ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 2, February 2018

Power Harmonic Analysis Based Voltage Control to Enhance Power System Stability

C.K.Sridhar[1], J.Jalendiran[2]

PG Scholar [PSE], Dept. of EEE, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India[1]

Associate Professor, Dept of EEE, Adhiyamaan College of Engineering, Hosur, Tamilnadu, India [2]

ABSTRACT: This paper presents a further significant development to the developed Flexible Line-Commutated Converter (LCC) based High Voltage Direct Current (HVDC) system with controllable capacitors, which can provide AC voltage/reactive power control. The development involves the installations of fixed parallel capacitors at the valve side of converter transformer, which brings the following significant benefits: 1) AC filter banks at the AC side of converter transformer are not needed as a better harmonic filtering performance can be achieved: 2) significant reduction of the HVDC station land requirement (compared with traditional LCC HVDC), as the AC filters together with the switchgear can occupy over 50% of the HVDC station footprint: 3) up to 50% reduction of the required voltage rating and more than 60% reduction of the capacitance of controllable capacitors for commutation failure elimination can be achieved while similar power system dynamic performance (AC voltage/reactive power control) compared with that can be demonstrated. Detailed analyses are presented to illustrate the effective commutation process and superb harmonic filtering performance. Selections of the component values are presented. Simulation results in RTDS are presented to verify the effectiveness of commutation failure elimination, power system dynamic performance, and harmonic filtering performance and show voltage/current stress of the fixed parallel capacitors.

KEYWORDS: Capacitors, Power harmonic filters, HVDC transmission, Passive filters, Harmonic analysis, Active filters, Voltage control.

I.INTRODUCTION

Over the past decades, Statnett has expanded the installation of (HVDC) subsea links to the continent. The interconnections increase security of power supply throughout the countries, and contribute greatly in terms of integrating more renewable energy into the grid [1]. Norway mainly produces electricity from hydro power, which is a renewable and highly controllable energy resource. In combination with other intermittent renewable sources, for example wind and sun, hydro power is particularly valuable. In 1976, two HVDC subsea cables named Skagerrak 1 and 2 (SK1 and SK2) were installed between Norway and Denmark, each with the capacity of 250 MW at 250 kV. The converters were built with thyristor valve technology and the cables connected in a bipolar scheme. A third Skagerrak link with a capacity of 440 MW at 350 kV went into operation in 1993. To reduce the earth current, SK1 and SK2 were converted into monopolar links and connected with opposite polarity to Skagerrak 3 (SK3). In 2008, the HVDC NorNed link between Norway and the Nederlands was installed, with the ability to transmit 700 MW [2-3]. A fourth Skagerrak subsea cable is currently being installed between Norway and Denmark, and scheduled to be operating by the end of 2014 with a rating of 715 MW at 500 kV. The converter technology chosen for SK4 is Voltage Source Converter (VSC) with a multilevel topology. At the moment, Statnett is planning two new HVDC subsea links to Germany and England, scheduled for 2018 and 2020, respectively.

In this paper, a reactive power (Q) balance strategy is planned to boost the stability of the HVDC electrical converter connected to weak grids. The most circuit topology of a replacement LCC based HVDC system is given, wherever a new converter transformer and related Fully Tuned (FT) branches area unit enclosed within the device scheme for implementing an inductive filtering methodology [4]. LCC based HVDC system is not able to control its reactive power and terminal AC voltages. So to control the reactive power and AC voltage consider the inverter side of LCC HVDC system with controllable capacitors. The system's ability of operating under negative extinction angle is utilized to achieve a wide range of reactive power control. A completely unique hybrid device configuration for typical LCC HVDC technology getting to eliminate commutation

