Enhancement of Power Supply with Paralleling of Transformers Using Same Parameters Approach

Igbogidi, O. N.[1], Dahunsi, A. A.[2]

[1]Lecturer, Dept. of Electrical Engineering, Rivers State University, Port Harcourt, Nigeria
[2]PhD Student, Dept. of Electrical Engineering, University of Port Harcourt, Nigeria

---

***Abstract**: Parallel operation of transformers is the connection of their primary windings to a common voltage supply and their secondary windings to a common load (bus). This research is a practical detail of enhanced power supply with paralleling of transformers using same parameters approach on Rivers State University 2 X 15MVA, 33/11kV Injection Substation in Nigeria. Data were collected from Port Harcourt Electricity Distribution Company and Transmission Company of Nigeria. However, appropriate equations were advanced to generate relevant data for successful load flow analysis. The data collected in conjunction with relevant data generated served as input source in Electrical Transient Analyzer Program 12.6 software. The load flow analysis at the first instance was conducted and a higher substation power loss of the value 1004.9kw was encountered. T1A carried 5.613MVA representing 37.4% was observed to have higher safe free space for further loads while T2A carried 9.443MVA representing 63.0% was observed to have reduced safe free space for further loads. Substation power loss was reduced from 1004.9kw to 945.2kw in the second load flow (New Case) analysis when T1A and T2A were connected in parallel. T1A and T2A shared equal loads of 7.596MVA each with adequate safe free space to accommodate further load as well as making sure essential loads are not interrupted in the event of the failure of one transformer. The New Case showed enhanced power supply with paralleling of transformers using same parameters approach.*

***Key words**: Load, Circulating current, Paralleling, Same parameters, Load sharing, Bus, Injection substation*

1. INTRODUCTION

Parallel operation of transformers can be said to be a common practice in the electricity utilities. Parallel operation of transformers provides for efficiency, availability, reliability and flexibility of the power system. Power transformers usually exhibit maximum efficiency when operating close to full load. When transformers are connected in parallel generally, one of them can be switched off for maintenance purposes without incurring an unwanted loss of load (especially where the remaining transformers have enough load supply capability). This accounts for increased availability of power supply. Similarly, a parallel connection facilitates the inclusion of back up transformers in the event of a fault which makes power supply reliable. Very importantly, paralleling of transformers adds flexibility to attend to the demand growth of a power system as new transformers can be incorporated in a modular fashion [1].

Electrical systems have been utilizing paralleled transformers over the years. Electrical utilities are ideal examples of these applications. Their main objectives have become reliability and power quality together with making sure consumers are on-line [2]. In most cases, existing transformers are connected in parallel in industrial and commercial facilities when facility engineers, consultants or maintenance staff are looking for ways of ensuring that power systems become more reliable, provide better power quality, prevent or inhibit voltage sags, or for additional load requirements [2]. For supplying a load in more than the rating of an existing transformer, two or more transformers are usually connected in parallel with the existing transformer. The transformers may be connected in this way when load on one is considered more than its capacity. Due to transformer parallel operation reliability of power system is increased and damage to the different types of equipment in substation especially transformers is reduced. To achieve parallel operation of transformers some conditions are to be satisfied compulsorily [3]. Power transformers represent vital equipment, and their availability has a major impact on the reliability of a power system. Being one of the major elements of a network, power transformers have been considered a major focus of a great number of studies with regards to so many issues that involve diagnostic methods, fault detection and the effects of loads in their ageing [1].

The present connection of transformers at the Rivers State University 33/11kV Injection Substation for example thus inhibits efficient and optimal utilization of the four transformers according to station records. Wokoma and Federal 11kV feeders seldom remain in service at peak due to excessive load leading to transformer trip. Incessant transformer tripping occurred resulting from transformer over-load set trip as the two feeders are tied to the same transformer. This affects the availability and reliability of power supply. This speaks negative volume on transformer efficiency. It does not allow for expansion and flexibility. This generally encourages unnecessary load shedding due to poor transformer capacity utilization at the Substation. It will be pertinent to observe that ideally, there is that dear need to provide quality power supply to the industrial, commercial and domestic environments. The Rivers State University

33/11kV Injection Substation is short of the capacity utilization requirement for future expansion except improvement strategy is employed.

