SRI VIDYA COLLEGE OF ENGINEERING & TECHNOLOGY, VIRUDHUNAGAR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

SHORT ANSWER QUESTIONS AND ANSWERS

EE 6701 –HIGH VOLTAGE ENGINEERING

UNIT – 3 GENERATION OF HIGH VOLTAGES AND CURRENTS

PART-A

1. **Give some uses of HVDC.**
   - Electron Microscopes
   - X-Ray units
   - Electrostatic precipitators
   - Particle Accelerators in nuclear physics
2. **What are the applications of impulse current wave forms of high magnitude?**
   - Testing of surge diverters
   - Testing of non-linear resistors
   - Electric arc studies
   - Studies of electric plasmas in high current discharges
3. **Explain the necessity for generating impulse currents and mention the features of impulse current generators**.

   Impulse current generation is required for,
   - Testing of surge diverters
   - Testing of non-linear resistors
   - Electric arc studies
   - Studies of electric plasmas in high current discharges

- For producing impulse currents of large value, a bank of capacitors connected in parallel are charged to a specified value and are discharged through a series *R-L* circuit.
- Waveshapes used in testing surge diverters are 4/10 and 8/20 μ s. The tolerances allowed on these times are ± 10% only.
- Rectangular waves of long duration are also used for testing. The rectangular waves generally have durations of the order of 0.5 to 5 ms, with rise and fall times of the waves being less than ±10% of their total duration.

4. **How are capacitances connected in an impulse current generator?**

   In high impulse current generation, a bank of capacitors connected in parallel are charged to a specified value and are discharged through a series *R-L* circuit.
5. **What are the types of wave form will be available in impulse current generator output?**
   1. Impulse current waves - 4/10 and 8/20 μ s; Tolerances are ± 10%.
   2. Rectangular waves - Durations of the order of 0.5 to 5 ms, with rise and fall times of the waves being less than ±10% of their total duration.

6. Draw a circuit diagram of a simple voltage doubler.

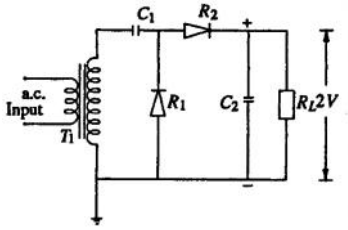

Fig.3.1. Voltage Doubler Circuit

7. Write the expression to find the optimum number of stages and %ripple in a voltage multiplier circuit.

$$n_{optimum} = \sqrt{\frac{V_{\max} fC}{I}}$$

8. What is tesla coil?

Tesla coil is the commonly used high frequency resonant transformer, which is a doubly tuned resonant circuit. The primary and the secondary are wound on an insulated former with no core (air-cored) and are immersed in oil.

9. Draw a simple tesla coil equivalent circuit for generation of high frequency AC high voltage.

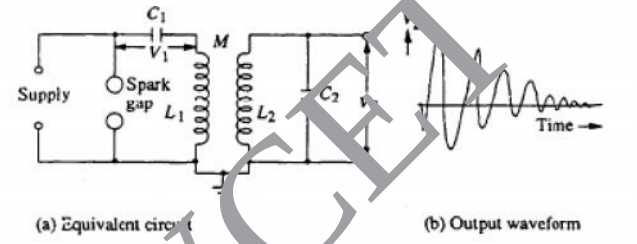

Fig.3.2. Tesla Coil & Output Waveform

10. What are the advantages of high frequency resonant transformer used in HVAC generation?

Advantages of these high frequency transformers are:

i. Absence of iron core saves in cost and size,
ii. Pure sine wave output,
iii. Slow build-up of voltage over a few cycles and hence no damage due to switching surges, and
iv. Uniform distribution of voltage across the winding coils due to subdivision of coil stack into a number of units.

