Analysis of Power Supply Operation in a Typical Nigerian Transmission Substation: A Case Study of Ota 132/33 kV Substation.

D. A. Daramola, P. K. Olulope

Abstract—This report presents an analysis of power supply operations in a typical Nigerian transmission substation. Ota 132kV substation was selected for the study. The performance and operations problems of the substation were investigated. In order to characterize the substation, power supply to the substation was evaluated using numerical statistical techniques, outage records and basic reliability indices such as mean time between failures, mean downtime, outage rate, reliability and supply availability to the station. In order to obtain efficiency of power supply through the substation, load flow computation was carried out using simulation model created in Matlab. Newton-Raphson method was applied in the load flow computation. The efficiency ranges between 92.3 to 94.4 % for the three scenarios used in the simulation model. The results analyses indicate that load shedding was the major cause of power outages in the substation's outgoing feeders. Due to both faults and load shedding on these feeders, the outage rate is 0.065 outage/hour and availability is 0.47. The load flow result showed that 200 MVA transformer is needed to service the station as against 100 MVA installed transformer. This is an indication that the present substation is inadequate and needs to be replaced with equipment having a greater capacity to meet present over load and future demand. Therefore, two number of 100 MVA transformers are required to take the total substation load of 200 MVA.

Keywords— Availability, Fault, Load shedding,Operation, Outages, Reliability, Transformer

1. Introduction

Energy provides the power for the progress of any country. The natural resources of a nation may be large but they can only be turned into wealth if they are developed, used and exchanged for other goods. This cannot be achieved without energy. The energy sector of any country occupies a place of central importance in term of its relative contribution to the national socio-economic goal of raising the productivity and therefore, higher living standard. Of all the sectors comprising the energy sector, electricity has greater impact on the lives of the citizenry [1].

From the very beginning, energy has played a vital role in the development of civilization. There has been a universal basic drive towards better living through expanded utilization of energy so far discovered. Power interruptions due to occurrence of system faults constitute a major challenge to electricity consumers in Nigeria. A power system supplies both large and small consumers with electrical energy. In modern society, continuous supply of energy is always expected but this is not possible practically due to random failures, which are generally outside the control of power system Engineers.

It is not always feasible and economical to generate electric power at the location of its use. Consequently, bulk energy generated in the generating stations must be transmitted over a long distance via an electric transmission network to consumer. In power network, bulk power move on the grid or transmission links. From the grid, power is then sub-divided into smaller blocks based on operating voltage level and fed into the sub-transmission portions of the power network. Finally, the individual small and large consumers are serviced from the distribution network [2].

Fault occurs on a power system when one or more energized conductors contact other conductors or ground. Of course, in the event of insulation failure, it may not be necessary for the conductor to be in contact. A fault can also occur with the current flowing through an ionized path, which could be through air or some other substances. Fault may also occur through breaking of conductor due to excessive heat or mechanical stresses. Therefore, fault in an electric power system can be defined as a defect in the electrical circuit due to which current is diverted from the intended path with increase in magnitude. In order words, fault is the abnormal condition of the electrical system which damages the electrical equipment and disturbs the normal flow of the electric current [3].

It is at the consumers' end the frequent faults are experienced. A fault occurs on a power system when one or more energized conductors contact other conductors or ground. These faults may be symmetrical or unsymmetrical. A symmetrical fault occurs when there is a contact between the three conductors of a 3 phase line which lead to equal magnitude of fault current with 120^0 'phase displacement while unsymmetrical fault always lead to an unequal fault currents with unequal phase displacement such as single phase to ground fault, two phase to ground fault, phase to phase fault. Of course, in the event of insulation failure, it may not be necessary for the conductor to be in contact. A fault can also occur with the current flowing through an ionized path, which could be through air or some other substances [4].

During fault, the voltage between the two parts is reduced to zero for metal-to-metal contact or to a very low value if the short circuit path is through an arc. Thus, currents of abnormally high magnitude flow through the system to fault point. When there is a fault, consumers are denied of electricity supply [5]. Hence, the need for this paper which is to investigate the problems of operation and service delivery on 132kV/33kV transmission station using Ota transmission station a case study. However, over the years, Ota has been experiencing erratic supply of electricity and of poor quality, which has made many industries to fold up in the area.

Similarly, due to accelerated growth and industrial development in Ota and the attendant increase in load demand, there is need for more transmission station connected to the grid in Ota. The substation should be designed and operated to meet customers' needs at the lowest possible cost commensurate with the quality of service desired. Hence, this paper work is to analysis the problems associated with the prevailing power failure in Ota transmission Station, suggest possible solution and specify measures necessary for a reliable and efficient operation.

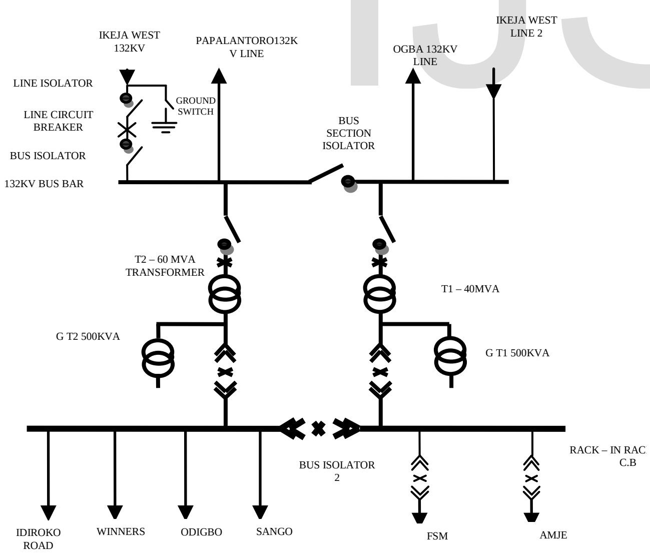

Fig 1: ***One Line Diagram Showing the Bus and Feeders in the Substation***

Ota transmission substation has two incoming transmission lines coming from Ayobo in Ikeja West area of Lagos state. Namely Ikeja west line 1 and 2. The power transformer in the substation is 100 MVA rated capacity comprises 60 MVA and 40 MVA. It has six numbers of outgoing feeders namely; Idiroko, Winner, Odigbo, Sango, FSM and Amje. The lines are interconnected so that there can be supply to all feeders in the station in case of a fault on one line or transformer or during normal maintenance as shown in figure 1.

