ELECTRIC FIELD AROUND HVDC INSULATOR STRING FOR VARIOUS CONTAMINATION LEVELS

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Abstract—**Electric field and voltage distributions along polluted insulator string are calculated using COULOMB which is a three –dimensional electric field analysis software package. This package calculates field using Boundary Element Method. This field distribution in dry band of insulator is found to be distorted by the presence of pollution layer on insulator surface. The models developed for the calculation, are based on pollution severity in ESDD (as per standard IEC 815). The field is analyzed along surface and near insulator of an insulator string for different severity levels**

Keywords: ceramic disc insulator string,pollution severity, flashover,corona,

I. INTRODUCTION

HIGH voltage direct current (HVDC) has been made an economically and ecologically attractive alternative to alternating current systems in transmission of huge blocks of electrical energy over long distances. More contaminants accumulate on dc insulators because of the static electric field of dc voltage, which is 1.2–1.5 times higher than that on ac insulators under the same atmospheric environment [1]. In the heavy contaminated areas, various forms of damage to the sheath and sheds were observed and a number of insulators flashed over. The flashover of polluted transmission line insulators is a major problem faced by power engineers. The performance of insulators under polluted conditions constitutes one of the guiding factors in the design and dimensioning of insulation in power transmission line. Under operating conditions a layer of pollution is deposited on the insulating surface. And the presence of pollution layer on HV insulators is very frequent in industrial and coastal regions. This pollution layer when combined with moisture becomes conducting and a leakage current flows through it. The phenomenon intensifies electric field in dry bands and potential distribution becomes distorted, as a consequence it initiates the surface corona discharges and accelerates the aging of the shed material, it also results to an undesirable flashover. Therefore, computation electric fields and potential is worthwhile for studying the aging process and the behavior of polluted insulators.

Several studies recommended that the threshold electric field at any point on the surface of dry insulator to prevent dry corona is 2.28 kV/mm. And for the wetted insulator the threshold electric field strength to prevent corona is 0.38 kV/mm.[2][3]

The objective of this paper is to study the electric field strength on the surface of polluted insulators string for different severity levels which could be helpful to identify the critical pollution severity to prevent undesired corona and flashover.

II. SOFTWARE DESCRIPTION

All the studies described in this paper are done on a commercially available software COULOMB, which developed by Integrated Engineering Software. This calculates electric field using Boundary Element Method, which gives accurate solution to open boundary problem.

III. SIMULATION MODEL

A string of four 33kV disk insulators is considered to develop a simulation model on the mentioned software package. The geometry and dimension of insulator string are shown in Fig. 1.

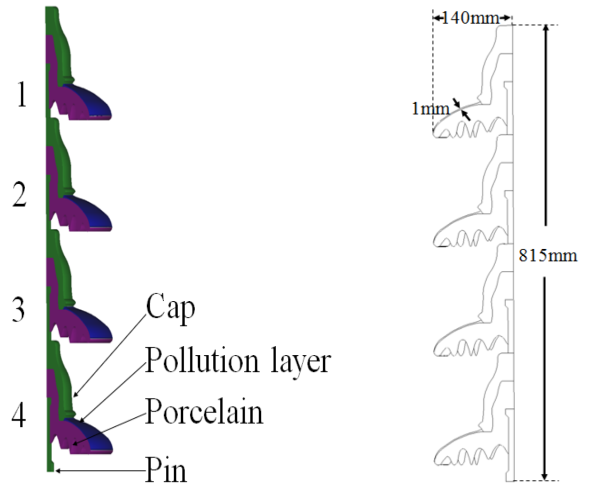


Figure 1. The model developed for simulation

The disks are numbered from 1-4 from ground to line and a line voltage of 100 kV is applied to the lowest disk number four, remaining caps and pin are treated as floating. A uniform pollution layer of 1mm is assumed on upper surface of all four insulator of the insulator string. To consider the effect of tower, a solid conducting plate has been considered at a distance of 400cm apart from insulator string. The size of plate has been determined such that the effect of tower and the plate were same. The model with this is shown in fig. 2. Several experim-

