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MEASUREMENT AND ESTIMATION OF VERY FAST RADIATED ELECTROMAGNETIC FIELDS IN A 245KV GAS INSULATED SUBSTATION

J. V. G. Rama Rao[1], J. Amarnath[2] and S. Kamakshaiah[3]
[1]Department of Electrical Engineering, J.N.T.U, Hyderabad, A.P., India
[2]Department of Electrical Engineering, J.N.T.U. College of Engineering, Hyderabad, India
[3]Department of Electrical Engineering, Vignan College of Engineering, Hyderabad, India
E-Mail: hodeee.bvcec@gmail.com

ABSTRACT

The transient high frequency electric and magnetic fields are generated in GIS systems during switching operations. In the present work, the measurement of magnetic fields and electric fields have been carried out at various locations of 245KV GIS (Gas insulated substation) during closing operation of disconnector switch 1 (DS1) is considered. The results of measured values are compared with the estimated values. The results shows that transient electric and magnetic field values are correlate with the measured values at bus link, near current transformer (CT) and at cable termination , the calculated values are slightly deviated from the measured values when moves along with XLPE cable. This may be due to a fast attenuation rate of electromagnetic fields with distance away from the DS1. The frequency spectrum of the time varying electric field and magnetic fields at various locations are also estimated. The magnetic field at CT is exceeding standard value during transient period, which is observed in both calculated and measured cases this may leads to malfunctioning of the secondary equipment connected to CT. The above results gives a basic idea of modeling of GIS systems for the estimation of high frequency electric and magnetic fields and also helps in preparing electromagnetic chart for the particular GIS system. These results are also useful in order to prepare some precautionary protection measures to avoid malfunctioning of secondary equipment and metering equipment in a GIS system.

Keywords: electric fields, magnetic fields, gas insulated substation, switching, disconnector, EMF measurements.

INTRODUCTION

Gas insulated substations (GIS) have been used in power systems for more than 30 years, even up to the system voltages of 745KV. However, the measurement estimation of transient electric and magnetic fields are important for the GIS systems more than 132KV. In the present study a 245KV GIS system is considered for the measurements, which is located at bandra - kurla complex to meet the power requirement in south Mumbai. The measurements are performed at three important locations during switching operation. Due to the switching operation of circuit breakers and disconnectors in GIS, a very fast transient over voltages and over currents will be generated along the three phases in the net work [2]. The generated transients are main reason for the generation of transient electromagnetic fields in a GIS today [3], secondary equipment in HV switch gear is processor oriented, entirely electronic and very sensitive to Electromagnetic disturbances. Cigre working group 23.02 stated in its report on 2nd international GIS service experience survey that of the sample of 73024 CB/bay/year, 16% reported problems with maloperation of control, protection or secondary circuits, although in general, improved reliability of GIS in service was confirmed [4] However, due to the switching operation of circuit breakers and disconnectors in GIS a very fast transient over voltages will be generated along the three phases [5]. Furthermore it will generate the transient potential rise on the external surface of GIS enclosure and then radiate electromagnetic fields from the enclosure to disturb control and protection devices nearby [5]. Considering the complexity of of GIS structure, the time-domain method to analyze the switching transient electromagnetic fields in AIS based on multi-conductor transmission lines and electrical dipole method and method of moment (MOM) can be used to calculate the very fast voltage transients in GIS and electromagnetic fields near by respectively [6-7], the process is very complex therefore, it is necessary to use the advanced software packages to analyze EM fields. The monitoring equipment for electronic and magnetic fields have improved considerably for detection and measurement of electric fields and magnetic fields have helped utilities to characterize exposure to these fields and to reduce RI effects on secondary equipment [8-9]. The switching transient fields have been measured in GIS sub stations by a number of investigators [9-10]. But recent measurements are carried out with advanced field meters with very high sensitivity [11].

The field measurements are carried out at three important locations in a 245KV GIS, in order to determine main field sources, the Electric and magnetic field sensors were placed a at required locations as shown in the Figure-2. Once the main field sources have been determined, recommendations can be made to reduce the field levels and substation design can be modified to make use of this information. This paper presents the results of measurement and simulation of electric and magnetic fields in a 245KV GIS system at bandra-kurla complex to meet the power requirement in south Mumbai, which is commissioned by TPC (TATA POWER COMPANY) and operated by MSEB (Maharashtra State Electricity Board). The measurements are taken in the month of November

2008. These studies are very useful for estimation of main field sources in the sub station. For taking measurements the meters Field star 1000EF and field star1000MF along with the field sensors are used. The main objective of this project is to carry out the accurate and detailed measurements of the transient electric fields and magnetic fields during switching conditions, and to develop a accurate computer model of the GIS system in order to estimate accurately the electric and magnetic fields in the substation and its vicinity.

