Vol III Issue VIII Feb 2014

Impact Factor : 2.2052(UIF)

ISSN No :2231-5063

International Multidisciplinary Research Journal

Golden Research Thoughts

Chief Editor
Dr.Tukaram Narayan Shinde

Publisher
Mrs.Laxmi Ashok Yakkaldevi

Associate Editor
Dr.Rajani Dalvi

Honorary
Mr.Ashok Yakkaldevi

IMPACT FACTOR : 2.2052(UIF)

Welcome to GRT

RNI MAHMUL/2011/38595 **ISSN No.2231-5063**

Golden Research Thoughts Journal is a multidisciplinary research journal, published monthly in English, Hindi & Marathi Language. All research papers submitted to the journal will be double - blind peer reviewed referred by members of the editorial board.Readers will include investigator in universities, research institutes government and industry with research interest in the general subjects.

International Advisory Board

Flávio de São Pedro Filho
Federal University of Rondonia, Brazil

Kamani Perera
Regional Center For Strategic Studies, Sri Lanka

Janaki Sinnasamy
Librarian, University of Malaya

Romona Mihaila
Spiru Haret University, Romania

Delia Serbescu
Spiru Haret University, Bucharest, Romania

Anurag Misra
DBS College, Kanpur

Titus PopPhD, Partium Christian University, Oradea,Romania

Mohammad Hailat
Dept. of Mathematical Sciences, University of South Carolina Aiken

Abdullah Sabbagh
Engineering Studies, Sydney

Catalina Neculai
University of Coventry, UK

Ecaterina Patrascu
Spiru Haret University, Bucharest

Loredana Bosca
Spiru Haret University, Romania

Fabricio Moraes de Almeida
Federal University of Rondonia, Brazil

George - Calin SERITAN
Faculty of Philosophy and Socio-Political Sciences Al. I. Cuza University, Iasi

Hasan Baktir
English Language and Literature Department, Kayseri

Ghayoor Abbas Chotana
Dept of Chemistry, Lahore University of Management Sciences[PK]

Anna Maria Constantinovici
AL. I. Cuza University, Romania

Horia Patrascu
Spiru Haret University, Bucharest,Romania

Ilie Pintea,
Spiru Haret University, Romania

Xiaohua Yang
PhD, USA

......More

Editorial Board

Pratap Vyamktrao Naikwade
ASP College Devrukh,Ratnagiri,MS India

R. R. Patil
Head Geology Department Solapur University,Solapur

Rama Bhosale
Prin. and Jt. Director Higher Education, Panvel

Salve R. N.
Department of Sociology, Shivaji University,Kolhapur

Govind P. Shinde
Bharati Vidyapeeth School of Distance Education Center, Navi Mumbai

Chakane Sanjay Dnyaneshwar
Arts, Science & Commerce College, Indapur, Pune

Awadhesh Kumar Shirotriya
Secretary,Play India Play,Meerut(U.P.)

Iresh Swami
Ex - VC. Solapur University, Solapur

N.S. Dhaygude
Ex. Prin. Dayanand College, Solapur

Narendra Kadu
Jt. Director Higher Education, Pune

K. M. Bhandarkar
Praful Patel College of Education, Gondia

Sonal Singh
Vikram University, Ujjain

G. P. Patankar
S. D. M. Degree College, Honavar, Karnataka

Maj. S. Bakhtiar Choudhary
Director,Hyderabad AP India.

S.Parvathi Devi
Ph.D.-University of Allahabad

Sonal Singh,
Vikram University, Ujjain

Rajendra Shendge
Director, B.C.U.D. Solapur University, Solapur

R. R. Yalikar
Director Managment Institute, Solapur

Umesh Rajderkar
Head Humanities & Social Science YCMOU,Nashik

S. R. Pandya
Head Education Dept. Mumbai University, Mumbai

Alka Darshan Shrivastava
Shaskiya Snatkottar Mahavidyalaya, Dhar

Rahul Shriram Sudke
Devi Ahilya Vishwavidyalaya, Indore

S.KANNAN
Annamalai University,TN

Satish Kumar Kalhotra
Maulana Azad National Urdu University

Address:-Ashok Yakkaldevi 258/34, Raviwar Peth, Solapur - 413 005 Maharashtra, India
Cell : 9595 359 435, Ph No: 02172372010 Email: ayisrj@yahoo.in Website: www.aygrt.isrj.net

Golden Research Thoughts
ISSN 2231-5063
Impact Factor : 2.2052(UIF)
Volume-3 | Issue-8 | Feb-2014
Available online at www.aygrt.isrj.net

STUDY OF FAULTS ON HVDC TRANSMISSION LINES

Manish Kumar , Manjeet and Pooja Khatri

Electrical department NIT Kurukshetra.
Asst. Prof, EEE department HCTM Kaithal.
Asst. Prof, EEE Department HCTM Kaithal.

Abstract:-In this paper, study of faults on HVDC transmission line, using Voltage Source Converter - HVDC scheme, has been carried out. In scheme electrical energy is transmitted through DC transmission lines with the help of rectifier and inverter operations, as done in LCC-HVDC. A 3-phase, 2-level, 6-switch VSC is connected to an active but weak AC system at both ends of the HVDC link. This VSC is controlled by vector control method. In this analysis system was simulated by introducing line-to-ground fault and line-to-line fault and circuit parameter have been found using VSC-HVDC scheme. A new approach has been proposed to recover normal condition by removing faults, which include the design of grounding impedance, adopting of HVDC mono-polar links and reconnecting transformer secondary winding in star (Yn) type and etc. Simulation of the system was carried out in Matlab environment.

