보안등 전기설비의 Igr 누설전류 검출 및 원격감시장치 개발

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Development of Remote Supervision System for Guard Lamps by Way of Leakage Current(Igr) Detection Method

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Abstract : The present study presented the implementation of a remote control/supervision system for guard lamps used in public illumination with little endeavor by far for safe management, which makes possible to supervise the state and to control the functions remotely including electric safety elements. Especially, the developed system adopts the measurement algorithm for detecting resistive leakage current(Igr) flowing based on the phase difference checkable for sensing at a monitor, being allowable for monitoring at MMI and transmitter for data transmittance. To verify reliability about the algorithm to accurately detect Igr leakage current, the laboratory-based functional test was performed.

초 록 : 본 논문에서는 일반용 전기설비 중에서 전기안전관리의 사각지대로 분류되는 보안등 전기설비를 대상으로 전기안전요소들을 계측하고 원격 모니터링 할 수 있는 보안등 원격점검시스템을 개발하였다. 단말기에서 센싱하는 누설전류는 위상차 측정법을 이용한 저항성분 누설전류(Igr) 측정 알고리즘을 이용하였으며, 계측데이터 전송을 위한 중계기와 MMI에서 모니터링 할 수 있는 시스템을 제작하였으며, Igr 누설전류 검출 알고리즘의 타당성을 확인하기 위해 실험실 기반의 성능시험으로 누설전류의 안정도를 확인하였다.
Key Words : resistive leakage current(Igr), gurad lamp, remote checkup system

1. Introduction

The Electrical Facilities for general use(below 75 kW capacity) are under regular checkups in every 1, 2 or 3 years by KESCO(Korea Electrical Safety Corporation) according to Article 66, Electrical Business-Related Law, where inadequate devices must be properly repaired or replaced. Meanwhile, the 2006 safety checkup report issued by KESCO showed that the inadequacy ratio with regards to guard lamps and street lamps was found up to 15%, arguing that there be a big problem in safety management. Under the situation there recently emerged a social issue that the non-execution for monitoring safety matters as for lamps in elevated position gives rise to more probable risks such as electric shock especially in rainy season[1,2].

In this regard, IT-based technological alternative could be adoptable; for example, to remotely monitor/supervise safety factors against illuminating systems. It is Japan that is at the forefront in this field, being

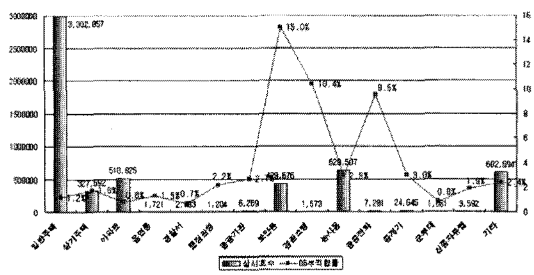

Fig. 1. The results of Electrical safety checkup.

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widely put into practice largely driven by safety-related associations. The technological development as for Korea has been attempted being centered on remote supervising system for electric leakage, smart home electic panel, etc. in connection with power-IT project and Smart-Grid project[3,4].

In this paper the principal concern is paid on guard lamps among street illuminating equipments which are, however, deemed as blind zone setting apart from proper safety controlling; more specifically, the study developed the system applicable for remote monitors as to guard lamps by designing related hardware/ software and performing the in-field application test while in consideration of cost, applicability and adoptability.

2. Remote Control/Monitoring System for Guard Lamps

2.1. Safety Management as to Guard Lamps

The electric installation categorized to guard lamps across the nation shares 7.4%(1,276,880units) out of total electrical Facilities for general use, the maintenance of which is assigned to local self-government, while being carried out for their safety checkups by KESCO periodically every third year. Fig. 2 shows the supervision tree; to wit, KESCO is responsible for in-field testing and report of its result to the concerned autonomous authorities, and then troubled devices/equipments are to be repaired or replaced by dedicated service providers through contracting with local governmental bodies, and finally the troubleshooting is reconfirmed by KESCO again[5].

Given the fact that, however, the newest guard lamps can be legally facilitated in highly elevated position(exceeding 3m), accessibility for safety check-up is actually hindered, being exposed as potent risks. What is worse, in spite of many reports related with malfunction of guard lamps by residents, the related local authorities cannot keep pace with the demand because of lack of manpower and budget, accordingly forcing guard lamps scattered across the nation being left at the dead zone.

