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This paper deals with harmonics compensation with reactive power control of the previously proposed constant dc-capacitor voltage-control (CDCVC)-based strategy in a smart charger (SC) for electric vehicles (EVs) in single-phase three-wire distribution feeders (SPTWDFs) under distorted load current conditions. For the control algorithm of SC, only the CDCVC block, which is typically used in grid-connected inverters including active power line conditioners, is used. No calculation blocks of the load-side fundamental active-reactive currents and harmonic currents are required. Thus, the authors propose a simplified harmonics compensation strategy with reactive power control for the SC in SPTWDFs. The basic principle of the CDCVC-based strategy is discussed in detail. Simulation and experimental results demonstrate that during battery-charging and battery-discharging operations in EVs, balanced and sinusoidal source currents with a predefined power factor of 0.9 on the source side, which is an acceptable value for Japanese domestic consumers, are achieved on the secondary side of the pole-mounted distribution transformer using the CDCVC-based algorithm. Simulation and experimental results also demonstrate that controlling the reactive power on the source side can reduce the capacity of the SC.

Keywords: single-phase three-wire distribution feeder, smart charger, reactive power control, three-leg PWM rectifier, constant dc-capacitor voltage control, single-phase d-q transformation

1. Introduction

Electric vehicles (EVs) are now commercially available. The Mitsubishi i-MiEV is a five-door hatchback kei car and the Nissan LEAF is a medium-size five-door hatchback electric car. The lithium-ion batteries equipped in the LEAF can store 30 kWh of electric energy. EVs are highly mobile with their stored electric power. Owing to this mobility, an interesting concept of injecting the stored power of EVs into their stored electric power. Due to this mobility, an interesting concept of injecting the stored power of EVs into the grid and home (Vehicle-to-Grid, and Vehicle-to-Home) was proposed (1)–(3). To achieve this, a pulse-width modulated (PWM) rectifier with a bidirectional dc-dc converter was proposed (4)–(5). However, the charger proposed in (4) and (5) could not be applied to domestic consumers in Japan as single-phase three-wire distribution feeders (SPTWDFs) with pole-mounted distribution transformers (PMDTs) are used there. In SPTWDFs, the secondary-side load conditions for domestic consumers are always unbalanced. The authors, thus, proposed a simple harmonics compensation method with the fundamental current feedback control in d-q coordinates. Simulation results demonstrated that balanced sinusoidal source currents with a unity power factor (PF) on the secondary side of PMDTs is possible. Simulation and experimental results demonstrated that balanced source currents with a unity PF are obtained on the source side of the SPTWDF during battery-charging and battery-discharging operations in EVs. Power electronic circuits are widely used in modern consumer electronics. Diode rectifiers are included in the modern consumer electronics. These diode rectifiers generate harmonic currents. The present authors, thus, propose a simplified model of the single-phase fundamental current feedback control in d-q coordinates. Simulation results demonstrated that balanced and sinusoidal source currents with a unity PF in SPTWDFs are obtained on the secondary side of the PMDT during both the battery-charging and battery-discharging operations in EVs. However, the harmonic components were slightly remained on the source side. In (7), the total harmonic distortion (THD) values of the source currents were improved than those in (7). The required rating of the PWM rectifier was also discussed in detail considering the load conditions with Japanese guidelines for domestic power use.
In (6)–(8), the source-side PF was unity. This perfect compensation of the reactive power on the source side increases the capacity of the PWM rectifier, which acts as an SC. The authors further proposed a power control strategy with CDCVC to reduce the capacity of the SC (10). In the reactive power control, the CDCVC-control-based strategy can achieve the balanced source currents with a PF of 0.9, which is an acceptable value by the general supply provisions of electric power companies (11). Since only linear loads were considered in Feeder1 and Feeder2, harmonic currents compensation with the CDCVC-based reactive-power-control strategy should be discussed for practical domestic consumers in SPTWDFs.