Modeling of the 245KV GIS

Referring to real generation of transients in GIS, the disconnector operation has been modeled with the help of modified kopplin-model which describes the disconnector arc resistance. The resistance of the arc discharge represents a substantial part of the damping of the whole GIS system normally resistance is a frequency dependent parameter due to the skin effect. In case of arc-discharge there exists a strong time-dependency according to temperature, diameter and losses of the discharge thus the time behavior of the sparks resistivity has to be evaluated correctly. The time behavior of the conductivity g (t) is mainly influenced by the time dependent temperature function τ (t) of the arc-discharge; both functions are displayed in equations (1) and (2)

$$\frac{1}{g}\frac{dg}{dt} = \frac{1}{\tau(g)}\left(\frac{ui}{P(g)} -1\right) \tag{1}$$

$$\tau(g) = \tau_0\left(1- e^{-(g/g_0)}\right) \tag{2}$$

Where u,i and p voltage , current and the power of the arc respectively;

τ_o = initial temperature of the arc

g_o = initial conductivity of the arc

This description of the physical arc- discharge process is valid from the beginning of the discharge up to its end

Modeling of GIS components: Electrical equivalent representation of GIS components [3], [8], [9] as shown in the Table-1.

Table-1.

Spacers	**Capacitance of 15pF towards ground**
Disconnector switch	Transmission line of surge impedance 70Ω and capacitance of 30pF towards ground on either end of the contents in open condition a capacitance of 30pF between contacts
ES	Capacitance of 15pF towards ground
PT	Capacitance of 100pF towards ground
Circuit breaker (CB)	Transmission line of surge impedance 46Ω and capacitance of 30pF towards ground on either end of the contents in open condition a capacitance of 50pF between contacts
XLPE cable	Transmission line of surge impedance 30pFand propagation velocity is 150m/µs. cable termination is simulated with a capacitance of 400pF towards ground.
Transformer1	Capacitance of 2nF towards ground
Gas to air bushing	Transmission line of surge impedance 250Ω. Capacitance of 30Pf towards ground on either end of the bushing
Open ends	Capacitance of 15pF towards ground
CT	Transmission line of surge impedance 70pFand lunped capacitance of 50pF towards ground

Figure-1 shows the single line equivalent circuit diagram of a 245KV GIS system considered for measurements. The equivalent circuit is obtained from the manufacturer’s drawings and from the internal physical arrangement.

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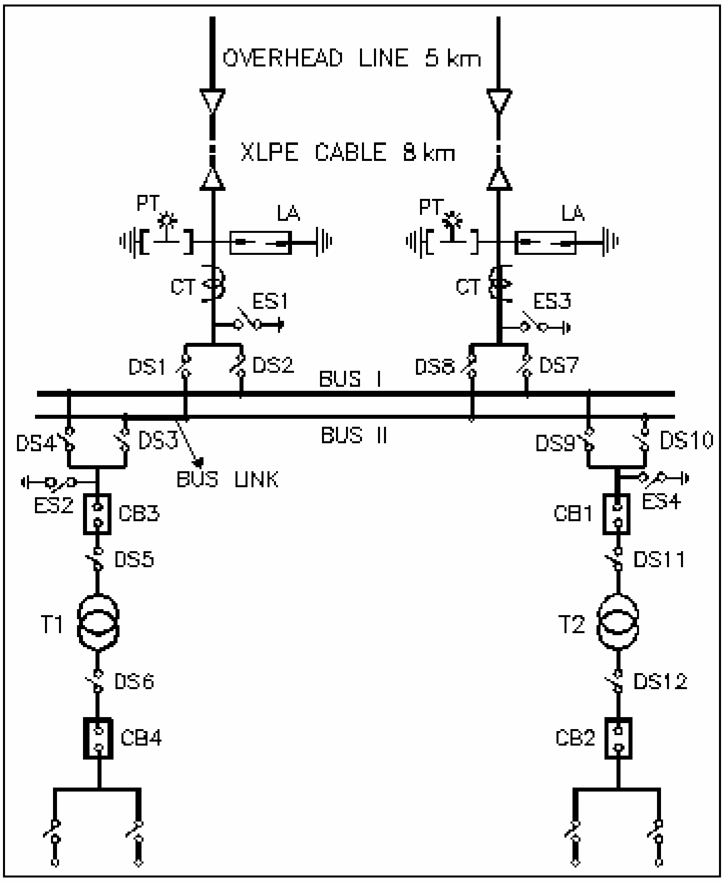


