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PERFORMANCE EVALUATION OF DUAL HALF CONTROLLED CONVERTER USING PULSE WIDTH MODULATION

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ABSTARCT:
In This paper performance of the dual-half controlled Converter (DHCC) using voltage compensation and current compensation technique is evaluated. The dual-half controlled Converter (DHCC) is a voltage-source active rectifier which can be considered as a potential alternative to the conventional three-phase six-switch boost rectifier. The DHCC is attractive due to its lower component current rating, immunity to shoot-through, simpler gate drive circuitry, lower semiconductor losses, and fault redundancy. Compared to a six-switch voltage-source-converter and a diode rectifier with a shunt active filter, DHCC presents some advantages and has good potentials for grid-tied and generator-tied applications. In the previous literature, the DHCC was controlled through a hysteresis regulator. This paper discusses in detail the current compensation and harmonic cancellation methodologies and presents improved control techniques for the three phase three-wire DHCC using interleaved pulse width modulation (PWM). PWM controllers require smaller filtering elements and/or a lower sampling frequency. The Matlab simulation results are presented to demonstrate the superiority of the proposed PWM control algorithm.

Keywords: *DHCC;Voltage Compensation; Current Compensation.*

1. INTRODUCTION

THE three-phase, current-source, and voltage-source halfcontrolled converters (HCCs) were presented in [1]–[3], respectively. The HCC, considered in this paper, is a voltagesource converter (VSC) having three active switches and six diodes, as shown in Fig. 1 [1]. The converter can be realized as either a common emitter (CE) or common collector (CC) configuration [3]. A CE configuration is usually preferred due to its simpler gate drive implementation. The CE and CC HCC phase-leg modules shown in Fig. 1 are basically buck and boost choppers, which are both widely available in the market. Amajor device manufacturer actually offers such three-phase chopper modules that can be directly used in HCCs [4]. In [3], a single HCC and its potential as controlled rectifier were explored and analyzed. The effect of a series line reactor and displacement power factor angle on the performance of a single HCC was also reported in the same paper. Other research efforts on the control and utilization of a single HCC have been presented very recently in [5]–[11], and a variety of pulse-width-modulation (PWM) control techniques were proposed in these publications that achieve better performance than the hysteresis regulator used in [3]. In [12], two cascaded single HCCs were used to drive an open-winding permanent magnet synchronous generator.

With a dual-half-controlled-converter (DHCC) consisting of two paralleled complementary HCCs [13]–[17], the harmonic content in the total input current is significantly reduced. The complementary configuration can be realized using complementary converter topologies (i.e., CE and CC) or by using a transformer with two secondary windings of opposite polarities [13]–[17]. The input current and power can be shared equally between the two HCCs, resulting in a lower component current rating. The DHCC is free of shoot-through and provides system redundancy, i.e., the system remains operational in case one of the two HCCs fails, at the price of reduced power output and increased harmonics. The issue of high dc output ripple as presented in [13] can be resolved by combining the two dc links [14], [15], while the input characteristics are identical. A simpler controller was introduced in [15], which imposed a 0.5 per-unit (p.u.) hard peak current limit for each HCC potentially reducing the power rating of the switching devices to half of the rated system power. A grid-tied

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DHCC can be used for applications that require good power quality, high reliability, and system redundancy, such as telecommunication power supplies. A DHCC can also be used with synchronous generator to provide boosted dc-link voltage and variable power output. In [16] and [17], for example, a similar DHCC was used for permanent magnet wind generator. Since these applications require only two-quadrant operation, additional switches for regenerative capability shown in [15] are not necessary, which simplifies the implementation.
Special hysteresis controllers were adopted in the previous literature for regulating ac currents in a DHCC [13]–[17] due to the lack of a linear controller modulator. The basic concept is to allow both HCCs compensate for the current error of each other. This method is here termed current command cross-coupling. A hysteresis regulator is simple and effective. However, it has inherent disadvantages of variable switching frequency, which complicates the thermal design and filter design. Also, successful implementation of such current regulators demands fast sampling. In this paper, PWM-based controllers are proposed that make DHCC a more attractive topology for active rectifiers. The resultant converter current rating and the impact of dc-link voltage rating are discussed.

