Development of High Voltage Using Buck Converter and Current Fed Push Pull Inverter

[1]Naveen R, [2]K.H.Sivanand

[1]Assistant Professor, [2]Assistant Professor
[1]Department of Electrical and Electronics Engineering,
[1]ACS College of Engineering, Bangalore, India

***Abstract*—High voltage AC supply is required for the applications like ozone generation, fluorescent lamp etc., which is difficult to control. In this project, buck converter and current fed push pull inverter topology is used to generate AC voltage for high voltage applications. The output voltage of the push pull inverter is controlled by varying the duty cycle of the buck converter switch. It is necessary to maintain output voltage constant during the fluctuation of the load; hence the circuit is operated in closed loop using the PI controller. The proposed model is designed to produce a high voltage of about 2100V AC with the input of 30V DC and it has been simulated using the software MATLAB/SIMULINK.**

***IndexTerms*— High voltage AC, Buck converter, Push pull inverter, PI controller.**

I. INTRODUCTION

Ozone is mainly used in the applications like disinfection, bleaching, water and air purification and in some pharmaceutical application. Ozone is highly unstable, hence it's not possible to store, even if Ozone is stored also, within an hour it will be decomposed into oxygen, therefore it has to be generated on spot wherever it is required. Dielectric discharge method is used to generate Ozone. In this arrangement, the feed gas, dried oxygen or air, flows through a discharge gap of 1-2mm width. One side of the gap is formed by a metal electrode at ground potential and the other one by a dielectric, usually glass or ceramic is used. An alternating high voltage is applied across the two electrodes so that the resulting alternating electric field is high enough to rise electrical breakdown. Traditionally, low switching frequency, high turns ratio transformer are used to supply Ozonizer. Low frequency system presents high volume, low efficiency and difficult to control. In this project the switches are operated at high frequency which increases the power density applied to Ozonizer electrode surface and increases the Ozone production for a given surface area and decreases the necessary peak voltage. By using MOSFET and IGBT frequency can be increased up to several kilo hertz allowing increase in efficiency. Buck converter is used as DC transformer, where the required step down DC voltage is obtained. In this project buck converter is used along with current fed push pull inverter. The DC output voltage of buck converter acts as DC input voltage for push pull inverter. Buck converter is used to control mean current injected to current fed push pull inverter to reduce the voltage stress on the switches of push pull inverter as the output voltage of buck converter is very low.

II. PROPOSED BLOCK DIAGRAM

Proposed Power Stage

The proposed power stage consists of buck converter and current fed push-pull inverter. The best way to control the output power is by changing the inverter dc input voltage. Buck converter is used to reduce voltage stress in the power switches. Buck converter incorporates an inductor in the output filter, which can also be used to supply the dc current needed by the current fed push-pull inverter. In order to achieve output regulation, the circuit is operated in closed loop. The duty cycle of the buck converter is used to control the mean dc current injected to the push pull inverter through the series inductor Li and consequently the power delivered to the load.

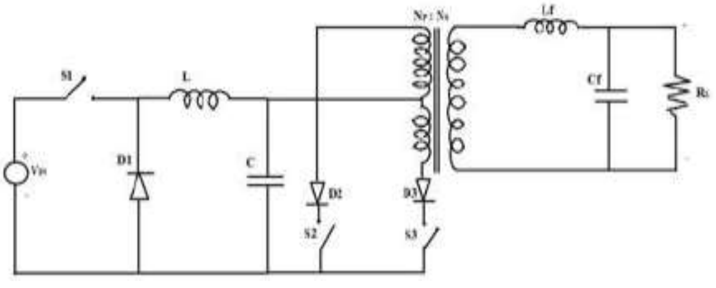

Fig 2.1 Open loop circuit diagram of proposed power stage.