Keywords:VSC-HVDC, Vector control method, DC transmission line, grounding design, fault recovery, bipolar transmission system, monopolar transmission system.

1. INTRODUCTION

High-Voltage Direct Current (HVDC) transmission using voltage-source converters (VSCs) came in service for the first time in Sweden in 1997 with a trial 3 MW scheme [1]. Since then, more VSC transmission schemes are being built and several are currently in commercial operation. Currently, a 350 MW VSC transmission system is in service. This immense increase in the power capacity is due to the synchronized development in a number of technical areas, including semiconductor switches ,dc transmission lines (especially the dc cables), main circuit of converter station and system controls [2]. VSC-HVDC is a new power transmission technology based on Voltage Sourced Converter and Selfturn-off devices. VSC-HVDC provides a new choice for grid inter-connection [3- 6].

VSC-HVDC realizes the power transmission from sending end to receiving end by connecting rectifier and inverter through DC transmission line. Considering the high fault probability, radio interference and audible noise of overhead line, most project applications of VSC-HVDC adopt cables as the DC line at present. As the voltage polarity reversal is not needed for VSC-HVDC, this allows new types of cables, such as extruded XLPE DC cables to be used in long distance VSC transmission systems.

The situations those the cables cannot be used, the overhead line will be the only choice for DC transmission. Some special demands should be considered such as DC line fault recovery.

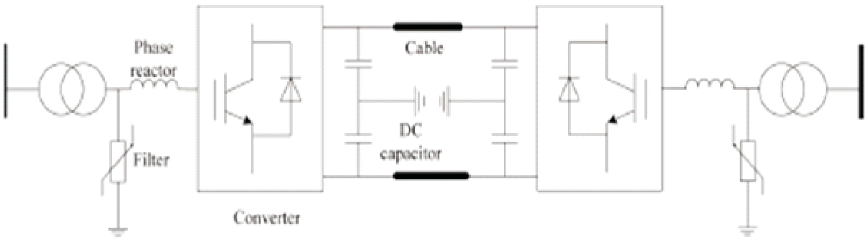


Figure 1: typical VSC-HVDC scheme structures

A typical scheme structure of VSC-HVDC is shown in Fig.1 which has a bipolar configuration for DC cable system. As the DC line fault will induce a significant influence on operation of VSC HVDC, therefore the fault characteristics and mechanism analysis is necessary for reasonable protection design. Especially for overhead line, the problem in recovery process should be taken into account to ensure that the system can restore rapidly under temporary fault condition.

2. CONTROL OF VSC-HVDC SYSTEM

The control modes are chosen according to the application and requirement of the given power system. The rectifier and inverter controllers take the control of any two of above mentioned four control strategies according to the system requirements and operating conditions. VSC1 controllers operate on active power and reactive power control whereas VSC2 controllers deal with DC voltage and reactive power control (Fig. 2) [7-8].

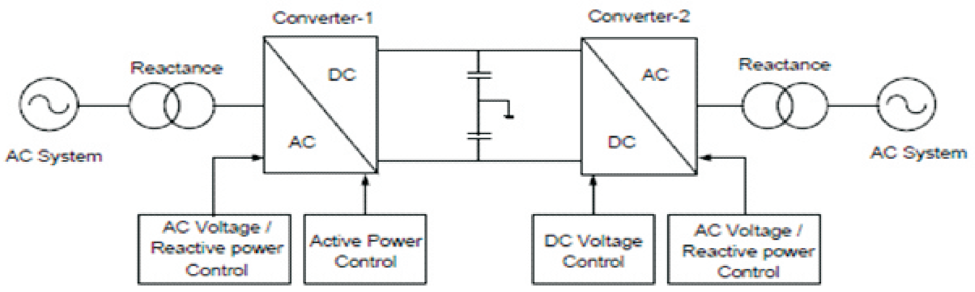


Figure 2: VSC-HVDC Control System

Two control method:- 1. Direct control method and 2. Vector control method. In this , the vector control method are implement.

2.1 Vector control method:- The P and Q controlled quantities of VSC-HVDC are coupled to each other such that any change in one quantity strongly affects the other. The vector control method removes the coupling between these quantities to ensure the independent control of each quantity. The vector control strategy consists of a cascade control system with faster inner controllers. The vector controller is accomplished by additional outer current controller which provides the reference values for inner controller. The outer controllers include active power controller, reactive power controller, AC voltage controller, DC voltage controller or frequency controller where the implementation of particular control strategy depends on the application and operating conditions of VSC-HVDC system.