This paper deals with reactive, unbalanced active, and harmonics currents compensation using the CDCVC-based strategy of an SC in SPTWDFs under distorted load current conditions with source-side reactive power control, which can reduce the capacity of the SC. The basic principles of the CDCVC-based strategy for SCs are discussed in detail. The instantaneous power flowing into the SC shows that the previously proposed CDCVC-based strategy can compensate fundamental reactive, unbalanced active, and harmonic currents on the source side, controlling the source-side fundamental reactive power. The balanced and sinusoidal source currents with a PF of 0.9, which is an acceptable value by the general supply provisions of electric power companies (11), are achieved using only the CDCVC-based strategy, which is commonly used in active power-line conditioners. A digital computer simulation is implemented to confirm the validity and high practicability of the CDCVC-based strategy under unbalanced and distorted load current conditions. A reduced-scale prototype experimental model is constructed and tested. Simulation and experimental results demonstrate that sinusoidal and balanced source currents with a PF of 0.9 are achieved on the secondary side of the PMDT during both the battery-charging and battery-discharging operations in EVs, reducing the capacity of the SC. Simulation and experimental results also demonstrate that controlling the source-side PF to 0.9 reduces the required-capacity of the SC by up to 35% as compared to that of the SC, where the source-side PF is unity in (7) (8).

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

Fig. 1 shows a circuit diagram with the proposed harmonics compensation strategy based on the CDCVC with reactive power control. Table 1 shows the constants for the circuit in Fig. 1, which are used in the subsequent simulation results. Diode rectifiers are included in modern consumer electronics. Thus, in addition to linear loads, diode rectifiers are connected to each feeder by a neutral line. The THD values are decided considering IEC61000-3-4 (12). For the control algorithm of the three-leg PWM rectifier, the CDCVC-based strategy is used (6)–(8). A proportional-integral (PI) controller is used in the CDCVC block (7). In this paper, a proportional-integral-derivative (PID) controller is used to improve the response of the CDCVC-based control strategy, because harmonic currents are included in addition to fundamental-reactive and unbalanced active components of the load currents $i_{L1}$ and $i_{L2}$. In three-phase circuits, some control strategies for these active power-line conditioners are based on pq theory, which was originally proposed by Akagi et al. (13). The instantaneous symmetrical component theory method, the sample and hold circuit method, and the $d-q$ transformation based method are also used for the calculation of the reference compensation currents $i_{ref}$ (14) (15). Single-phase pq theory was proposed for single-phase active power line conditioners (16). In this method, the instantaneous active-reactive
power calculation block is also included. On the other hand, in Fig. 1, no calculation blocks of the reactive, unbalanced active, and harmonic components of the load currents are necessary. Thus, this simplified algorithm for SC achieves balanced and sinusoidal source currents with a PF of 0.9.

The basic principle of the previously proposed harmonics compensation strategy with reactive power control is discussed. It is assumed that the primary-side voltage $v_S$ and secondary-side voltages $v_L1$ and $v_L2$ are

$$v_S = \sqrt{2}V_S \cos \omega t,$$

$$v_L = v_L1 = v_L2 = \sqrt{2}V_L \cos \omega t,$$ .......................... (1)

The load currents $i_L1$ and $i_L2$ in Feeder1 and Feeder2 are also expressed as

$$i_L1 = \sqrt{2}I_{L1F} \cos(\omega st - \phi_{L1F}) + \sqrt{2} \sum_{n=2}^{\infty} I_{L1n} \cos(n\omega t - \phi_{L1n}),$$

$$i_L2 = \sqrt{2}I_{L2F} \cos(\omega st - \phi_{L2F}) + \sqrt{2} \sum_{n=2}^{\infty} I_{L2n} \cos(n\omega t - \phi_{L2n}),$$ .......................... (2)

