Grid input current feedback active damping control method for IPMSM drives with small DC-link capacitor

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Abstract

With large input line inductance and low dc-link capacitance, the small dc-link drive system shows an instability problem, which is mainly caused by LC resonance between the line side inductor and the dc-link film capacitor. This paper proposes a grid current feedback active damping control method to improve system stability and suppress the LC resonance. The feedback variables are analyzed, and the detected grid current is selected. Thus, the damping current is consistent with the LC resonance components in grid current, which benefits the drive system power factor and grid current quality. Furthermore, the grid current feedback control loop has been established, and the feedback gain is designed based on system parameters that can be adjusted to fit different systems. The stability margin and robustness of the drive system to the changes in line inductance and dc-link capacitance are improved. Compared with the conventional voltage-based damping method, the power factor is increased to 0.984 and the grid current harmonics are reduced to satisfy the requirements of EN61000-3-2. The effectiveness of the proposed active damping method is verified by the experimental results.

1 | INTRODUCTION

Nowadays, interior permanent magnet synchronous motor (IPMSM) has been widely used in industrial and white home applications due to their superior efficiency, power density, and torque-to-inertia ratio [1–3]. Generally, in traditional AC–DC–AC IPMSM drive systems, a large electrolytic capacitor is utilized at dc link to buffer energy and stabilize the dc-link voltage. It leads to high cost, large volume, short lifetime [4–6], and greatly deteriorates the grid input current quality [7, 8]. To solve these problems, a film or ceramic capacitor can be used to replace the electrolytic capacitor, and the small dc-link capacitor IPMSM drive system has been developed [9–12].

Since there is no energy buffer at the dc link, the small dc-link drive systems may become unstable. It is well known that the constant power load (CPL) has negative impedance characteristics [13]. When the dc-link voltage increases, the load current is getting smaller so as to maintain constant power to the load. This interaction between the dc-link side and the load side may cause instability [13–15]. Furthermore, the LC oscillations with large ripple currents and voltages may occur, which significantly shorts the lifetime of the dc-link capacitor and switching devices due to overvoltage or overcurrent faults [16–19].

Meanwhile, the grid input current quality is another important issue in small dc-link drive systems. In [20–24], the inverter power and the motor torque control methods were proposed to obtain high power factor and low grid input harmonics, and the grid input performance was effectively improved. However, these power control methods only focused on the grid input current fundamental harmonics, the stability issue and input LC resonances were not considered. As the input line inductance is large, the LC resonance will be incorporated into the grid supply current, which degrades the input power factor and increases the grid current distortion. The harmonics around the resonant frequency would also exceed the standards of EN-61000-3-2.

In order to solve the aforementioned problems, the oscillation components are required to be damped properly. Recently, much research effort has done in the suppression methods for the LC resonance. Several passive control methods were applied in [25] and [26]. However, the passive damping circuits must have additional resistors, capacitors and inductors to improve system stability and increase the system cost and volume. It is not suitable for economical motor drive systems.
Therefore, the active damping control methods were preferred to improve the stability in small dc-link drive systems [27–34]. In [27], a dc-link stabilization control law was realized by adding the LC resonant components to the $q$-axis current reference. The drive system was stabilized effectively. In [28], a virtual resistance method was proposed to stabilize the dc-link voltage, and the virtual resistor paralleled to the line inductor changes the dynamic impedance of the system. The damping current, which is proportional to the difference between the dc-link voltage and the estimated source voltage, was injected into the $d$-axis voltage reference to damp the LC resonance. A novel dc-link voltage compensation method was proposed in [29] and [30], where the frequency-locked loop and an adaptive band-pass filter were used for signal decomposing. The damping pulse voltage was injected to the space vector pulse width modulation module according to the rectifier diodes switching instant, and large dc-link voltage variation was eliminated from the motor current to damp the LC resonance. In [31] and [32], the dc-link voltage feedback-based active damping method was proposed, where the damping current was extracted by the high-pass filter (HPF) directly. It was injected to the $dq$-axis voltage reference to mitigate the grid side LC resonance.

Besides the dc-link voltage feedback damping methods above, the inductor current feedback (ICF) damping method has also been used to suppress the LC resonance. All possible configurations of the virtual resistor have been analyzed in [33] and [34], and the optimal solution was selected. In [34], the ICF damping method was proved to improve the drive system stability, but the inductor current was calculated from the dc-link voltage variation. An inverter-current-feedback resonance-suppression method was proposed to damp the LCL resonant peak value in [35]. A stabilization control method based on the grid current feedback loop was proposed in [36], where the relationship between the drive system stability and the grid current harmonics suppression was analyzed by the impedance model. The damping current was extracted from the grid current directly and injected into the $q$-axis voltage reference to suppress the LC resonance effectively.

