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# TRANSMISSION LINE LOSSES WITH REFERENCE TO TEMPERATURE

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**ABSTRACT**

*Climate change is the hot topic in today's time, with the change in climatic condition it is affecting our lives in numerous ways the health and the wealth part as well. Climate change affects electric power infrastructure, mitigation options, and adaptation options. Electricity infrastructure categories include power generation technologies, transmission lines, substations, and building loads. the effect of climate change in machineries and other equipment. In This paper we are going to summarize the transmission line losses with reference to temperature.*

**KEYWORDS:** *Temperature, Transmission line, Sag, Resistance, Matlab, Capacitance, Conductance, Resistance.*

## 1. Introduction

Transmission line is a special type of cable or say a type of structure that is designed to conduct electromagnetic waves in a suitable manner. These are used to connect the electric generatoing substations to various distribution units of electrical power to various part of the world or we can say that it is a medium that used to transmist the wave of voltage and current from one end to another. Transmission lines are made up of a conductor which is having a uniform cross-section along the line. Air act as an insulating or dielectric medium between the conductors. For safety purpose, the distance between the line and ground is given much more. These lines are installled on electrical tower which is used for supporting the conductors of the transmission line. These towers are made up of steel for providing high strength to the conductor. For transmitting high voltage, over long-distance high voltage direct current is used in the transmission line.

Transmission lines have four types of parameters :-

1. Line inductance
2. Line capacitance
3. Capacitance
4. Shunt conductance

As we know that air acts as a dielectric medium between the conductors. When the alternating voltage applies in a conductor, some current flow in the dielectric medium because of dielectric imperfections. Such current is called leakage current. Leakage current depends on the atmospheric condition and pollution like moisture and surface deposits.

Electricity is transmitted from large power plants to the consumers via extensive networks. The transmission over long distances create power losses. A major part of the energy losses comes from Joule effect in transformers and power lines. The energy is lost as heat in the conductors.

Considering the main parts of a typical Transmission & Distribution network, here are the average values of power losses at the different steps*:

1-2% – Step-up transformer from generator to Transmission line

2-4% – Transmission line

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1-2% – Step-down transformer from Transmission line to Distribution network
4-6% – Distribution network transformers and cables

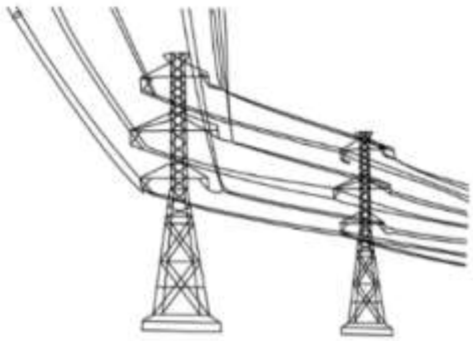

**Figure 1. Transmission Line**

The overall losses between the power plant and consumers is then in the range between 8 and 15%.
Intense heat can cause transmission lines to become less efficient. Because of the increase in demand, more energy is running along the wires — when combined with warmer air, that can cause the transmission lines to swell and lead to sagging that topples some of the infrastructure.

- For this paper we have gone through few research papers and journal.
- In those few research papers and journal, we have found that following points mentioned below-

1. Temperature produced by electro-thermal causes the change of transmission components and electrical characteristics.
2. Considering temperature power flow model provides an idea for the electro-thermal analysis of power flow.
3. In some branches, the loss is obvious, so the electric heating factor is considered in the power flow analysis necessarily.
4. Through the power flow model, the transmission current-carrying capacity can be determined by temperature and then it can make a judgment to power system decision-making and predict, improving the security and stability of power system.
5. By analyzing the correlation of power consumption and temperature, the temperature sensitivity is determined for each type of customer. The impact of the temperature change on the power consumption of each service area can therefore be estimated by considering the class and energy consumption of all the customers within the study area.
6. The temperature sensitivity analysis of customer power consumption provides important information for the load forecast of the distribution system in a very accurate manner.
7. With the temperature change, the power loading of the service area is determined and load transfer among the distribution feeders and main transformers can be obtained by performing the optimal switching operation.
8. The resistance of the metals in transmission lines is the primary source of losses. Power is dissipated in a section of the line as the current overcome the ohmic resistance of the line and it is directly proportional to the square of the root mean square (rms) current travelling through the line. Change in temperature affects the line resistance.
9. The effect of temperature change on the resistance of transmission line losses in electrical power network has been established. Change in temperature affects the line resistance.
10. For small change in temperature, the resistance increases linearly with temperature.
11. The losses due to the resistance can be reduced by raising the transmission voltage level even though there is a limit to which the cost of the power transformers and insulators will exceed the savings.