The desired source-side current $i_S^c$, which is balanced and sinusoidal, in Feeder1 and Feeder2 is expressed as

$$i_S^c = i_S1^c = i_S2^c = i_Sp^c + i_Sq^c = \sqrt{2}i_{SP} \cos(\omega st - K \sin \omega st) + \sqrt{2}i_{SQ} \cos(\omega st + \phi),$$

$$= \sqrt{2}i_{SP} \cos(\omega st - K \sin \omega st) + \sqrt{2}i_{SQ} \cos(\omega st - \phi),$$ .......................... (3)

where $i_{SP}$ is the desired source current $i_s$ in the desired source currents $i_S^c$, which are $i_S1^c$ and $i_S2^c$, is generated by the output value $2I_{SP}$ of the PID controller with $\sqrt{2} \cos \theta_s$. Thus, by adding $T$ to $i_S^c$, the desired source current $i_S^c$ is calculated. The reference active component $i_{SP}$ is obtained by multiplying $i_S^c$ with $\sqrt{2} \cos \theta_s$, which is a single-phase phase-locked loop (PLL) is used to detect the electric angle $\theta_s = \omega st$ of $v_S$ (Fig. 1). The RMS value $I_{SP}$ is further multiplied with the control gain $K$, where this control gain can control the amplitude of the fundamental reactive component $i_{SP}$. The reference reactive component $i_{SQ}$ is obtained by multiplying $K_{SP}$ with $\sqrt{2} \sin \theta_s$. By adding $i_{SP}$ to $i_{SQ}$, the desired source currents $i_S^c$ are obtained. The reference active component $i_{SP}$ is equal to that stated in (3). In the single-phase PLL, the source voltage $v_S$ is detected. This $v_S$ corresponds to the detected $\alpha$-phase component $v_{\alpha}$. The component delayed by $T/4$ corresponds to the $\beta$-phase component $v_{\beta}$. Then, $v_{\alpha}$ and $v_{\beta}$ are transformed to $v_{d}$ and $v_{q}$ in $d$-$q$ coordinates using the generated electric angle $\theta_s$, respectively. When $v_{\alpha}$ is controlled to zero by a PI controller in $d$-$q$ coordinates, it is possible to

<table>
<thead>
<tr>
<th>Table 1. Circuit Constants for Fig. 1</th>
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<tr>
<td>Item</td>
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<td>--------------------------------------</td>
</tr>
<tr>
<td>Filter inductor</td>
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<tr>
<td>Filter capacitor</td>
</tr>
<tr>
<td>Switching inductor for three-phase inverter</td>
</tr>
<tr>
<td>DC capacitor</td>
</tr>
<tr>
<td>Reference value for DC-capacitor voltage</td>
</tr>
<tr>
<td>Switching inductor for dc-dc converter</td>
</tr>
<tr>
<td>Filter capacitor for dc-dc converter</td>
</tr>
<tr>
<td>Battery voltage</td>
</tr>
<tr>
<td>Inductor current</td>
</tr>
<tr>
<td>Internal resistance of battery</td>
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<tr>
<td>Switching frequency</td>
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<td>Dead time</td>
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</table>
generate an electrical reference angle $\theta_i$ that is synchronized with $\theta_S$, which has angular frequency $\omega_S$. Finally, by subtracting the calculated $i^*_S$ from the detected load currents $i_{L1}$ and $i_{L2}$, the reference values $i^*_1$, $i^*_2$, and $i^*_3$ for the three-leg PWM rectifier are calculated as

$$
\begin{align*}
    i^*_1 &= i_{L1} - i^*_S, \\
    i^*_2 &= -i_{L2} + i^*_S, \\
    i^*_3 &= -(i^*_1 + i^*_2).
\end{align*}
$$

