Electrical Power Engineering

By

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Lecture (4)

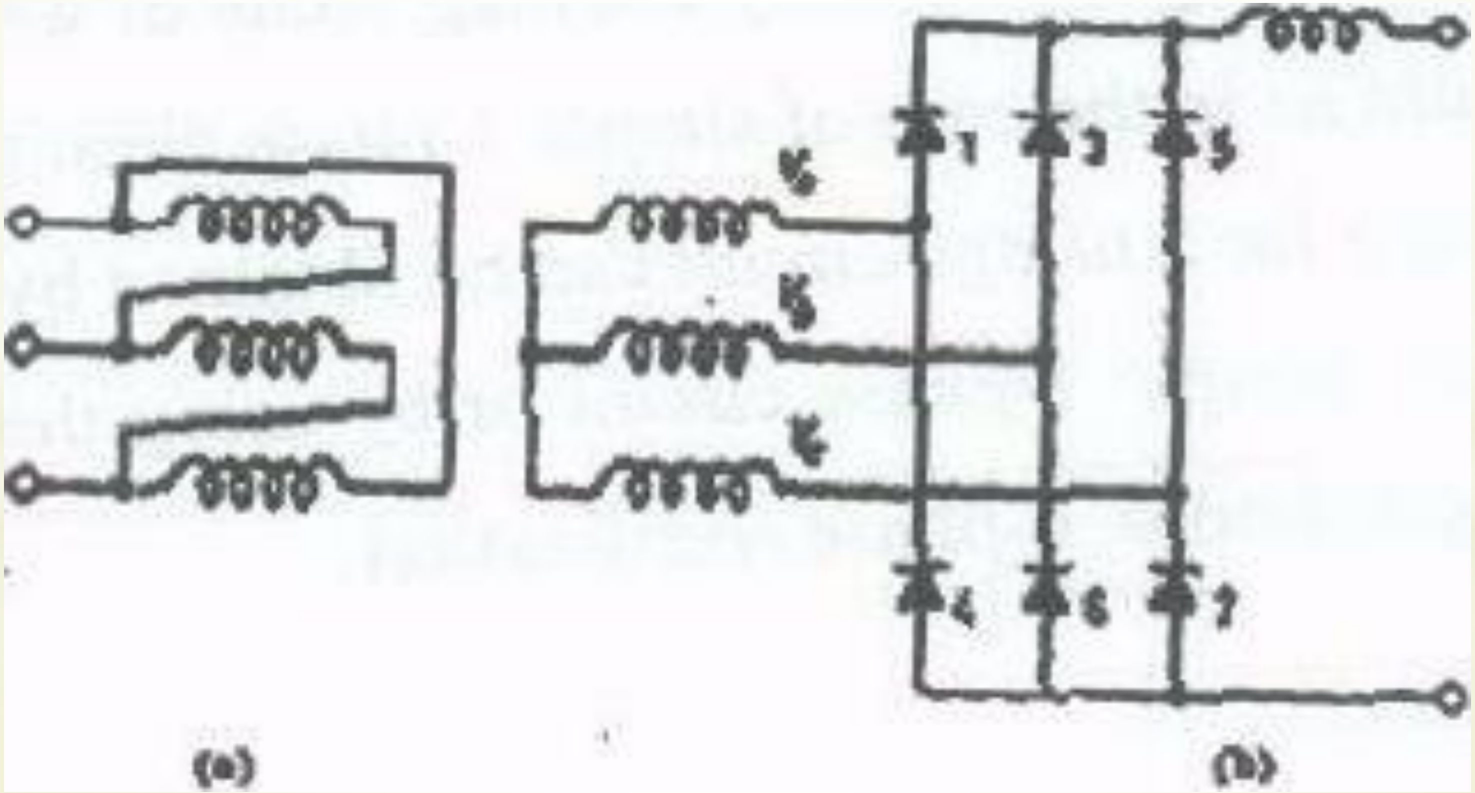
D.C. Power Transmission

The 3-phase Bridge Rectifier or Gratz Circuit

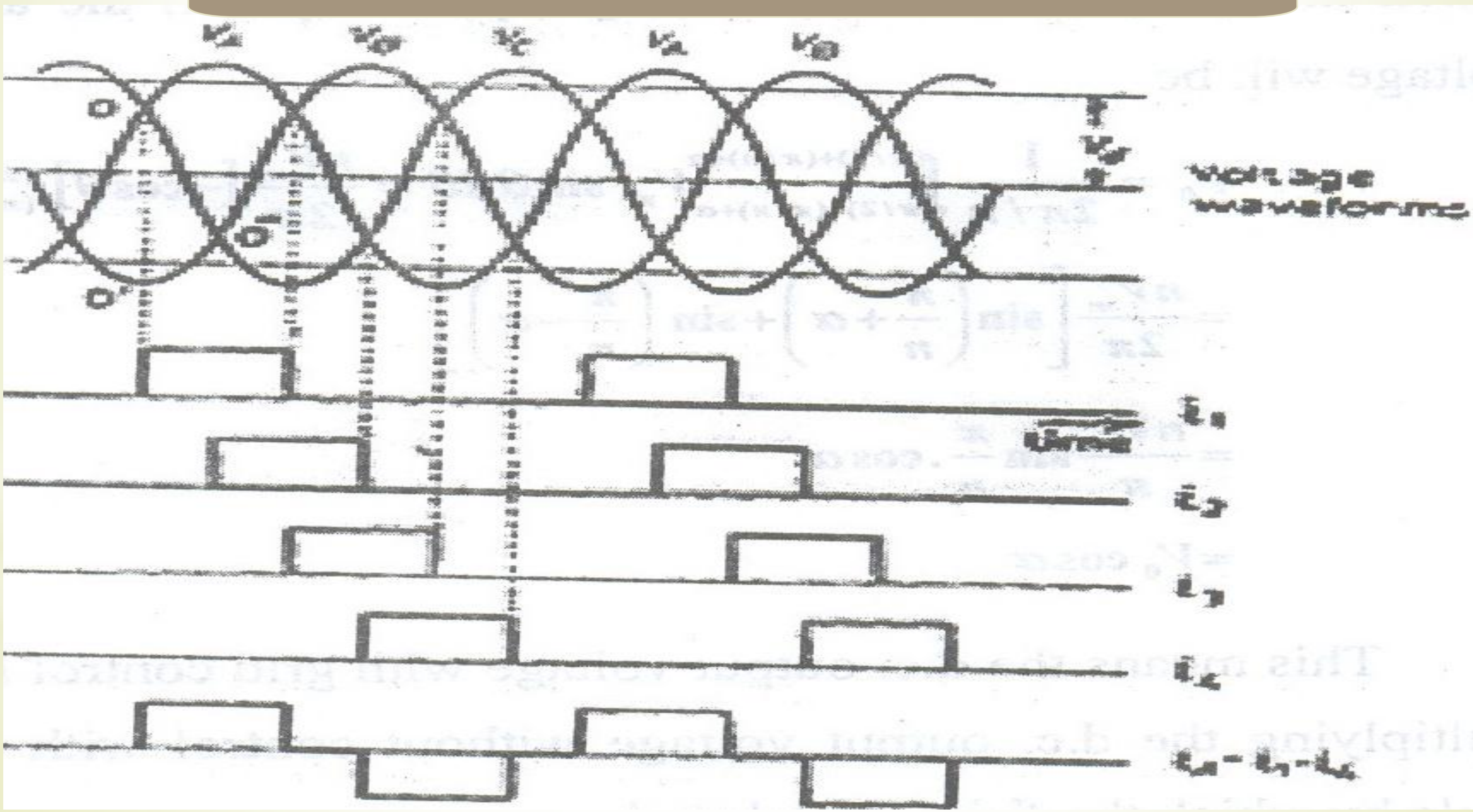
- The bridge rectifier is the most practical circuit used for converting a.c. into d.c. for HVDC transmission. For a given alternating voltage the output direct voltage is doubled as the two anodes conduct simultaneously and hence the power is doubled.
- There is no current in the windings of the transformer bank and the r.m.s current is less than twice that of the 3-phase circuit; thereby the winding is used efficiently.

