WIND INDUCE CLEARANCES INFRINGEMENT OF OVERHEAD POWER LINES

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A report submitted in partial fulfilment of the requirement for the award of the degree of Master of Electrical Engineering

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APRIL 2011

Abstract

This paper presents a methodic approach, suggestions and information to design 400 kV transmission line in Libya and investigate which type of towers, conductors and insulators suitable to use in that particular country. The work also calculate the affect of wind on L12 tower top geometrics and keep the probability of flashover very low. In this project, the weather and climate are considered to design overhead line. The purpose of this work is to determine the clearances necessary to withstand the 400 kV line at normal and abnormal weather conditions. In addition, it is also important to make sure that conductors have to maintain the clearances under lightning, switching and TOV (temporary over voltage). The work in this project have used Excel and Visio to analyze the results and plot them to determine the swing angle of movement of the insulator and conductor, and the minimum clearances produced under certain wind speed. Finally, the return period per year and the probability of conductor infringes the clearances per year are calculated.

Abstrak

Tesis ini menerangkan metodologi , cadangan, dan maklumat untuk merekabentuk 400kV talian penghantaran (*transmission line)* di Libya serta mengkaji jenis pencawang, konduktor, serta penebat yang sesuai di gunakan di negara tersebut. Sebagai tambahan, kajian ini juga focus kepada menganalisa dan mengira kesan angin kepada geometri pencawang L12 dan megekalkan percikan *(flashover)* pada tahap yang rendah. Selain daripada itu, kesan cuaca dan iklim di ambil kira di dalam kajian ini. Tujuan utama kajian ini adalah untuk menentukan 400kV penghantaran talian (*transmission line)* akan tetap bertahan tidak kira di dalam keadaan cuaca buruk atau pun normal. Konduktor yang di gunakan mestilah bertahan di bawah keadaan kritikal seperti kilat, perubahan mendadak dari voltan rendah ke tinggi *(switching)*, dan beban sementara yang berlebihan *(TOV)*. Di dalam projek ini, perisian Excel, dan Visio digunakan untuk menganalisa dan menentukan kesan pergerakan dan peralihan angin pada penebat dan konduktor serta menentukan pergerakan minima yang terjadi akibat daripada kelajuan angin. Sebagai pengukuhan kajian, kesan angin tersebut dan kebarangkalian keadaan kritikal konduktor di kira dengan kaedah matematik berulang kali selama setahun.

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LIST OF ABBREVIATIONS AND ACRONYMS

GECOL	-	General Electricity Company Of Libya
AAC	-	All Aluminium Conductor
AAAC	-	All Aluminium Alloy Conductor
ACSR	-	Aluminium Conductor Steel Reinforced
ACAR	-	Aluminium conductor, alloy reinforced
AACSR	-	Aluminium alloy conductor, steel reinforced
EHV	-	Extra High Voltage
NGT	-	National Grid Technical
Vm	-	Maximum velocity
BVm	-	standard deviation of the statistical distribution
KR	-	Ground roughness coefficient
Ac	-	Wind loads acting on insulator sets
G_i	-	Drag factor
qz	-	Dynamic pressure
Ω	-	Wind direction angle
VR	-	Wind velocity reference
Ai	-	Wind loading area of the insulators
Wc	-	Total weight of the conductors
Wi	-	Total weight of the insulator
Vη	-	Wind velocity with a 2 year return period
CC’	-	Top Cross-arm length
AB	-	Insulator length
kn	-	The possible distance between Top conductor and tower body
kw	-	Distance between Top conductor and top cross-arm
kw'_2	-	Distance between the conductor and cross-arm below

$C_2C'_2$	-	Middle Cross-arm length
k_3g_3	-	Vertical distance between lower conductor and ground
U_{50FF}	-	Lightning impulse voltage which result in 50% flashover
U_{maxSF}	-	Highest switching impulse that can occur on the lines
$U50_{sfo}$	-	Switching impulse voltage which result in 50% flashover
k_2n_2	-	Possible distance between middle conductor and tower body
k_3n_3	-	Possible distance between bottom conductor and tower body

CHAPTER I

INTRODUCTION

1.1 Background Of The Project

The power transmission line is one of the major components of electrical power system. It is the major function to transport electric energy, with minimal losses, from the power source to the load centres, usually separated by long distance. Therefore, this long distance exposed to some natural phenomena such as wind, temperature and humidity, which affects the tower top geometry and clearances.

The tower top geometry and the structure must assure the adequate electrical clearances necessary between live parts and supporting structures under various conditions. The available clearances themselves depend on the conductor position which varies due to action of wind. Therefore, wind action plays an important role when defining tower top geometries.

The clearances between conductors and earth structures under the action of wind will be studied in this project. High wind speed could cause the insulators and conductor swing closer to tower body, thus reduces the clearances. In the same way, could also affect the clearances between the conductors in mid span. Therefore, a wind velocity consider as the basis for structural design representing an ultimate load which may stress the structure to its maximum strength capacity. Plus the wind velocity there are some other parameters should take into consideration, for instance wind direction, time distribution of wind velocities, return period and maximum wind velocity.

The weather and wind velocity in north Libya selected as reference in this case of study. According to General Electricity Company of Libya (GECOL) the wind velocity in that area is $35 m.s^{-1}$, and the tower type is L12 for 400 kV transmission line. In these conditions the probability of flashover has to be in acceptable low limit.

Finally, the aim of this project is not to establish a new approach to determine clearances, but to demonstrate how to apply well-known methods for design tower top geometry in Libya.

1.2 Problem Statement

Underground cable is the alternative for overhead transmission lines. But
The cost to build, install and operate underground cables is greater than overhead lines. This is due to the higher cost of materials (more underground cables are required to carry the same amount of power as one overhead line), the more labour and time intensive construction process and the higher cost of maintaining underground facilities and higher line losses associated with underground cables operated at certain load levels. Furthermore capacitance problem will reside if the underground cables used.

Most of the overhead transmission lines expose to some natural phenomena such as wind, temperature and humidity, which affects the tower top geometry and clearances. Overhead line tower is a tall structure, and it may be subjected to strong winds. Besides causing vibrations in the conductor system itself, high wind speeds can also cause it to move closer to or away from the tower body.

