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An easy-implemented confidence filter for signal processing in the complex electromagnetic environment

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ABSTRACT

With the fast development of microgrids in more electric aircrafts and ships, the higher reliability of signal acquisition and processing systems are required in the complex electromagnetic environment. This paper presents a novel easy-implemented nonlinear confidence filter to record data accurately and reliably extract in the case of the complex electromagnetic environment, which can retains the convictive signal characteristics, and eliminates the noises. The arithmetic of the signal confidence takes consideration of the influence of the amplitude deviation and time deviation, which is implemented with synthesize two evaluated indexes based on fuzzy control strategy. The experimental results show that, the reliability and timeliness of the signal can be guaranteed in the complex electromagnetic environment.

1. Introduction

With the fast development of microgrids (MGs) in more electric aircrafts and ships, the electrical equipment with various power levels is integrated in limited space [1–4]. Thus, a complex electromagnetic environment appears in MGs. Meanwhile, compared with conventional MGs in the power system, many of different sensors are used [5] for system health-status monitoring and also real-time protection. Hence, a highly reliable and robust signal process system is required in complex electromagnetic environments.

In aircrafts and ships, the fuel supply system is the core system [6], which is complex and varying. Its subsystem operates in the severe environment with high temperature vibration and multiple interferences [7], which can be either mechanical or electrical with different frequencies and statistical properties. The high *du/dt* or *di/dt* could be generated by the switching of power semiconductors used in the high power electronic equipment in the system [8], such as the airborne power source and motor-driven fuel pump. The motor drive in the fuel pump is taken as an example, which is a high power system used for variable frequency speed control. In this case, both the high-frequency chopping and low frequency commutating noises are emitted in operation [9]. Furthermore, the interference frequency changes with the speed and load variation. Therefore, the signal processing system is exposed to an extreme electromagnetic interference environment, where an anti-interference design is necessary to ensure the reliability and robustness of the processing.

Due to its high precision, high signal-to-noise ratio (SNR) and high reliability, the digital anti-interference filter is an effective method to eliminate electromagnetic interferences [10]. Digital finite-impulse response (FIR) filters [11–14] and Digital infinite-impulse-response (IIR) filters [15–18] can often provide a high performance in wideband image/video processing systems [15]. The FIR filters have a truly linear phase characteristic. However, the computational cost of the FIR filters is high, and the step response delay is long. By contrast, the IIR filters often provide a much better performance and less computation cost. However, because the error surface of IIR filter is usually nonlinear and multimodal, conventional gradient-based design methods may easily be stuck in the local minima of error surface [15]. As aforementioned, in various power electronics control systems, the noise is wideband [14], including high-frequency chopping noises and low frequency commutating noises.

Different from classic digital filters, a novel nonlinear filter is presented in this paper to increase the reliability of the signal processing. With the proposed algorithm, the comprehensive influence of the amplitude deviation and time deviation can be determined. Moreover, the filter is implemented based on the fuzzy-logic control. The paper is organized as follow. The theory and the structure of the proposed confidence filter is introduced firstly. Then, the evaluation and calculation method of the signal confidence are given. Furthermore, a first-order RC filter is illustrated to elaborate the proposed filter frequency

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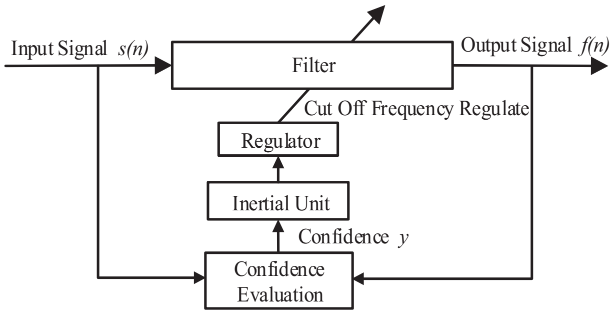

Fig. 1. Structure of the proposed confidence filter.

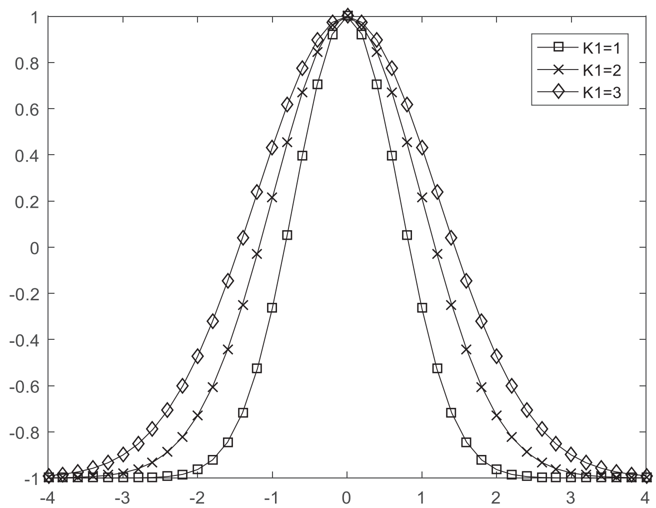

Fig. 2. Curve of evaluation function E_1 (p).

