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Safety Based High Step Up DC-DC Converter for PV Module Application

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ABSTRACT

Solar energy is most widely used Renewable Source such as PV modules, fuel cells. The power capacity range of a single PV panel is about 100W to 300W, and the maximum power point (MPP) voltage range is from 15V to 40V, which will be the input voltage of the ac module; in cases with lower input voltage, it is difficult for the ac module to reach high efficiency. However, employing a high step-up dc– dc converter in the front of the inverter improves power-conversion efficiency and provides a stable dc link to the inverter.The main concept is to obtain high step-up voltage from low voltage delivering devices like photovoltaic panels etc. In this paper presented a DC-DC converter with coupled inductor in open loop and closed loop operation during critical loading condition is proposed. Furthermore, a general conceptual circuit for high-step-up, low-cost, and high efficiency dc/dc conversion is proposed to derive the next generation topologies for the PV connected system. The total power generated from the PV array is sometimes decreased remarkably when only a few modules are free from shadow effects to overcome this problems several necessary steps are taken. To maintain high step up voltage with respect to sudden changes in load. A high gain dc-dc boost converter was required which can be used to boost the output from a PV module. In this paper a High step up DC-DC converter in critical loading condition with high voltage gain. simulations are carried out without and with PI controller using open loop and closed loops, With the numerous turns-ratios of a coupled inductor, this converter achieves a high step-up voltage-conversion ratio, with PI controller gives better results with Low steady state error, fast dynamic response & high reliability. A PI Controller (proportional-integral controller) is a special case of the PID controller in which the derivative (D) of the error is not used. The Proportional-Integral (P-I) controller is one of the conventional controllers and it has been widely used. A pi controller attempts to correct the error between the measured process variable and desired set point by calculating and then outputting a corrective action that can adjust the process accordingly The major features of the P-I controller are its ability to maintain a zero steady-state error to a step change in reference. The proposed converter has several features: 1) The connection of the two pairs of inductors, capacitor, and diode gives a large step-up voltage-conversion ratio; 2) the leakage-inductor energy of the coupled inductor can be recycled, thus increasing the efficiency and restraining the voltage stress across the active switch; and 3) the floating active switch efficiently isolates the PV panel energy during non operating conditions, which enhances safety. The low voltage rated MOSFET can be adopted for reductions of conduction losses and cost. The results are obtained through Matlab/Simulink software package.

KEYWORDS: *PV Module, Coupled Inductor, DC-DC Power Converters, PI Controller, Single Switch*

I. Introduction

The power-electronic technology plays a vital role in distributed generation and in integration of renewable energy sources into the electrical grid. The increasing number of renewable energy sources and distributed generators requires new strategies to improve the power-supply reliability and quality. In addition, liberalization of the grids leads to new management structures, in which trading of energy and power is becoming increasingly important.

Now-a-days, solar panels are becoming accepted as an important mean for the power generation. Also, there are installations in locations where other means of electricity supply would be as costly as photovoltaic panels. Unfortunately, once there is a partial shadow on some panels, the system's energy yield. becomes significantly reduced [2]. An ac module is a micro inverter configured on the rear bezel of a PV panel [1]–[3]; this alternative solution not only immunizes against the yield loss by shadow effect, but also provides flexible installation options in accordance with the user's budget [4]. Clearly understanding the specifications of coupled inductors is essential to using them to their full advantage. Most of these coupled inductors have the same number of turns—i.e., a 1:1 turn's ratio—but some newer one have a higher turns ratio [12]. Also, the current specifications for a coupled inductor are different depending on whether its windings are physically connected in series or in parallel. For example, when the windings are connected in series, the equivalent inductance is more than twice the rated inductance due to the mutual inductance. .

The power capacity for a single PV panel[1]-[3] is about 100W to 300W, and the maximum power point (MPP) voltage range is about 15V to 40V, which will be the input voltage of the ac module; in cases with lower input voltage, it is difficult for the ac module to reach high efficiency [3]. However, by employing a high step- up dc–dc converter [6], [9] in the front of the inverter improves power-conversion efficiency and provides a stable dc link to the inverter. When installing the PV generation system during daylight, for safety reasons, the ac module outputs zero voltage.