All of these active damping control methods above could effectively stabilize the drive system. However, the damping current was mainly extracted from the dc-link voltage [27–32], [34], which would be inconsistent with the LC resonance components in the grid current when the dc-link voltage is low. Therefore, this inaccurate damping current may affect the system power factor and the grid current quality. Furthermore, system stability is heavily dependent on system parameters, such as line inductances $L_d$ and dc-link capacitances $C_{dc}$. They may vary for different systems. Thus, the robustness of the damping controller to the system parameters should be concerned.

This paper proposes a grid input current active damping control method to improve the drive system stability and the grid current performance. After the damping feedback control types are analyzed, the grid current is selected as the feedback variable, and it is detected by a current sensor. The sampled current is used to improve the damping current accuracy. The system power factor and the grid current quality can also be improved. Moreover, the grid current feedback control loop is designed based on the system stability analysis. The feedback gain is directly calculated according to the system parameters; it can be adjusted in real time to fit different systems and improve the active damping control robustness. The active damping method not only suppresses the LC resonance effectively but also improves the power factor and reduces grid current harmonics. Hence, the proposed small dc-link drive system is well suitable for the applications that interested in the low cost and high reliability, it is mainly applied in household appliances, such as air conditioners and refrigerators, which the speed and torque response with high precision do not require [23].

This paper is organized as follows. In Section 2, the system stability is analyzed, and the power factor of the small dc-link drive system with different damping control methods is analyzed in Section 3. The proposed grid current feedback active damping stabilization scheme is presented in detail in Section 4. Finally, the effectiveness of the proposed active damping control method is verified by experiment in Section 5.

2 | STABILITY ANALYSIS OF SMALL DC-LINK DRIVE SYSTEM

The typical topology of the IPMSM drive system with a small dc-link capacitor is shown in Figure 1(a). It consists of a single-phase diode rectifier, a small film capacitor at the dc-link and a three-phase inverter with an IPMSM. The capacitance of the film capacitor is remarkably reduced compared with the electrolytic capacitor. The grid filter inductor is applied as a passive component to mitigate high-order harmonics. Assuming that the voltage drop in the diode rectifier is ignorable and all components are ideal, the model in Figure 1(a) is approximated by a simplified model in Figure 1(b).
In Figure 1(b), at the grid side, the current equation of the drive system is presented as

$$i_{inv} = i_g - C_{dc} \frac{du_{dc}}{dt}$$  \hspace{1cm} (1)

where $i_{inv}$ and $i_g$ are the inverter and grid current, respectively, $C_{dc}$ is the film capacitor at dc-link, and $u_{dc}$ is the dc-link voltage.

As the diode rectifier of the motor drive is conducted on, the voltage equation of the drive system is

$$u_{dc} = u_g - L_g \frac{di_g}{dt} - R_g i_g$$  \hspace{1cm} (2)

where $L_g$, $R_g$ and $u_g$ are the line inductance, the equivalent resistance and the grid input voltage, respectively.

Ignoring the power loss of the inverter, the inverter and the motor can be regarded as the CPL. For a small deviation of the dc-link voltage, according to the first-order Taylor series expansion, the linearization equation of the inverter output current $i_{inv}$ can be obtained by $[31, 32]$:

$$i_{inv} = \frac{P_L}{u_{dc}} = \frac{P_L}{u_{dc,0} + \tilde{u}_{dc}} \approx \frac{P_L}{u_{dc,0}} - \frac{P_L}{u_{dc,0}} \tilde{u}_{dc}$$  \hspace{1cm} (3)

where $P_L$, $u_{dc,0}$ and $\tilde{u}_{dc}$ are the load of the motor, the mean value and the deviation of the dc-link voltage, respectively.

