ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

Analysing Electric Field Distribution of HV Standard Capacitor Using Finite Element Method

Basavareddy[1], Puvada Praveena[2], Poornima D[3]

Assistant Professor, Dept. of EEE, MVJ College of Engineering, Bangalore, Karnataka, India[1]

Assistant Professor, Dept. of EEE, MVJ College of Engineering, Bangalore, Karnataka, India[2]

Assistant Professor, Dept. of EEE, MVJ College of Engineering, Bangalore, Karnataka, India[3]

ABSTRACT: Standard capacitors are loss free (negligible loss) capacitors. Hence, they are gas filled capacitors. For high voltage applications they also need to be corona free at the operating voltages. The paper deals with modelling and Analysing 12 kV, 100 pF Standard Capacitor using Finite Element Method (FEM) Software package . FEM Basics and how it is used to solve the voltage distribution in two dimension area is discussed. The various factor that effects on capacitance like re-entrant edge radius , height of capacitor above ground level are analysed using simulation result. The effect of eccentricity on capacitor maximum stress and capacitance is done using both simulation and Experimentation.

KEYWORDS: Finite Element method, Electric Field intensity, High voltage, Standard Capacitor.

I.INTRODUCTION

In all engineering undertakings, economical, technical and practical aspects are taken into consideration to establish the optimum solution or design. Generally electrical insulating materials convert some electrical energy into heat while being stressed by an electrical alternating field. This is termed as dielectric loss. It is important to measure the loss aspects of dielectric material. Practical measurements often involve measuring the capacitance and the dissipation factor of insulation, concurrently. In high voltage systems the dielectric loss of the insulating system needs to be measured at the system voltages or higher [1-3].

Measurement of dielectric loss will involve use of standard capacitor [4, 5]. Standard capacitors can also be used in measurement of peak value of alternating voltages. Standard capacitors also find their use in many other applications like partial discharge measurements [6]. These applications require standard capacitors, which are loss free.The present paper work deals with, modeling of HV standard capacitor of 100 pF,12 kV (rms), using FEM software package. Analysis of variation in electric stresses and capacitance of standard capacitor with variation of eccentricity of standard capacitor.

The present project work deals with, modeling of HV standard capacitor of 100 pF,12 kV (rms), using FEM software package. Analysis of variation in electric stresses and capacitance of standard capacitor with different conditions.

II. ANALYTICAL CALCULATION FOR COAXIAL CAPACITOR

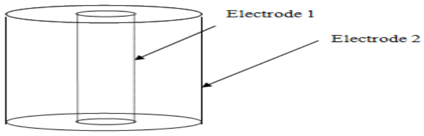

Fig 2.1 Co-axial capacitor without re-entrant edge

Following are the assumptions made for the calculation of capacitance of co-axial capacitor.

1. Charge over the surface of both electrodes is uniformly distributed.
2. The edge effect is not considered.
3. The ground effect is not considered.

Let us assume that electrode 1 and electrode 2 carry a charge of +Q and –Q respectively.
By applying Gauss's law to an arbitrary Gaussian cylinder surface of radius r we get

$$Q = \varepsilon \oint E.dS = \varepsilon E_r 2\pi r L \qquad \text{-----(1)}$$

From equation 1

$$E = \frac{Q}{2\pi\varepsilon r L} a_r \qquad \text{-----(2)}$$

By using above Expression

$$V = \int E.dl = \frac{Q}{2\pi\varepsilon L} \ln(r) + A \qquad \text{-----(3)}$$

Where A depends on voltage of both electrodes
By replacing $r = r_1$ in equation 3 we get voltage on conductor 1

$$V_1 = \frac{Q}{2\pi\varepsilon L} \ln(r_1) + A \qquad \text{-----(4)}$$

By replacing $r = r_2$ in equation 3 we get voltage on conductor 2

$$V_2 = \frac{Q}{2\pi\varepsilon L} \ln(r_2) + A \qquad \text{-----(5)}$$

Voltage difference between two electrodes

$$V = V_2 - V_1 = \frac{Q}{2\pi\varepsilon L} \ln\left(\frac{r_2}{r_1}\right) \qquad \text{-----(6)}$$

Capacitance of coaxial capacitor is given by

$$C = \frac{Q}{V} = \frac{2\pi\varepsilon L}{\ln\left(\frac{r_2}{r_1}\right)} \qquad \text{-----(7)}$$

To consider ground and edge effect on capacitor the numerical method toll is required.

