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Research article

EFFECT OF TEMPERATURE CHANGE ON THE RESISTANCE OF TRANSMISSION LINE LOSSES IN ELECTRICAL POWER NETWORK

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Abstract

The resistance of the metallic conductor in transmission lines is the primary source of losses. Power is dissipated in a section of the line as the current overcomes the ohmic resistance of the line and it is directly proportional to the square of the root mean square (r.m.s) current travelling through the line. This research paper develops a model for the effect of temperature change on the resistance of transmission lines losses in electrical power network. The mathematical notations of power dissipation and transmission line efficiency were used as input parameters for the development of the model.The result of the model shows that the resistance of the transmission lines increases inversely with the temperature. An initial temperature of 570^0K gives rise to corresponding final temperature of 552^0K. Similarly, an initial temperature of 560^0K gives rise to a corresponding final temperature of 542^0K. As the temperature ratio increase, the transmission line offers more resistance to the flow of electric current, thus increasing the resistance of the transmission line. The transmission lines offer a resistance of 24.21 Ohm to the flow of current at a temperature ratio of 0.9684. Throughout the transmission lines, a temperature ration of 0.9929 gives a resistance of 24.82 Ohm to the flow of electric current.The model developed stresses the inverse relationship between the temperature change and the resistance of the transmission lines.

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I. Introduction

When currents flow in a transmission line, the characteristics exhibited are explained in terms of magnitude and electric field interaction [6]. Thephenomenon that results from field interaction is represented by circuit elements or parameters. A transmission loss consists of four parameters which directly affect its ability to transfer power efficiently. These elements are combined to form an equivalent circuit representation of the transmission lines, of the transmission losses [[4],[12]]. The parameters associated with the dielectric losses that occur is represented as a shunt conductance. Conductance from the line to line or a line to ground accounts for losses which occur due to the leakage current at the cable insulation and the insulators between overhead lines. The conductance of the line is affected by many unpredictable factors, such as atmospheric pressure, and is not uniformly distributed along the line [5]. The influence of these factors does not allow for accurate measurements of conductance values. The leakage in the overhead lines is negligible, even in detailed transient analysis. This allows this parameter to be completely neglected [[10], [16]].

In a transmission system, the primary source of losses incurred is in the resistance of the conductors. For a certain section of the line, the power dissipated in the form of useless heat as the current attempt to overcome the ohmic resistance of the line, and is directly proportional to the square of the r.m.s current travelling through the line. It follows that the losses due to the line resistance can be lowered by raising the transmission voltage level, but there is a limit at which the cost of the transformers and insulators will exceed the savings [[1], [13], [14]]. The efficiency of a transmission line is defined as [[3], [15]].

$$\eta = \frac{P_R}{P_S} = \frac{P_R}{P_R + P_{Loss}} \quad 1$$

Where P_R is the load power and $P_{Loss}$is the net sum of the power lost in the transmission system. As the transmission line dissipates power in the form of heat energy, the resistance value of the line changes. The line resistance will vary, subject to maximum and minimum constraints, in a linear fashion [[7], [11], [14], [12]].

Given that R_1 = resistance at some temperature T_1 and R_2 is the resistance at temperature T_2:

Then

$$R_2 = R_1 \left(\frac{235+T_2}{235+T_1}\right) \qquad 2$$

Provided that T_1 and T_2 are given in degree centigrade.

In the transmission line, the capacitive resistance is due to the interaction between the electric field from conductors to conductors and from conductor to ground. The alternating voltages transmitted on the conductor causes the charge present at any point along the line to increase and decrease with the instantaneous changes in the voltage between conductors or the conductors and ground. This flow of charge is known as charging current and is present even when the transmission line is terminated by an open circuit [[8], [9]]. The alternating currents present in a transmission system are accompanied by alternating magnetic fields. The interaction of these magnetic fields between conductors in relative proximity creates aflux linkage. These charging magnetic fields induce voltages in parallel conductors which are equal to the time rate of change of the flux linkages.The constant of proportionality is called inductance [[5], [16]].

$e = L\frac{di}{dt}$ 3

The mutual coupling will cause voltages to be induced as a result of the relative positioning of the lines. The induced voltage will add vector/ally with the line voltages and cause the phases to become unbalanced [[6], [13]]. When a 3-phase set is unbalanced, the lines do not equally share the current. Looking at only the simple resistive losses in the circuit, and noting that the power loss is directly proportional to the square of the magnitude of the current flowing in the line; it is easy to see that the losses in one line will increase significantly more than the reduction of losses in the other lines. This suggests that a simple way to minimize the total I^3R losses is to maintain a balanced set of voltages [[8], [10]]. The mutual coupling also increases the total line reactance. The line reactance further adds to the losses because it affects the power factor on that line [[3], [5], [2], [13]].

