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Overview Of Losses And Solutions In Power Transmission Lines

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ABSTRACT--- **Growing popupulations and industrilization creat huge need for electrical energy. Unfortunately, electricity is not always used in large demand in the same location it is been generated. So, long cables or wires are used to transmit the generated electricity either through Underground or Overhead system method, which is reffereed to as Transmission of Electrical Energy. This transmission those not take place without encoutering loses, which is the soul aim of this report. Studying the various types of loses encouted during electrical transmission.**

The losses are either Technical losses or Non-technical Losses. The technical losses, which includes the; Corona loss, Juole effect, Magnetic Losses, and skin effect. While the Non-technical (commercial) losses include, theift of electricity, vandalism to electrical substatio ns, poor meter reading, poor accounting and record keeping, etc.

There could be no best way, by explaining the various methods of Analysing calculations on how to solve this technical losses, and also explaining measures to be taken to makesure that transmission losses can be reduced to bearess minimum.

KEYWORDS----- Transmission Line, Losses, Energy, Electricity, Distribution Line, Voltage, Power Station, Corona Effect, Resistive Effect, Technical Losses, and Electrical Power.

1.0 INTRODUCTION

Electrical energy is the most important form of energy in the present world. it is an energy that drives the economy of any society or country and makes the common citizen happy. Electricity is been generated from the power station, needs to be transmitted to the end users, through transmission and distribution lines. This transmitted energy is not without losses, but the capacity to transmit at minimal losses is what this report entails to x-tray.

Nigeria transmission of electricity is through a nation grid, which could be in 330kv or 132kv. Transmission grid is a network that consist of conductors carried on steel towers in between transformer stations, which conveys generated power from power stations to major load centres, and interconnecting all power stations to form a solid network that is accessible to all load centres. [1]

In electricity supply to final consumers, losses refer to the amounts of electricity injected into the transmission and distribution grids that are not paid for by users.

Transmission of power and energy must be done at minimaum technical and non-technical loses which are refered as Total Losses during transmission. [2]

2.0. REVIEW OF RALATED RESEARCH EFFORT

2.1. PREVIEW OF TECHNICAL LOSSES IN TRANSMISSION LINE

These are losses that occur naturally and consist mainly of power dissipation in electricity system components such as transmission and distribution lines, transformers and measurement systems.[5]. The distance of transmission line are usually vey long from the generating stations and also a very good distance to the distributing stations, there by generating losses as: the joule effect, where energy is lost as heat in the conductor (a copper wire for example); megnetic losses, where energy dissipates into the dielectric effect, where energy is absorbed in the insulating material. The Joule effect in transmission cables accounts for losses approximately 2.5% while losses in transformers ranges between 1% and 2%.

2.1.1. Resistive (Skin) Loss

Although the conductors in a transmission line have extremely low resistivity, they are not perfect. This section seeks to quantify that loss through computation of the skin depth and power attenuation factors [7]. The amount of resistive loss in a system can be found estimated by using corona-free transmission line equations to find the amount of power delivered to any point along the wire and subtracting the initial amount of power. The equations are as indicated in [8]

$$P(z) = P(0)e^{-2\alpha z} = P(0)e^{-zR_l/(Lc)} \text{-------- eq. 2.1}$$

$$P_{Rloss}(0:z) = P(0) - P(z) \text{------------------------- eq. 2.2}$$

$$\%P_{Rloss} = \frac{P(0) - P(z)}{P(0)} = 1 - e^{-zR_l/(Lc)} \text{-------------eq. 2.3}$$

Where, c is the speed of light and L, the inductance per unit length of the transmission line is given as:

$$L = \frac{\mu}{\pi} \ln(\frac{d}{a}) \text{-------------------------------eq. 2.4}$$

Table 1.0: Resistive loss values using sample parameters and the formulas listed above. [8]

Parameter		Case 1	Case 2	Case 3
D	Line separation	10m		
A	Conductor radius	0.015m		
L	Inductance per meter	2.6uH/m		
F	Frequency	60Hz	50Hz	60Hz
Σ	Conductivity of the metal	3.82 x 10^7 S/m (Al)	3.82 x 10^7 S/m	6.17 x 10^7 S/m (Ag)
IB	Bessel Correction Factor	1.1	1.1	1.1
&delta	Skin Depth	10.5mm	11.5mm	8.3mm
Rl	Resistance per Meter	29.1 µΩ/m	26.5 µΩ/m	22.9 µΩ/m
&alpha	attenuation factor	18.6 x 10-9/m	17.0 x 10-9/m	14.7 x 10-9/m
µ0	Permeability of Free Space	4π x 10-7 H/m		
C	Speed of Light	3 x 108 m/sec		
	%PRloss (1km)	37.2 ppm	34.0 ppm	29.3ppm
	%PRloss (1000km)	3.66%	3.34%	2.89%

