



## Loaded Distribution Transformers Measurement Method for Reliability Benin Electricity Distribution Company (BEDC) Environ: A Case Study

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### ABSTRACT

*Distribution Transformers (DTs) are a very vital kit. It makes certain the network is stable and reliable. Transformers can break down over time owing to numerous causes such as excess load, broken-down insulation, cellulose wear and tear, and poor dielectric intensity. Nevertheless, transformer vendors have become aware of the difficulty in monitoring the operation of DT relevance which ends in usage malfunction. Investigations of loaded DT workings culminate in the secondary interconnected to Power Analyzer PCE-PA 8000. The method for conducting investigational set-up of loaded reliability quantities DTs 1000 kVA and 500 kVA, 11/0.415 kV for analysis include the management and protection engineers' responsibility to act following the parameters examined. The methodology of utilizing the agreed power quality (PQ) apparatus provides a reliable investigational technique for appraising the operation of DTs.*

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### INTRODUCTION

Transformers are PS paraphernalia employed that transform AC voltage source with a matching variation in the current (Ullah et al, 2018; Eyenubo and Oshevire, 2017). Fields of transformer usage in PS set-up comprise generation, transmission establishments and DSP systems. A transformer is comprised of two sections of distinct steel foliation denoted as fundamental and secondary sides. Two groups of corresponding to voltage change in transformers: firstly, if the turns ratio is increased in the secondary coil this causes higher voltage in the lower part; by arrangement, NP and NS have corresponding voltages i.e. VP and VS (Edan, 2013). Similarly, transformers are characterized either by core or Shell arrangements. In the latter, the passage on the flux returns is outwardly constructed to include the windings while in the former limbs are intended to be concentrically enclosed.

As a rule, DTs are generally employed by the ESPs for their proposed capability to convert MV from PV to a usable voltage. Some practices for transforming 3-phase voltage to high or low are obtainable in practice; commonly amongst connections are open-delta and Scott connections (Vintan and Buta, 2006; Eyenubo, 2016). In DSS connections are generally utilized to ensure consumers are reachable. If a step-up transformer is used, the secondary section will

be joined together in a star. Contrariwise, when operated as a step-down, the secondary unit will be a star since the electricity delivered to end users will need an earthed neutral (Oluwajobi et al, 2012).

Concerning power production, the quantity and dislodgment of the 3-phase output are seen to be side-by-side attainable in distribution/transmission set-ups. The outcome is unequal voltage reduces the set-up and operation of electrical paraphernalia such as DTs (Mirzai et al, 2006). This paper targets to examine three-phase DTs set up power service undergoing unbalanced voltage settings will be requiring an algorithm of on-load DT approach reliability. Factors of the preferred DT substations used are presented as list figures and depictions are shown (Indulkar and Ramalingam, 2008).

### DISTRIBUTION SYSTEM FUNCTIONING FACTORS

The Nigerian procedure has remained challenging to efficiently observe functional DTs in the circle of service providers, possibly as there are frequently various DTs on specified feeders. Loading is a parameter applied in transformer operation. This explains the purpose why a substantial number are lost. Consequently, PACE-PA 8000 for experimentations ascertains parameters valuable in censoring distribution transformers'



operation on-load. The distribution set-up factors are often established in evaluating network proficiency, power configurations, functioning frequency, phase-neutral voltage, phase-phase voltage, a current flowing, PF, harmonics etc.

Associated with PF are AP and APP (Malengret1 and Gaunt, 2020) since distribution

$$\cos \phi = \left[ \frac{S}{1.73(IV)} \right] \quad (1)$$

Where,

$S$  = APP in Volt-amperes.

$I$  = Current in the circuit.

$V$  = Line voltage.

$$\text{Power factor} = \frac{\text{kW (real power)}}{\text{kVAR (apparent power)}} \quad (1)$$

But,

$$\text{kW} = \text{KVA} \cos \phi; \text{kVAR} = \text{KVA} \sin \phi$$

$$\text{Therefore, } \text{KVA} = \sqrt{\text{KW}^2 + \text{KVAR}^2} \quad (3)$$

Where,

$\text{KVA}$  = APP in kilovolt-amperes

$\text{kW}$  = AP in kilowatts

$\text{kVAR}$  = RP in kilovolt-amperes reactive

In expressions (1) - (3), it is obvious that PF fluctuates and the value varies between 0 and 1. A PD setup largely includes linear and non-linear loads. If APP is greater than AP in value it suggests its nonlinear loads which alter the current waveform. Customer with high PF attracts less current when compared with low those of PF. Therefore, managing set-up with a high PF reduces losses rather than operating it at a low PF. Thus, set-up at low PF pulls higher currents and adds to the loss in the system (Mercer and Miclaus, 2018).

