An Impulse Interference Suppression Algorithm for Electric Energy Data Acquire System

Li Qilin[1, a], Wang Wupeng[2], Qin Jian[1], Xiang Jingrui[1], Li Fangshuo[1]

[1] Metering Center of Sichuan Electric Power Corporation, Chengdu, China

[2] National Key Laboratory of Science and Technology on Communications, Chengdu, China

[a]li_qi_lin@163.com

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Abstract. Impulse interference is one of the major interferences in power system, and the existed algorithms mainly focus on narrow-band interference when using wireless communication, which have little effect on impulse interference. Aiming at this problem, this paper proposes an impulse interference suppression algorithm combined with adaptive gain control (AGC) in Electric Energy Data Acquire System, which uses correlation of the interference to suppress the interference. Simulation results show that: On the condition of Gaussian noise plus impulse interference, when the interference to signal ratio (ISR) is 25 dB, compared with AGC, the algorithm can have a 1.2~5.1 dB promotion of the bit error ratio (BER).

Introduction

As the rapid development of the communication technology and the microelectronic technology, The Electronic Power System develops gradually towards informatization and intellectualization. The Electric Energy Data Acquire System is an important part of Smart Grid which covers the power users and electrical information [1]. Stable and reliable communication network is the guarantee of energy data acquisition. Compared with the optical fiber network, wireless communication network has a lower cost, and can directly use of the existing mobile communication network to establish connections quickly.

In the complicated wireless environment, Electric Energy Data Acquire System will be affected by kinds of interferences, impulse interference is one of the main interferences. Impulse interference has a big influence on system performance due to their short duration and big instantaneous power.

Common algorithms in mobile communication system, such as the temporal prediction, transform domain interference suppression and code auxiliary algorithm mainly focus on narrow-band interference. As the impulse interference is unpredictable, temporal prediction algorithm based on interference prediction technology can’t effectively suppress impulse interference [2,3].What’s more, as the frequency band of impulse interference is wide, transform domain interference suppression technology of spectral line treatment will lead to loss of useful signal, which affect system performance heavily [4]. Code auxiliary algorithm needs large amount of calculation, and it can only be adopted after synchronization, while systems can’t be well synchronized in the case of strong impulse intensity [5]. Above all, these interference suppression technologies do not get well performance in the field of impulse interference.

Local discrete cosine transform can accurately describe the signal characteristics of the different period of time, adaptively tracking signal changes [6,7], which can be used to suppress various time-varying impulse interference. But the algorithm is complicated, especially it is hard to get the best basis function, which brings certain difficulty to engineering implementation. As the burst error caused by impulse interference can be detected by error correction coding, communication system often adopts interleaving with forward error correction coding method to solve the error brought about by the impulse interference [8,9]. But these systems can introduce large delay causing by encoding and decoding, which are not suitable for fast real-time demand.

Aiming at these problems, this paper proposes an impulse interference suppression algorithm, which suppresses the interference energy in the use of AGC and make full use of the related characteristic of the signal at the same time, in which interference suppression matrix is constructed for subsequent interference suppression. Simulation result shows that in the AWGN channel plus impulse interference model, the proposed method is superior to the traditional AGC on condition of different ISR in the BER performance.

System Model

Electric Energy Data Acquire System consists of three parts: Master station, communication network and collectors, its structure is shown in Fig. 1.Master station is the center of Electric Energy Data Acquire System, which is responsible for controlling the data acquire terminals, processing and sharing information of electric energy, and offering the data interface to services of electric power department and the marketing applications. Communication network provides a communication channel to connect data acquire terminals and master station, including fiber optic private network, 230 MHz wireless private network, CDMA/3G wireless public network, etc.

