5.2 DC link Model

The major advantage of a HVDC link is rapid controllability of transmitted power through the control of firing angles of the converters. Modern converter controls are not only fast, but also very reliable and they are used for protection against line and converter faults.

The control of power in a DC link can be achieved through the control of current or voltage. From minimization of loss considerations, we need to maintain constant voltage in the link and adjust the current to meet the required power.
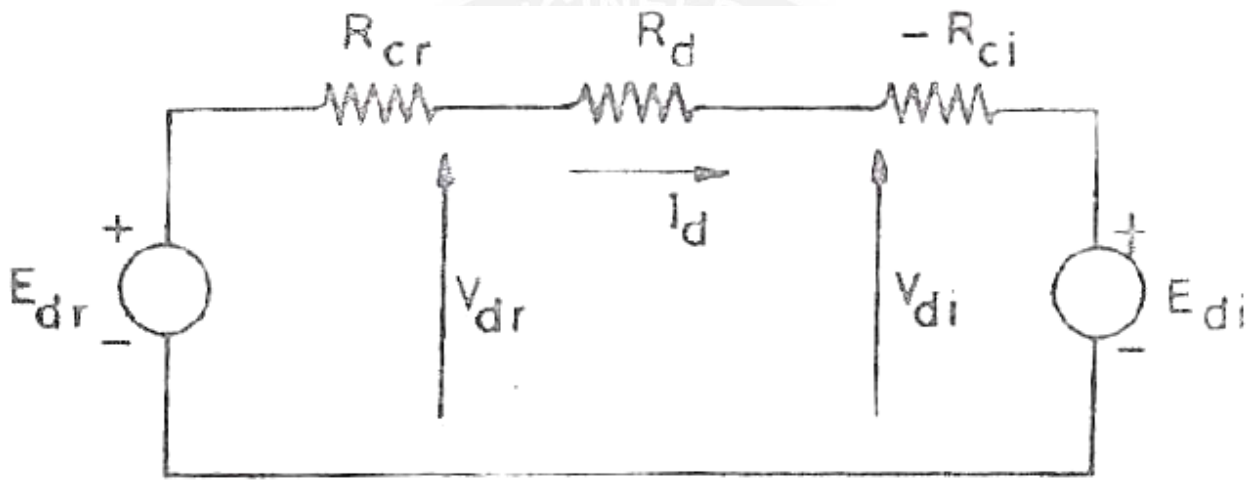

Figure 5.2.1 Steady state equivalent circuit of a 2 terminal DC link

[Source: "HVDC Power Transmission Systems" by K.P.Padiyar, page-84]

Consider the steady state equivalent circuit of a two terminal DC link. This is based on the assumption that all the series connected bridges in both poles of a converter station are identical and have the same delay angles. Also the number of series connected bridges (n_b) in both stations (rectifier and inverter) are the same.
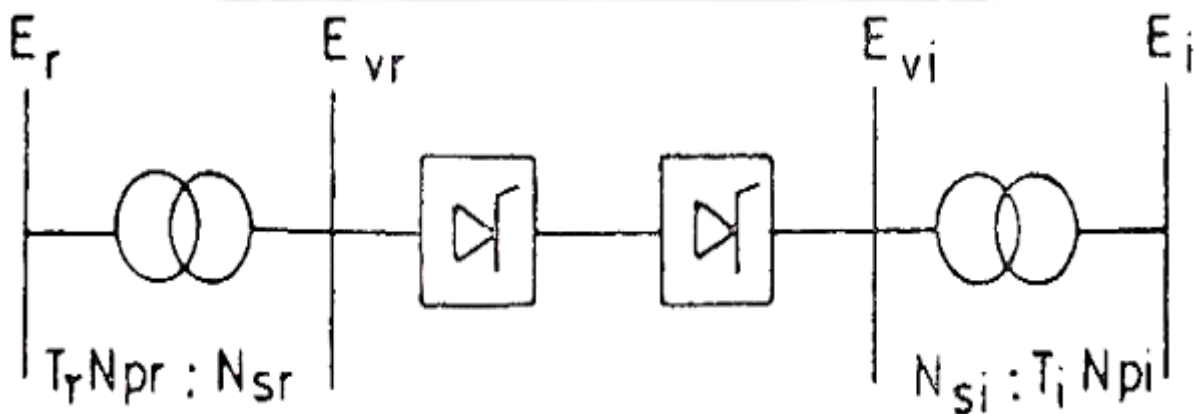

