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Enhancement of Fault Ride-Through Capability for VSC-HVDC Systems Provisioning for Passive Industrial Installations

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Abstract -This work suggests a frequency hysteresis control (FHC) and a modified current limit strategy (MCLS) to enhance a VSC-HVDC link that supplies passive industrial installations' disturbance ride-through capabilities. It is crucial to provide voltage stability during severe breakdowns because industrial loads are more susceptible to voltage decreases than frequency aberrations. Three steps are involved in the development of the control approaches. In order to more successfully improve the voltage stability, the primary factor influencing the ac voltage in the passive industrial system is first examined. Second, the MCLS is suggested to raise the ac voltage under transitory circumstances based on the analytical results. Thirdly, the FHC is added to the VSC controller together with the MCLS to improve the control result of the MCLS. This can also further increase the passive system's ac voltage. The correctness of the control methods is verified by the results of simulation tests conducted in MATLAB/SIMULINK under metallic single-phase and three-phase failures.

Keywords- Passive Industrial Installations, Voltage Stability, Voltage Source Converter (VSC), Modified Current Limit Strategy, Frequency Hysteresis Control.

I. INTRODUCTION

Two converter topologies in the VSC-HVDC system have been examined. The most basic circuit configuration is the two-level bridge, which is used in a number of commissioned projects. By using capacitors and diodes to increase the number of levels, modern techniques have extended the principle to multilevel converters. A three-level neutral point clamped voltage source converter and a three-level flying capacitor voltage source converter are two examples of voltage sources that can have their levels of clamping varied. These multilevel converters offer lower power losses and better waveform quality. It states that, when operating at 1 pu power, the usual losses of the two-level and three-level VSC are greater than 3% and between 1% and 2%, respectively. Nonetheless, two-level converter technology is still the most widely utilised since multilevel converters enhance the complexity of the converter design. Appropriate control algorithms are required in order for the VSC-HVDC to reach its full potential. Numerous studies, including have examined the various VSC-HVDC control systems. The usage of an inner current control loop in conjunction with a carrier-based PWM is demonstrated. When the converter is connected to a powerful AC network, the inner current control loop is intended to be used for both dead-beat control of the converter current and digital control implementation. An examination is conducted on a discrete vector current controller-based grid-connected VSC.

Additionally discussed are the effects of grid voltage harmonics and improper controller tuning on current frequency responses at an operational point. Additionally, a few particular facets of the VSC-HVDC are also examined in the literature. An analytical model of a VSC-HVDC system's power control terminal, for example, is also examined and presented. It is looked into how much VSC-HVDC contributes to short circuit currents. We examine the local area damping and inter-area decoupling caused by the VSC-HVDC. Additionally, there exist additional avenues for enhancing VSC-HVDC. To enhance the dynamic properties of the VSC-HVDC connection, a static synchronous series compensation (SSSC) is integrated into the VSC-HVDC station. Connecting a wind farm to the AC grid is one

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of the VSC-HVDC's more alluring uses, as it can address possible issues like voltage flicker. Analysis, both technical and financial, is provided to assess the advantages and disadvantages of grid-connected offshore wind farms via DC links. The behaviour of a VSC-HVDC system is examined when power generated by an offshore wind farm (WF) of induction generators is fed into a weak AC network. In certain commissioned projects, the VSC-HVDC method of linking a wind farm to an AC system has also been used. Onshore wind power is supplied to the AC system by two commercial VSC-HVDC transmission systems projects, Gotland and Tjaereborg. These efforts have demonstrated that VSC-HVDC can effectively counteract voltage changes by handling wind power and responding quickly enough.

Nevertheless, the system cannot be started consistently since the controller has not established the passive network's frequency for steady-state operation, and this control method might not be able to sustain passive networks through serious breakdowns. A VSC inverter's droop frequency controller is created in. The primary objective of the controller is to generate a novel reference frequency for the VSC output voltage by analysing the dc voltage performance. However, the passive industrial system's voltage stability in the event of severe defects remains inadequate.

A nonlinear control approach was provided in with the goal of enhancing the VSC output voltage's waveform quality; the ac grid dynamics were disregarded. In order to enhance passive industrial installations' fault ride-through capabilities, this research suggests innovative control methodologies for a VSC-HVDC link. A modified current limit strategy (MCLS) and a frequency hysteresis control (FHC) make up the new VSC controller, which is based on the conventional ac voltage control (CAVC). The control schemes are intended to improve passive industrial systems' voltage stability. To test the suggested methods, the effects of metallic single-phase and three-phase faults in the transmitting side of the VSC-HVDC system are simulated and examined in MATLAB/SIMULINK.

