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# Study of 30 kV, 3 kJ/s Capacitor Charging Power Supply

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***ABSTRACT:*** *This Project aims in the study of 30kV, 3kJ/s Capacitor charging power supply (CCPS). It is a special kind of power supply where its load is purely capacitor. Conventional high voltage dc power supplies are designed to operate at a given output voltage into a constant or near constant load. Pulse lasers, flash lamps, rail guns, and other pulse power systems, however, require short but intense burst of energy which may be derived from rapidly discharging the capacitor. The most important difference between a CCPS and a conventional power supply is the wide range of load conditions over which the CCPS is required to operate.*

*The CCPS must be able to operate from near short circuit conditions at the beginning of the charge cycle to very light load conditions at the end of the cycle when the target voltage has been reached. So, the topology must be such that it should withstand short circuit condition. For these reasons, a conventional power supply is usually not suitable to perform the task of a CCPS, as most are designed for constant power applications and cannot handle the stresses involved in pulsed power applications. Capacitor charging power supply is most efficient and effective means of charging capacitive loads to high voltages at high repetition rate.*

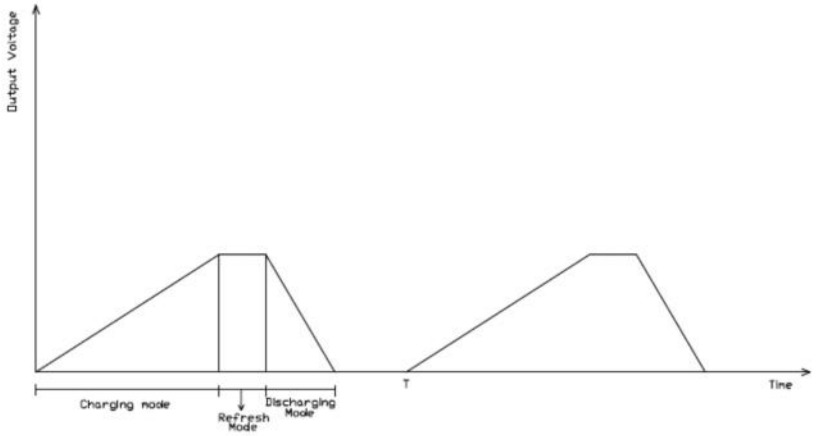
## 1. INTRODUCTION

### 1.1 OVERVIEW OF CAPACITOR CHARGING POWER SUPPLY

Flash lamps, which may be used in sterilization or other applications that require flashes of high intensity light, and pulsed lasers, which may be used in cutting or welding, both derive the required bursts of energy in this fashion. The capacitors used in these types of equipment are energy storage capacitors and must be charged by a capacitor charging power supply (CCPS) prior to each repetition of energy release to the load. The rate at which the capacitor discharges is called the repetition rate. It may be a few 0.01Hz for large capacitor banks to a few kHz for certain lasers with small stored energy. After the energy storage capacitor discharges, it must recharge to a specified voltage with the capacitor charging power supply (CCPS).

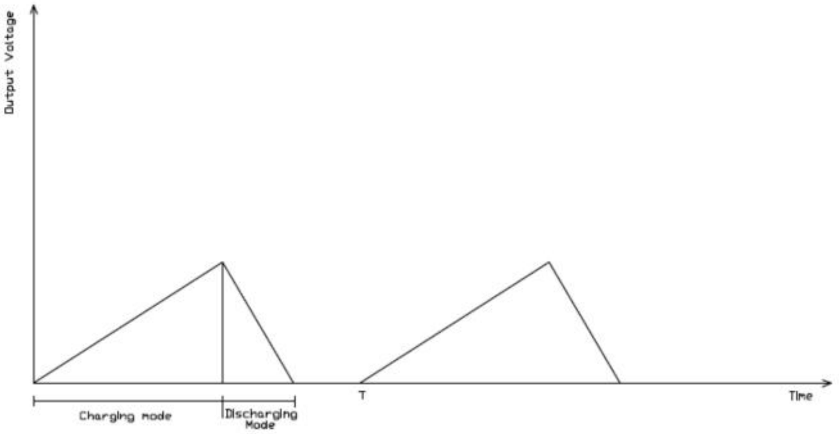
Capacitor Charging Power Supplies are specifically designed as current sources for use in pulsed power applications. The most commonly used methods of charging capacitors in pulsed applications are full discharge and partial discharge. Full discharge, as the name implies, allows the capacitor to be discharged to zero every shot. The power supply is then enabled, the capacitor is charged to the set voltage and the discharge cycle is repeated. Partial discharge methods take advantage of semiconductor switches to turn on and off the discharge from the capacitor to the load allowing the designer to vary the pulse width along with the energy delivered. The specified capacitor is usually large enough so that only a small percentage of the energy is taken form it each shot hence the name “partial discharge”.