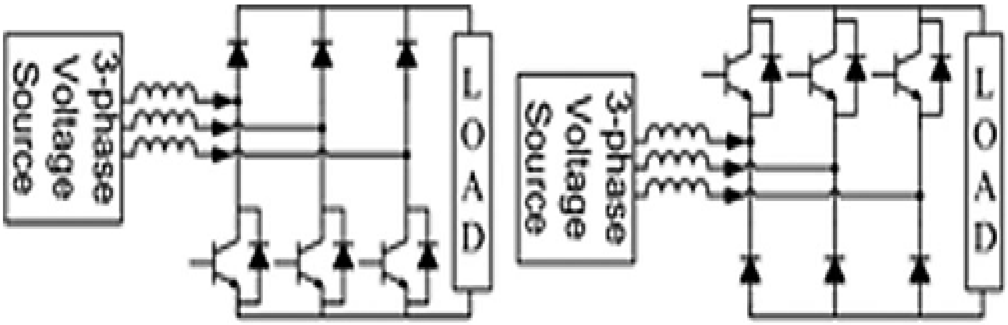

Fig.1.HCC configurations:(a)CEand(b)CC

2. DHCC CONFIGURATIONS AND COMPENSATION TECHNIQUES

The DHCC ***rectifier*** shown in Fig. 2 [15] has been adopted for all the analyses presented in this paper. The isolation transformer has two secondary windings of opposite polarities, which effectively make the two CE HCCs complementary to each other. Each side of the transformer can be either Y or delta connection as long as the two secondary circuits are coupled in the same magnetic path. By paralleling complementary HCCs, the even harmonics generated by each HCC are automatically canceled in the mains, but proper control techniques are still needed to eliminate the non triplen odd harmonics.

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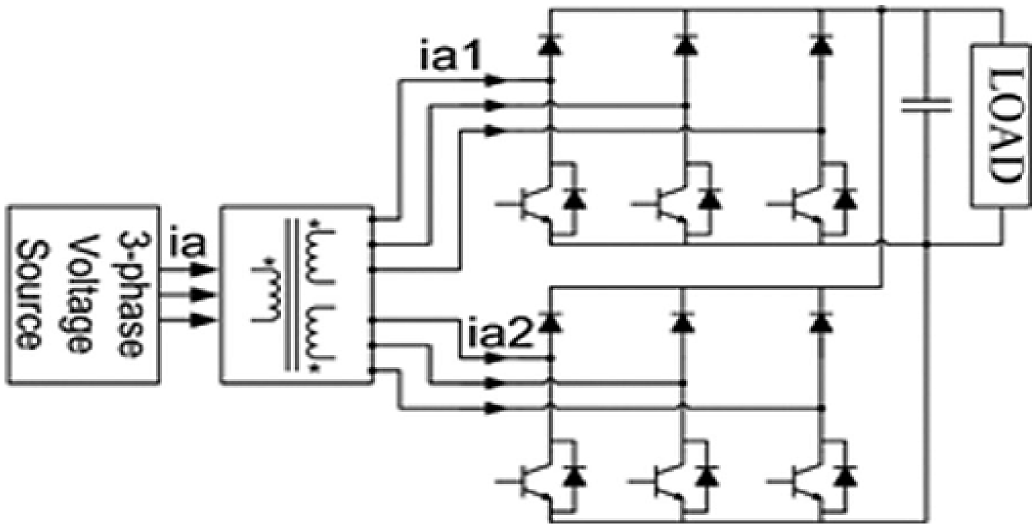

Figure2. DHCC Rectifier

In each HCC contains even order harmonics while the total current does not. However, nontriplen odd harmonics in both HCCs add up in the total current. To eliminate these harmonics, an active compensation technique was presented in an earlier paper which utilizes current command cross-coupling and a hysteresis switching method. In this paper, however, two improved PWM-based techniques will be presented, namely the formulated current compensation and coordinated volt-second modulation.

when the currents in two phases are directed into the HCC, it is a fully controlled period; otherwise, it is a partially controlled period. These two types of periods are of equal length and occur in an alternating manner. The key to synthesizing sinusoidal total line current is to utilize the fully controlled periods to compensate for the partially controlled periods of the complementary HCC The desired compensated phase current in each HCC which a sinusoidal total current can be achieved. Unfortunately, such an ideal compensation is not feasible because the current direction cannot be reversed during the fully controlled periods. As a result, a compromise must be made, i.e., either accepting a slightly imperfect compensation or adopting a slightly lagging power factor for perfect compensation.

