Ministry of Higher Education and Scientific Research

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College of Technology And Health Sciences

Radiological Equipment Techniques

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Lecture 3 : x_ray High voltage generators

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X_ ray High voltage generators

X-ray high-voltage generator means a device which transforms electrical energy from the potential supplied by the x-ray control to the tube operating potential. The device may also include means for transforming alternating current to direct current, filament transformers for the x-ray tube(s), high-voltage switches, electrical protective devices, and other appropriate elements.

The high-voltage generator of an x-ray imaging system is responsible for increasing the output voltage from the autotransformer to the kVp necessary for x-ray production.

 For example, imaging a knee using a single-phase generator requires more mAs than imaging a knee using a three-phase generator.

High-Voltage Transformer

The high voltage transformer is a step-up transformer. The turns ratio of a high-voltage transformer is usually between 500:1 and 1000:1. Because transformers operate only on alternating current, the voltage waveform on both sides of a high-voltage transformer is sinusoidal.

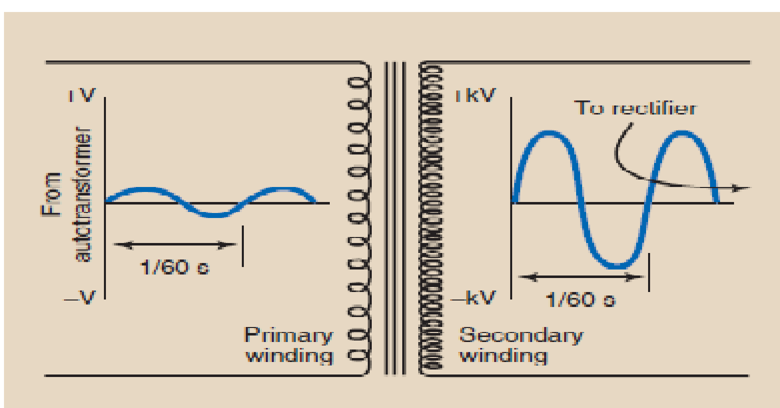

Figure 1

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Voltage Rectification

- An x-ray tube requires a ***direct current (DC) because electrons flow in one direction***.
- ***The electronic device that allows current flow in only one direction is a rectifier.***
- The secondary voltage of the high-voltage transformer must be rectified.
- Rectification is accomplished with ***diodes***.
- Rectifiers are located ***in the high-voltage section***.

Half-Wave Rectification

The inverse voltage is removed from the supply to the x-ray tube by rectification.

During the positive portion of the AC waveform, ***the rectifier allows electric current to pass through the x-ray tube***.

During the negative portion of the AC waveform, however, ***the rectifier does not conduct, and thus no electric current is allowed***.

The resultant electric current is a ***series of positive pulses*** separated by gaps when the negative current is not conducted.

Half-wave–rectified circuits ***contain zero, one, or two diodes***. The x-ray output from a half-wave high-voltage generator ***pulsates, producing 60 x-ray pulses each second***

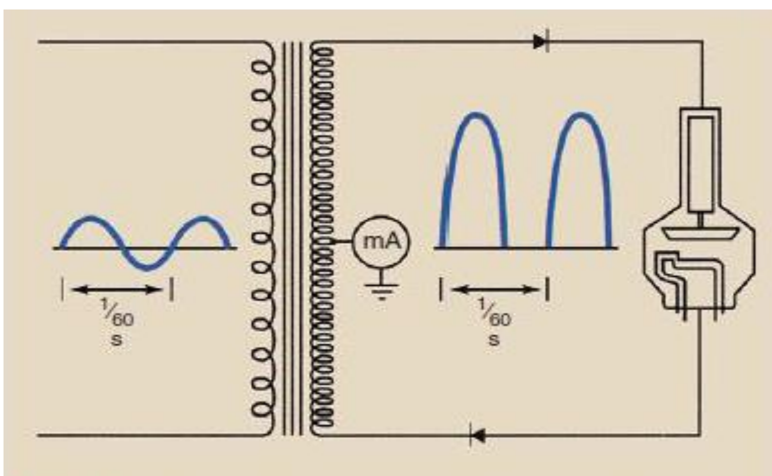

Figure 2

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Full-Wave Rectification.

