Harmonic Current Compensation Using Constant DC-Capacitor Voltage-Control-Based Strategy of Three-Level Neutral-Point-Clamped Inverter-Based STATCOM with Reactive Power Control

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This paper proposes a constant dc-capacitor voltage-control (CDCVC)-based reactive power control strategy of a static synchronous compensator (STATCOM) with a three-level neutral-point-clamped (NPC) inverter, in which the source-side harmonic currents are also compensated. The CDCVC-based reactive power control strategy uses only a CDCVC, which is always used in the grid-connected inverters, STATCOMs etc. Calculation blocks of fundamental active, reactive, and harmonic components are not needed. Thus, the authors offer a simplified strategy for a source-side reactive power control with source-side harmonic current compensations. The instantaneous power flowing into the STATCOM with a three-level NPC inverter is discussed in detail. The instantaneous power flow shows that using the CDCVC-based strategy for the STATCOM achieves sinusoidal source currents using the controlled source-side reactive power compensating the harmonic currents on the source side. A digital computer simulation is implemented to confirm the validity and high practicability of the CDCVC-based strategy. A reduced-scale prototype experimental model is constructed and tested. The simulation and experimental results demonstrate that sinusoidal source currents are obtained with the CDCVC-based strategy controlling the reactive power on the source side.

Keywords: neutral-point-clamped inverter, static synchronous compensator, constant dc-capacitor voltage control, reactive power control, harmonics compensation

1. Introduction

Static synchronous compensators (STATCOMs) are now on practical to solve the reactive power interferences. A three-level neutral-point-clamped (NPC) inverter, which was originally proposed by Prof. Nabae, *et al.*⁽¹⁾, is widely used in industries^{(2)–(5)}. The three-level NPC inverter-based STATCOM can be directly connected to the 6,600-Vrms high-voltage distribution feeders. This is a great advantage of the three-level NPC inverter-based STATCOM. For the control strategy of the STATCOMs, the instantaneous active-reactive power theory originally proposed by Prof. Akagi, *et al.* is widely used^{(6)–(10)}. Most of this control algorithm is based on instantaneous active-reactive power theory and its extensions for the calculation of reference currents. A synchronous reference frame, decomposition in the time domain of the load currents and theory of instantaneous symmetrical component are also proposed^{(11)–(13)}. These reference current calculation methods require a large number of computation steps including transformation blocks. In single-phase

three-wire distribution feeders, the present authors proposed a constant dc-capacitor voltage-control (CDCVC)-based strategy of the smart charger (SC) for electric vehicles (EVs) that can achieves sinusoidal and balanced source currents with a controlled reactive power on the source side⁽¹⁴⁾.

This paper proposes a CDCVC-based reactive power control strategy for a three-level NPC inverter-based STATCOM, in which the source-side harmonic currents are also compensated. The CDCVC-based reactive power control strategy uses only a CDCVC, which is always used in the grid-connected inverters, STATCOMs etc. Calculation blocks of fundamental active, reactive, and harmonic components are not needed. The authors offer a simplified strategy for a source-side reactive power control with source-side harmonic current compensations. The instantaneous power flowing into the STATCOM with a three-level NPC inverter is discussed in detail. The instantaneous power flow shows that using the CDCVC-based strategy for the STATCOM achieves sinusoidal source currents using the controlled source-side reactive power compensating the harmonic currents on the source side. The simulation and experimental results demonstrate that the sinusoidal source currents are obtained with the CDCVC-based strategy controlling the reactive power on the source side.

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Fig. 1. Circuit diagram of a three-level neutral-point-clamped (NPC) inverter-based static synchronous compensator (STATCOM) with the proposed constant dc-capacitor voltage-control (CDCVC)-based reactive power control strategy

2. Constant DC-Capacitor Voltage-Control-Based Strategy for Harmonics Compensation with Reactive Power Control

Figure 1 shows a circuit diagram of a three-level NPC inverter-based STATCOM with the proposed CDCVC-based reactive power control strategy. The part enclosed by the dotted line shows the proposed CDCVC-based reactive power control strategy. The proposed strategy uses only the CDCVC block, which is always used in the grid-connected inverters, STATCOMs etc.

