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BIPOLAR HVDC GRID INTEGRATION OF PROACTIVE HYBRID CIRCUIT BREAKER AND CURRENT FLOW CONTROLLER

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ABSTRACT

The most effective and trustworthy way to install HVDC grids across long distances is via a voltage source converter-based high voltage direct current (VSC-HVDC). A meshed HVDC transmission grid typically has significant issues managing the power flows across the lines and protecting against faults.

Current flow controllers (CFCs) are required in mesh-HVDC grids because line currents between nodes must be balanced. Hybrid circuit breakers with forced commutation can protect HVDC grids against dc faults, but the present dc breakers' fault clearing periods are too slow or unreliable to provide adequate protection against de faults on multiterminal networks. CFCs are used in conjunction with a hybrid dc circuit breaker to address these issues. The CFC's control effectiveness and design will be examined by Simulink in MATLAB. The two cases are examined, comprise a combined system made up of CFC and Circuit Breakers (CBs) and the distinct design contains CFC and CB, which are contrasted individually, Therefore, power losses can be minimized.

Keywords: Voltage Source Converter, DC Circuit Breaker, Load Commutation Switch, HVDC Grid, And Current Flow Controller.

I. INTRODUCTION

The rapid development of HVDC systems in recent years and the quick rise in the number of HVDC projects being planned or completed suggest a revived interest in VSC-HVDC technology on a worldwide scale. Meanwhile, multi-terminal HVDC (MT-HVDC) networks are becoming efficient in modern power systems. [I]. VSCHVDC systems, which also enable cross-border energy exchange, are predicted to make it easier to integrate large-scale renewable energy production into power grids [2].

The two MT-VSC-HVDC systems already in service are the Zhou Shan network (five terminals) and the Nano HVDC system (three terminals) [3], [4], while several other DC grid topologies have been suggested to depict the structure of a future grid in Europe [5, 6, 7].

Meshed HVDC (MHVDC), a complicated type of MT-HVDC grid, faces problems controlling power flows in addition to protection issues. The power flow in the M-HVDC grid is specifically controlled by converters that regulate the de-side voltage and by considering the impedance of the transmission line. Additionally, there are numerous paths for the current to travel between two separate nodes. Circuit breakers (DCCB) and CFCs are integrated, respectively, to address these issues [8].

To combat cable currents in an overloaded environment, CFCs in mesh grids (dc) are necessary [9]. Basically, there are two alternative ways to control the current flow in a mesh circuit: changing the branch resistance(s) or adding a voltage source.

There have been several topologies proposed, however CFCs dependent on de-de converters offer the most potential and do not need isolation transformers in comparison to deac converter conversion [10], [II]. In contrast, DCCBs are necessary for protection against de faults and act when the mechanical breaker has a chance to interrupt the current within a short period of time due to the power electronic path [12].

There is an opportunity to merge fault protection and CFC functionality into one system because their respective roles are distinct. This study investigates how CFC can be integrated into the design of a hybrid de-circuit breaker, paying close attention to the PHCB [13] if it has an LCS.

While hybrid de-circuit breakers and CFCs need power electronic components that are constantly connected to lines carrying de-current. The control and functioning of CFC are dependent on the converter's (de-de) topology, which consists of two converters with half-bridges next to each other and a series connection between each half-bridge and the dc line. After that, a summary of the two systems under investigation reveals an in-depth perspective on organizing DCCBs into CFCs.

This paper is divided into five sections: Section II introduces the basic idea and operation of PHCB; Section III provides a brief analysis of CFCs; Section IV provides a detailed description of a VSC-HVDC based on a multi-terminal system; and Section V presents simulation results and a discussion of the coordination of PHCB with or without CFC.

II. CURRENT FLOW CONTROLLER

The CFC diagram is displayed in Fig. 6. Each of the CFC's eight independent IOBT switches has an antiparallel freewheeling diode. The CFC topology of this paper is explained in [12]. In essence, CFC impose a variable voltage supply and prevent line overloading by drawing electricity from one line and feeding it to the other.

By flowing through the HYDC grid lines in this manner, the decurrent can be effectively increased or lowered. When an input current of i and two branch currents of i, i" i z > O are applied, Table I shows the operation switching states for CFC. The CFC only controls two wires (currents), hence it has four modes of operation. First, there are two forward modes for currents flowing out of the CFC in the forward direction (one for i] > i z and the other is for i z > i]), and two reverse modes for currents flowing into the CFC in the opposite direction (one for i, > i z and the other is for i z > i), where "I" denotes the switches on state and "0" denotes the switch's off state.