When design overhead transmission line, electricity consumption in load side should be taken in to consideration. Currently a 275 kV used in Libya to supply all the cities. Due to the increase of population and the manufacturing in Libya, a 400 kV transmission line will be replacing a 275 kV. Also there is another project to connect North Africa with South Europe with 400 kV lines. In this project, the study of wind affects on the tower top geometrics is significant to determine whether L12 tower is suitable in that area under some weather condition.

This project gives suggestions and information to design 400 kV transmission line in Libya and check the suitable types of towers, conductors and insulators. Work also calculates the affect of wind on tower top geometrics in order to keep the probability of flashover very low. For this, the weather and climate considered to design overhead line.

According to various investigations of swing angles on the line, it was indicated that the measured swing angles are smaller that those theoretically expected from the recorded instantaneous peak wind speeds [4]. One of ideas to overcome this problem is to adapt the relation between wind velocity and swing angle.

1.3 Objectives Of The Project

The objective of this project is as described below

- To determine the clearances necessary to withstand The 400 kV line at normal and abnormal conditions. The conductors have to maintain the clearances under lightning, switching and TOV (temporary over voltage).

- To find the swing angle of movement of the insulator and conductor, and the minimum clearances produced under certain wind speed.

- To find the minimum clearances, swing angle and the probability of conductor infringement per year.

- To determine if the L12 tower suitable to be used in significant place (north Libya) or not. If not another tower should be used.

1.4 Project Scopes

The purpose of this report is to propose relationships between loads imposed on transmission lines and the strengths of transmission line components in order to obtain safe and economical designs. This report also provides a framework for the preparation of national standards dealing with design of overhead transmission lines based on probabilistic or semi-probabilistic methods.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

Probabilistic methods are recommended for the design of transmission lines as opposed to deterministic methods because they openly acknowledge that in practice there is always some risk that design loads can be exceeded and as a result complete reliability cannot be achieved. The proposed methods also provide for designing according to different levels of reliability depending on either the importance of lines in the system, or on varying requirements for public safety. The techniques described enable the designer to assess the reliabilities of existing lines or to design new lines for target reliabilities provided that the data required for such analysis are available [6].

However, it is recognized that for many locations and situations much of the data may not be available to the extent necessary for confidence in the calculation of absolute reliability. In such cases the recommended methods will be effective for estimating the relative reliabilities of different designs. It will be noted that the alternative to designing to target reliabilities ends up as one of designing for varying return periods of climatic events, specifically 50, 150 and 500 years [4]. It is considered that these represent reasonable differences between reliability levels, although different return periods may be selected if desired.

The actual reliability of lines is sensitive to the accuracy of many design parameters. Some of the typical parameters which may affect reliability are discussed hereafter. Although the basic formula for calculating wind loads from measured velocities is well known, it requires the use of a number of coefficients that may be not accurate enough. For instance drag coefficients for conductors and bundles depend on conductor stranding and bundle configuration. It is not possible to give an absolute recommendation covering all conductors in all situations in a research such as this, and the best that can be achieved represents some sort of compromise. Similarly, the effects of varying terrain are not exact and inaccuracies in selecting the appropriate coefficient may lead to differences as large as that separating reliability levels. The estimation of wind speeds between widely-spaced measuring situations is likely to be in accurate and can lead to unpredictable errors in load calculations [3].

Comments may be made with respect to the strength of line components, although in general they are more precisely known than climatic loads with the exception of foundations. The use factors of these components (the percentage of their rated strength that is used to carry loads) may not be known and can affect reliability.

Although our project does propose a method for estimating use factor, there is room for error which in general should be on the side of safety. The above discussion does not represent a complete catalogue of all grounds for uncertainties but does indicate the type of analysis that the designer shall go through in order to design for target reliabilities with confidence. Having done this and if the designer is satisfied with the completeness and accuracy of the data for the particular situation, the report may be used as originally intended, (i.e. providing for reliability based design of transmission lines).

Notwithstanding the uncertainties of the existing probabilistic methods, it shall be pointed out the deterministic methods have many of the same pitfalls that are generally not acknowledged. The approach recommended in this report provides a consistent and logical way of relating loads and strengths, and will result in economic and safe transmission lines whenever the required data is available.

Finally, it is important to compare the results obtained by the proposed methods with existing ones which have proved to be satisfactory. This comparison should allow further adjustment of some of the proposed factors according to local experience.

2.2 Transmission Line Components

Over head power line mainly consists of three parts tower, conductor and insulator. Structure (tower) for overhead lines take a variety of shapes depending on the type of line [6]. Conductor is a material which contains movable electric charges in metallic conductors, such as copper or aluminium. Insulators are non-conducting materials with fewer mobile charges, which resist the flow of electric current. Insulator is a material contains unmovable electric charge and it use for hold and support the conductors and maintain sufficient distance between conductor and tower structure.

2.3 Conductor

It is a material which contains movable electric charges in metallic conductors, such as copper or aluminium. Overhead cable use for transmit power between two side. Aluminium is a good current conductor; low in cost and lighter weight compare to copper [18]. These advantages enhance the usage of aluminium conductor as overhead line of transmission system. Aluminium based for overhead lines like All Aluminium Conductor (AAC) is favourably used compared to copper because of several factors such as price, weight and availability. In fact, strength to weight ratio of AAC has to improve because this results in smaller sags, hence shorter towers. Some modifications have been done therefore, All Aluminium Alloy Conductor (AAAC) and Aluminium Conductor Steel Reinforced (ACSR) are produced. Continuous effort must be done to overcome the small conductivity value in both AAAC and ACSR conductor.

Aluminium conductors reinforced with steel (known as ACSR) and all aluminium alloy conductor (AAAC) are primarily used for medium and high voltage lines. The aluminium conductors have the advantage of better resistivity/weight than copper, as well as being cheaper. Some copper cable is still being used, especially at lower voltages and for grounding. AAAC conductor has a better corrosion resistance and better strength to weight ratio and improved electrical conductivity than ACSR conductor on equal diameter basis [18, 19].