2. RELATED WORKS

If a large size or rating of transformer is not available particularly that that can supply the total load requirement, two or more small size transformers can be linked in parallel to raise the capacity. If installation area such as substation is located far away, consequently, transportation of smaller size of transformer becomes a lot easy and may be economical. It will directly affect the cost. In a case where one of the transformers run in parallel is out of the system, it becomes obvious that the system will share the load accordingly without interrupting power supply. If certain number of transformers are run in parallel, we can therefore shut down any one of the transformers to carry out the required maintenance. Other parallel transformers in the system will fulfill the load without total interruption of power [3]. This condition generally occurs in the power system particularly when the load on the transformer is made to fluctuate outside the normal or approved operating range which may lead to overload condition and damage of the insulation of windings resulting to failure in transformer operation thereby making way for the interruption of power supply. One of the actual reasons that trigger overloading is the unbalanced load sharing of transformers. One of the best solutions to stop the overloading is to operate the number of transformers in parallel. It is same as parallel operation of transformers where certain number of transformers share the system load. The transformers work efficiently and therefore, damage is avoided or prevented [3]. The Paralleling of power transformers usually provides reliable power supply as well as being a well-known method for maximizing the power system efficiency, flexibility and availability. On the other hand, it is an economical way of making power available. Another advantage is the fact that, depending on the load, power can still be delivered even when just one of the transformers is in circuit. Also, paralleling transformers allows reducing the transformer size and power loss [4].

Circulating current method assumes that a continuous circulating current path is observed and maintained for all system operating conditions or configurations, and that any changes or deviations in the circulating current magnitude are a result of an unwanted or undesirable change in the relative tap positions of the paralleled transformers. The circulating current approach biases all paralleled controls in order to operate next in the direction that minimizes the circulating current [5]. Additional equipment is required to separate the total transformer currents into a load current segment and a circulating current portion. These separate or individual currents form the input to the voltage control in which the direction and amount of the individual biases are determined. Rather than varying the voltage bias between units based on VAr flow, as in the negative reactance method, the higher-tapped transformer control set point is biased down while the lower-tapped transformer control is usually biased up by an equivalent or equal amount. The actual center of the set points of the combination is still equal to the original set point. This assures proper voltage levels which are maintained on the bus. An overcurrent relay in the circulating current path is generally used with the circulating current technique to block subsequent operations if the change in the transformers' tap positions becomes too great [5]. If the intersystem flow is VArs, the circulating current technique would bias the tapchangers operation in trying to offset the flow. This would result in correct operation at several tap positions for the two transformers and balanced VAr load sharing from the two sources. That is, the tap difference would eventually equal the voltage difference thus stopping the flow-through VArs. This is satisfactory operation. If the intersystem flow is KW, the circulating current approach would also bias the operation of the tapchangers in a way to offset the flow. However, the KW flow cannot be corrected with tapchanger operations. The result is generally unpredictable but does result in circulating VAr's in one direction and KW in the other. This condition usually results in "hunting" between tapchangers [5]. The circulating current technique being the most widely used technique assumes that a circulating current path is maintained and that any difference in current between the transformers is a result of an undesirable relative tap positions on the transformers in parallel operation. Any difference in transformer ratings (as reflected in relative impedances) must be compensated for with auxiliary current transformers. If the impedance difference is too extreme, operation may be made manifest because an actual circulating current will always appear differently in the individual or separate controls [5]. Circulating current is fully independent of the load and load division. If transformers were full load there will be a certain amount of overheating arising from circulating currents. Remember, as much as circulating currents do not and cannot flow on the line, they cannot be quantified provided monitoring equipment is made available upstream or downstream of the commonly connected points [2].

