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DC Motor Speed Calculation Based on Armature Current Measurement

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***Abstract*—DC motor speed can be indirectly obtained by measuring armature current. As for steady armature current, period estimation method in time domain and spectrogram method in frequency domain have both been adopted to calculate DC motor speed, and experiment results indicate that the spectrogram method has better accuracy. As for starting armature current, the current can be de-noised by the method of wavelet packet floating threshold, its high frequency component can be extracted by a high pass filter, and DC motor speed can be calculated by wavelet analysis with high effectiveness and accuracy proven by the results.**

Keywords- DC motor speed calculation armature current wavelet packet analysis

I. INTRODUCTION

Speed is one vital parameter in DC motor test and the basis of mechanical characteristic measurement. Conventional measurement methods require the transformation from speed to electrical signal by speed sensors in order to represent speed changes by the changes of certain parameter (usually frequency) in the electrical signal, and use digital measurement methods (period measurement method, frequency measurement method and TM method) to obtain the speed[1]. The addition of speed sensors limits the application situations of speed measurement, increases system complexity, and decreases measurement efficiency. In order to improve the deficiencies above, new methods on DC motor speed indirect obtainment by measuring steady armature current and starting armature current have been presented in this paper.

II. ANALISIS ON DC MOTOR ARMATURE CURRENT RIPPLE

Whether as electromotor or generator, DC motor always has current ripples due to commutating and slot effect, so that one high frequency component, which frequency is related to motor speed, will be superposed on the armature current.[2][3]

In such supposition that DC motor has k commutating segments and p antipodes and no situations that several brushes pass through the insulated slot between commutating segments at the same time, one commutating occurs which will generate one ripple in armature current when one brush passes through an insulated slot. In one entire period, $2pk$ ripples totally will be generated because the motor has $2p$ brushes and k ripples generated per brush in one period. The relation between ripple frequency f and speed n is as below:

$$f = \frac{2pkn}{60} \tag{1}$$

Considering the situations that several brushes pass through the insulated slot between commutating segments at the same time, the relation can be modified as below:

$$f = \frac{2pkn}{60 \times G_{CD}(k,2p)} = \frac{L_{CM}(k,2p) \times n}{60} \tag{2}$$

n—DC motor speed (r/min);

f—current ripple frequency (Hz);

$G_{CD}(k,2p)$—greatest common divisor of k, $2p$;

$L_{CM}(k,2p)$—least common multiple of k, $2p$.

III. SPEED CALCULATION BASED ON STEADY ARMATURE CURRENT ANALYSIS

In this paper, the measurement on no-load steady speed is carried on one permanent-magnet DC motor labeled as 36V rated voltage, 1170~1370 r/min no-load rated speed, 23 slots and 1 antipode. By the method of flashing speed measurement, the measured no-load steady speed of this motor is 1265r/min.

A. Speed calculation based on period estimation

Motor speed can be estimated according to ripple current period. Due to the 23 commutating segments (k=23), 1 antipode (p=1) and 2 brushes of this motor, 46 armature current ripples, calculated by the method in Part II, will be generated in single period. Steady armature current is shown in Fig.1. The time of 46 armature current ripples is 0.04732s, which means single period of the motor is the same time, so the motor speed is as below:

$$n = 60 / 0.04732 = 1267.9 \approx 1268 r/\min$$

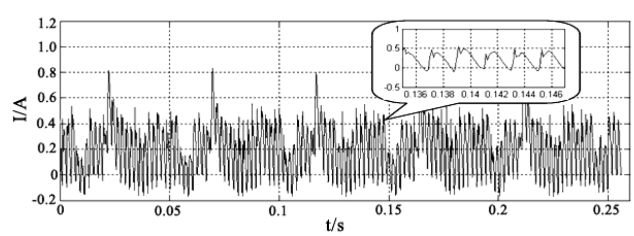

Figure1. Stable armature current

For the reason of single period estimation, the result cannot be highly accurate, so estimation of multiple ripple periods can improve the accuracy. For example, the time of 4 periods of 46 ripples, shown in the Fig.1, is 0.2115-0.02214=0.18936s and the motor speed is:

$$n = \frac{60}{0.18936/4} = 1267.4 \approx 1267 r/\min$$

B. Speed calculation based on spectrogram

After FFT transformation on steady armature current, the spectrogram and frequency of armature current can be achieved, on which base motor speed can be calculated. This method is similar with the former one but more accurate. The spectrogram of steady armature current shown in Fig.1 can be achieved shown in Fig.2. The ripple frequency is 968.8Hz, and according to Equation (2) the motor speed is:

$$n = \frac{60f}{2pk} = \frac{60 \times 968.8}{2 \times 1 \times 23} = 1263.7 \approx 1264 r/\min$$

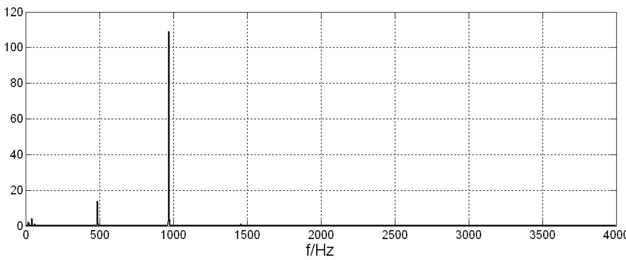

Figure2. Frequency spectrum analysis

IV. SPEED CALCULATION BASED ON STARTING ARMATURE CURRENT ANALYSIS

Armature current, in DC motor starting process, is the superposition of large amplitude DC component and small amplitude high frequency component which both components decay exponentially. The high frequency component can be extracted by high pass filter, and put into wavelet packet analysis. As result, the motor speed can be achieved by calculating.

The speed calculation principle by utilizing wavelet packet analysis: [4] firstly, filter and reconstruct the de-noised starting armature current; secondly, wavelet packets decompose on the reconstructed signals into 2^N signal coefficient packets which each packet corresponds to one frequency band and the coefficients in the packets are time sequencing. However, the coefficient packets after wavelet packets decomposition are not arranged in the sequence of frequency increasing, so it is necessary to rearrange them in such a sequence. In the rearranged coefficient packets, the maximum coefficient can be found, and the corresponding time of the coefficient is the spot when the central frequency component is the most significant. 2^N coefficient packets mean 2^N spots in time domain. According to the corresponding relation between time and frequency domains, time-frequency distribution can be achieved, and according to the relation between ripple frequency and motor speed shown in Equation (2), the motor speed-time curve can be achieved.

The calculation process will be explained in details combining practical data as below.

A. Signal de-noising

De-noising is the priority because of the massive high frequency noises in sampled armature current signals. In this paper, the method of wavelet packet floating threshold de-noising is adopted. The floating threshold is $t_k = \sqrt{2\ln(n)}\sigma \big/ \sqrt{n}$ and db10 wavelet is taken as wavelet base, because for db wavelet higher order means higher vanishing moment of wavelet function and better corresponding filter length (if vanishing moment is N, filter length is 2N) which can achieve better frequency division. As for de-noising, better frequency division is needed because the high frequency components for speed obtainment have to be extracted from the frequency division. Fig.3 shows the effect of wavelet package de-noising of armature current, and the zoomed part of this figure shows that this method has better effect and the noise components have been greatly reduced after noise smoothing, which sets a good basis for further analysis.

