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Harmonic Immunity in Voltage Source Converter HVDC Transmission using Application of SHE-PWM

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ABSTRACT:

Control methods based on selective harmonic elimination pulse-width modulation (SHE-PWM) techniques offer the lowest possible number of switching transitions. This feature also results in the lowest possible level of converter switching losses. For this reason, they are very attractive techniques for the voltage-source-converter-(VSC) based high-voltage dc (HVDC) power transmission systems. The paper discusses optimized modulation patterns which offer controlled harmonic immunity between the ac and dc side. The application focuses on the conventional two-level converter when its dc-link voltage contains a mix of low-frequency harmonic components. Simulation and experimental results are presented to confirm the validity of the proposed switching patterns.

Index Terms—***Amplitude modulation (AM), dc-ac power conversion, harmonic control, HVDC, insulated-gate bipolar transistor (IGBT), power electronics, power transmission system, pulse-width modulation, voltage-source converter (VSC).***

INTRODUCTION:

The Continuous growth of electricity demand and ever increasing society awareness of climate change issues directly affect the development of the electricity grid infrastructure. The utility industry faces continuous pressure to transform the way the electricity grid is managed and operated. On one hand, the diversity of supply aims to increase the energy mix and accommodate more and various sustainable energy sources. On the other hand, there is a clear need to improve the efficiency, reliability, energy security, and quality of supply. With the breadth of benefits that the smart grid can deliver, the improvements in technology capabilities, and the reduction in technology cost, investing in smart grid technologies has become a serious focus for utilities Advanced technologies, such as flexible alternating current transmission system (FACTS) and voltage-source converter (VSC)-based high-voltage dc (HVDC) power transmission systems, are essential for the restructuring of the power systems into more automated, electronically controlled smart grids. An overview of the recent advances of HVDC based on VSC technologies is offered in [2]. The most important control and modeling methods of VSC-based HVDC systems and the list existing installations are also available.

Existing System:

The optimized SHE-PWM technique is investigated on a two level three-phase VSC topology with IGBT technology, shown A typical periodic two-level SHE-PWM waveform is Using five switching angles per quarter-wave in SHE-PWM, 5, ,7, 11, 13 to eliminate the 5th, 7th, 11th, and 13th harmonics. During the case of a balanced load, the third and all other harmonics that are multiples of three are cancelled, due to the 120 symmetry of the switching function of the three-phase converter. The even harmonics are cancelled due to the half-wave quarter-wave symmetry of the angles, being constrained .

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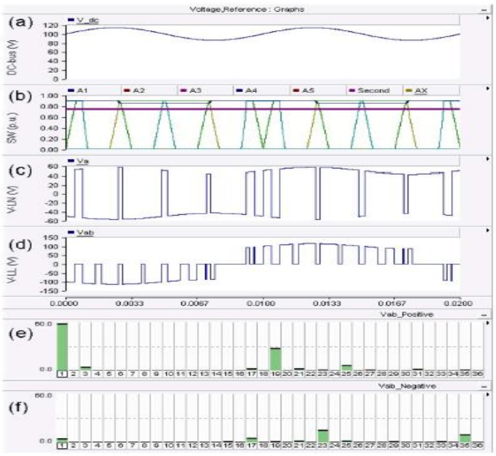
Proposed System:

In this section, the technique to reposition the low-order harmonics produced by the dc-link ripple voltage of a VSC is described. The switching angles are pre calculated for every available modulation index to obtain the trajectories for the SHE-PWM, as shown in Fig. 4. The complete sets of results are presented in [20]. The intersections of the trajectories shown in Fig. 4 with any horizontal straight line, called the modulating signal (i.e., an imaginary line of 0.75 p.u.), give the switching angles of the specific modulation index. Those switching angles are identical to the solution of the conventional SHE-PWM method, so when the dc bus voltage is constant, all harmonics before the 17th one are eliminated. However, when the dc bus voltage is fluctuating, other harmonics are introduced.



For a constant dc-bus voltage, the modulating signal is a straight line of magnitude equal to the modulation index. For the fluctuating dc-bus voltage, the modulating signal is divided by , which is the sum of the average per-unit value of the dc link and the ripple voltage in order to satisfy the repositioning technique. So when the magnitude of the dc-link voltage is instantaneously increased by a certain amount, the modulating signal's amplitude is reduced by using the switching angles of a lower modulation index. Therefore, by using the higher modulation index at the instants that the voltage is reduced and lower modulation index at the instants that the voltage is increased, the amount of ripple is reversed.

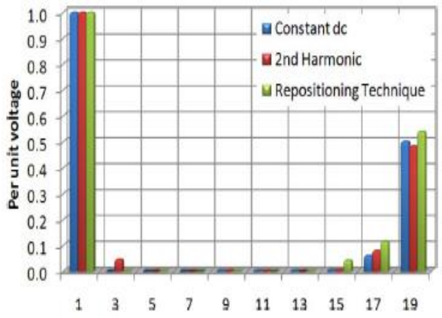


Fig. 9. Per-unit values of the low-order harmonics up to the 19th for the dc bus with a ripple of 10% 2nd harmonic.

