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An Efficient Light Load Operation with Faster Transient Response of Very High Frequency Resonant Boost Converter

Chitranshi Mishra[1]; Deeksha Singh[2]; Mrs. Sangeetha[3]&Snow Saraswat[4]
Student, Department of electrical and electronics engineering, SRM University, Ghaziabad, India
EMAIL: mishrachitranshi333@gmail.com
Student, Department of electrical and electronics engineering, SRM University, Ghaziabad, India
EMAIL: singhdeeksha3001@gmail.com
Assistant Professor, Department of electrical and electronics, SRM University, Ghaziabad, India
EMAIL: sangeetha.c@ncr.srmuniv.ac.in
Student, Department of electrical and electronics engineering, SRM University, Ghaziabad, India
EMAIL: snow.saraswat1103@gmail.com

ABSTRACT

With many versions of inverters available, a control of VHF resonant boost dc-dc converter is described in this paper. Though, a Class- Φ inverter is well documented in the literature, this is a new version and also coupled to resonant rectifier. The twin aspect of any design of resonant boost topology is to feature low device voltage stress and to have high efficiency over wide range of loads. Increased switching frequency allows smaller passive components of small size, allowing one to use air-core magnetic, and thereby reducing core loss. The output is regulated by the MPPT controller. The converter achieves higher than 87% efficiency at nominal input and output voltages, and maintains a good efficiency down to 5%of full load. Resonant gate drive schemes suitable for VHF operation that provides rapid start-up and low-loss operations. Both the converters regulate the output using higher bandwidth, ON–OFF hysteretic control, that enable fast transient response and efficient light-load operation. The performance analysis was carried out on the MATLAB/Simulink platform and performance characteristics are presented along with the values of components.

Keywords Class-E inverter; class-Φ inverter; harmonic peaking; resonant boost converter; resonant dc–dc converter; resonant rectifier; a MPPT controller; Zero-Voltage-Switching topology (ZVS).

INTRODUCTION

THERE is a persistent demand for power electronics that have reduced size, weight, and cost, as well as improved dynamic performance. Passive components typically dominate the size and the weight of a power converter. Increased switching frequency reduces the required energy storage and allows the use of smaller passive components. Furthermore, higher frequency can improve the transient performance and control bandwidth. A sufficiently high frequencies permit the use of air-core magnetics, making the way that is fully integrated power converters. Thus, many advantages can be realized by operating power converters at high increased switching frequencies if the loss, the efficiency, and the control challenges are known. This converter has several derived advantages then the other mainstream converters to name them,

- The main advantage is reduced weight, size and cost required in the present power electronics.

 Due to the resonant boost topology with Zero voltage switching the switching losses will be utterly reduced to enhance the efficiency.

 With the operation of the resonant rectifier at VHF in the range of KHz to MHz improves transient response.

 The operation at VHF requires very low energy storage requirements. With this framework the size of passive elements will be reduced. Especially in the case of inductance, air-core inductors can be used which removes the magnetic core loss.

 In case of hard switched converter the voltage stress on switch will be of the order of nearly 3.6 or more times the input voltage. With the very high frequency resonant boost topology and ZVS this may be reduced to nearly 2 times the input voltage.

 This high frequency converter along with ZVS and with MPPT controller method it is possible to achieve higher efficiency even at lower loads.

Resonant Boost DC-DC Converter are referred to as Soft Switched Converter. Soft switching techniques are Zero-Voltage-Switching , or Zero-Current-Switching , this soft switching is used to maintain high efficiency at high frequency. Resonant converters provide ZVS or ZCS by using resonant components such as inductors and capacitors to control the switch voltage and/or current during on-off transitions. In hard switching power converter, during turn-on and turn-off of the semiconductor switches, the currents and the voltages cannot change instantaneously. The output current-voltage overlap results in a power loss, that increase linearly with frequency. A conventional hard-switched design, has some disadvantages. One of the example is control of converter, which becomes more complex as frequency increases. So to regulate resonant converters frequency control is often used. This work introduces MPPT control circuit and algorithm to regulate the output of resonant boost dc-dc converter.

NEW RESONANT BOOST TOPOLOGY

Fig. 1 shows a schematic of the new resonant boost dc–dc converter topology. The design is thus optimized for low device voltage stress and VHF operation at a fixed frequency and duty ratio. This simply enables the use of resonant gating and zero-voltage switching for high efficiency. The output is regulated using ON–OFF control of the converter.

