High Voltage Engineering – BEE515A

Module-2

Prepared By,

Mr. Raghavendra L

Associate Professor

Dept of EEE

ATMECE, Mysuru

Course Outline

Course Code	Course Title	Core/Elective	Prerequisite	Contact Hours			Total Hrs/ Sessions
				L	T	P	
BEE515A	High Voltage Engineering	Core	-	3	-	-	40

Course Module Details

Module-2

Generation of High Voltages and Currents: Generation of High Direct Current Voltages, Generation of High Alternating Voltages, Generation of Impulse Voltages, Generation of Impulse Currents, Tripping and Control of Impulse Generators.

Objectives of Today's Session

- Introduction

- Generation of High voltage DC

1. Rectifier circuits
2. Van de Graff generators
3. Cock croft- Walton type high voltage DC set
4. Numericals

Introduction

- Need for HV DC Generation
- High voltage dc require for industry, medical sciences, HVDC transmission etc.

Applications of high voltage DC: Electrostatic precipitator (EPS) in thermal power plant for the ash handling unit, electrostatic paint, cement industry etc.

Applications of high voltage AC: Power transmission

Generation of High voltage DC

1. Rectifier circuits
2. Van de Graff generators
3. Cock croft- Walton type high voltage DC set

1. Rectifier circuits

- Rectifiers are the devices to AC to DC
- Rectifier circuits for producing high DC voltages from AC sources.

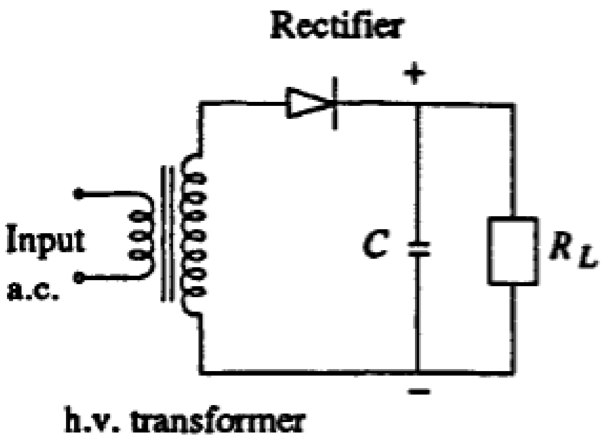
(a) Half wave rectifiers.

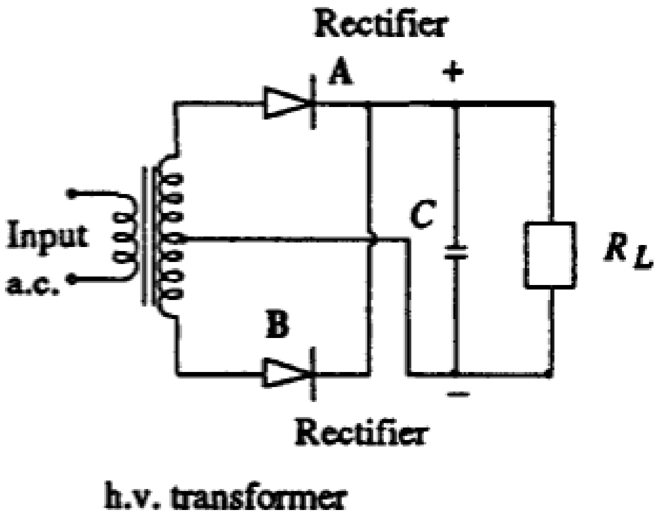
(b) Full wave rectifiers.