It is important to note that paralleling of delta-delta to delta-wye transformers should not be attempted. This is because secondary line-ground voltages (assuming balanced voltages) are shifted by 30° in the wye transformer as compared to the delta. This generates extremely high circulating currents in the transformers [2]. According to Lakdawala et al. [3], when two or more transformers are operated in parallel, they must have same voltage ratio or turns ratio, same polarity, same phase sequence and same impedance for satisfactory performance. The satisfactory parallel operation of transformers depends largely on five characteristics; that, any two transformers which it is designed to operate in parallel should possess: identical turn ratios and voltage ratings, equal percentage impedances, equal ratios of resistance to reactance, same polarity, same phase angle shift [1]. Transformers connected in parallel usually have the same voltage on the primary and secondary winding terminals. The voltage difference between the primary and secondary windings is the turns ratio. For these terminal voltages to be identical for the paralleled transformers their impedance drop must always be identical. Based on this, no matter what especially on any load condition, the current will always be shared in a way that the product of impedance and current in one transformer is not greater or less than the product of impedance and current in the other. Also, if the turn ratios of the transformers are not the same though with the primary and secondary terminal voltages being the same in both transformers, it becomes obvious that the circulating currents must be maintained between the transformers even at no load [2]. Transformers are generally suitable to be paralleled when their turn ratios, percent impedances and $X/_R$ ratios are the same. Connecting transformers when one of these parameters is different, results in either circulating currents or undesirable current division. These situations bring down the efficiency and the maximum amount of load the combined transformers can carry [2]. Typically, according to SCHNEIDER [2], transformers should not be operated in parallel particularly in the presence of the following conditions:

i. When the division or sharing of load is in a way that, if the total load current equal to the combined KVA transformer rating, one of the transformers is considered being overloaded
ii. When the no-load circulating currents in any of the transformer is greater than 10% of the full load rating
iii. When the combination of the circulating currents and full load current becomes higher than the full load rating of any of the transformers.

According to NEPA [7], the following conditions must be strictly observed for 3-phase transformers to operate in parallel:

i. The secondaries must have identical phase sequence or the same phase rotation
ii. All corresponding secondary line voltages must remain in phase
iii. The same inherent phase angle difference between primary and the terminals
iv. Same polarity
v. The secondaries must give the same magnitude of line voltages. In addition, it is desirable that:
vi. The impedances of each transformer referred to its own rating should be the same, i.e. each transformer should possess the same percentage or per unit resistance and reactance.

The conventional way of linking transformers in parallel is to observe the same turn ratios, percent impedances, and KVA ratings. This is typically fulfilled by putting a tie breaker in the normally closed (NC) position. Connecting transformers to operate in parallel with the same parameters gives birth to equal load sharing and no circulating currents occur in the windings of the transformers [2]. For a single phase parallel operation according to SCHNEIDER [2], it can be seen by using equations (2.1) and (2.2) below, that if the percentage impedances in every transformer are the same, that there will be equal current and load sharing on each of the transformers. Frequently in practice, an engineer tries to enhance the plant power system by linking existing transformers in parallel operation with the same KVA rating but with different percent impedances [2]. This is usual especially when budget constraints limit the buying of a new transformer possessing the same parameters. The engineer should always know that the current divides in inverse proportions to the impedances making larger current to flow through the smaller impedance. Thus, the lower percent impedance transformer can be heavily loaded thereby lightly loading the other higher percent impedance transformer [2]. Although it is not common practice for new installations, sometimes two transformers with different KVA's same percent impedances, are linked to one common bus. In this situation, the current division causes each transformer to its rated load. There will be no circulating current because the voltages (turn ratios) are the same [2].

Seldom are transformers in industrial and commercial facilities connected to a common bus having different KVA and unequal percent impedances. However, ta situation that requires two single-ended substations to be tied together through bussing or cables just to make available better voltage support especially at large motors starting period. If the percent impedances and KVA ratings are not the same, care must be taken while loading these transformers. As with the unequal percent impedances so indicated in the "Unequal Impedances – Equal Ratios (Same KVA)" section, the load current carried by the combined transformers will become less than their rated KVA [2]. If both the ratios and the impedances are not the same, the circulating current resulting from the unequal ratio should be combined with each transformer's portion of the load current to get the actual total current in each unit. For unity power factor, 10% circulating current due to unequal turn ratios gives rise to only half percent to the total current. At lower power factors the circulating current will vary dramatically [2].

