Efficient Utilization of Solar Power in High Frequency Applications

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***Abstract*: The world wide electrical energy consumption is progressively escalating and the installed conventional high power station cannot accomplish the demand. Now a days nonconventional energy sources are taking a vital role for the power generation. In this paper modelling of solar PV panel for high frequency application is introduced with the help of boost chopper and high frequency hybrid resonant inverter. A series and parallel combined circuit forms hybrid inverter and it is used to maximize the utilization efficiency by reducing switching losses.**

***Keywords*: Solar energy, boost chopper, resonant inverter, hybrid inverter, ZCS**

I. INTRODUCTION

In this present era, it is a great deal for the researchers to meet the huge power demand. Conventional energy sources being limited in nature and gradually their amount is decreasing, since researchers are more concerned to find ways of efficiently utilizing the non conventional resources. Solar energy is very important and most sustainable choice for power generation among the renewable energy families. The main drawback of solar energy is its low efficiency. So efficiently use of solar power can increase its effectiveness. On the other hand, use of energy saving appliances in domestic as well as industry is quite helpful for conservation of energy. As an example, in electrical heating process high frequency electrical heating is more energy efficient as compared to other power frequency electrical heating for domestic cooking purpose. High rate of heat generation, immediate response, more uniform heat distribution, precise temperature control, full automation, good compactness and high reliability are major features of high frequency electrical heating. Induction cooker is one of the energy efficient cooking devices that can be used as domestic and industrial purpose [1]. The photovoltaic cells are basically a p-n junction diode. The incident sunlight is absorbed within the semiconductor and the photon energy excites free electrons from a low energy label to high energy label. So when solar energy incident at PV cell, excess electron hole pairs are generated throughout the semiconductor and p-n junction shorted electrically and current flows. The rate of generation of electric current depends on the irradiance of incident light and the absorption capacity of the semiconductor. The capacity of absorption depends mainly on the semiconductor band-gap energy, reflectance from surface, temperature, etc. In the solar PV system batteries are essential and used as energy buffer. The buffer is necessary due to non availability of sun due to various factors like weather, partial shedding, night time etc. A DC/DC converter is used to interconnect the voltage from solar pv array with the battery voltage. It is also operated as maximum power point tracker (MPPT) by frequently adjusting the operating voltage of the solar panel to its maximum power with the help of a controller. Different kinds of DC/DC converter can be used such as buck, boost, buck-boost, cuk converter etc. The duty cycle of the conventional boost converter increases with increase of voltage gain. It becomes a problem to maintain high efficiency due to high duty cycle. In this regard, suitable choice of duty cycle is essential to get higher efficiency. In this paper, to attain maximum efficiency the duty cycle is iteratively selected by the authors. DC load is directly connected with boost chopper or it can be connected through battery. To drive AC load a DC to AC inverter is used between DC-DC converter and AC load. Different inverter topologies are provided in reference [2-5]. Here, hybrid inverter is used in high frequency applications and for achieving maximum benefit it is operated at resonant frequency. In this paper, hybrid resonant inverter is modelled and simulated in MATLAB/SIMULINK.

II. MODELING OF SOLAR PV SYSTEM FOR HIGH FREQUENCY APPLICATIONS

A general block diagram of solar power system is shown in Fig. 1. In the present scheme a DC-DC boost converter and a high frequency hybrid resonant inverter is used for high frequency applications like high frequency induction heating.