## 2. CHARGING PATTERN OF CCPS:




Charging patterns of CCPS (1/T is the repetition rate)

In the above Figure the charging pattern shows that the voltage across the energy storage capacitor connected after the capacitor charging power supply. In CCPS, the charging pattern is same. Above is the capacitor charging voltage, refresh mode is presents so that the average output voltage is decreased.




Charging patterns of CCPS without refresh time

In the above figure the charging pattern shows that, as soon as the capacitor is charged to the particular voltage it discharges, hence per cycle time is reduced and the average output is increased.

## 3. CAPACITOR CHARGING TECHNIQUES:

It involves different kind of charging method to charge the energy storage capacitor.

### 3.1 RESISTIVE CHARGING

In resistive charging, a resistor is connected in series with a voltage source and the storage capacitor. Fig. 1 shows schematic of the resistive charging power supply.

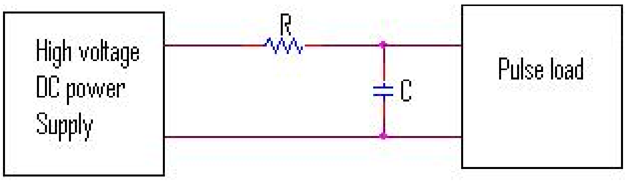



Fig. 1 Schematic diagram of Resistive Charging

The charging mode ends when the capacitor voltage is equal to the output voltage of the power supply. The capacitor is continually refreshed by the power supply. During the discharge mode, the charging resistor isolates power supply from the pulse load. The advantage of this method is simplicity, reliability and low cost. The disadvantage of this technique is its poor efficiency. In this method the energy dissipated in the charging resistor is equal to the energy storage capacitor. In an ideal case maximum efficiency is 50%. As a result this technique is utilized in the circuits, where the charge rate low, approximately 200J/s. The rate of charging of the capacitor is exponential and dictated by RC time constant, and hence it is slow. For this technique more than five time constants {5RC} is required for the capacitor voltage to reach 98% of maximum required voltage. Due to simplicity and ruggedness, this method is used when average output power is very low and the size, regulation, efficiency are not important.

### 3.2 ONE CYCLE RESONANT CHARGING

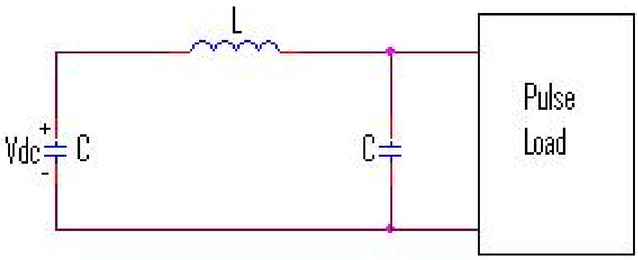



Fig. 2 Schematic of Resonant charging

Fig.2 shows the schematic of the resonant charging power supply. For medium and high power applications, one cycle resonant charging is used. One-cycle resonant charging is also a relatively simple circuit topology; however, the achievable regulation is equal to the AC line regulation. In addition to the basic transformer rectifier, the system must have an additional energy storage capacitor, inductor and a switch. This switch can be a simple diode or a unidirectional closing switch like a Thyratron or SCR While one-cycle resonant charging can result in well regulated relatively efficient capacitor charging, it utilizes bulky 60Hz technology and requires the storage of energy in the circuit.

### 3.3 CONSTANT-CURRENT CHARGING

For medium and high power systems where minimum volume, high frequency and regulation are critical design criteria, high frequency constant current charging may be the most practical capacitor charging technique. To limit the output current during the start of charging mode and also to control precisely the charging interval as well as the final voltage level, constant-current charging techniques is advantageous. During charging, it is important to limit the output current for safe operation and CCPS operates in constant current (CC) mode. Once the capacitor is charged to required voltage level, the charging power supply changes its mode from CC to CV to maintain constant voltage across the capacitor.