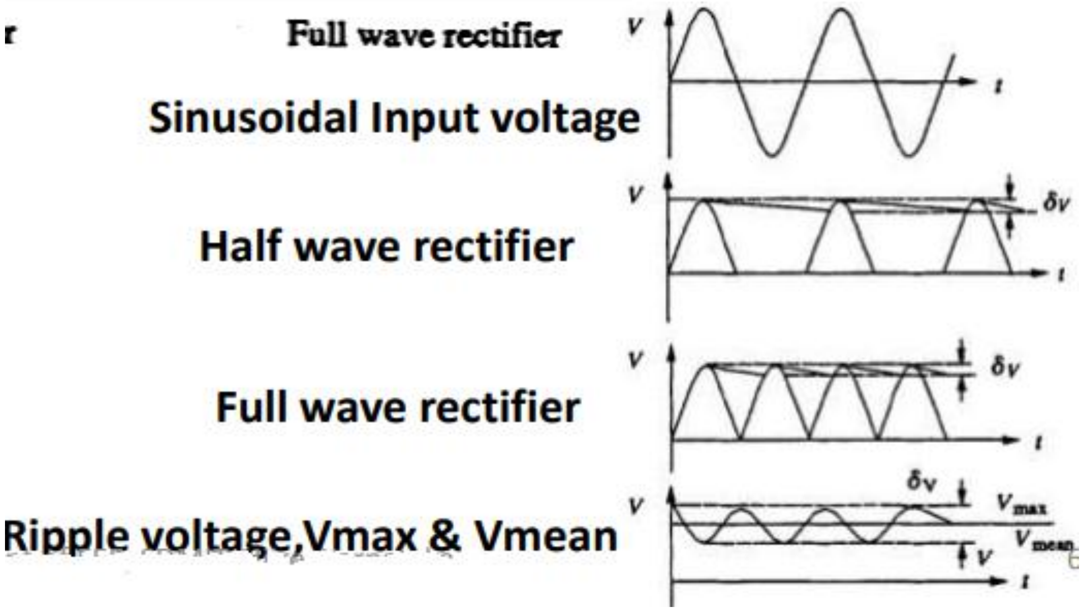
(c) Voltage doubler type rectifiers

1. Rectifier circuits

(a) Half wave rectifiers & b) Full wave rectifiers



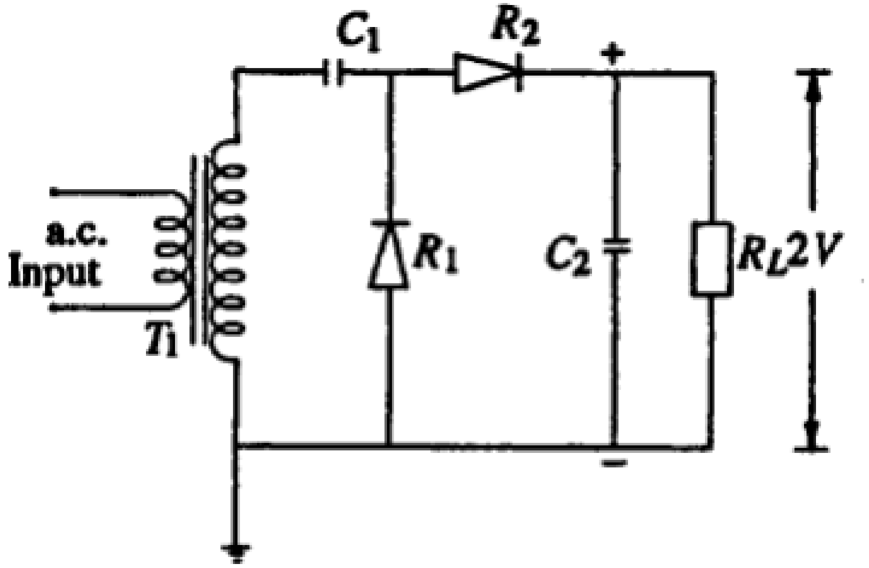




1. Rectifier circuits

c) Voltage doubler type rectifiers

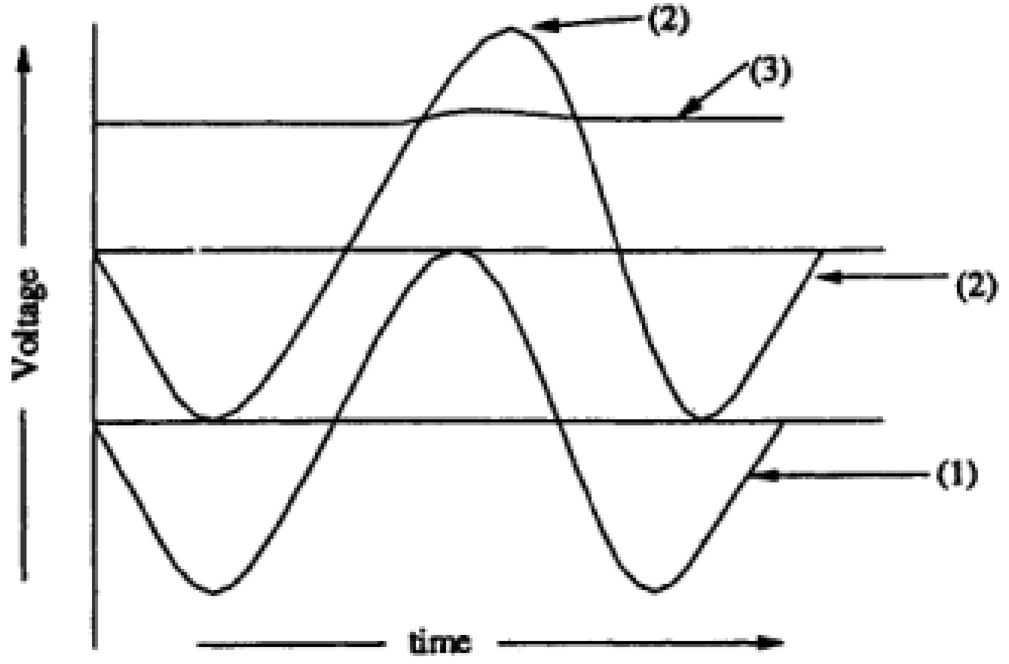
- Both half and Full wave rectifier circuits produce DC voltage less than AC Maximum voltage
- Voltage doubler is used to achieve higher DC voltages



