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Chapter 2
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Design Parameters Specification for the Construction of 33kV Overhead Lines across Lagoon Using Transmission Towers

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ABSTRACT

Overhead aluminium conductors used for both medium and high voltage installations are flexible and uniform in weight along their lengths. They often take the form of catenary changes with conductor temperature, ice and wind loading and time. Adequate vertical and horizontal clearance under all weather and electrical loading conditions are guaranteed by ensuring the breaking strength of the conductor is not exceeded. Thus, the behaviour of the conductor catenary under all conditions need to be incorporated into the transmission line in the constructional design regardless of the length of the transmission line. Overhead transmission lines constructed across water such as Lagoon are good illustration of the characteristics described above. Therefore, this research presents a case study of 33kV overhead line construction crossing 265 m wide 'Lagoon' which requires Sag parameter calculations. Detail description of the case study, specifications for Aluminium conductor steel reinforced (ACSR) type A1/S1A IEC 61089 standard and sag calculations with and without wind or ice weather conditions are presented. The design calculation for weight of a required Dead-End Lattice Tower via determination of weight of the individual 5 components of a Tower are also presented. The obtained results are presented and discussed. The Sag parameter results and that of Dead-end lattice tower and its components weights evaluated were applied to the proposed project. The method of this research work generated reliable results suggesting that it can be applied to any other Transmission tower successfully.

Keywords: Conductor catenary; constructional design; electrical loading; sag parameters; tower support weight; transmission lines.

1. INTRODUCTION

In power system networks, electricity supply is made available to utility companies from nearby transmission substations via the use of high tension (HT) supports (Transmission Towers) strung with aluminium conductors. A transmission tower is a tall structure usually a steel lattice tower, used to support an overhead power line. They are used in high voltage AC and DC systems and come in a wide variety of shapes. The height of towers ranges from 15 to 55 m. Although, the tallest towers carry 370 m height and are in 2,700 m span of Zhoushan Island Overhead power tie [1]. There are four major categories of transmission towers, suspension, terminal, tension, and transposition. Tension towers meant for straight runs that have the capability to withstand stress due to the weight of the line alone. While transitional towers are for changing of route, known as deviation towers. This type of tower has the capacity to withstand the resultant forces set up when the line changes direction [2]. However, some transmission towers combine these basic functions [1,3]. Transmission towers and their overhead power lines are often considered to be a form of visual pollution. Methods to reduce the visual effect include undergrounding [4].

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Typical of such transmission substation as source-station ranges from 30MVA 132/33kV to 100MVA 132/33kV Power transformers in Nigeria as example. The acceptable span of 33kV line stringing between two high tension supports is about 50m for concrete poles and on virgin land. Aluminium conductor used for these overhead lines for the distribution of electric supply are usually of different types depending on the user's choice and area of application. Thus, aluminium Conductor is a physical medium used to transmit or distribute electrical energy from one place to other. It is an important component of overhead and underground electrical transmission and distribution systems. The choice of conductor however depends on the cost and efficiency. Typical aluminium conductor possesses properties such as High electrical conductivity, High tensile strength so that it can withstand mechanical stresses, Low specific gravity i.e. weight/unit volume and Low cost of installation without sacrificing other factors [5,6].

Aluminium Conductors are often preferred over copper because it costs less than copper to produce and offers larger diameter for the same amount of current which reduced corona. Aluminium conductors commonly used as overhead lines are All Aluminium Conductor (AAC), Aluminium Conductor Alloy Reinforce (ACAR), All Aluminium Alloy Conductor (AAAC), Aluminium Conductor Steel Reinforced (ACSR) and Aluminium Conductor Composite Core (ACCC) [5,6,7]. The choice of conductor type and size has a major impact on transmission/distribution line design and subsequent financial returns. For any given project, however, this choice is often limited to a narrow set that conform to specified criteria, including, but not limited to [6,7]:

- Electrical load requirements
- Load growth projections
- Network voltage requirement and/or accessible voltage ranges.
- Support structure requirements, limitations and/or the availability of extant infrastructure such as towers for transmission lines and concrete poles for distribution lines.
- Environmental Considerations.
- Regulatory Statutes.

