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AC Grid Resilience Enhancement using VSM Control of HVDC Interties

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ABSTRACT

Inertia is one of the major concerns of our time these days, and visible inertia is seen as an inevitable part of the modern energy system of the future. This has been particularly important with the introduction of renewable energy grids (low wind and solar), which have a very sensitive effect on the power supply. Recent research trends in various parts of today's energy systems are directed at real-world simulation methods, and many research projects have taught us this topic. In this paper, we measure frequency response by giving the result in visual inertia and frequency of the power grid when the conversion terminals are controlled as a virtual synchronizer (VSM). It assesses the performance of visual inertia support by looking at the power system by examining the impact of synchronization control, downtime HVDC, and VSM HVDC control over frequency response. Note how VSM-based HVDC controls provide internal support and improve recovery response frequency. The Power Factory Dig SILENT commercial software simulation introduces the same AC grid case connected to the HVDC transmission system modeled by default parameters. The results confirm the beneficial effect of virtual inertia support on frequency dynamics and how VSM-based control significantly improves the nadir frequency nadir and frequency change response (RoCoF) compared to the traditional frequency reduction of HVDC connectors.

KEYWORDS: *HVDC, VSM, Dig SILENT, Frequency Response, Virtual Inertia*

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INTRODUCTION

Excessive production of renewable energy in energy systems leads to a decrease in the same inertia and an increase in the frequency change rate (RoCoF) in response to disturbance [1], [2]. This situation makes it difficult to use systems outside the high-powered grid, such as Ireland and the United Kingdom [3], [4]. However, in large connected power systems such as the European continent, it is expected that similar inertia will decrease as renewable energy production increases [5]. In Nordic power systems, where high hydropower power reigns, problems related to low load and low inertia at high voltages arise from existing and future HVDC connectors with nearby power systems [6]. In this case, a VSM HVDC-controlled power converter with real-time inertia is an effective way to increase the equivalent inertia time and improve grid frequency fluctuations. Several recent publications have suggested using the HVDC system with voltage source converter (VSC) to provide visual inertia. However, many of the proposed control methods use frequency output (i.e., df / dt or RoCoF) to calculate the corresponding inertial response [7] - [11]. Such control strategies can be easily integrated into the control constraints of a traditional power source (VSC), but rely on dynamic power synchronization to measure df / dt. Instead of providing visual inertia for a variety of applications, synchronization machines (VSMs) explicitly mimic the vibration parameters of sync machines (SM) have been widely studied [12] - [15].

This control strategy relies on a balanced power synchronization method based on visual vibrations and behaves like a synchronized machine (SM), so it does not rely on phase-locked loops (PLLs) to synchronize the network. Therefore, it offers the same flexibility that works as SM, such as solid networks, autonomous systems with local loads, or operating capabilities under any intermediate conditions. This white paper examines the use of VSM-based control systems in HVDC and AC systems and evaluates the impact of VSM-based controls on HVDC systems in response to frequency of AC systems. The number simulation effect is displayed. The simulation was done using commercial software for DIgSILENT PowerFactory. Since simulation is primarily designed to study inefficient power, a standardized model representing the HVDC converter connection is used. This white paper is structured as follows: Phase II describes the implementation of VSM-based HVDC converter control. Phase III mimics and shows results. In Section IV, the work concludes with some conclusions.

VSM BASED HVDC CONVERTER CONTROL IMPLEMENTATION:

The control logic used in this article is based on the use of visual alignment described in [16]. Figure 1 shows a summary of HVDC transmission lines controlled as VSMs. The VSM-based virtual inertia simulation provides the frequency (ωVSM) and phase angle (θVSM) used for internal understanding, and the active power controller provides voltage reference (vr).