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 2, February 2018

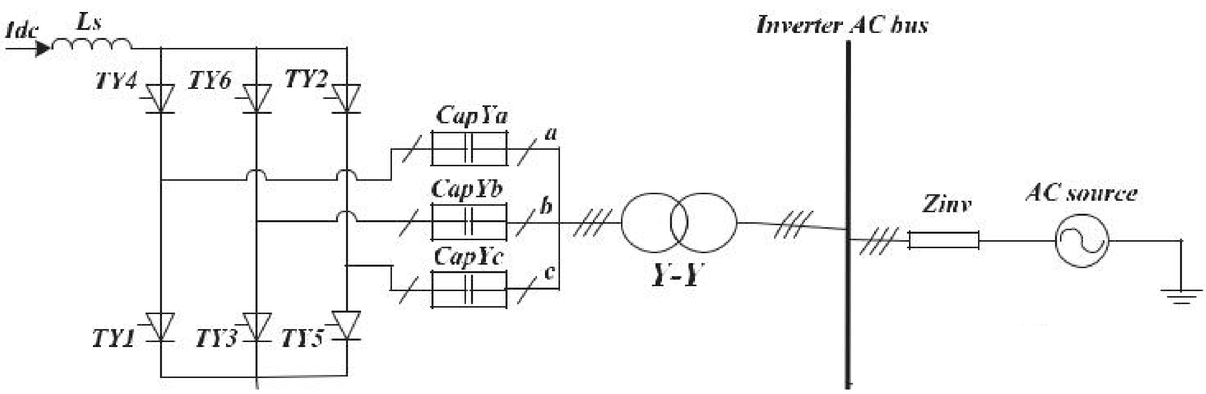
failures beneath serious faults. Dynamic series insertion of capacitors throughout commutation is used to extend the effective commutation voltage [5-6]. HVDC systems are bring wide utilized in numerous applications because of their advantages, like bulk power transmission, long-distance transmission, and power-flow control. However, HVDC systems suffer from commutation failure, a significant drawback that leads to increase device stress, interruptions in transmitted power, and issues associated with protection relay setting, in turn, leading to system instability throughout operation [7-8]. Therefore, several studies have investigated the mitigation of commutation failure by considering its underlying factors, that is, ac voltage reduction, dc current increment, and crossing point shifts of phase voltage.

II.AC VOLTAGE CONTROL AT THE INVERTER SIDE OF THE LCC HVDC SYSTEM

HVDC transmission is a safe and efficient technology designed to deliver large amounts of electrical power over long distances with minimal losses and at low costs. HVDC links require expensive converters and filters at both terminal stations, but the overall savings with fewer and thinner transmission lines and lower losses make it advantageous. HVDC technology can synchronize AC power networks that are otherwise incompatible. Today there are more than 100 HVDC installations in the world, and the ratings are in the 100–10,000 MW range. The core component of the HVDC system is the power converter that connects the DC and AC systems together. The LCC HVDC system with controllable capacitors and the connected AC system at the inverter side are shown in Fig. 1.

The conversion from AC to DC, and vice versa, is achieved through electronic switches. There are two main topologies of electronic converters for HVDC transmission available today; LCC and VSC. The classical topology is the LCC with thyristor valves from the 1970’s, which is present in most of the HVDC systems in operation today. The VSC technology was first utilized in a real network by ABB in 1997, when a HVDC transmission line between Hells Jon and Grängesberg in Sweden was successfully installed.

The technology has proven efficient with its many advantages compared to LCC. A further development of the VSC technology, with a multilevel topology, is the Modular Multilevel Converter (MMC). It was first successfully installed in 2010 with the Trans Bay Cable project in San Francisco where Siemens delivered HVDC PLUS converters. Upgraded its HVDC Light converter to the fourth generation, an MMC variant called Cascaded Two-Level converter (CTL).