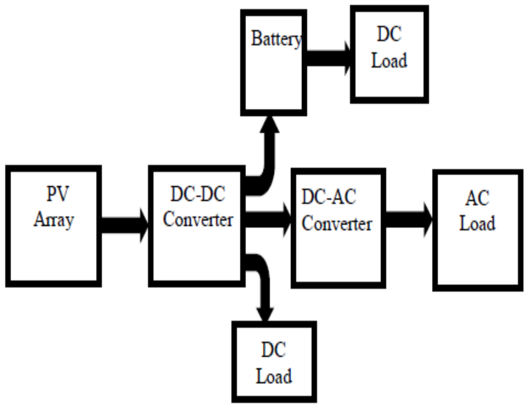

Fig 1: Block diagram of solar power system

The resonant inverter comprises resonant circuit and it provides maximum power to the load at resonant frequency. Resonant inverters are favoured in low power high frequency induction heating appliances like induction Cooker. Resonant inverters are of two types i.e. series and parallel. Series resonant inverters reduce switching losses
for the power-devices and have attractive potential for high frequency operations. Furthermore, it possesses higher effectiveness, lightweight and straightforwardness in terms of inverter control, protection and maintainability. In most of the inverter applications the control of output voltage and harmonic reduction are equally important.
A hybrid resonant inverter [6] is shown in Fig.2. The inverter consists of four semiconductor switches preferably IGBT as IGBT has its inherent advantages [2]. The switching frequency of present scheme lies in several kHz range. The hybrid inverter is a combination of both series and parallel resonant circuits where the switching is made at zero current (ZCS). The load can be of series type or parallel type. The main advantage of series circuit is that both zero current (ZCS) and zero voltage switching (ZVS) are possible [1]. However, as the full resonant current flows through the switches it causes conduction losses. On the other hand, it operates at comparatively low voltage so, a
DC/DC converter must be used. In case of parallel load, on-load conduction losses are lower, but turn-on and turn–off losses would be more as the switching takes place at high voltage or current. Therefore, by using both series and parallel combined circuit hybrid inverter can be used to reduce the switching losses. The operation of this type of inverter is based on the interaction between two resonant circuits where the energy is transferred from the series resonant circuit to the parallel resonant circuit.

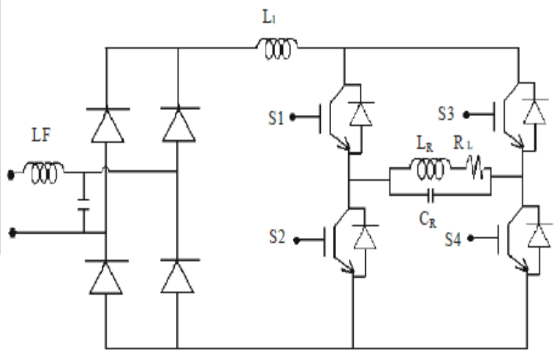

Fig 2: Hybrid resonant inverter

In the hybrid inverter, two pairs of switches S1, S4 and S2, S3 act step by step (refer to Fig.2). While turn on one of the transistor pairs, a resonant current starts flowing through L1 to CR and in off condition the series resonant circuit is disconnected and the current flowing in the parallel resonant circuit and the energy which already transferred to CR is now dissipated as heat in RL. RL is mainly an equivalent resistance for the magnetic loss in the induction heating system and it also represents the ohmic resistance of the parallel resonant circuit component.

III RESULTS AND DISCUSSION

The DC power generated from solar pv panel is fed to DC/DC boost type chopper for step up the voltage. By controlling the duty cycle maximum efficiency is achieved. The input parameters of boost chopper are shown in TABLE I. The DC/DC boost chopper is simulated in MATLAB/SIMULINK. The schematic simulation diagram is shown in Fig. 3. The simulation results of output voltage and power from boost chopper are shown in Fig. 4 and Fig.5 respectively.