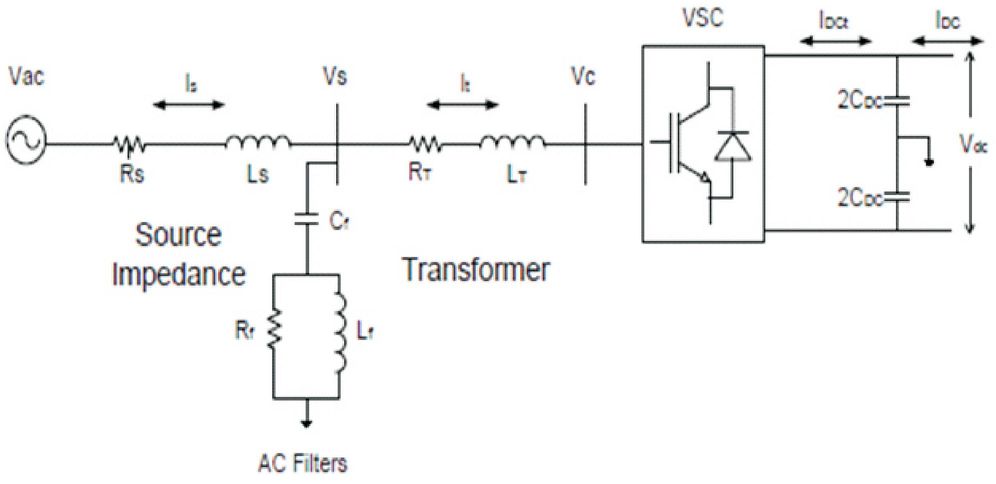


Figure 3: Vector Control System of VSC-HVDC System

The mathematical model presented here, the filter resistances and inductances can be neglected. From the single line diagram (Fig. 3), the voltage across the transformer, the current to the filter and the voltage across the source impedance can be obtained in three phase instantaneous form as follows:

The voltage across the source impedance is

$$V_{ac}(t)_{abc} - V_S(t)_{abc} = R_s i_S(t)_{abc} + L_S \frac{d}{dt} i_S(t)_{abc} \qquad \ldots 1$$

The current through the filters is

$$i_S(t)_{abc} - i_L(t)_{abc} = C_f \frac{d}{dt} V_s(t)_{abc} \qquad \ldots.\ 2$$

The voltage across the transformer is

$$V_S(t)_{abc} - V_C(t)_{abc} = R_T i_L(t)_{abc} + L_T \frac{d}{dt} i_L(t)_{abc} \qquad \ldots 3$$

From (1), (2) and (3), the following differential equations can be derived:

$$\frac{d}{dt} i_S(t)_{abc} = -\frac{R_S}{L_S} i_S(t)_{abc} + \frac{1}{L_S}\{V_{abc}(t)_{abc} - V_S(t)_{abc} - V_S(t)_{abc}\} \qquad \ldots.4$$

$$\frac{d}{dt} V_S(t)_{abc} = \frac{1}{C_f} i_S(t)_{abc} - \frac{1}{C_f} i_t(t)_{abc} \qquad \ldots.\ 5$$

$$\frac{d}{dt} i_t(t)_{abc} = -\frac{R_T}{L_T} i_t(t)_{abc} + \frac{1}{L_T}\{V_S(t)_{abc} - V_C(t)_{abc}\} \qquad \ldots.6$$

By using Clark's transformation matrix , quantities from ABC-frame can be converted to αβ-reference frame as follows,

$$\begin{vmatrix} x_\alpha \\ x_\beta \end{vmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \cos\gamma & \cos 2\gamma \\ 0 & \sin\gamma & \sin 2\gamma \end{bmatrix}\begin{bmatrix} x_a \\ x_b \\ x_c \end{bmatrix} \qquad \ldots\ 7$$

Where $\gamma=2\pi/3$

Equations (4), (5) and (6) can be converted in to αβ frame as follows:

$$\frac{d}{dt} i_S(t)_{\alpha\beta} = -\frac{R_S}{L_S} i_S(t)_{\alpha\beta} + \frac{1}{L_S}\{V_{abc}(t)_{\alpha\beta} - V_S(t)_{\alpha\beta} - V_S(t)_{\alpha\beta}\} \qquad \ldots\ 8$$

$$\frac{d}{dt} V_S(t)_{\alpha\beta} = \frac{1}{C_f} i_S(t)_{\alpha\beta} - \frac{1}{C_f} i_t(t)_{\alpha\beta} \qquad \ldots\ 9$$

$$\frac{d}{dt} i_t(t)_{\alpha\beta} = -\frac{R_T}{L_T} i_t(t)_{\alpha\beta} + \frac{1}{L_T}\{V_S(t)_{\alpha\beta} - V_C(t)_{\alpha\beta}\} \qquad \ldots\ 10$$

By using the transformation angle Θ derived from a phase-locked loop (PLL), the above equations are further transferred to the synchronously rotating dq-reference frame, using Park's transformation, as follows:

$$\begin{bmatrix} x_d \\ x_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix}\begin{bmatrix} x_\alpha \\ x_\beta \end{bmatrix} \qquad \ldots\ 11$$

$$\frac{d}{dt} i_S(t)_{dq} = -\frac{R_S}{L_S} i_S(t)_{dq} - j\omega i_s(t)_{dq} + \frac{1}{L_S}\{V_{abc}(t)_{dq} - V_S(t)_{dq} - V_S(t)_{dq}\} \qquad ..12$$

$$\frac{d}{dt} V_S(t)_{dq} = \frac{1}{C_f} i_S(t)_{dq} - \frac{1}{C_f} i_t(t)_{dq} - j\omega V_S(t)_{dq} \qquad ..13$$

$$\frac{d}{dt} i_L(t)_{\alpha\beta} = -\frac{R_T}{L_T} i_L(t)_{\alpha\beta} - j\omega i_L(t)_{dq} + \frac{1}{L_T}\{V_S(t)_{\alpha\beta} - V_C(t)_{\alpha\beta}\} \qquad \ldots 14$$

