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VOLTAGE DISTRIBUTION ACROSS STRING INSULATORS BY SPHERE GAP METHOD

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ABSTRACT

Insulators for overhead lines are considered to be of basic importance to the transmission system, through their ability to insulate the power lines as well as their function in carrying the weight of the line conductor. For higher voltages, a string of suspension insulators is used where the number of insulator units used depends on the voltages of the lines. The voltage is not equally shared between the units in a suspension insulator string. The unequal distribution of the voltage is due to the presence of stray capacitance of the hardware to earth and to line. Hence in this paper we are calculating the voltage distribution by sphere gap methods and comparing the results and we are also trying to make the voltage distribution across the insulators as uniform as possible by Guard rings. In this paper, we are also calculating the voltage distribution across the string insulators theoretically and comparing the results with practical values.

I. INTRODUCTION

Power transmission by overhead lines is the means of transportation of electrical energy from source to load centers. The insulator must also provide the necessary mechanical supports for the conductor against the worst likely mechanical loading conditions. The presence of pollution on the surface of insulators considerably modifies the voltage distribution across the insulator string. The pollution flashover poses serious threat to reliability of the system. The main reasons for the failure of insulators appear to be the insulator surface erosion and ion migration within its volume across each insulator in the string. This implies that the voltage distribution across the string is responsible for the uneven accumulation of the pollutants on the surface of insulators. Non uniform adherence of the surface of insulator surface has been reported both under laboratory and field conditions. The uneven voltage distribution across the string insulator will increase the probability of the puncture or shattering of insulators, if the condition such as surface erosion and increase in sodium ion concentration in the insulator volume due to pollution dominate. From the point of view of accumulation of the pollutant on the surface of the insulator, uneven voltage distribution and the failure of insulators occur.Thus the necessity to measure the voltage distribution along the insulator string has opened an interesting and challenging field of research. Hence simulation of voltage distribution calculation methods over a string of suspension insulators in case of clean - dry condition is presented. The voltage distribution across an insulator is not uniform, and the unit nearest to the line end is stressed to their maximum allowable value. Therefore, we have discussed a method in calculating the voltage distribution and have compared the string efficiency.

II. CONVENTIONAL METHODS

Methods of Measurement of Voltage Distribution:

The methods used for measurement of voltage distribution across the string insulator under AC voltages in dry conditions, are discussed in the following sections.

Sphere Gap Method:

This method consists of installing a sphere-sphere gap across the desired insulator, and then increasing the applied voltage to the string until the gap sparks over, thus determining the relative value of the voltage across the insulator.

Experimental Setup for Measurement of AC Voltage Distribution along String Insulators

The experiment setup used for the voltage distribution by sphere-gap method under AC voltage is shown in the below figure Theexperimental setup consisted of 4 and 6 strings of porcelain and glass disc insulators, (AC voltage) suspended vertically by means of a rope. The high voltage is applied to the pin of lowest insulator of the string. The porcelain insulators used were new, clean and dry. A power frequency test transformer of 50kV, 5KVA was used as the voltage source for the study of AC voltage distribution for 4 and 6 insulators string.

Experimental Procedure for Measurement of Voltage Distribution under AC Voltages By Sphere Gap Method

The experimental setup used for the study of AC voltage distribution is shown in the fig.1 where 2.0cm diameter sphere-gap is used for measurement of voltage distribution.

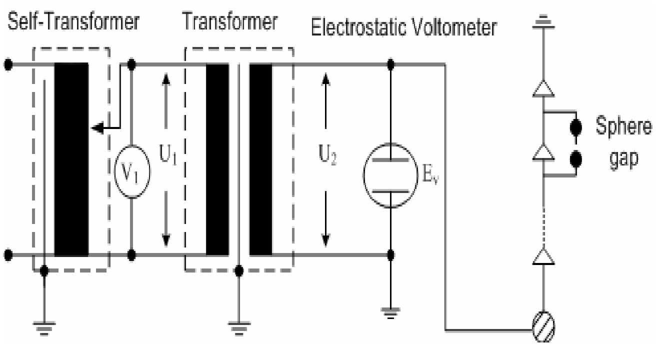

Fig.1: Measurement of Voltage Distribution by sphere gap

In this method of measurement, the spacing of the sphere-sphere gap was pre-set at a particular value. The electrode system was then connected across the insulator and the voltage applied to the string was raised till the spark over of the sphere-gap occurred. The above procedure was repeated for three or four times, and the average of these values was considered for the evaluation of the percentage voltage shared by the given insulator, which is expressed as,

$$\%V = \frac{\text{Spark over voltage of the sphere-sphere}}{\text{Voltage applied to the string to cause the sphere gap breakdown}}$$

The procedure is repeated on every insulator of 4 and 6 disc insulator strings. The percentage voltage shared by all the insulators was calculated after applying correction for the corresponding measured values to the string

Calibration of Sphere Gap

The voltage distribution of string of insulators is determined by sphere-gap method. Therefore break down of sphere-gap and its characteristics are very much important for accurate values of voltage across the insulators therefore the calibration of sphere-gap was carried out.

