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A Study of the Real-time Sensing by the Optical Current Sensor for GIS

Won-Zoo Park* · Yeong-Min Kim**

Abstract

In this study, a Web server was constructed using LabVIEW's DataSocket, which makes possible acquisition, analysis, and saving in real time. The output value of the optical current sensor at the web server PC was measured and the output value was displayed using the Web browser of the client PC. DataSocket by LabVIEW makes the construction of a Web server easier than other languages and is compatible with other application programs.

An optical current sensor was composed using a 1310 [nm] laser diode, and 9/125 [μm] standard single mode optical fiber and was created to be a close type sensor. Data measurement using Web servers has the advantage of monitoring electric power systems at a great distance and can fuse IT technology and electric power systems.

Also, this measurement uses inexpensive mounting and programming when compared to existing measurement equipment allowing the construction of a measurement system in any situation or surrounding.

Key Words : Magneto-Optical Current Transformer, Online Monitoring, Faraday Effect

1. Introduction

Supply power has been on an increase in terms of voltage and capacity in an effort to satisfy the sharply rising demand for electricity. Under these circumstances, GIS has advantages in electrical insulation and compact installation capacity. For accurate, reliable regular diagnosis, which is necessary for the prevention of accidents and stable operation, therefore, it is essential to secure online voltage/current measurement and partial discharge detection technologies.

In addition, as technologies have become more complicated due to fusion, requiring better compatibility, the power IT industry has become more important. Power IT refers to artificial intelligent devices and systems that make real-time communication-based operating control and monitoring possible by applying IT technology to the conventional analogue-based power industry. Both the government and the private sector have made great investment in the power

* Main author : Professors at Yeungnam Univ.
** Corresponding author : Senior Researcher Hyosung Corporation
Tel : +82-53-810-2581, Fax : +82-53-810-4767
E-mail : wzpark@yumail.ac.kr
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IT industry [1].

This study has complemented the disadvantages of conventional CT and measured current using optical current sensors which have signal output fit for an intelligent transformer substation. LabVIEW's DataSocket-based web server was then established, and a current monitoring system fit for a digital substation prepared.

2. Theories

2.1 Faraday Effect

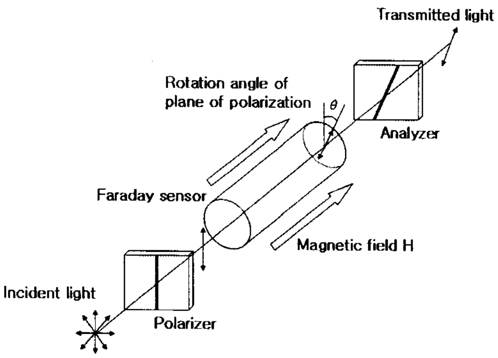

Fig. 1. A schematic diagram of the Faraday Effect

$$\theta = V \cdot H \cdot L \cdot \cos\Phi \quad (1)$$

Here,

V: Verdet constant [rad/A]

H: Magnetic field imposed on the medium [A/m]

L: Length of element (optical axis) [m]

Φ: Angle between the direction of the light and magnetic field

For optical current measurement, the Faraday Effect is used, in which the polarization axis is rotated by a magnetic field in the case in which an optical signal is delivered to the inside of the magnetic medium. Fig. 1 shows a schematic diagram of the Faraday Effect, a magneto-optical phenomena. When linearly polarized optical signals pass through Faraday elements, the vibration axis of the polarization rotates by θ as shown in Equation (1). The rotation angle θ on the plane of polarization is satisfied with the primary current [2-4].

2.2 Signal processing methods

Maximum sensitivity and linearity are acquired when the angle (45[°]) between the analyzer and initial polarization board (I=0) is measured. The light signals measured at the Photo Detector (PD) become dependent on the function ($e(t)$) of light intensity change and noise ($n(t)$) in the optical circuit. Despite the proportion between the Faraday rotation and induced current I, the relationship between measured currents is non-linear.

