Control, Operation and Protection of Low Voltage DC Systems

Abstract: Increasing share of direct current (DC) loads in the load profile across the world with high penetration of DC generating distributed energy resources integrated to the system with advanced power electronics devices has led to a focused discussion on LVDC system. This dissertation intends to contribute towards the same discussion showcasing the advantages of the LVDC systems.

LVDC is a challenging area of multidisciplinary research with research focus on (a) system configuration (constant power loads, DC cables, etc.), (b) power flow management, (c) converter control strategies, (d) integration of renewable energy sources, (e) storage operation in LVDC systems, (f) protection philosophy and so on, as discussed below.

1) System modelling, capacity, etc. are the questions related to system configuration which are application dependent. Therefore, preliminary steps include the study of various structural blocks to be utilized in DC system, their implementation, and operational constraints to develop the test system.
2) To regulate the DC system voltages, active power is the key indicator. An integrated power management strategy is developed to maintain power equilibrium. Various system transients such as load fluctuations, intermittent power due to uncertain weather conditions, accidental islanding, are arrested by local converter control of the corresponding sources. Event triggered communication signals are exchanged with power control unit to take control decisions in case of load shedding, autonomous mode of operation of storage units, and mode transition by grid connected voltage source converter.
3) Operation of battery energy storage systems (BESSs) are inevitable in the system with intermittent power sources. Interfacing the BESSs and to accommodate the operational constraints of batteries, a decentralized bi-directional converter control has been developed. Secondary control loop has two integrated loops, *P-loop* and *V-loop* working simultaneously as per the feedback due to system conditions. The default mode of operation for BESSs is power regulation but due to accidental grid disconnection, there is a smooth transition to voltage regulation mode.
4) Apart from operation and power management of LVDC systems, protection aspect of these systems is studied in detail. The information regarding the during fault topology has been analyzed and an equivalent RLC network is developed to study fault current

characteristics. Already available dedicated protection schemes are explored and are implemented on simulation platform to identify the literature gaps.

5) In case of DC faults, it is important to detect, identify and isolate the faulty segment without the intervention of converter's inherent protection. In case the protection scheme is not prompt enough, the converters block themselves leading to the disconnection of the sources. This de-energizes the complete system. To avoid this, a dedicated protection scheme to detect and isolate feeder faults in LVDC systems has been developed utilizing single-ended information.

Key words: LVDC system, Power Management, Bi-directional Converter Control, Battery Storage, LVDC Protection, DC-AC Converter Control.