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Simulation and Analysis of a VSC-HVDC Transmission System Based on DC Line-Line Fault

***Abstract**. HVDC is a well-established technique for transferring the electrical energy over long distances via overhead transmission lines. At three-levels, the HVDC systems utilizing voltage-source converters (VSCs) are such a major concern that complete displacement of the infamous system is not an option. This study invistigates the behavior of HVDC systems activated by a multi-level VSC. This investigation provides a systematic assessment of the normal state, the nature of a DC link fault in a HVDC system and through a permanent line-to-line fault.*

Streszczenie. *HVDC to dobrze znana technika przesyłania energii elektrycznej na duże odległości za pośrednictwem napowietrznych linii przesyłowych. Na trzech poziomach systemy HVDC wykorzystujące przetwornice napięcia (VSC) są tak poważnym problemem, że całkowite przemieszczenie niesławnego systemu nie wchodzi w grę. Niniejsze badanie bada zachowanie systemów HVDC aktywowanych przez wielopoziomowy VSC. Badanie to zapewnia systematyczną ocenę stanu normalnego, charakteru zwarcia łącza DC w systemie HVDC oraz trwałego zwarcia międzyprzewodowego.* (***Symulacja i analiza systemu przesyłowego VSC-HVDC w oparciu o usterkę DC Line-Line***)

Keywords: VSC-HVDC, Line-to-Line fault, Fault characteristics, DC fault clearing methods.
Słowa kluczowe:linie przesyłowe HVDC, Błędy i usterki przesyłabnia.

Introduction

When large amounts of power are needed to be transmitted over long distances, the advantage of using a High Voltage Direct Current (HVDC) system is that the power losses are reduced, and the low cost of a DC line structure can compensate for the additional cost of converter stations at each end of the link [1-3]. Many researchers have been drawn to this purpose, and numerous projects have been constructed all over the world [4]. Much of the research at VSC-HVDC has so far concentrated on the work precept while controlling approach. DC fault testing research is still in the earliest stage of line protection. HVDC dependent transmission system VSC has developed using power electronic techniques and a relatively high switching frequency to pulsed width modulation (PWM) [5,6].

DC L.L. faults are usually due to the failure of insulation between the two DC connectors. The faults of DC L.L. are scarce. While L.L. faults occur in the DC line, the capacitor is emptied very fast [7].

When there is a fault on the DC side, the IGBTs may be plugged for self-protection, exposing the inverting diodes to over-current. The fault necessitates the blocking of both converters. Because a DC line failure cutting does not require any mechanical force, it is quicker than that of an AC line fault clearing, and because the DC fault is less than the AC fault current, the dead time before restarting is shorter. HVDC is also distinguished by its low voltage relaunch. If the fallen line bottom is ignored, DC line faults on such a bipolar line affect only one magnate. The voltage and current characteristics of a VSC-HVDC system following a DC fault differ from those of a conventional HVDC system. This is to ensure that large DC capacitors are present at both terminals of DC cables. Fig. 1 depicts a three-level VSC-HVDC pattern used in this paper.

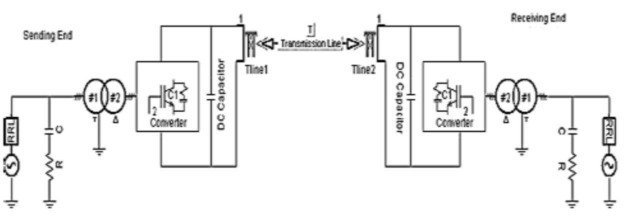


Fig.1. Three level VSC-HVDC pattern.

This model includes three major VSC-HVDC components: a part of the VSC ac lateral, a dynamic part of the DC system and a part of the control system. The MATLAB/POWER SYSTEM BLOCKSET is used to simulate the system's transient stability. The analysis of the transient characteristics of electric amounts on the VSC-HVDC line is then analyzed. This paper may serve as a straightforward and useful reference for future research on the fault evaluation of these structures. It establishes the guidelines for principles of research protection for VSC-HVDC system [8].

