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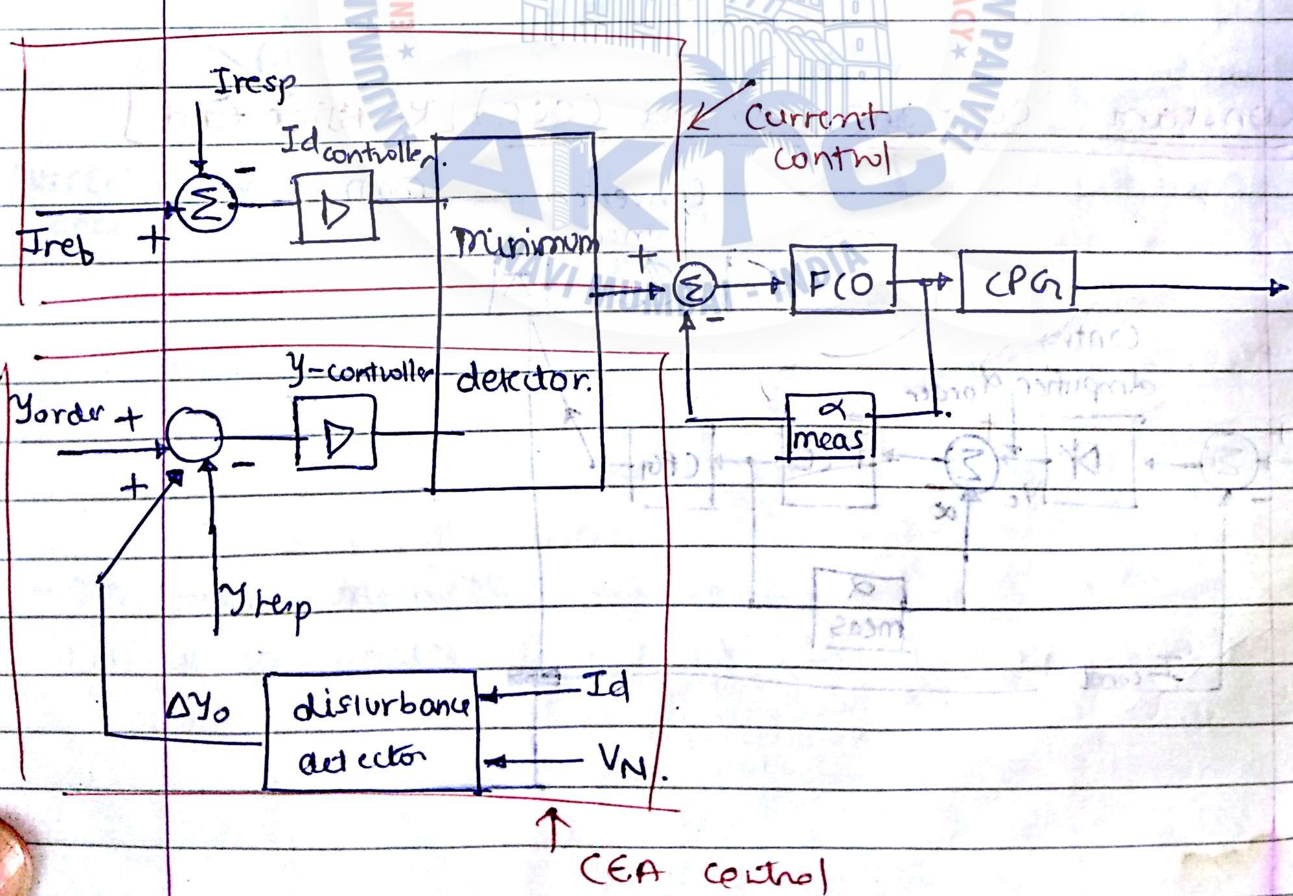
- let us suppose we are measuring the rectifier end current. The rectifier is supposed to maintain constant current
- This current is measured & compared with referance value.
- The error is amplified to get a voltage function ie Vc. The (Vc) is generating 'α'. The ~~act~~ current 'α' value is compared with 'α' generated by Vc'
- If 'α' error is there the FCO will try to shift 'α' slowly to desired value.