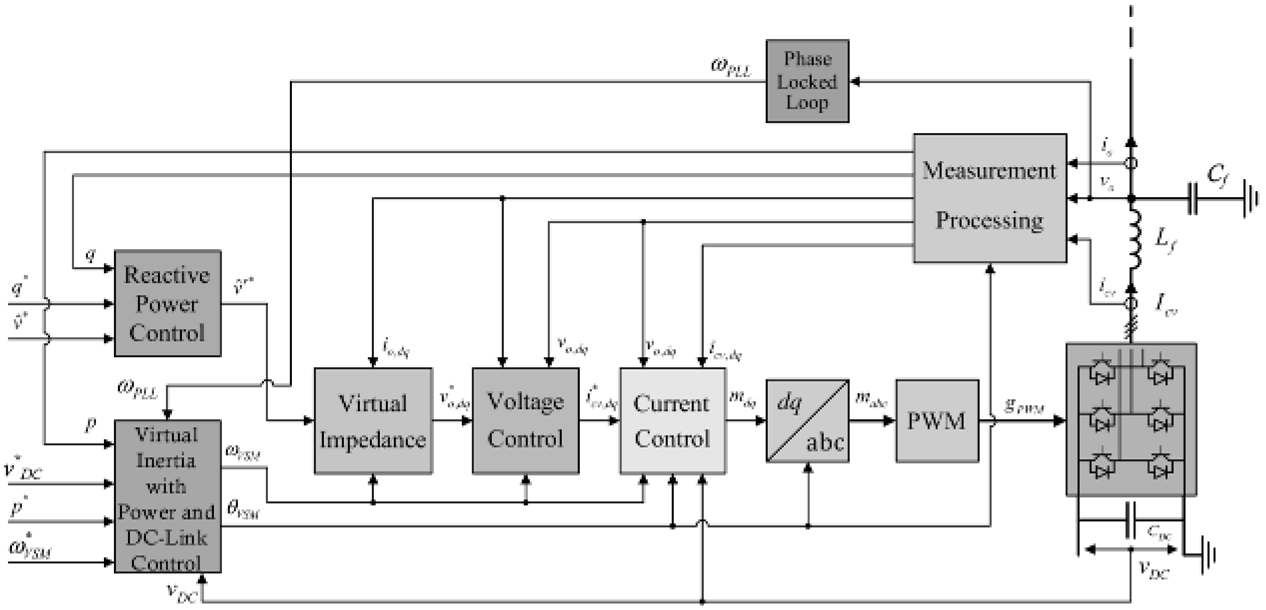


Fig. 1. Overview of the control system for an HVDC converter terminal operated as a Virtual Synchronous Machine

The power factor control and visual inertia simulation is seen as an external loop that provides reference to the current broken controls and power controls. The phase-locked loop (PLL) is used to measure the real CCC frequency and to use the melting point in vibration calculations. A block diagram showing the use of the VSM swing equation is shown to the right in Figure 2.

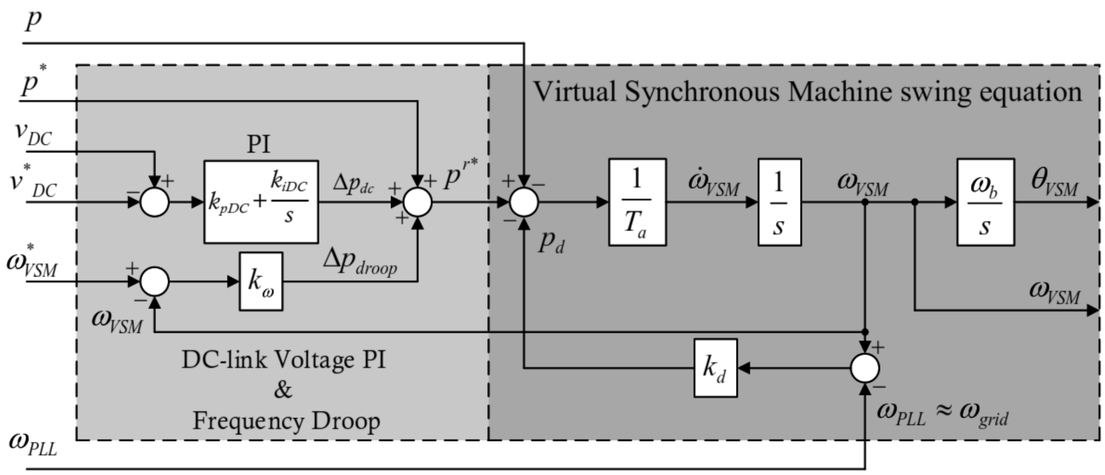


Fig. 2 Virtual Synchronous Machine swing equation with power- frequency droop or dc-voltage controller