Substituting Equation (1) and Equation (3) into Equation (2), the small-signal equivalent model of the drive system can be obtained by

$$G_u(s) = \frac{\tilde{u}_{dc}}{u_{dc}} = \frac{1}{L_g C_{dc} s^2 + \left( R_g C_{dc} - \frac{P_L}{u_{dc,0}} \right) s + \left( 1 - \frac{P_L R_g}{u_{dc,0}^2} \right)}.$$  \hspace{1cm} (4)

From the Routh–Hurwitz criterion, the stability conditions of the system can be written as follows $[27, 32]$:

$$\frac{C_{dc}}{L_g} R_g > \frac{P_L}{u_{dc,0}^2}.$$  \hspace{1cm} (5)

Root locus diagrams of Equation (4) with different values of the $L_g$, $R_g$ and $C_{dc}$ are shown in Figure 2. Obviously, as the $L_g$ increased or the $C_{dc}$ decreased, the characteristic roots move from left to right-half plane and the system stability is remarkably reduced.

At the same time, according to Figure 2, Equation (4) has a pair of characteristic roots. Thus, the dc-link voltage and the grid current of the drive system will be resonant. The resonance frequency $\omega_r$ between the $L_g$ and the $C_{dc}$ can be calculated as

$$\omega_r = \frac{1}{\sqrt{L_g C_{dc}}}.$$  \hspace{1cm} (6)

Therefore, the LC resonance harmonics in the grid current would exceed the standard requirements of EN61000-3-2 easily. It is necessary to adopt a damping method to suppress LC resonance both in dc-link voltage and the grid current. The system’s stability can also be improved.

### 3 ANALYSIS OF DIFFERENT VARIABLE FEEDBACKS

As for the LC resonance is contained both in the dc-link voltage and the grid input current, the active damping control methods can be classified into two major categories: (1) the dc-link voltage feedback $[27–32]$; (2) the grid current feedback $[33, 34]$, as shown in Figure 3. $R_d$ and $Y_d$ are the feedback gains.

Bode diagrams of the drive system with different feedback types are shown in Figure 4. It can be seen that the system is unstable without any active damping control methods. As
the feedback gains increase, system stability is improved. Compared with Figure 4(a), the grid current feedback type owns a higher gain in the low-frequency range, which benefits the system power factor. It is the optimal solution for active damping control.

In the grid current feedback control method, the grid current variation can be rebuilt from the dc-link voltage variation. It is the same as the voltage feedback that the damped current is extracted from the voltage.

However, these voltage-based methods mentioned above may lead to the inconsistency between damping current and LC resonance components in the grid current. Actually, at the valley of the source voltage, the dc-link voltage is difficult to track the source voltage completely, and cannot drop to zero. Then, \( u_g < u_{dc} \), and the grid current is clamped to zero. The changes in grid current and dc-link voltage are inconsistent. Hence, the LC components in grid current are different from the ones in dc-link voltage. Then, if the voltage based method is applied, it may affect the grid current quality.

As shown in Figure 5, from time \( t_0 \) to \( t_3 \), the motor operates in the regenerative braking mode, and the inverter current \( i_{inv} < 0 \). Thus, the motor current flows into the dc-link capacitor. The dc-link voltage pumps up with the grid current clamping to zero. Obviously, the damping current and the dc-link voltage change in the opposite direction; therefore, the damping control method may prevent the voltage from increasing. This “voltage holding” phenomenon is more obvious from time \( t_2 \) to \( t_3 \). In the voltage-based damping method, the dc-link voltage increases slowly, so \( u_g < u_{dc} \), and the grid current \( i_g \) stays at zero for a longer time. According to the relationship between diode conduction width and power factor [21], the narrow conduction width leads to a lower power factor. Moreover, after time \( t_3 \), the grid current should increase quickly to its peak value to generate the same power as the current-based method. Therefore, the grid current is similar to a triangular wave. The grid current is sharply distorted and the system power factor is only 96.8% in Figure 5.

FIGURE 4  Bode diagrams of the drive system with different feedback types. (a) DC-link voltage feedback. (b) Grid current feedback

Obviously, the current detection method can solve the above problems. The damping current is consistent with the LC component in the grid current at any time. Therefore, the damping method cannot affect the quality of the grid current. The system power factor is up to 98.4% in Figure 5.

The grid current sampling circuit is shown in Figure 6; obviously, only several resistors, capacitors, and an operational amplifier need to be added. It is expected that the proposed grid current sampling circuit does not harm the advantages of the small dc-link drive system in terms of cost and size, even in home appliances such as air conditioners. The detailed analysis of the proposed damping control method is illustrated as follows.

