PLS-Cadd based Transmission Line Desining and Analysis of Various Input Loads and Checking Real Time Structure Strength in India

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Abstract

Accurate real-time monitoring of sag in transmission lines involves measurement of temperature and tension of the conductor rather than weather-based monitoring. Transmission lines carry electrical energy from power generating stations to long distances and reaches substations. These transmission lines are passing through a wide range of terrains, climates and physical environments and are always at risk to experience catastrophic events, both weather-related and man-made. In India, transmission scenario is progressing towards establishing 765 KV lines to strengthen in recent trends its transmission infrastructure. Massive expansion of the inter-state transmission system is under way to provide to the transmission requirement of new generation projects. In India, Power Grid Corporation of India inherited more than 100 different types of designs of transmission suspension towers and transmission tension or dead-end towers. In this paper, it has been analysed about various recent innovation technologies and transmission components, which can be used for the better designing, operation and maintenance of the transmission lines in Indian conditions and standards adopted. Also, utilisation of state of the art transmission line designing software like PLS-Cadd and its applications in Indian conditions have been analysed and discussed.

Keywords — *Transmission Line, PLS-Cadd, Indian Standards, Power Grid Corporation, TL Designs.*

I. INTRODUCTION

Standards for Transmission lines are adopted for country specific and it is necessary that designs be adaptable to various conditions and local requirements. Design engineers should investigate local weather conditions, soil conditions, operation of existing lines, environmental conditions and evaluate known appropriate factors in arriving at design recommendations. Transmission line design should result in high endurance of service, long life of physical equipment, low maintenance costs, and safe operation. Reliability levels are an indicator of the strength of the tower and divided into three parts. Reliability level 1 was adopted for EHV transmission lines up to 400 kV, reliability level 2 was adopted for EHV transmission lines above 400 kV. Reliability level 3 was selected in special cases like near river crossings.The mechanical and metallurgical properties of the various materials used in the tower are specified in several standards. If a tower is designed for installation in India, it should be following the Indian Standards. Some of the Indian standards which govern the design of towers is IS-802.

The Power Grid Corporation of India Limited (PGCIL) - key organization entrusted within Indian Power Sector framework for implementing and performing all kind of projects related with design, installation, operation and smooth evacuation of electric power through EHV Transmission Systems network, has prescribed optimum line designing. Specifications for conductors for the electrical parameter of transmission lines resistance, inductance and capacitance can be obtained.

A. PLS-Cadd Software

Power **L**ine **S**ystems **C**omputer **A**ided **D**esign and **D**rafting (PLS-CADD) is an MS-WINDOWS program for the analysis and design of overhead transmission lines. It integrates into a single computer environment all the data and algorithms necessary for the geometric and structural design of a transmission line. It enables surveyors, line layout designers, structural/ geotechnical engineers and drafters to better work together and thus increase efficiency of productivity and reduce the chance of errors. It supports the entire design process, from the selection of a line route all the way to the produce of construction documents and drawings. PLSCADD seamlessly integrates many programs developed for long time by Power Line Systems. This software has handled such varied tasks as line routing and design, structural design of latticed towers, poles and frames of different materials, sag and tension calculations, optimum structure spotting, automatic production of plan view, profile sheets and other calculations.

A 3-dimensional Geographic Information System (GIS) type terrain model was adopted in PLSCADD for its flexibility and compatibility with modern surveying equipment and mapping techniques. Terrain data are normally collected electronically using GPS, total station and photogrammetry are subsequently downloaded into ASCII terrain files. In PLSCADD, a terrain model normally includes information about the location and type of the large number of terrain points or above-terrain points. Above-terrain points will be referred to as "obstacle" points like line crossing and railway track crossing.

The XYZ terrain model was used by PLSCADD consists of individual points with their coordinates and feature codes. The Triangulated Irregular Network (TIN) model of the XYZ terrain is a surface made up of triangles having the terrain points at their apexes. PLSCADD can automatically create the TIN model of an XYZ terrain using triangles shown in fig .i.