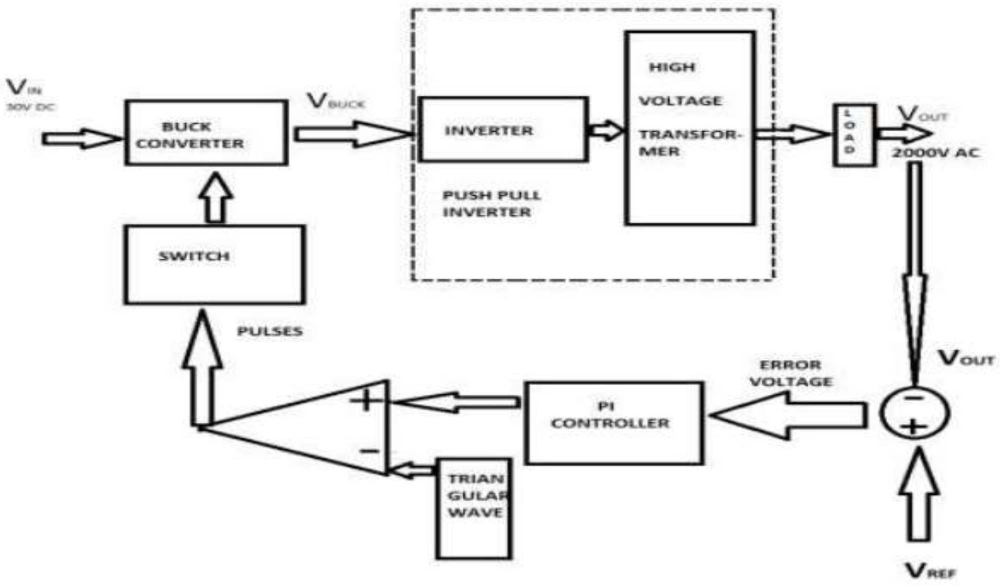

Fig 2.2 Closed Loop Block Diagram of Proposed Power Stage

The Buck converter generates a square voltage waveform, V_{buck} , whose mean value is proportional to the duty cycle D and to the dc input voltage V. V_{buck} = Ve×D The control signal of the buck stage is synchronized with one half of the output voltage period Therefore, one buck period is considered to take half period T/2, T being the period of the sinusoidal output voltage.

Input of 30V is given to the buck converter of switching frequency 50 KHz. By varying the duty cycle of buck converter from 0% - 25%,input to the current fed push pull inverter can be varied from 0V to 7.5V.The switching frequency of the two switches of push pull inverter is 25KHz and the duty cycle is 50% with a time delay of 10 micro seconds. The buck converter output is fed to the push pull inverter which is employed with the high voltage transformer. The output of the high voltage transformer is rectangular waveform. With the help of the LC filter output becomes sinusoidal waveform of frequency 50 KHz. To maintain the output voltage constant PI controller is used. As shown in the figure.2.2, reference voltage is compared with actual output voltage and error in the output voltage e is calculated. Error e is passed through PI controller.

The output controller is compare with triangular wave which will generate pulses which is given to the MOSFETs of the buck converter and current fed push-pull inverter. So closed loop control makes the output voltage constant.

III. DESIGN OF PROPOSED TOPOLOGY

Buck Converter

The proposed topology has been designed for the below mentioned specification.

F = 50 KHz

V_{in} = 30V

D = 0.25

R = 10Ω

V_{ou} = D×Vin ……………………………..… (1)

= 0.25×30

= 7.5V

L_{min} = {(1-D)×R}/(2F)……………………..…(2)

= {(1-0.25)10}/(2×50K)

= 75µH

L = 1.25Lmin ……………………………. (3)

= 1.25×75µ

L = 93.75µH

C = (1-D)/{8L(ΔVo/Vo)(F×F)}…………..…(4)

= (1-0.25)/{8×93.75µ×0.005×50K×50K}

C =80µF

Transformer

Primary voltage V_p = output of buck converter

= 7.5V

Turns ratio = Ns/NP = 266

Secondary voltage = (Ns/Np) ×Vp

= 2100V

Specification of Proposed Topology

Table: 1 Specification of Proposed topology

SL NO	Parameters	Values
1	Vout (Inverter)	2100V
2	F (Buck Converter)	50KHz
3	F (Push Pull)	25KHz
4	R	7666Ω
5	L	93.75µH
6	C	80µF
7	P	611.94W

IV. PI CONTROLLER

The gains of PI controller are determined by various methods. The gain Kp of PI controller gives fast acting correction for the output if any errors arises and the gain Ki has capability to make steady state speed error zero. In this project the tuning of PI controller is done by using Ziegler-Nichols method. Ziegler–Nichols method is better for tuning of PID controller. This was developed by John G. Ziegler and Nathaniel B. Nichols. In this project work Z-N method is used to tune the PI controller. It is performed initially by setting the I and D gains to zero. The "P" gain is increased (from zero) until it reaches the critical gain Kc at which the output of the control loop start to oscillate with constant amplitude. Kc and the oscillation period Pc are used to determine the P, I, and D gains depending on the type of controller are used.