## 2. LOSSES IN TRANSMISSION LINE

Like all other power system systems, no matter how carefully the system is designed, losses are present and must be modeled before an accurate representation of the system response can be calculated. Due to the size of the area that the power system serves, most of the system components are dedicated to power transmission.

- Conductor Loss:- Conductor losses mainly occur due to the current flow in the conductor. Since the transmission line contains more considerable resistance, this type of injuries is unavoidable. This type of losses is also known as heating losses because it also generates heat energy.
- Radiation Loss:- It happens when the distance between the conductors in the transmission line is comparable to the wavelength. In such cases the electromagnetic and electrostatic field of the conductors acts as small antennas which

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conducts out energy to the nearby conducting materials.

- Dielectric Heating Loss:- Dielectric loss is caused when the insulating material inside the transmission line absorbs energy from the alternating electric field and converts it to heat.
- Coupling Loss:- Coupling loss, also known as connection loss, is the loss that occurs when energy is transferred from one circuit, circuit element, or medium to another. Coupling loss is usually expressed in the same units such as watts or decibels as in the originating circuit element or medium.
- Corona Effect:- The phenomenon of ionisation of surrounding air around the conductor due to which luminous glow with hissing noise is rise is known as the corona effect. Air Acts as the medium between Transmission Lines
- Skin effect reduces the effective cross-section of the conductor and thus increases its effective resistance. Skin effect is caused by opposing eddy currents induced by the changing magnetic field resulting from the alternating current.

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## 3. EFFECT OF TEMPERATURE ON TRANSMISSION LINE

There are various things that affect transmission line when there is rise and fall in temperature. Some parts of india are having a major heat stroke while some of them are flooded some are covered in ice some of them are having storms and high pressure winds these are the sudden changes in temprature which are affectng the resistivity of conductors the sag and tension of cables which leds to corona loss , skin leffect, Coupling loss and these losses leads to harm the human life and property, suddenly the natural climatic disaster leds to man made disaster due to these losses.

$$R_2 = R_1\left(\frac{T + t_2}{T + t_1}\right)$$

- Resistivity of conductor :- The resistivity of any conductive material varies linearly over an operating temperature, and therefore, the resistance of any conductor suffers the same variations. As temperature rises, the conductor resistance increases linearly, over normal operating temperatures, according to the following equation:

  Where
  R2= resistance at second temperature t2
  R1= resistance at initial temperature t1
  T = temperature coefficient for the material ($^0$C)
  Resistivity (r) and temperature coefficient (T) constants depend upon the conductor material.

- Ice and Wind Conductor Loads:- When a conductor is covered with ice and/or is exposed to wind, the effective conductor weight per unit length increases. During occasions of heavy ice and/or wind load, the conductor catenary tension increases dramatically along with the loads on angle and deadend structures. Both the conductor and its supports can fail unless these high-tension conditions are considered in the line design.
- Sag changes with Thermal Elongation as conductor elongate with increasing conductor temperature.
- Sag changes due to combine Thermal and Elastic effects as the increase in temperature caused an increase in length and sag and a decrease in tension.
- The Ultimate Tensile Strength will start reducing as well as due to expansion, tension will reduce in conductor. In case the tension doesn't decrease much but Ultimate Tensile Strength decreased more it will snap.

## 4. MATHMATICAL MODELLING OF SAG

- In a transmission line, **sag** is defined as the vertical difference in level between points of support (most commonly transmission towers) and the lowest point of the conductor.
- The calculation of **sag** and tension in a transmission line depends on the span of the overhead conductor.
- Keeping the desired sag in overhead power lines is an important consideration. If the amount of sag is very low, the conductor is exposed to a higher mechanical tension which may break the conductor.
- Whereas, if the amount of sag is very high, the conductor may swing at higher amplitudes due to the wind and may contact with alongside conductors.
- Lower sag means tight conductor and higher tension. Higher sag means loose conductor and lower tension.

Sag in an overhead transmission line for two cases.

