DEVELOPMENT OF GIS FAULT SECTION DETECTION SYSTEM

Bong-Hee Lee[1*], Sang-Dong Jeon, Ju-Heon Lee, Do-won Kim
Korea Electric Power Corporation, Seoul, Korea
<bongheel@kepco.co.kr>

Abstract: As of the end of 2010, 639 of 731 substations were equipped with GIS systems in KEPCO. A GIS has a small footprint, is easy to install and reduces maintenance cost compared to AIS. However, one of the drawbacks in using GIS with an enclosed metal case is that it is hard to accurately ascertain where a malfunction has occurred inside the GIS. It can cause delays in the fault recovery time and diffusing defective sections. This paper introduces how a setting value of a gas pressure sensor has been decided in a proper operation when the pressure rises rapidly through failure of GIS. Also, GIS fault section detection system with SCADA is shown. The reliability was verified by energizing the actual fault current into GIS. This detection system has been applied in two KEPCO substations. We expect the fault situation to be recovered rapidly by shutting off only the fault section. Above all, we expect that this system will lighten the burden of substation operators and reduce the mal-operations.

1 INTRODUCTION

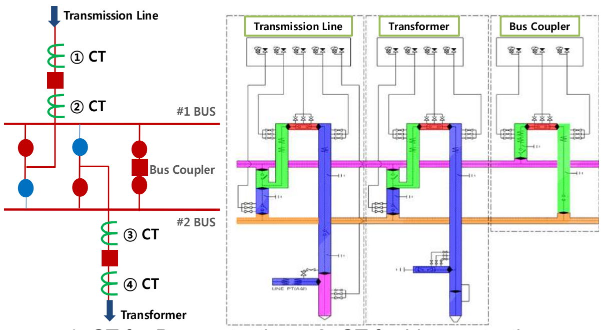
Since the 1980s more GIS has been built in Korea because of limited space and public complaints. There are approximately 6.8 faults in GIS every year, and it takes 16.3 minutes to recover from a power failure. When a failure occurs, which cannot be seen, the only way to detect the malfunction of each GIS module is by energizing the intact buses. These operations, however, can cause the enlargement of the fault section and the increase of the recovery time. In particular, when the failure happens between the disconnect switches in the double buses of GIS, the substation is not able to supply any power at all when the operators make errors during an emergency. If there was an advanced system for the detection of the fault section, the power could be quickly restored and the recovery time would be much shorter. For this reason, a GIS fault section detection system, which can ensure the failure area and notify the operators, is needed. This system has been developed as a result of research on variation when an arcing effects on SF6 gas in an encapsulated tank.

2 GENERAL INSTRUCTIONS

2.1 Drawbacks of GIS

A GIS has gas barrier insulators to prevent the mixing of the pure gas and the contaminated gas by arcing. When a breakdown inside of GIS occurs, incoming currents for protective relays are induced by a current transformer. Then the protective relays determine whether or not the circuit breakers should be opened to separate from the fault section. A current transformer however has several gas sections and it is impossible to set this device individually on all of compartments. (Figure. 1) When the bus protection relays operate, the operator must find the area in which the fault occurs immediately.

For this reason, the procedure of restorations is complicated and moreover incorrect operations can happen.



1. CT for Bus protection 2. CT for Line protection
3. CT for Transformer 3. CT for Bus protection

Figure 1 : CTs and Gas compartments in GIS

2.2 Present Condition

The operators cannot promptly restore from the failure inside of GIS because of the metal enclosures therefore suspected GIS must be energized several times to find the fault section.

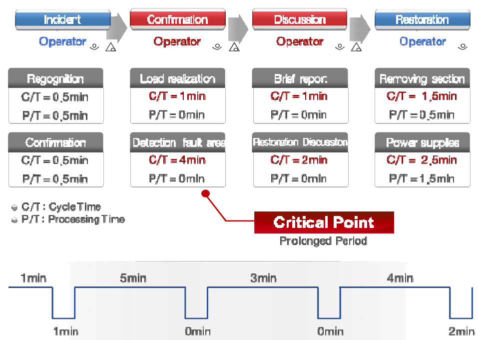


Figure 2 : the procedure of the restoration

For this reason, the operators can misake the cause of the failure and the size of the fault can increase. In experiments with 168 operators in a training simulator, it took 16 minutes to normalize supply of electric power when the operators restored the malfunction without the knowledge of the fault location.