• Current & CEA control [Inverter end]



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- Either current control or CEA control will be executed
- Since the extinction angle cannot be controlled directly, either a predictive or a feedback control has to be used
- A predictive method is used to ensure that adequate commutation voltage-time area is available at the instant of firing for successful commutation
- The firing angle is based on calculation of the overlap angle (u) from measured values of current & voltage.

* Valve Blocking and Bypassing:

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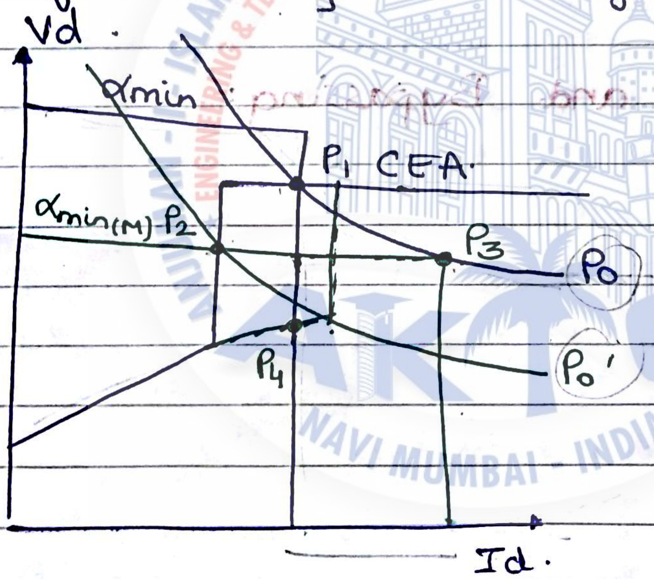
* Constant Power Control:

- When Rectifier is on CC control, P_1 is the original operating point
- When inverter is operating in CC mode, the power in link becomes P_2.
- To maintain the constant power, current order of the inverter is increased so that operating point is P_3
- But if inverter current order is increased, then power order will be P_4 which is further reduced instead of increasing & voltage is also reduced.



* Start up of DC link

- HVDC link can be started using long (120°) or short (60°) gate pulses.

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- Start up with long gate pulses:

 - Deblock inverter at around $\gamma = 90°$
 - Deblock rectifier at $\alpha = 85°$ to force low DC current
 - Ramp up voltage by inverter control & current by rectifier control.

- Start up with short gate firing pulse:

 - The current extinction during the start up is a problem as valve with forward bias is not put in conduction
 - Sequence as follows.
   (1) Open bypass switch at one terminal
   (2) De-block the same terminal & load to minimum current in the rectifier mode.
   (3) open bypass switch at second terminal & commutate the current to the bypass pair.
   (4) Start the second terminal also in the rectifier mode.
   (5) Inverter terminal is put into the inversion mode
   (6) Ramp up voltage by inverter control & current by rectifier control.
   (7) Before raising the current, the voltage is raised
   (8) Rate of increase of power is 2-10 pu/second.

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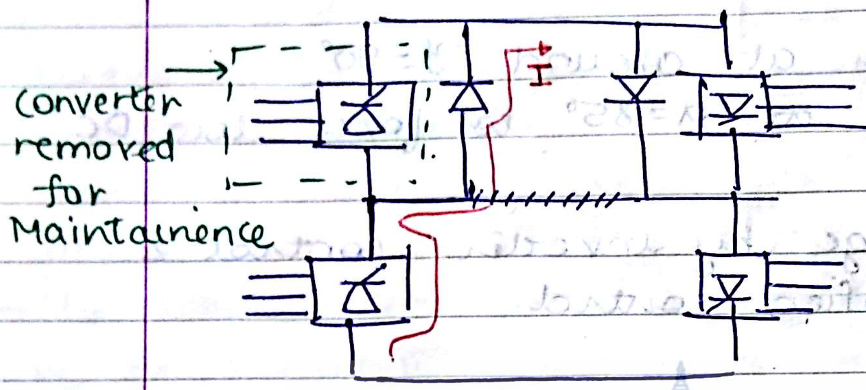
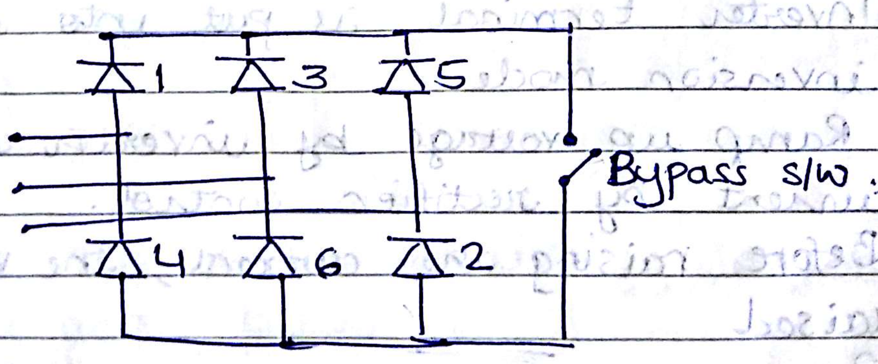
• Bypass Valve / Bypass Switch:



- If a converter is to be removed for maintainence, the current path is maintained by the bypass valve.

- If a bypass switch is used the voltage across the s/w is to be made zero before switching to avoid large transients. Bypass switch is represented by a switch in place of the valve & functions same as the bypass valve.

- The voltage is made zero across the s/w as follows.



'5' & '2' are made conducting so that net voltage across s/w is zero & the bypass switch can be switched. '5' & '2' are thus known as bypass pair.

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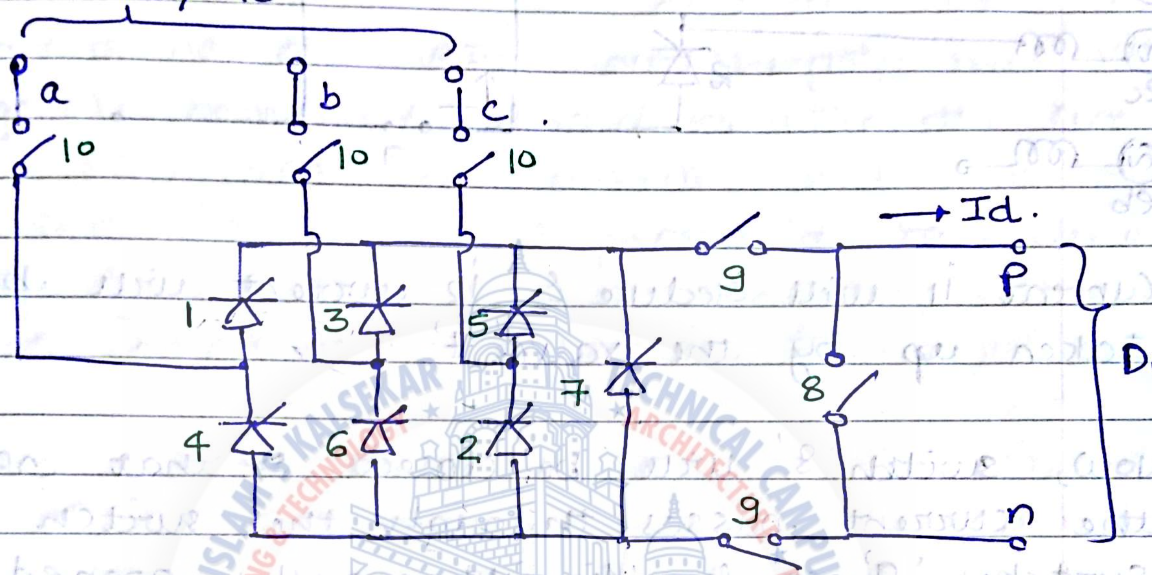
* De-energization of bridge.

- Normally each bridge has a bypass valve.