3. MATERIALS AND METHOD

3.1 Research Materials

The required data needed to conduct a study of the existing connection of transformers at the Rivers State University 2 X 15MVA, 33/11kV Injection Substation were collected from the Port Harcourt Electricity Distribution Company (PHEDC) and Transmission Company of Nigeria (TCN). The method and procedure used in this work are described accordingly.

3.2 Method of Analysis

To establish whether improvement of power supply was achievable with parallel operation of transformers, Rivers State University 2 X 15MVA, 33/11kV Injection Substation in Nigeria having two separate 15MVA transformers was used as case study. The injection substation has one transformer known as T1A feeding Ojoto and RSU 11kV feeders respectively and another transformer known as T2A feeding Federal and Wokoma 11kV feeders, respectively.

Rivers State University 2 X 15MVA, 33/11kV Injection Substation receives power supply from Port Harcourt Town Transmission Station which derives its power supply from Afam Generation Station on Afam/Port Harcourt 132/33kV line 2. Rivers State University injection substation located left wing about five poles from the main entrance to the university feeds from a 30MVA transformer at the transmission station with approximately 9.5km route length [8].

At the first instance, data collected in conjunction with the ones generated served as input data to model and run load flow analysis using ETAP 12.6 software to ascertain the load flow of the station. The first case of simulation was based on the existing configuration of the injection substation where the transformers are not connected in parallel.

In the second case, same parameters approach was used to determine appropriate transformer loadings. Loading considerations at the Rivers State University 2 X 15MVA, 33/11kV Injection Substation were considered with practical demonstration of the workability of parallel transformers that will positively adjust transformer loading efficiency. Transformer parallel connection type for the injection substation considered here are equal percentage impedances, equal voltage ratios and same MVA. The available data served as input data for a second simulation using ETAP 12.6 software. In this case the two transformers are paralleled. T1A and T2A are tied to the same bus known as Bus3 (T1A & T2A). Paralleling was accomplished by maintaining a tie breaker in the normally closed position referred to as Bus3 (T1A & T2A).

Table 3.1 Data Considerations in Software

S/NO	Parameter	Assumptions
1	33kV transmission line route length	9.5km
2	T2 30MVA impedance at transmission station	12.27%
3	T1A 15MVA impedance at RSU Injection Substation	11.10%
4	T2A 15MVA impedance at RSU Injection Substation	11.10%
5	33kV line load (maximum)	20MW
6	Average load on Ojoto 11kV feeder	230A
7	Average load on RSU 11kV feeder	170A
8	Average load on Federal 11kV feeder	320A
9	Average load on Wokoma 11kV feeder	400A
10	Conductor type	AAC
11	Conductor size	$150mm^2$
12	Cable size	$240mm^2$
13	System	3-phase AC
14	Conductor resistivity at 20°C	$2.83X10^{-8}$
15	33kV line spacing	1219.2mm

3.3 Existing Case of Load Flow Analysis on Rivers State University Injection Substation

Primary data and data derived from appropriate equations became input data to the first load flow conducted analyzed on Electrical Transient Analyzer Program (ETAP) environment. Some of the data as contained in Table 3.1 were used in the simulation to obtain the station load flow result with the transformers functioning independently.

When DC is flowing around cylindrical conductor, the DC resistance becomes:

$$R_D = \rho \frac{l}{A} \ (\Omega) \quad (3.1)$$

Where

ρ = conductor resistivity at a given temperature in Ω/m

l = conductor length in m

A = conductor cross-section area in m^2

Assuming cross – section area, A is $\pi \left(\frac{d}{2}\right)^2$ (3.2)

The diameter becomes, $d = 2r$ (3.3)

