Electrical Power Engineering

By

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Lecture (3)

D.C. Power Transmission

D.C. Power Transmission

- Frequency of large systems would produce serious problems of power transfer control in the small capacity link.
- Extensive research has been carried out especially in Sweden for the development of high voltage converters.
- Thyristors of ratings 50 kV and 100 amperes have been developed and now there are many countries in; the world where the transmission of power over longer distances and high voltages is being done by d.c.
- A D.C transmission line requires converter at each end. At the sending end a.c. is converted into d.c. and at the receiving end it is converted back to a.c. for use.

D.C. Power Transmission

- A valve normally conducts in one direction only from anode to cathode and while it is conducting there is a small drop of volts across it.
- While analyzing the rectifier circuits, the valves, the transformers are assumed to be ideal i.e. without any voltage drop and the d.c. load is assumed to have infinite inductance from which it follows that the direct current is constant i.e. free from ripples.

D.C. Power Transmission

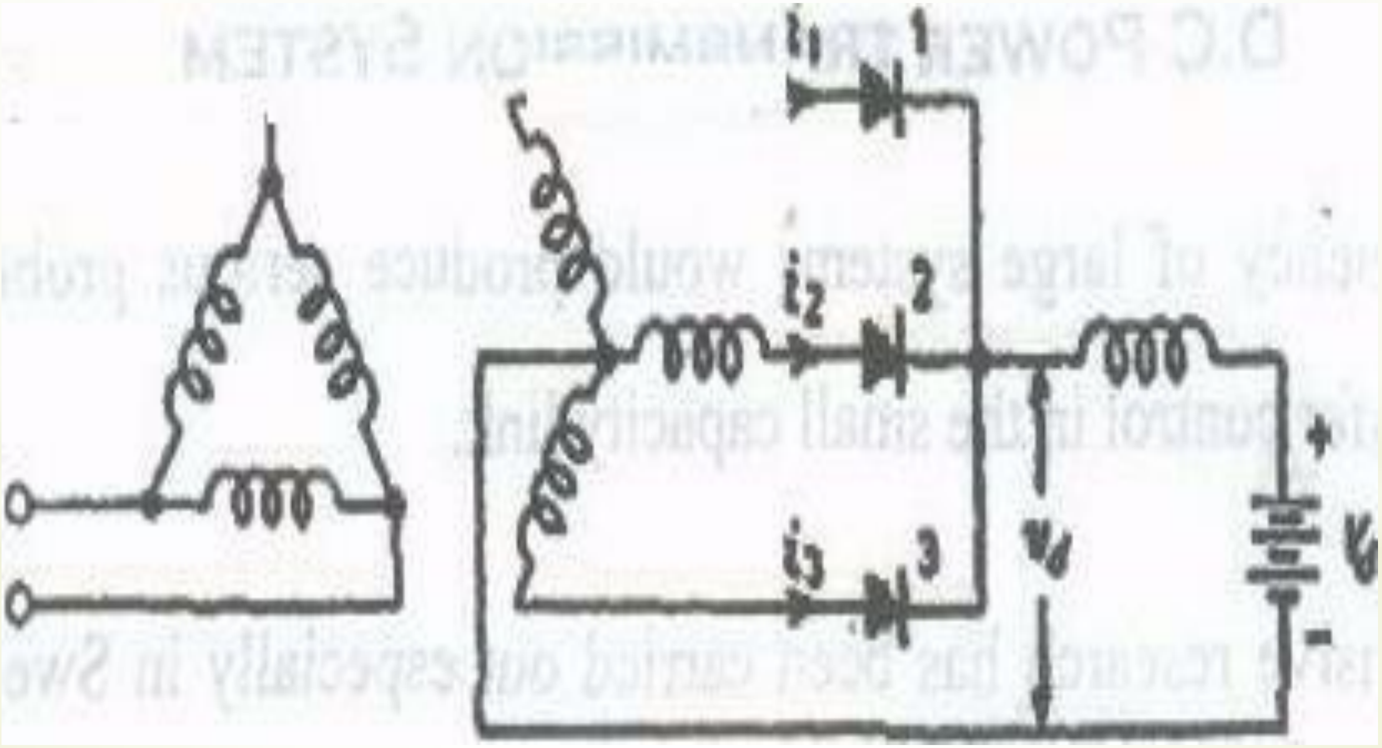
- Transformer secondary can be connected to give 3-phase, 6-phase and 12-phase supply to the rectifier valves.
- The larger the number of phases, lower is the ripple content in the d.c. output. But 6-phase connection is found to be sufficiently good from all practical viewpoints.
- To begin with, a 3-phase arrangement will be described but analysis will be done for a general n-phase system.

