SNS COLLEGE OF ALLIED HEALTH SCIENCES- COIMBATORE 35

DEPARTMENT : RADIOGRAPHY AND IMAGNG TECHNOLOGY

SUBJECT : GENERAL PHYSICS, RADIATION PHYSICS AND PHYSICS OF DIAGNOSTIC RADIOLOGY

PAPER : PAPER II (UNIT 5 – PHYSICS OF DIAGNOSTIC RADIOLOGY : X-ray TUBE)

TOPIC : 4. TYPES OF GENERATORS

A SINGLE-PHASE X-ray GENERATOR

- A single-phase X-ray generator utilizes a single-phase AC supply as input.
- These generators employ full wave rectification, which utilizes the full potential of the electrical supply.
- Figure shows the full wave rectified single-phase generator and its wave form.
- Both half cycles of the AC is used to produce X-rays. Hence, the X-ray output per unit time is twice as large as that of half wave rectification.
- The voltage across the circuit is supplied by the step up transformer. In the first half cycle (A is negative and B is positive), the electrons will flow from A through the rectifier D1 to the X-ray tube, and return through rectifier D2 to the side B.
- In the next half cycle (A is positive and B is negative), the electrons will flow from B through the rectifier D3 to the filament and return through the rectifier D4 to side A.
- Thus, the four rectifiers produce pulsating DC through the X-ray tube and the voltage across the tube fluctuates from zero to maximum.

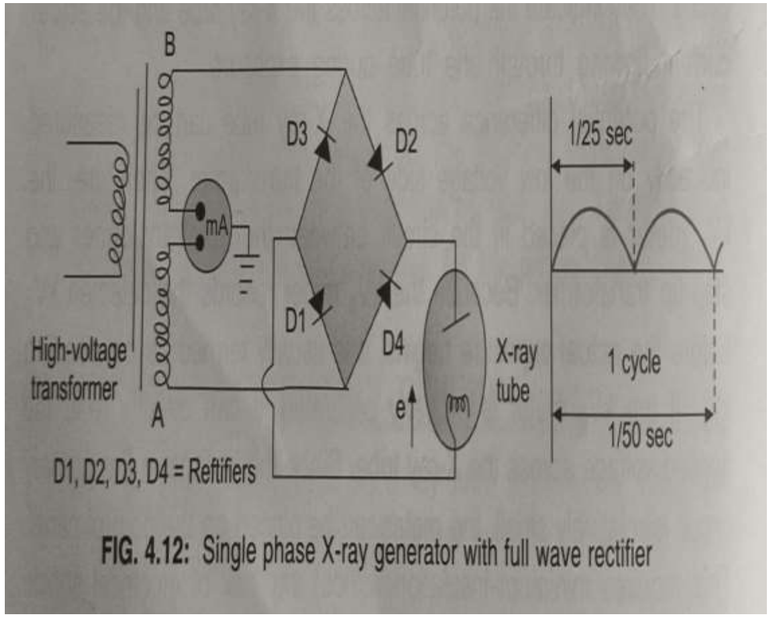


FIG. 4.12: Single phase X-ray generator with full wave rectifier

A SINGLE-PHASE X-ray GENERATOR

- The generated X-rays have 100 short pulses in one second (2 pulses/cycle, frequency 50 cycles/sec). The exposure time for each = X-ray pulse is 1/100 s = 10 ms.
- The AC waveform can be easily switched off, when the voltage in the circuit is at zero level. It is at this point, the primary voltage switches can be opened easily.
- Hence, the timer is calibrated in fractions of seconds in most of the single-phase generators. Most of the X-ray pulses are generated during the peak value of the applied voltage.
- The tube current follows the kV in a nonlinear way below 40 kVp due to space charge effect. A typical single-phase X-ray generator circuit design is shown in the Figure.
- Thus, half wave and full wave rectifier circuits are generating only pulsating potential. The principal disadvantage of pulsed radiation is that a considerable portion of the exposure time is lost while the voltage is in the valley between two pulses.
- This will enable the low energy electron to bombard with the target, by giving heat and low energy X-rays. These X-rays are absorbed in the patient and raise patient dose.