III.STANDARD CAPACITOR DIMENSIONS WITH RE-ENTRANCE EDGE

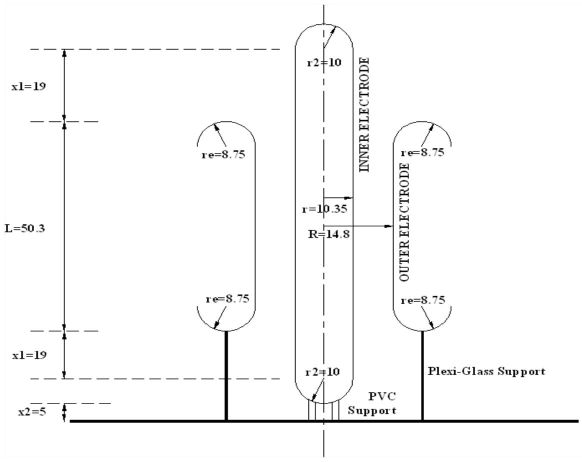

Fig 3.1 Standard capacitor front view dimensions.

The fig 3.1 is standard capacitor which is designed to minimize the edge effect. The analysis of this type of structure can't be done by normal techniques, numerical methods are required to solve this types of examples. FEMM is one such software which provides graphical interface to solve Electric stress analysis by FEM method.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

IV. FEMM MODEL OF STANDARD CAPACITOR

Finite Element Method Magnetics (FEMM) is a FEM software package used for solving 2D planar and axis symmetric problems in electrostatics and problems in low frequency magnetic. FEMM is freely available software. The standard capacitor modelling comes under axis symmetric problem as the field distribution along one axis of capacitor is same thought 360^o.

The FEMM model of standard capacitor will appear as shown in fig 4.1

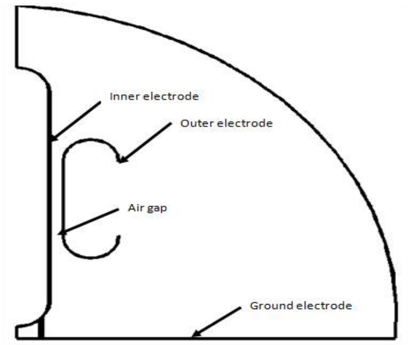

Fig 4.1 FEMM standard capacitor model

V. FEMM RESULT ANALYSIS

V.I ELECTRIC FIELD INTENSITY AT EDGE OF CAPACITOR

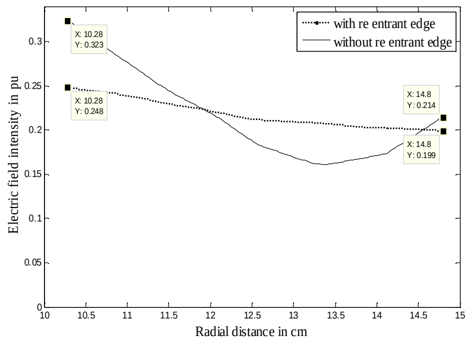

Fig 5.1 FEMM simulation result of variation of radial electric field intensity (with re-entrant edges in the coaxial capacitor)

From fig 5.1 it can deduce that the electric field intensity at edge of HV electrode without re-entrant edge is 0.25 times more than electric field intensity with re-entrant edge. The electric field intensity at edge of ground electrode without re-entrant edge is 0.21 times more than electric field intensity with re-entrant edge. Which infer that the electrodes without re-entrant edge will stress more at edge.

V.II VARIATION OF CAPACITANCES WITH LENGTH OF CAPACITOR

V.II.A. WITHOUT REENTRANT EDGE WITHOUT GROUND EFFECT

From fig 5.2 It can deduce that the variation capacitance of capacitor (without re-entrant edge and not considering ground effect) plotted using FEMM and analytical (equation 3.7) are same. Even though the FEMM considers the edge

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

effect there is not much variation in capacitance value of FEMM and analytical .therefore it can infer that the edge doesn't effects on capacitances of capacitor.

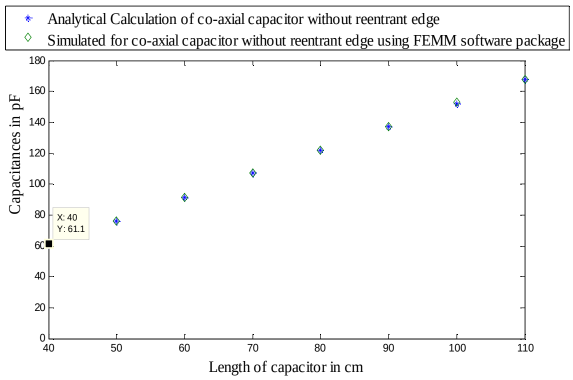

Fig 5.2 Variation of capacitances of capacitor with change in length of capacitor without re-entrant edge and without considering ground effect

