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Data Transmission through Power Line of Smart Transmitter

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Abstract

In this study, the method to use the phase shift keying (PSK) communication technique in smart transmitter is presented. In nuclear applications, smart transmitters for various parameters are expected to improve the accuracy of measurement and to reduce the load of calibration work. The capability of communication in field level is the most important merit of the smart transmitter. The most popular method is using of digital and analog techniques simultaneously - transmitting measurements from the field at 4~20mA while modulating the current to carry digital information in both directions over the same twisted pairs. Conventional smart transmitters use the frequency shift keying (FSK) method for digital communication. Generally, however, the FSK method has the speed limit at 1200 bps. Amount of information to transmit becomes increasing as the processing technique is improved. The PSK method is noticeable alternative for high speed digital communication, but it has non-zero DC component. In order to use the PSK method in the field transmission with smart transmitter, the method to remove the DC component is studied in this work.

1. Introduction

Most electronic process control loops use transmitters to convert low-level sensor outputs to standard 4~20mA signal spans. Some signal processing is performed in conventional units - for instance, cold junction compensation and linearization are often implemented in temperature transmitters. Distributing microprocessor intelligence to transmitters can lead directly to lower instrument maintenance and inventory costs with greater flexibility and better overall loop performance. Smart transmitters for various parameters are expected to improve the accuracy of measurement and to reduce the load of calibration work. In nuclear applications, the digital data processing of the smart transmitter can be expected to provide more operation margin by reducing the uncertainty due to the instrumentation system. The capability of communication in field level is the most important merit of the smart transmitter. In recent years, the importance of field communication is more and more emphasized[1].

Digitization at the transmitter for direct interfacing to a data bus or computer port is feasible and is being used in many integrated digital systems. However, till now, the approach has neither gained broad acceptance for upgrading existing plants nor for new units in established facilities because it implies dramatic modifications to installed plant wiring and commitments to communication links for which no standards are available.

2. Communication Methods

An alternative is to employ digital and analog techniques simultaneously - transmitting measurements from the field at 4~20mA while modulating the current to carry digital information in both directions over the same twisted pairs. This utilizes existing equipment and techniques for process computer input/output and permits the gradual introduction of smart transmitters into existing plants, without forcing users to make early decisions about protocols, data formats, and error checking techniques. The conventional use of the smart transmitter with controller and computer terminal is as shown in Figure 1. With the technique of transmitting digital signal over the power line with conventional analog signal, the remote configuration which is the most important function of smart transmitter can be performed[2].

This study is concentrated on the physical layer of OSI model (physical transmission method). There are several conventional methods used in this layer. The properties of several representative transmission methods are listed in Table 1.

Table 1. The properties of several representative transmission methods

Method	Property	
	General characteristics	DC component
ASK	high quality but low baud rate	non-zero
FSK	low baud rate	zero
PSK	high baud rate	non-zero

The DC component of digital communication carrier should be zero because non-zero DC component affect on the analog 4~20mA signal. In the view point of DC component, the FSK method is the most suitable alternative[3,4]. Generally, however, the FSK method has the speed limit at 1200 bps. Amount of information to transmit becomes increasing as the processing technique is improved. The PSK method is noticeable alternative, but it has the problem of non-zero DC component. In order to use the PSK method in the field transmission with smart transmitter, the DC component should be removed.

3. Modeling and DC Component Calculation of the PSK Method

The DC component of communication signal, S_{DC}, can be defined as follows :

$$S_{DC} = \frac{1}{T}\int_0^T S(t)dt \tag{1}$$

where, T : average time [sec]

$S(t)$: waveform of communication signal [V]

In smart transmitter application, S_{DC} should be zero in order not to affect the measurement signal of 4 ~ 20mA.

In this paper, the signal of the differential phase shift keying (DPSK) communication method which has the 2400 bps data transmit rate is modeled. The DPSK changes the phase of carrier wave by the 2 bit digital data (4-ary modulation). The phase of 45 °, 135 °, 225 °, and 315 ° are used[5,6]. This means that the phase of carrier wave is changed 1,200 times in 1 second. From equation (1), the DC component, S_{DC} , of DPSK signal can be calculated as follows :

$$S_{DC} = \frac{N/B}{B}\left[\int_0^{1/B} A\cos(2\pi f_c + \phi_1)dt + \int_{1/B}^{2/B} A\cos(2\pi f_c + \phi_2)dt + \dots + \int_{(B/N-1)/B}^{(B/N)/B} A\cos(2\pi f_c + \phi_{B/N})dt\right] \tag{2}$$

where, B : transmit speed [#/sec]

N : controller sampling rate [#/sec] = 1/sampling period

A : Amplitude of carrier signal [V]

ϕ_n : 45 °, 135 °, 225 °, or 315 ° (depends on content data of signal)

f_c : carrier frequency [Hz]

When we determine B=1200 [#/sec], N=100 [#/sec], A=0.9 [V], and f_c = 1800 [Hz] for 2400 bps DPSK modem, from equation (2), the DC component can be calculated. ϕ_n is set randomly. Figure 2 shows the results of S_{DC} along the carrier frequency. S_{DC} of N=100 is greater than that of N=10. That is, controller samples the measurement signal faster, the DC component affection of PSK communication method becomes severer.

