IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 16, Issue 4 Ser. I (Jul. – Aug. 2021), PP 38-48
www.iosrjournals.org

Load Flow Modeling and Performance Analysis of Suleja 132/33 kV Sub-transmission Station

Onah, C. O., Agber, J. U., Ufene, F. A.
Federal University of Agriculture, Makurdi, Nigeria
Abuja Electricity Distribution Company, Suleja Business Unit, Nigeria

Abstract – *The load flow analysis of an interconnected power system is highly imperative as it reveals the electrical performance and power flow (real and reactive) for specified conditions when the system is operating under steady-state.* Therefore, *this paper presents the load flow modeling and performance analysis of Suleja 132/33 kV sub-transmission station to ascertain its steady-state operating conditions and adequately mitigate the losses associated with the network. Electrical Transient Analyzer Program (ETAP) software was employed in the modeling and analysis of the load flow using the single line diagram (SLD) with the actual data obtained from the station. The results obtained from the load flow analysis showed several voltage violations at Abuja steel, Jere, Madalla, Rafinsanyi, Suleja town and Tommy buses with magnitudes of 93.631%, 87.149%, 89.268%, 89.165%, 90.503% and 94.767 % respectively. The results from the analysis also indicated that before compensation, an overall system loss of 1457.5 kW and 4425.8 kVAr was observed. The losses in the network were compensated using the ETAP Optimal Capacitor Placement (OCP) module. The OCP module optimally sized and placed capacitors on the affected buses, which improved the bus voltages of the entire network. The results from the OCP revealed that it optimally sized and placed four capacitors at Suleja town bus, Tommy bus, Abuja steel bus and Jere bus with total bank rating of 12000 kVAr, 6000 kVAr, 6000 kVAr and 13500 kVAr respectively. Consequently, an improvement of the bus voltages from 93.631%, 95.602%, 96.127%, 87.149%, 89.268%, 89.165%, 90.503%, 94.767% to 97.634%, 102.299%, 99.192%, 98.754%, 100.498%, 100.382%, 101.888%, 98.31% for Abuja Steel bus, Bus 3, Bus 4, Jere bus, Madalla bus, Rafinsanyi bus, Suleja Town bus and Tommy bus respectively were recorded. The total active and reactive power losses were also reduced from 1457.5 kW and 4425.8 kVAr to 1408.4 kW and 4078.6 kVAr respectively.*

Keywords*: Power generation, Load flow, Steady-state, Power loss, Optimal capacitor placement, ETAP*

Date of Submission: 13-07-2021 Date of Acceptance: 29-07-2021

I. Introduction

The power flow analysis, which is also known as load flow study is an important tool involving numerical analysis applied to a power system. The study reveals the electrical performance and power flows (real and reactive) for a specified condition when the system is operating under steady-state. Power flow studies are typically used to obtain the magnitude and phase angle of the voltage at each bus and the real and reactive power flow in each line and are considered one of the most intensively used tools in power system analysis [1 - 4].

In a three-phase alternating current (AC) power system, active and reactive power flow from the generating stations to the load through different network buses and branches. This flow of active and reactive power in an electric power system is referred to as power flow or load flow. Power flow studies provide a systematic mathematical approach for the determination of important information about the power system [5 -7].

Load flow solution is the core requirement for designing a new power system and for planning an extension of the existing one for increasing demand. These analyses require a large number of load flow solutions under both normal and abnormal operating conditions, i.e. during cases of transmission lines or generators outages. Similarly, load flow analysis is highly relevant in the study of the transient behavior of the electric power system by providing the initial conditions [8, 9].

Under the steady-state condition, the network equations are expressed in the form of simple algebraic equations. The loads and generation continuously change in a real power system, but for the solution of load flow equations, it is assumed that loads and generation are fixed for a particular value over suitable periods.

For the past three decades, several methods of numerical analysis have been applied in solving load flow analysis problems. The prevalent iterative methods are the Gauss-Seidel, the Newton-Raphson and Fast Decoupled method [11]. With the industrial developments in society, the power system increases and the dimension of the load flow equation also kept increasing to several thousand. With such increases, any numerical mathematical method cannot converge to a correct solution. Thus, power engineers have to seek more reliable methods. The problem that faces the power industry is how to determine which method is most suitable for a power system analysis. In load flow analysis, high degree accuracy and faster solution time are required to determine which method is best to use.

In this paper, detailed load flow modeling and performance analysis of the electric power sub-transmission system is reported with Suleja 132/33 kV sub-transmission station as the case study using the Newton-Raphson method in an Electrical Transient Analyzer Program (ETAP) environment.

