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**Abstract**— In This Paper, at some point of this letter, a protection method captivated with converter-implanted twofold thyristors is proposed to cope with those troubles. The twofold thyristors are added in corresponding with each SM inside the decrease hands of the converter. By placing off the twofold thyristors, the SPG shortcoming is changed over right into a three-level forestall ensures contemporary zerocrossings inside the framework aspect ACCB. Also, due to the fact the voltages of converter ac transports are clipped with the aid of using the lowest via the go away twofold thyristors, the higher arm overvoltage is alleviated. The viability of the proposed protection method has been checked at some point of a bipolar HB-MMC HVdc join labored in PSCAD/EMTDC

**Keywords:** half-bridge modular multilevel converter (HBMMC), ac circuit breaker (ACCB), Double-Thyristor-Based Protection, Single-Phase-To-Ground Faults.

## INTRODUCTION

However, bipolar MMC-HVdc exhibits some special technical issues. For instance, dc voltage offsets at the valve-side of the converter transformer and the severe consequences caused

by the valve-side single-phase-to-ground (SPG) faults in half-bridge (HB) MMC-based systems [4], [5]. According to the studies in [6]–[8], the valve-side SPG faults in bipolar HB-MMCs will lead to grid-side nonzero-crossing currents and overvoltage of the submodule (SM) capacitors in converter upper arms. The grid-side ac circuit breaker (ACCB) may have difficulty in interrupting such nonzero-crossing fault currents [4], [5], [9]. The upper arm overvoltage may damage the SM capacitors and threaten the insulation of the converter. To address the above problems, some solutions have been proposed in the literature. In [4] and [5], an auxiliary grounding ACCB is installed on the grid-side of the converter to create zerocrossings in the total currents in the grid-side ACCB. However, the three-phase-to-ground fault created by the auxiliary ACCB may aggravate the fault impact on the AC grid. Li et al. [8] employ an LR circuit as the dc-side grounding of the HB-MMC to create grid-side zero-crossing currents. However, a large reactance is needed to guarantee continuous current zero-crossings. Moreover, the application of the LR circuit will worsen the upper arm capacitor overvoltage and produce large disturbances on the healthy pole. One mixed-SM

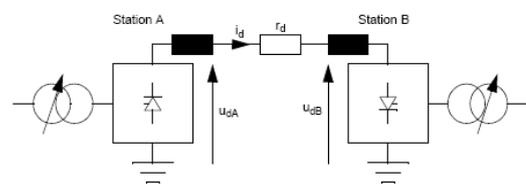
MMC proposed in [6] uses full-bridge (FB) SMs in the upper arms and HB-SMs in the lower arms. Although this topology can mitigate the upper arm overvoltage, the grid-side nonzero-crossing currents still exist. Both FB-MMCs and the mixed-SM MMC (which uses HB-SMs in the upper arms and FB-SMs in the lower arms) proposed in [7] can eliminate the issue of grid-side nonzero-crossing currents [10]–[12]. However, the SM capacitors in the upper arms of them will still suffer severe overvoltage. Moreover, the capital cost and power losses of the above mixed-SM MMCs and FB-MMCs are much higher than HB-MMCs due to the additional application of insulatedgate bipolar transistors (IGBTs). HB-MMC HVdc systems. The double-thyristors are placed in parallel with each SM in converter lower arms. Current zerocrossings will quickly appear in grid-side ACCB due to the symmetrical short-circuit created by the triggered double-thyristors. Given that the ac bus voltages are clamped by the ground through the triggered double-thyristors, the upper arm capacitor overvoltage will be mitigated as well.

## HVDC CONVERTER STATIONS

An HVDC converter station is normally built up of one or two 12-pulse converters as described above, depending on the system being mono- or bipolar. In some cases each pole of a bipolar system consists of two converters in series to increase the voltage and power rating of the transmission. It is not common to connect converters directly in parallel in one pole. The poles are normally as independent as possible to

improve the reliability of the system, and each pole is equipped with a DC reactor and DC filters. Additionally the converter station consists of some jointly used equipment.

This can be the connection to the earth electrode, which normally is situated some distance away from the converter station area, AC filters and equipment for supply of the necessary reactive power.