The overall controller structure is shown in Fig. 3. The two PWM carriers for two HCCs are interleaved with 180◦ out-of-phase switching, so that the switching ripple in the total current will be further reduced.

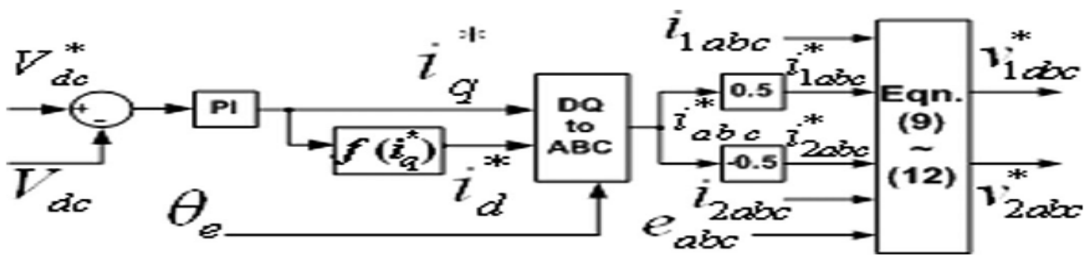

Figure3. Overall controller diagram of formulated current compensation

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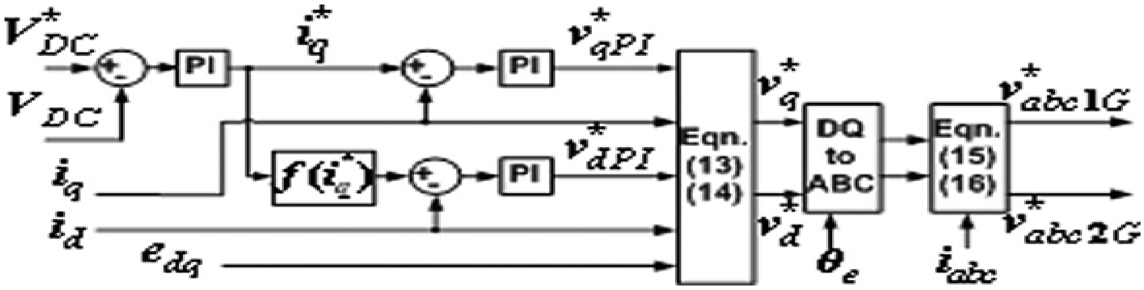

Figure4. Overall controller diagram of coordinated volt-second modulation

Instead of using pre calculated current commands for harmonic cancellation, a more robust solution is to directly adjust the volt-second output. A coordinated volt-second modulation with fixed-frequency PWM is proposed to mimic the volt-second output of the current-command-cross-coupling hysteresis regulator used in . The controller block diagram shown in Fig. 4. Besides the feedback PI regulator and decoupling terms, volt-second compensation is added to improve the harmonic cancellation and dynamic performance, which to some extent resembles deadbeat control.

3. SIMULATION RESULTS

The simulation Results using Matlab simulink is shown in below figures.

