CHAPTER 2

LITERATURE SURVEY

2.0 LITERATURE SURVEY

This work is mainly focused on the estimation of Very Fast Transient Over-voltages levels and their suppression across terminal equipment connected in GIS during switching operations. The main content of the project is taken from these transactions.

Lu Tiechen, Zhang Bo [1], discussed the concept of 500kV GIS and gives information about the generation of VFTOs during switching operations and described the equivalent circuit of GIS.

J.A. Martinez, et al. [2], and J.Meppelink et al. [29] and Alvinson et al. [30], described the origin of Very Fast Transients during switching operations in a GIS lead to very fast transient phenomena, which can be subdivided into internal and external very fast transients and L.V.Bewley [28] explained the Travelling waves on Transmission system. Christos A. Christodoulou, et al. [3], discussed the calculations of the Metal Oxide arrester used in the GIS. V.Vinod Kumar, et al. [4], discussed the various components of GIS and Grover Frederick W [25] explained the inductance calculations. S.A Boggs, et al. [5] carried outfield tests for measurement of disconnector switch operation induced transients and indicated that transients do not exceed 2.0 p.u. Further it gives that the trapped charge left during disconnector switch opening depends on the design of the switch.
Hongsheng Li, et al. [6] analyzed the effect of protection measures on GIS components, such as adding resistor, MOA, R-C absorber, and Ferrite rings. Y. Shibuya, et al. [7] analyzed the Very fast transients in transformer windings and described the modeling of transformer winding parameters. Nobuhiko Shimoda, et.al. [8], J. Ozawa, et.al. [9], describes the method of suppression of transient overvoltages caused by disconnector switch. This is obtained by insertion of resistor with appropriate value during switching operation. Mr. Z. Haznadar, et al. [11] developed more accurate modeling of GIS components in digital simulations of very fast electromagnetic transients. Coaxial conductors in Gas Insulated Substations have higher specific capacitance to earth in comparison with the open air substations. Therefore, the capacitive currents of off-loaded bus in GIS are larger than the capacitive currents in open air substations. Further differences between the characteristics of these two types of substations are lower characteristic surge impedance and inductance as well as larger gradient of electric field between the prestrike and restrike arcs in sulphur-hexa-fluoride gas under pressure in reference to grounded enclosure. This causes very fast transient with wave shapes characterized by surge fronts of very short durations (about 10 nano seconds). The disconnector contacts in GIS are moving slowly (in the order of 1 cm/s) causing numerous strikes and restrikes between contacts. When the contacts are closed the capacitive
charging flowing through the contacts is from 0.3 to 1A r.m.s., depending on the rated voltage and length of the bus which is switched. Strikes and restrikes occur as soon as the dielectric strength of the gas between contacts is exceeded by overvoltage. The overvoltage is defined by the distance between contacts, the contacts geometry and the pressure of the gas as well as by characteristics of the gas at the instant of strike. Every strike causes high frequency currents tending to equalize potentials at the contacts. When the current is interrupted, the voltages at the source side and the loading side will oscillate independently. The source side will follow the power frequency while the loading side will remain at the trapped voltage. As soon as the voltage between contacts exceeds the dielectric Strength of the gas between contacts defined by the distance between contacts, the restrike will occur and so on. Successive strikes are occurring during the closing and opening operations of off-loaded bus by disconnectors.

H.W. Dommel [27] developed the Non Linear and time – varying elements in digital simulation of Electromagnetic Transients. S.Ogawa, et al. [13] proved that restriking surge of disconnector switches can be estimated by conducting calculations with considerably high accuracy than measured waveforms. Accuracy of as low as 3% to 5% has been achieved for measured and calculated values. R.Wiltzmann [14] has developed models for different components and conducted experiments with regard to waveform distortion on various models consisting of
spacers, bends, bushing etc. Working Group 33/13-09, CIGREE [24] has given qualitative description of origin of fast transient over voltages associated with GIS. S.Yanabu [15] has experimentally estimated fast transient over voltages in GIS. The maximum FTO estimated from observation was 2.7 p.u. This was observed in frequently and occurred only at open bus bars. M. Mohana Rao and M.S.Naidu [16] have developed a suitable simulation model for the estimation of fast transient over voltages with variable resistance. A. Ardito, R. Lorio and G. Santagosting [17] have developed accurate models for capacitively graded bushing for calculation of Very Fast Transient Over Voltages in GIS. Dr. M.Mohan Rao, et al, [18][10] discussed the very fast transient over voltages (VFTO) are generated due to switching operations in GIS. These transient overvoltages and the associated fast transient currents (FTC) develop transient Electromagnetic (EM) fields during its propagation through HT conductor of GIS. The transient Electromagnetic fields due to these transient Voltages/currents may leak out into external environment through discontinuities like SF6 to air bushing, SF6 to cable termination, non-metallic viewing ports, insulated flanges, CT, CVT etc.

