Module-IV

Control of HVDC Link

Desirable control Features:

i) Controller should not be sensitive to normal variations in voltage & frequency.

50Hz ± 0.5Hz

Mismatch between generation & demand

⇒ If G > D, f↑

If G < D, f↓

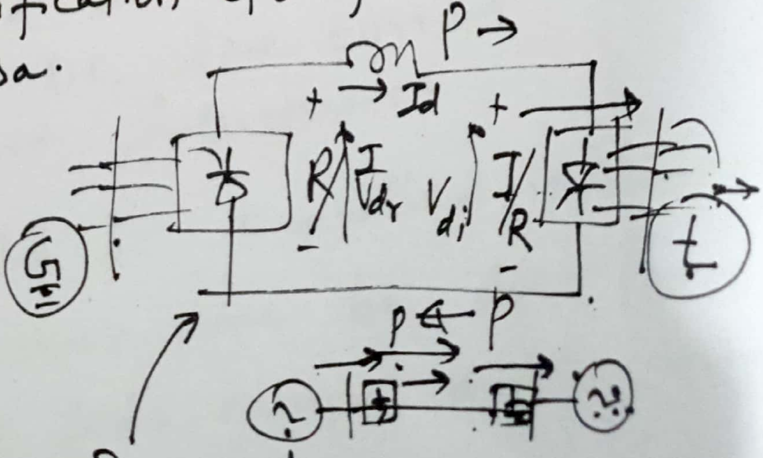
ii) Control should be fast, reliable and simple to implement

→ converter control
↓
delay angle control
(α)

OLTC Xmer
↳ slow in response

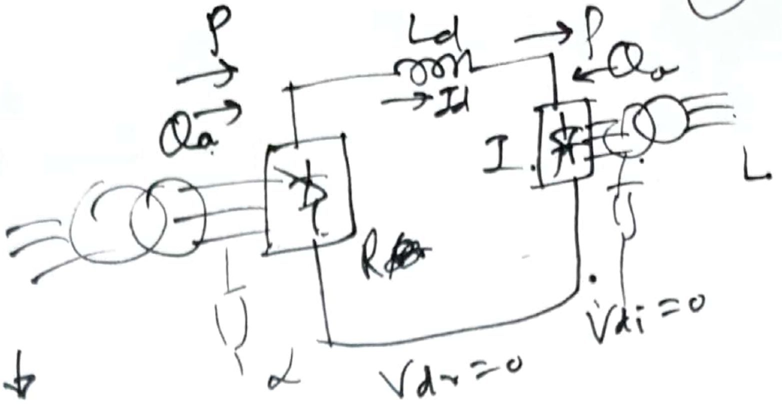
iii) There should be continuous operating range from full rectification to full inversion and vice versa.

iv) Control should be such that it requires less reactive power



Back-to-Back HVDC link

α



If $\alpha \uparrow$,

$\cos\alpha \downarrow$, pf $\downarrow$

$\alpha_{max} \simeq 10-25°$

V) Under s.s. conditions, the valves must be fired symmetrically

61 → 12 → 23 → 34 → 45 → 56

← 60 →

Valves are symmetrically fired at 60° intervals.

characteristic harmonics,

$h = np \pm 1$

5, 7, 11, 13, - -

11, 13, - - -

→ Inter-harmonics

Vi) control should be such that it controls the max. DC line current and limits the current fluctuation.

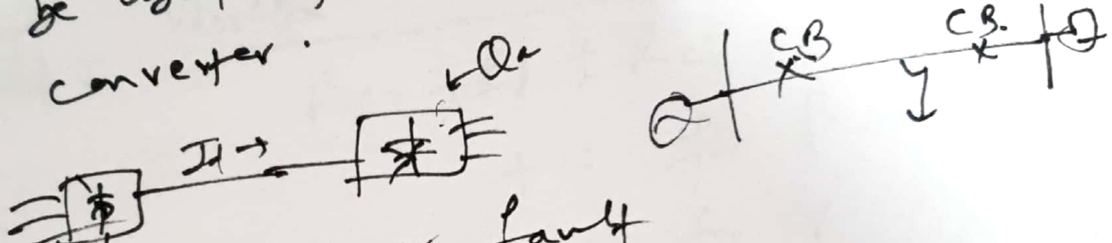
Vii) Power should be controlled independently and smoothly which can be done by controlling the DC side current and/or voltage simultaneously in the line.

