A VOLTAGE MEASUREMENT ACCURACY ASSESSMENT SYSTEM FOR SMART DISTRIBUTION EQUIPMENT

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ABSTRACT

As Smart Grid is being applied to distribution power system, SDMS (Smart Distribution Management System) has been developed for distribution power system management. Distribution power system has been changed from radial system to closed loop or mesh systems due to connection of distributed generation growth. Data from distribution equipments which are installed at distribution line must be accurate for the performance of SDMS. This study analyzes the voltage measurement data from distribution equipment. However, the results of the analysis confirm to have some errors in voltage measurement data from distribution equipment. These errors come from aging of voltage sensor in distribution equipment and inaccurate data transfer to FRTU through the controller. The main problem is not to assess the voltage measurement data after first installation of distribution equipment at the distribution line. This paper shows the voltage measurement accuracy assessment system that is to evaluate the voltage measurement data from distribution equipment on live-line to solve the problem. This system had a field test to check its performance. It will be used to assess the performance of distribution equipments and smart distribution equipments.

INTRODUCTION

Distribution power system has been changed from radial system to closed loop or mesh system according to connection of renewable energy resources such as photovoltaic power and wind power generation and so on. Therefore, distribution management system should use the environmental factors and the closed loop topology due to the output of renewable energy resources. Smart Distribution Management System (SDMS) is being developed to solve the problem of distribution system for smart grid. As shown in Fig. 1, the role of the SDMS is to provide the real-time situation information and predictive operation of distribution power system.

The accumulation and exchanging of information relative to fault detection, loading, operation, and efficiency of the distribution system is important part of SDMS. It is not sufficient to obtain information only at the substation for the reliability and efficiency of the distribution system. It would be smarter and more informative if a few select points along the distribution feeder were providing real time information on the state of the system at those feeder locations. In some instances, real time data requirements to enhance the Smart Grid operation may mean deploying more sensors on a distribution feeder.

Then, in the late 1980s, as the vision of an automated distribution system began to surface, a need was recognized for distribution equipments such as switchgear and recloser and so on that could detect the magnitudes of the distribution system's line voltages and currents. Almost voltage sensor of distribution equipments is capacitive voltage divider which is traditional PT with transducer because that would be less expensive and less cumbersome to install.

The availability of metered data, and especially real-time data, at distribution equipments along the distribution line can help reduce or eliminate the multipliers and assumptions applied in the SDMS.

However, when distribution equipment is installed at distribution line first, it is set to measure the standard operating line voltage without measurement of real line voltage. In addition, effects of environment have degraded performance of the voltage sensor at distribution equipment. Therefore, it is not expected that voltage measurement data from distribution equipments is the accurate real time data. Consequentially, regular accuracy assessment for voltage measurement data from distribution equipments is necessary in the SDMS for smart grid.

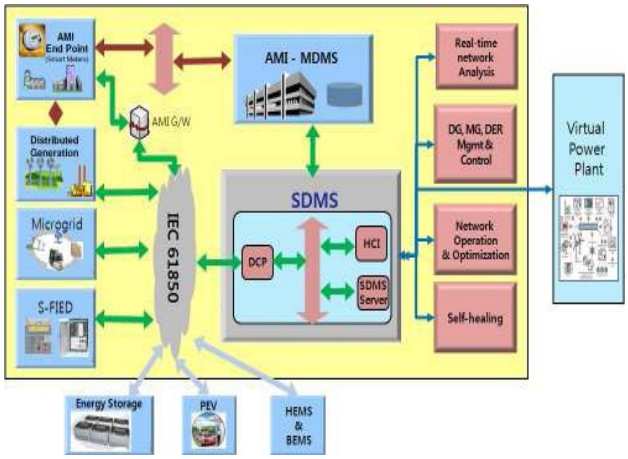

Fig. 1. Role of SDMS

In this paper, the values obtained by measuring the voltage data of switchgear installed test distribution line at the KEPCO Power Test Center (KEPCO PT Center) are analyzed. Then, this study has developed the voltage measurement accuracy assessment system to assess voltage data accuracy of distribution equipments periodically. In addition, this paper presents experiment results of the voltage measurement accuracy assessment system to apply to distribution equipments installed at the distribution line.

VOLTAGE MEASUREMENT ACCURACY ASSESSMENT SYSTEM

First of all, it is important to receive the accurate real time line voltage date for reliability and efficiency of distribution power system in smart grid. Currently, it is only to check the existence of voltage by the voltage detector and the phase comparator in maintenance for distribution line or distribution equipment. Therefore, it is necessary that the system is to assess the accuracy of the distribution equipment voltage measurement data. The system is called the voltage measurement accuracy assessment system have to make a high precise measurement of the distribution line voltage on live-line safely, easily and directly.

