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Power Loss Reduction for a Proposed 330 KV Transmission Line for Improve Performance

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Abstract:- Energy supply and stability are important topics in modern society. In order to address both of these needs, we have investigated ways of an improvement on electrical transmission. Transmission lines naturally lose energy that flows through them. We analyzed the quality of being possible, making our current electrical grid methods opposing the customarily alternating current (AC) to lessen power lost in an economical way. By comparing cost and energy loss. This work aim at examining the power losses in Nigerian 330kV network, to provide dependable models and techniques for the optimization of loss minimization in 330kV transmission network to provide dependable technical model for loss reduction strategies implementation. Electrical Transmission system takes electric power from generation system and delivers it to distribution. Moreover, an important parts of the electric power generated is lost on the transmission network. The implementation of the loss reduction strategies was done using ETAP 16.0. The sum of all energy loss is 824.184 MW which represent 21.41% of total energy generation, by implementation of the losses reductions strategies the total losses on the network, the losses reduce to 657.734 MW which represents 17.1% of the total sum of energy generated and represent 20.2% reduction of the total sum of energy loss. This percentage (17.1%) revels that there is a total loss reduction of about 4.31% of losses for strategy one. Losses reduced from 639 MW to 200.990 MW representing 44.8% of the sum of energy losses of 824.142 MW and losses reduced from 200.990 MW to 158.64 MW which represents 19.25 % of energy losses on the previous strategy on the network for the case of strategy 2 and 3 respectively. The total energy recovered from the implementation of the loss strategies to the network is 521.69 MW which represents 63.2% of the energy loss recovered

***Keywords*:-** *Loss Reduction, Transmission Line, Power System, Energy Economy, Total Energy Loss.*

I. INTRODUCTION

The losses of energy in lines transferring energy from generation to distribution network is mainly cause by the resistance of conductors to the flow of current. Heat generated in the conductor as a result of the current flow increases its temperature. This increase in conductor's temperature results to increases the current opposition of the conductor and this will consequently increase the losses. This implies that ohmic power loss is the major apparatus that causes losses in transmission and sub-transmission lines, [1]

According to [5] transmission system losses are calculated for every hour in a year in accordance with the Loss factor. This steps involves uses terms from power system simulation software. [6] large proportion of Nigerians have felt the debilitating effects of epileptic, unstable and unreliable electricity supply and incessant power breakdown of power infrastructure due to immoderate power losses and low bus voltages. [1], [2]. It has been found out that, this immoderate power losses and low bus voltages influence the operation of power system, and give its quota in the manner of power failures, instability and unreliability to the Nigeria electric power system. A large part of the end users such as industrial, commercial and technological sectors have felt the implication and causes a lot of effects of power loss and unfavorable effect of low bus voltages in the National grid [3]. Major investment choices and judgment are also a threat to the system. The electro technical components and equipment are prone to incessant failures and breakdowns. Therefore, it becomes necessary to design a reliable means of minimizing losses as well as ensuring generators are runs at its optimum operating point. Plan for future expansion and provide a safe, affordable, stable and reliable electricity for consumers. [5,6]

II. MODEL FORMULATION

Transformer losses are jointly iron loss and copper loss [6]. These losses are generally classified into three as given below [1, 4]

$$L_f = \frac{KVA_{average}}{KVA_{MaxDemand}} \quad (1)$$

Load Loss Factor is presented as:

$$L_{lf} = \frac{\text{Actual Loss at a given time (Kwh)}}{\text{Loss At Maximum Current (Kwh)}} \quad (2)$$

The relationship between L_f and is L_{lf}

$$L_{lf} = k * L_f + 1 - k * (l_f)^2 \quad (3)$$

Where k is co-efficient of loading, as per loading.

$$K = \frac{\text{Minimum Demand } (KVA_{min})}{\text{Maximum Demand } (KVA_{max})} \quad (4)$$

Giving the Total power loss in the transformer (WT_{Loss}) in KW to be

$$WT_{Loss} = \{\text{Load Loss } W_L + \text{No Load Loss } W_{NL}\} * 10^{-3} \quad (5)$$

$$W_{TL} = \{W_C(KVA_{MD}/KVArating)^2 * L_{lf} \quad (6)$$

W_C is copper loss at full load and KVA_{MD} is maximum KVA Demand in a given time.
KVA_{Rating} is transformer rating