D.C. Power Transmission

- The 3-phase system is the simplest converter circuit but is not practical because the direct current in the secondary windings saturates the transformer core.
- This could be avoided by using zig-zag connections.
- The 3-phase system as shown in the following figure is, however, useful in explaining other connections.

Three Phase half Wave Rectifier (Uncontrolled)

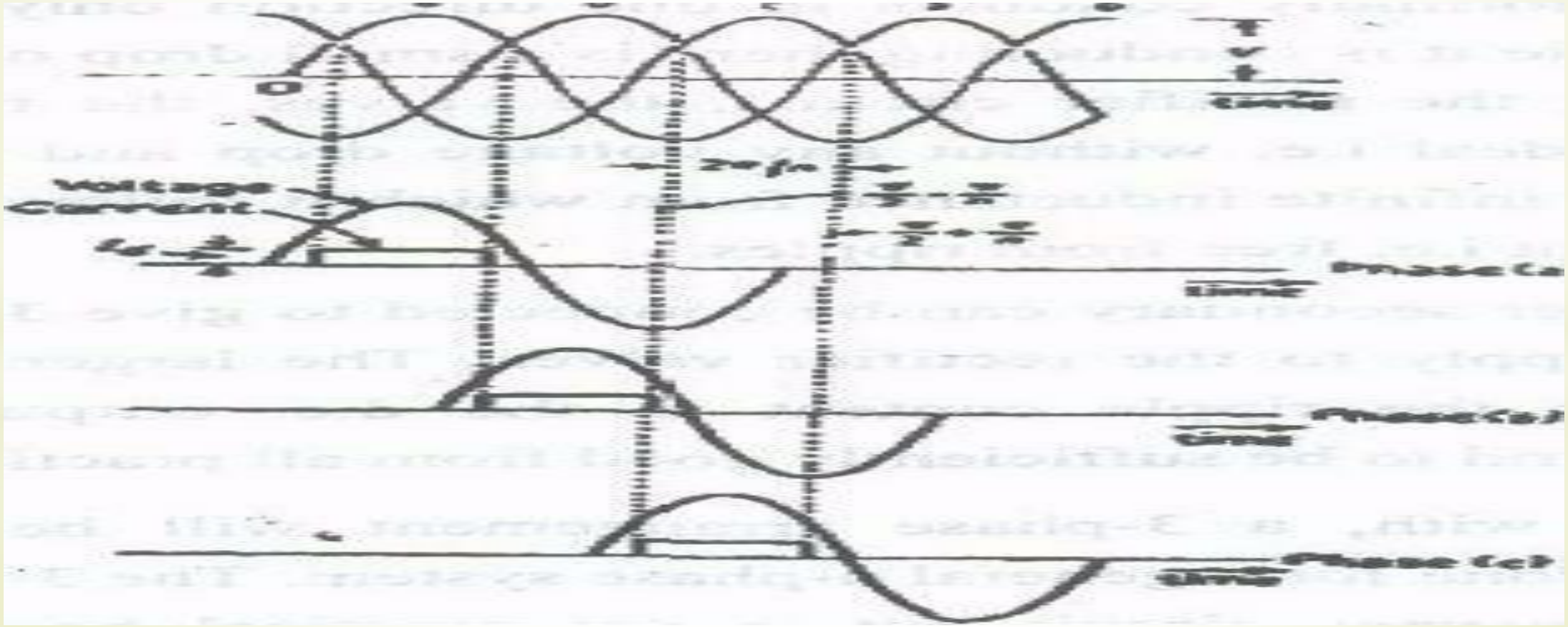
- The following figure shows the three phase rectifier.



3-Phase Rectifier

Three Phase half Wave Rectifier (Uncontrolled)

- The following figure shows current and voltage wave-forms in the three phases of the supply transformer.



Wave-forms of anode voltage and rectified current In each phase

Three Phase half Wave Rectifier (Uncontrolled)

- Taking point '0' as the reference, the conduction starts from 30" and continues up to 150° i.e. $(\pi/2 - \pi/3)$ to $(\pi/2 + \pi/3)$
- in general for an n-phase or n-anode system the change-over takes place at $(\pi/2 - \pi/n)$ and conduction continues up to $(\pi/2 + \pi/n)$. Now since conduction takes place only during the positive half cycle, the average value of the d.c. voltage will be