The AC filter voltage, the current through the transformer and the AC side voltage of VSC can be expressed as:

$$V_S(t)_{dq} = -L_S\frac{d}{dt}i_S(t)_{dq} - R_S i_S(t)_{dq} - j\omega L_S i_S(t)_{dq} + V_{ac}(t)_{dq} \quad \ldots 15$$

$$i_t(t)_{dq} = i_S(t)_{dq} - C_f\frac{d}{dt}V_S(t)_{dq} - j\omega C_f V_S(t)_{dq} \quad \ldots 16$$

$$V_C(t)_{dq} = -L_T\frac{d}{dt}i_t(t)_{dq} - R_T i_t(t)_{dq} - jL_T\omega i_t(t)_{dq} + V_S(t)_{dq} \quad \ldots 17$$

From equation (17), the dq-current component through the transformer can be given as,

$$\frac{d}{dt}i_t(t)_d = \omega i_t(t)_q + \frac{V_S(t)_d - V_C(t)_d}{L_T} - \frac{R_T}{L_T}i_t(t)_d \quad \ldots 18$$

$$\frac{d}{dt}i_t(t)_q = \omega i_t(t)_d + \frac{V_S(t)_q - V_C(t)_q}{L_T} - \frac{R_T}{L_T}i_t(t)_q \quad ..19$$

Equations (18) and (19) present the relationship between input reference current and the converter output AC voltage in dq-reference frame.

Limitation:-

$$Q_{max} = V_C I_{lim}^{(q)}, \quad P_{max} = \sqrt{V_C^2 I_{lim}^2 - Q_{max}^2} \quad \ldots 20$$

Where, $I_{lim}^{(q)}$ is the pre-set maximum reactive reference current.

Outer controller :-The outer controller consists of the DC voltage controller, active power controller and reactive power controller. The proposed simulation model consists of active power and reactive power controllers at VSC1 and DC voltage and reactive power controllers at VSC2. The outer controller creates the reference values of the dq-current components for inner current controllers. The outer controller gains are smaller when compared to the inner controller to ensure the stability of the complete system.

(a)DC voltage controller:-

$$i_d^* = \frac{2}{3}\frac{V_{DC}}{V_S}\left(C_{DC}\frac{dV_{DC}}{dt} + I_{DC}\right) \quad \ldots 21$$

The d-component of the current derived in the equation (21) gives the reference current for the inner current controller for DC voltage control.

(b)Active power controller:- For accurate control of the active power, a combination of a feedback loop and an open loop is used.

$$i_d^* = \frac{2}{3}\frac{P_{ref}}{V_S} + \left(K_{P1} + \frac{K_{i1}}{s}\right)(P_{ref} - P_{actual}) \quad \ldots 22$$

Where, K_{p1} and K_{i1} are the proportional and integral gains respectively of the active power controller.

© Reactive power controller

$$i_q^* = \frac{2}{3}\frac{Q_{ref}}{V_S} + \left(K_{P2} + \frac{K_{i2}}{s}\right)(Q_{ref} - Q_{actual}) \quad \ldots 23$$

Where, K_{p1} and K_{i1} are the proportional and integral gains respectively of the reactive power controller.

Fig.4 shows active and reactive power control system for VSC1. The control block of PLL is shown from which the synchronization angle Θ is derived and fed to the ABC to dq block.

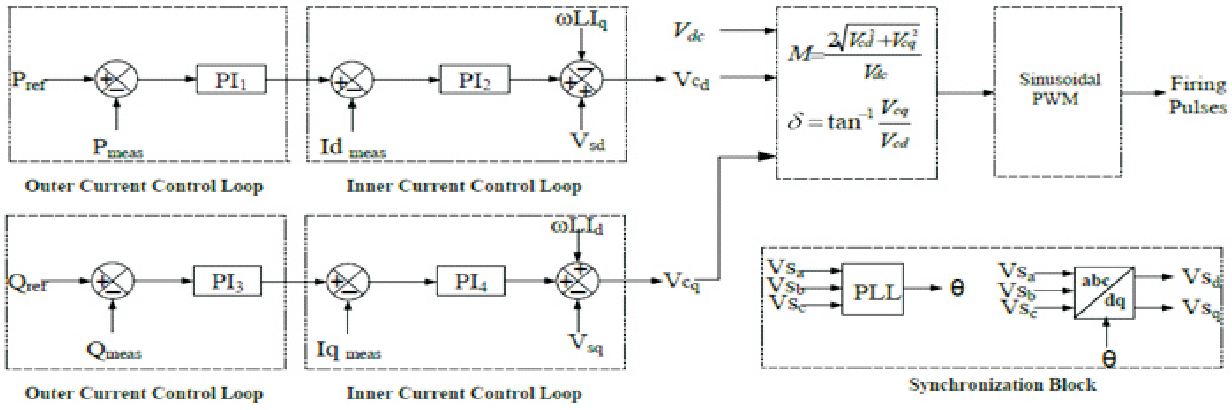


Figure 4: reactive and active power control system

3. FAULTS ANALYSIS AND RECOVERY PROCESS

Analyzes the mechanism of DC line-to-ground faults and line-to-line faults in HVDC transmission lines by using VSC-HVDC scheme, and then proposes the recovery demand of temporary faults at overhead line scheme. According to the characteristics under simulation, the solutions of recovery process are proposed, which include the grounding design, adopting mono-polar topology and reconnecting transformer secondary winding etc.

Type of fault:

Line -to- ground fault.
Line-to-line fault.

The common fault types for DC transmission line are line-to- ground fault and line-to-line fault, because faults of cables are usually caused by external mechanical stress. Therefore the faults are generally permanent, for which a lengthy repair is needed. The converters should be stopped immediately while a cable fault is detected. But for overhead line, the faults are always caused by lightning strikes and pollution .The faults along the line are likely to be temporary, which demands a fault restoration after the fault clearance.