Combining (5) and (6) to have (7) as shown below:

$$W_{TL} = \{W_C(KVA_{MD}/KVArating)^2 * L_{lf} + W_{NL} \quad (7)$$

The power loss (P_{LOSS}) is given as;

$$P_{LOSS} = I_L^2 R \quad (8)$$

Putting lost factor in consideration, (8) is expressed as:

$$P_{LOSS} = I_L^2 R * (\text{Loss Factor}) \quad (9)$$

Where Loss Factor is

$$\text{Loss } Factor = 0.3 * Load\ Factor + 0.7 * (Load\ Factor)^2 \quad (10)$$

And,

$$Load\ Factor = Averag\ Load / Peak\ Load \quad (11)$$

I_{max} (I_L) in Ampere is expressed as:

Current drawn from line $(I_L) = \dfrac{P}{\sqrt{3} V \cos\theta}$ (12)

Resistance of line (Ω) $R = \dfrac{\ell L}{A}$ (13)

Power losses (MW) $P = I_L^2 \cdot R$ (14)

Where P is Power, V is voltage, ℓ is resistivity, R is resistance, A is cross sectional area in, L is length.

2.1. FOR TRANSMISSION LINE

The value of the ohmic power loss, is obtain as

$$Lohmic = 1^2 RKW/km/\text{phase} \tag{15}$$

Where I is the current on the conductor and R is the conductor resistance.
Corona effect on the efficiency of the transmission line has the value of

$$Lcorona = 242 \frac{(f+25)}{\delta} . \sqrt{\left(\frac{r}{a}\right) . (v - v_0) 2} . 10^{-5} . KW/km/\text{Phase} \tag{16}$$

Where f is the frequency of transmission, δ the air density factor, r the radius of the conductor, d is the distant between the transmission line, V as operating voltage and v_0 the disruptive voltage. Summing the ohmic and corona loss, we have

$$T_{loss} = L_{ohmic} + L_{corona} \tag{17}$$

i.e.

$$T_{loss} = 1^2 R + 242 \frac{(f+25)}{\delta} . \sqrt{\left(\frac{r}{d}\right) . (v - v_0) 2} . 10^{-5}\ KW/km/Phase \tag{18}$$

In generality (4) is given by

$$T_{loss} = 1^2 = \frac{pL}{A} + 242 \frac{(f+25)4}{\delta} . \sqrt{\left(\frac{A}{\pi d^2}\right) . (v - v_0) 2} . 10^{-5}\ KW/km/Phase \tag{19}$$

Where
P is the resistivity, L the length and A is the cross-sectional area of the conductor.

2.2. MINIMIZATION OF POWER LOSSES

The challenge of finding the optimum electric power loss during transmission can therefore be minimize as,

$$T_{loss} = 1^2 = \frac{pL}{A} + 242 \frac{(f+25)4}{\delta} \sqrt{\left(\frac{A}{\pi d^2}\right) . (v - v_0) 2} . 10^{-5}\ KW/km/Phase \tag{20}$$

This problem is nonlinear multivariable unconstrained optimization. Let the transmission related factors be continuous, then (20) can be solved by the classical method optimization. To determine the stationary points of (20), we differentiate with respect to the selected variables to get

$$\frac{\partial T_{Loss}}{\partial I} = \frac{21pL}{A} \tag{21}$$

$$\frac{\partial T_{Loss}}{\partial V} = 484 \frac{(f+25)4}{\delta} \sqrt{\left(\frac{A}{\pi d^2}\right)} (v - v_0) 10^{-5} \tag{22}$$

$$\frac{\partial T_{Loss}}{\partial d} = 121 \frac{(f+25)4}{\delta} \sqrt{\left(\frac{A}{\pi}\right)} . (v - v_0) 2_d \frac{3\pi}{2} 10^{-5} \tag{23}$$