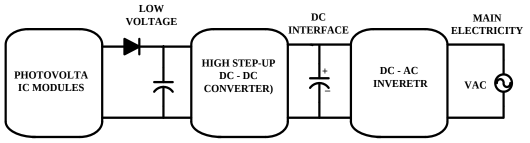

Fig.1. General Power generation system with a high step-up converter

Fig.1 shows the General power generation system with a high step-up converter. A floating active switch is designed and placed in series to isolate the dc current from the PV panel, for when the ac module is off-grid as well as in non-operating condition. This isolation ensures the operation of the internal components without any energy being transferred to the output or input terminals, which could be unsafe.

The dc–dc converter requires large step-up conversion [6]-[7] from the panel's low voltage to the voltage level of the application. The efficiency and voltage gain of the dc–dc boost converter are constrained by either the parasitic effect of the power switches or the reverse recovery issue of the diodes. In addition, the equivalent series resistance (ESR) of the capacitor and the parasitic resistances of the inductor also affect overall efficiency [8].

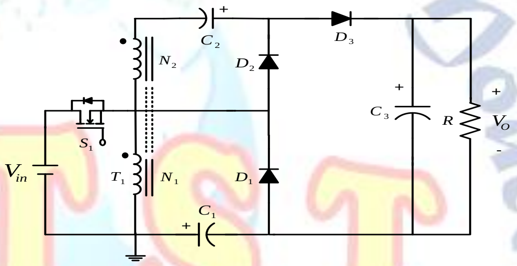

Fig.2. Circuit configuration of proposed converter

The proposed converter, shown in Fig. 2, is comprised of a coupled inductor T_1 with the floating active switch S_1 and capacitor C_1 and diode D_1 receive leakage inductor energy from N_1. The secondary winding N_2 of coupled inductor T_1 is connected with another pair of capacitors C_2 and diode D_2, which are in series with N_1 in order to further enlarge the boost voltage. The rectifier diode D_3 connects to its output capacitor C_3. The operating principles and steady-state analysis of the proposed converter are presented in the following sections

II. Operating principles of the proposed converter

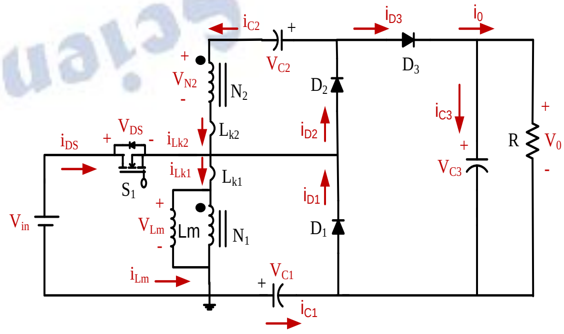

Fig.3. Polarity definitions of voltage and current in proposed converter

The simplified circuit model of the proposed converter is shown in Fig. 3. In order to simplify the circuit analysis of the proposed converter.

1) All components are ideal, except for the leakage inductance of coupled inductor. The on-state resistance R_{DS} (ON) and all parasitic capacitances of the main switch S_1 are neglected, as are the forward voltage drops of diodes $D_1 \sim D_3$.
2) The capacitors $C_1 \sim C_2$ are sufficiently large that the voltages across them are considered to be constant.
3) The ESR of capacitors $C_1 \sim C_2$ and the parasitic resistance of coupled inductor T_1 are neglected.
4) The turn's ratio n of the coupled inductor T_1 windings is equal to $N_2\ /N_1$.

The operating modes are described as follows.

Mode I $[t_0, t_1]$**:** In this transition interval, the magnetizing inductor L_m continuously charges capacitor C_2 through T_1 when S_1 is turned ON. switch S_1 and diode D_2 are conducting this mode ends at $t = t_1$.

Mode II $[t_1, t_2]$**:** During this interval, source energy V_{in} is series connected with N_2, C_1, and C_2 to charge output capacitor C_3 and load R; meanwhile magnetizing inductor L_m is also receiving energy from V_{in}. The current flow path is shown in Fig.4, where switch S_1 remains ON and only diode D_3 is conducting. This mode ends when switch S_1 is turned OFF at $t = t_2$.

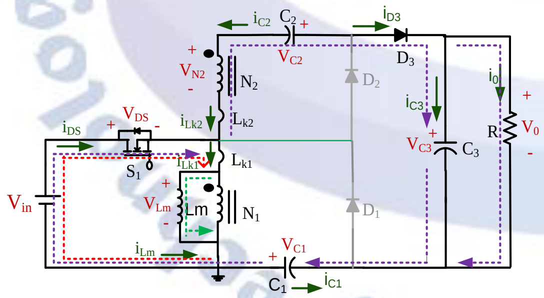

Fig.4. Mode II: $t_1 \sim t_2$

Mode III $[t_2, t_3]$**:** During this transition interval, secondary leakage inductor L_{k2} keeps charging C_3 when switch S_1 is OFF only diode D_1 and D_3 are conducting this mode ends at $t = t_3$.