2.3.1 Type Of Conductors

- **ACSR -** Aluminium conductor, steel reinforced.
- **ACAR** - Aluminium conductor, alloy reinforced.
- **AAAC** - All Aluminium alloy conductor.
- **AACSR**- Aluminium alloy conductor, steel reinforced

2.3.2 Advantages of AAAC

- Excellent corrosion resistance, especially in coastal (saline) areas and in chemically polluted industrial area [19, 16].
- High strength/weight ratio. The span length can be increased between 2% and 15% [16], resulting in saving of towers/supports and other accessories.
- High durability. The life of the conductor is longer than ACSR and AAC.
- High carrying capacity. It can carry 8% extra current on the line for an equal temperature rise of the equivalent size of ACSR conductor.
- Lower power-losses. Due to the lower AC resistance, compared to that of equivalent ACSR, the power loss is less. Due to absence of steel core in the conductor, there are no magnetic losses due to electromagnetic effects[19].
- It is hard to cut and impossible to recycle. Due to the presence of alloy elements, the conductor cannot be subjected to melting and hence is not prone to theft.
- Surface hardness: twice that of aluminium strands and hence less prone to damage and scratches during stringing.

2.3.3 Bundle conductors.

Bundle conductor is a number of conductors in parallel. Bundle conductors are used to increase the amount of current that may be carried in a line. Due to the skin effect, ampacity of conductors is not proportional to cross section, for the larger sizes. Therefore, bundle conductors may carry more current for a given weight [18, 19]

Using Bundle conductors result in lower reactance, compared to a single conductor. Also Reduces corona discharge loss at EHV (extra high voltage). The use of bundle conductors in high voltage system will reduce the voltage gradient and also reduce the interference with communication system. On the other hand, the bundle conductors have higher wind loading and it is difficult to install.

The preferred conductor bundles for each of NGT's tower designs are given in table 2-1 below. Conductor bundles that are likely to require significant structural modifications to the relevant tower design are indicated with an asterisk (*) and appear in italic type [17].

Table 2-1 Definition of ground roughness [17]

Tower Design	Bundle Designation	Conductor System	Nominal Rated Temperature (°C)
L4 132 kV	L4 (M)	1 x 175 mm^2 ACSR	50
L7 132 kV	L7 (C)	2 x 175 mm^2 ACSR	50
L3 275 kV	L3/1	1 x 700 mm^2 AAAC	50
	*L3/2**	*2 x 300 mm^2 AAAC*	*50*
L66 275 kV	L66/1	1 x 700 mm^2 AAAC	50
	*L66/2**	*2 x 300 mm^2 AAAC*	*50*
L2 400 kV	L2/2	2 x 500 mm^2 AAAC	75
	L2/6	2 x 620 mm^2 GZTACSR	170
	*L2/4**	*2 x 570 mm^2 AAAC*	*75*
L8 400 kV	L8/2	2 x 500 mm^2 AAAC	75
	L8/6	2 x 620 mm^2 GZTACSR	170
	*L8/4**	*2 x 570 mm^2 AAAC*	*75*
L6 400 kV	L6/2	2 x 700 mm^2 AAAC	75
	L6/3	2 x 500 mm^2 AAAC	75
	L6/4	2 x 850 mm^2 AAAC	75
	L6/5	3 x 700 mm^2 AAAC	50
L12 400 kV	L12	2 x 700 mm^2 AAAC	75
	L12/1	2 x 850 mm^2 AAAC	75

Conductor selection.

In this case of L12 400 kV tower the suitable conductor from the table above is 2□700 mm^2 AAAC (Araucaria xl) as shown in appendix 1 [20].

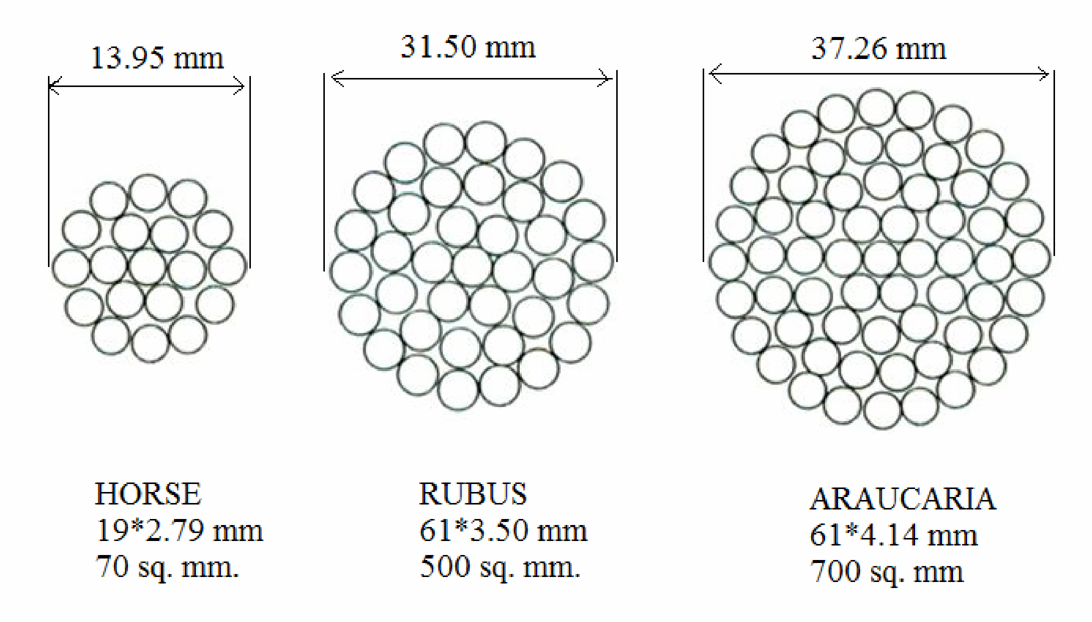

Figure 2-1: All Aluminium Alloy Conductors (AAAC).

2.4 Insulators

Insulators are broadly classified as either pin-type, which support the conductor above the structure, or suspension type, where the conductor hangs below the structure. At higher voltages only suspension-type insulators are common for overhead conductors. Insulators are usually made of wet-process porcelain or toughened glass, with increasing use of glass-reinforced polymer insulators. However, with increasing voltage levels and changing climatic conditions, polymer insulators (silicone rubber based) are seeing increasing usage. Suspension insulators are made of multiple units, with the number of unit insulator disks increasing at higher voltages.