Having the cross – section A:

$$d = 2.\sqrt{\frac{A}{\pi}} = 2r \equiv 1.1284\sqrt{A} \quad (3.4)$$

From eqn.3.3, the radius can be resolved as:

$$r = \frac{d}{2} \quad (3.5)$$

Per kilometer reactance of one phase can be resolved using:

$$x_o = 0.1445\log_{10}\left(\frac{D_{GMD}}{r}\right) + 0.0157 \quad (3.6)$$

Where

D_{GMD} = the geometric mean distance between the line conductors

r = radius of conductors

The line reactance X, is given as:

$$X = x_o \, l_o \quad (3.7)$$

The distributed series impedance becomes:

$$Z_1 = R + jX \quad (3.8)$$

The equivalent admittance is given as:

$$Z_o = Y = \frac{1}{Z} = G + jB \quad (3.9)$$

From the above relation, the following can be deduced as:

$G = \frac{1}{R}$ (3.10)

and

$jB = j\frac{1}{X}$ (3.11)

For two or more transformers to run in parallel,

$\frac{V_1}{V_2} = \frac{N_1}{N_2}$ (3.12)

3.4 Network Model and Simulation

Considering the equation

$R_D = \rho\frac{l}{A}\ (\Omega)$

$R_D = 2.83 \times 10^{-8}\frac{9500}{1.5 \times 10^{-4}}$

$= 1.7923\Omega$

From equations 3.4 and 3.5:

$d = 2.\sqrt{\frac{A}{\pi}} = 2r$

$d = 2.\sqrt{\frac{150}{\pi}}$

$= 13.82mm$

and

$r = \frac{d}{2}$

$r = \frac{13.82}{2}$

$= 6.91mm$

Using equations (3.6) and (3.7), we have:

$x_o = 0.1445\log_{10}(\frac{D_{GMD}}{r}) + 0.0157$

$x_o = 0.1445\log_{10}(\frac{1219.2}{6.91}) + 0.0157$

$= 0.3404\Omega/km$

and

$X = x_o\, l_o$

$X = 0.3404 \times 9.5$

$= 3.2338\Omega$

From the equation

$Z_1 = R + jX$

$Z_1 = 1.7923 + j3.2338$

$Z_1 = \sqrt{((1.7923)^2 + (j3.2338)^2)}$

$= 3.6973\Omega$

Considering the equation

$Z_o = Y = \frac{1}{Z} = G + jB$

Where

$\frac{1}{Z} = \frac{1}{1..7923 + j3.2338}$

$\frac{1}{Z} = (0.1311 - j0.2366)\text{Siemens}$

Series combination of 1.7923Ω and 3.2338Ω is equivalent to $\frac{1}{0.1311} = 7.628\Omega$ resistance in parallel with a $\frac{1}{0.2366} = 4.227\Omega$ inductive reactance.

Using the equation

$Z_o = G + jB$

$Z_o = (7.628 + j4.227)\Omega$

$Z_o = \sqrt{((7.628)^2 + (j4.227)^2)}$

$= 8.721\Omega$

Upon getting all the data required the network was modelled and simulated to ascertain the present load flow on Rivers State University 2 X 15MVA, 33/11kV Injection Substation with the use of ETAP 12.6 software as shown in Figure 3.1.

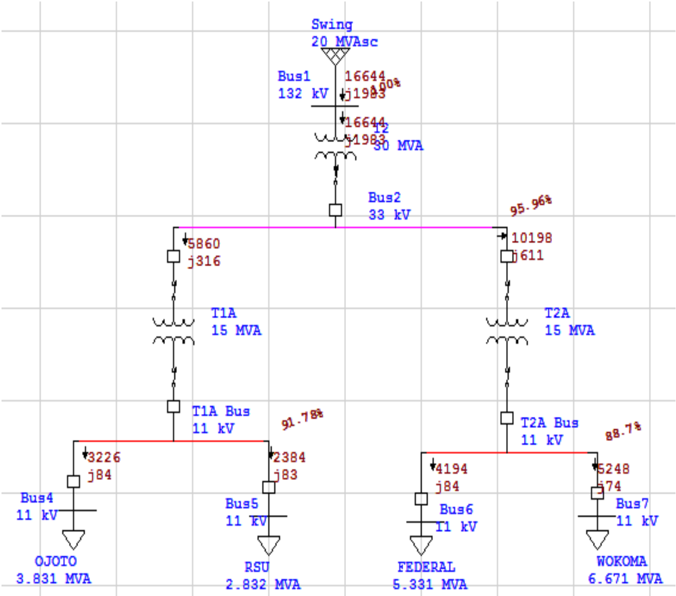

Figure 3.1: Load Flow Analysis of Rivers State University Injection Substation in ETAP 12.6 Software without Transformers in Parallel

