'90 KACC 1990. 10. 26~27

A METHOD OF ALTERNATING NOISE-CANCELING FOR AN INSTRUMENTATION USING A PAIR OF IDENTICAL POTENTIAL TRANSFORMERS

Katsutoshi Mine, Masato Kitazaki, Katsuyoshi Wakabayashi, Yuji Morimoto
Department of Electrical Engineering
Faculty of Engineering

Kyushu Institute of Technology, Kitakyushu city, 804 Japan

ABSTRACT

This paper describes a new method of noise-canceling in an instrumentation using a pair of identical Potential Transformers (PT). This method allows us to get reliable signals without any noise, not only on the transmission line, but also on the sensors; even if we do not have a reference noise or a specific noise. In this case "any noise" means normal mode noise (NMN), under a quarter frequency of the switching.

We proposed to call this method alternating noise-canceling (ANC). The accuracy of this new method has been verified by experimentations.

1. INTRODUCTION

Recently inaccurate data has been a problem in the instrumentation and control of electrical power systems because of noise. Malfunctioning is another problem caused by noise. Another problem has occurred when testing the power characteristics of commercial based electric generators and transformers. In this situation noise induced on the transmission line by electro-magnetic interference distorts instrumentation[1].

Random noise is generated by the vibration of electrons in the sensor and in the instrumentation circuit[2]. Wiener[3] and Kalman and Bucy[4] have presented methods for countermeasuring random noise. If the signal and the noise are separated in the frequency domain, the noise can be reduced by filtering or by using a cepstrum[5]. These methods effectively reduce both additive and convoluted noises. By acquiring the reference noise, the adaptive noise canceler cancels the noise[6]. The noise within the signal is reduced by finding the specific noise[7], even if neither the signal nor the noise can be separated in the frequency domain. The switching noise is canceled by using a sensor and a sensordummy[8], but this method cannot cancel noise on a transmission line. We have proposed three methods of alternating noise-canceling(ANC). These methods do not need the acquiring of the reference noise for noise canceling even if the signal and the noise can not be separated in the frequency domain. One method uses a sensor-sensordummy[9], the second method used a dual sensor and finally, the third method uses one sensor for the purpose of canceling noise on the transmission line[10]. The noise added on the transmission line between the sensor and the analog switch could not be canceled using all of these methods.

In this paper we will discuss a new method of ANC. The problem which arises between the sensor and the analog switch is eliminated by using this method.

We made two signals using a pair of PT. The first signal was made by the first PT which was connected 'order connection' to a transmission line by an analog switch. The second signal was made by the second PT which was connected 'reverse connection' to the transmission line by the analog switch. We subtracted the second signal from the first signal, and got a reliable signal without the noise not only on the transmission line but also on the sensor. In this case 'any noise' means normal mode noise (NMN) which frequency is under a quarter frequency of the switching frequency.

The accuracy of this method, without acquiring the reference noise, has been verified by experiments even where there was signal overlap noise in the frequency domain.

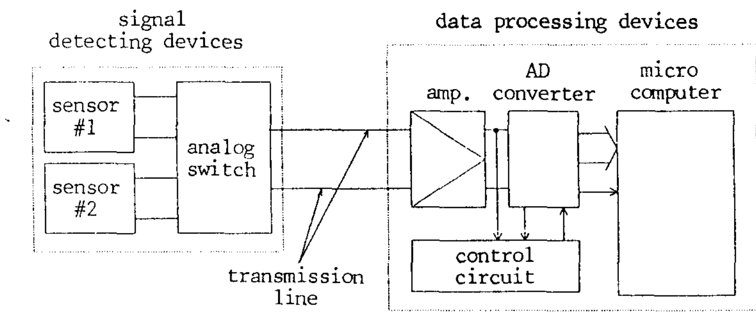


Fig. 1 Schematic diagram of Alternating Noise-Canceling System

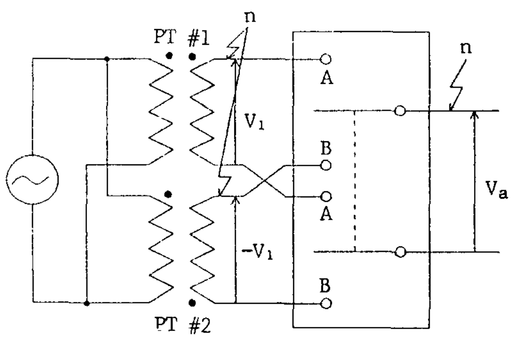


Fig. 2 Block diagram of detecting devices. Where "n" is noise. When an analog switch selects "A", the output (v_a) is a positive signal with noise (V_1+n). When an analog switch selects "B", the output (V_a) is a negative signal with noise ($-V_1$+n).