Figure-1. The single line equivalent circuit diagram of a 245KV GIS system.

Figure-1 shows the incoming line of the GIS is comprised of an overhead transmission line of 5km length, an XLPE cable of 8km length, PT, Lightning arrester (LA), earth switch (ES), Disconnector switch (DS). The operation of disconnector switch 1 is considered for the analysis. The electromagnetic field and electric fields are estimated at three important locations i.e. at bus link, C.T and at XLPE cable termination respectively. The transient electromagnetic fields are calculated using OPERA (Electromagnetic field analysis software) has been used to analyze magnetic fields. The results from these software's are loaded into SIGWAVE signal analysis software to obtain frequency spectrums of transient fields. The results are shown in the Figures 6(a)-(h).

Experimental measurements

The investigated GIS Banda-Kurla is installed in Mumbai, India in order to distribute electrical power in south Mumbai. The normal voltage of the device is 245KV. Figure-2 shows the completed 245KV GIS Banda-Kurla GIS system in which the experiments were carried out. The field measurements are carried out in a 245KV GIS which is shown in the Figure-2. This was commissioned in the year 2001 by TPC (Tata power company, India). The measurements are taken in the month of November 2008. In order to identify the main field sources in the substation. The high frequency magnetic field meter and electric field meters were used and the sensors of these meters are mounted near the buslink, C.T and at cable termination. The field data was collected in accordance with ANSI/IEEE standard 644-1987. The field sensors are placed about one meter above the ground. The maximum of the normal component of electric field (E) intensity, the normal component of the magnetic field (H) intensity are measured in each spot. The meters measured the data at high frequency levels and stored in the memory. This stored data can be transmitted to computer for further analysis; each meter is calibrated by the manufacturer within one year of the measurement.

