PERIODICA POLYTECHNICA SER. EL. ENG. VOL. 41, NO. 1, PP. 15-25 (1997)

CASE STUDY ON GIS DEFECTS AND NEW POSSIBILITIES FOR PREVENTIVE MAINTENANCES

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Received: November 1, 1996

Abstract

The paper reports on the practical aspects of diagnosis of gas insulated systems (GIS). The defects frequency in a GIS probably reflects the care taken during assembling, commissioning and in-service. A preventive maintenance system for gas insulated system (GIS) is suggested. This new system serves for diagnosing defects and injecting different types of gases into the section where corona discharges (CD) or particle discharges (PD) are occurring. Automatic injection of SF6 gas and/or a special gas mixture improves the dielectric strength and so prevents faults in service. Criteria for source discrimination, localisation and evaluation for the developed system are discussed.

Keywords: preventive maintenance, GIS, diagnosis, gas pressure drop, particles, discharges.

1. Introduction

The presence of free moving or fixed particles can reduce the power frequency, lightening and switching voltage strength of the insulation of gas insulated substation (GIS). Additionally, secondary breakdowns and flashover tracks occur as a consequence of very fast transient overvoltages (VFTO) during power frequency voltage tests in GIS, when the system is contaminated by particles. Such failures can be avoided by using an advanced diagnostic system, which is able to give information about the location and type of defects in GIS. The modern diagnostic methods are in many aspects superior to conventional simple voltage tests, if they are sufficiently sensitive and give valuable information about the state of the internal insulation system with regard to many types of defects, even if the real insulation cannot be gained.

Diagnostic systems are described in papers, which constantly monitor the level of ultra high frequency (UHF) signals generated by partial discharges (PD) or corona discharges (CD) propagating in the GIS, by using capacitive couplers built into the apparatus. The existence of such level of diagnostics offers the possibility for the implementation of a preventive automatic maintenance controlled by an advanced diagnostic system. By the application of this complex system an automatic, preventive maintenance could be realised: after detecting and locating the CDS or PDS the required gas (SF6 or a special mixture) should be injected into the section where PDS or CDS have occurred, in order to improve the dielectric strength. It is expectable that such an automatic and complex system will be able to prevent faults in service and allow remedial action to be taken. Namely, according to the reported experience, the dielectric strength can be raised in range of 20% by injecting a quantity of (5-10%) of C4 F8 gas into GIS in case of occurring PDS.

2. The Types of Defects to be Detected

Types of defects affecting the dielectric performance of GIS and therefore being to be detected by the advanced diagnostic system, fall into the following main categories [9]:

1 Gross assembly errors.
2 Contamination by free moving metallic particles.
3 Loose electrical and mechanical contact between conducting parts, including electrostatic shields and other floating components.
4 Fixed defects such as metallic protrusions and particles attached to solid insulator (spacer) surfaces.
5 Manufacturing insulator defects and surface tracks caused by testing flashovers.
6 Contaminants which affect the quality of the SF6 gas (by-products, moisture content, erroneous gas filling).

2.1 Gross Assembly Defects

Gross assembly defects may occur due to shipping purposes such as a bag of desiccant. Such a type of defects might not lead to a failure during commissioning.

2.2 Contamination by Free Moving Metallic Particles

Such a type of defects can be generated inside the SF6 compartment from the moving parts of disconnect switches during assembly. Particle can cause a breakdown, if it is very near to the high voltage conductor but not in contact with it [5,6].

2.3 Loose Electrical and Mechanical Contact

Poor mechanical contacts of disconnect switches may cause a mechanical vibration induced by electrostatic forces [9]. These vibrations may lead to electrical floating components the capacitance of which will be charged discharge and gives partial discharge signals.