Measurement of voltage error for switchgear

It was selected the switchgear which is installed and operated at the test distribution line in the KEPCO PT Center to check the voltage measurement error of it. As shown in Fig. 2, it was measured the values that is transmitted from voltage sensor to the Feeder Romote Terminal Unit (FRTU) of switchgear by dividing voltage. Almost distribution equipments are designed to transmit 4V to FRTU when distribution standard operating voltage is 13.2kV by capacitive voltage divider. The standard operating voltages of distribution system at the KEPCO (Korea Electric Power Corporation) are line to line 22.9kV and phase to ground 13.2kV at present.

It was measured 3.17V that is transmission value of the switchgear phase c to FRTU as shown in Fig. 3. At the same time, it is measured 13,170V at the phase c distribution line by the standard voltage transformer which has the 0.2% precision class as shown in Fig. 4. By switchgear voltage dividing ratio, when it is measured 13,170V, it transmits 3.99V to FRTU not 3.17V. Therefore, it is explained that there are 20% errors of voltage measurement by voltage sensor of the switchgear.

The reason why the switchgear has been occurred the voltage measurement errors is not to measure real line voltage when distribution equipment is installed at distribution line first so that it is set to measure the standard operating line voltage uniformly. And after installed distribution equipment at the distribution line, there are not any method to measure and assess the voltage measurement accuracy of the distribution equipment on live-line although despite of aging of the voltage sensor and controller in the distribution equipment by the effect of environment.

Fig. 2. Measurement of switchgear voltage error

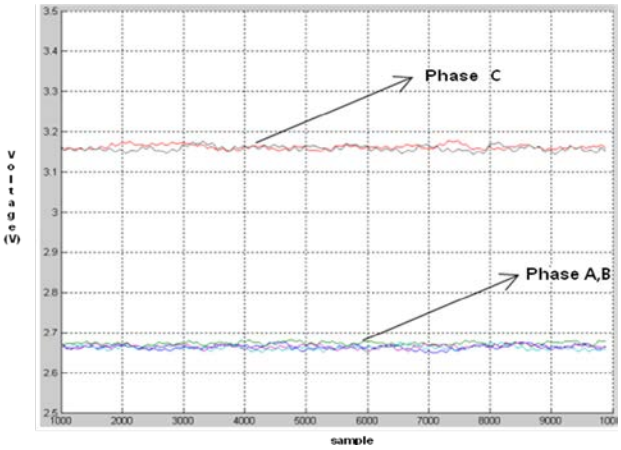

Fig. 3. Graph of switchgear voltage measurement data

Fig. 4. Standard voltage transformer

Conception of system

It is not measured the voltage of the distribution equipments which are installed at the distribution line on live-line. As mentioned above, it is only to check the existence of voltage by the voltage detector and the phase comparator in maintenance for distribution line or distribution equipment.

As shown in Fig. 5, the voltage measurement accuracy assessment system is designed. It is to measure the voltage of the live distribution line part which is close the installed distribution equipment with high precision safely, easily and directly. This system is to assess the accuracy of the distribution equipment voltage measurement data based on direct voltage measurement data. In other words, the voltage measurement accuracy assessment system compares the values from the system's voltage sensor to the data from the distribution equipment's FRTU.

The voltage sensor of the system is like a live-stick because of the crew's safety. In addition, the sensor is communicated with the assessment system by Zigbee wireless networking. Simultaneously, the assessment system receives the transmission voltage data measured by the distribution equipment to distribution management system from distribution equipment's FRTU with serial communication. The voltage measurement accuracy assessment system could evaluate the accuracy of the distribution equipment's voltage measurement data based on comparing and analyzing two data from the voltage sensor and the FRTU. In addition, this system is portable and could run with the battery without the power source.