To claim the novelty, simplicity, and practicability of the proposed CDCVC-based reactive power control strategy, the authors, now, compare the proposed strategy to the reactive power control strategy with the instantaneous active-reactive power theory originally proposed by Prof. Akagi, *et al.*⁽⁶⁾. In Figure 1, three-phase terminal voltages v_{Ta} , v_{Tb} , and v_{Tc} are expressed as

$$\begin{aligned} v_{Ta} &= \sqrt{2}V_T \cos \omega t, \\ v_{Tb} &= \sqrt{2}V_T \cos \left(\omega t - \frac{2}{3}\pi \right), \\ v_{Tc} &= \sqrt{2}V_T \cos \left(\omega t + \frac{2}{3}\pi \right). \end{aligned} \quad (1)$$

Let assume that the three-phase load currents i_{La} , i_{Lb} , and i_{Lc} include harmonic currents. The three-phase load currents i_{La} , i_{Lb} , and i_{Lc} are expressed as

$$i_{La} = \sqrt{2}I_{L1} \cos(\omega t - \phi_1)$$

$$+ \sqrt{2} \sum_{h=2}^{\infty} I_{Lh} \cos h(\omega t - \phi_1),$$

$$i_{Lb} = \sqrt{2}I_{L1} \cos \left(\omega t - \frac{2}{3}\pi - \phi_1 \right)$$

$$+ \sqrt{2} \sum_{h=2}^{\infty} I_{Lh} \cos h \left(\omega t - \frac{2}{3}\pi - \phi_1 \right),$$

$$i_{Lc} = \sqrt{2}I_{L1} \cos \left(\omega t + \frac{2}{3}\pi - \phi_1 \right)$$

$$+ \sqrt{2} \sum_{h=2}^{\infty} I_{Lh} \cos h \left(\omega t + \frac{2}{3}\pi - \phi_1 \right).$$

$$\dots\dots\dots (2)$$

When the terminal voltages v_{Ta} , v_{Tb} , and v_{Tc} , and the load currents i_{La} , i_{Lb} , and i_{Lc} are transformed into α - β coordinates, the instantaneous active power p and instantaneous reactive power q are given by

$$\begin{pmatrix} p \\ q \end{pmatrix} = \begin{pmatrix} v_{T\alpha} & v_{T\beta} \\ -v_{T\beta} & v_{T\alpha} \end{pmatrix} \begin{pmatrix} i_{L\alpha} \\ i_{L\beta} \end{pmatrix}. \quad (3)$$

From (3), the three-phase load currents on α - β coordinates are decomposed as

$$\begin{aligned} i_{L\alpha} &= \frac{v_{T\alpha}}{v_{T\alpha}^2 + v_{T\beta}^2} \bar{p} + \frac{v_{T\alpha}}{v_{T\alpha}^2 + v_{T\beta}^2} \tilde{p} \\ &\quad - \frac{v_{T\beta}}{v_{T\alpha}^2 + v_{T\beta}^2} \bar{q} - \frac{v_{T\beta}}{v_{T\alpha}^2 + v_{T\beta}^2} \tilde{q}, \end{aligned}$$

Fig. 2. Control circuit diagram for STATCOMs. (a) Block diagram of the instantaneous active-reactive power theory-based reactive power control strategy. (b) Block diagram of the proposed CDCVC-based reactive power control strategy, which is the part enclosed by the dotted line in Figure 1

$$i_{L\beta} = \frac{v_{T\beta}}{v_{T\alpha}^2 + v_{T\beta}^2} \bar{p} + \frac{v_{T\beta}}{v_{T\alpha}^2 + v_{T\beta}^2} \tilde{p} + \frac{v_{T\alpha}}{v_{T\alpha}^2 + v_{T\beta}^2} \bar{q} + \frac{v_{T\alpha}}{v_{T\alpha}^2 + v_{T\beta}^2} \tilde{q}, \dots \dots \dots (4)$$

where $\bar{p}$ and $\bar{q}$ are originated in the fundamental components of the load currents in (2) because the terminal voltages in (1) contains the fundamental components, and $\tilde{p}$ and $\tilde{q}$ are originated in the harmonic components in (2). In (4), controlling the dc component $\bar{q}$ on the source side with $\bar{p}$ achieves the reactive power control on the source side.

Figure 2 shows a control circuit diagram for STATCOMs. Figure 2(a) shows a block diagram of the instantaneous active-reactive power theory-based reactive power control strategy. Figure 2(b) shows a block diagram of the proposed CDCVC-based reactive power control strategy, which is the part enclosed by the dotted line in Figure 1. The authors, thus, claim that the simplified source-side reactive power control strategy is offered.

