PV fed Novel High Step up Soft Switching Interleaved DC-DC Boost Converter with Coupled Inductors

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Abstract: In this paper, a novel high step-up dc-dc converter for distributed generation systems is proposed. The concept is to utilize two capacitors and one coupled inductor. The two capacitors are charged in parallel during the switch-off period and are discharged in series during the switch-on period by the energy stored in the coupled inductor to achieve a high step-up voltage gain. In addition, the leakage-inductor energy of the coupled inductor is recycled with a passive clamp circuit. Thus, the voltage stress on the main switch is reduced. The switch with low resistance RDS (ON) can be adopted to reduce the conduction loss. In addition, the reverse-recovery problem of the diodes is alleviated, and thus, the efficiency can be further improved. The operating principle and steady-state analyses are discussed in detail.

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INTRODUCTION

The energy demand in the world is steadily increasing and new types of energy sources must be found in order to cover the future demands, since the conventional sources are about to be emptied. The reasons behind increase in the usage of electricity is due to the increase in the population. In order to meet the demand many generating units are set up in the country. There are two types of electricity generation in the present days. The power that is generated from these plants is delivered to the consumer through the grid. Electrical energy plays a key role for industrial and all round development of society. In everyday life the consumption of electrical energy is through many ways such as usage of geyser, heater, toaster etc. The bulk generation and transmission of power economically is needed to meet the consumers demand. The beauty of electrical energy is that it can be adapted easily and efficiently to domestic and industrial applications (i.e., lighting, mechanical work).The per capita consumption of electrical energy is a very reliable indicator of a country's state of development. Other indicators like owing of cars, mobiles and houses.

Conventional sources are obtained by conversion from fossil fuels (coal, oil, natural gas), nuclear and hydro resources. The coal, oil, natural gases can be burnt to produce heat energy which can be later on converted to mechanical energy and subsequently to electrical energy. By 2020, the total power generation in world will be 80% by conventional energy only but renewable energy will take 20% of the total generation. Heat energy by burning fossil fuel (or fission of nuclear material) is converted to mechanical form through a thermo cycler and then mechanical energy to electrical energy through generators. Thermal efficiency is low (<40%)[2]. The conventional sources are limited. There is a need to conserve economize or minimize on burning of coal and hence we need to take help of other sources of energy i.e., renewable, the green or natural energy by considering the environmental and economical considerations. The per capita energy consumption has been increasing day by day due to exponentially rising population, technologists has already seen the end of earth's non-replenishable fuel resources.

DC-DC CONVERTERS:

DC-DC converter is a device which converts DC voltage from one level to another level. It can be from low voltage to high voltage or high voltage to low voltages. Before the development of power semiconductors and allied technologies, one way to convert the voltage of a DC supply to a higher voltage, for low-power applications, was to convert it to AC by using a vibrator, followed by a step-up transformer and rectifier.

For higher power an electric motor was used to drive a generator of the desired voltage (sometimes combined into a single "dynamotor" unit). These were relatively inefficient and expensive procedures used only when there was no alternative, as to power a car radio (which then used thermionic valves/tubes requiring much higher voltages than available from a 6 or 12 V car battery).

The introduction of power semiconductors and integrated circuits made it economically viable to use techniques as described below, for example to convert the DC power supply to high-frequency AC, use a transformer—small, light, and cheap due to the high frequency—to change the voltage, and rectify back to DC. Although by 1976 transistor car radio receivers did not require high voltages, some amateur radio operators continued to use vibrator supplies and dynamotors (a motor and generator combined into one unit, with one winding driving the motor and the other generating the output voltage)[15] for mobile transceivers requiring high voltages, although transistorized power supplies were available.

Types of DC-DC Converters:

Buck Converters:

A buck converter (dc-dc) is shown in below Fig. Only a switch is shown, for which a device as described earlier belonging to transistor family is used. Also a diode (termed as freewheeling) is used to allow the load current to flow through it, when the switch (i.e., a device) is turned off. The load is inductive (R-L) one. In some cases, a battery (or back emf) is connected in series with the load (inductive). Due to the load inductance, the load current must be allowed a path, which is provided by the diode; otherwise, i.e., in the absence of the above diode, the high induced emf of the inductance, as the load current tends to decrease, may cause damage to the switching device. If the switching device used is a thyristor, this circuit is called as a step-down chopper, as the output voltage is normally lower than the input voltage. Similarly, this dc-dc converter is termed as buck one, due to reason given later.