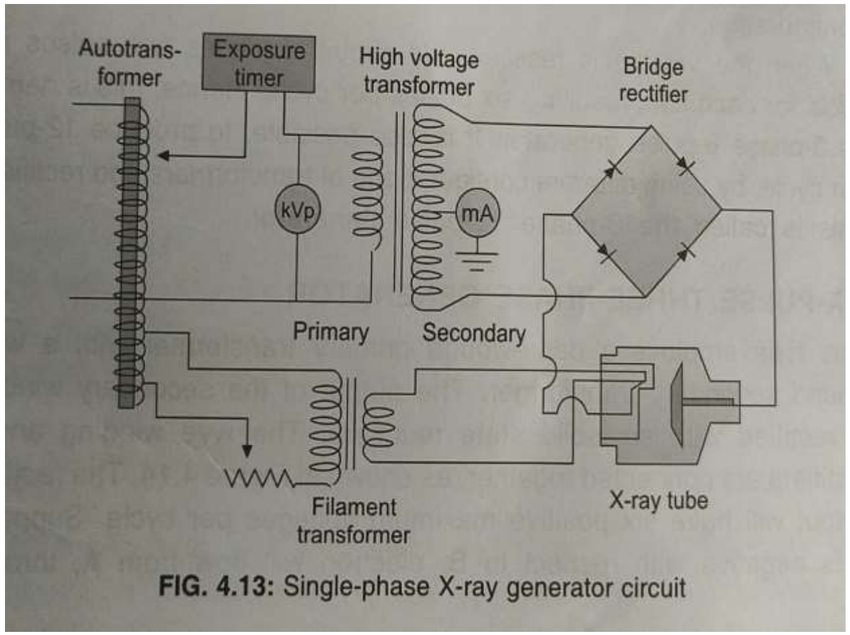


FIG. 4.13: Single-phase X-ray generator circuit

A SINGLE-PHASE X-ray GENERATOR

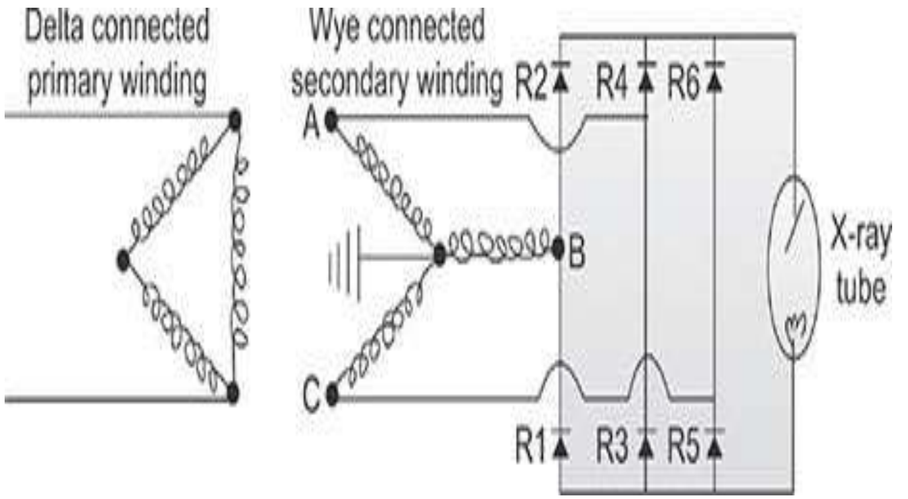
- Hence, there is a need for constant potential circuits, which can give better X-ray output with more penetration.
- To achieve this, a condenser C is connected parallel to the X-ray tube. As a result, sufficient charge may be stored on it to maintain a constant voltage to the X-ray tube.
- Alternatively, three-phase generator can be used to produce constant potential across the X-ray tube..