The basic principle of the proposed CDCVC-based reactive power control strategy is, now, discussed in detail. When the harmonic currents of the three-phase load currents i_{La} , i_{Lb} , and i_{Lc} are compensated on the source side by the STATCOM with the proposed CDCVC-based reactive power control strategy, the three-phase source currents i_{Sa} , i_{Sb} , and i_{Sc} are sinusoidal with a controlled reactive power. Three-phase source currents, therefore, can be expressed as

$$\begin{aligned} i_{Sa} &= \sqrt{2} I_S \cos(\omega t - \phi) \\ &= \sqrt{2} I_P (\cos \omega t + K \sin \omega t), \\ i_{Sb} &= \sqrt{2} I_S \cos\left(\omega t - \frac{2}{3}\pi - \phi\right) \\ &= \sqrt{2} I_P \left\{ \cos\left(\omega t - \frac{2}{3}\pi\right) + K \sin\left(\omega t - \frac{2}{3}\pi\right) \right\}, \\ i_{Sc} &= \sqrt{2} I_S \cos\left(\omega t + \frac{2}{3}\pi - \phi\right) \\ &= \sqrt{2} I_P \left\{ \cos\left(\omega t + \frac{2}{3}\pi\right) + K \sin\left(\omega t + \frac{2}{3}\pi\right) \right\}, \dots \dots (5) \end{aligned}$$

where $I_P = I_S \cos \phi$ and $K = \tan[\cos^{-1}\{\text{power factor (PF)}\}]$. This I_P is the theoretical root-mean-square (RMS) value of the active currents in each phase on the source side, which

equal that in each phase on the load side. In Figure 1, the compensation currents i_{Ca} , i_{Cb} , and i_{Cc} of the STATCOM with a three-level NPC inverter are given by

$$\begin{aligned} i_{Ca} &= i_{La} - i_{Sa}, \\ i_{Cb} &= i_{Lb} - i_{Sb}, \\ i_{Cc} &= i_{Lc} - i_{Sc}. \dots \dots \dots (6) \end{aligned}$$

The purpose of this paper is to demonstrate the validity and high practicability of the proposed CDCVC-based harmonic current compensation strategy with reactive power control. Thus, balanced load conditions are considered in this paper. The instantaneous power p_c flowing into the STATCOM is given by

$$\begin{aligned} p_c &= v_{Ta} \cdot i_{Ca} + v_{Tb} \cdot i_{Cb} + v_{Tc} \cdot i_{Cc} \\ &= 2 V_T \left\{ \frac{3}{2} I_{L1} \cos \phi_1 + \cos \omega t \cdot \sum_{h=2}^{\infty} I_{Lh} \cos h(\omega t - \phi_1) \right. \\ &\quad + \cos\left(\omega t - \frac{2}{3}\pi\right) \cdot \sum_{h=2}^{\infty} I_{Lh} \cos h\left(\omega t - \frac{2}{3}\pi - \phi_1\right) \\ &\quad + \cos\left(\omega t + \frac{2}{3}\pi\right) \cdot \sum_{h=2}^{\infty} I_{Lh} \cos h\left(\omega t + \frac{2}{3}\pi - \phi_1\right) \\ &\quad \left. - \frac{3}{2} I_P \right\}. \dots \dots \dots (7) \end{aligned}$$

If the mean value of the dc-capacitor voltage v_{DC} is maintained at constant by the CDCVC in the STATCOM in Figure 1, the mean value $\bar{p}_c$ of the instantaneous power p_c flowing into the STATCOM should be zero. In (7), thus,

$$\bar{p}_c = 3 V_T (I_{L1} \cos \phi_1 - I_P). \dots \dots \dots (8)$$

The RMS value I_P of the active currents in each phase on the source side in (5) is given by

$$I_P = I_{L1} \cos \phi_1. \dots \dots \dots (9)$$

Note that this I_P equals the RMS value of the active currents $I_P = I_{L1} \cos \phi_1$ on the load side. Thus, it is concluded that the CDCVC of the STATCOM in Figure 1 can calculate the fundamental active current of the load currents i_{La} , i_{Lb} , and i_{Lc} in three-phase circuits. In the control circuit block of Figure 1, the dc-capacitor voltages v_{C1} and v_{C2} are detected. Then, the

