International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 2, Mar-Apr-2020, ISSN (Online): 2395-566X

A Review Article of Hvdc Based Power Loss Reduction and Estimation of Power Transmission

ME Scholar Prashant Sharma, Anil Kumar Kori
Department of Electrical Engineering, Jabalpur Engineering College, Jabalpur India
prashant93sharma@gmail.com, akkori1@rediffmail.com

***Abstract* – Line commuted converter user in HVDC transmission systems inject harmonics into their associated AC and DC systems. A conventional approach to filter these harmonics is to use passive filters on both AC and DC sides of the converter. Apart from their technical problems, harmonic filters constitute a considerable part of the volume and cost of present DC terminal stations. Another possible alternative of harmonic suppression is to increase the number of pulses of AC-DC converters by transformer phase-shifting techniques, but the resulting complicated circuitry together with its problems of insulation produce significant technical and economical disadvantages. This Paper presents an overview of classical HVDC transmission system. It also provides a brief historical development of the technology and state of art in the field of HVDC transmission system. Based on outcome of literature survey, broad research goals are identified.**

***Keywords*– Development of HVDC & FACTS, Current status of power electronics techniques, Future development of HVDC & FACTS.**

I. INTRODUCTION

The development of power system is increased demand for electrical energy in industrial countries. In next 20 years, the power consumption is developing and emerging countries is expecting more than double [1, 2]. The basic energy consumption of driven factors is shown in figure 1. As an energy demand growth, high voltages are needed. In industrialised countries, the demand level is increased. There is a gap between transmission capacity and actual power demand, which leads to technical problem in the system like voltage problem, stability limitation etc. This problem can be solved by using interconnection of separated grids. In large AC transmission and synchronous interconnection, technical problems can be expected [3, 4].

The rapid development of power systems generated by increased demand for electric energy initially in industrialized countries and subsequently in emerging countries led to different technical problems in the systems, e.g., stability limitations and voltage problems. However, breaking Innovations in semiconductor technology then enabled the manufacture of powerful thrusters and, later of new elements such as the gate turn-off thrusters (GTO) and insulated gate bipolar transistors (IGBT).
Development based on these semiconductor devices first established high-voltage dc transmission (HVDC) technology as an alternative to long-distance ac transmission. HVDC technology, in turn, has provided the basis for the development of flexible ac Transmission system (FACTS) equipment which can solve problems in ac transmission. As a result of deregulation, however, Operational problems arise which create additional requirements for load flow control and needs for ancillary services in the system. This paper summarizes Flexible ac transmission system (FACTS),High-Voltage DC Transmission (HVDC), FACTS devices, Power transfer controllability, Faults in HVDCThe rapid development of power systems generated by increased demand for electric energy initially in industrialized countries and subsequently in emerging countries led to different technical problems in the systems, e.g., stability limitations and voltage problems.

However, breaking Innovations in semiconductor technology then enabled the manufacture of powerful thrusters and, later of new elements such as the gate turn-off thrusters (GTO) and insulated gate bipolar transistors (IGBT). Development based on these semiconductor devices first established high-voltage dc transmission (HVDC) technology as an alternative to long-distance ac transmission. HVDC technology, in turn, has provided the basis for the development of flexible ac Transmission system (FACTS) equipment which can solve problems in ac transmission.

As a result of deregulation, however, Operational problems arise which create additional requirements for load flow control and needs for ancillary services in the system. This paper summarizes Flexible ac transmission system (FACTS),HighVoltage DC Transmission (HVDC), FACTS devices, Power transfer controllability, Faults in HVDC System are discussed in this paper to

explain how greater performance of power network transmission with various line reactance can be achieved.
(a) Reduced maintenance
(b) Better availability
(c) Greater reliability
(d) Increased power
(e) Reduced losses
(f) Cost-effectiveness
During the state of power exchange in interconnected lines to a substation under variable or constant power, the HVDC converters comprehends the power conversion and later stabilizes the voltage through the lines giving a breakeven margin in the power transmission. The first large-scale thyristors for HVDC were developed decades ago. HVDC became a conventional technology in the area of back-to-back and two- terminal long-distance and submarine cable schemes [3].