Steps:

- Set the controller with low gain, Kp and gain, $Ki$is reset to zero.
- Gradually increase gain, Kp along with making small changes in the set point, until oscillations start.
- Adjust gain Kc make the oscillations continue with constant amplitude.

Table 2: Ziegler Nichols method formulae for different controller

CONTROLLER TYPE	K_P	K_I	K_D
P	$0.50K_C$	0	0
PI	$0.45K_C$	$1.2K_P \frac{dT}{P_C}$	0
PID	$0.60K_C$	$2K_P \frac{dT}{P_C}$	$\frac{K_P P_C}{8dT}$

The tuned value of KP and Ki for PI controller by Ziegler-Nichols method is found to be

Table 4: Tuned value of K_P and K_i

K_P	K_i
$K_p = 0.007$	$K_i = 0.24$

V. SIMULATION RESULTS

The proposed topology is been simulated using MATLAB/SIMULINK among the various available software tools because it has got following advantages.

- User friendly.
- Wide option of tools which can be helpful in implementation of proposed model.
- Yields us with the accurate results.

SIMULATION MODEL

Simulation model of open loop proposed topology is as shown in figure 5.1

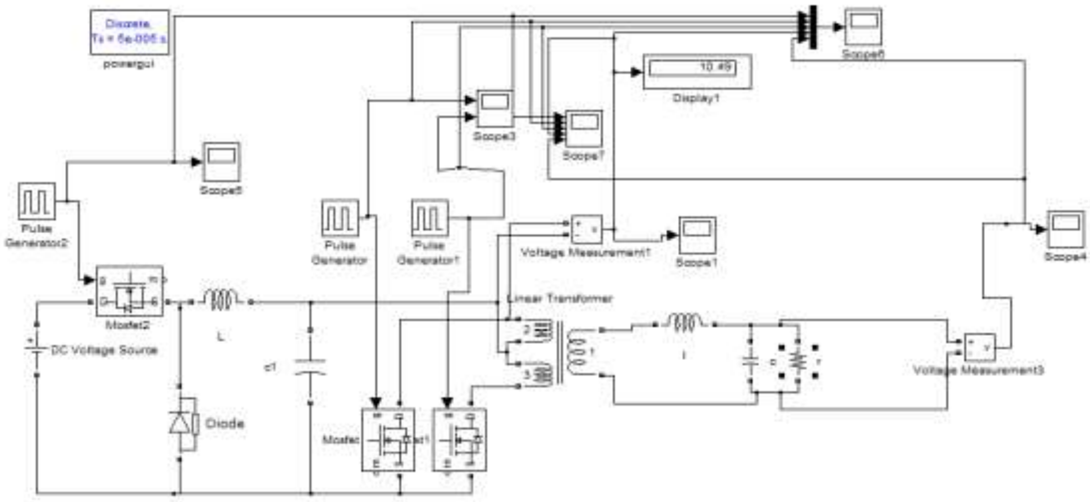

Fig. 5.1 Open loop simulation model of proposed model

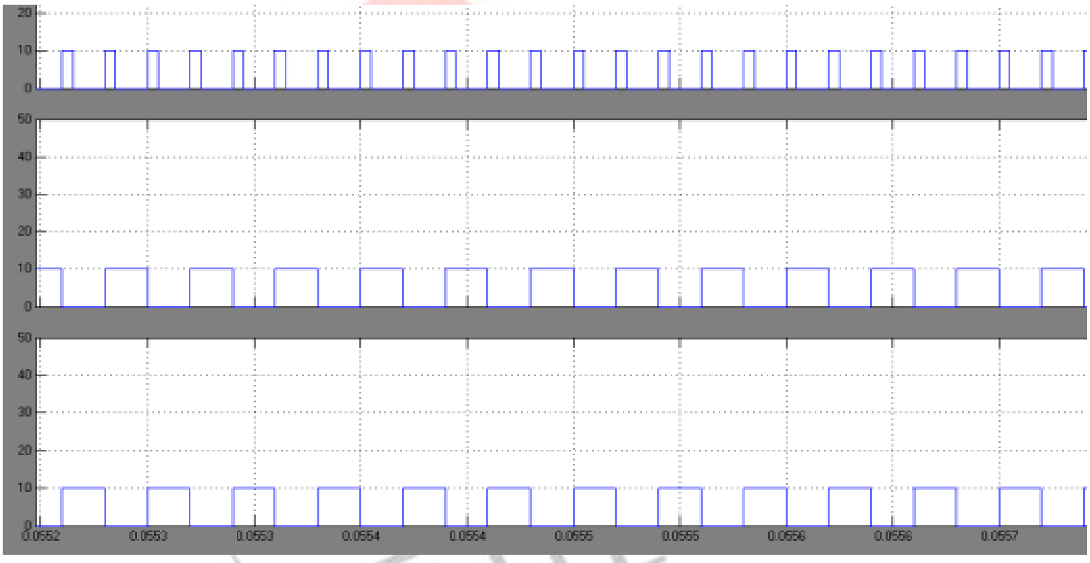

Fig 5.2 Pulses generated to S_1 (buck converter) and S_2,S_3(push pull inverter)