As shown at the bottom left of Figure 2, VSM power controls include an external frequency drop corresponding to the normal speed control system features of the sync. As the vibration rate used in line use relative to speed, the speed of inertia is determined by the energy balance as follows:

$$s \cdot \omega_{VSM} = \frac{p^{r*}}{T_a} - \frac{p}{T_a} - \frac{p_d}{T_a} \qquad (1)$$

Where,
p^{r*} = virtual mechanical input power,
p = measured electrical power injected by the VSM,
pd = damping power.
ω^{*}_{VSM} = frequency reference
ω_{V} = actual VSM speed
k_{ω} = the droop constant (difference between a frequency reference and the actual VSM speed)
p^{r*} = the virtual mechanical input power to the VSM swing equation (sum of the external power reference set-point and the frequency droop effect)
pr = power reference set-point,
$\Delta_{p\ droop}$ = frequency droop effect

By substituting the droop expression into (1), and reorganising the damping term, the virtual swing equation is given by:

$$s \cdot \omega_{VSM} = \frac{p^{r*}}{T_a} - \frac{p}{T_a} - \frac{k_d\left(\omega_{VSM} - \omega_{PLL}\right)}{T_a} - \frac{k_{\omega}\left(\omega_{VSM} - \omega^{*}\right)}{T_a} \qquad (2)$$

SIMULATION STUDY & RESULTS:

This chapter presents the numerical simulation results of the HVDC connector to test the VSM-based control effect of the HVDC system in response to the frequency of the AC power grid. The simulation is done using the commercial software of DIgSILENT Power Factory, as shown in Figure 4. The load is expressed as a flat load of 200 MW. The AC system connected to the Area 2 conversion channel contains 30 Numbers. Type 4 WEC is 6.67 MVA each at 0.4 kV (between rms lines), with an installed power of 200.1 MVA. It also includes 05 compatible synchronizers rated at 255 MVA and 19 kV (between rms lines), resulting in a total installed capacity of 1275 MVA. In the 2nd position, HVDC is connected to the descent control analysis and VSM control is used to extract the 450 MVA load requirement limit. All outputs are analyzed in WTG, SM, HVDC, and common coupling points (PCC) where the load is connected to 155 kV interphase rms. Since simulation is primarily designed to study inefficient power, it uses an ideal model with automatic parameters to represent the HVDC converter connection.

TABLE I VSM controller Units & data

Description	Name	Value	Unit
Acceleration time constant	Ta	3	[s]
Damping coefficient	Dp	300	[p.u.]
Voltage setpoint low-pass filter time constant	T_LPF_u	0.003	[s]
Initial speed setting	f_setpoint	1	[p.u.]

TABLE II Droop controller Units & data

Description	Name	Value	Unit
Active power droop coefficient	mp	0.01	[p.u.]
Reactive power droop coefficient	mq	0.05	[p.u.]
Low-pass filter cut-off frequency	w_c	60	[rad/s]
Initial speed setting	f_setpoint	1	[p.u.]

TABLE III STG controler units and data

Description	Name	Value	Unit
Voltage regulator proportional gain	Kpr	50	[p.u.]
Voltage regulator integral gain	Kir	20	[p.u./s]
Inner loop field regulator proportional forward gain	Kpm	1	[p.u.]
Inner loop field regulator integral forward gain	Kim	14.9	[p.u./s]

The system is expected to operate steadily. This equates to 200 MW of electricity in an area of 0.95 power. Additionally, for each controller, a single transmission with a transfer of 200 MW is considered.