However, only few multi terminal schemes have been realized up to now. However, further multi terminal HVDC schemes are planned in the future (Fig. 1.1). The main application area for HVDC is the interconnection between systems which cannot be interconnected by AC because of different operating frequencies or different frequency controls. This type of interconnection is mainly represented by back-to-back stations or long-distance transmissions when a large amount of power, produced by a hydropower plant, for instance, has to be transmitted by overhead line or by submarine cable. HVDC schemes to increase power transmission capability inside of a system have been used only in a few cases in the past. However, more frequent use of such HVDC applications can be expected in the future to fulfill the requirements in deregulated.

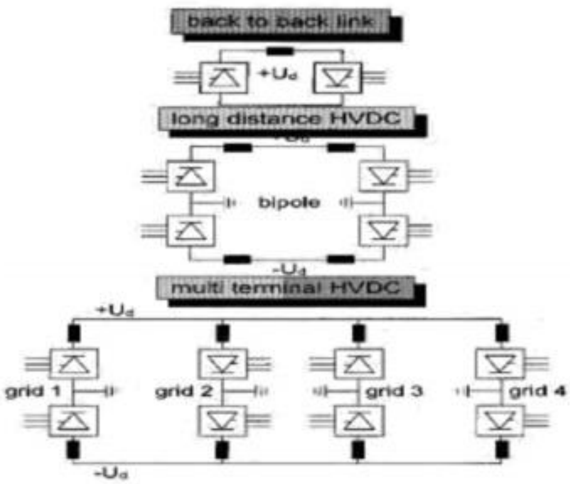

Fig.1. various types of HVDC Connections.

Earlier, large AC system with long transmission and synchronous interconnection had some technical limitations .These factors are given in Later, the performance of long distance AC transmission system was improved by FACTS (Flexible AC Transmission system) with help of power electronics. This FACTS system was introduced by Dr. N. G. Hingorani, from EPRI, USA. FACTS devices are based on solid - state control that performances are control transmission line power flow and magnitude and phase of line end voltages. Now, FACTS technology has been extended and excellent operating performances are available worldwide. It became more mature and reliable.

Static var compensators control only one of the three important pameters (voltage, impedance, phase angle) determining the power flow in ac power systems: the amplitude of the voltage at selected terminals of the transmission line. Theoretical considerations and recent system studies (1) indicate that high utilization of a complex, Interconnected ac power system, meeting the desired objectives for availability and operating flexibility, may also require the real time control of the line impedance and the phase angle.

(2) proposed the concept of flexible ac transmission systems or FACTS, which includes the use of high power electronics, advanced control centers, and communication links, to increase the usable power transmission capacity to its thermal limit. When using carrier based Pulse Width Modulation (PWM), its switching frequency has to be increased (typically, 33 times fundamental frequency even higher) , which cause considerable power losses. It reduces the total efficiency and economy of the UPFC-HVDC project. And they are also the Impediments for equipment aimed at the green, renewable Sector.

Therefore, with regard to PWM technology suited for UPFC-HVDC, how to reduce switching frequency and possess good harmonics performance, excellent transient control capability simultaneously become critical. And this is exactly the aim of the paper. The paper presents an innovative hybrid PWM technology, which comprises a combination of a first PWM with a first switching pattern and a second PWM with a second switching pattern. Hence during a first mode of operation, which may be a steady-state operation, the converter is controlled by the first PWM and during a second mode of operation, which may be a transient operation, the converter is controlled by the second PWM. An intelligent detection function which enables the modulation and the corresponding control system will smoothly switch from the first PWM to the second PWM and vice-versa when a disturbance causing a transient occurs.

II. TYPES OF HVDC

Comparison of AC-DC transmission
HVDC is an efficient technology for long distance power transmission. It can replace the AC transmission between two grids. The advantages of the two methods of

International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 2, Mar-Apr-2020, ISSN (Online): 2395-566X

transmission (AC and DC) which should be considered by designer are based on the following factors [2]:

- Economics of power transmission
- Technical performance
- Reliability

The increased power demand makes power system expansion important. This means that the construction of a transmission line must be considered as a part of a long term planning.

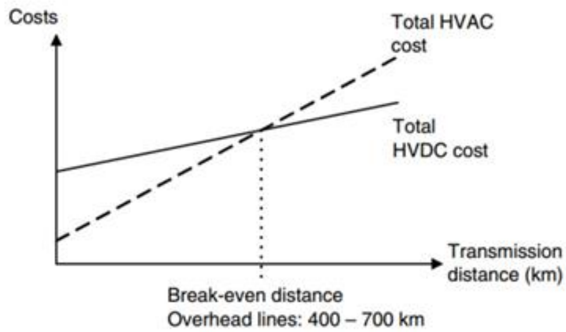

Fig.2. Comparison of AC-DC transmission.