Simple voltage doubler

1. Rectifier circuits

c) Voltage doubler type rectifiers



Waveforms of a.c. voltage and the d.c. output voltage on no-load of the voltage doubler shown in Fig

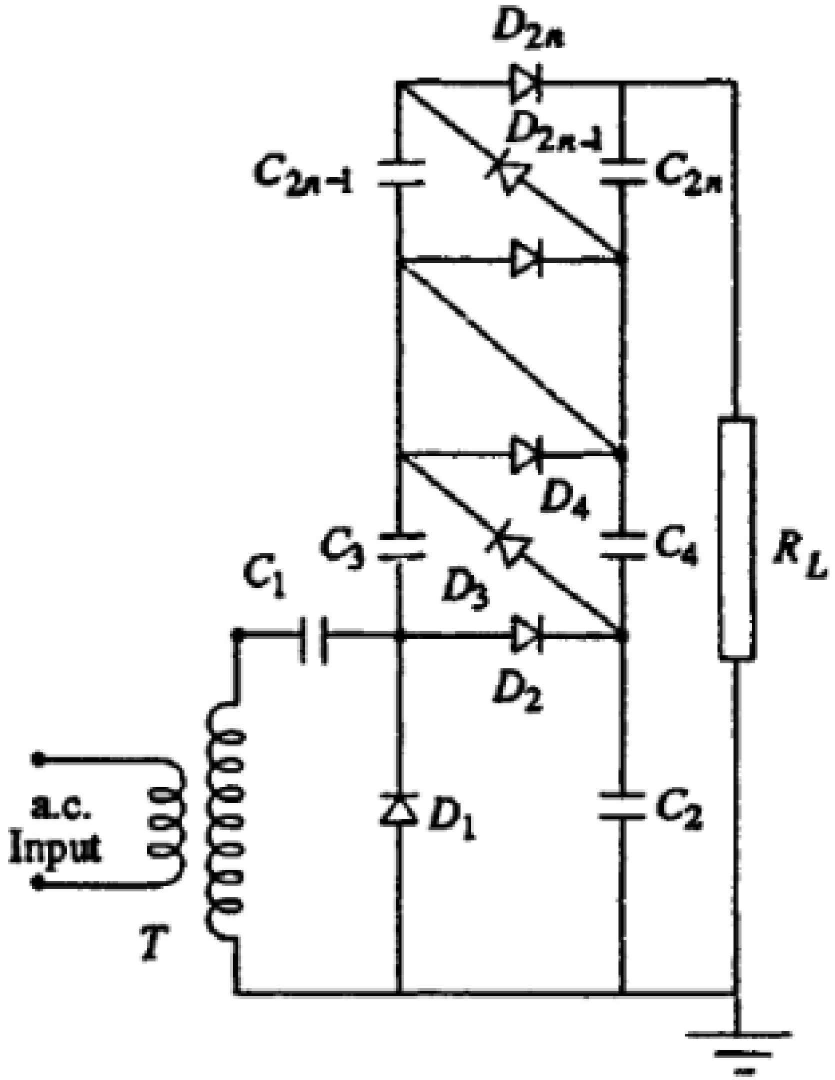
Note:

1. AC input voltage waveform

2.AC output voltage waveform without condenser filter

3.AC Output voltage waveform with condenser filter

Cock croft- Walton type high voltage DC set



D1, D3, D2n-1 conduct: positive half Cycle.

D2, D4, D2n conduct: Negative half cycle.