The number of disks is chosen based on line voltage, lightning withstand requirement, altitude, and environmental factors such as fog, pollution, or salt spray. Longer insulators, with longer creepage distance for leakage current, are required in these cases. Strain insulators must be strong enough mechanically to support the full weight of the span of conductor, as well as loads due to ice accumulation, and wind. Porcelain insulators may have a semi-conductive glaze finish, so that a small current (a few milliamperes) passes through the insulator. This warms the surface slightly and reduces the effect of fog and dirt accumulation. The semiconducting glaze also ensures a more even distribution of voltage along the length of the chain of insulator units [21, 22].

2.4.1 Pin Insulator

Usually constructed of porcelain with a pin or stud that screws into a lead or cement insert. These insulator usually being used in 33kV or straight line poles and o angle poles to support the jumper as shown in figure 2-2 (a).

2.4.2 Post Insulator

This type of insulator mainly used in substation to support busbars etc, they are usually constructed as individual unit and socket one above the other for the higher voltage. Depending on voltage, there are stacked together to become 5 units for 132kV and 8 units for 275kV. Higher voltages usually incorporate multicone post insulator which perform a similar function to normal post type but consist of large number of sheds [21].

2.4.3 Long Rod Insulator.

Suspension or tension insulator consisting of an approximately cylindrical insulating part provided it sheds and equipped at the ends with external metal fittings the insulator is designed in such a manner that the shortest puncture path through solid insulating material is at least equal to half the arcing distance. It is consider as class A insulator according to [21] as shown in figure 2-2 (b).

2.4.4 Cap and Pin (ball and socket) Insulator.

This is the type used for overhead transmission line insulation in UK. The string length required is obtained by connecting the individual units together. The insulators are prevented from becoming detached by the use of a phosphor bronze security clip commonly called a 'W' pin [20]. The new 300kN insulator used on 700mm² AAAC lines have the same 24 mm ball and socket as 190kN units. In order to distinguish these insulators the continental split pin type of security clip is used to prevent the ball from detaching socket.

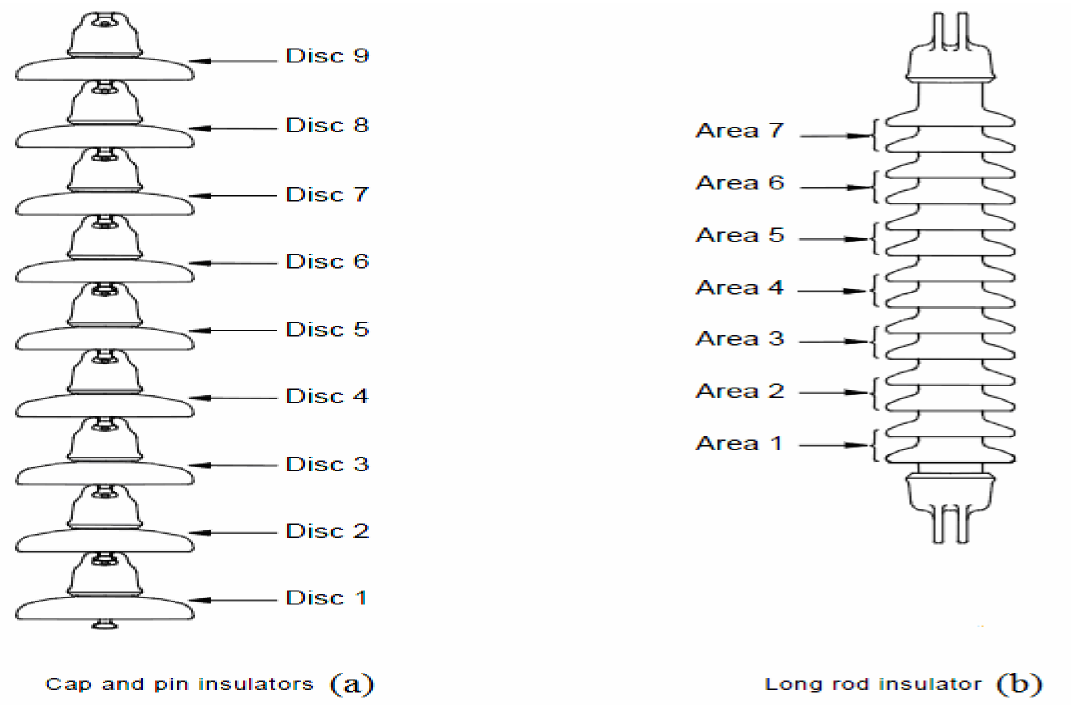

Figure 2-2: Cap and pin insulators and Long rod insulator[21]

2.4.5 Creepage Length and Insulator String Length

The choice and performance of insulators for polluted environments is very often expressed solely in terms of the creepage distance necessary to withstand the polluted conditions under the system voltage. This may lead to the comparison of insulators in terms of necessary ceepage distance per unit voltage.

The overall length of the insulator set shall be such that, after the conductor clamp is attached to it, no part of the insulator set that is at system voltage shall infringe the clearances from live parts to the tower.

The minimum creepage length and length of the insulator string will be as specified in Table 2-2. there is no tolerance permitted on minimum creepage length of the insulator string. The overall length of the insulator string shall be measured from the bottom of the ball of the last insulator to the bottom of an imaginary ball fitted into the socket of the first insulator. In the case of a composite unit the length is measured from the bottom of the ball to the bottom of an imaginary ball fitted into the socket end fitting.

Table 2-2 Overhead line 400 kV insulator string [21].

	Minimum creepage length(mm)	Insulator string length(mm) ± 2%
Tension	9000	4200
Suspension	12500	4100

2.5 Loadings Applied To Transmission Line Components

Overhead transmission lines are subjected to various loads during their lifetime. Wind load is one of the important factors should take in consideration when design reliable overhead transmission line. The displacement of live conductors and insulators towards the tower body will shorten the clearances, increasing the risk of electrical flashover, while movement away from the tower body may cause an infringement of the shielding angle coverage and expose lines to direct lightning strike.