The 3-phase Bridge Rectifier or Gratz Circuit

- The following figure shows the bridge circuit



The 3-phase Bridge Rectifier or Gratz Circuit



The 3-phase Bridge Rectifier or Gratz Circuit

- The sequence of operation of the bridge circuit can be explained as follows:
- Let V_a be the most positive at the beginning of the sequence say point 0 in the last figure.
- Corresponding to this point V_b is most negative; Therefore, the conduction will take place between phase a and b from a to b.
- The rectifiers will be 1 and, 6.

The 3-phase Bridge Rectifier or Gratz Circuit

- V_b continues to be most negative from 0' to 0'' and after 0'' , V_c becomes most negative and then conduction takes place between phases a and *e* from a to c through the rectifiers 1 and 2.
- Next diode 3 takes over from 1 and current returns through 2.
- The complete sequence of the diodes conducting is, therefore, land 6, land 2 ,3 and 2,3 and 4, 5 and 4,5 and6and 1 and 6 again.

The 3-phase Bridge Rectifier or Gratz Circuit

- The grid control and overlapping will modify the magnitude of voltage and can be taken into account as in the case of simple 3-phase circuit.
- The output voltage for a bridge circuit can be obtained by either doubling the voltage of the simple 3-phase circuit or by using the line voltage in the formula for six diodes, 6-phase rectification.

The 3-phase Bridge Rectifier or Gratz Circuit

We know that the output voltage of a 3-phase circuit is $\frac{3\sqrt{3}}{2\pi}V_m$

There fore, for a bridge circuit it will be ;

$$\frac{3\sqrt{3}}{\pi}V_m$$

The output voltage for an n-phase circuit is $\frac{V_m \sin \pi / n}{\pi / n}$

For 6-phase circuit n = 6 and maximum value of voltage is √ 3Vm. Substituting these values,

$$V_0 = \frac{\sqrt{3}\,V_m \ \sin \pi / 6}{\pi / 6} = \frac{\sqrt{3}\,V_m}{\pi}.6.\frac{1}{2} = 3\sqrt{3}\,\frac{V_m}{\pi}$$

Current relationship in a bridge circuit

- In case of a bridge circuit, two valves conduct simultaneously.
- These two valves correspond to two different phases i.e. two phases are short circuited.
- Let L be the inductance in henries for each phase and I_s be the current at any instant; then the equation describing the circuit will be

Current relationship in a bridge circuit

$$2L\frac{di_s}{dt}=\sqrt{3}V_m \sin \omega t$$

$$\text{or} \quad \frac{di_s}{dt}=\sqrt{3}\frac{V_m}{2L}\sin \omega t\, dt \qquad \text{or} \quad i_s=-\sqrt{3}\frac{V_m}{2L}.\frac{1}{\omega}\cos \omega t + A$$

at the beginning when $\omega t=\alpha, i_s=0$ *and at the end when* $\omega t=\alpha+\gamma,\ i_s=I_d$

$$\therefore A=\frac{\sqrt{3}V_m}{2\omega L}\cos\alpha$$

Current relationship in a bridge circuit

$$I_d = \frac{\sqrt{3}V_m}{2\omega L}\left[\cos\alpha - \cos(\alpha+\gamma)\right]$$

$$= \frac{V_l}{\sqrt{2}\,X}\left[\cos\alpha - \cos(\alpha+\gamma)\right]$$

Current relationship in a bridge circuit

where V_L is the rms line to line voltage. Now for the bridge circuit

$$V_0 = \frac{3\sqrt{3}V_m}{\pi}$$

$$\therefore \sqrt{3}V_m = \frac{\pi V_0}{3}$$

$$\therefore I_d = \frac{V_0}{6X}[\cos\alpha - \cos(\alpha+\gamma)]$$

We know that bridge output voltage after taking into account gird control and overlap γ is

$$V_d = \frac{V_0}{2}[\cos\alpha + \cos(\alpha+\gamma)]$$

Here V_o is the bridge rectifier voltage without grid control and overlap. Now adding the two equations (2.7) and (2.8),

