Approved in 37th BoA Meeting (29-10-2020)

Course Number: EE630
Course Name: HVDC Transmission and Flexible AC Transmission Systems
Credits: 3-0-0-3
Prerequisites: EE-303 (Power systems) and EE-309 (Power electronics)
Intended for: PG
Distribution: Elective for M.S., M. Tech. & Ph.D.

Preamble: The deregulation of the electricity market together with increasing constraints resulting from social opposition to the installation of new facilities brings great pressure to the operators of transmission and distribution systems. Large scale integration of renewable energy into power supply brings further pressure on how to operate and control future power networks. These new trends require the need for flexibility, power quality and increased availability of electricity transmission and distribution systems by using new devices which can be implemented with limited investments, short delivery times and short planning and decision-making horizons. FACTS (Flexible AC Transmission Systems) is a terminology to describe a whole family of concepts and devices for improved use and flexibility of electrical power systems. HVDC is used for long distance power delivery, interconnection of asynchronous AC systems and integration of large-scale renewable energy systems.

Course Outline: The course covers the basic concepts and operating principles for integration of HVDC system and FACTS devices to the existing power network. The students will be introduced to the evolution of HVDC systems, and comparison of HVAC and HVDC transmission systems. The components involved in HVDC transmission system, analysis of HVDC converters, and HVDC control will be taught. The course will also focus on FACTS devices and their use to improve the operation of power networks. Application of HVDC system and FACTS devices to existing power system in relation to integration of renewable energy will be covered. Also, the new developments in multi-terminal HVDC Grid will be discussed.

Course Modules with Quantitative lecture hours:

Introduction to HVDC – 5 hours
Introduction of DC power transmission technology, comparison of AC and DC transmission, limitation of HVDC transmission, reliability of HVDC systems, application of DC transmission, description of DC transmission system, planning for HVDC transmission, modern trends in DC transmission, advantages of HVDC.

Analysis of HVDC converters – 4 hours
Simple rectifier circuits, required features of rectification circuits for HVDC transmission, choice of converter configuration, converter bridge characteristics

Control of HVDC converter and systems: – 5 hours
Necessity of control of a DC link, rectifier control, compounding of rectifiers, power reversal of DC link, voltage dependent current order limit (VDCOL) characteristics of the

converter, inverter extinction angle control, pulse phase control, starting and stopping of DC link, constant power control, control scheme of HVDC converters.

Harmonics and filters: – 5 hours
Generation of harmonics by converters, characteristics of harmonics on DC side, characteristics of current harmonics, characteristic variation of harmonic currents with variation of firing angle and overlap angle, effect of control mode on harmonics, non-characteristic harmonic.

FACTS devices: – 5 hours
Introduction to FACTS; Compensation of transmission systems, Series and Shunt FACTS controllers - variable impedance type and switched converter type, Unified Power Flow Controller and other types of FACTS devices.

Load flow and stability analysis: – 5 hours
Component Models for the Analysis of AC DC Systems, Power flow analysis of AC-DC systems, Transient stability analysis, Dynamic stability analysis. Application of FACTS controllers in improvement of power system operation and stability.

Reactive power control: – 3 hours
Reactive power requirements in steady state, sources of reactive power, static VAR systems, reactive power control during transients

Fault and protection schemes in HVDC systems: – 5 hours
Nature and types of faults, faults on AC side of the converter stations, converter faults, fault on DC side of the systems, protection against over currents and over voltages, protection of filter units.

Multiterminal HVDC systems: – 5 hours
Types of multiterminal (MTDC) systems, parallel operation aspect of MTDC. Control of power in MTDC. Power upgrading and conversion of AC lines into DC lines, Parallel AC/DC systems, FACTS and HVDC system application in wind power generation- VSC based applications for wind power systems

Text book:

1. K. R. Padiyar, *HVDC Power Transmission Systems*. Wiley, 1990
2. J. Arrillaga, *High Voltage Direct Current Transmission.* The Institution of Electrical Engineers, London, UK, 1998.
3. N. G. Hingorani, *Understanding FACTS*, IEEE Press, 2001.

References:

1. K. R. Padiyar, *FACTS Controllers in Power Transmission and Distribution.* New age international (p) limited, 2007.
2. EW Kimbark, *Direct Current Transmission.* Wiley-Interscience. New York, 1971.
3. S N Singh, *Electric Power Generation, Transmission and Distribution.* PHI, New Delhi 2nd edition, 2008.
4. T J E Miller, *Reactive Power Control in Electric Systems*, Wiley, 1982

Similarity Content Declaration with Existing Courses:
NA

Proposed by: **Pratim Kundu** School of Computing and Electrical Engineering