3.5 Second Case of Load Flow Analysis on Rivers State University Injection Substation

Some of the primary data in conjunction with data derived using appropriate equations served as input data to generate and run a second case of load flow analysis on Rivers State University 2 X 15MVA, 33/11kV Injection Substation. This was analyzed on Electrical Transient Analyzer Program (ETAP) environment to obtain the needed result. Having considered the desire to improve power supply, the two transformers at the injection substation were paralleled. The network was reconfigured by way of connecting the two transformers to a common load (bus) with all the parameters unchanged as shown in Figure 3.2. A tie breaker referred to as Bus3 (T1A & T2A) was maintained in the normally closed position.

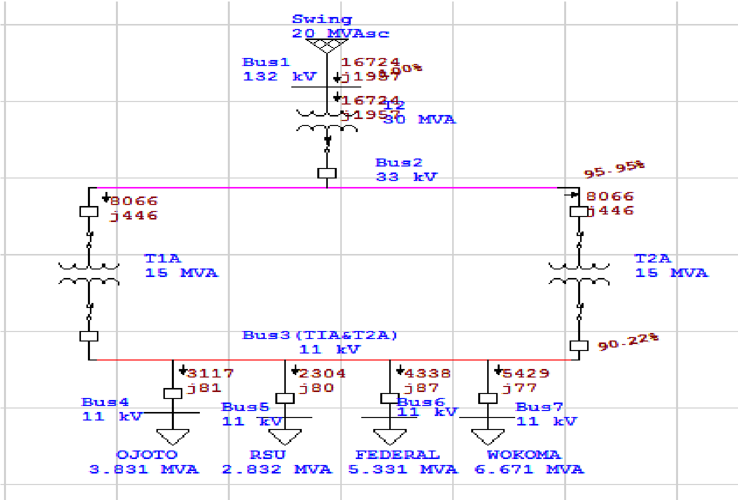

Figure 3.2: Load Flow Analysis of Rivers State University Injection Substation in ETAP 12.6 with Transformers in Parallel

4. RESULTS AND DISCUSSION

4.1 Load Flow Result Summary

The results obtained from the injection substation load flow analysis based on its present configuration are shown in Tables 4.1 and 4.2, respectively. T1A and T2A are separated in their connection (Existing Case). However, results from second case load flow analysis on the injection substation are summarized in Tables 4.3 and 4.4, respectively. In this new case load flow analysis, T1A and T2A are connected to a common load (bus) referred to as Bus3 (T1A & T2A). This depicts that T1A and T2A of the new case load flow analysis are maintained in parallel operation.

However, Tables 4.5, 4.6 and 4.7 respectively show precisely results curled of existing case and new case load flow analysis whereas Figures 4.1, 4.2 and 4.3 respectively show the comparison between the two different cases of load flow analysis with regard to transformer loading in MVA, transformer percentage loading and station losses in kw.

Table 4.1: Branch Loading Summary for Transformers not Connected in Parallel

Transformer	Loading (Input)		Loading (Output)	
	MVA	%	MVA	%
T2	16.761	55.9	16.084	53.6
T1A	5.868	39.1	5.613	37.4
T2A	10.216	68.1	9.443	63.0

Table 4.2: Branch Losses Summary for Transformers not Connected in Parallel

Transformer	Vd % Drop in Vmag	Kw	Kvar
T2	4.04	586.3	1055.3
T1A	4.18	249.3	149.6
T2A	7.26	755.6	453.4
Total		1591.2	1658.3