The converter is special version of the Class-Φ inverter, coupled with a resonant rectifier, as illustrated in Fig. 1.we treat the design of each of the inverter and the rectifier, and then work on their interconnection.

The Class-Φ inverter works using a shorted, quarter-wave transmission line at the input to give the drain voltage waveform. This leads to reduction in the peak voltage stress as compared to other resonant topologies, like Class-E converter, and simply eliminates the need for a “choke” or “bulk” inductor that slows the transient response at time of ON–OFF control.

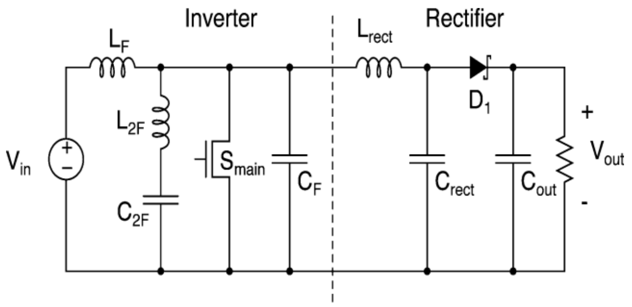

Fig 1. Very High Frequency Resonant Boost Dc-Dc converter.

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A. Inverter

The multiresonant network including LF , L2F , CF , andC2F is a low-order network designed to approximately the symmetrising properties of quarter-wave transmission line. This network is set to achieve zero voltage switching while continuously maintaining low device voltage stress. the drain to source voltage is shaped to approximate a trapezoidal waveform. This leads to reduction in peak voltage stress across the switch Smain to two times the input voltage in comparison to other single-switch inverters like class-E inverter that has a peak voltage stress of approx. 3.6 times the input voltage. To achieve this, the components LF , L2F , CF , and C2F are chosen as per the following manner. L2F and C2F are tuned to resonate near to the second harmonic of the switching frequency fs to attain a low drain to source impedance at the second harmonic. In addition, the elements LF and CF are tuned in combination with L2F and C2F and the load impedance to achieve a high drain to source impedanceclose to the fundamental and third harmonic of fs . The relative impedance in between the fundamental and third harmonic can be modified to shape the drain to source voltage to approx a square wave, an appopriate means to limit the peak switch voltage stress to two times the input voltage. A complete discussion of the tuning method for these components is found in. It is worth repeating here that LF , L2F , and C2F are all resonant components, and can be selected relative to the component CF in a manner that allows the parasitic output capacitance of the switch to be completely absorbed by the multiresonant network. CF can include only the parasitic switch capacitance, or if so required, can be augmented with an additional discrete capacitor in parallel with the switch.

B. Rectifier

The inverter coupled to a resonant rectifier, is shown in Fig. 2, albeit with many operating characteristics owing to our use of ON–OFF control that controls the output. The substitution of the properly tuned rectifier for the inverter load resistance can be accomplished with very less effect on the inverter. The pairing is done in a way that allows dc power flow from input to output. As the fraction of the total power which is transferred at dc is subject to much lower loss in the switch or resonant components than the ac portion, higher efficiency can be achieved as compared to a design that delivers all the power through ac coupling. The resonant elements Lrect and Crect of Fig. 1 are chosen so that the rectifier delivers the required power at the specified output voltage. In the rectifier topology presented, the parasitic capacitance of diode is absorbed by Crect . The discrete capacitor Crect can, therefore, be reduced, and in some cases, completely eliminated, when all of the desired capacitance is provided by the diode. This can be beneficial in avoiding ringing between Crect and parasitic inductance of the diode element.

However, when precise selection of the diode's die area is

possible during design, reducing loss may become an overriding concern. Optimal diode size depends upon the distribution of loss between the diode forward drop and the circulating current in the lossy diode capacitance. Assuming the total capacitance across the diode to be kept constant, increasing diode area decreases conduction loss, but causing an increase in the reverse current conducted from the diode capacitance. Since Crect will be almost loss less in comparison, scaling the diode area evinces a die size yielding a minimum loss.