2.2. Remote Checkup System

The remote electric safety checkup system as described in Fig. 3 is as follows; detecting(sensing) data for voltage/current and leakage current from electric distribution boxes each of which is equipped in every guard lamp is conveyed to a relay system by way of wireless communication method; from a relay system to a server, wired/wireless communications method such as TCP/IP or CDMA is made; finally, the central monitoring station monitors and controls the lamps on basis of real-time. The configuration as such can be divided into three segments; namely, terminal system model to measure electricity-related safety factors, repeater(network) model to transmit the supervision data, and server model to provide remote checkup service based on the acquired data.

3. Dvelopment of Remote Supervison System

3.1. Igr Current Detection

The phase difference measurement is to be performed phase difference using circuit-based induced voltage and leakage current measured by zero current transformer(ZCT) to detect ground insulation resistance. In other words, Igr resistive leakage is calculated from the vector value based on phase difference Θ, mak-

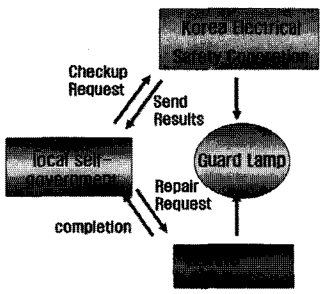

Fig. 2. The system of guard lamp safety checkup.

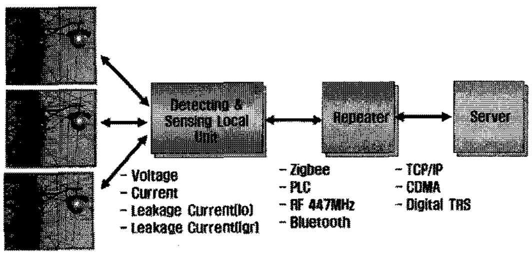

Fig. 3. The System of remote checkup for guard lamp.

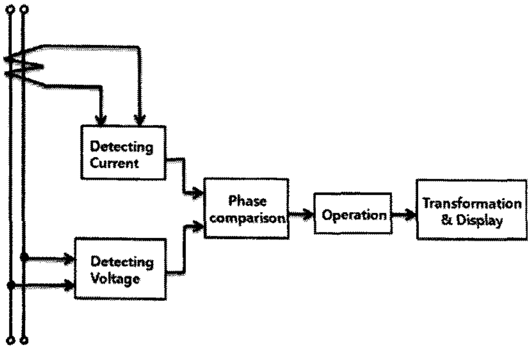

Fig. 4. The detecting circuit for phase comparison.

ing the Igr leakage analyzed by technology to be led to minimalization with accuracy which is applicable for earth leakage breaker.

Fig. 4 shows its structural diagram, consisting of voltage detector that measures induced voltage and transforms its magnitude, current detector that detects leakage current and transforms to needed magnitude of voltage using ZCT, and the phase difference measurement to measure phase differences in current and voltage. Furthermore, the arithmetic function is to calculate Igr value making use of detected phase differences and induced voltage the result of which is expressed through display. Herein, the equation applied to the above arithmetic function is;

$$Igr = \frac{V}{Zsin\theta}$$

The schematic advantages are characterized by the measurement of pure resistive leakage current getting rid of capacitive leakage current in the wire as well as realization of lesser-sized cost effectiveness.

The arithmetic application adopted by the developed system is as follows; AD-converting is made utilizing ZCT waveform(leakage current) and AC-input waveform(voltage) at MCU(micro controller unit), while the data collected together with 128 samples are converted to FET to get the vector sum of ZCT (leakage current) and AC input(voltage) data.

The leakage current Igr is obtained using the following equation;

$$ZCT = Zx + jZy,\ \ AC = Ax + jAy$$

$$|ZCT| = \sqrt{(Zx^2 + Zy^2)},\ \ ZCT\ \theta = \frac{\tan^{-1}(\frac{Zx}{Zy}) \times 180}{\pi}$$

$$|AC| = \sqrt{(Ax^2 + Ay^2)}$$

$$AC\ \theta = \frac{\tan^{-1}(\frac{Ax}{Ay}) \times 180}{\pi}$$

$$I_{gr} = (\cos((ZCT\theta - AC\theta) - (\frac{22 \times sampling\ time}{90°})) \times \frac{\pi}{180}) \times \frac{|ZCT|}{31.0398}$$

where the reason of deducting(22/(90°/sampling no.) is to experimentally compensate the phase error arised from HW Noise Filter and ZCT Sensor and 31.0398 is the factor to normalize in the unit of mA.

3.2. Design and Fabrication of Remote Check-up System

Fig. 5 shows block diagram of a terminal that is composed of; CT and ZCT sensors for sensing malfunction in the circuit of guard lamp; the filter part eliminating noise existent from detected signal and amplifying it; MCU converting analog signal to digital signal and functionally processing calculation, transmittance, storage and display of abnormal information; fixed-voltage supplying part; Zigbee module conveying processed signals to relay sistems through wireless communications.