V.II.B. WITHOUT REENTRANT EDGE WITH GROUND EFFECT

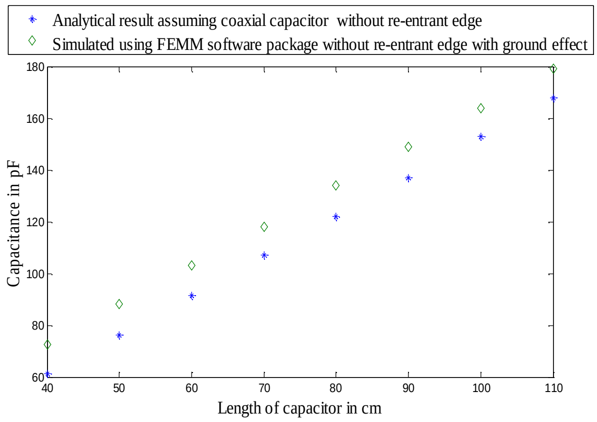

Fig 5.3 Variation of capacitances of capacitor with change in length of capacitor without re-entrant edge and with considering ground effect

From fig 5.3 it can deduce that the variation of capacitance of capacitor (without re-entrant edge and considering ground effect) with variation of length of capacitor plotted using FEMM has incremented by 15 pF value with analytical (equation 3.7) value. It is because the ground effect has not considered in analytical equation. It can also be infer that the ground capacitances is not much varied with variation of length of capacitor.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

V.II.C. WITH RE-ENTRANT EDGE WITH GROUND EFFECT

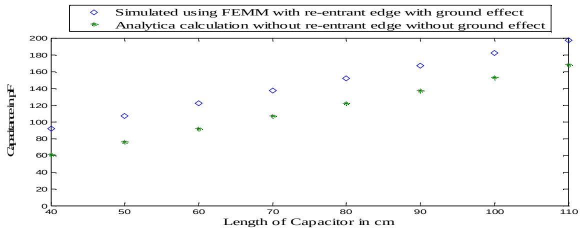

Fig 5.4 Variation of capacitances of capacitor with change in length of capacitor with re-entrant edge and with considering ground effect

From fig 5.4 it can deduce that the variation capacitance of capacitor (with re-entrant edge and with considering ground effect) with variation of length of capacitor plotted using FEMM has incremented by 25 pF value with analytical (equation 3.7) value. It is because the ground effect and re-entrant edge effect has not considered in analytical equation. The effect of ground and re-entrant edge on capacitance with variation of length of capacitor is constant.

V.III ELECTRIC FIELD DISTRIBUTION OVER HV ELECTRODE OF STANDARD CAPACITOR

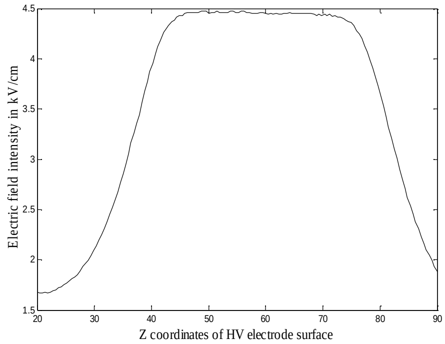

Fig 5.5 FEMM simulation result of variation electric field intensity over HV electrode (inner electrode) surface

From fig 5.5 it can deduce that the maximum electric field stress over HV electrode is not more than 4.5kV/cm at 17kV applied at HV electrode. It can also deduce that the electric stress at re-entrant edge is much lesser than maximum electric stress.

V.IV ELECTRIC FIELD DISTRIBUTION OVER GROUND ELECTRODE OF STANDARD CAPACITOR

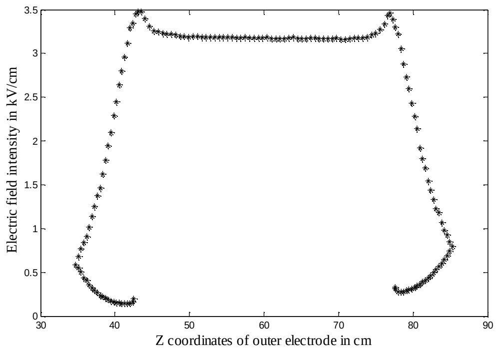

Fig 5.6 FEMM simulation result of variation electric field intensity over ground electrode (outer electrode)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

From fig 5.6 it can deduce that the maximum electric field stress over ground electrode is not more than 3.5kV/cm at 17kV applied at HV electrode. It can also deduce that the electric stress at re-entrant edge is much lesser than maximum electric stress.

V.V VARIATION MAXIMUM ELECTRIC STRESS OF STANDARD CAPACITOR AS FUNCTION OF HEIGHT OF STANDARD CAPACITOR ABOVE THE GROUND PLANE

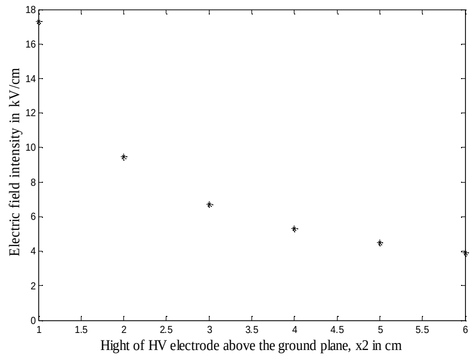

Fig 5.7 FEMM Simulation result of variation of maximum electric field intensity over HV electrode (inner electrode)

From fig 5.7 it can deduce that the maximum electric field intensity over HV electrode is more than 5kV/cm if the height of HV electrode is less than 4.5 cm so minimum height of capacitor above ground level should be more than 4.5 cm.