The correction of PF incurs an obvious cut in APP drawn from the AC source bringing about a decrease in distribution deficiencies. This affects RP operation in the

level could be expressed as a ratio of AP to APP supplied to customers denotes electrical proficiency (Eyenubo and Otugoma, 2016). A phase variance is present amid the power delivered in the set-up; thus, the PF of a network is depicted and is symbolized as (Malengret1 and Gaunt, 2020):

set-up. Unique procedures cause RP to correct the network (Malengret1 and Gaunt, 2020). Among the procedures is the RP compensation valuable know-how used in enhancing the functioning of PSs. The RP most time brings about high productivity and reliability setup. It is worth stating that RP compensators (VAR) require control to improve RP corroborations for both static and dynamic power arrangements. PQ problems may arise due to voltage/current or operating frequency dropping less than specified levels. The economic effect of PQ for end users comprises the failure to use the electric power delivered by utility providers especially on the accumulated revenue collections and power paraphernalia breakdown

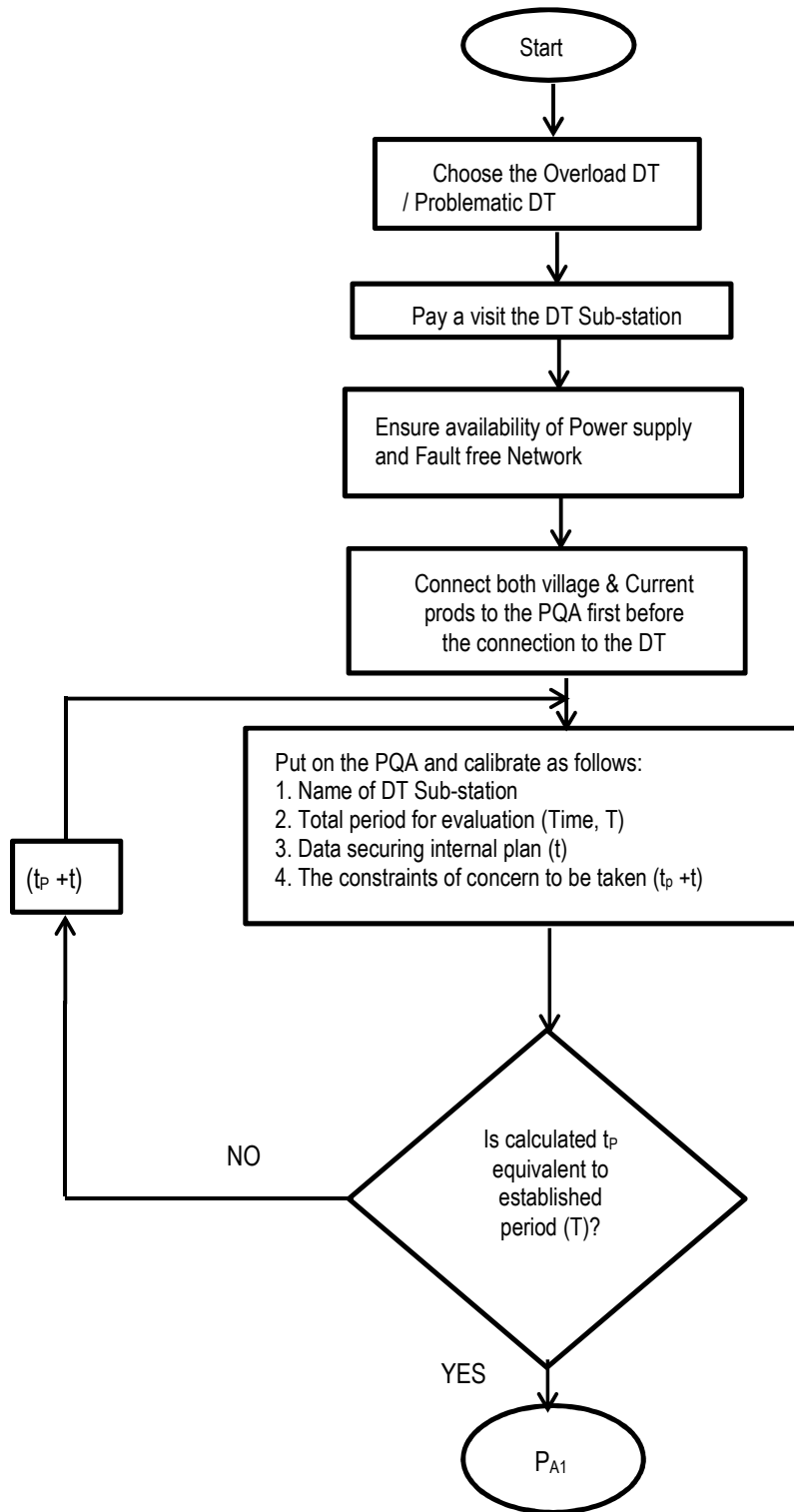
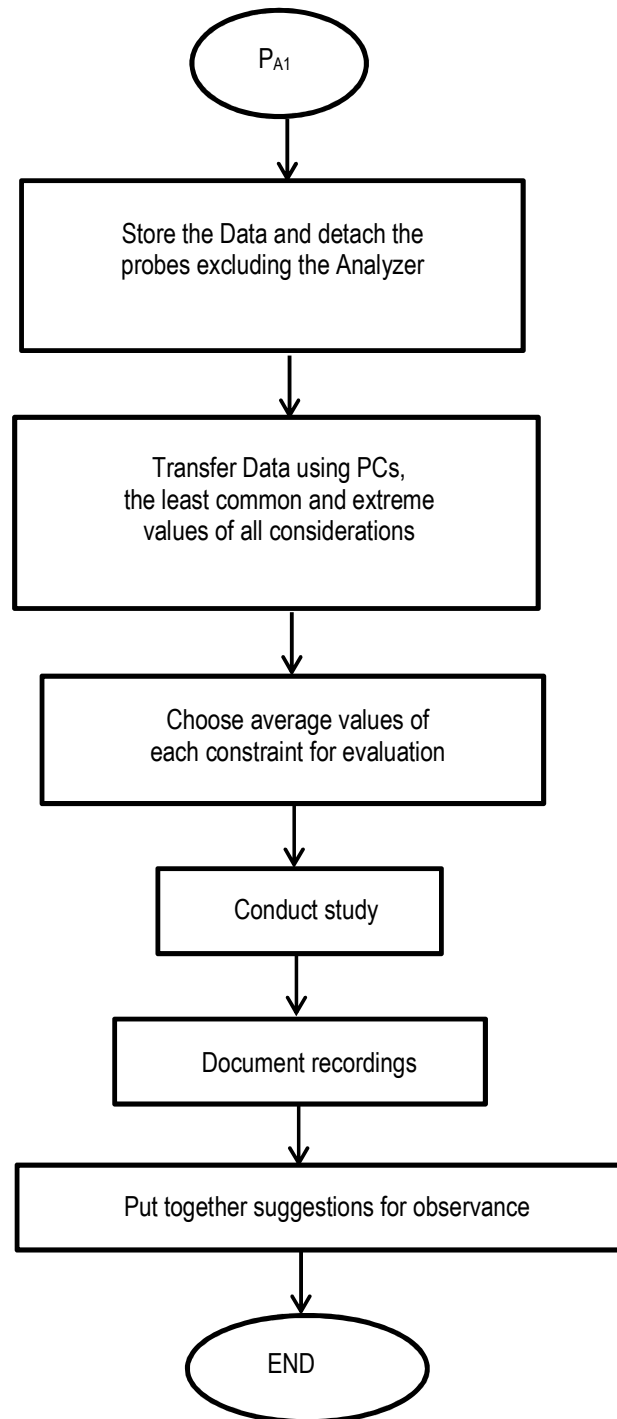


Figure 1: Flow activity of a characteristic DT power study applying PQ and Energy Analyzer Apparatus



**Figure 2:** Protraction of Flow progression of typical DT power examination using PQ and Energy Apparatus



**Table 1:** Quantity of transformers per voltage sub-populace in different sites for the year 2010 – 2016

		Transformers in locations (kV)							
Locations		2010	2011	2012	2013	2014	2015	2016	Ave
Koko Feeder	1000	2	2	2	2	2	2	2	2
	500	9	8	10	13	15	11	12	11
Nekpenekpe Feeder	1000	4	5	5	6	7	4	6	5
	500	12	11	13	12	11	15	11	12
Ikpoba Dam Feeder	1000	7	8	6	6	7	8	7	7
	500	15	14	14	13	15	14	16	14
Etete Feeder	1000	4	4	5	4	4	4	4	4
	500	23	21	23	25	30	45	50	31
Guinness Feeder	1000	7	7	6	5	6	7	7	6
	500	32	56	62	45	75	67	74	59
Street	1000	4	3	4	5	4	4	4	4
Feeder I	500	112	145	170	155	165	172	155	153
Street	1000	4	4	5	4	4	4	5	4
Feeder II	500	120	113	161	172	155	169	156	149

**The Technique of Investigational Plan for Reliability Magnitude of On-Load DT**

The method required for investigating overloaded DTs in utility provider set-ups with various power statuses is carefully selected and inspected. In an instance where the set-up is very large, pre-inspection is made to the substation, the physical condition of both the HT and LT lines, cleanliness of the cable, lugs, bushings, earthing, feeder pillar etc. are carried out; accessibility of feeders in the substation of the DT selected for the experiment thoroughly checked. Testing is done online while the feeder line is ON and end users on such DT are on electricity supply. The representation of the experimental correlation of the Feeder line, DT, Feeder pillar and the Testing equipment PAPCE-PA 8000 instrument is shown in the flow diagram in Figure 1.

Two DT substations were chosen, this includes, 1000 kVA and 500 kVA, and 11/0.415 kV are set up in Table 1. At both DT substations, the procedures of connection in Figure 1 are ensured below:

1. Confirm a fault-free set-up and that the powered.
2. Connect the PAPCE-PA 8000 device to the bushings of the secondary terminal DT
3. Attach the other side of the device to the incomer cable terminuses Feeder Pillar.
4. Ascertain standardization of the device so that the period (T) is chosen and the time interval (t) of

documentation is selected. While these controlled time ranges may differ from person to person. Nonetheless, in this study, Duration time T and interval time t were taken as 60 and 5 minutes for the scenario.

5. Ensuring that earthing of DT and the device is carried out.
6. Settings of the functioning factors proposed to be determined by the device, for this experimentation, the considerations include RMS values of voltage/current, frequency, and PF.
7. Use the device linked to the PC to record the current/voltage data that traversed the DT.
8. Allow all connections then switch – on the device.
9. Let the apparatus stay ON for the duration time (T) regulated.
10. Once period (T) is achieved, the apparatus will be removed.
11. The documented results in paraphernalia at an interval of time (t) in duration time T operational deliberations are stored in the PC for further consideration.
12. Plots from each consideration were analyzed using a computer Excel application.

**RESULTS AND DISCUSSION**

**Scenario: 1000 kVA, 500KVA, 11/0.415 kV**

**DTs**

The process depicted was pragmatic in the study of transformer substation utilizing the planned calibrations as follows:

1. Total Period of Assessment ( $T_1$ ) = 60 minutes (for voltages/current and frequency)
2. Total Interval of Examination ( $T_2$ ) = 1 hour (for AP, APR and RP and PF)
3. Number of analyses = 4 (For voltages/currents and frequency magnitudes in time ( $T_1$ ))

4. Number of readings = 4 (During AP, APR and RP and PF dimensions in time ( $T_2$ ))
5. Data time interval ( $t$ ) = 8 minutes

The outcomes of the experimentation are displayed in Table 2 - 8 while its graphical assessment making use of computer Excel is presented in Figures 3 - 8.

Table 2: Rms Voltage (Phase to Neutral)

Time	Vrms L1-N (V)	Vrms L2-N (V)	Vrms L3-N (V)	Vrms N-G (V)
1	215.21	217.15	214.42	1.42
2	221.42	212.01	222.52	2.06
3	195.23	220.42	214.21	2.04
4	200.95	202.52	213.63	1.98
5	222.42	198.85	211.56	1.96
6	205.01	211.12	225.41	2.18
7	215.21	224.45	211.56	2.03
8	198.86	213.45	223.62	1.94