Transmission lines do not connect between their supporting towers/poles in a straight line. The Shape formed by a line strung between the two supports is called catenary [5,7-9]. If the line is much tensioned, sag will be minimized, and the disadvantage is the possibility of line snapping after a long use [5,8]. But if the line is much sagged, it will increase the quantity of conductor used and hence increasing the cost of the project [5,8,9]. Therefore, a reasonable sag level is allowed, to prevent too much tension on the line [5,8-11].

2. REVIEW OF ALUMINIUM CONDUCTOR SAGGING, TENSIONING, CATENARY EQUATIONS AND PARAMETERS IN TWO EQUAL LEVEL SUPPORTS

This section discusses a review on causes of conductor sag and mitigation. It includes the description of conductor catenary (Sag D) and the parameters associated with it. The general equation of conductor catenary is presented along with vertical component equation as well as the tension equation which comprises of the algebraic sum of both vertical and horizontal tensions. The equation that determines the catenary length between the supports, and the conductor slack equation are discussed. Wind load and effective conductor weight equations are equally itemised.

2.1 Aluminium Conductor Sagging and Tensioning

The primary function of the conductor is to transfer electrical load, it must also be strong enough to support its own weight as well as any other weight (or Stress) caused by ice, wind and pole movement [7,8]. Other causes of conductor sag include age of conductor, conductor load per unit length (span), conductor tension and level of supporting towers/poles [9]. Conductor sag to some degree can be mitigated by installing the conductor at a higher initial tension but higher tensions tend to increase the conductor's susceptibility to premature fatigue failure due to Aeolian vibration. For this reason, most conductors are installed at relatively low catenary constant [6,7,8]. Some conductor types/sizes adopt larger sags with imposed loads or high temperatures than others [1,5]. This can

impact span length and support structure combination dramatically. The choice of conductor, based on its sag and tension characteristics, have a large impact on overall project costs.

2.2 Sag and Tension Equations

The catenary of 33 kV overhead line between two supports erected about the same level is shown in Fig. 1 [1,5]. The conductor catenary is very nearly a parabolic shape defined by the conductor's weight per unit length (W) and the Horizontal tension (H). The sag of the conductor (D) is a function of W, H, Span length (S), and the difference in elevation between the span supports.

The catenary equation for a conductor between supports is expressed in terms of the horizontal distance (x) from the lowest point (or vertex) of the catenary to a point on the catenary that is y(x) above the vertex is given as [1,5,6,11].

$$y(x) = \frac{H}{W}\left[\cosh\left(\frac{W.x}{H}\right) - 1\right]$$

$$\cong \frac{wx^2}{2H} \tag{1}$$

The expression on the right side of equation (1) is an approximate parabolic equation based upon the first term of the MacLaurin expansion of the hyperbolic cosine. The approximate parabolic equation is valid if [8],