2.4 Fixed Defects such as Metallic Protrusions and Particles Attached to Solid Insulator (Spacer) Surfaces

Such a type of defects might occur due to particles being in contact with the surface of spacers mechanically or electrostatically or becoming fixed by grease. Particles in that condition behave like metallic protrusions. The mechanical damages during assembly are often the results of creating metallic protrusions defects. It is recommended that the manufacture insulator design should be less sensitive to particle contamination [7].

2.5 Manufacturing Insulator Defects

Defects of the insulator surface can be caused by partial discharges due to metallic particles or by existing moisture above the allowed limits in the SF6 gas.

Tracking of the insulator surface can be caused by flashovers during commissioning tests [15].

2.6 Contaminants Affecting the SF6 Gas Insulation

The dielectric performance and the integrity of SF6 gas is mostly affected by the level of moisture in the insulating gas. The sudden change of temperature with over limits of moisture will produce condensation in SF6 compartment. The strength of the insulator surface can be affected by the condensation in combination with other impurities existing in the gas.

One of the most important components of the material of insulators which act as moisture absorber is the bulk epoxy [8]. Therefore it is required from manufacturers to control the desorption process in the gas insulated equipment used.

It is remarkable that every kind of defects mentioned above generates PDS, as the universal experience shows. So sensing the PDS level seems to be a general method for detecting the different types of defects.

3. The Effects of the SF6 Gas Pressure Drop in GIS Systems

Defects caused by the presence of free moving or fixed particles are frequently described. However, the defects originated by the drop of the gas pressure in GIS have not been dealt with in details in the papers published in this area. Such a type of defects should be taken into consideration due to the possible severity of their effects which may arise in GIS systems.

It is worthwhile to mention that site experiences of the author concerning the maintenance of different types of SF6 switchgears (3 phases or single phase in one compartment) show: the SF6 gas pressure drop occurs in GIS systems frequently. Therefore these defects are also among the most important factors affecting the performance of GIS systems.

The gas pressure has significant influence on the nature of the corona phenomenon. It was observed at site investigations that the intensity of the corona increases significantly, as the pressure decreases. If corona discharges go undetected, the process can lead to ultimate failure of the insulation. One has to take into consideration that the corona effect can reach a dangerous level even at normal SF6 gas pressure as a consequence of SF6 gas decomposition.

Due to decreasing of the growth of electric energy demand it is expected that the service duration of GIS systems will elongate and so the importance of the consequences of the gas leakage will increase as a result of ageing. This fact emphasises the significance of the defects caused by the drop of the SF6 gas pressure .

A so-called 'blocking system' is used in GIS as a rule, which prevents any switching operations inside GIS compartment, if the pressure of SF6 gas reaches the allowed lower limits. The operation of the blocking system aims for avoiding any ultimate insulation failure which may lead to a damage in GIS as a result of SF6 gas pressure drop.

The network experience shows that for raising the gas pressure to the required level, by the existing regular way (manual filling) the gas filling time expectancy is extended to 5–6 hours. However, one has to take into account that the probability of a fault arising in the network connected to this compartment during the blocking time required for refilling the gas cannot be neglected. Such faults cannot be cleared because the operation of the given compartment is blocked. In such cases a big disturbance for the GIS loads will occur due to isolating the fault through the adjacent compartments.

On the other hand, a malfunction of blocking system of operation may result in insufficient dielectric strength inside the enclosure, so spark-overs can occur between the grounded enclosure and the high voltage conductor, leading to compartment damage. Therefore, the early detection and the consequent prevention of gas pressure drops in GIS is of considerable interest for improving the reliability of GIS.

Metallic particles can be early detected by using an advanced diagnostic technique meanwhile the preliminary stages of putting the GIS system into service. But the gas leakage problems may sustain during the whole service life time of the GIS system.

4. Diagnostic Techniques

High frequency voltage and current pulses, acoustic noise, light, gas decomposition, electromagnetic waves, etc. are generated by CD and PD inside the GIS. Various methods shown in *Table 1* have been developed for the detection of these phenomena [10,11].