### 3.4 CONSTANT POWER CHARGING

Large accelerator facilities have multiple modulators each typically delivering few tens of MW. In order not to disturb mains with the peak pulsed power, energy storage capacitors are used. Power supplies are needed to charge these capacitors. The recharging of power supply is also required to be done in such a manner that the main is not significantly disturbed. Electricity supply authorities will not allow more than 3% of short circuit power of the mains. More importantly, the pulse repetition rate of such modulator is low, typically 5 to 10Hz. The mains disturbance of low frequency comes in detectable visual range (flicker) of the human eye. The allowed distortion in this flicker frequency is even more restricted. For 5 Hz repetition rate, the allowed amplitude distortion is reduced to 0.5% of the short circuit power. This in turn, translates into a very small allowable variation in the power drawn by each modulator. In order to comply with stringent mains voltage variations, the charging power supplies are operated with so called constant-power charging techniques. In the charge cycle, initially the charging current is high which progressively decrease during the charging with the same factor with which voltage increases. In this way instantaneous power delivered in the charge cycle is constant and therefore the current drawn from three phase mains also remains constant.

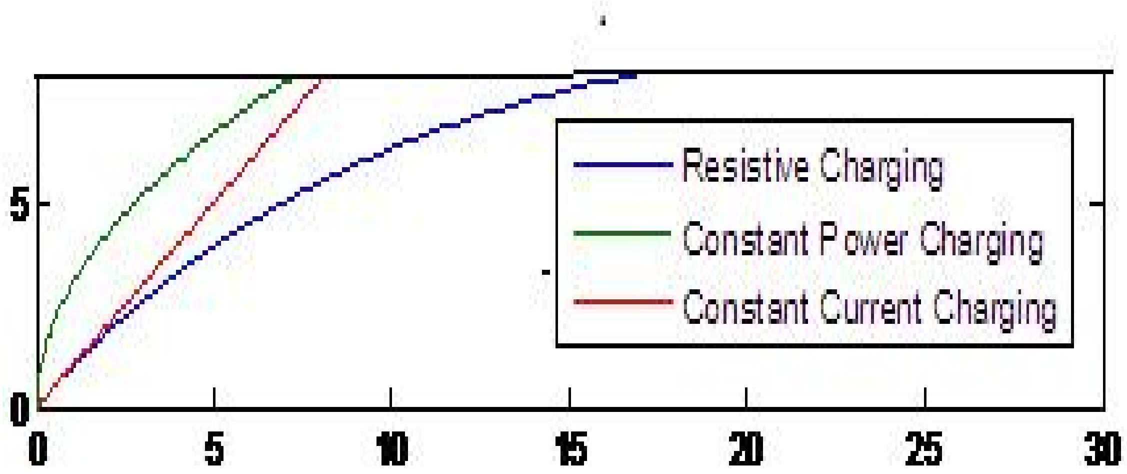



Fig.3 Comparison of Characteristics the Different Charging Scheme.

### 4. SPECIFICATIONS OF 30 KV, 3 KJ CAPACITOR CHARGING POWER SUPPLY.

| | |
|---|---|
| Average charging rate | : 3kJ/s |
| Output maximum voltage | : 30kV |
| Polarity | : positive |
| Mains input | : 400V-440V input, 50Hz three phase |
| Power factor | : 0.9 (lagging) |
| Output Current | : 200mA |
| Efficiency | : 89% at full load. |
| Cooling | : Air cooling. |