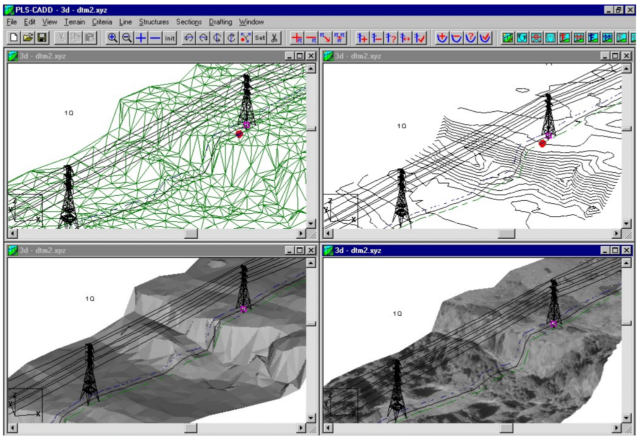

Fig. i Advanced use of TIN Model in PLS-Cadd software

II. MATERIALS and METHODS

For this study, we have selected two transmission line from the state of Rajasthan and Uttar Pradesh in India.

1. Agra - Sikar 400kV DC Line Total Length of 386 KM
2. Neemrana - Sikar 400kV DC Line Total Length of 176 KM

As these two 400kV lines are passing through various severe weather conditions like severe heat waves, cold waves, thunderstorms etc. Profile and plan drawings are drawn with the help of given XYZ points, conductor and line details in PLS-Cadd software. A typical working model of PLS-Cadd software with required input data and its various process and output have been shown in Figure .ii as flow chart model.

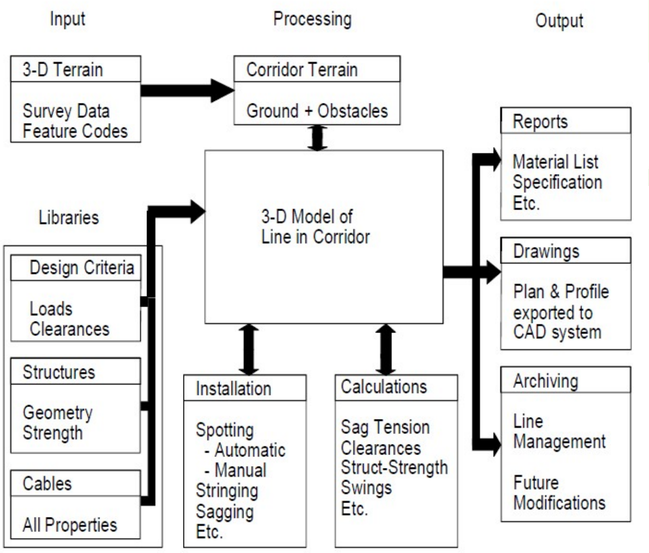

Fig. ii A typical working data model of PLSCADD software

In PLS-CADD software various engineering calculation are done with the integration of terrain, weather conditions, tower models, conductor parameters. The steady-state thermal rating for given conductor properties and ambient weather conditions we can determine the conductor temperature for a given electric current, determine the current that causes a given conductor temperature and display the relationship between the two.

If we know the maximum temperature that a conductor can have before violating some vertical clearance requirements in a span, these calculations let us determine the maximum current that the limiting conductor can carry. Finding the maximum temperature that a conductor can have in a particular span is automated in PLS-CADD as shown in Figure . iii.

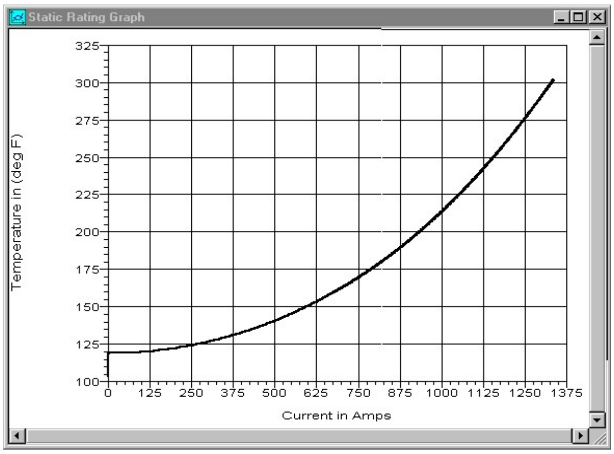

Fig. iii Conductor Temperature vs. Current in PLS-Cadd

Conductor loss of strength at high temperature happens when operated at very high temperatures above 90 degrees Celsius for aluminum conductors. This is discussed in the IEEE Guide for Determining the Effects of High Temperature Operation on Conductors, Connectors, and Accessories (IEEE 1283, 2002).

A. Sag and Tension Calculation

Sag and tension calculation in transmission line depends on the span of the conductor. Sagging is the specification of a sufficient number of conditions, so that the computer can determine what is the unstressed length of cable in each span. In the transmission line, the sag should be so adjusted that tension in the conductors is within safe limits.The tension is determined by conductor weight, effects of the wind, ice loading and temperature variations.It is a standard practice to keep conductor tension less than 50% of its ultimate tensile strength i.e., minimum factor of safety in respect of conductor tension should be 2. Calculate sag and tension of a conductor when (i) supports are at equal levels (ii) supports are at unequal levels which means generally come across conductors suspended between supports at unequal levels in hilly areas.

Consider a conductor between two equilevel supports A and B with O as the lowest point as shown in the figure .iv below. It can be proved that the lowest point will be at the mid-span. Let

l = Length of span
w = Weight per unit length of conductor
T = Tension in the conductor.

Consider a point P on the conductor.Taking the lowest point O as the origin, let the coordinates of point P be x and y.Assuming that the curvature is so small that curved length is equal to its horizontal projection (i.e., OP = x), the two forces acting on the portion OP of the conductor are :

(a) The weight wx of conductor acting at a distance x/2 from O.

(b) The tension T acting at O.

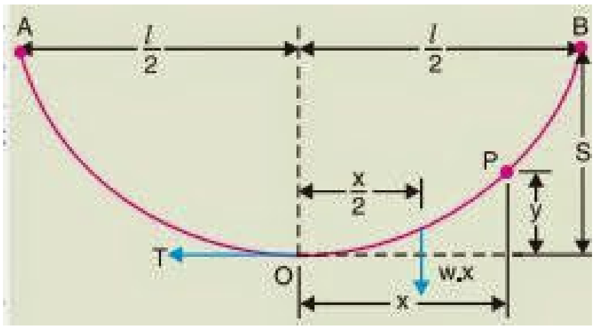

Fig. iv Sag at equal levels of support

Sag, $S = w(l/2)/ 2T = wl^2 /8T$

In the case of hilly areas, generally come across conductors suspended between supports at unequal levels.The shape of the conductor between the supports may be assumed to be a part of the parabola. In this case, the lowest point of the conductor will not lie in the middle of the span.

Consider a conductor suspended between two supports A and B which are at different levels as shown in figure.v.

Let
l = Span length
h = Difference in levels between two supports
x1 = Distance of support at the lower level (i.e., A) from O
x2 = Distance of support at the higher level (i.e. B) from O
T = Tension in the conductor.

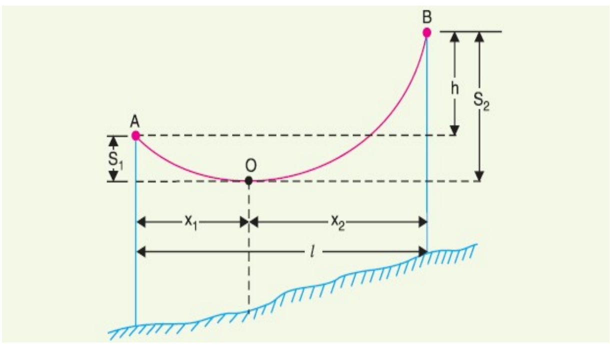

Fig. v Sag at unequal levels of support

If w is the weight per unit length of the conductor, then,

Sag $S_1 = wx_1^2/2T$

and Sag $S_2 = wx_2^2/2T$

Also $X_1 + X_2 = l$ ....(i)

Now $S_2 - S_1 = \frac{w}{2T}[x_2^2 - x_1^2] = \frac{w}{2T}(x_2 + x_1)(x_2 - x_1)$

∴ $S_2 - S_1 = \frac{wl}{2T}(x_2 - x_1)$ $[\because x_1 + x_2 = l]$

But $S_2 - S_1 = h$

∴ $h = \frac{wl}{2T}(x_2 - x_1)$

or $x_2 - x_1 = \frac{2Th}{wl}$ ...(ii)

Solving exps. (i) and (ii), we get,

$x_1 = \frac{l}{2} - \frac{Th}{wl}$

$x_2 = \frac{l}{2} + \frac{Th}{wl}$

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$X_1 = l/2 - Th/wl$

$X_2 = l/2 + Th/wl$

Having found X_1 and X_2, values of S_1 and S_2 can be easily calculated.

Weather based sag monitoring uses anemometers, which are quite unstable and susceptible to measurement errors unless calibrated frequently. More than one monitoring locations are required for long line sections making measurement becomes expensive. Accurate real-time monitoring of sag involves measurement of temperature and tension of the conductor rather than weather-based monitoring. Weather based sag monitoring uses anemometers, which are quite unstable and susceptible to measurement errors unless calibrated frequently. More than one monitoring locations are required for long line sections making measurement becomes expensive.

Sag and Tension model can be done in different options as one is to force a uniform tension throughout the tension section at the reference sagging condition, and another is to force the sag of each span to match a measured value at a field condition. The reference condition is the combination of cable condition, temperature and horizontal tension in the sagging area. First option is almost universally used when modelling new lines, but it can also be assumed in some cases of existing lines even though the measured field tensions in each individual span are not the same throughout the tension section. Another option is used in existing lines by design or due to some accidental change in wire length or structure position, the tensions in the spans of the tension section are not uniform.

B. Electro-Magnetic Field Calculations

All EMF calculations in PLSCADD are based on the EPRI Red Book methodology (EPRI, 1982). We can use EMF Calculator to generate graphs of the electric and magnetic fields for a user defined cross section of the transmission line. Electric and Magnetic Fields in of a Span as shown fig.vi. The field contributions from multiple circuits can be accounted for calculate. The calculations are based on the methodology described in Chapter 8 of the EPRI Red Book (EPRI, 1982). A short list of assumptions considered are given here:

1) The wires are infinitely long and straight.
2) The effects of earth return currents are ignored when calculating the magnetic field.
3) The ground is flat and all points reported on have the same elevation as that of centerline.
4) The earth is a perfect conductor.
5) The permittivity of air is independent of weather case and equal to the permittivity of free space.
6) Shielding effects from structures at ground potential are ignored.

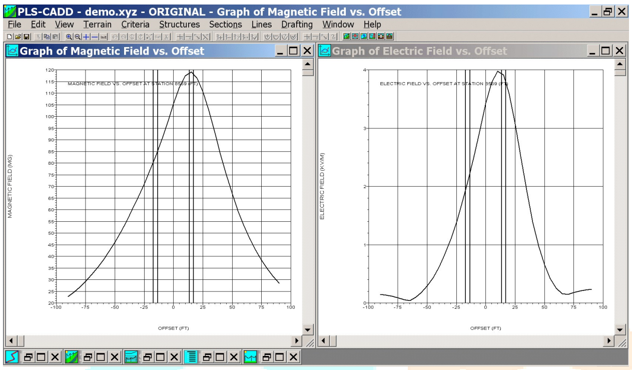


Fig. vi Electric and Magnetic Fields in of a Span

III. ANALYSIS AND DISCUSSION

We construct our transmission lines in accordance with approved Indian Standards like IS-802(Part-1 and Part-2) unless the regulations of the state in which the particular transmission line is being constructed are more stringent than those of current standard. In IS-802, Part-1 provides use of Structural Steel in Overhead Transmission Line for Materials, Loads and Design Strengths. Normally standards do not provide detailed specifications for all locations, but they intended to cover the more important requirements from the safety to the transmission line maintenance force and to the public. The feature codes are important to specify clearances, grades of construction, design loadings for conductors and supporting structures, strength requirements and special requirements for crossings of railroads, power line crossings and communication line crossings. The feature codes also specify the general geographic areas in which the design of transmission lines shall be based on light, medium or heavy loading conditions.

However, when designing a particular transmission line, local weather and other parameter should be also taken into account as local conditions may indicate the use of heavier loading conditions than those prescribed by existing standards for that general area. As per the Indian standards followed by PGCIL, selected two lines survey data and design data has used to prepare line profile in PLSCadd software. Various output of the line profile is discussed as below.