Table 1: Switch States of CFC

Mode	Higher Current	Current Direction	Switching States							
			S a1	S a2	S b1	S b2	S c1	S c2	S d1	Sd2
1	I1	Forward	0	0	0	1	PWM	PWM	0	0
2	I2	Forward	0	0	1	0	PWM	PWM	0	0
3	I3	Reverse	PWM	PWM	0	0	0	0	0	1
4	I4	Reverse	PWM	PWM	0	0	0	0	1	0

III. SYSTEM DESCRIPTION & MODELLING

The M-HVDC grid is made up of four stations connected by four cables, each of which is reliant on a single VSC. As shown in Fig. 1, a hybrid-CB is located at each tail of the lines, and the CFC is housed in Station I. The CFC coordinates its operation with two direct current CBs.

High-pass filters, a DC chopper, a DE inductor, a PHCB, and capacitors make up the four-terminal VSC-HVDC network in Fig. 8 that runs at 200 kV. The inverter and rectifier in this circuit use neighboring IGBT/Diodes and are three-level (NPC)-VSC devices. The inverter and rectifier are combined using two 8 ml-l smoothing reactors and two 100 km lines. Many of the projects that have been given the go-ahead use three-level converters despite the current trend in the VSC-HVDC industry toward using more CFC. Therefore, it is crucial to consider key interactions because it is possible that future MT-dc grids will be dependent on the CFC and three-level composition. The configuration grounding of this MT system grounds the midpoints of all three level converters.

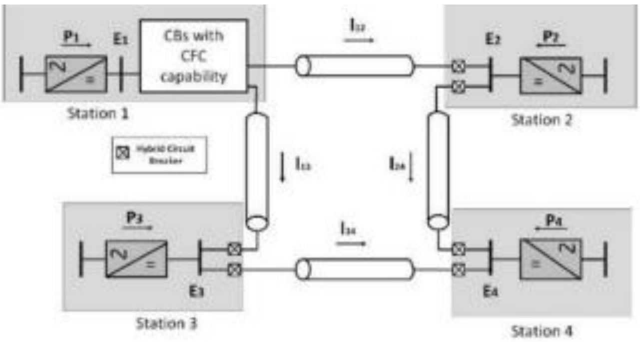

Fig. 1 Single line diagram of integrated CFC and CBs

A. VSC based HVDC system modelling

The three-level NPC is set up using transformers, switching IGBTs, phase reactors, and capacitors (de). For the VSC-HVDC MT system, voltage droop, voltage margin control, etc. have all been established, but the three-level model employed here employs the P-Q control strategy. There have been some DC choppers utilized; a list of them is shown in Table II. Table III uses the parameters for the circuit breaker. The active & reactive power (P, Q) control system for VSC-based HVDC transmission is used for independent control.

The basic equations for active and reactive power flow in a VSC-HVDC system are as follows:

$$P = \frac{V_s V_c}{X} \text{Sin}\,\delta$$

$$Q = \frac{V_s\left(V_s - V_c \text{Cos}\,\delta\right)}{X}$$

When V is the maximum supply voltage, X is the reactance, tS is the phase angle difference within V, and is the maximum voltage.

Reactive power can be limited by adjusting the amplitude of the two converter voltages, whereas active power can be limited by adjusting the phase angle of the two converter voltages, as shown above equations. If the converter voltage Vc is behind the source voltage by an angle tS, the converter will act as a rectifier; if it is ahead of the source voltage, the converter will act as an inverter.

The control system and sub-system at the sending end converter (SEC), which operate the rectifier side converter stations using three-level PWM and a current controller, respectively, are shown in Figures 2 and 3. A phase-locked loop (PLL), initializing filters, P, Q control, and the receiving end converter's (REC) control system are all shown in further detail in Figure 4. These components are used to ensure the smooth operation of converter stations on the inverter side.

