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Resonant Boost Dc-Dc Converter for a High Frequency Operation

Tejaswini. R

***Abstract*— With different versions of inverters available, a control of VHF resonant boost dc-dc converter is described in detailed in this paper. Though, a classical Class- Φ inverter is well documented in the literature, this is a new version and coupled to resonant rectifier. The twin aspect of any design of resonant boost topology is to mainly feature low device voltage stress and to have high efficiency over wide range of loads. Increased switching frequency allows smaller size of the passive components, allowing one to use air-core magnetic, and thereby reducing core loss. The output is regulated by MPPT controller. The performance analysis was carried out on MATLAB/Simulink platform and performance characteristics are presented along with the values of components.**

***Index Terms*— Class- Φ inverter, resonant rectifier, MPPT controller, Zero-Voltage-Switching (ZVS).**

I. INTRODUCTION

In recent years, with the fast emerging technological innovations, there is an increasing demand for reduced size, weight and cost. In this present work resonant boost dc-dc converter is operated at very high frequency in the range of MHz and controlled by MPPT Controller. This converter has several derived advantages then the other conventional converters to name them,

- The main advantage is reduced weight, size and cost which is required in the present day power electronics.
- Due to resonant boost topology combined with Zero voltage switching the switching losses will be drastically reduced to enhance the efficiency.
- With the operation of the resonant rectifier at VHF in the range of KHz to MHz improves the transient response.
- The operation at VHF demands very low energy storage requirements. With this background the size of passive elements like inductors and capacitors will be reduced. Especially in the case of inductance, air-core inductors can be used which eliminates the magnetic core loss.
- In case of hard switched converter the voltage stress [2,3] on switch will be of the order of 3.6 or more times the input voltage. With the very high frequency resonant boost topology and ZVS this may be brought down to nearly 2 times the input voltage.
- This high frequency converter along with ZVS and with efficient MPPT controller method it is possible to achieve higher efficiency even at lower loads. [it has been reported in [1,4,5] that with this type of topology along with better controlling circuits, the efficiency of the order 87% at full load and 82% at 5% of the full load can be achieved].

Resonant Boost DC-DC Converter are referred as Soft Switched Converter. Soft switching techniques are Zero-Voltage-Switching (ZVS), or Zero-Current-Switching (ZCS), this soft switching is incorporated in [2,6] is used to maintain high efficiency at high frequency. Resonant converters provide ZVS or ZCS by using resonant elements such as inductors and capacitors to control the switch voltage and/or current during on-off transitions. In hard switched power converter, during turn-on and turn-off of the semiconductor switches, the currents and voltages cannot change instantaneously. The resulting current-voltage overlap results in a power loss, which increases linearly with frequency. The conventional hard-switched designs, has some disadvantages. One of the example is control of converter, which becomes more difficult as frequency increases. So to regulate resonant converters frequency control is often used. This present work introduces a MPPT control circuit and algorithm to regulate the output of resonant boost dc-dc converter.

The following section includes operation of the resonant boost dc-dc converter which operates at very high frequency. The section 3 shows the control circuit. The MATLAB/SIMULINK results are discussed in last section.

II. RESONANT BOOST DC-DC CONVERTER TOPOLOGY AND ITS OPERATION

Schematic arrangement of the resonant boost dc-dc topology is shown in fig1, which operates at very high frequency. It is basically a interconnection of Class- Φ inverter described in [7, 8] and resonant rectifier in [9,10]. The Class- Φ inverter is a multi-resonant network comprises L_F, L_{2F}, C_F, and C_{2F}. This low ordered network is designed to approximate the symmetrising properties of a quarter-wave transmission line [7,8]. To reduce peak voltage stress across the switch the component L_F, L_{2F}, C_F and C_{2F} are configured as per the criteria given in [7, 8, 9]. The tuning methodology of this component is found in [9]. The resonant rectifier coupled to the inverter shown in fig1 is discussed and analysed in [10]. The design of resonant rectifier can be explained by creating spice model detailed in [1]. The converter uses air-core inductors required for the low energy storage, which eliminates magnetic core loss and introduces the possibility of easy integration. This design is used for low device voltage stress and VHF operation for a fixed frequency and duty ratio. Ac-Dc power conversion is controlled by switching frequency.