Fig. 3. Per-phase phasor diagram for the terminal voltage $\dot{V}_T$, the source current $\dot{I}_S$, and the load current $\dot{I}_L$

difference between the detected dc-capacitor voltage $v_{C1} + v_{C2}$ and the reference value V_{DC}^* of the dc-capacitor voltage is amplified by the proportional-integral (PI) controller. A moving-average low-pass filter (LPF) is used to remove the 6ω angular frequency component, where ω is the angular frequency of the terminal voltages v_{Ta} , v_{Tb} , and v_{Tc} . Then, the RMS value I_p of the active currents in each phase is obtained. With the control gain K , the RMS value of the fundamental reactive currents on the source side is calculated, where this control gain K can control the reactive power on the source side. Figure 3 shows a per-phase phasor diagram for the terminal voltage $\dot{V}_T$, the source current $\dot{I}_S$, and the load current $\dot{I}_L$. From Figure 3, controlling the control gain K can control the source-side reactive power. The line-to-line voltages v_{Tab} and v_{Tbc} are detected, and then, an electrical angle θ_S is generated using a three-phase phase-locked-loop (PLL)⁽¹⁵⁾. Using this θ_S , I_p , and KI_p , the source currents i_{Sa}^* , i_{Sb}^* , and i_{Sc}^* with the controlled reactive power in a-b-c coordinates are calculated. Subtracting the calculated i_{Sa}^* , i_{Sb}^* , and i_{Sc}^* from the detected load currents i_{La} , i_{Lb} , and i_{Lc} gives the reference values i_{Ca}^* , i_{Cb}^* , and i_{Cc}^* of the STATCOM. The reference values i_{Ca}^* , i_{Cb}^* , and i_{Cc}^* in a-b-c coordinates are given by

$$\begin{aligned} i_{Ca}^* &= i_{La} - i_{Sa}^*, \\ i_{Cb}^* &= i_{Lb} - i_{Sb}^*, \\ i_{Cc}^* &= i_{Lc} - i_{Sc}^*. \end{aligned} \quad (10)$$

The PI controllers in d - q coordinates are used to control the output currents i_{Ca} , i_{Cb} , and i_{Cc} . Thus, the differences between the reference values i_{Ca}^* , i_{Cb}^* , and i_{Cc}^* and the detected values i_{Ca} , i_{Cb} , and i_{Cc} in a-b-c coordinates are transformed into i_{Cd} and i_{Cq} , respectively. i_{Cd} and i_{Cq} are amplified by the PI controllers in d - q coordinates. The amplified differences are retransformed into a-b-c coordinates. It is well known that two dc-capacitor voltages v_{C1} and v_{C2} are unbalanced⁽¹⁶⁾.

Prof. H. Akagi *et al.* proposed a voltage-balancing control with the 6th-order zero-sequence voltage $\cos(6\theta_S + \phi)$ for a three-level NPC inverter⁽¹⁷⁾. The basic principle of the proposed voltage-balancing control was discussed in detail. The experimental results demonstrated that adding $\cos(6\theta_S + \phi)$ to the reference values of the three-phase output voltages well balanced two dc-capacitor voltages, where $\phi = 1.4$ rad. In this paper, the 6th-order zero-sequence voltage is, thus, added to the reference values of the three-phase output voltages v_{Ba} , v_{Bb} , and v_{Bc} in Figure 1. For more detail, see the literature (17). The 6th-order zero-sequence voltage is added to the three-phase reference voltages v_{Ba} , v_{Bb} , and v_{Bc} ⁽¹⁷⁾. A sine-triangle intercept technique is used to generate the gate signals for twelve insulated-gate bipolar transistors (IGBTs).

Table 1. Circuit constants for Figure 1

Item	Symbol	Value
Source inductor	L_S	0.8 mH
Switching inductor	L_f	1.28 mH
Filter capacitor	C_f	6.0 μ F
Reference dc-capacitor voltage	V_{DC}^*	400 Vdc
DC capacitor	C_1, C_2	11200 μ F
Unit capacitance constant	H	44.8 ms
Carrier frequency	f_{sw}	7.2 kHz

Fig. 4. Simulation waveforms for Figure 1 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0$ as shown in Figure 3