In this, focus on the fault analysis of DC line and demonstrates the demand and solution of VSC-HVDC system restoration after DC temporary faults for overhead line.

3.1 CHARACTERISTICS OF DC LINE FAULT

3.1.1 Line-to-ground fault

As shown in Fig5, the line-to-ground fault means insulation failure between one DC conductor and ground, and for overhead line, the fault is usually temporary which is caused by lightning strikes and pollution.

The primary fault consequence is the direct discharging of the capacitor on faulty pole. The voltage of the healthy pole will rise to 2.p.u because of the action of the DC voltage controller. Which will impose an overvoltage on healthy pole capacitor even if the restriction of DC pole arrestor is considered, for DC cable, the system does not need to be restored due to the permanence of the fault. But for overhead line the restoration of the system should be considered.

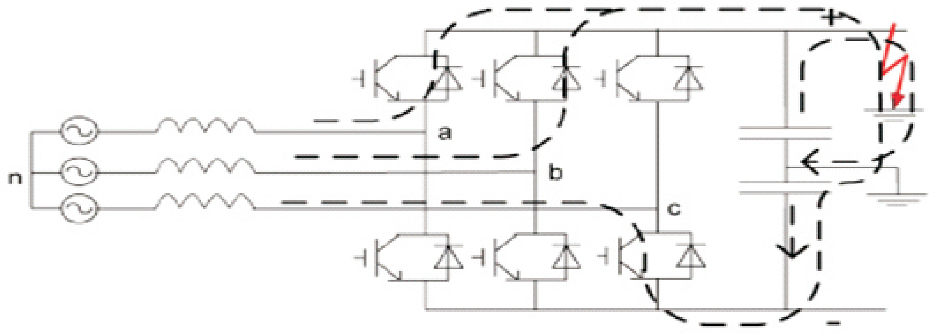


Figure 5: Discharging path under line to ground fault of bipolar system

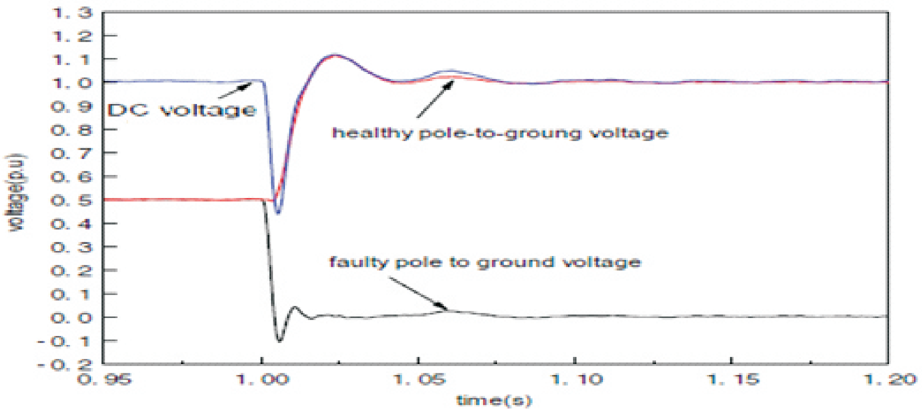


Figure 6: DC voltage waveform under temporary line-to-ground fault of bipolar system

Considering the line-to-ground fault under bipolar system, the faulty pole capacitor suffers an over current due to the rapid discharging through fault position. The voltage of DC capacitor will also decrease to a very low level, as shown in Fig6. The healthy pole capacitor will be charged to 2.p.u because of the DC voltage controller.

3.1.2. Line-to-line fault

The line-to-line fault means insulation failure between the two DC conductors. The capacitor will be rapidly discharged due to fault. Simultaneously the ac system will be three phases short-circuited through fault point, as shown in Fig7. Obviously the valve will be over current stressed.

The fault demands that both converters should be blocked. But we should note that, the ac system is still short-circuited through the VSC Free Wheeling Diodes (FWD). Which means the ac system will continue to feed current into the fault even if the converter is blocked, to avoid this besides blocking the converters. The DC line is also needed to be isolated from the ac system by tripping ac breakers to enable the air insulation to de-ionize. Another method is to introduce DC breakers and open these breakers when a fault is detected.

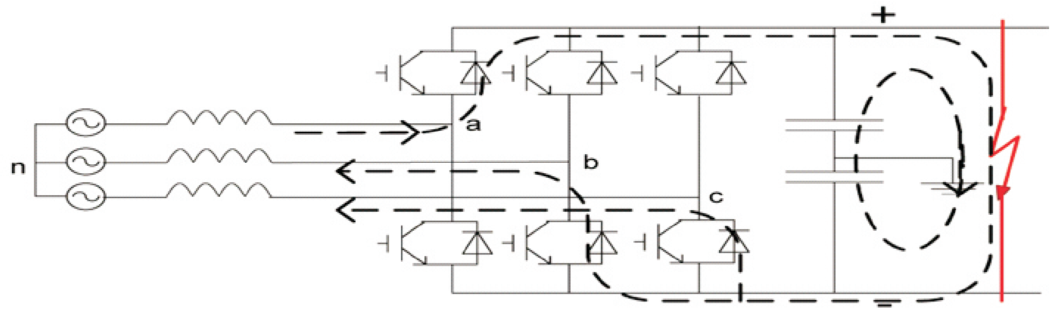


Figure7: Discharging path under line-to-line fault of bipolar system

3.2 PROTECTION AND RECOVERY DEMANDS

3.2.1. Line-to-ground fault

The demand for cable faults is to correctly detect the faults and then block and trip the converter for repairing. The demand for overhead line faults is also to block and trip the converter, but a recovery process should be involved. However, as the capacitors are difficult to be rebalanced even if the fault is cleared. Therefore the rebalance of capacitors becomes the key point before system restart. Typically, the capacitor should be discharged and after that a normal start-up of the system should be performed. If the unbalance of the DC voltage disappears, then the system can be normally restarted. Otherwise the whole system should be stopped for a fault investigation.