Three Phase half Wave Rectifier (Uncontrolled)

$$V_0 = \frac{1}{2\pi/n}\int_{\pi/2-\pi/n}^{\pi/2+\pi/n} V_m \sin\theta\, d\theta = -\frac{nV_m}{2\pi}\left[\cos\theta\right]_{\pi/2-\pi/n}^{\pi/2+\pi/n}$$

$$= \frac{V_m \sin \pi/n}{\pi/n}$$

For $3\phi, n = 3$, and

$$V_0 = \frac{V_m \sin \pi/3}{\pi/3} \frac{3V_m}{\pi} = \frac{3\sqrt{3}}{2} = \frac{3\sqrt{3}}{2} V_m = 0.83\, V_m = 0.83\, V_m$$

For $6\phi, n = 6$, and

$$V_0 = \frac{V_m \sin \pi/6}{\pi/6} = \frac{3V_m}{\pi}$$

Three Phase half Wave Rectifier (Uncontrolled)

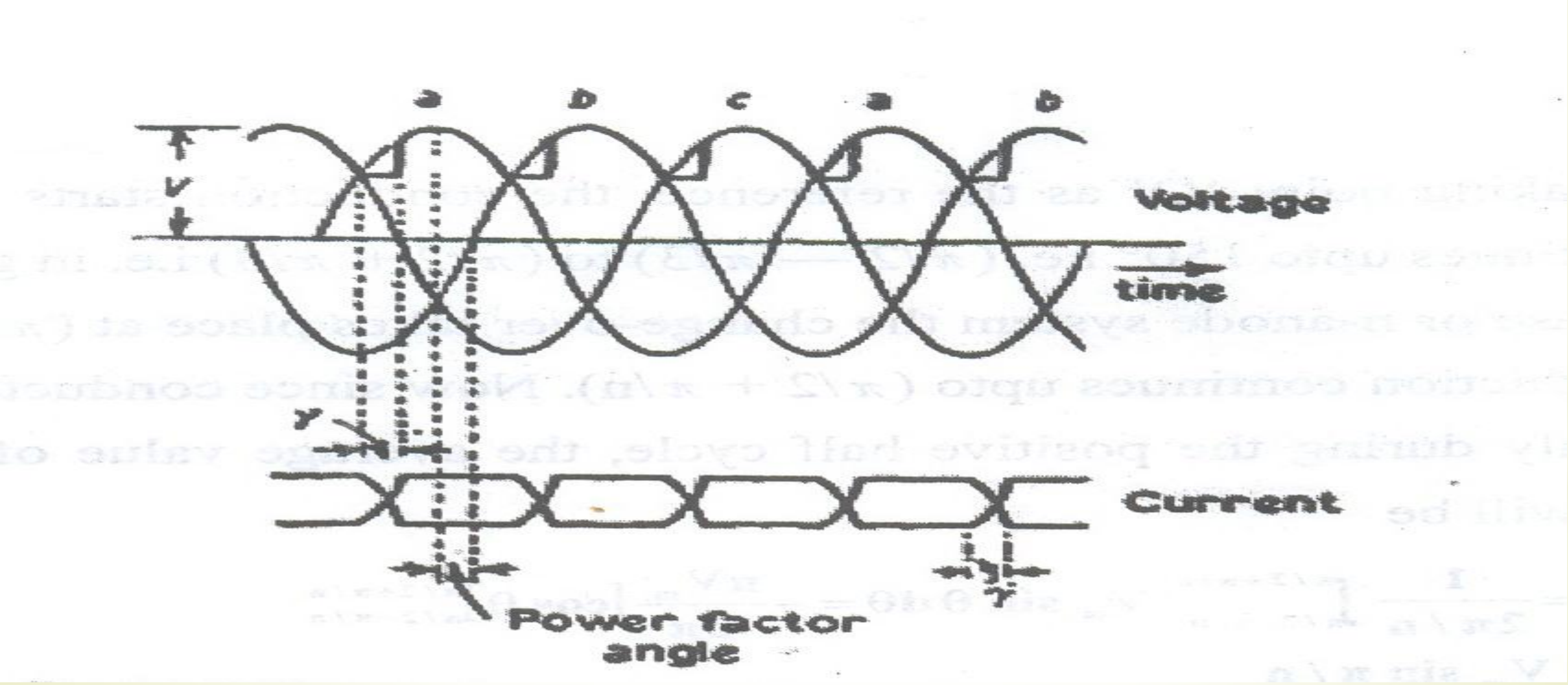
- The wave of anode current is a rectangular pulse of height /a and length 120°.
- Its average value is $I_d/3$ and the r.m.s value $I_d/\sqrt{3} = 0.577\, I_d$.
- The transformer secondary current is the same as the anode current.
- The current in actual practice can't reduce to zero instantly nor it can rise to a finite value instantly because of the finite inductance of the system.

Towards the Controlled Three Phase half Wave Rectifier

- Hence two anodes conduct simultaneously over a period known as the commutation period or overlap period (overlap angle γ) Say initially anode a is conducting.
- When anode b commences to conduct, it short circuits the a and b phases which results in zero current in a and Id in b finally.

