EXPERIMENTAL STUDIES ON THE MITIGATION OF CHANCE OUTAGES IN GIS DUE TO CONDUCTING PARTICLES

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ABSTRACT

Gas Insulated substations or GIS operable at medium voltages are in vogue for sometime now. In view of their compactness, GIS posses a high degree of reliability of operation in power utility systems. Among the more important problem areas concerning GIS is the adverse effect of metallic particle contamination of the gas medium. In order to be able to improve the operation of GIS in the inevitable presence of particles, a novel method by which the particles are passivated has been suggested. Studies have been conducted to obtain optimal value **of** conductivity of the coating material to have a better performance.

INTRODUCTION

Gas insulated substations have been a major innovation in power transmission and distribution with proven reliability, and nearly maintenance free operation. The other attractive features being compactness, easy operability and less affected by external disturbances. GIS inherently are prone to failures due to certain internal and external causes. GIS are very sensitive to minute disturbances because of high electrical stress in relatively small geometries. Inadvertent outages are more often traced to particle induced breakdown. Owing to its large physical dimension and the presence of the gaseous medium, which has a tendency to keep the particles floating, their occurrence cannot be completely eliminated. Minute particles enter the system during various stages of assembly, erection, and regular re-filling of the gas. Their later occurrence are due to internal faults like the disconnector and circuit breaker operation, periodic arcing of corona ring or any floating electrode [1].

Thin filamentary particles are found to be detrimental to the operation of the GIS under normal operating stress levels. The field at the particle tip exceeds the limiting dielectric strength **of** the gas at least locally, initiating a corona discharge, which in time fructifies into a breakdown. This is highly undesirable. Recent studies have indicated that GIS can be operated successfully operated in the presence of the particles. Methods have been suggested to restrain the movement of the particle into the high stress zone [2].

It has been proposed elsewhere[3] that dielectric coating using selected dielectric with modified conductivities has yielded significantly higher lift-off voltages. There is however an alternate possibility for immobilizing the conducting particles by deliberately inducing a charge of opposite polarity to that of the acquired charge. This new technique is called the ‘reverse polarity charging’ appears to be a very promising technique.

EXPERIMENTAL

A prototype GIS chamber designed and fabricated with necessary features was used to carryout the proposed studies. The chamber was provided with ports for visual observation, illumination and connection to the gas handling system. A hollow, thick walled, cylindrical electrode acting as the high voltage electrode and a Rogowski-profiled electrode at ground potential was the chosen electrode geometry in the experiments reported here. Electrodes were profiled to avoid corona by providing sufficient field relief at the edges. The surfaces were polished and degreased before the experiment

A test transformer rated for 10kVA, 220V/115kV (GE) generated high voltage at power frequency. The low voltage supply to the transformer was given from a regulator rated for 60A, 240V, 50Hz. A current limiting resistor of 40-50MΩ provided for limiting the current, which would otherwise vaporize the particles. An auxiliary transformer rated for 1.5kVA, 230V/50kV along with a 25kVA, 110A, 230V variac and a 45kR current limiting resistor were used to obtain the phase reversed supply. Fig. (1) shows the schematic representation of the entire experimental system. The chamber was equipped with vacuum and pressure gauges. A high capacity pump (200l/m) fitted with magnetic isolation valve was used to evacuate the chamber to pressure of about 10^{-3} Torr. Nitrogen gas was used in the studies reported here. The gas was passed through moisture traps and the flow of the dried gas regulated. Pressure was maintained in the range **of**

0.1-0.5Mpa absolute. Copper and aluminum particles were used in the experiments. Particles were cut to desired length (l) with no attempt made to smooth the wire ends, in order to simulate the actual condition in a GIS.

RESULTS AND DISCUSSION

The particle activity depends on the electrostatic force experienced by it at lift-off. This force in turn is related to the quantity of charge acquired and the local field seen by the particle. If the charge acquired by the particles could by some means reduced/neutralized to levels below the threshold value, they could be immobilized. There appears to be a critical voltage for lift-off corresponding to a certain amount of charge induced in the particle by the field. During the process of lowering the applied voltage, the particles become immobile at lower voltage levels compared to the corresponding value for the increasing cycle as depicted in Fig. (2). The figure is a plot of the lift-off voltage (U_L) versus the fall down voltage (U_{FD}). The charge acquired by the particle exhibits an electrostatic hysterisis effect. Arguably, this tendency can be attributed to the charge decay at a lower rate than charge acquisition.

In an effort to mitigate the problem of particle charging and the ensuing breakdown a new method of stripping the charge was carried out. The results of the experiments based on this technique, alternative to dielectric coating are depicted in Figs. (3a, 3b & 3c). The graphs are obtained by plotting the applied voltage U_{main} as a function of the reverse polarity charging voltage $U_{rpc.}$ The series of experiments include considerations of bare and coated electrodes with copper particles (0.24mm dia.), at different pressures of the gas medium. Nearly closed two-loop curves are realized. This is an interesting and hither-to unreported result. The area of the loop being proportional to energy, the charge acquired by the particles seems to diminish with pressure. The same behavior is noted with coated electrodes Figs. (4a & 4b). The charge acquired by coated electrodes seem to reduce in comparison to the bare electrodes at corresponding pressure levels as shown in Figs. (3a & 4a) and Figs. (3b & 4b). Thus the particles require a much higher voltages to acquire the threshold value of charge, for lift-off.The magnitude of the acquired charge by the copper particles seems to be more than the aluminum particles.