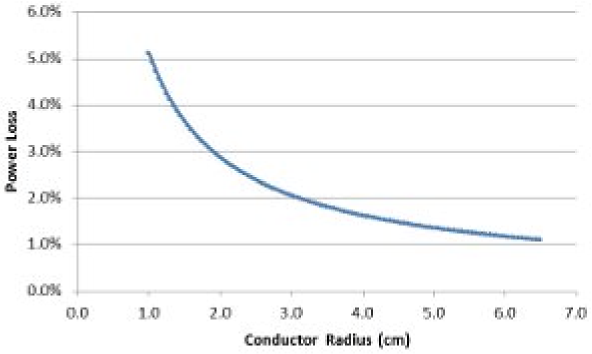

Fig. 1: Resistive Loss on a Al transmission line as a function of radius as a percentage loss over 1000km. The equations for calculating Rl, the resistance per unit length, can be shown below. It includes the formula for finding the wire's skin depth (&delta), which shows how far into the conductor 90% of the power is carried by current.[8]

Parameter	Sample Value

$$\delta = \frac{1}{\sqrt{\pi f \mu_0 \sigma}} \text{ ------------------------------ eq. 2.5}$$

$$R_l = \frac{I_B}{2\pi a \sigma \delta} \text{ -------------------------------- eq. 2.6}$$

IB in this equation is correction factor found by using the first two Bessel I function

Using the above equations, the total amount of power lost due to resistance is equal to the power at a given distance minus the inital power. The parameters listed bellow summaries the results of these equations can be found in Table 1. In it, there are estimated losses of a typical US power line made of aluminum (case 1), a Nigeria power line at 50Hz (case 2), and a line made out of silver (case 3). A comparison of cases 1 and 3 show that building a long transmission cable can save in resistance loss (about $19M/year), but would cost significantly more to build ($18.5B) at 2010 market prices [8]

2.1.2. Corona Losses

Corona loss occurs if the line to line voltage exceeds the corona threshold [8]. Corona can occur within voids of an insulator, at the conductor or at the insulator interface. Rough surfaces are more liable to corona because the unevenness of the surface decreases the value of the breakdown voltage. It can be detected due to its visible light in form of purple glow consisting of micro arcs and its sound can be heard through its hissing and cracking sound. The smelling of the presence of ozone production is noticed during corona activity. The effects of corona are cumulative and permanent and the failure can occur without warning. The effects of corona associated with the operation of high voltage transmission lines include radio interference, audible noise, gaseous effluents (Ozone and Nitrogen oxide) and shock potential. Conductor voltage, diameter and shape, dusts, water drops, and surface irregularities such as scratches are factors that affect the performance and conductor’s electrical surface gradients. The energy loss due to corona is transformed into sound, radio noise, chemical reactions of the air components and heat. Corona reduces the reliability of insulation system thereby degrading insulation and causes system failure due to dielectric breakdown. The power loss under fair weather conditions and under stormy weather conditions when investigated analyzed and simulated using matlab programs gives the results which help us to take necessary measures to minimize the power loss under fair and stormy weather conditions.[13]

The corona factor equation was empirically derived by F.W. Peek and published in 1911. In a later publication, he modified the original equation and he showed that the total amount of power loss in a wire due to the corona effect was equal to the equation below [8]:

$$P = \frac{k_0}{k_d}(f+25)\sqrt{\frac{a}{d}}[V_0 - g_0 k_i a k_d ln(\frac{d}{a})]^2 \times 10^{-5} \text{ kW/km} \text{ ----eq.2.7.}$$

For examples of these values and their meaning, please refer to Table 2

k0	Fixed Constant	241
g0	Disruptive Gradient in Air	21.1 kv/cm
Kd	Normalized Air Density Factor 1 (25 ℃, 76 cm pressure)	1
A	Radius of Conductor	3.5 cm (see Fig. 2)
D	Conductor Spacing	1000 cm
F	Frequency	60 Hz
Ki	Wire Irregularity Factor	0.95 (weathered wires)
V0	Line Voltage to Neutral (1/1.73 x Voltage Between Conductors)	442 kV (765 kV/1.73)
	Disruptive Critical Voltage (g0 ki a kd ln(d/a))	397 kv
	Corona Loss kW/km/line	25 kW/km
	Corona Loss % (1000km line at 2.25 GW)	3.3%

As can be seen in Fig. 2, the radius of the conductor has a large effect on the total amount of corona loss. One way of getting lines with a larger effective radius is through the use of bundles, where 2-6 separate, but close lines are kept at the same voltage via intermittent

connectors. This reduces the amount of metal needed to achieve a given radius and corona loss. Transient calculations of corona loss can be found in reference [10].Looking at voltages greater than 765kV, the Hydro-Quebec Institute of Research measured the amount of corona loss at voltages up to 1200 kV. [8] They found that the corona loss of a 6 and 8 conductor bundles were 22.7 kW/km and 6.2 kW/km, respectively. These

numbers were measured in "heavy artificial rain". The discrepancies between [6] and [8] probably stemmed from different radii and conductor spacing.