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Tejaswini R, M.Tech Research Scholar, Department of Electrical and Electronics, Dayananda Sagar College of Engineering, Bangalore, India.

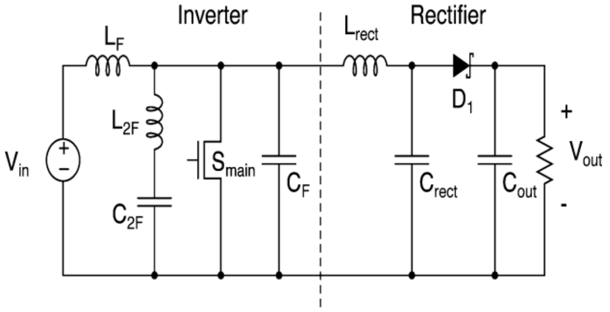

Fig 1. Very High Frequency Resonant Boost Dc-Dc converter.

Operation:

Resonant boost dc-dc converter operates at VHF with ZVS to achieve high efficiency. When the switch S_{main} is turned-on at Zero-voltage, the inductors L_F and L_{2f} stores energy, this stored energy is delivered to the load through resonant rectifier with in a nano-seconds due to high switching frequency, when the switch S_{main} is turned-off. The elements $L_{rect,}$ and C_{rect} produces certain oscillation to the rectifier to deliver a desired output power to the load. The out capacitor C_{out} is designed depending on the load that eliminates the output ripples.

III. CONTROL STRATEGY

A very high frequency resonant boost dc-dc converter is controlled by MPPT (Maximum Power Point Tracking) algorithm. MPPT is a efficient controller compared to hard switched converter controller that is PWM method of controlling the output. In this present work the output voltage of a converter is efficiently regulated by MPPT controller shown in fig 2.

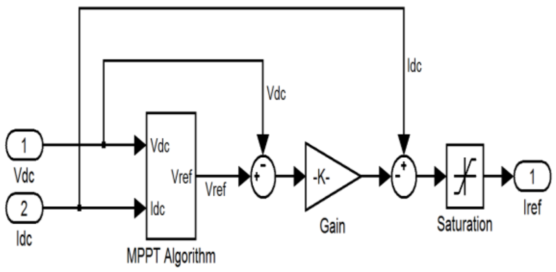

Fig 2. MPPT Controller

Mppt controller operates with a contineous reference voltage. Reference voltage is set according to the input voltage. Mainly MPPT is used in PV applications because the MPP of a solar panel varies with the irradiation and temperature, so the use of MPPT algorithms is requried in order to obtain the maximum power from a solar array. In this work the incremental conductance MPPT algorithm is used. This algorithmis 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 algorihm is described in [11].

IV. OPEN LOOP AND CLOSED LOOP SIMULATION

This section presents open loop and closed loop results of a VHF resonant boost dc-dc converter. MATLAB-SIMULINK platform is carried out for performance analysis. Fig 3 shows open loop circuit of VHF resonant boost dc-dc converter. The nominal input voltage applied is 14.4V, the resulted boost voltage is 25V. Fig 4 shows the input voltage, output voltage, output current, and inverter output voltage respectively. The converter operates at 110MHz with duty cycle 50%.

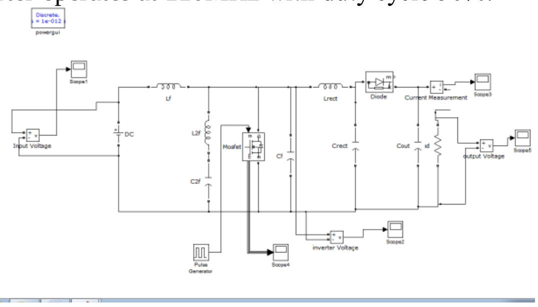

Fig 3. Open loop circuit.

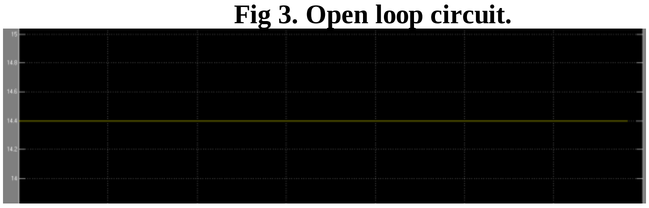

Fig 4.a. Input voltage.