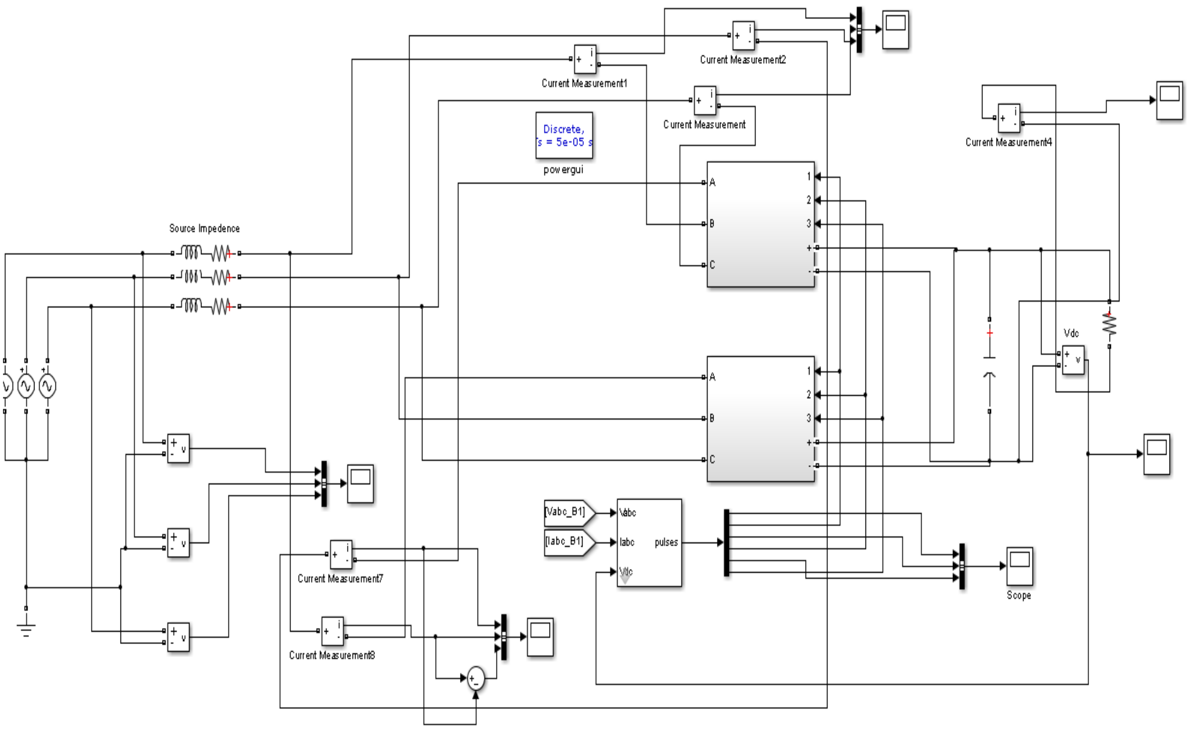

Figure5. Matlab Simulation of proposed DHCC Using Voltage Compensation and