ABSTRACT

The long-distance power transmission using the HVDC network has been gaining increasing acceptance in recent years. However, in DC transmission, it is difficult to exchange small amount of power from HVDC transmission networks whereas it can be done very easily achieved in HVAC transmission networks using simple AC transformers. But there may be many isolated villages/remote renewable energy sources along the route of long-distance HVDC transmission lines which could be integrated into the main power system network. This has attracted industry as well as academia to explore the possibility of tapping power from HVDC transmission lines and also to inject remotely located renewable energy power to HVDC transmission lines. In this thesis, the concept of exchange of small amount of power from an HVDC transmission line to supply power to isolated rural villages or to integrate remote renewable sources is explored.

The single-stage parallel scheme to integrate a remote AC network with a long-distance LCC-based HVDC system using VSC converter is investigated in chapter 3. The single-stage parallel power tapping scheme combines the advantages of bulk power transmission capability of Line Commutated Converters and the ability of Voltage Source Converters to connect to a passive network. In order to achieve DC fault tolerant capability , the full-bridge Modular Multi-Level Converter (MMC) is used to integrate a weak AC network located near the long-distance Line Commutated Converter (LCC) based HVDC transmission line. The coordinated control of the LCC HVDC system with the MMC tapping station is presented. The operational performance of the HVDC system with the MMC-based shunt tap and its performance during DC side fault is analyzed using the time domain simulation model built in PSCAD/EMTDC. The limitation of a single-stage parallel HVDC tap is that the DC link voltage rating of the VSC should be rated for the operating voltage of the HVDC transmission line irrespective of the power rating of the shunt tap. In a two-stage power tapping scheme, the DC-DC converter could be used to reduce the DC voltage level of the HVDC transmission line to an intermediate value. The thesis investigates new circuit topologies with modular structure and explores their suitability in tapping power from the HVDC system as well as the evacuation of renewable power to HVDC and MVDC networks.

A new circuit topology of DC-DC converter with high step-down ratio to tap power from HVDC system to feed the local loads which are located in the vicinity of HVDC transmission corridor is presented in chapter 4. The proposed DC-DC converter consists of a large number of identical submodules each having one controllable switch, two diodes, and one capacitor.

The operation of the DC-DC converter is based on repeated charging and discharging of capacitors through a resonant circuit. Zero current switching (ZCS) is achieved for all the switches used in the converter. In case of failure of one submodule, the failed submodule could be bypassed without affecting the normal operation of the HVDC tap. Equations governing the behavior of the proposed converter and the design of the components have been presented. The operational performance of line commutated converter (LCC) based HVDC system along with HVDC tapping scheme with the proposed converter is investigated using a simulation model developed in PSCAD/EMTDC. The proposed circuit topology has also been verified with a downscaled experimental prototype

In Chapter 5, a fault-tolerant scheme for integrating renewable energy sources to symmetrical monopolar VSC HVDC system using a new modular resonant DC-DC converter is presented. The proposed DC-DC converter consists of many identical low voltage submodules which consist of two controllable switches, one diode, and a capacitor. The switches of the proposed DC-DC converter are configured to provide the converter an inherent fault-tolerant feature which enables it to isolate itself during DC faults in the HVDC system. The integration of renewable energy sources to a symmetrical monopolar VSC HVDC transmission system using the proposed tapping scheme is presented. However, the DC-DC converter has limitations for use in the LCC HVDC system. During the commutation failure /DC side disturbances, the freewheeling diode of the tapping station will conduct thereby feeding power to the inverter HVDC station thus delaying the recovery of the HVDC system from such disturbances. Thus, the DC-DC converter used for such a power-tapping scheme needs to isolate itself during the DC faults and should not feed the converters of the LCC HVDC system. Thus, a modified modular resonant DC-DC converter is presented to evacuate power to LCC-based HVDC systems is presented. The inherent fault-tolerant capability of the converter prevents feeding to any fault in the HVDC line and enables faster recovery from commutation failures in the main HVDC system. The operational performance of the proposed scheme is verified using a simulation model developed in PSCAD/EMTDC and an experimental prototype.

In chapter 6, a new scheme to directly integrate the output of wind generators and solar PV panels with an MVDC system using a DC-DC converter is presented. This will reduce the number of equipment involved in the energy conversion process. In the scheme presented in this paper, the output of a permanent magnet synchronous generator coupled with a wind turbine is converted to a low voltage DC by AC-DC converter and then directly connected to an MVDC system using a fault torrent soft switched high gain DC-DC converter. The output from high voltage solar PV panels is also connected with the MVDC transmission network