Greatest power density DC-DC Parallel Resonant Converter for Capacitor Charging

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Abstract: Pulsed power system find many application in the field of industries ,medical and even in the military field, nowadays the demand is concentrated on high power density and compact size, this will lead to increase the operating frequency of converter However increasing the frequency of operation also increases switching losses and hence reduces system efficiency. in order to reduce the losses resonant converters are used, in this paper proposed dc-dc resonant converter with high power density for capacitor charging is analyzed ,designed and verified with matlab simulation .

Keywords- capacitor charging ,power density, resonant converter, matlab simulation.

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1-Introduction:

A growing demand for size reduction of power systems has stimulated substantial development and research efforts in high power density power supplies. The compact high-voltage converters has been widely used in applications such as portable medical imaging, aerospace and military electronics[2]. To achieve high power density converters, it is required that they operate at high switching frequencies [2]. Resonant converters can achieve zero-voltage-switching (ZVS) and enable power supplies to operate at high switching frequencies. Specially, the parallel resonant converter (PRC) can fully absorb the leakage inductance and stray capacitance of the high voltage transformer. Therefore, the parallel resonant converter is very suitable for high-voltage converters. The converter topology has to be selected carefully in order to meet high power density high efficiency requirement, the three level structure is selected at input stage in order to decrease the voltage stress at switches and allow to use high frequency switches such as MOSFET[3][4],the parallel resonant tank is selected due to high voltage gain, relatively low circulation energy and is suitable for applications where the load is widely varied as in the case of charging capacitor ,high power density transformer, a nanocrystalline core material is used for the isolation transformer core because of its high saturation flux density (> 1 T), superior low los density, and high operating temperature characteristics[3], and full bridge rectifier with capacitive filter ,the proposed converter is shown in Fig 1.in order to fully absorb the parasitic capacitance that is being generated by the transformer the tank capacitor is connected to the secondary winding of the transformer [3].

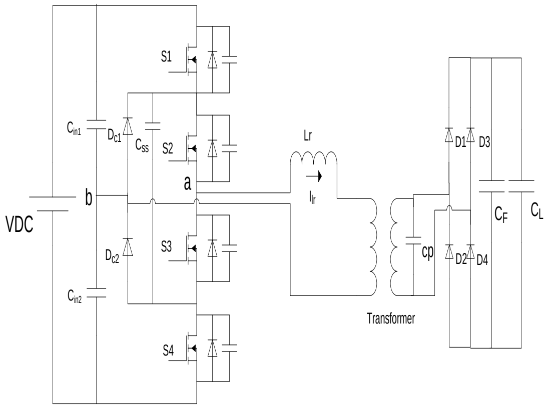

Fig.1. the proposed converter

2-Analysis:

2.1 DC Characteristics :

for the converter design The DC characteristic is the most important information. To choose the parameter converter ,For PRC resonant converter, the DC characteristic will define the relationship between voltage gain and switching frequency as shown in Fig.2. for different load condition. and the DC characteristics equations can be derived as follows:

$$\frac{V0}{Vin}=\frac{\frac{\pi}{4Kv}}{\sqrt{\left(1-wn^2(1+ke)\right)2+\frac{4wn^2}{QL^2KV^4}}}$$

