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STUDY OF 132 KV TRANSMISSION LINE DESIGN AND CALCULATION OF ITS PARAMETERS

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ABSTRACT

An electrical power system comprises of three main networks namely, generation network, transmission network and distribution network.It has becomenecessary to construct new substations, power-plants and transmission lines in order to meet the energy demand, reduce the losses and optimization of power supply. Electrical power system is necessary to meet the demands of the consumers for proper and smooth running of the equipments. In this paper we deal with the study of the parameters required in a transmission line design and the calculation of parameters. This would help the designers to implement the values while installing a transmission line under various environmental conditions.

Keywords: Critical Disruptive Voltage, Voltage Regulation, Geometric Mean Radius, Geometric Mean Distance, Transmission Line Parameters.

I INTRODUCTION

Power systems nowadays are extremely interconnected which requires mass transfer of electrical power. A certain type of transmission line is considered which will be able to transfer a fixed amount of power through it. In India, 765 KV lines are rarely used and it is still under construction in most of the places but 400KV, 220 KV and 132KV lines are mostly used for the long distance transmission. Here, in this paper we will discuss about the 132 KV transmission line and the parameters involved with it.

In this paper, IEEE and ANSI standards are used in relation to 132 KV, 220KV and 400KV standards, electrical design of 132KV transmission line is shown. A transmission line is a distributed parameter circuit and it comprises of energy storing elements like inductance and capacitance.

The transfer of bulk electrical energy from generating plants to substations is done by transmission of electric-power. When interconnected the transmission lines become transmission networks. Power is usually transferred through overhead power lines. The Overhead lines are much advantageous than the underground cables because transmission of power is generally done over long distance to load centre as the installation cost of underground cables are high. Moreover, for economic reasons the electric power is to be transmitted at high voltages where it

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is not possible to provide proper insulation to the cables for withstanding such amount of high pressures. Underground cables are limited strictly by their thermal capacity permitting fewer overloads.

II.OVERHEAD TRANSMISSION

High-voltage overhead conductor does not have a insulated covering. The conductor material is always an aluminium alloy, divided into several strands and reinforced with strands of steel. Copper was usually used for overhead transmission but aluminium is lighter, only marginally reduced performance is yielded, and cost is much lesser. Overhead conductors are supplied by several companies worldwide is considered a commodity. Improving the conductor material and shapes are regularly been used to allow modernize transmission circuits and increase the capacity. Now-a-days, the level of transmission voltages are usually considered to be 110 kV and above. Lower voltages such as 66 kV and 33 kV are usually considered sub transmission voltages but are occasionally used with light loads in long lines. Voltages less than 33 kV are usually used for distribution. Voltages above 220 kV are considered extra high voltage and demands different designs when compared to equipment used at lower voltages. Overhead transmission wire depends on air for insulation, so the design of these lines requires minimum clearances to be observed to maintain safety. Weather conditions of high wind and low temperatures which is adverse can lead to outage of power.

2.1 Main Components of Overhead Lines

The mechanical design is the most important factor that is to be considered for the successful operation of an overhead line. While constructing an overhead line, the mechanical strength of the line should be such so that it can withstand the most probable weather conditions. In general, the main components of overhead lines are: Towers**,** Conductors**,** Insulators**,** Cross arms**,** miscellaneous items**,** Earth wire**,** Foundation.

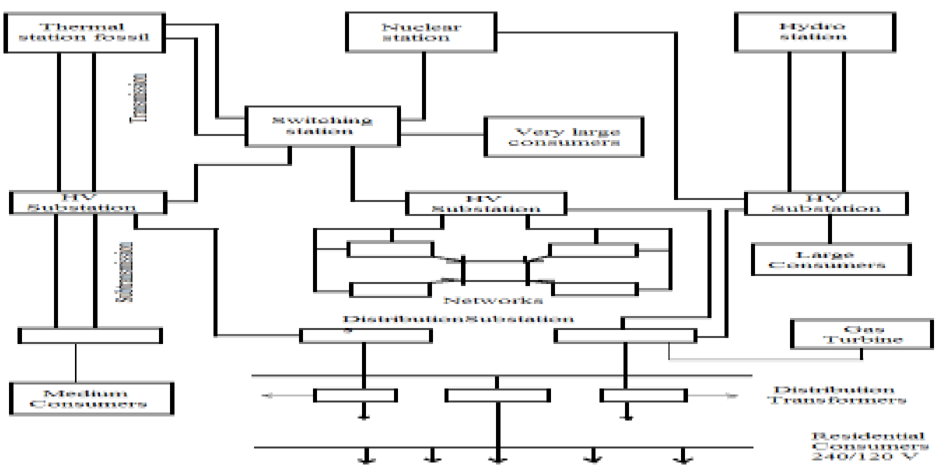

Figure 1: Basic components of a power system

III. SPECIFICATIONS OF TRANSMISSION LINE DESIGN

The conductors and towers of a transmission line are considered as the familiar elements in our landscape. However, inspecting closely, each transmission line possesses unique characteristics that have correspondingly unique implications for the environment. We list the design specifications (line characteristics) that are commonly required to define a transmission line in this section. Many of these specifications have implications for the net environmental effects.The most basic descriptive specifications include a line name or other identifier, nominal voltage, length of line, altitude range, and the design load district. The nominal voltage is an approximation to actual line voltage that is convenient for discussion. Actual voltage will vary according to distance,line resistance, interaction with connected equipment, and electrical performance of the line. For AC lines, the nominal voltage is close to the RMS (root mean square) voltage. The altitude range is a rough surrogate for weather and terrain. This is important as nearly all the aspects of construction, line design, and environmental impacts are linked to weather. The design load district is another surrogate for weather. The design load district is to design the wind and ice loading on lines and towers. This affects the specifications of insulators as well as the dimension of towers, tower design, span length and conductor mechanical strength and wind dampening.

3.1 Appropriate Cross-Section from the Viewpoint of Short-Circuit

The cross-section of conductor is determined according to the rated current, and then on the basis of the level of short-circuit tests. We require the following formulas to calculate the minimum cross-section required for withstanding the heat that is generated due to the short-circuit.

$$S = \frac{Isc.\sqrt{t}}{K}$$

$$K = \sqrt{\frac{W.C.\Delta\theta}{0.24\rho}}$$

Where:

S= Conductor cross-section (mm), I_{sc}=Standard short circuit current (A), t = the persistence time of short circuit current (s)

K= coefficient which is a constant and is dependent on the following:w= specific weight of the conductors (g/cm^3), C= specific heat of the conductor metal (cal/g-0c), $\Delta\theta$= temperature rise of the conductor(0c), ρ= specific resistance of the conductor (ohm/mm^2), K value for ACSR conductors is 85, I_{sc} for a 132kv line is 70 kA, and t=0.5s

The calculated value of cross-section of conductor, S=582.32mm.

3.2 Determination of Appropriate Distance from the Bundle, GMD AND GMR

The transmission line under study is a single-circuit horizontal line with six conductors per bundle. According to the standards, the maximum distance between conductors in bundled lines is 455 mm.

The the geometric mean distance (GMD) and geometric mean radius (GMR) are calculated using the following formulas:

$$GMR = \sqrt[6]{(6D.d^5)}$$

$$GMD = \sqrt[3]{D_{12}D_{23}D_{13}}$$

Where:GMR: Geometric Mean Radius (m), GMD: Geometric Mean Distance (m), d =distance between the conductors in the bundle (m), D: distance between the phases (m).

The calculated values are GMR=0.0105m and GMD=4.9m.

MUTUAL- GMDis the geometrical mean of the distances from one conductor to the other and therefore, must be between the largest and smallest such distance. The equivalent geometrical spacing is simply represented by mutual- GMD.

For a single circuit three phase line, the mutual – GMD is equals the equivalent equilateral spacing i.e. $\sqrt[3]{d_1 d_2 d_3}$.

SELF-GMD or Geometrical Mean Radius (GMR): It has been proved mathematically for a solid round conductor of radius r, the self-GMD or GMR=0.7788r.

3.3 Constants of Transmission Lines

The sending end input voltage per phase (Vs) and the sending end input current (Is)of a transmission line with three phase can be expressed as:

V_s=AV_r+ BI_r

I_s=CV_r + DI_r

Where, V_s= per phasesending end voltage, I_s= per phasesending end current, I_r=receiving end current per phase, V_r= per phase receiving end voltage.

A, B, C, D are the generalised circuit constants of the transmission line. The value of these constants depends upon the particular method of solution adopted. After determination of their values the performance of the line can be easily evaluated.

The values of A, B, C and D can be determined as follows:

A=D=cosh$\sqrt{YZ}$

B=$\sqrt{\frac{Y}{Z}}$sinh$\sqrt{YZ}$

For long transmission lines:

$V_s = V_r \cosh\sqrt{YZ} + I_s\sqrt{\frac{Z}{Y}}\sin\sqrt{YZ}$

$I_r = V_r\sqrt{\frac{Y}{Z}}\sinh\sqrt{YZ} + I_r\cosh\sqrt{YZ}$

The calculated values of A, B, C and D vectors are

A=D=1.009

B=55.89, C=0.75

3.3 Determining the Voltage-Gradient

Voltage gradient around the conductor and fittings plays an important role in the phenomenon of resultant losses and corona. The voltage gradient for six-bundled rail conductors in each phase is obtained by the following equation.

$$g_{max} = \frac{18.C.V}{nr}\left[1 + \frac{2(n-1)r\sin\frac{\pi}{n}}{GMR}\right]$$

Where, g_{max}: maximum voltage gradient at the surface of conductors. (Kv/cm), V: Line phase voltage (Kv), n: The number of bundled conductors per phase, C: Line Capacitance (F/cm, r = radius of conductor (cm)

The calculated value of g_{max}=0.294V/Km

According to the Power Ministry's standard, g_{max}value must not exceed the critical voltage gradient g_0=21.2 Kv/cm, the performed calculations are also within the desired range. Considering the values of V, C, r, n as 132kV, 9.04x10^{-12} F, 0.0132m, 6, respectively for a 132kV transmission line.

3.4 Calculating the Critical Voltage

If the applied voltage in a transmission line reaches to the critical value, the surrounding air begins to get ionised. Critical Voltage value can be calculated by the following equations.

$$g_v = g_0(1 + \frac{.3}{\sqrt{\partial r}})$$

$$\partial = \frac{298P}{T}$$

$V_c = g_v$.m.$\partial.r.\ln(\frac{GMD}{r})$

Where, g_v: Critical voltage gradient (kV/cm), g_0: threshold breakdown voltage(kV/cm), r: conductor radius in cm, ∂: Relative density, P: Air Pressure (At.), T: Air temperature (K), m: Conductor surface roughness coefficient, The value of m for ACSR conductors is .85

Here for a 132kV transmission line design we consider T=313K, P=76 mm of Hg, $\partial = 0.95$,g_o =21.2 kV/cm, we obtain g_v=26.65kV/cm,V_c= 104.73 kV.

3.4 Amount of Corona Losses

The Corona phenomenon has a few disadvantages one of which is the resulted losses which may be increased ten times during snowy or rainy days. In a typical HV transmission line, the losses can be over significant value. Therefore, in designing transmission line the corona losses should be also calculated.

$$P_c = \frac{0.545}{\partial}(V - V_c)\sqrt{\frac{r}{GMD}}$$

Where:

Pc= Corona losses (kW/km), V= Effective-phase voltage (kV), r = Radius of conductor (cm),V_c= Critical voltage (kV), GMD= Geometric mean distance between conductors (cm).As the amount of V_{ph} /V_c is lesser than 1.8, so, for calculating the corona losses Peterson equation is used:P_c= 1.44 kW/km. Corona losses in a 1000km transmission line arealmost 1.5MW/km which is a considerable value.