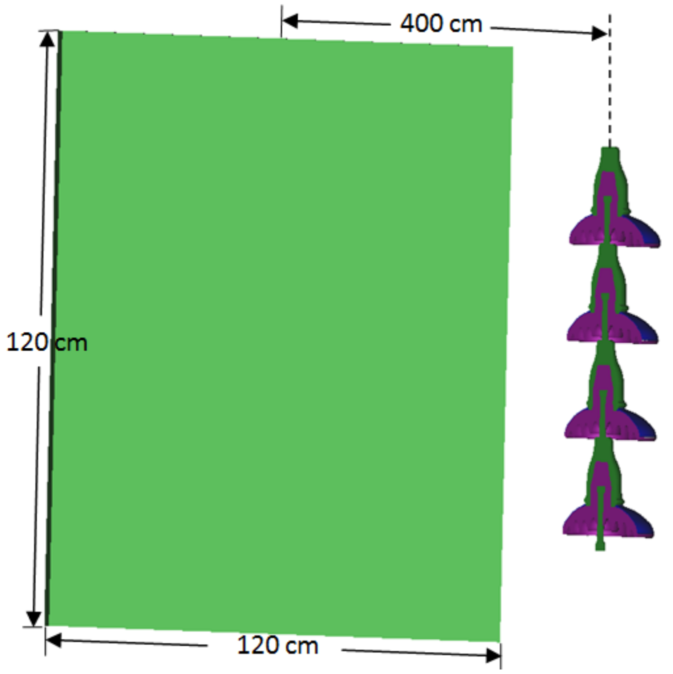


Figure 2 Model of insulator string with equivalent tower

ents have been performed for different IEC 815 pollution severity standard as given in table 1. As the software package accepts data only in terms of conductivity therefore to assign a

TABLE I. IEC 815 CONTAMINATION SEVERITIES

Pollution level	ESDD mg/cm^2
Light	Less than 0.06
Medium	0.20
Heavy	0.60
Very heavy	Greater than 0.60

pollution layer, severity level ESDD has been defined in term of conductivity. M. A. Salam [4] has experimentally found the relation between ESDD and conductivity as given in following table 2. Using the data of table 2 a graph has been drown as given in figure 2, which appears as an straight line and it has been approximated as an straight line to fine the conductivity for several value of ESDD as given in table 3 that include the approximate value of conductivity for several value of ESDD which has been used in the stimulation.

TABLE II. CONDUCTIVITY OF 20×20 CM CONTAMINATED GLASS PLATE

Conductivity σ (S/m) at 20˚C	ESDD (mg/cm^2)
0.01562	0.041401
0.021562	0.057706
0.24663	0.066272
0.039284	0.107044
0.045647	0.124944

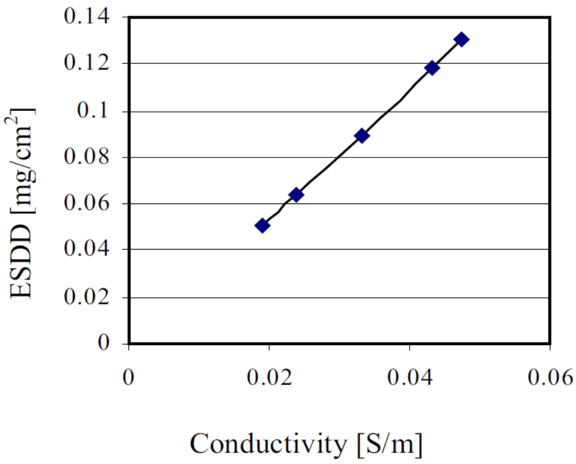


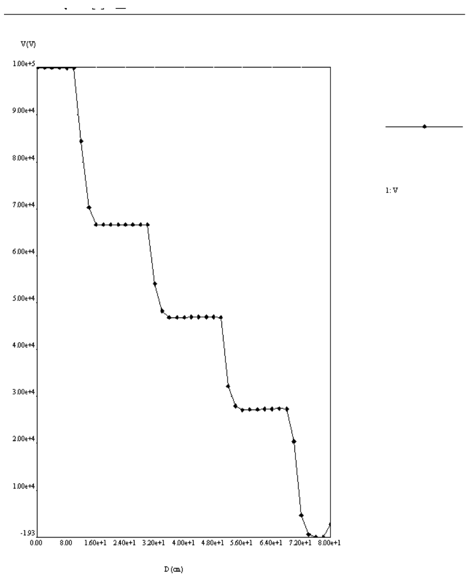
Figure 3 Characteristics of Conductivity Vs ESDD