3. Simulation Results

Digital computer simulation is implemented to confirm the validity and high practicability of the proposed CDCVC-based reactive power control strategy using PSIM software. The three-phase load currents i_{La} , i_{Lb} , and i_{Lc} include the 5th- and 7th-order harmonic currents in following simulation results. The ratings of three-phase source voltages are 200 Vrms and 60 Hz. The rated three-phase load is 10 kVA. Therefore, the RMS value of the fundamental components of the load currents is 28.7 Arms. The 5th-order components of 5.7 Arms, which is 20% as compared to the RMS value of fundamental component, and the 7th-order components of 4.1 Arms, which is 14.3%, are also included in the load currents i_{La} , i_{Lb} , and i_{Lc} . Thus, total harmonic distortion (THD) values of i_{La} , i_{Lb} , and i_{Lc} are 24.6%. The PF between the terminal voltages and load currents is 0.70. Table 1 shows circuit constants for Figure 1, which were used in the following simulation results.

Figure 4 shows simulation results for Figure 1 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0$ as shown in Figure 3. v_{Ta} , v_{Tb} , and v_{Tc} are the terminal voltage waveforms and i_{Sa} , i_{Sb} , and i_{Sc} are the source current waveforms. i_{La} , i_{Lb} , and i_{Lc} are load current waveforms; i_{Ca} , i_{Cb} , and i_{Cc} are the compensation current waveforms of the STATCOM with the three-level NPC inverter; and v_{C1} and v_{C2} are the dc-capacitor voltage waveforms. Although the load currents i_{La} , i_{Lb} , and i_{Lc} are distorted with the PF of 0.70, the source currents i_{Sa} , i_{Sb} , and i_{Sc} are sinusoidal with the PF of 1.00. The THD values of i_{Sa} , i_{Sb} , and i_{Sc} are 5.8%, 5.9%, and 5.8%, respectively. The dc-capacitor voltages v_{C1} and v_{C2} are well balanced with the method proposed in (17). The ripples of v_{C1} and v_{C2} are $\pm$

Fig. 5. Simulation waveforms for Figure 1 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0.484$ as shown in Figure 3

Fig. 6. Theoretical values and simulated values between the control gain $K = \tan\{\cos^{-1}(\text{PF})\}$ and the source-side PF

0.75%, respectively.

Figure 5 shows simulation results for Figure 1 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0.484$ as shown in Figure 3. Although the load currents i_{La} , i_{Lb} , and i_{Lc} are distorted with the PF of 0.70, the source currents i_{Sa} , i_{Sb} , and i_{Sc} are sinusoidal with the PF of 0.90. The THD values of i_{Sa} , i_{Sb} , and i_{Sc} are 5.5%, 5.6%, and 5.6%, respectively. The dc-capacitor voltages v_{C1} and v_{C2} are well balanced with the method proposed in (17). The ripples of v_{C1} and v_{C2} are $\pm 0.60\%$, respectively.

Thus, the CDCVC-based strategy for the STATCOM with a three-level NPC inverter achieves not only the source-side harmonic current compensations but also reactive power control with the proposed CDCVC-based reactive power control strategy.

Figure 6 shows theoretical and simulated values between the control gain $K = \tan\{\cos^{-1}(\text{PF})\}$ and the source-side PF. Figure 6 demonstrates that controlling the control gain K can achieve the desired PF on the source side.

4. Experimental Results

A prototype experimental model was constructed and tested to demonstrate the validity and high practicability

of the proposed control method, which uses only CDCVC for the STATCOM. Figure 7 shows a block diagram of the constructed prototype experimental model. The ratings of three-phase source voltage are 200 Vrms and 60 Hz. Three-phase load consists of three-phase diode rectifier and Y-connected inductor. The rated three-phase load is 6.7 kVA. The PF between the terminal voltages and load currents is 0.60, and THD values of i_{La} , i_{Lb} , and i_{Lc} are 13.6%. Table 2 shows circuit constants for Figure 7, which were used in the following experimental results. The detected line-to-line voltages v_{Tab} and v_{Tbc} , load currents i_{La} and i_{Lc} , compensation currents i_{Ca} and i_{Cc} , and dc-capacitor voltages v_{C1} and v_{C2} are fed into a SH microcomputer (SH7216 Renesas Electronics Corp.) through 12 bit A/D converters, where sampling frequency f_{sw} is 7.2 kHz. In the SH microcomputer, the reference values i_{Ca}^* , i_{Cb}^* , and i_{Cc}^* for the NPC inverter, which acts a STATCOM, are calculated by (10). The feedback control in d - q coordinates of Figure 1 is used. This current feedback control is carried out in the SH microcomputer.

