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PERFORMANCE METRIC OF ABUJA NETWORK POWER SYSTEM RELIABILITY

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ABSTRACT

This paper presents common key performance indices (KPIs) to evaluate system performance measurement on the power system network. This is to establish acceptable benchmarks for the proposed KPIs. The common epileptic occurrence in the nation's power supply system, recent blackout events which were majorly due to transmission and distribution network failure in Abuja inspired this work. The outage reports of the 132/32kV transmission substation were obtained from the primary data where the frequency and time duration were extracted using a Logical IF program. The time series load records were used to determine expected daily load curves and maximums for the said transmission substation feeders using a statistical-heuristic algorithm that dampens the inconsistencies in records due to load shedding. The result obtained was used to calculate the failure rate for the period of twelve months. The customer-oriented indices for each year, Average service availability index and average service unavailability index were computed. The feeder tripping profile to plan preventive maintenance schedule for a reliable network and efficient customer service was calculated. Programming codes for this method was written in Mathcad Software for quick computation and the results obtained include voltage and power flow profiles in the network, and network efficiency. Reliability indices were also computed for Abuja district PDN in order to characterize or define its reliability with respect to standards.

KEYWORDS: Algorithm, blackout, Feeders, Load, maintenance.

1. INTRODUCTION

Reliability is the probability that an item or collection of items will perform satisfactorily under specified conditions during a given period [6]. Reliability can also be described as the function of an electric power system that satisfies the system load requirement with reasonable assurance of continuity and quality. The measurement of reliability in quantitative terms have been increasable used in recent years to achieve consistency in system performance, assist in making a weighted choice between alternative planning schemes to improve the performance of a particular network and to provide background information which can become a basis for evaluating day to day planning [6]. The rel iability indices or key performance indicator generally used are: System Average Interruption Duration Index, S ystem Average Interruption Frequency Index, Customers Average Interruption Duration Index, Average System Availability Index, Average Service Unavailability Index. The performance of transmission line can be improved by reactive compensation [2], [5], [8] [7]. It is possible to transmit large amount of power efficiently with flat voltage profile if proper types of compensation. These are provided in proper quantity at appropriate places to achieve the desire voltage control. Transmission line loaded to its surge impedance loading will have no net reactive power flow into or out of the line; it will approximately have a flat voltage profile along its length. The voltage at the receiving end will rise beyond the sending end voltage if the line is lightly loaded or due to charging capacitance along the line. In order to maintain a stable voltage and power factor level, compensating element must be employed at both ends of the line. Shunt reactors, shunt capacitors, static-var control, and synchronous condensers are equipment used for compensation. [2] Described a power transmission network as the main energy corridor through which electricity is being transferred to distribution centres. [7] Define transmission network as the medium through which power is being transmitted to the utilisation point. [8] Described transmission network

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as a set of conductors being run from one place to another supported on transmission towers. From the studies of these authors, it can be seen that a transmission networks in power systems are considered to be the medium for transferring generated electrical energy from remotely located power stations to the distribution centres for onward distribution to the consumers or users through a power distribution network (PDN). [1] Stated that all power systems (utility, industrial, commercial, and residential) have in common, the function of providing electric energy safely, reliably, and as economically as possible. Practically all the equipment on the power systems are designed to operate satisfactorily only when the voltage levels on the system correspond to their rated voltage or at most the variations are within 5%. If the voltage variation is more than specified value, the performance of the equipment suffers and the life of most equipment is shortened. He further stated that the power delivered must be characterised by constant or nearly constant voltage, quality voltage and efficiency.[3] expressed the same opinion with [1] that the power supply at every point must also be dependable so as to meet the upmost desire of the customers. [3] Further said that voltage variation has a large effect upon the operation of both power machine and lightings. He explained that a motor is designed to have its best characteristics at the rated voltage and consequently voltage that is too high or low will result in decrease of efficiency.[4] Stated that the quality of the sending end voltage must be within the acceptable range for optimal efficiency of the connected appliances. They emphasised that overvoltage or under voltage may lead to the tripping of circuit breaker and consequently interrupting the service to the customers. [4] Stated that a problem of major importance in power system is the flow of load over transmission lines such that the voltage at various nodes is maintained within specified limit. [1] Description of power system performance as a measure of the output at the customer end can be taken to actually determine the performance of the lines. Assessment of power system helps to evaluate the past performance of power system. This will also help to discover the weak part of the network and reinforcement will be made which will eventually result in optimisation of the system.