HVDC Converters and Functionalities for Power Transmission Enhancements: During the state of power exchange in interconnected lines to a substation under variable or constant power, the HVDC converters comprehends the power conversion and later stabilizes the voltage through the lines giving a break even margin in the power transmission .

The operation of HVDC filters any system harmonics developed in the network and improves the power transmission to the receiving end by independently adjusting the real and reactive power control. The significance of HVDC controller considered as part of FACTS family device is a structure of the back-to-back converter that governs the conversion of ac-dc-ac; like FACTS . HVDC is assigned for frequency and phase independent short or long distance overhead or underground bulk power transmission with high speed controllability.

This provides greater real power transmission and less maintenance. It reduces the chances of installing power cables Especially in difficult transmission that travels under water . By making use of the back-to-back converters, power transmission under non-synchronous ac systems is easily adaptable. The installation of smoothing reactor the DC Current and reactive power compensation at the sending and Receiving-ends smoothing reactor and AC harmonics filter as Shown in Fig.2.2.The installation of HVDC also depends on the dc voltage and current ratings desired in the network that Yields for optimum converter cost. The converters terminate. The DC overhead lines or cables that are linked to AC buses and network [9].HVDC used for submarine cables connection will normally have 12-pulse converters as shown in Fig.2.2.The bridge converter circuit contains delta and Wye type transformer. The transformer windings filter out system harmonics that occur by using the 6-pulse Graetz bridge converter. Passive filters involved components like reactors, capacitors and resistors are the ones that remove the Harmonics . For instance harmonics filtration Insulated Gate Bipolar Transistor (IGBT) or gate-turn-off thyristors (GTO) are the passive filters used for HVDC connection.

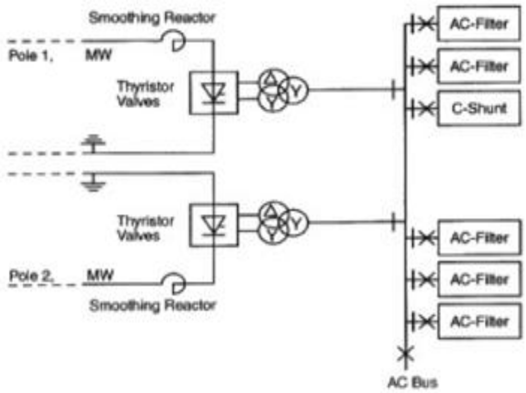

Fig.3. HVDC terminal station in cable transmission.

III. PROJECT OBJECTIVE

1. High Voltage Direct Current (HVDC) has many advantages in power transmission which is widely used to transmit large amounts of power over long distances. A Flexible Alternating Current Transmission System (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy .
2. FACTS devices are used to provide flexible power flow control, support system voltage and improve stability. Multiple FACTS devices in cooperation of HVDC links can greatly improve system performance.
3. However, there are interactions between FACTS and HVDC which could cause unexpected adverse impact on operation system. HVDC system requires an electronic converter to convert electrical energy from AC system to DC system or vice versa. There are two types of HVDC converters which are Current Source Converter (CSC) and Voltage Source Converter (VSC).
4. CSC–HVDC is the technology that applies line-commutated, current-source converters (LCC-CSC) with thyristor valves (figure 1.4). These converters require a relatively strong synchronous voltage source in order to commutate.
5. VSC-HVDC is the technology based on Voltage Source Converter (VSC) with controllable turn-off device (figure 3.1). The current in this technology can both be switched on and off at any time independent of the AC voltage, that is, it creates its own AC voltages in case of blackstart.

International Journal of Scientific Research & Engineering Trends
Volume 6, Issue 2, Mar-Apr-2020, ISSN (Online): 2395-566X

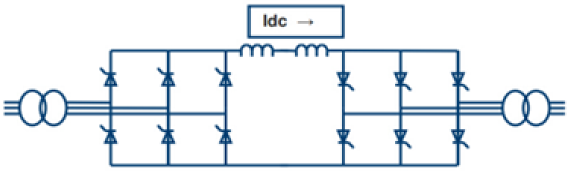

Fig.4. HVDC transmission based LCC technology with thristors.

