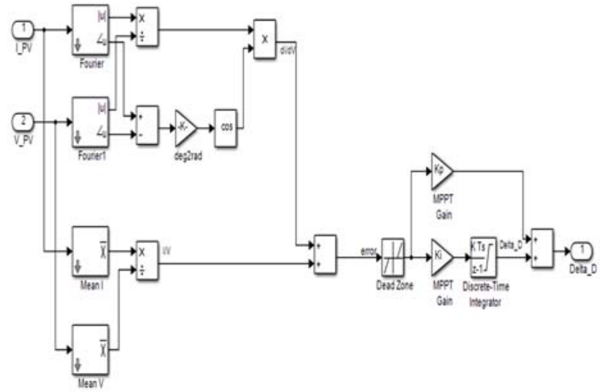
According to the IC algorithm given in Figure-4, the current and voltage are to be measured, then a test is conducted to assess on one side if the difference in voltage and current is equal to zero respectively, and on the other side if the variation of voltage is equal to zero and the balancing condition di/dv + I/V= 0 at MPP is obtained. If so, no changes take place in the operation's process. If not, the IC method acts to increase or decrease the voltage according to the difference in the current or the condition di/dv + I/V is superior or inferior to zero respectively.

SIMULATION RESULTS AND DISCUSSION

Simulation is carried out using MATLAB/ Simulink software. Figure-5 shows the Simulink model arrangement of PV array stand-alone system using the MPPT technique of the type Incremental Conductance method. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum power.



(a) Luo converter with PV array stand-alone system



(b) Simulink model arrangement Increment Conductance algorithm

Figure-5. Simulink model arrangement of Positive output Luo (DC-DC) converter with stand-alone photovoltaic system.

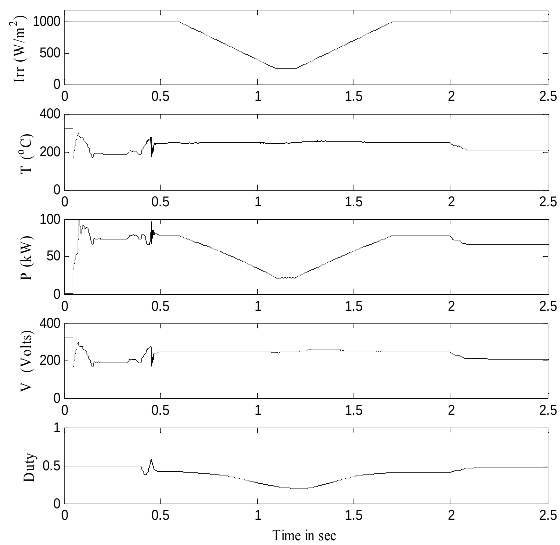


Figure-6. Simulated overall response of Increment Conductance MPPT based PV system.

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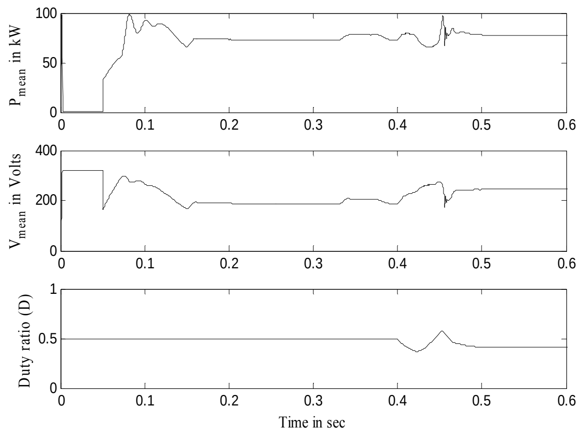

Figure-7. Simulated response of proposed system at time t=0 sec to t=0.6 sec (Irr = 1000, T=25°C).

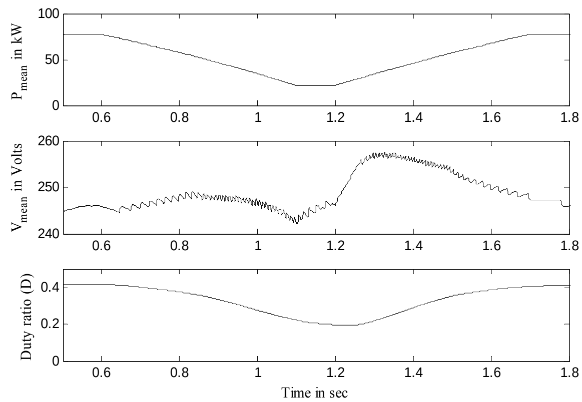

Figure-8. Simulated response of proposed system at time t=0.6 sec to t=1.8 sec (Irr = 200, T=25°C).

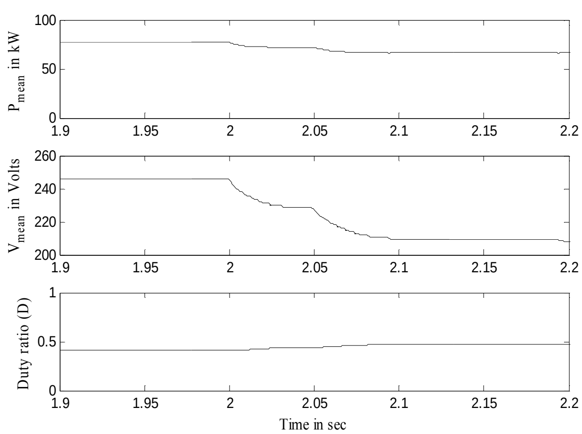

Figure-9. Simulated response of proposed system at time t=0.6 sec to t=1.8 sec. (Irr = 1000, T=75°C).

Simulation is carried out over a time period of 2.5 Sec. Analysis has been carried out for both changes in irradiance as well as temperature. At time t=0 to t=0.6 Sec input parameter for PV panel is Irr = 1000 W/m^2, T= 25°C; at t=0.6 to t=1.1, Irr = 200 W/m^2, T=25 °C; at t=1.2 to t=1.7 Irr = 1000 W/m^2, T=25°C and at t=2.1 Irr = 1000 W/m^2, T=75°C. Response of output power, voltage and duty ratio of the incremental conductance algorithm for proposed Luo converter. Figures 6-9 show the simulated responses of the incremental conductance MPPT algorithm based stand-alone PV system. Figure-6 shows the overall performance of the proposed system. Figure-7 shows the response of power, voltage and duty ratio with 1000 W/m^2, 25°C. Figure-8 shows the response of power, voltage and duty ratio with 200 W/m^2, 25°C. Figure-9 shows the response of power, voltage and duty ratio at 1000 W/m^2, 75°C.

CONCLUSIONS

Solar PV is a technology that provides a resolution for a number of problems connected with fossil fuels. It is clean, decentralized and indigenous and does not need the continuous import of a resource. On top of that, India has among the highest solar irradiance in the world which makes solar PV all the more attractive for India. In this work, PV array and MPPT technique plays a really significant part. Mainly, the study of the interconnected stand-alone system is carried out with the help of the PV array and MPPT (Maximum Power Point Tracking) technique of the type Incremental Conductance algorithm. From Figures 7-9 show, clearly the proposed converter suits with Incremental conductance algorithm and achieved maximum power.

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