Erratum

Erratum to "Sideband Harmonics Identification and Application for Slip Estimation of Induction Motors Based on a Self-Adaptive Wiener Filter"

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In Section II-B2 of the above article [1], the autocorrelation function $r[\tau]$, which should be calculated through the amplitude of fundamental frequency component (FFC) of source voltage signal, was calculated through the amplitude of FFC of stator current signal by mistake. Because the amount about correction of the wrong part in Section II-B2 is a little big large, we rewrite Section II-B2 as follows:

2) FFC Suppression: The methodology for suppressing the FFC of the SC signal through the WF is to first get an estimation of the FFC of the SC signal, followed by subtracting this estimated FFC from the SC signal. Mathematically, the SC signal can be regarded as a random process $i[k]$ composed of several sinusoid random processes and AGN, i.e.,

$$i[k] = A_0\cos\left(2\pi\frac{f_e}{f_s}k+\theta_0\right) + \sum_{j=1}^{\infty}A_j\cos\left(2\pi\frac{f_j}{f_s}k+\theta_j\right)+n_I[k] \tag{14}$$

where A_j $(j = 0, 1, 2, \ldots)$ denotes the amplitude, f_j $(j = 1, 2, 3, \ldots)$ denotes the frequency of harmonics in the SC signal, f_s denotes the sampling rate, $n_I[k]$ denotes the AGN, and θ_j $(j = 0, 1, 2, \ldots)$ denotes the phase of harmonics in the SC signal, which are independent of each other and subject to uniform distribution between $-\pi$ and π. Furthermore, for conducting MCSA, the SV and SC signals are usually recorded when the induction motors are in steady or quasi-steady operation state. Thus, the AGN mainly originates from the measurement error, which has been reduced significantly due to technological advance in digital sampling. As a result, the mean value and average power of $n_I[k]$ are considerably small, which can be neglected.

Due to frequency fluctuation, the actual frequency of the FFC of the SC signal cannot be definitely determined. However, in alternating current circuit, the current frequency is determined by the voltage frequency, which means that the frequency of the FFC of the SC signal is equal to the frequency of the FFC of the SV signal. The mere differences between the FFCs of the SC and SV signals exist in the aspects of amplitude and phase, due to the impedance of induction motors. Therefore, it is reasonable to use the FFC of the SV signal as the input of the WF to estimate the target signal, namely the FFC of the SC signal. The random process $u[k]$ related to the FFC of the SV signal can be expressed as

$$u[k] = B_0\cos\left(2\pi\frac{f_e}{f_s}k+\theta_0+\theta\right)+n_U[k] \tag{15}$$

where B_0 denotes the amplitude, θ denotes the phase difference between the SC and SV signals due to the impedance of the induction motor, and $n_U[k]$ denotes the AGN in the SV signal, which can be neglected as $n_U[k]$ of the SC signal.

Then, through (8) and (15), the autocorrelation function $r[\tau]$ of the FFC of the SV signal can be expressed as

$$r[\tau] \approx \frac{B_0^2}{2}\cos\left(2\pi\frac{f_e}{f_s}\tau\right) \tag{16}$$

and through (7), (14), and (15), the cross correlation function of the FFCs of the SV and SC signals is given by

$$p[\tau] \approx \frac{A_0B_0}{2}\cos\left(2\pi\frac{f_e}{f_s}\tau+\theta\right). \tag{17}$$

Because the mere distinctions between the FFCs of the SV and SC signals are the amplitude and phase, if B_0 and θ in (15) are estimated, so is the FFC of the SC signal. For sinusoidal signals, the phase shift operation can be realized through a length-2 convolution. Thus, the number of tags of the WF only needs to be 2. Then, based on (4), (9), (10), (13), (16), and (17), we get the estimation of the FFC of the SC signal, i.e., $I_{\mathrm{FFC}}[k]$, as