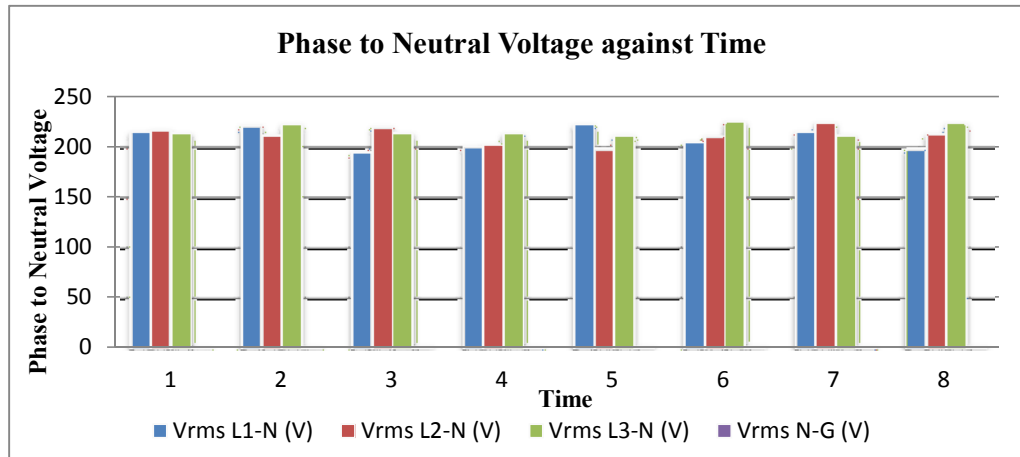
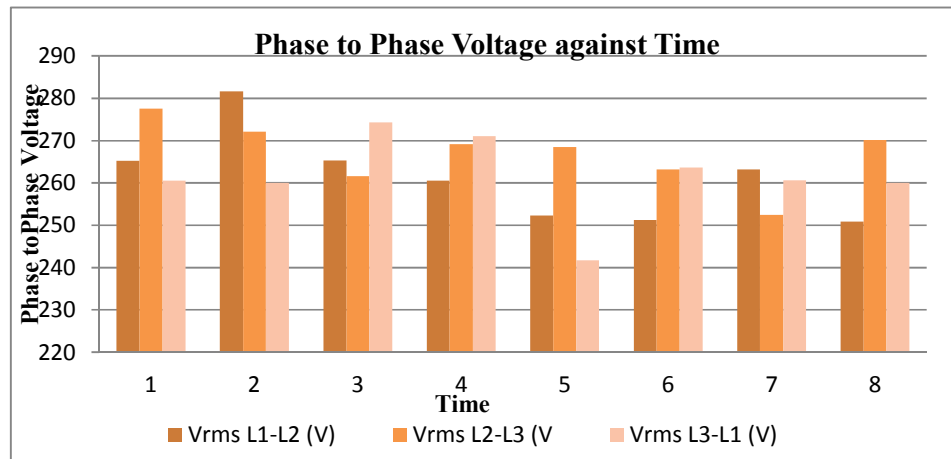


Figure 3: Phase to Neutral Voltage



**Table 3:** Rms Voltage (Phase to Phase)

Time (hr)	Phase 1 (V)	Phase 2 (V)	Phase 3 (V)
1	265.18	277.54	260.54
2	281.62	272.09	260.02
3	265.25	261.61	274.32
4	260.55	269.22	271.03
5	252.25	268.45	241.65
6	251.21	263.24	263.63
7	263.25	252.45	260.56
8	250.86	270.15	260.02



**Figure 2:** Phase-to-Phase Voltage against Time

**Table 4:** Current

Time (hr)	Line 1 (A)	Line 2 (A)	Line 3 (A)	N- (A)
1	115.21	117.15	114.42	56.5
2	165.41	154.01	161.48	65.4
3	185.23	176.23	175.25	68.8
4	176.36	165.32	155.98	71.5
5	182.51	198.01	173.32	78.1
6	151.21	165.24	168.44	77.5
7	145.42	152.47	160.25	70.9
8	161.25	157.35	160.32	67.8

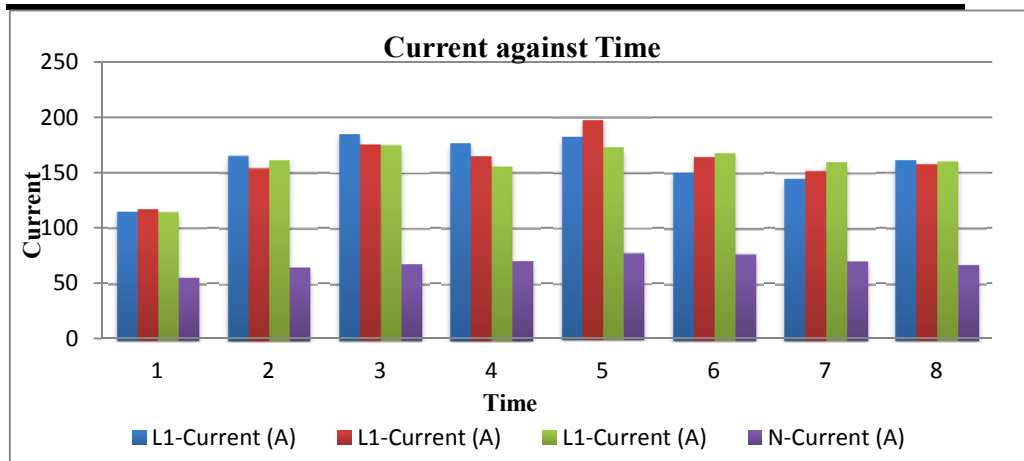


Figure 3: Display of Current on each Phase against Time

Table 5: Frequency

Time (hr)	Frequency (Hz)
1	50.521
2	50.623
3	50.259
4	50.550
5	50.257
6	50.258
7	50.356
8	50.865

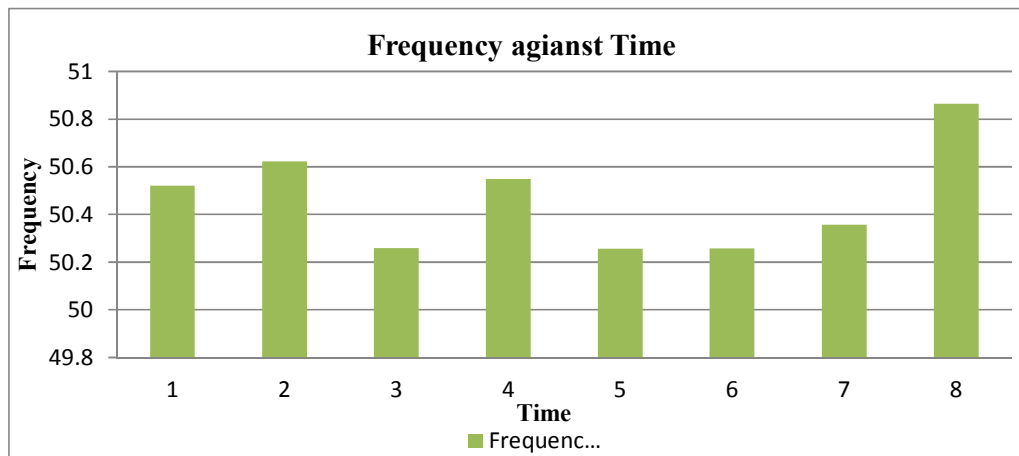


Figure 4: Frequency against Time





**Table 6:** Apparent Power

Time	Line 1 (VA)	Line 2 (VA)	Line 3 (VA)	Total (VA)
1	25652	26770	27521	79943
2	30245	32152	31563	93960
3	33324	34123	32571	100018
4	34695	33782	32951	136123
5	33625	33894	32768	100287
6	32560	31862	32454	96876
7	31456	32333	31865	95645
8	30780	31223	32524	66827

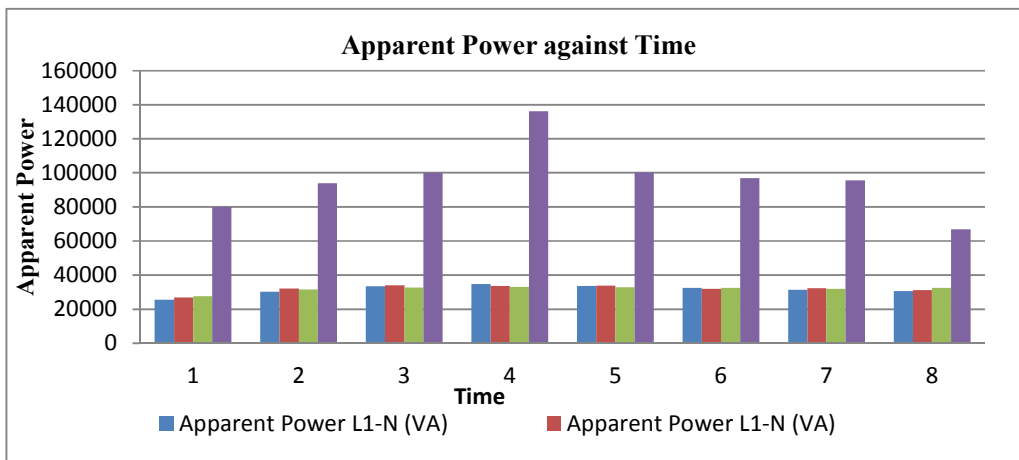


Figure 5: Apparent Power against Time

TOTAL APP = 769, 676KVA  
 AVE APP = 96,210 KVA

**Table 7:** Reactive Power

Time (hr)	Line 1 (VAr)	Line 2 (VAr)	Line 3 (VAr)	Total (VAr)
1	6465	8985	10256	25,706
2	6742	8536	10652	25930
3	6964	8872	10666	26502
4	6846	8756	10685	26287
5	6633	8569	10624	25816
6	6568	8473	10486	25367
7	6365	8285	10326	24976
8	6188	8216	10314	24718