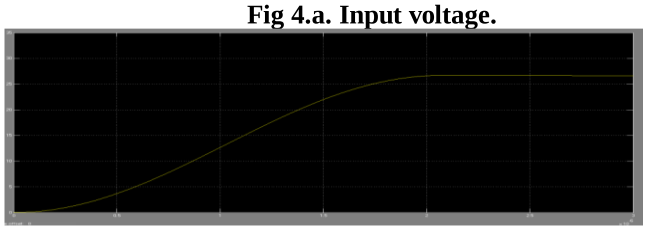

Fig 4.b. Output voltage.

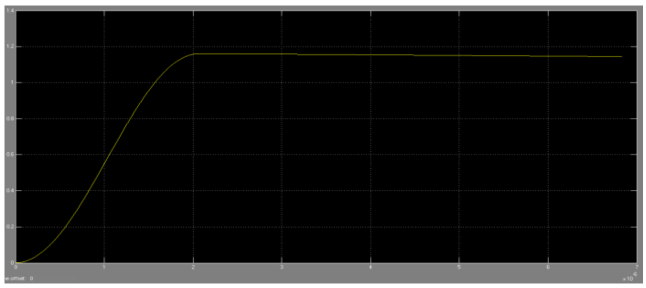

Fig 4.c. Output current.

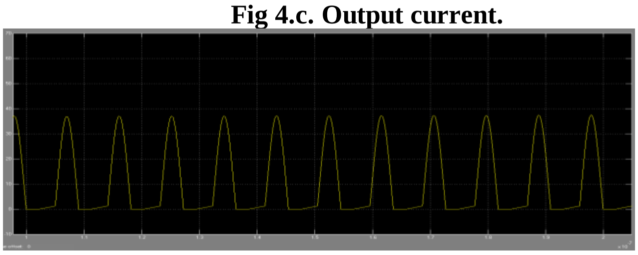

Fig 4.d. Inverter output voltage.

Closed loop circuit and results.

As discussed in section 2. Resonant boost dc-dc converter is basically interconnection of Class- Φ inverter and resonant rectifier. Resonant rectifier acts as resistive load for the Class- Φ inverter. ON-OFF control or burst mode control detailed in [1] is used for the control of the converter. This on-off control regulates the output only for the ladder load network or impedance load network. To overcome this, the MPPT control algorithm is used for the control of the converter. MPPT control algorithm gives better results than the on-off control. Fig 5

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shows the Class- Φ inverter closed loop circuit and fig 5.a, 5.b shows the step response of the output regulated voltage changed from 6V to 8V and the gate pulses of the Class- Φ inverter.

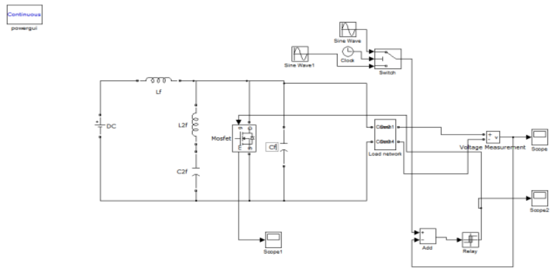

Fig 5. Closed loop Class- Φ inverter cicuit.

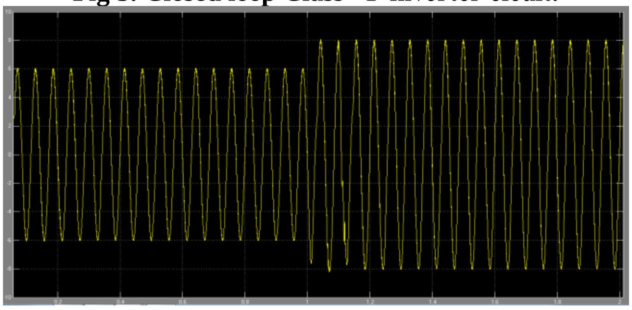

Fig 5.a. step response output regulated voltage changed from 6V to 8V.