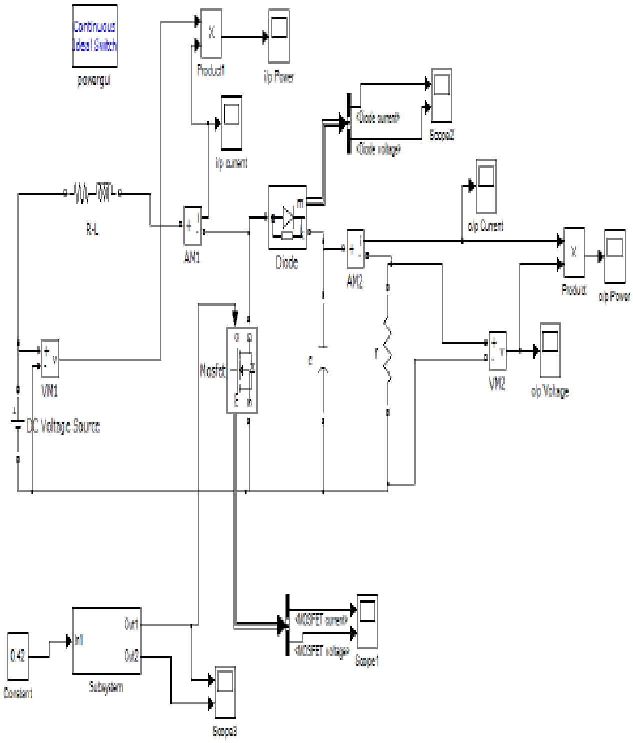

Fig 3:Schematic diagram of DC/DC boost chopper

TABLE I. INPUT PARAMETERS OF BOOST CHOPPER

R	10 ohm	V	20V
L	120µH	C	330µF
D	0.44	P_{out}	50 watt

Efficiencies at different duty cycle is calculated from simulation and shown in TABLE II. It is observed from TABLE II that by changing duty cycle of boost converter, the efficiency can be changed. The duty cycle (D) is PV Array DC-DC Converter DC-AC Converter AC Load DC Load Battery DC Load iteratively selected by small steps and it is shown that at D = 0.44 the chopper has maximum efficiency of 92.86%.

TABLE I I. DUTY CYCLE VS EFFICIENCY OF BOOST CONVERTER

DUTY CYCLE	EFFICIENCY
0.20	65%
0.25	70%
0.28	78.5%
0.32	78.87%
0.35	79%
0.42	80%
0.44	92.86%
0.45	89.29%
0.46	86%
0.48	74%

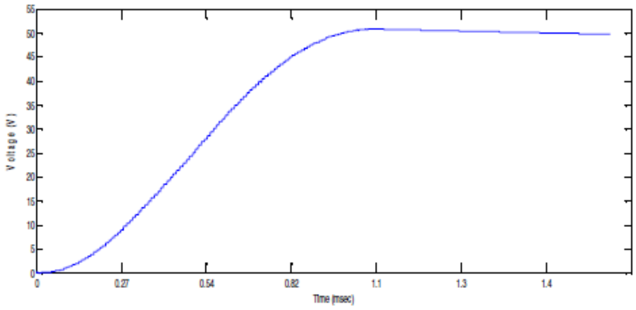

Fig 4: Output voltage of boost converter

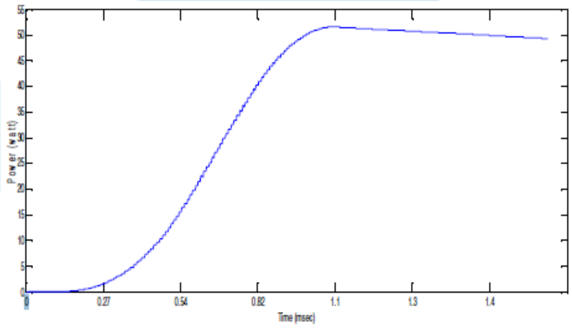

Fig. 5. Output power of boost converter

The out put power from boost chopper can be stored in a battery for future use or it can be directly used for DC load. Fig. 6 shows the MATLAB/SIMULINK simulation model of high frequency hybrid inverter which is used to convert the DC power into AC to drive high frequency AC load. Here, high frequency induction heating application is used as load. The value of equivalent load resistance (Req) and inductance (Leq) of heating coil is taken as 0.69 ohm and 119 uH respectively [7]. The input voltage of hybrid inverter is taken as 20V, source inductance (L1) is 100uH and capacitor C1 is taken as 0.2uF. The ON time of IGBT is 42%.