Mode IV $[t_3, t_4]$**:** During this transition interval, the energy stored in magnetizing inductor L_m is released to C_1 and C_2 simultaneously. The current flow path is shown in Fig.5. Only diodes D_1 and D_2 are conducting. The energy stored in capacitor C_3 is constantly discharged to the load R. This mode ends when current i_{Lk1} is zero, at $t = t_4$.

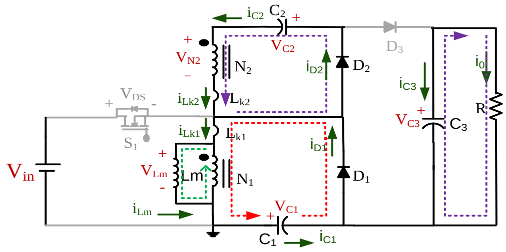

Fig.5. Mode IV: $t_3 \sim t_4$

Mode V $[t_4, t_5]$**:** During this interval, only magnetizing inductor L_m is constantly releasing its energy to C_2. The current flow path is shown in Fig.8, in which only diode D_2 is conducting. The energy stored in capacitor C_3 is constantly discharged to the load R. This mode ends when switch S_1 is turned ON at the beginning of the next switching period.

III. STEADY-STATE ANALYSIS OF PROPOSED CONVERTERS

To simplify the steady-state analysis, only modes II and IV are considered for operation, and the leakage inductances on the secondary and primary sides are neglected. The following equations can be written.

$$V_{Lm} = V_{in}\,,\ V_{N2} = nV_{in} \tag{1}$$

During mode IV

$$V_{Lm} = -V_{C1}\ ,\ \ V_{N2} = -V_{C2} \tag{2}$$

Applying a volt-second balance on the magnetizing inductor L_m yields

$$\int_0^{DT_s}(V_{in})dt\ +\ \int_{DT_s}^{T_s}(-V_{C1})dt = 0 \tag{3}$$

$$\int_0^{DT_s}(nV_{in})dt\ +\ \int_{DT_s}^{T_s}(-V_{C2})dt = 0 \tag{4}$$

From which the voltage across capacitors C_1 and C_2 are obtained as follows:

$$V_{C1} = \frac{D}{1-D}V_{in}\ \ ,\ \ V_{C2} = \frac{nD}{1-D}V_{in} \tag{5}$$

During mode II, the output voltage $V_0 = V_{in} + V_{N2} + V_{C2} + V_{C1}$ becomes

$$V_0 = V_{in} + nV_{in}\frac{nD}{1-D}V_{in} + \frac{D}{1-D}V_{in} \tag{6}$$

The DC voltage gain M_{CCM} can be found as follows:

$$M_{CCM} = \frac{V_0}{V_{in}} = \frac{1+n}{1-D} \tag{7}$$

IV. STEP UP CONVERTER WITH PI CONTROLLER

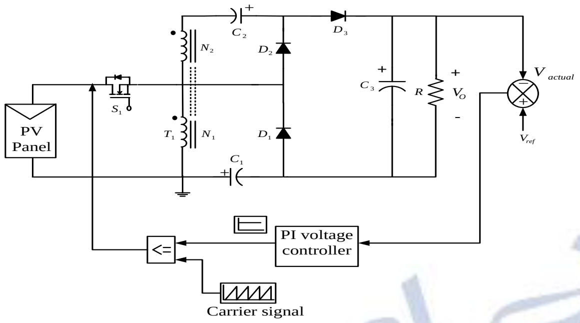

Fig.6. New proposing system of an effective high step up dc-dc converter PV system with PI controller.

For getting constant load achieving condition we need to go for closed loop operation with the help of second order compensators such as P,PI,PID controllers with respect to maintain constant voltage at load.

Here PI controller is used because of its fast dynamic response with respect to steady state error $e_{rr}\approx0$, without any load changes. In this the V_{act} and V_{ref} is compared, with respect to these changes the switching operation depends on the reference signal coming from proposed controller, compare reference signal with carrier (saw tooth) for generation of pulses with respect to load changes, with the help of pulse converter actuates and maintain constant output voltage and achieve load condition.