The effect of this mutual coupling is often reduced by performing a transposition of the transmission lines at set intervals [3]. The transposition governs the relative positioning of the transmission lines. Each phase is allowed to occupy a position, relative to the other two phases, for only one third of the distance. The phases are then rotated at their positions relative to one another. The actual phase transposition usually, does not take place between the transmission towers. A certain safe distance must be maintained between the phases and because of the need to maintain the required distances between the phases, transposition is most likely to take place at a substation.

II. Materials and Method

Development of Mathematical Model

The resistance of the conductors is a major source of losses incurred in a transmission system.

The power dissipated is

$P = i^2R$ 4

$R = \frac{eL}{a}$ 5

Where;

P = Power dissipated

i= Current

e= Resistivity of the conductors(Ωm)

L= Length in meters

a= Cross sectional area in m^2

The resistance increases linearly with temperature and resistance at a temperature ‘t’ given by:

$R_t = R_0(1 + a_0t)$ 6

Where;

R_t = Resistance at t^0c

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a_0 = Temperature Coefficient of resistance at 0^0c

R_0 = Resistance at 0^0c

Between two intermediate temperatures $t_1$and t_2 ,

$\frac{R_2}{R_1} = \frac{1+at_2}{1+at_1}$ 7

Where:

R_1 = Initial resistance

R_2 = Final resistance

a = Temperature coefficient

t_1 = Initial temperature; measured in o_C

t_2 = final temperature; measured in o_C

$\frac{R_2}{R_1} = \frac{\frac{1}{a_0}+t_2}{\frac{1}{a_0}+t_1}$ 8

Let$\frac{1}{a_0} = T$;

Then,

$R_2 = R_1\frac{T+t_2}{T+t_1}$ 9

Where;

a_0= Constant temperatures that depend on some factors, T = Absolute temperature, 273^0k.

It implies that the losses due to the line resistance can be reduced by raising the transmission voltage level, even though, there is a limit to which the lost of the transmission and insulators will exceed the savings.

For the transmission line,

Efficiency $\eta = \frac{P_R}{P_S} = \frac{P_R}{P_R+P_{Loss}}$ 10

Where;

P_R = Load power

P_{Loss} = Net sum of the power lost.

From equation (6)

$$R_2 = R_1\left[\frac{T+t_2}{T+t_1}\right]$$

Let $T + t_1 = \theta_1,\ T + t_2 = \theta_2$

Then,

$$R_2 = R_1 \left[\frac{\theta_2}{\theta_1}\right] \quad 11$$

$$R_1 = R_2 \left[\frac{\theta_1}{\theta_2}\right] \quad 12$$

Equation (11) is the model developed for the variation of temperature change on the resistance of transmission line losses in electrical power network.

III. Discussion of Results

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. The temperature sensitivity analysis of customer power consumption provides important information for the load forecast of the distribution system in a very accurate manner. 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.

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.

The variations of the temperatures are illustrated in Figure 1. The initial temperatures decrease progressively throughout the study period while the final temperatures increase accordingly, thus suggesting that the two temperatures are inversely related. Thus, an initial temperature of 570^0K gave a corresponding final temperature of 552^0K. In the same manner, an initial temperature of 560^0K gave a final temperature of 542^0K.

Figure 2 shows the relationship between the final resistance of the transmission lines and the temperature ratio. From the figure, it is observed that as the temperature ratio increases, the transmission lines offer more resistance to the flow of electric current thus increasing the resistance of the transmission lines accordingly. At temperature ratio of 0.9684, the transmission lines offered a resistance of 24.21Ω to the flow of current.

A temperature ratio of 0.9929 also gave a resistance of 24.82Ω to the flow of electric current through the transmission lines.

