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SOFT-SWITCHING FRONT-END CONVERTER FOR RESIDENTIAL P-V SYSTEM

Masarath Unnisa[1], Fahmida Iqbal[2], S. Humera Sadiya[3], Ishrath Jahan[4], Mohammed Abdul Rahman Uzair [5], Mohd Abdul Kareem[6]

[1,2,3,4,5,6]Assistant Professor, Nawab Shah Alam Khan College of Engg & Tech, Hyderabad, (India)

ABSTRACT

This paper presents a Photovoltaic (PV) residential power system is an important application of renewable energy. The parallel-connected configuration of PV modules rather than the series-connected configuration become popular considering the safety requirements and making full use of the PV generated power for the PV residential generation system. In this paper, a novel soft-switching current-fed push-pull front-end converter based inverter is proposed. Push-pull converter has only two primary devices with common ground to supply and results in simple and reduced gating requirement. The device voltage is clamped naturally by secondary modulation without active clamping circuit or passive snubbers. Zero-current switching (ZCS) of primary devices and zero-voltage switching (ZVS) of secondary devices is achieved. Soft-switching is inherent owing to proposed secondary modulation, load independent and is maintained during wide variation of input voltage and power transfer capacity, and thus is suitable for PV applications.

Keywords: Push-Pull Front-End Current-Fed Converter, Soft-Switching, Residential Photovoltaic Power System, Coupled Inductor, Photovoltaic Effect, Resonant Inverter, DC-DC Converter.

I. INTRODUCTION

Renewable energy has experienced impressive growth over the past decade due to the fast depletion of fossil fuels concern of energy security and green gas emission. According to the report of international energy agency (IEA), 57% of new power capacity to 2030 will be in the form of renewable technologies Different renewable energy resources like wind and solar energy among others, are integrated together with the energy storage devices and relevant power conditioning, control and management systems to form a hybrid distributed generation system to provide long term sustainability. Since distributed Generation system is close to electricity users, it can overcome the inefficiency and environmental issues from the centralized power plants. Among a variety of renewable energy resources, solar photovoltaic (PV) has been proven to be very promising. Solar PV generation is pretty flexible that is scalable from small scale residential application to large scale solar power plants. It will comprise a large amount of share of the new power capacity added to 2030, accounting for almost 27%. The residential PV power system plays an increasing important role in solar renewable energy. However, PV modules have highly non-linear voltage-current characteristics and the maximum power point (MPP) varies dramatically with Hybrid distributed power generation system. For residential applications, the performance of PV inverter system is easily to be affected by partial shadows and mismatch of electrical parameters.

II. HARD-SWITCHING FRONT-END DC/DC CONVERTER

Design of a high step-up front-end dc/dc converter is critical to convert wide input voltage range into regulated higher dc voltage with high efficiency. Hard-switching have been proposed and analyzed for solar inverter applications. Parasitic effect of devices and reverse recovery issue of diodes are the main issues and constraints for those converters with low efficiency and voltage gain.

III. SOFT-SWITCHING FRONT-END DC/DC CONVERTER

High frequency (HF) transformer isolated dc/dc converter is preferred to obtain high step-up ratio and the galvanic isolation between the PV modules and the utility. For voltage-fed topologies, considerably large electrolytic capacitor is generally required to suppress the large input current ripple, resulting large size, high cost and shortened lifetime of PV system. In this paper, Zero-voltage switching (ZVS) or zero-current switching (ZCS), a dual stage dc/ac inverter is proposed that is composed of high step-up snubber-less current-fed push-pull front-end converter and standard full-bridge inverter. It has smaller input current ripple, Lower transformer turns-ratio, Capacitive output filter, No flux-imbalance problem.

IV. CIRCUIT DIAGRAM

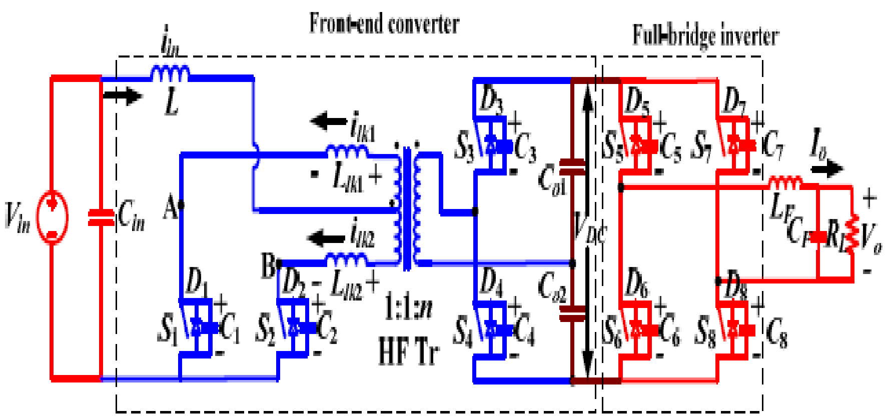

Figure1: Circuit Diagram

Operation of the proposed Converter:

In this section, steady-state operation and analysis of proposed high step-up front-end current-fed converter have been explained. To simplify the analysis, the following assumptions are made:

1) Boost inductor L is large enough to maintain constant current through it.

2) All the components are ideal.

3) Series inductors L_{lk1} and L_{lk2} include the leakage inductances of the transformer. The total value of L_{lk1} and L_{lk2} is represented as L_{lk_T}.

4) Magnetizing inductance of the transformer is infinitely large.

The steady-state operating waveforms are the primary switches S_1 and S_2 are operated with identical gating signals phase shifted with each other by 180o with an overlap using fixed-frequency duty cycle modulation. The overlap varies with duty cycle and the duty cycle should be kept above 50%. Steady-state operation of the

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converter during different intervals in a one half HF cycle is explained using equivalent circuits for the rest half cycle, the intervals are repeated in the same sequence with other symmetrical devices conducting to complete the full HF cycle.

V. OPERATION MODES

Interval 1 ($t_o < t < t_1$):

In this interval, primary side switch S_2 and anti-parallel body diode D_3 of the secondary side switch are conducting. Power is transferred to the load through HF transformer. The non-conducting secondary device S_4 is blocking output voltage V_{DC} and the non-conducting primary device S_1 is blocking reflected output voltage V_{DC}/n. The values of current through various components are: i_{S1} =0, i_{S2} =I_{in} , i_{Llk1}=0, i_{Llk2}= I_{in}, i_{D3} = I_{in}/n. Voltage across the switch S_1: V_{S1} = V_{DC}/n. Voltage across the switch S_4: V_{S4} = V_{DC}.

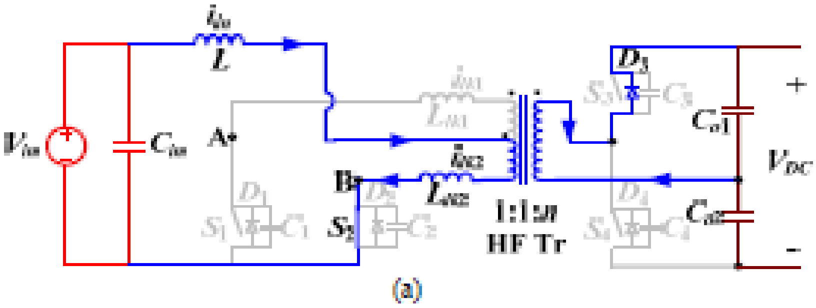


Figure2: Interval-1

Interval 2 ($t_1 < t < t_2$):

At t = t_1, primary switch S_1 is turned-on. The corresponding snubber capacitor C_1 discharges in a very short period of time. At the end of this interval, S_1 is fully conducting and C_1 is completely discharged.

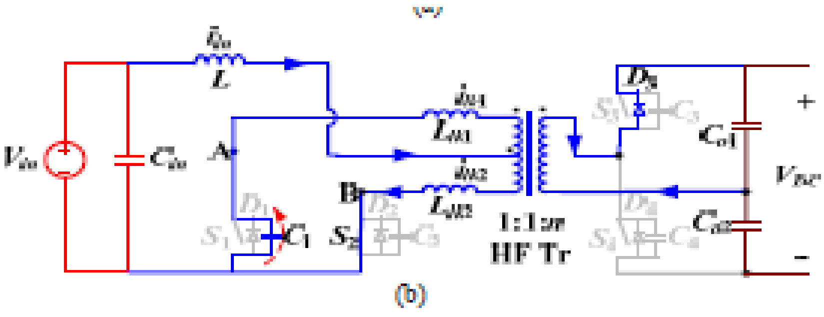


Figure3 : Interval-2

Interval 3 ($t_2 < t < t_3$):

Here, all two primary switches are conducting. Reflected output voltage appears across series inductors L_{lk1} and L_{lk2}, diverting/transferring the current through switch S_2 to S_1. It causes current through previously conducting device S2 to reduce linearly. It also results in conduction of switch S_1 with zero current which helps reducing associated turn-on loss. The currents through various components are given. Where L_{lk_T}= L_{lk1}+L_{lk2}. Before the end of this interval t=t_3, the body diode D_3 is conducting. Therefore S_3 can be gated on for ZVS turn-ON. At the end of this interval, D_3 commutates naturally. Current through all primary devices reaches $I_{in}/2$. Final values are: $i_{Llk1}= i_{Llk2}=I_{in}/2$, $i_{S1}= i_{S2} =I_{in}/2$, $i_{D3} =0$.