TABLE III. CONTAMINATION SEVERITIES AND CONDUCTIVITY

Pollution level	ESDD mg/cm^2	Conductivity σ (S/m)
Light	0.02	0.0065
	0.04	0.0136
	0.05	0.0172
Medium	0.06	0.0208
	0.10	0.0352
	0.15	0.0532
	0.20	0.0711
Heavy	0.30	0.1071
	0.40	0.1430
	0.50	0.1790
	0.60	0.2149
Very Heavy	0.80	0.2868
	1.00	0.3587

IV. RESULTS AND DISCUSSION

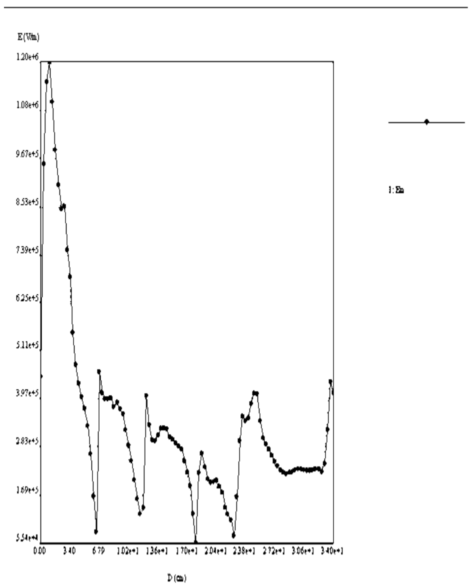
The results obtained using the model as shown in figure 1 and by varying the conductivity of pollution layer are shown below. The voltage drop along the central axis has been found as in fig. 4, and it can be said that voltage drop along the lowest insulator is highest so the field will be greater along this insulator and it will more worth to study the field along this insulator. It is found from the simulation result that the field along the insulator surface is higher in the region near line conductor fig. 5.



	Curve 1 D	Curve 1 V
1	0.0000000e+000	1.0002820e+005
2	2.0000000e+000	1.0003981e+005
3	4.0000000e+000	1.0005414e+005
4	6.0000000e+000	1.0003799e+005
5	8.0000000e+000	1.0000020e+005
6	1.0000000e+001	9.9995058e+004
7	1.2000000e+001	8.4430081e+004
8	1.4000000e+001	7.0372725e+004
9	1.6000000e+001	6.6595940e+004
10	1.8000000e+001	6.6598511e+004
11	2.0000000e+001	6.6620135e+004
12	2.2000000e+001	6.6653770e+004
13	2.4000000e+001	6.6672625e+004
14	2.6000000e+001	6.6658446e+004
15	2.8000000e+001	6.6644234e+004
16	3.0000000e+001	6.6626496e+004
17	3.2000000e+001	5.4153456e+004
18	3.4000000e+001	4.8195872e+004
19	3.6000000e+001	4.6778079e+004
20	3.8000000e+001	4.6793214e+004
21	4.0000000e+001	4.6804965e+004
22	4.2000000e+001	4.6875723e+004
23	4.4000000e+001	4.6883006e+004
24	4.6000000e+001	4.6884971e+004
25	4.8000000e+001	4.6868987e+004
26	5.0000000e+001	4.6838729e+004
27	5.2000000e+001	3.2107719e+004
28	5.4000000e+001	2.7906802e+004
29	5.6000000e+001	2.7084665e+004
30	5.8000000e+001	2.7112402e+004
31	6.0000000e+001	2.7125307e+004
32	6.2000000e+001	2.7280113e+004
33	6.4000000e+001	2.7298249e+004
34	6.6000000e+001	2.7331693e+004
35	6.8000000e+001	2.7288256e+004
36	7.0000000e+001	2.0323537e+004
37	7.2000000e+001	4.6551226e+003
38	7.4000000e+001	5.1665074e+002