The Zigbee wireless communications method is the

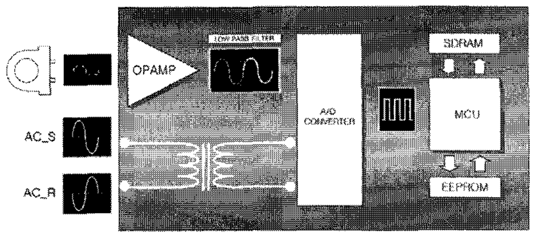

Fig. 5. block diagram of the local unit.

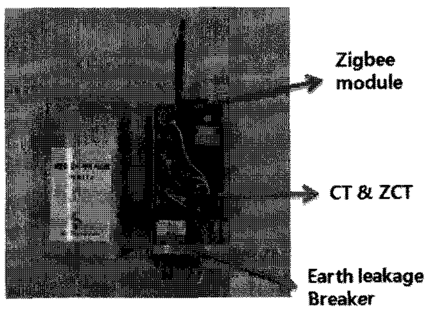

Fig. 6. The internal structure of developed local unit.

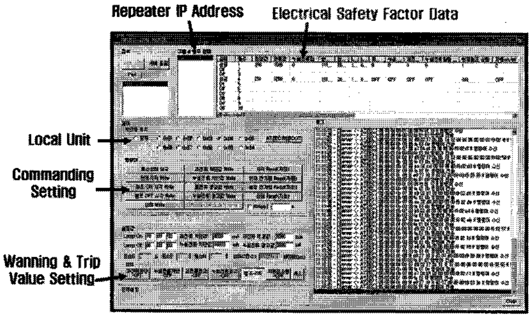

Fig. 7. Remote monitoring system MMI.

fittest way for communications not only because no interference occur in between the adjacent controller or other auxiliary devices with no cost saving but because the communication coverage is around 50m between guard lamps[6,7].

Fig. 6 shows the fabricated internal structure of terminal unit in the remote checkup system for gurad lamps.

And repeater is composed of module that converts the data transmitted from Zigbee relay system to the form of TCP/IP data for Ethernet transmittance.

Fig. 7 shows the MMI screen at that system making advantage of TCP/IP protocol. It is identifiable that real-time monitoring as to target factors for electric safety management be possible through bi-directional communication regarding preset values and detected data where the event is transmitted when there happens malfunction in guard lamps.

The key functions available from the system; for example, grouping management by IP address in relay systems, localized management by lamp poles and instruction setting enabling the administrator to make input of necessary wordings in advance as per overcurrent, leakage current including trip control. Moreover, On/Off timing can be controllable subject to seasonal sunrise/sunset time including automatic On/Off function through remote control, which is expected to be energy saving and compatible for prompt action against residents' petitions.

4. Experimental Results and Discussion

4.1. Measurement Test for Igr Curruent

To see if there exist significant reliability as to the proposed algorithm in this study to detect Igr leakage current, tests against the terminal manufactured for the experiment were made by diversifying values of both resistive current(Ir) and capacitive current(Ic). Fig. 8 shows the circuit diagram for leakage current test as mentioned at IEC 61008-1 with which our experimental circuit complied. The input voltage was induced with single-phase 220V and 60 Hz, while the variable resistance was at 22K~2.2KΩ using leakage current simulator and the capacitive load varied with 0.12~0.38μF to measure the resistive leakage current(Igr) and the resultant current(Io).

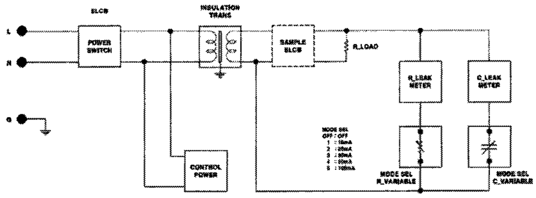

Fig. 8. Leakage test circuit based on IEC 61008-1.

Figs. 9 show the general view of the prepared experimental device at which MMI program was incorporated to measure Igr leakage current transmitted through Zigbee communication at a guard lamp terminal. Meanwhile, Igr earth leakage analyzer and leakage current tester(manufactured by J Co.) that are commercially available were implemented to compare and measure Igr leakage current and Io resultant leakage current.