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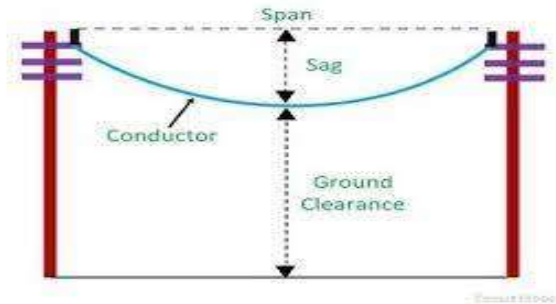


**Figure 2. Sag in Overhead transmission lIne**

**Case1:** When the conductor supports are at equal level.
Let us consider an overhead line supported at two different towers which are at same level from ground. The point of support are A and B as shown in figure below. O in the figure shows the lowest point on the conductor. This lowest point O lies in between the two towers i.e. point O bisects the span equally.
Let,
L = Horizontal distance between the towers i.e. Span
W = Weight per unit length of conductor
T = Tension in the conductor

Let us take any point P on the conductor. Assuming O as origin, the coordinate of point P will be (x,y).

Therefore, weight of section OP = Wx acting at distance of x/2 from origin O.

As this section OP is in equilibrium, hence net torque w.r.t point P shall be zero.

Torque due to Tension T = Torque due to weight Wx

Ty = Wx(x/2)

Therefore, y = Wx2 / 2T ……………………….(1)

For getting Sag, put x = L/2 in equation (1)

Sag = WL2/8T

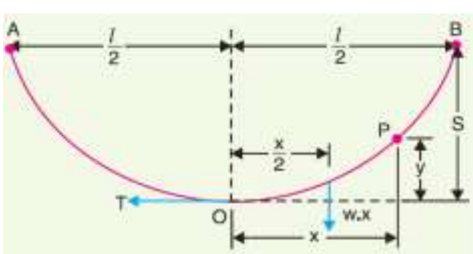


**Figure 3. Conductor supports are at equal level.**

**Case2:** When the conductor supports are at unequal level.
In hilly area, the supports for overhead transmission line conductor do not remain at the same level. Figure below shows a conductor supported between two points A and B which are at different level. The lowest point on the conductor is O.
Let,

L = Horizontal distance between the towers i.e. Span

H = Difference in level between the two supports

T = Tension in the conductor

X1 = Horizontal distance of point O from support A

X2 = Horizontal distance of point O from support B

W = Weight per unit length of conductor

From equation (1),

Sag S1 = WX12/2T

and Sag S2 = WX22/2T

Now,

S1 – S2 = (W/2T)[ X12 – X22]

= (W/2T)(X1 – X2)( X1 + X2)

But X1 + X2 = L …………………….(2)

So,

S1 – S2 = (WL/2T)(X1 – X2)

X1 – X2 = 2(S1 – S2)T / WL

X1 – X2 = 2HT / WL (As S1 – S2 = H)

X1 – X2 = 2HT / WL ………………..(3)

Solving equation (2) and (3) we get,

X1 = L/2 – TH/WL

X2 = L/2 + TH/WL

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By putting the value of X1 and X2 in Sag equation, we can easily find the value of S1 and S2.

The above equations for Sag are only valid in ideal situation. Ideal situation refers to a condition when no wind is flowing and there is no any effect of ice loading. But in actual practise, there always exists a wind pressure on the conductor and as far as the ice loading is concerned, it is mostly observed in cold countries. In a country like India, ice loading on transmission line is rarely observed

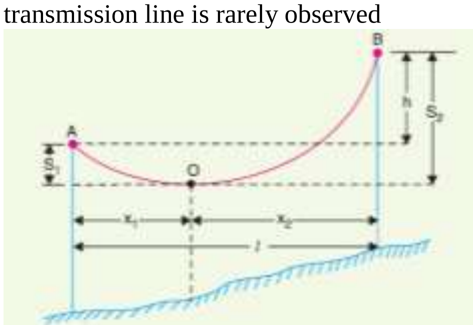


**Figure 4. Conductor supports are at unequal level.**

## 5. MATLAB Simulation

- MATLAB stands for Matrix Laboratory.
- It is a high-performance language for technical computing.
- It integrates computation, visualization, and programming environment.
- MATLAB has many advantages compared to conventional computer languages for solving technical problems.
- Initially it was developed to provide easy access to matrix software developed by LINPACK and EISPACK.
- MATLAB has been commercially available since 1984.
- It also has all the modern programming language attributes such as Data structures, contain built-in editing and debugging tools, and support object-oriented programming.
- It is widely used in universities and industries.