(a)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 2, February 2018

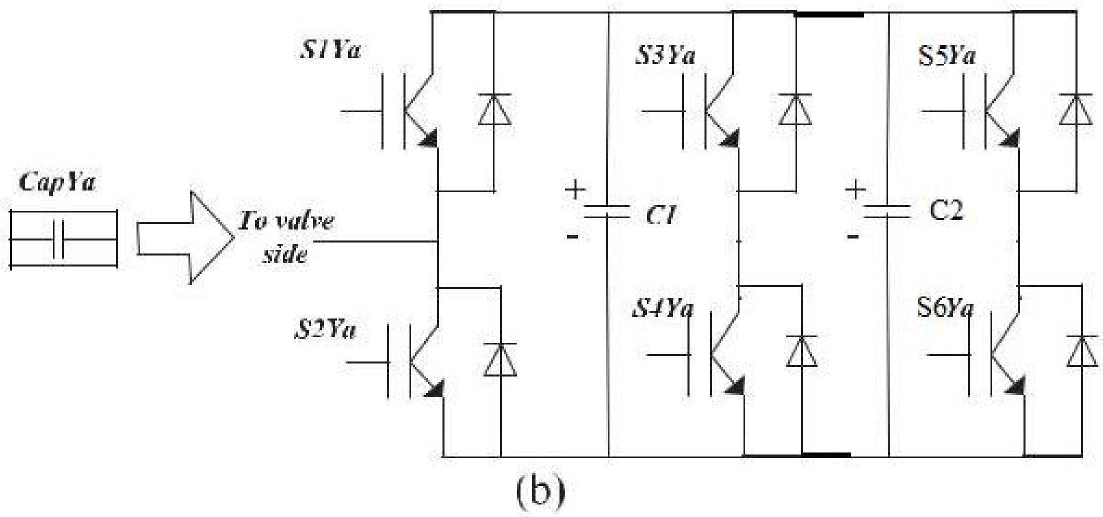


Fig. 1. Configuration of LCC HVDC system with controllable capacitors. (a) Inverter and connected AC system. (b) Capacitor module configuration

III.HVDC SYSTEM CONFIGURATION

There are multiple HVDC configurations that can be chosen when designing new HVDC links. Factors like location, power and voltage capability of the link, chosen cable technology and so on, are used to decide which configuration to use Monopolar. A monopolar link consists of a single conductor and a return path through the ground or the sea by the use of electrodes. Many subsea cables are installed as a Monopolar scheme to reduce costs. However, the use of return path through the sea or earth leads to questions of corrosion on metallic objects and other environmental concerns. In some areas, conditions are not conductive enough for earth or sea return, such as fresh water cable crossings, or areas with high earth resistivity. In such cases, a metallic neutral- or low-voltage cable is used for the return path, and the DC circuit uses a simple local ground connection for potential reference.

$$SCL = \frac{E_{ac}^2}{Z_{ac}} \tag{1}$$

$$SCR = \frac{SCL\,[MVA]}{P_d\,[MW]} \tag{2}$$

The main component of an LCC converter is the thyristor switch. It is very suitable for LCC-HVDC systems because of its large voltage blocking capability and current conduction capability, low switching losses, and robustness. The thyristor behaves like a controllable diode, and current is conducted from the anode to the cathode when the thyristor is positively biased (the anode has a higher potential with respect to the cathode), and when a small current signal is supplied to the gate terminal. It will then continue to conduct until the current drops to zero. In order to achieve the desired DC voltage rating, the thermistors are stacked together in series. It is generally necessary to connect an RC snubber circuit across the power semiconductor device, in order to protect it from system transients, dv/dt, and high recovery voltages.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

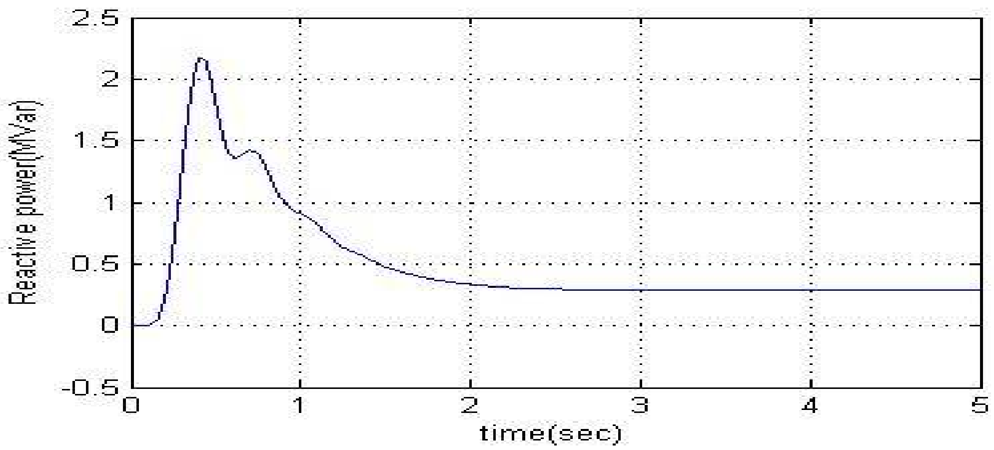
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

