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Design the Pulsed Power Supply for Plasma Reaserch Experiment using Pulse Forming Network

Mr. J. B. Solanki
Lecturer, B.& B. Institute of Technology,
Vallabhvidyanagar. Anand, Gujarat, INDIA
Email: jayraj_ee@yahoo.co.in

Abstract - The power supply is very important in the plasma research project. This paper is try to get theory technical knowledge of designing a 1.5 KV Pulsed power supply for plasma research experiment. Different capacitor bank is used for pulsed power supply which is discharged into coils. For designing the pulsed power supply, design of voltage multiplier, Triggering circuit for Thyristor, 15 V power supply circuit are required for experiment of pulsed electromagnetic analysis for future plasma experiments. 15 V Power supply is required for triggering circuit and DC current transducer.[7],[8].using this 1.5 kv pulsed power supply verified the experiment on two coils. Theoretical and Simulation results have been validated.

Index Terms: *Electromagnetic Solenoied coil, PFN, IES, PSCAD Software..*

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I. Introduction

This paper reports the inspiration, design process, and test results of the inductive pulsed-power supply project. For some time, capacitor-based systems and pulsed alternators have been the focus of research on pulsed-power supplies for plasma experiments. However, both of these systems have major, unresolved problems.[1] Pulsed power science and technology have accumulated many means of pulse generation in a wide range of parameters, with duration from picoseconds to seconds at power levels going up to terawatts for shorter pulses. A recent book by Mesyats [2] can serve as an encyclopedia on this subject. [3] As a result, pulse power supplies that are capable of controlling many of the important pulse parameters over a wide range, and provide certain pulse shapes regardless of the load conductivity, are highly desirable. Therefore, the research in this thesis is focused on designing a pulsed power supply that is capable of producing pulses that can be controlled, and are less dependent on the load.[4]

II. Pulsed Power supply

Pulsing has been shown to do all of the above, but not all at the same time. There is a growing body of literature on the subject showing sometimes conflicting results and indicating that the field is still too new to have settled into a clear body of knowledge. A glossary of terms is given at the end of this paper, but here it will be useful to separately define pulsing. If a system is pulsed, the power may either contain a periodic transient followed by a return to steady state, or it may consist of a periodic variation between two states. In the former case, the transient may be self-generated or may occur in response to a plasma event, such as an arc. In either case, the pulse may be represented by a change in the level of a dc voltage or current.[3].

Square-Wave Voltage-Fed Systems

In this approach, semiconductor switches place a large charged capacitor across the plasma periodically. The switches may disconnect during the pulse, may reverse the polarity of the capacitor, or may switch a different capacitor across the plasma. The capacitor appears as a constant voltage for short periods, so the system appears to have near-zero output impedance. Such a system is commonly used for substrate biasing (in which case the capacitor is applied for a short time and then disconnected for a longer time). A simple circuit is shown in Figure 1. The result is a pulse of voltage on the substrate, which attracts ions from the vapor stream. If the stream is largely ionized, the ions will be strongly attracted to the substrate and arrive with high energy. This can greatly enhance film adhesion and affect stress and other film properties. During the interpulse period, there is no ion bombardment. The power dissipated in the substrate is equal to the ion current times the pulse voltage times the duty factor; if the last is kept small, the power may be small even with high voltages and currents, avoiding excessive substrate heating.[3]

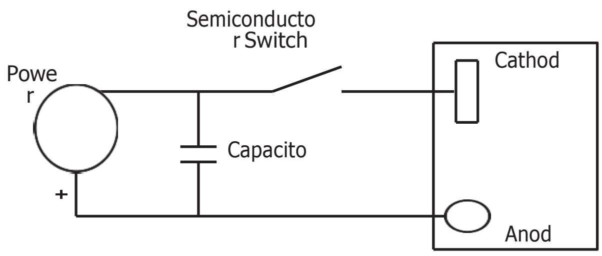

Figure: 1

Voltage-fed systems are used in substrate biasing and plasma diffusion, but are not so effective when applied to sputtering applications because of difficulties with ignition, the delay time in building the plasma density, and, therefore, the sputtering rate. When the voltage source is disconnected, the plasma decays with a two-fold time constant—fast at first (□□□□5 μs) as the hot electrons leave the plasma, and more slowly later (□□□□50 μs) as particles with slower velocity are lost to the chamber walls. [3]