## 5. BLOCK DIAGRAM OF 30 KV, 3 KJ CAPACITOR CHARGING POWER SUPPLY.

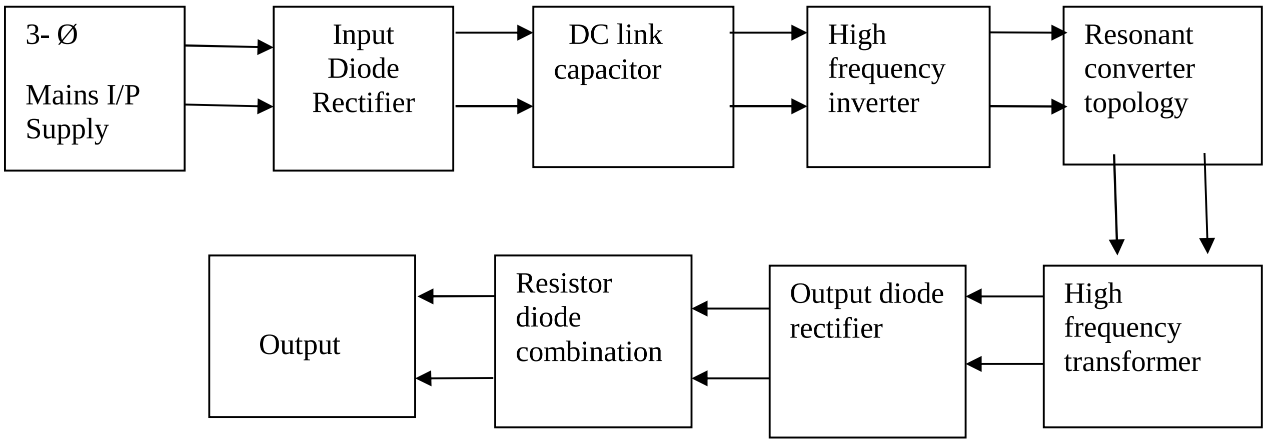



Fig. 4 Blocks of 30 kV, 3 kJ Capacitor charging power supply.

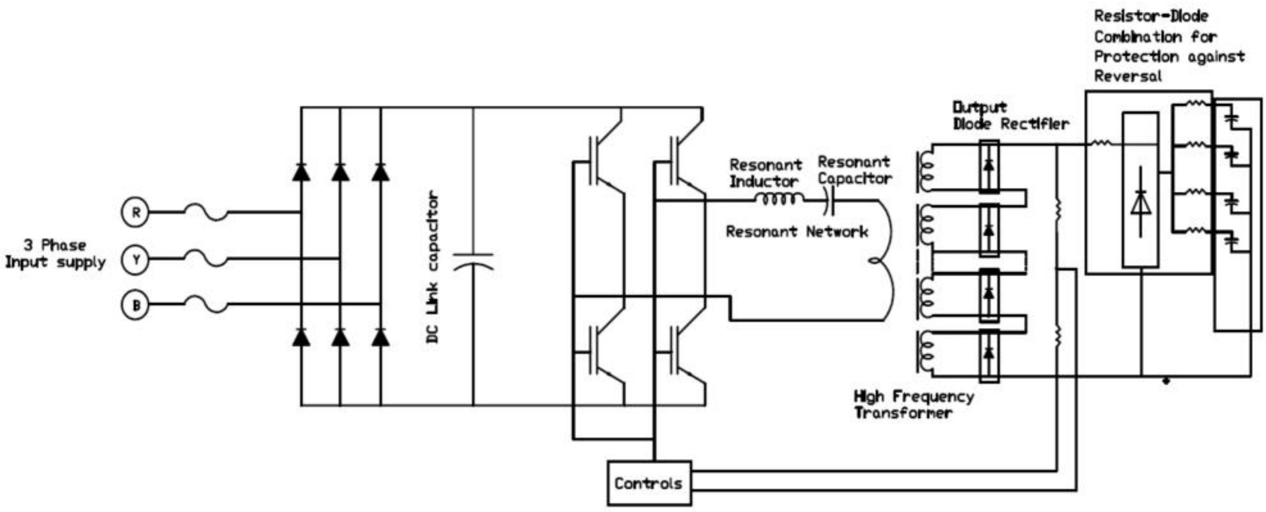



Fig. 5 Schematic diagram of 30 kV, 3 kJ Capacitor charging power supply

Fig.5 shows the Schematic representation of 30 kV, 3 kJ Capacitor charging power supply. The input 3 phase mains connected to the input side of 3 phase 6 pulse diode rectifier to provide DC supply to the High frequency inverter, in-between DC link capacitor is connected to smoothen the output voltage of the DC supply so that the voltage remains within the range specified. Inverter output is fed to primary of High voltage transformer with three secondary's and each of 10 kV and the same is rectified using bridge rectifier, protection circuit also provided to protect against reversal.