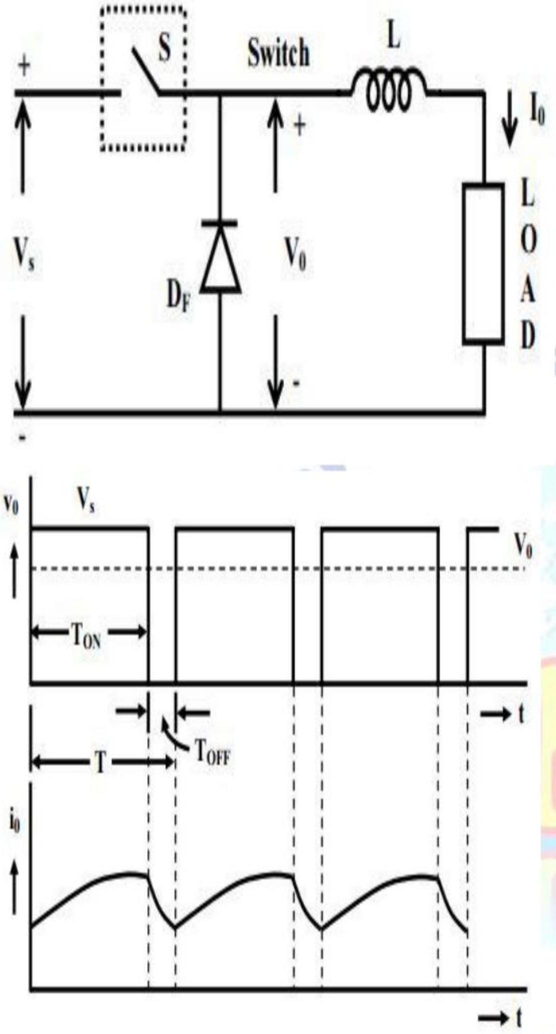


Fig 4.1: Buck converter circuit, output voltage and current waveforms

Boost Converters:

A boost converter (dc-dc) is shown in below figure. Only a switch is shown, for which a device belonging to transistor family is generally used. Also, a diode is used in series with the load. The load is of the same type as given earlier. The inductance of the load is small. An inductance, L is assumed in series with the input supply. The position of the switch and diode in this circuit may be noted, as compared to their position in the buck converter.

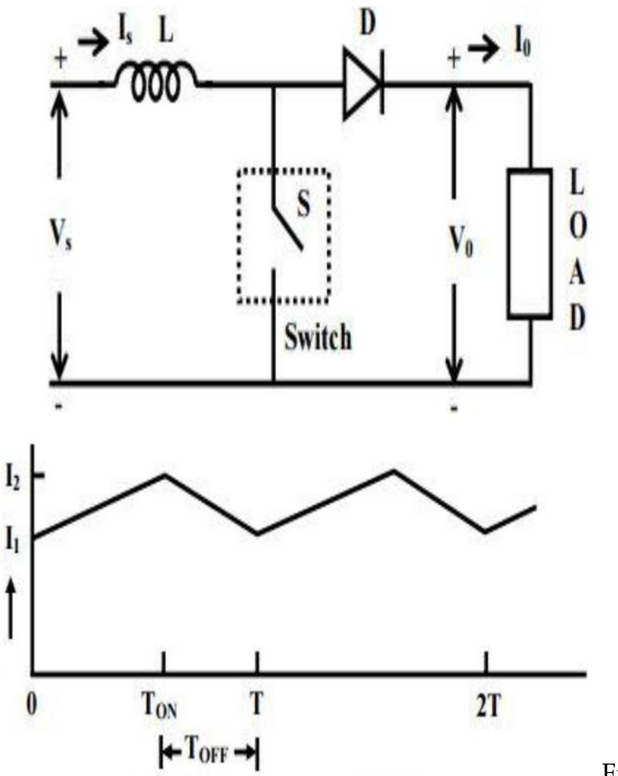
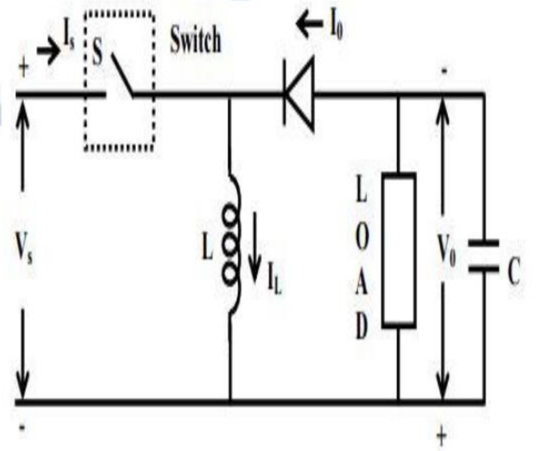