Need to point out that, if there is a convenient method to rebalance the capacitors. The converters do not need to be stopped, because there is no current entering fault point after faulty pole capacitor is fully discharged. After the fault is cleared, the capacitors can be rebalanced automatically.

3.2.2. Line-to-line fault

The demand for cable faults is also to correctly detect the faults and then block and trip the converter for repairing. To avoid the over current stress of FWD after blocking, the DC breakers can be introduced.

Overhead line faults also demand the blocking and trip of the converters after a certain time. The ac circuit breaker with closing resistor should be closed to charge the DC capacitors, if the DC voltage can be re-established. The converters can be deblocked for normal operation. Otherwise, the whole system should be stopped for a fault investigation. DC breakers can also be introduced to avoid the overstress of FWD. But the restarting procedure of the converters should be reconsidered.

3.3. SOLUTIONS FOR FAULT RECOVERY

The main issues about fault recovery are the rebalance of the capacitors and the design of the fast DC breakers 3.3.1to 3.3.3 will discuss the solutions for capacitor rebalance and 3.3.4 will give out the design philosophy of fast DC breakers.

3.3.1. Grounding by high impedance branch

In direct grounding system, the unbalance of capacitor is caused by the discharging of the faulty pole and the DC voltage controller. In high impedance grounding system, the discharging current is very small so that the voltage of the capacitor can maintain without any over current stress. The pole -to-ground voltage can be recover after fault as shown in Fig8.

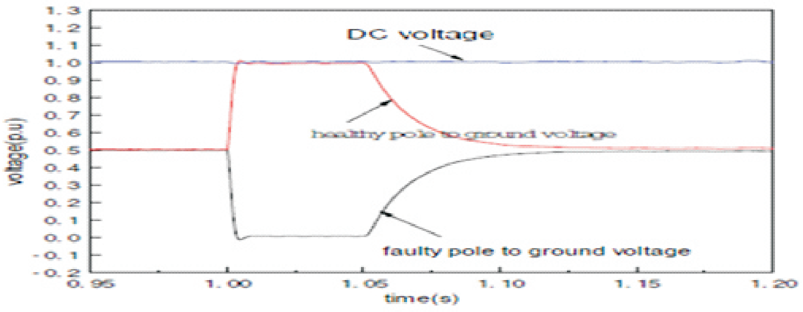


Figure8: DC voltage waveform under temporary line-to-ground fault of bipolar high

Impedance grounding system

3.3.2. Reconnecting transformer secondary winding to Yn type

By changing the transformer secondary winding to Y_n. The unbalance of capacitors will rebalance automatically through the path shown in Fig9. However, if there is no suppressing method, the balancing current will be too large for operating securely [9]. According to this, a high resistor can be added to the neutral point of transformer.

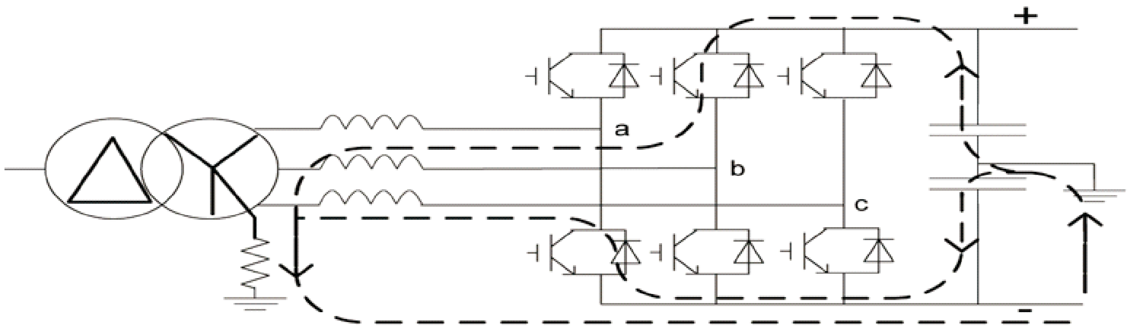
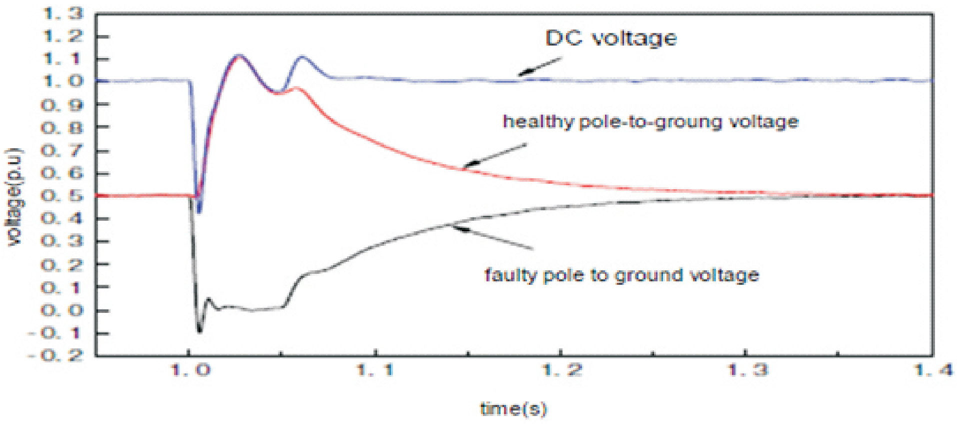
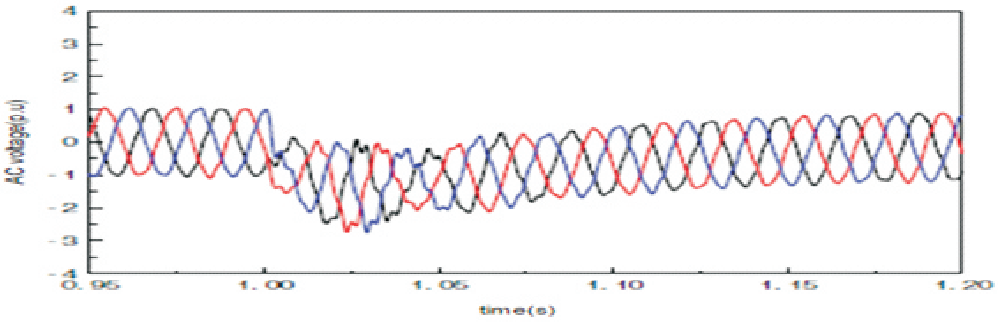