Table 1
Conventional Discharge Sensing Technology

Detection method	Principle	Sensitivity
Spacer coupling method	Discharge pulse voltage is detected by using spacer capacitance	100pc
Tank potential method	Pulse voltage on a tank induced by discharge is detected	100pc
Electromagnetic coupling method	Discharge pulse current flowing in grounding conductor is detected	50 to 100pc
Magnetic radiation method	Magnetic field radiation is detected by loop antenna	200pc
Vibration method	Tank vibration generated due to discharge detected	50 to 100pc

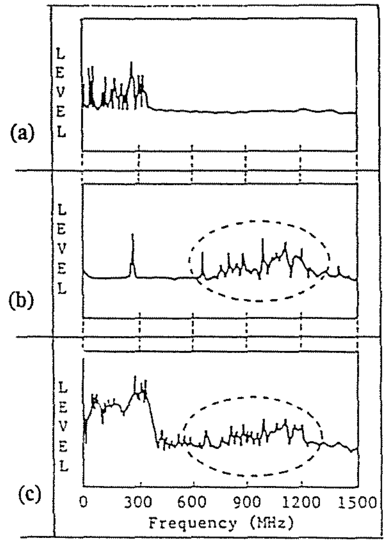

Fig. 1. Partial discharge sensing technology [1] by frequency analysis

Fig. 1b shows the frequency spectrum of the internal PDS originating from a conducting particle. The intensity of the PD is 8 pC. The frequency components are mainly in the range 750–1500 MHz. On the other hand, the frequency range of the harmonics coming from outside (generated in air) and propagating into the GIS is less than 300 MHz if 400 pC partial discharge is generated outside of GIS as shown in *Fig. 1a.*

The spectrum of *Fig. 1c* is an overlap of the spectra of *Figs. 1a, 1b.* The Figure reflects that the frequency components in the range of 700–1500 MHz can be separated from the external PDS. Accordingly, internal PDS can be detected by measuring UHF (700–1500 MHz) component even if there are intensive external PDS.

5. Preventive Maintenance System with Different Gases Injection

One of the advantages of the UHF technique is its suitability for monitoring the state of the insulation of GIS continuously. The continuous monitor is presently on site trials, and when it has been completely installed in a GIS, so it is expected to be used not only during commissioning tests, but also in service.

The purpose of the SF6 pressure test is to ensure that the GIS operates correctly at the allowed SF6 pressure, and that its dielectric strength is high before it is put into service. In order to check the same parameters during the service condition the data about the SF6 pressure should be transferred via gas pressure sensor installed on each compartment of GIS substation to the utility headquarters in remote control substations.

When the diagnostic system detects a harmful level of CD or PD, there is a possibility to prevent breakdowns by means of the complex automated system allowing a margin for maintenance by injecting different gases to improve the dielectric strength. Even if the improvement is of temporary character and lasts only for a few weeks, it can be very useful for the availability of that part of the power system, operation and maintenance. This effect can be reached by the application of the aforementioned automated preventive maintenance system injecting the required kind of gas into the GIS compartment.

For reaching the optimum condition for refilling the SF6 gas up to the required pressure level, one has to minimise the time during which the operation of the blocking system is necessary. *Fig. 2* shows the block diagram of the system which can satisfy this requirement.

As shown in *Fig. 2* the controller controls each valve and regulates the quantity of the injected gas by measuring the gas pressure via gas pressure sensors. The discrimination of the sources of defects is rather easy, knowing the feature of various defects types. Comparing them with the data recorded at testing, it is possible to deduce the type of the source. To some extent it is possible to distinguish noise signals from defect generated signals. A sliding sensor or filters can be used in order to discriminate noise signals from those set up by the relevant defects.

Based on the shape and the amplitude of the signal, on the length of the signal, front duration and voltage level, where the signal appears, the diagnostic system is going to classify possible sources. It is therefore of great importance to register the features correctly.