2. MATERIALS AND METHODS

2.1 Reliability parameters

Table 2.0 Transformer Parameters

	Name of Substation	Capacity (MVA)	Z_T (ohms)	R_T (ohms)	X_T (ohms)
1	Katampe	2*60	42.76	14.52	40.218
2	Central Area	2*60	30.54	14.52	26.87
3	Apo	165	29.961	14.52	26.207

Table 1.1: Power Holding Company of Nigeria Average Customer Population for 2009

Customer Population by Tariff Classification		Customer Type	Inactive	Active	Total	Energy Delivered (kWh)
Residential	77,026	Maximum Demand	200	406	606	
Commercial	10,387	Prime	160	580	740	

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Industrial	6	Non-Maximum Demand	3,452	43,78 9	47241	
Street Lighting	274	Prepaid Meter	10	80203	80213	
Sub-total	87,693	Total	3,812	124,9 78	128,79 0	100,808,256

The outage reports obtained from the 132/33kV transmission substations were studied to extract the frequency and time duration from it. The outage frequency and duration were obtained using a logical IF programme. The result obtained was used to calculate the failure rate. The failure rate was computed for the period of twelve months from the equation (3.18) below:

$$Failure\ rate(\lambda) = \frac{Total\ number\ of\ failures}{Total\ operating\ times} \quad \text{(i)}$$

$$The\ probability\ failure = \frac{Time\ of\ outage}{Time\ Duration\ in\ the\ year} \quad \text{(ii)}$$

Customer-oriented indices

In addition to the determination of the failure rate, the customer-oriented indices for each year, which are also important reliability parameters, were also computed from the expressions in equations below:

Customer average interruption frequency index, CAIFI

$$CAIFI = \frac{Total\ number\ of\ customer - interruptions}{Total\ number\ of\ customers\ affected} \quad \text{(iii)}$$

System average interruption frequency index, SAIFI

$$SAIFI = \frac{Total\ number\ of\ customer - interruptions}{Total\ number\ of\ customers\ served} \quad \text{(iv)}$$

Mathematically represented as:

$$SAIFI = \frac{\Sigma \lambda_i N_i}{\Sigma N_i} \quad \text{(v)}$$

$where\ \lambda_i\ is\ the\ failure\ rate\ and\ N_i\ is\ the\ number\ of\ customers\ of\ load\ point\ i$

System average interruption duration index, SAIDI

$$SAIDI = \frac{Sum\ of\ customer - interruption\ durations}{Total\ number\ of\ customers} \quad \text{(vi)}$$

Mathematically represented as:

$$SAIDI = \frac{\Sigma U_i N_i}{\Sigma N_i} \quad \text{(vii)}$$

$where\ U_i\ is\ the\ annual\ outage\ time\ and\ N_i\ is\ the\ number\ of\ customers\ of\ load\ point\ i$

Customer average interruption duration index, CAIDI

$$CAIDI = \frac{Sum\ of\ customer - interruption\ durations}{Total\ number\ of\ customer\ interruptions} \quad \text{(viii)}$$

Mathematically represented as:

$$SAIDI = \frac{\Sigma U_i N_i}{\Sigma \lambda_i N_i} \quad \text{(ix)}$$

$where\ \lambda_i\ is\ the\ failure\ rate, U_i\ is\ the\ annual\ outage\ time$
$and\ N_i\ is\ the\ number\ of\ customers\ of\ load\ point\ i$

Average service availability index, ASAI

$$ASAI = \frac{Customer - hours\ of\ available\ service}{Customer\ hours\ demanded} \quad \text{(x)}$$

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Mathematically represented as:

$$= \frac{\Sigma U_i \times 341 - \Sigma U_i N_i}{\Sigma N_i \times 341} \qquad \text{(xi)}$$

Average service unavailability index, ASUI

$$ASUI = 1 - ASAI = \frac{Customer - hours\ of\ unavailable\ service}{Customer\ hours\ demanded} \qquad \text{(xii)}$$

Mathematically represented as:

$$= \frac{\Sigma U_i N_i}{\Sigma N_i \times 341} \qquad \text{(xiii)}$$

3. RESULT AND ANALYSIS

Table 4.29 ***132kV and 32kV Reliability Assessment***

Customer Oriented Interruption Indices	Symbol	Value (133kV)	Value (32kV)
		2005	2005
Number of outage incidences		89	2734
Outage duration, (hrs)		107.00	24489.00
Failure rate	λ_i	89.00	2734.00
Mean Time Between Failure	MTBF	0.0112	0.0004
Mean Downtime Between Failure		0.0102	0.3121
Number of customers on load point *i*	N_i	47677	47677
Number of load points	*i*	3	3
Annual outage time (hrs)	U_i	127	127
Active customer population		44538	44538
Inactive customer population		3139	3139
Total number of customers	$\sum N_i$	47677	47677
Total number of customer-interruptions	$\sum \lambda_i N_i$	4243253	130348918
Sum of customer-interruption durations, customer (hrs)	$\sum U_i N_i$	6054979	6054979
Customer hours of available service		8633	8633
Customer hours of unavailable service		127	127
Customer hours demanded		8760	8760
System Average Interruption Frequency Index	SAIFI	95.27	2926.69
System Average Interruption Duration Index	SAIDI	89	2734
Customer Average Interruption Frequency Index	CAIFI	127	127
Customer Average Interruption Duration Index	CAIDI	1.43	0.05
Average Service Availability Index	ASAI	75625080	75625080
Average Service Unavailability Index	ASUI	0.01	0.01

