

# تقنيات أجهزة التصوير التقليدية/ الكورس الاول

## HIGH-VOLTAGE GENERATORS



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Second Stage

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## (INTRODUCTION)

The high-voltage generator in X-ray machines is responsible for converting low-voltage electrical input into the high voltages necessary to accelerate electrons across the X-ray tube. Typical ranges are 25–150 kVp. The generator ensures stable, reliable, and controlled voltage, which directly determines both the quality and safety of X-ray production.

## (TRANSFORMER BASICS)

Transformers are electromagnetic devices that change the magnitude of alternating voltage through electromagnetic induction. In radiology, they are used to adjust the voltage for different parts of the circuit: the step-up transformer increases voltage to kilovolts for tube operation, while the step-down transformer lowers voltage for the filament circuit.

## (STEP-UP TRANSFORMER)

The step-up transformer is crucial for providing the kilovoltage required between the cathode and anode of the X-ray tube. With a primary coil of fewer turns and a secondary coil of many turns, it increases the voltage by a factor corresponding to the turns ratio. This voltage defines the energy of the produced X-rays and affects penetration and contrast.

## (STEP-DOWN TRANSFORMER)

The step-down transformer reduces line voltage to approximately 6–12 V, which is used in the filament circuit. This current heats the filament to release electrons by thermionic emission. The magnitude of filament current ultimately determines tube current (mA).

## (VOLTAGE RECTIFICATION)

Rectification converts alternating current (AC) into direct current (DC), as the X-ray tube requires electrons to flow in one direction only—from cathode to anode. Without rectification, alternating polarity would cause inefficient and damaging reverse electron flow.

## (HALF-WAVE RECTIFICATION)

In half-wave rectification, only one half of the AC cycle is used for X-ray production. The other half is blocked, resulting in pulsating radiation output. This method is inefficient and produces images with more fluctuations in density. It is now largely obsolete but important historically.

## (FULL-WAVE RECTIFICATION)

Full-wave rectification inverts the negative half of the AC cycle, allowing both halves to be used for X-ray production. This doubles the output efficiency compared to half-wave rectification and produces smoother radiation, improving image consistency.

## **(SINGLE-PHASE POWER)**

Single-phase power systems deliver voltage in pulses, producing radiation output that fluctuates significantly between peaks and valleys. This variability results in lower image quality and increased patient dose due to less efficient X-ray production.

## (THREE-PHASE POWER)

Three-phase power reduces voltage fluctuations by overlapping three alternating currents offset by 120 degrees. This ensures a nearly constant voltage across the tube, yielding higher radiation output, shorter exposure times, and improved image quality compared to single-phase systems.

## (HIGH-FREQUENCY GENERATORS)

Modern high-frequency generators convert incoming power into very high frequency (20,000 Hz or more), then rectify and smooth it to nearly constant DC voltage. These systems provide stable output, reduce exposure time, minimize patient dose, and produce superior image quality.

## (X-RAY CIRCUITS)

The X-ray circuit consists of two major parts: the filament circuit (controls electron production at the cathode) and the high-voltage circuit (accelerates electrons to the anode). Together, they control the quantity (mAs) and quality (kVp) of the X-ray beam.

## (FILAMENT CIRCUIT)

The filament circuit uses step-down transformers to supply high current at low voltage to heat the cathode filament. This heating causes thermionic emission, releasing electrons that will be accelerated in the main tube current. Precise control of filament current is crucial for reproducible exposures.

## (EFFECT OF WAVEFORM ON RADIATION OUTPUT)

The waveform of the applied voltage greatly affects X-ray production. Single-phase systems have large ripples in output, producing inconsistent beams. Three-phase and high-frequency generators reduce ripple, providing nearly constant voltage, higher X-ray intensity, and better image quality with reduced patient dose.

## (SUMMARY)

High-voltage generators include transformers, rectifiers, and different phase power designs. Modern systems with high-frequency generators minimize ripple and maximize efficiency. Understanding these electrical components is essential to appreciating their effect on radiation output and diagnostic image quality.

# QUIZ

Q1 (MCQ): WHICH COMPONENT IN THE X-RAY GENERATOR INCREASES THE VOLTAGE TO THE KILOVOLT LEVEL REQUIRED FOR ELECTRON ACCELERATION ACROSS THE TUBE?

- A) STEP-DOWN TRANSFORMER                      B) STEP-UP TRANSFORMER                      C) RECTIFIER                      D) FILAMENT CIRCUIT

Q2. EXPLAIN WHY RECTIFICATION IS NECESSARY IN THE X-RAY CIRCUIT, AND DESCRIBE THE CONSEQUENCES IF RECTIFICATION FAILS.

Q3. COMPARE SINGLE-PHASE, THREE-PHASE, AND HIGH-FREQUENCY GENERATOR SYSTEMS IN TERMS OF VOLTAGE RIPPLE, RADIATION EFFICIENCY, AND IMAGE QUALITY.

Q4. A RADIOGRAPHER SELECTS 80 KVP AND 200 MA. DESCRIBE THE ROLE OF THE FILAMENT CIRCUIT AND THE HIGH-VOLTAGE CIRCUIT IN PRODUCING THE X-RAY EXPOSURE UNDER THESE SETTINGS.

Q5. DISCUSS HOW THE VOLTAGE WAVEFORM AFFECTS BOTH THE PATIENT DOSE AND THE DIAGNOSTIC QUALITY OF RADIOGRAPHS, WITH EXAMPLES OF SINGLE-PHASE VS HIGH-FREQUENCY GENERATORS.

Any questions?

*Thank  
You*