Reactive Power and AC Voltage Control of LCC HVDC System with Controllable Capacitors

Introduction:

Traditional Line-Commutated Converter (LCC) based High Voltage Direct Current (HVDC) technology has played an important role in long distance bulk power transmission around the world since its first application 60 years ago. However some well-known limitations associated with it still exist today which to a certain extent limit further applications of such a technology. One of the limitations is significant reactive power requirement at both sides of the HVDC system. The reactive power requirement originates from the firing of thyristors after commutation voltage becomes positive, which in effect delayed the current waveforms with respect to the voltage waveforms.

Existing system:

In this case since the two converter stations are located on the same site, the problems of communication delay and the risk of loss of communications between rectifier and inverter control systems are minimized. Also the measurements from both terminals are readily available for both control systems. Hence it is possible for the inverter to control its reactive power consumption by varying its extinction angle while the danger of losing commutation margin can be mitigated by the rectifier controller modifying its operating conditions. This type of control helps improve the AC voltage stability at the inverter bus by controlling reactive power consumption, but considerable steady state reactive power...
consumption still remains. In addition this type of control strategy is limited to back-to-back HVDC schemes. For point to point HVDC schemes, unlike back-to-back schemes, the communication delay and/or the requirements for the system to operate without communications largely limit the possibility of reactive power control. Most of the literatures are then focused on reactive power compensation rather than reducing reactive consumption level of converter.

Disadvantages:

- Significant reactive power requirement at both sides of the HVDC system.
- Due to no voltage control the large AC disturbances in the system.

Proposed system:

The LCC HVDC system with controllable capacitors and the connected AC system at the inverter side. In the figure, TY1-TY6 and TD1-TD6 are thyristor valves, CapYa, CapYb, CapYc and CapDa, CapDb, CapDc are capacitor modules, SIYa-S4Ya are four Insulated Gate Bipolar Transistor (IGBT) switches for capacitor module CapYa. An induction machine is added to the inverter AC bus to test the AC voltage controller performance. Capacitor modules are connected in series between the secondary side of converter transformers and thyristor valves. Each capacitor module can be realized by a single
module (as that for 2-level VSC) or by a number of series connected sub-modules to achieve higher insertion voltage. Each module consists of four IGBT switches with anti-parallel diode across each one of them. The reference polarity of the capacitor is shown in Figure. Each capacitor module will be inserted as a positive voltage when $S1$ and $S4$ are switched on and $S2$ and $S3$ are switched off, and will be inserted as a negative voltage when $S2$ and $S3$ are switched on and $S1$ and $S4$ are switched off. Bypass is achieved by switching $S1$ and $S3$ on or $S2$ and $S4$ on at the same time.

**Advantages:**

- An induction machine is added to the inverter AC bus to test the AC voltage controller performance.
- Commutation voltage from the inserted capacitors guarantees the successful commutations when inverter is exporting reactive power.
Application:
- Bulk power transmission applications.

Block diagram: