ANALYSIS OF ENHANCEMENT OF TRANSMISSION CAPACITY AC OVERHEAD LINES INTO DC LINES

Mr.Anil Boyal, Mr.Gaurav Srivastava

Abstract- **Limited transmission capacity of a line with respect to the needs is a serious problem to be faced while transmitting electrical energy. Tremendous difficulties in getting necessary permissions for new lines to be constructed in the areas of dense population result in seeking new ways of enhancing the transmission capacity of the existing extra-high voltage lines. At the same time, social pressure is building up to restrain acceptable values of electric and magnetic fields in the neighborhood of the existing and newly built transmission lines. To find solutions to both of the problems was the purpose of carrying out simulations of the conversion of alternating current lines into direct current lines.**

I. INTRODUCTION

INCREASING demand of electric power and addition of new generation capacity to meet the demand, necessitate enhancement of large transmission capacity between generation and bulk consumption points.

In India, major energy resources like coal and hydro potential are confined to a few pockets and located far-off distance from the load centres.

II. METHOD OF CONVERSION

With the conversion method adopted, it was assumed that the existing conductors should be used and insulators replaced for such ones that are adapted to direct current transmission and have the same length as the original insulators. Also, a method of the conversion was analysed with a new conductor added what increased the number of possible variations of the conversion. In each variation presented, the height of the tower has remained unchanged. Due to the fact that there is a wide variety of towers supporting conductors in 220 kV lines in india, the research was limited to the straight-line towers being in common use. Their silhouettes have been shown in Fig. 1. The towers with a delta configuration of conductors (Fig. 1a), with a horizontal conductor configuration (Fig. 1b) and with a vertical configuration of conductors (Fig. 1c) are to be found amongst them.
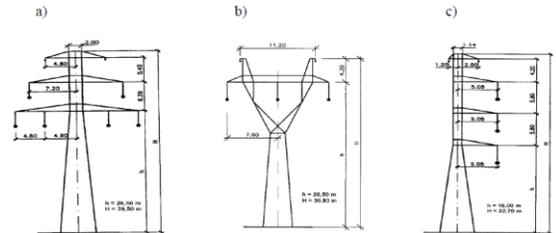
a) For 220 kV double circuit lines with a delta conductor configuration
b) for 220 kV single circuit lines with a horizontal conductor configuration and
c) for 220 kV single circuit lines with a vertical conductor

III. CALCULATION OF OPERATING VOLTAGES OF THE LINES CONVERTED

The method of calculation is based on the distance between a cross-arm of the tower and conductors of the line as defined by the length of the alternating current insulator to be used to the maximal extent. When the insulator was replaced by a direct current insulator of the same length, but with a different structure and longer creep age distance, it was possible for the direct current operating voltage to be identified.

The following assumptions were made for the purpose of the calculations:-
- The existing insulator strings adapted to alternating voltage are to be replaced by cap and pin insulators adapted to direct voltage;
- It is assumed that the cap and pin insulator creepage distance is equal to 550 mm, and the length of a single cap and pin insulator is equal to 171 mm;
- It is assumed that the specific creepage distance for individual pollution zones are equal to 26-34 mm/kV for zone I 32-44 mm/kV for zone II, 56 mm/kV for zone III and 70 mm/kV for zone IV. The difference made between the minimal and maximal values is due to the fact that it is not possible to determine unequivocally (at the stage of theoretical considerations) the value of a specific creepage distance since this parameter depends on the location and climate the line is working in.
On the basis of the analysis of the insulator strings used in India, it was determined that it would be

reasonable to convert 220 kV lines into direct voltage lines of ± (290-380) kV for pollution zone I and of ± (225-305) kV for zone II. In case of the remaining pollution zones, the conversion into direct current lines would not be advisable as the voltage values possible to be reached in a line converted, with the specific creepage distance assumed, are too low.

IV. ANALYSIS OF THE CONVERSION

In order to check whether the conversion proposed would result in the acceptable values of electric and magnetic fields and the ion current density under the lines converted being reached, a series of simulations of different variants of the conversion of the alternating.

Those variations were considered to be optimal which – under the lines - satisfied the following requirements and did not exceed the values as follows:
- For the electrostatic field strength: 16 kV/m,
- For the electric field strength with the presence of space charge (an average value) equal to
  35 kV/m,
- For the ion current density: 100 nA/m2;
- For the magneto static field strength: 8 kA/m.
  Some examples of especially advantageous methods of the conversion of 220 kV alternating Current lines will be shown further in the paper.

V. CONVERSION OF A DOUBLE CIRCUIT LINE WITH A DELTA CONDUCTOR CONFIGURATION

A system of the biggest increase of transmitted power from among all the variations analysed was created for the conversion of 220kV double circuit lines built on towers i.e. those with a delta conductor configuration (Fig. 1a). With the voltage of ± 350 kV, the increase of the transmission capacity of the line is 175% in relation to the alternating current transmission capacity. Such an increase of transmission capacity was to be observed with all the phase conductors being employed and three bipolar lines created with the configuration of poles as that in Variation A shown in Fig. 2. The polarization configuration presented is the only one that enables it for the voltage of ± 350 kV to be used, because it is characterized by the most advantageous distribution of the average value of electric field strength with the presence of a space charge as compared with the other variations of the conversion into three bipolar lines.

38 meters	Right of way	29.5 meters
Transmission capacity		Increase of 175 %

Conversion of a 220 kV double circuit alternating current line with a delta conductor configuration into three bipolar lines, for U= ± 350 kV.