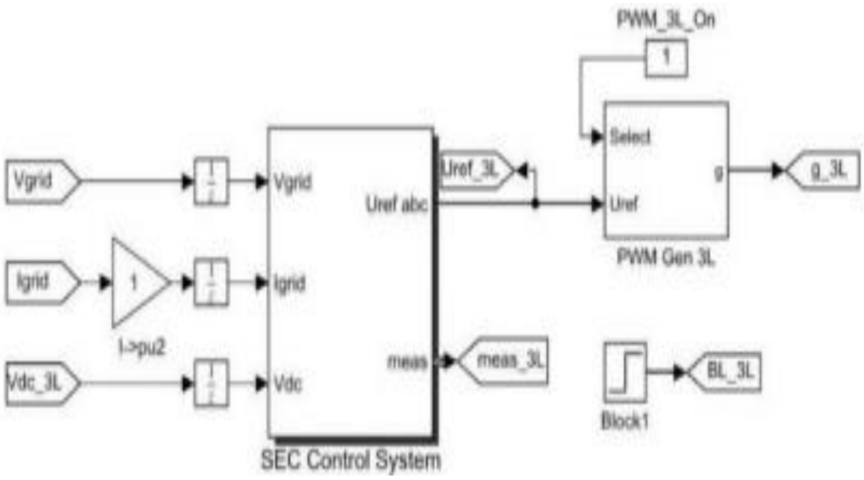

Fig. 2 Control System at Sending End Converter

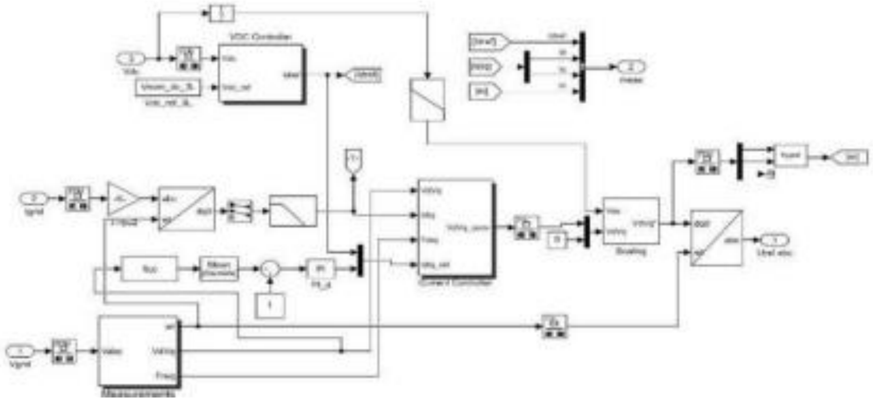

Fig. 3 Sub-system of Sending End Converter Control System

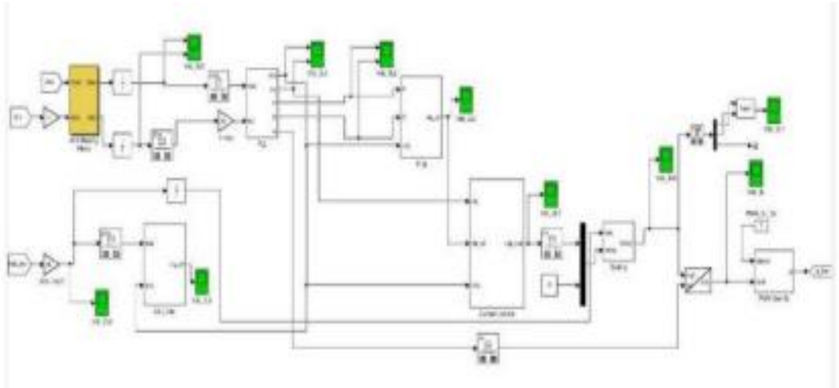

Fig. 4 Control System at Receiving End Converter

Table 2: Voltage & Current Relationship of DC chopper

Voltage (pu)	Current (KA)
1	0
1.01	0
1.02	0.5
1.03	1
1.05	1.25
1.15	1.25

Table 3: Circuit Breaker Parameters

Parameters	Values
Stray Inductance (L1/Ls)	30 H
LCS snubber capacitance	5.5 F
LCS varistors knee voltage rating	7.92 kV
Main breaker snubber capacitor	0234 F
Main breaker knee voltage rating	320 kV
dc-line inductor	100 mH
Mech. Operating time	2 ms

IV. SIMULATION RESULT & DISCUSSION

Fig. 5 shows the direct-axis reference current at 1.5 pu, as well as the direct and quadrature-axis current at SEC. Figure 6 displays the active and reactive power output at REC conflict systems.

