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Economic Effects of Technical and Non Technical Losses in Nigeria Power Transmission System

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Abstract: *The Nigerian 330Kv transmission network is faced with various problems. This paper has focused on the technical and non-technical losses estimated in the network. The network is characterized by high voltage drops and power losses which can be attributed to low generation, long and fragile radial network, making it highly prone to failure, unreliability, inefficiency and poor performance. The network was analyzed using Power World Simulator (PWS), the result showed that the energy loss due to the 330Kv transmission network is about 454.73 GW amounting to over 4.4 billion naira.*
Keywords:*Transmission, Losses, Technical, Energy, Electricity*.

I. Introduction

Electric power system involves the way in which electricity is generated and distributed. The rate of transmission and distribution losses in Nigeria has been quite high based on an article published by the World Bank group (2012) estimating the annuallossof Nigeria due to electricity theft to be in the billions of naira. According to the World Bank group, about 25% of electricity generated revenues indebted are actually retrieved making Nigeria's condition one of the worst. Generally, the operating cost of electric utilities is increased by system losses therefore reflecting in the cost of electricity. It would be unfair to the consumers if alternatively, the burden of these losses, no matter the magnitude, were passed on fully to them. Hence there would be no incentive for utility companies to put in effect loss reduction measures. This is because the certain losses caused by operating inefficiencies of the utility companies would be passed on also. On the other hand, unfair if the entire burden of system losses is left for the utility companies to handle. Singh (2009) referred the term 'distribution losses' to the difference between the amount of energy delivered to the distribution system and the quantity of energy consumers are actually billed. So in the end everyone is affected by system losses, the electric utilities, the consumer and the nation as a whole. These electrical transmission and distribution line losses that electrical utility companies are greatly affected by are made up of two major constituents: technical and non-technical.

1.1Technical Losses

Technical losses in transmission systems are caused by the physical properties of the components of the power system. These technical losses are normally **22.5%**, and directly depend on the network characteristics and the mode of operation (Parmar, 2013).These technical losses are of two types, Permanent technical losses which are naturally occurring losses (internal action to the power system), basically caused by the dispersal of heat resulting from current passing through conductors and from magnetic losses in transformers. And secondly, Variable technical losses which vary based on the amount of electricity distributed and are, more precisely, proportional to the square of the current.

1.2 Non-Technical Losses

These are caused by external actions not related to the physical characteristics and functions of the power system, primarily by human error (intentional or not). This could also be caused by conditions and loads that weren't considered during theevaluation of technical losses. Non-technical losses include energy lost due to meter tampering, bypassing the meter and meter/ billing inaccuracies. Losses due to metering inaccuracies are defined as: the difference between the amount of energy actually delivered through the meters and the amount registered by the meters(Navani et al, 2003). The problem is that these losses are really difficult to calculate because system operators don't usually account for them and hence have no recorded information. Suriyamongkol (2002) states that, in practice, administrative losses are determinant of proper measurement, thus the accuracy of the estimate of non-technical losses depends hugely on the accuracy of the estimation of technical losses. In definition, therefore, non-technical losses are the residual loss remaining from the subtraction of the precise computation of administrative and technical losses from the total distribution network losses (Fritz and Dolores, 2002).

The major issues affecting the Nigerian power sector are losses generated during the transmission and distribution of power and the steps taken to minimize the effects of these losses. Stated by the International Energy Agency (2011), the value of electric power transmission and distribution losses (% of output) in Nigeria was 17.72 as of 2010, with a maximum value of 49.27 in 1981 and a minimum value of 5.87 in 2009. These numbers are really high in comparison to the transmission and distribution losses of about 7 – 8% in developed countries. The reduction of these losses is important for economic growth because the utility companies such as the Transmission Company of Nigeria (TCN) will not take entire responsibility for them hence shifting a good percent to the consumers. An increase in losses eventually would increase the cost of electricity. Consumers who do not comply with this increase would simply be 'cut-off', also increases load shedding which is the deliberate shutting off of power to parts of the electricity network, hence to consumers in that area.

Aim of this research is to study the nature of technical and non-technical losses in transmission systems and their impact on the power sector and economic growth in Nigeria. To achieve this objectives, visits to various TCN stations was carried out. Also data from reports, literatures, survey carried out and published by the World Bank group, National Electricity Regulatory Commission (NERC) and other researchers' works were used and simulated using Power World Simulator.

The importance of an effective and efficient energy sector to a developing economy such as Nigeria, India etc. and how to improve on this efficiency by adopting different methodologies that conserve and eradicate line losses, will be reviewed.Ayodele (1998), made it clear that the electricity crisis in Nigeria makes many of her inhabitants, most especially the poor, miserable. Archibong (1997) argued that the positive side of the Structural Adjustment Program (SAP) could not be fully established due basically to numerous bottlenecks, rigidities and poor infrastructure especially in electricity supply. This undermined the effectiveness of fiscal and other incentives designed to simulate the growth and diversification of the economy.Upong (1976) established the existence of a positive relationship between electricity consumption and economic development. In addition, he submitted that the expansion of the energy sector on the supply side is an important factor for accelerating the growth of the industrial sector.Subair and Oke (2008), pointed out that the presence of suspicion and conflict between power distribution officials and consumers have given rise to illegitimate activities such as electricity theft, illegal connections to either the existing residential terminals or the national grid, under/overbilling by officials. Onohaebi (2007) studied the Nigerian 330kV transmission network and proposed a modified network which incorporated some additional lines to form more loops and minimal compensation, meting the acceptable voltage limits of ±5%. It also reduces the power losses in his simulations from 337.5 MWH to 189.9 MWH, representing 45% improvement over the existing network and enhances reliability and security of the transmission grid. Omorogiuwa and Odiase, (2011) in their analysis of the Nigerian Transmission network proposed the implementation of Interline Power Flow Controllers (IPFC), which is a modern control Flexible Alternating Current Transmission System (FACTS) device on the network, using Genetic Algorithm (GA) for its optimal placement and an option for power improvement. The result obtained showed improvement of weak bus voltages and loss reduction with IPFC devices on incorporation in the network. Izuegbunam et al. (2011) also proposed a fortified and expanded grid schematic of the 330kV transmission system in which after simulation initial losses of 85.3MW were reduced substantially to 24.7MW.

1.3 Effect of Power Losses on the Nigerian Economy

Transmitting electricity at high voltage reduces the fraction of power lost due to joule heating. For a given amount of power, a higher voltage reduces the current and thus the resistive losses in the conductor. For example, raising the voltage by a factor of 10 reduces the current by a corresponding factor of 10 and therefore the copper losses (I^2R) by a factor of 100, provided the same type of conductor is used in both cases.

