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Improved SPWM Modulation Technique to Reduce Harmonic Distortion in Voltage Source Converter

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ABSTRACT: This paper addresses the timely issue of analyzing the custom power controllers based on an improved Pulse-Width Modulation (PWM) technique called the Inverted - Sine PWM (ISPWM). These controllers are also named as Distribution - Flexible AC Transmission System (DFACTS). DFACTS are a new generation of power electronics based equipment aimed to enhance the reliability and quality of power flow in low-voltage distribution networks. The proposed ISPWM technique can be used to control Voltage Source Converters (VSC) of custom power devices. This switching technique uses a sinusoidal reference signal and an inverted-sine as carrier signal. The ISPWM technique generates low voltage Total Harmonic Distortion (THD) in comparison with conventional Sinusoidal Pulse Width Modulation (SPWM) technique. This type of switching technique called the ISPWM has been used on a simple VSC for analyzing its impact.

KEYWORDS: IPWM, ISPWM, Power quality, Harmonics, VSC, THD.

1 INTRODUCTION

Problems related to electrical system always occur regardless of time and place. This may cause impact to the entire electricity supply system. The last decade has marked with tremendous increase in the deployment of end-user equipment that is highly sensitive to quality electricity supply. Several large industrial users are reported to have faced large financial losses as a result of even minor lapses in the quality of power supply [1], [2]. Great efforts have been made to overcome the situation, where solutions based on the use of the latest power electronic technology figures out prominently.

Indeed, in custom power technology, the low voltage counterparts, which are more widely known are flexible AC transmission system technology [3]. Installed at low-voltage distribution applications (named DFACTS), has emerged as a credible solution to solve many of the problems related to continuity of supply up to the end-user level. At present a wide range of flexible controllers, which capitalize on newly available power electronics components are emerging for custom power applications [4]. Among those, the Distribution Static Compensator (D-STATCOM) and the Dynamic Voltage Restorer (DVR), both of them based on the VSC principle are the controllers which have gained the prime attention [5], [6]. Inverters based on Voltage Source Converters are widely used as a basic component in custom power devices. These devices will improve power quality problems such as voltage sag, swell, flicker and harmonics [7]. These controllers produce voltage harmonics due to switching operation of power electronic converters [8]. The harmonics in the output voltage of power electronic converters can be reduced using Pulse-Width Modulation switching techniques.

2 VOLTAGE SOURCE CONVERTER

Voltage Source Converter technology has been selected as the basis for several recent projects due to its controllability, compact modular design, ease of system interface and low environmental impacts. Reactive power compensation using VSC technology has certain attributes which can be beneficial to overall system performance. In FACTS concept, the voltage source converter is the building block of STATCOM, Static Synchronous Series Compensator (SSSC), Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC) and any other controllers [9], [10]. Converters applicable to FACTS controllers would be of the self-commutating type.

In voltage source converter, the DC voltage always has one polarity and the power reversal takes place with the help of the DC current polarity reversing. Some FACTS devices made use of VSC based controller, which increased power transmission capability as well as improved power quality over existing transmission and distribution circuit. VSC based FACTS controller are capable of providing fast voltage support and active power flow control to improve the power transfer capability over available congested transmission path [11], [12]. The three phase voltage source converter is the basic building block of most new FACTS and custom power equipments. The converter may be employed as a shunt compensator, series compensator or even a hybrid of both.

In recent years, VSC technology has made significant progress through the development and advancement of high power controlled type semiconductor devices such as Gate TurnOff Thyristor (GTO), Insulated Gate Bipolar transistor (IGBT) and Integrated Gate Commutated Thyristor (IGCT). There are several VSC topologies currently in use in actual power system operation. The Common aim of these topologies is to minimize the switching losses of the semiconductors inside the VSC and to produce high quality sinusoidal voltage waveforms with minimum harmonics or no filtering requirements.

2.1 BASIC SCHEME OF VOLTAGE SOURCE CONVERTER

The Voltage source converter is a Power electronic device which can supply variable voltage, variable frequency and variable phase angle sinusoidal supply. They have been widely used for speed control of the electrical drive system which is used in power quality improvement purpose [13]. The basic voltage source converter scheme for reactive power generation is shown in the form of a single line diagram as in Fig 1.