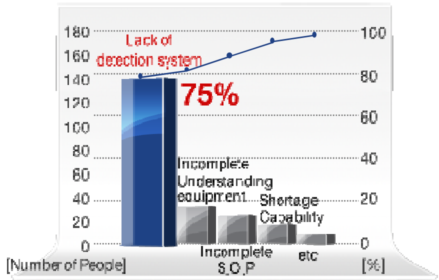


Figure 3 : the causes of the prolonged period

According to the test result, 75% of participants responded that the expedient detection system is necessary to rapidly clarify where the malfunction is.

3 DETAILED INSTRUCTIONS

3.1 Design of GIS fault section detection system

In the GIS fault section detection system, sensors are placed on the each compartment. The operators can know which sensors have operated through SCADA(Supervisory Control And Data Acquisition). For the precise design of this system, it is necessary to define that which methods are applicable and how much the temperature would increase by the arcing energy. In addition, economic feasibility, simple installation, ability of information delivery and prevention of incorrect operations should be also considered.

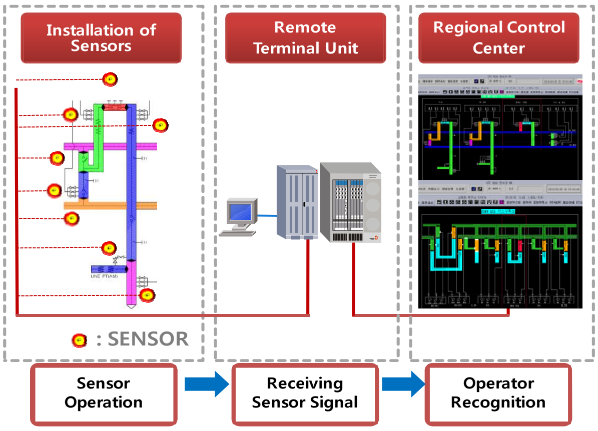


Figure 4 : Brief design of the system

3.2 The method for the detection

For the accurate detection of faults, it is generally required that both the physical phenomenon and the electrical phenomenon should be regarded such as a protective scheme of a power transformer. When a malfunction occurs inside the airtight space then arcing light, variation of gas pressure, increasing temperature and decomposed gases occur. With these considerations the gas pressure method has been adopted.

Table 1 : Comparison of detecting methods

Detecting	Applicable sensor	Criterion			Adoption
		Ability of Installation	Technical skill	Economic feasibility	
Gas pressure rise	Pressure	Good	Good	Good	Yes
Temperature rise	Thermo	Good	Fair	Poor	No
Arcing light	Light	Good	Fair	Poor	No
Decomposed gases	HF	Fair	Fair	Poor	No
Magnetic tape	Magnetic tape	Poor	Poor	Good	No

In order to prevent misoperations of this system, the contacts of the pressure sensors and the contacts of the bus coupler circuit breakers are connected in series on SCADA. Therefore, the detection system will not show any information to operators when the pressure sensors only operate without failures.

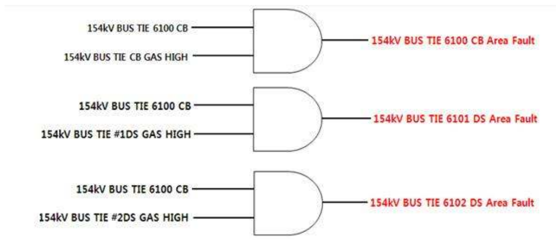


Figure 5 : Logic gates to prevent misoperations

3.3 Degree of gas pressure during fault

According to GIGRE SC23(Electra No.42,1975), the degree of gas pressure rise (ΔP) during fault is able to be calculated by the empirical formula.(1)

$$\Delta P = C \times I \times T / Vgas \text{ [kgf/cm}^2\text{]} \qquad (1)$$

Where C = Constant [C = 5.62 × 10-4 × Varc]

I = Fault current [kA]

T = Fault current duration [ms]

Vgas = amount of gas [ℓ]

In order to verify the validation of the empirical formula, the degrees of the pressure rise were measured when 20kA currents were energized inside the tank. It is shown that the pressure rise were not much different with the calculation of the formula.

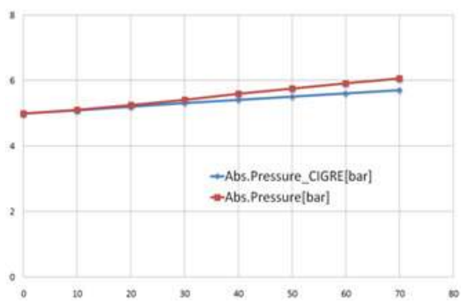


Figure 6 : Comparison the gas pressure rises

The result shows that the demonstration is reliable and applicable to design the sensor. The pressure sensor must be sensitive enough detect at least 0.3kgf/cm² pressure difference. For the detection of the pressure difference, the sensors which have 0.3kgf/cm² sensitivity are necessary on each GIS compartments.