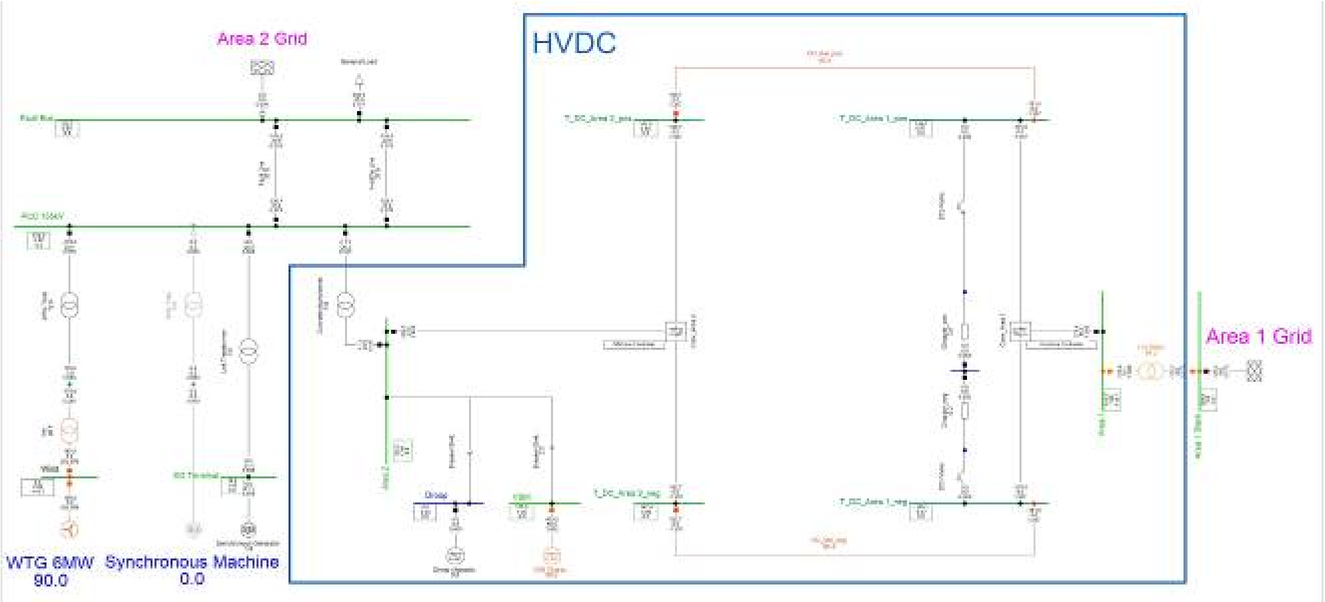
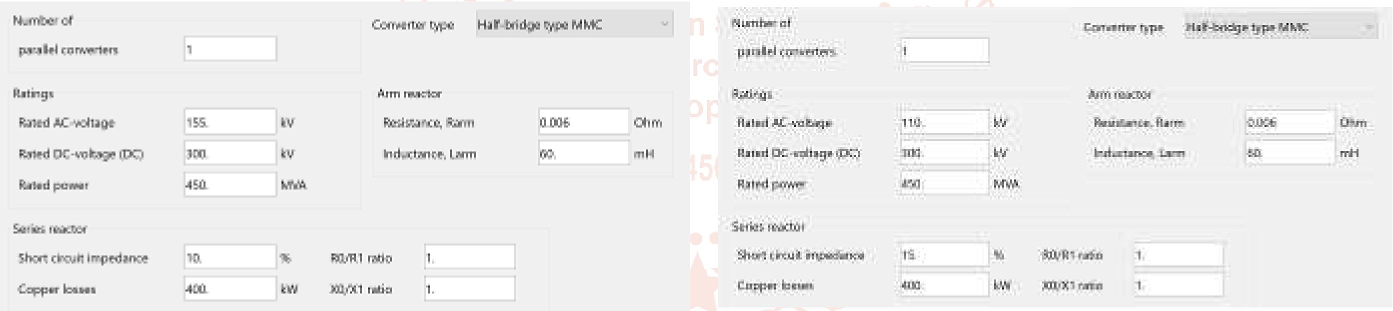


Fig. 4 Overview of investigated system configurations for AC system with HVDC transmission interties

HVDC links to a simulated system are based on a standard model. This model connects Area 2 AC grid with Area 1 AC grid and incorporates a 100 km bipolar HVDC link with 450 MVA power and ± 300 kVDC. The HVDC parameters are shown in Figure 5. In the simulated case, the HVDC switching station is designed to have normal value and voltage curves called AC area 1 and location 2 in 50 and two synchronization centers 110 kV and 155 kV rms (between rows).



Number of
parallel converters 1
Converter type Half-bridge type MMC

Ratings
Rated AC-voltage 155. kV
Rated DC-voltage (DC) 300. kV
Rated power 450. MVA

Arm reactor
Resistance, Rarm 0.006 Ohm
Inductance, Larm 60. mH

Series reactor
Short circuit impedance 10. %
Copper losses 400. kW
R0/R1 ratio 1.
X0/X1 ratio 1.