where

$$ke=\frac{2tan(\beta)}{wnQLKV^2}$$

$$\beta=\frac{\pi(-25\sin\theta)}{180}$$

$$K_V=1+.27\sin\theta$$

$$\theta=2\mathrm{atan}\left(\sqrt{\frac{\pi}{2}}\frac{1}{wnQl}\right)$$

Equivalent load resister $R_{eq}=R_O\frac{KV}{2\pi^2}$

$C_{eq}=\tan(\beta)\frac{2n^2}{R0Wnw0kv^2}$

Load quality factor $Q=\frac{R0}{Z0n^2}$

Characteristic impedance $Z_0=\sqrt{\frac{Lr}{Cp}}$

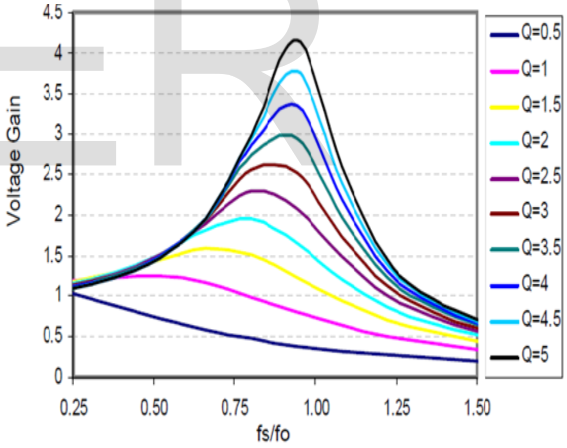

Fig.2. DC Characteristics of PRC

2.2 Power Factor :

The efficiency of PRC is depending on power factor, as converter operate as high as power factor the efficiency will be at highest value so the conduct and switch losses will be at low values.

$$\mathrm{PF} = \frac{Po}{Vi\,Ii}$$

Where v_i and I_i are the r.m.s values at the input resonant tank .The voltage gain(M) :

$$\mathrm{M} = \frac{V0}{Vi\,n}$$

Where n is the transformer ratio

$$\mathrm{I_N} = \frac{IiZo}{Vi}$$

Where I_N ,Zo normalized resonant current ,characteristic impedance respectively

$$\mathrm{I_{oN}} = \frac{Io\ Zo\,n}{Vi}$$

I_{On} is the normalized output current

$$\mathrm{P_{oN}} = \frac{Po}{\frac{Vi^2}{Zo}} = \frac{M^2}{Ql}$$

$$\mathrm{PF} = \frac{\mathrm{PoN}}{IN}$$

$$\mathrm{f_r} = \frac{1}{2\pi\sqrt{Lr\ Cp}}$$

2.3-OperationWaveform and Control Strategy :

The efficiency ,power density and ZVS of the converter are sensitive to the control strategy selection for better performance the converter Must be charging with constant power factor without phase shift as shown in Fig .3.

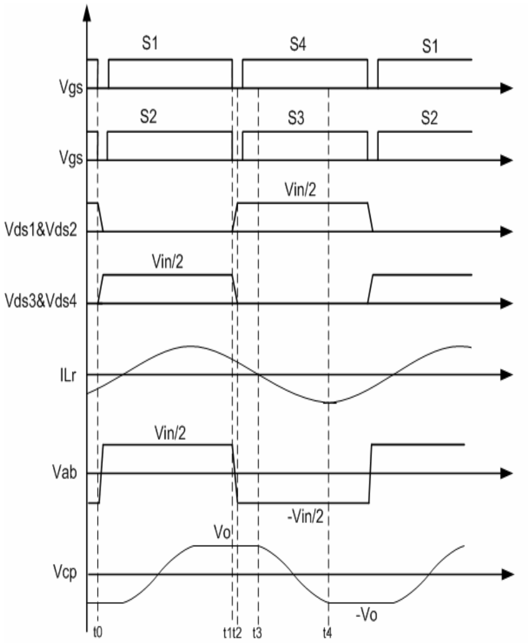

Fig.3.Three level PRC NPS ZVS Operation

3-Design:

The converter is designed to obtain as greatest as power density and efficiency with output voltage 5kv , the best operation of parallel resonant converter the value of Q should be chosen from 2-5[1] [4] ,from fig.4 The Q value is chosen 5,because at this value the voltage gain M will be at high value (3.5),the power losses is at minimum as shown in fig.5., the switching frequency can be widely varied, so the power density and efficiency will be increased [2][3].Q=5, from fig.4.M =3.5 and the normalized frequency =.88, with V_O = $5K_V$, the transformer ratio n can be calculated from:

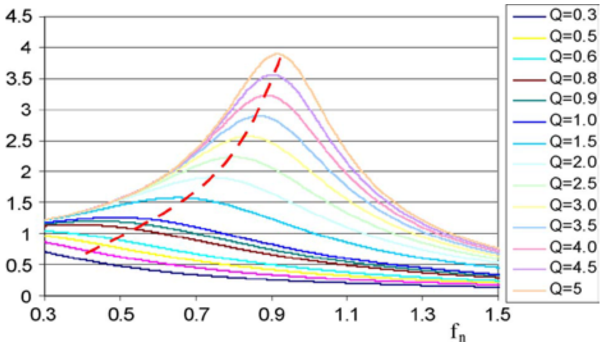

Fig.4.PRC voltage gain curves

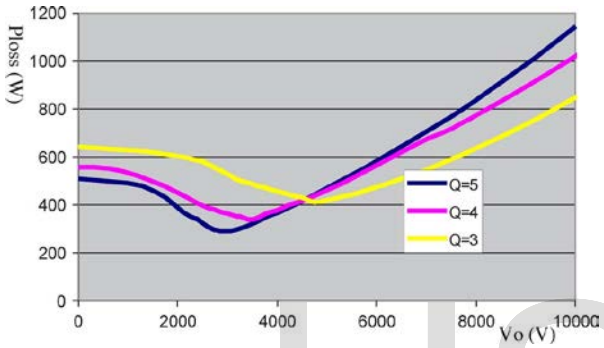

Fig.5. Power loss estimation versus V_O

$$M=\frac{VO}{n\,\text{vin}}\ ,\ V_{in}=\ 300v$$

$$n=\frac{VO}{M\,\text{Vin}}=\frac{5}{3.5*.3}=4.76$$

by choosing switching frequency fs=240k_{HZ}

$$\text{normalized frequency}=\ \frac{fs}{fr}=.88$$

f_r=270.73K_{HZ}

$$f_r=\frac{1}{2\pi n\sqrt{Lr\ Cp}}\ ,\ \text{let Cp}=1.12\text{nf}$$

$Lr = 13.4\mu F$

$$\mathbf{Z_0}=\sqrt{\frac{\boldsymbol{Lr}}{\boldsymbol{Cp}}}\ =109.4\Omega$$

The values of input capacitors shouldbe the same to avoid abnormal operation and can be calculated form this formula:

$$C_{in1}=C_{in2}>=\frac{\text{Ir.m.s}}{\Delta v/\Delta t}$$

Where Δv is maximum ripple voltage,and Δtv is half of switching period for better performance of converter their values should be at least 24μF .Flying capacitor should be large For a better decoupling and voltage clamping effect[ ], the minimum can be calculated from the following formula

$$\frac{vcss}{vswan}=\frac{css}{csw}$$

Vcss is the voltage of flying capacitor,vswan
Is the minimum forward voltage drop of one of the main switches during on state,Css capacitance of flying capacitor,Csw is the sum of switch capacitor and parallel capacitor,Vswan should be near zeroAnd the value of flying capacitor should be at least >1μF, if 10nF Csw is considered and 1% VCss for Vswan .

4-Simulation And Results :

Matlab simulink is used to simulate the converter as shown in fig.6 with the following values :
Vdc = 600 v, C_{in1}= C_{in2} =24 μF , flying capacitor=1μF,load capacitor C_l =.2mF, fs (70 – 240) k_{HZ}