World Bank Data of 2010 states that, Transmission and distribution losses in the US and UK were established at 7.2% and 7.4% respectively. Of this value, less than 1% can be attributed to transmission losses even across the greatest of distances. Countries such as China that have attached importance to loss minimization to enhance efficiency have about 13% transmission and distribution losses. India, Pakistan, Thailand, Philippines, Korea, Japan have an estimate of about 22%, 28%, 18%, 18%, 12.5% and 9% losses respectively. This reduction in losses in these countries can be attributed to technological advancement and installation of generating stations near load centers.

In Nigeria, PHCN's severe technological deficiencies are prevalent throughout the power system both up and down stream. For example, with the advancement of modern technology, about 40% of the energy consumed by thermal plants can be converted to electrical energy. As Nigeria lacks the technology for such, the figure can be as low as 12% of the power produced in which there is further loss through transmission and distribution.

Losses in transmission and distribution lines in Nigeria are peaked at 44.5% of power generated. The transmission lines alone were estimated at 9.2% of this value. It is impossible to determine exactly how much of this inefficiency is due to illegal power connections or under investment in technology. Lack of modern standardized components and qualified maintenance staff pose serious problems for adequate power generation and distribution.

II. Materials And Method

2.1 Analysis of Technical losses in power system

Technical losses in power system can be defined as power losses incurred by the physical properties of components in the power systems' infrastructure. These losses include those in the conductors, transmission line equipment, transformers, buses, distribution line and magnetic losses in transformers.

Technical losses are normally at 22.5%, and depend directly on the characteristics and mode of operation of the network (Parmar, 2013).

Considering a transmission network of figure 1 below

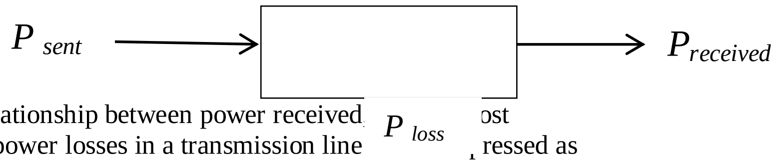

Figure 1: Relationship between power received ... ost

The average power losses in a transmission line ... ressed as

$$P_{loss} = P_{sent} - P_{received} \qquad (1)$$

Where P_{sent} is the average power that the source injects into the transmission line and $P_{received}$ is the power consumed by the load. In this equation, both power and current functions are dependent on time. Energy is power accumulated over time, or

$$W_{loss} = \int_a^b Ploss[t]dt \qquad (2)$$

Where a andb are the starting and ending time intervals being evaluated respectively.

We need an accurate description of P_{loss} as a function of time to make a reliable prediction of the energy loss. And power, in a single phase case, with sinusoidal voltage and current can be represented by

$$P_{1-\varphi} = IV\cos\Theta \qquad (3)$$

WhereP=average power, V=rms voltage, I=rms current, $\cos\Theta$=power factor, with Θ being the phase difference.

2.2 Basic Load Flow and Loss Calculations

Electrical power that flows through power systems consist of real (P) and reactive (Q) power and the two components combine to make apparent power(S)

$$S = \sqrt{P^2 + Q^2} \qquad (4)$$

The apparent power (S) generated or consumed by a given element in the power system is the product of the phasor voltage across it and the complex conjugate of the phasor current through it. The real and reactive power in turn, can be calculated using the apparent power and the angle representing the phase difference between the current and voltage, known as the power factor angle (Θ)

$$\left.\begin{array}{l} S = VI^* \\ S = P + jQ \end{array}\right\} \quad (5)$$

The voltage and current have their own relationships based on ohms law

$$\left.\begin{array}{l} V = IZ \\ Z = R + jX \end{array}\right\} \quad (6)$$

Where Z, R and X are the element's impedances, resistance and reactance respectively.

It is worth noting that all the quantities represent steady state, single phase operation. Through all power systems that operate with more than 220V are 3 phase systems, the discussions and calculation here will treat the value as a single phase equivalent. In order to do this, the 3 phase is assumed balanced i.e, all 3 phases have exactly the same amount of power flowing through each of them.

The general practice in power flow studies is to identify three types of buses in the network.

2.3 Line Flow and Losses

Consider the line connecting the two buses i and j in the figure 2 below. The line current I_{ij}, measured at bus i and defined positive in the direction i - j is given by

$$I_{ij} = I_L + I_{io} = y_{io}V_i + y_{ij}(V_i - V_j) \qquad (7)$$

Similarly, the line current I_{ij} measured at bus j and defined positive in the direction j - i is given by

$I_{ji} = -I_L + I_{jo} = y_{jo}v_j \quad + y_{ij}(v_j - v_i)$ (8)

The complex powers Sij from bus i to j and Sji from bus j to i are

$S_{ij} = V_i I^*_{ij}$ (9)

$S_{ji} = V_j I^*_{ji}$ (10)

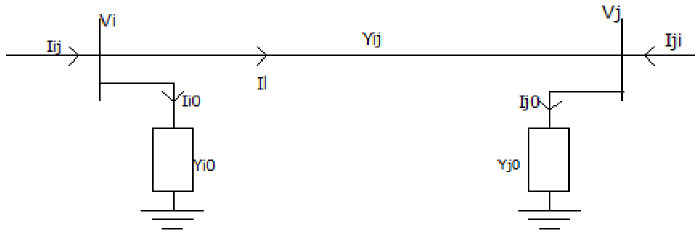

Figure 2: Transmission line model for calculating line flows.

The power loss in line i – j is the algebraic sum of the power flows determined from (3.12) and (3.13), i.e.

$SL_{ij} = S_{ij} + S_{ji}$ (3.14)

2.4 Power Flow Analysis of Existing 28 Bus 330kv Nigerian TransmissionSystems.

The 330kV network was analyzed using Power World Simulator (PWS). The one line circuit diagram of the network was redrawn using the edit mode in the simulator. The input data for load flow analysis includes;Generator's power output, Maximum and minimum reactive power limit of the generator, MW and MVAR peak loads, Line Impedance and Voltage and power ratings of the lines and transformer data.

These were entered into the dialog box of the simulator using Newton-Raphson iterative method available in run mode.

The Nigeria power system network was modeled into 5 control regions. A control region is an area responsible for maintaining its own generation and load balancing including its scheduled interchange. These regions/zones include; North-West, North-East, South-West, South-East and South-South.

The entire system was modeled into a 28 bus network (including generating and load buses) divided into five control regions. According to the data source from PHCN, these five control regions put together gives a total generation of 3353MW through the different generators with an actual load demand of over 10GW minus unseen loads on the network. As at the time of writing this report, the monthly schedule load was about 3188MW which is being shared among the different regions as shown in table 1 below.