Equations (7), (8) and (9) Give the extreme points as I=0, V=v_0 and d ∞.s $\rightarrow$
The second derivatives with respect to the variables are

$$\frac{\partial 2 T_{Loss}}{\partial I^2} = \frac{2pL}{A} \tag{24}$$

$$\frac{\partial 2 T_{Loss}}{\partial I \partial V} = 0 \tag{25}$$

$$\frac{\partial 2 T_{Loss}}{\partial I \partial d} = 0 \tag{26}$$

$$\frac{\delta^2 \text{T Loss}}{\delta \text{V}^2} = 484 \frac{(\text{f}+25)}{\delta} . \sqrt[4]{\left(\frac{\text{A}}{\pi \text{d}2}\right)} .\ 10^{-5} \tag{27}$$

$$\frac{\delta^2 \text{T Loss}}{\delta \text{V}\ \delta \text{d}} = -242 \frac{(\text{f}+25)}{\delta} . \sqrt[4]{\left(\frac{\text{A}}{\pi}\right) .\ (\text{V} - \text{V}_0) \text{d} \frac{3}{2} 10^{-5}} \tag{28}$$

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$$\frac{\delta^2 \mathrm{TLoss}}{\delta d \delta t} = 0 \quad (29)$$

$$\frac{\delta^2 \mathrm{TLoss}}{\delta d \delta V} = 242\ \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right).\ (V - V_0) d \frac{3}{2} 10^{-5}} \quad (30)$$

$$\frac{\delta^2 \mathrm{TLoss}}{\delta d^2} = \frac{363}{2} \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right).\ (V - V_0) d \frac{3}{2} 10^{-5}} \quad (31)$$

The Hessian matrix, is therefore given by:

$$H = \begin{pmatrix} \frac{\delta^2 T}{\delta t^2} & \frac{\delta^2 TLoss}{\delta t \delta V} & \frac{\delta^2 TLoss}{\delta t \delta d} \\ \frac{\delta^2 TLoss}{\delta V \delta 1} & \frac{\delta^2 TLoss}{\delta V^2} & \frac{\delta^2 TLoss}{\delta V \delta d} \\ \frac{\delta^2 TLoss}{\delta d \delta 1} & \frac{\delta^2 TLoss}{\delta d \delta V} & \frac{\delta^2 TLoss}{\delta V^2} \end{pmatrix}$$

i.e.

$$H = \begin{pmatrix} \frac{2PL}{A} & 0 & 0 \\ 0 & 484 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi d^2}\right)} . 10^{-5} & -242 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right)} . (v - v_0) d \frac{3}{2} 10^{-5} \\ 0 & -242 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right)} . (v - v_0) d \frac{3}{2} 10^{-5} & \frac{363}{2} \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right) . (v - v_0)^2 d \frac{5}{2} 10^{-5}} \end{pmatrix} \quad 32$$

For which $|H_1| = \frac{2PL}{A} > 0$ 33

$$H_2 = \begin{vmatrix} \frac{2PL}{A} & \\ 0 & 484 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi d^2}\right)} . 10^{-5} \end{vmatrix} = \frac{2PL}{A} . 484 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi d^2}\right)} . 10^{-5} > 0 \quad 34$$

$$H_3 = \begin{vmatrix} \frac{2PL}{A} & & \\ 0 & 484 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi d^2}\right)} . 10^{-5} & -242 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right)} . (v - v_0) d \frac{3}{2} 10^{-5} \\ 0 & -242 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi}\right)} . (v - v_0) d \frac{3}{2} 10^{-5} & \frac{363}{2} . \frac{(f+25)}{\delta} . \sqrt[4]{\left(\frac{A}{\pi}\right) . (v - v_0)^2 d \frac{5}{2} 10^{-5}} \end{vmatrix}$$

$$= \frac{2PL}{A} \left(484 \frac{(f+25)}{\delta} \cdot \sqrt[4]{\left(\frac{A}{\pi d^2}\right)} . 10^{-5} \right) \left(\frac{363}{2} . \frac{(f+25)}{\delta} . \sqrt[4]{\frac{A}{\pi} . (v - v_0)^2 d \frac{5}{2} 10^{-5}} \right) \quad 35$$

Where H_1, H_2 and H_3 are more than zero. Hence, the power loss is minimum at 1=0, $V=V_0$ and $d \rightarrow \infty$