2. Algorithm For Evaluating Power Supply Reliability

2.1 Monthly Outage Events and Durations on 33 kV Lines

Let monthly outage events on 33 kV systems be represented as O_m^S [events]. Then, O_m^S is evaluatedas in equation 1:

$$O_m^S = O_m^f + O_m^l = \sum_L O_{m,L}^f + \sum_L O_{m,L}^l \qquad 1$$

where $O_{m,L}^f$ is outage events on feeder L for month m due to fault f, $O_{m,L}^l$ is outage events on feeder L for month m due to load shedding l; and O_m^f and O_m^l are monthly outages due to fault and load shedding respectively.

2.2 Monthly duration of outages for the system

The monthly duration of outages for the system T_m^S [hrs] can be expressed analogically to Equation.2:

$$T_m^S = T_m^f + T_m^l = \sum_L T_{m,L}^f + \sum_L T_{m,L}^l \qquad 2$$

2.3 Monthly operating time for the system

The monthly operating time for the system T_m^S [hrs] can be expressed analogically to Equation 3

$$\tau_m^S = \tau_m^f + \tau_m^l = \sum_L \tau_{m,L}^f + \sum_L \tau_{m,L}^l \qquad 3$$

where $\tau_{m,L}^f$ is the operating time on line L and for month m due to fault f, $\tau_{m,L}^l$ is the operating time for month m due to load shedding l.

2.4 Monthly failure rate for the system

Let monthly failure rate of the system be λ_m^s

The monthly failure rate for the system λ_m^s can be expressed analogically to Equation 4

$$\lambda_m^s = \frac{O_m^s}{\tau_m^s} = \frac{O_m^f + O_m^i}{\tau_m^f + \tau_m^i} = \frac{\sum_L O_{m,L}^f + \sum_L O_{m,L}^i}{\sum_L \tau_{m,L}^f + \sum_L \tau_{m,L}^i} \qquad 4$$

2.5 Monthly Mean Time Between Failure for the system

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Let Monthly Mean Time between Failure be $MTBF_m^s$

The monthly Mean Time between Failures for the system $MTBF_m^s$ can be expressed analogically to Equation 5

$$MTBF_m^s = \frac{1}{\lambda_m^s} = \frac{\tau_m^s}{O_m^s} = \frac{\tau_m^f + \tau_m^i}{O_m^f + O_m^i} = \frac{\sum_L \tau_{m,L}^f + \sum_L \tau_{m,L}^i}{\sum_L O_{m,L}^f + \sum_L O_{m,L}^i} \quad 5$$

2.6 Monthly Mean Down Time for the system

Let Monthly Mean down Time be MDT_m^s

The monthly Mean Time between Failures for the system MDT_m^s can be expressed analogically to Equation 6

$$MDT_m^s = \frac{T_m^f + T_m^i}{O_m^f + O_m^i} = \frac{\sum_L T_{m,L}^f + \sum_L T_{m,L}^i}{\sum_L O_{m,L}^f + \sum_L O_{m,L}^i} \quad 6$$

2.7 Monthly Availability for the system

Let Monthly Availability be A_m^s

The monthly Mean Time between Failures for the system A_m^s can be expressed analogically to Equation 2.7

$$A_m^s = \frac{MTBF_m^s}{MTBF_m^s + MDT_m^s} \quad 7$$

In order to calculate the failure rate, reliability, and availability, duration of outages, frequency of outages were calculated and tabulated as follows:

3. Modeling Of The Existing Substation

Transmission efficiency of existing station configuration was conducted using a power load flow model based on Newton Raphson iterative scheme created in Matlab.

This Method of calculating load flow is more efficient, faster and practical for large power system. The main advantage is that the number of iterations required to

obtain a solution is independent of the size of the problem and computationally it is very fast [5]. However, the Newton-Raphson method suffers from the disadvantage

that a "flat start" is not always possible since the solutionat the beginning can oscillate without converging towards the solution. [6].

The load flow calculation is the most common power system analysis tool for examining the network within the scope of operation and strategic planning. On the basis of the network topology with the impedances of all devices as well as with the incoming and the consumers, the load-flow calculation can provide voltage profile for all nodes and loading of network components. The iteration algorithm for the solution of the load flow problem is shown below:

$$P_i^r = \sum_{k=1}^{n} |V_i|^r \, |V_k|^r |Y_{ik}| \cos(\theta_{ik} + \delta_k^r - \delta_i^r) \quad 8$$

$$8Q_i^r = \sum_{k=1}^{n} |V_i|^r \, |V_k|^r |Y_{ik}| \sin(\theta_{ik} + \delta_k^r - \delta_i^r) \quad 9$$

Both real and reactive powers are function of (|V|,δ), where

$$||V| = (|V_1|, \ldots |V_n|^T)\delta$$

$$\delta = (\delta_{1,\ldots\ldots,}\delta_n)^T.$$

In solving load flow, there is need to determine these four quantities at each three-phase or single –phase bus:

- The net active power P and reactive power injected into the bus
- The voltage magnitude V and angle Θ
  $P_{i=}^r$ Real power
  $Q_{i=}^r$ Reactive power
  $|V| =$ Voltage magnitude
- θ_{ik} = Angle difference between current and voltage in degree
- δ = Phase angle difference between sending end-voltage and receiving end-voltage in radian
- $|Y_{ik}|$ = Bus Admittance

3.1 Bus Types

In this method, it is important to define the three bus types that are used by the load flow tool to solve a load flow. Before solving the load flow, two of the above quantities are known at every bus and the other two are to be determined. Therefore, the following bus types are used:

i. PV bus: For PV bus, the active power P and voltage magnitude V are specified as known variables while reactive power Q, required to maintain the reference voltage magnitude V and voltage angle Θ are to be resolved. Usually, PV bus should have some controllable reactive power resources and can thus maintain bus voltage magnitude at a desirable value.

ii. PQ bus: For PQ bus, the active and reactive power (P, Q) are specified as known parameters, and the complex voltage (V, Θ) is to be resolved. Usually, substation buses are taken as PQ bus where the load powers are given constant. Most buses in power systems belong to the PQ type in load flow calculation.

iii. Slack bus: In load flow studies, there should be one and only one slack bus in the power system, which is specified by a voltage, constant in magnitude and phase angle. Therefore, V and Θ are given as known variables at the slack bus, while the active power P and reactive power Q are the variables to be solved in order to balance generated power, loads, andlosses. At least one bus in the model must be defined as a slack bus, but usually a single slack bus is required unless there are isolated networks [7].