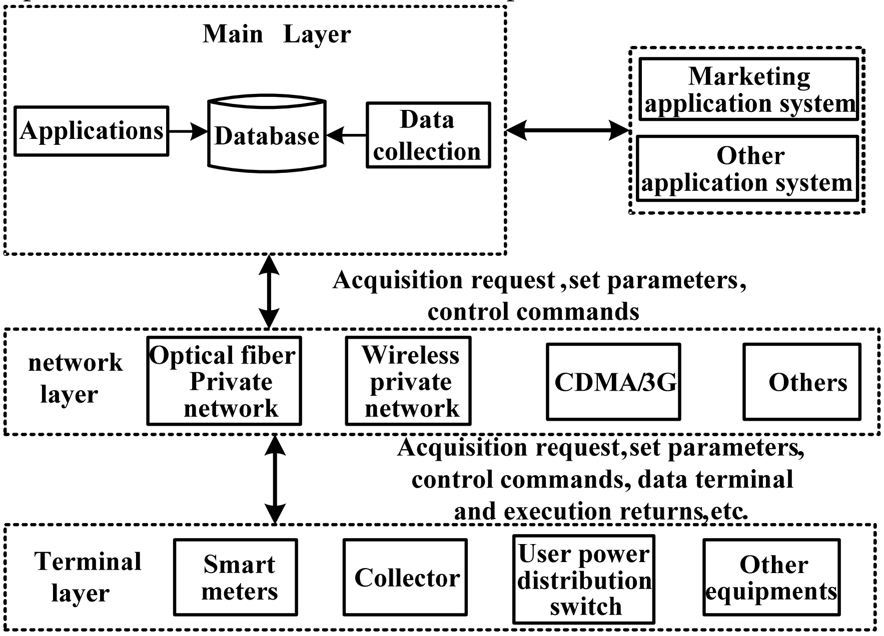

Figure 1 Structure of electric energy data acquire system

Taking single input single output CDMA system for an example, when despreading received signal without interference suppression, the despreaded signal can be expressed as

$$u(t) = v(t)c(t)\cos(2\pi f_c t) + i(t) \tag{1}$$

Where $v(t)$ is baseband signal sending by transmitter, $c(t)$ is spread spectrum code generated by a random sequence generator, and $i(t)$ is impulse interference.

After dispreading on the received signal, we can get

$$u(t)c(t) = v(t)c(t)\cos(2\pi f_c t) + i(t)c(t) \tag{2}$$

The power spectrum and signal form of impulse interference is similar to the random sequence $c(t)$, which have a certain correlation, so that the interference part $c(t)i(t)$ is also an impulse. This will lead to distortion of the useful signal, affecting the subsequent demodulation which in turn makes system performance deterioration.

Impulse Interference Suppression Algorithm

Taking anti-jamming capability, signal energy loss and the degree of difficulty in implementation into consideration, this paper combines AGC with interference suppression to suppress the impulse interference. Our algorithm firstly implements AGC to the received signal according to the amplitude fluctuation degree, cutting down the energy intensity of impulse interference. Then, we suppress the interference part of gain controlled signal, taking advantage of related characteristics of received signal.

The proposed method can suppress the impulse interference and avoid loss of useful signal at the same time, besides, as the intensity of the impulse is cut down, it is easy for receiver to realize synchronization, which benefits despreading in the receive end.

Implementation. After removing out-band interference and noise by matched filter, the received signal can be expressed as:

$$r(n) = s(n) + j(n) + n(n) \tag{3}$$

Where *r*(*n*) is the received signal, *s*(*n*) is the desired signal, *j*(*n*) is impulse interference, *n*(*n*) is white gaussian noise.

Firstly, we cache the received signal into a vector, in which every M chips are composed into a M dimensional vector, the k^{th} received vector can be expressed as:

$$\hat{r}[k] = [r(kM), r(kM-1), \ldots, r(kM-M+2), r(kM-M+1)]^T \tag{4}$$

$(.)^T$ denotes vector or matrix transpose and k≥1, $\hat{r}[k]$ is defined as:

$$\hat{r}[k] = s[k] + j[k] + n[k] \tag{5}$$

Where, $\hat{r}[k]$ denotes M dimensional received vector, *s*[*k*] denotes M dimensional direct spread spectrum signal vector, *j*[*k*] denotes M dimensional impulse interference vector, *n*[*k*] denotes M dimensional white gaussian noise vector.