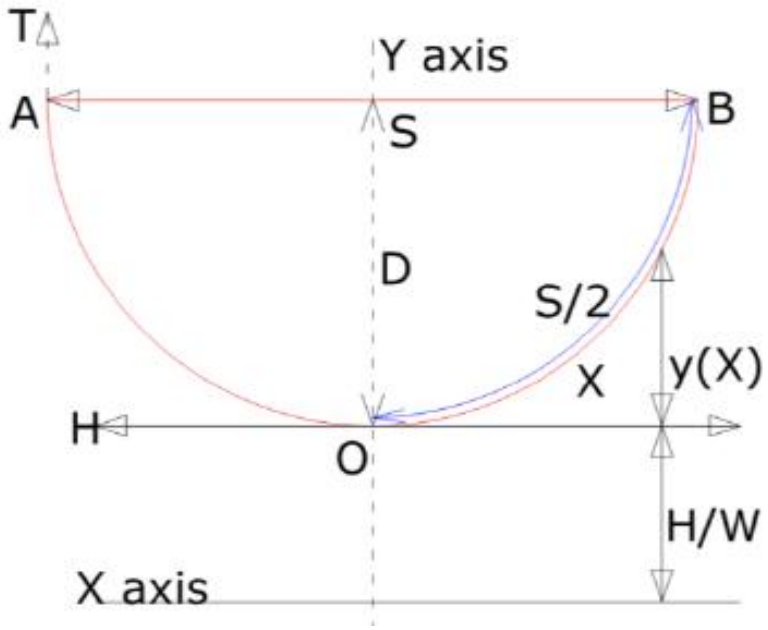


Fig. 1. The catenary curve for the two-level supports

$$\frac{x^2w^2}{12H^2} \leq 1 \tag{2}$$

Where,

W = Weight per unit Length of conductor
H = Horizontal Tension in the conductor

For a level span with the vertex in the centre, sag (D) is found by substituting $\boldsymbol{x} = \frac{\boldsymbol{s}}{\boldsymbol{2}}$ in equation (1).

The exact catenary and approximate parabolic equation for sag is

$$D = \frac{H}{W}\left[\cosh\left(\frac{WS}{2H}\right) - 1\right]$$

$$\cong \frac{WS^2}{8H} \tag{3}$$

Where

S = Length of span

The ratio $\frac{H}{W}$, is commonly referred to as the catenary constant, C. An increase in the catenary constant causes the catenary curve to become shallower and the sag to decrease. The catenary varies as a function of conductor temperature, ice and wind loading and time [5,6,8,9]. The Catenary constant typically has a value in the range 500 – 2000 meters for most transmission catenaries under most conditions [8]. The approximate or parabolic expression is sufficiently accurate if the sag is less than 5% of the span length [9]. The horizontal component of tension H as measured at the vertex is the same at all points within the catenary, but the total tension increases as the support points are approached, due to added vertical components [3]. Given a level span at the supports, the vertical component V of tension is equal to one half of the weight of the conductor as [6,8,9].

$$V = \frac{WL}{2} = H\sinh\left[\frac{WS}{2H}\right] \tag{4}$$

At the end of level supports the conductor tension is the vector sum of the horizontal and vertical tension given as,

$$T^2 = H^2 + \left(\frac{W \cdot L}{2}\right)^2 \tag{5}$$

Using equations (4) and (5)

$$T = H\sqrt{1 + \sinh^2\left(\frac{WS}{2H}\right)}$$

$$= H\cosh\left(\frac{WS}{2H}\right) \tag{6}$$

Relating total tension to sag in a level support, the equation becomes

$$T = H + W\left(\frac{H}{W}\cosh\left(\frac{WS}{2H}\right) - \frac{H}{w}\right) \tag{7}$$

Relating equations (3) and (7)

$$T = H + WD \tag{8}$$

Equation (8) implies that at the ends of the level support, the conductor tension T is equal to the horizontal component plus the conductor weight per unit length W multiplied by the Sag (D).

2.3 Conductor Length Estimation

Applying calculus to the catenary equation allows the calculation of the conductor length L(x) measured along the conductor from the lowest point of the catenary in either direction. The equation for catenary length between the support is given as [5,6,9].

$$L(x) = \frac{H}{W} Sinh \left(\frac{wx}{H}\right)$$

$$\cong x \left(1 + \frac{x^2 w^2}{6H^2}\right) \quad (9)$$

For a two-level support, the conductor length corresponding to $x = \frac{s}{2}$, is half of the total conductor length L as shown in equation (10) [5,6,9].

$$L = \frac{(2H)}{W} \sinh\left(\frac{sw}{2H}\right)$$

$$\cong S\,(1 + \frac{S^2 W^2}{24H^2}) \quad (10)$$

The parabolic equation for conductor length can also be expressed as a function of Sag (D) by substituting the Sag parabolic equation i.e. equation (3) [5,6,9];

$$L = S + \frac{8D^2}{3S} \quad (11)$$

The conductor slack defined is the difference between the conductor Length L and span Length S. The parabolic equation for slack may be found from equations (3), (10) and (11) as in equation (12) [5,6,9];

$$L - S = S^3 \left(\frac{w^2}{24H^2}\right)$$

$$= D^2 \left(\frac{8}{3s}\right) \quad (12)$$

Equation (11) can be rearranged to obtain an equation showing the dependence of sag D on slack $L - S$ as,