Figure 4 Voltage waveform along central axis of string

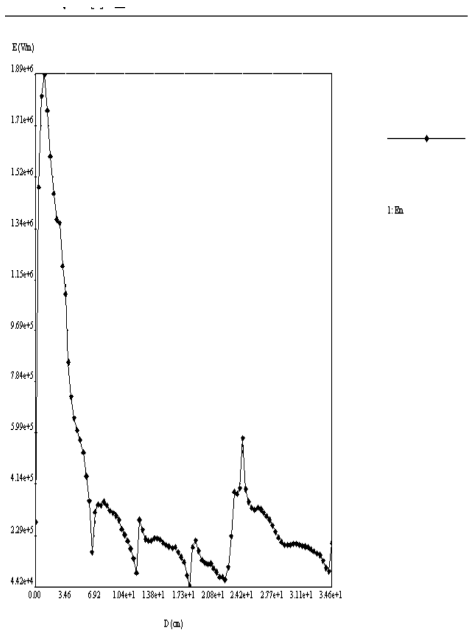
Without any contamination the highest electric field strength on the insulator surface is 1.19517 kV/mm at line voltage of 100 kV which is shown in fig. 5. The highest electric field



	Curve I D	Curve I E
1	0.0000000e+000	4.5000128e+005
2	3.3971998e-001	9.5484108e+005
3	6.7943997e-001	1.1492136e+006
4	1.0191599e+000	1.1951761e+006
5	1.3588799e+000	1.1020887e+006
6	1.6985999e+000	9.8874454e+005
7	2.0383199e+000	9.0397061e+005
8	2.3780399e+000	8.4745279e+005
9	2.7177599e+000	8.5508875e+005
10	3.0574798e+000	7.5072405e+005
11	3.3971998e+000	6.8671105e+005
12	3.7369198e+000	5.5230452e+005
13	4.0766398e+000	4.7723437e+005
14	4.4163598e+000	4.3324412e+005
15	4.7560798e+000	4.0254875e+005
16	5.0957997e+000	3.7427610e+005
17	5.4355197e+000	3.3293560e+005
18	5.7752397e+000	2.6606476e+005
19	6.1149597e+000	1.6654187e+005
20	6.4546797e+000	8.1828175e+004
21	6.7943997e+000	4.5967778e+005
22	7.1341196e+000	4.1137990e+005
23	7.4738396e+000	3.9693025e+005
24	7.8135596e+000	3.9618935e+005
25	8.1532796e+000	3.9890384e+005
26	8.4929996e+000	3.7674834e+005
27	8.8327196e+000	3.8914121e+005
28	9.1724395e+000	3.7264884e+005
29	9.5121595e+000	3.6220610e+005

Figure 5 Electric field along the surface of insulator in normal condition

strength on the surface of insulator in contaminated condition is 1.9374kV/mm (at ESDD= 0.02mg/cm^2 for light pollution level) and 2.131kV/mm (at ESDD=0.80 mg/cm^2 for very heavy pollution layer). It clearly show that the pollution layer enhance the electric field strength in the dry band by a factor of about 1.62 and 1.78 respectively.