Figure 8 shows experimental results for Figure 7 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0$ as shown in Figure 3. v_{Ta} , v_{Tb} , and v_{Tc} are the terminal voltage waveforms and i_{Sa} , i_{Sb} , and i_{Sc} are the source current waveforms. i_{La} , i_{Lb} , and i_{Lc} are load current waveforms; i_{Ca} , i_{Cb} , and i_{Cc} are the compensation current waveforms of the STATCOM with the NPC inverter; and v_{C1} and v_{C2} are the dc-capacitor voltage waveforms. Although the load currents i_{La} , i_{Lb} , and i_{Lc} are distorted with the PF of 0.60, the source currents i_{Sa} , i_{Sb} , and i_{Sc} are sinusoidal with the PF of 1.00. The THD values of i_{Sa} , i_{Sb} , and i_{Sc} are 9.0%, 9.0%, and 8.9%, respectively. The dc-capacitor voltages v_{C1} and v_{C2} are well balanced with the method proposed in (17).

Figure 9 shows experimental results for Figure 7 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0.484$ as shown in Figure 3. Although the load currents i_{La} , i_{Lb} , and i_{Lc} are distorted with the PF of 0.60, the source currents i_{Sa} , i_{Sb} , and i_{Sc} are sinusoidal with the PF of 0.90. The THD values of i_{Sa} , i_{Sb} , and i_{Sc} are 8.1%, 8.5%, and 8.6%, respectively. The dc-capacitor voltages v_{C1} and v_{C2} are well balanced with the method proposed in (17). Thus, the CDCVC-based strategy for the STATCOM with a three-level NPC inverter achieves not only the source-side harmonic current compensations but also reactive power control with the proposed CDCVC-based reactive power control strategy. The experimental results of Figure 8 and Figure 9 are in good agreement with the simulation results of Figure 4 and Figure 5.

5. Conclusion

This paper has proposed a CDCVC-based reactive power control strategy of a STATCOM with a three-level NPC inverter, in which the source-side harmonic currents are also compensated. The CDCVC-based reactive power control strategy uses only a CDCVC, which is always used in the grid-connected inverters, STATCOMs etc. Calculation blocks of fundamental active, reactive, and harmonic components are not needed. The authors offer a simplified strategy for the source-side reactive power control with the source-side harmonic current compensations. The instantaneous power flowing into the STATCOM with a three-level NPC inverter has been discussed in detail. The instantaneous

Fig. 7. Block diagram of constructed experimental model for STATCOM with three-level NPC inverter in Figure 1

Table 2. Circuit constants for Figure 7

Item	Symbol	Value
Switching inductor	L_f	1.28 mH
Filter capacitor	C_f	6.0 μ F
Reference dc-capacitor voltage	V_{DC}^*	400 Vdc
DC capacitor	C_1, C_2	11200 μ F
Unit capacitance constant	H	44.8 ms
Carrier frequency	f_{sw}	7.2 kHz
Inductor	L	20 mH
DC-side resistor of three-phase diode rectifier	R_d	16.7 Ω
AC-side inductor of three-phase diode rectifier	L_c	1.2 mH

Fig. 8. Experimental waveforms for Figure 7 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0$ as shown in Figure 3

Fig. 9. Experimental waveforms for Figure 7 with the control gain $K = \tan\{\cos^{-1}(\text{PF})\} = 0.484$ as shown in Figure 3

controlled source-side reactive power compensating the harmonic currents on the source side. A digital computer simulation has been implemented to confirm the validity and high practicability of the CDCVC-based strategy. A reduced-scale prototype experimental model has been constructed and tested. The simulation and experimental results have demonstrated that the sinusoidal source currents are obtained with the CDCVC-based strategy controlling the reactive power on the source side.

In this paper, balanced load conditions have been considered to demonstrate the validity and high practicability of the proposed CDCVC-based harmonic current compensation strategy with reactive power control. The compensation

power flow shows that using the CDCVC-based strategy for the STATCOM achieves sinusoidal source currents using the

performance of the proposed CDCVC-based strategy of the three-level NPC inverter-based STATCOM under unbalanced load conditions is a next issue for further study. This will be reported in another article.

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