4 | PROPOSED GRID CURRENT FEEDBACK ACTIVE DAMPING CONTROL METHOD

Figure 7 shows the overall block diagram of the proposed active damping method. The grid current is detected by a current sensor from the grid side directly. The inverter power controller is used to control the inverter power, which mainly generates the \( q \)-axis current reference to obtain high power factor and low grid input current harmonics [22–24]. The grid voltage phase \( \theta_g \).
is detected by a phase-locked loop. Meanwhile, the generation of the \(d\)-axis current reference for flux weakening should take the dc-link voltage fluctuation into consideration [20]. The damping current can be extracted from the grid input current by an HPF and the proposed differential controller. In the voltage injection module, the damping parts are added to the motor voltage reference. Therefore, the LC oscillation components can be eliminated to achieve a high damping performance.

4.1 Grid current variation extraction

For the damping current is extracted from the grid input current, first, it is necessary to detect the grid current variation \(\tilde{i}_g\), which has a high frequency. Therefore, an HPF can be applied. The variation \(\tilde{i}_g\) is presented as

\[
\tilde{i}_g = \frac{s}{s + \omega_b} i_g
\]

where \(\omega_b\) is the bandwidth of the HPF, which is determined by the frequency of the LC resonant in (6). In order to allow the resonant components to pass through, the bandwidth must be set a suitable value, such as \(\omega_b = \omega_r / 2\) [27, 31, 32].

4.2 Grid current feedback control loop

According to Equation (4) and Figure 3, the feedback gain \(R_d\) can be regarded as a virtual damping resistor in series with the line inductor, as shown in Figure 8. It is the optimal solution to achieve high damping performance [34, 35].

Therefore, substituting \(R_g + R_d\) into Equation (4) and Equation (5), the transfer function and the stability conditions of the drive system with virtual resistor are represented as

\[
G_u(s) = \frac{1}{L_g C_{dc} s^2 + ((R_g + R_d) C_{dc} - \frac{P_L}{\bar{u}_{dc,0}}) s + \left(1 - \frac{P_L (R_g + R_d)}{\bar{u}_{dc,0}^2}\right)}
\]

\[
\begin{align*}
R_d &< \frac{P_L}{\bar{u}_{dc,0}^2} - R_g \\
R_d &< \frac{1}{\bar{u}_{dc,0}^2} - R_g.
\end{align*}
\]
However, it is still difficult to get the damping current directly in Figure 3. Therefore, the grid current feedback loop needs to be moved forward to the inverter current side, as shown in Figure 9.

Then, the proposed control algorithm is presented as

$$I_{\text{damp}}(s) = R_d \left( C_{\text{dc}} s - \frac{P_L}{\eta_{\text{dc},0}} \right) I_g(s)$$  \hspace{1cm} (11)

where $C_{\text{dc}}$, $P_L$, and $\eta_{\text{dc},0}$ are the system parameters and $R_d$ is the control parameter determined by the damping performance requirements of the drive system.

The root locus of Equation (8) with $R_d$ changes shown in Figure 10 ($L_g = 5 \text{ mH}$, $C_{\text{dc}} = 20 \mu\text{F}$), it can be seen that characteristic roots move from right to left-half plane as $R_d$ increases, which means that the drive system is more stable. At the same time, the characteristic roots move toward the real axis, which indicates that the amplitude of $L_C$ oscillations in grid current also decreased. To avoid overdamping control and obtain high damping performance, the damping ratio $\varepsilon$ often selected as $0 < \varepsilon < 1$. The optimal value is about 0.707.

On the basis of the above analysis, it can be concluded that the system stability and the feedback gain depend mainly on the system parameters. Therefore, if $R_d$ is selected based on the root locus of Equation (10), it cannot fit for different systems and the robustness of the damping control methods to system parameters is low.

According to Equation (8), the drive system is a typical second-order system and the feedback gain can be calculated as

$$R_d = \left[ (1 - 2\varepsilon^2) \eta + 2\varepsilon \sqrt{(\varepsilon^2 - 1) \eta^2 + 1} \right] n_{\text{LC}} - \frac{P_L}{\eta_{\text{dc},0}}$$  \hspace{1cm} (12)

$$n_{\text{LC}} = \sqrt{\frac{L_g}{C_{\text{dc}}}} \quad \eta = \frac{n_{\text{LC}}^2}{\eta_{\text{dc},0}}$$  \hspace{1cm} (13)

Obviously, the expression of Equation (12) contains $L_g$ and $C_{\text{dc}}$, and $R_d$ is related to the system parameters. It can be adjusted to fit different systems. Actually, according to Equation (9), Equation (10), and Equation (12), the system stability depends mainly on the ratio of $L_g$ and $C_{\text{dc}}$. The $R_d$ values with different parameters are shown in Figure 11. It can seem that $R_d$ can still be in the stable region when $L_g$ and $C_{\text{dc}}$ change.