The procedure adopted is as follows:

The gap-spacing of the sphere-gap was kept at a particular value and the voltage was increased till spark over display. Average of 3 spark over values were considered for evaluation. The gap-spacing was increased by 1 mm or 2 mm and the procedure is repeated. The entire break down values was corrected to the standard atmospheric condition. The graph of break down voltage V/s gap-space was drawn for the corresponding sphere which was used for determination of voltage distribution.

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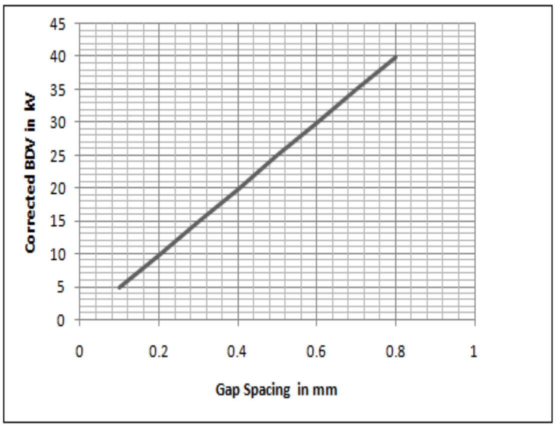

Calibration of spheres

III. SPHERE GAP METHOD USED FOR MEASUREMENT OF VOLTAGE WITH AND WITHOUT GUARD RING

The experiment setup used for the voltage distribution by sphere-gap method with and without guard ringsThe above figure shows the arrangement of voltage distribution without guard rings

Fig.2 Arrangement of voltage distribution without guard rings

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Fig.3 Sphere gap arrangement with the appearance of spark between the spheres without guard ring

Fig.4The arrangementof voltage distribution with guard rings and the theoretical values is calculated as below

Voltage Distribution Across 4 Disc Insulators Under AC Voltage Without Guard Ring calculation for theoretical

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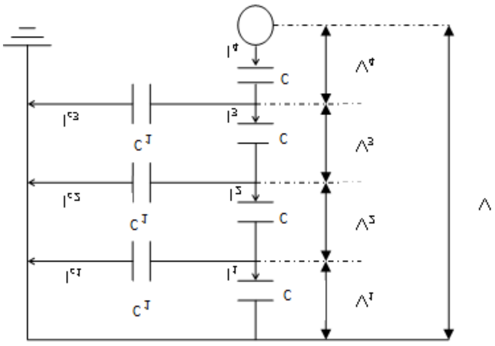

Fig 5 V across String Insulators

Let,

$$k = \frac{\text{Capacitance per ground}}{\text{Capacitance per insulator}} = \frac{C_1}{C}$$

Let V be the operating voltage (line to ground)

$V=V_1+V_2+V_3+V_4$

$I_2 =I_1+I_{C1}$

$2\pi fCV_2 = 2\pi fC_1V_1+2\pi fCV_1$

On simplifying we get

$V_2 = V_1 (1+k)$, where $k = C_1/C$

$I_3 = I_2+I_{c2}$

$2\pi fCV_3 = 2\pi fC_1 (V_1+V_2) +2\pi fCV_2$

$V_3= (k^2+3k+1) V_1$

$I_4 = I_3+I_{c3}$

$2\pi fCV_4 = 2\pi fC_1 (V_1+V_2+V_3) +2\pi fCV_3$

$V_4= (k^3+5k^2+6k+1) V_1$

$V=V_1+V_2+V_3+V_4$

Normally

$V_1<V_2<V_3<V_4$

Thus the lowermost unit is full stressed or utilized. As k value decreases the division of voltage becomes more equalized. "String Efficiency" is a measure of utilization of material in the string and is defined as

String Efficiency = Voltage across the string

n*voltage across unit

adjacent to line

Where, n is the number of insulators.