Current Compensation

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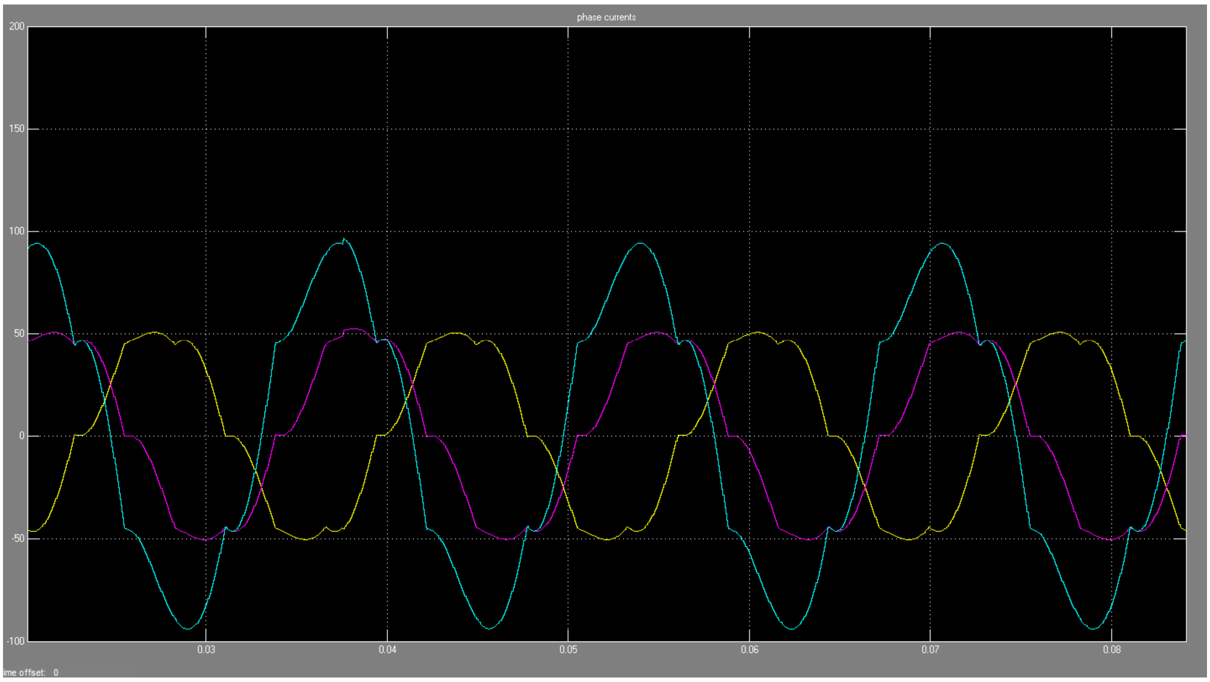