II. PROPOSED METHOD

A novel DC transmission system technology is called VSC-HVDC. IGBTs construct the valves, and PWM is employed to provide the required voltage waveform. Any waveform, any phase angle, and any amplitude of the fundamental frequency component can be produced with PWM. There are numerous applications possible because to its strong controllability. Figure 1 depicts the components of a typical VSC-HVDC system, which include phase reactors, DC capacitors, converters, transformers, AC filters, and DC cables.

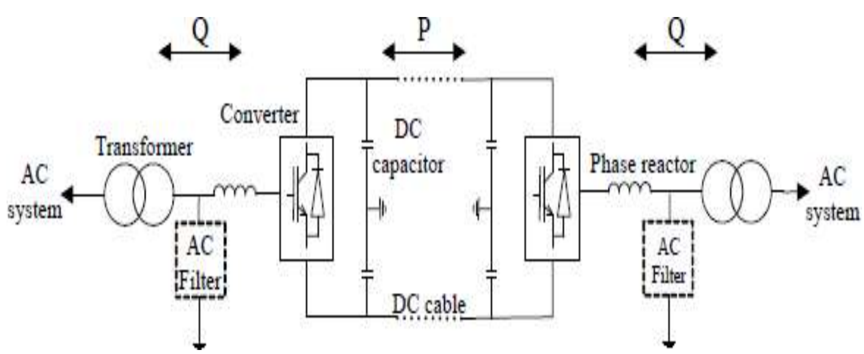

Figure 1 : A VSC HVDC System

Figure 2 shows how a VSC-HVDC transmission system transfers power from the main grid to the passive industrial system. This paper's analysis focuses mostly on induction motors because they are thought to be the dominant load in industrial systems. Since protective features and variable frequency drives are assumed to make up a minor portion of the passive load, they are left out of this article.

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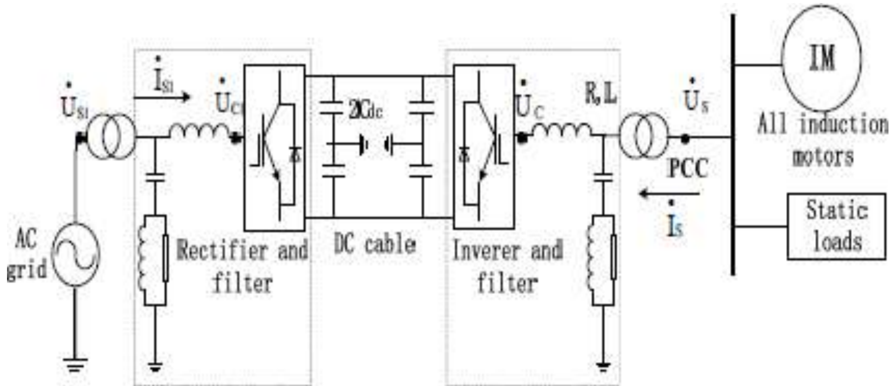

Figure 2 : Network Topology

The inner and outer control loops provide the foundation for the VSC-HVDC's control. Ensuring that the isd and isq dq-axis current components follow the references produced by the outer control loop is the primary responsibility of the VSC inner control loop. When a VSC-HVDC system feeds power into a passive network, the outer control loop of the rectifier station runs on the dc voltage control mode and the ac voltage or reactive power control mode in order to suppress negative sequence currents during unbalanced failures. Phase Locked Loop (PLL) synchronisation between VSC and the main grid can be accomplished at the grid side. Fig. 3 depicts the rectifier station's control scheme. Q represents the reactive power that is transmitted from the ac grid to the rectifier station, Us1 denotes the ac grid's voltage amplitude (refer to Fig. 2).

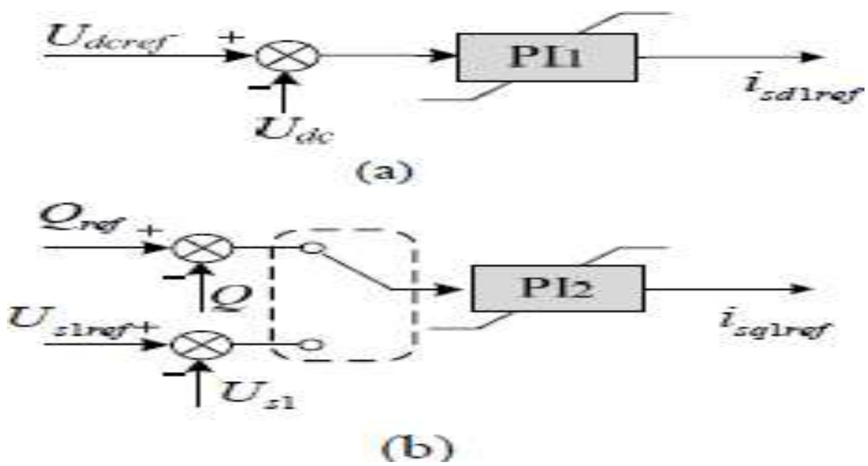

Figure 3 shows the rectifier station's outside control loop. (a) mode of DC voltage regulation. (b) Reactive power or ac voltage control mode