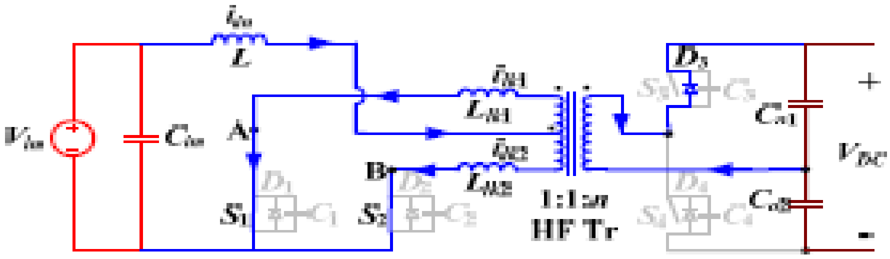
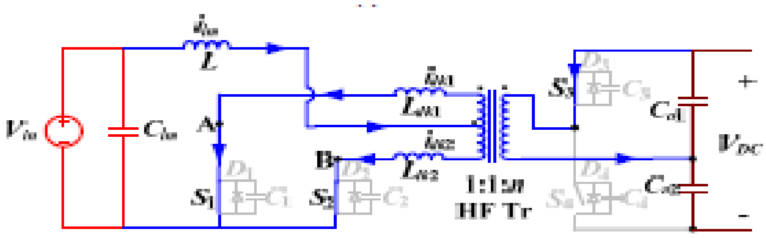


Figure4: Interval-3

Interval 4 ($t_3 < t < t_4$):

In this interval, secondary device S_3 is turned-on with ZVS. Currents through all the switching devices continue increasing or decreasing with the same slope as interval 3. At the end of this interval, the primary device S_2 commutates naturally with ZCC and the respective current i_{S2} reaches zero obtaining ZCS. The full current, i.e. input current is taken over by other device S_1. Final values are: $i_{Llk1}=i_{S1} =I_{in}$, $i_{Llk2}=i_{S2} =0$, $i_{S3} = I_{in}/n$.

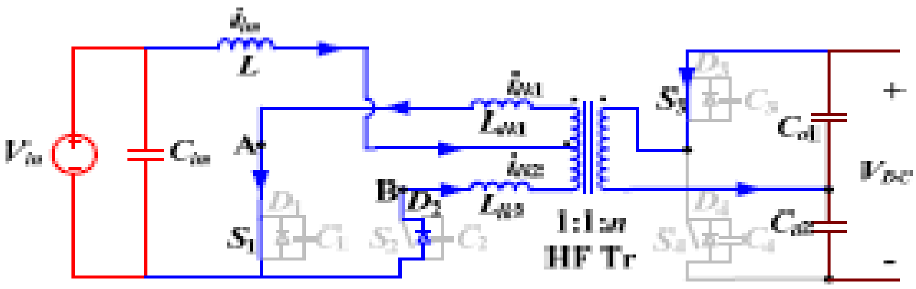


(d)

Figure5 : Interval-4

Interval 5 ($t_4 < t < t_5$):

In this interval, the leakage inductance current i_{Llk1} increases further with the same slope and anti-parallel body diode D_2 starts conducting causing extended zero voltage to appear across commutated switch S_2 to ensure ZCS turn-off. Now, the secondary device S_3 is turned-off. At the end of this interval, current through switch S_1 reaches its peak value. This interval should be very short to limit the peak current though the transformer and switch reducing the current stress and kVA ratings



(e)

Figure6: Interval-5

Interval 6 $t_5 < t < t_6$):