Another interesting variation of the conversion of a double circuit line with a delta conductor configuration is represented by Variation B, in which as a result of the conversion, the lower line has a double conductor which has been created by the two lower circuits of the tower being combined (Fig. 3). Tower being converted into a system of two bipolar lines, the transmission
Capacity increases by 136 %. In comparison with Variation C, in which the configuration of conductors has been retained, in case of Variation B, the average value of electric field strength is reduced by 5 kV/m at the ground level with the line voltage of ± 300 kV. In addition, Variation B is characterised by the right of way narrower by 4 meters for which the requirement related to the ion current density has been satisfied.
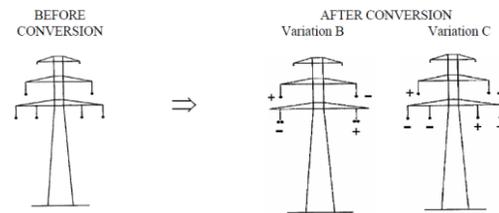
38 meters	Right of way	26 meters	30 meters
Increase of Transmission capacity		136 %	136 %

Conversion of a 220 kV double circuit alternating current line with a delta conductor Configuration into two bipolar lines, for U= ± 300 kV

VI. SELECTION OF THE BEST SOLUTIONS OF THE CONVERSION OF A LINE WITH RESPECT TO TRANSMISSION CAPACITY

In the calculation of transmission capacity, the differences in long-term load capacity between

alternating current and direct current as resulting from the different conductor resistance for both currents have been omitted. Also, no allowance has been made for the fact that in case of direct current transmission a skin effect cannot be observed which makes it possible for bigger power transmission to be carried out. A comparative list of power enhancement for some selected variations of the conversion of a 220 kV line has been presented in Table 1.

Line Type	Converted Line Parameters	Transmission Capacity for AC *) [MVA]	Transmission Capacity for DC [MW]	Transmission Capacity Increase [%]
single circuit, horizontal conductor configuration	± 250 kV ; I=0,8kA; 1 bipolar line (Variation E) ± 250 kV; I=1,6kA; 1 bipolar line	305	400 800	31 162
double circuit, delta conductor configuration	3 bipolar lines ± 300 kV ; I=0,8kA; 2 bipolar lines ± 300 kV; I=0,8 and 1,6kA; 2 bipolar lines	610	1,680 960 1,440	175 57 136

The following parameters were set up while determining the transmission capacity of alternating current lines:
- admissible temperature of working conductors: + 600C;
- in 220 kV lines, a single conductor AFL-8 525 mm2 is employed of the long-term summer-time
  loading for the temperature of + 600C equal to 800 A.

VII. CONCLUSION

- In single circuit lines with a horizontal conductor configuration with the voltage of ± 250 kV;
- In single circuit lines with a vertical conductor configuration with the voltage of ± 250kV, ± 400 kV;
- In double circuit lines with a delta conductor configuration with the voltage of ± 300 kV, ± 350 kV;
 The levels of direct voltages in the lines converted being dependant on a variation of the conversion. The

results of the analyses of the conversion of the 220 kV alternating current lines existing in india into direct current lines prove that their transmission capacity can be increased substantially. The conversion of 220 kV double circuit lines with a delta conductor configuration has turned out to be the most advantageous, with the increase of the transmission capacity up to 175%. In case of 220 kV single circuit lines, the increase can achieve the level of up to 162.

REFERENCES

[1] Edward Wison Kimbark, "Direct Current Transmission, Volume 1" John Wiley & Sons, Inc., 1971, ISBN 0-471-47580-7

[2] Jos Arrillaga "High Voltage Dirrect Transmission" 2nd Edition, IEE power and energy series 29, 1998, ISBN 0 85296 941 4

[3] Leonard A. Bateman, R.W Haywood, " Nelson River DC Transmission Project", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-v 88, No. 5, pp. 688-693, May 1969.

[4] R.M. Morris, A.R. Morse, J.P. Griffin, O.C. Norris-Elye, C.V. Thio, and J.S. Goodman, "The Corona and Radio Interference of the Nelson River HVDC Transmission Lines," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-98, No. 6, pp. 1924-1936, Nov.-Dec., 1979.

[5] Erich Uhlmann, "Power Transmission by Direct Current", Springer-Verlag Berlin Heidelberg New York 1975, ISBN 3-540-07122-9

[6] Willis F. long, Editor "Comparison of costs and benefits for DC and AC transmission", OAK Ridge national laboratory, ORNL-6204, Feb 1987.

[7] J.P Bowles, V. Burtnyk, C.C Diemond, M.A. Lebow, E.G. Neudrof, D. Povh, E.C. Starr, C.W. Taylor, R.A. Walling, edited by C.T. WU " ACDC economics and alternatives- 1987 panel session report", IEEE transactions on power delivery, Vol.5, No.4, pp.1241-1248, November 1990

[8] Consumer Price Indexes, US Department of Labor, Bureau of Labor Statistics, Available [On-Line], http://www.bls.gov/cpi/

[9] Gerhard Schmidt. Bernd Fiegl and Stefan Kolbeck "HVDC transmission and the environment" power engineering journal, p 204-10, Oct 1996.

[10] P.S. Maruvada , R.D. Dallaire, O.C. Norris-Elye, C.V. Thio, and J.S. Goodman, "Environmental Effects of the Nelson River HVDC Transmission Lines – RI, AN, Electric Field, Induced Voltage, and Ion Current Distribution Tests," IEEE Transactions on Power Apparatus and Systems, Vol. PAS-101, No. 4, pp. 951-959, April., 1982.