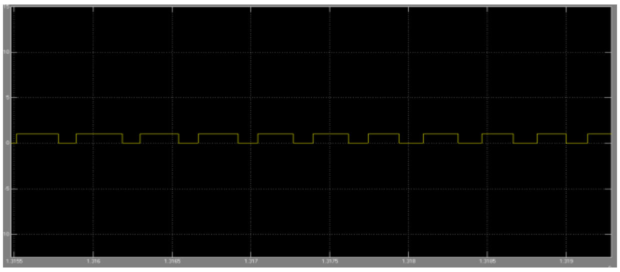

Fig 5.b. Gate pulses to the MOSFET.

As per the Incremental Conductance method, PV voltage and current is given to a sampler and subtracted. So we get change in I and change in V is calculated. By dividing the two we get DI/DV and I/V so the DI/DV is added with the I/V i.e. error is added with the main voltage. So the error will not reflect in the output. According to that, error pulses can be generated and converter will try to maintain the power. Fig 6 shows the closed loop circuit and fig 7 shows the results.

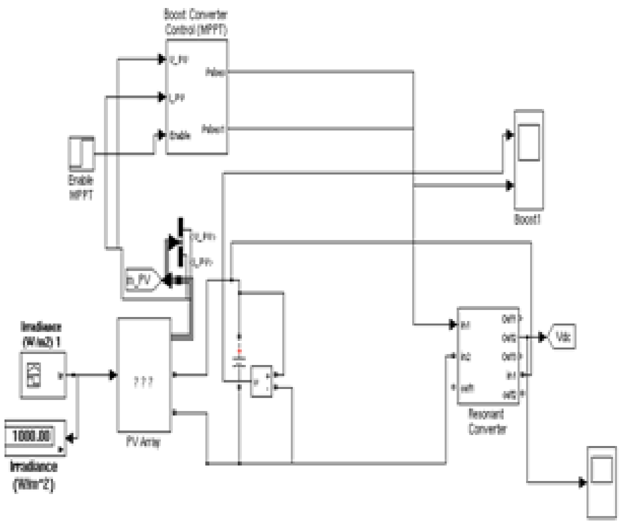

Fig 6. Closed loop circuit.

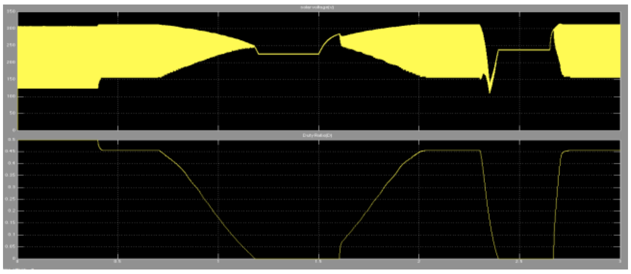

Fig7. Accordance to the change in input voltage we can see the change in duty cycle.

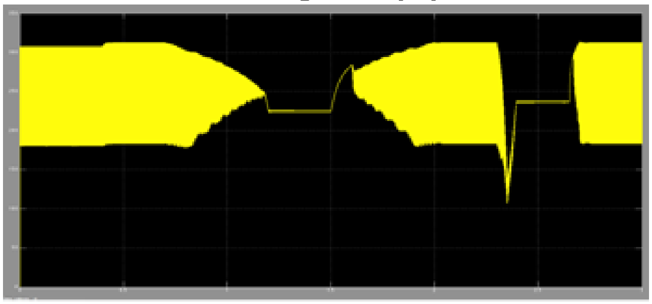

Fig 7.a. The output voltage we can be seen greater than the input voltage.

V. CONCLUSION

This work explains the operation of VHF resonant boost dc-dc converter. This converter operates at a high frequency, which overcomes the shortcoming of various designs. This work also introduces MPPT improved algorithm for the control of converter. The converter can also achieves higher efficiency using Zero-Voltage-Switching and efficient MPPT controller. Converter operating at higher frequency gives an inherently fast response. For emerging technologies, reduce size, cost and weight of the converter is required, which is also demanded in modern power electronics applications.

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AUTHOR PROFILE

Tejaswini R has received B.E degree in 2011 from VTU, Belgaum, Karnataka, India. Currently she is pursuing M.Tech in VTU. Her areas of interest include application of power electronics.