III. RESULT PRESENTATION AND DISCUSSION

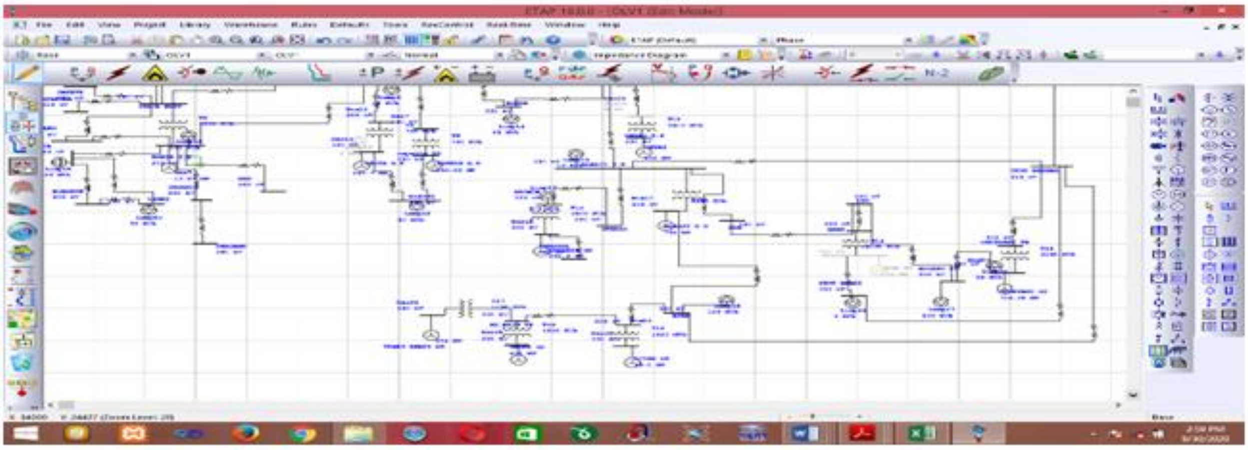

Fig.1.0: ETAP model at normal operation mode not simulated

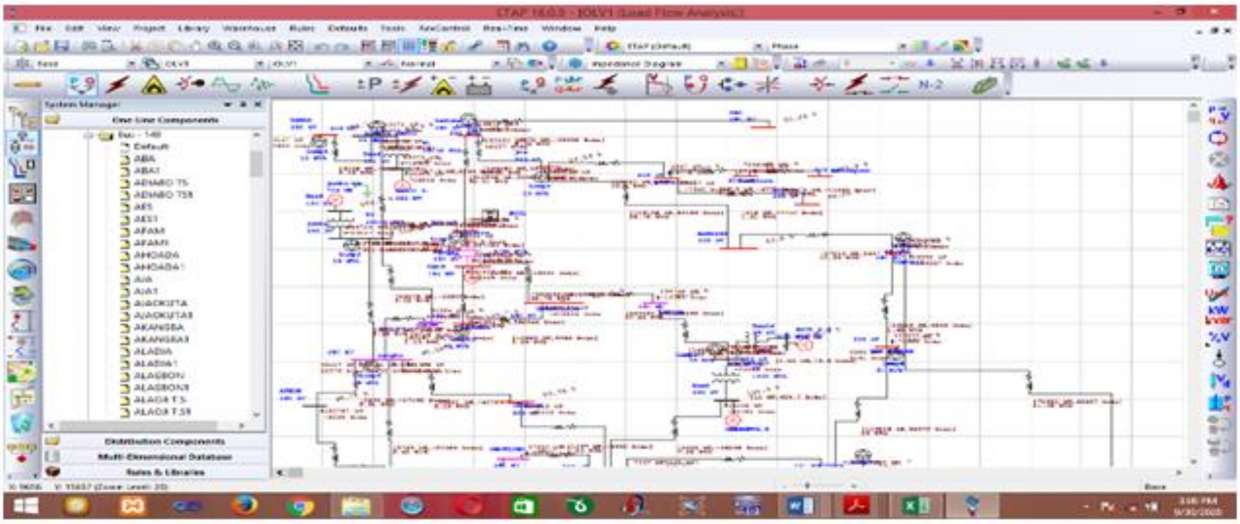

Fig. 2.0: ETAP model simulation at normal operation mode

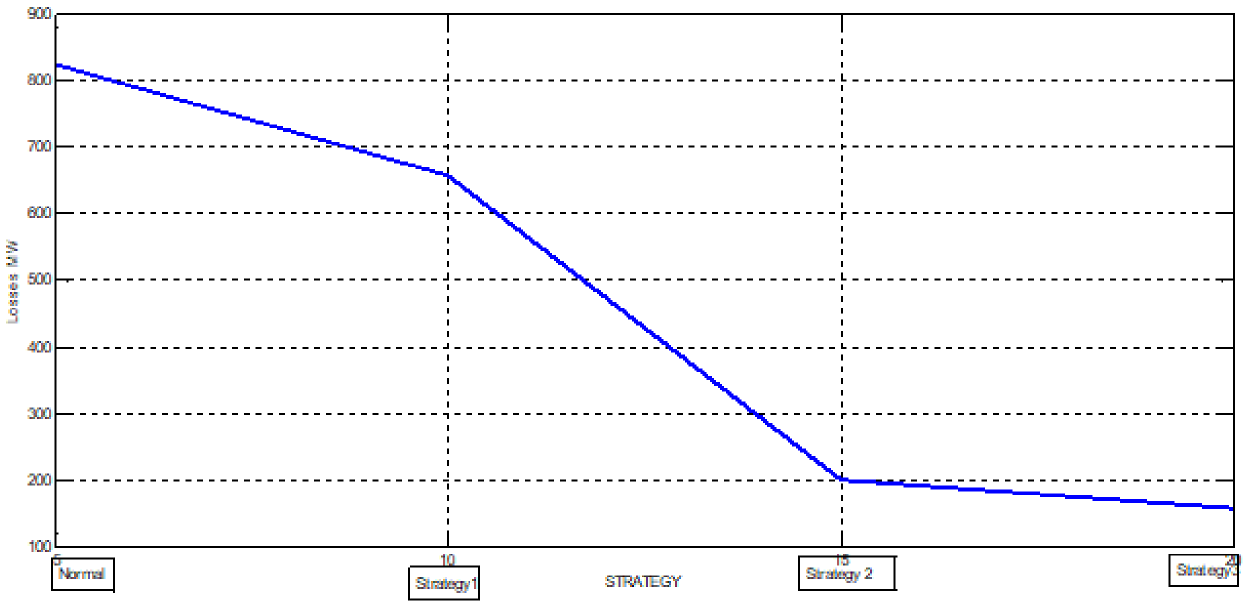

Fig. 1.0: Graph of Energy Losses against Loss Reduction Strategies

IV. DISCUSSION OF RESULT

Figure 1, figure 2 and figure 3 are ETAP model at normal operation mode not simulated, ETAP model simulation at normal operation mode and Graph of Energy Losses against Loss Reduction respectively. Implementation of loss reduction strategy 1, implementation of loss reduction strategy 2 and implementation of loss reduction strategy 3. At normal network conditions, the total energy loss is 824.184MW which represent 21.41% of total energy generation of 3850MW. This is about one quarter of energy generated. These amount of energy is loosed is due to some network parameters and network configurations. It is necessary to look inward in order to reduce it. These losses on the transmission line network of 330KV is due to some parameters which has been considered some in the strategies of loss reduction when implement the loss reduction strategies on the network.

4.1 IMPLEMENTATIONS OF LOSS REDUCTION STRATEGIES

All the strategy are implemented using ETAP16.0 and the result of the different strategies are as follows:

4.1.1 STRATEGY 1

Implementation of strategy 1 involves the reconfigurations of the network parameters that causes the high losses on the network. This parameter is reduction of the distances between the transmission stations and busses on the network. On implementation of the strategy, the losses reduce to 657.734MW which represents 17.1% of the total energy generated and represent 20.2% reduction of the total energy loss. This percentage (17.1%) revels that there is a total loss reduction of about 4.31% of losses. Thus these percentages of energy will be added into the network. Converting this additional losses percentages of 4.31% of energy losses, this results to about 165MW energy recovered from losses by the strategy 1. This indeed a good strategy of reducing losses on the transmission lines.