II. Classification Of Buses For Load Flow Analysis

In load flow analysis, four quantities are associated with each bus. These quantities include voltage magnitude V, phase angle δ, active power P and reactive power Q. In the analysis, two out of the four quantities are specified and the remaining two quantities are to be determined through the solutions of the load flow equations [12]. The buses are categorized based on the two specified variables as summarized in Table 1.

2.1 P-V buses

This is a voltage controlled bus. For P-V buses, active power P and voltage magnitude V are specified as known variables, while reactive power and phase angle are to be resolved through the analysis. Usually, PV buses should have some controllable reactive power resources and can thus maintain bus voltage magnitude at a desirable value [13]. Generally, the buses of power plants can be taken as PV buses, because voltages at these buses can be controlled with the reactive power capacity of their generators. Some substations that have enough reactive power compensation devices to control the voltage are also considered as PV buses.

2.2 P-Q buses

For P-Q buses, the active P and reactive power Q are specified as known parameters, and the voltage magnitude and the phase angle are to be resolved. Usually, substation buses are taken as PQ buses where the load powers are given constants. When output P and Q are fixed in some power plants, these buses can also be taken as P-Q buses. Most buses in power systems belong to the P-Q type in load flow analysis.

2.3 Slack bus

In load flow analysis, only one slack bus is required in the power system, which is specified by a constant voltage magnitude and phase angle. Therefore, voltage magnitude and phase angle are given as known variables at the slack bus, while the active power and reactive power are the variables to be solved using power flow equations. The effective generator at this bus supplies the losses to the network. This is necessary because the magnitude of losses will not be known until the calculation of currents is complete [13].

Table 1. Summary of classification of buses

S/N	Bus Type	Specified Quantities	Unspecified Quantities	Remarks
1	P-V bus	P, V	Q, δ	A generator is present at the machine bus
2	P-Q bus	P, Q	$\|V\|$, δ	About 80% buses are P-Q type
3	Slack bus	$\|V\|$, δ	P, Q	$\|V\|$, δ are assumed if not specified as 1.0 and 0°

III. Formulation Of Load Flow Problem

In the load flow problem, the analysis is restricted to a balanced three-phase power system for the analysis to be performed on a single-phase basis. The first step in the analysis is the formulation of suitable equations for the power flows in the system. The power system is a large interconnected system, where several buses are connected by transmission lines. At any bus, complex power is injected into the bus by the generators and complex power is drawn by the loads. The nodal equation for a power system network using Y_{bus} can be described by equation (1).

$$I = Y_{bus} V$$

(1)

In a general form for an n-bus system, the nodal equation can be defined by equation (2).

$$I_i = V_i Y_{ii} + \sum_{\substack{j=1 \\ j \neq i}}^{n} V_j Y_{ij} \qquad for \;\; i = 1, 2 \cdots, n$$

(2)

The complex power injection into bus i, is given by equation (3).

$$S_i = P_i + jQ_i = V_i I_i^* \quad (3)$$

where * indicates a complex conjugate value, P_i and Q_i are the active and reactive power at bus i respectively.

Equation (3) is rewritten as equation (4) and the injected currents obtained as equation (5).

$$S_i^* = P_i - jQ_i = V_i^* I_i \quad (4)$$

$$I_i = \frac{P_i - jQ_i}{V_i^*} \quad (5)$$

From equations (2) and (5), the expression in equation (6) is obtained.

$$\frac{P_i - jQ_i}{V_i^*} = Y_{ii} V_i + \sum_{\substack{j=1 \\ j \neq i}}^{n} Y_{ij} V_j \quad (6)$$

$$V_i = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{j=1 \\ j \neq i}}^{n} Y_{ij} V_j \right] \quad (7)$$

Equation (7) represents a mathematical formulation for load flow problems resulting in a system of non-linear algebraic equations, which must be solved by iterative techniques [13, 14]. In this paper, the Newton-Raphson technique is adopted for the analysis.

3.1 Newton-Raphson technique of load flow analysis

Newton-Raphson technique is an iterative technique, which approximates the set of non-linear simultaneous equations to a set of linear equations using Taylor's series expansion and the terms are restricted to first-order approximation [15]. Two methods of solutions for the load flow using Newton-Raphson technique are obtainable, which are rectangular coordinate and the polar coordinate. The load flow problem formulated in polar form as adopted in this paper, using the nodal current equation (9) in terms of the bus admittance matrix is given by equation (10).

$$I_i = \sum_{j=1}^{n} Y_{ij} V_j \quad (9)$$

Expressing equation (9) in polar form yields equation (10).

$$I_i = \sum |Y_{ij}| |V_j| \angle \theta_{ij} + \delta_j \quad (10)$$

The complex power at bus i is given by the expression in equation (11).