Fig. 2 shows phasor diagrams for the source voltage $v_S$, source current $i_S$, and load current $i_L$ using each control strategy. The primary-side voltage phasor $V_S$, the average source current phasor $I_S$, the average load current phasor $I_L$, the active component phasor $I_{Lp}$ for $I_L$, the reactive component phasor $I_{Lq}$ for $I_L$, the average charger current phasor $I_C$, and the active power component phasor $I_{Cp}$ for $I_C$ should be compensated because the PF on the source side was controlled to unity in (6). Thus, the amplitude $I_C$ of the SC current becomes large. In Fig. 2(b), only the reactive power component $I_{LA} - KI_{SA}$ is compensated when the PF of 0.9 is achieved. As compared to the previously proposed control strategy, the reactive power control strategy can reduce the amplitude $I_C$ of the charger current. Thus, controlling the PF to 0.9 can reduce the required rating of the SC.

It is well known that a steady-state error remains when a current controller that is a triangle intersection method based PI controller in a single-phase PWM rectifier is used. To avoid this steady-state error, an interesting current feedback PI controller in a single-phase PWM rectifier is used. To reduce the required rating of the SC.

In this paper, the primary-side voltage $v_L$ is detected to generate the electrical angle $\theta_L$ with the single-phase PLL. Detecting the secondary-side voltage $v_{L1}$ or $v_{L2}$ may be more practical. This is an important issue for a further study.

### 3. Simulation Results

The validity and high-practicability of the CDCVC-based strategy for the proposed SC are confirmed by digital computer simulation using PSIM software. The rating of the PMDT are 6.6 kVrms, 5.0 kVA, and 60 Hz on the primary side, and 105 Vrms and 24 Arms on the secondary side. The unbalanced ratio (UR) between Feeder1 and Feeder2 is defined by

$$
\text{Unbalanced ratio (UR)} = \frac{|S_1 - S_2|}{S_\lambda \times 0.5} \times 100 \, [\%],
$$

where $S_1$ is the apparent power of Load1 on Feeder1 and $S_2$ is the apparent power of Load2 on Feeder2. $S_\lambda$ is the total apparent power, which is the sum of the apparent powers $S_1$ and $S_2$ in Feeder1 and Feeder2, respectively. According to the Japanese guidelines for personal power use, the unbalanced ratio should be less than 40% in domestic power consumption. Thus, Load1, which is connected on Feeder1, is 1.2 pu where PF is 0.87, and THD is 26.3%. Load2, which is connected on Feeder2, is 0.8 pu where PF is 0.88, and THD value is 23.5%, respectively. $K_P = 0.8$, $T_1 = 24$ ms, and $T_2 = 0.6$ ms were used in the PID controller for CDCVC, and $K_P = 0.04$ and $T_1 = 8$ ms were used in the PI controllers for current feedback control in d-q coordinates in Fig. 1 in the following simulation results. The circuit constants of Table 1 are used in the following simulation results.

Fig. 3 shows the simulation results for Fig. 1 where the proposed SC charges the battery with constant battery current control. $v_{L1}$ and $v_{L2}$ are the secondary-side voltage waveforms; $i_{S1}$ and $i_{S2}$ are the secondary-side current waveforms; $i_{L1}$ and $i_{L2}$ are the load-side current waveforms of the domestic consumer; $i_{C1}$, $i_{C2}$, and $i_{C3}$ are the output current waveforms of the SC; $v_{DC}$ is the dc-capacitor voltage waveform; and $i_{S2}$ is the current of switching inductor for dc-dc converter waveform. Although the load currents $i_{L1}$ and $i_{L2}$ are unbalanced and distorted, the source currents $i_{S1}$ and $i_{S2}$ are balanced and sinusoidal with a PF of 0.9. The THD values of $i_{S1}$ and $i_{S2}$ are 4.7% and 1.6% under the steady state, respectively, and the ripple of $v_{DC}$ is 0.6%. The CDCVC-based control algorithm can compensate unbalanced active, reactive, and harmonic currents on the secondary side of the PMDT controlling the reactive power.