bundling wires: about 2.5-5x for each conductor added between 1-3. Under frost conditions, they show that the loss of the lines is about 21 kW for a 2 conductor bundle of a 400kV three phase transmission line.
Finally, researches in Finland measured the amount of corona loss in transmission lines under frost conditions. [9] This paper also shows the large reduction in corona loss from been able to estimate the technical loss, we need to be able to calculate the efficency of transmission. The steps in calculating the efficency is give below:

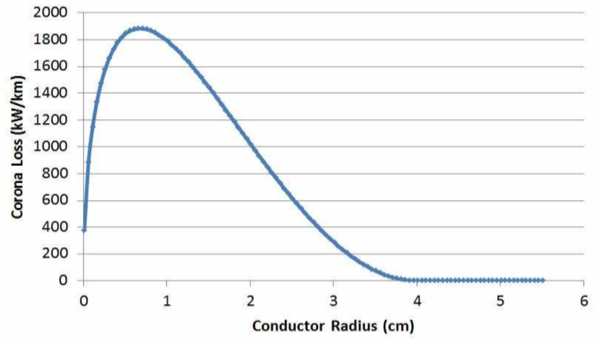

Fig. 2: Corona loss in kilowatts lost per kilometer of wire as a function of radius. An Al 3 phase 765kV transmission line [8]

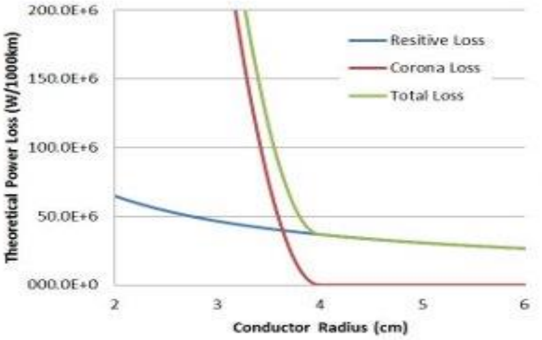

Fig.3: Total loss of a 2.25 GWm 3 phase 765 kV transmission line as a function of radius. [8]

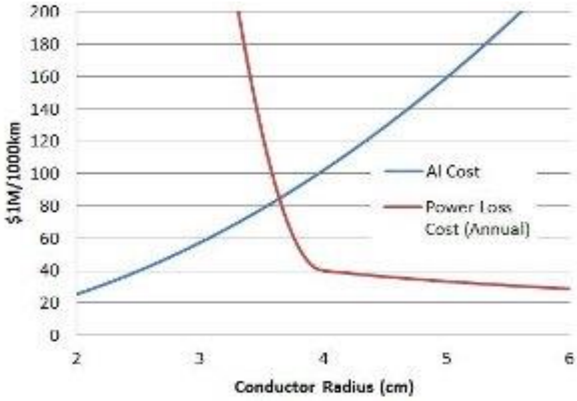

Fig. 4: Cost of a 2.25 GWm 3 phase 765 kV transmission line as a function of radius. The cost of a transmission line was found by taking the total wire volume and multiplying by the 2010 market price of aluminum ($1.14 per pound). [8]

Ploss = Power Sent – Power Received

The relationship between power sent and power received and associated losses in the power system are illustrated in the efficiency of transmission; [9]

Efficiency, ɳ = $\frac{\text{Power received (per unit value)}}{\text{Power sent}}$ ....(10)

= $\underline{\text{Power sent-power loss in line}}$
1 – Power loss in line……. (11)

Power sent = 1 – $\frac{\text{2I2R (2 wire system)}}{\text{IV}}$……… (12)

Transmitted Power, P = √3 x VI x cosϴ
V = Line-line Voltage; I = Line current (ampere). [14]

Cosϴ = Power factor.

Electrical Losses [14]
Ploss = 3 R(Tc) x I^2 x L
R(Tc) = Resistance of phase bundle at operation;
I = Line current;
Ploss = Power loss (watt);
L = Line length

Cost of phase conductor [14]
£Loss = 3 x R(Tc) x I^2 x L x t(hrs) x £/watt-hr
Work example : Consider the 10mile 115-KV line with normal current of 300A and emergency current of 1000A for 24hrs/yr.
Normal-losses = 3 x 0.12 x 300^2 x 8736 = 2830MW-hr
Emergency losses = 3 x 0.15 x 1000^2 x 24 = 2938MW-hr. [14]

2.2. NON- TECHNICAL LOSSES

Non-technical losses represent an avoidable financial loss for the utility.