$$\frac{2V_d}{V_o} + \frac{6XI_d}{\pi V_o} = 2\cos\alpha$$

or

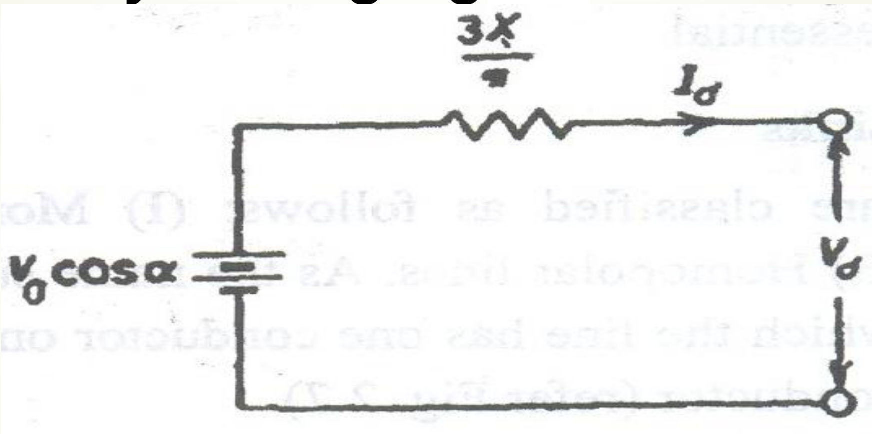
$$\frac{V_d}{V_o} + \frac{3XI_d}{\pi V_0} = \cos\alpha$$

or

$$V_d = V_0 \cos\alpha - \frac{3XI_d}{\pi}$$

Current relationship in a bridge circuit

- The following figure shows the equivalent circuit represented by the last equation. It is to be noted that the drop 3X represents the voltage drop due to commutation and not a physical resistance drop.
- V can be varied by varying the V_0 which in turn can be varied by changing the tap change of the transformer and by changing α



D.C. Power Transmission

- In fact there are various circuits used for rectification, of which, the best converter circuit for high voltage d.c. transmission is the 3-phase bridge circuit. This has the following advantages:

(i) The transformer connections are very simple. It does not require any tapping. The secondary connection may be connected in Y or in delta.

D.C. Power Transmission

(ii)For a given power output, the rating of the transformer secondary is less than any other circuits. Therefore, the rating of the primary of the transformer is less than any other circuit.

(iii) For a given output voltage, the PIV of the valves is only half that of any of the other circuits and therefore for a given PIV the output voltage is twice that of some other circuits.

(iv) Arc backs can be suppressed by grid control and a bypass valve.

Inversion

- In case of valves the conduction takes place in only one direction and, therefore, the current in a converter cannot be reversed.
- With rectifier operation the output current I_d and output voltage V_d are such that power is absorbed by a load.

D.C. Power Transmission

- For inverter operation it is required to transfer power from the direct current to the alternating current system which can only be obtained by the reversal of the average direct voltage The voltage then opposes the current as in a d.c. motor and is called a counter voltage.
- Therefore, for inversion, an alternating voltage system must exist on the primary side of the transformer and grid control of the converter is essential.

Types of D.C. Links

- D.C. lines are classified as follows:

(I) Monopolar lines.

(2) Bipolar lines.

(3) Homopolar lines.

Monopolar Lines

- As the name suggests Monopolar lines are those in which the line has one conductor only and the earth is used as the return conductor.
- The line is normally operating with negative polarity as the corona loss and the radio interference are reduced.

Bipolar Lines

- The bipolar lines have two conductors. one operating with +ive polarity and the other negative polarity.
- There are two converters of equal voltage rating and connected in series at each end of the d.c. line.
- The rating of the bipolar line is expressed as ±650 kV for example and is pronounced as plus and minus 650 kV.
- The junction of the converters may be grounded at one end or at both the ends. If it is grounded at both the ends each line can be operated independently.

Homopolar Lines

- The Homopolar lines have two or more conductors having the same polarity usually negative for the reason of corona and radio interference and always operate with ground as the return.