Fig 4.2: Boost converter circuit, output voltage and current waveforms

Buck-Boost Converters:

A buck-boost converter (dc-dc) is shown in below figure. Only a switch is shown, for which a device belonging to transistor family is generally used. Also, a diode is used in series with the load. The connection of the diode may be noted, as compared with its connection in a boost converter. The inductor, L is connected in parallel after the switch and before the diode. The load is of the same type as given earlier. A capacitor, C is connected in parallel with the load. The polarity of the output voltage is opposite to that of input voltage here.



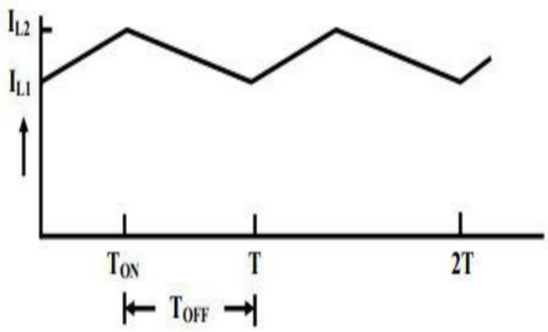


Fig 4.3: Buck-Boost converter circuit, output voltage and current waveforms

SOFT SWITCHING INTERLEAVED BOOST CONVERTER

The main part of MPPT hardware is a DC-DC converter the block diagram shown in Figure 4. It tracks the MPP and guarantees the DC link voltage under low irradiance condition. The conventional DC/DC converters such as buck, boost, buck-boost, cuk, sepic, and zeta converters etc. are operated under high switching frequenciecs resulting in high switching losses, noises, and component stresses. These problems deteriorate the performance of conventional boost converters and leads to the reduction of output power. To solve aforementioned drawbacks, authors proposed a modified interleaved boost converter with dual Inductors and voltage multiplier to satisfy the high step-up applications and low input current ripple.

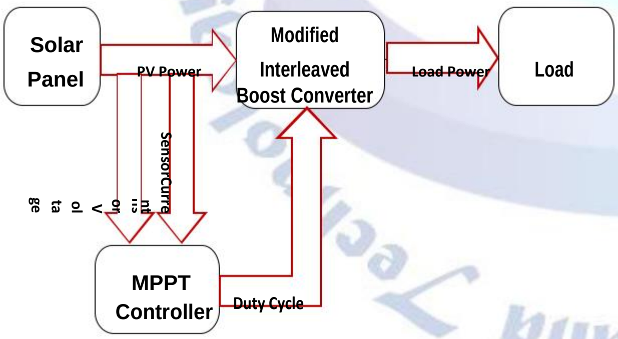


Fig 4.4: Block diagram of Proposed DC/DC conversion

4.3.1 Principle of operation of SSIBC:

The proposed topology is shown in figure. The SSIBC of two single-phase boost inverters that are linked in parallel and inverters operating 180 degree out of phase with 30 kHz switching frequency, corresponding circuit and gate control diagrams as shown in Figure 4.5and 4.6.

This circuit having two parts

(i) Modified Interleaved boost converter and

(ii) voltage multiplier.

The main functions of modified Interleaved boost control:

(i) low output ripple due to interleaved series connected capacitors

(ii) low switch voltage stress.