One shortcoming of half-wave rectification is that it wastes half the supply of power. It also requires twice the exposure time. It is possible, however, to devise a circuit that rectifies the entire AC waveform. This form of voltage rectification is called full-wave rectification.

Full-wave–rectified x-ray imaging systems contain at least four diodes in the high-voltage circuit, usually arranged as in next figure:

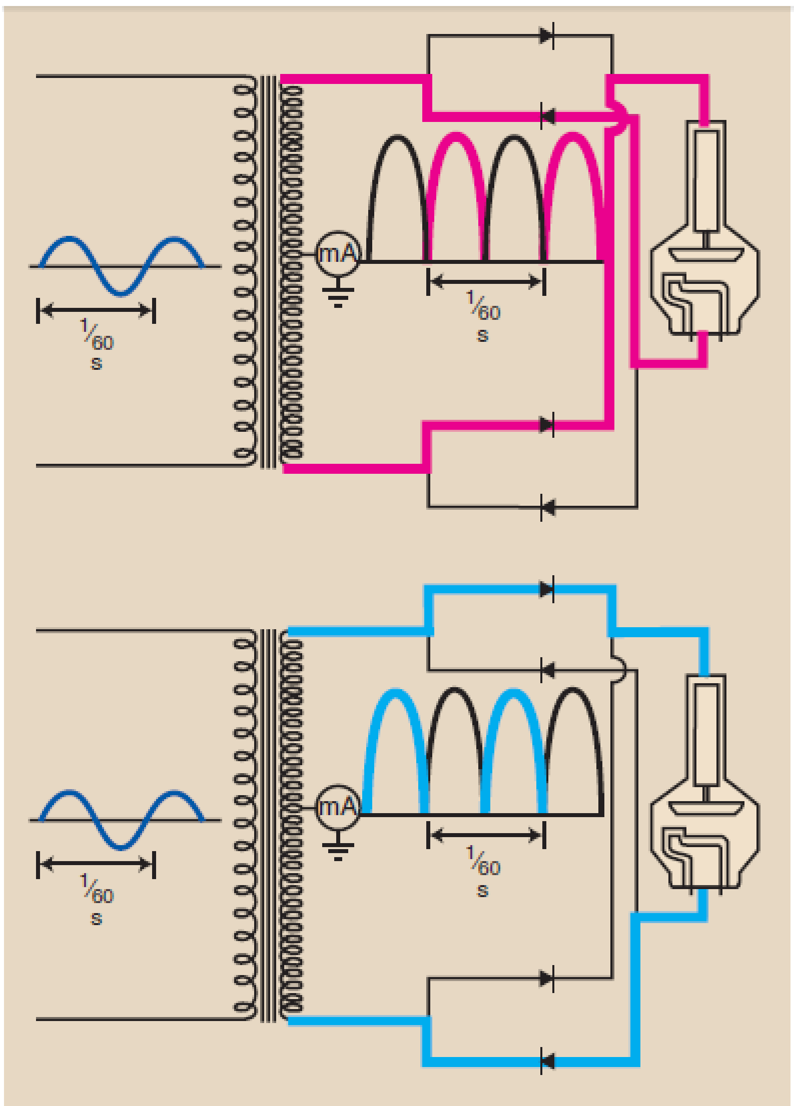

Figure 3

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Single-Phase Power

Single-phase power results in a pulsating x-ray beam. This is caused by the alternate swing in voltage from zero to maximum potential 120 times each second.

 The principal disadvantage of pulsed radiation is results in a longer exposure time. These lower energy X-rays are absorbed in the patient and greater patient dose.

 With full-wave rectification, they produce a voltage ripple of 2 pulses per hertz or 120 pulses per second.