After gain controlling to the cached signal, we can get:

$$r[k] = \hat{r}[k] / RMS(\hat{r}[k]) \tag{6}$$

RMS(.) denotes root mean square value of a vector, so that computing root mean square value of vector $X = [x_1, x_2, \ldots, x_M]$ an be expressed as:

$$RMS(X) = \sqrt{\frac{x_1 + x_2, \ldots, + x_M}{M}} \tag{7}$$

Since the spread spectrum code has good autocorrelation, this feature can be used to implement interference suppression to received signal. First of all, estimate *P*[*k*], which is the inverse matrix of autocorrelation matrix of the received signal vector. Then use *P*[*k*] do linear transformation to received signal vector, by doing these steps, the received signal vector $\hat{r}[k]$ after narrowband interference suppression can be got. The process is shown as follow:

$$\tilde{r}[k] = \hat{r}[k] r[k] \tag{8}$$

After normalization and sampling recovery the signal after interference suppression can be restored to normal receiving signal:

$$\dot{r}(n) = \tilde{r}_i[\left\lfloor \frac{n}{M} \right\rfloor] \tag{9}$$

Where $i = n - M\left\lfloor \frac{n}{M} \right\rfloor$, $\lfloor \square \rfloor$ denotes round down function, $\tilde{r}_i$ represents the i^{th} element of $\tilde{r}$.

Estimation of autocorrelation matrix. When the prior information of interference have obtained, Let $P[k] = R^{-1}[k]$ or $P[k] = (R_j[k] + \beta I)^{-1}$. $R[k]$ denotes M dimensional autocorrelation matrix of the received signal vector, $R_j[k]$ denotes M dimensional autocorrelation matrix of the interference vector, I is M dimensional unit matrix. $\beta \geq 0$, the typical value is 0 or σ^2 , σ^2 is the power of white noise, $(.)^{-1}$ represents inverse matrix.

When the prior information of interference is unknown, $P[k]$ is estimation of R^{-1} $[k]$ $R^{-1}[k]$, There are many ways to estimate $R^{-1}[k]$, such as the least squares algorithm, recursive least squares algorithm, etc. Taking recursive least squares algorithm for example to show how to get $P[k]$.

Firstly, initialize the matrix, that is set $P[0]$ and the convergence factor λ. Let $P[0]=I_M$, where I_M is M order unit array, and $0<\lambda<1$.

Update the intermediate vector can be expressed as:

$$k[k] = \frac{P[k-1]r[k]}{\lambda + r^H P[k-1]r[k]} \tag{10}$$

Update matrix P[k], we can get:

$$P[k] = \frac{1}{\lambda}\{P[k-1] - k[k]r^H[k]P[k-1]\} \tag{11}$$

Thus, the inverse matrix of autocorrelation matrix of the received signal vector can be got by recursive way.

Simulation results

In order to verify the algorithm performance, simulation parameters are shown in Table 1.

Table 1 Simulation Parameters

SNR	-14 dB、-8 dB
System setup response time	15 [s]
System query response time	5 [s]
Channel	AWGN
Interference type	Impulse (Duty ratio 20%)
Modulation type	BPSK
Spreading factor	50

The system BER performance of different interference suppression algorithms of are shown in Fig. 2 and Fig. 3.