$$I_{\mathrm{FFC}}[k] = \left(\begin{bmatrix} \frac{B_0^2}{2} & \frac{B_0^2}{2}\cos\left(2\pi\frac{f_e}{f_s}\right) \\ \frac{B_0^2}{2}\cos\left(-2\pi\frac{f_e}{f_s}\right) & \frac{B_0^2}{2}\end{bmatrix}^{-1} \cdot \begin{bmatrix} \frac{A_0B_0}{2}\cos\theta \\ \frac{A_0B_0}{2}\cos\left(-2\pi\frac{f_e}{f_s}+\theta\right)\end{bmatrix}\right)^{\mathrm{T}} \cdot \begin{bmatrix} u_{\mathrm{FFC}}[k] \\ u_{\mathrm{FFC}}[k-1]\end{bmatrix}. \tag{18}$$

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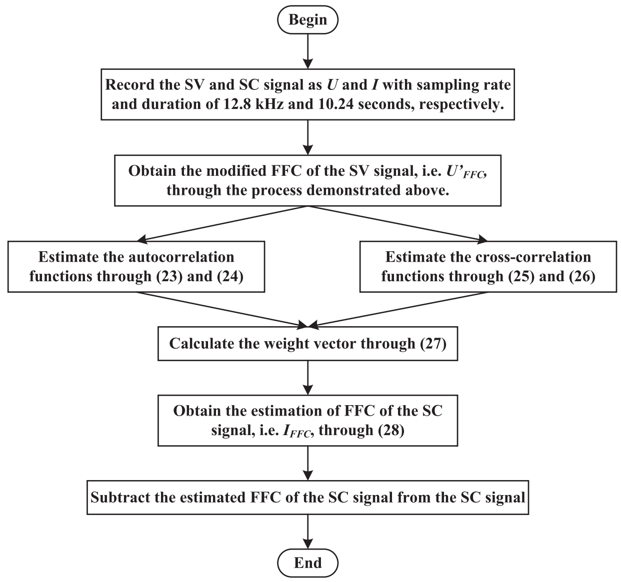

Fig. 1. Correction of Fig. 4 in [1].

Due to ergodicity, the ensemble average of wide-sense random process equals the time average of random process [40]. Then, if the sampling duration is long enough, we get

$$\frac{B_0^2}{2} \approx \frac{1}{N}\sum_{k=0}^{N-1} u_{\mathrm{FFC}}[k]u_{\mathrm{FFC}}[k] \tag{19}$$

$$\frac{B_0^2}{2}\cos\left(2\pi\frac{f_e}{f_s}\right) \approx \frac{1}{N}\sum_{k=0}^{N-1} u_{\mathrm{FFC}}[k+1]u_{\mathrm{FFC}}[k] \tag{20}$$

$$\frac{A_0B_0}{2}\cos\theta \approx \frac{1}{N}\sum_{k=0}^{N-1} u_{\mathrm{FFC}}[k+1]i[k] \tag{21}$$

$$\frac{A_0B_0}{2}\cos\left(-2\pi\frac{f_e}{f_s}+\theta\right) \approx \frac{1}{N}\sum_{k=0}^{N-1} u_{\mathrm{FFC}}[k-1]i[k]. \tag{22}$$

Based on (18)–(22), $I_{\mathrm{FFC}}[k]$ can be calculated. Then, the FFC of the SC signal can be suppressed by subtracting the FFC estimation from the SC signal, i.e., $i[k]-I_{\mathrm{FFC}}[k]$. The approach for FFC suppression proposed here is straightforward and only depends on the recorded data of SV and SC signals without the need to the actual value of FF, which reveals its inherent self-adaptability.

Thus far, correction about the wrong part in Section II-B2 of [1] is completed. Because one formula is removed from [1], the numbers of the formulas following Section II-B2 of [1] should be reduced by one. In addition, due to the change of formula numbers, Fig. 4 in [1] should be changed to Fig. 1 in this Erratum.

References

[1] Y. Fu, L. Cheng, J. Yu, X. Duan, and H. Tian, “Sideband harmonics identification and application for slip estimation of induction motors based on a self-adaptive Wiener filter,” *IEEE Trans. Instrum. Meas.*, vol. 72, pp. 1–12, 2023, doi: 10.1109/TIM.2023.3289561.