The voltage control mode that the VSC on the receiving side uses is intended to regulate the ac voltage at the PCC. In Fig. 4, the control method is shown. Both the active and reactive power are transferred from the VSC inverter under the dq-axis form. This section introduces two ride-through approaches, a modified current limit strategy (MCL) and a frequency hysteresis control (FHC), to improve the voltage stability of the passive industrial system. Both of them are predicated on the traditional ac voltage control (CAVC) that the receiving side VSC has chosen. The high voltage transmission cables' inductive properties are primarily responsible for the close connection between the ac voltages. The system's reactive power fluctuation could significantly affect the power grid's ac voltage. The rectifier station runs in the dc voltage control mode when a VSC-HVDC is providing power to passive industrial installations. When

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transmitting side faults occur, the grid experiences an ac voltage drop and the VSC rectifier's current hits its limit. Consequently, the grid side VSC is unable to sustain the dc voltage. Since the ac voltage in the passive system is regulated from the dc voltage of the VSC-HVDC, variations in the active power may result in fluctuations in the dc voltage, which could perturb the ac voltage at the PCC. As a result, the active power will affect the passive industrial systems' ac voltage during severe breakdowns.

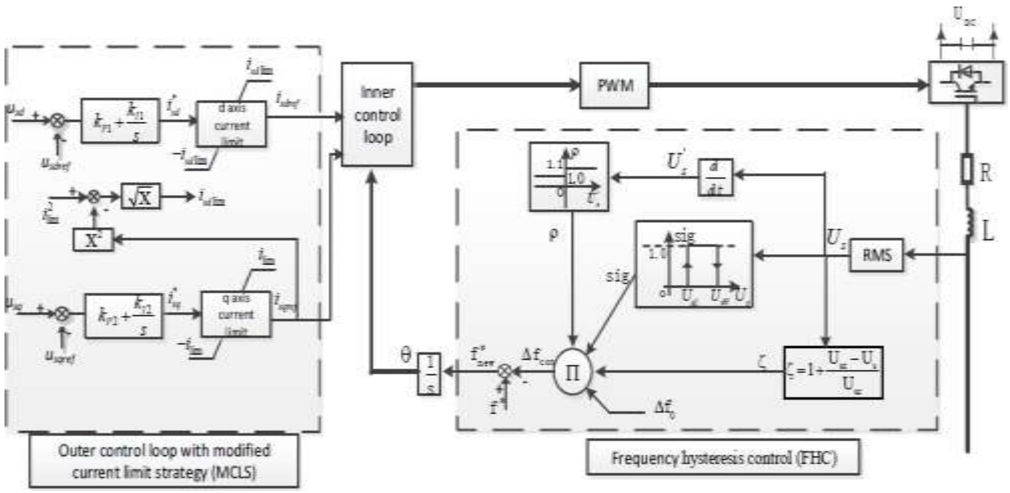

Fig. 4. Schematic scheme diagram of VSC-HVDC receiving side control.

However, reactive power is essential for maintaining the passive system's voltage stability. Therefore, an analysis should be conducted to determine whether the active power or the reactive power is the primary factor impacting the ac voltage at the receiving side. A metallic three-phase failure is simulated at the transmitting side of the VSC-HVDC in the system depicted in Fig. 2. The error occurs at 0.5 s and is fixed at 0.6 s.

III. SIMULATION RESULTS

The project employs the test system in matlab/simulink to confirm the correctness of the control schemes suggested above, as per the topology in Fig. 2. The sending side VSC in the simulation runs in both the reactive power control and dc voltage control modes. The VSC-HVDC system's inverter is equipped with an ac voltage controller.