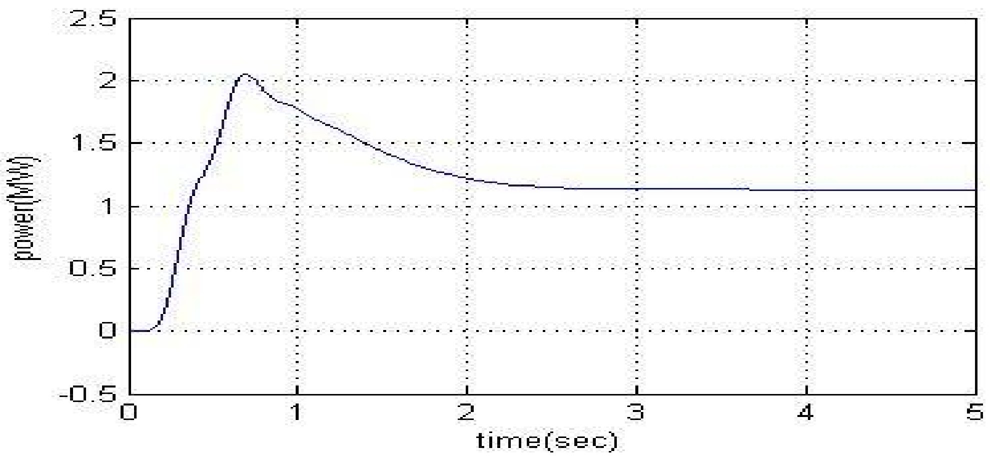
Vol. 7, Issue 2, February 2018

IV.SIMULATION AND RESULT DISCUSSION

Fig. 2 shows the system responses following changes of reactive power reference the DC voltage control at the inverter side. The reference current supplied by the outer loop control increases from -1 Pu to 1 pu at the moment of the fault at t = 2.5 s. After the fault is cleared at t = 2.6 s, the reference current oscillates between these values, until slowly settling down back to approximately -1 Pu. The system current tries to follow the reference current, and at around t = 2.9 s the control system has stabilized. Finally, AC voltage control at the inverter side. During the fault, the system current oscillates around 1.0 pu, before settling down at 0.0 pu again at t = 2.8 s. The reference current supplied by the outer loop control is almost unaffected by the DC fault.



(a)



(b)

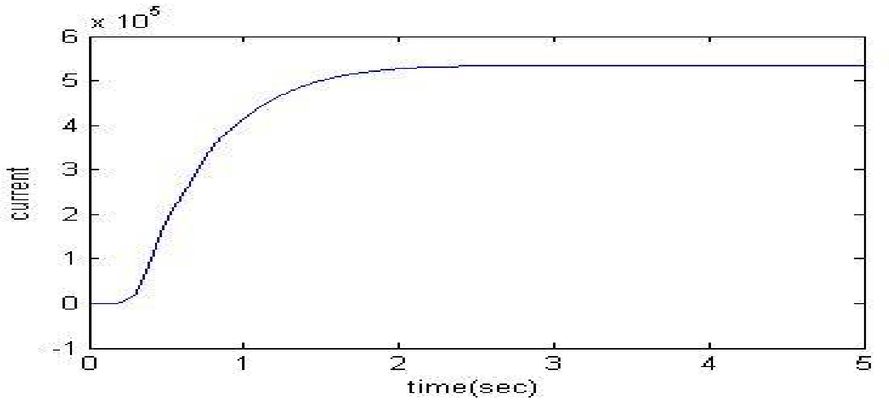
ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