Table 1: Actual load demand, scheduled load & generation

	BUSES		**ACTUAL**	**SCHEDULED**	**GENERTED(MW)**
S/No	**NAME**	**NO**			
	NORTH EAST				
1	GOMBE	20	450	130	
2	JOS	19	250	98	
	NORTH WEST				
3	KANO	11	350	126	
4	KADUNA	12	500	160	
5	B. KEBBI	01	250	89	
6	KATAMPE	14	450	236	
7	KAINJI	02			259
8	SHIRORO	13	600	126	408
9	JEBBA TS	04	350	39	
10	JEBBA GS	03			402
	SOUTH WEST				
11	OSHOGBO	05	650	194	
12	AIYEDE	06	400	180	
13	AES	12			235
14	IKEJA WEST	07	1532	384	
15	EGBIN	09	556	174	900
16	AJA	10	362	150	
17	AKANGBA	08	160	189	
	SOUTH				
18	AJAOKUTA	15	80	72	
19	ALADJA	18	120	120	

20	DELTA	26	160	105	281
21	SAPELE	17	140		
22	BENIN	16	900	136	
	SOUTH EAST				
23	CALABAR	21			Nil
24	AFAM	23	120	120	60
25	OKPAI	27	220		223
26	NEW HAVEN	24	200	110	
27	ALAOJI	22	800	148	
28	ONITSHA	25	480	102	
	TOTAL		**10080**	**3188**	**3353**

The schematic of the existing 330KV Nigeria transmission network with 52 bus and 17 generating stations is shown in figure 3 below, with each area shown.

Table 2: Generators Installed and Available capacities.

S/N	STATION	STATE	TURBINE	INSTALLED CAPACITY	AVAILABLE CAPACITY
1	Kainji	Niger	Hydro	760	259
2	Jebba GS	Niger	Hydro	504	402
3	Shiroro	Niger	Hydro	600	408
4	Egbin	Lagos	Steam	1320	900
5	Sapele	Delta	Gas	1020	170
6	Okpai	Delta	Gas	900	223
7	AfamGS	Rivers	Gas	726	60
9	Delta	Delta	Gas	912	281
10	Calabar	Cross River	Gas	563	Nil

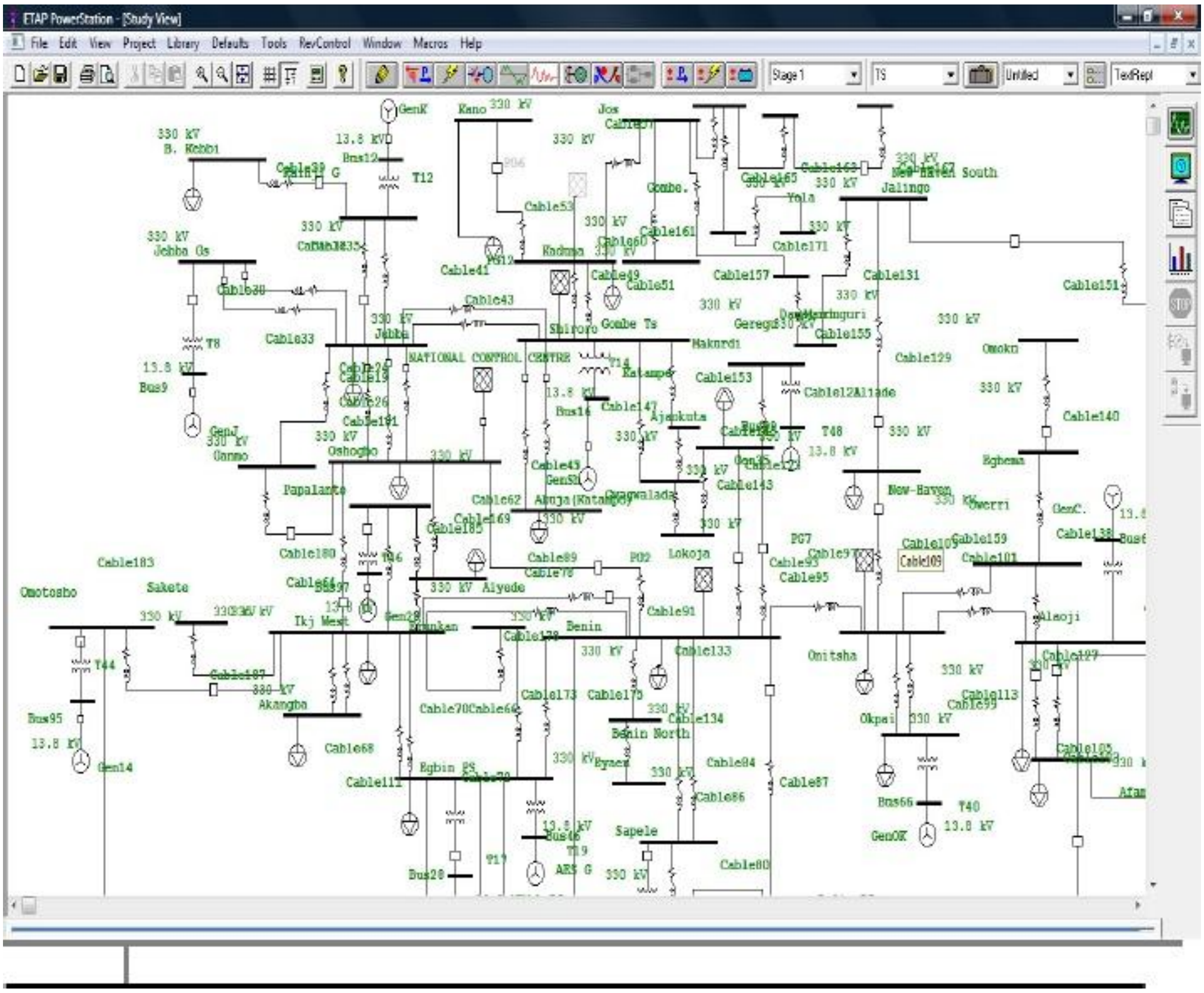

Figure 3: Existing 330KV Nigeria Transmission Network

The existing 330KV 28 bus Nigeria transmission network was simulated using the Power World Simulator to ascertain the various flow configurations as shown below.