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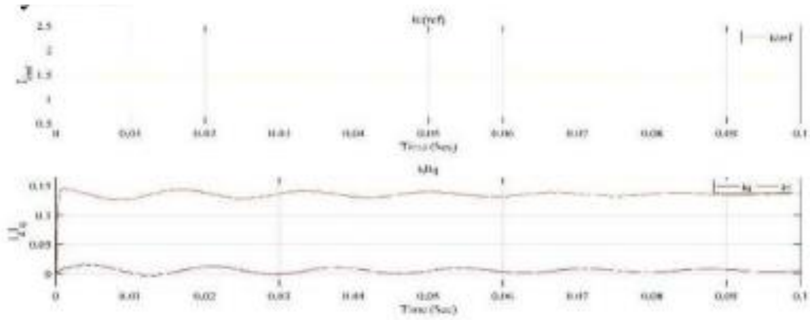

Fig. 5 d, q-axis Current at Sending End Control System

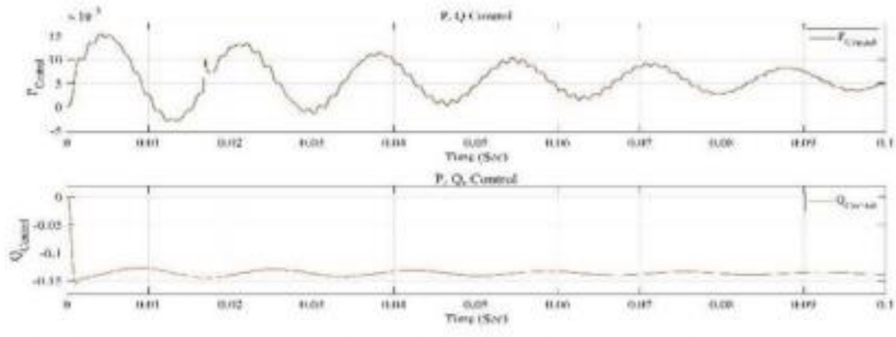

Fig. 6 P, Q output at Receiving End Control System

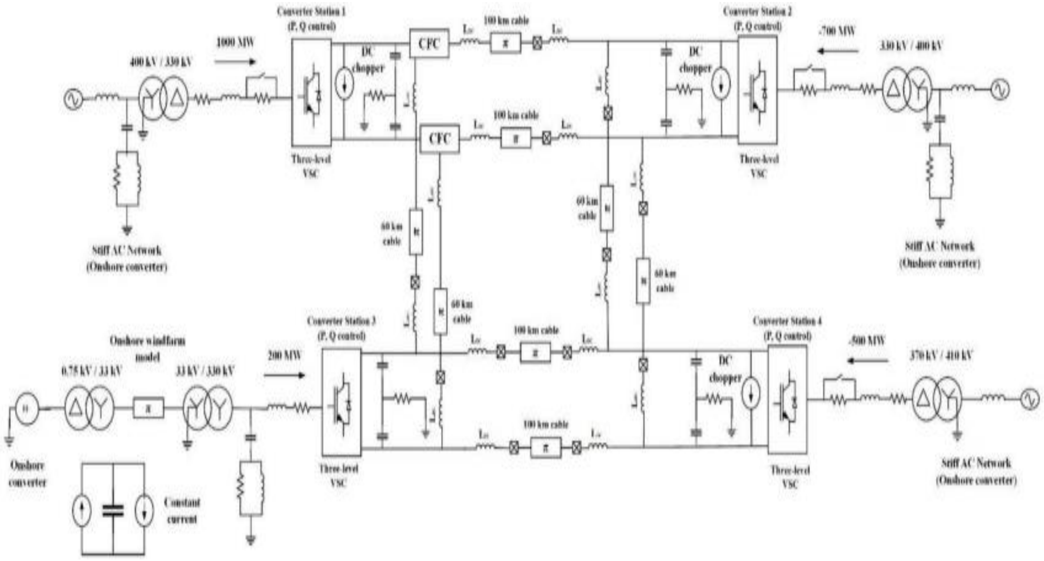

Fig. 7 Schematic Diagram of multiterminal VSC-HVDC system

The MATLAB SIMULINK software is used to simulate the system depicted in Figure 7 to evaluate the reaction of the created control system. Throughout the experiment, three-level NPC-VSC converters were used.

The result shows that the combined CFC and circuit breaker operation reduces both space and power losses. The circuit breaker also guards against overvoltage since transient current is redirected away from CFC during a malfunction. The voltage decrease permits a reduction in power losses when comparing the combined case studies to individual systems.

The sole distinction in this study's methodology is the addition of PHCB and CFCs. The P and Q power settings are 13 KW and 1.3 VAR, respectively. While DC voltage is indicated to be at 0.0 17 pu, the input for a three-level VSC is set at 0.2 pu. Results are analyzed using Figures 8–11. Compared to Study I, the P and Q power exhibits less distortion because of this coordination. Controlling power flow and offering fault prevention are both accomplished by CFC as it balances the currents in the lines.