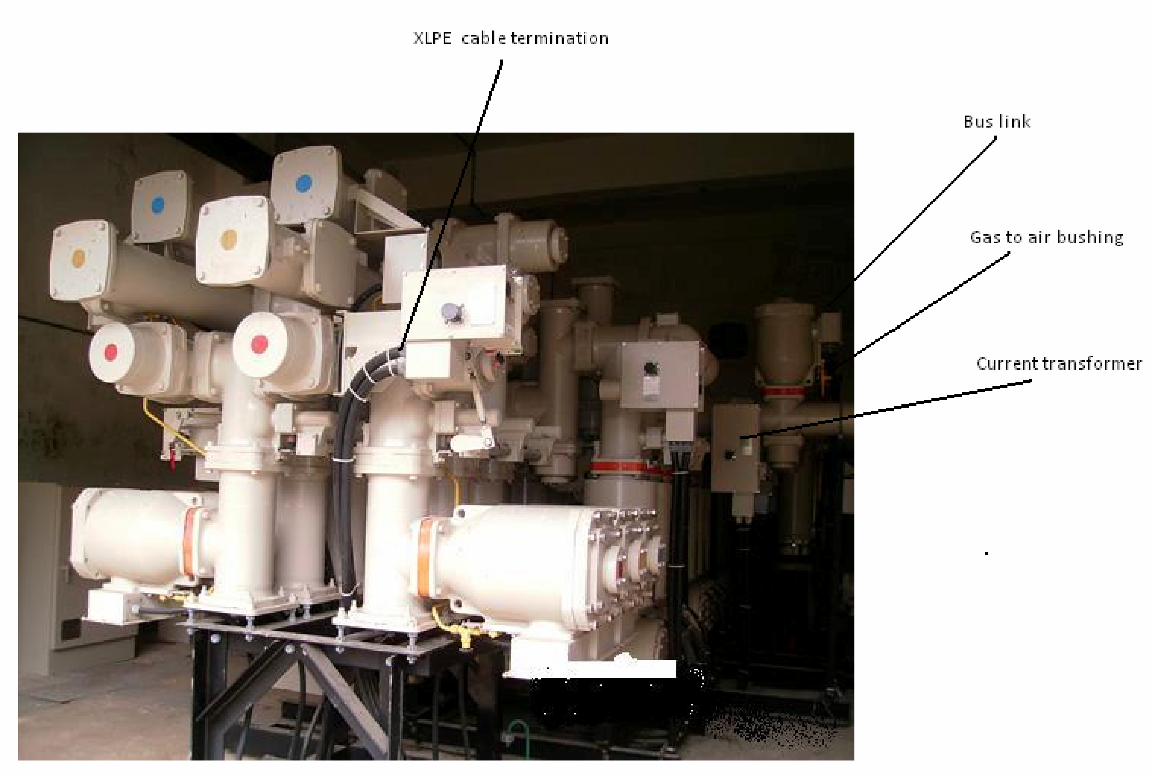


Figure-2. The 245KV- GIS at Bandra-kurla substation.

Simulation method

The electrical equivalent circuit for the 245KV GIS systems is shown in the Figure-1. The simulations are carried out using software's OPERA and ELECNET in order to estimate transient magnetic fields and electric fields in and around the GIS equipment. The simulation results are loaded in to signal analysis software SIGWAVE to obtain frequency spectrum of the transient fields. The computer simulations are presented in the Figure-3(a) and (b).

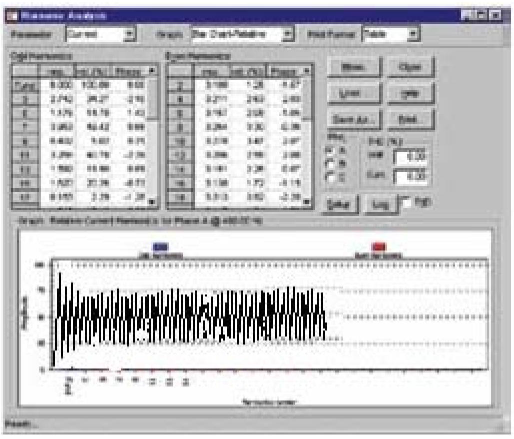


Figure-3(a). Calculated electric field in time domine during disconnector switch operation.

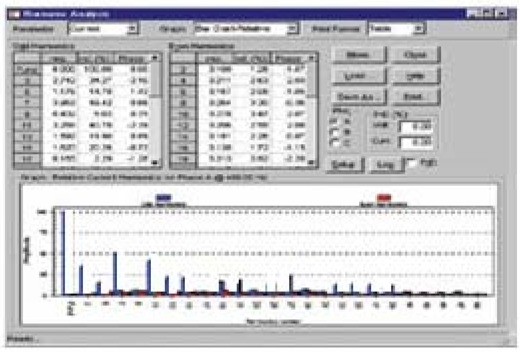


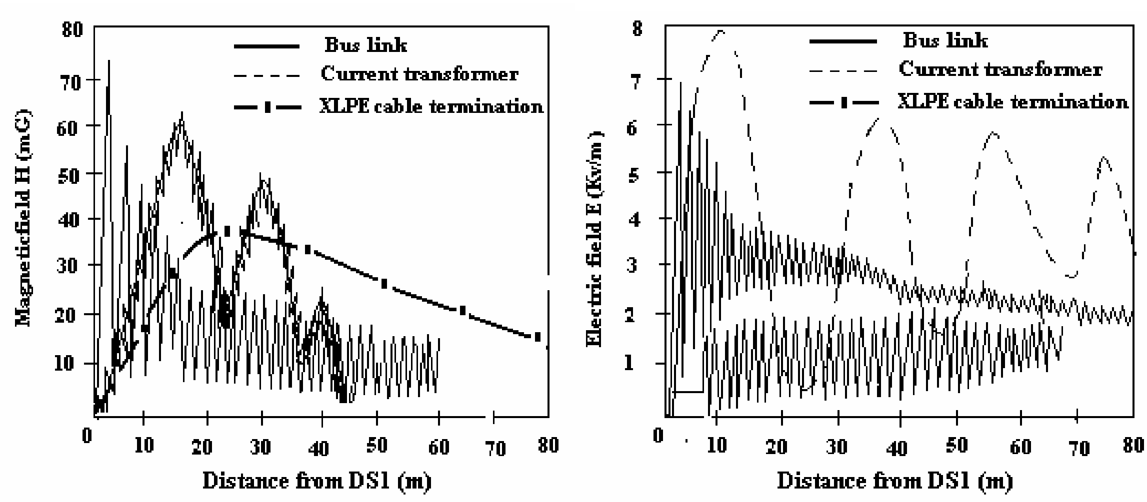
Figure-3(b). Frequency spectrum of calculated electric field during disconnector switch operation.