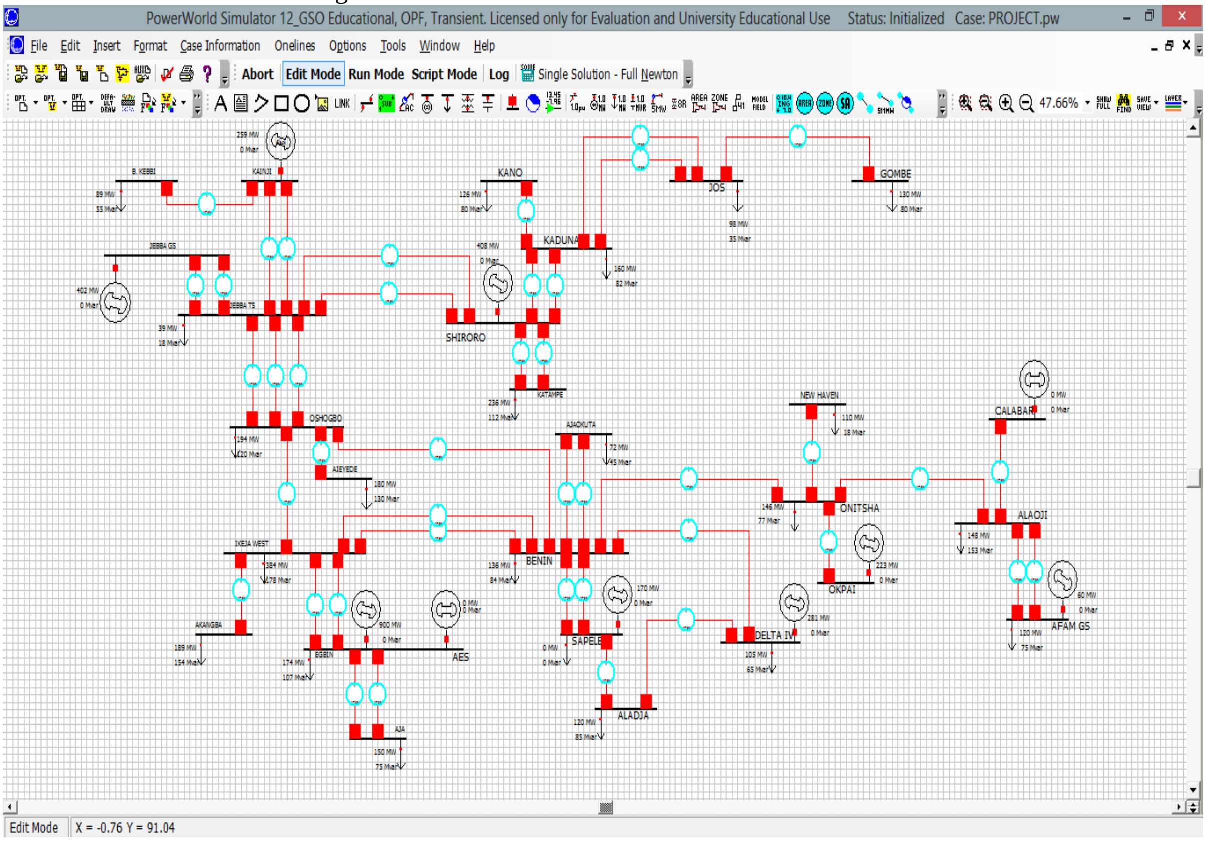

Figure 4: Existing 330KV transmission network with scheduled load in the PWS Edit mode

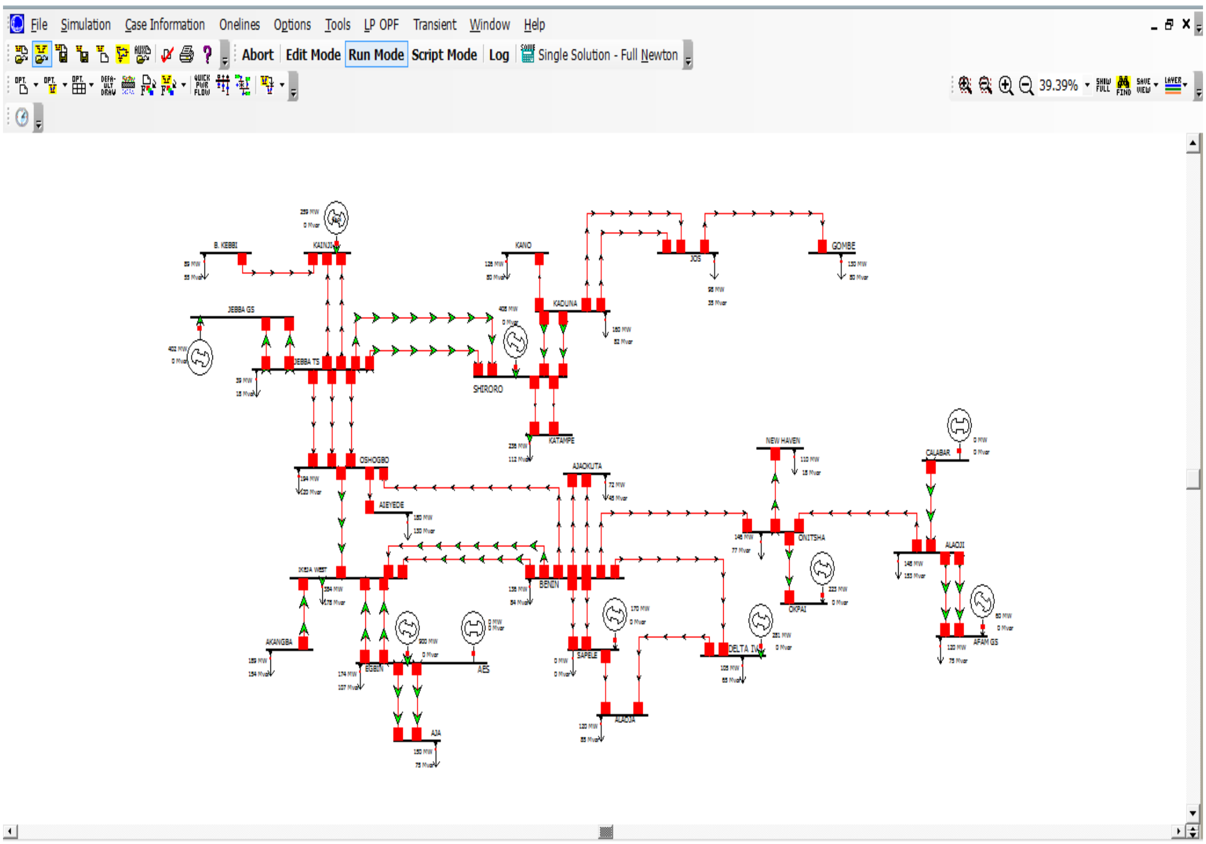

Figure 5: Existing generation with estimated actual load demand in run mode

2.5 Load Factor

Loads of power systems are divided into industrial, commercial and residential. Very large industrial loads may be served directly from the transmission system. Large industrial loads are served directly from the sub transmission network. Industrial load are composite loads, and induction motors form a high proportion of these load. Commercial and residential loads consist largely of lighting, heating and cooling. The magnitude of loads varies throughout the day and the power must be available to consumers on demand.