$P_d \uparrow = V_d \uparrow \times I_d \uparrow$

$V_d \uparrow \leftarrow \alpha \uparrow$ $\quad I_d$: constant

$P_d \uparrow = V_d \uparrow \times I_d$

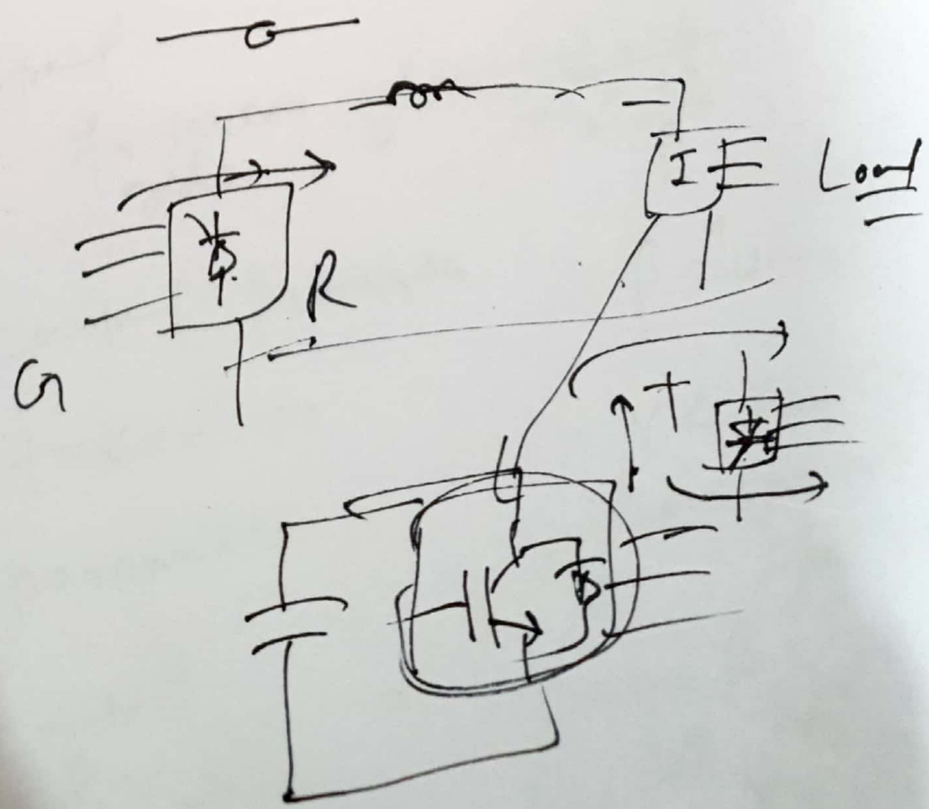
viii) Control should be such that it can be used for protection of line and converter.



S.C. or fault

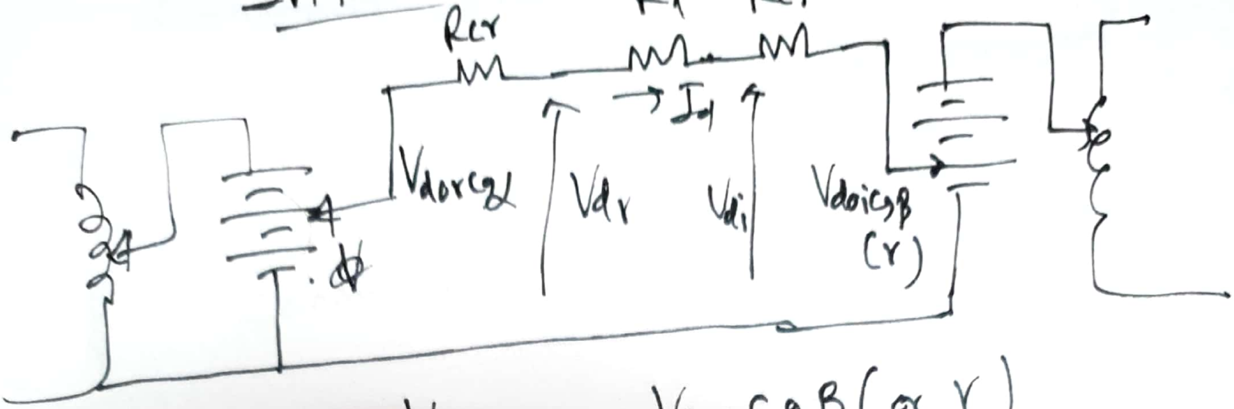
α control $\quad V_{dr} = V_{di} = 0$

$I_d = 0 \downarrow$



Control characteristics:

Introduction:



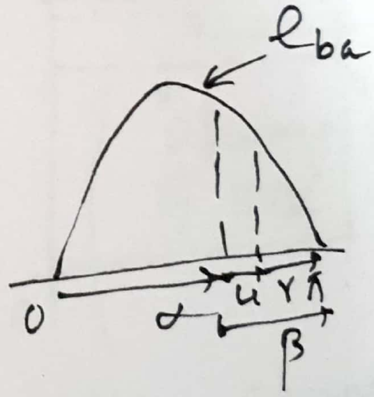
$$I_d = \frac{V_{dor}\cos\alpha - V_{doi}\cos\beta(\text{or } \gamma)}{R_{cr} + R_l \pm R_{ci}}$$

$+$: for β

$-$: for γ

$V_{di} = V_{doi}\cos\beta + R_{ci} I_d$

$V_{di} = V_{doi}\cos\gamma - R_{ci} I_d$



- β as control parameter for inverter side

or

- γ as control parameter

$\beta = u + \gamma$

$\therefore$ γ is taken as control parameter

- $\gamma < \gamma_{min}$ (lo...
- commutation failure

$\gamma \rightarrow$ control

$\gamma \not< \gamma_{min}$.

$\gamma \geq \gamma_{min}$.

Increase β

$u\uparrow$ $\gamma\uparrow$

$\gamma \geq \gamma_{min}$.

On inverter side, we have Constant Extinction Angle (CEA) control.

CEA → γ = constant at γ_{min}.

R : constant Ignition Angle (CIA) control

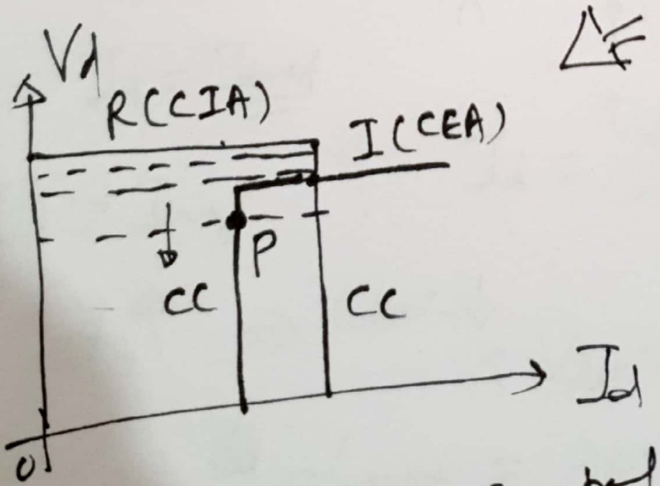
$\alpha \leq \alpha_{max}$.

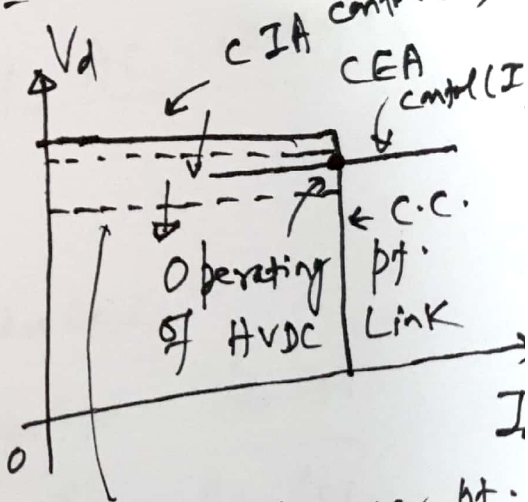
I : Constant Extinction Angle (CEA) control

$\gamma = \gamma_{max}$. (constant)

