HVDC Circuit Breakers

The HVDC circuit breaker is a switching device that interrupts the flow of normal and abnormal direct current. The challenge in breaking direct current is the absence of zero current crossings. An additional component must be used that either generates zero-crossings by application of special oscillating circuit and mechanical circuit breakers or power electronics to break the current. The HVDC circuit breakers are required for meshed DC-grids and multi-terminal DC links.

Requirement for HVDC Circuit Breaker

The HVDC circuit breaker operation & design is complex as compared to AC circuit breaker due to the absence of natural zero crossing. The arc generated in HVDC will never extinguish & it will heat up the contacts of the breaker & eventually destroy the contacts rendering the whole CB useless.

Not to mention, the circuit will still be complete & the equipment connected will get damaged due to the fault current. Therefore, the following requirement must be completed to ensure safe circuit breaking in HVDC circuit breaker,

• Creation of artificial zero crossing

• Dissipation of the stored energy inside the LC circuit

• Withstanding the voltage between its contact

. prevention of arc restriking

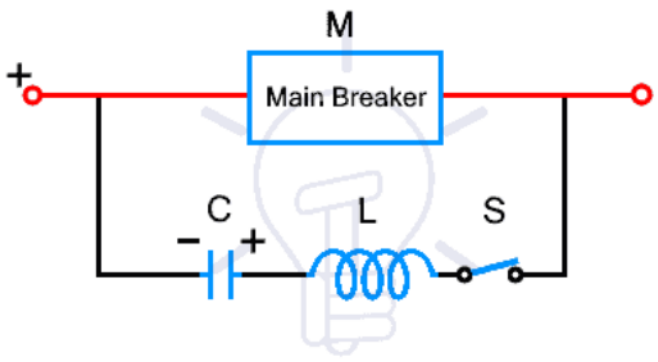
In order to fulfill the above requirements, an LC circuit is introduced with the circuit breaker in parallel which will generate artificial zero current across the line to safely break open the circuit. The strength of the arc is directly proportional to the voltage level & the current. Therefore the fault current must be brought down to zero using an external circuit before breaking it.

Working Principle of HVDC Circuit Breaker

In order to generate artificial zero current in the system, an LC circuit is connected in parallel with the circuit breaker.

Method 1:

The following figure shows a typical HVDC circuit breaker & its working principle.



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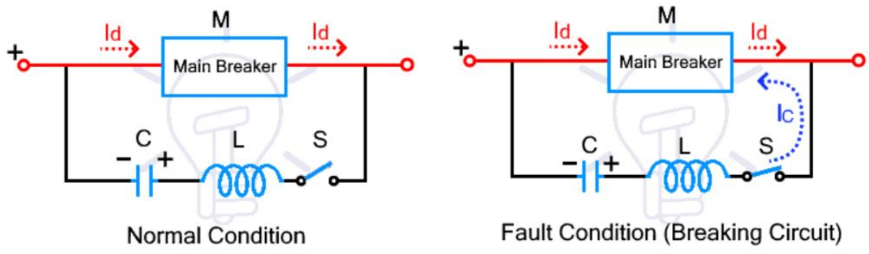
A pre-charged capacitor C is connected having reversed polarities as shown in the figure. An inductor L & a switch S is connected in series with the capacitor C. this extra circuit is connected in parallel with the main breaker M.



Under normal conditions, the switch S is open & the main breaker M is closed & the current flow through it.

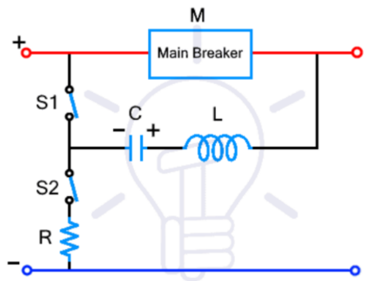
During current interruption or fault current conditions, the switch S is closed which completes the LC circuit & the main breaker M is opened.

During this time, the capacitor C start discharging & it pushes the current in reverse direction through the breaker M, forcing the arcing current to oscillate (reaching to zero point) which results in artificial commutation or zero crossing. This artificial zero commutation generated by the LC circuit allows the arc to extinguish at zero current point. The extra energy is dissipated with in the LC circuit.

This type of DC circuit breaker can work on a single power line & does not require the second opposite polarity line.

Method 2:

Another method of arc quenching in HVDC circuit breaker is explained using the following design that uses both lines of a DC transmission.



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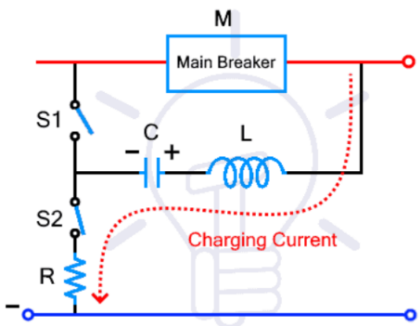
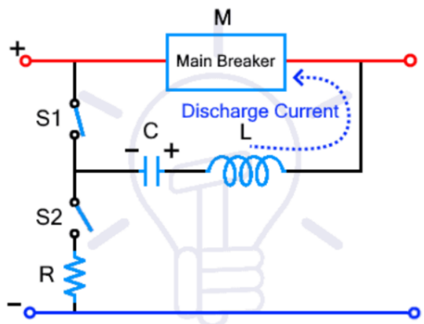
In this method, the Main breaker M is connected on the live or hot line. An LC circuit is connected in parallel with the main breaker M using two switches Sl & S2. The S2 switch connects the LC circuit to the ground through a high resistance R.



Normal Condition



Fault Condition (Breaking Circuit)

Under normal condition, the main breaker M & the switch S2 is closed, while the Sl is open. The current flows through the main breaker M to the load & also through the switch S2 to charge the capacitor. The capacitor is charged through the high resistance.

During current interruption or fault current, the switch S2 is opened & the Sl is closed. The charged capacitor starts discharging the current in reverse direction through the main breaker M. The LC circuit starts resonating & creates oscillating current that forces the current through the main breaker M to cross zero.

The main breaker M contacts separate at this zero current, resulting in the extinction of the arc. As soon as the M contacts open, the switch S2 is closed & Sl is opened. The S2 allows the extra energy to dissipate in the heavy resistance R. This prevents the arc from re-striking.