Measured results

The experimental investigations of the transient fields during disconnector switch operation described earlier have been performed. The electric and magnetic field measurements were taken at 1m height above the ground 1m away from the XLPE cable termination. The FIELD STAR 1000 electric and magnetic field exposure meters used to measure and record the data as function of time, distance and position and analyzed high frequency EM fields. The measurements are stored in the meters memory and later transferred through a serial communications port to the personal computer storage, display and analysis, the measured values of magnetic field and electric field at various locations are presented in the form of graphs for the specified voltages, current and time conditions of the 245KV GIS. Usually the meters are calibrated to measure the peak values and some of them are shown in the Table-2.

RESULTS AND DISCUSSIONS

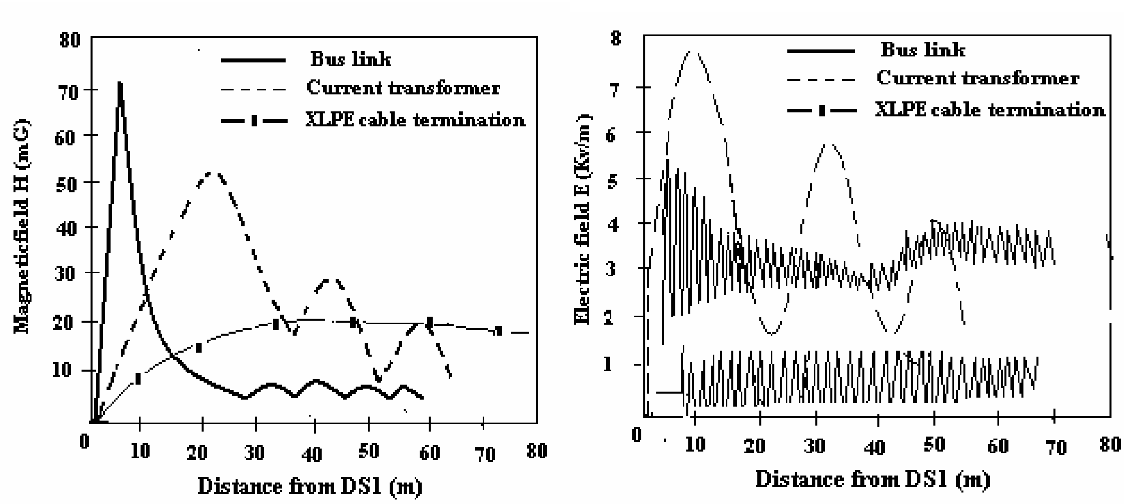
The EM plots were developed by using measured data at important locations i.e. at bus link, C.T and at XLPE cable termination from the DS1 position were presented in Figure- 4(a) and (b).



(a) (b)

Figure-4(a) and (b). Plots of magnetic field and electric fields from calculated values.

The transmitted EM field magnitudes are measured during disconnector switching operations, from the measurement results the corresponding graphs were developed for analysis, which are given shown in the Figure-4(a). The resultant magnetic field (H) is increased up to 72mG and it is decreased to 12mG about 60m from the DS1position. The value of magnetic field (H) at current transformer is about 49mG and it is decreased to 9mG at 75m axial distance from DS1, similarly the peak value of field (H) is 28mG near the XLPE cable termination .The peak values of transient electric fields obtained are 7.9KV/m,6.8KV/m and 4.1KV/m at bus link, current transformer and XLPE cable, respectively.



(a) (b)

Figure-5(a) and (b). Plots of magnetic field and electric fields from measured values.