$$D = \sqrt{\frac{3S(L-S)}{8}} \quad (13)$$

2.4 The Wind Load and Effective Conductor Weight

In a situation where the environment is tense with wind pressure that is above normal wind and blowing with ice presence, it is important to obtain wind load (W_w) and effective conductor weight (W_{eff}) as shown in equations (14) and (15) respectively [6,8,10];

$$\text{Wind Load } (W_w) = \frac{P(2K+x)}{1000} \text{ N/M} \quad (14)$$

$$\text{Effective conductor Weight } (W_{eff}) = \sqrt{[weight\ of\ conductor]^2 + \frac{(wind\ load)^2}{g^2}} \text{ kg/m} \quad (15)$$

Where,

P = Wind pressure in N/m^2
K = Radial thickness of ice in mm
X = Conductor diameter in mm
V = Wind speed in m/s

The wind pressure (P) and design wind speed (V_s) can be calculated using equations (16) and (17) respectively [1,5,6],

Wind Pressure (P) = 0.613 V_s^2 (16)

Design Wind Speed (V_s) = V x S_1 x S_2 x S_3 (17)

Where,

V_s = Design wind speed
V = Wind speed
S_1 = Topography factor; 1.0 for normal sites
S_2 = Ground roughness; $0.5 \leq x \leq 1.3$
S_3 = Security factor; usually 1.0

3. DESCRIPTION OF CASE STUDY

A Customer of an electricity distribution company, located in Badagry area of Lagos, Nigeria is desired to install a 1 MVA, 33/0.415 kV Transformer. This project also requires the construction of 4 spans of overhead lines strung with Aluminium conductor from a T – off 33/11kV Injection Substation to the point of installation of the proposed transformer. However, between the second and third span is a Lagoon with an approximate length of 265 m. Therefore, completion of this project require installation of 2 Lattice Towers at the two ends of the Lagoon through which the overhead lines can be strung. Consequently, overhead sag, tower height, conductor weight and tower foundation designs are required to be carried out.

3.1 Estimation of Catenary Parameters for an Equal Level Support

This estimation of Catenary parameters is categorised into Parameter specifications, Sag calculation without wind or ice environmental conditions and Sag calculation with wind and Ice environmental condition.

(i) Parameter Specifications

Aluminium Conductor Steel Reinforced ACSR type A1/S1A conductors IEC 61089 standard is recommended to construct the overhead. The ACSR parameter specifications are as follows [5,12].

1. Nominal cross-sectional area of Aluminium = 160 mm^2
2. Steel Cross-sectional Area = 8.89 mm^2
3. Total Cross-sectional Area of selected ACSR (sum of 1 and 2 above) = 168.89 mm^2
4. Approximate overall Diameter = 16.8 mm
5. Approximate Overall Weight = 509.3 kg/km
6. Maximum DC Resistance at 20°C = 0.18 Ω /km
7. Rated Strength = 36.18 kN
8. Electrical Resistivity at 20°C = 0.028264 $\mu\Omega$m
9. Temperature coefficient of resistance = 0.00403 /°C
10. Density at 20°C = 2.703 kg/m^3
11. Coefficient of Linear Expansion = 23 x 10^{-6} /°C
12. Final Modulus of Elasticity = 68000MPa
13. Coefficient of Linear Expansion for Galvanised steel = 11.5 x 10^{-6} /°C
14. Density of steel at 20°C = 7.80 kg/m^3
15. Proposed Height of Tower = 18m

(ii) Sag Calculation without wind or ice environmental conditions

Length or span of the overhead line S (Across Lagoon water) = 200 m

Weight of conductor (W) = 509.3 kg/km = 0.5093 kg/m

Acceleration due to gravity (g) = 9.81 m/s^2
Tension on Conductor (W_l) = Weight x Acceleration due to gravity (18)

= 0.5093 x 9.81 = 4.99N

Rated strength (Tension) of conductor = 36.18kN = 36180N

Working Tension = $\frac{Rated\ Strength}{Safety\ factor}$ (19)

But, Safety factor = 2 was used because the conductor tension shall not exceed 50% of its breaking load [5,11]. Using equation (19),

