OPTIMIZATION OF GRADING RINGS FOR VOLTAGE DISTRIBUTION IN 1200 KV SINGLE ‘V’ SUSPENSION INSULATOR STRING

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Abstract: Insulator string is the one of the most vital components of the transmission line. The common problem is non uniform voltage distribution along the string, due to the stray capacitance between the disc and the tower frame and ground. The voltage distribution depends on the dimensions of insulator string, hardware, the grading rings and the conductor. The discs, closer to the high voltage end, are normally stressed more. This high stress may initiate corona discharges and possible flashover. Hence ensuring the uniform voltage distribution along the insulator string is important.
The paper gives the results of the study conducted on 1200 kV Single ‘V’ suspension insulator string, for voltage distribution in each disc. The string, used for study, consisted of 46 numbers, 420 kN standard porcelain disc insulators with its complete hardware as in service. Eight Corona free polished tubes, with diameter of each tube as that of ACSR Bersimis conductor and spacing between the tubes as 550 mm were used to simulate the octagonal bundle conductor.
The voltage distribution was determined by measuring the voltage applied to the complete string and the voltage across each disc. The voltage across each disc was measured by using a sphere gap. Eight different configurations were used for the study. The variable parameters used were the grading ring tube diameter, ring diameter, its position from the high voltage end, tower window simulation. The results of all configurations and the optimized configuration are presented in the paper.

1 INTRODUCTION

To meet the growing demand of electricity, India is planning to introduce 1200 kV AC and 800 kV DC transmission system in the near future. A 1200 kV national test station is planned to collect data, which will be useful for operation and maintenance of the 1200 kV and 765 kV systems. As a part of this 1200 kV transmission line project, the study of optimization of the grading rings was undertaken at UHV research laboratory. The study was focused on obtaining an optimum grading ring configuration for uniform voltage distribution across the insulator string. .

2 METHODOLOGY

Methodology adopted is provided in the following sections.

2.1 Test samples and stringing details

New disc insulators of 420 kN, shown in Fig 1 were used in the string.

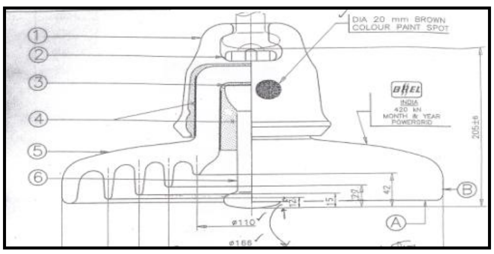


Figure 1: Disc Insulator

These were subjected to 60 kV rms power frequency withstand voltage test for one minute duration, to ensure their healthiness before assembly.

The V string was made with 2 X 46 numbers of disc insulators (Fig. 2) and suspended from a cross-arm as shown in Fig.4 with hardware suitable for octagonal ACSR Bersimis conductor. Eight smooth aluminium tubes of 36 mm diameter of length 18 m were provided at the line end yoke plate of the string with sub-conductor spacing of 550 mm to simulate octagonal Bersimus conductor. The hardware, conductors and grading ring were provided at the line end ‘V’ point of the string. These items are corona free up to a test voltage of 800 kV rms.

The ground clearance of the conductor was about 12 m and an air clearance of minimum 8.5 m was maintained from other nearby objects.

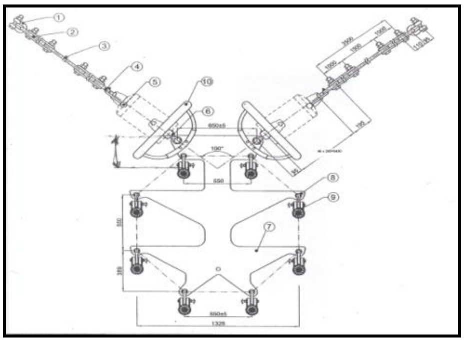


Figure 2: Insulator string drawing

To complete the test quickly, few of the insulators were selected in the string for obtaining the voltage distribution. The voltage distribution was measured for 10 discs from live end, 6 discs at the centre and 10 discs at the ground end. The experiments were conducted with eight different grading ring configurations. Based on evaluation of the results, ring configuration 8 was used to measure the voltage distribution across all 46 discs.

The voltage across each disc was measured by using a sphere gap. The sphere gap conforms to IEC: 60052[1].