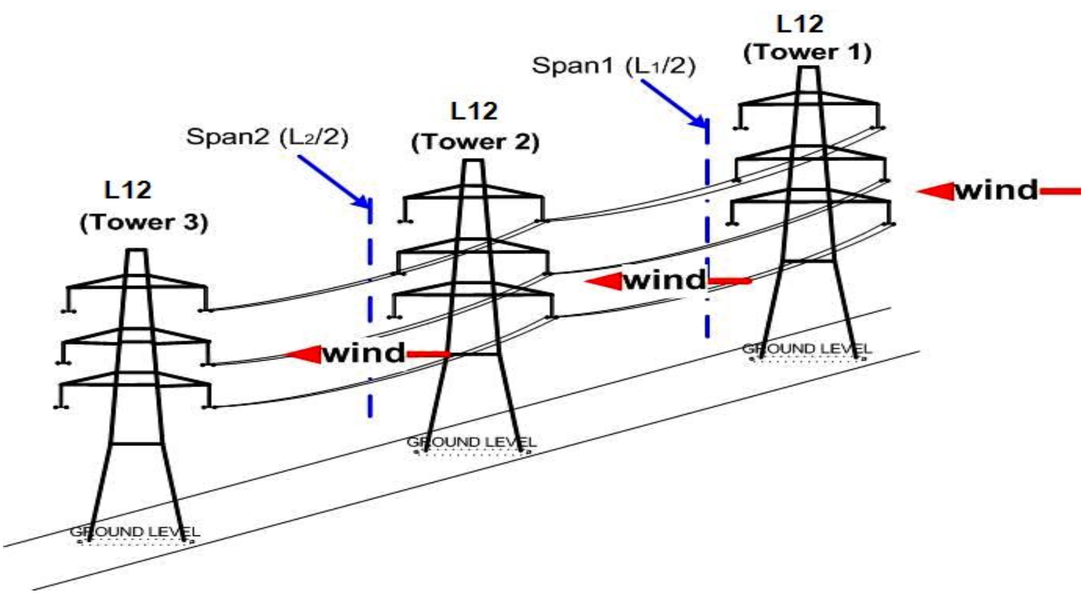

Figure 2-3: Configuration of L2U tower for wind impact analysis[24]

2.5.1 General conditions.

Although the wind load could apply to design any overhead transmission line, it is better limited to the following conditions [2]:

- Span length between 200 m and 800 m as calculations of the various coefficients (in particular for gusty winds) have not been checked for span lengths beyond this range. However, for span lengths greater than 800 m, a gust coefficient corresponding to 800 m span could be chosen with safety.

- Height of supports less than 60 m. Higher supports could be designed following the same principles, but the calculated wind actions would need to be checked.

- Altitude of crossed areas not exceeding 1 300 m above the average level of the topographic environment, except where specific study results are available.

- An adjustment may be made for lines in mountain areas because the roughness can vary according to the vegetation (large trees), snow-covered slopes and rough topography.

2.5.2 General Definitions and Parameters (Ground Roughness).

Wind action depends on the ground roughness. The greater this roughness, the more turbulent and slower is the wind. The ground roughness has an influence both on the determination of the wind velocity for the design and on the determination of the gust factor. Four categories of ground, of increasing roughness, are considered as indicated in Table 2-3 [6].

Table 2-3 Definition of ground roughness [6]

Roughness	Characteristics of the ground crossed by a line
A	Large stretch of water up-wind, flat coastal area, flat deserts
B	Open country with very few obstacles, for instance, moorlands or cultivated fields with a few trees or buildings
C	Terrain with numerous small obstacles of low height (hedges, trees and buildings)
D	Suburban areas or terrains with many tall trees

- **Meteorological wind velocity (V).**

The meteorological wind velocity (V), is defined as an average velocity of the wind during a 10 min period at a level of 10 m above the ground: in relatively open country (roughness B) in Table 2-3. The wind velocity varies with time and space. With reference to the line the wind velocity varies along the span and with the height above the ground level (increase as height increase). To determine the conductor position depending on the wind it is necessary to consider the distribution of the wind velocity along the span and variation with the height above ground level. Additionally, the wind direction is important as well. The studies are concerned only with the wind impact at maximum swing angle, so the wind direction is taken to be perpendicular to the span, meaning that the wind incident angle (Ω) is taken to be equal to 90°.

- **Maximum Yearly Wind Velocity (Vm).**

This velocity Vm is the maximum of V measured over a year. This amount of wind cause the maximum swing angle, but the peak wind velocities of short duration will not affect either the swing angles or the forces acting on the tower. Only the mean values of wind velocities taken over a sufficient long period of time affect the swing angle [3].

- **High wind.**

Determination of the high wind velocity V_m the choice of the high wind velocity, it is depends upon the reliability level for which the line will be designed. The high wind velocity V_m is determined from the average velocity of the maximum yearly velocities V_m and the standard deviation of the statistical distribution of these velocities, according to Table 2-4. in this project the value of σ_{vm}=0.12 will be used as base.

Table 2-4 Values of high wind velocity [6].

Reliability level	**Vm / V¯m**		
	σ_{vm} =0.12 V_m	**σ_{vm} = 0.16 Vm**	**σ_{vm} = 0.20 Vm**
1	1.30	1.41	1.52
2	1.41	1.55	1.7
3	1.51	1.7	1.87

- **Ground roughness coefficient K_R.**

K_R is a coefficient which takes into account the roughness of the ground at the location of the line and in the surrounding area. K_R can be chosen in accordance with the value given in Table 2-3, according to the roughness of the ground crossed by the line [6]. For sites of intermediate roughness, K_R can be interpolated. In estimating the value of the ground roughness, it is necessary to consider the foreseeable changes in the surroundings of the route of the line. In this project ground roughness class B selected as base of study.

Table 2-5 Values of KR for different ground roughness [6]

Ground roughness	A	B	C	D
K_R	1.08	1.00	0.85	0.67
The values of KR correspond to an average 10 min wind velocity V				

- **Coincident temperature.**

The wind velocities defined above for computation shall be considered as occurring at an air temperature equal to the average of the minimum daily temperatures, peculiar to the site. The average minimum daily temperature may be obtained by means of analysis of the recordings over a certain number of years in a meteorological station as close as possible to the location of the line. As an alternative, it would be possible to take as a coincident air temperature the minimum temperature defined hereinafter increased by 15 °C. the minimum daily temperature in north Libya is 14 °C which is the location of the case study used in this research.