Figure 5.2.2 Schematic of DC link showing transformer ratios

[Source: "HVDC Power Transmission Systems" by K.P.Padiyar, page-84]

The voltage sources E_{dr} and E_{di} are defined by

$$E_{dr} = (3\sqrt{2}/\pi)\, n_b\, E_{vr} \cos\alpha_r \quad ---- (1)$$

$$E_{di} = (3\sqrt{2}/\pi)\, n_b\, E_{vi} \cos\gamma_i \quad ---- (2)$$

where E_{vr} and E_{vi} are the line to line voltages in the valve side windings of the rectifier and inverter transformer respectively. From the above figure these voltages can be obtained by

$$E_{vr} = \frac{N_{sr} E_r}{N_{pr} T_r} \quad , \qquad\qquad E_{vi} = \frac{N_{si} E_i}{N_{pi} T_i} \quad ---- (3)$$

where E_r and E_i are the AC (line to line) voltages of the converter buses on the rectifier and inverter side. T_r and T_i are the OFF-nominal tap ratios on the rectifier and inverter side.

Combining equations (1), (2) and (3),

$$E_{dr} = (A_r\, E_r\, /T_r)\, \cos\alpha_r \quad ---- (4)$$

$$E_{di} = (A_i\, E_i\, /T_i)\, \cos\gamma_i \quad ---- (5)$$

where A_r and A_i are constants.

The steady-state current I_d in the DC link is obtained as

$$I_d = \frac{(E_{dr} - E_{di})}{R_{cr} + R_d - R_{ci}}$$

Substituting equations (4) and (5) in the above equation, we get

$$I_d = \frac{(A_r E_r / T_r)\cos\alpha_r - (A_i E_i / T_i)\cos\gamma_i}{R_{cr} + R_d - R_{ci}}$$

The control variables in the above equation are T_r , T_i and α_r , β_i . However, for maintaining safe commutation margin, it is convenient to consider γ_i as control variable instead of β_i .

As the denominator in the final equation is small, even small changes in the voltage magnitude E_r or E_i can result in large changes in the DC current, the control variables are held constant. As the voltage changes can be sudden, it is obvious that manual control of converter angles is not feasible. Hence, direct and fast control of current by varying α_r or γ_r in response to a feedback signal is essential.

While there is a need to maintain a minimum extinction angle of the inverter to avoid commutation failure, it is economical to operate the inverter at Constant Extinction

Angle (CEA) which is slightly above the absolute minimum required for the commutation margin. This results in reduced costs of the inverter stations, reduced converter losses and reactive power consumption. However, the main drawback of CEA control is the negative resistance characteristics of the converter which makes it difficult to operate stably when the AC system is weak (low short-circuit ratios). Constant DC Voltage (CDCV) control or Constant AC Voltage (CACV) control are the alternatives that could be used at the inverter.

Under normal conditions, the rectifier operates at Constant Current (CC) control and the inverter at the CEA control.

The power reversal in the link can take place by the reversal of the DC voltage. This is done by increasing the delay angle at the station initially operating as a rectifier, while reducing the delay angle at the station initially operating as the inverter. Thus, it is necessary to provide both CEA and CC controllers at both terminals.

The feedback control of power in a DC link is not desirable because

1) At low DC voltages, the current required is excessive to maintain the required level of power. This can be counterproductive because of the excessive requirements of the reactive power, which depresses voltage further.

2) The constant power characteristic contributes to negative damping and degrades dynamic stability.