V. MATLAB MODELLING AND SIMULATION RESULTS

Here simulation is carried out in four different conditions both for open loop and closed loop loading conditions.

Case-1: Open Loop Operation of proposed high Step up DC/DC Converter

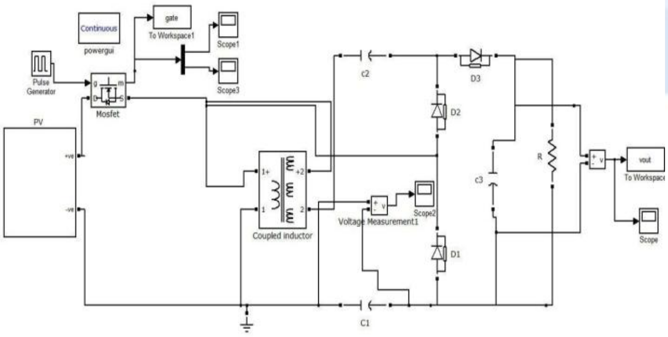

Fig.7. Matlab/Simulink of Proposed high step-up DC-DC converter using Matlab/Simulink Platform.

As above Fig.7. Shows the Matlab/Simulink model of proposed high step-up DC-DC converter.

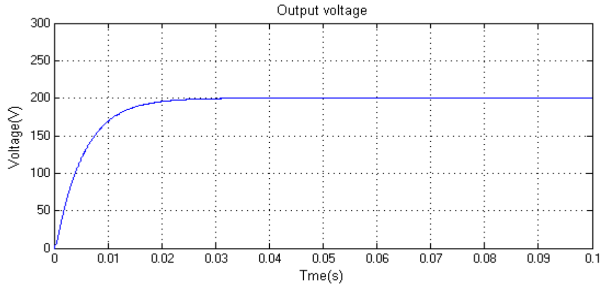

Fig.8 Output voltage of Proposed high step-up DC-DC converter.

The output voltage waveform of proposed high step-up DC-DC converter shown in Fig.8. In this input voltage is V_{in}=15v and obtained output voltage V_o=200v here the steady state output achieved at t=0.035sec.

The output voltage and current waveforms of capacitors and diodes of the proposed converter are shown in Fig.9(a).

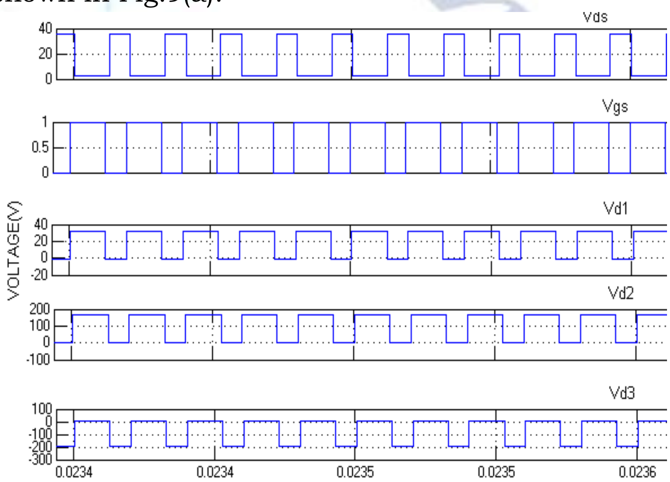

Fig.9(a) output voltage waveforms of capacitors and diodes

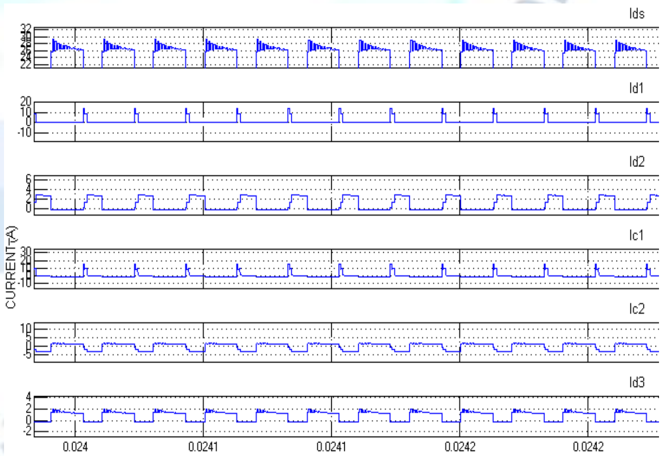

Fig.9(b) output Current waveforms of capacitors and diodes

The output current waveforms of capacitors and diodes of the proposed converter are shown in Fig.9 (b).

