Harmonic Current Suppression of MSR System Via Odd-Harmonic Fractional Repetitive Control

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Abstract: Magnetically suspended rotor (MSR) system, which possesses the remarkable characteristics of micro-vibration, no lubrication, low energy consumption, and long life span, has been widely used in a variety of rotating machine, such as molecular pumps, centrifugal compressors, and control moment gyroscopes, etc. However, due to the limited manufacturing precision and uneven electromagnetic properties around sensing surface, there exists inevitable rotor mass imbalance and sensor runout, which lead to harmonic current in coils. Research on harmonic current suppression is of great value.

Repetitive control (RC), using internal model principle, provides an effective approach to suppress harmonic signals. In the conventional repetitive controller (CRC), the ratio of sampling frequency to the fundamental frequency is an integer, and the technique has been applied to MSR system for harmonic suppression. However the rotation speed can be arbitrarily set within a large range in MSR system, which results that the ratio is often fractional with the fixed sampling rate. In this case, the gain of CRC at each harmonic frequency is reduced greatly, which leads to significant suppression degradation.

From another aspect, it is usual that the odd-harmonic components dominate the total harmonic current appearing in MSR system; if CRC is adopted in this condition, infinite gain is engendered at even-harmonic frequencies equivalently, thereby reducing system robustness without boosting its performance.

Based on the above analysis, an odd-harmonic fractional repetitive control (OFRC) strategy is proposed for MSR system in this paper to suppress odd-harmonic current. In contrast with CRC, only half of the delay units are required in the proposed control scheme and the computational burden is reduced as well. Therefore, faster convergence rate can be achieved. A modified inserted mode of OFRC is adopted in this paper for easier practical implementation. Additionally, suppression accuracy of RC is vastly improved by adopting fractional delay filters especially in fractional scenarios.

Experimental results are given. The experimental setup is composed of a power source, a communication interface, and a magnetically suspended flywheel prototype, etc. The MSR system is controlled by digital signal processor (DSP) & field-programmable gate array (FPGA) in the experiment. The current signal is detected by oscilloscope (Agilent 54624A) with the sampling frequency of 5 kHz. Experiments on a magnetically suspended flywheel have been carried out to demonstrate the effectiveness and advantages of the proposed control method, which is very suitable for micro-vibration applications with MSR system.

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