Working Tension = $\frac{36180}{2}$ = 18090N

Therefore, Using equation (3) above,

Sag (D) = $\frac{4.99 \times 200^2}{8 \times 18090}$
= 1.38meters

Using equation (12), conductor slack (L-S) is obtained as

Conductor Slack = $(1.38)^2$ x $\frac{8}{3 \times 200}$
= 0.025
= 2.5 % of span Length

(iii) Sag calculation with Wind and Ice environmental condition

Given that, the design wind speed V= 8.06m/s, S_1 = 1, S_2 = 0.99 (using data table) and S_3 = 1

The design wind speed V_S from equation (17) is

V_S = 8.06 x 1 x 0.99 x 1 = 7.98 m/s

The wind pressure, from equation (16)

Wind pressure (P) = 0.613 x 7.98^2 = 39.04 N/m^2

However, in the climate of Nigeria, there is no ice at all. Therefore the wind load (W_w) from equation (14) with y = 0, is

Wind Load (W_w) = 39.04 [2x0 + $\frac{16.8}{1000}$] = 0.66 N/m

Substituting weight of conductor stated in the list of specifications for 160 mm^2 ACSR Conductor, the estimated Wind Load and acceleration due to gravity in equation (15) gives the effective weight of conductor W_{eff} as

Effective Weight of Conductor (W_{eff}) = $\sqrt{0.5093^2 + \frac{0.66^2}{9.81^2}}$ = 0.51 kg/m

Using equation (17), Tension on conductor (W_{eff1}) becomes,

W_{eff1} = 0.51 x 9.81 = 5.0N

Substituting the following parameter values i.e W_{eff1} = 5.0 N, S = 200m and H = 18090N in equation (3) gives Sag (D) as:

$Sag\ (D) = \frac{5 \times 200^2}{8 \times 18090}$ = 1.38m

Table 1. Results of Sag Parameters Calculation

S/N	Sag parameters	Calculated values
1	Tension on conductor (WI)	4.99N
2	Rated Strength of Conductor	36.18 Kn
3	Working Tension	18090N
4	Sag (D) [without wind or ice environmental conditions]	1.38m
5	Conductor slack (L-S)	2.5% of span length
6	Design Wind Speed (Vs)	7.98 m/s
7	Wind Pressure (P)	39.04 N/m^2
8	Wind Load (Ww)	0.66 N/m
9	Effective weight of conductor (Weff)	0.51 kg/m
10	Sag (D) [with wind and Ice environmental conditions]	1.38 m

3.2 Estimation of Dead-End Lattice Tower Weight

A Dead–End Lattice Tower is broken down into 5 components: namely, Tower Stand, Tower Braces, Tower Cross Arm, Cross Arm Braces, and Bolts and Nuts. Weight estimation of each these components were carried out as analysed in subsections 3. 2. 1 to 3. 2. 5. The summation of the weights obtained from these five components of the specified tower gives the overall weight of the Dead-End Lattice Tower.

Consider that,

Size of MS (mild steel) Angle Iron Selected = 45 x 45 x 4 mm

(Take into consideration that mild steel is known for its light weight)

The Approximate weight of MS iron per meter = 2.7 kg/m [5,13].

3.2.1 Tower stand

Proposed height of the tower excluding base = 18 meters

Total Number of stands required = 4

Therefore, Total length of iron = 4 x 18
= 72 meters

Total weight, (A_T) = 72 x 2.7 = 194.4 kg (without Braces)

Total Weight of Tower Stand (A_T) = 194.4 kg.

3.2.2 Tower braces

Approximately 24 Braces per side from average of several sample pictures of lattice tower of similar structure.

Total length is obtained by adding 25% of approximate number of braces per side to account for extra braces requirement

∴ Total length of Braces per side ≅ 30 meters

Total length of Braces for 4 sides ≅ 30 x 4 = 120 meters

Size of MS Angle Iron Selected for Braces = 35 x 35 x 4 mm

Approximate weight of MS iron per meter = 2.1 kg/m [5,13].

Total weight (B_T) = 2.1 x 120 meters = 252 kg

Therefore,

Total Weight of Tower Braces (B_T) = 252kg

3.2.3 Dead - End Tower Cross Arm

Standard Cross arm length for a 33kV line is 2.75 m (9 ft).

