2.1 Line commutated converter

The conversion from AC to DC and vice-versa is done in HVDC converter stations by using three phase bridge converters. The configuration of the bridge (also called Graetz circuit) is a six pulse converter and the 12 pulse converter is composed of two bridges in series supplied from two different (three-phase) transformers with voltages differing in phase by 30^o.

Pulse Number

The pulse number of a converter is defined as the number of pulsations (cycles of ripple) of direct voltage per cycle of alternating voltage.

The conversion from AC to DC involves switching sequentially different sinusoidal voltages onto the DC circuit.

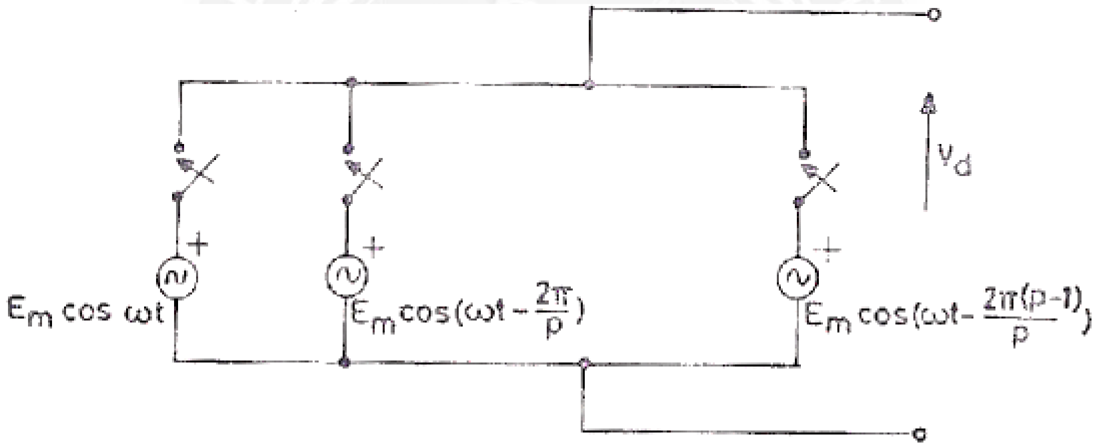

Figure 2.1.1 A Valve group with 'p' valves

[Source: "HVDC Power Transmission Systems" by K.P.Padiyar, page-32]

A valve can be treated as a controllable switch which can be turned ON at any instant, provided the voltage across it is positive.

The output voltage V_d of the converter consists of a DC component and a ripple whose frequency is determined by the pulse number.

Choice of Converter Configuration

The configuration for a given pulse number is so chosen in such a way that the valve and transformer are used to the maximum.

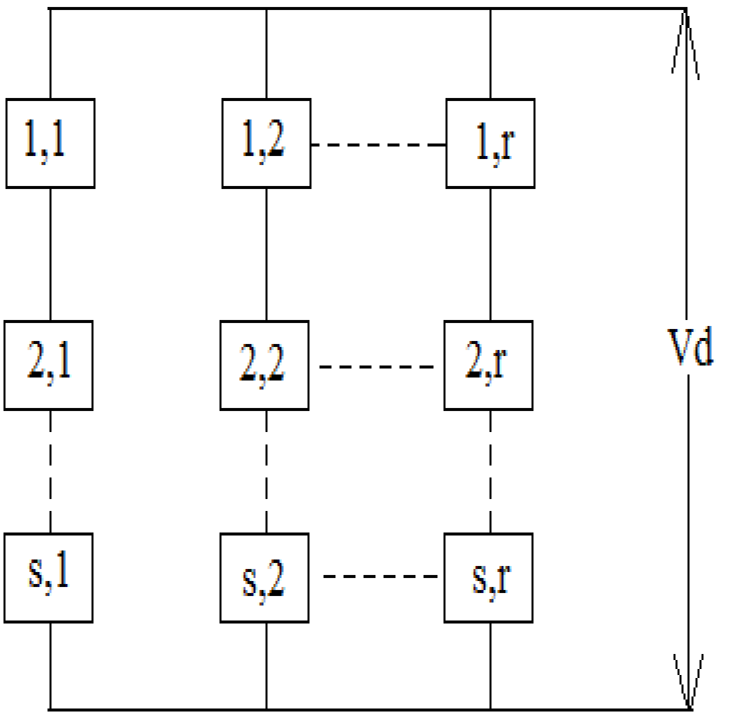

Figure 2.1.2 Converter made up of series and parallel connection of communication groups

[Source: "HVDC Power Transmission Systems" by K.P.Padiyar, page-33]

A converter configuration can be defined by the basic commutation group and the number of such groups connected in series and parallel.

If there are 'q' valves in a basic commutation group and r of those are connected in parallel and s of them in series then,

$$p = q\ r\ s$$

Note:

A commutation group is defined as the group of valves in which only one (neglecting overlap) conducts at a time.

Valve Rating:

The valve rating is specified in terms of Peak Inverse Voltage (PIV). The ratio of PIV to average DC voltage is an index of valve utilization.