Case-2: *Closed Loop Operation of proposed high Step up DC/DC Converter*

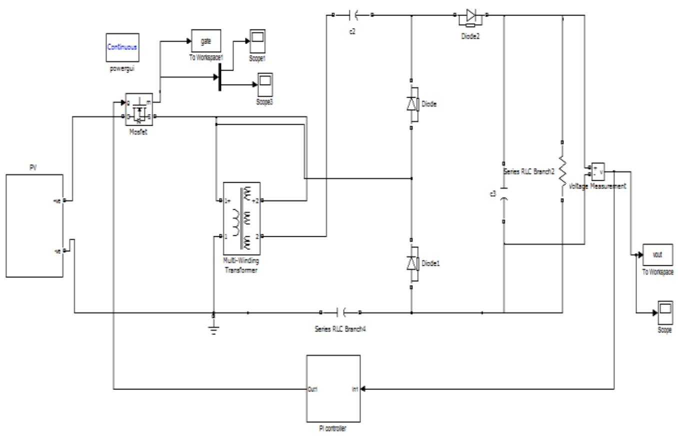

Fig.10. Matlab/Simulink of High step-up DC-DC converter using PI controller using Matlab/Simulink platform

As above Fig.10. Shows the Matlab/Simulink model of High step-up DC-DC converter using PI controller.

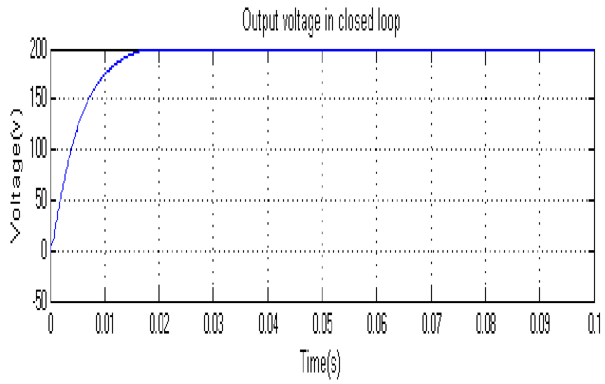

Fig.11. output voltage of High step-up DC-DC converter using PI controller

The output voltage waveform of High step-up DC-DC converter using PI controller is shown in Fig.11.

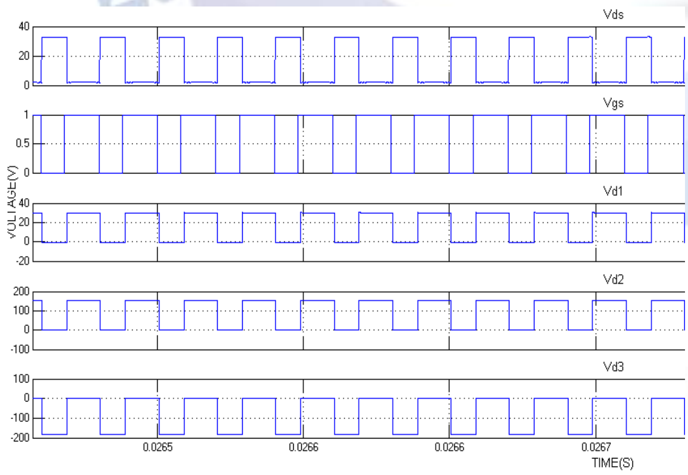

Fig.12. output voltage waveforms of capacitors and diodes of High step-up DC-DC converter using PI controller.

As above Fig.12 output voltage waveforms of capacitors and diodes of High step-up DC-DC converter using PI controller.

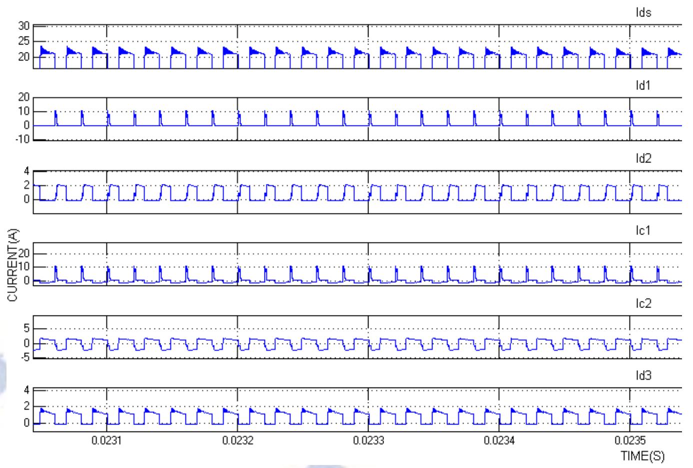

Fig.13. output current waveforms of capacitors and diodes of High step-up DC-DC converter using PI controller