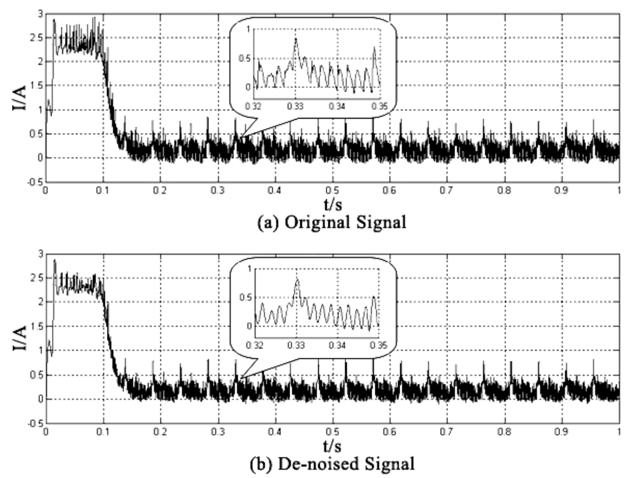

Figure3. Wavelet package de-noising of armature current

B. Filter and reconstruction

8 times decompose (decomposition times usually cover 7~10, depending on the sample frequency and usable signal's maximum frequency) on de-noised starting armature current utilizing half-band low-pass filter (db20 wavelet adopted in this paper for its good effect in frequency division). Selectively (high frequency components only) reconstruct the wavelet coefficients obtained from the former 8 times decomposition, so the high frequency components in starting armature current can be obtained shown in fig.4.

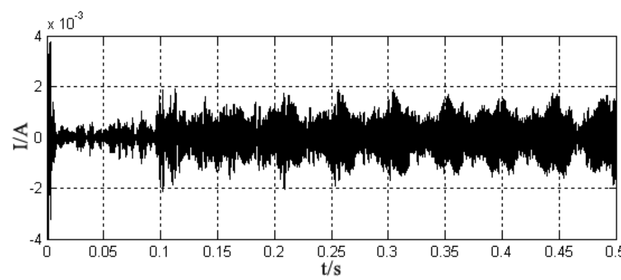

Figure4. High frequency components of armature current

C. High frequency component signal extraction by wavelet packets decomposition

4-layer wavelet packets decompose on the frequency components in fig.4, 16 signal coefficients packets can be obtained, rearrange them in the sequence of frequency increasing, find out the time spot corresponding to the maximum coefficient in each coefficient packet, draw the time-frequency distribution corresponding to the maximum coefficient, get the curve fitting of the speed and time on the 16 spots, and the speed-time curve can be achieved shown in Fig.5.

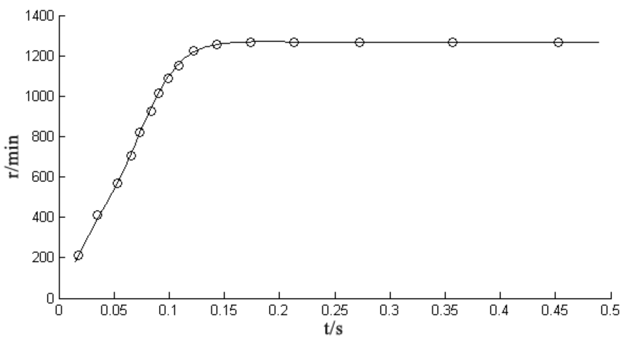

Figure5. Speed-time curve

From this speed-time curve, the motor reaches its steady speed within 0.2s after electrified, and the steady speed is 1266r/min approximately.

V. CONCLUSIONS

In this paper, three methods are adopted in DC motor speed calculation such as period estimation, spectrogram and wavelet packets analysis, which can avoid the problems as installation difficulties and adjustment complexities utilizing speed sensors. As for application situations, period estimation and spectrogram methods are suitable for analysis on steady armature current only, and wavelet packets analysis is suitable for analysis on steady armature current and starting armature current both. As for accuracy, period estimation method does not have stable accuracy for it is based on estimation, while spectrogram and wavelet packets analysis methods have higher accuracy.

REFERENCES

[1] Yang Lin. Study on the Parameter Test System of Permanent-magnet DC Motor with No-coupling Method. Harbin: Harbin Institute of Technology, 2006.(in chinese)

[2] Shumei Cui, Feng Chai, Hongxing Wu, et al. Virtual test system for permanent-magnet DC motor [J]. Journal of Harbin Institute of Technology, 2003, 35 (2):13-20.

[3] Yang Lin, Cui Shumei, Liu Manlan. Analysis of Existing Problems of Testing DC Motor Rotating Speed Utilizing Fluctuating Current[J]. Micromotors, 2007, 40(4):82-85.(in chinese)

[4] Huang Jin, Huang Jianhua, Chen Dun, et al. Measurement of DC Motor Torque-speed Characteristic Based on Wavelet Analysis [J]. Electric Machines, 2001, 28(2):49-52.(in chinese)