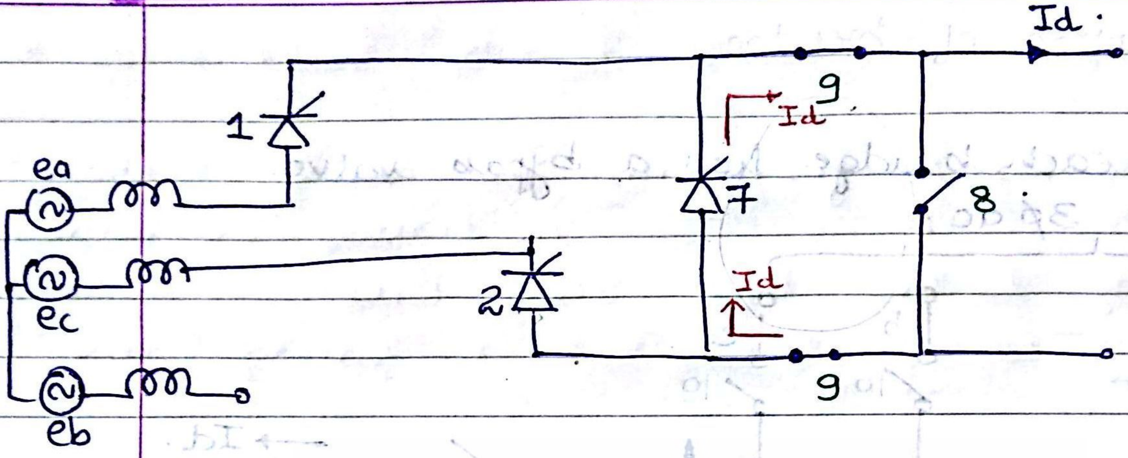


- Deenergization of bridge is carried out when some valves are damaged and are to be taken out for repair.

- It is not easy to switch & instantaneously remove the bridge for maintainence purpose as it introduces large harmonics both in ac side & dc side.

- In order to fire valve '7', the voltage across it should be +ve. Thus we have to wait for an appropriate instant to fire 7.

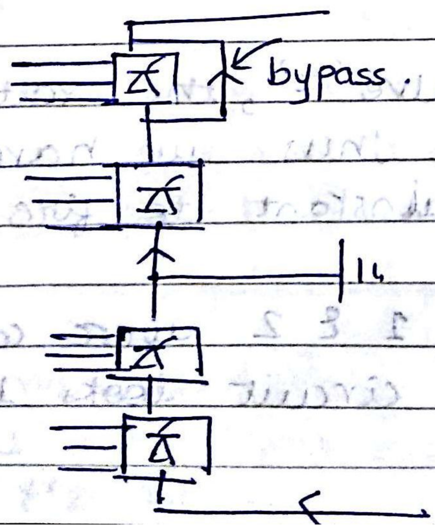
- let us assume valve 1 & 2 were conducting when '7' was fired the circuit looks like below



- Current i_1 will reduce & i_2 current will be taken up by the valve '7'.

- Now, switch '8' will be closed so that now the current passes through the switch & switches '9' can be simultaneously opened. thereby helping in succesful de-energisation of the bridge.

- De-energization /energization of bridges is only executed when there are more than one converter bridge/pole such that a bypass has to be created across the bridge to be removed/added as shown below.



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- But for a single bridge/pole, the entire HVDC link has to be started up or stopped for maintainence purpose.

- One bypassing a bridge from the pole, the voltage is reduced & the current in the link is not constant. The converter bridge at the other end has to be bypassed too to reduce voltage from other end as well & make current constant.

* Energization of bridge

- The current is diverted to bypass pair from switch S1
- Some voltage is required to be generated by switch. AC breaker can be used to have some arc voltage
- Inverter can be operated as rectifier with $\beta = 90°$.

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* Reversal of Power flow:

- HVDC systems are inherently capable of power flow in either direction
- HVDC systems have full control features that permit bi-directional power flow.

- Power Reversal steps:

(1) Reduction of current to 0.1 or 0.5 pu via step or ramp
(2) Decrease/Increase of voltage via ramp or exponential function followed by current ramp to reach the required level.

- Typically fast power reversal times would be of the order of 20 to 30 ms although ac system limitations, dc cable design constraints, or power dispatch conditions may increase it to several ~~conditions~~ seconds.

* Controls for enhancement of AC system performance:

(1) Supplementary controls are required to exploit the controllability of DC links for enhancing 'ac' system dynamic performance.

(2) Following are major reasons to use Supplementary controls.

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- Improvement of damping of ac system electromechanical oscillations.
- Improvement of transient stability
- Isolation of system disturbance.
- Frequency control of small isolated systems
- Reactive power regulation & reactive power support.

(3) The supplementary controls use signals derived from ac systems to modulate dc quantities

(4) The modulating signals can be frequency, voltage magnitude and angle, and line flows. The particular characteristics depends upon system characteristics & desired result.