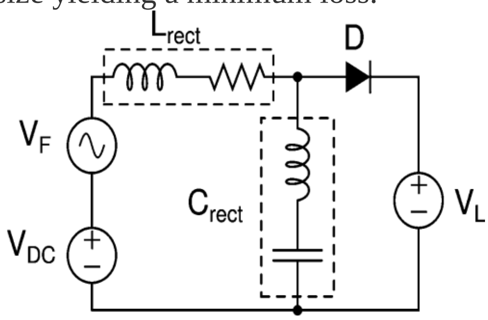

Fig. 2. Schematic of rectifier is implemented in the Matlab for designing purpose.

Rectifier design proceeds by creating a model for a simulation program such as MATLAB. A suitable model is detailed in Fig. 2. At the rectifier input, two source model the voltage produced by the inverter, i.e., which is across the drain–source terminal of the switch. Assuming

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that nearly all the power is delivered at the fundamental and dc, this voltage could be modelled by a sinusoidal source and a dc offset equal to VIN . These sources are designated as VF and VDC, respectively.

C. Converter Realization

In order to design the inverter, the ac and dc portions of the total power delivered to the rectifier is treated independently. The inverter has to deliver the desired ac power into an equivalent resistance. This resistance is calculated from the fundamental voltage and current at the rectifier input port. Once the inverter design is achieved, connecting the inverter to the rectifier gives a total power that is close to the designed power Operation:
Resonant boost dc-dc converter works at VHF with ZVS to attain high efficiency. When the switch Smain is turned-on at the Zero-voltage, the inductors LF and L2f stores energy, this stored energy is delivered to the load from the resonant rectifier with in the nano-seconds due to high switching frequency, when the switch Smain is turned-off. The electronic elements Lrect, and Crect produces certain oscillation to the rectifier to deliver a proper output power to load. The out capacitor Cout is designed according to the load removing the output ripples.

CONTROL STRATEGY

A very high frequency resonant boost converter is controlled by MPPT (Maximum Power Point Tracking) algorithm. MPPT is an efficient controller compared to hard switched converter controller that is PWM method of controlling the output.

MPPT Controller

MPPT controller operates with a continuous reference voltage. Reference voltage is set according to the input voltage. Mainly an MPPT is used in PV applications because the MPPT of a solar panel varies with the irradiation and the temperature, so the use of MPPT algorithms are required in order to obtain the maximum power through a solar array. In this work an incremental conductance MPPT algorithm is used. This algorithmic based on fact that the slope of the curve power vs. voltage or current of the PV module is Zero at the MPP, positive(negative) on the left of it and negative(positive) on the right. By comparing the increment of the power vs. the increment of the voltage or current between the two consecutives samples, the change in the MPP voltage can be determined. A scheme of the algorithm is described in FIG. 3

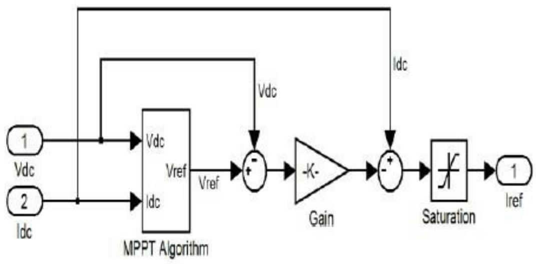

Fig. 3 MPPT CONTROLLER

SIMULATOR

We are using MATLAB SIMULINK platform along with the values of components.

EXPERIMENTAL RESULTS

This portion presents the design and experimental evaluation of two converters of the type proposed here. The first operates at open loop and uses a high-performance RF LDMOSFET, while the second operates at closed loop using an LDMOSFET at very high frequency.

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TABLE 1
Closed Loop Inverter Components Values

S.No.	COMPONENTS	PARAMETERS
1	Vin	500V
2	L_f	0.001H
3	L_{2f}	0.001H
4	C_f	10^{-6}F
5	C_{2f}	10^{-6}F
6	V_{out}	500.45V