Non-technical losses are also referred to as commercial losses, which are caused by pilferage, defective meters, errors in meter reading and in estimating unmetered supply of energy, divergence of generated income to useless purposes, natural disasters, terrorism, errors in accounting and record keeping, etc. All this can be said as to be the major problems where Nigeria can not have a stable power supply.

2.2.1. Reasons For High Technical Losses In Transmission Of Electricity [2]

The following are the major reasons for high technical losses in our country: -

1. Inadequate investment on transmission and distribution, particularly in Sub-transmission and distribution. While the desired investment ratio between generation and T&D should be 1:1, during the period 1956 -97 it decreased to 1:0.45. Low investment has resulted in overloading of the distribution system without commensurate strengthening and augmentation.
2. Large scale rural electrification through long 11kV and LT lines.
3. Too much stage of transformations and improper load management.
4. Poor quality of equipment used in agricultural pumping in rural areas, cooler air-conditioners and industrial loads in urban areas.

2.2.2. Factors influencing system losses

Following are some of the factors that influence system losses [3]:

1. Circulating current: In modern highly interconnected networks, failure to maintain a flat voltage profile across networks will result in the flow of circulating currents. It is therefore important for a power system to maintain stringent voltage limits to minimize losses.

2. Phase balancing: This is of significance when dealing with heavily loaded lines, the objective is to balance the phase load, so that the maximum deviation from the average is below 10%.

3. Power factor: At unity power factor the current is minimum and any reactive component will cause an increase in current with a resultant increase in real power losses. For large inductive loads losses due to volt ampere reactive (VAR) become significant and demand side compensation become necessary (i.e. by installation of shunt capacitors). Furthermore as a result of increase in current in the system the voltage drop due to line resistance is greater than it would be at unity power factor.

4. Voltage regulation: since line losses increase with the square of load current either maintaining and or increasing the normal operating voltage of the system, can reduce both maximum demand and energy losses.

2.2.3. Measures To Ensure High Drop In Non-Technical Losses During Transmission Of Electricity

1. For case of theft of electricity, a capital law that is enforceable should be put in place, and utility technicians should be trained on how to carry out effective metering of a particular community, and finally regular auditing of the company utility account, at least monthly or quarterly[2].
2. Reduction of tax or tariffs paid by some small and medium scale business citizen (e.g. agricultural farmers, tailors, barbers, etc.), should be given subsidies in utility usage. This will encourage them to stay out of crime and give back to the society.
3. Good government policies, like encouraging the industries to relocate to rural communities, which will reduce the migration of people to the major urban areas, which are already over population like Lagos, Onitsha, Aba, etc. And also giving this industries or companies a tax free for like 10 years of set-up in that rural location, e.g. Indonesia and Singapore.[5]

2.2.4. Measures For Reducing Technical Losses [2]

1. Identification of the weakest areas in the distribution system and strengthening/improving them so as to draw the maximum benefits of the limited Resources
2. Reducing the length of LT lines by relocation of distribution sub stations/installations of additional distribution transformers (DTs).

3. Installation of lower capacity distribution transformers at each consumer premises instead of cluster formation and substitution of DTs with those have lowered no load losses such as amorphous core transformers.
4. Installation of shunt capacitors for improvement of power factor.
5. Mapping of complete primary and secondary distribution system clearly depicting the various parameters such as conductor size line lengths etc.
6. Compilation of data regarding existing loads, operating conditions, forecast of expected loads etc.
7. Carrying out detailed distribution system studies considering the expected load development during the next 8-10 years.
8. Preparation of long-term plans for phased strengthening and improvement of the distribution systems along with associated transmission system.
9. Estimation of the financial requirements for implementation of the different phases of system improvement works.
10. Formulation of comprehensive system improvement schemes with detailed investment program so as to meet system requirement for first 5 years period.

3.0. Conclusion

The main aim of this report is to eliminated electrical power transmission losses to its nearest minimal, for example 4%-3% comparing it with the estimated 8.5% average of the present state in developing country like Nigeria. African nation have to ensure Technical and Non-technical Losses in the Utility distribution and transmission business should be manage by high standard engineering companies and institution. Cause, energy should be safe, pure, accessible, generate income, develop the lives of citizen and easy to purchase by all. [1]

Also, improvement of other sources of Electricity generation like Nuclear, wind, and Solar should be invested into, other than the water and gas electricity generation, to increase the supply of utility to the consumer by meeting the high demand.

Employment of direct citizens to the sites where these stations are located gives them a self ownership. The Government should also know that Losses can be avoided by making good policies, like passing of Petroleum Industrial Bill will ensure that gas station and energy companies gives better energy to the people, cause transmission losses is has lot of hazard effects to the citizens of that Nation at large.[4]

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