The EM plots at various locations from DS1 along axial length are simulated and the corresponding wave forms are given in the Figure-5(a) and (b). The resultant magnetic field is raised up to 69mG at about 9m from the DS1, the value is 36mG at C.T position and it is 20mG near the XLPE cable termination. The variation of resultant electric field (E) at various locations from DS1 also shown in Figure-5(b).

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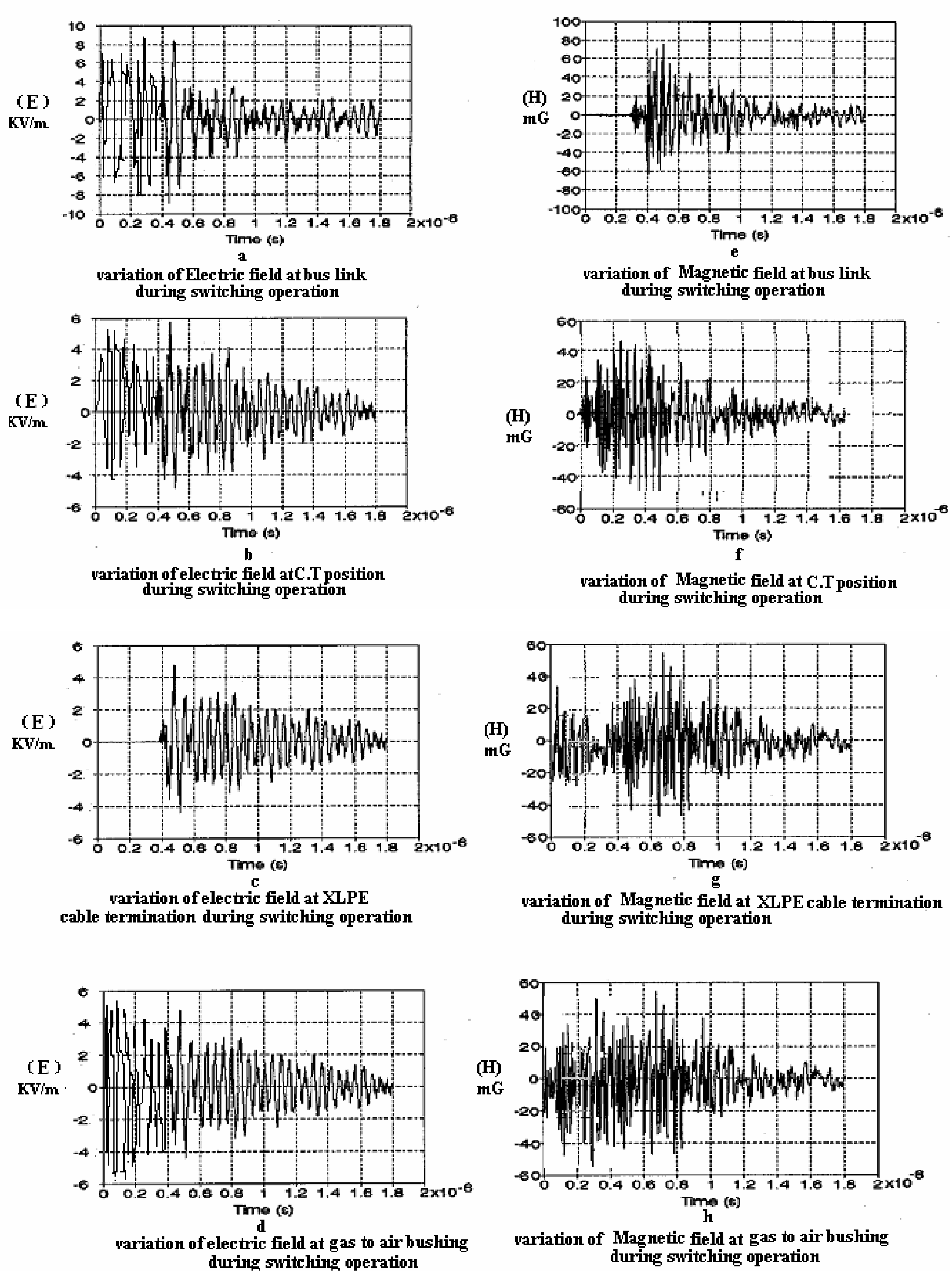