The daily load curve of a utility is a composite of demands made by various classes of users. The greatest value of load during a 24hr period is called the peak or maximum load demand. In order to access the usefulness of the generating plant the load factor is defined.

The load factor is the ratio of average load over a designated period of time to the peak load occurring in that period. Load factor may be given for a day, month or year. The annual load factor is the most useful since a year represents a full cycle of time.

$$\text{Daily load factor (DLF)} = \frac{\text{averageload} \times 24\text{hr}}{\text{peakload} \times 24\text{hr}} = \frac{\text{energyconsumed} \times 24\text{hr}}{\text{peakload} \times 24\text{hr}} \qquad (11)$$

$$\text{Annual load factor (ALF)} = \frac{\text{totalannual energy}}{\text{peakload} \times 8760\,\text{hr}} \qquad (12)$$

$ALF = DLF \times R_{DM} \times R_{MA}$

Where: ALF = Annual Load Factor, DLF = Daily Load Factor, R_{DM} = Ratio of average daily peak load to monthly peak load, R_{MA} = Ratio of average monthly peak to annual peak load

$$\text{Load loss Factor (LLF)} = C(LF) + (I\text{-}C)LF^2 \qquad (13)$$

Where: C = 0.3 for transmission lines

Annual MWH loss = LLF x Peak loss in MW x 8760hr

Therefore, Total energy loss = Annual MWH loss.

Evaluation, Analysis And Results

The power flow analysis carried out on the existing condition of the Nigerian 330kv transmission line shows that this transmission network is unsatisfactory.

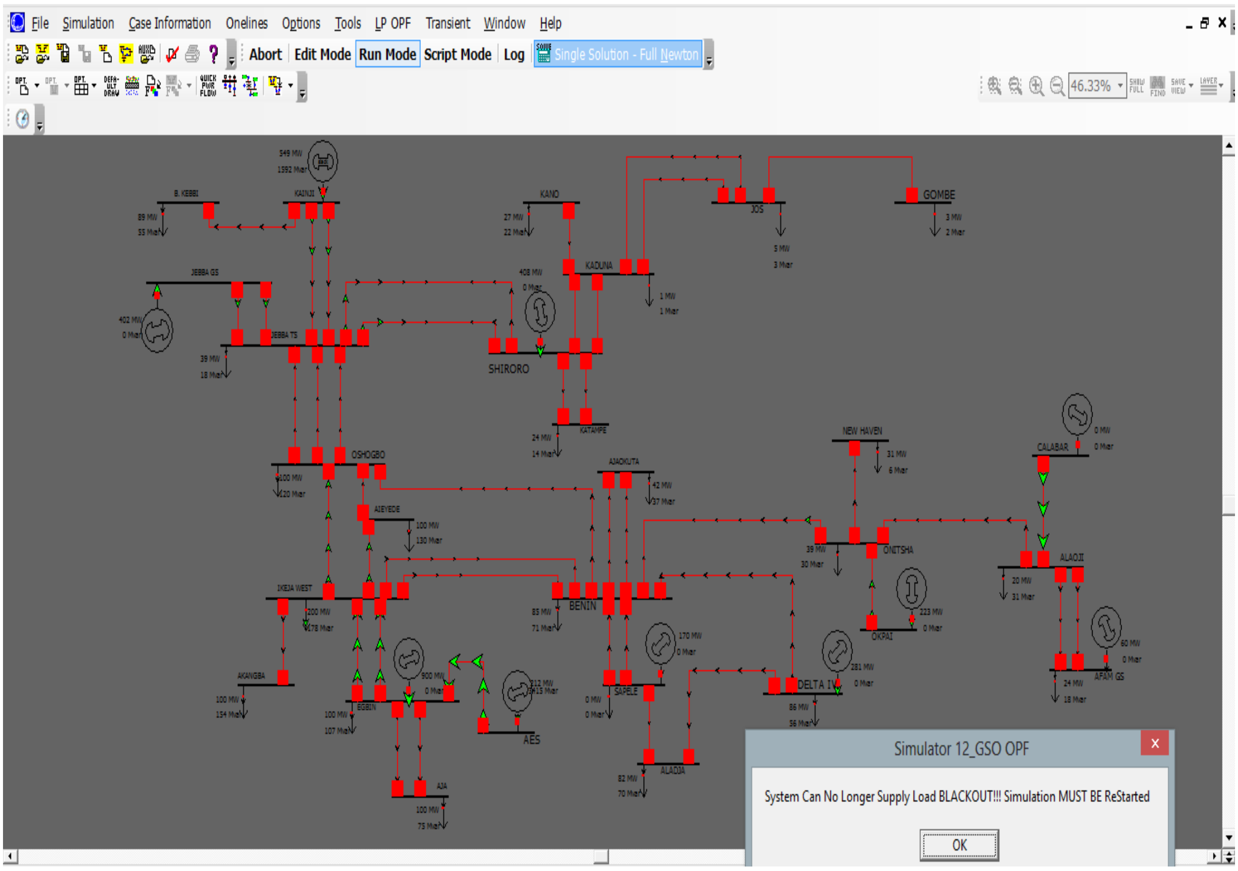

Figure 6: Blackout occurring when simulation is solved

With the present generation capacity of about 3353MW which is far less than one thirds of the actual load demand, when simulated a BLACKOUT occurred. It was observed that part of the reasons for that was as a result of:

- Limit voltage violations in majority of the lines
- Any fault in two of the triple circuit line linking Oshogbo and Jebba buses (the major Tie line between the south and north) can result into failure or separation of the grid network.
- A fault in the transmission line connecting Benin and Onitsha buses (Tie-Line connecting South-South and South-East)
- A fault in any of the three major buses in the grid network (Benin, Ikeja west, and Oshogbo).