Numerical

Q.2

An 8 stage Walton Circuit has a capacitance of 0.05μF. The secondary voltage of supply transformer is 125kV at a frequency of 150Hz.If the load current is 5mA, Solve for:

i) % Voltage Regulation

ii) % Ripple

iii) Optimum number of stages for maximum output

iv) Maximum output voltage

Numerical

Q.3

A 10 Stage Cock croft Walton circuit has all capacitors of 0.06μF. The secondary voltage of the supply transformer is 100kV at a frequency of 150Hz. If the load current is 1mA. Solve i) Percentage of Voltage regulation ii) Percentage Ripple iii) Optimum Number of Stages for maximum output voltage iv) The Maximum output voltage

Generation of HV AC Voltage

Need for Cascade transformer

1. Single transformer can be used for the voltage requirement < 300 kV
2. For Higher voltage requirements, Single Unit construction will be difficult
3. May result in Insulation, Transportation and Erection problem and not economical

To Overcome:

1. Several Identical Transformers can be connected in series to Generate HV-AC

Generation of HV AC Voltage

Necessary conditions of HV Transformer for Testing purpose

1. The impedance of the transformer should be generally less than 5%
2. Transformer must be capable of providing the short circuit current for one minute or more depending on the design.
3. In addition to LV and HV winding, “Meter Winding” has to be provided to measure output voltage

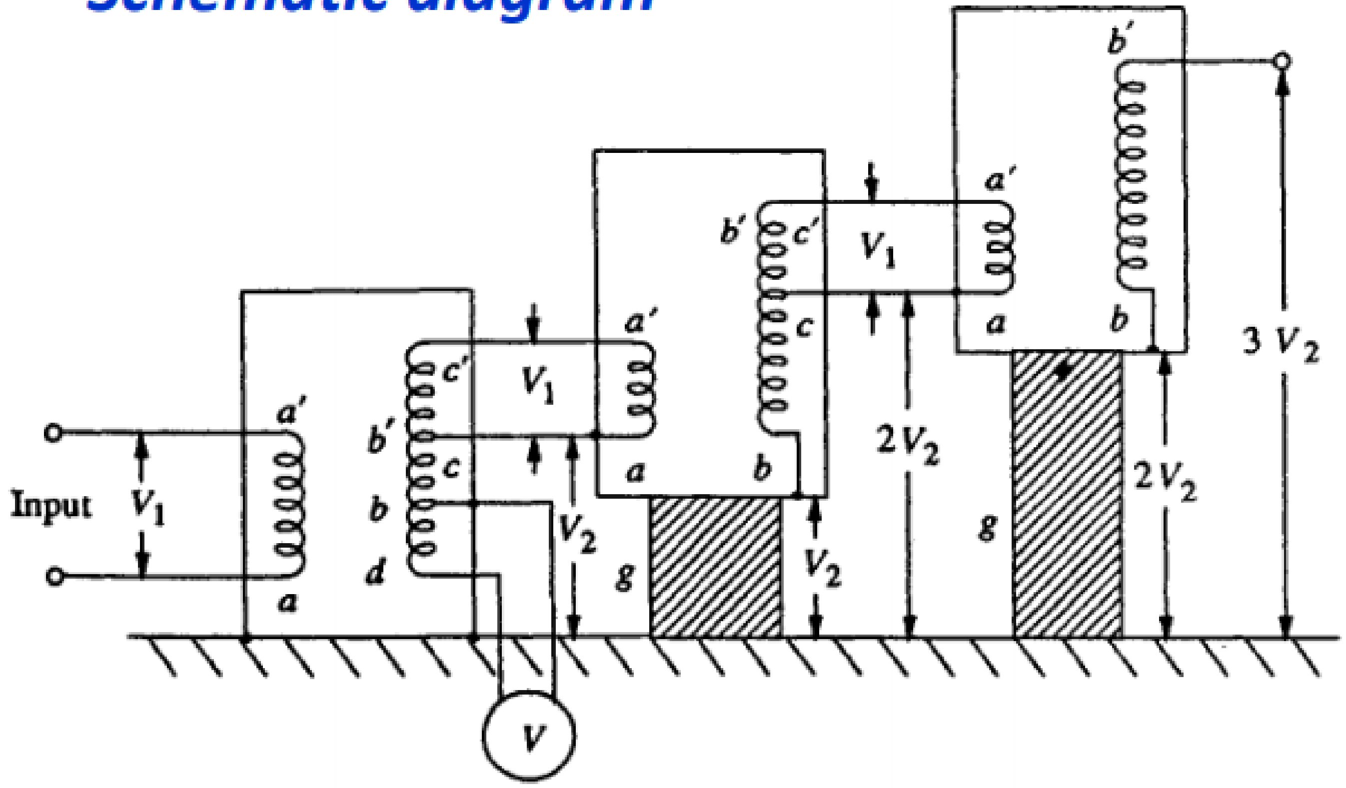
Generation of HV AC Voltage

Necessary conditions of HV Transformer for Testing purpose

1. Testing Transformers are designed specially as they are subjected to Transient Over Voltage during the operation.
2. If Test specimen breaks electrically, It gets short circuited result in severe Transient voltage appears across secondary terminals of Transformer
3. Resulting in High current flow
4. It can be limited by liquid Rheostat/Water Resistor