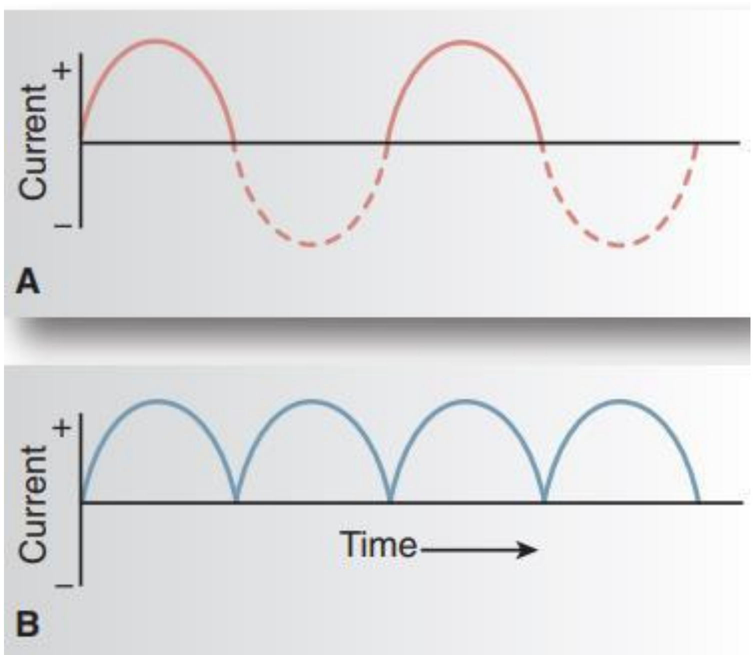

Figure 4 Single-phase power: (A) incoming line; (B) full-wave rectified

In figure below (A) X-Ray are not powerful enough for diagnostic purpose these are when current drop to zero
In figure below (B)shows the kilovolt peak and the root mean square (rms), (rms) is similar to the average voltage for the cycle

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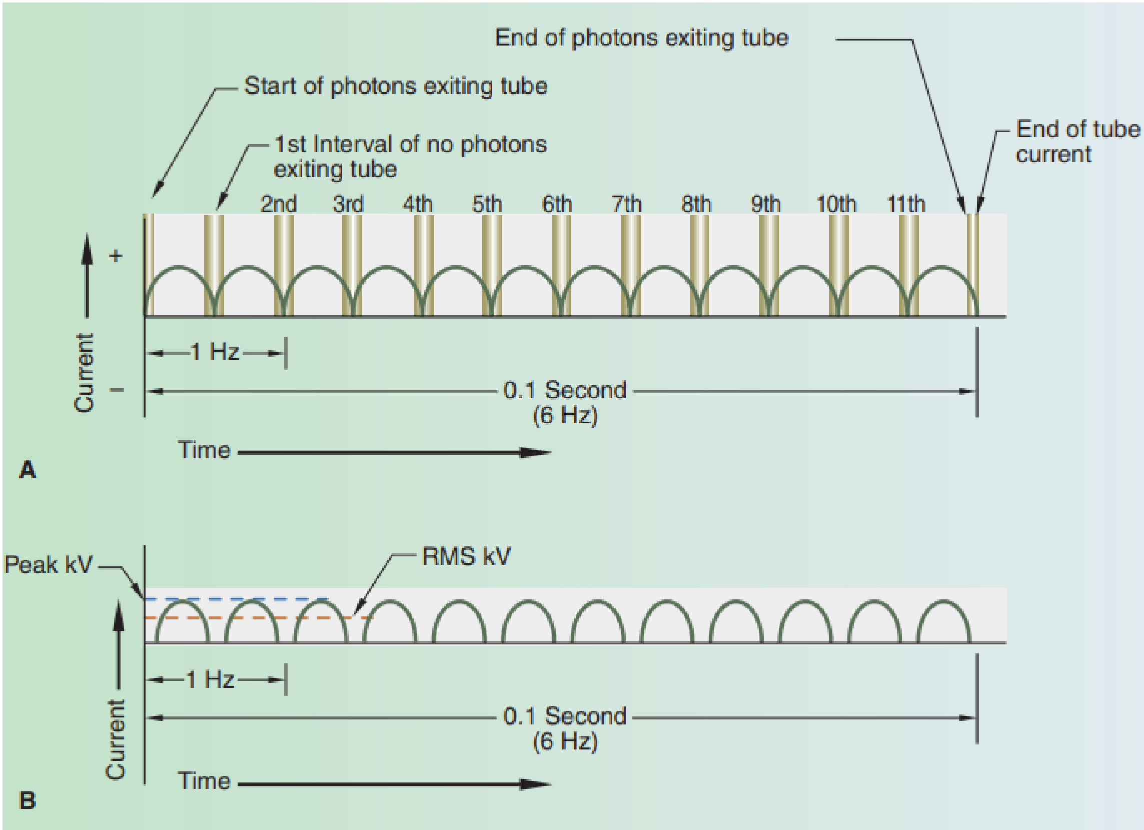