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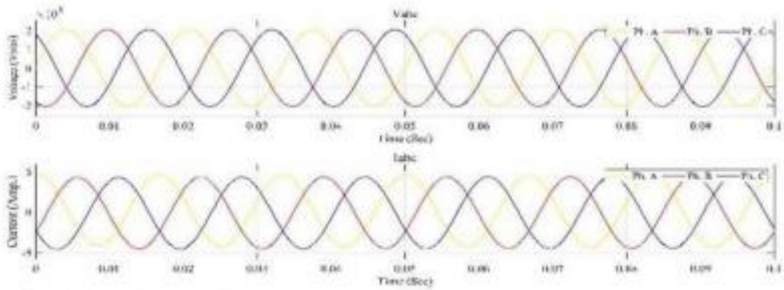

Fig. 8 Three-Phase V-I Measurement

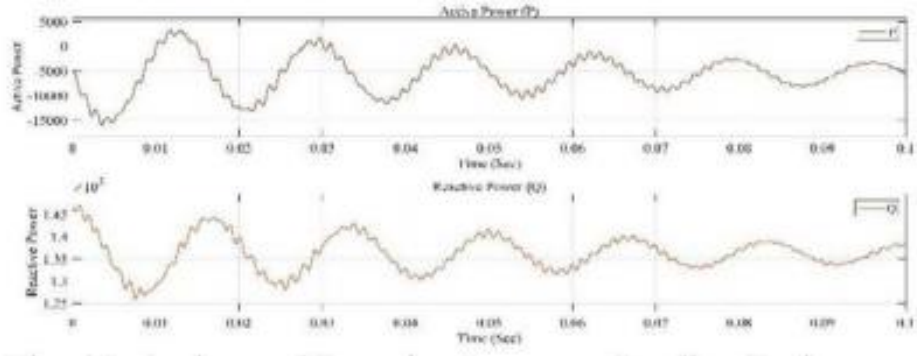

Fig. 9 Active and Reactive Power at Sending End

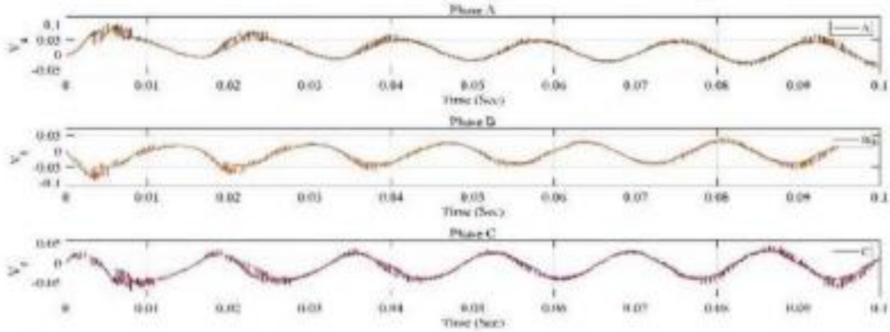

Fig. 10 Input Signal at Three-level VSC

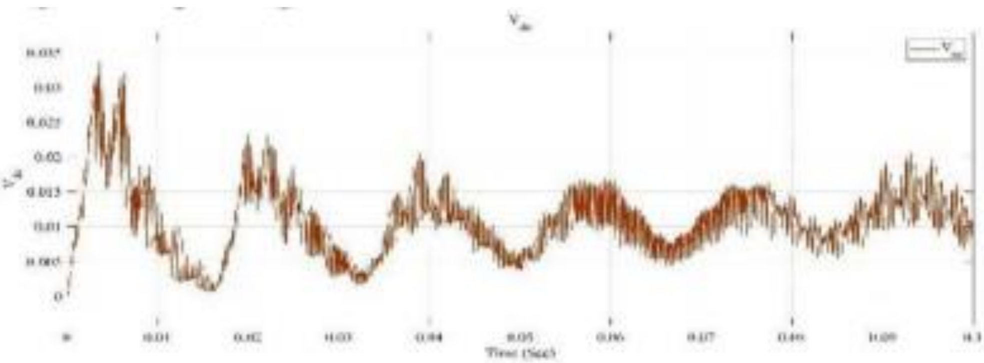

Fig. 11 Output Signal at Three-level VSC

V. CONCLUSION

Combining CFC with hybrid circuit breaker design has many advantages. Utilizing a 4-terminal VSC grid with two independently running converters, these concepts have been tested. The CFC controls the current flowing across the DC grid to prevent overloading separate cables or to lower overall grid power losses. The controller may also hold other grid operations like line switching while minimizing the switching devices.

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