The Polarization Beam can be separate by a cast of orthogonal two vector ingredient ($\theta = \pm 45°$) using PBS. By using a Polarization Beam Splitter (PBS), the linear relationship between the Faraday rotation and the induced current can be estimated after calculating the non-linear relationship. The two output signals of the PBS can be stated as Equation (2) and Equation (3) which include AC and DC components and noise that occurs in the joint of optical elements in optical circuit [5-6].

$$J_a = \frac{J_1 e(t)}{2}(1 + \sin 2\theta) + n_1(t) \quad (2)$$

$$J_b = \frac{J_2 e(t)}{2}(1 - \sin 2\theta) + n_2(t) \quad (3)$$

Here,

$J_{a,b}$: PBS output signal

$n_{1,2}(t)$: Noise in optical circuit

$e(t)$: Optical density change in light source

DC and AC components can be stated as $\frac{J_{1,2}}{2}$ and $\pm\frac{J_{1,2}}{2}\sin 2\Theta$ respectively. The elements that have impact on linearity and sensitlity of optical current are noise ($n_{1,2}(t)$) in the optical circuit and light intensity ($e(t)$). These factors have a great impact on the linearity and sensivity of optical current. However, they can be improved by signal processing. In Equation (4), Equation (2) and Equation (3) have been calculated for signal processing.

$$\frac{AC_a}{DC_a} = -\sin 2\Theta \frac{2n_1(t)}{J_1 e(t)}$$
$$\frac{AC_b}{DC_b} = \sin 2\Theta \frac{2n_2(t)}{J_2 e(t)}$$
$$S_{out} = \frac{AC_a}{DC_a} - \frac{AC_b}{DC_b}$$
$$= -2\sin 2\Theta + \frac{2[J_2 e(t) n_1(t) - J_1 e(t) n_2(t)]}{J_1 J_2 e(t)} \quad (4)$$

S_{out} is approximated to $J_1 \approx J_2 = J_0$, $n_1(t) \approx n_2(t) = n(t)$ and stated as follows: [7-8]

$$S_{out} \approx -2\sin 2\Phi_F \quad (5)$$

2.3 Data sharing

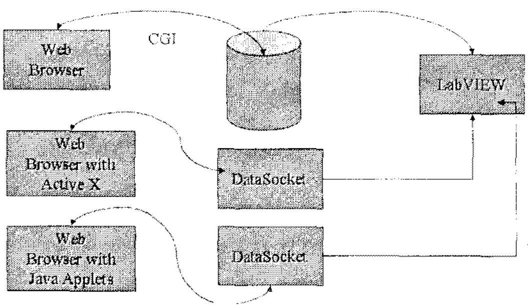

Fig 2. Data sharing between LabVIEW and application program

To share data through the network in LabVIEW, CGIscript and DataSocket should be used. Fig. 2 shows a schematic diagram of the data sharing between LabVIEW and application programs.

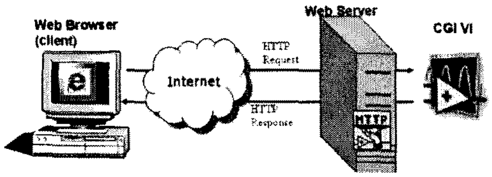

Fig 3. A schematic diagram of CGI

Fig. 3 shows a schematic diagram of Common Gateway Interface (CGI). CGI is the standard of application programs and information servers such as HTTP and web server. CGI programs exist in and are executed by web servers. They are executed on a real-time basis and create HTML pages (Dynamic HTML) [9].

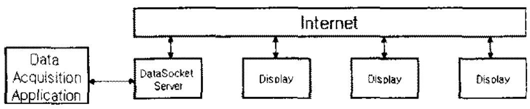

Fig 4. A schematic diagram of DataSocket

Fig. 4 shows the schematic diagram of DataSocket. The programming technology on real-time data sharing is used between different application programs in the same computer or among different computers through the network.