SIMULATION RESULTS OF CLOSED LOOP INVERTER

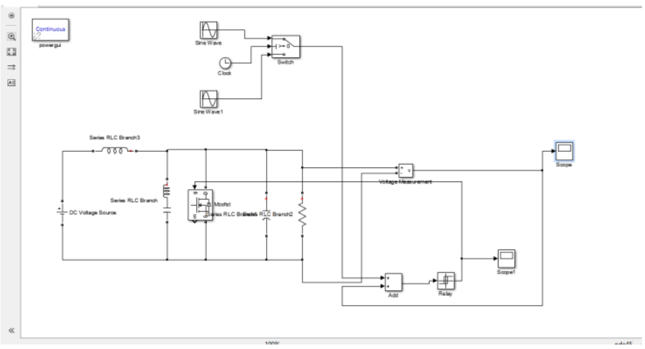

Fig.8

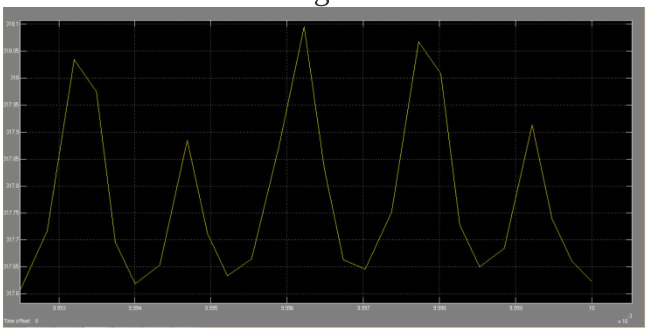

Fig.8.a OUTPUT VOLTAGE

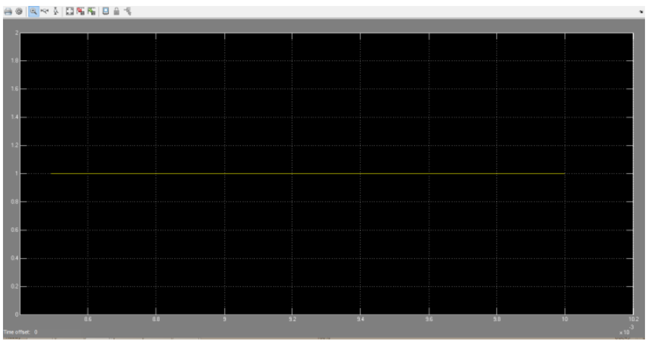

Fig.8.b RELAY

TABLE 2
Closed Loop Rectifier Components Values

AC	V (Peak Amplitude)	500 V
	Frequency	60 Hz
	V_{out}	500 V
	I_{out}	500 Amps
DC	V_{in}	500 V
RL BRANCH	R	1 Ohms
	L	10^{-3} H
LC BRANCH	L	10^{-3} H
	C	10^{-6} F
DIODE	R_{on}	10^{-3} Ohms
	V_f	0.8 V
	R_s	500 Ohms
	C_s	$250X10^{-9}$ F
	R	1 Ohms