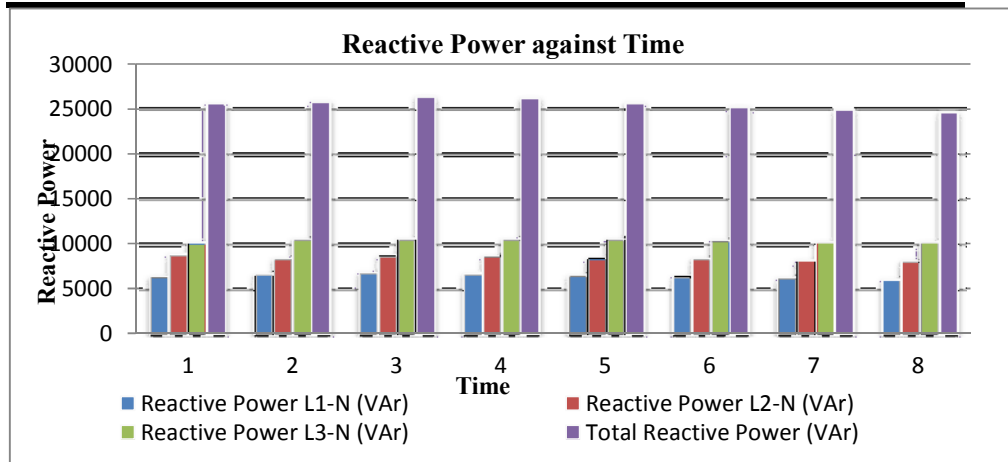


Figure 6: Reactive Power against Time

TOTAL RP =205,302 KVA  
 AVE RP = 25.66 KVA

Table 8: Active Power

Time (hr)	L1-N (W)	L2-N (W)	L3-N (W)	Total (W)
1	34657	39853	42561	117071
2	37422	35363	46524	119309
3	39647	48725	56662	145034
4	38462	47569	56854	142885
5	36336	45696	56243	138275
6	25688	34735	44868	105291
7	23652	32853	43264	99769
8	21889	32165	33145	87199

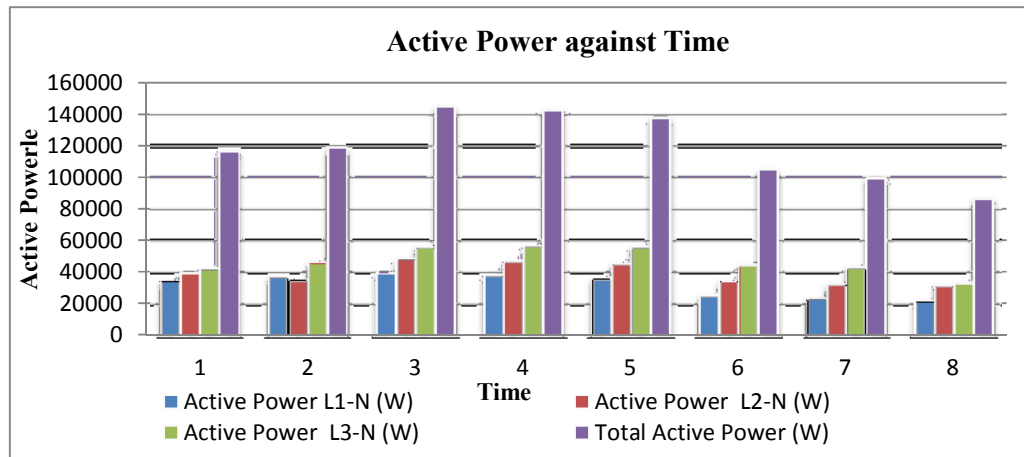
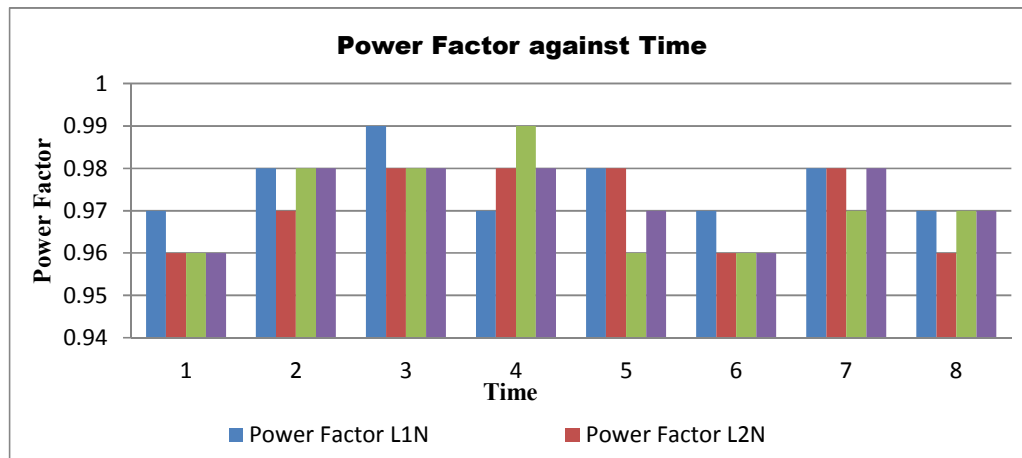