Figure 2 shows the load flow tool used to perform load flow analysis of the load flow

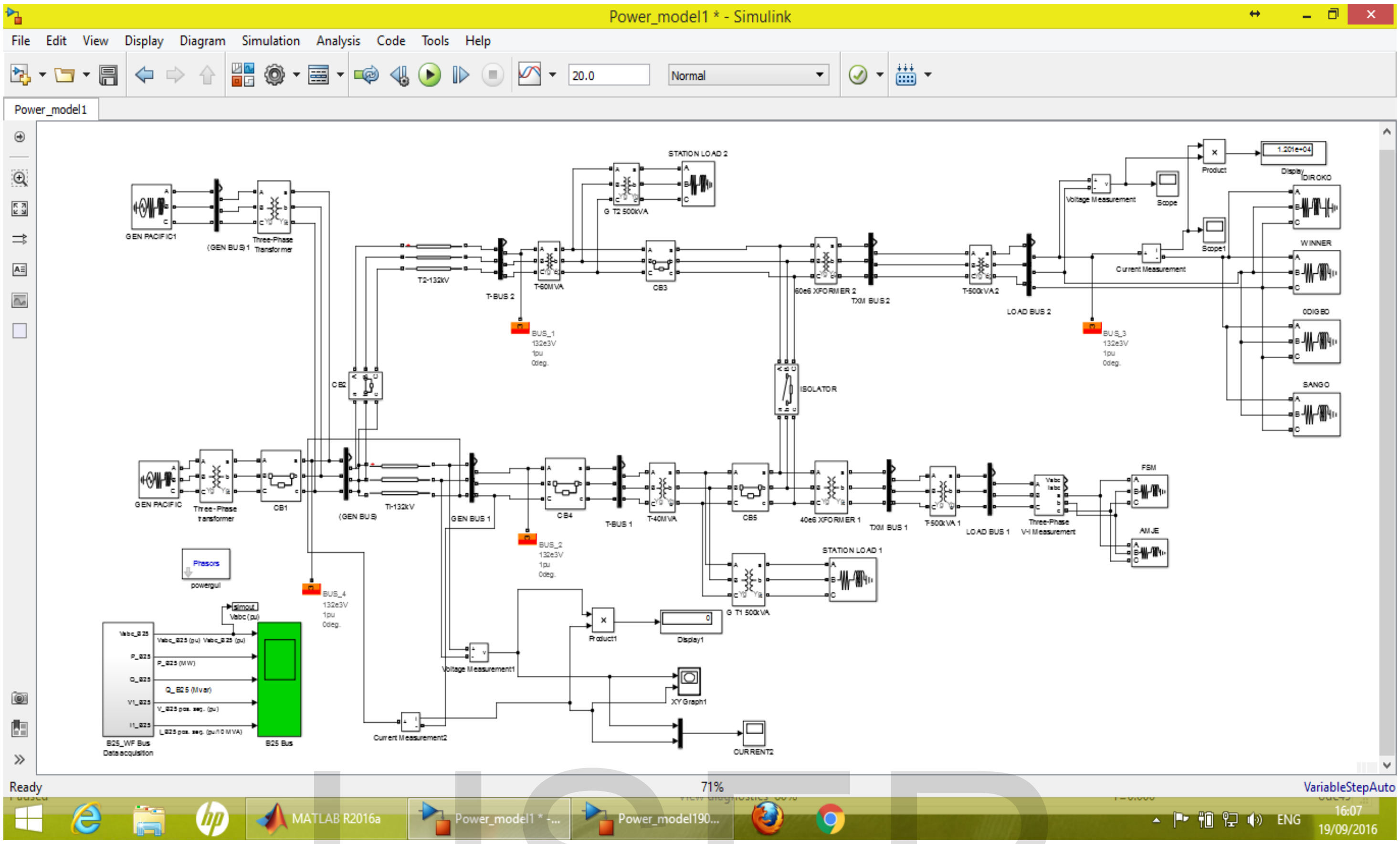


Fig 2: Power Modelling for Ota Substation

The modeling of Ota transmission substation comprises of two forms of generator source, step up transformer, circuit breakers at different voltage level, infinite bus bars, three sets of step down transformer measuring devices and six outgoing feeders. The first generator contains swing bus and its serves as reference bus for all other buses in the model while the second generator has PQ bus so that measurement of electrical variable such as active power, reactive power, voltage and current at different buses can be obtained. The step up transformer transforms 11 kV from the generator to 132 kV for easy and efficient transmission. Circuit breakers employed are for switching purposes. There are numbers of bus bars used at different voltage level to allow easy connection for efficient transmission. The step down transformer are used to transform the voltage to 33kV, 11 kV and finally to 0.415 kV and load points of six feeders are connected since the efficiency of station is the function of load drawn from it by the customers on it. The load flow tool of the Powergui block used Newton-Raphson method with an interface to display load flow solution at all buses. The load flow parameters in the Powergui are used to build the Ybus network admittance matrix and to solve the load flow which is the numeric inverse of impedance and is represented by the letter Y.