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For efficient customer service, the feeder tripping number as well as interruption duration should be at minimum. This study helps in the transmission network expansion planning also by identifying the frequently tripping feeders enabling the transmission company either by effective maintenance scheduling or by laying standby feeder network for minimizing electric supply interruptions.

3.1. 132 kV Apo Feeder

Figure 4.1 shows the curve for active load consumption of Apo feeder. The activities here are very high because of offices, pure domestic use and industrial processes. The active load increases progressively every quarter. The peak for the first quarter is 104MW; second quarter is 120MW and third quarter is 154MW. This is an indication that the rate of load growth in this area is very high. The loads start to pick at 4:00hour in the morning and remain a bit stable for about 7hours. Afterwards, a gradual drop is expected before another pick in the evening peak. The active peak load consumption on Apo feeder is 154MW at 19:00hour. The total installed capacity of this station is 128MW; it is obvious that the network is overloaded. The loading of the substation is 120% at maximum load. The total loss on 33kV network is 27172MWhr which translates to N334, 216,000.00 in year 2009. On 132 kV , the total loss is 444MWhr

The maximum load demands for 33kV Central Area, Apo, and Central area are 63.3, 144.9 and 108MW respectively while the minimum loads are 60, 131 and 97.55MW. The maximum demands for 132kV Katampe, Apo, and Central area are 142, 154 and 89MW respectively. The 132 and 33kV load curves help to determine the maximum load of the Abuja feeders at a glance. With these, the power utilities are enabled to prepare the operation schedule of the station so as to avoid overloading.

The voltage profile graph is a veritable tool for the system operator to monitor the system voltage and enhance his quick reaction to salvage the network in case of voltage deterioration. The maximum permissible limit reference recommended by the Institute of Electrical Engineers (IEE), U.K regulation is ±5% which PHCN adhered to Voltage range on 132kV Katempe, Central Area, 33kVGarki2, Domestic and international Airport, Gwagwalada, Life Camp, Jabi and Maitama are below the acceptable value.

The failure rate of the 132 and 33kV network are 89 and 2734 respectively. Reliability is an indispensible method of measuring the performance of power system.

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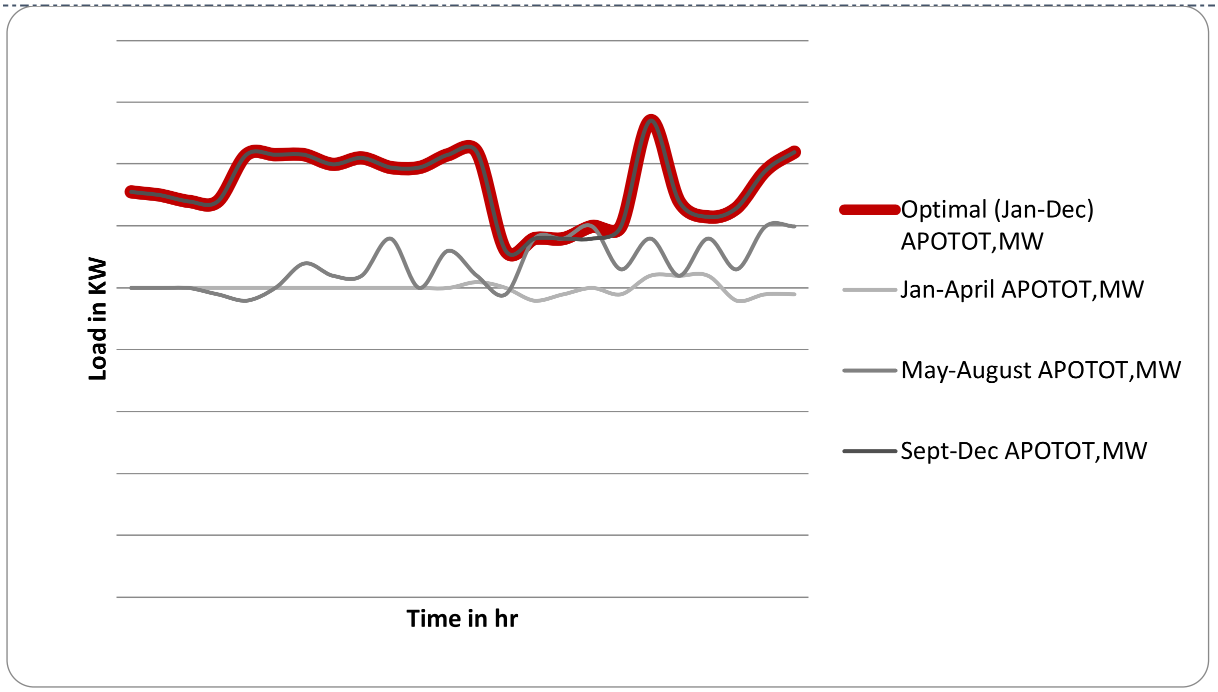