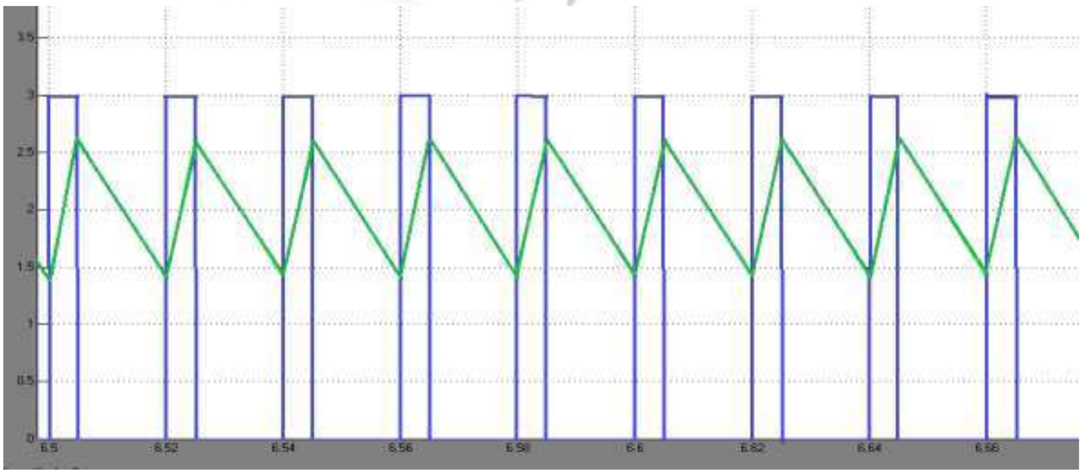

Fig 5.3 Current through inductor at D = 0.25

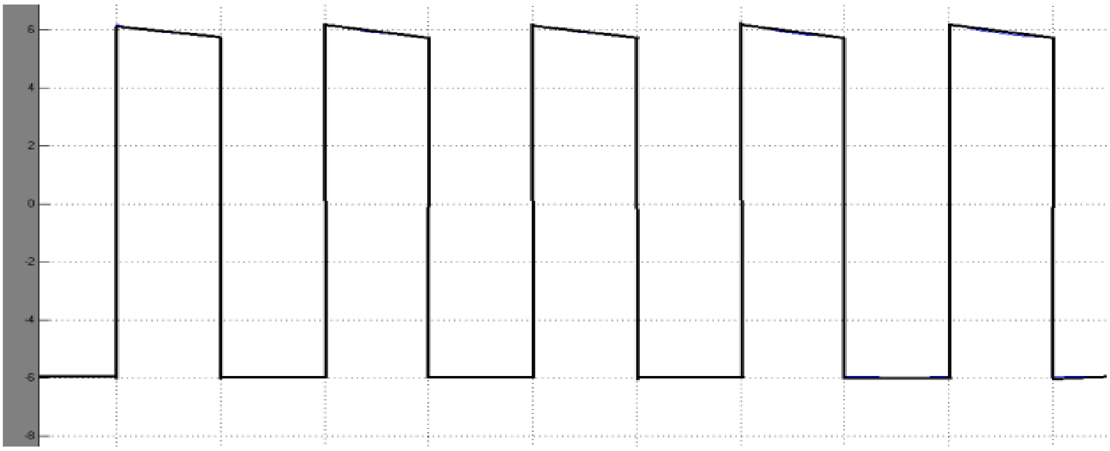

Fig 5.4 Voltage across the transformer tapping

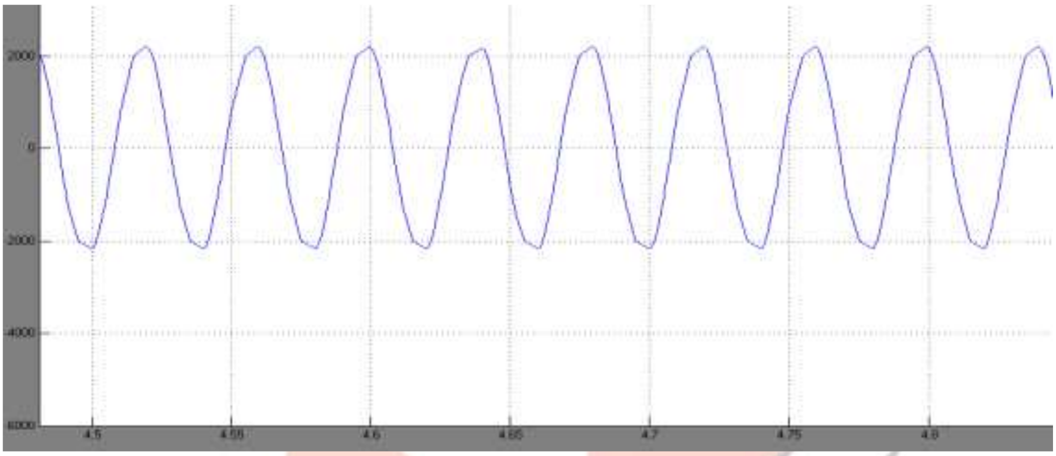