(Figure 5) The difference between the photons produced inside the x-ray tube during an exposure and the photons emitted from the tube during the same exposure.

 With the 60-Hz line, an exposure of 0.1 second with a single-phase full-wave rectified unit results in 12 intervals of no photon production.
 The x-rays produced when the single-phase voltage waveform has a value near zero are of little diagnostic value because of their low energy; or they do not contribute to the radiographic image because they are absorbed before reaching the image receptor. The voltage ripple for single-phase generators is said to be 100% because there is total variation in the voltage waveform, from peak voltage to zero voltage.

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 The term voltage ripple describes voltage waveforms in terms of how much the voltage varies during x-ray production.

Three-Phase Power

Multiphase power is produced by the generator and is the common form in which power is supplied to users by power companies. With three-phase power, multiple voltage waveforms are superimposed on one another, consequently, the voltage applied across the x-ray tube is nearly constant, never dropping to zero during exposure.

 The three-phase X-ray generator uses a 3-phase AC line supply for the purpose of creating more pulsations per unit time. This effectively reduces voltage ripple and increases the efficiency of x-ray production

 With full-wave rectification is applied to 3Φ current, it produces a voltage ripple of 6 pulses per hertz (three-phase, six-pulse (3Φ 6P) waveform)

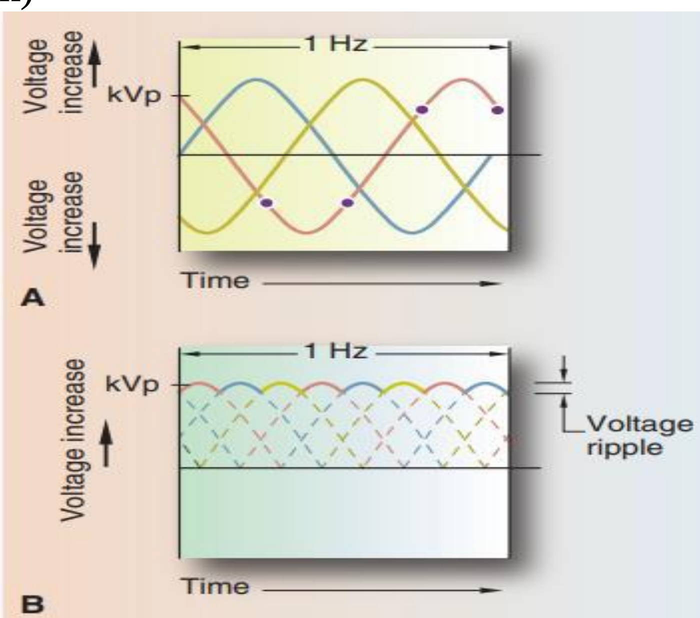

Figure 6 :(A) Three-phase incoming-line current. (B) Full-wave rectified three-phase current

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For three-phase generators, the voltage ripple is 13% for the 6-pulse mode and 4% for the 12-pulse mode.