$$P_i - jQ_i = V_i^* I_i \quad (11)$$

Equation (12) is obtained from equations (10) and (11).

$$P_i - jQ_i = |V_i| \angle -\delta_i \sum_{j=1}^{n} |Y_{ij}| |V_j| \angle \theta_{ij} + \delta_j \quad (12)$$

The distinction between the real and imaginary parts can be obvious through the expansion of equation (12), which leads to equations (13) and (14).

$$P_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\cos(\theta_{ij} - \delta_i + \delta_j)$$
(13)

$$Q_i = -\sum_{j=1}^{n} |V_i||V_j||Y_{ij}|\sin(\theta_{ij} - \delta_i + \delta_j)$$
(14)

The equations (13) and (14) represent a set of non-linear algebraic equations in terms of voltage magnitude $|V|$ in per unit and δ in radians [11]. Application of Taylor's series expansion to equations (13) and (14) about the initial estimate but neglecting all higher order terms, a set of linear equations as described by equation (15) can be obtained.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \hline \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{ccc|ccc} \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n} & \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n} & \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \\ \hline \frac{\partial P_2^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n} & \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n} & \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{array}\right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \hline \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix}$$
(15)

From equation (15), the Jacobian matrix expresses the linearized relationship between small changes in voltage angle $\Delta \delta_i^{(k)}$ and voltage magnitude $\Delta |V_i^{(k)}|$ with small changes in active and reactive power $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$. The elements of the Jacobian matrix are the partial derivatives of equations (13) and (14), evaluated at $\Delta \delta_i^{(k)}$ and $\Delta |V_i^{(k)}|$. Equation (15) can be written in short form as equation (16).

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \tag{16}$$

where, J_1, J_2, J_3 and J_4 are the elements of the Jacobian matrix.

The terms $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$ represent the difference between the scheduled and calculated values at bus i, referred to as the power residuals, given by equations (17) and (18).

$$\Delta P_i^{(k)} = P_i^{schedued} - P_{i(calculated)}^{(k)}$$
(17)

$$\Delta Q_i^{(k)} = Q_i^{schedued} - Q_{i(calculated)}^{(k)}$$
(18)

The new estimates for bus voltage magnitudes and phase angles are given by equations (19) and (20) respectively.

$$|V_i|^{(k+1)} = |V_i|^{(k)} + \Delta |V_i|^{(k)} \tag{19}$$

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta \delta_i^{(k)} \tag{20}$$

IV. Simulation

The simulation for the model of the case study was performed in Electrical Transient Analyzer Program (ETAP) environment using the Newton-Raphson technique (Polar coordinate method).

4.1 Data collation

The essential data used for study was obtained from the Abuja Electricity Distribution Company (AEDC), Suleja business unit. Data collated include the Single Line Diagram (SLD) of the 132/33 kV Suleja sub-transmission Station, equipment ratings, line and load data.

4.2 Single line diagram

The single line diagram as obtained from the station is as shown in Fig. 1. The Suleja sub-transmission power network comprises four (4) power transformers, seventeen (17) circuit breakers, fourteen (14) current Transformers, four (4) potential transformers and eight (8) isolating switches. The network draws power from the grid at a voltage level of 132 kV through Minna line 1 and 2. The 132 kV voltage level is been stepped down to 33 kV using two (2) power transformers. The power network consists of four (4) 33 kV feeders (i.e. Suleja town line, Jere line, Tommy line and Abuja Steel line). The Suleja Town 33 kV line is stepped down into and two (2) 11 kV feeders (i.e. Rafinsanyi and Madalla) also using two (2) power transformers.

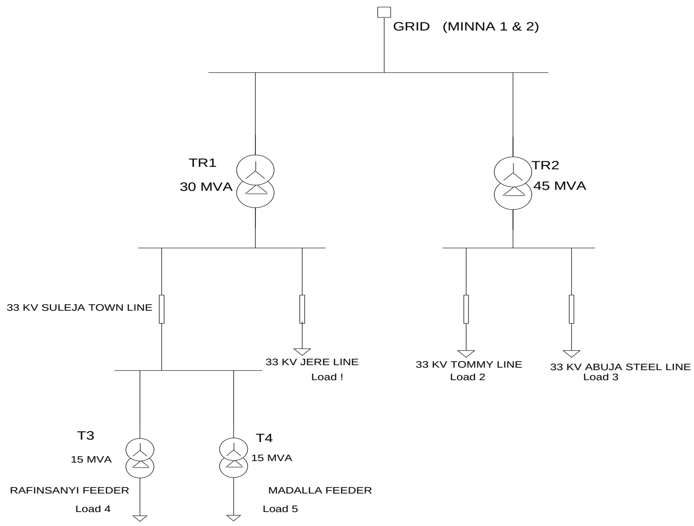

Figure 1: Single line diagram of the 132/33 kV Suleja sub-transmission power network

4.3 Equipment rating

The equipment ratings as obtained and used in this paper are shown in the Tables. Table 1 represents the transformer data while Table 2 depicts ratings of other equipment. Table 3 shows the load data.