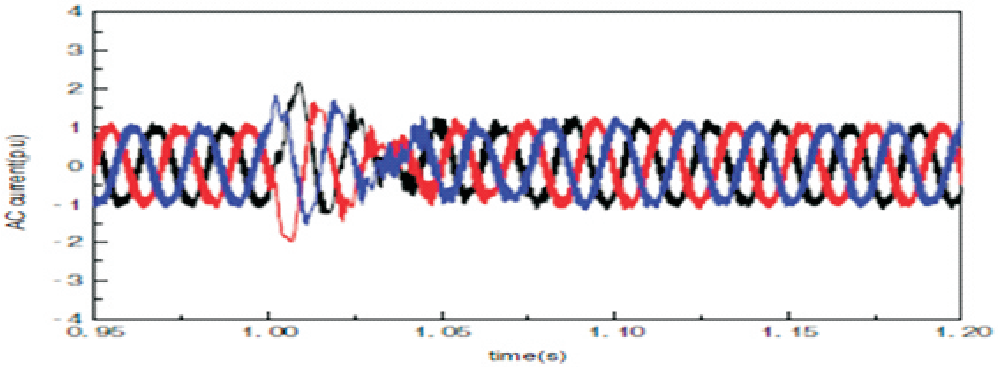
Figure9: DC voltage rebalancing path under temporary line-to-ground fault



10(a) Rebalancing waveform under line -to-ground DC voltage



10(b) AC bus voltage



10(c) AC terminal current

Figure10: rebalancing waveforms under temporary line-to-ground fault

3.3.3. Monopolar scheme operation

The common arrangement of monopolar scheme is shown in Fig11. Obviously, the consequences of line-to-ground fault of monopolar system are similar to line-to-line fault; there is no unbalance during the fault.

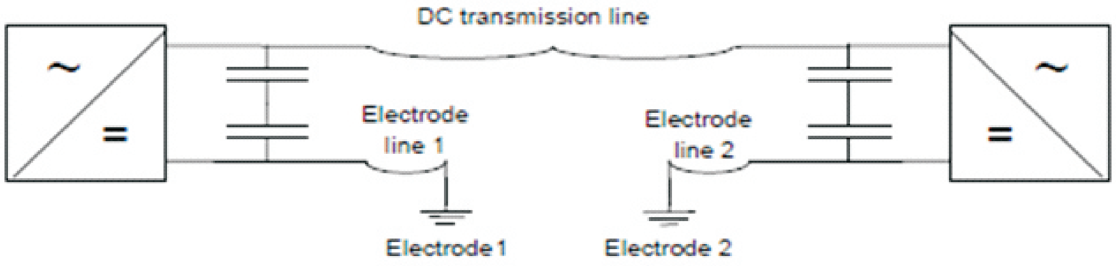


Figure11: Arrangement of Monopolar scheme

For overhead line system, adopting of Monopolar scheme has the advantages as follows:

The system can adopt DC current grounding return arrangement for saving investment.
The system is generally grounded by positive pole, so the total corona noise and fault probability can be reduced.

Generally, the Monopolar scheme is better for overhead line system as compared with bipolar scheme.

3.3.4. The design philosophy of fast DC breakers

The basic demand of fast DC breakers is to isolate the DC pole and converter punctually so as to avoid the ac system feeding current to DC side by FWD [10]. A representative design is shown in Figure 12.