 Three-phase power is a more efficient way to produce x-rays than is single-phase power

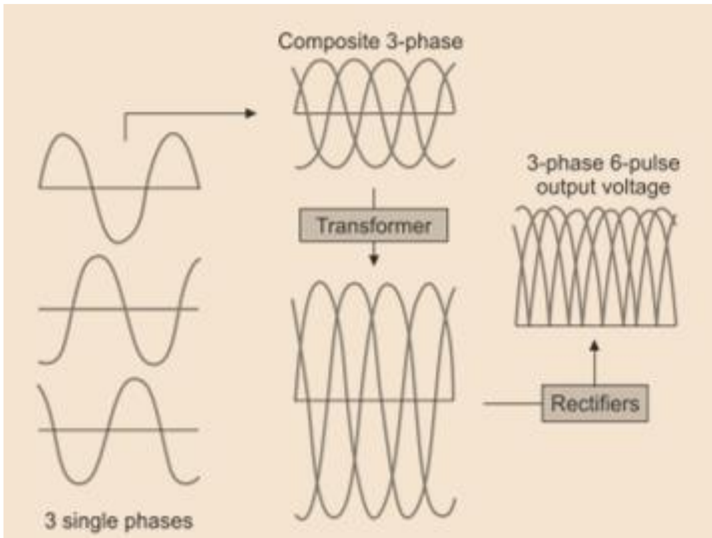

Figure 7 : The wave form of 3 phase, 6 pulse X-ray generator

The ripple factor of an DC voltage is the ratio of the difference between the maximum and minimum voltage divided by the maximum voltage.

$$\text{Ripple factor (\%)} = \frac{(V_{max} - V_{min})}{V_{max}} \times 100$$

 Less voltage ripple results in greater radiation quantity and quality

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High-Frequency Generator

High-frequency generators use AC and DC power converters to change the incoming-line voltage frequency from 60 Hz to thousands of Hz, and then is transferred to high voltage.