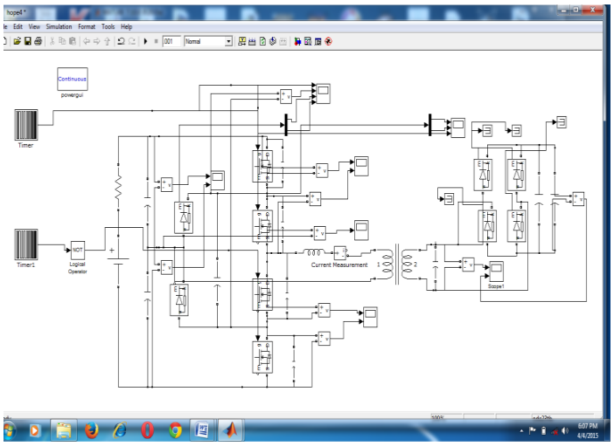

Fig.6. Circuit Simulation

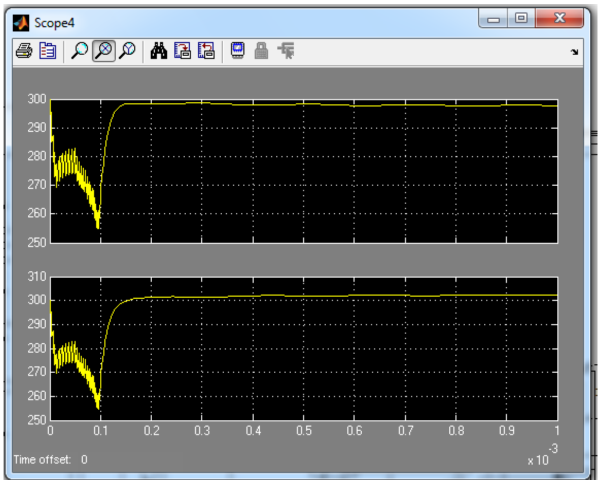

Fig.7. voltage across Cin1 and Cin2

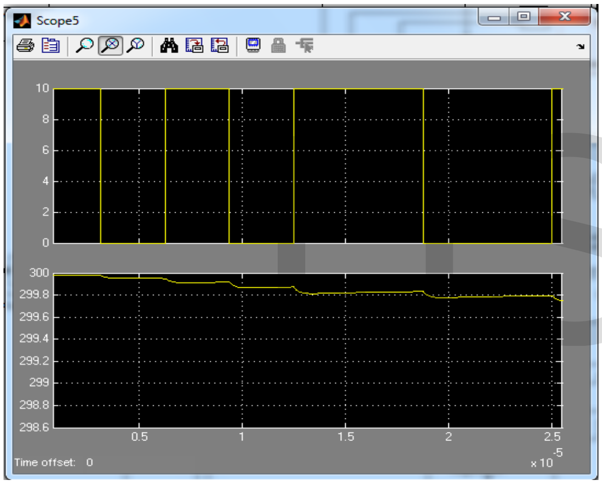

Fig.8. gate pulses and flying capacitor voltage

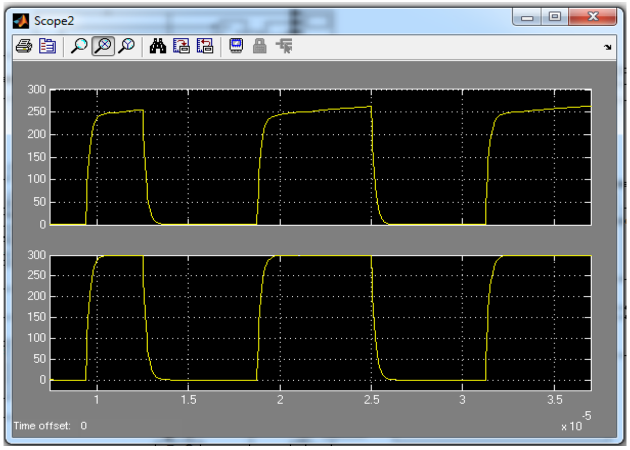

Fig.9. s1,s2 voltages

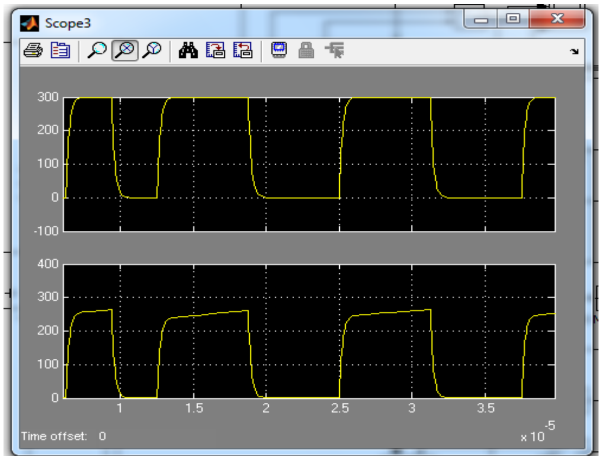

Fig.10. s3,s4 voltages

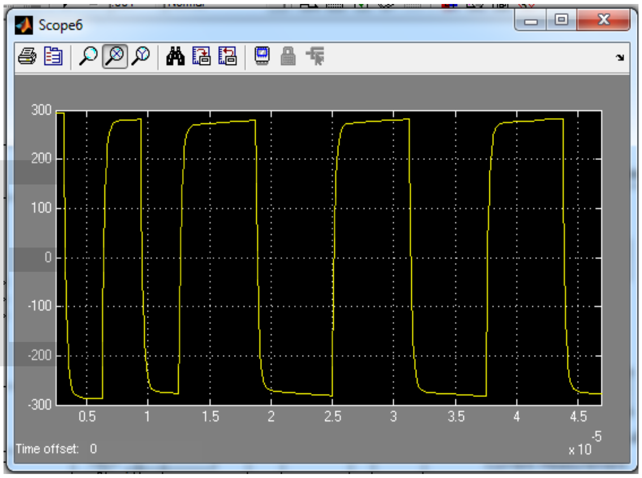

Fig.11.voltage across ab

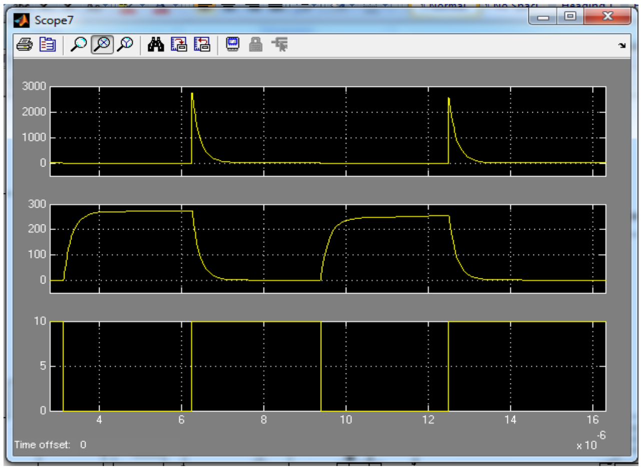

Fig.12.s1 ZCV

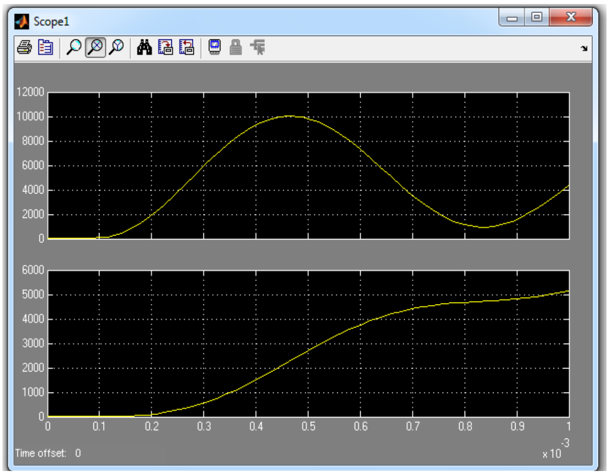

Fig.13. Output voltage

5- Conclusion:

In this paper the dc-dc converter for Capacitor charging with high power density is analysed , designed and simulated ,the simulation results Showed that the resonant topology is good choice for such kind of application where the zvs can be achieved ,the three level structure reduced the Voltage stress across the switches and the target Output voltage 5 K_V is achieved, since the converter used as minimum elements as possible And operated at max frequency 240K_{HZ} the power density is as greatest as possible, and due to high value of Q at max vo 5Kv the converter efficiency is improved as well.

6-References :

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BIOGRAPHY

Elmokhtar.A.Elhamruni received the BS_C degreeincommunication Engg.from higher institute of electronics, BeniWaled,Libya in 1989, MS_C degree in the field of electronics from Belgrade University ,Serbia in 2000. He is currently working toward Ph.D degree at Sam Higginbottom Institute of Agriculture, Technology & Sciences (Formerly AAI-DU) Allahabad.His area of interests power electronics and instrumentation .

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