D.C. Links

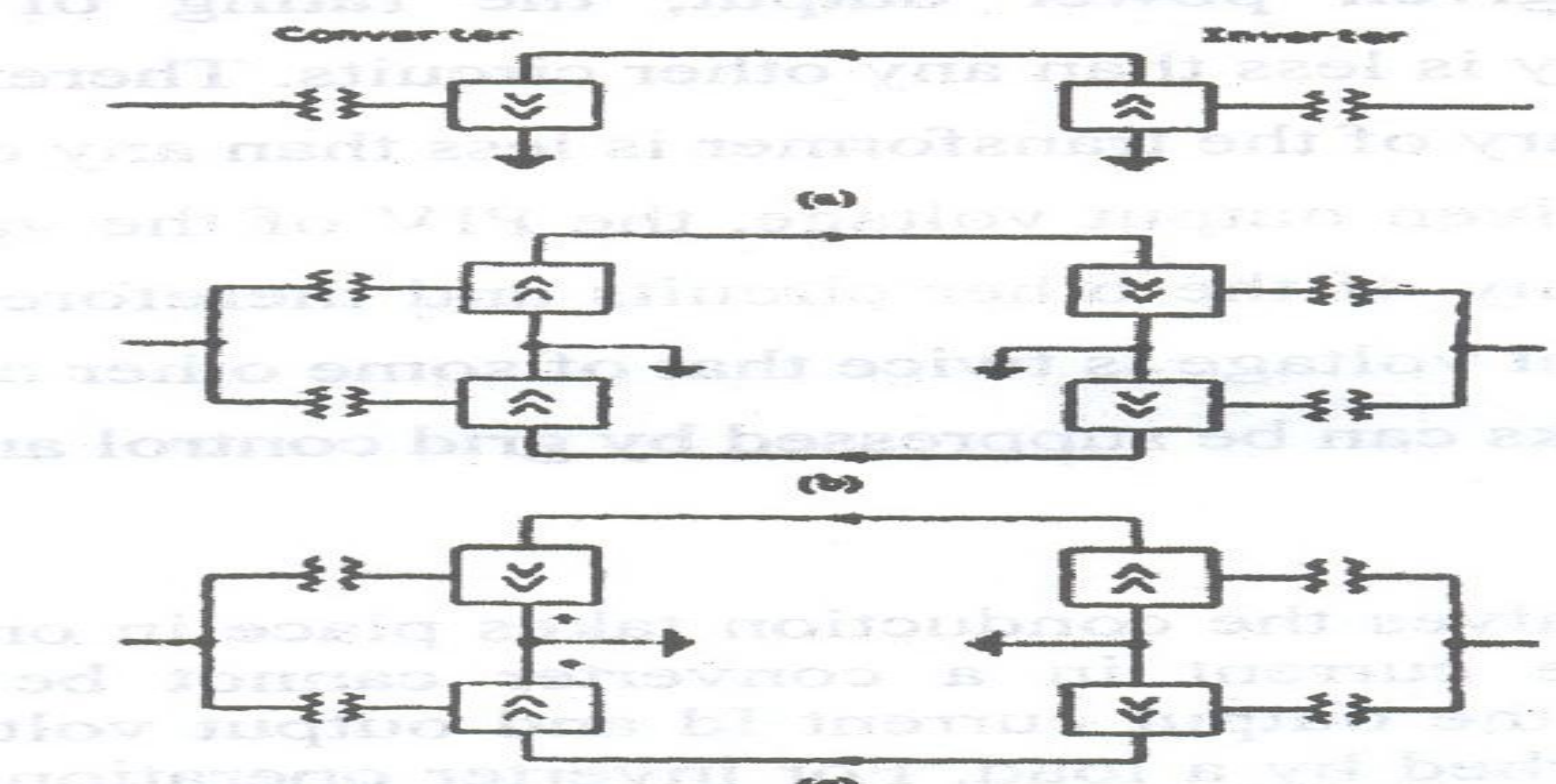


Fig · Kinds of d.c. links: (a) Monopolar, (b) Bipolar, and (c) Homopolar lines

Thank You
For Your Attention

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