2.2 Test set-up details

Test source: The AC test source consists of 1600 kV, 6 A outdoor cascade power frequency test transformer along with a 1600 kV capacitive divider for measurement of high-voltage. All the tests were carried out outdoor. Figure 3 gives the view of the AC test transformer.

Figure 3 : A view of the 1600 kV Test transformer along with the divider.

Test assembly area: The study was carried out by stringing the test sample in Mock up test tower area. This facility comprises of two dead end towers each of 48m height and 20 m width and located 80 m apart. These two towers were used to suspend the insulator string and its conductor. The facility is provided with motorized winches to lift the string. A view of this facility is shown in Figure 4.

Figure 4: A view showing 1200 kV Single ‘V’ string suspended from a cross-arm.

Conductor and hardware: Octagonal smooth aluminium tubes of 36 mm diameter and 18 m length with suitable spacers was connected at the line end yoke plate of the string with sub-conductor spacing of 550 mm. The conductor and hardware assembly was corona free up to the test voltage.

Grading ring configurations and insulators studied: The grading rings were fabricated based on the laboratory test data for 400 & 765 kV strings. These rings are high grade aluminium and corona free up to the test voltage of 800 kV rms.

Table 1: Grading ring details

Config. No.	Grading Ring details		
	OD, mm	Height, H, mm	Tube diameter, d, mm
1	700	700	70
2	700	500	70
3	700	300	70
4*	700	700	70
5*	700	500	70
6*	1200	700	100
7*	1200	500	100
8*	Single ring		
	1113	700	100

* with side tower simulation on one limb.

Insulators used: M/s. BHEL make

The drawings of the rings used as shown in Figures: 5 and 6.

Table 2: Gap spacing of and test voltages.

Disc No. (from HV end)	Sphere gap spacing, mm	Test voltage range, kV rms
1 to 10	6	280 to 400
21 to 36	3	530 to 590
37 to 46	3	230 to 790

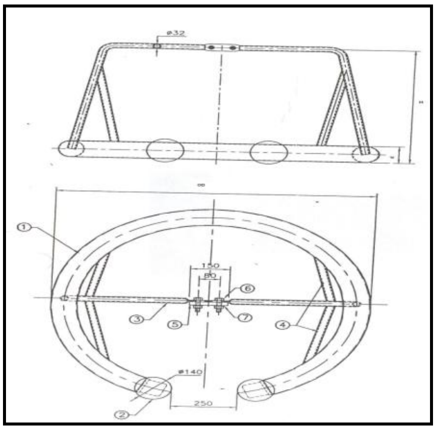


Figure 5: Ring drawing used for config. 1 to 7.

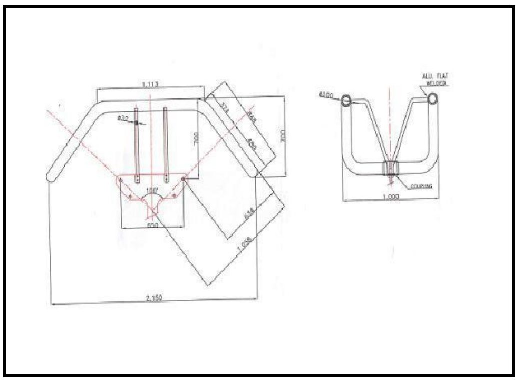


Figure 6: Ring drawing used for config.8.

Tower simulation: The Side tower simulation was carried out with MS angles of 50x50x5mm sections in the main frame and Aluminium angles in the inner bracing of size 50x 50 x 3mm.This tower simulation was done with a width of 5 m and a length of 18 m and a clearance of 8.0 m from the string.

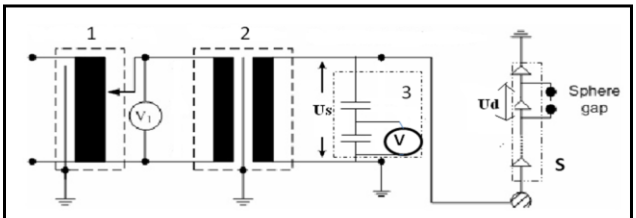
Method of voltage application and test voltages:

High voltage was connected to one end of the simulated conductor. Tower end of the string was connected to earth. The sphere gap was connected across the disc under test. The test voltage **Us** was gradually raised till the BDV of the gap was observed. The string voltage at the time of breakdown of sphere gap was recorded. The procedure was repeated three times and the average of three string voltages was used for calculation of voltage distribution across the disc under test. The experimental set up is shown in Fig.7. The ambient conditions prevailing during the test are also recorded. The procedure was followed for other discs in the string. The insulators were clean and dry.