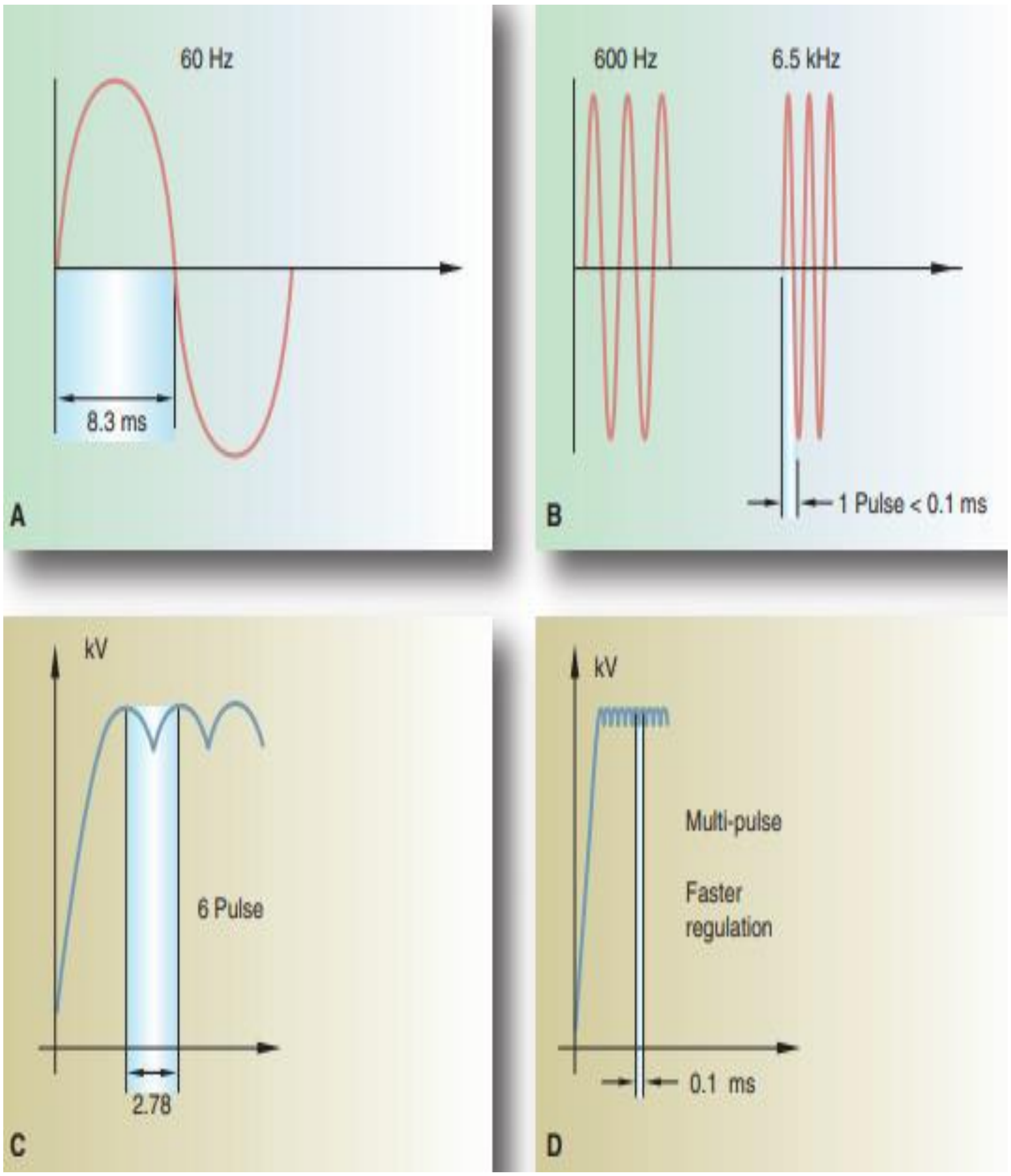

Figure 8 : High-frequency voltage waveform.

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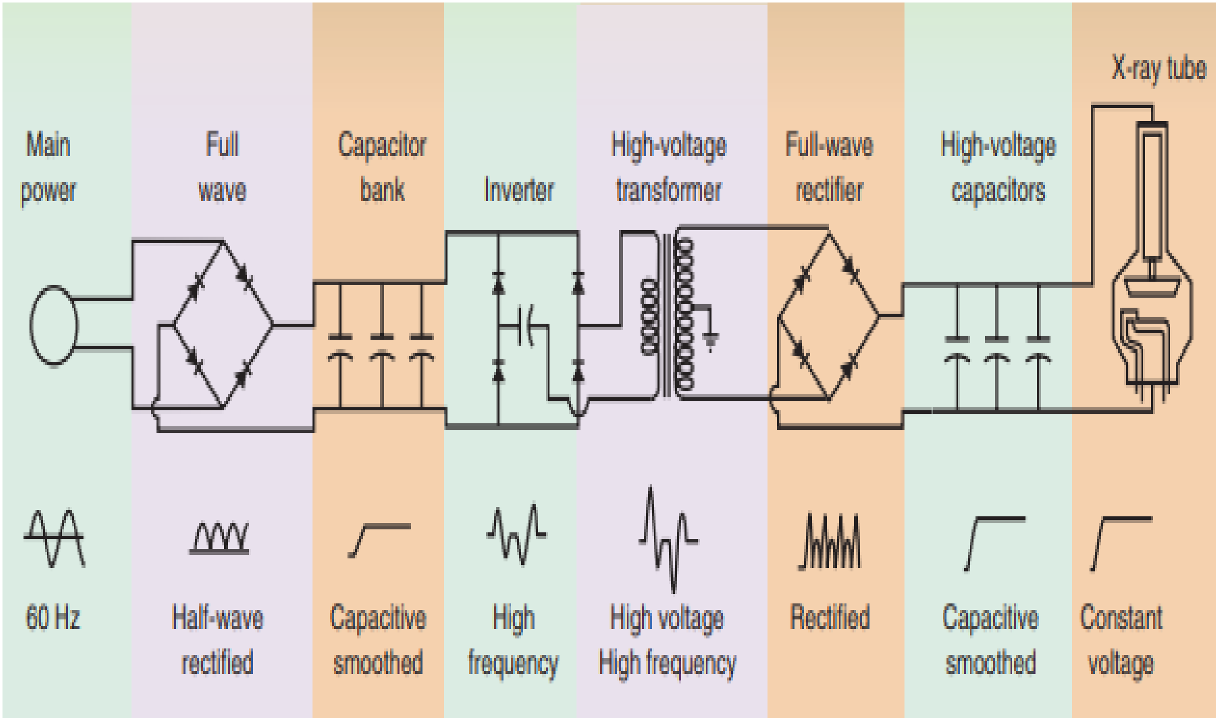

Figure 9 : Inverter circuit of a high-voltage generator.