**OBJECTIVE: Calculation of Sag and Tension in Transmission Line**.

**PROGRAM:**

clc
clear all
fprintf('Calculation of sag and tension in transmission line\n')
fprintf('\n')

*EX: An overhead transmission line has a span of 230 m and the conductor % Weight is 650 kg/km. Calculate the maximum sag if the breaking stress is % 4465 kg/cm^2 while the area of the conductor is 1.29 cm^2. Assume factor % of safety as 2;*

**fprintf('*********INPUT PARAMETERS************\n')**
fprintf('\n')
l=input('enter the value of length of span in m = ');
w=input('enter the value of weight of conductor in kg/m = ');
b=input('enter the value of breaking stress in kg/cm^2 = ');
sf=input('enter the value of factor of safety = ');
a=input('enter the value of area of conductor in cm^2 = ');
bs=b*a;
t=bs/sf;
s=(w*l^2)/(8*t);
fprintf('\n')
**fprintf('************OUTPUT PARAMETERS*************\n')**
fprintf('\n')
fprintf('The value of Tension is %f \n',t)
fprintf('The value of Sag is %f \n',s)

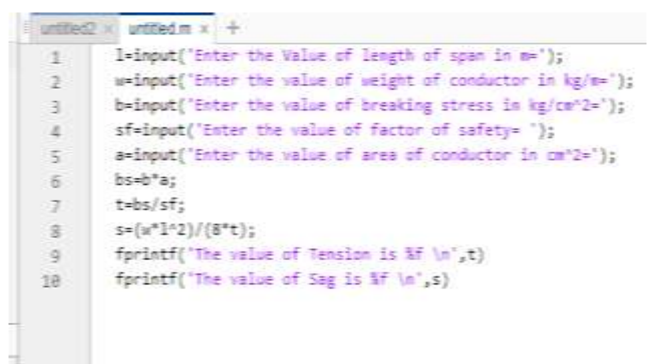


**Figure 5. Input parameters of MATLAB**

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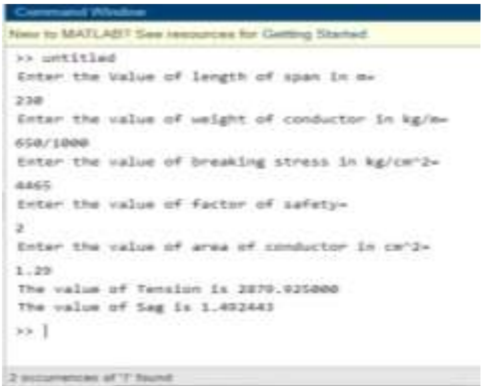


**Figure 6. Output of MATLAB**

**Calculation by theoretical method.**

L = Span = 230 m

W = 650 kg/km $=\frac{650}{1000}$ kg/m = 0.65 kg/m

Breaking Stress = 4465 x 1.29 = 5759.85 kg

$S_f = \frac{BreakingStress}{WorkingStress(T)}$

$2 = \frac{5759.85}{T}$

T = 2879.925 kg = Tension

$S = \frac{wL^2}{8T}$

$= \frac{0.65*(230)^2}{8*2879.925}$

= 1.4924 ……Maximum Sag

Simulation of Sag and tension at different temperature and wind Pressure for this we have considered the parameters from table 1.

When there is rise in conductors span length with temperature on the sag and tension the effects are reflected in the simulation. The impact of wind pressure on the conductors is also presented. In Figure 7, the effects of temperature variation with negligible wind pressure on the sag and tension of the overhead line conductor for a level land topography is presented. The result indicated that as the temperature is varied with a negligible wind pressure of 0 Nm−2, the tension exerted on the conductor decreased in the follwing sequence: [2000; 1500; 1250; 1000; 750; 500] N whereas the sag on the overhead line conductor increased in the sequence [0.5445; 0.7260; 0.8712; 1.089; 1.452; 2.178] m . The increase in sag is a consequence of temperature change from ambient value leading to a slight thermal expansion of the conductor span length. In Figures 8 and 9, the effect of height difference between towers for unequal level (upland) topography with respect to changes in the sags at varied temperature and negligible pressure from the wind was presented. The magnitude of sag increased as the tension decreased. It is observed that for the same tension values the sag differs in magnitudes. This is due to the obvious height difference between the two towers that support the overhead line conductors. In Figure 10, a wind pressure of 150 Nm−2 was applied on the overhead line conductors. It is observed that the magnitude of tension changed with the wind pressure to support the variation in sag values. The magnitude of sag increase in Figure 10 is in the sequence of [1.156; 1.444; 1.926; 2.889; 3.852; 5.778] m which is almost twice the values obtained in Figure 5. Therefore, under this condition, more tension is needed on the stringed conductor in Figure 6 to avert the dangerous effect of short-circuit that may arise from conductor swinging during a high wind. In Figures 11 and 12, it is evident that as a wind pressure of 150 Nm−2 is exerted on the overhead line conductor, the tension on the line increased and subsequently decreased in proportion to the increase in sag. The rate of increase in sag values for the upland topography is indicative of the height difference between towers and their distance of separation. The deflected angle during wind loading on the overhead line conductor is plotted in Figure 13. This plot shows that the critical deflection angle occurs at 450 which implies that deviation from this value can lead to a dangerous sway of the conductor which may give rise to an explosive short circuit.