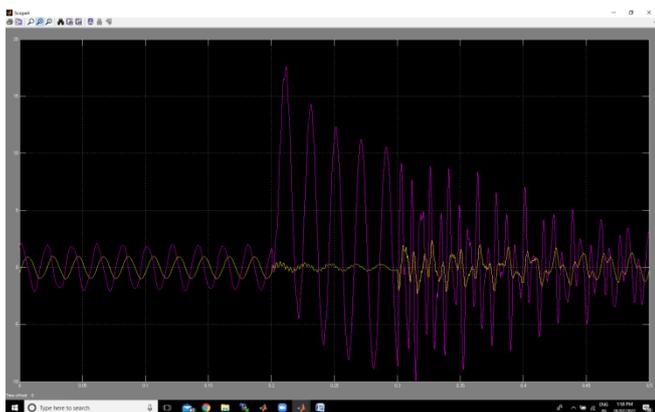
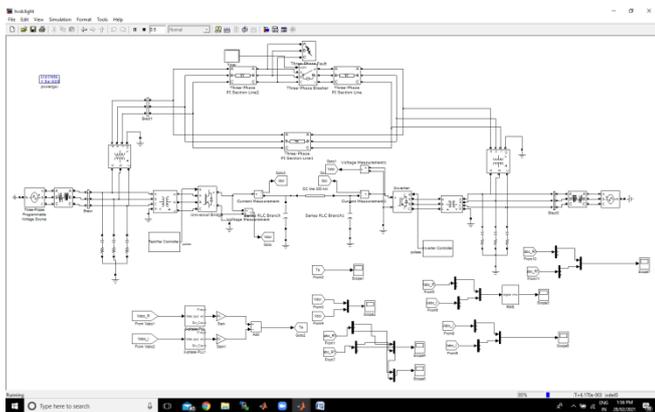
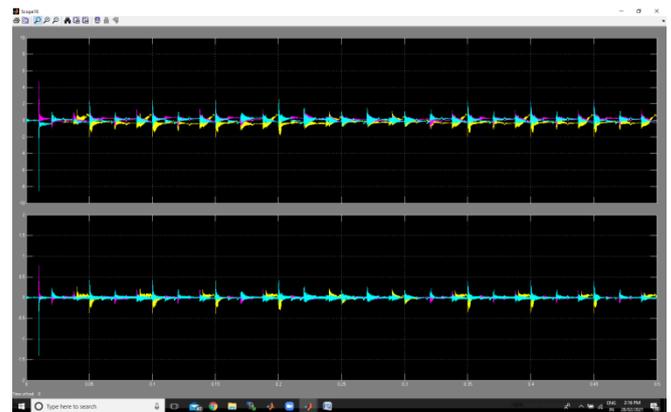
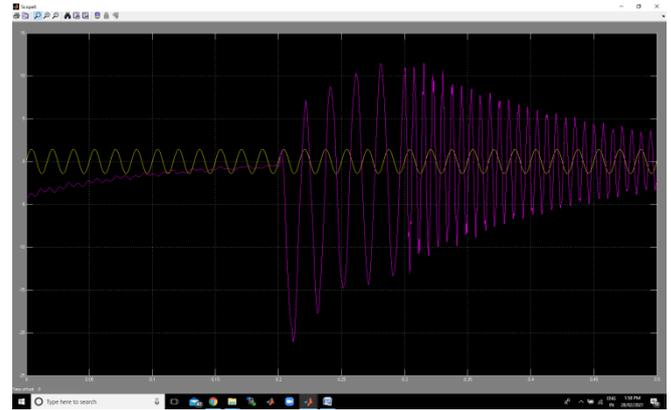
Mono-polar HVDC transmission Voltage in station B according to reversed polarity convention.

## DOUBLE-THYRISTOR-BASED PROTECTION STRATEGY

a typical positive terminal in a bipolar HBMMC station. Single-bypass-thyristors are installed in each SM. As a valve-side SPG fault is usually caused by the insulation failure of the wall bushing of converter ac buses, it is normally a permanent fault [7], [11]. Therefore, the converter should be blocked immediately once a valve-side SPG fault is detected. Fig. 1(b) illustrates the equivalent circuit and fault behavior of the blocked HB-MMC due to a valve-side SPG fault at phase A.  $u_a$ ,  $u_b$ , and  $u_c$  are valve-side post-fault voltages.  $i_{g a}$ ,  $i_{g b}$ , and  $i_{g c}$  are grid-side post-fault currents. The fault characteristics can be summarized as the following [8]. 1) The voltages of all SM capacitors in the lower arms will remain

constant when the converter is blocked. 2) The SM capacitors in the upper arm of the faulted phase will only be charged by the dc terminal transient overvoltage caused by the SPG fault. 3) The SM capacitors in the upper arms of the two nonfaulted phases will be charged during every negative half-cycle of the valve-side post-fault ac voltages. The maximum voltages that the SM capacitors can be charged are mainly determined by the parameters of the arm reactor and the leakage inductor of the converter transformer. 4) Due to the free-wheeling effect of diodes and the small resistance in the current paths, the currents flow through the lower arms in the two nonfaulted phases are always positive and have no zero-crossing.

### **SIMULATION RESULTS**



### **CONCLUSION**

In this project, a converter embedded double-thyristor-based protection strategy was proposed to address the problems caused by valve-side SPG faults in bipolar HB-MMC HVdc systems. The proposed protection strategy, which was verified through simulations conducted in PSCAD/EMTDC, could effectively mitigate the upper arm overvoltage and create grid-side current zero-crossings. Moreover, the proposed method presented great advantages compared with other methods: no further aggravation of upper arm overvoltage, no more occupation of converter station footprint, no impact on the healthy pole, and no risk of overtemperature of thyristors due to the lower arm residual current.

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