Therefore, Y is given as

$$G + jB \qquad 10$$

Y is network admittance

G is Conductance and B is Susceptance

Where G is expressed as

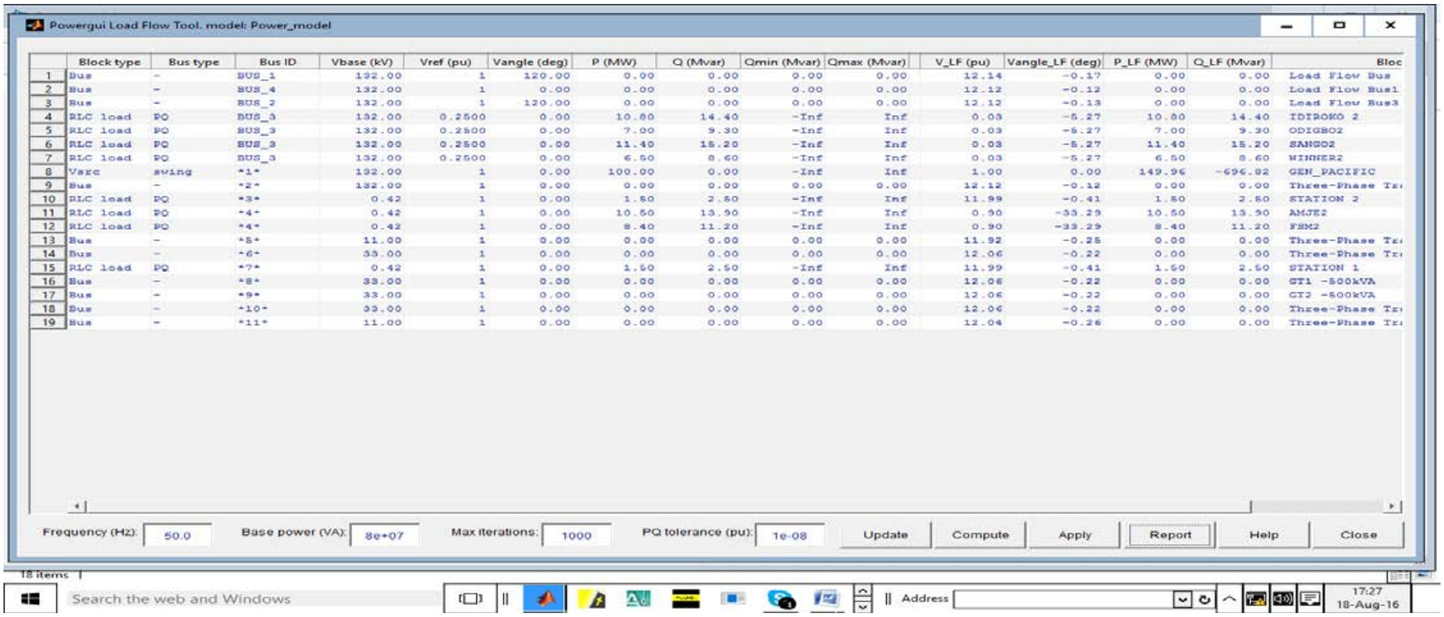
$$g = \frac{r}{r^2+x^2} \qquad 11$$

$$b = \frac{-x}{r^2+x^2} \qquad 12$$

The base power is used to specify units of the normalized Ybus matrix in pu/Pbase and bus base voltages [8].

The measuring devices are connected so the values of input and output can be measured in order to determine the efficiency of the existing station configuration as shown in figure 3.

From figures 2 and 3 different scenarios was considered to enable the selection of suitable transformer for the station base on the amount of loads drawn from the generator by each feeder. To achieve this, minimum load, maximum load and installed capacity load for each feeder were considered with different generator input and maintained throughout the scenarios for effective selection of transformer with the load flow result summary showing in table 1.



Powergui Load Flow Tool. model: Power_model

	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (Mvar)	Bloc
1	Bus	-	BUS_1	132.00	1	120.00	0.00	0.00	0.00	0.00	12.14	-0.17	0.00	0.00	Load Flow Bus
2	Bus	-	BUS_4	132.00	1	0.00	0.00	0.00	0.00	0.00	12.12	-0.12	0.00	0.00	Load Flow Bus1
3	Bus	-	BUS_2	132.00	1	120.00	0.00	0.00	0.00	0.00	12.12	-0.13	0.00	0.00	Load Flow Bus3
4	RLC load	PQ	BUS_3	132.00	0.2500	0.00	10.80	14.40	-Inf	Inf	0.03	-5.27	10.80	14.40	IDIROKO 2
5	RLC load	PQ	BUS_3	132.00	0.2500	0.00	7.00	9.30	-Inf	Inf	0.03	-5.27	7.00	9.30	ODIGBO2
6	RLC load	PQ	BUS_3	132.00	0.2500	0.00	11.40	15.20	-Inf	Inf	0.03	-5.27	11.40	15.20	SANGO2
7	RLC load	PQ	BUS_3	132.00	0.2500	0.00	6.50	8.60	-Inf	Inf	0.03	-5.27	6.50	8.60	WINNER2
8	Vsrc	swing	*1*	132.00	1	0.00	100.00	0.00	-Inf	Inf	1.00	0.00	149.96	-696.82	GEN_PACIFIC
9	Bus	-	*2*	132.00	1	0.00	0.00	0.00	0.00	0.00	12.12	-0.12	0.00	0.00	Three-Phase Tr
10	RLC load	PQ	*3*	0.42	1	0.00	1.50	2.50	-Inf	Inf	11.99	-0.41	1.50	2.50	STATION 2
11	RLC load	PQ	*4*	0.42	1	0.00	10.50	13.90	-Inf	Inf	0.90	-33.29	10.50	13.90	AMJE2
12	RLC load	PQ	*4*	0.42	1	0.00	8.40	11.20	-Inf	Inf	0.90	-33.29	8.40	11.20	FSM2
13	Bus	-	*5*	11.00	1	0.00	0.00	0.00	0.00	0.00	11.92	-0.25	0.00	0.00	Three-Phase Tr
14	Bus	-	*6*	33.00	1	0.00	0.00	0.00	0.00	0.00	12.06	-0.22	0.00	0.00	Three-Phase Tr
15	RLC load	PQ	*7*	0.42	1	0.00	1.50	2.50	-Inf	Inf	11.99	-0.41	1.50	2.50	STATION 1
16	Bus	-	*8*	33.00	1	0.00	0.00	0.00	0.00	0.00	12.06	-0.22	0.00	0.00	GT1 -500kVA
17	Bus	-	*9*	33.00	1	0.00	0.00	0.00	0.00	0.00	12.06	-0.22	0.00	0.00	GT2 -500kVA
18	Bus	-	*10*	33.00	1	0.00	0.00	0.00	0.00	0.00	12.06	-0.22	0.00	0.00	Three-Phase Tr
19	Bus	-	*11*	11.00	1	0.00	0.00	0.00	0.00	0.00	12.04	-0.26	0.00	0.00	Three-Phase Tr

Fig 3: Power gui Load Flow Tool, Model for Ota substation

Table 1: Load Flow Result Summary for Ota 32/33 kV Transmission

	Active Power P (MW)	Reactive Power Q (Mvar)
Total Generation	149.96	-696.82
Total PQ Load	57.60	77.60
Total Zshunt Load	81.98	-1190.48
Total ASM Load	00.00	0.00
Total Losses	10.38	416.06

From the above scenarios, each scenario was repeated as shown in the Table 2 with both minimum and maximum loads on each feeder are taken into consideration. It was observed that only the load has effect on the modeled result as shown above.