Cascade Transformer for HVAC Generation

Schematic diagram



V_1 — Input voltage
V_2 — Output voltage
aa' — L.V. primary winding
bb' — H.V. secondary winding
cc' — Excitation winding
bd — Meter winding (200 to 500 V)

Cascade transformer connection (schematic)

Cascade Transformer for HVAC Generation

1. The first transformer is at the ground potential along with its tank.
2. The second transformer is kept on insulators and maintained at a potential of V2, the output voltage of the first unit above the ground.
3. The high voltage winding of the first unit is connected to the tank of the second unit.
4. The low voltage winding of this unit is supplied from the excitation winding of the first transformer, which is in series with the high voltage winding of the first transformer at its high voltage end.
5. The rating of the excitation winding is almost identical to that of the primary or the low voltage winding

Cascade Transformer for HVAC Generation

- Supply to the units can be obtained from a motor-generator set or through an induction regulator for variation of the output voltage.
- Isolating transformers IS1,IS2 and IS3 & are 1:1 ratio transformers
- They are insulated to their respective tank potentials and are meant for supplying the excitation for the second and the third stages at their tank potentials
- Power supply to the isolating transformers is also fed from the same AC input

Cascade Transformer for HVAC Generation

Advantages of cascade connection

1. Natural cooling is sufficient
2. Transformers are light and compact
3. Ease of transportation & assembly
4. Either star or delta connection are possible

Draw backs

1. More space requirement and expensive

Resonant Transformers

1. Resonant transformer, an electrical component which consists of two coils with high Q factor wound on the same core with capacitors connected across the windings to make two coupled LC circuits.
2. Resonant transformer is one of the best choice for high voltage generation which operates on resonance phenomenon ($X_L = X_c$).
3. In resonance condition, the current through test object is very large and that is limited only by the resistance of the circuit.
4. The waveform of the voltage across the test object will be purely sinusoidal

Applications of Resonant Transformer:

This principle is utilized in testing at very high voltages and on occasions requiring large current outputs such as cable testing , dielectric loss measurements, partial discharge measurements, etc