4.1.2. STRATEGY 2

This involve the combinations of strategy 1 and the uses of low resistance cables on the transmission lines. When implementing the strategies into the network, a great break through is achieved. The losses reduced from 639MW to 200.990MW. This represent 44.8% of the total energy losses of 824.142MW. This represents 414 MW energy recovered. This revealed that the major causes of energy losses on the transmission line are the two parameters combine in this methods. This also show that, this strategies is a powerful strategy in reducing losses on the power system transmission lines and distributions lines.

4.1.3. STRATEGY 3

By implementation of strategy 3, that's the uses of compensators on the network, the losses further reduced from 200.990MW to 158.64MW which represents 19.25 % of the total energy losses on the network. The total energy of 189.2MW is recovered into the network. The total energy recovered from the implementation of the loss strategies to the network is 521.69MW which represents 63.2% of the energy loss recovered. After the strategies implementations the total losses on the network is 303.65MW. Thus, the total of 13.5 % of energy is recovered from the total energy generation of 3850 MW. Thereby remaining energy loss percentages of 7.89% which represent 303.65 MW.

4.2 THE ECONOMIC IMPACT OF ENERGY LOSSES ON THE NETWORK (330 KV/132 KV)

Energy losses results to loss of capital, high energy tariff, disturbances and di-stability on the network. During energy generations, the cost of generating a unit of energy is accountable for, so when there is a losses on the process, it results to the high cost of energy uses. The major thing here is that, the cost of producing the energy that is being wasted must have been paid or must be paid for either by the generations companies or the distributions which is then pay by the consumers of the electricity. This is one of the reason why the estimated bills, load shading or scheduling is being employed in the network. These will help the generations and distributions companies to pay for the losses the incurred on the network.

By simple calculations of the electricity tariff, it was discovered that 1KW of electrical energy is being sold at the rate of #6.40 by the distribution companies in the country in one hour. For a day is #110.4, for a week will be #772.80, a month will be #3091.20 and #37094.40 for a year. That is to say the cost of energy loss for one day at normal operation of the network will be #900,989.913. For a week the cost of energy loss will be # 6,369,290.40 for a month will be #20,820,687.32 and for the year the cost of energy loss will amount to #330,848,247.86. That is to say, this the amount of money that has been wasted for one year on the network due to losses. And this is must be added to the energy generation account for every year. This fractions account for 21.8% of the total energy generation investments. Thus, this reveals why energy generations are not improved on the network, consistent loss of supply, high electricity tariff, excess load scheduling, and continuous forced outages and finally excess system collapses. By implementing the loss reduction strategies on the network (330KV/132 KV) using ETAP 16.0 version a great breakthrough has been achieved. With strategy 1 the total losses reduced to 657.734 MW which results to the amount of #1,016,593,670.40 for a year as the cost of the losses. Strategy 2 losses cost #310,050,144.0 for a year. And strategy 3 further reduced the loss cost to #245,192,438.40. A huge amount of capital invested is wasted due to losses on the transmission lines, but by the implementation of loss reduction strategies some of the losses had been recovered and the losses reduced from 824.738 MW to 15863 MW that is to say from #1,273,858,790.38 to 158.63 MW. This shows that about 91.3% of the losses recovered back to the network. Now, the total energy on the network will be 3696.38 MW. There is still 9.86% losses remaining on the network. Although acceptable loss range is 5%. This losses can still further be reduced by the implementations of others loss reduction strategies like, the uses of artificial intelligent, network automations etc which are not covered in the scope of this work. The losses has a very big negative impacts both on the network, economic and even the society itself.

V. CONCLUSION

Energy losses on 330KV/132 KV lines network has been evaluated, simulated, analyzed and the reduction strategies implemented. It was discovered that the total energy losses on the network is 824.184 MW which represent 21.41% of the total generated energy of 3850 MW. This energy loss amount to #1,273,858,790.40 for a year. By implementation of the loss reductions strategies the total losses on the network reduced to 158.64 MW which represent 8.37% of energy losses and its amount to #245,192,438.40 for a year. That is to say, there is a reduction in cost of energy since there is an additional energy to the network when implemented the strategies. The total losses percentages of 8.37% is above the acceptable loss range on transmission lines. With this further reductions has to be done on the network in order to be at the acceptable limit. The total amount of energy recovered back to the network is 676.544MW.

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