In all the results generated, the reference bus or swing bus was used to compare the result from each scenario. It was revealed that at minimum load (scenario 1) the power drawn by the feeders was 175. 94 MW and -703.14 Mvar. Whereas at

Table 2: Station Efficiency for Different Scenarios

SCENARIOS	POWER INPUT (MW)	POWER OUTPUT (MW)	EFFICIENCY (%)
1	187.46	176.96	94.4
2	207.4	197.33	92.3
3	149.96	138.44	92.38

the maximum load (scenario 2) the power drawn by the feeders was P= 195.88 MW and Q= -708.88 Mvar but at installed capacity the power consumed was

138.44 MW and -708.34 Mvar. In the three scenarios the load consumption in is greater than the designed load. Therefore, there is need to upgrade the station to meet the load consumption of the customers service by Ota transmission substation.

3.2 Estimation of Substation Maximum Load.

After obtaining maximum load for each feeder, equation 13 was used to calculate the total substation maximum load as follows:

$P_T = P_1 + P_2 + P_3 + - - + P_6$ 13

$\sum_{i=1}^{6}(Pi)$

Where i is the serial number of feeders

3.3 Station Transformer Rating Calculations.

Transformers for the substation were carefully selected by using data from the station logbook to calculate the rating that is suitable for the substation transformers. At 0.8p.f lagging, maximum load of 197.38 MVA, by applying transformer rating coefficient,

$S_{max} \leq 1.2 \times S_T$ 14 13

Where S_{max} is Maximum Power consumed.

S_T is power rating of the Transformer

Therefore,

$$S_T \geq \frac{S_{max}}{1.2}$$

$$S_T \geq \frac{197.38}{1.2} 164.48\ MW$$

At 0.8 *p.f* lagging, of 164.48 MW

$$S_{max} = \frac{164.48}{0.8} = 205.6\text{MVA}$$

SPECIFICATION

Since the rating of the transformer should be greater or equal to 196 MVA, 2 x 100 MVA transformers were chosen for the station considering diversity factor.

3.4 Substation Maximum Load Calculation.

After obtaining minimumand maximum loads for each feeder as shown in tables 4 and 5, it was revealed that the individual maximum demand is greater than the station load which is used to calculate the diversity factor (DF) as shown below:

$$DF = \frac{Sum\ of\ Individual\ \ Maximum\ \ Dema\,nd\ Load}{Maximum\ \ Demand\ \ Load\ \ of\ the\ Station} \quad 15$$

$$\frac{19+20+22+22+25+22}{124} = 1.048$$

3.5 Transformer Loading

AT 0.8p.f lagging, maximum load of 205.6MVA

Apply diversity factor of 1.048

$$\frac{205.6}{1.048} = 196 \text{ MVA}$$

Loading coefficient $= \frac{S_{max}}{nS_T}$

Where n is number of transformers

$$= \frac{196\ _{X}10^6}{2\text{x}125\ \text{x}10^6} x\ 100\%$$

$= 0.784\%$

With the calculation above, the two transformers are loaded by 78%. This shows that 22% capacity of each transformer will be available for future expansion.

3.6 Transformer Efficiency (μ).

This can be defined as the ratio of power output to power input.

$$\frac{power\ output}{Power\ input} x\ 100\%$$

Scenario 1

$$\frac{176.96}{187.46} x\ 100\%$$

0.944 x 100

94.4%

The results for the other scenarios are shown in table 2

4 RESULTS AND ANALYSIS

In order to calculate the failure rate, reliability, and availability, duration of outages, frequency of outages were calculated and tabulated. The results obtained on causes of frequent power outage are presented in Tables 1 –5 and their corresponding figures below.

Table 3: Statistical Monthly Failure Rate and Availability

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Months	Mean Downtime (Hr/Event)	Mean Time Between Failure	Mean Downtime (Hr/Event)	Mean Tinme Between Failure	Network Failure Rate	Supply Failure Rate	System Failure Rate	Network Availability	Supply Availability	System Availability
	$MDT^{f}_{m,L}$	$MTBF^{f}_{m,L}$	$MDT^{S}_{m,L}$	$MTBF^{S}_{m,L}$	$\lambda^{f}_{m,L}$	$\lambda^{ls}_{m,L}$	$\lambda^{S}_{m,L}$	$A^{f}_{m,L}$	$A^{ls}_{m,L}$	$A^{S}_{m,L}$
January	8.41	17.68	9.09	9.27	0.01	0.02	0.03	0.68	0.50	0.61
February	14.84	9.11	8.95	6.7	0.02	0.03	0.05	0.38	0.43	0.40
March	11.06	8.79	7.91	12.46	0.02	0.01	0.03	0.44	0.61	0.53
April	17.36	6.11	9.72	12.78	0.02	0.02	0.04	0.26	0.57	0.41
May	8.12	7.4	6.76	7.53	0.02	0.02	0.04	0.48	0.53	0.50
June	12.08	7.1	6.53	11.54	0.02	0.02	0.04	0.37	0.64	0.50
July	6.78	9.98	9.28	5.68	0.02	0.03	0.05	0.60	0.38	0.49
August	9.59	7.37	11.35	3.62	0.03	0.04	0.07	0.43	0.24	0.34
September	17.7	5.05	7.38	12.36	0.02	0.02	0.04	0.22	0.63	0.41
October	6.36	9.72	8.88	8.85	0.02	0.02	0.04	0.60	0.50	0.55
November	8.16	13.04	8.82	11.39	0.01	0.01	0.02	0.62	0.56	0.59
December	7.77	11.99	7.96	8.59	0.01	0.02	0.03	0.61	0.52	0.57
Total	11.04	8.76	8.78	8.36	0.02	0.02	0.04	0.44	0.49	0.46