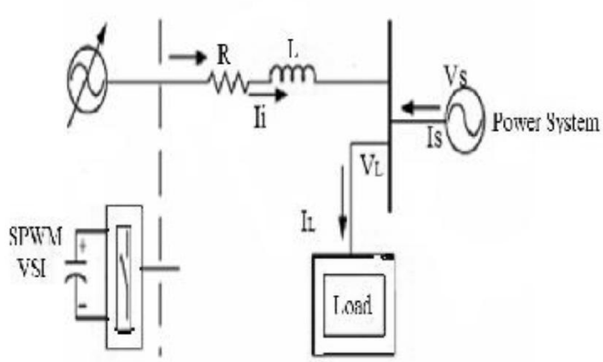

Fig. 1. Standard Voltage Source Converter Scheme

From DC voltage source, provided by the charge capacitor, the converter produces a set of controllable three phase output voltages with the frequency of the AC power system. By varying the amplitude of the output voltages produced, the reactive power exchange between the converter and the AC system which can be controlled in the following ways. If the amplitude of the output voltage is increased above that of the AC system voltage, then the current flows through the tie resistance from the converter to the AC system and the converter generates reactive power for AC systems. If the output voltage is decreases below that of the AC system, the reactive current flows from the AC system to the converter and the converter absorbs reactive (inductive) power [14]. If the amplitude of the output voltage is equal to that of the AC system voltage, the reactive power exchange is zero. VSC is widely used in adjustable-speed drives, but can also be used to mitigate voltage dips [15], [16].

3 MODULATION TECHNIQUES

3.1 EXISTING SPWM TECHNIQUE

In general, the PWM technique for high power applications has a switching frequency that is fixed and low [17]. The PWM method reduces the harmonics by shifting the frequency spectrum to the vicinity of high frequency band of carrier signal. In the case of sinusoidal PWM scheme, the control signal is generated by comparing a sinusoidal reference signal and a triangular carrier signal. The SPWM technique is effective which means to control the voltage, frequency and magnitude. The SPWM in VSC is used only because of its technical behavior. It also provides most complex calculations relating to VSC behavior. The SPWM technique. However, inhibits poor performance with regard to maximum attainable voltage and power.

3.2 PROPOSED ISPWM TECHNIQUE

A novel PWM technique called ISPWM for harmonic reduction of the output voltage of AC -DC converters are presented in this paper. In addition, the control scheme based on ISPWM maximizes the output voltage for each modulation index. In this paper, the ISPWM switching technique has been developed for controlling the VSC based inverters, which has lower THD than other conventional techniques. The proposed ISPWM for DC to AC conversion in inverter has new forms of carriers namely carrier1 and carrier2. The capability of ISPWM schemes for improving frequency spectrum and thereby reducing the THD in output can be seen in Fig.2. We can say that the proposed ISPWM technique has always lower THD than the conventional SPWM techniques.

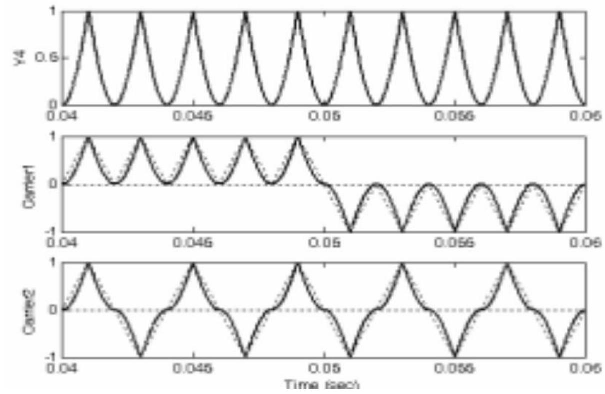

Fig. 2. Proposed ISPWM Carrier

It is obvious that the line voltage V_{ab} has no triple harmonics. The Fig.2 shows the carriers of the proposed ISPWM technique. It includes the carrier1 and carrier2 with its time in seconds. Fig.3 shows the triggering pulse used in the propounded technique.

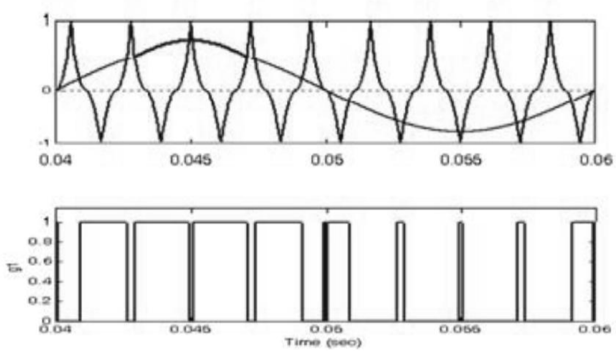

Fig. 3. Firing pulses generation in the proposed ISPWM Technique

3.3 Advantages of ISPWM

1. It has a better spectral quality and a higher fundamental component compared to the conventional sinusoidal PWM without any pulse dropping. 2. The ISPWM strategy enhances the fundamental output voltage specified at lower modulation index ranges. 3. There is a reduction in total harmonic distortion and switching losses. 4. The appreciable improvement in the total harmonic distortion in the lower range of modulation index attracts drive applications where low speed operation is required. 5. Harmonics of carrier frequencies or its multiples are not produced.