	Curve 1 D	Curve 1 E
1	0.0000000e+000	2.7875799e+005
2	3.4598165e-001	1.4884217e+006
3	6.9196331e-001	1.8140983e+006
4	1.0379450e+000	1.8937499e+006
5	1.3839266e+000	1.7636963e+006
6	1.7299083e+000	1.5993613e+006
7	2.0758899e+000	1.4642390e+006
8	2.4218716e+000	1.3718310e+006
9	2.7678532e+000	1.3576911e+006
10	3.1138349e+000	1.2023716e+006
11	3.4598165e+000	1.1017812e+006
12	3.8057982e+000	8.5321647e+005
13	4.1517799e+000	7.2882819e+005
14	4.4977615e+000	6.5418237e+005
15	4.8437432e+000	6.1048150e+005
16	5.1897248e+000	5.7457407e+005
17	5.5357065e+000	5.2964354e+005
18	5.8816881e+000	4.4235308e+005
19	6.2276698e+000	3.5264390e+005
20	6.5736514e+000	1.6732316e+005
21	6.9196331e+000	3.1223104e+005
22	7.2656147e+000	3.4121463e+005
23	7.6115964e+000	3.3971336e+005
24	7.9575780e+000	3.5167732e+005
25	8.3035597e+000	3.3875153e+005
26	8.6495414e+000	3.1722521e+005
27	8.9955230e+000	3.1151081e+005
28	9.3415047e+000	3.0007505e+005
29	9.6874863e+000	2.8410582e+005

Figure 6 Electric field along the surface of insulator in polluted condition

The simulation is repeated for various values of pollution severities and the maximum electric field strength in the dry band has been represented in table 4 and fig. 7. And it is found that it increases with the pollution severity.

TABLE IV. ELECTRIC FIELD WITH VARIOUS POLLUTION SEVERITY LEVELS

Pollution level	**ESDD mg/cm^2**	**Maximum Electric Field E (kV/mm)**
Light	0.02	1.8937499
	0.04	1.8989849
Medium	0.06	1.9042602
	0.10	1.9148861
	0.15	1.9284281
	0.20	1.9421608
Heavy	0.30	1.9703949
	0.40	1.9997659
	0.50	2.0302912
	0.60	2.0622436
Very Heavy	0.80	2.1310601
	1.00	2.2187683

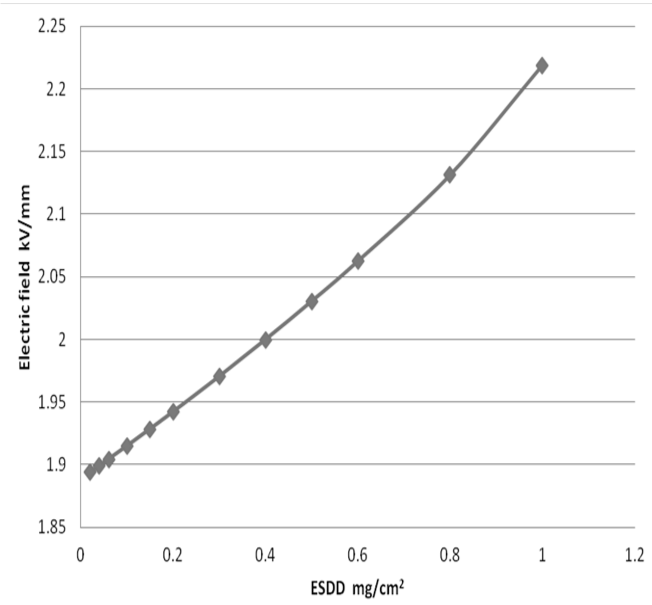


Figure 7 Maximum Electric field along the surface of insulator in different contamination levels.

V. CONCULUSION

The used PC package is a user friendly and interactive package for the analysis of an insulator model and can be successfully utilized for the performance evolution.

In this paper a dc insulator model has been developed and analyzed its performance for different pollution severity levels. Evaluated results clearly explain that the electric field strength increase with the severity levels. This type of simulation results can be used to find the critical pollution severity for a particular insulator model and the model can be modified before the hardware fabrication. These data can also be used for maintenance by periodic inspection few insulator severity level.

VI. ACKNOWLEDGEMENT

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[5] *http://www.integratedsoft.com/technology/BEM.asp*,Integrated Emgineering Software COULOMB.

APPENDIX

COULOMB is powerful 3D electric field design and analysis software developed by INTEGRATED Engineering Software which makes use of the mathematical technique of Boundary Element Method. The Boundary Element Method is well suited for open boundary problems. And design and analysis of an insulator requires a large open field analysis so it allows exact modeling of an insulator or insulator string.