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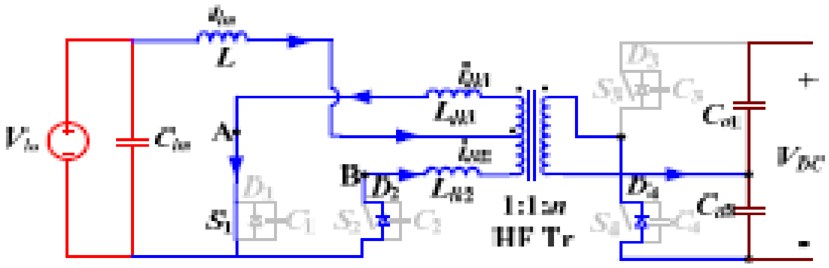
During this interval, secondary switch S_3 is turned-off. Anti-parallel body diode of switch S_4 takes over the current immediately. Therefore, the voltage across the transformer primary reverses polarity. The current through the switch S_1 and body diodes D_2 also start decreasing. At the end of this interval, current through D_2 reduce to zero and is commutated naturally. Current through S_1 reaches I_{in}.

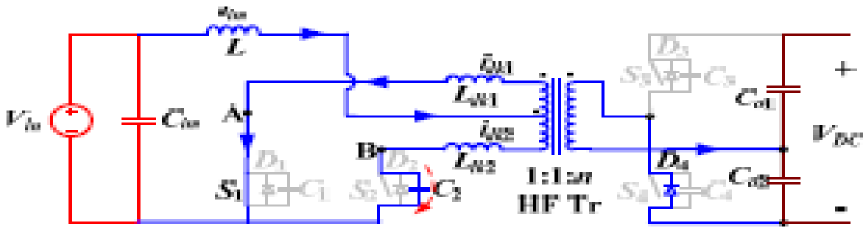


(f)

Figure7: Interval-6

Interval 7 ($t6 < t < t_7$):

In this interval, snubber capacitor C_2 charges to V_{DC}/n in a short period of time. Switch
S_2 is in forward blocking mode now.

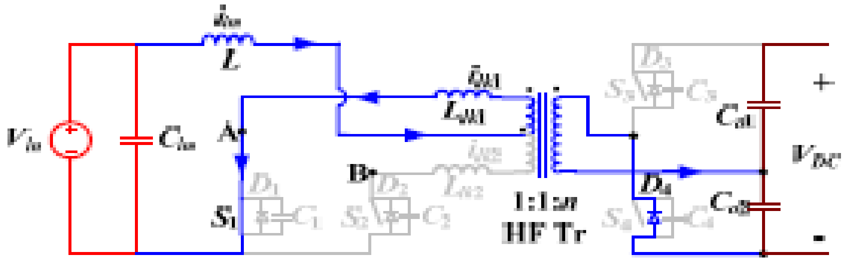


(g)

Figure8: Interval-7

Interval 8 (Fig. h; $t_7 < t < t_8$):

In this interval, currents through S_1 and transformer are constant at input current I_{in}. Current through anti-parallel body diode of the secondary switch D_4 is at I_{in}/n. The final values are: $i_{Llk1}=i_{S1}=I_{in}$, $i_{Llk2}=i_{S2}=0$, $i_{D4}=I_{in}/n$. Voltage across the switch S_2, $V_{S2}=V_{DC}/n$. In this half HF cycle, current has transferred from switch S_2 to S_1, and the transformer current has reversed its polarity.



(h)