The DSTP (DataSocket Protocol) is an application layer protocol on measured data. It is supported under different environments such as Java, C++ and VB. A system that includes DSTP data is generally converted into three configurations: ① the DataSocket server, ② Publisher and ③ Subscribers. Publisher requests data from local and remote data collection equipment and sends them to the server. Subscriber can then request data from the server.

A client maintains a session while communication with the server continues. The information the client provided to the DataSocket server as measured data is sent from Publisher. The client that converts the measured data provided from Publisher is sent to Subscribers.

3. Signal processing by optical current sensor

3.1 Test equipment and methods

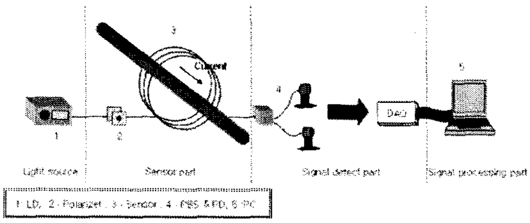

Fig. 6. A schematic diagram of the optical CT

Test equipment can be divided into four sectors as shown in Fig. 6.

The laser diode with a 1,310nm light source was used. Using the Faraday Effect, the sensor part in which current was measured was wound with optical fiber (9/125[㎛]) and configured in a closed loop. The signal detection section converts optical into electrical signals using PD after separating two crossed vector components.

The signal processing section in which signals can be collected on a real-time basis, analyzed and stored at the same time consists of LabVIEW-based optical current signal processing and a DataSocket-based web server.

3.2 Output result of optical current sensors

Fig. 7 shows a schematic diagram of the signal processing. Even though there are many signal processing methods for optical current sensors, the signal processing with the highest sensitivity and the lowest error rate was used.

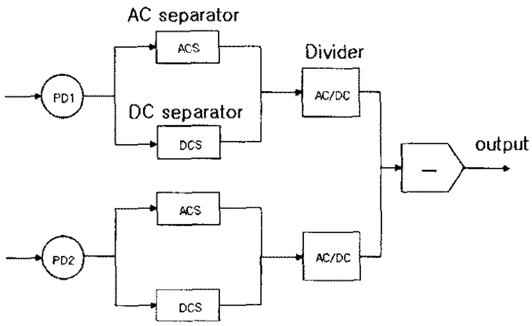

Fig. 7. A schematic diagram of the signal processing

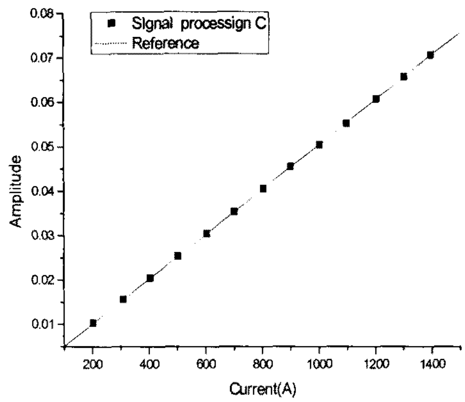

Fig. 8. A comparison between the signal processing C and a reference value

Each PBS signal has been divided into AC and DC components to avoid the change in polarization by the change in light intensity. The function for the change in noise in the optical circuit and the output of light source has been eliminated to acquire stable signal output.

In Fig. 8, the signal processing output shows high linearity and sensitivity after eliminating the impact of light intensity and noise in the optical circuit.

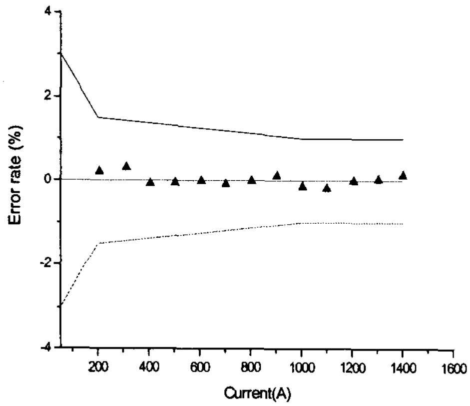

Fig. 9. Error limits of the accuracy class 1 after the signal processing

In particular, in terms of output error rate after the signal processing using Equation (6), stable error rates (within 1[%]) were observed in 200-1,400[A] (Fig. 9), compared to Class 1.