The GIS has to be equipped with three diagnostic systems, namely:

1. SF6 gas pressure drop diagnostic
2. PD diagnostic system and
3. system for different gases injection.

The SF6 gas pressure drop and PD diagnostic system detect and locate signs of defects according to the way mentioned above . The third system injects different gases into the section where SF6 pressure drop and/or PDS occur, for improving the dielectric strength of the SF6.

As shown in *Fig. 3*, the dielectric strength should be improved by 20% or more in case of PDS [4]. It means that if GIS is contaminated by

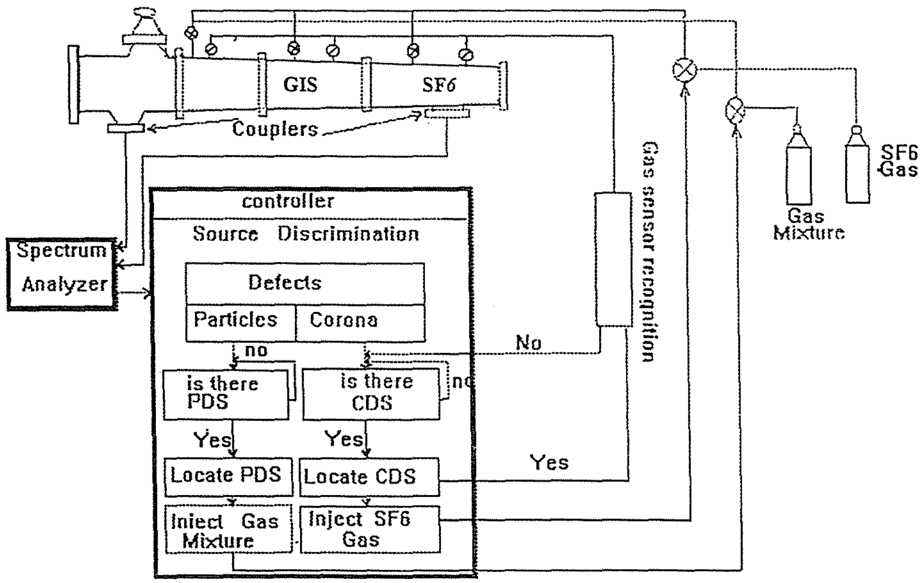

Fig. 2. Block diagram of the preventive maintenance system SF6 gas injection and mixture gas injection

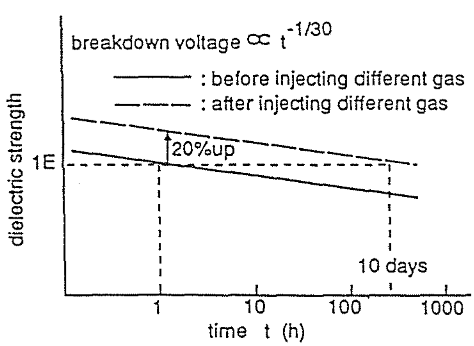

Fig. 3. Long term $V-t$ characteristics before and after mixture gas injection [4]

such a particle that is able to cause a breakdown in one hour, the life time expectancy can be extended to 10 days by gas injecting.

The extended expectancy enables remedies to be implemented with a time margin, so the improvement of the dielectric strength is set at 20% in case of PDS.

The system serving for different gases injection uses a controller, a gas pressure sensor and controllable valves installed on the piping between the sheaths and a gas supply cylinder. The controller controls each valve and regulates the quantity of the injected gas by measuring the gas pressure.