## 6. FLOW CHART:

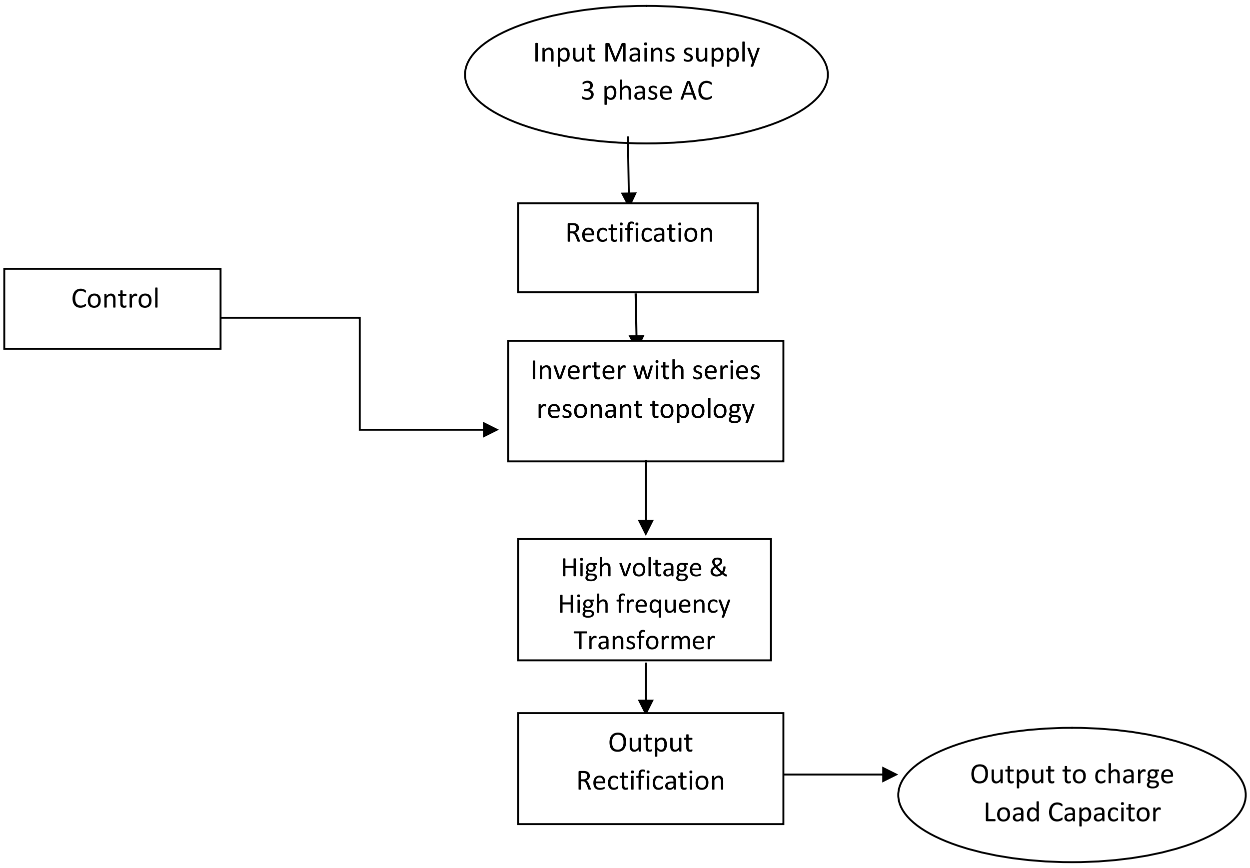



Fig.6 Flow chart of 30 kV, 3 kJ/s Capacitor charging power supply

Fig.6 represents the flow of sequence of operations of the Capacitor charging power supply, where input 3 phase AC fed to the rectification which includes DC link capacitor to supply DC voltage to the Inverter with Series resonant topology & output of Inverter is fed to the primary of High voltage and high frequency transformer (With multiple secondary's) & the output of the transformer is again rectified through bridge rectifiers to charge the load capacitor.

## 7. PRINCIPLES OF OPERATION

### 7.1 INPUT RECTIFICATION

Three phase circuit breaker, three phase contactor, bridge rectifier are the basic components required for input rectification. 400V-440V input, 50Hz three phase input is provided to unit, Circuit protection is provided by MCB (Miniature Circuit Breaker), the MCB is connected to a three phase contactor. Contactor provides fail-safe type disconnection of the line voltage to the power supply rectification circuit. The soft start circuitry is used to charge the DC link capacitors before turning ON Contactor, The soft start circuit consisting of a 3-phase bridge rectifier and a series resistor through which the DC link capacitor is charged, once the capacitor through series resistor charged, soft start change over takes place to main charging path by turning on contactor & this can be achieved by using time delay relay. The generated DC voltage is applied to inverter circuit.