3.4 Invention pressure sensor

The pressure of SF6 gas varies with temperature, therefore the sensor should not give a warning signal during the usual pressure variations on account of the temperature fluctuation or the rushing supplementary gas into the tank. Thus the sensor has been designed that operates in the specific conditions when 0.3kgf/cm² variation is detected within 30 milliseconds. The sensor does not give a warning when the temperature changes gradually or the supplementary gas is supplied because of the function of the time variation.

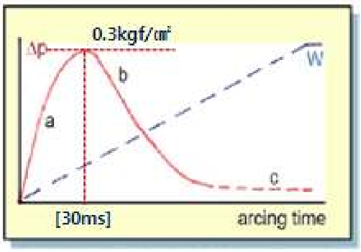


Figure 7. Pressure and time variation

For the proper operation, the stability of the invented sensor was proved by several tests at KERI(Korea Electrotechnology Research Institute) in Feb. 2010. 40kA currents were energized 25 times into the tank of the gas circuit breaker (145kV, 40kA) and the reliability of the sensor was investigated. The sensor operated properly and surge defects were not found during all tests.

3.4.1 Positioning of sensor

If the pressure sensors are placed on the surface of the GIS tanks, the sensors are able to work properly because the attenuation of the pressure is negligible. However, the sensors might be installed with difficulty due to the limited space among the tanks. Cables for the power supply and the communications can mess up the appearance of the substation. Furthermore the surface current on the metal enclosure can cause the sensors to malfunction, and the SF6 gas can be lost due to connections between gas pipes.

Table 2 : Comparison of sensor locations

Location	Ease to set	Reliability	Prevention of misoperation	Appearance
Tank cover	Poor	Good	Poor	Poor
Tank Valve	Fair	Fair	Poor	Poor
LCC	Good	Fair	Good	Good

For this reason, the sensors are installed on the gas inlet in LCC(Local Control Cabinet).

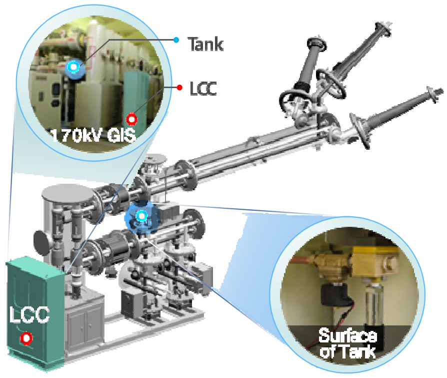


Figure 8 : Sensor installation in LCC

The surge defect with the abnormal voltage and unexpected operations with the leakage currents can be eliminated because the sensor on the inlet is away from the GIS tank. In consequence, the setting value of the pressure sensor was changed to 0.05kgf/cm² from 0.3kgf/cm² because the attenuation of the pressure by the distance of the gas pipe must be considered.

3.4.2 Verification of the sensor

In order to verify the reliability of the sensor, the solenoid valve was set on the gas pipe between tank A and tank B to keep a differential gas pressure to 0.3kgf/cm². In this way, it can be demonstrated that the gas pressure rise happens in tank A.

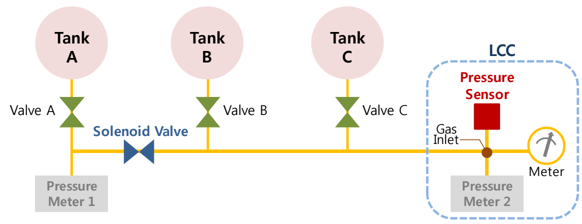


Figure 9 : Verification of the sensor

Tank A remains at 6.0kgf/cm² gas pressure, and the tank is separated by the solenoid valve from tanks B and C which remain at 5.7kgf/cm² gas pressure. When the solenoid valve opens, 0.3kgf/cm² differential gas pressure is simultaneously forced through the pipe into the sensor. During 20 tests, the sensor on the gas inlet in LCC properly operated.