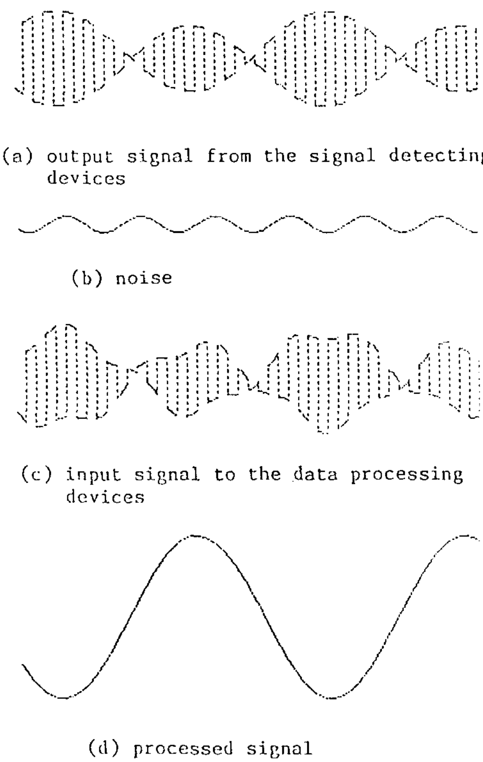


Fig. 3 The waveform of each devices in ANC system.

2. ANC

Fig. 1 shows a schematic diagram of the ANC system. This system is composed of three parts: signal detecting devices, a transmission line and data processing devices. Fig.2 shows a block diagram of signal detecting devices. The signal detecting devices have two sensors and an analog switch. The two sensors have the same characteristics and detect the same object. "Sensor #1" connected orderly and "Sensor #2" connected reversely. Since an analog switch selects one of these sensors alternately, the output of the signal detecting devices becomes a time-sharing signals (positive signal and negative signal).

Fig. 3(a) shows a waveform of this signal. When noise mixes in the sensors or the transmission line, the input to the data processing devices is a positive signal with noise $(Va)_{i-1}$, and then a negative signal with noise $(Va)_i$ alternately. Figs. 3(b) and 3(c) shows these waveforms.

From Fig. 1 and Fig. 2

$$(V_a)_{i-1}=(V_1+n)_{i-1} \quad \text{at } t=i-1 \qquad (1)$$

$$(V_a)_i=(-V_1+n)_i \quad \text{at } t=i \qquad (2)$$

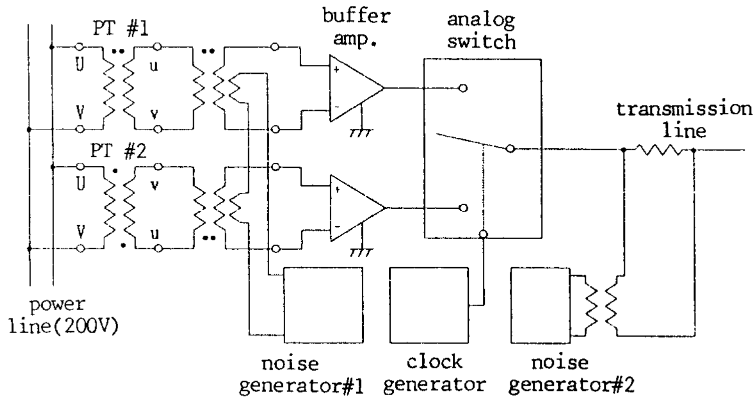


Fig. 4 Details of the signal detecting devices.