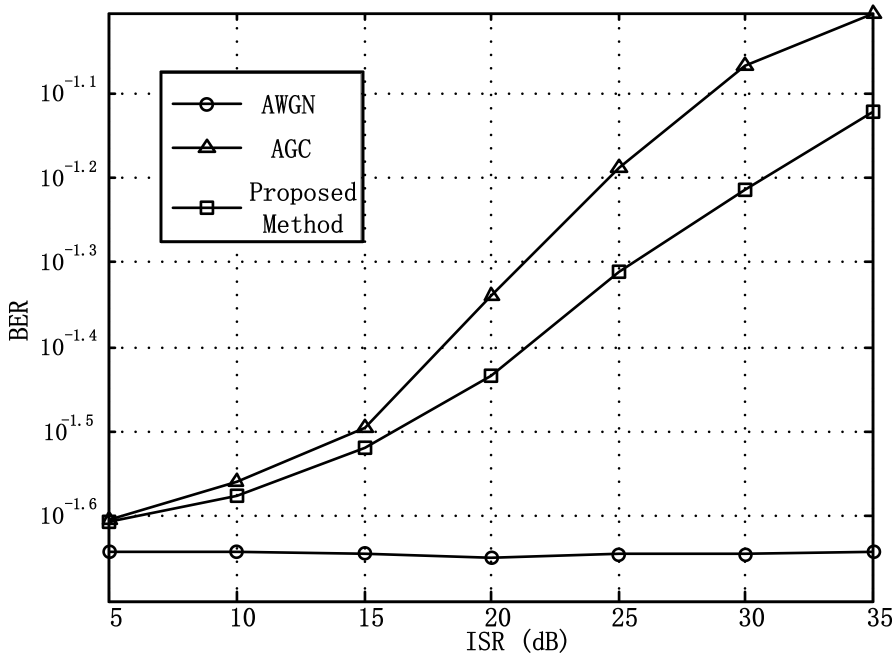

Figure 2 SNR = -14 dB

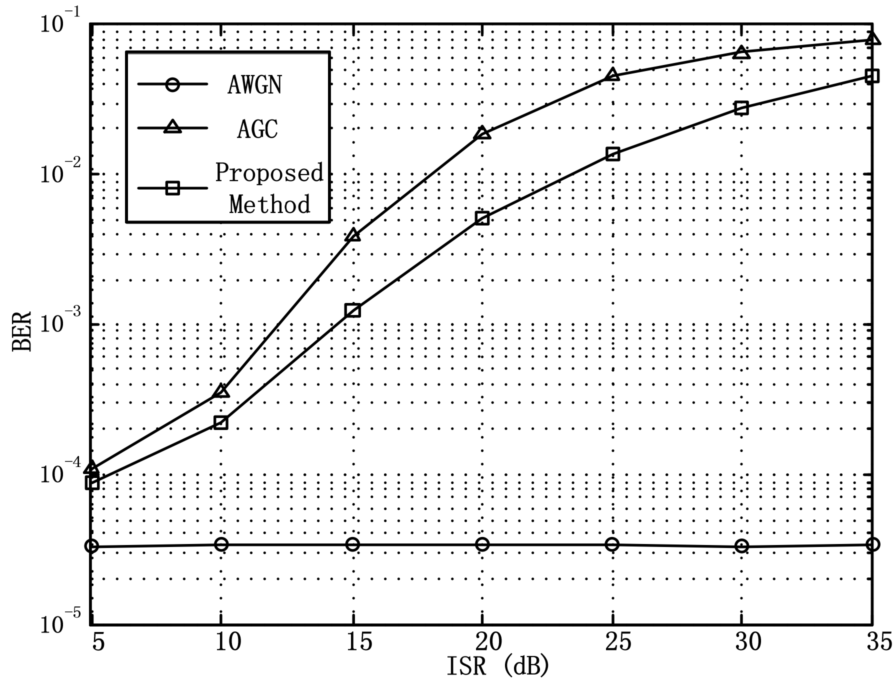

Figure 3 SNR = -8 dB

It can be seen from the simulation result that when SNR is -14 dB and -8 dB, ISR is 25 dB, The system BER performance improvement is 1.2 dB and 5.1 dB compared with the original AGC. The reason is that the proposed algorithm cuts down impulse interference signal power and makes full use of the autocorrelation characteristic of the jamming signal to suppress interference at the same time, which has obtained a better interference suppression effect.

Summary

This paper proposes an impulse interference suppression algorithm combined with adaptive gain control (AGC) in Electric Energy Data Acquire System, which uses correlation of the interference to suppress the interference. The algorithm can be implemented by adding an interference module without changing the existed system, which is easy to implementation in project. Simulation shows that under the condition of different SNR, when ISR is 25 dB, proposed method has a 1.2 to 5.1 dB benefits in BER performance to the original AGC. The method proposed in this paper presents an effective way of solving impulse interference, which can be implemented in the Electric Energy Data Acquire System using wireless network to communicate.

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