For 4 discs

String efficiency = $V_1+V_2+V_3+V_4$

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$4*V_4$

Calculation for 4 Disc Insulators

k = C1= 3pF = 0.1

C 30pF

$V_2 = V_1 (1 + k) = V_1 (1 +0.1)$

$V_2= 1.1 V_1$

$V_3 = V_1 (1 + 3k + k^2) =V_1 (1 +3* 0.1+ 0.1^2)$

$V_3 = 1.31 V_1$

$V_4 = V_1 (1 + 6k + 5k^2 + k^3) = V_1 (1 + 6*0.1 + 5*0.1^2 + 0.1^3)$

$V_4 = 1.65 V_1$

$V= V_1 + V_2 + V_3 + V_4$

$38.10 = V_1 + 1.1 V_1 + 1.31 V_1+ 1.65 V_1$

$5.06 V_1 = 38.10$

$(V_1+V_2+V_3+V_4) = 72.06\%$

Theoretical String Efficiency = $(V_1+V_2+V_3+V_4)$

$4V_4$

Theoretical String Efficiency=76.67%

Practical String Efficiency = $(V_1+V_2+V_3+V_4)$

$4V_4$

Practical String Efficiency = 72.06%

Theoretical Calculation without guard ring :

Insulator Number	%age of Voltage Shared	Voltage in kv
1(Line End)	32.6	12.42
2	25.88	9.86
3	21.73	8.28
4(Ground End)	19.76	7.53

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Thus the String efficiency and total percentage voltage shared by each insulator without guard ring practically is taken below and the graph is plotted with voltage across each unit and values are given

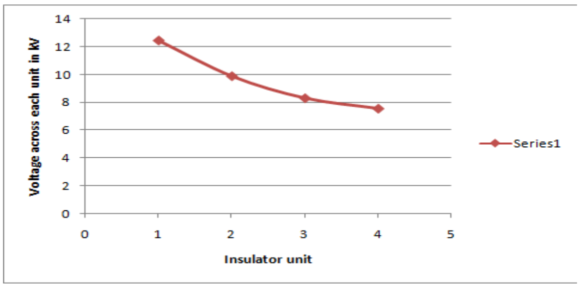

Fig. 6: Graph between voltage across each unit and given insulator value

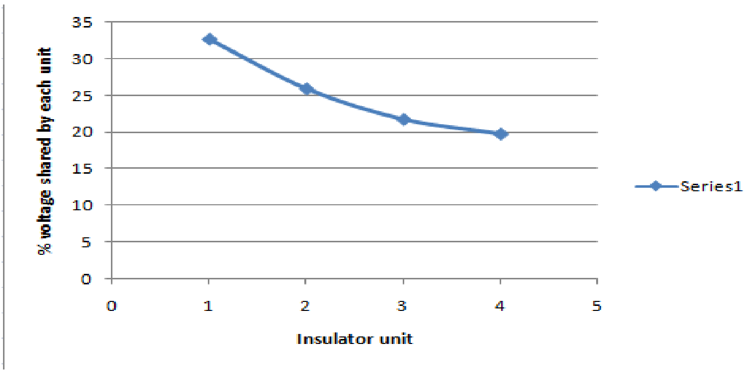

Fig. 7: Graph between percentage voltage shared by each unit and given insulator value

String Efficiency (%)	Total %age of Voltage Shared
76.67	99.8

Standard Method by sphere gap without Using Guard Ring For 2mm Gap Spacing

Insulator Number	Breakdown Voltage in kV	%age of Voltage Shared	Voltage in kv
1(Line End)	15	33.33	12.6
2	25	20	7.62
3	29	17.64	6.56
4(Ground End)	20	25	9.52

Voltage distribution across a string of 4 disc insulators calculated practically for 2mm gap spacing without guard ring

Standard BDV for 2mm spacing is 5kV(Corrected)

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String efficiency and total percentage voltage shared by each insulator