Fig 5.4 Voltage across the transformer tapping

CLOSED LOOP SIMULATION MODEL

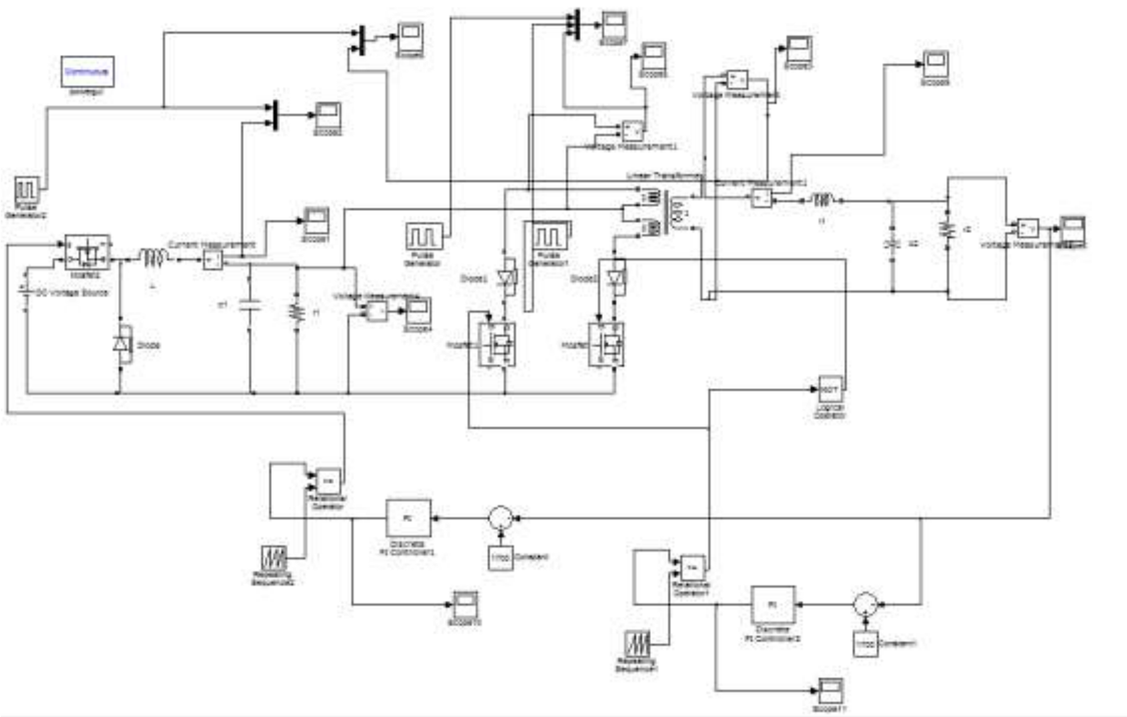

Fig 5.7: Closed loop simulation model

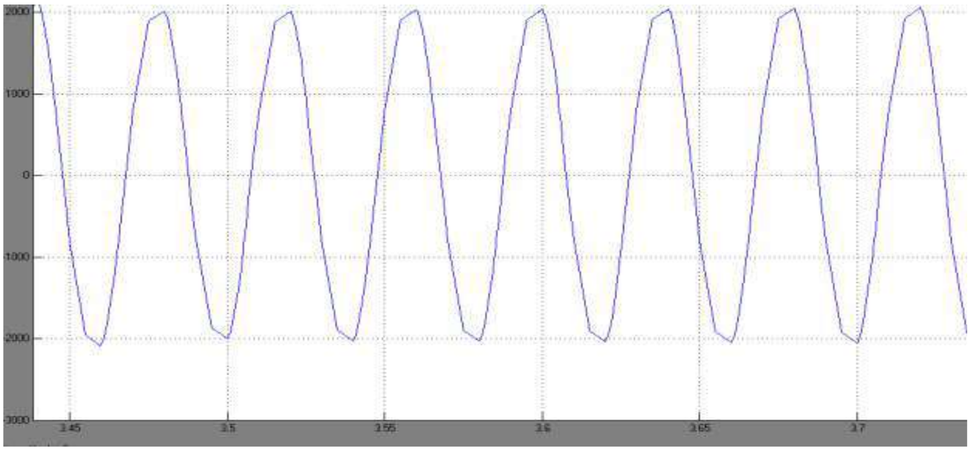

Fig 5.8 Closed loop model output at R_L= 47KΩ