THREE-PHASE X-ray GENERATOR

- The three-phase X-ray generator uses a 3-phase AC line supply. There are three wires, each with a single phase AC sinusoidal wave. Each wave is out of phase with the other two for one-third (120°) of a cycle.
- A three-phase transformer is used to convert the low voltage AC to high voltage AC. It has three sets of primary and secondary windings.
- These windings are connected in one of the two configurations, namely, delta and wye (star). Generally, the primary windings are of delta configuration and the secondary is connected with wye configuration.
- When the voltage is rectified, the circuit produces two pulses per cycle for each line, resulting six pulses per cycle.
- Hence, this is named as 3-phase 6-pulse generator. It is also possible, to produce 12-pulse per cycle, by using different configurations of transformers and rectifiers. This is called the 3-phase 12-pulse generator.

THREE-PHASE X-ray GENERATOR

- This type employs a delta-wound primary transformer with a wye-wound secondary transformer. The output of the secondary winding is rectified with six solid state rectifiers.
- The wye winding and 6 rectifiers are connected together, as shown in Figure. The rectified output will have six positive maximum voltages per cycle.
- Suppose, A is negative with respect to B, electron will flow from A, through rectifier R3 to the filament of the X-ray tube, then to the target of the tube and through the rectifier R2 and to the coil B.
- During the next half cycle, B would be negative with respective to A and the electron flow from B, through R1, X-ray tube, through R4 to A.
- By this method, full wave rectification of all three phases will produce six pulses per cycle.



THREE-PHASE X-ray GENERATOR

- Since voltage supplied to the X-ray tube never falls to zero, the ripple factor is very low (13.5%), as shown in Figure.
- The ripple factor of an DC voltage is the ratio of the difference between the maximum and minimum voltage divided by the maximum voltage.
- Ripple factor (%) =(Vmax – Vmin) / Vmax × 100
- The ripple factor is the variation of voltage across the X-ray tube expressed as a percentage of the maximum value. For example, a ripple factor of 13.5% means that at 100 kV voltage fluctuates between 86.5 and 100 kV.
- The single phase X-ray generator ripple factor is 100, but in practice it is less than 100, due to capacitance effect of the cable.
- It means that the cable offers capacitance, which smoothens the DC voltage. The ripple factor for high frequency and constant potential generators are 4-15% and < 2%, respectively.