AC Test voltage was applied as per IEC 60060-1 [2]. The percentage voltage across each disc is calculated as under:

% of Voltage distribution= (BDV of the sphere gap (rms) X K / average string voltage (rms) X 100

Where K is the correction factor for ambient conditions calculated as per IEC: 60052.



1: Regulating transformer
2:UHV cascade transformer
3:Capacitive voltage divider with RMS voltmeter
Us: String voltage RMS value
Ud: Gap break down voltage, Peak value
S:String

Figure 7: Experimental setup

3 TEST RESULTS

3.1 Voltage distribution for ring configuration 1, 2 & 3 (Without tower simulation).

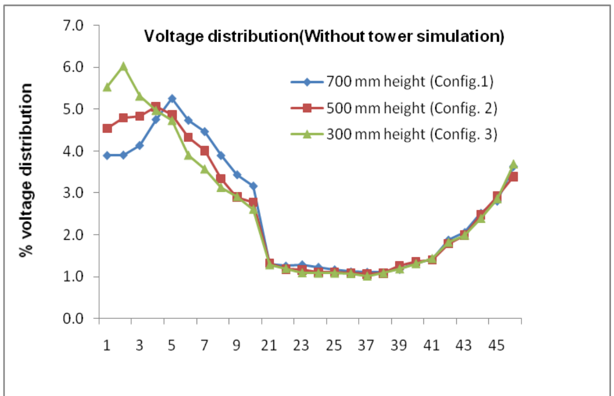


Figure 8: Voltage distribution for ring configuration 1, 2 & 3 (Without tower simulation).

3.2 Voltage distribution for ring configuration 4 & 5 (With tower simulation)

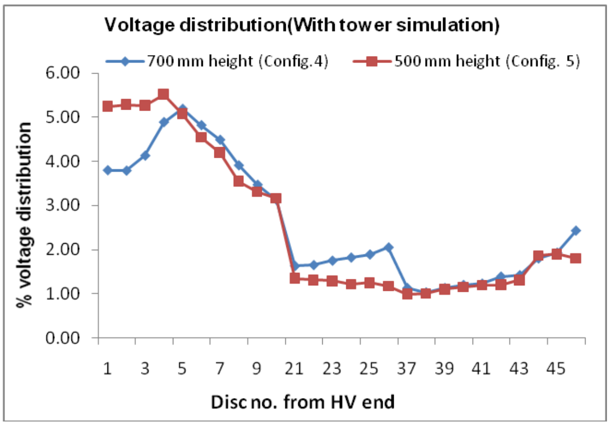


Figure 9: Voltage distribution for ring configuration 4 & 5 (With tower simulation).

3.3 Voltage distribution for ring configuration 6 & 7 (With tower simulation).

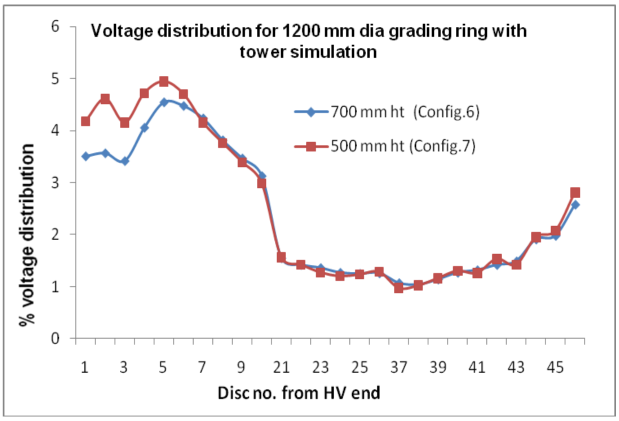


Figure 10: Voltage distribution for ring configuration 6 & 7 (With tower simulation).

3.4 Voltage distribution for ring configuration 8 (With tower simulation).

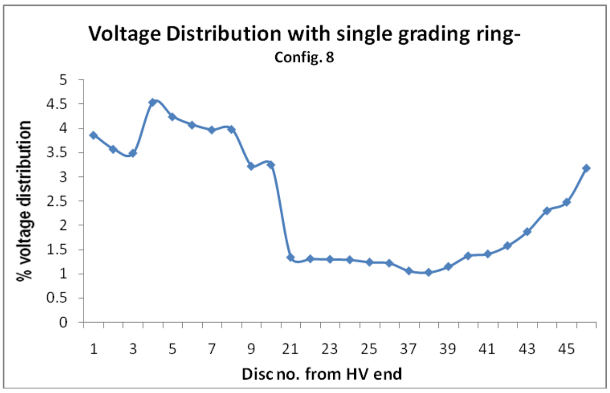


Figure 11: Voltage distribution for ring configuration 8 (With tower simulation)

From the voltage distribution curve (fig:11) obtained for all the discs in the string config 8 reveals that the field is uniform in the centre discs and gives a complete picture of the string voltage distribution.