Figs. 10 show the data on Igr leakage current obtained by use of our terminal along with J's Igr leakage analyzer. In the event that there existed capacitive load at Igr leakage current measured through

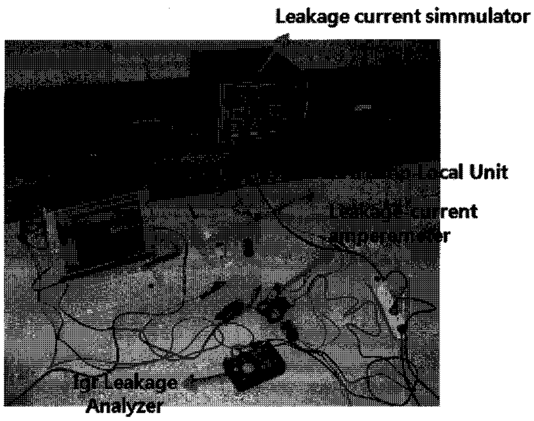

Fig. 9. Resistive Leakage Current(Igr) measurement.

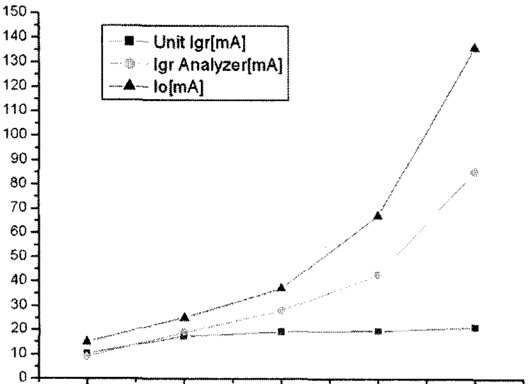

Fig. 10. The result of leakage current measurement.

terminal unit, the data was a little bit different from that obtained by J's Igr leakage analyzer. the Igr leakatge current is saturated at the point of about 20mA. This might be caused by the fact that the detection algorithm for leakage current only adopts fundamental wave, which means that there requires algorithmic compensation by addition of harmonic wave.

4.2. Load Current Test by AC Load Bank

The following procedure has been made in an attempt to see if our detection algorithm against overcurrent at CT of a lamp terminal; pre-fabricated AC load bank was connected with the terminal output and current at the secondary terminal was measured with load current varying from 1A to 10A by use of a calibrated current tester.

Fig. 11 shows its measurement result, which demonstrates that the load current is saturated at the point of 5A. This is because it was not taken into consideration at the initial designing in that rated current in guard lamps be not more than 5A. In consequence, there came to a conclusion that the algorithmic compensation or replacement by sensors capable of higher saturation against current be required.

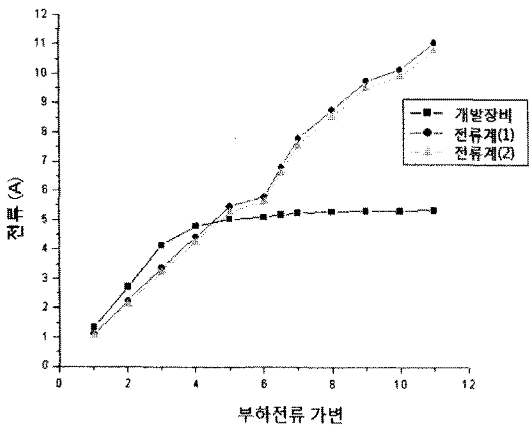

Fig. 11. The result of load current measurement.

5. Conclusion

The present study presented the developmental review on a remote control/supervision system for guard lamps used in public illumination with little endeavor by far for safe management by providing the best modeling in full consideration of the facilitation environment for terminals as well as economical factor so as to easily transplantable to the field.

The conceptual design for the system was composed of; sensing of voltage, current and leakage current at a terminal by making advantage of the phase difference measurement as Igr leakage current-detecting algorithm, data transmittal using Zigbee wireless communication and TCP/IP protocol from a relay system to a server, and MMI-based monitoring system.

IEC 61008-1 standard was taken into account to draw out the circuit for electric leakage testing for the purpose of proving the reliability in the assumed algorithm for detecting Igr leakage current at a designed terminal in such a way that resistive and capacitive components were varied as laboratory-based functional tests to ensure the stability of leakage current(Igr). The results of this study suggest that the existence of the capacitive error requires the algorithmic compensation regarding harmonic wave, and furthermore, the phenomena to cause current saturated at exceeding 5A calls for a sensor with higher accuracy.

In closing, the designed remote supervision system for guard lamps expectedly paves the way for better efficiency in safety management, reduction of safety-related accidents and activation of related industry, especially including the benefit of energy saving, thus being ideally suitable for the governmental policy drive oriented for green growth to the end.

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