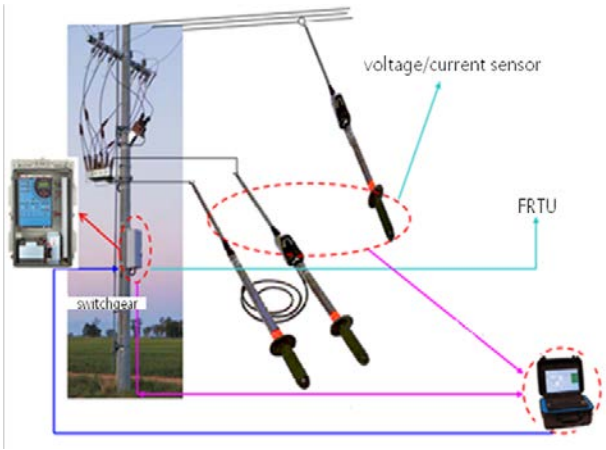

Fig. 5. Conception of the assessment system

Configuration of assessment system

The voltage measurement accuracy assessment system consists of voltage sensor, accuracy assessment device and operating software. The voltage sensor is to measure the Medium Voltage distribution line directly. The sensor could measure 0 ~ 25kV voltage range and has the 0.5% precision class. The measuring voltage data which is converted analog to digital by the sensor is sent to the accuracy assessment device with wireless communication. The accuracy assessment system performs the comparative analysis with the line voltage data from the system's voltage sensor and the distribution equipment's voltage measurement data from the FRTU. Additionally, the operating software of the system carries out the following functions that are network communication, calculation of the error ratio, monitoring of the communication condition and display. The function of the network communication is the process which is to acquire data between the assessment system and the voltage sensor or the FRTU by Zigbee wireless and serial communication method. In addition, the operating system estimates the accuracy of the voltage measurement according to the error ratio from the comparison analysis of the two data. And it could monitor the condition of the communication with the voltage sensor and the FRTU and display the system's output.

As shown in Fig. 6, the prototype of the voltage measurement accuracy assessment system is developed. Especially, the voltage sensor is measured and displayed the RMS values of the voltage. And it has the Zigbee protocol and display the connection condition with the assessment device. In addition, it receives the signal of the GPS (Global Positioning System) from the assessment device and synchronizes the time periodically and consistently.

The assessment device is to determine the degree of the voltage measurement precision based on calculation of the error ratio with the comparison analysis of the two data from the voltage sensor and the FRTU. And it monitors the communication connection of each device consistently. The assessment process of the system is performed in HMI (Human Machine Interface) and then the results data are saved as type of history data in the system according to time and equipments. It would help the crew maintain the distribution equipments. It could minimize the human error and maximize the reliability and the efficiency of the maintenance for distribution equipments.

Fig. 6. Prototype of the assessment system

Field Test

The field tests were conducted to verify the performance of the system at KEPCO PT Center's test distribution line. The voltage measurement test on live line is most important part of the system performance. Therefore, the voltage sensor of the system and the standard voltage transformer which has the 0.2% precision class as shown in Fig. 4, were measured same spot of the distribution line at the same time. Then, each measurement data was compared.

On the other hand, the voltage sensor of the system made up for weak points of the electromagnetic shielding to block the effect of other lines during the field test. In addition, the safety tests of the sensor were carried out before the field test because this system will apply to the live distribution lines. The safety test were conducted based on IEC 61243-2, IEC 61481, IEC 60855-1, IEC 61000-4-2 which are standards of the voltage detector, portable phase comparators, insulation solid rod since there are not same products.

As shown in Fig. 7, the voltage measurement test of the voltage sensor was performed at the distribution line. Si multaneously, the standard voltage transformer was meas ured at the same spot. The measurement result of the stan dard voltage transformer was 13,170V. As shown in Fig. 8, the voltage measurement accuracy assessment system was measured 13,036.8V ~ 13,154.3V and were assessed error ratio that was 0.12% ~ 1.01%. These results were to verify the system's performance in consideration of the st andard voltage transformer's precision class.

Fig. 7. Field test of the assessment system

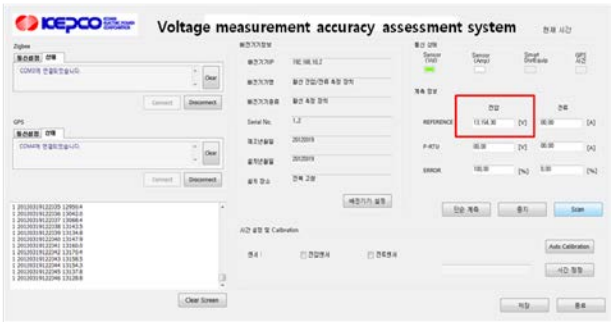

Fig. 8. HMI of the assessment system

CONCLUSION

The voltage measurement data of the distribution equipments is important part of the distribution system that has been changed to smart grid. This study analyzes the voltage measurement errors by measuring the voltage data of switchgear installed test distribution line. Then, the voltage measurement accuracy assessment system has been developed to evaluate the voltage data accuracy of distribution equipments. The field tests of the voltage measurement accuracy assessment system were conducted to verify the performance of the system.

It will be used to assess the performance of the distribution equipments and to calibrate the errors of them after the improvement. The recommendations for future work are summarized in the following:

a) Testing of lots of distribution equipments under more realistic filed environment
b) Development of the current sensor and field test
c) Advanced calibration algorithm and device

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