Table 3: Power flow simulations by Newton-Raphson method

Records ▾ Set ▾ Columns ▾ Options ▾

Bus Records | Custom Case Information | Outages | Branches | Areas | Generators | Loads | YBus | Power Flow Jacobian

	Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar	Switched Shunts Mvar	Act G Shunt MW	Act B Shunt Mvar	Area Num	Zone Num
1	B. KEBBI	1	330.00	0.98500	325.050	7.32	89.00	55.00			0.00	0.00	0.00	1	1
2	KAINJI	1	330.00	1.00000	330.000	0.00			548.85	1591.99	0.00	0.00	0.00	1	1
3	JEBBA GS	1	330.00	1.02300	337.590	-15.43			402.00	0.00	0.00	0.00	0.00	1	1
4	JEBBA TS	1	330.00	1.04500	344.850	-7.97	39.00	18.00			0.00	0.00	0.00	1	1
5	OSHOGBO	1	330.00	1.04400	344.520	-12.66	100.00	120.00			0.00	0.00	0.00	1	1
6	AIYEDE	1	330.00	1.03800	342.540	-14.47	100.00	130.00			0.00	0.00	0.00	1	1
7	IKEJA WEST	1	330.00	1.00200	330.660	-27.61	200.00	178.00			0.00	0.00	0.00	1	1
8	AKANGBA	1	330.00	1.02100	336.930	12.45	100.00	154.00			0.00	0.00	0.00	1	1
9	EGBIN	1	330.00	1.02739	339.038	18.99	100.00	107.00	900.00	0.00	0.00	0.00	0.00	1	1
10	AJA	1	330.00	1.01210	333.992	18.57	100.00	75.00			0.00	0.00	0.00	1	1
11	KANO	1	330.00	0.99400	328.020	-9.05	100.00	80.00			0.00	0.00	0.00	1	1
12	KADUNA	1	330.00	0.99220	327.426	-8.61	100.00	82.00			0.00	0.00	0.00	1	1
13	SHIRORO	1	330.00	1.04100	343.530	-26.02			408.00	0.00	0.00	0.00	0.00	1	1
14	ABUJA	1	330.00	0.99800	329.340	-24.32	200.00	112.00			0.00	0.00	0.00	1	1
15	AJAOKUTA	1	330.00	0.98600	325.380	-8.95	50.00	45.00			0.00	0.00	0.00	1	1
16	BENIN	1	330.00	1.03200	340.560	-8.45	100.00	84.00			0.00	0.00	0.00	1	1
17	SAPELE	1	330.00	1.02900	339.570	-11.31	0.00	0.00	170.00	0.00	0.00	0.00	0.00	1	1
18	ALADJA	1	330.00	1.00100	330.330	-11.69	100.00	85.00			0.00	0.00	0.00	1	1
19	JOS	1	330.00	0.93700	309.210	-11.44	50.00	35.00			0.00	0.00	0.00	1	1
20	GOMBE	1	330.00	0.94100	310.530	-25.65	100.00	80.00			0.00	0.00	0.00	1	1
21	CALABAR	1	330.00	1.03500	341.550	0.00			0.00	0.00	0.00	0.00	0.00	1	1
22	ALAOJI	1	330.00	1.03400	341.220	-6.53	100.00	153.00			0.00	0.00	0.00	1	1
23	AFAM GS	1	330.00	1.03800	342.540	-34.59	100.00	75.00	60.00	0.00	0.00	0.00	0.00	1	1
24	NEW HAVEN	1	330.00	1.05200	347.160	-23.58	100.00	18.00			0.00	0.00	0.00	1	1
25	ONITSHA	1	330.00	1.02100	336.930	-9.72	100.00	77.00			0.00	0.00	0.00	1	1
26	DELTA IV	1	330.00	1.04500	344.850	-10.69	100.00	65.00	281.00	0.00	0.00	0.00	0.00	1	1
27	OKPAI	1	330.00	1.03400	341.220	-12.45			223.00	0.00	0.00	0.00	0.00	1	1
28	AES	1	330.00	1.02300	337.590	-12.21			211.80	3414.78	0.00	0.00	0.00	1	1

After a thorough study of the topology of the grid, it was observed that there is only one viable loop in the entire system, which ran from Benin-IkejaWest-Aiyede-Oshogbo-Benin. The consequences of this is that in case of a fault condition in any line or bus, there would be severe consequences on the grid system as a whole resulting in major loss of power.

Secondly, the distances between the generating stations and the load centers where very long, leading to a high power loss along the transmission lines. The real power loss in the network under the existing scheduled load condition amounted to about 154.4MW; this is a fraction of about 7% of the actual real power generated in the system.

Table 4: Transmission Line and loss Information

BUS INFORMATION									
	FROM		**TO**						
Line Arrangement	**Bus No**	**Bus Name**	**Bus No**	**Bus Name**	**Line(Km)**	**Circuit type**	**Power Sending End(MW)**	**Power Receiving End(MW)**	**Losses (MW)**
A	5	OSHOBGO	16	BENIN	251	S	53.7	50.8	2.9
B	5	OSHOGBO	7	IKJ-WEST	252	S	20.8	20.6	0.2
C	5	OSHOGBO	25	AIYEDE	115	S	79.1	78.1	1.0
D1	4	JEBBA TS	5	OSHOGBO	157	T	102.5	100.9	1.6
D2	4	JEBBA TS	5	OSHOGBO	157	T	102.5	100.9	1.6
D3	4	JEBBA TS	5	OSHOGBO	157	T	102.5	100.9	1.6