Figure9: Interval-8

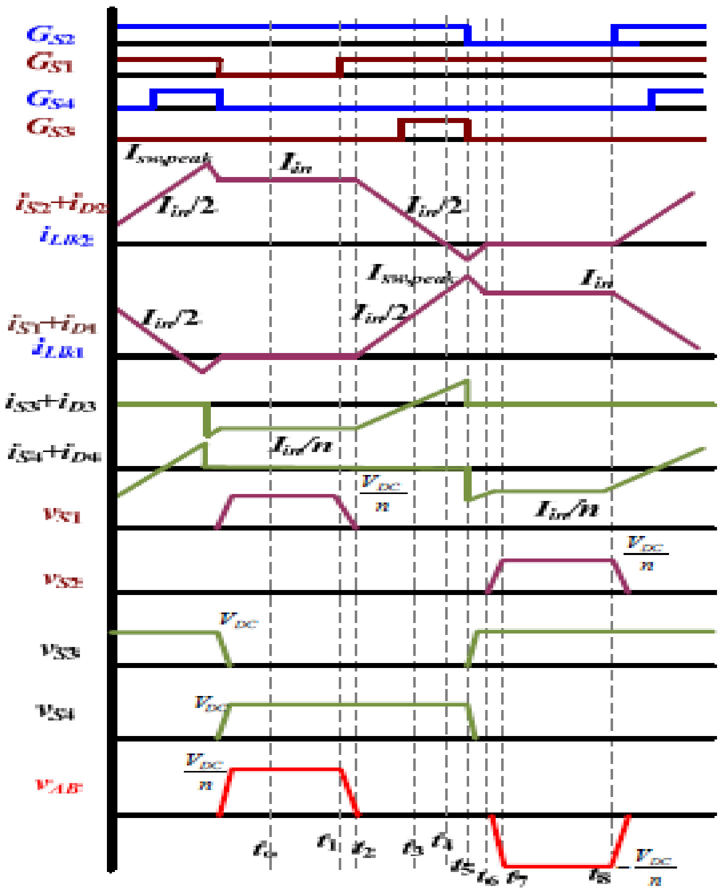


Figure10: Output Waveforms

The residential PV power system plays an increasing important role in solar renewable energy. However, PV modules have highly non-linear voltage-current characteristics and the maximum power point (MPP) varies dramatically with the ambient environmental factors such as solar irradiance and temperature.

For residential applications, the performance of PV inverter system is easily to be affected by partial shadows and mismatch of electrical parameters.

VI. SIMULATION RESULTS

Simulation Result For open loop:

A simulation design open loop system is implemented in MATLAB SIMULINK with the help of inductor, multi winding transformer, switches and diodes we get desired output voltage level which is shown
Output voltage V_o, at the inverter is as shown in Fig. 15. Fig. 15(b) gives the experimental result for peak is connected at the output of the inverter. Reduction in harmonics in output voltage (THD of less than 1%) due to LC filter is adequate to supply domestic loads.

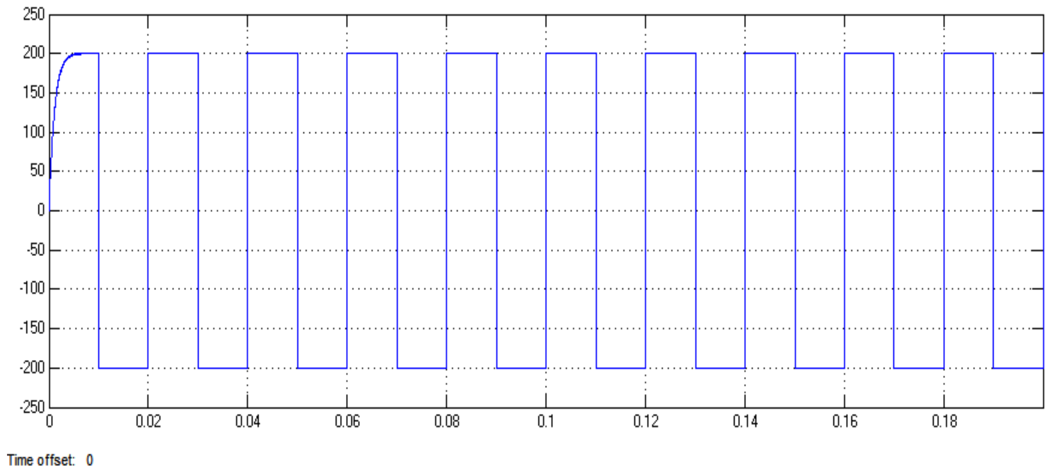


Figure11: Output Voltage 200V (AC)

Simulation Result For closed loop

A simulation design open loop system is implemented in MATLAB SIMULINK with the help of coupled inductor, multi winding transformer, switches and diodes we get desired output voltage level as shown in **Fig.4.6**