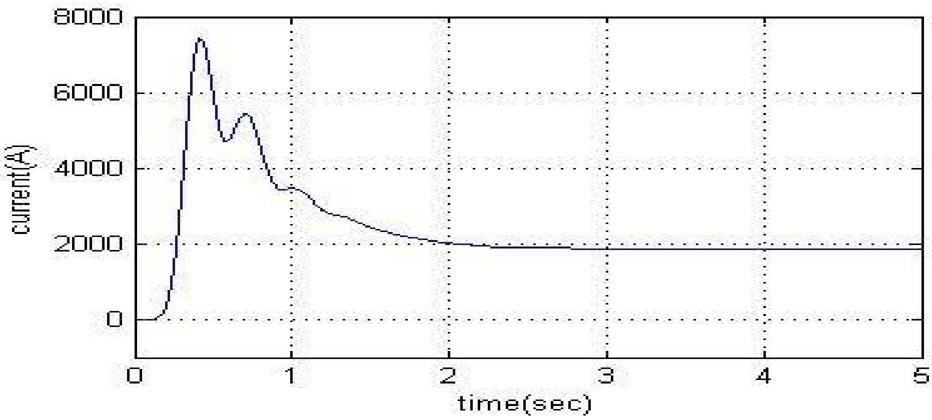
(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

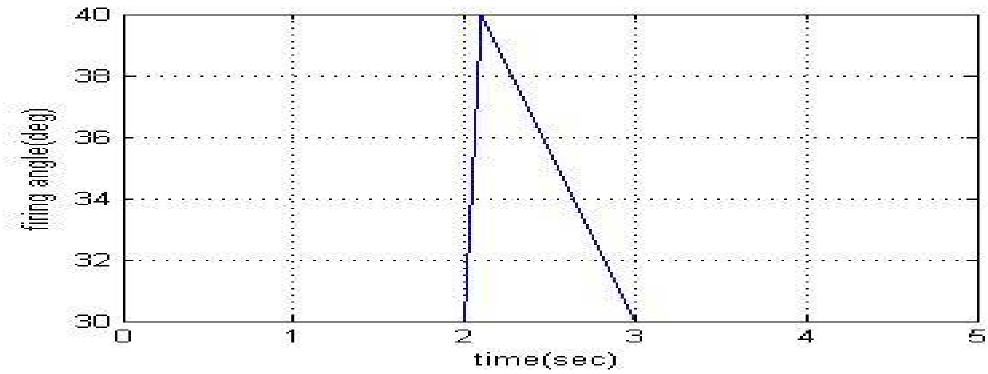
Vol. 7, Issue 2, February 2018



(c)



(d)



(e)

Fig 2. System responses with reactive power reference step changes. (a) Reactive power consumption at inverter. (b) Active power transfer. (c) DC voltage. (d) DC current. (e) Inverter firing angle.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijareeie.com