Now, all radiography, mammography and computed tomography systems use high-frequency circuits because:

1. Higher frequency would be obtain
2. Produce a nearly constant potential voltage waveform
3. Produce a voltage ripple of less than 1%
4. lower patient radiation dose
5. Circuits are much smaller, less costly
6. More efficient than 60-Hz high-voltage generators.
7. Increased radiation quality and quantity
8. Shortest exposure time.
9. Increase x-ray tube life.

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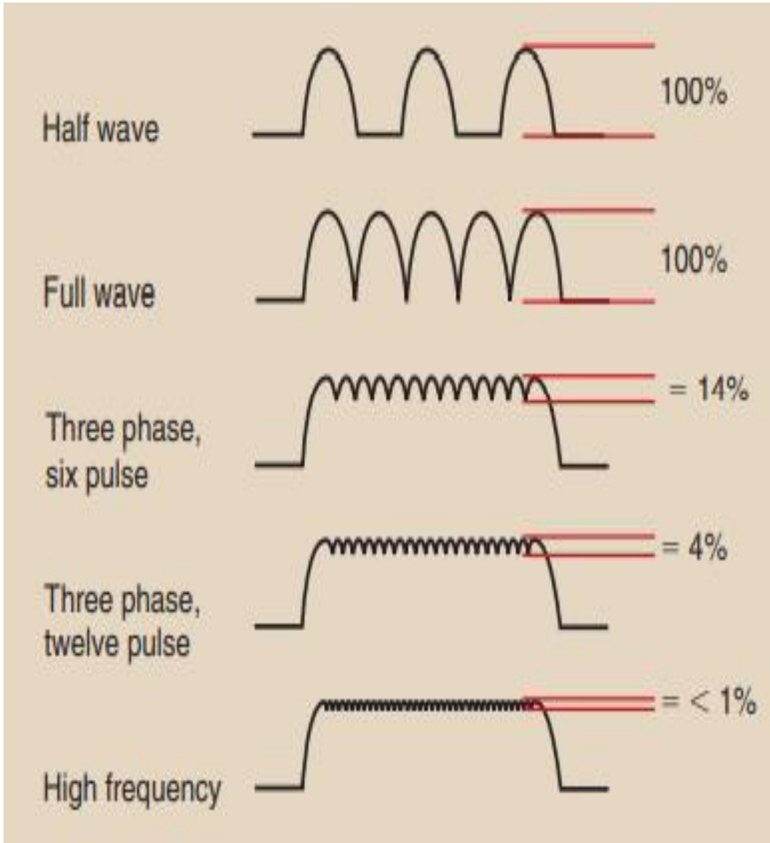

Figure 10 : Voltage waveforms resulting from various power supplies

Power	% Voltage Ripple	The Effect
Single phase (1Φ 2P)	100%	increase patient dose and longer exposure time
Three phase, six pulse (3Φ 6P)	14%	voltage supplied to the x-ray tube never falls below 86% of peak value
Three phase, twelve pulse (3Φ 12P)	4%	voltage supplied to the x-ray tube never falls below 96% of peak value.
High frequency	1%	higher x-ray quantity and quality.

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Questions

1- What is X-ray high-voltage generator ?
2- What is High-Voltage Transformer ? with drawing .
3- Explain Half-Wave Rectification with drawing ?
4- Explain full -Wave Rectification with drawing ?
5- What is The ripple factor?
6- List properties of high-frequency circuits ?

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