III. DESIGN OF VOLTAGE MULTIPLIER FOR PULSED POWER SUPPLY OF PLASMA EXPERIMENTS

3.1 Specification of 15 v DC Supply

- 230 V/18 V transformer
- No.of Diode =4 ,B159
- Two 1000 uF ,50V
- Two 47uF, 63 V
- L7815 Regulator IC
- L7915 Regulator IC

3.2 Specification Triggering Ckt for Thyristor

- 900 PB 120 To 220 Phase control Thyristors
- 1:1 Pulse Transformer
- Transistor
- Diodes

Voltage multipliers are AC-to-DC power conversion devices typically comprised of diodes and capacitors[7]. Voltage multipliers produce a high potential DC voltage from a lower voltage AC source Originally used for television CRT's, voltage multipliers are used in laser systems, x-ray systems, traveling wave tubes, ion pumps, electrostatic systems, copy machines, scientific instrumentation, oscilloscopes, and many other applications that utilize high voltage DC.

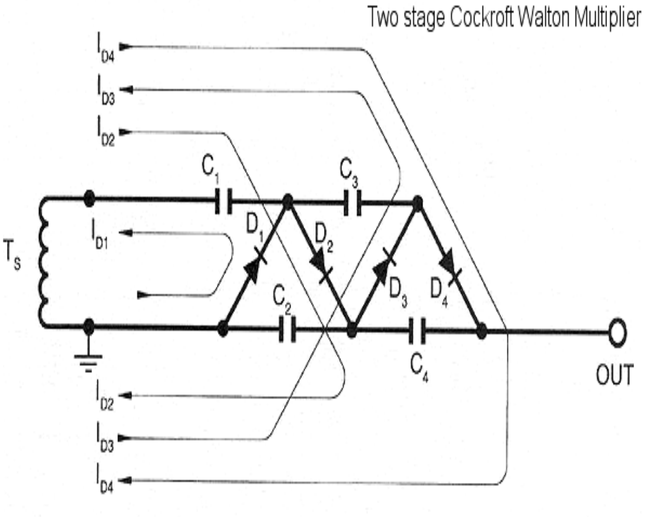

Figure 2 : Ckt of Voltage multiplier

3.3 Specification of Voltage multiplier

- stage voltage multiplier
- Input Voltage=230 V
- Output Voltage =1.3KV
- 2 uF Capacitor, 2KV
  No.of capacitor = 4
- No.of Diode,2KV = 4

Characteristic Impedance of coil

$$Z_0 = \sqrt{\frac{L}{C}} \quad , \quad \delta = \frac{R}{2L} \quad ,$$

Angular frequency of coil for capacitor discharge

$$\omega_0 = \frac{1}{\sqrt{L.C}} \quad , \quad t = \frac{2\pi}{\omega}$$

Current in Coil for pulsed power supply is calculated by

$$I_{MAX} = \frac{e^{-\delta t}}{\omega L} . U_0$$

3.4 Simulation Of Voltage Multiplier

Voltage multiplier is require for the Pulse forming network .To replace the DC source and to use AC source economically a voltage multiplier circuit is used as shown in figure . Each diode here has the voltage rating of 1200 V and 1 KA current rating. Capacitor used is of 2.0 μF and voltage rating of 2 KV. Input Voltage for Voltage multiplier is 230 AC 50 Hz With Isolation Trnasformer. By Using 4 stage Capacitor, It Converts 230 to 1.5 KV .[8]