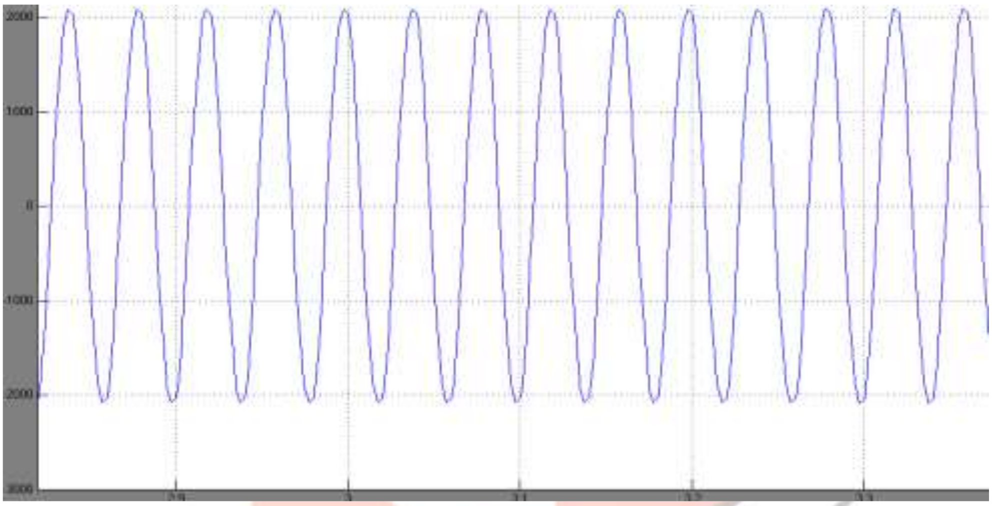

Fig 5.9 Closed loop model output at R_L= 40KΩ

Table: 5 shows the values of output current, output voltage and output power with respect to different values of duty ratio.