So, average maximum DC voltage across the converter is given by,

$$V_{do} = s\frac{q}{2\pi}\int_{-\pi/q}^{\pi/q} E_m \cos\omega t\, d(\omega t)$$

$$= s\frac{q}{2\pi}E_m(\sin\omega t)_{-\pi/q}^{\pi/q} = \frac{sq}{2\pi}E_m\left[\sin\frac{\pi}{q} - \sin\left(-\frac{\pi}{q}\right)\right] = \frac{sq}{2\pi}E_m.2\sin\frac{\pi}{q}$$

$$V_{do} = \frac{sq}{\pi}E_m\sin\frac{\pi}{q} \quad \text{----- (1)}$$

If ‘q’ is even, then maximum inverse voltage occurs when the valve with a phase displacement of 180^{o} is conducting and is given by,

$$PIV = 2E_m$$

If ‘q’ is odd, then maximum inverse voltage occurs when the valve with a phase shift of $\pi \pm (\pi/q)$ is conducting and is given by,

$$PIV = 2E_m \cos(\pi/2q)$$

The valve utilization factor is given by

For q even, $$\frac{PIV}{V_{do}} = \frac{2E_m}{\frac{sq}{\pi}E_m\sin\frac{\pi}{q}} = \frac{2\pi}{s.q.\sin\frac{\pi}{q}}$$

For q odd, $$\frac{PIV}{V_{do}} = \frac{2E_m\cos\frac{\pi}{2q}}{\frac{sq}{\pi}E_m\sin\frac{\pi}{q}} = \frac{2\pi.\cos\frac{\pi}{2q}}{sq.\sin\frac{\pi}{q}} = \frac{2\pi.\cos\frac{\pi}{2q}}{sq.2\cos\frac{\pi}{2q}\sin\frac{\pi}{2q}}$$

(Since $\sin 2\theta = 2\sin\theta\cos\theta$ and $2\cos\frac{\pi}{2q}\sin\frac{\pi}{2q} = \sin\frac{2\pi}{2q} = \sin\frac{\pi}{q}$)

$$\frac{PIV}{V_{do}} = \frac{\pi}{sq.\sin\frac{\pi}{2q}} \quad \text{(For q odd)}$$

Transformer Rating:

The current rating of a valve is given by,

$$I_v = \frac{I_d}{r\sqrt{q}} \quad \text{------ (2)}$$

where, I_d is the DC current which is assumed to be constant.

The transformer rating on the valve side (in VA) is given by,

$$S_{tv} = p\frac{E_m}{\sqrt{2}}I_v$$

From equations (1), (2) & p=qrs, we have

$$S_{tv} = p\frac{V_{do}.\pi}{\sqrt{2}.sq.\sin\frac{\pi}{q}}.\frac{I_d}{r\sqrt{q}}$$

$$S_{tv} = \frac{\pi}{\sqrt{2}}.\frac{V_{do}I_d}{\sqrt{q}.\sin\frac{\pi}{q}}$$

Transformer utilization factor $\left(\frac{S_{tv}}{V_{do}I_d}\right)$ is a function of q.

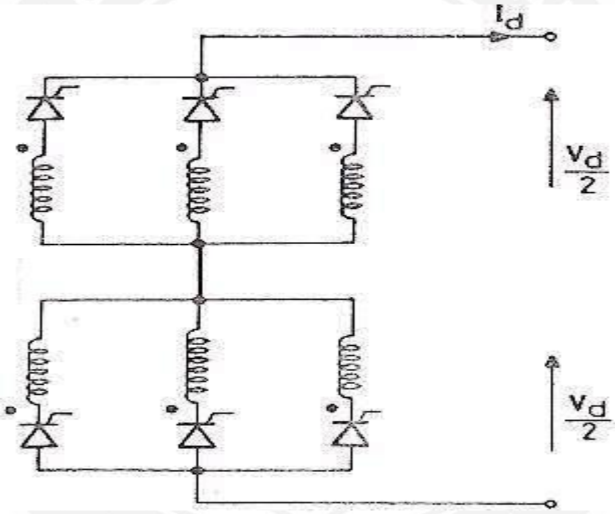

Figure 2.1.3 Six pulse converter

[Source: "HVDC Power Transmission Systems" by K.P.Padiyar, page-35]

As AC supply is three phase so, commutation group of three valves can be easily arranged. So, for q = 3,

$$\frac{S_{tv}}{V_{do}I_d} = \frac{\pi}{\sqrt{(2X3)}\sin\frac{\pi}{3}}$$

$$\frac{S_{tv}}{V_{do}I_d} = \frac{\pi}{\sqrt{6}\sin 60^o}$$

$$\frac{S_{tv}}{V_{do}I_d} = 1.48$$

Transformer utilization can be improved if two valve groups can share single transformer winding. In this case, the current rating of the winding can be increased by a factor of √2 while decreasing the number of windings by a factor of 2.

It is a 6-pulse converter consisting of two winding transformer where the transformer utilization factor is increased when compared to three winding transformer.

The series conduction of converter groups has been preferred because of controlling and protection as well as the requirements for high voltage ratings. So, a 12 pulse converter is obtained by series connection of two bridges.

The 30° phase displacement between two sets of source voltages is achieved by transformer connections Y-Y for one bridge and Y-Δ for the other bridge.

The use of a 12 pulse converter is preferable over the 6 pulse converter because of the reduced filtering requirements.