- **Reduced wind velocity**

The reduced wind velocity will be equal to the reference wind velocity VR chosen for the high wind assumption multiplied by a coefficient chosen according to local meteorological conditions. Where there is no reliable knowledge of local conditions, a value of 0.6 for this coefficient is suggested.

2.5.3 Unit-action of the wind on any element of the line.

The characteristic value a of the unit-action, due to the wind blowing horizontally, perpendicularly to any element of the line (conductors, insulators, all or part of the support) is given by the following expression [4].

$$a = q_z * C_X G \tag{2.1}$$

Where: q_z = dynamic reference pressure. The dynamic reference pressure q_z is given in terms of the average value of wind velocity occurring at a specified height above the site ground level Vz at the location of the line.

C_X = drag (or pressure) coefficient.

G = Combined wind factor.

$$q_z = \frac{\rho}{2} * \bar{V}_z^{\,2} \qquad \text{Pascals (Pa)} \qquad \textbf{(2.2)}$$

Where: V_z= the average value of wind velocity occurring at a specified height above the site ground level. And the air density, ρ, depends on the temperature and the altitude of the line above sea level.

CHAPTER III

METHODOLOGY

3.1 Introduction

The available clearances between phase conductors or between phase conductors and earthed tower elements depend on the conductor and insulator position which vary under the action of wind. The wind load causes swinging of the conductors and insulators, thus reducing the still air clearances. The wind action varies with time and location and can be described as randomly distribution, the conductor position will be randomly as well. Additionally, the swing angles depend on line parameters, such as ratio of wind to weight span, conductor type etc

Conductors possess a certain mass which has to be accelerated first and moved into a swung position before the wind force will be transmitted to the support. Therefore, peak wind velocities of short duration will not affect neither the swing angles nor the forces acting on the tower. Only the mean values of wind velocities averaged over a sufficiently long period of time affect the swing angle. In this chapter, particular equations will be used to calculate some interested parameters such as: $V_{T,}$ V_{z} , ect. Also swing angle calculation method and the approach will be demonstrated and showing in figure 3-1 to figure 3-3.

3.2 Flow chart

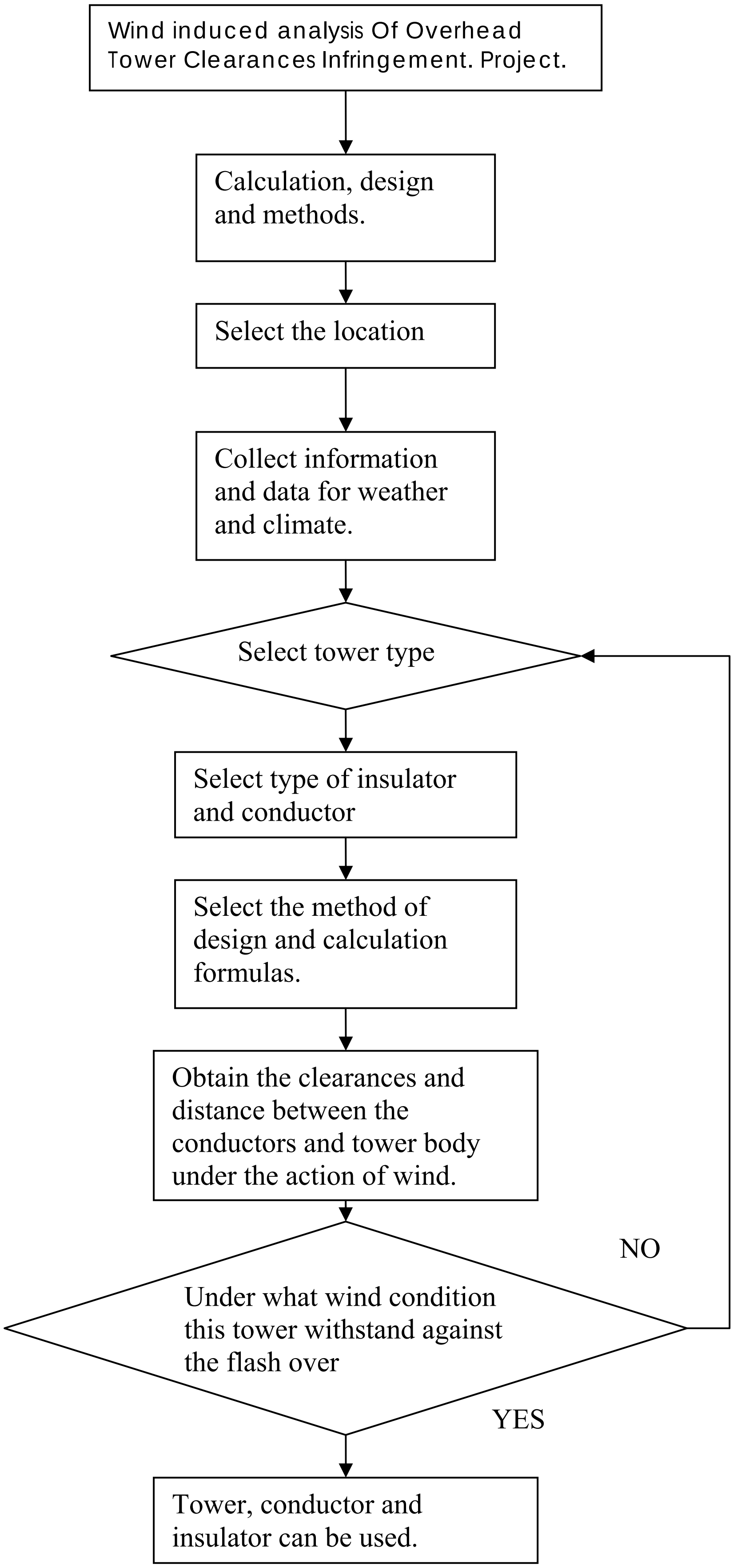

Figure 3-1 General flow chart for the project.