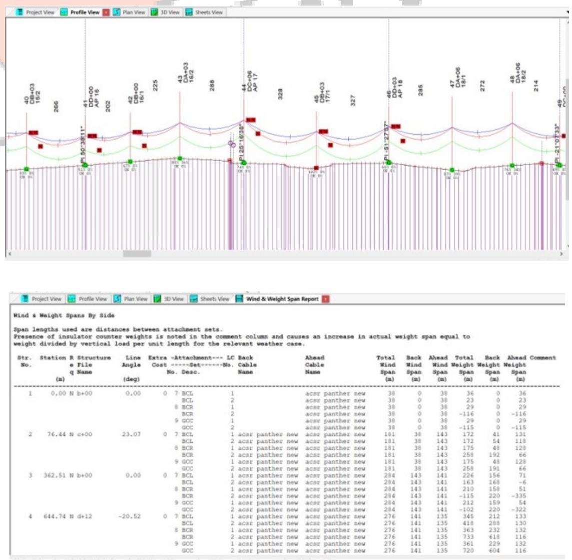
Case Studies:-
Two Transmission lines selected for detailed case studies as

1. Agra - Sikar 400kV DC Line Total Length of 386 KM
2. Neemrana - Sikar 400kV DC Line Total Length of 176 KM

Profile of both the lines are prepared in PLS-Cadd software shown in fig. vii & ix and did the analysis for both the lines. Various output generated are as shown in fig. viii & x given below :-

Case Study 1: TL Profile of Agra - Sikar 400kV DC Line of Total Length of 386 KM

Fig. vii Profile and Route alignment of Agra – Sikar Line



Wind & Weight Spans By Side

Span lengths used are distances between attachment sets.
Presence of insulator counter weights is noted in the comment column and causes an increase in actual weight span equal to weight divided by vertical load per unit length for the relevant weather case.

Str. No.	Station (m)	Req	Structure File Name	Line Angle (deg)	Extra Cost	Attachment Set No.	Set Desc.	LC No.	Back Cable Name	Ahead Cable Name	Total Wind Span (m)	Back Wind Span (m)	Ahead Wind Span (m)	Total Weight Span (m)	Back Weight Span (m)	Ahead Weight Span (m)	Comment
1	0.00	N	b+00	0.00	0	7	BCL	1		acsr panther new	38	0	38	36	0	36	
							BCL	2		acsr panther new	38	0	38	23	0	23	
						8	BCR	1		acsr panther new	38	0	38	29	0	29	
							BCR	2		acsr panther new	38	0	38	-116	0	-116	
						9	GCC	1		acsr panther new	38	0	38	29	0	29	
							GCC	2		acsr panther new	38	0	38	-115	0	-115	
2	76.44	N	c+00	23.07	0	7	BCL	1	acsr panther new	acsr panther new	181	38	143	172	41	131	
							BCL	2	acsr panther new	acsr panther new	181	38	143	172	54	118	
						8	BCR	1	acsr panther new	acsr panther new	181	38	143	175	48	128	
							BCR	2	acsr panther new	acsr panther new	181	38	143	258	192	66	
						9	GCC	1	acsr panther new	acsr panther new	181	38	143	175	48	128	
							GCC	2	acsr panther new	acsr panther new	181	38	143	258	191	66	
3	362.51	N	b+00	0.00	0	7	BCL	1	acsr panther new	acsr panther new	284	143	141	226	156	71	
							BCL	2	acsr panther new	acsr panther new	284	143	141	163	168	-6	
						8	BCR	1	acsr panther new	acsr panther new	284	143	141	210	158	51	
							BCR	2	acsr panther new	acsr panther new	284	143	141	-115	220	-335	
						9	GCC	1	acsr panther new	acsr panther new	284	143	141	212	159	54	
							GCC	2	acsr panther new	acsr panther new	284	143	141	-102	220	-322	
4	644.74	N	d+12	-20.52	0	7	BCL	1	acsr panther new	acsr panther new	276	141	135	345	212	133	
							BCL	2	acsr panther new	acsr panther new	276	141	135	418	288	130	
						8	BCR	1	acsr panther new	acsr panther new	276	141	135	363	232	132	
							BCR	2	acsr panther new	acsr panther new	276	141	135	733	618	116	
						9	GCC	1	acsr panther new	acsr panther new	276	141	135	361	229	132	
							GCC	2	acsr panther new	acsr panther new	276	141	135	720	604	116	

Fig. viii Final Tower Spotting and Wind and Weight Span Report of Agra – Sikar Line

Case Study 2: TL Profile of Neemrana - Sikar 400kV DC Line of Total Length of 176 KM

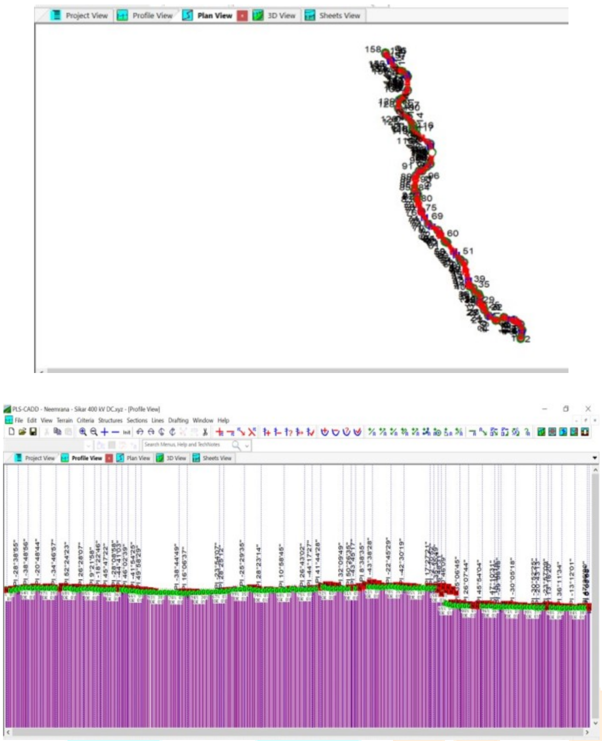


Fig. ix Profile and Route alignment of Neemrana – Sikar Line

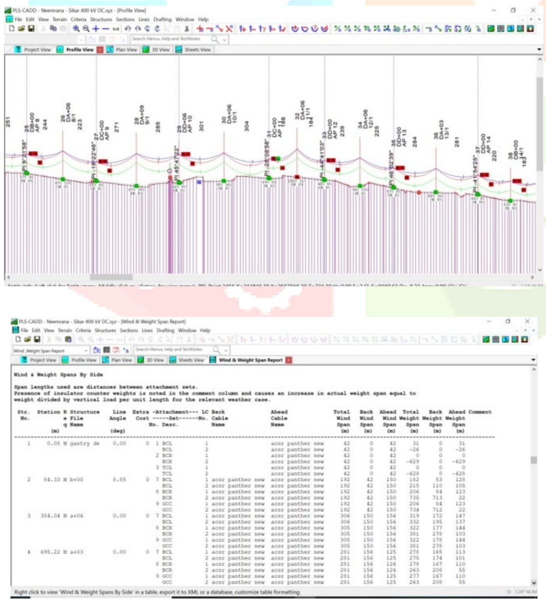


Fig. x Final Tower Spotting and Wind and Weight Span Report of Neemrana – Sikar Line

It will be very much useful to study the performance of these lines in various temperature and problems faced during the operation and maintenance of these lines. The determination of sags and corresponding tensions for any conductor under various conditions of temperature and loading is of basic parameter in transmission line design. This determination enables design elements, such as the most economical span length, to be established and allows the use of sag templates, stringing tables, and other benefits. With help of profile drawing, we can find the loads like actual wind span and weight span loads.

IV. CONCLUSION

From the results of both case studies and analysis shows accurate calculation of wind span and weight span of each section can be thoroughly checked in PLSCADD. Sag and Tension calculation can be easily generated using the stringing chart option available in PLSCADD with different temperature intervals. This stringing chart is very much useful to calculate the sag at the time of construction at different temperature. Integrated approach of PLSCADD combining terrain data, clearance conditions, weather criteria, design data, tower types and conductor details are giving state of art engineering outputs. The wind and weight span report in PLS-Cadd shows the percentage of the allowable wind and weight span when compared to the actual wind and weight spans of each structure, which helps to check the structure strength at any point of time.

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