**Table 1 Simulation Parameters**

| Overhead Conductor Parameter (AAAC) | Values |
|---|---|
| Ambient Temperature ($^oC$) | 20.7and 30.5 |
| Transmission Voltage (kV) | 330 |
| Frequency of transmission (Hz) | 50 |
| Overhead conductor spacing between towers (m) | 300 |
| Wind pressure $Nm^{-2}$ | 0 and 150 |
| Assumed Varying Temperature ($^oC$) | 50, 55, 60, 65, 70 |
| Assumed Varying Span Length (m) | 60, 70, 80,90,100 |
| Coefficient of Thermal expansivity (0C-1) | 19 × 10−6 |
| Assumed height difference between Towers (m) | 10 |

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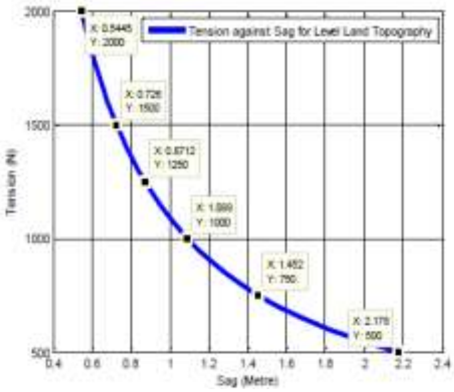