Number of
parallel converters 1
Converter type Half-bridge type MMC

Ratings
Rated AC-voltage 110. kV
Rated DC-voltage (DC) 300. kV
Rated power 450. MVA

Arm reactor
Resistance, Rarm 0.006 Ohm
Inductance, Larm 60. mH

Series reactor
Short circuit impedance 15. %
Copper losses 400. kW
R0/R1 ratio 1.
X0/X1 ratio 1.

Fig. 5 Overview of HVDC converter parameters

The power system was then interrupted in a step that increased the load collected in Area 2 by 0.5 pu in 0.1 seconds. It is noted that the load increase in Area 2 is handled only by the HVDC system. Each simulation works for each 2 seconds. The first simulation is the HVDC with VSM control connected to the AC grid, the SM and HVDC with the curve control are separated, and the second is the HVDC which controls the decrease in frequency connected to the AC grid, with SM. VSM-based HVDC disconnected and last SM connected to AC grid while HVDC disconnected from system. The effect of this simulation is shown in Figure 6. Here, the intermediate frequency at 2 PCC (155 kV) is shown, and in Figure 7, the intermediate voltage in phase 2 PCC (155 kV) is shown. Each plot in the picture shows the results of three cases. H. i) The reference case uses a local synchronization system control system 2 ii) A standard control system using HVDC which can control the frequency of the local converter frequency 2 iii) A VSS-based VDC control system that uses the HVDC Area 2 control VSM used for inverters inside.

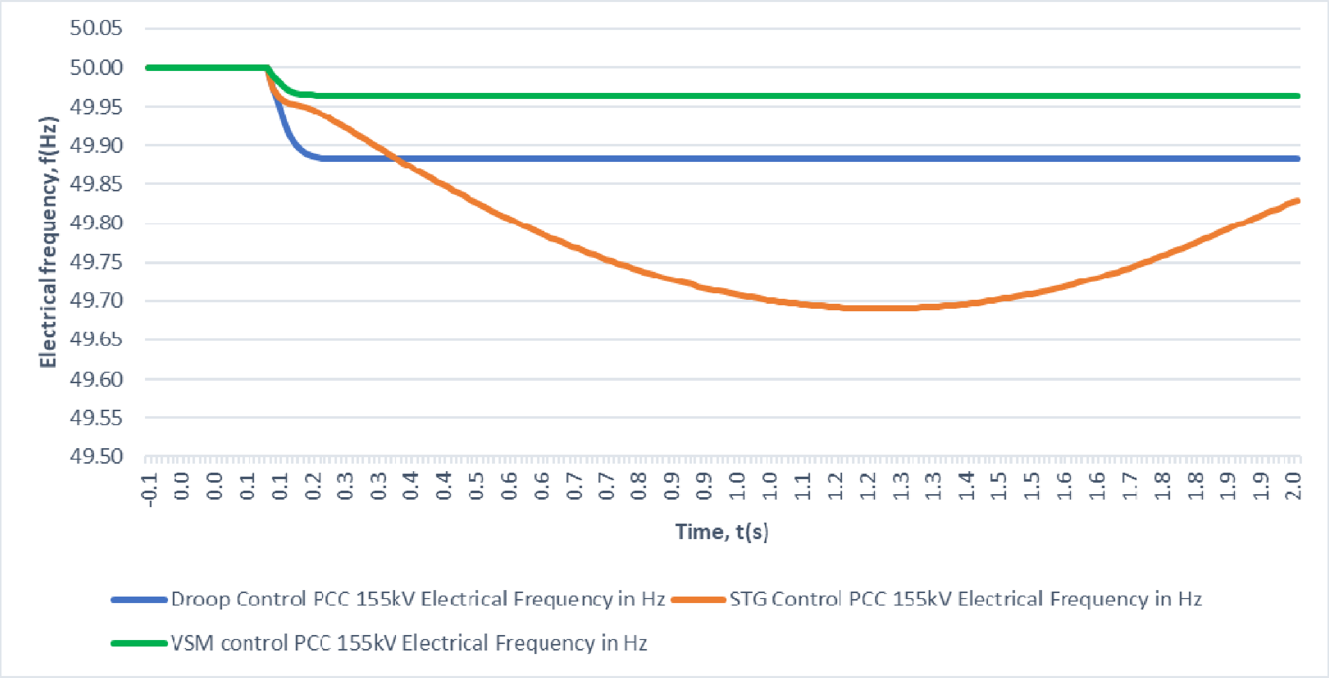


Fig. 6 Electrical frequency transient response at PCC(155kV)