SIMULATION RESULTS OF CLOSED LOOP RECTIFIER

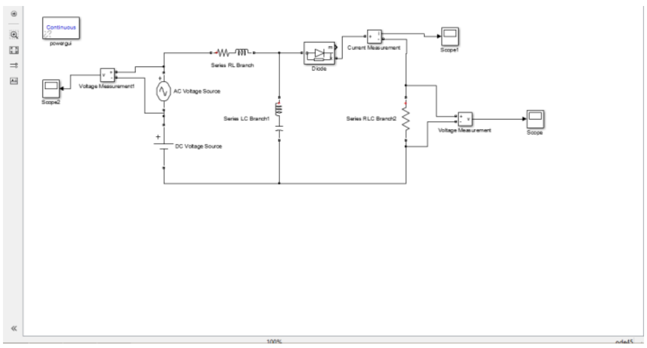

Fig. 9

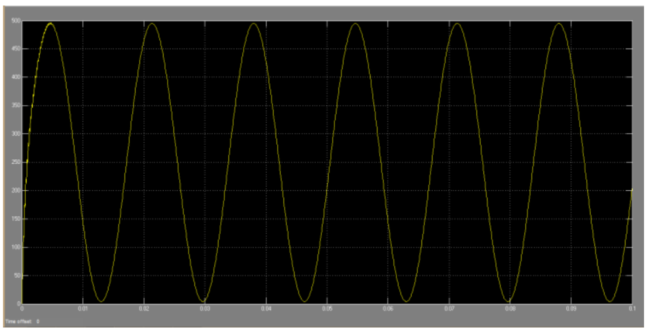

Fig.9.a CURRENT

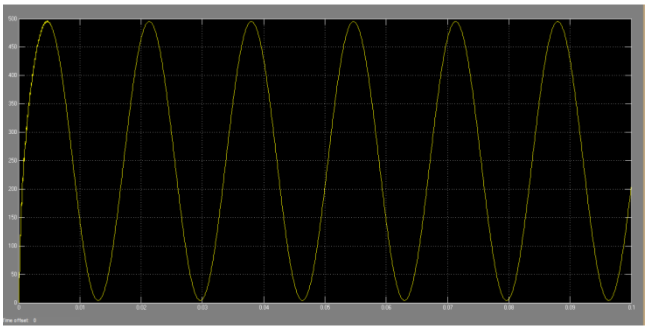

Fig.9.b VOLTAGE

TABLE 3
OPEN LOOP CIRCUIT PARAMETERS

S.No.	COMPONENTS	PARAMETERS
1	L_F	0.001 H
2	L_{2F}	0.001 H
3	C_F	10^{-6} F
4	C_{2F}	10^{-6} F
5	L_{RECT}	0.001 H
6	C_{RECT}	10^{-8} F
7	V_{IN}	500 V
8	V_{OUT}	500.45 V

TABLE 3.A

MOSFET	R_{ON}	0.1 Ohms
	R_D	0.001 Ohms
	R_S	10^{-5} ohms
DIODE	R_{ON}	0.001 Ohms
	V_F	0.8 V
	R_S	500 Ohms
	C_S	$250X10^{-9}$ F