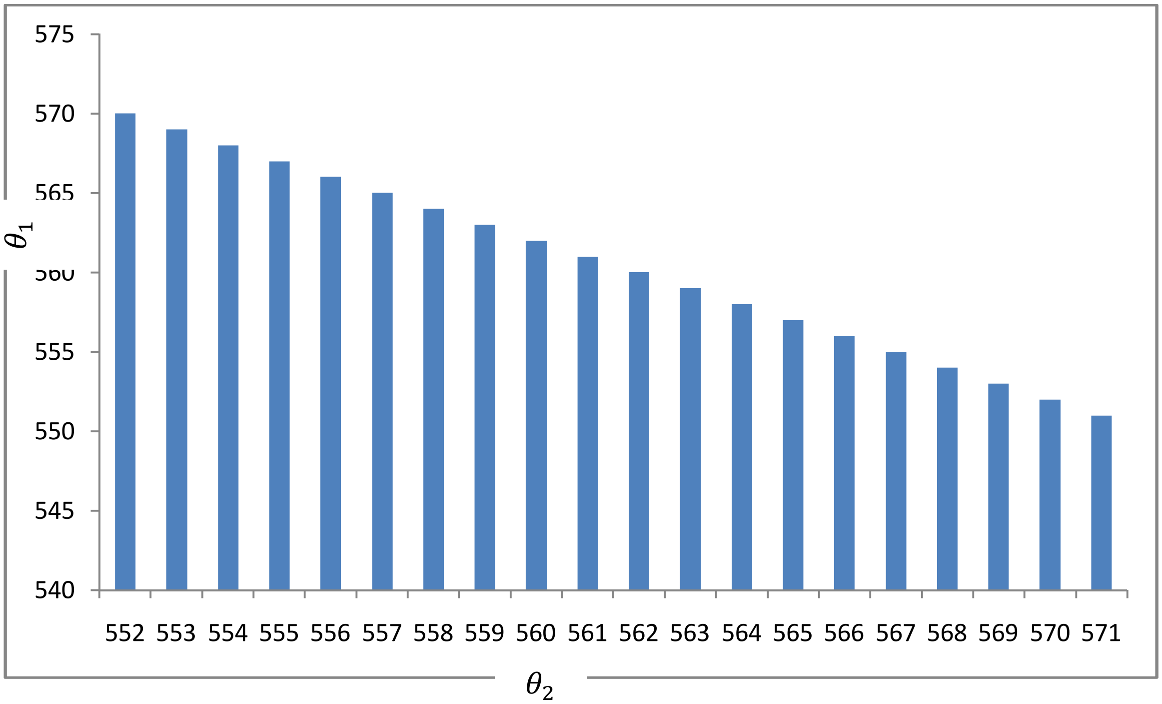

Figure 1:θ_1 versus θ_2

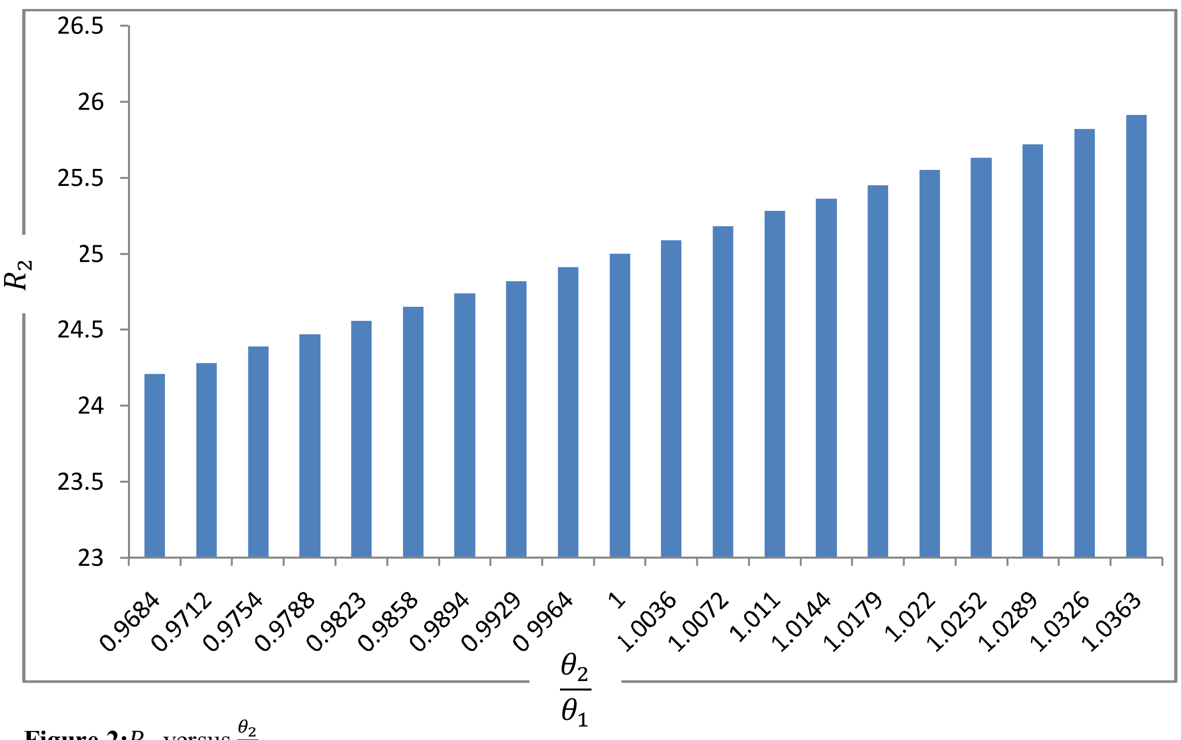

Figure 2:R_2 versus $\frac{\theta_2}{\theta_1}$

IV. Conclusion

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. For small change in temperature, the resistance increases linearly with temperature. 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.

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