The conducted/inducted voltages on control cables/control circuit due Transient EM fields depend on its frequency components and amplitude of transient voltages/currents. During switching operations
dictate the frequency components and amplitude of transient fields respectively for a particular GIS configuration.

N. Fujimotto, S. J. Croall and S. M. Foty [19] discussed Line to ground faults in GIS generate fast nanosecond rise time transients which cause sparkovers across the insulating flange of high pressure oil filled cable/interfaces. The ionized path for power frequency fault Very fast transient over voltages are generated due to restriking during switching of DS, an earth switch, etc in GIS. Line to ground faults in GIS generate fast nanoseconds rise time transients which cause spark over current, resulting in flange damage with potentially serious consequences. The various techniques such as by the use of capacitors, metal oxide varistors (MOV), shunting bar, etc for protecting the insulating flange from such damages are investigated and discussed.

Amir Mansour Miri and Zlatan Stojkovic [20] discussed the numerical and experimental evaluation of the transient behavior of GIS has been discussed. The electrical equivalent circuits chosen to represent the main components of GIS are implemented. The effect of mutual coupling between phases is included in the model, which is the importance for analyzing a modern GIS, containing three phases in one encapsulation. With the help of this model the generation and propagation of transients in GIS have been evaluated with regard to VFTOs in secondary circuits of voltage and current transformers.
Yoshibumi Yamagata, et al. [21] of Tokyo Electric power Co., Japan discussed and analyzed the disconnecting switches (DS) fitted with resistors and high-speed grounding switches (HSGS) for 1000 kV transmission system. At the UHV equipment test site, DS surge and HSGS closing surge tests were conducted. Then the Very Fast Transient Overvoltages (VFTO) controlling the performance of the DS and the surge voltage level due to HSGS closing were confirmed. In the same tests, the surge level transferred into the protecting and controlling components were confirmed low enough for them to operate properly.

In 1000 kV transmission system, the retaining time of the secondary arc at the grounding fault points may be comparatively longer due to induced current from the sound phases and other lines to shorten the secondary arc remaining time, high-speed grounding switches (HSGS) which ground the fault lines before reclosing gas circuit breaker (GCB) will be employed in 1000 kV closing an HSGS when a voltage remains in the line will generate VFTO as grounding surges. The highest voltages remaining in the high-voltage circuits are expected to be as 640 kV. The level of Very Fast Transients (VFT) in the grounding circuit increases according to the voltage remaining in the voltage circuit and Ragaller K., [26] explained the Surges in High Voltage Networks.

Mr. V. VinodKumar, et al. [22] discussed, In GIS, a large number of restrikes occur across the switching contacts when disconnector switch or circuit breaker is operated and each strike leads to generation of a
VFTO. VFTO thus generated have rise-times in the range of a few nanoseconds and is followed by high frequency oscillations. Even though their magnitudes are lower than BIL of the system, they contribute to reduction in the life of insulation in the system due to their frequent occurrences. Also under VFTO, the dielectric strength of SF6 in presence of free metallic particles is reduced considerably and may lead to flashover and thereby a ground fault. VFTO can also influence the insulations of other GIS equipments such as transformers where the inter-turn insulation maybe stressed with a higher voltage than under chopped lightening impulse voltages of same peak value. Hence, there is a need to estimate the magnitudes of VFTO generated during switching Operations in GIS. Since the VFTO magnitude depends on the location of the switching point, the substation layout as well as the magnitude of trapped charge on the HV bus, it is necessary to study their influence on the VFTO Magnitudes.

Mr. Y. Shibuya, et al. [23] discussed the very fast transient overvoltage (VFTO) generated by restrikes of a disconnector in the Gas Insulated switchgear (GIS) which has a very short rise time of less than 0.1 µs and a oscillatory component of several mega Hertz. In the system the main transformer is directly connected to GIS, and there have been concerns that the VFTO may set off a high frequency oscillation in the transformer winding and overstress the winding insulation many have considered the initial abrupt voltage change in VFTO as the source of
excitation, but some have argued that the oscillatory components can increase the internal oscillation. An analytical solution is found using the Laplace transform to describe the very fast transient overvoltage (VFTO) in the Gas Insulated Switchgear (GIS) connected directly to a transformer. The oscillation frequencies and other properties are explicitly given in terms of system parameters. The magnitude of VFTO at the transformer is suppressed due to the transformer capacitance. The magnitudes of the initial abrupt voltage change and oscillatory voltage are assessed. The Abrupt voltage is larger, but not enough to induce a harmful voltage in the transformer. The Oscillatory components may damage the winding insulation at the occurrence of resonance.

M. Ishikawa, et al. [32] discussed the surges induced in the sheath of a SF$_6$ gas insulated switchgear/power cable connection system. High frequency switching surges generated from the GIS induce sheath surges across insulation sleeves located at GIS/power cable connection points. Various sheath surge suppression methods were investigated such as by the use of capacitors, zinc oxide arrestors, etc.