Figure6. Phase currents with unity power factor

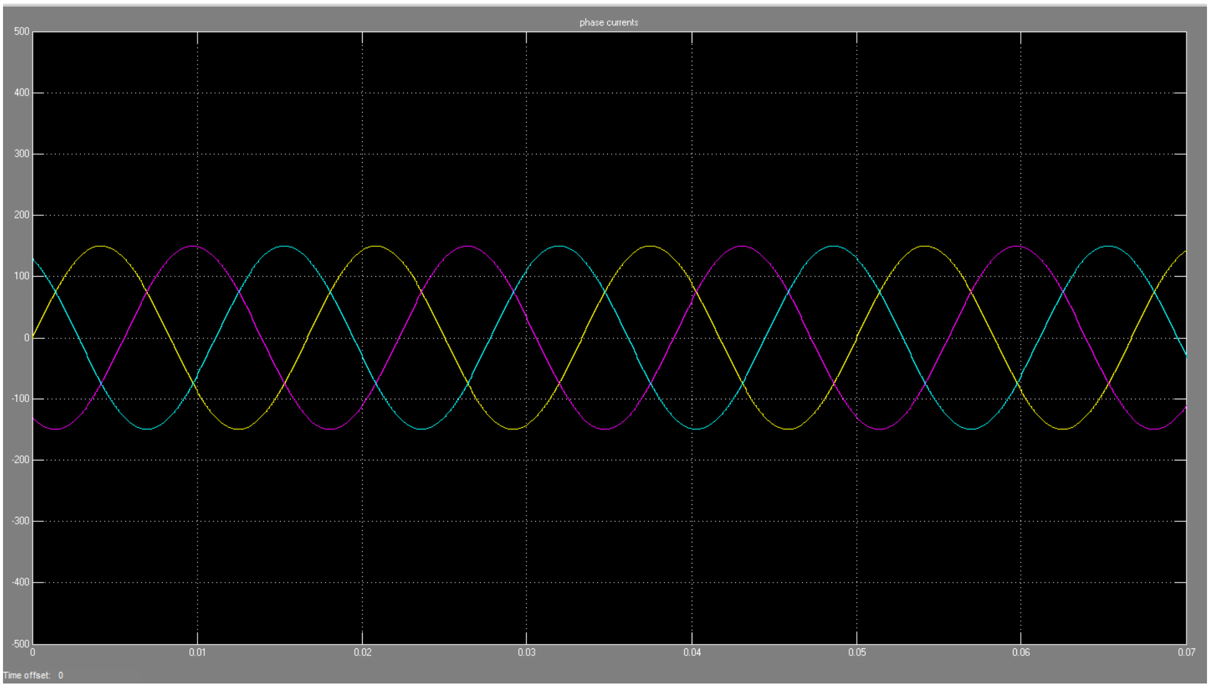

Figure6. Phase Voltages

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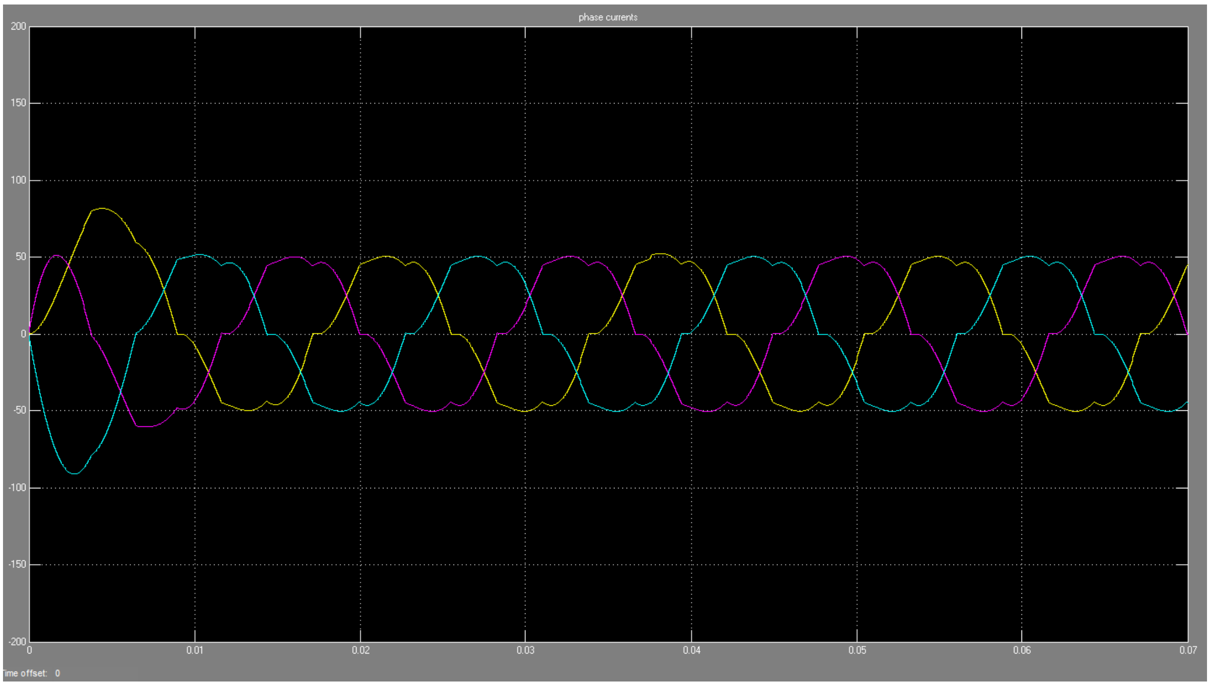