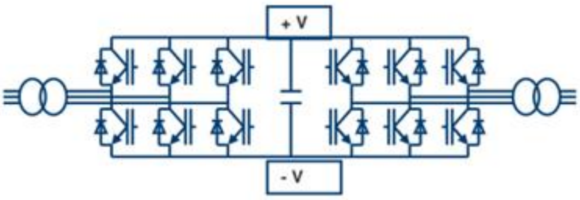

Fig.5. HVDC system based on VSC technology with IGBTs.

IV. LITERATURE REVIEW

S. Mohamed Yousuf, M. Siva Subramaniyan "HVDC and Facts in Power System"(2013) The development of electrical power supplies began more than hundred years ago. At the beginning stage, there were only small DC networks within the local boundaries, which were able to cover of industrial plants. An increasing demand on energy, technology changed to be transmitted from DC to AC power and voltage levels. The driving force for the development of power systems is the increase of electrical power demand. Therefore, power system developed from the regional to national systems. To achieve technical and economic advantages, extend further to large continental systems by applying interconnections to the neighbouring systems. This paper will treat benefits of HVDC and FACTS devices applied in power systems such as increased power transmission capability, improved static and dynamic stability, an increase of a availability and a decrease of transmission losses by using power Electronics techniques.

M. Ramesh, A. Jaya Laxmi "ENHANCEMENT OF POWER TRANSMISSION CAPABILITY OF HVDC SYSTEM USING FACTS CONTROLLERS" (2011) The necessity to deliver cost effective energy in the power market has become a major concern in this emerging technology era. Therefore, establishing a desired power condition at the given points are best achieved using power controllers such as the well known High Voltage Direct Current (HVDC) and Flexible Alternating Current Transmission System (FACTS) devices. High Voltage Direct Current (HVDC) is used to transmit large amounts of power over long distances. The factors to be considered are Cost, Technical Performance and Reliability. A Flexible Alternating Current Transmission System (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system. A Unified Power Flow Controller (or UPFC) is a FACTS device for providing fast-acting reactive power compensation on highvoltage electricity transmission networks.

The UPFC is a versatile controller which can be used to control active and reactive power flows in a transmission line. The focus of this paper is to identify the improved Power Transmission Capability through control scheme and comprehensive analysis for a Unified Power Flow Controller (UPFC) on the basis of theory, computer simulation. The conventional control scheme cannot attenuate the power fluctuation, and so the time constant of damping is independent of active- and reactivepower feedback gains integrated in its control circuit. The model was analyzed for different types of faults at different locations, keeping the location of UPFC fixed at the receiving end of the line, With the addition of UPFC, the magnitude of fault current and oscillations of excitation voltage reduces. Series and Shunt parts of UPFC provide series and shunt injected voltage at certain different angles.

A. Sumit Kumar Sah "FACTS and HVDC Technologies for the Development and Enhancement of Future Power Systems" (2010) The fast development of power electronics based on new and powerful semiconductor devices has led to innovative technologies, such as high voltage dc transmission (HVDC) and flexible ac transmission system (FACTS), which can be applied in transmission and distribution systems. This paper has discussed the application of high voltage power electronics FACTS and HVDC controllers, needs of advance FACTS and HVDC based control for future power system and enhancing system stability and its development. HVDC and FACTS offer major advantages in meeting these requirements.

PatlollaSatishReddy , Mondi VinodKmar , Dr. S. Siva Prasad "Improvement of Stability of HVDC Transmission System using a FACTS Device UPFC" (2015) This paper presents An Improvement of Stability of HVDC Transmission System using a FACTS Device UPFC. Control methods based on selective harmonic elimination pulse-width modulation (SHEPWM) techniques with fuel cell system offer the lowest possible number of switching transitions and improve the voltage level in HVDC transmission system. This feature also results in the lowest possible level of converter switching losses. For this reason, they are very attractive techniques for the voltage-source-converter-(VSC) based high-voltage dc (HVDC) power transmission systems. The project discusses optimized modulation patterns which offer controlled harmonic elimination between the ac and dc side. The application focuses on the conventional two-level converter when its dc-link voltage contains a mix of low-frequency harmonic components. Simulation results are presented to confirm the validity of the proposed switching patterns.