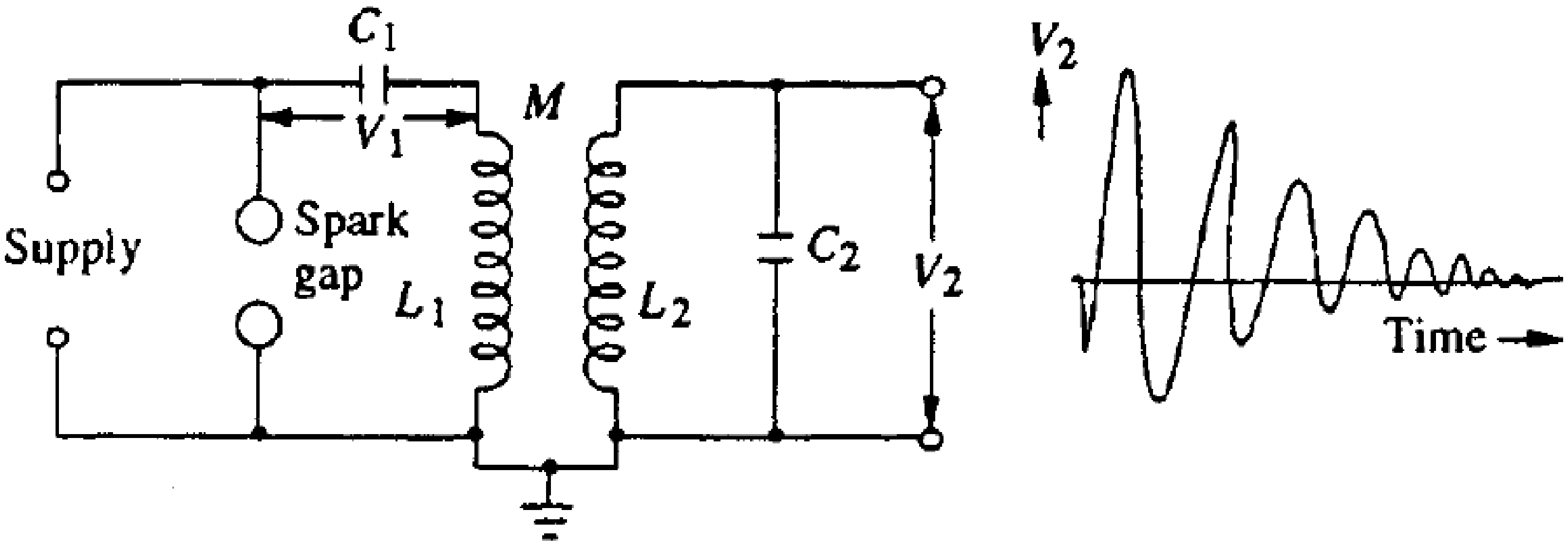
Tesla coil

1. Tesla coil is an electrical resonant transformer circuit designed by inventor Nikola Tesla.
2. It is Used to generate or produce high voltage, low current & high frequency AC power
3. High frequency transformer is required.
4. The commonly used high frequency resonant transformer is the Tesla coil.
5. Tesla coil is a doubly tuned resonant circuit.
6. The primary voltage rating is 10 kV and the secondary may be rated to as high as 500 to 1000 kV.
7. Output frequency range: 50kHz to 1 MHz.
8. Damped oscillations can be obtained by using Tesla Coil.

Applications:

1. X-ray generation, experiment in electrical Lighting etc

Tesla coil



(a) Equivalent circuit (b) Output waveform

Tesla coil

1. The primary is fed from an AC supply through the condenser C1.
2. A spark gap G connected across the primary is triggered at the desired voltage V, which induces high self excitation in the secondary.
3. Spark gap G act as a switch of the circuit.
4. The primary and the secondary windings (L1 and L2) are wound on an insulated former with no core (air-cored) and are immersed in oil. The windings are tuned to a frequency of 10 to 100 kHz by means of the condensers C1 and C2.
5. The output voltage V is a function of the parameters LI, L2, C1, C2 and the mutual inductance M.
6. Usually, the winding resistances will be small and contribute only for damping of the oscillations.

Tesla coil

1. If W1 is the energy stored in C1 and W2 is the energy transferred to C2 and if the efficiency of the transformer is η, then

$$W_1 = \frac{1}{2}\eta C_1 V_1^2 = (\tfrac{1}{2}C_2 V_2^2)$$

$$V_2 = V_1\sqrt{\eta\frac{C_1}{C_2}}$$

Advantages of Tesla coil

- The absence of iron core in transformers and hence saving in cost and size.
- pure sine wave output (Less wave form distortion).
- Slow build-up of voltage over a few cycles and hence no damage due to switching surges
- Uniform distribution of voltage across the winding coils due to subdivision of coil stack into a number of units.

- Tripping and Control of Impulse Generators
- Generation of Impulse Currents

Triggering and Synchronization of the impulse Generator

Why triggering & synchronization?

- Used to Control for charging process of impulse generator
- To integrate the measuring devices.
- CRO is used for measuring and studying the effect of impulse wave on the performance of the insulation of the equipment
- Impulse waves are of shorter duration
- It is necessary that operation of the generator and the oscillograph should be synchronized accurately
- Time sweep circuit is main part of oscillograph
- The time sweep circuit of the oscillograph should be initiated at the time slightly before the impulse wave reaches the deflecting plates
- The impulse generator drives both sweep and triggering circuits