VSC-based Researchers are interested in HVDC current transmission because it provides significant operational elasticity to renewable energy, which is a primary condition [9]. Such a paper should focus on DC line fault analysis and explain the application and resolution of VSC-HVDC system recovery next overhead line DC precarious faults [10]. Another approach would be to insert DC circuit breakers that are then opened when a fault occurs [11].

HVDC line faults

L.L. faults are uncommon, but they can be problematic for the system. A three-level VSC fed line fault has three stages, which are as follows:

1- Line-to-Line Fault Stage

This fault is a scarce fault in the L.L. transmission fault direct current. Generally, it is the most harmful bug to VSCs [12].

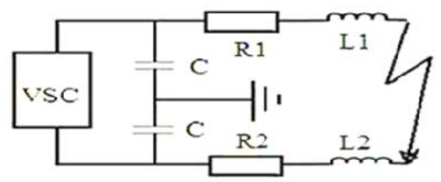


Fig.2. Equivalent circuit of DC L.L. fault.

To avoid being exposed to fault-induced overcurrent, IGBTs must be plugged. A L.L. DC fault could be expressed using the valent circuit depicted in Fig 2. R1, R2, L1, L2 are the valent resistors as well as inductors from VSC's positively and negatively lines to fault position, respectively, and C is just the capacitance of the DC-link connected in parallel in within VSC.

Capacitor Recharging Stage

In Fig.3, the equivalent circuit is represented by the capacitor's recharging phase. The current is injected within the direct current fault side when the IGBTs are plugged as well as the transformer is managed as that of an uncontrolled rectifier. It now forces a response to the dc-link capacitor, the cable's inductance, and the AC side, causing the capacitor to charge. As a result, the DC voltage increases. Figure 4 shows an actual representation of the capacitor recharging stage.

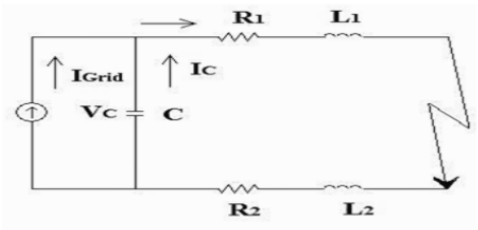


Fig.3. DC Line-to-Line Fault Equivalent Circuit.

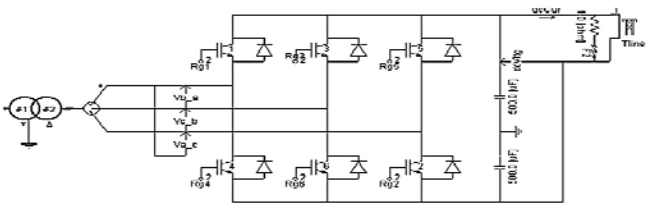


Fig.4. An acutal representation of capacitor recharging stage.

Freewheeling Diode

This stage began when the DC fault was transmitted to free-wheeling. When the widespread fault current threatens to destroy the parallel counter diodes, this is the most dangerous period. In Fig.5, represent the equivalent circuit of the diode's freewheel part. When the DC junction voltage reaches zero, the line's freewheel diodes and inductance form a loop. To protect itself, the IGBT is initially blocked by an increase in elementary over-current in the diodes, which can cause significant diode damage. Similarly, the current of the DC fault and diodes will be reduced very quickly.

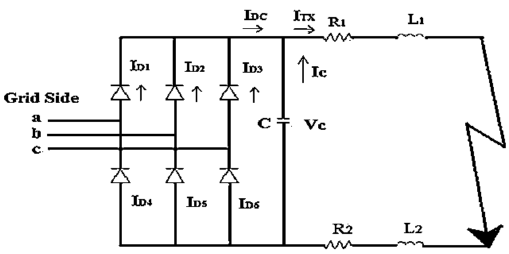


Fig.5. Equivalent Circuit of Diode Freewheel Stage.