11. Find the percentage ripple in the output voltage produced by an 8 stage Cockcroft-Walton multiplier circuit with a capacitance all equal to 0.05μF. The supply transformer secondary voltage is 125kV at a frequency of 150Hz and the load current is 5mA.

$$\text{Percentage Ripple} = \frac{\delta v \times 100}{2nV_{\max}}$$

$$\text{Ripple Voltage, } \delta v = \frac{I_1}{fC}\frac{n(n+1)}{2}$$

where, No.of Capacitances,n=2 X No.of Stages

$n = 2 \times 8 = 16$

$Load\ Current, I_1 = 5 \times 10^{-3} A$

$$\delta v = \frac{5 \times 10^{-3} \times 16 \times (16+1)}{150 \times 0.05 \times 10^{-6} \times 2} = 90.67 kV$$

$$\%Ripple = \frac{90.67 \times 10^3 \times 100}{2 \times 16 \times 125 \times 10^3} = 2.2667\%$$

12. **A Cockcroft Walton type voltage multiplier has 8 stages with capacitances all equal to 0.05μF. The supply transformer secondary voltage is 125kv at a frequency of 150Hz and the load current is 5mA.Find the optimum number of stages for minimum voltage regulation**.

Maximum Voltage, V_{max}=125kV=125X10^3V

$$n_{optimum} = \sqrt{\frac{V_{\max} fC}{I}}$$

$$= \sqrt{\frac{125 \times 10^3 \times 150 \times 0.05 \times 10^{-5}}{5 \times 10^{-3}}}$$

$$= 13.693 \approx 14\ Stages$$

13. **A tesla coil has a primary winding rated for 10kV with 2μF capacitance on primary side and 1nF capacitance on secondary side. If the energy efficiency is 5%. Calculate the output voltage**.

Output Voltage is given by,

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

$$V_2 = 10 \times 10^3 \times \sqrt{\frac{5}{100} \times \frac{2 \times 10^{-6}}{1 \times 10^{-9}}} = 10 \times 10^3 \times 10$$

$V_2 = 100kV$

14. **A 12 stage impulse generator has a 0.126μF capacitor. The wave front and wave tail resistances are 800ohms and 5000ohms respectively. If the load capacitor is 1000pF, find the front and tail times of the impulse wave produced.**

Generator Capacitance, C_1=(0.126/12)=0.0105 μF

Load Capacitance, C_2=1000X10^{-12}F=0.001 μF

R_1=800Ω and R_2=5000Ω

Front Time, $t_1 = 3R_1C_e = 3R_1\left(\frac{C_1C_2}{C_1 + C_2}\right)$

$$t_1 = 3 \times 800 \times \left(\frac{0.0105 \times 10^{-6} \times 0.001 \times 10^{-6}}{0.0105 \times 10^{-6} + 0.001 \times 10^{-6}}\right) = 2.19 \mu Sec$$

Tail Time, $t_2 = 0.7(R_1 + R_2)(C_1 + C_2)$

$$t_2 = 0.7(800 + 5000)(0.0105 \times 10^{-6} + 0.001 \times 10^{-6})$$

$$t_2 = 46.69 \mu Sec$$

15. What is voltage multiplier circuit?

- Multiplier circuit is a circuit to generate very high d.c voltages from single supply transformers by extending the simple voltage doubler circuits.
- This is simple and compact when the load current requirement is less than one milliampere, such as for cathode ray tubes, etc.
- Multiplier Circuits are designed to overcome the difficulties in higher voltage generation using cascaded voltage multiplier circuits which require too many supply and isolating transformers.

16. Distinguish between electromagnetic and electrostatic machines.

Electromagnetic machines: Current carrying conductors are moved in a magnetic field, so that the mechanical energy is converted into electrical energy.

Electrostatic machines: Charged bodies are moved in an electric field against an electrostatic field in order that mechanical energy is converted into electrical energy.

17. Name the circuits used to generate HVDC.

- High Voltage Half Wave and Full Wave rectifier
- Voltage Doubler and Cascaded Voltage Doubler
- Voltage Multiplier : Cockcroft Walton Multiplier
- Deltatron Circuit
- Electrostatic Machines: a.Van De Graff Generator, b.Electrostatic Generator

18. What are the advantages and disadvantages of Deltatron circuit?

- Can produce high voltages
- Gives high stability
- Small ripple factor
- Fast regulation

19. What are the limitations of Van de graff generator?

- Applicable only in low current applications
- Belt velocity is limited due to vibration
- Difficult to have an accurate grading of fields.
- Maintenance is required due to mechanically stressed parts.