Vol. 7, Issue 2, February 2018

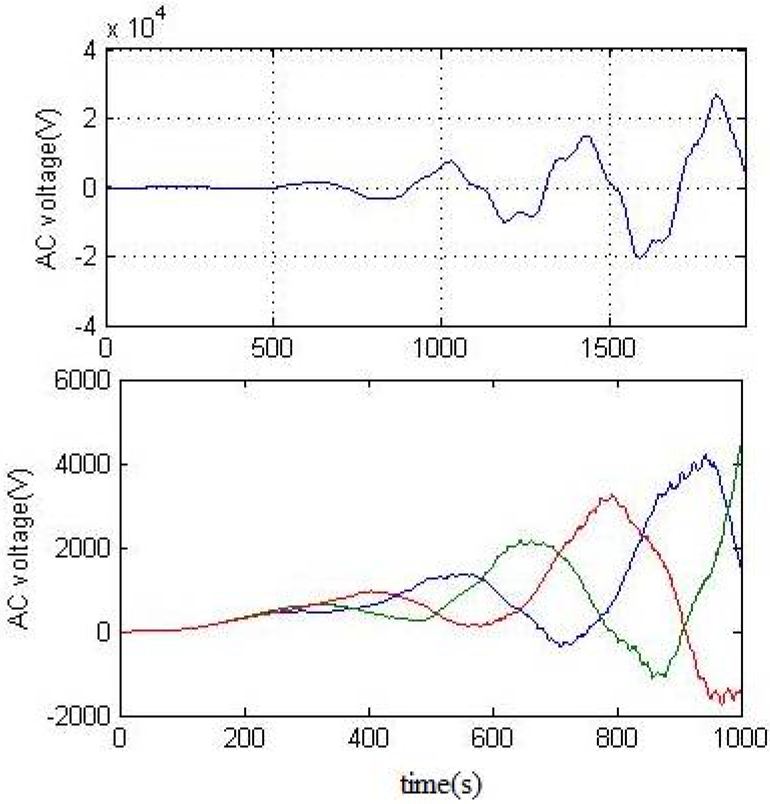


Fig.3 Inverter AC voltage

It can be seen from fig. 2(a) waveform indicates the measurement of reactive power successfully. At the same time active power transfer on DC link is controlled at the rated value shows in fig. 2(b). In fig. 2(e) and (c) shows the waveform of inverter firing angle and dc voltage. In fig. 2(d) shows the DC current is slightly changed to keep active power constant. In fig.3 shows the inverter AC voltage.

V.CONCLUSION

The module has been proposed in this paper to achieve the elimination of commutation failure for HVDC systems. The module is based on thyristors only hence the proposed method is suitable for HVDC systems with higher power/current ratings. Detailed operating principles, capacitor voltage control strategy and mathematical analysis of the module have been explained, and the selection of parameters has been given. To validate the effectiveness of the proposed method, comparisons are made with Capacitor Commutated Converter (CCC)-HVDC and LCC-HVDC using systems rated at 500kV/3kA. Additional simulation results of the HVDC with larger AC systems at both rectifier and inverter sides have been presented. 800kV/4kA system is further developed and simulated to demonstrate the capability of the proposed method in application to HVDC systems. In addition, the analysis of voltage & current stresses of thyristors and the estimation of power losses have been carried out. Comparisons of the proposed method with that in have been made.

REFERENCES

1. ABB, "Special Report 60 years of HVDC," July 2014.
2. U. Astrom and V. Lescale, "Converter Stations for 800 kV HVDC," in 2006 International Conference on Power System Technology, 2006, pp. 1-7.

3. D. Huang, Y. Shu, J. Ruan, and Y. Hu, "Ultra High Voltage Transmission in China: Developments, Current Status and Future Prospects," Proceedings of the IEEE, vol. 97, pp. 555-583, 2009.
4. L. Yong, L. Longfu, C. Rehtanz, S. Ruberg, and L. Fusheng, “Realization of reactive power compensation near the LCC-HVDC converter bridges by means of an inductive filtering method,” *IEEE Trans. Power Electron.*, vol. 27, no. 9, pp. 3908–3923, Sep. 2012.
5. Ying Xue and Xiao-Ping Zhang, “Reactive Power and AC Voltage Control of LCC HVDC System With Controllable Capacitors,” IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 32, pp. 753 - 764, 2016. .
6. Y. Xue, X. P. Zhang, and C. Yang, "Elimination of Commutation Failures of LCC HVDC System with Controllable Capacitors," IEEE Transactions on Power Systems, vol. 31, pp. 3289-3299, 2016.
7. H. I. Son and H. M. Kim, "An Algorithm for Effective Mitigation of Commutation Failure in High-Voltage Direct-Current Systems," IEEE Transactions on Power Delivery, vol. 31, pp. 1437-1446, 2016.
8. Z. Lidong and L. Dofnas, "A novel method to mitigate commutation failures in HVDC systems," in Proceedings. International Conference on Power System Technology, 2002, pp. 51-56 vol.1.