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### 7.2 DC LINK REQUIREMENT

This DC link supply is required to supply DC power to a capacitor charging unit employing a high frequency inverter stage. The inverter stage will be taking highly discontinuous current from this DC supply. The DC supply will be made of a 3-phase rectifier unit followed by a LC filter. Input current to the inverter contains substantial ripple current and capacitor of the filter will smoothen the output voltage of the DC supply so that the voltage remains within the range specified.

### 7. 3 INVERTER WITH SERIES RESONANT TOPOLOGY:

Rectified DC voltage is applied to inverter circuit. The inverter employs a series resonant topology.

1) The CCPS adopts series resonant converter topology which operates at half the resonant frequency corresponding to the discontinuous load currents.
2) This topology has been chosen because it gives the constant current and it is short circuit proof.
3) The advantage of this topology is that all the components are turn on and off at zero current, so switching losses are reduced to the maximum
4) In resonant inverters, the controllable switches turn on and off at zero voltage and/or zero current that opens the way to the frequency increasing. Therefore, less volume is required for the converters and reactive components can be reduced in size, resulting in design that is more compact
5) The gate control for the switching devices & the control signals provided by control circuit.

### 7.4 HIGH VOLTAGE TRANSFORMER:

The output of inverter is connected to the primary of the high voltage transformer. The high voltage transformer is a set-up type. The transformer having three secondary's are in the range of 10kVeach.

### 7.5 HIGH VOLTAGE ASSEMBLY:

High voltage assembly consists of full wave bridge rectifier for the output voltage in the range of 10kV each and for total of 30 kV along with resistor diode combinational circuit for protection against reversal.