The dielectric strength of SF6 /C-C4 F8 and SF6 /C3 F8 mixture was examined in [4]. *Fig. 4* shows the particle-initiated breakdown voltages of the aforementioned mixture.

a) *b)*

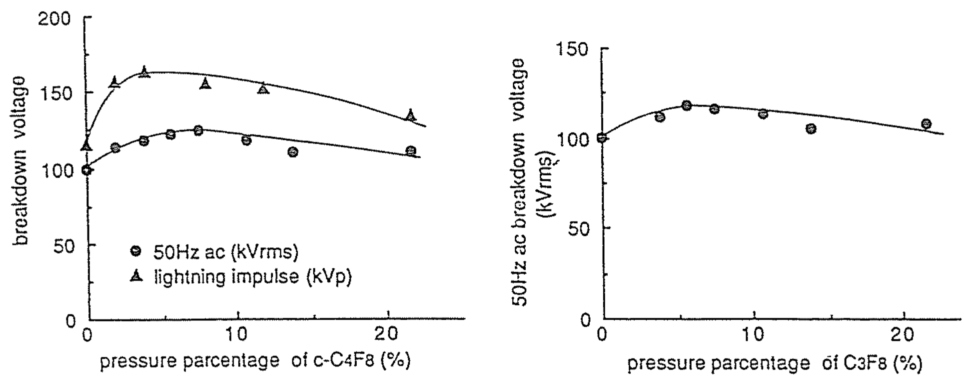

Fig. 4. a) Breakdown voltage of SF6/C-C4F8 mixture
b) Breakdown voltage of SF6/C3F8 mixture

The content of C-C4 F8, C3 8 in SF6 were varied from 0 to 20% based on the test above. *Fig. 4-a* shows the breakdown voltage of SF6 /C-C4 F8 mixture in range 4–11%. The Figure reflects that both ac and lightning breakdown voltages increase more than 20%. However, when the rate of C-C4 F8 is more than 11%, the increase of the breakdown voltages becomes less than 20%. Therefore C-C4 F8 is suitable when injected from 4–11% in case of PDS [4].

Fig. 4-b [4] shows ac breakdown voltages of SF6 /C3F8 mixtures. When the C3F8 is in the range 4–11%, breakdown voltages rise more than 15%. However, when it is more than 11%, the increase of the breakdown voltage becomes less than 15%. Therefore the breakdown voltages of SF6/C3 F8 are lower than those of SF6/C-C4 F8.

The presented solution has the following advantages :

1 The duration time needed to increase the SF6 gas pressure up to the required level will be mainly minimised.
2 The on-line process for sensing the pressure drop and refilling continuously the SF6 gas into the dropped pressure compartment is for avoiding any severity of operation blocking for the system in operation.
3 The severity of occurring faults during the SF6 gas pressure drop will be vanished.
4 Automatic gas feeding into the gas pressure drop compartment will minimise the costs rather than if it is manually operated due to saving the costs of labours, overheads and special tools for this type of work.
5 The block diagram achieved in the system shown in *Fig. 2* will be economical to use for remedial action to be taken in case of CDS and PDS.
6 The developed system allows for a sufficient margin of time for maintenance action to be taken while it is in service.

6. Conclusions

1 The present status of the GIS diagnostics completed by an automation injecting the required gases into the section contaminated by CDS or PDS results in an advanced preventive maintenance system.
2 The diagnostic system detects UHF signals generated by PDS or CDS and locates them. The source discrimination system identifies the type of defects. If the section is contaminated by particles, then the suggested system injects a little quantity of C-C4 F8 into that section which improves the dielectric strength up to 20%. Therefore the life expectancy to breakdown is extended to essentially prevent breakdowns in service. Also a time to allow maintenance is extended.
3 If the SF6 gas pressure has dropped, the system injects the SF6 gas automatically and continuously into section for reducing the corona effect instantaneously which in turn enhances the dielectric strength, to avoid any severe case which can occur due to the time required for manual gas refilling.
4 The proposed automatic preventive maintenance system can be applied very advantageously at remote controlled GIS.

Acknowledgements

The author wishes to thank Prof. Dr. G. Ban and Dr. Bánfai for the help they provided in writing this paper. Also wish to acknowledge the assistance and hospitality of Miss Zsuzsa Kiss. This Research work was sponsored by the Hungarian Research Fund under contract 748.

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