For a 132 transmission line design if we consider V=132kV, V_c=104.73kV, r=1.362cm, GMD= 490cm, we obtain P_c= 0.78 kW/km

3.5 Voltage Regulation Percentage

The change of voltage from zero to the rated voltage divided by the nominal value is the voltage regulation percentage which is expresses by,

$$VR\% = \frac{V_s - V_r}{V_r} * 100$$

Where: VR%= Voltage regulation percentage of the line, V_s= voltage at Sending end (kV), V_r= Voltage at receiving end (kV), $V_r$is the rated line voltage and V_s in long transmission lines is found to be 142kV.

For a 132kV transmission line, considering V_r=132kV, V_s=142kV,

We obtain VR%= 7.5%

IV. RESULTS OF CALCULATIONS

1	Line Current (I)	I= S/√3V	0.18KA
2	Cross section of conductor (mm)	$S = \frac{Isc * \sqrt{t}}{K}$	582.32mm
3	Geometric mean radius (GMR)	GMR=0.76r	0.0105m
4	Geometric mean distance (GMD)	GMD= $\sqrt[3]{D12 * D13 * D23}$	4.9m
5	Capacitance	C=$\frac{2\pi\epsilon o}{\ln(GMD/GMR)}$	9.05PF
6	Inductance	L=2*10^{-7}ln $\frac{GMD}{e^{-1/4}GMR}$	1.28µF
7	Inductive Reactance	X_L=2πfL	4.02*10^{-4}Ω/Km
8	Capacitive reactance	$X_C=\frac{1}{\omega C}$	351723631.11/Ω Km
9	Reactance	X=X_L-X_C	-3.519*10^8 Capacitive
10	A Parameter	$\vec{A}=\cos h\sqrt{YZ}$	1.009
11	B Parameter	$\vec{B}=\sqrt{\frac{Z}{Y}}\sin h\sqrt{YZ}$	55.89
12	C Parameter	$\vec{C}=\sqrt{\frac{Y}{Z}}\sin h\sqrt{YZ}$	0.75
13	D Parameter	$\vec{D}=\cos h\sqrt{YZ}$	1.009
14	Receiving end voltage (V_r)		132KV
15	Receiving end current (I_r)		180A
16	Sending end voltage (V_s)	V_s= $V_r \cos h\sqrt{YZ}$+Ir $\sqrt{\frac{Z}{Y}}\sin h\sqrt{YZ}$	142KV
17	Sending end current (I_s)	I_s= $V_r\sqrt{\frac{Z}{Y}}\sin h\sqrt{YZ} + I$	99KA
18	Resistance (R)	R=$\frac{pi}{A}$	0.04852
19	Impedance (Z)	Z=$\sqrt{R^2+X^2}$	3.519*10^8
20	Relative Density (δ)	δ =$\frac{298P}{T}$	0.95
21	Critical voltage gradient(g_V)	$g_V=g_O(1+\frac{0.3}{\sqrt{\delta r}})$	37.91KV/cm

22	Voltage gradient (g_{max})	$\frac{18.C.V}{nr}[1+\frac{2(n-1)r\sin(\pi/n)}{GMR}]$	0.294V/Km
23	Critical voltage(V_C)	$V_C=g_V.m.\delta.r.\ln(GMD/r)$	245.38KV
24	V_{ph}/V_c		0.31

Table 1: Results of Calculations

V. CONCLUSION

As the need of electrical energy is increasing day after day the appropriate measures are becoming more necessary to overcome the problems of electrical power transmission lines, reducing the permitted distances, increasing network reliability with proper power quality with less chance of outage, reduction of power loss especially corona losses, communication disturbances reduction and many other issues. In this paper the various components of overhead line is studied along with the various parameters to be considered while designing a 132kV transmission line. The results are shown along with their formulas and equations.

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