Table 3 : Results of the sensor verificaion

Number	Pressure of Phases		Differential Pressure	Operation	Time [ms]
	A	B,C			
1	6.301	6.002	0.299	○	55.78
2	6.141	5.841	0.300	○	64.89
3	5.993	5.692	0.301	○	56.89
		⋮			
20	3.268	2.968	0.300	○	58.89

[setting value of sensor : Δ P=0.05kg]

The sensitivity and the stability were proven. The sensor operated in 56ms since 0.3kgf/cm² difference of the gas occurred with the solenoid valve opening and the degree of the pressure rise on the gas inlet was measured at 0.054kgf/cm².

3.5 System Development for 25.8kV GIS

It is impossible to set several sensors in 25.8kV GIS due to the restricted space. When a breakdown happens inside a 25.8kV GIS, SF6 gas pressure can raise up to 4 times normal pressure. The pressured gas will be released through the relief valve when the relief valve is not able to keep the high-pressure gas. According to inspections of 25.8kV GIS faults for last 10 years, the relief valves ruptured in all cases when the malfunctions occur in the tank. Therefore, the gas low alarm has been adopted to detect the fault area in 25.8kV GIS because use of the alarm circuit is simpler and more economical than use of the pressure sensor. However, a low gas alarm on SCADA contains several feeders of GIS because amount of the communication modules for the information delivery were limited when the substation automation was introduced. Today, with the developments in technology it is now possible to easily set the communication devices. Thus the tied alarm circuits were individually separated by the connection of additional control cables between LCC and RTU(Remote Terminal Unit).

3.6 Application of SCADA

The graphical page on SCADA is required to monitoring in the distance. The gas sections are drawn on the monitoring page and the fault spot blinks when the gas pressure sensor or the gas low alarm operates while the fault inside of GIS. In addition, the pop-up alarm is used to avoid confusions with other warning messages. The operator can accurately recognize the fault area with the alarm and the pop-up alert. It only shows the alerts when both the contact of the bus coupler circuit breaker and the contact of the pressure sensor operate.

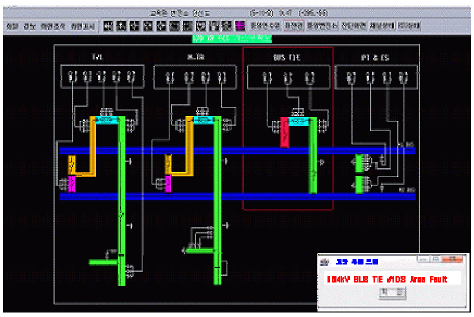


Figure 10 : Monitoring page on SCADA

3.7 Verification of GIS area fault detection system

Although these devices for the gas detection and the communication were proved individually, the completed system needs to be demonstrated. GIS are fault detection system was proven by the practical GIS and RTU in the training centre of KEPCO. When the differential pressure occurs in the specific area of GIS, the sensor works and RTU receive the sensor's signal. Eventually, the operator who is in charge of remote supervisory control will be informed where the fault is through the graphical alert. GIS area fault detection system worked properly in several tests.

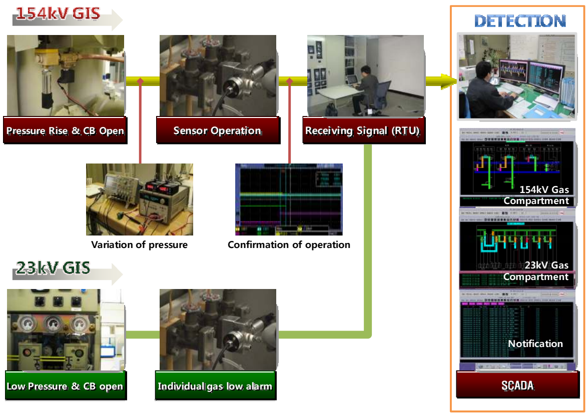


Figure 11 : Verification of the system

4 CONCLUSION

For the rapid and precise restoration from the malfunction inside of GIS, GIS area fault detection system has been developed. 50 operators participated in the exam to clarify the effectiveness of the developed system. A hypothetical failure was given to them and the recovery time was recorded with a training simulator. It took 12.86 minutes when operators restored without the knowledge of the fault location. However the recovery time was dramatically reduced by 3.25 minutes in the operators' recognizing where the fault area was in advance. GIS area fault detection system has been applied in two substations since July 2010. No drawbacks of this system have been found yet. As the fault location can objectively be found, the procedure of restoration can be much simpler and the mal-operations are prevented using this system. In addition the recovery time to back in service from the power cut can be decreased. It is expected that this system will reduce the burden of the operators

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