The Bode diagram of the drive system with different values of $L_g$ and $C_{\text{dc}}$ is shown in Figure 12. It can be concluded that the stability margin is less sensitive to the changes of the $L_g$ and $C_{\text{dc}}$ with the proposed active damping controller, which could enhance the robustness of the stability strategy.

### 4.3 Motor stationary voltage injection

In the small dc-link drive system, the motor load determines the output of the inverter current. The grid current and the capacitor current must be passively followed. In order to eliminate the
LC resonance, the solution is to inject the damping current into the inverter as shown in Figure 13.

Generally, the power balance plays an important role between the grid side and the inverter side. Therefore, the damping current can be transformed into the equivalent damping power, which is injected into the IPMSM.

Ignoring the voltage drop and switching loss of the inverter, the inverter power is presented as follows:

$$P_{\text{inv}} = \frac{3}{2} (u_\alpha i_\alpha + u_\beta i_\beta)$$ (14)

where $u_\alpha$, $u_\beta$, $i_\alpha$, and $i_\beta$ are the voltages and currents in the stationary frame, respectively.

In Figure 13, the output power of the drive system can be calculated as follows:

$$P_{\text{out}} = i_{\text{dc}} u_{\text{dc}} = (i_{\text{inv}} + i_{\text{damp}}) u_{\text{dc}} = \frac{3}{2} [(u_\alpha + \Delta u_\alpha) i_\alpha + (u_\beta + \Delta u_\beta) i_\beta]$$ (15)

where $\Delta u_\alpha$ and $\Delta u_\beta$ are the injected voltages, which are generated by the damping current. Subtracting Equation (11) from Equation (12), the equivalent damping power can be given by

$$P_{\text{damp}} = i_{\text{damp}} u_{\text{dc}} = \frac{3}{2} (\Delta u_\alpha i_\alpha + \Delta u_\beta i_\beta).$$ (16)

With the bandwidth limitation of the current control loop, the damping power tends to be injected into motor voltage [27, 31, 32], as shown in Figure 7. The amplitude of the voltage vector in the stationary frame is presented as

$$|\Delta u_{\alpha\beta}| = P_{\text{damp}} \sqrt{i_\alpha^2 + i_\beta^2}$$ (17)

$$\Delta u_{\alpha\beta} = |\Delta u_{\alpha\beta}| \frac{i_{\alpha\beta}}{\sqrt{i_\alpha^2 + i_\beta^2}}$$ (18)

where $\Delta u_{\alpha\beta}$ is the injecting voltage vector.

5 | EXPERIMENTAL RESULTS

In order to verify the effectiveness of the proposed active damping control method, the IPMSM drive system with a small dc-link capacitor from Figure 7 has been established, and experiment results are carried out. The motor and the system parameters are listed in Table 1.

The experimental hardware is shown in Figure 14. The load motor was used as a generator and consumes power at a load resistor. The inverter was realized by Mitsubishi module PS21767. The proposed control method was implemented with a Texas Instruments TM320F28075 floating-point digital signal processor.

Figure 15 shows experimental results of the proposed active damping control method with different virtual damping resistors. The resonant frequency is about 500 Hz ($L_g = 5$ mH, $C_{\text{dc}} = 20$ µF). The blue, green, magenta measured waveforms are the grid voltage, the dc-link voltage, and the grid current, respectively. In Figure 15(a), the damping ratio is set as $\varepsilon = 0$ ($R_d \approx 0$ Ω) that means no damping method is applied. It can be seen that the LC oscillations between the line inductor and the grid current are too large and the amplitude of
the 9th harmonic is up to 1.05 A. The resonance harmonics in the grid current exceed the standards of EN61000-3-2. Therefore, the LC resonance degrades the quality of the grid input current and reduces the stability of the drive system. If the peak value of the LC resonance is too large, it leads to overvoltage or overcurrent faults, which may destroy the drive systems.

In Figure 15(b), the proposed active damping method with $\varepsilon = 0.35$ ($R_d = 10 \, \Omega$) is applied. It can be seen that the amplitude of LC resonance both in dc-link voltage and the grid current is still high. According to Figure 11, the drive system is operating in an under-damping state. Therefore, the active damping method cannot completely eliminate the LC resonance.