It has been reported in [4] the particles get charged due to partial discharges/micro-discharges at low pressures/high fields. With alternating voltages, charges were found to accumulate in the negative half cycle and discharge in the positive half cycle. The difference of the charges generated in every half cycle was accumulated until the total charge reached a critical value for lift-off. The charges acquired by the particles are partially being nullified by the very nature of the supply and the process of neutralization further being enhanced by the spray of reverse polarity charges.

In literature [2,3] methods of mitigating of particle activity have been suggested in which dielectric coated electrode application is the most prominent one. It seems to reason that higher levels of lift-off voltages are really effected by proper choice of dielectric material. There is an added advantage of using suitable coatings as it has a prominent effect of filtering the micro-projections and also reduces the bounce height of the particle [5]. The coating forms a RC circuit limiting the charge on the particle thus increasing the lift-off voltage levels.

In a quest to determine an optimal value of conductivity of the coating material, experiments conducted suggested a range of preferred values at different pressures as shown in Figs. (5a & 5b).

Coating of either electrodes enhanced the performance, than with only coated enclosure or bare electrodes. Figs. (6a & 6b) depict the above observation with materials of conductivity in the range of $10^{-9}\Omega^{-1}$ and $10^{-5}\Omega^{-1}$ at lower pressures, but vice versa at relatively higher pressures.

CONCLUSIONS

The lift-off voltage is accentuated quiet considerably when both the electrodes are coated with dielectric material of chosen surface conductivity in comparison with bare electrodes and coated enclosures. Reverse polarity technique seems to offer a promising solution in mitigating the associated problems due to particle infestation. This method tends to exhibit an enhanced performance with both bare as well as coated electrodes. Copper particles seem to acquire more charge in comparison to aluminum particles. It is observed that over certain range of the values of surface conductivity of the coating material, the lift-off voltages are considerably higher.

REFERENCES

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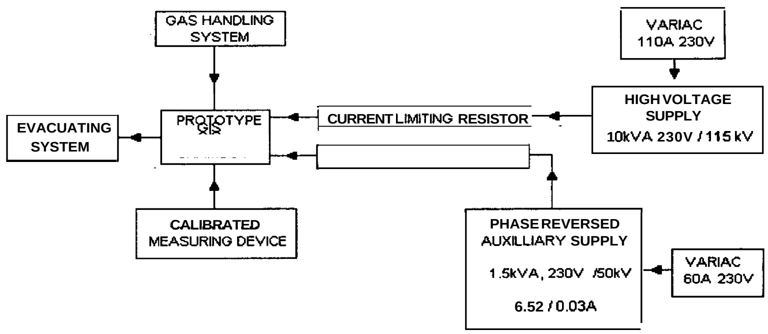


Fig. 1 SCHEMATIC DIAGRAM OF THE EXPERIMENTAL SET-UP FOR REVERSE POLARITY CHARGING

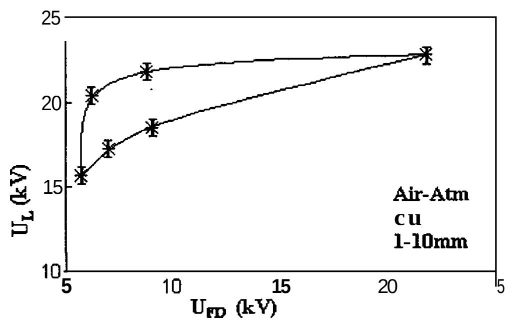
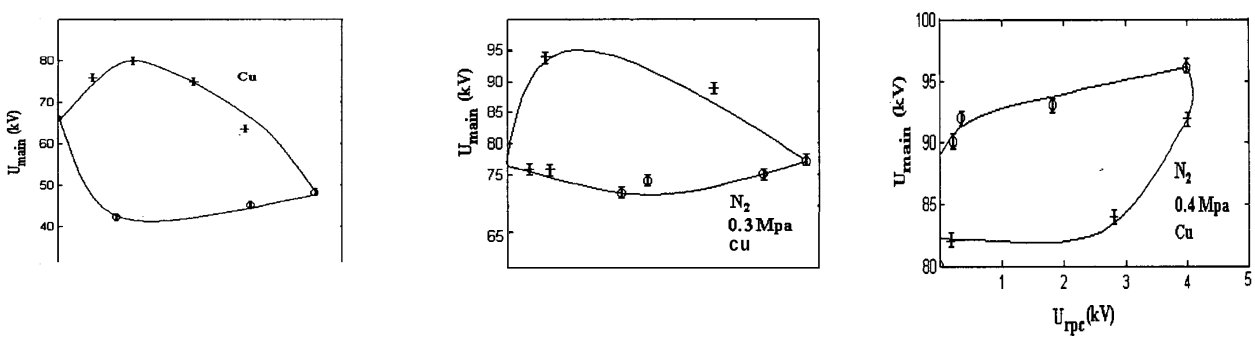
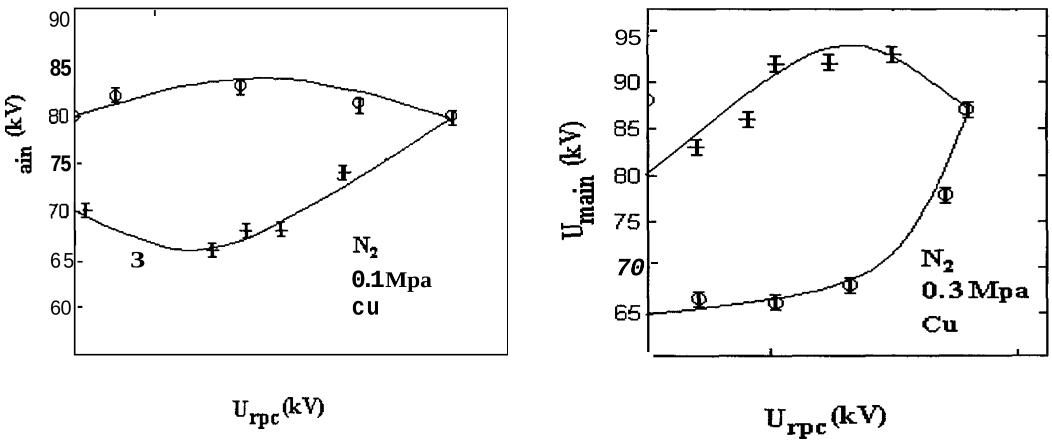