E1	16	BENIN	7	IKJ-WEST	280	D	31.7	29.8	1.9
E2	16	BENIN	7	IKJ-WEST	137	D	31.7	29.8	1.9
F	25	ONITSHA	16	BENIN	107	S	172.4	155.3	17.1
G	26	DELTA PS	16	BENIN	107	S	107.2	105.9	1.3
H1	17	SAPELE	16	BENIN	50	D	32.3	32.1	0.2
H2	17	SAPELE	16	BENIN	50	D	32.3	32.1	0.2
I1	16	BENIN	15	AJAOKUTA	195	D	36.2	36.0	0.2
I2	16	BENIN	15	AJAOKUTA	195	D	36.2	36.0	0.2
J	7	IKJ-WEST	6	AIYEDE	137	S	104.2	101.9	2.3
K	7	IKJ-WEST	8	AKANGBA	17	S	189.9	189.0	0.9
L1	9	EGBIN PS	7	IKJ-WEST	62	D	325.8	319.7	6.1
L2	9	EGBIN PS	7	IKJ-WEST	62	D	325.8	319.7	6.1
M	5	JOS	20	GOMBE	264	S	155.4	130.0	25.4
N	28	KADUNA	19	JOS	196	S	282.7	253.4	29.3
O	27	OKPAI	25	ONITSHA	28	S	371.7	369.4	2.3
P	25	ONITSHA	24	N.HAVEN	96	S	110.4	110.0	0.4
Q	25	ONITSHA	22	ALAOJI	138	S	15.4	15.4	0.0
R1	13	SHIRORO	14	ABUJA	144	D	118.3	118.0	0.3
R2	13	SHIRORO	14	ABUJA	144	D	118.3	118.0	0.3
S	28	AES	9	EGBIN PS		S	235.0	220.0	15.0
T1	9	EGBIN PS	10	AJA	16	D	75.0	75.0	0.0
T2	9	EGBIN PS	10	AJA	16	D	75.0	75.0	0.0
U	26	DELTA PS	18	ALADJA	32	S	185.8	185.0	0.8
V	21	CALABAR	22	ALAOJI		S	0.0	0.0	0.0
W	18	ALADJA	17	SAPELE	63	S	65.0	64.6	0.4
X	12	KADUNA	11	KANO	230	S	127.0	126.0	1.0
Y1	23	AFAM GS	22	ALAOJI	25	D	82.5	81.7	0.8
Y2	23	AFAM GS	22	ALAOJI	25	D	82.5	81.7	0.8
Z1	3	JEBBA GS	4	JEBBA TS	8	D	169.5	168.6	0.9
Z2	3	JEBBA GS	4	JEBBA TS	8	D	169.5	168.6	0.9
AA1	2	KAINJI	4	JEBBA TS	81	D	219.3	218.2	1.1
AA2	2	KAINJI	4	JEBBA TS	81	D	219.3	218.2	1.1
BB1	4	JEBBA TS	13	SHIRORO	244	D	272.8	265.6	7.2
BB2	4	JEBBA TS	13	SHIRORO	244	D	272.8	265.6	7.2
CC	2	KAINJI	1	B. KEBBI	310	S	89.9	89.0	0.9
DD1	13	SHIRORO	12	KADUNA	96	D	290.7	285.2	5.5
DD2	13	SHIRORO	12	KADUNA	96	D	290.7	285.2	5.5

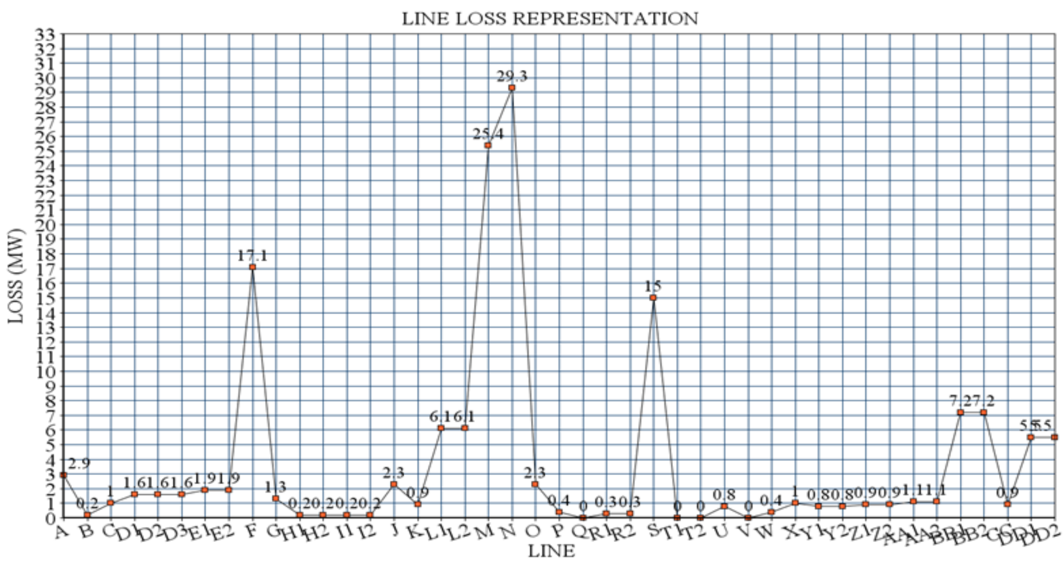

Figure 7: Graphical representation of line losses

Table 5: Regional losses

REGION	TOTAL LOSS(MW)	% LOSS
SOUTH WEST	42.8	39.41068
SOUTH SOUTH	3.3	3.038674
SOUTH EAST	4.3	3.959484
NORTH WEST	32.6	30.01842
NORTH EAST	25.6	23.57274
	108.6	

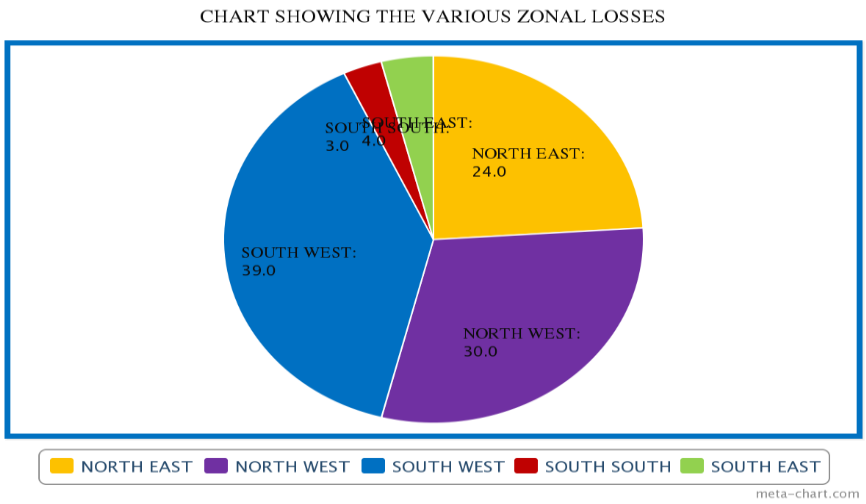

Figure 8: Chart showing the zonal losses

Table 6: Tie Line losses in transmission network

TIE LINE	LOSSES
SW/SS	6.7
SW/NW	4.8
SS/SE	17.1
NW/NE	29
TOTAL	57.6

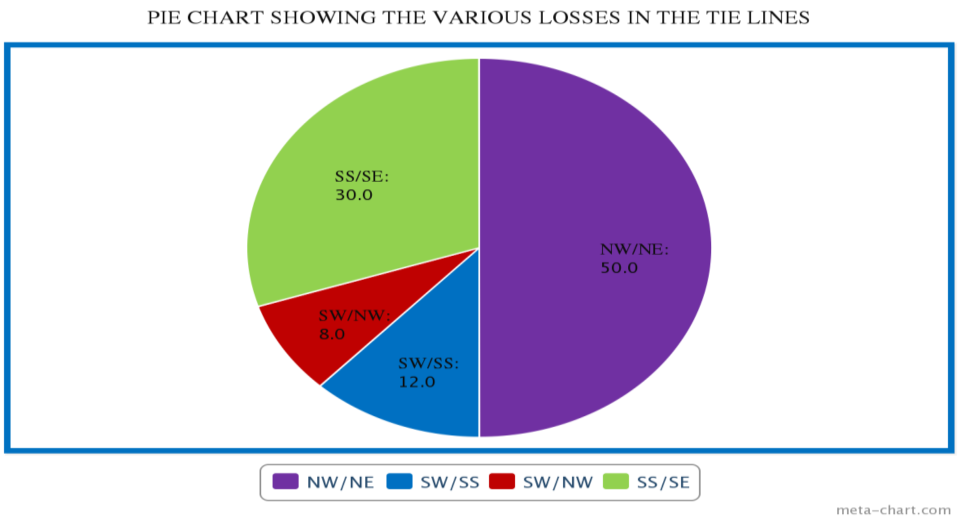

Figure 9: Pie chart representation of losses in the tie-lines.