Table 4.3: Branch Loading Summary for Transformers Connected in Parallel

Transformer	Loading (Input)		Loading (Output)	
	MVA	%	MVA	%
T2	16.838	56.1	16.157	53.9
T1A	8.079	53.9	7.596	50.6
T2A	8.079	53.9	7.596	50.6

Table 4.4: Branch Losses Summary for Transformers Connected in Parallel

Transformer	Vd % Drop in Vmag	Kw	Kvar
T2	4.05	591.7	1065
T1A	5.74	472.6	283.5
T2A	5.74	472.6	283.5
Total		1536.8	1632.1

Table 4.5: Comparing Transformer MVA Loading (Existing Case and New Case)

Transformer	Loading (Output)MVA	
	Existing Case	New Case (in Parallel)
T1A	5.613	7.596
T2A	9.443	7.596

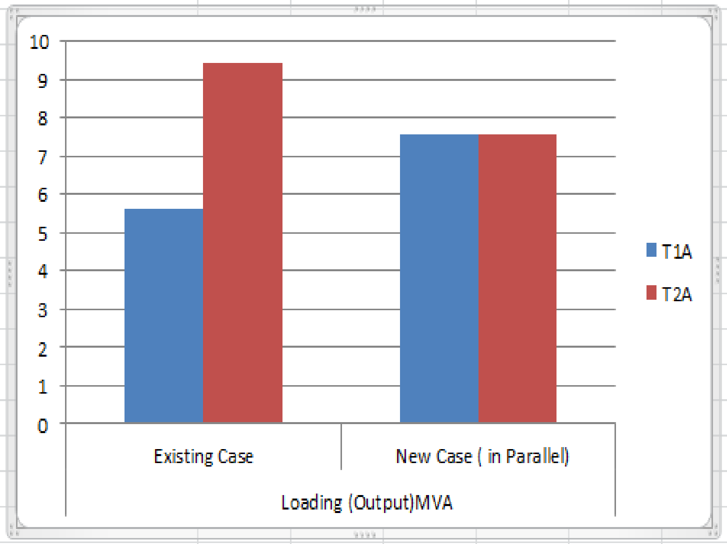

Chart 4.1: Comparing Transformer MVA Loading (Existing Case and New Case)

Table 4.6: Comparing Transformer % Loading (Existing Case and New Case)

Transformer	Loading (Output)%	
	Existing Case	New Case (in Parallel)
T1A	37.4	50.6
T2A	63	50.6

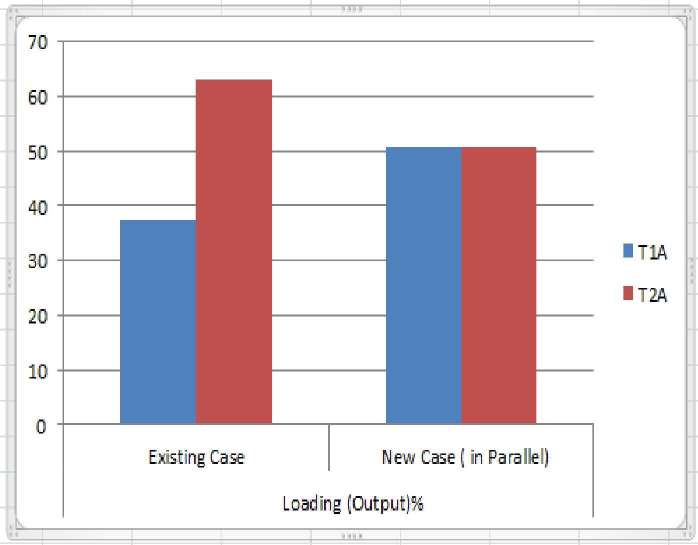

Chart 4.2: Comparing Transformer % Loading (Existing Case and New Case)

Table 4.7: Comparing Station Real Power Losses (Existing Case and New Case)

Transformer Condition	Losses (Kw)
T1A & T2A (Existing Case)	1004.9
T1A & T2A in Parallel (New Case)	945.2