Fig. 2 Plot of Electrostatic Hysterisis



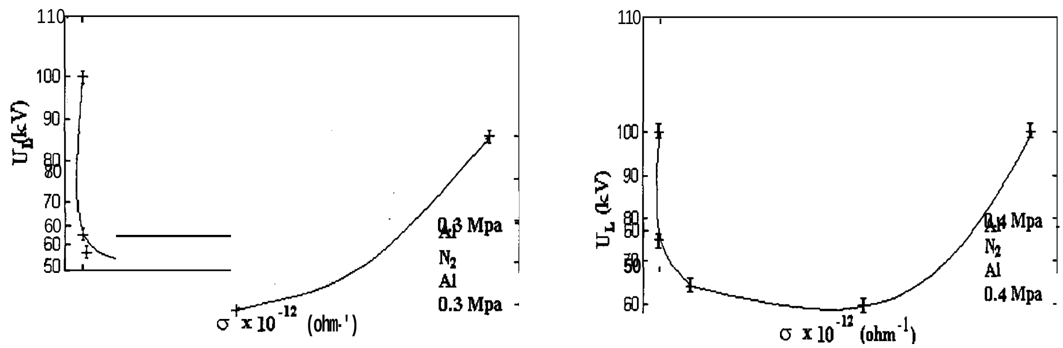
(c) 0.4Mpa

Fig. 3 Hysterisis Effect with Bare Electrodes at different Pressures



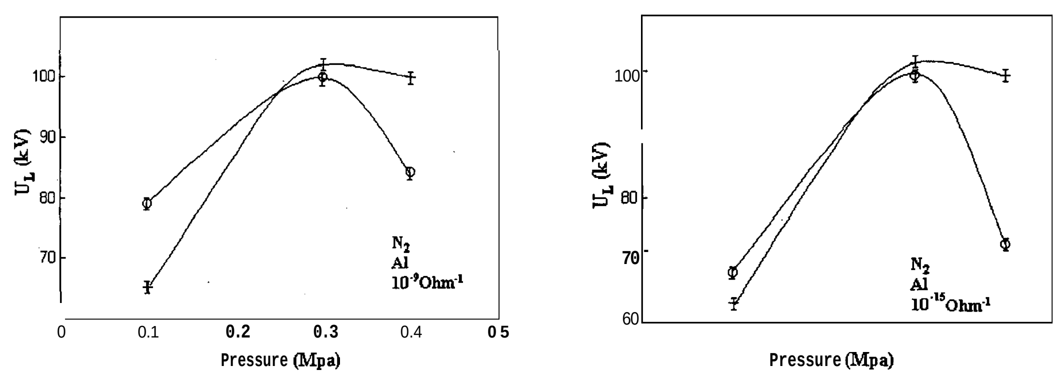
(a) 0.1Mpa (b) 0.3 Mpa

Fig. 4 Hysteritic Effect with Coated Electrodes at different Pressures



(a) 0.3 Mpa (a) 0.4 Mpa

Fig. **5** Measured Lift-off Voltages as a Function of the conductivity of the coating material



(a) $\sigma = \mathbf{10^{-9}\Omega^{-1}}$ (b) $\sigma = \mathbf{10^{-15}\Omega^{-1}}$

Fig. 6 Measured Lift-off Voltages as a Function of Pressure
+ coated grounded enclosure o both elctrodes coated