Total length of arm = [Both receiving and sending end] = 2.75 m x 2 = 5.5 m

Size of MS (mild steel) Angle Iron Selected = 45 x 45 x 4 mm

The Approximate weight of MS iron per meter = 2.7 kg/m [5,13].

∴ Total weight of cross arm (C_T) = 5.5 x 2.7 = 14.85 kg

Total Weight of Dead-End Tower Cross Arm (C_T) = 14.85 kg

3.2.4 Cross Arm Braces

4 braces are required for each side of tower to support cross arm

Therefore, Braces for Length the cross arm = 4 x 2 meter = 8 meters

Size of cross arm = 45 x 45 x 4 mm

The Approximate weight of MS iron per meter = 2.7 kg/m [5,13].

Weight of Cross Arm Braces (D_T) = 8 x 2.7= 21.6 kg

Total Weight of Cross Arm Braces (D_T) = 21.6 kg

3.2.5 Nut and Bolt: 5/8" - 11 x 2 ASTM F3125 Grade A325 Hot Dipped Galvanized

Steel Structural Bolt w/A563 DH Nut-Nap is Specified [5,14].

Parameters of specification:

Head: Hex
Diameter: 5/8"
Grade: A325
Thread Size: 11
Length: 2"
Product Weight: 0.37 lbs
Thread Type: cut
Thread Length: 1"
From the 30 braces per side stated earlier above,
Since each brace requires 2 Nuts and Bolts, then
30 Braces will have = 30 x 2 = 60 Nuts and Bolts per side
Total Bolt and nut for the 4 sides of the Tower = 60 x 4 = 240 Nuts and Bolts
Nut for cross arm = 10 for each arm
Nuts for the 2 sides of cross arm = 10 x 2 = 20
Total Number of Nuts, Approximately = 240 +20 = 260

The value of specification above i.e. Length, Diameter, Thread Size and Head Type in calculating total weight (E_T) of the bolts & nuts and washers using online calculator [15] at "http://www.portlandbolt.com/technical/tools/bolt-weight-calculator" is obtained to be 55.34 kg

Therefore,

Total Weight of Nuts and Bolts (E_T) = 55.34 kg
Weight of Aluminium Conductor is negligible

Total Weight of Dead -End Lattice Tower $= A_T + B_T + C_T + D_T + E_T$
$= 194.4 + 252 + 14.85 + 21.6 + 55.34$
$= 538.19$ kg
≈ 538.2 kg

Table 2. Results of dead-end lattice tower and components weights evaluation are shown in Table 2

S/N	Tower components	Calculated weights
1.	Weight of Tower Stand	194.4 kg
2.	Tower Braces	252 kg
3.	Tower Cross arm	14.85 kg
4.	Cross arm braces	21.6 kg
5.	Nuts & Bolts	55.34 kg
	Total weight of Dead-End Lattice Tower	538.2 kg

4. RESULTS AND DISCUSSION

A typical dead-end transmission tower expected to be used based on estimated parameters is shown in Fig. 2. The summary of sag parameter results is shown in Table 1. This result was used in designing the 33kV overhead lines shown in Fig. 3. It could be observed that the sag calculated for the overhead transmission lines considering that no serious wind is blowing, and no ice environment, have the same value of 1.38 meters with that other condition of serious wind plus icing environment. From equation (12), it becomes glaring that conductor slack of 0.025 (i.e 2.5% of span length) estimated for situation where the environment is considered as normal atmospheric pressure and without ices as it is found in the Nigerian environment, maintained the same value with condition of serious wind plus ice. This implies that the average wind parameters for the Lagoon in question (Lagos State, Nigeria) has minimal sagging effect on the overhead lines constructed across it. Also, the slack values of 0.025 estimated (i.e. 2.5% of span length) is accurate because conductor slack not greater than 5% of span length is allowed and recommended in overhead transmission line stringing regardless of the voltage level [1,5].