## 8. SIMULATION CIRCUIT AND RESULTS

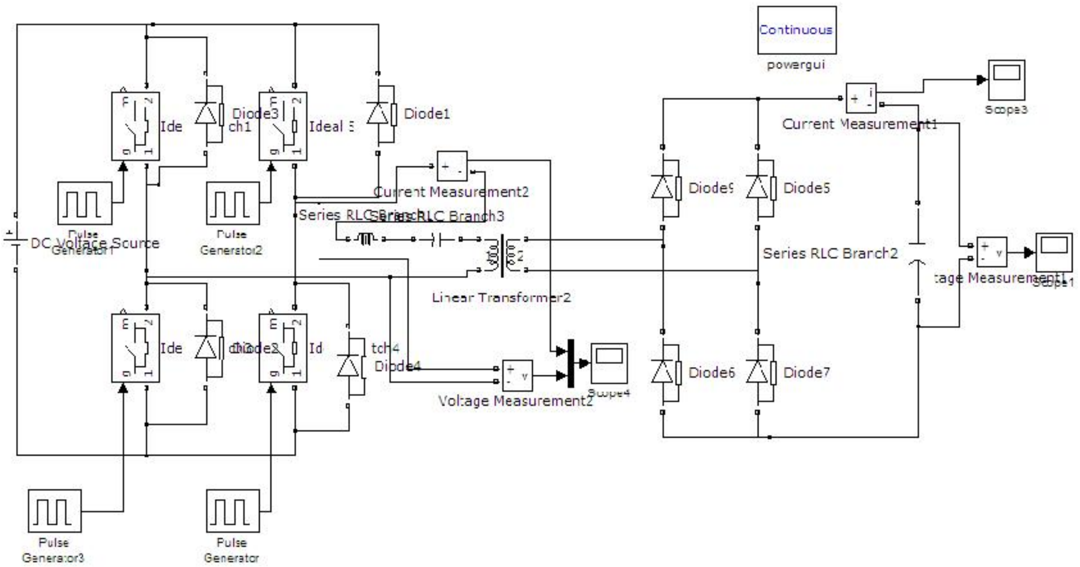



Fig.7 Simulated circuit of CCPS with DC supply

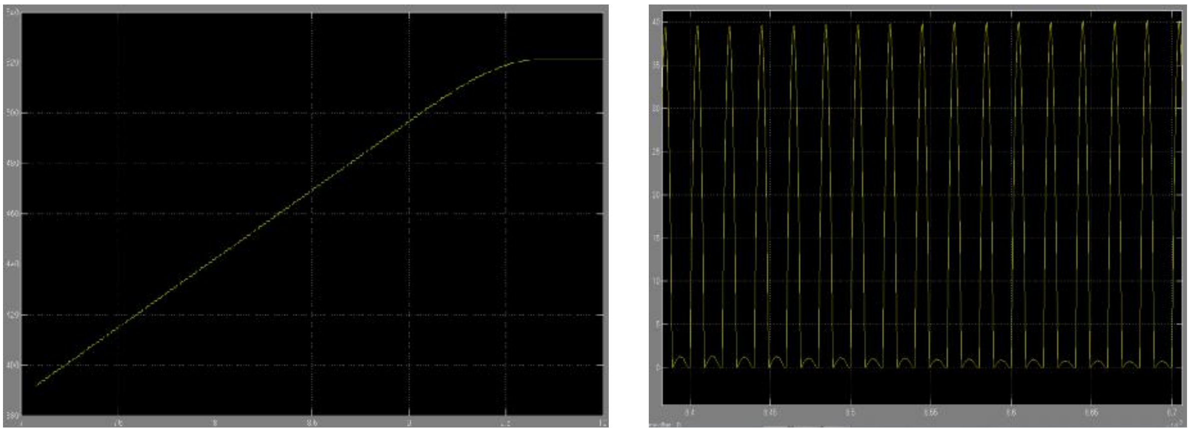
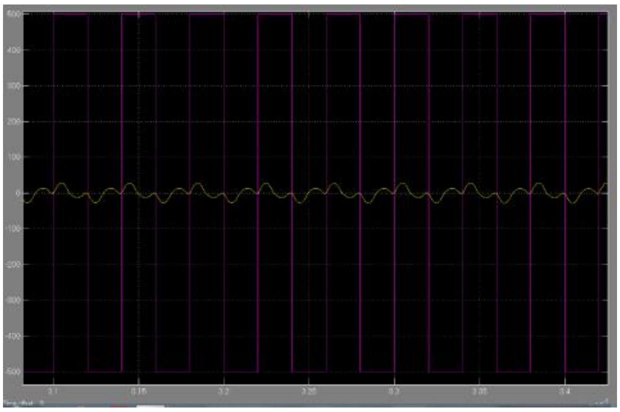


Fig.8. Voltage and current waveforms of a 220µF output capacitor



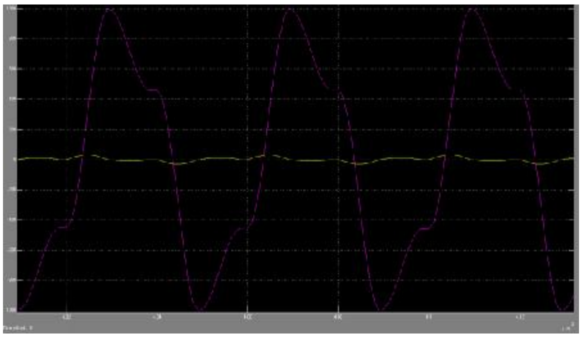


Fig.9.Output voltage form of Inverter and Current wave form Resonant Inductor

Fig 10. Resonant capacitor voltage and resonant current VS time

As it can be seen from the simulation results the charging voltage of capacitor increases at the constant rate (Fig. 8) while the pulsed charging current average value is constant during all cycles.

Fig.9 & 10 shows the current flowing in the series- resonant load Cr and Lr is a series of sinusoids and switches are commutated when the currents are zero.

## 9. CONCLUSION

The series resonant inverter power supply is designed and constructed for the capacitor charging applications. The performance of this capacitor-charging power supply (CCPS) has been evaluated by charging several values of capacitance load at various repetition rates. Future works will needed to improve the system efficiency to reduce the charging time, burst mode charging and higher charging voltages.

## 10. REFERENCES:

[1]. M.H. Rashid, Power electronics: Circuit, Devices, and Applications, [Book], Prentice Hall, Inc, 1988.

[2]. P. K Bhadani, Capacitor charging power supply for laser pulsars using boost circuit, Rev. Sci. Instrum., 1989, 60(4), pp. 605-607.

[3]. A.C. Lippincott, R.M. Nelms, M. Garbi, and E. Strickland, A series resonant converter with constant on-time control for capacitor charging applications.

[4]. Basic Resonant Topologies For Switching Power Supplies, Zacharias K. Vachaparambil Purdue University School of Electrical Engineering

[5]. B. K. Bose, Modern power Electronics: Evolution, Technology and applications,

[6]. Suvarun Dalapati, Chandan Chakraborty, Single phase, full bridge, controlled capacitor charging (CCC) type inverter, Member, IEEE,IEEEInternational Conference on Industrial Technology, 2006.

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