In Figure 15(c), the damping ratio is set as $\varepsilon = 0.707$ ($R_d = 20 \, \Omega$). Obviously, the LC oscillation disappears. Comparing to Figure 15(a) and Figure 15(b), as the virtual resistance increases, the stability of the system is enhanced. On the other hand, according to Figure 10, the characteristic roots of the current model move toward the real axis, so the amplitude of LC resonance in the grid current is decreased. Therefore, the proposed current model can be used to tune the control parameters of the drive system effectively.

The Fourier analysis of the grid current is shown in Figure 15(d). With the proposed method applied, the amplitudes of the 9th, 11th, and 13th harmonics are 0.38 A, 0.34 A,
Figure 17 Experimental results of the proposed damping method when $L_g = 3 \text{ mH}$ and $C_{dc} = 15 \mu\text{F}$ (waveforms are: top—grid and dc-link voltage; bottom—grid current). (a) Without the active damping method. (b) With the proposed damping control method. (c) FFT analysis results of grid current and 0.09 A, respectively. The proposed active damping method can suppress the LC resonance and enhance the drive system stability effectively. Furthermore, comparing to the voltage based method in Figure 5, the grid current is close to a sinusoidal signal, and the power factor is increased up to 0.984.

In order to validate the impact of the motor power load change on the proposed active damping effect, the experimental results of the drive system at 2500 r/min are shown in Figure 16. The simplest way is to increase the motor speed. According to [4], the ideal average value of the dc-link voltage can be calculated as $310 \times 2/\pi \text{V} = 197 \text{ V}$. Since the maximum speed of the motor is about 3900 r/min in Table 1, the operation speed can be set as $3900 \times 2/\pi \text{ r/min} = 2500 \text{ r/min}$. As shown in Figure 16, it can be seen that LC resonance reduced, the proposed method could stabilize the drive system and suppress the grid current harmonics when the power load increases.

To evaluate the effect of the changes in line inductance $L_g$ or the dc-link capacitance $C_{dc}$ on the proposed active damping method, the experimental results of a small dc-link drive system with $L_g = 3 \text{ mH}$ and $C_{dc} = 15 \mu\text{F}$ are shown in Figure 17. The resonance frequency is about 750 Hz. According to Equation (12), the virtual resistor can be calculated as $R_d = 19 \Omega$. Then, as the damping control method is applied, the amplitudes of the 11th, 13th, 15th and 17th harmonics around the resonance frequency are 0.26 A, 0.12 A, 0.03 A and 0.07 A, respectively. The grid current and the dc-link voltage distortion are reduced. It can be seen from Figure 17 that the proposed active damping method can effectively stabilize the drive system as the system parameters change.

The experimental results of the power factor and the THD at different operating speeds are shown in Figure 18. The proposed active damping method can effectively maintain a high power factor and low THD in the wide speed range. The maximum power factor is 0.984. The harmonics satisfy EN61000-3-2 and the minimum THD is 16.2%.

Besides the steady-state performance of the proposed current based active damping control above, Figure 19 shows the system transient performance when enabling the active damping control. It can be seen that the proposed active damping method can damp the LC resonance fast and effectively without generating additional transient time.

Figure 20 and Figure 21 show the dynamic load and speed performance of the proposed active damping control method. In Figure 20, the step load is changed from 1.0 to 3.2 N·m at
2000 r/min. In Figure 21, the speed is changed from 1500 to 2500 r/min at 3.2 Nm, and the acceleration time is 1000 ms. When the power load and the grid current is increasing, the proposed damping method can still suppress LC resonance effectively and it is able to handle various operating conditions properly.

6 CONCLUSION

This paper proposes a grid current feedback active damping method in the small dc-link drive system equipped with a single-phase diode rectifier. The detected current was selected as the feedback control variable, and the damping current is consistent with the LC resonance components in grid current when the dc-link voltage is low. Therefore, the system power factor and the grid current quality were improved when crossing zero. In order to improve the system stability and suppress the LC resonance, the grid current feedback control loop is established and the feedback gain is calculated based on the system parameters. The stability margin to the changes in the inductance and capacitance is analyzed. The robustness of the drive system to the parameters is also improved. Compared with the conventional voltage-based method, the proposed current based active damping method not only suppresses the LC resonance effectively but also enhances the grid input power factor. Nevertheless, the current sample delay time and the filtering delay may worse the damping performance and generate some additional harmonics in grid current. Thus, future work focuses on the damping degradation caused by these delay times.

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