Fig. 5. AC voltage at the PCC

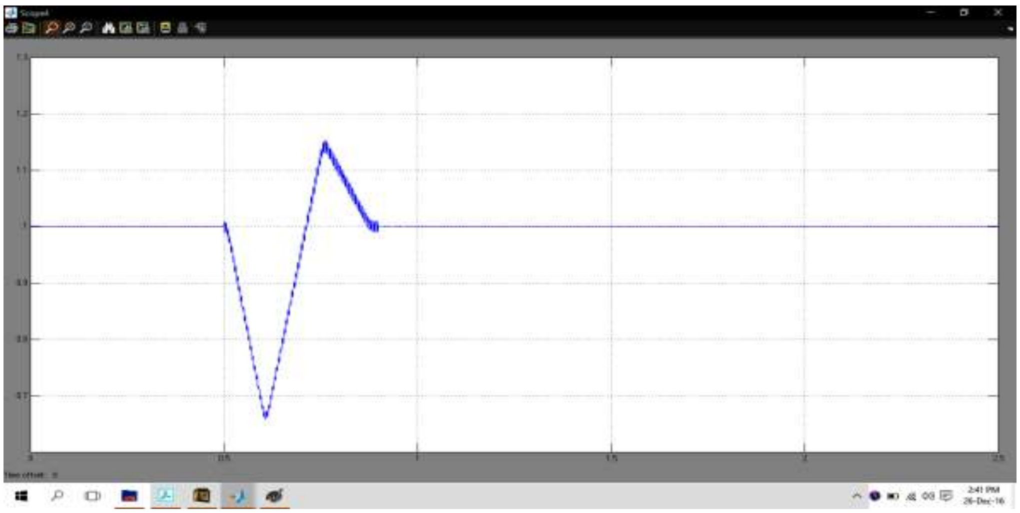

Fig.6 . DC voltage of the rectifier VSC.