Methods of Triggering and Synchronization of Impulse Generator

1. **Three electrode gap arrangement**
2. **Trigatron gap**

1. Three electrode gap arrangement

1. This is one of the method for triggering and synchronization of impulse generator.

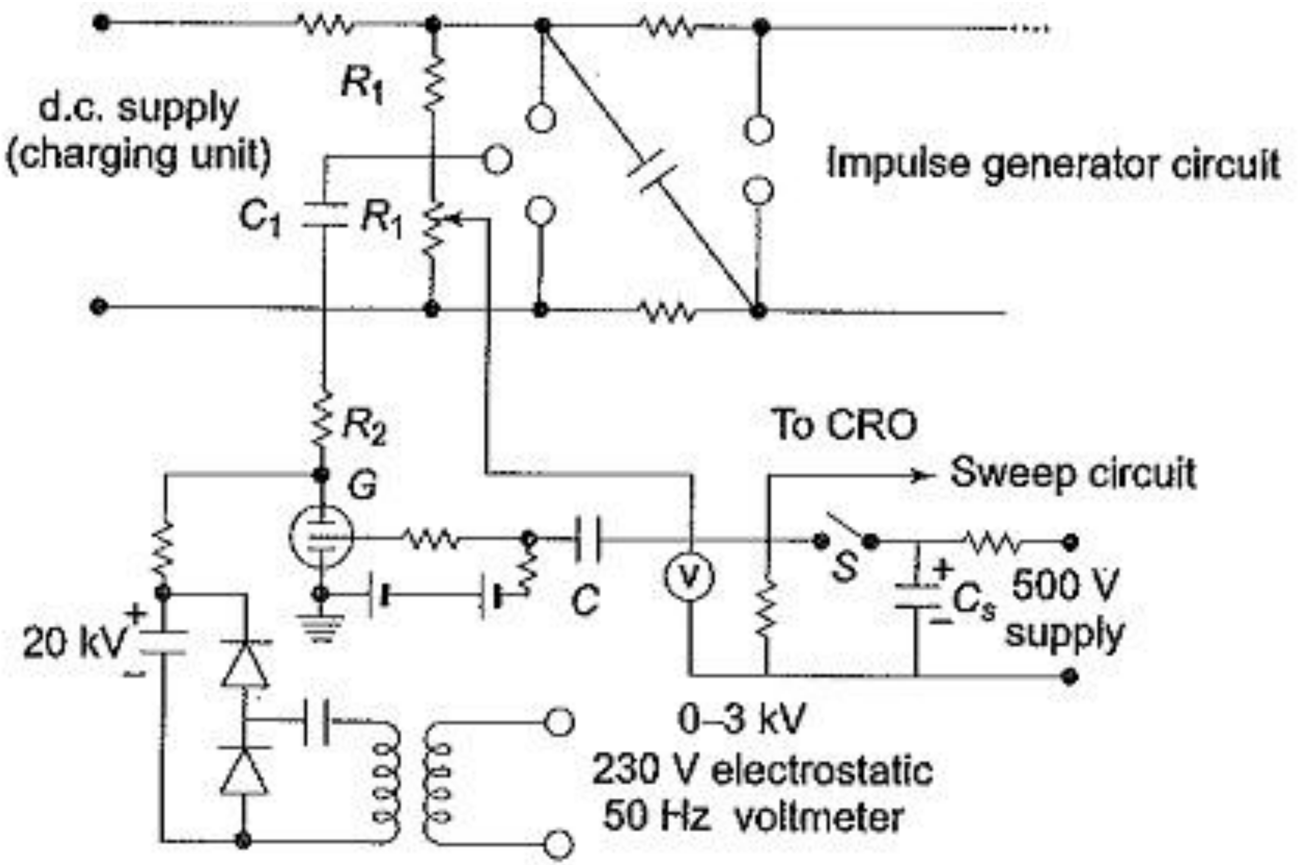
2. The spacing between 2 spheres is adjusted so that two series gap are able to withstand charging voltage of impulse generator.

3. Central sphere is called control sphere.

4. A high resistance is connected between the outer sphere and its centre point is connected to control sphere.

5. The voltage between outer sphere is equally divided between two sphere gap

1. Circuit Diagram of Three electrode gap arrangement



Operation:

1.The switch‘s’ is closed which initiate the sweep circuit of the oscillograph.

2.The same impulse is applied to the thyratron tube.

3.The inherent time delay of thyratron ensure sweep circuit operate first before the starting of high impulse wave.

4. Further delay can be created by using Capacitance-Resistance (R1C1) circuit.

5.The tripping impulse is applied through capacitor C2.

6. During charging period the voltage across thyratron is about +20kV.

Trigatron gap

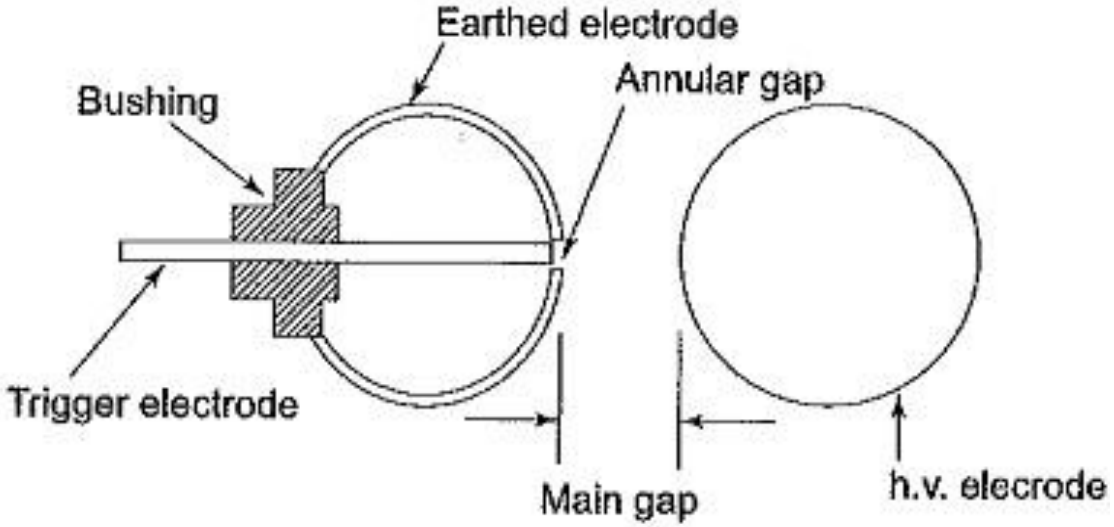
"Trigatron", is used to control the flash over at the spark gaps in order to get a desired magnitude of the output voltage repeatedly.