Figure 7: Active Power against Time

TOTAL AP = 954833 KW  
 AVE AP = 119.354KW

**Table 9: Power Factor**

Time	Line 1	Line 2	Line 3	Mean
1	0.97	0.96	0.96	0.96
2	0.96	0.97	0.96	0.96
3	0.96	0.96	0.96	0.96
4	0.96	0.96	0.96	0.98
5	0.96	0.96	0.96	0.96
6	0.96	0.96	0.96	0.96
7	0.98	0.96	0.96	0.98
8	0.96	0.96	0.97	0.96



**Figure 8: Power factor against time**

Observations: the attained phase-to-neutral voltage varies from 195.23V to 224.45V whereas the phase-to-phase RMS voltage goes from 250.86V to 281.62V. The two classes of voltage fall in satisfactory values of ranges of 220V for single phase and 415V for 3- correspondingly. The load on this transformer is not balanced since the 3-phases do not possess the same values that are reasonably close. The functioning frequency was between 50.257Hz to 50.865Hz, thus the procedure is thought steady. The mean values corresponding to AP, APP and RP are 119.35 kW, 25.66 kVA and 96,210 kVA respectively. The ratio of RP to AP in this DT arrangement is 22.59% which is comparatively satisfactory by criteria taking into account the values of average AP and RP. Lines PF is remarkably good, and they are within the set of values minimum being 0.96 and a maximum of 0.99 amidst the three phases.

The network system PF ranges from 0.96 to 0.99 and the general standard system PF were projected 0.97. Bearing in mind the

normal apparent power value of 96,210 kVA loading of this DT with its 1000/500kVA assessed capability, this suggests the proportion loading of this DT at that hour was 25.39%. The records were acquired at the off-peak load of the DT substation. The Energy Indicator of Reliability (EIR) is expressed as the proportion of the predictable energy not supplied (PENS) all through long intervals of adherence to the complete energy need (CEN) all through the same interval. In this setting with a routine PF of 0.97, the total attainable load on 1000/500 kVA, 11/0.415 kV transformer is 119.354 kW. Consequently, the energy indication of reliability is 2.73.

**Post Investigative Proposals**

When the experiment was completed the results are achieved; it becomes essential to relate the recommendations to the owner of the DT and how the network reliability can be further enhanced. Such views are

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accomplished by the field operating engineers. Consequently, these suggestions comprise:

1. The unbalanced loads in the DT substation analyzed necessitate high documentation of neutral current shown in Table 2; it becomes obligatory for the control Engineers to explore the set-up and balance load in all the phases. Hypothetically, the 3-phase loads ought to be equal which will lead to zero neutral currents.
2. The mean PF for the DT is 0.97 shown in Table 8. Over time when the network PF drops below 0.85 on the field, installing a suitable range of capacitor bank will become necessary for PF correction to desired specification (0.9 to 0.95)
3. The usage of basic gadgets in the substation is essential.
4. Appropriate grounding of substation equipment must not be compromised.
5. The DT substation must be kept tidy and free from moisture ingress.

## CONCLUSION

Functional transformer consideration is for regular allocation for utility companies; manufacturing productions, joint corporations and other exclusive owners of the transformer. This paper has offered On-load techniques for measurement reliability of DTs. It entails the growth of the algorithm and the preparation of a flowchart that illustrates the experimental processes. The case reviewed public DTs belonging to the Nigerian power utility stationed at Benin City in Edo State and environs; different results are generated and extensively deliberated. Power factor classification for transformers is an extremely crucial part of these outcomes. Where the ascertained PF is high, a need for power factor correction mechanism would be needed. Thus, it is obvious that online censoring of DTs' accomplishments would improve the high-reliability operation of such transformers.

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