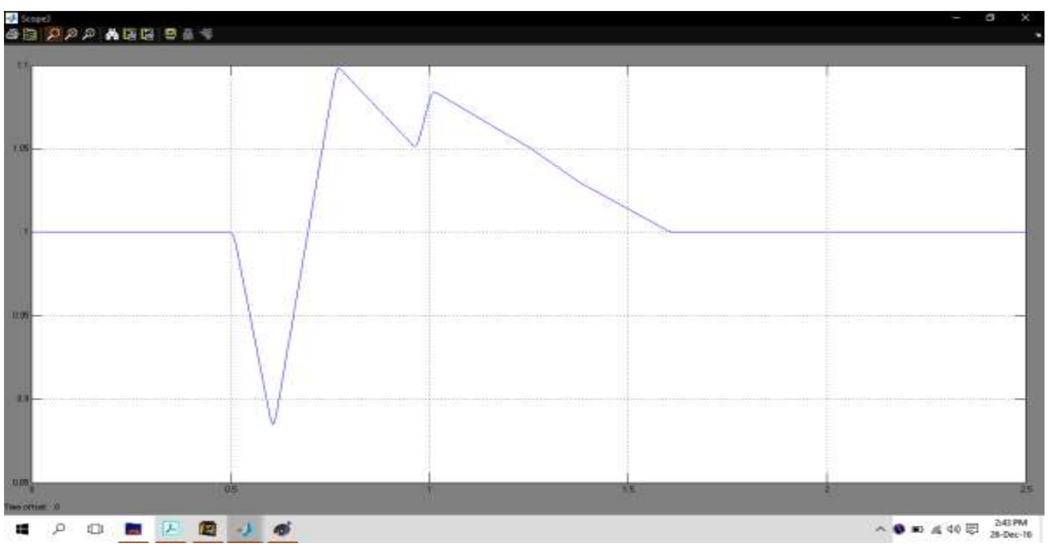

Fig.7. Frequency of the passive system

Fig.8. VSC current

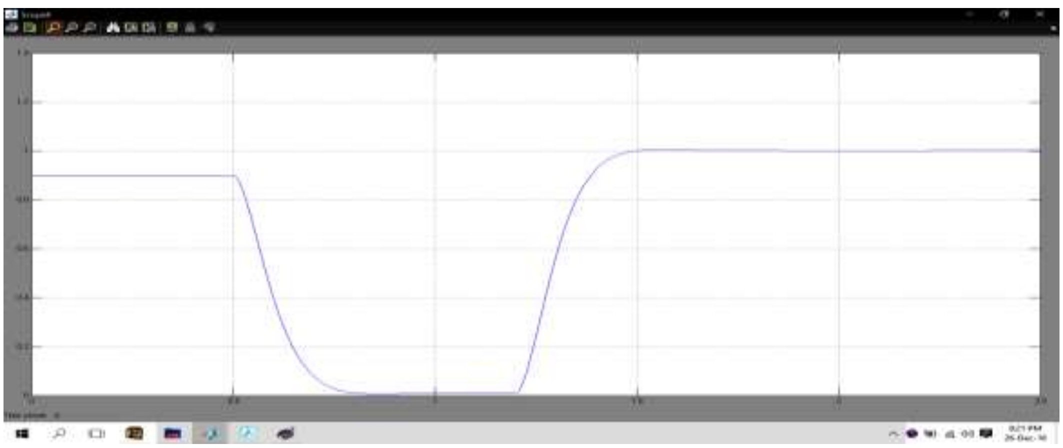

Fig.9 . Consumed active power

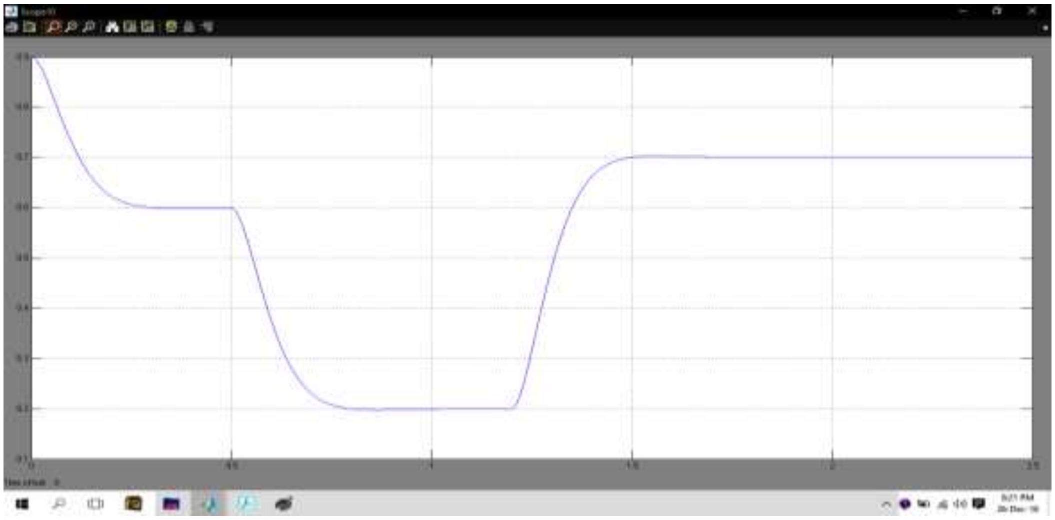

Fig.10 . Consumed reactive power

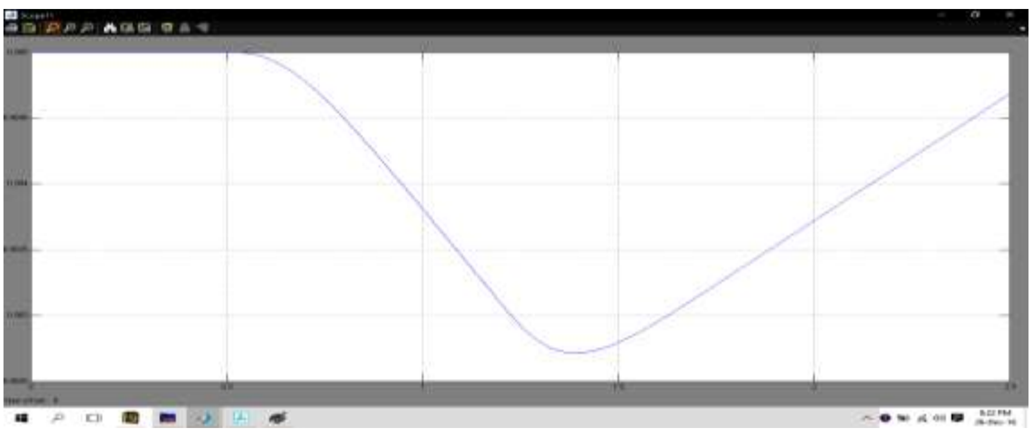

Fig.11. IM speed

IV. CONCLUSION

The purpose of this paper was to create control strategies to improve the voltage stability of the VSC-HVDC-supplied passive industrial systems. Reactive power is the primary component influencing the ac voltage of the passive system, according to the analytical conclusion. Therefore, two control strategies—a modified current limit strategy and frequency hysteresis control—are suggested. The MCLS was selected due to the fact that isq, the q axis component of the VSC current, primarily determines the reactive power transferred from the inverter of the VSC-HVDC under both constant and transient conditions. Reactive power production from the VSC can be increased by preferring meeting the isq setting when the MCLS is incorporated into the inverter station's outer control loop. An additional frequency control is suggested, based on the MCLS. The FHC's concept is to lower the VSC's set frequency at the receiving end in accordance with the passive industrial system's ac voltage measurement. This can help to increase the MCLS's control impact. Furthermore, lowering the target frequency may raise the isq, which raises the reactive power output even more.

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