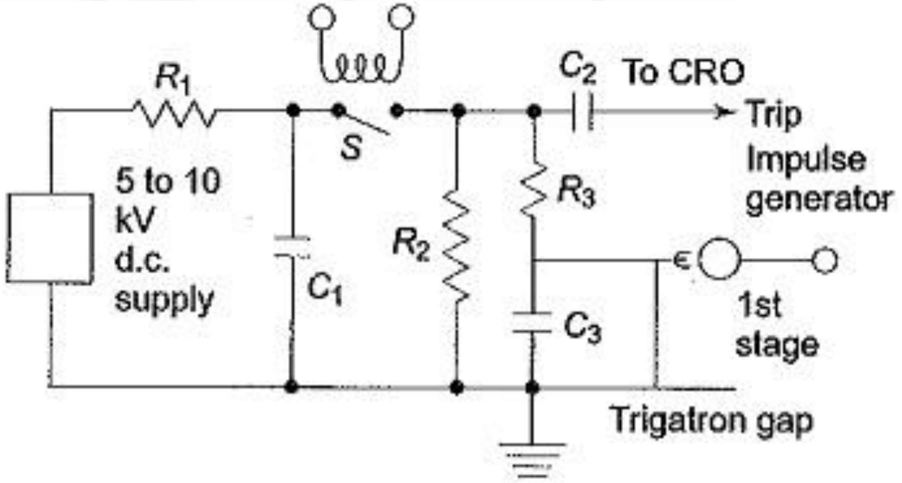
2. Used as ‘First gap of impulse generator’

3. "Trigatron", consists essentially of Earthed Electrode and Trigger Electrode

Trigatron gap

1. A small hole is drilled into earth electrode into which metal rod projects (trigger rod).
2. The annular gap between the rod and the surrounding hemisphere is 1 mm.
3. A glass tube is fitted over rod electrode.
4. The potential of metal electrode and earth electrodes are same.
5. Tripping pulse or control pulse applied between metal and earth electrodes.
6. When the tripping pulse is applied, main field is distorted results in Break down.

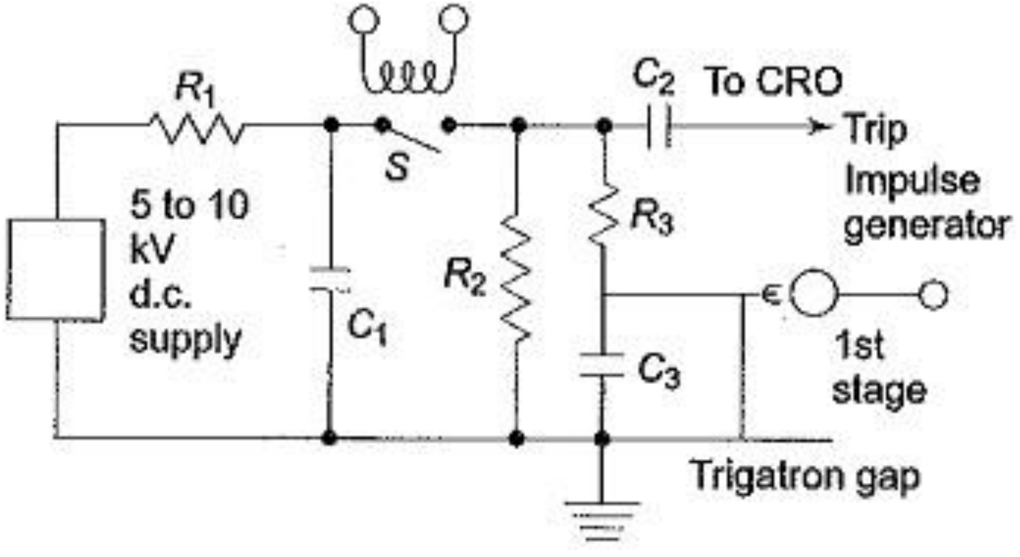




(b) Tripping circuit using a trigatron

Operation of Trigatron gap

- The *capacitor C1* is charged through *high resistance R1*
- Switch S is closed
- *A pulse is applied to a sweep circuit* of the oscillograph through the *capacitor C2*
- Same time capacitor *C3 is charged*
- Triggering pulse is applied through *trigger electrode* (metal rod electrode)
- The *requisite delay* in triggering the generator can be provide by *R3 and C3*



(b) Tripping circuit using a trigatron

THANK YOU