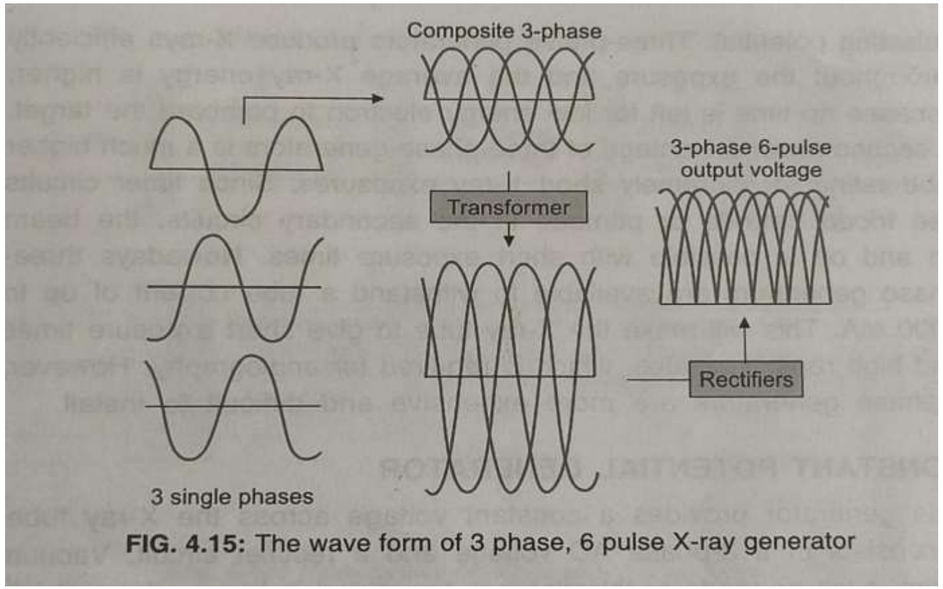


FIG. 4.15: The wave form of 3 phase, 6 pulse X-ray generator

THREE-PHASE X-ray GENERATOR

- Three-phase generators produce a nearly constant potential. This is a major advantage over single-phase generators that produce a pulsating potential.
- Three-phase generators produce X-rays efficiently throughout the exposure and the average X-ray energy is higher, because no time is left for low energy electron to bombard the target.
- A second major advantage of three-phase generators is a much higher tube rating for extremely short X-ray exposures. Since timer circuits use triode, tetrode or pentode in the secondary circuits, the beam on and off is possible with short exposure times.
- Nowadays three- phase generators are available to withstand a tube current of up to 2000 mA.
- This will make the X-ray tube to give short exposure times and high repetition rates, which is required for angiography. However, 3-phase generators are more expensive and difficult to install.

CONSTANT POTENTIAL GENERATOR

- This generator provides a constant voltage across the X-ray tube. It consists of a 3-phase AC voltage and a rectifier circuit.
- Vacuum tubes, such as triode or tetrodes are connected in line on the cathode side and on the anode side (Fig)
- They control the kV and exposure time, on the high voltage side of the transformer. A comparator circuit measures the difference between the set kV (console) and the actual KV in the circuit, and adjusts the grid of the triode or tetrode tubes.
- These vacuum tubes provide extremely fast kV and mA regulation and exposure timing, so that flat output waveform is obtained.
- This generator also gives higher average X-ray energy, with shortest exposure time (1 ms). But these generators are bulky, higher cost, and involves inefficient power consumption.

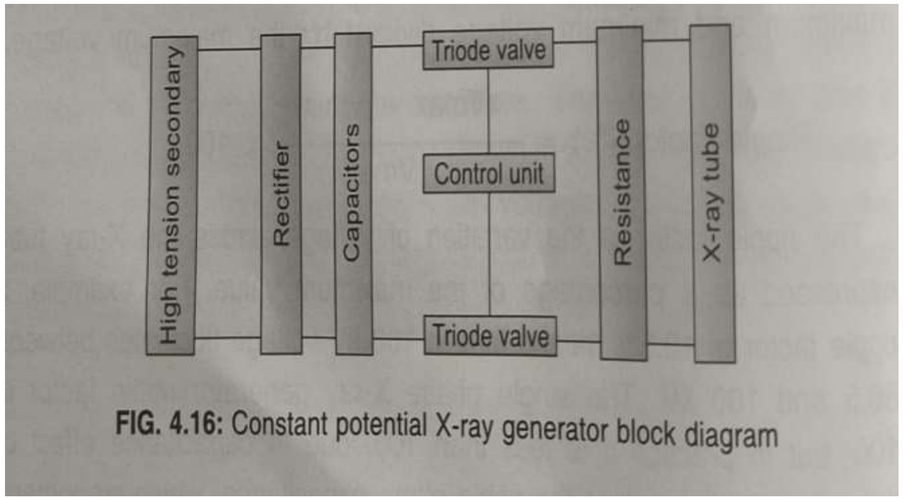


FIG. 4.16: Constant potential X-ray generator block diagram

HIGH FREQUENCY GENERATOR

- A high-frequency generator provides high-frequency AC waveform up to 50,000 Hz.
- After rectification and smoothing, it will provide a constant voltage supply. Both single phase and three phase line supply can be used in high frequency generator.
- They provide accurate kV and mA with reproducibility. The high frequency generator transformers are efficient, compact and less costly.
- A single-phase or three-phase AC line supply is rectified and smoothened, before fed into an inverter circuit (Fig).
- The inverter gives a high frequency AC waveform, which is fed into the transformer.
- The transformer provides a fixed high voltage with low current. After rectification and smoothening, it is fed to the X-ray tube.
- At the same time two capacitors accumulate charges from the smoothened voltage.