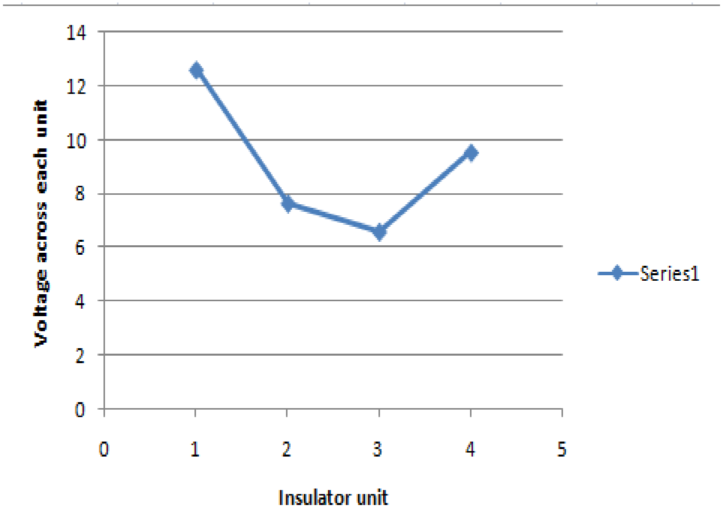

Fig. 8: Graph between voltage across each unit and given insulator value

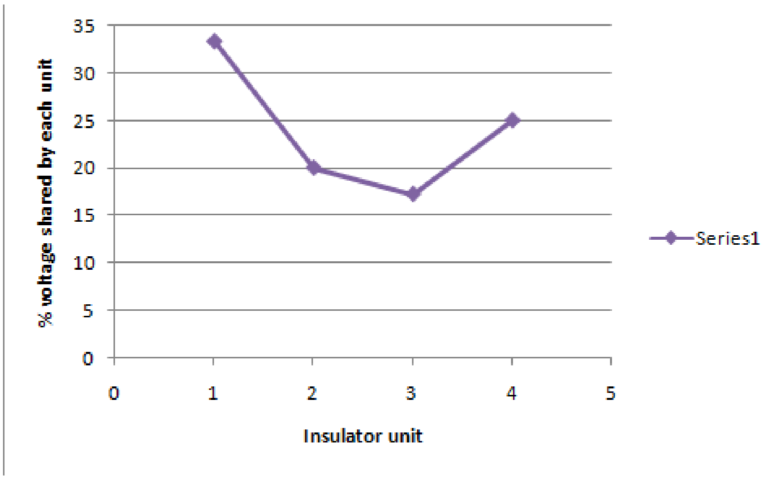

Fig. 9: Graph between percentage voltage shared by each unit and given insulator value

Standard Method by Using Guard Ring for 2mm Gap Spacing

Insulator Number	Breakdown Voltage in kV	%age of Voltage Shared	Voltage in kv
1(Line End)	15	25.12	13.049
2	16	24.13	13.049
3	15	25.13	13.057
4(Ground End)	15	24.13	13.049

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Voltage distribution across a string of 4 disc insulators calculated practically for 2mm gspacingusingguard rings

Thus the voltage is distributed equally by means of guard ring and the different comparison of string efficiency and total percentage of voltage shared for a string of 4 disc insulators is shown below

String Efficiency (%)	**Total %age of Voltage Shared**
72.06	95.6

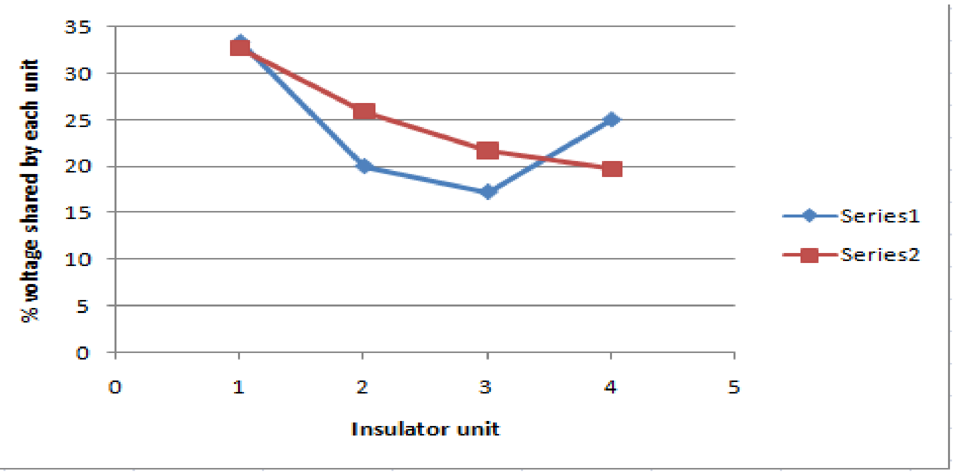
Comparison of String Efficiencyfor a String of 4 disc Insulators

Theoretical	**Standard method without guard ring**
76.6	72.6

Comparison of Total Percentage of Voltage Shared For a String of 4 disc Insulators

Theoretical	**Standard method without guard ring**
99.8	95.6

The belowgraph shows the comparison of voltage distribution with theoretical and practical method which is sphere gap method.



Series 1- Practical Series 2- Theoretical

Fig. 10: Graph showing comparison of voltage distributionboth theoretically and practically.

IV. CONCLUSION

The conclusions that can be drawn from the tests, which have been carried out to determine the voltage distribution for string of 4 disc insulators subjected to AC voltage using sphere-gap method with and without Guard ring are given below.Here the voltage distribution along 4 disc insulators is obtainedtheoretically and practically.The voltage distribution along 4 disc insulators calculated theoretically shows that the distribution is linear and the voltage goes on decreasing as we move from the line end to ground end but, the voltage distribution along 4 disc insulators calculated practically shows that the distribution is nonlinear and the voltage goes on decreasing as we move from the line end and slightly rises at the ground thus we can conclude that sphere gap method is efficient method.The voltage distribution for 4 disc insulators is approximately made uniform by connecting guard ring at the line end. This test shows that the line end insulator shares a higher percentage voltage which leads to Radio Interference Voltage.

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