M. A. HANNAN , HUSSIN , P. J. KER , M. M. HOQUE , M. S. HOSSAIN LIPU , A. HUSSAIN, M. S. ABD. RAHMAN , C. W. M. FAIZAL , AND F. BLAABJERG "Advanced Control Strategies of VSC Based HVDC Transmission System Issues and Potential Recommendations" (2018) The converters and their control strategies play an important role in converting, transmitting, and improving the performance of high-voltage direct current (HVDC) system. There are different types of converter and their control strategies being employed in the HVDC system, such as line-commutated converter and voltage source converter (VSC). However, the existing converter controllers have still some limitations on certain deficiencies in certain aspects such as in weak AC grid or at high voltage and power level.

Thus, an advanced converter control strategy is very much important in order to ensure optimal power transfer with minimal loss and stable voltage. This paper presents a comprehensive review of the advanced control strategies to address the problems and enhance the performance of the VSC-based HVDC (VSC-HVDC) transmission system. A detailed study on the overview of VSC-HVDC and their converter classifications are investigated. The main contribution of this paper is to carry out the different types of VSC-HVDC control strategies in controlling voltage, current, power, and the control parameters of the HVDC transmission system. This paper also highlights several factors, challenges, and problems of the conventional VSC-HVDC controllers. Furthermore, this paper provides some suggestions for the advanced control for the future research and development of the HVDC system.

X.-P. Zhang, L.Yao, B. Chong, C. Sasse, and K.R. Godfrey "FACTS and HVDC Technologies for the Development of Future Power Systems" The present status and future prospects of FACTS devices and HVDC technologies for modernizing future power systems are reviewed and discussed. The power system across continental Europe is continuing to change due to the integration of renewable energy sources into power grids, leading to the growing need for advanced FACTS and HVDC control with the possibility of integration with wide area stability control and protection systems to prevent cascading outages and system blackouts.

ZhouLi1,RuopeiZhan1,YazhouLi1,YanHe1,JinmingHou2,XiaolingZhao2,Xiao-PingZhang3"Recent developments in HVDC transmission systems to support renewable energy integration"(2018) The demands for massive renewable energy integration, passive network power supply, and global energy interconnection have all gradually increased, posing new challenges for high voltage direct current (HVDC) power transmission systems, including more complex topology and increased diversity of bipolar HVDC transmission. This study proposes that these two factors have led to new requirements for HVDC control strategies. Moreover, due to the diverse applications of HVDC transmission technology, each station in the system has different requirements. Furthermore, the topology of the AC-DC converter is being continuously developed, revealing a trend towards hybrid converter stations.

MollaShahadat Hossain Lipu ,TahiaFahrin Karim "Effectiveness of FACTS controllers and HVDC transmissions for improving power system stability and increasing power transmission capability" With an increasing demand on energy and the construction of large generation units especially opening of electric power markets, it becomes more and more important to provide stable, secure, controlled and high quality electric power on today's environment. The regulatory constraints on the expansion of the transmission network has resulted in reduction of stability margins and increased the risks of cascading outages and blackouts. Among many possible solutions to overcome these challenges, FACTS devices and HVDC systems play an important role.

These type of devices/systems have shown to be capable in stabilizing transmission systems, resulting in higher transfer capability. FACTS devices and HVDC transmissions have emerged as important solutions to help power systems to increase stability margins. Some of these power electronics-based components have the main function of controlling reactive power (SVC and STATCOM) and some others to control active power (as TCSC and CSC-HVDC transmission). All these devices are also capable of damping electromechanical oscillations. This paper presents a comprehensive review of operation of different types of FACTS controllers in the power system for stability enhancement in term of shunt compensators, series compensators as well as combinations of these two types of compensators. The paper also demonstrates different types of HVDC technology as well as its effectiveness to improve the voltage profile of power system.

Koganti Sri Lakshmi, G.Sravanthi, L.Ramadevi, Koganti Harish chowdary "Power quality and stability improvement of HVDC transmission System using UPFC for Different uncertainty conditions" The requirement of delivering economic quality power supply has become a major concern in this developing technology therefore this desired power control at every point of power system is obtained by power controllers like HVDC and FACT devices. Considering the benefits of HVDC like cost, Technical Performance and reliability with full control over the power transmission it is used for long bulk power transmission and asynchronous interconnection. FACTS are power electronic based equipment used to control the power transfer in AC Networks. UPFC is FACT device which can provide power quality and also used for control of active and reactive power flow in transmission line. The main objective of this paper is to improve power transmission capacity and power quality of hvdc transmission using UPFC .The Conventional control scheme cannot control power fluctuations. Here we dealt different types of faults at different locations placing UPFC permanent at receiving end of the line so that the magnitude of fault current and variations of excitation voltage reduced and finally voltage magnitude is improved by UPFC. At the end, Fast Fourier Transformation analysis is carried out to determine total Harmonic Distortion with and without UPFC for different faults.