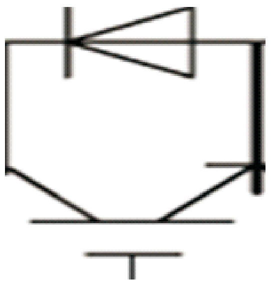


Figure12: fast DC breaker

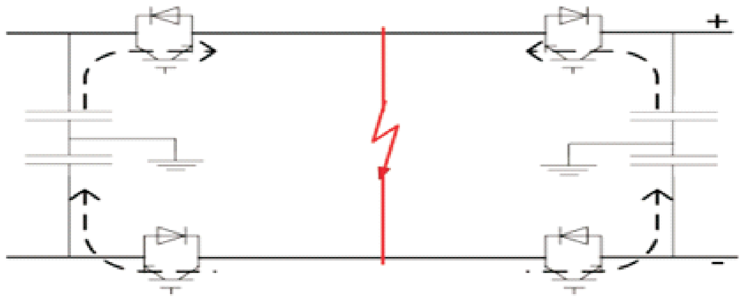


Figure13: discharging current direction in fast DC breaker under line-to-line fault

By using IGBT with anti-paralleled diode, the normal operating current can pass through IGBT of the sending end and diode of the receiving end. While the DC line is under fault condition, the discharging current will force the IGBT to turn off immediately to realize the pole isolation. This can avoid the ac breaker tripping, and then the converter can restart faster.

4. CONCLUSION

The analysis and simulation shows the characteristics of DC line faults of VSC-HVDC system as follows. The line-to-ground fault leads to the unbalance of DC voltage which is difficult to rebalance. The line-to-line fault leads to the fast discharging of DC capacitor and AC system is short-circuited by fault point, the current fed by FWD can only be cut off by AC breaker or DC breaker.

For overhead line temporary line-to-ground faults .The rebalance of capacitors can be realized by:

High impedance grounding.
Reconnecting transformer secondary winding to Yn type.
Operate in Monopolar scheme.

REFERENCE

[1]. Johan Setreus, Lina Bertling, “Introduction to HVDC Technology for reliable Electrical Power Systems,” in Proc.10th International Conference on Probabilistic Methods applied to Power Systems, 2008 pp: 1-8.

[2].HVDC Transmission: yesterday and today, by Willis Long and Stig Nilsson, IEEE Power and Energy Magazine March/ April 2007.

[3].B.R.Andersen, “Wind Farms Interconnections,” 2006 International Conference on Power System Technology, Chongqing, China.

[4]. Juan Dixon, Luis Moran, Jose Rodriguez, “Reactive Power Compensation Technologies ” State-of-the Art Review. Proceedings of the IEEE P, 2005(93): 2144-2164.

[5].Larsson, T, “Eagle pass hack-to-back tie: a dual purpose application of voltage source converter technology,” IEEE Power Engineering Society Summer Meeting, 2001.

[6]. Lianxiang Tang, “Control and protection of multi-terminal DC transmission systems based on voltage-source converters,” Dissertation, 2003, pp. 165-166

[7]. Nikolas Flourentzou, Vassitios G. Agelidis, Georgios D.Demetriades, “VSC- Based HVDC Power Transmission Systems: An Overview,” IEEE Transactions on Power Electronics, vol. 24, No.3, March 2009.

[8]. Gengyin Li, Ming Yin, Ming Zhou, Chengyong Zhao, “Modeling of VSC- HVDC and control strategies for supplying both active and passive systems,” IEEE Power Engineering Society General Meeting, 2006.

[9]. Lianxiang Tang, Boon-Teck Ooi, “Managing zero sequence in voltage source converter,” Proc. Ind. Appl. Soc. Conf. Rec., 2002, vol. 2, pp. 2186–2192.

[10] Gunnar Asplund, Kjell Eriksson, Hongbo Jiang, Johan Lingberg, Rolf. Pålsson, Kjell Svensson, “DC transmission based on voltage source converters,” CIGRE conference in Paris 1998.

APPENDIX
Parameter value

Table1: DC cable RLC-Parameters

Parameters	Value per km	Total value
Resistance R_{DC}	0.013 Θ/km	1Θ
Inductance L_{DC}	0.16mH/km	12mH
Capacitance C_{DC}	--	100µF

Table 2: Parameters of VSC-HDVC simulation model

Parameters	Rating
System Power Level	100 MVA
Frequency	60 Hz
Converter Transformer Primary Voltage	230 kV
Converter Transformer Secondary Voltage	49 kV
DC Voltage	$\pm 40\ kV$
Switching Frequency of PWM	1440 Hz
Source Impedance(Inductance)	176.1Θ(467mH)
DC Cable length	75km
AC Filter Rating	70MVAR

Table 3:VSC-HVDC PI-controller gains

Controller	Outer current controller gain		Inner current controller gain	
	K_p	K_i	K_p	K_i
Active power(VSC1)	0.15	10	5	75
Reactive power(VSC1)	0.1	10	2	50
DC voltage(VSC2)	1	25	3	35
Reactive power(VSC2)	0.25	20	2	25

Publish Research Article
International Level Multidisciplinary Research Journal
For All Subjects

Dear Sir/Mam,

We invite unpublished Research Paper,Summary of Research Project,Theses,Books and Book Review for publication,you will be pleased to know that our journals are

Associated and Indexed,India

- International Scientific Journal Consortium
- OPEN J-GATE

Associated and Indexed,USA

- EBSCO
- Index Copernicus
- Publication Index
- Academic Journal Database
- Contemporary Research Index
- Academic Paper Databse
- Digital Journals Database
- Current Index to Scholarly Journals
- Elite Scientific Journal Archive
- Directory Of Academic Resources
- Scholar Journal Index
- Recent Science Index
- Scientific Resources Database
- Directory Of Research Journal Indexing

Golden Research Thoughts
258/34 Raviwar Peth Solapur-413005,Maharashtra
Contact-9595359435
E-Mail-ayisrj@yahoo.in/ayisrj2011@gmail.com
Website : www.aygrt.isrj.net