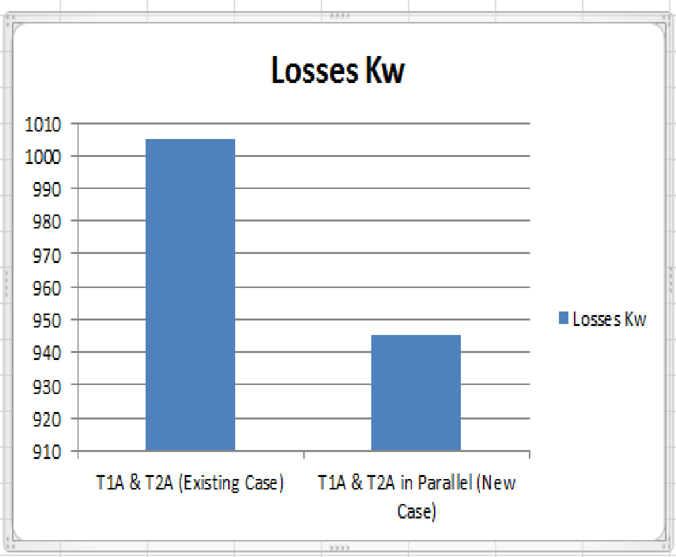

Chart 4.3: Comparing Station Real Power Losses (Existing Case and New Case)

5. CONCLUSION

This work has practically shown possible achievement of improved power supply using same parameters approach to connect transformers in parallel. This was possible using Rivers State University 2 X 15MVA, 33/11kV Injection Substation in Nigeria as case study.

Load flow analysis conducted on the injection substation based on its present configuration showed that T1A carried 5.613MVA representing 37.4% loading. This implies under-utilization and comparatively low power loss. Secondly, the transformer has adequate space to accommodate more loads. Also, T2A carried 9.443MVA representing 63.0% loading. This implies adequate power utilization devoid of safe space for further power utilization expansion. The station incurred power loss of 1004.9kw. Generally, flexibility and load expansion may be difficult with this substation configuration.

A new case of load flow analysis was conducted on the injection substation where T1A and T2A were maintained in parallel operation linked by a bus referred to as Bus3 (T1A & T2A). The analysis showed that T1A and T2A carried 7.596MVA each out of 15MVA capacity representing 50,6% loading with a total station power loss of 945.2kw. This indicates that each of the transformers still has safe free space to accommodate more loads. In the case of maintenance or fault on one transformer, essential loads may not be interrupted.

REFERENCES

[1] A. J. Duque, N. M. Galeano, J. R. Castrillon, J. M. Lezama and R. A. Sanchez, “Power Loss Minimization for Transformers Connected in Parallel with Tap Based on Power Changeability Balance,” Energies, 11, 2018, pp.439.
[2] SCHNEIDER Electric Industries Loading Considerations When Paralleling Transformers,” Schneider Electric USA, Inc. 2011.
[3] M. A. Lakdawala, V. Patel, B. Patel, P. Jadeja and M. Mishra, “A Review on Load Sharing of Transformers,” International Journal of Science & Technology & Engineering, vol.3, issue7, 2017, pp.181-185.
[4] ZIV Instruction Manual-Automatic Voltage Regulator, “Analysis of OLTC Control of Parallel Transformers,” IEC Model RTV, Zamudio (Spain), 2013, Reference BRTV1110Dv03.
[5] Beckwith, “Advance Transformer Paralleling,” Beckwith Electric Co. Inc. 2017.
[6] ABB, “Instruction Leaflet on Parallel Operation of Transformers,” Technical Data 2008, ILUS010001-LFE.
[7] NEPA, “Basic Protection Course P1 Training and Development Programme,” Port Harcourt, National Electric Power Authority, 2005.
[8] D. C. Idoniboyeobu, S. L. Braide and O. N. Igbogidi, “Improved Relay Coordination in Port Harcourt Distribution Network: Case Study of RSU 2 X 15MVA, 33/11kV Injection Substation,” American Journal of Engineering Research, vol.7, issue7, 2018, pp.43-56.