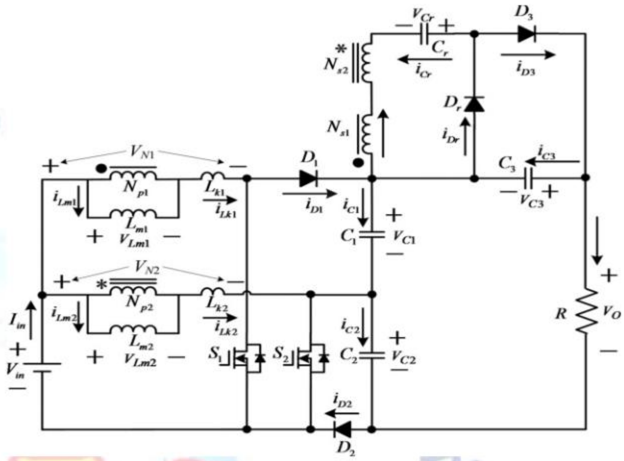


Fig 4.5: Circuit diagram of SSIBC

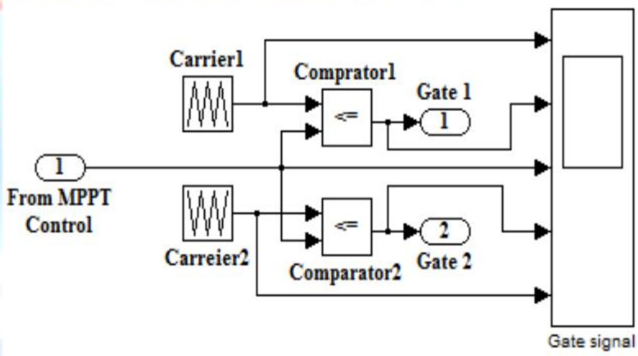
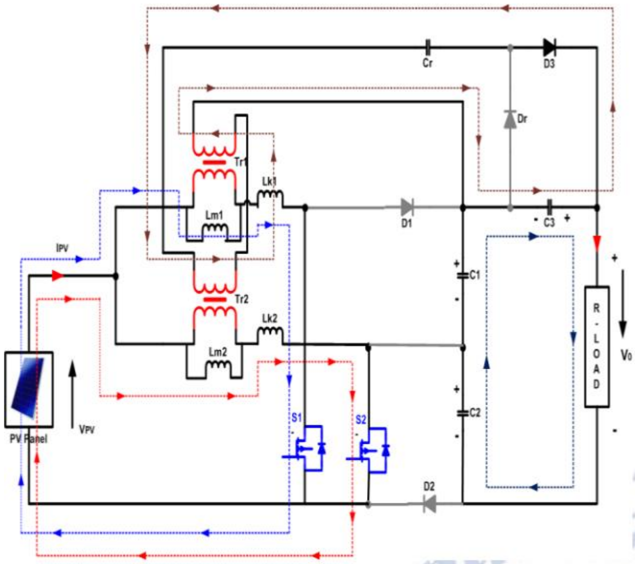


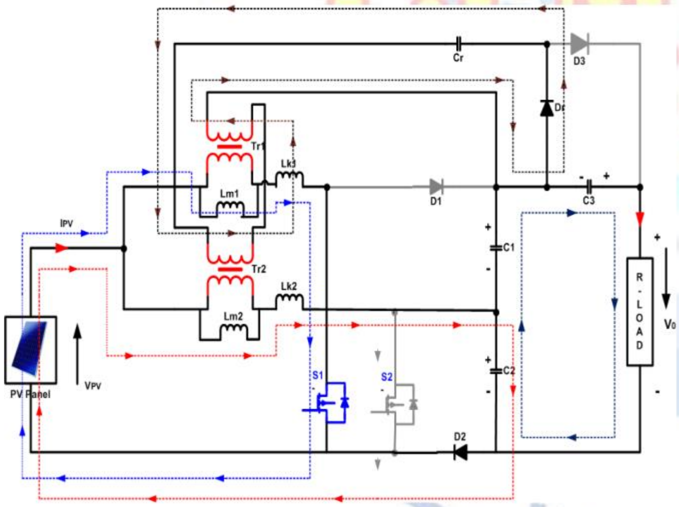
Fig4.6: Gate control signal

The operating stages can be explained as follows:

First stage ($t_0 - t_1$):-At t= t_0 , Power switch S_1 is turn ON with ZCS due to leakage Inductance L_{k1}, while S_2remains turned ON, all the diodes are turned OFF except D_3 as shown in Fig 4.10. The current falling rate through D_3 can be controlled by leakage Inductances and minimizes the reverse recovery problem. The magnetizing Inductances L_{M1} and L_{M2}, leakage inductances L_{K1} and L_{K2} are linearly charged by the input voltage source V_{in}