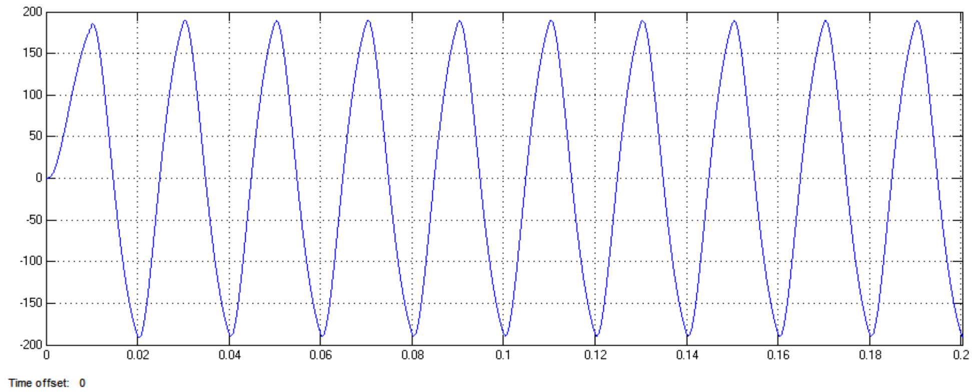


Figure12: Closed Loop Circuit Output

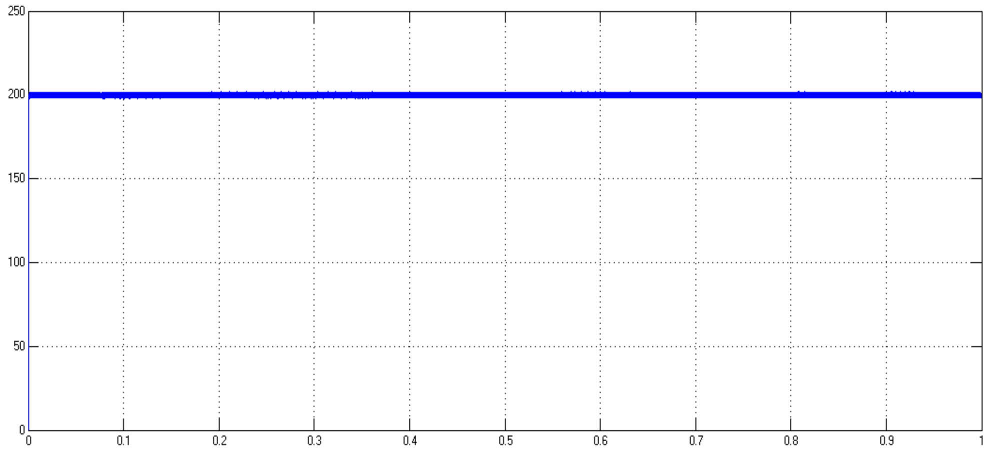


Figure13: Closed Loop Circuit DC Output

Here the Input given to the circuit is 40V Vrms and the output got is 200V AC Voltage

Plot of efficiency versus output power for different load conditions of proposed front-end converter with V_{in}= 22 V and V_{in} = 41 V.

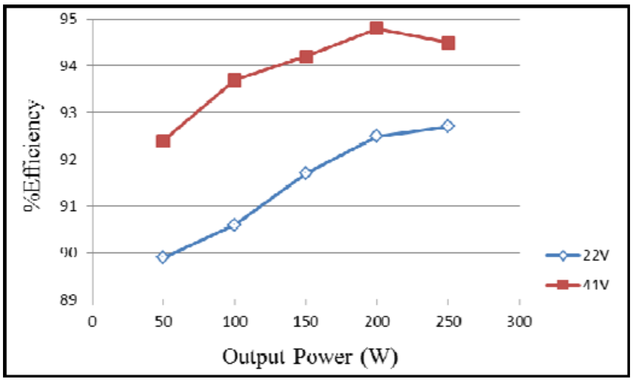


Figure14: Output Power Vs Efficiency Plot

Table below shows loss distribution estimation of the experimental front-end converter at full load condition with V_{in} = 22 V and V_{in} = 41 V.

Table-1: loss distribution estimation

Loss Type	Power Loss(W) at V_{in}= 22V	Power Loss(W) at V_{in}= 41V
Primary switches conduction loss	2.3	0.89
Primary switches switching loss	3.6	3.6
Secondary switches conduction loss	3.67	1.59
Secondary switches switching loss	0.05	0.05
Boost inductor loss	2.2	1.61
HF transformer loss	3.4	2.25
Series inductors loss	1.5	1.15
Others	3	3.3
Total loss	19.7	14.5

VII. CONCLUSION

Recent innovations have enhanced even further the attractiveness of using photovoltaic systems to satisfy energy needs. For example, instead of mounting PV modules on separate support structures, they may be mounted on buildings or integrated into the building structure. Building integrated PV systems do not require additional space and offset construction costs by replacing conventional building materials. Another innovation is to use the heat collected by PV modules for space heating or hot water heating. The PV modules then serve a dual function as photovoltaic modules and heat collectors in an active solar system. In this way, more of the sun's energy is converted to a usable form. As the technology improves and is applied in even more innovative ways, photovoltaic promise to cleanly provide a significant portion of the world's electricity. The cost of PV systems has steadily fallen and continues to do so. Their use will dramatically increase as they become more cost competitive with conventional forms of electrical generation. PV systems are already the best choice in hundreds of important applications.

In this paper, the use of PV system has been enhanced by the addition of high frequency transformer, push-pull front end converter and bi-directional inverter.

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