The development of suitable high-voltage DC (HVDC) breakers is an important element in the design of HVDC transmission systems as fault protection in DC systems is more complicated than in AC systems. The lack of zero crossing between DC voltage and current is a serious challenge, making it more difficult to meet the protection requirement of a DC system.

In recent years, several new HVDC breakers and relevant protection schemes have been proposed. These topologies and protection schemes have a variety of advantages and disadvantages. This dissertation compares different fault current protection schemes with regard to power loss, switching time, the number of semiconductor elements and so on, proposes a new protection scheme, and discusses the overvoltage protection scheme of insulated-gate bipolar transistors (IGBTs) in multilevel modular converters (MMCs, called random first blocking). With this method, there are many possible fault current slopes after the first blocking. The threshold current can be determined using this method.

**Protection schemes independent of HVDC converters**

- All-solid HVDC breaker
  - Short switching time, the over-current can be limited very fast
  - The conduction loss of semiconductor devices is very large
  - During normal operation, the resonant HVDC breaker has no extra loss
  - There is always plasma between the contact of the mechanical switch
  - Low power loss during normal operation, the switching time is limited between several milliseconds
  - The over-current is sometimes too large, and the IGBTs in the main switch must be designed specifically

- Resonant HVDC breaker

- Hybrid HVDC breaker
  - The over-current is sometimes too large, and the IGBTs in the main switch must be designed specifically

**Protection schemes based on classical MMC converters**

- Full bridge sub-module (FB SM)
- Clamp double-sub-module (CDSM)
- Five-level cross-connected cell type (FCCCT)
- Four-level MMC cell type (LCT)

**Protection schemes based on new MMC converters**

- One-arrester version for double-thyristor-switch MMC sub-module
- Two-arrester version for double-thyristor-switch MMC sub-module

**Conclusion**

1. Different HVDC breakers have different advantages and disadvantages. The design of HVDC breakers is a trade-off between switching time, loss power and so on.
2. The fault ride-through capability of MMCs leads to large power loss and high hardware costs. MMCs, which can work under overmodulation state, have even greater loss and cost.
3. All MMCs with fault ride-through capability can use the first blocking method to reduce the stress of semiconductor devices. A suitable threshold current can limit the maximum fault current and ensure anti-disturbance ability.
4. The new MMC protection scheme combines MMC topology and HVDC breakers, giving it the advantages of these protection schemes.

**HVDC systems and their protection**

Thyristor converters are widely employed as rectifiers in linear current constant (LCC)-based drives to provide an adjustable DC current. A thyristor converter can work in either rectifying or inverting mode. When the fault occurs in LCC HVDC, the thyristors are all blocked. Thyristors can be turned off at the zero crossing point of current.

For two-level and three-level VSCs, large capacitors are installed at the DC side. They smooth the DC voltage and make sure that the DC side reacts like a voltage source. However, when the DC fault occurs, due to the discharging of the DC link capacitor, substantial overcurrent is generated due to the rapid decrease in DC voltage. On the other hand, when the fault is detected, fully controllable switches are all blocked. However, the anti-paralleled diodes act as an uncontrolled rectifier, which cannot block the fault current.

For modular multilevel converter (MMC), because of its modularized structure, it is easy to realize hundreds voltage levels to approximate AC voltage and the THD can be reduced to a great extent. Hence, only small filters are needed or may even be omitted. However, the MMC with half-bridge cannot block the current path during the DC fault, because the diodes act as an uncontrolled rectifier. In order to realize the protection of HVDC system, different protection schemes are proposed.