4 Hardware implementation

Fig. 4. Hardware setup for analyzing ISPWM in Voltage Source Converter

The Fig.4 shows the hardware implementation for performing the analysis of ISPWM technique. We have made a voltage source converter in which we are using SPWM and ISPWM technique to generate the triggering pulse.

After providing the pulse, we have analyzed the output obtained for both the technique. Fig. 5 shows the actual pulse generated using ISPWM technique and shows the comparison between the VSC output & Harmonic spectrum. It includes the triangular wave and the carrier wave as seen in the Fig. 5. These generated pulses will be given to the switching devices so that the output obtained can be analyzed.

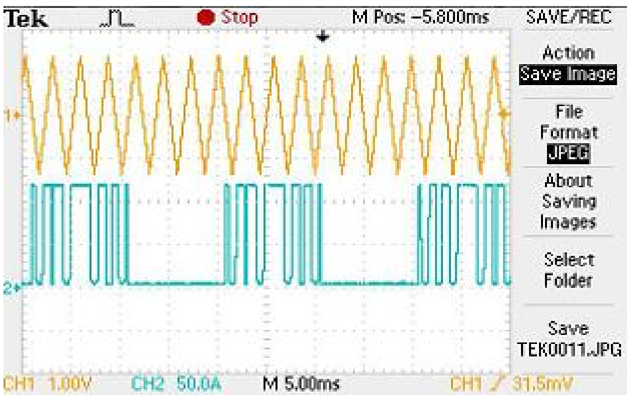

Fig. 5. Pulses generated using ISPWM Technique

The generated pulse is now given to the VSC and when the triangular carrier wave is given to the arrangement for the study, the output obtained is as shown in Fig.6.

Fig. 6. Output at triangular carrier wave

After that we gave the inverted sine carrier wave to the test arrangement. The output obtained from the input is as shown in Fig.7.

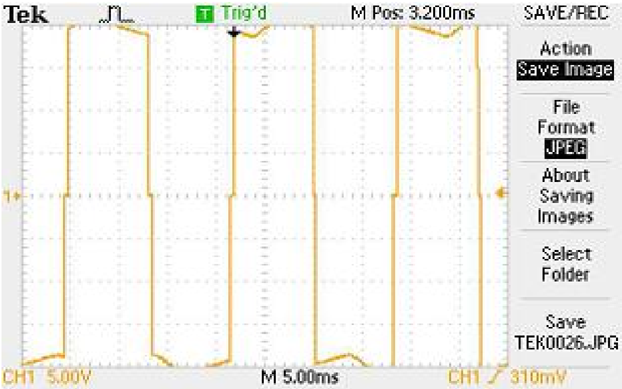

Fig. 7. Output at Inverted Sine carrier wave

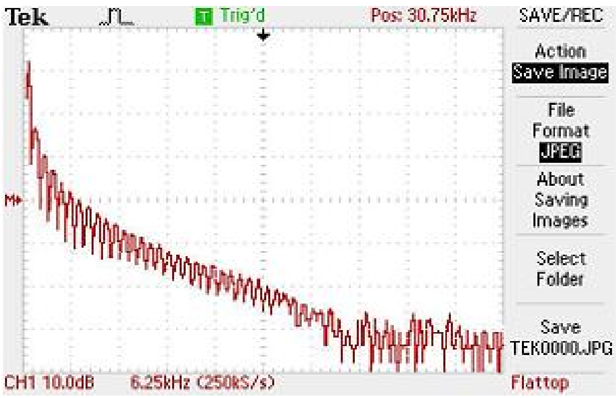

Fig. 8. Fast Fourier transform of the VSC output with SPWM technique

The Fast Fourier Transform (FFT) analysis of the output obtained from VSC using SPWM is shown in Fig.8. It shows that there are more harmonics in the system output when SPWM modulation technique is employed for the system.

Fig. 9. FFT of VSC output with ISPWM

While the same Fourier analysis of the output obtained from VSC using ISPWM is shown in Fig.9. It shows that there is much reduction of harmonics in the system output when compared to the SPWM modulation technique. The capability of ISPWM schemes for improving frequency spectrum and hence reduction of THD output can be seen from the above results. Hardware results show that the output of VSC is of high quality when ISPWM technique is employed. Hence it can be seen that the proposed ISPWM technique has always lower THD than the conventional SPWM.

5 Conclusion

Many new modulation techniques were found out for use in power electronic devices. These techniques have been analyzed and implemented in industrial applications. It is seen that such techniques are more advanced compared to the traditional ones. Likewise the VSC based on proposed switching technique has a lower THD than the conventional SPWM technique. The Hardware results show that the output voltage is more pure with lower harmonic distortion using ISPWM technique. This proposed work is carried out on a simple VSC hardware model and the results are obtained. As ISPWM technique gives good quality output than SPWM, reactive power injected into the system is almost a sine wave which increases the power quality of the system.

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