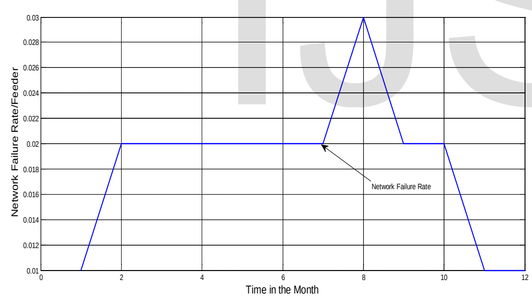

Fig 4: Network Failure Rate-Time Graph

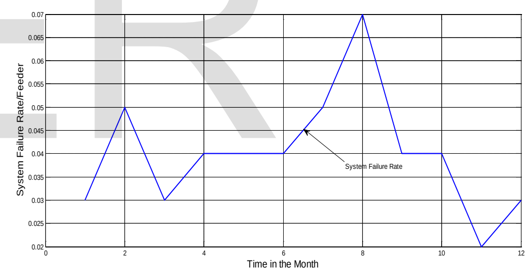

Fig 6: System Failure Rate-Time Graph

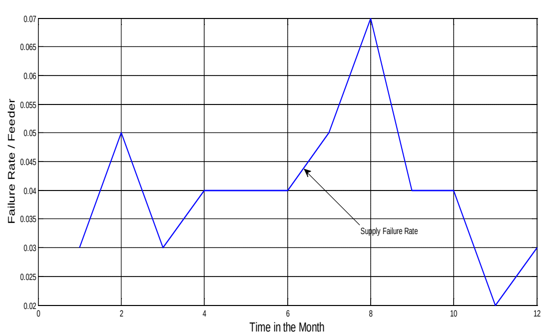

Fig 5: Supply Failure Rate-Time Graph

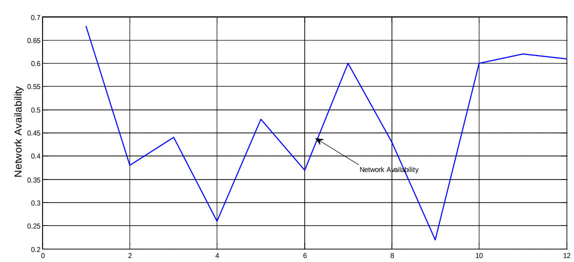

Fig 7: Network Availability Curve

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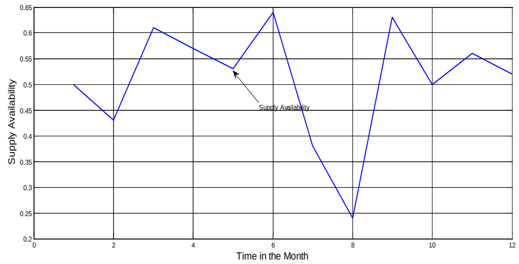

Fig 8: Supply Availability Curve

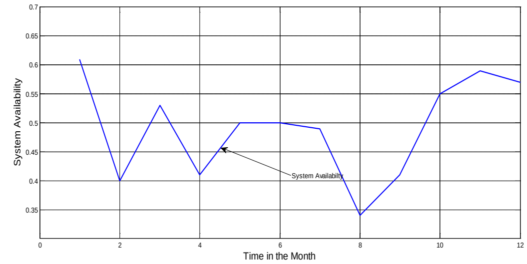

Fig 9: System Availability Curve

Table 4: Hourly Station and Feeders Minimum Load (MW)

Time	Idiroko	Winner	Odigbo B10	Sango B11	FSM	Amje B16	Station
HOUR	MIN	MIN	MIN	MIN	MIN	MIN	MIN
1	13	5	5	8	10	8	5
2	13	5	5	8	10	10	5
3	10	5	3	8	8	10	3
4	8	5	3	8	9	11	3
5	3	5	5	8	9	12	3
6	8	5	3	10	8	14	3
7	8	4	2	10	8	13	2
8	8	5	5	2	10	8	2
9	10	5	5	0	8	6	0
10	8	5	4	0	8	9	0
11	0	6	6	15	9	9	0
12	5	6	7	11	10	6	5
13	0	5	4	5	8	8	0
14	0	5	4	5	12	8	0
15	0	5	4	5	10	8	0
16	0	5	3	5	8	8	0
17	0	4	4	5	10	8	0
18	0	4	3	4	8	7	0
19	0	4	3	4	10	5	0
20	0	4	5	4	10	5	0
21	0	2	5	2	10	5	0
22	0	2	5	2	5	6	0
23	0	5	5	0	10	6	0
24	10	5	5	5	10	7	5

Table 5:Hourly Station and Feeders Maximum Load (MW)

Time	Idiroko	Winners	Odigbo	Sango	FSM	Amje	Station	Feeders Load Boundary	
HOUR	MAX	MAX	MAX	MAX	MAX	MAX	MAX	:MIN	:MAX
1	17	15	12	20	16	18	98	12	20
2	17	15	12	20	17	17	98	12	20
3	15	15	12	20	17	17	96	12	20
4	15	15	11	20	15	17	93	11	20

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5	16	16	14	20	15	18	99	14	20
6	18	16	14	20	15	20	103	14	20
7	17	16	15	21	20	20	109	15	21
8	16	20	15	22	15	20	108	15	22
9	16	20	15	21	15	20	107	15	21
10	16	18	15	20	15	20	104	15	20
11	15	20	14	20	15	20	104	14	20
12	15	15	12	22	15	18	97	12	22
13	18	18	15	20	15	19	105	15	20
14	18	17	17	20	21	18	111	17	21
15	16	17	17	20	21	17	108	16	21
16	17	18	19	20	21	19	114	17	21
17	17	18	19	20	21	20	115	17	21
18	18	18	20	20	21	20	117	18	21
19	19	18	22	22	21	22	124	18	22
20	18	20	17	22	21	22	120	17	22
21	18	16	16	22	25	22	119	16	25
22	17	16	18	22	20	22	115	16	22
23	17	15	17	19	20	20	108	15	20
24	16	15	17	19	20	17	104	15	20

Table 6: Yearly summary of Station and feeders Maximum Load in Mega Watt

Feeders	Maximum Loads (MW)
Idiroko	19
Winners	20
Odigbo	22
Sango	22
FSM	25
Amje	22
Total	130
Station	124

Table 7: Maximum Load Loss

Time	Idiroko	Winners	Odigbo	Sango	FSM	Amje	Substation
HOUR	MAX	MAX	MAX	MAX	MAX	MAX	MAX
1	0.24	0.67	0.58	0.60	0.38	0.56	0.58
2	0.24	0.67	0.58	0.60	0.41	0.41	0.58
3	0.33	0.67	0.75	0.60	0.53	0.41	0.75
4	0.47	0.67	0.73	0.60	0.40	0.35	0.73
5	0.81	0.69	0.64	0.60	0.40	0.33	0.79
6	0.56	0.69	0.79	0.50	0.47	0.30	0.79