Fig. 4 shows the simulation results for Fig. 1 where the proposed SC discharges the battery with constant battery current control. Although the load currents $i_{L1}$ and $i_{L2}$ are unbalanced and distorted, the source currents $i_{S1}$ and $i_{S2}$ are balanced and sinusoidal with a PF of 0.9. The THD values of $i_{S1}$ and $i_{S2}$ are 9.6% and 6.8%, respectively, under the steady state, and the voltage ripple of $v_{DC}$ is 0.9%. Simulation
results of Fig. 3 and Fig. 4 demonstrate that the sinusoidal and balanced source currents with a PF of 0.9 are achieved on the secondary side of the PMDT during both battery-charging and battery-discharging operations in EVs, compensating unbalanced active, reactive, and harmonics currents, even though the load currents are unbalanced and heavily distorted.

Fig. 5 shows the simulation results for Fig. 1, where an EV is not connected to the proposed SC. Thus, the SC acts as an active power-line conditioner for the domestic consumer. Although the load currents \( i_{L1} \) and \( i_{L2} \) are unbalanced and distorted, the source currents \( i_{S1} \) and \( i_{S2} \) are balanced and sinusoidal with a PF of 0.9. The THD values of \( i_{S1} \) and \( i_{S2} \) are 6.3% and 2.8%, respectively, under the steady state, and the voltage ripple of \( v_{DC} \) is 0.5%. Thus, the proposed SC can solve the power quality problems and reduce losses in PMDTs.

The required rating of the SC is discussed here. The definition of apparent power is generally used to calculate the required capacity of the three-leg PWM rectifier. However, the third-leg that is connected to the neutral line is grounded. Thus, the authors proposed a current capacity \( A_C \) for the three-leg PWM rectifier\(^{10}\). \( A_C \) is defined as

\[
A_C = \frac{\sum_{n=1}^{3} I_{Cn}}{2I_A} \text{ pu},
\]

where \( I_A \) is the rated current of the secondary side of the distribution transformer, which is 24 Arms, and \( I_{C1}, I_{C2}, \) and \( I_{C3} \) are the RMS values of the output currents of the three-leg PWM rectifier of the SC. From the simulation results of Figs. 3, 4, and 5, \( A_C \) is 0.63 pu, 0.66 pu, and 0.75 pu, respectively, when the proposed reactive power control was used. In (7) (8), the balanced and sinusoidal source currents with a unity PF were obtained. Then, \( A_C = 0.88 \text{ pu}, 0.83 \text{ pu}, \) and 0.75 pu, respectively. Therefore, controlling the PF to 0.9 on the source side with reactive power control can reduce the capacity of the SC by 28%, 20%, and 35%, respectively, as compared to the SC capacities with the previously proposed control strategy.