Table: 5 Variation of Output Voltage with respect to Duty Ratio

SL NO	DUTY RATIO (D IN %)	OUTPUT CURRENT (A)	OUTPUT VOLTAGE (V)	OUTPUT POWER (W)
1	2	0 .00184	14.2	0.0261
2	4	0.00235	20	0.047
3	6	0.0115	88	1.012
4	8	0.04	308	12.32
5	10	0.0689	528	36.38
6	12	0.097	746	70.87
7	14	0.125	950	118.75.
8	16	0.154	1184	182.33
9	18	0.1835	1403	257.45
10	20	0.210	1635	343.35
11	22	0.240	1840	441.6
12	25	0.282	2170	611.94

The graph of output voltage v/s duty ratio is as shown in the figure5.10 for the values tabulated in the table1.This graph depicts that as the duty ratio of the buck converter increases the output power also increases(power delivered to the load).

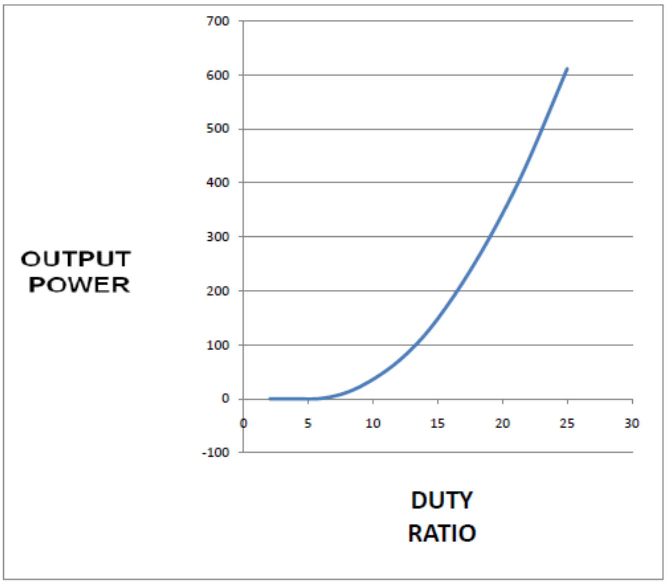

Fig 5.10: Graph showing variation of output power with Duty ratio

VI. CONCLUSION

An upstream buck converter has been proposed as a solution to control and regulate the power delivered to the load. The inclusion of the buck converter can be made at low cost, since only an extra power switch is required in addition to the inverter stage. As final conclusion, it can be said that the proposed topology appears as one of the best suited solutions for high voltage generation.

REFERENCES

[1] R. Rice; "The use of Ozone to Control Trihalomethanes in Drinking Water Treatment", Ozone science & engineering, Vol. 2, no. 1, pp75-99, 1980.

[2] U. U. Kogelschatz and B. Eliasson; Handbook of Electrostatic Processes. Chapter 26. Marcel Dekker, Inc. 1995.

[3] J. M. Alonso, J. García, A. J. Calleja, J. Ribas, J. Cardesín; "Analysis, Design and Experimentation of a High-Voltage Power Supply for Ozone Generation Based on Current-Fed Parallel Resonant Push-Pull Inverter," IEEE Transaction on Industry Applications, Vol.: 41, Nº 5, pp.1364-1372, 2005.

[4] J. H. Song, H. S. Shin, C. H. Choi; "A capacitor-charging power supply using a series resonant three-level inverter topology". Pulsed Power Plasma Science, 2001. PPPS-2001. Vol. 2, 2001, pp. 1583 - 1586.

[5] J. M. Alonso, J. Cardesín, J. A. Martín, J. García, M. Rico; "Using Current-Fed Parallel- Resonant Inverters for Electro-Discharge Applications: A Case of Study," Proceedings of IEEE Applied Power Electronics Conference, Anaheim,CA,2004.