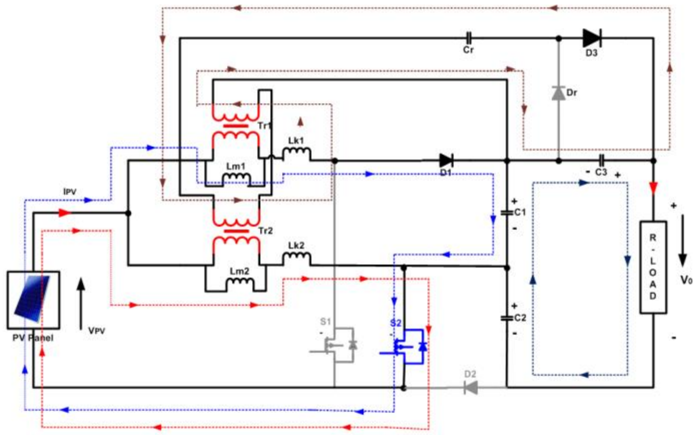


Second stage *($t_1 - t_2$):-*At t=t₁ switch *S_2* is turn OFF, diodes *D_2* and *D_r*turn ON. The input voltage source, magnetizing Inductances *L_{K2}* discharges the energy to C_2 through diode *D_2* as shown in Fig 4.11. When total energy of leakage Inductance *L_{K2}* discharges completely to the capacitor and magnetizing Inductance *L_{M2}* still discharges energy to secondary side charging the capacitor C_r through diode *D_r*.



Third stage ***(*** *$t_2 - t_3$* ***):-*** A t= t_2 switch *S_2* is turned ON with ZCS condition. *S_1* remains in ON state as shown in Fig 4.12. The current flowing through *D_r* is controlled by *L_{K1}* and *L_{K2}* which minimizes the diode reverse recovery problem.

Fourth stage ***(*** *$t_3 - t_4$* ***):-*** A t= *t_3* switch S1 turn OFF and S2 remains in conducting state (ON state), V_PV, Lm1, Lk1 release their energy to C1 via S2 as shown in Fig 4.13. Energy stored in Lm1 is transferred to sec. side of transformer. The current through sec. sides in series flows to the capacitor C3and load through D3



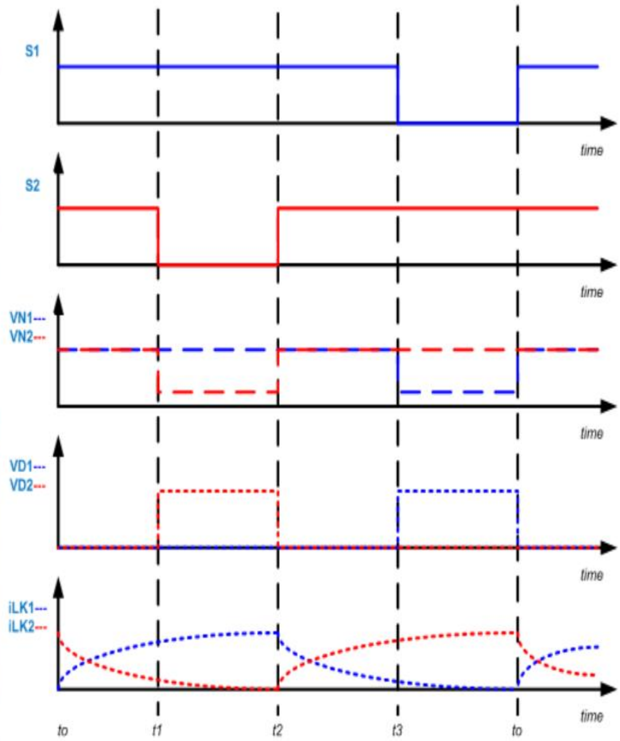


Figure Switching sequence of proposed SSIBC

Voltage Gain Expression

At stage second

$V_0 = V_{c1} + V_{c2} + V_{c3}$ 4.1)

At stage three

$V_{cr} = V_{s1} - V_{s2} = KNV_{c2}$ (4.2)

$V_{c3} = V_{cr} + V_{s2} - V_{s1} = KN\,(V_{c1} + V_{c2})$ (4.3)

Voltage across the capacitors C₁and C₂ are obtained as

$$V_{c1} = V_{c2} = \frac{V_{in}}{1-D} \qquad (4.4)$$

Voltage across the capacitors C₃and Cᵣ are obtained as

$$V_{c3} = \frac{2KN}{1-D} V_{in} \qquad (4.5)$$

$$V_{cr} = \frac{KN}{1-D} V_{in} \qquad (4.6)$$

Substituting (4) and (5) in (1) to obtain output voltage

$$V_0 = \frac{V_{in}}{1-D} + \frac{V_{in}}{1-D} + \frac{2KN}{1-D} V_{in} \quad (4.7)$$

Voltage gain is obtained as the ration of output voltage to the input voltage

$$\frac{V_0}{V_{in}} = \frac{2}{1-D}(1+KN) \quad (4.8)$$

If the impact of leakage inductances is neglected the coefficient of coupling K=1.Then voltage gain is rewritten as

$$\frac{V_0}{V_{in}} = \frac{2(1+N)}{1-D} \quad (4.9)$$

The voltage stress on the power switches S_1 and S_2 are derived from

$$V_{s1-stress} = V_{s2-stress} = \frac{V_{in}}{1-D} = \frac{V_0}{2(1+N)} \quad (4.10)$$