Case-3: *open Loop Operation of proposed high Step up DC/DC Converter during critical loading condition*

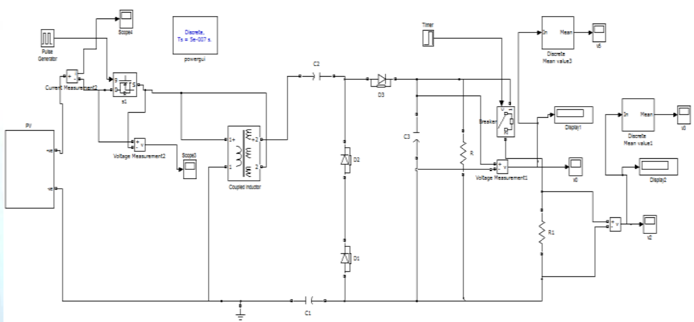

Fig.14. Matlab/Simulink of High step-up DC-DC converter during critical loading condition using Matlab/Simulink platform

The Matlab/Simulink of High step-up DC-DC converter during critical loading condition is shown in Fig.14.when compared to open loop, here fast response was achieved and steady state output at t=0.023sec. Compared to two conditions the steady state output obtained 0.012sec earlier in closed loop controller.

Case-4: Closed Loop Operation of proposed high Step up DC/DC Converter during critical loading condition

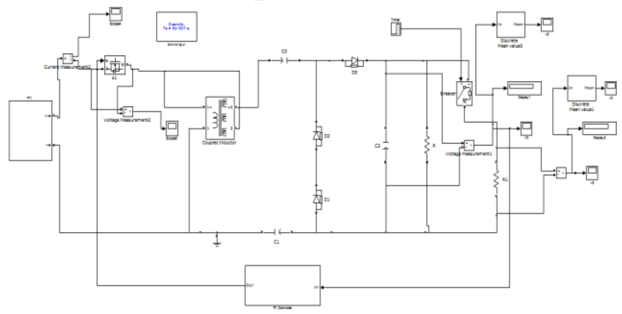

Fig.15. Matlab/Simulink of High step-up DC-DC converter during critical loading condition using PI controller using Matlab/Simulink platform

As above Fig.15. Shows the Matlab/Simulink model of High step-up DC-DC converter during critical loading condition using PI controller

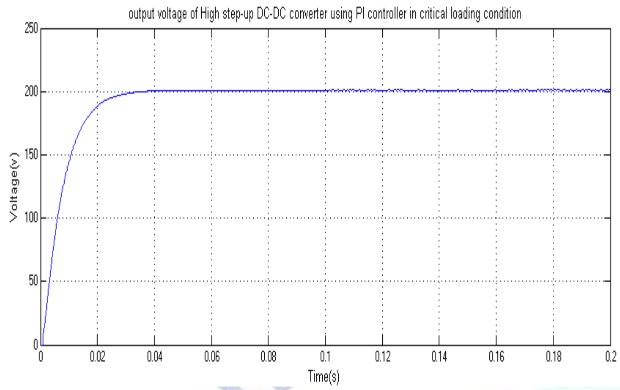

Fig.16. output voltage of High step-up DC-DC converter using PI controller in critical loading condition

Above Fig.16 shows the output voltage of High step-up DC-DC converter using PI controller in critical loading condition. It was clearly shows the sudden voltage drop during loading condition as earlier shown in the open loop condition is reduced by using this PI controller.

V. Conclusion

Renewable energy resources (RES) are being increasingly applications to many more systems with help of power electronic conversion technology, by using this technology we achieve high reliability to support the grid connected system as well as standalone system. Here we proposed high step up dc-dc converter with closed loop combination for attaining the constant load condition with respect to time. Since the energy of the coupled inductor's leakage inductor has been recycled, the voltage stress across the active switch S1 is constrained, which means low ON-state resistance R_{DS} (ON) can be selected. With the help of reference values provided constant Kp & Ki values, for controlling the active converter with intern of sudden loading conditions and also achieves high step-up voltage gain up to 13 times of input voltage, the high performance of closed loop operation provides better results with better steady state error & fast dynamic response, high reliability.

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