From the figure 9, it was observed that the Tie-line from Kaduna to Jos (NW/NE Zone) presented the highest amount of loss of 29.3MW which is about 50.35% of the total loss in the network. This large amount of loss can be linked to the long length of the transmission line which was 196km, the fairness of these buses from a generating station, the single circuit line used for transmission and the limit voltage violation at these buses.

The Tie line from Oshogbo to Jebba (SW/NW) has the lowest amount of power loss of 4.8MW; this is about 8.3% of the total losses in the network. This low loss is attributed to the closeness of these buses from the generating stations in the grid, the triple circuit transmission line running from Jebba to Oshogbo.

Looking at the losses in the grid from the zoning perspective, it would be observed in Figure 7 that the South-South zone has the lowest amount of loss of 3.3MW which is about 3.04% of the total loss in the network, this was not strange because there are over 3 generators in this region and secondly the transmission lines linking buses in this zone are of the medium type. While the South-West zone has the highest amount of loss of 42.8MW which is about 39.41% of the total loss in the network.

From Table 3, it was observed that the transmission line linking Jos to Gombe has the highest loss in a single region of 25.4MW which is about 16.45% of the total loss in the network.

Table 7: Hourly load demand for Ajaokuta bus

Time(hour)	1	2	3	4	5	6	7	8	9	10	11	12
Load(MW)	30	25	27	27	27	32	38	35	32	25	23	25
Time(hour)	13	14	15	16	17	18	19	20	21	22	23	24
Load(MW)	27	41	41	52	25	25	38	47	43	38	32	25

Table 8: Daily load demand for Ajaokuta bus

Time(days)	1	2	3	4	5	6	7	8	9	10	11
Load(MW)	59	63	62	64	58	58	50	56	57	47	49
Time(days)	12	13	14	15	16	17	18	19	20	21	22
Load(MW)	48	45	55	57	70	72	70	55	55	65	50
Time(days)	23	24	25	26	27	28	29	30	31		
Load(MW)	64	55	60	61	50	58	54	70	72		

Table 9: Monthly load demand for Ajaokuta bus

Time(months)	1	2	3	4	5	6	7	8	9	10	11	12
	70	62	68	67	62	55	59	72	71	70	68	64

From table 6, the daily load factor is calculated as:

Daily average load = $\frac{totalload}{24\ hour}$

$= \frac{700}{24}$ = 32.5 MW

Daily load factor =$\frac{dailyaverageload}{peakload}$

$= \frac{32.5}{47}$ = 0.6915

From Table 7, the monthly load factor is calculated as:

Monthly average load = $\frac{totalload}{31\ hour}$

$= \frac{1809}{31}$ = 58.35MW

Monthly load factor = $\frac{mont\ hlyaverageload}{peakload}$ = R_{DM}

$= \frac{58.35}{72}$ = 0.8104

From Table 8, the annual load factor is calculated as:

Average monthly load = $\frac{totalmont\ \ hlyload}{12\ mont\ h}$

$= \frac{788}{12}$ = 65.67 MW

$R_{MA} = \frac{averagemont\ \ hlyload}{peakload}$

$= \frac{65.67}{72}$ = 0.912

Thus Annual Load Factor = DLF xR_{DM}x R_{MA}

= 0.6915 x 0.8104 x 0.912

= 0.5111

Load Loss Factor (LLF) = C (LF) + (1-C) LF^2

Where C = 0.3 for transmission lines

LLF = 0.3(0.5111) + (1 – 0.3)0.5111^2

= 0.3362

Annual MWH Loss = LLF x Peak Loss in MW x 8760

= 0.3362 x 154.4 x 8760

= 454.73GW

Thus the real power losses in the network under the existing condition amounted to **154.4MW**. The energy loss estimated as at October 2012 due to 330kV transmission lines was found to be 454.73GW which amounted to over 4.4 billion naira using the average billing rate of that year which was at
N11.10 = 1kW.

III. Conclusion And Recommendation

The Nigerian 330Kv transmission network is faced with various problems. This paper has focused on the technical and non-technical losses estimated in the network. The network is characterized by high voltage drops and power losses which can be attributed to low generation, long and fragile radial network, making it highly prone to failure, unreliability, inefficiency and poor performance. The energy loss at October 2012 due to the 330Kv transmission network is about 454.73 GW amounting to over 4.4 billion naira.

The technical information provided in this paper forms a veritable database for future work towards improving Nigeria's power system operation. It is highly recommended that

- The length of transmission and distribution lines should be as short as possible by introducing more substations in the network. Voltage drops and power losses increase with increase in the line length and loading.
- While the expanded network is graduallybeing implemented, the existing transmission lines and substations should be upgraded to improve voltage profile of vulnerable buses like Gombe, Damaturu, Jos and Kumbotso buses with appropriately sized VAR compensators.
- By fortifying the expanded grid, that is, double and triple circuits should be used to replace those lines with single circuits to increase the efficiency and the reliability of the network.
- Provision of multiple loops in a fortified network will guarantee continuity of supply in the event of any contingency or fault.
- Provision of two double circuit transmission lines to interconnect Egbin and Oshogbo, and double circuit lines to connect Oshogbo to Aieyede and Kainji to Birin-Kebbi will greatly enhance the efficient operation of the grid.
- Provision of adequate generation capacity in each zone of the Federation through distributed generation scheme to minimize line losses and cost of power spiraling.
- The government should implement the Independent Power Projects for lack of political will and policy inconsistency was responsible for the power sector to deliver 6,000MW last December
- Existing power stations should be rehabilitated and the transmission lines that are over age should be replaced
- Planned and routine maintenance should be carried out on the network.

  If all these recommendations are looked into as well as those from future research on this topic by stakeholders in the power sector, then we can look forward to having a system with reliable and efficient power supply.

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