Three Phase half Wave Rectifier (Controlled)

- The following figure shows voltage and current wave forms with commutation angle.



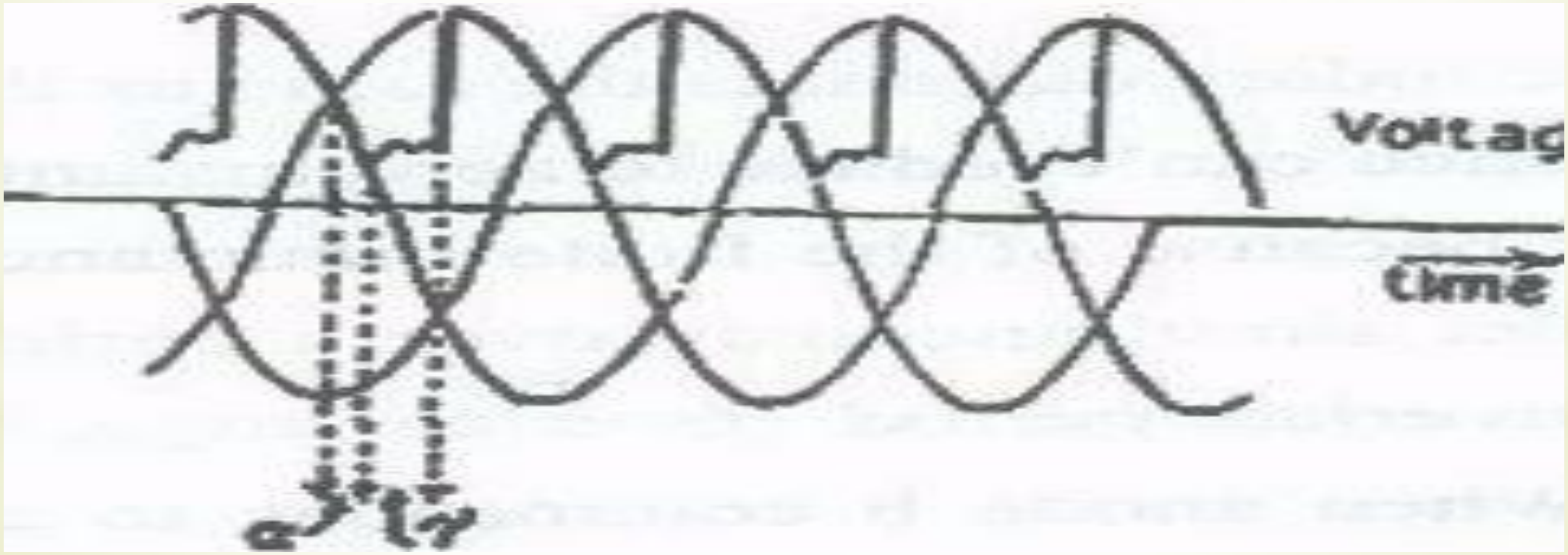
Voltage and current wave forms with commutation angle γ

Three Phase half Wave Rectifier (Controlled)

- The instant of conduction of an anode can be controlled by applying a suitable pulse at a suitable instant to a third electrode known as grid which is placed in between the cathode and anode.
- Once the conduction starts, the grid of course loses control over the conduction process.

Three Phase half Wave Rectifier (Controlled)

The following figure shows the use of grid control for the firing of the anodes, Say a positive pulse is applied to the grid such that the conduction is delayed by an angle γ.



Voltage wave form with grid control

Three Phase half Wave Rectifier (Controlled)

- When the delay is γ considering n-phase system the average output voltage will be

$$V_0 = \frac{1}{2\pi/n}\int_{(\pi/2)-(\pi/n)+\alpha}^{(\pi/2)+(\pi/n)+\alpha} V_m \sin\theta \, d\theta = \frac{nV_m}{2\pi}\left[-\cos\theta\right]_{(\pi/2)+(\pi/n)+\alpha}^{(\pi/2)+(\pi/n)+\alpha}$$

$$= \frac{nV_m}{2\pi}\left[\sin\left(\frac{\pi}{n}+\alpha\right)+\sin\left(\frac{\pi}{n}-\alpha\right)\right]$$

$$= \frac{nV_m}{\pi}\sin\frac{\pi}{n}.\cos\alpha$$

$$= V_0 \cos\alpha$$

Three Phase half Wave Rectifier (Uncontrolled versus Controlled)

- This means the d.c. output voltage with grid control is obtained by multiplying the d.c. output voltage without control with cosine of the angle by which the firing is delayed.

Thank You
For Your Attention

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