Oluwafemi E. Oni, Kamati I. Mbangula, and Innocent E. Davidson "A Review of LCC-HVDC and VSC-HVDC Technologies and Applications" High Voltage Direct Current (HVDC) systems has been an alternative method of transmitting electric power from one location to another with some inherent advantages over AC transmission systems. The efficiency and rated power carrying capacity of direct current transmission lines highly depends on the converter used in transforming the current from one form to another (AC to DC and vice versa). A well-configured converter reduces harmonics, increases power transfer capabilities, and reliability in that it offers high tolerance to fault along the line. Different HVDC converter topologies have been proposed, built and utilised all over the world. The two dominant types are the line commutated converter LCC and the voltage source converter VSC. This review paper evaluates these two types of converters, their operational characteristics, power rating capability, control capability and losses. The balance of the paper addresses their applications, advantages, limitations and latest developments with these technologies.

V.CONCLUSION

The HVDC transmission technology can be realized by using current source converters (CSCs) commutated thyristor switches, known as traditional HVDC or classic HVDC, or by using voltage source converters (VSC-based HVDC). Due to the rapid development of power electronic devices with turn-off capability and of DSPs, which are generating the appropriate offering patterns, the VSC are getting more and more attractive for HVDC transmission. Usually, the VSCs are using insulated gate bipolar transistor (IGBT) valves and pulse width modulation (PWM) for creating the desired voltage wave form. On the market, mainly two manufacture refer to the technology of DC transmission using VSC; these are: ABB under the name HVDC Light R, with a power rating from tenths of megawatts up to over 1000 MW, and the second manufacturer is Siemens under the name HVDC Plus ("Plus" - Power Link Universal Systems).

REFERENCES

[1]. Dr. Madan Mohan, Bhim Singh and B.K. Panigrahi, " A 2-level, 48-Pulse Voltage SourceConverter for HVDC Systems", in 15thNPSC conference, IIT Bombay, Dec'2008 p.p.
[2]. Dr. Madan Mohan, Bhim Singh and B.K. Panigrahi, " A new control strategy for active andreactive power control of 3-level VSC based HVDC system", in IEEE INDICON 2010, p.p.
[3]. Y.H. Liu R.H. Zhang, J.Arrilllaga and N.R.Watson, " An overview of self commutatingconverters and their application in transmission and distribution", in IEEE/PES Trans and Distr.Conf. & Exhibition, Asia and Pacific Dalian, China 2005, p.p.
[4]. N. Flourentzou, V.G. Agelidis, and G.D. Demetriades, " VSC-Based HVDC Power
[5]. Transmission Systems: An Overview", published in Power Electronics, IEEE Transactio nson (Volume:24, Issue: 3), p.p.
[6]. K.R. Padiyar and N. Prabhu, " Modelling, control design and analysis of VSC based HVDCtransmission systems", published in Power System Technology, 2004. PowerCon 2004. 2004International Conference on (Volume:1)
[7]. John J. Paserba," FACTS Controllers Benefits AC Transmission Systems" IEEE, 2000
[8]. Rafferty, J.; Xu, L. and Morrow, D.J., " DC fault analysis of VSC based multi-terminal HVDCsystems", published in AC and DC Power Transmission (ACDC 2012), 10th IET InternationalConference, p.p.
[9]. N. Mohan, T.M. Undeland and W.P.Robbins, " Power Electronics: Converter, applicationsand design", 3rdedition, wiley& sons, New York, 2003, p.p.
[10]. R. Mohan Mathur, Rajeev K. Verma, " Thyristor based FACTS controllers for electricaltransmission system", IEEE press, Wiley India, edition 2012, p.p.
[11]. Narain G. Hingorani and Laszlo Gyugyi, " Understanding FACTS – Concepts andtechnology of Flexible AC transmission system", IEEE press, Wiley Interscience publications,1999, p.p.