Fig. 3.1 DAILY ACTIVE LOAD CURVE AT 132KV AT APO FEEDER FOR 2009

3.2. 132 kV Katempe Feeder

Figure 4.1 represents the load curve for 132kV Katampe feeder. The curve represents the summation of all the loads at different instants during different hours from where the peak load and its time are obtained. It was observed from the curve that, there is an increase in the active load demand at about 17:00hours largely due to the industrial load connected.

The load starts to pick at 17:00hour and peak at 19:00hours with maximum load of 142MW. The installed capac ity is 141MW; the loading of the station is 100%.

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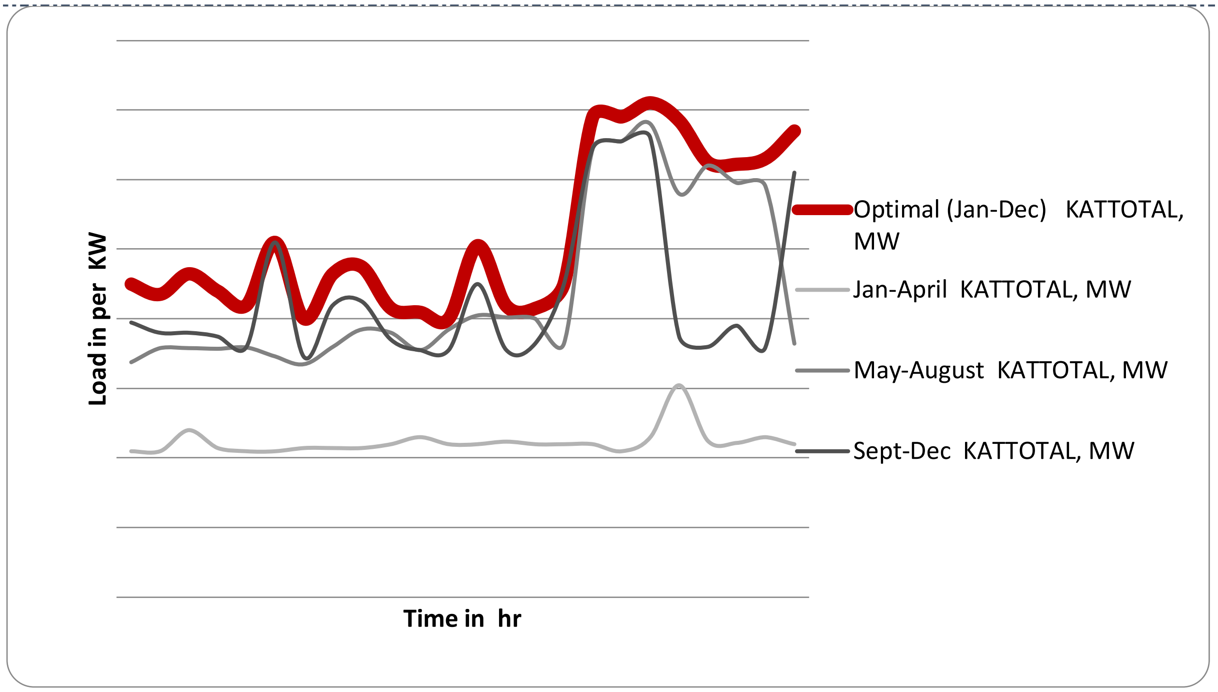

Fig.3.2 DAILYACTIVE LOAD CURVE AT 132KV AT KATAMPE FEEDER FOR 2009

3.3 33kV Central Area Feeder

Figure 3.3 is the daily load curve at 33kV voltage level. The trend is similar to that of 132kV except that the magnitude of the load power demand differs. The maximum load power for the day is 63.3MW and it occurred at 11:00hour.

Fig. 3.3 DAILY ACTIVE LOAD CURVE 33KV AT CENTRAL AREA FEEDER FOR 2009

4. CONCLUSION

This study has focussed on the technical losses estimation in the network. The system is characterised by high voltage drops and power losses associated with long line and fragile radial network, which make it vulnerable to

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failure and poor performance. The truth is that the number of tripping on 33kV is more due to long length of some of the feeders which was achieved by the KPI's.

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