20. What are the advantages and disadvantages of using cascaded transformer?

Advantages:

- Better cooling
- Easy to transport since the units are light and compact
- Construction is identical
- Three phase connection in delta or star is possible for three units
- Available for both indoor and outdoor applications

Disadvantage:

- Costly and requires more space for installation

21. What are impulse wave specifications?

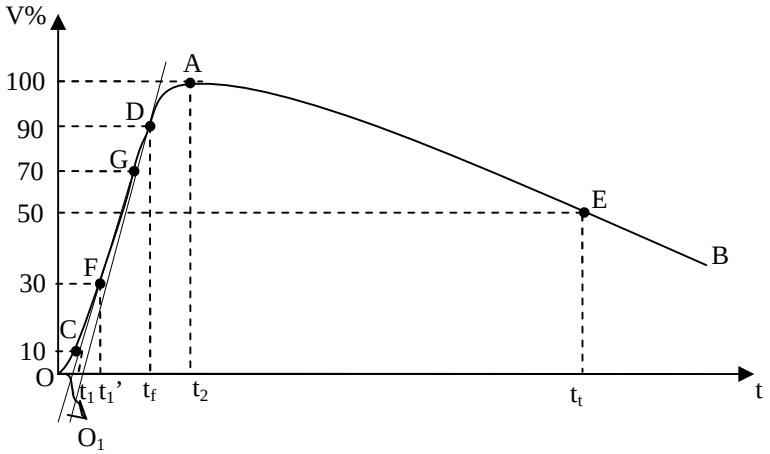

Fig.3.3. Impulse waveform and its definitions

t_f - Front Time (1.2μSec)

t_t – Tail Time (50 μSec)

22. What is the front and tail time of a standard impulse wave? What are the tolerances allowed as per the specifications?

i. **Front Time:** Time required for the wave to rise from 10% to 90% (or 0% to 100%) of the peak value at first instance.
Tolerance: ± 30%

ii. **Tail Time:** Time corresponding to 50% of the peak value during its tail.
Tolerance: ± 20%.

23. How is the wave front and wave tail times controlled in impulse generator circuits?

For a given impulse generator, the generator capacitance C_1 and load capacitance C_2 will be fixed depending on the design of the generator and the test object. Hence, the desired waveshape is obtained by controlling R_1 and R_2.

Front Time, $t_1 = 3R_1C_e = 3R_1\left(\frac{C_1C_2}{C_1+C_2}\right)$

Tail Time, $t2 = 0.7(R_1+R_2)(C_1+C_2)$

24. What is peak value?

The maximum positive deviation of the output with respect to its desired value is known as peak value.

25. Give four components of a multistage impulse generator.

1. D.C. Charging Set
2. Charging Resistors
3. Generator Capacitors and Spark Gaps
   Wave-shaping Resistors and Capacitors

PART-B

1. What is the principle behind the electrostatic method of energy conversion? Explain the construction and operation of vandegraff generator with neat sketch.

2. Starting from basic marx circuit develop the circuit of modern multistage impulse generator and explain its operation. Discuss significance of various parameters.

3. Explain the operation of simple voltage doubler circuit & Cockcroft -Walton voltage multiplier circuit with expression.

4. Explain in detail about cascade transformer connections and resonant transformer to generate high alternating voltage.

5.Explain in detail how the impulse current is generated using capacitor bank & also explain tripping & control of impulse generators with Trigatron gap Arrangement.

6.(i) A ten stage Cockraft-Walton circuit has all capacitors of 0.04 µF. The secondary voltage of the supply transformer is 120 kV at a frequency of 150 Hz. If the load current is 1.2 mA, determine (1) voltage regulation (2) the ripple (3) the optimum number of stages for maximum output voltage (4) the maximum output voltage.

7. A 12 stage impulse generator has 0.126microF capacitors .The wave front & wave tail resistance are 800 ohms and 5000 ohms respectively. For a load capacitor of 1000pF,obtain the front and tail times of the impulse wave produced.

8.A 8 stage impulse generator has 0.12microF capacitors rated for 167 KV.What is the maximum discharge energy ? If it has to produce 1/50 micro second waveform across a load capacitor of 1500 Pico Farad,find the values of front and tail timings.