V.VI ELECTRIC FIELD DISTRIBUTION OVER GROUND SURFACE

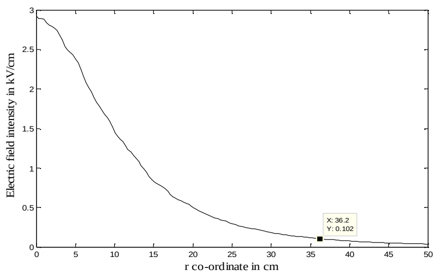

Fig 5.8 FEMM simulation result of variation of electric field intensity along ground surface

From fig 5.8 it can deduce that the maximum electric field intensity over ground surface is less than 3kV/cm. It can also infer that the effect of ground on capacitor is less after 36 cm away from centre axis.

V.VII Electric field distribution from ground surface to bottom edge of inner electrode of standard capacitor

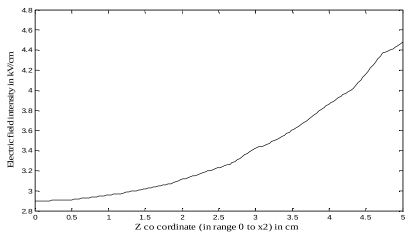

Fig 5.9 FEMM simulation result of variation of electric field intensity in the range of 0 to x2

From fig 5.9 it can deduce that the electric field intensity from ground surface to bottom edge of HV electrode is increasing. And stress at bottom point of HV electrode is 4.4kV/cm which is less than maximum stress.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 3, March 2017

VI.CONCLUSION

The electric field intensity and capacitance is analysed for various conditions using FEMM 2D software. The maximum value of electric field strength along the inner electrode and outer electrode surface occurs close to upper re-entrant edge and it is less than designed value of 5 kV/cm .This avoids the possibility of corona. The maximum value of stress without re-entrant edge is 1.25 times than maximum stress with re-entrant edge.

REFERENCES

[1] Deepesh.S.Kanchan,G.S.Punekar"Design and Fabrication of High Voltage Standard Capacitor," E&E Dept, NITK, Suratkal, M.tech Thesis 2008.K. M. Passino, "Biomimicry of bacterial foraging for distributed optimization," IEEE Control Systems Magazine, vol. 22, no. 3, pp. 52-67, 2002.
[2] Dieter, "Fundamental Principles of high voltage test techniques", 2nd Edn. Newnes Publication, 2001.
[3] Kuffel.'High voltage Engineering Fundamentals", 2nd Edn.Newnes Publication.
[4] M.S. Naidu, "High Voltage Engineering", 2nd Edn. McGrawHill Publication.
[5] E.W.Golding, "Electrical Measurement and Measuring Instruments", Pitman, 3rd Edn. 1950.
[6] IS 13203, "Method for Verifying Accuracy of Tan Delta Measurements", 1991.
[7] IS 6209, "Methods for partial discharge measurement (first revision)", 1982.
[8] William.E.Anderson, "A Calibration Service for voltage Transformers and High Voltage Capacitors", NBS measurement services, June 1988, www.ts.nist.gov.
[9] Hillihouse.D, "A 300 kV compressed gas standard capacitor with negligible voltage dependence", IEEE Trans, on Instrumentation and Measurement, Vol. IM-22, No. 4, Dec. 1973.
[10] J. Rungis, D.E.Brown, "Experimental study of factors affecting capacitance of high voltage compressed-gas capacitors", IEE proceedings, vol. 128, May 1981, 5p.
[11] Cesar Penz, Carlos Flesch, "Influence of standard capacitors on the quality of high voltage tests on electrical energy transmission equipment", XVIII World Congress on Metrology for a sustainable development, September 2006.
[12] W.E. Anderson, W.M. Moore, "An International comparison of high voltage capacitor calibrations", IEEE Trans, on PAS, Vol. 97, No. 4, July/Aug 1978.
[13] GaoGuanggan, "The effect of the electric field of the grounded electrode on the capacitance of compressed-gas capacitors", CPEM '90-Conference on precise electromagnetic measurements, June 1990b, 1 p.
[14] Peterson.O, "A wide range high-voltage capacitance bridge with one ppm accuracy", IEEE trans, on Instrumentation and measurement, vol. IM24, No. 4, December 1975.