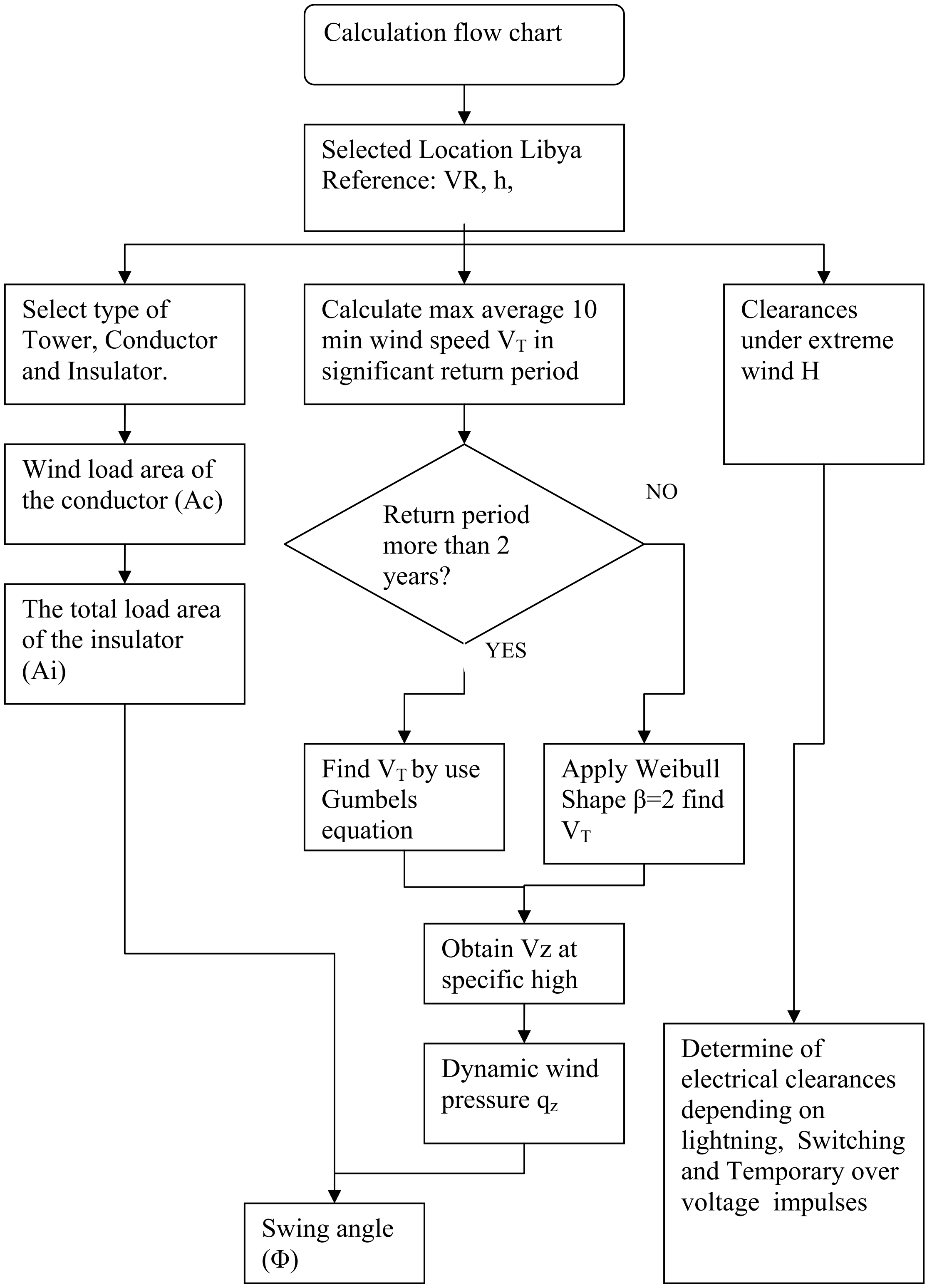

Figure 3-2 calculation flow chart part1

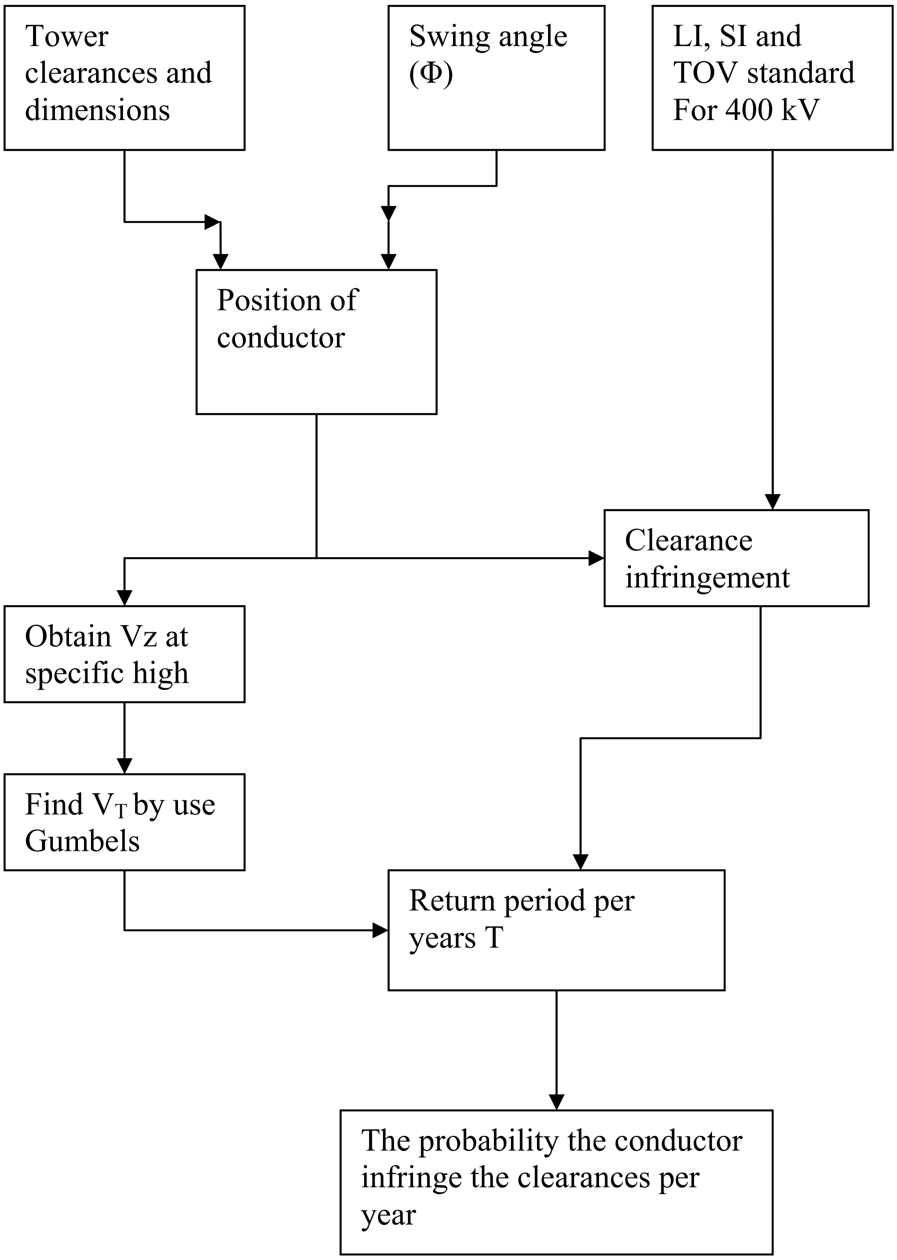

Figure 3-3 calculation flow chart part 2.

3.3 Wind loads on conductors and insulators.

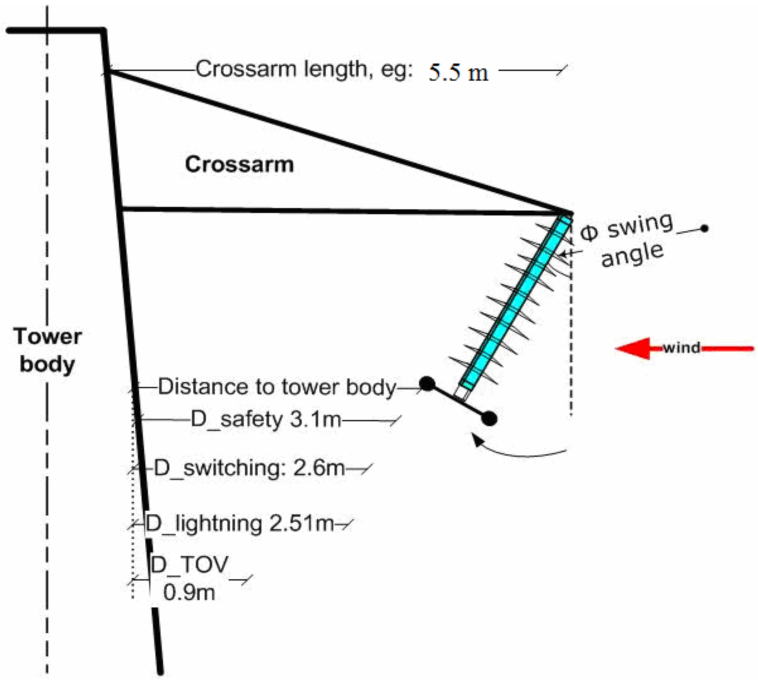

Figure 3-4: Swing angle and related required clearances for 400 kV systems [24]

Wind effect on conductors consists of loads due to wind pressure as well as the effect of the increase in the mechanical tension. Wind pressure loads, the load (Ac) due to the effect of the wind upon a span length L, applied at each attachment point of this span and perpendicularly to the span, is given by the following expression:

$$A_c = C_c * d_{cr} * k * \frac{L_1 + L_2}{2} * \sin^2 \Omega \qquad m^2 \ [24] \qquad \textbf{(3.1).}$$

In equation 3.1 above, C_c is the drag coefficient factor, d_{cr} is the conductor diameter in meters and k is the span correction factor. L1 and L2 are the span of a line erected on three towers, shown in Figure 3-5 below. Ω is the wind direction angle in degrees with respect to the span line (also shown in Figure 2-3).