SIMULATION RESULTS OF OPEN LOOP RESONANT BOOST CONVERTER

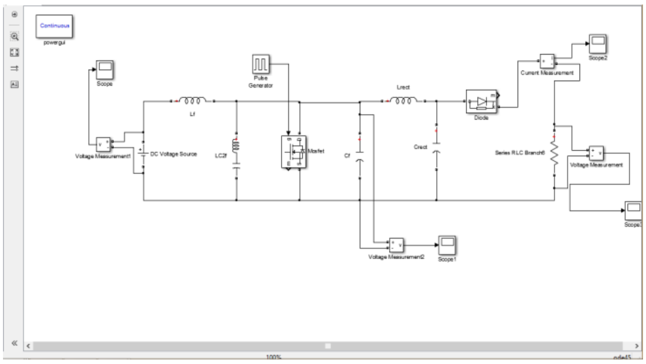

Fig.10

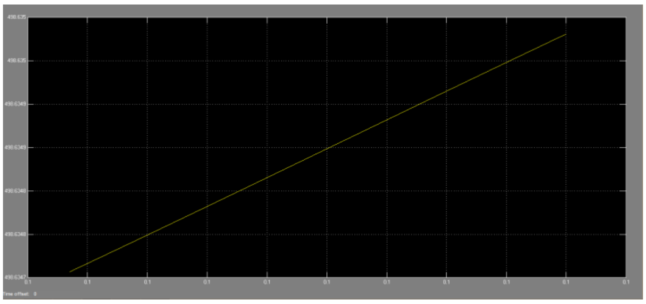

Fig.10.a CURRENT

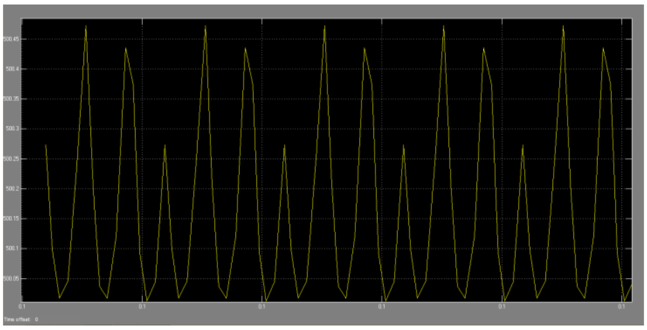

Fig.10.b INVERTER VOLTAGE

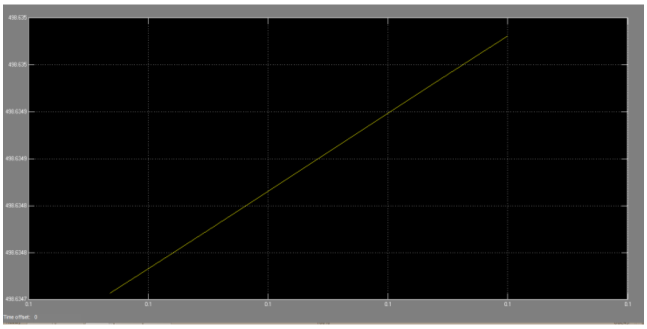

Fig.10.c OUTPUT VOLTAGE

TABLE 4
PARAMETERS OF SUNPOWER SPR-305-WHT PV ARRAY

S.NO.	COMPONENTS	PARAMETERS
Number of cells per module= 96		
1	N_S	5
2	N_P	66
3	V_{OC}(ARRAY)	64.2 V
4	I_{SC}	5.96 Amps
5	V_{MP}	54.7 V
6	I_{MP}	5.58 Amps
7	V_{OC}(CELL)	0.66875 V
8	Q_D	1.3
9	R_P	993.51 Ohms
10	R_S	0.037998 Ohms
11	I_{SAT}	$1.1753e^{-8}$ Amps