Figure-6(a-h) Variation of transient Electric field (E) and Magnetic field (H) in time domine different locations during closing operation of disconnecter switch (DS1) The time demine EM fields at various locations are given have shown the Figure-6(a-h). The peak magnitude of E (KV/m) at the bus link is about 8.4kv/mat 200MHz frequency. The frequency plots are not shown in this paper. The peak magnitude of E at C.T position is about

7kv/m at 160MHz frequency similarly from the Figures 6(c-d) these values are 5.1kv/m and 6.7kv/m at XLPE cable termination and gas to air bushing respectively. The Figure-6(d-h) shows the variation of transient magnetic field density (H) this value is 78mG which is occurs at bus link. The values of magnetic fields are obtained as 55mG, 59mG and 61mG occurs at C.T position, XLPE termination and at gas to air bushing respectively.

(a) Measured values

Table-2. Comparison of measured and calculated values of electric and magnetic fields at various locations during switching operation of DS1.

Location at which measurements were conducted	**Measured magnetic field** (H_r), **MG** (peak value)	**Dominant frequency** (MHz)	**Measured electric field** (E_r) **in KV/m** (peak value)	**Dominant frequency in MHz**
Bus link	79	40	7.4	145
Current transformer	48	35	5.9	115
XLPE cable termination	62	45	4.1	96
Gas to air bushing	54	55	5.3	12

(b) Calculated values

Various locations considered for estimation of EM fields	**Calculated magnetic field (H), MG** (peak values)				**Dominant frequency** (MHz) **for H_r**	**Calculated electric field** (E) **in KV/m** (peak values)				**Dominant frequency in MHz for E_r**
	H_x	H_y	H_z	H_r		E_x	E_y	E_z	E_r	
Bus link	43.9	38.1	42.4	72	35	5	4.35	4.47	8.2	129
Current transformer	33.1	23.5	33.9	53	39	3.37	3.16	2.82	5.6	109
XLPE cable termination	36	34.3	31.6	59	55	2.73	2.44	2.00	4.3	74
Gas to air bushing	37.4	36.3	33.4	57	62	3.0	2.45	2.824	4.9	22

VERIFICATION OF THE MEASUREMENT RESULTS

The OPERA and ELECNET programs and measuring meters are used to provide closer look at the variation of the magnetic field and electric field with some specified locations inside the 245KV GIS and to present direct comparison between measured and calculated EM fields at that defined locations inside the substation. It can be observed that the modeling and simulation agrees with the measurements in the sense that overall distribution fields are similar. The results are lower than the limits presented by international guide lines [6-7]. The measured and calculated EM fields are presented in Table-2.

CONCLUSIONS

The EM fields due to disconnector switch have been analyzed on the existing 245KV GIS. The transient magnetic fields (H) and transient electric fields (E) are generated during switching operation of Disconnetor switch1 were measured and computed, but both measured and computed results indicate that these fields are significantly influenced by the position of the disconnector switch and the measuring point. In particular the highest peaks occurred at XLPE termination. From the Figure-4 the highest peak of magnetic field (H) occurs about 10m from the DS1 to low value about 20mG at axial distance of 80m from DS1. From the Figure-4(b) the electric field is high frequency transient with peak value of 7.1kv/m at bus link the value is 8kv/m,2.1kv/m at C.T and XLPE cable terminations respectively. These values are in agreement with the computed values. Small deviations were observed at XLPE cable terminations and are attributed mainly to uncertainties in the geometry of the GIS system and also due to fast attenuation rate of transient fields. From the results it is clear that the peak amplitudes of fields are strongly dependent on the measurement location and can be significantly influenced by near by objects. The principal frequency components observed in switching transients is quite high these are 10 times higher than in case of Air insulated sub stations. The Switching operations in a SF6 gas insulated substations lead to very fast electromagnetic transients which can affect the performance of the secondary equipment. The accurate computer simulations provide deeper insight in transient phenomena which are decisive for insulation coordination, protection techniques and optimal substation design.

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REFERENCES

[1] B. W. Jaekel. 1998. Electromagnetic Compatibility of Distribution Switchgear Installations. IEE Conferences. pp. 52-57.

[2] R. P. P. Smeets, W. A. Linden, M. Achterkamp, G. C. Damstra and E. M. d. Meulemeester. 2000. Disconnector Switching in GIS: Three-Phase Testing and Phenomena. IEEE Transaction on Power Delivery. 15(1): 122-127.