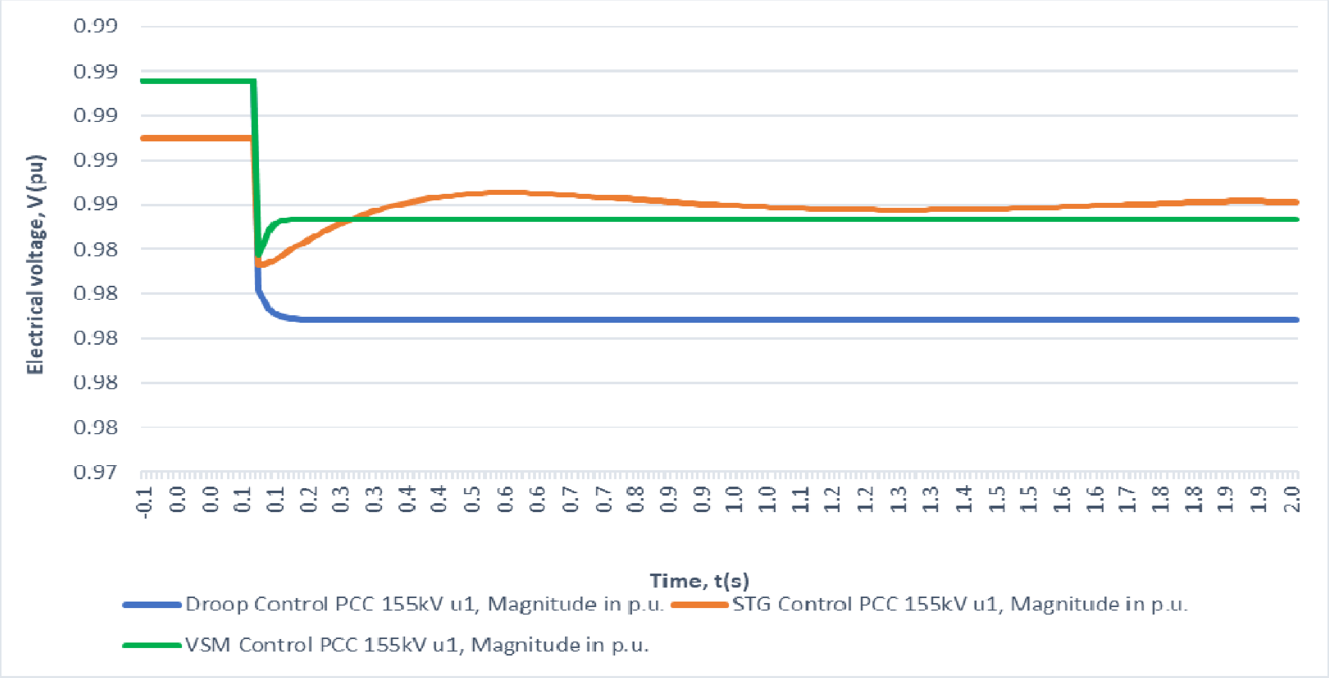


Fig. 7 Electrical voltage transient response at PCC(155kV)

In the event of a temporary load, the electrical frequency in Regional 2 begins to decrease, as shown in Figure 6. The curve reveals that the apparent inertia of the VSM control switch connector immediately after the loading step contributes to the RoCoF reduction. In addition, these statistics show how additional visual inertia can help improve frequency bottom.

Conclusions:

Synchronverter (VSM) control of HVDC converters is an effective way to improve inertia and reduce the challenges of low power systems for modern inertia. This article introduces a VSM-based control configuration for HVDC connectors and evaluates the frequency and voltage response in PCC (155 kV) in comparison to the normal frequency drop in power conversion terminals and synchronizers. he did. In the first case, the HVDC conversion port is controlled and used as a VSM, adding visible inertia to the AC system. In the latter case, the HVDC conversion hole is controlled and used as a traditional ground control. Also, check the AC system frequency response using SM of the same volume. Numeracy results show that VSM-based HVDC controls can significantly contribute to frequency control during a temporary interruption by improving the frequency change rate (RoCoF).

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