Figure7. Phase Currents

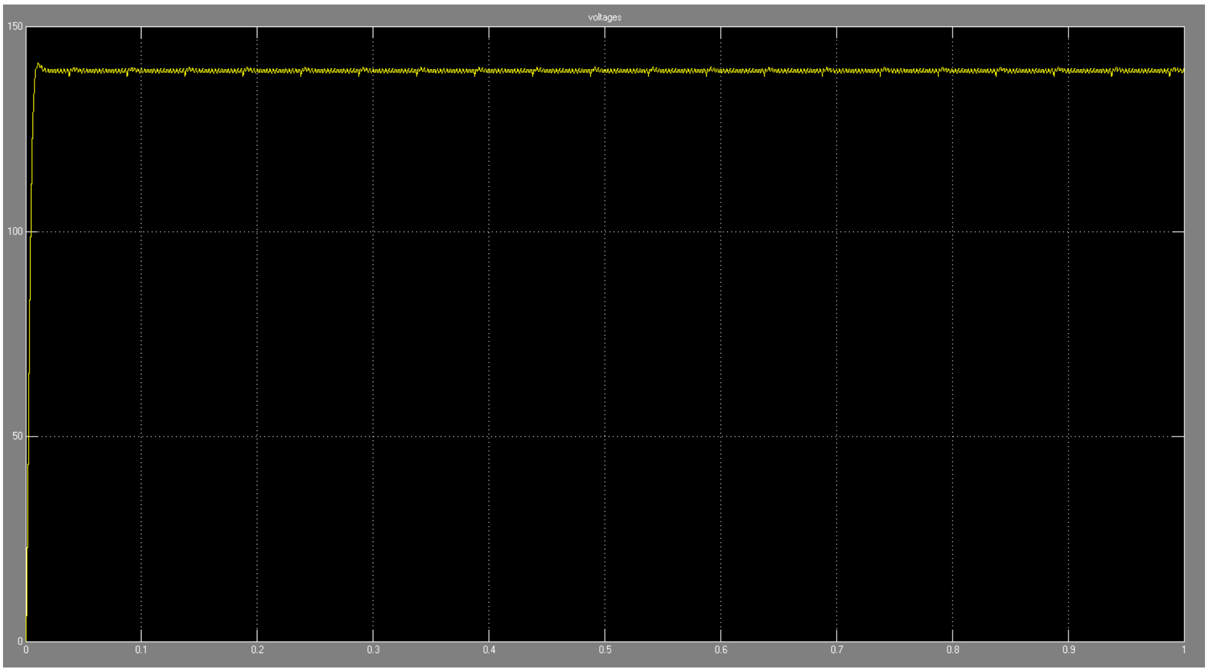

Figure7. DHCC Output

All the simulation results are presented in per unit. The voltage base is the phase-to-neutral voltage peak, and the current base is the phase current peak.

The simulation of a formulated current compensation is done with a 10-kHz PWM frequency and 0.14 p.u. line reactance. In order to achieve ideal compensation, a 10◦ lagging power factor was adopted. The necessary lagging angle depends on the line reactance per unit value. The current amplitude is slightly increased by 1.5% due to lagging power factor, which is almost negligible. The current in each HCC is 53.4% of *I*rated in terms of RMS value and about 51.5% in terms of peak. The THD of the total phase current is 3.5%, while the THD of the current in each HCC is 29%. One can note that the even-order harmonics in each HCC are much lower than in case A.

The simulation of coordinated volt-second modulation is done at unity displacement power factor, with 10-kHz PWM,and 0.14 p.u. line reactance. The resultant current in each HCC is 59.2% of *I*rated in terms of RMS value and about 72% in terms of peak. The THD of the total phase current is 3.2%, while the THD of the current in each HCC is 64.3%. One can note that the even-order harmonics in each HCC are higher than the other two cases.

4. CONCLUSION

This paper has presented two fixed-frequency PWM-based control techniques that boost the overall system performance of the three-phase three-wire DHCC rectifier. The benefits and limitations of both proposed techniques are discussed and compared with the existing hysteresis regulator for DHCC presented in the earlier literature. The analysis suggests that the coordinated volt-second modulation is a superior control technique for DHCC, and the corresponding experimental results have demonstrated its performance and confirmed the theoretical analyses.

In addition to the inherent advantages of the DHCC, such as lower device current rating, simpler gate driver, shoot through- safe nature, and fault-redundancy, by employing fixed frequency PWM technique, the loss estimation becomes simpler and more definitive. This facilitates the optimum thermal design and makes the DHCC more attractive for practical implementation.

The fixed-frequency PWM also helps in optimizing the passive components such as input reactor and filter capacitor. All these advantages are sacrificed in variable-frequency hysteresis current regular where the thermal design and passive component design are neither easy nor optimized. The fixed frequency PWM also facilitates interleaved switching through
upper and lower HCC inductors and thus potentially may reduce the inductor size.

The impact of input reactors and dc-link voltage rating on overall converter current rating and overall THD of the system has also been illustrated which can be used as a general design guideline for the DHCC. The DHCC is further compared with regular VSC-based active rectifier as well as diode rectifier with shunt VSC active filter. Advantages and limitations of DHCC are discussed.

Enabled by the proposed control techniques, the DHCC promises to be a very economic solution for active rectifiers with boosted power capability, as well as improved system reliability and fault redundancy.

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