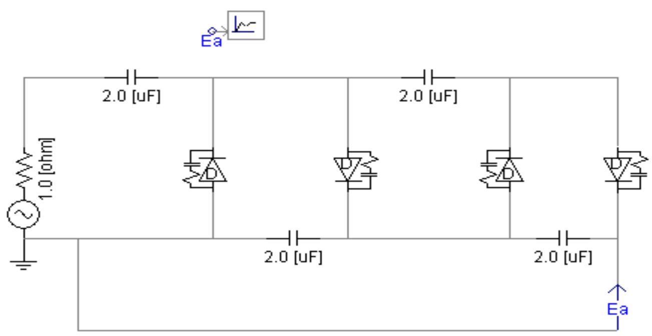

Figure 3: Voltage multiplier circuit to replace the DC source

This is output of Voltage multiplier 1.3 KV.

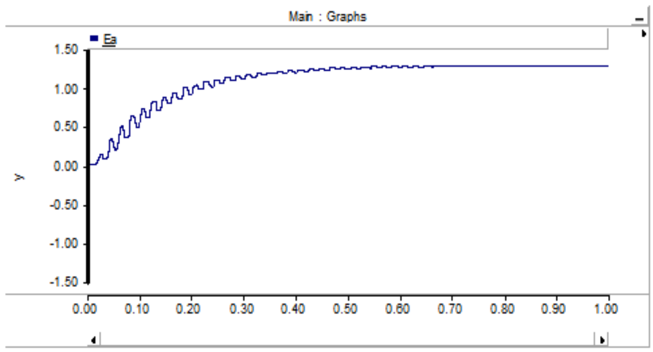

Figure. 4: Voltage wave forms obtained from the voltage multiplier

IV. Pulse Forming Network Parameters

- Peak pulse voltage = 1 KV
- Capacitance used = 40 µF
- Inductance used = 16 µH
- Resistance used in series with the coil = 10 Ω

Equation supporting PFN design

For resistive load

$$Z_0 = \left(\frac{L_p}{C}\right)^{0.5}$$

Where,

L_p = PFN inductance of a single stage

Z_0 = load resistance

For inductive load

$$Z_0 = \left(\frac{L_p + L_l}{C}\right)^{0.5}$$

Where,

L_p = PFN inductance of a single Stage.

Z_0 = load resistance

L_l = load inductance

C = PFN capacitance

Time of pulse

$$T = 2n(LC)^{0.5}$$

Where,

n = No of stages in PFN

With these equations 1 KV and 250 µsec pulse forming network is designed.

4.1 Simulation of PFN with PSCAD software.

A 2 stage PFN is designed and simulated in PSCAD. IN PSCAD DC source is used instead of Voltage multiplier The circuit arrangement is shown in figure 3.