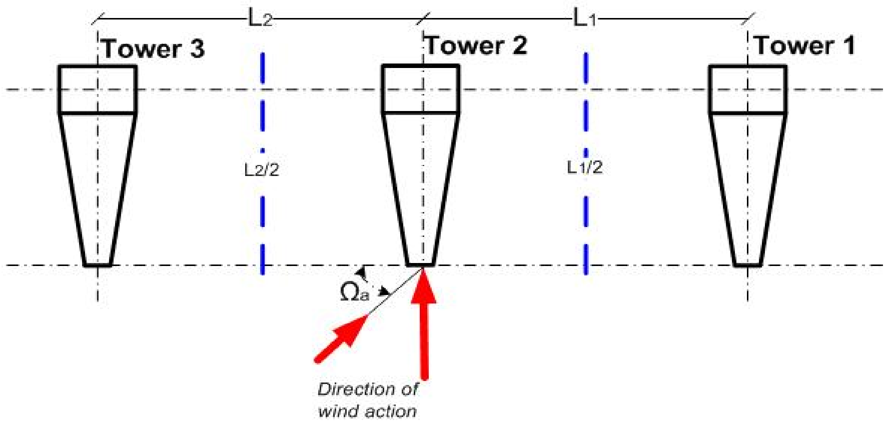

Figure 3-5: Illustration method in determining the wind loading conductor [24]

Wind effect on conductor tension, the mechanical tension of the conductor shall be the more critical of either the one at the corresponding coincident temperature with a wind of velocity VR for the high wind assumption or at the minimum temperature with a wind of coincident velocity for the low temperature assumption.

Wind loads acting on insulator sets come from the load Ac transferred by the conductors and from the wind pressure acting directly on the insulators. The latter load is acting applied conventionally at the attachment point to the tower in the direction of the wind and its intensity is given by:

$$A_c = a_i * G_i \qquad m^2 \quad [24] \qquad \textbf{(3.2).}$$

The total wind loading area of the insulators is determined by multiplying the total area seen in side view, ai, by the drag factor, Gi, as shown in equation 3.2

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