$V_{dr} = V_{dor} \cos\alpha - (R_{cr} + R_d) I_d$

$V_{di} = V_{doi} \cos\gamma - R_{ci} I_d$





No operating pt. → No power transfer

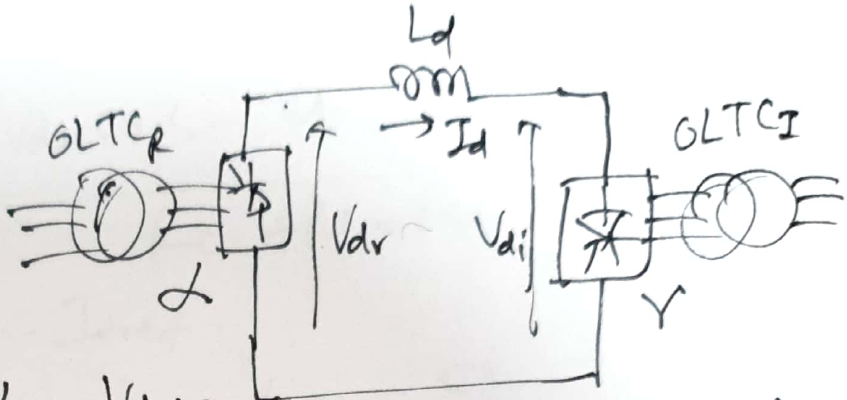
HVDC Link control Charact:

R : CIA + CC

I : CEA + CC

Effect of AC side voltage on DC link current:

Aim: To keep I_d always constant.



$$I_d = \frac{V_{dor}\cos\alpha - V_{doi}\cos\gamma}{R_{cr} + R_l - R_{ci}}$$

$\gamma \to$ const param

i) Increase in Rectifier-end AC voltage.

$$\uparrow V_{dor} = \frac{3\sqrt{3}E_m\uparrow}{\pi}$$

Aim: $I_d = I_{dref}$

$\uparrow V_{dor}\cos\alpha$

$$I_d = \frac{\uparrow V_{dor}\cos\alpha - V_{doi}\cos\gamma}{R_{cr} + R_l - R_{ci}}$$

$I_d > I_{dref}$

$\alpha\uparrow \Rightarrow \cos\alpha\downarrow$

$\uparrow V_{dor}\cos\alpha\downarrow \quad \uparrow$

$\alpha_{max.} = 20 - 25°$ $\quad I_d > I_{dref}$

OLTCR operation $\to E_m\downarrow$

$\downarrow V_{dor}$

OLTCI

V_{doi}

$I_d > I_{dref}$

$\Rightarrow$ $\boxed{I_d = I_{dref}}$.

ii) Decrease in Rectifier-end AC voltage:

$$\downarrow V_{dor} = \frac{3\sqrt{3}E_m \downarrow}{\pi}$$

$$\downarrow I_d = \frac{\downarrow V_{dor} \cos\alpha - V_{doi} \cos\gamma}{R_{cr} + R_l - R_{ci}}$$

$I_d < I_{dref}$.

Controller: $\alpha \downarrow$ $\alpha_{min.} = 5°$

$\cos\alpha \uparrow$ $I_d < I_{dref}$.

- OLTC$_R$ — $E_m \uparrow$ $V_{dor} \uparrow$

$I_d < I_{dref}$.

- OLTC$_I$ $V_{doi} \downarrow$

$V_{di} \downarrow$

$\uparrow I_d = I_{dref}$

iii) Increase in inverter-side AC voltage:

- $I_d < I_{dref}$ CEA $\gamma \downarrow$ $\gamma_{min.}$

R: $\alpha \downarrow$ $V_{dor} \cos\alpha \uparrow$

$I_d < I_{dref}$. $I_d \uparrow$ $\alpha_{max} = 5°$

OLTC$_R$: V_{dor} $I_d < I_{dr}$

OLTC$_I$: V_{doi} $I_d = I_{dref}$.

iv) Decrease in Inverter-side AC voltage:

$$\downarrow V_{doi} = \frac{3\sqrt{3}E_m \downarrow}{\pi}$$

$$I_d = \frac{V_{dor}\cos\alpha - \downarrow V_{doi}\cos\gamma}{R_{cr} + R_l - R_{ci}}$$

$I_d > I_{dref}$

$\cos\alpha \downarrow$

$R = \alpha \uparrow$

$V_{dor}\cos\alpha \downarrow$ $\quad I_d \downarrow$

$\alpha_{max} = 20 - 25^\circ$

$I_d > I_{dref}$.

$OLTC_R$: $V_{dor} \downarrow$

$I_d > I_{dref}$

$OLTC_I$: $V_{doi} \uparrow$

$V_{doi}\cos\gamma \uparrow$

$I_d \downarrow$

$I_d = I_{dref}$.