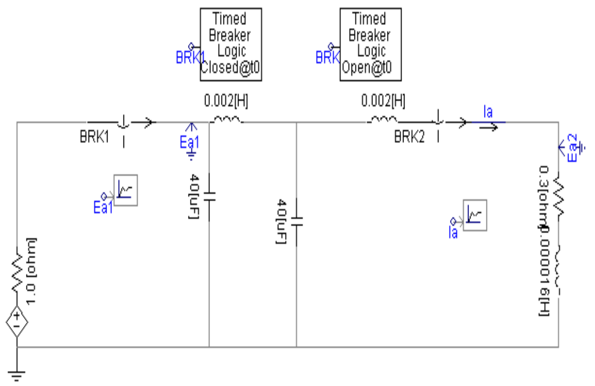

Figure.5: 1KV pulse Discharge with PFN arrangement

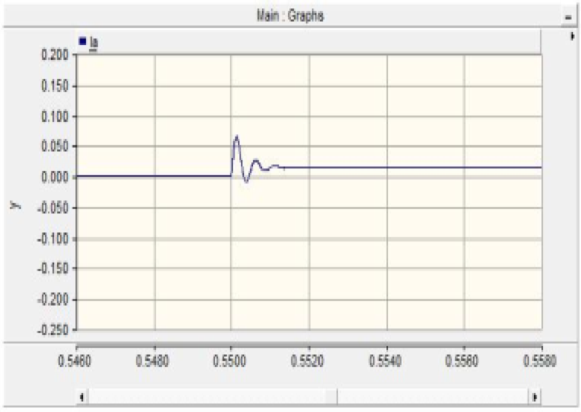

Figure.6: Current Waveform in 0.2T Inner coil

Here from the graph it can be seen that 80 A is dumped in the coil to produce peak flux density of 0.2T at the peak current.

V. Description of 1.5 kV Pulsed Power Supply

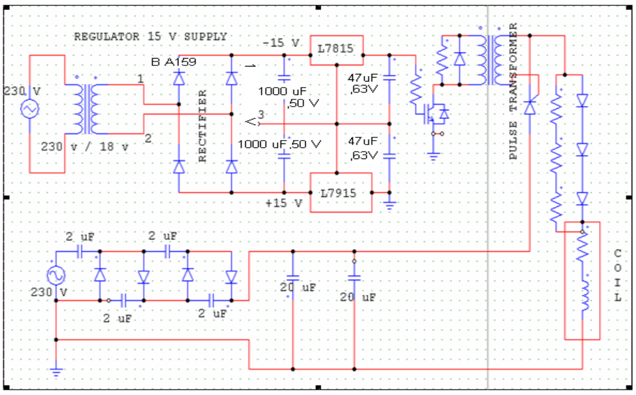

Figure 7 : : Circuit Diagram for 1.5 kv Pulsed Power supply

Voltage multiplier require for the Pulse forming network .To replace the DC source and use AC source economically a voltage multiplier circuit is used as shown in figure . Each diode here has the voltage rating of 1200 V and 1 KA current rating. Capacitor used is of 20 µF and voltage rating of 2 KV.Input Voltage for Voltage multiplier is 230 AC 50 Hz With Isolation Trnasformer.By Using 4 stage Capacitor , Its Convert The 1.5 KV .

In this Pulsed Power supply ,230V 50 Hz Supply is given to the 4 stage voltage multiplier which gives output approximately 1.311 KV .Triggering circuit and DC current transducer are supplied by 15 V DC supply[7,8]. Thyrister triggering circuit is triggered by Function Generator Which is set at 10 KHz frequency. By Voltage multiplier the capacitor bank has been charged for 1000v. Then it discharged into the coil through Thyrister triggering circuit.

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VI. EXPERIMENTAL SET UP & PROCEDURE.

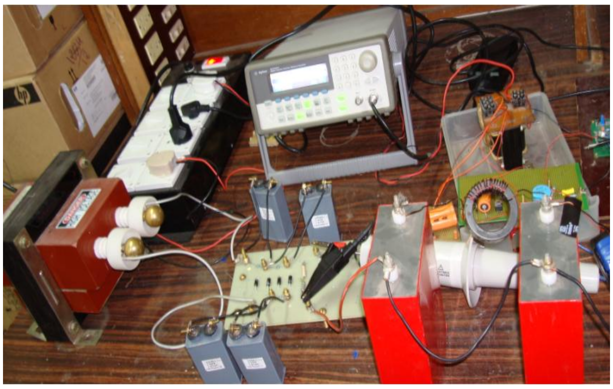
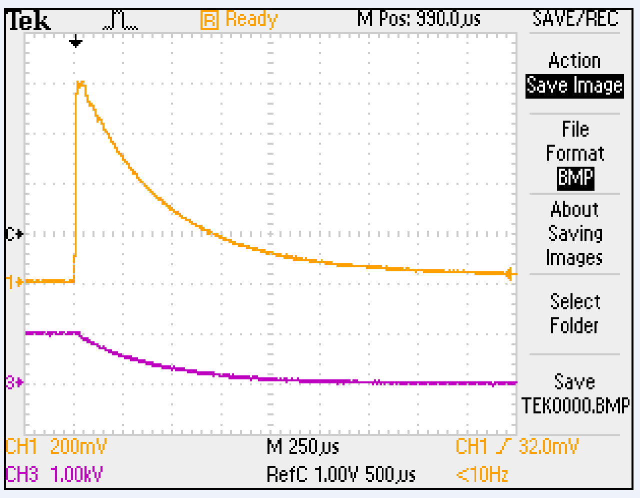