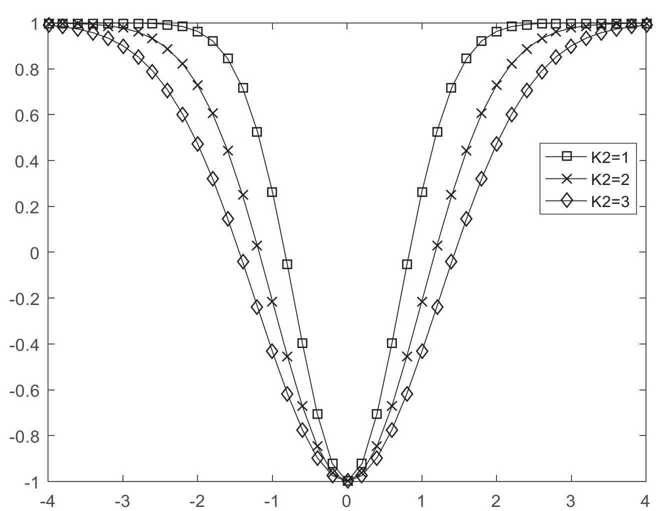

Fig. 3. Curve of evaluation function E_2 (p).

regulation capability. Finally, the experiment results are given to verify the effectiveness of the proposal.

2. Operational principle

Considering numerous sources, complex radiation rules, wide frequency bandwidth, the relationship between the space and the interference signal distribution can vary significantly [19]. Thus, it is difficult to build up an interference transfer model. Moreover, using the frequency domain analysis to design the filter for signal processing is also a challenging task. Therefore, a modified nonlinear filter algorithm taking the signal confidence as basis is proposed, and its structure is shown as Fig. 1.

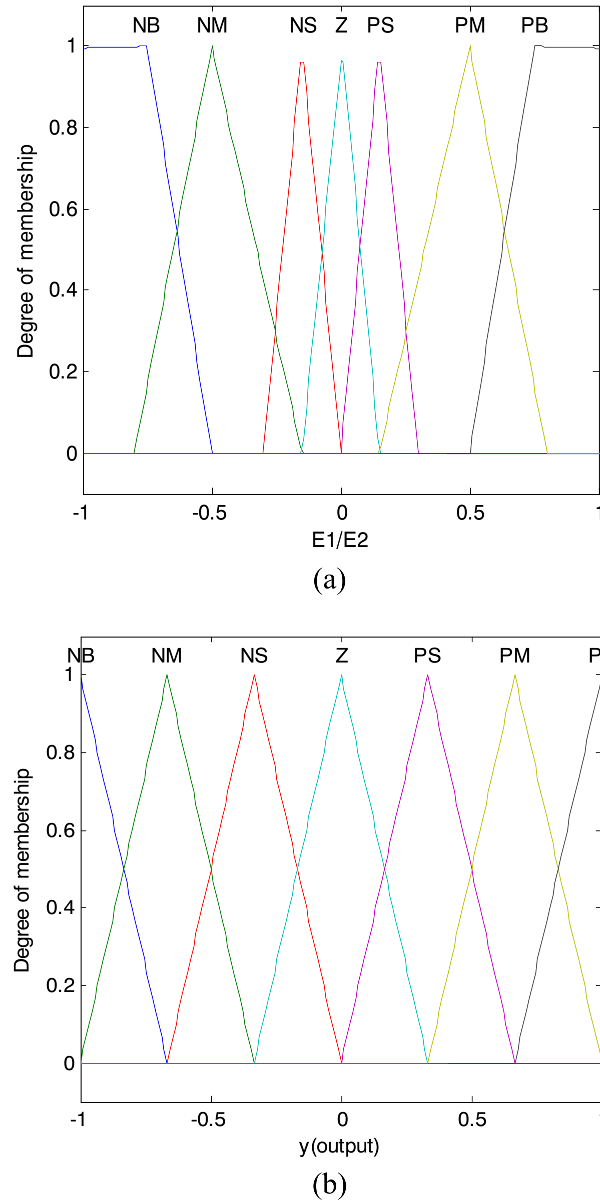

Fig. 4. Membership functions of the evaluation functions. (a) input index E_1 and E_2. (b) output index y.

The designed confidence filter can be applied as the low-pass characteristic. Most of the processing signals vary slowly but continuously. Therefore, when the input signal has an abrupt change, such as high power electronic equipment in start-up, the output signals deviate from the preconception. The exceptional change can be a normal variation or environmental noise. Considering the finite noise energy, the environmental noise has a limited impact on the input signal in a short period. Moreover, the frequency of environmental noise is higher. Consequently, a “confidence evaluation” unit is used to evaluate whether the signal change is induced by the environmental noise, as shown in Fig. 1.

If the input signal is changed by the environmental noise, the “confidence evaluation” unit determines that the current signal is not trustable and thus the signal confidence of the current signal is “low”. Being considered as noise, the signal is then modified by the “inertial unit”, and it is further passed to the “regulator” unit. The “regulator”