4. Experimental Results

It is difficult to construct an experimental model with the actual voltage rating of the PMDT for the SC in Fig. 1 in the laboratory. A reduced-scale experimental model was, thus, constructed and tested to demonstrate the validity and high applicability of the proposed control method, which uses only CDCVC for the SC. Fig. 6 shows a block diagram of the constructed prototype experimental model. The ratings of the PMDT are 180 Vrms, 3.7 kVA, and 60 Hz on the primary side and 90 Vrms and 20.6 Arms on the secondary side. Load1 of 1.2 pu is connected in Feeder1, where the PF is 0.87, and the THD value is 23.8%. Load2 of 0.8 pu is connected in Feeder2, where the PF is 0.88, and the THD value is 24.1%, where UR is 40%. Table 2 shows the circuit constants for Fig. 6, which were used in the following experimental results. The charged power is consumed by a 60 Ω resistor, which is connected in parallel to capacitor \( C_2 \) as shown in Fig. 6(b), during the battery-charging operation. For the battery-discharging operation, a dc power supply (Takasago: HX0300-25) is connected to \( C_2 \) as shown in Fig. 6(c), where the voltage is 257 Vdc. The detected primary-side voltage \( e_p \), load currents \( i_{L1} \) and \( i_{L2} \), output currents of three-leg PWM rectifier \( i_1 \) and \( i_2 \), and dc-capacitor voltage \( v_{DC} \) are fed into a digital signal processor (DSP) (TMS320C6713, 225 MHz) through 12 bit A/D converters, where the sampling time \( T_S \) is 106.9 μs. In the DSP, the reference values \( i_1^*, i_2^*, \) and \( i_3^* \) for the three-leg PWM rectifier, which acts a power quality compensator, are calculated by (8). The output currents \( i_{C1}, i_{C2}, \) and \( i_{C3} \) of the SC and the output current \( i_{LS2} \) of the bidirectional dc-dc converter are also fed into the DSP through 12 bit A/D converters. The feedback control in \( d-q \) coordinates for the single-phase circuits of Fig. 1 is used. This current feedback control is carried out in the DSP. In the experimental model, the circuit conditions shown in Table 2 were used. \( K_P = 0.6, T_1 = 30 \text{ ms}, \) and \( T_D = 0.01 \text{ ms} \) were used in the PID controller for CDCVC in the experiment. \( K_P = 0.06 \) and \( T_1 = 8 \text{ ms} \) were used in the PI controller for current feedback control in \( d-q \) coordinates for the single-phase circuits in the experiment. Moreover, \( K_P = 0.15 \) and \( T_1 = 3 \text{ ms} \) were used in the PI controller for the current feedback of the bidirectional

\[ \text{Fig. 4. Simulation results for Fig. 1 during battery-discharging operation} \]

\[ \text{Fig. 5. Simulation results for Fig. 1 without battery} \]
Constant DC-Capacitor Voltage-Control-Based Strategy for Smart Charger

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Fig. 6. Block diagram of constructed experimental model for SC in Fig. 1. (a) Power circuit and control block diagrams of experimental model. (b) Battery model in EVs during battery-charging operation. (c) Battery model in EVs during battery-discharging operation

Table 2. Circuit Constants for Fig. 6

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<th>Item</th>
<th>Symbol</th>
<th>Value</th>
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<td>Lf1</td>
<td>0.46 mH</td>
</tr>
<tr>
<td>Filter capacitor for three-leg PWM rectifier</td>
<td>C1</td>
<td>10.4 μF</td>
</tr>
<tr>
<td>Switching inductor for three-leg PWM rectifier</td>
<td>Ls1</td>
<td>1.0 mH</td>
</tr>
<tr>
<td>DC capacitor</td>
<td>Cdc</td>
<td>2.00 μF</td>
</tr>
<tr>
<td>Reference value for DC-capacitor voltage</td>
<td>VDC</td>
<td>360 Vdc</td>
</tr>
<tr>
<td>Switching inductor for dc-dc converter</td>
<td>Ls2</td>
<td>4.4 mH</td>
</tr>
<tr>
<td>Filter capacitor for dc-dc converter</td>
<td>C2</td>
<td>1000 μF</td>
</tr>
<tr>
<td>Battery voltage</td>
<td>Vbat</td>
<td>257 Vdc</td>
</tr>
<tr>
<td>Inductor current</td>
<td>Ls2</td>
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</tr>
<tr>
<td>Switching frequency</td>
<td>fsW</td>
<td>9.36 kHz</td>
</tr>
<tr>
<td>Dead time</td>
<td>TD</td>
<td>3.5 μs</td>
</tr>
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</table>

dc-dc converter during both the battery-charging and battery-discharging operations in the experiment.