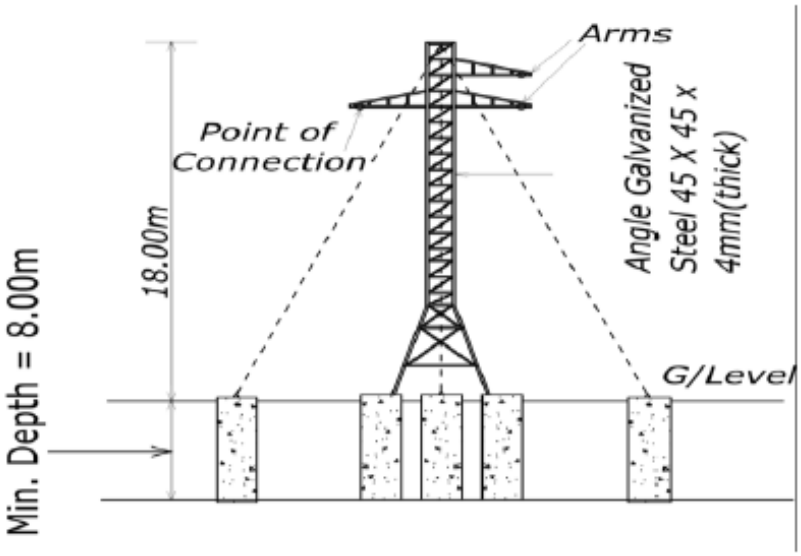


Fig. 2. Front view of a dead end tower

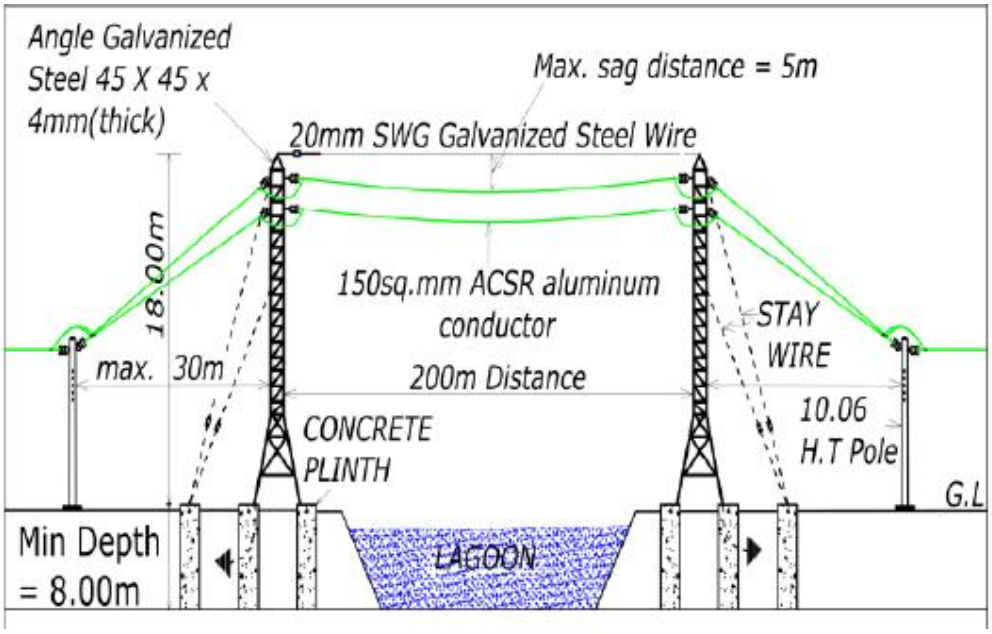


Fig. 3. Side view of designed 33kV overhead lines

Furthermore, the results of Dead-End Lattice Tower and components weights evaluation are shown in Table 2. From this table, a total of 538.2 kg was estimated as the Weight of Dead-End Lattice Tower. Tower Braces and Tower Stand got an average weight of 252 kg and 194.4 kg respectively and constituting 46.82% and 36.12% of the total weight of the Dead-End Lattice Tower respectively. While Tower cross arm (14.85 kg), Cross arm braces (21.6 kg) and Bolts & Nuts (55.34 kg) jointly constitute the remaining 17.06% of the total tower weight.