[3] N. Hardt and D. Koenig. 1999. over voltages in Secondary Circuits of Medium-Voltage Switchgear Generated by Multiple Reignitions of Circuit Breakers. IEEE Transaction on Electromagnetic Compatibility. 41(4): 510-515.

[4] A. Kazemi, H. Heydari and F. Faghihi. 2004. Electromagnetic Compatibility Considerations for Control Circuits of Medium Voltage STATCOM. WSEAST ransaction on Communication. pp. 595-602.

[5] S. Shihab K. Debnat. 1995. EMI and EMC in High Voltage Energy Systems. IEEE Conferences. pp. 1-3.

[6] M. D. Grijp and C. Borm. 1996. Electromagnetic Compatibility in Open Air Substation. IEEE Conferences. pp. 1044-1050.

[7] IEC50 (161): (BS4727: Pt1: Group09) Gossary of Electrotechnical, power, Telecommunication, Electronics, Lighting and Colour Terms: Electromagnetic Compatibility.

[8] T. Williams. 2001. EMC for Product Designers. Newnes. Third edition.

[9] T. Williams and K. Armstrong. 2000. EMC for Systems and Installations. Newnes.

[10] C. Bayliss. 2001. Transmission and Distribution Electrical Engineering. Newnes, Second edition.

[11] Sadiku and Matthew. 2001. Numerical Techniques in Electromagnetic. Second Edition, CRC Press.

[12] D. Stinson. 2002. Cryptography, Theory and Practice. CRC press.

[13] P.R. Kasselman. 1997. A Fast Attack on the MD4 Hash Function. Information Theory. IEEE. pp. 27-31.

[14] H. Dobbertin. 1996. Cryptanalysis of MD4. Proceedings of the 3rd Workshop on Fast Software Encryption, Cambridge, U.K. pp. 53-70

[15] J. Meppelink, K. Diederich, K. Feser and P. Pfaff. 1989. Very Fast Transients in GIS. IEEE Trans. Power Delivery. 10(1): 223-233.

[16] Amir Mansour Miri and Zlatan Stojkovic. 2001. Transient Electromagnetic Phenomena in the Secondary Circuits of Voltage and Current Transformers in GIS (Measurements and Calculations). IEEE Trans. Power Delivery. 16(4): 571-575.

[17] D.E. Thomas, C.M. Wiggins T.M. Salas F.S. Nickel and S.E. Wright. 1994. Induced Transients in Substation Cables: Measurements and Models. IEEE Trans. Power Delivery. 9(4): 1861-1868.

[18] C.M. Wiggins and S.E. Wright, Switching Transient Fields in Substations. IEEE Trans. Power Delivery. 6(2): 591-600.

[19] C.M. Wiggins, D.E. Thomas, F.S. Nickel, T.M. Salas and S.E. Wright. 1994. Transient Electromagnetic Interference in Substations. IEEE Trans. Power Delivery. 9(4): 1869-1884.

[20] S. Nishiwaki, K. Nojima, S. Tatara, M. Kosakada, N. Tanabe and S. Yanabu. 1995. Electromagnetic Interference with Electronic Apparatus by Switching Surges in GIS - Cable system. IEEE Trans. Power Delivery. 19(2): 739-746.

[21] M. Mohana Rao, M. Joy Thomas and B.P. Singh. 2002. Frequency Spectrum Analysis of Fast Transient Currents (FTC) during Switching Operation in a 245 kV GIS, IEEE/PES T and D Conference, Japan. pp. 2239-2243.

[22] P. Osmokrovic, S. Krstic, M. Ljevak and D. Novakovic. 1992. Influence of GIS Parameters on the Toepler Constant. IEEE Trans. Electrical Insulation. 27(2): 214-220.

[23] S. Yanabu, H. Murase, H. Aoyagi, H. Okubo and Y. Kawaguchi. 1990. Estimation of Fast Transient Over voltage in Gas Insulated Substation. IEEE Trans. Power Delivery. 5(4): 1875-1882.

[24] Masatake Kawada, Ampol Tungkanawanich, Zen-Ichiro Kawasaki and Kenji Matsu-ura. 2000. Detection of Wide-Band E-M Signals Emitted from Partial Discharge occurring in GIS using Wavelet Transform. IEEE Trans. Power Delivery. 15(2): 467-471.