**Figure 7. A plot of Tension against Sag(δ) at varied temperature with wind pressure = 0 N/m2 for a Level land.**

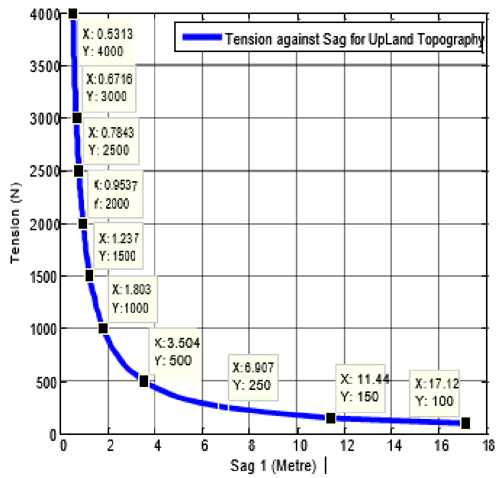


**Figure 8. A plot of Tension against Sag 1(δ1) at varied temperature with wind pressure = 0 N/m2 for an Upland**

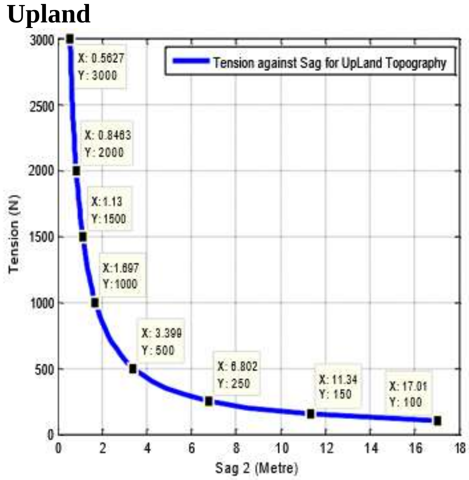


**Figure 9. A plot of Tension against Sag 2 (δ2) at varied temperature with wind pressure = 0 N/m2 for an Upland**

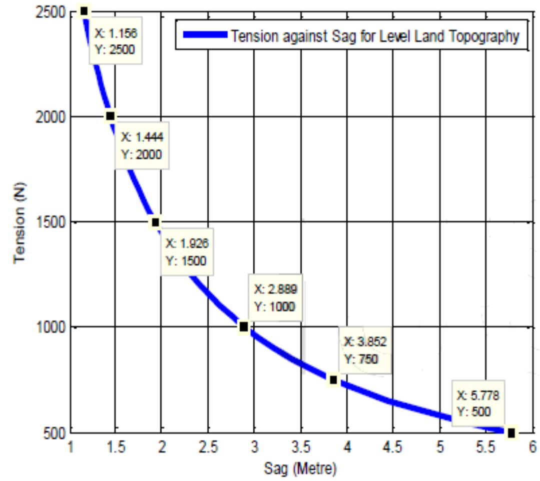


**Figure 10. A plot of Tension against Sag (δ′) at varied temperature with wind pressure = 150 N/m2 for a level land.**

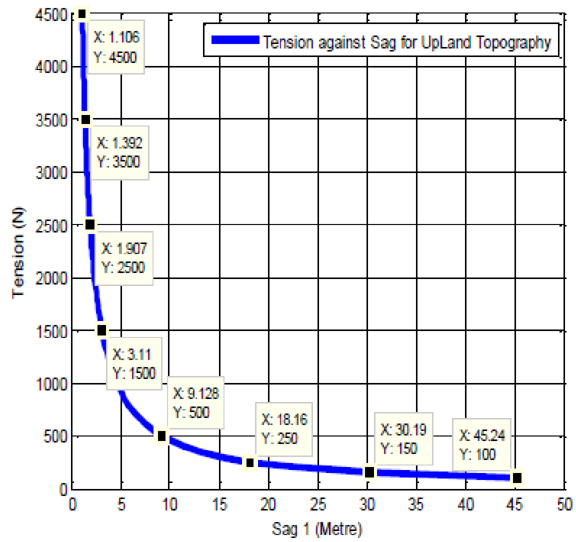


**Figure 11. A plot of Tension against Sag 1 (δ1′) at varied temperature with wind pressure = 150 N/m2 for an Upland Topography.**

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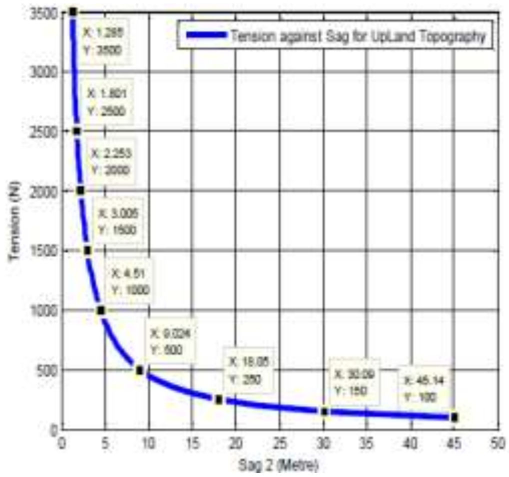


**Figure 12. A plot of Tension against Sag 2 (δ2′) at varied temperature with wind pressure = 150 N/m2 for an Upland Topography.**

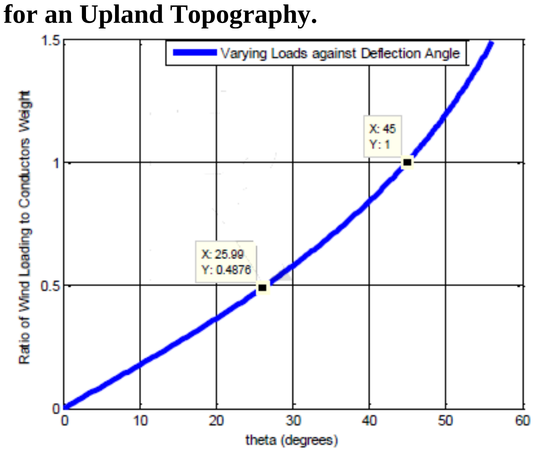


**Figure 13. Varying Load $\frac{Wh}{Wc}$ against Deflection Angle for a Level land Topography.**

## 6. CONCLUSION

In this paper we have discussed that what will be the effect of temperature on the transmission line and the losses occurance due to climate change we have gone through the studies what will happen to conductors and the cables how the sag will cause a huge number of losses. We have also explaine the sag calculation for both equal level land and unequal level of land by theoretical method and how MATLAB will help in calculation of sag and tension in very less effort, and we can simpulta various effects of temperature and other factors afffecting sag and tension in condurtors, cables and other component of Transmission Line.

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