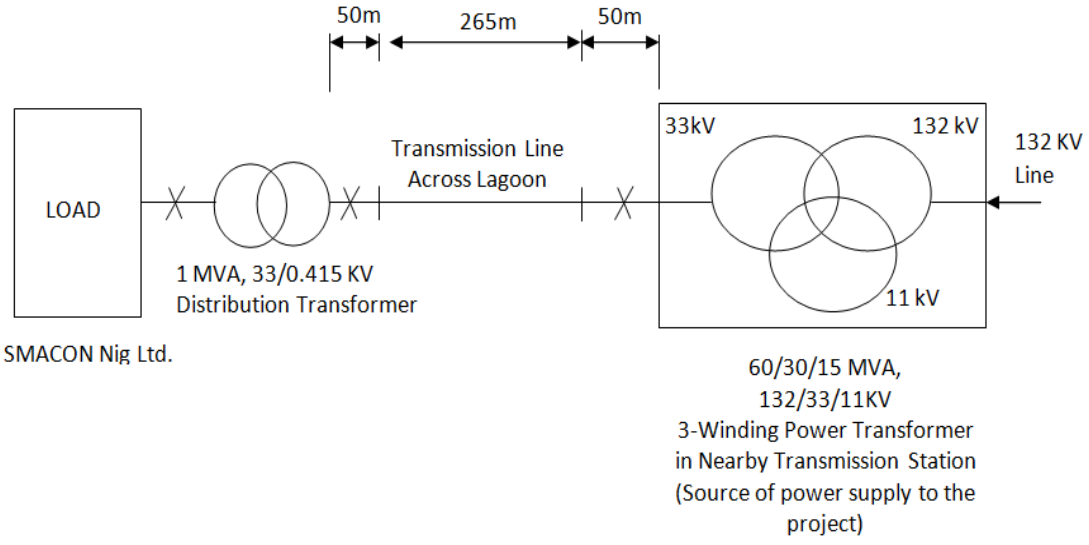


Fig. 4. Network of power supply to customer (SMACON Nigeria limited)

The proposed customer in question is expected to take electricity supply from a 1MVA, 33/0.415kV Distribution transformer substation which would also be fed by the newly constructed 33kV line across the Lagoon. This new transmission line will in turn takes source from a nearby 60/45/15MVA,

132/33/11kV Transmission substation. The power system network arrangement that suit the above network interconnection is shown in Fig. 4. Therefore, when 1 MVA, 33/0.415kV substation is finally energized, the load will be operating at an approximate short distance of about 365m which will definitely measure low value of Total harmonic distortion and the greater the distance of the load from the source of supply the higher the harmonics [16]. Low harmonics in power system network implies a reduction in Technical losses [17]. Hence, marginal cost of Transmission or Distribution expansion is achieved [18]. Also, commissioning of such substation will have impact on sub-grid allocated distributable generation capacity or allocated parts of generation capacity [19].

Also, the approximate total weight of the specified dead-end tower which was estimated to be 538.2kg per tower will be used in guiding the determination of the weight of structural foundation of the Tower. This is because the structural Engineers in charge of the project often use such value as a guide. In practise, the civil engineering foundation weight designed will normally be made greater than the tower weight since the civil foundation will be carrying the weight of the Tower.

Finally, for this scenario of project to be successful, Tower height of 18 m, Sag Value, $1.3 < \text{Sag} < 2$ m, and Tower weight value, $535 < \text{Tower weight} < 550$ kg would be specified and recommended accordingly.

5. CONCLUSION

A review of overhead transmission line support and conductor has been presented. Aluminium conductor with its unique properties which makes it more relevant in power transmission were highlighted. The theory of Sag and Tension in equal Level supports has also been extensively discussed and applied to the case study. A practical project design and construction of 33 kV overhead line which requires 265 m crossing of Lagoon was used as case study. Sag and catenary parameters required for the overhead construction were evaluated and presented. The overall results obtained are presented and discussed accordingly. The presented results include, estimated value of total weight of a dead-end tower, which will in turn determine the weight of the civil engineering design for the tower structural foundation. Thus, the height of Tower, Sag and weight of the Tower values have been specified and used for the design of the selected scenario project considered as case study. The obtained results are generally reliable, and the method is suitable in specifying design parameters for any type of Transmission tower.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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