In the data processing devices these signals are sampled, and then converted to digital data. The sampling and AD conversion are synchronized with the alternating switching by a control logic circuit. The input to the microcomputer is discrete and has a time lag between $(V_a)_{i-1}$ and $(V_a)_i$. Interpolation processing is done by microcomputer. The interpolation value of the opposite signal with noise at t=i-1 is composed for as follows:

$$(\hat{V}_a)_{i-1}=((V_a)_i+(V_a)_{i-2})/2$$

$$=(\widehat{-V_1+n})_{i-1} \qquad (3)$$

In the microcomputer the subtractive processing is done using the Eq. (4) at t=i-1, and the noise is erased and we have only twice the amplitude of the signal that Fig. 3(d) shows.

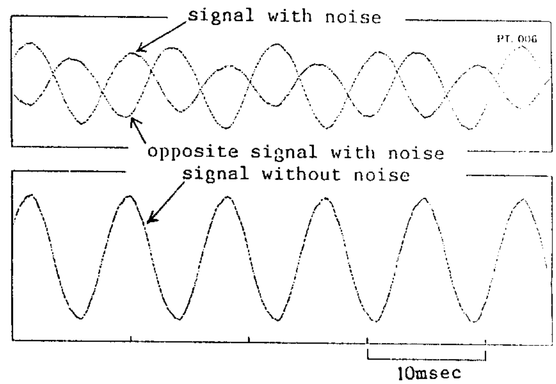
$$(V_a)_{i-1}-(\hat{V}_a)_{i-1}=(V_1+n)_{i-1}-(\widehat{-V_1+n})_{i-1}$$

$$\fallingdotseq(2V_1)_{i-1} \qquad (4)$$

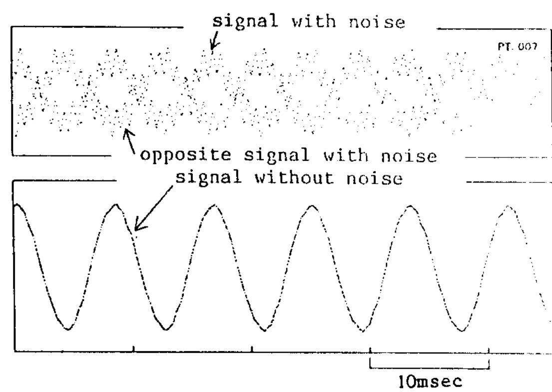
where, $(V_1+n)_{i-1}=(V_1)_{i-1}+(n)_{i-1}$
$(\widehat{V_1+n})_{i-1}=-(\hat{V}_1)_{i-1}+(\hat{n})_{i-1}$
$(V_1)_{i-1}\fallingdotseq(\hat{V}_1)_{i-1}$, $(n)_{i-1}\fallingdotseq(\hat{n})_{i-1}$

3. THE RESULTS USING ANC METHOD

In this experiment, we measured a commercial frequency voltage,(60Hz, 200V). Fig.4 shows the details of the signal detecting devices.

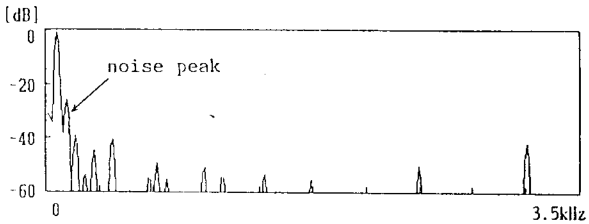


(a) n_1 : 120Hz , n_2 : 120Hz



(b) n_1 : 360Hz , n_2 : 720Hz

Fig. 5 The results of noise-canceling.
Where; n_1:the noise induced to sensors
n_2:the noise induced to the transmission line.



(a) signal with noise

(b) signal without noise

Fig. 6 The power spectrum of the waveform in Fig. 5(a).

The primary rated voltage of the PT is 220V and the secondary voltage is 110V.

In this case a second transformer was connected to the output of the PT. Noise was added to a second transformer and to a transmission line using a noise-generator. The frequency of alternating switching is 14kHz.

In the control logic circuit the time-sharing signal is changed to a differentiation signal using HPF (High Pass Filter). This signal is absolutely amplified and changed to pulse using a one-shot multivibrator. The phase of this pulse is stabilized using PLL (Phase Locked Loop), and this pulse is used as a synchronizing pulse. Figs. 5(a) and 5(b) shows the results of this experiment.