Figure 8: . Set up of 1.5 KV Pulse forming power supply

Fig 9:. central solenoid coil with single turn outer coil

A 1 KV 250 μsec 2 stage pulse forming network is used to give supply to the air cored coil with Outer toroidal shaped single turn coil. Actually DC supply is required to have charging of capacitor but for economy consideration a voltage multiplier circuit is used with A.C. supply as shown in section 2 where design of the same is not shown. A TEXTRONIX DSO is used for measurement. A 1.5 KV 640 μsec 2 stage pulse forming network is used to give supply to the air cored coil with Outer single turn coil. Actually DC supply is required to have charging of capacitor but for economy consideration a voltage multiplier circuit is used with A.C. supply as shown in section 2 where design of the same is not shown. A Textronix Digital Signal Oscilloscope is used for measurement.[10]



Fiugure.10. 1.5 KV and 96 A current dumped in Central solenoid coil

VII. RESULT OF EXPERIMENTS

For taking practical results a TEKTRONICS Digital oscilloscope is used. Practical results are neatly matching with the simulation results from FEM analysis.

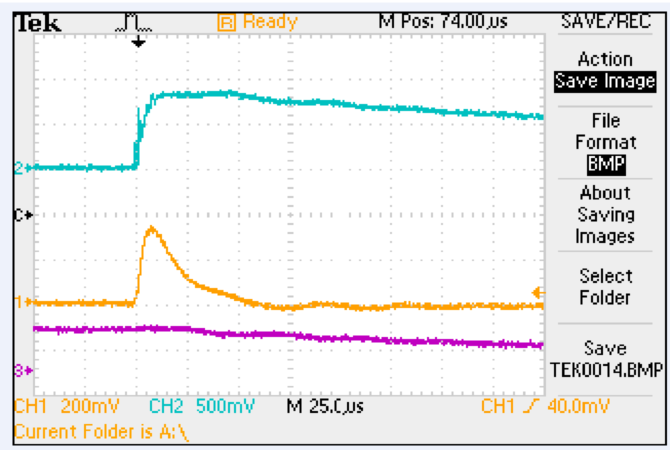


Figure11 . DSO results showing induced current

For measuring current use 2 Different the DC current Transducer like Series AAC- 947-500A and 218-100A.For Voltage Measurement TEXTRONIX 1000 X HIGH VOLTAGE Probe used .

In DSO Result,

Chanel –1 shows the Induced current in Outer single turn coil, 3.52 A,

Ch-2 Shows the Current in Inner central solenoid Coil

Ch-3- Voltage Across the PFN

VIII. CONCLUSION

While the power supply described in this paper accomplished its goals, the low currents necessitated by the small scale of system limited the system's energy density. Periodic reversal of the voltage of an electrode can clear a buildup of charges by attracting the opposite charge during the pulse Here pulsed power supply designed for high voltage plasma application. By designing this pulsed power supply we can develop similar power supply complicated experiment of high voltage experiment. DC supply replaced by designing Voltage multiplier. Simulate the Circuit of Voltage Multiplier and Pulse forming network in PSCAD which is compared with experiment result. Theoretical, simulation ,experiment result are validated. This paper is intended to present the state-of-the-art in power supplies for plasma processing with particular emphasis on pulsed power equipment.

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