7	0.53	0.75	0.87	0.52	0.60	0.35	0.87
8	0.50	0.75	0.67	0.91	0.33	0.60	0.87
9	0.38	0.75	0.67	1.00	0.47	0.70	1.00
10	0.50	0.72	0.73	1.00	0.47	0.55	1.00
11	1.00	0.70	0.57	0.25	0.40	0.55	1.00
12	0.67	0.60	0.42	0.50	0.33	0.67	0.58
13	1.00	0.72	0.73	0.75	0.47	0.58	1.00
14	1.00	0.71	0.76	0.75	0.43	0.56	1.00
15	1.00	0.71	0.76	0.75	0.52	0.53	1.00
16	1.00	0.72	0.84	0.75	0.62	0.58	1.00
17	1.00	0.78	0.79	0.75	0.52	0.60	1.00
18	1.00	0.78	0.85	0.80	0.62	0.65	1.00
19	1.00	0.78	0.86	0.82	0.52	0.77	1.00
20	1.00	0.80	0.71	0.82	0.52	0.77	1.00
21	1.00	0.88	0.69	0.91	0.60	0.77	1.00
22	1.00	0.88	0.72	0.91	0.75	0.73	1.00
23	1.00	0.67	0.71	1.00	0.50	0.70	1.00
24	0.38	0.67	0.71	0.74	0.50	0.59	0.67

Table 8: Differential Load Trend of the Station.

80 MW Source Generation	Total Generation		Total PQ Load		Total Zshunt Load		Total ASM Load		Total losses	
	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
Scenario 1 (Minimum load)	187.46	-691.62	95	77.6	81.96	-1190.25	0	0	10.5	421.03
Scenario 2 (Maximum Load)	207.4	-697.36	115.4	91.4	81.98	-1190.45	0	0	10.02	401.69

scenario 3 (installed capacity)	149.96	-696.82	57.6	77.6	81.98	-1190.48	0	0	10.38	416.06

Table 9: Station Efficiency

SCENARIOS	POWER INPUT (MW)	POWER OUTPUT (MW)	EFFICIENCY (%)
1	187.46	176.96	94.4
2	207.4	197.33	92.3
3	149.96	138.44	92.38

4.2 Discussion

A comprehensive study of 132/33 kV Transmission Substation in Ota network was carried out in this research work. Outage due to faults and load shedding were recorded from their daily logbook and the result was presented in table 3.These were collated, studied and analyzed mathematically. The tables revealed that the outage due to load shedding was greater than the outage due to fault.

From the collated fault data, downtime, mean downtime, failure rate and availability were evaluated for each cause of outage. The results show that outages were not due to fault alone but majorly it was due to load shedding in all the areas serviced by the substation. The following assessments were conducted as reported below:

4.2.1 Failure Rate Assessment

Failure rate of the station was evaluated for network, supply and the entire system as shown in Table 3. In order to establish the causes of failure on the system, both network failure rate, supply failure rate and system failure rate were evaluated. The results revealed that network failure rate, supply failure rate and system failure rate range between 0.01 – 0.03, 0.01 – 0.04, 0.02 – 0.07 failures per month respectively. It is evidently shown that the system failure rate is too high.

Consequently, the reasons for the high in failures were being assessed so that the rate of failure can be reduced. The failure rate- time graph is shown in Figures 4 to 6.

4.2.2 Availability Assessment

The system availability assessment of the substation was carried out using collated data for mean downtime and mean time between failures. From Table 3 network availability, supply availability and system availability were evaluated and the results show that the network availability ranges between 0.26 – 0.68, supply availability ranges between 0.24 – 0.64 and system availability ranges between 0.34 – 0.61. The overall system availability shows that the system was availability for 46% out of 100%. Hence, the people in this area were predominantly in darkness for most of the time. The respective curve analysis of all the availability were shown in Figures 7-9

Consequently, actual causes of this low availability were due to fault and load shedding.

In figure 4, the network availability shows an average value of 0.47 (47 %) which is extremely low. In figure 5, the supply availability shows an average of 0.50 (50 %) which is very low and in figure 6, the system availability shows an average of 0.49 (49 %) which is extremely low. With the analysis above, it is clearly shown that provision of reliable power supply in Ota transmission substation is a problem in the current substation-load scheme

4.2.3 Load Trend Analysis for the station

Tables 4 and 5 indicated the minimum and maximum loads taken by each of the feeders in the station. These were evaluated to know the actual load drawn by each of the feeders in the station. The summation of load drawn by each feeder shows that maximum demand occurred at 19 hrs which is 124 MW as shown in table 5.The maximum supply per hour is 80 MW. It shows that there is insufficient supply which leads to excessive load shedding.

Consequently, it was shown that the station transformer limitation, faults and poor generation are the major causes of outage in the station.

The corresponding daily load curve patterns for feeders in the station are shown in Figures 10 – 16 below.