$$E = \frac{I_{out} - I_s}{I_s} \qquad (6)$$

Here,

I_{out}: FOCS output signal,

I_s: FOCS output reference value

4. Network-based remote monitoring

4.1 Test equipment and methods

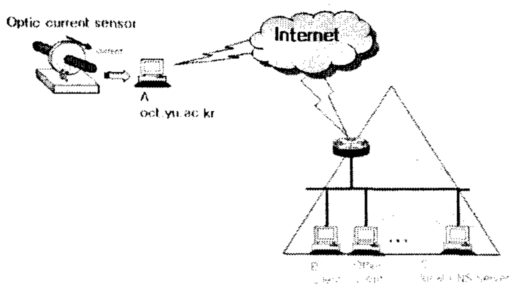

Fig 10. A schematic diagram of network for remote monitoring

In Fig. 10, 'A' is the server that collects and provides current data using optical current sensors. It was implemented using DataSocket, which was supported by Windows XP-based LabVIEW.

'B' is a client through which signals can be checked at optical CT from a remote location. The widely used Windows XP-based Internet Explorer was used as software.

'C' is a local Domain Name System (DNS) that is used only to help Client B easily get access to Server A.

LINUX 9.X-based BIND 8.X was configured. Among zone databases, the domain names and IP addresses in Computer A were inputted in a file that handles forward zone (/var/named/db.xxxx.xxx).

4.2 Test results

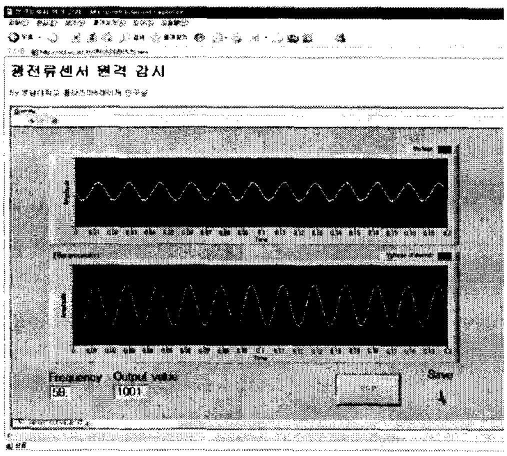

Fig 11. Online measurement based on Web

Fig. 11 shows a search of data that are being measured at optical current sensors after accessing 'A' with a domain name at Computer B. The figure illustrates online monitoring in which an operator can utilize web-based monitoring despite being in a remote location. This was programmed based on LabVIEW's DataSocket. Using a web browser, the measured values can be easily displayed.

6. Conclusion

This study has configured optical current sensors that fit an intelligent closed-loop substation using 1,310[nm] laser diode or single mode 9/125 [㎛] and a system through which current can be measured from a remote place using LabVIEW's DataSocket, which is successfully operated in the digital network of a substation.

After applying 200-1,400 [A] of current, web-based measurement / monitoring was enabled using a web browser at a client PC.

The said results are available as basic data for the establishment of a system through which remote current monitoring could be enabled.

Because of the relatively low-priced equipment as compared to current equipment and programming-based measurement, a flexible measurement system available in any circumstances has been established.

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Biography

Won-Zoo Park

Won-Zoo Park was born in Korea in 1954. He graduated from Yeungnam University in 1978 He obtained his M.S. from Yeungnam University, Korea in 1980 and his Dr. Eng. from Kyushu University, Japan in 1993. Presently he is a Professor at Yeungnam University. His research interest is plasma process and application.
Tel : (053)810-2581
E-mail : wzpark@yumail.ac.kr

Young-Min Kim

Young-Min Kim was Born Sep 15th, 1979. He graduated from the Electrical Engineering Department of Yeungnam University with a Bachelors degree and with his Master's in Electrical Engineering from the same. Currently, he is a Senior Researcher at Hyosung Corporation.
E-mail: kym1777@hyosung.com