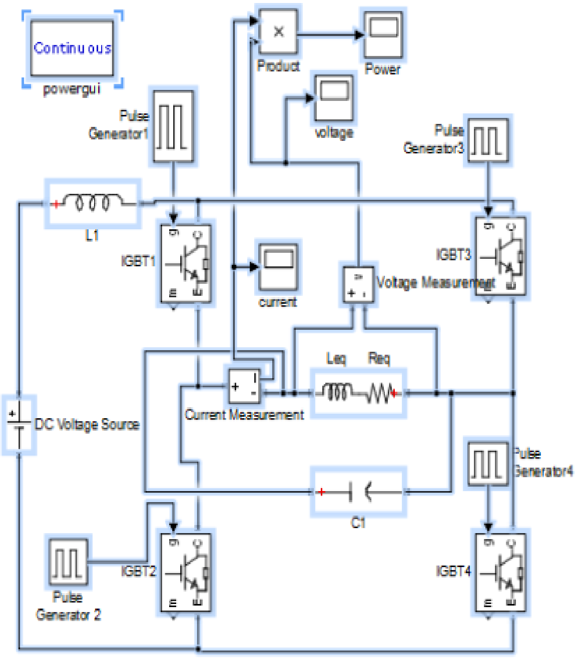

Fig 6: The schematic diagram of the hybrid resonant inverter

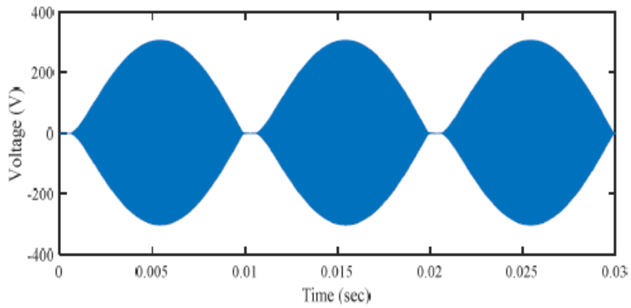

Fig.7. Output voltage of hybrid inverter

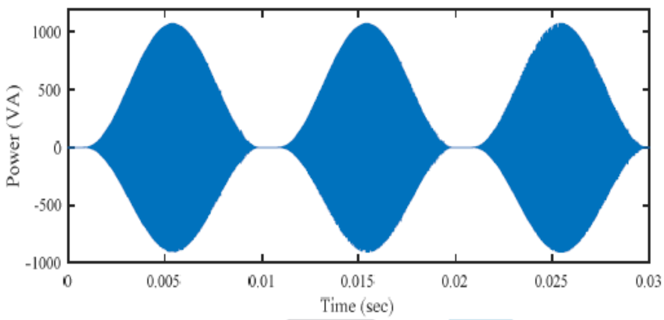

Fig.8. Output power of hybrid inverter

The output voltage and power of hybrid inverter is shown in Fig. 7 and 8 respectively. The operating frequency is 38.5kHz. The authors have used this hybrid inverter for high frequency low power (1kVA) application and this topology can also be used for low to medium power (upto10kVA) applications.

CONCLUSION

Efficiently utilization of PV system is essential to improve its efficiency. Some energy enhancement approaches are considered in this paper by modelling of solar power system. A DC-DC boost chopper is used to get maximum efficiency with iteratively selected duty cycle. A battery is connected with this chopper to store energy for future use. An energy efficient high frequency hybrid resonant inverter is designed for high frequency applications for low to medium power applications.

REFERENCES

[1] N. Pal, P.K. Sadhu, D. Sinha, A.Bandyopadhyay, Selection of Pan Material - a Tool to Improve Output Heating Response of Hybrid Resonant Inverter Fed Four Zones Induction Cooker, Journal of Energy, Heat and Mass Transfer, Asia and the Pacific, vol. 33, p.p.-
169-185, 2011.

[2] Dola Sinha, Pradip Kumar Sadhu, Nitai Pal, Mathematical Analysis of the Mirror Inverter based High Frequency Domestic Induction Cooker, International Journal of Engineering, Science and
Metallurgy, vol. 1, no. 2, pp. 271-277, 2011.

[3] Jia-Min Shen, Hurng-Liahng Jou, Jinn-Chang Wu, and Kuen-Der Wu, Five-Level Inverter for Renewable Power Generation System, *IEEE Transactions on Energy conversion*, Vol. 28, No. 2, pp.257- 266. June 2013.

[4] Alexander M. Latham, Charles R. Sullivan et al.,Performance of Photovoltaic Maximum Power Point Tracking Algorithms in the Presence of Noise, Energy conversion congress and exposition
(ECCE) pp. 632-639.

[5] Billy M. T. Ho *and* Henry Shu-Hung Chung, An Integrated Inverter With Maximum Power Tracking for Grid-Connected PV Systems, *IEEE Transactions on Power Electronics*, Vol. 20, No.5. pp. 953- 962. July 2005.

[6] Bhagwat, P. M., 1984, *US patent 4482946.*

[7] D. Sinha, A.Bandyopadhyay, P.K.Sadhu and N. pal, Computation of Inductance and AC Resistance of a Twisted Litz-Wire for High Frequency Induction Cooker, *in the proceeding of IEEE sponsored International Conference on "Industrial Electronics, Control & Robotics" (IECR 2010)* at NIT, Rourkela, India, 2010.