4 ANALYSIS OF TEST RESULTS

4.1 Voltage distribution for 10 discs at ground end (Disc no 37 to 46 from HV end) with and without tower simulation:

Config. 1 & 2 are without tower simulation. Config 4 & 5 is corresponding results with tower simulation (Fig12).

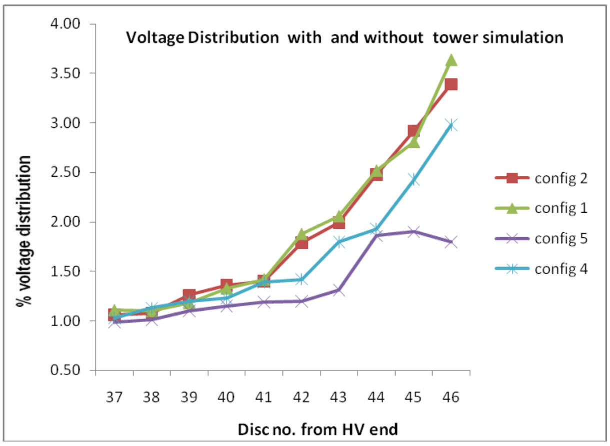


Figure 12: Voltage distribution With & without tower simulation.

The above reveals that relatively less voltage appear on ground end insulators in case of tower simulation.

4.2 Voltage distribution for first 10 discs from HV end with tower simulation:

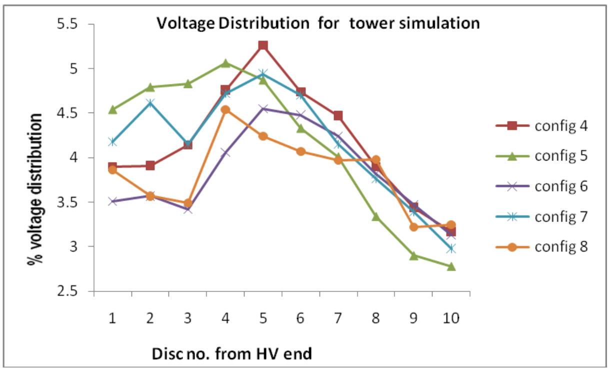


Figure 13: Voltage distribution for tower simulation configuration.

The test results (fig.13) of various geometrical corona rings reveals that voltage distribution is maximum on the disc just outside the corona ring.

4.3 Voltage distribution for 6 discs (Disc 21 to 26 from HV end) in the canter for all configurations:

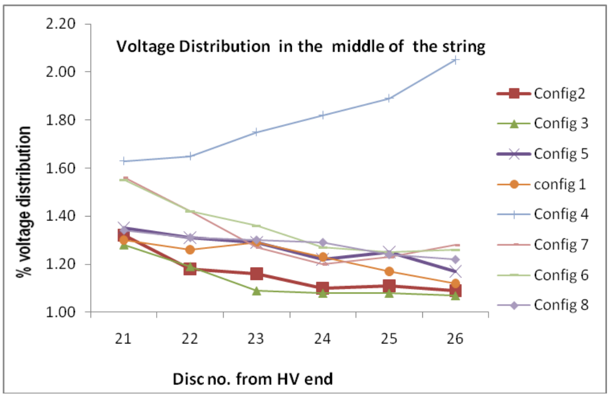


Figure 14: Voltage distribution in the middle of the string.

From the graph (fig14) reveals that the voltage distribution in middle discs remains low and about half the value to that of the insulators at HV end.

5 CONCLUSION

The paper provides the inputs for optimising the corona ring for UHV transmission lines strings. The voltage across the maximum stressed disc, with optimised configuration was 4.54%.This gives about 32 kV rms on the maximum stressed disc (1200/√3* 0.454=32).

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] IEC 60052 - Voltage measurement by means of standard air gaps.

[2] IEC 60060-1 - High-voltage test techniques - Part 1: General definitions and test requirements.