HIGH FREQUENCY GENERATOR

- When the X-ray tube is switched on, feedback circuits measure the difference between the set KV and the available KV.
- The comparator circuit generates trigger pulses, whose frequency is proportional to the difference of set and available KV.
- Based on the trigger pulse, the inverter produce corresponding output pulse.
- This is passed on to the transformer for further change in its output.
- The capacitor which has stored charges, increase the potential difference across the X-ray tube.
- Thus, the desired kV is obtained across the X-ray tube.

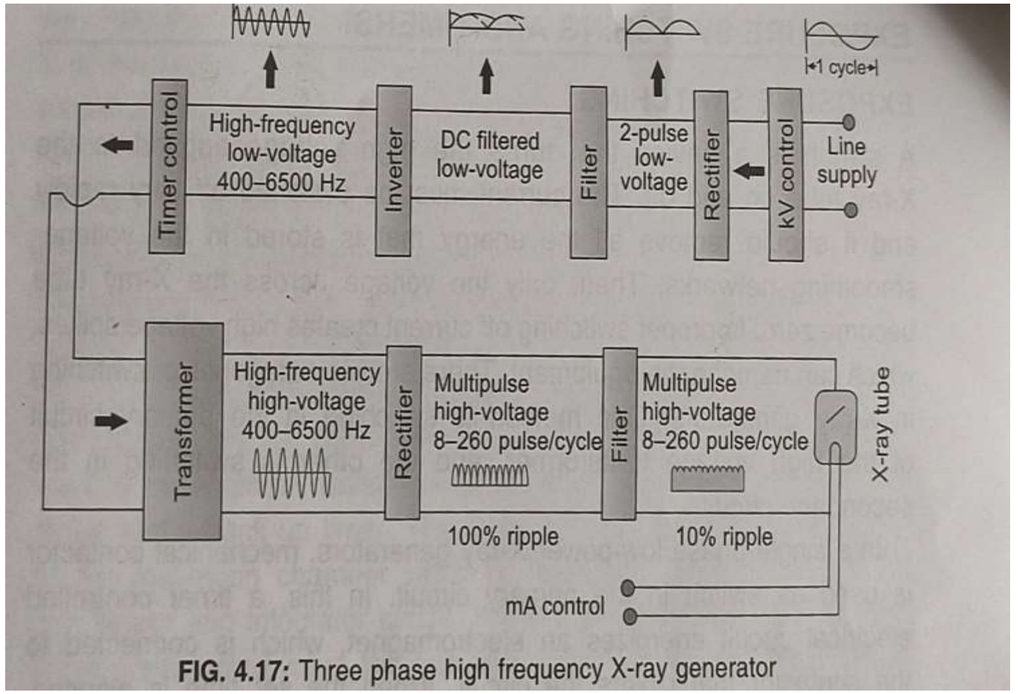


FIG. 4.17: Three phase high frequency X-ray generator

HIGH FREQUENCY GENERATOR

- The feedback pulse rate depends upon the tube current and there is no need of autotransformer for kV control.
- The mA is also controlled similar to that of kV. If the available mA is low, the trigger pulse boosts the power to the filament and increase thermionic emission.
- The feedback circuit also eliminates the need for space charge compensation circuits and also correct for filament aging effects.

INTERROGATIONS

1. The difference between kV and mA circuit in X-ray tube
2. What dose the kVp and mA control in the X-ray tube ?
3. How dose kV and mAs effect image quality ?

INTERROGATIONS

1. What is the X-ray Generator ?
2. What are the basic principles of X-ray generator ?
3. What is three – phase X-ray generator ?

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THANK YOU