The voltage stress on the diodes D_1, D_2, D_3 and D_r related to the turns ratio and the output voltage can be derived as

$$V_{D1-stress} = \frac{2V_{in}}{1-D} = \frac{V_0}{(1+N)} \quad (4.11)$$

$$V_{D2-stress} = \frac{V_{in}}{1-D} = \frac{V_0}{2(1+N)} \quad (4.12)$$

$$V_{D3-stress} = V_{Dr-stress} = \frac{2NV_{in}}{1-D} = \frac{NV_0}{(1+N)} \quad (4.13)$$

Here the circuit is connected with two dual coupled inductors, Two classical boost converters connected in parallel and add voltage multiplier across it. When supply is on the input voltage passes through the inductors then the inductors gets charged, when switch S1 is on position. when S2 is on, then the inductors are discharged connect the voltage multiplier across the circuit. Power switch S_1 is turn ON with ZCS due to leakage Inductance L_{k1}, while S_2remains turned ON, all the diodes are turned OFF except D_3. The current falling rate through D_3 can be controlled by leakage Inductances and minimizes the reverse recovery problem. The magnetizing Inductances L_{M1} and L_{M2}, leakage inductances L_{K1} and L_{K2} are linearly charged by the input voltage source V_{in}

At t=t_1 switch S_2 is turn OFF, diodes D_2 and $D_r$turn ON. The input voltage source, magnetizing Inductances L_{K2} discharges the energy to C_2 through diode D_2. When total energy of leakage Inductance L_{K2} discharges completely to the capacitor and magnetizing Inductance L_{M2} still discharges energy to secondary side charging the capacitor C_r through diode D_r.

A t= t_2 3 switch S_2 is turned ON with ZCS condition. S_1 remains in ON state. The current flowing through D_r is controlled by L_{K1} and L_{K2} which minimizes the diode reverse recovery problem.

SIMULATION RESULTS:

Table: Specifications of Proposed Converter

Parameter	Value
PowerRating	500VA
InputVoltage	36V
OutputVoltage	720V
MagnetizingInductance(L_m)	120μH
LeakageInductance(L_k)	2.1μH
ClampCapacitors(C_1&C_2)	220μF
ClampCapacitor(C_3)	470μF
RegenerativeCapacitor(Cr)	47μF
TurnsRatiooftransformer	1.055

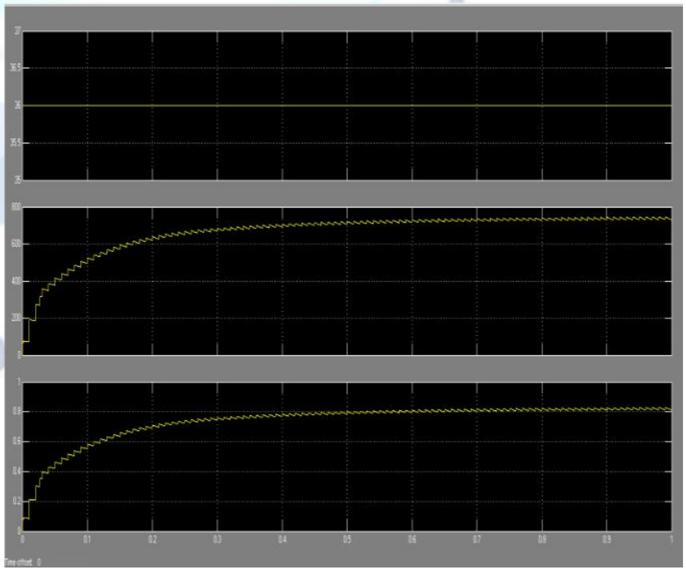


Fig:simulation Result for proposed Interleaved Boost Converter

CONCLUSION:

Thus, finally the analysis is carried on the characteristics of PV module with different irradiations and different temperatures are studied. The modified MPPT control improves the PV system performance mainly in dynamic states, thus reducing the loss of power and enhancing the tracking efficiency. Now, the SSIBC is suitable to interface for PV cells to convert low voltage input into a high voltage output. The proposed MPPT algorithm has advantages when compared to the classical one are reduces voltage stress, faster transient response for varying irradiation, low input current ripple, high efficiency, and improved reliability.

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