Fig. 7 shows the experimental results for Fig. 6, where the proposed SC charges the battery with constant battery current control. vL1 and vL2 are the secondary-side voltage waveforms; iS1 and iS2 are the secondary-side current waveforms; iL1 and iL2 are the load-side current waveforms of the domestic consumer; iC1, iC2, and iC3 are the output current waveforms of the SC; vDC is the dc-capacitor voltage waveform; and iLS2 is the inductor current waveform. Although the load currents iL1 and iL2 are unbalanced and distorted, the source currents iS1 and iS2 are balanced and sinusoidal with a PF of 0.9. The THD values of iS1 and iS2 are 6.9% and 4.1%, respectively, under the steady state, and the voltage ripple of vDC is 1.2%.

Fig. 8 shows the experimental results for Fig. 6, where the proposed SC discharges the battery with constant battery current control. Although the load currents iL1 and iL2 are unbalanced and distorted, the source currents iS1 and iS2 are balanced and sinusoidal with a PF of 0.9. The THD values of iS1 and iS2 are 16.2% and 9.8%, respectively, under the steady state, and the voltage ripple of vDC is 1.7%.

Fig. 9 shows the experimental results for the experimental model in Fig. 6, where the proposed SC without the battery

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Fig. 7. Experimental waveforms for SC during battery-charging operation

Fig. 8. Experimental waveforms for SC during battery-discharging operation

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with constant current control. Although the load currents \(i_{L1}\) and \(i_{L2}\) are unbalanced and distorted, the source currents \(i_{S1}\) and \(i_{S2}\) are balanced and sinusoidal with a PF of 0.9. The THD values of \(i_{S1}\) and \(i_{S2}\) are 9.4% and 5.5%, respectively, under the steady state, and the voltage ripple of \(v_{DC}\) is 1.8%. The experimental results of Figs. 7, 8, and 9 are in good agreement with the simulation results of Figs. 3, 4, and 5, respectively. From the experimental results of Figs. 7, 8, and 9, \(A_C\) is 0.63 pu, 0.66 pu, and 0.49 pu, respectively, when the proposed reactive power control was used. In (7) (8), the balanced and sinusoidal source currents with a unity PF were obtained. Then, \(A_C\) was 0.91 pu, 0.82 pu, and 0.76 pu, respectively. Therefore, controlling the PF to 0.9 on the source side with reactive power control can reduce the capacity of the SC by 24%, 20%, and 36%, respectively, as compared to the SC capacities with the previously proposed control strategy.

In both simulation and experimental results of Figs. 4 and 8 during battery-discharging operations, the fundamental components of the source currents \(i_{S1}\) and \(i_{S2}\) are smaller than those in simulation and experimental results of Figs. 3 and 7. These smaller fundamental components result is the higher THD values of the source currents \(i_{S1}\) and \(i_{S2}\) in Figs. 4 and 8. However, these THD values satisfy the regulation (12).

5. Conclusion

This paper has presented reactive, unbalanced active, and harmonic current compensation using the CDCVC-based strategy of an SC in SPTWDFs under distorted load current conditions, with source-side reactive power control, which can reduce the capacity of the SC. The basic principles of the CDCVC-based strategy for SCs have been discussed in detail. The instantaneous power flowing into the SC has shown that the previously proposed CDCVC-based strategy can compensate fundamental reactive, unbalanced active, and harmonic currents on the source side, controlling the source-side fundamental reactive power. Simulation and experimental results have demonstrated that sinusoidal and balanced source currents with a PF of 0.9 are achieved on the secondary side of the PMDT during both the battery-charging and battery-discharging operations in EVs, reducing the capacity of the SC. Simulation and experimental results further demonstrated that controlling the source-side PF to 0.9 reduces the required-capacity of the SC by up to 35% as compared to that of the SC, where the source-side PF is unity in (7) (8).

Finally, this paper is an improved and revised version of the conference paper (20). The authors would like to express their gratitude to the audiences for their valuable discussions at the IEEE Energy Conversion Congress and Expo. (ECCE2016).

Reference:

Constant DC-Capacitor Voltage-Control-Based Strategy for Smart Charger (Kei Nishikawa et al.)

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