In Figs. 5(a) and 5(b), the noise is induced to sensors and to the transmission line. Figs. 6(a) and 6(b) show the power spectrums one of these results. In Fig. 6(a) we can recognize the noise peak, but in Fig. 6(b) the noise peak disappears.

The results of these experiments are that the noise has been canceled using the ANC method and we have obtained only the signal without noise.
We evaluated the validity of the ANC method by using a cross-correlation function shown in Eq.(5)

Table 1 The evaliatioin by cross-correlation function and SNR.

noise frequency[Hz]		cor(a)	cor(b)	SNR(a)	SNR(b)
n_1	n_2				
60	60	0.953	0.999	23.926	48.590
120	120	0.963	0.999	17.197	50.736
360	720	0.927	0.999	18.836	49.913

n_1 : The noise induced in sensors

n_2 : The noise induced on the transmission line

$$R=\frac{\Sigma xy}{\sqrt{\Sigma x^2+\Sigma y^2}} \quad (5)$$

where, X:original signal
Y:signal with noise (cor(a))
signal without noise (cor(b))

Furthermore, in order to examine the degree of the noise-reduction, we made an evaluation by using the SNR (Signal to Noise Ratio) shown in Eq. (6).

$$SNR=20\log_{10}(rms(s)/rms(n)) \quad (6)$$

where, rms(s):r.m.s. value of signal
rms(n):r.m.s. value of noise

Table 1 shows the results of the cross-correlation and the SNR. "cor(a)", "SNR(a)" are the results before noise-canceling and "cor(b)", "SNR(b)" are the results after noise-canceling.

From these results we can say the validity of this method has been verified.

4. CONCLUSION

(1) We have developed a method of noise-canceling in an instrumentation, using a pair of identical PTs, analog switch, an AD converter and a microcomputer.

(2) This method allows us to get reliable signals without any noise not only on the transmis-

sion line, but also on the sensors, even if we do not have a reference noise or a specific noise.
(3) The accuracy of this method has been verified by experiments and evaluation using the cross-correlation function and SNR.

ACKNOWLEDGEMENT

The authors wish to express their sincere appreciation to president S.Shibata of Yasukawa Control Sales Co.LTD.

REFERENCES

[1] Y.Murayama, "Countermeasures and obstacles of electro-magnetic interference against the wiring of instrumentation and control". J.of The Institute of Electrical Installation Engineers of Japan. pp.505-511, July, 1989.

[2] L.Jones and A.F.Chin, Electronic Instruments and Measurements. pp.282-296, New York:Wiley, 1983.

[3] N.Wiener, Extrapolation, Interpolation and Smoothing of Stationary Time Series, The M.I.T. Press, 1949.

[4] R.E.Kalman and R.S.Bucy, "New results in linear filtering and prediction theory," Trans. ASME, Basic Eng., pp.95-108, March 1961.

[5] R.C.Kemerait and D.G.Childers, "Signal detection and extraction by Cepstrum techniques," IEEE Trans. Inform. Theory, Vol.IT-18 no.6, pp.745-759, 1972.

[6] B.Widow and R.Winter, "Neural nets for adaptive filtering and adaptive pattern recognition," IEEE Comput., Vol.IT-18 no.3, pp.25-39, 1988.

[7] K.Mine, K.Ogawa, M.Yamada, Y.Morimoto and Y.Jinnouchi, "A method for the removal of the specific noise." Acta IMEKO 1988, Applications, pp.55-62, 1989.

[8] H.Ozaki and K.Taniguchi, Sensor and Signal Processing, Tokyo: Kyoritsu, 1988.

[9] K.Mine and Y.Morimoto, "A method of noise-canceling for an instrumentation using a sensor-dummy," Trans. IEICE Japan, Vol.E73, No.5, pp.684-687, May 1990.

[10] K.Mine and Y.Morimoto, "Methods of Alternating Noise-Canceling for an instrumentation using strain gages", IEEE Trans. Ind. Electro. Vol.37, No.3, pp.250-252, June 1990.