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SIMULATION OF PV ARRAY

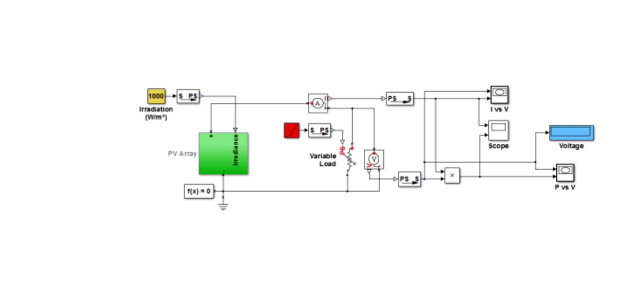

Fig. 11

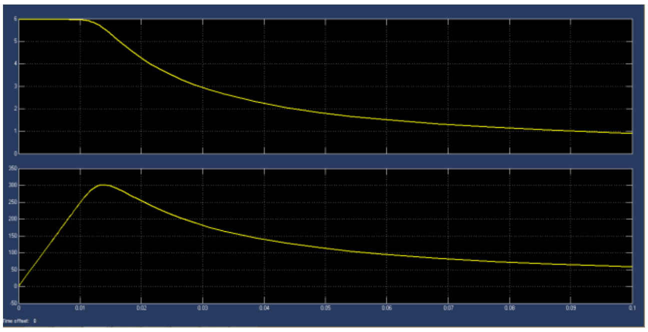

Fig. 11.a CURRENT AND VOLTAGE

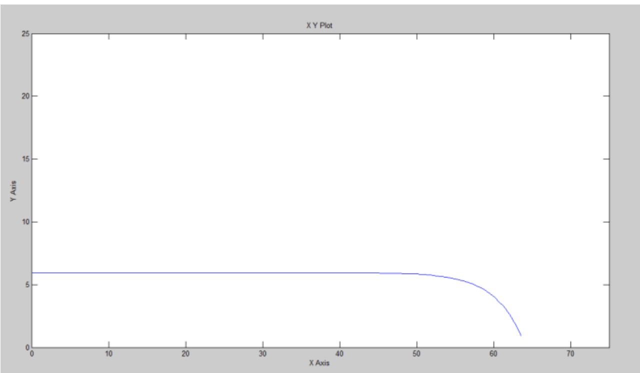

Fig. 11.b I vs. V

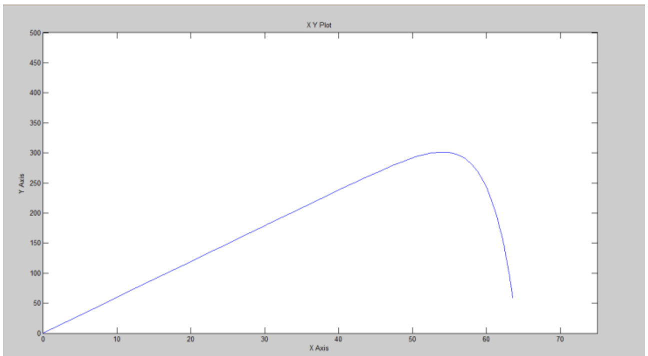

Fig. 11.c P vs. V

SIMULATION RESULTS OF MPPT

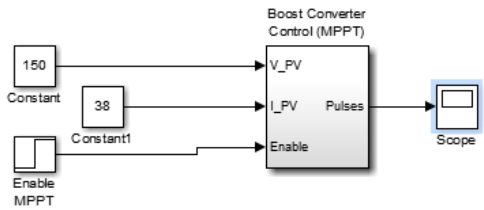

Fig 12

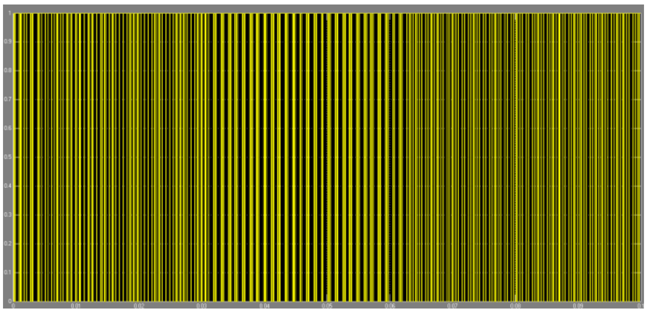

Fig. 12.a MPPT

SIMULATION OF CLOSED LOOP RESONANT CONVERTER

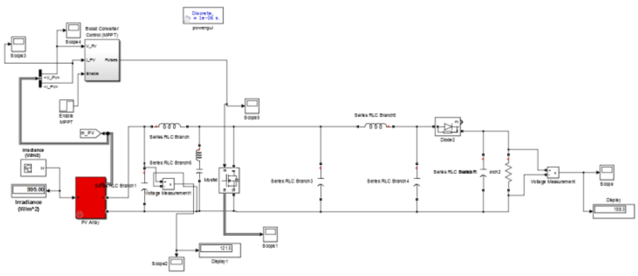

Fig. 12

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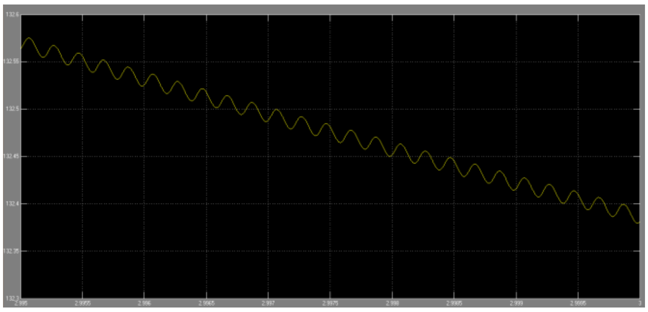

Fig. 12.a OUTPUT VOLTAGE OF PV ARRAY

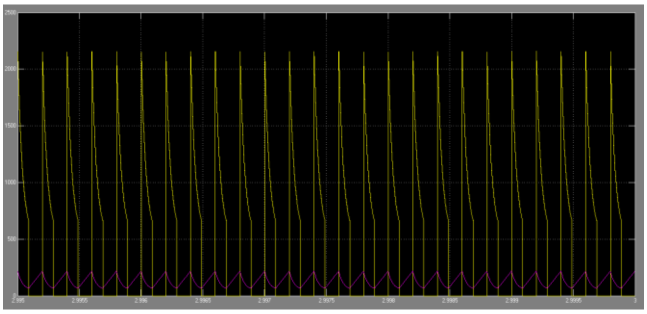

Fig. 12.b OUTPUT VOLTAGE ACROSS MOSFET

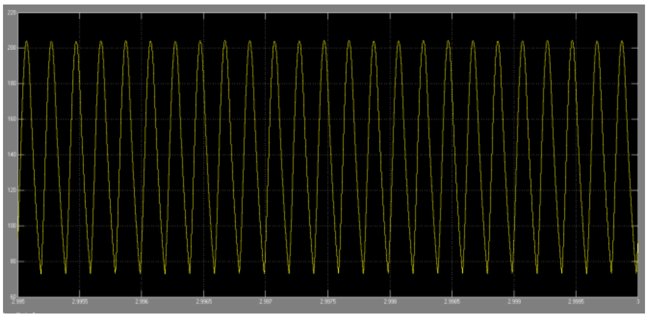

Fig. 12.c OUTPUT VOLTAGE AFTER BOOSTING

CONCLUSION

This project explains the operation of resonant boost dc-dc converter. This converter operates at a very high frequency, which simply overcomes the shortcoming of various designs. This project also introduces MPPT algorithm for the converter control. The converter can also reaches at high efficiency using Zero-Voltage-Switching and proper MPPT controller. Converter operating at higher frequency gives automatically fast response. For emerging technologies, reduce size, cost and weight of the converter should be present, which is also demanded in modern power electronics applications.

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V_{in}=500V	V=500V			
	F=60Hz			
	V_{out}=500V			
	I_{out}			