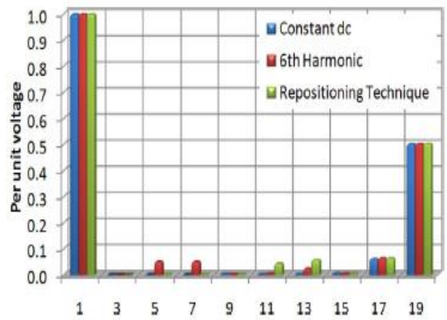


Fig. 10. Per-unit values of the low-order harmonics up to the 19th for a dc bus with a ripple of 10% 6th harmonic.

Effect of the Method

The immunity from the dc to ac side for extreme cases is investigated by using the repositioning technique. The case of the dc bus with 10% of the 2nd harmonic ripple voltage, shown in Fig. 9, is the first case. The individual voltage distortion limit for bus-voltage harmonics in power systems is 3% according to the industry standards [27]. Hence, 10% of 2nd harmonic ripple voltage is an extreme case, but is used as a way to illustrate the performance of the technique under this scenario. The case of a dc bus with 10% of 4th harmonic ripple voltage is studied in [28]. However, it is beyond the scope of this paper to study the 4th harmonic content in the dc-link voltage.

EXPERIMENTAL RESULTS

The repositioning technique is verified by experimental results which are taken with a two-level three-phase VSC prototype, controlled by the ds1104 R&D Controller Board and with a 100-V dc-bus voltage. The dc–ac inverter operates at 10-Hz

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frequency using SHE-PWM [Fig. 3(d)]. The time-step of the real-time program is 50 s. The operating frequency of 10 Hz is selected to avoid additional harmonics being introduced in the signals due to the large time-step resolution of the real-time interface. The ac side is a star-connected load of 20 and 20 mH. Experimental results are shown in Figs. 13–17 proving the theory and the simulation results. Fig. 13 shows the line-to-line voltage waveform and harmonic spectrum for SHE-PWM by using the repositioning technique for a constant dc bus. The voltage waveform and spectrum of Fig. 13 are identical to the results taken by the conventional SHE-PWM.

Fig. 14(a) proves that the dc-link ripple voltage of the 2nd harmonic increases the fundamental and creates a 3rd harmonic to the line-to-line voltage. The repositioning technique regulates the fundamental component and eliminates the 3rd harmonic but increases the switching frequency and its sidebands, as observed by Fig. 14(b). As shown in Figs. 15 and 16, the technique also removes the 5th and 7th harmonics from the line-to-line voltage created by the 6th harmonic ripple voltage of the dc bus. Those ac-side harmonics are moved to the 11th and 13th harmonics.

The magnitude of the 5th and 7th harmonics is 5% of the fundamental and the magnitude of the reflected ones, 11th and 13th,are 5% of the switching frequency, which is much lower than the fundamental. It is observed that the repositioning technique eliminates the low-order harmonics caused by the dc-bus ripple voltage when it satisfies the constraint It is also observed that the fundamental component is increased when a second harmonic is added in phase for a conventional SHE-PWM. Using the repositioning technique, the magnitude of the fundamental is controlled. However, as shown in Fig. 17(b), when the technique is used out above , the magnitude of the fundamental is lower than the required value but the harmonic spectrum is still better than the spectrum taken by using the conventional SHE-PWM.

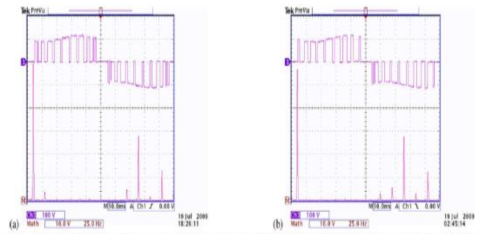

Fig. 14. Line-to-line voltage spectra for a dc bus with a ripple of (a) 10% 2nd harmonic without the repositioning technique and (b) when the technique is used.

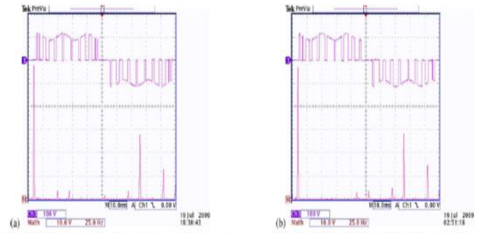

Fig. 15. Line-to-line voltage spectra for a dc bus with a ripple of (a) 10% 6th harmonic without the repositioning technique and (b) when the technique is used.

CONCLUSION

An optimized SHE-PWM technique, which offers immunity between the ac and dc side in a two-level three-phase VSC, is discussed in this paper. The technique is highly significant in HVDCs due to the elimination of every low-order harmonic of the ac side produced by the dc-link ripple voltage. The dc-link ripple repositioning technique regulates the magnitude of the fundamental component and eliminates the low-order harmonics of the ac side even when the dc bus voltage fluctuates. This is an online method which can be applied for eliminating any low-order harmonic frequency regardless of amplitude or phase shift of the ripple. There are some limitations related to the maximum modulation index available for SHE-PWM angles. The repositioning technique also causes a reflection with respect to the midpoint between the fundamental component and the first significant harmonic. There are cases where the technique is not beneficial. On the other hand, it eliminates all low-order ac-side harmonics for every dc-bus ripple voltage of frequency below the midpoint harmonic.

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