As shown in Figure 2, by the carrier frequency tuning, the DC component of PSK modulation method can be removed. Following equations show the tuned carrier frequency for M-ary PSK modulation method. The carrier frequency, f_c^0 , which makes the DC component zero can be calculated as follows :

$$\frac{\log_2 M}{R} = \frac{n}{f_c^0} \tag{3}$$

$$\therefore f_c^0 = \frac{n}{\log_2 M} R = nB \tag{4}$$

where, R : data transmit speed [bps]

M : M-ary modulation

n = 1,2,3 ...

For 2400 bps, 4-ary modulation DPSK modem, the carrier frequency should be 1200 Hz or 2400 Hz as shown in Figure 2.

4. Simple Experiment and Result

In order to prove the validity of the model in the paper, simple experiment is designed and carried out. The communication signal shape is acquired by high speed oscilloscope, and transmitted to the analysis computer. Figure 3 shows the acquired signal shape of 2400 bps, 4-ary modulation DPSK modem. In the case of N=100, the expected value of S_{DC} is 0.0319 [V/sec] by the model calculation. The average value of S_{DC} in the experiment is 0.0299 [V/sec]. This experiment shows 6.27 % error from expected value. However, when we take into account of inaccuracy of oscilloscope instrumentation, this experiment is believed to show the validity of modeling successfully.

5. Conclusion

In order to meet need of high speed digital communication, application of the PSK modulation method to smart transmitter is expected. The PSK method, however, has non-zero DC component. In this study, the DC component generated by PSK method is modeled and simple experiment is performed to prove the validity of the model. 2400 bps, 4-ary modulation DPSK modem is examined. By the established model, it is shown that the DC component can be zero in certain carrier frequencies. This shows that the PSK modulation method can be applied to smart transmitter when the carrier signal frequency is well-tuned. The modeling presented in this paper can be extended to the other PSK modulation methods by simple modification.

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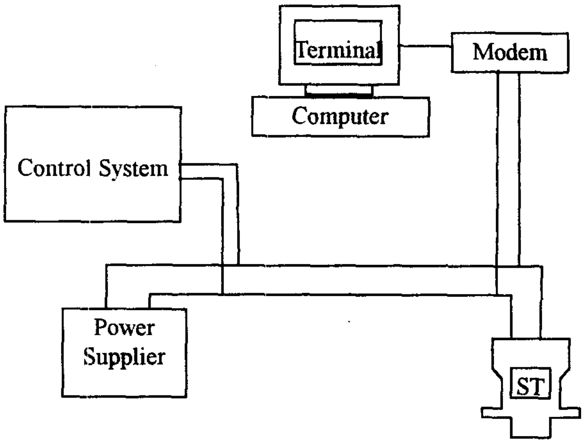

Figure 1. The conceptual diagram of smart transmitter installation

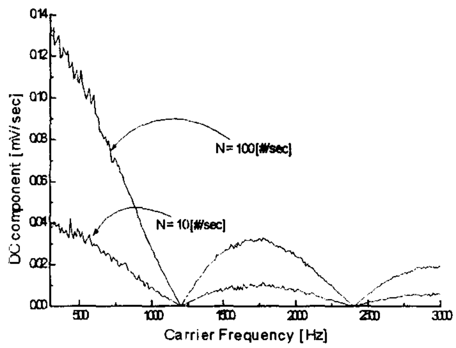

Figure 2. The results of S_{DC} along the carrier frequency

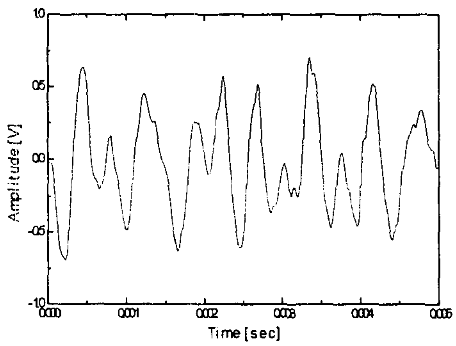

Figure 3. The acquired signal shape of 2400 bps, 4-ary modulation DPSK modem