Analysis of the Demand Manner

The faults analysis of DC L.L. fault solution of VSC-HVDC system recuperation was the focus of this paper, followed by DC faults for HVDC transmission line. The VSC - HVDC system is simulated using MATLAB/SIMULINK. Simulating instantaneous time domain responses, which are also common in transient electromagnetic analysis of electrical systems, is nearly compatible with MATLAB. In a fully integrated graphical environment, MATLAB allows circuit assembly, simulation run, results analysis, and data management.

The system's performance was evaluated using the MATLAB/SIMULINK software during a transient in the DC transmission line. The circuit simulation demonstrates the characteristics of the DC L.L. HVDC system, and it is then suggested to request the retrieval of faults at the line scheme. Figure 6 depicts a DC L.L. Fault model in MATLAB/SIMULINK.

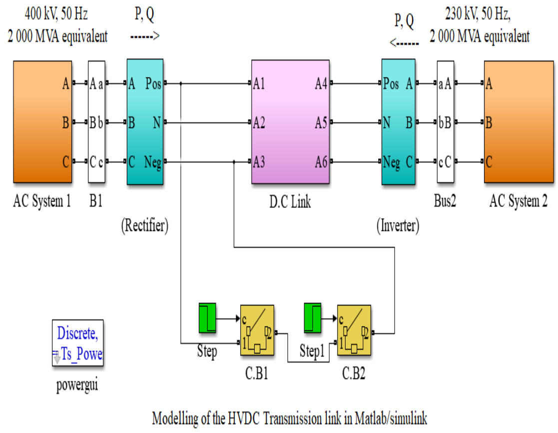


Fig.6. Modelling of the VSC-HVDC transmission line in MATLAB/SIMULINK.

The simulation test is used to perform the system's sending end. A L.L. fault causes a serious failure of the DC transmission system. The L.L. fault is clarified in this system, and the system response is analyzed.

Figures 7 (a&b) show the simulation results of DC Link current and voltage in a VSC-HVDC system operating under normal conditions. When an L.L. fault occurs with t=2.8s on the sending end of the HVDC line, the capacitor voltage rapidly drops, resulting in an increase in DC fault current, as shown in Fig.8 (a&b).

a)

b)

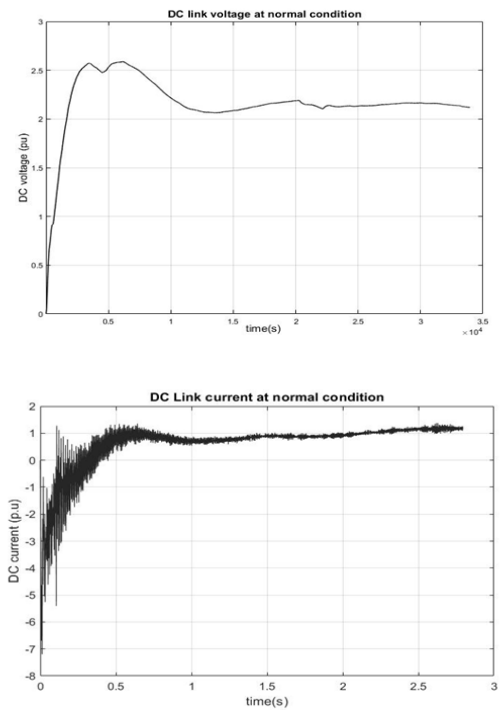


Fig.7. Simulation results for VSC-HVDC system at normal condition. (a) DC link current, (b) DC link voltage

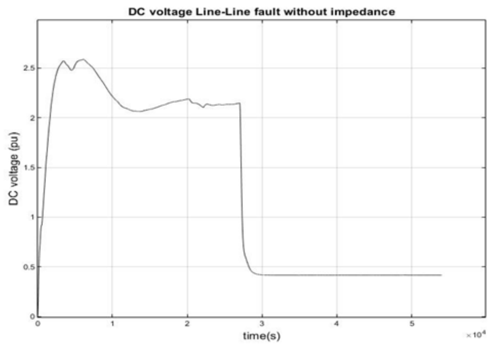
Recapture Technique

Request faults for transmission lines are detected properly, with the converter blocking and tripping it for reform. DC breakers could be used to prevent overcurrent compression in freewheeling diodes upon blocking. Interim L-G faults on the line. The capacitors can be rebalanced using [13,14]:

- Grounding with a high impedance branch
- Unipolar of the scheme operation
- The purpose of fasting DC breakers

Reconnect the secondary winding of transformer to star-neutral (Yn) form.

a)



b)

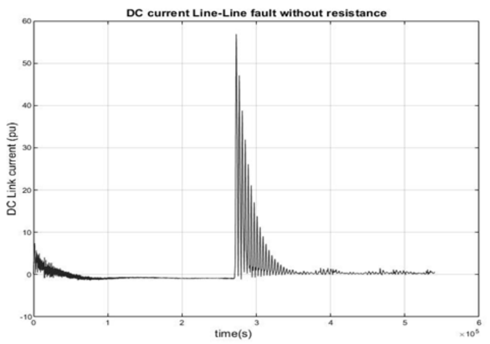


Fig.8. Simulation results for L.L. fault without grounding. (a) DC Link voltage, (b) DC link current.

Grounding with a high impedance branch technique

The discharges of the defective magnate and constant voltage controller cause capacitor imbalance in a direct grounding system. The discharge current in a high resistance grounding system is really low that the capacitor could be maintained without overstressing the current. When a fault occurs, as shown in Fig.9, the L.L. voltage could be managed to recover. Figure 10 depicts the output voltage waveform of the recovery technique.

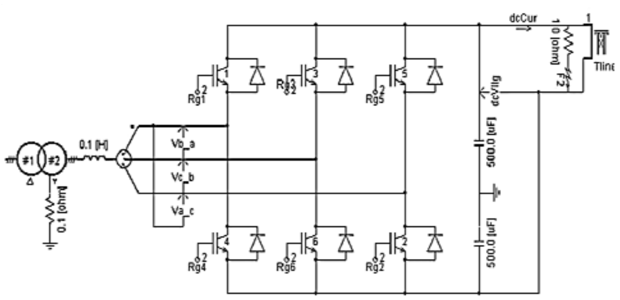


Fig.9. Recovery technique by grounding with a high impeadance branch Line-to-Line fault.

The purpose of fasting DC breakers

The primary requirement for quick DC circuit breakers is to insulate the DC magnate and transformer within the time constraints in order to prevent the AC system. Normal working current could transfer through the IGBT of the sending terminal as well as the diode of the receiving terminal by using an IGBT with such a paralleled diode. In order to achieve magnte insulation when the direct current line is in a down fault, a discharge current must cause the IGBT to instantly blow out. This may prevent the tripping of the AC circuit breaker, allowing the converter to restart quickly.

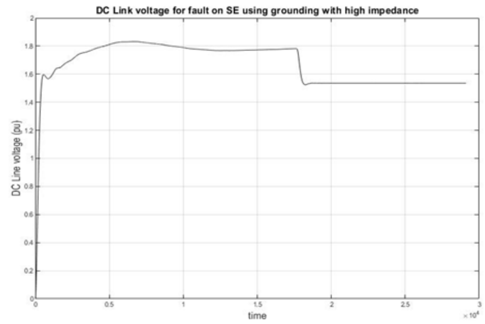


Fig.10. Results of a DC link voltage simulation for a VSC-HVDC system with grounding through a high impedance branch

Conclusions

The VSC-HVDC technique is constantly being improved and is increasingly being used to incorporate renewable energy, and it has a promising future. DC line faults have a negative impact on the VSC-HVDC system's operation and can destroy components. This study looks at the transient properties of electric amounts in a twice-way VSC-HVDC system after an L.L. fault.

The results, which show the L.L. DC fault characteristics of a VSC-HVDC system, are analyzed in detail using MATLAB/SIMULINK. A L.L. fault results in a DC voltage imbalance that is difficult to correct. If a line interim fault occurs, the capacitor can be rebalanced using a high resistance grounding system. In such a retrieval technique, the discharge current is so small that the capacitor voltage can be kept constant in the absence of any over-current strain.

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