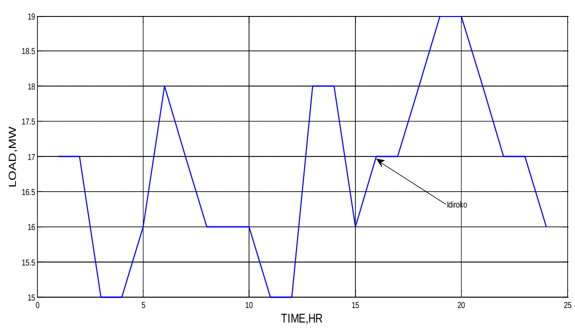

Fig 10: Load Curve for Idiroko

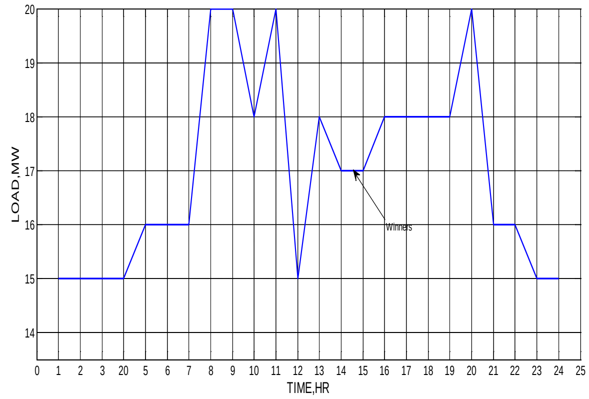

Fig 11: Load Curve for Winners

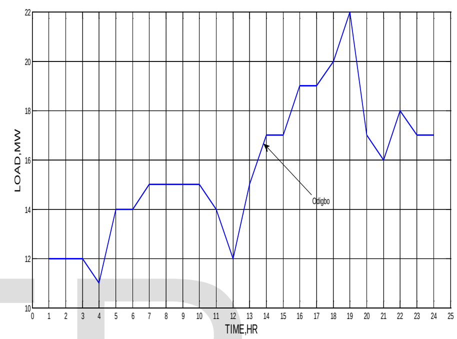

Fig12: Load Curve for Odigbo

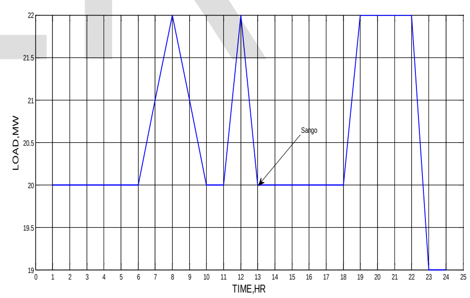

Fig13: Load Curve for Sango

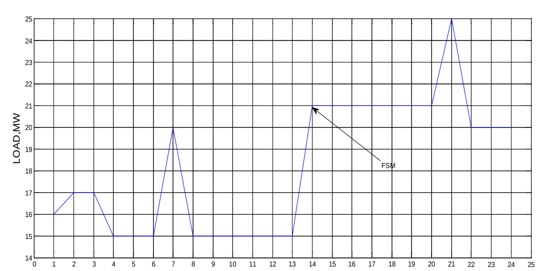

Figure 14: Load Curve for FSM

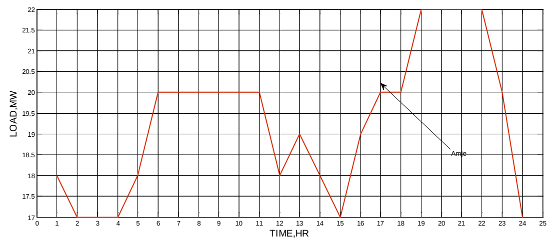

Fig 15: Load Curve for Amje

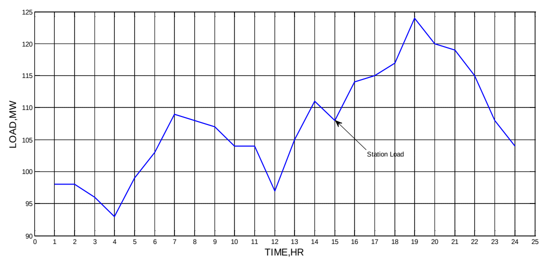

Fig16: Load Curve for the Station

4.2.4 Station Transmission Efficiency Evaluation.

Load measurement was carried out in 132 kV/33 kV Transmission substation Ota as shown in table 4 and 5. The measurements were made all through the twenty four hours, and it was observed that the peak period was between the hours of 7pm to 11pm. The table revealed that FSM has highest load of 25 MW follow by Sango, Odigbo and Amje with 22MW each while winners consumed 20MW and Idiroko with the lowest load of 19 MW as against Station installed capacity of 18 MW, 10.2 MW, 13.95 MW, 19 MW, 11.62 MW, 17.4MW for Idiroko, Winner, FSM, Sango, Odigbo and Amje respectively. It was noted that all the feeders are loaded beyond their installed capacity. Hence, the loading was done in an alternate manner to maintain the power for the station and regulate frequency.

Furthermore, table 6 showed the load on feeders and station load. This was used to calculate the diversity factor in order to calculate the suitable transformer rating for the station. Using equation 14, the result show that the calculated station load is 124 MW and calculated feeders load is 130 MW while the calculated transformer capacity is 205.6 MVA. After the diversity factor was applied 200 MVA transformers will be suitable for the station instead of 205.6 MVAtransformers as against 100MVA installed capacity. This is an indication that the station is overloaded.

4.2.5 Measures for Improving Power Supply to Connected Loads

The energy crisis, which has engulfed Ota for more than decade, has been enormous and has largely contributed to the incidence of poverty by paralyzing industrial and commercial activities in the area. The outage in the area has been assessed and the causes have been ascertained so that measures can be induced to improve power supply to the connected load.

The result of the analysis revealed that at maximum output load, maximum generation of 207.40 MW active power and -697.36 Mvar reactive power were obtained and the total PQ load is 115.40 MW active load and 91.40 Mvar, total Zshunt load (Z type RLC loads and magnetizing branches of transformers) is 81.98 MW active power and -1190.45 Mvar reactive power while the total power losses is 10.50 MW active power and 421.03 Mvar reactive power.

The total generation power at station installed capacity was 149.96 MW, -696.83 Mvar for active and reactive power respectively. Meanwhile the active power supply to the grid was 138.44 MW and the reactive power was -708.34 Mvar and the power loss was 11.52 MW, 11.52 Mvar as shown in the swing bus above an indication that reactive power is flowing from the load into the source of supply due to the under excitation of supply source. With this situation, the power supply was less stable and can cause frequent outage to the system.2 x 100 MVA transformer is therefore recommended with maximum loading of 78%.

Therefore, the following measures are essential tools recommended for improving power supply in Ota transmission substation. The station efficiency of different

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scenarios was obtained as shown in table 4.7. The station is load up to 94.4 % which is too much for the station.

1. To prevent the forced shedding of load at the peak period, the capacity of Ikeja West connection point to Ota transmission substation must be increased.
2. Following the fact that the substation transformer is overloaded, the network system of the station must be upgraded to meet the standard consumer's load in the city.
3. Energy sector should continue to install more and more power plants especially at locations where the fuel such as gas and coal are available until we can generate what is called "maximum demand" in the country.
4. There is need for the continuous training and re-training for the maintenance of generation, transmission and distribution systems.
5. Development of Blue-prints for new Gas, Hydro, Coal, Wind, Solar, Nuclear and Biodiesel Power Plants.
6. Rehabilitation of Existing Power Plants, Transmission and Distribution Systems to Operate Optimally
7. The power factor of the station should be improved in order to reduce reactive power so that more power can be available for use.
8. Improved Gas Supply to the Existing Power Generating Stations especially Pacific power plant (Olorunsogo) in Ogun State so that it can operate at optimum capacity. The installed capacity of this plant is 304MW but what is generating now is 76MW to the national Grid.
9. Efforts should also be made to expand and fortify the transmission infrastructure to ensure deliverability of the power to load centers with minimum loses.
10. There is need to extensively evaluate the potential of all the primary energy sources available in the country. This will give an insight on where to put more investments.

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