Table 1: Transformer Data

Component	Type	Rating
Transformer	TR1	30 MVA
	TR2	45 MVA
	T3	15 MVA
	T4	15 MVA

Table 2: Equipment Data

Component	Type	Rating	
Circuit Breaker	CB 1-4	145 kV/1600A	
	CB 11-12	12 kV/1250A	
	CB 5-10; 13-17	33 kV/400A	
Current Transformer		**Primary**	**Secondary**
	CT 1,3	600A	1A
	CT 2	75A	1A

	CT 4	200A	1A
	CT 11-12	400A	5A
	CT 5-10;13-14	1200A	5A
Potential Transformer	PT 1	132 kV	110V
	PT 2-4	33 kV	110V
Isolating Switches	SW 1-6	132 kV/1600A	
	SW 7-8	33 kV/400A	

Table 3: Load Data

Component	Type	Rating
Feeders	Load 1	270A
	Load 2	210A
	Load 3	195A
	Load 4	260A
	Load 5	240A

Table 4: Resistance and reactance values

Equivalent Area (mm^2)	Resistance (Ohms/km)	Reactance (Ohms/km)
150	0.223	0.245

The route lengths of the corresponding lines are given below in table 3.5.

Table 5: Route length of the lines

Lines	From	To	Route Length (km)
Suleja Town	Bus 3	Suleja Town Bus	20
Jere	Bus 3	Jere Bus	25
Abuja Steel	Bus 4	Abuja Steel Bus	8
Tommy	Bus 4	Tommy Bus	4

V. Results

The load flow analysis was carried out on the Suleja sub-transmission network with the results presented in this section.

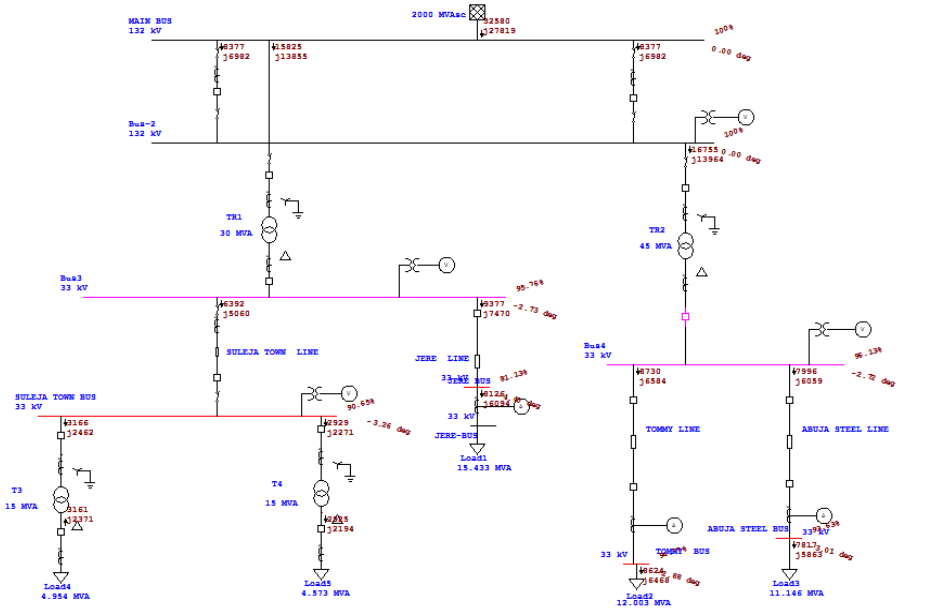

Figure 2: Simulated model of the Suleja Substation

Table 6: Load flow report before compensation

Bus		Voltage		Generation		Load		Load Flow		
ID	kV	%Mag	Ang			MW	Mvar	ID	MW	Mvar
ABUJA STEEL BUS	33	93.631	-3.0	0	0	7.817	5.863	Bus4	-7.817	-5.863
Bus-2	132	100	0.0	0	0	0	0	Bus4	16.755	13.964
								MAIN BUS	-8.377	-6.982
								MAIN BUS	-8.377	-6.982
Bus3	33	95.602	-2.9	0	0	0	0	JERE BUS	10.155	7.887
								SULEJA TOWN BUS	6.371	5.043
								MAIN BUS	-16.526	-12.931
Bus4	33	96.127	-2.7	0	0	0	0	ABUJA STEEL BUS	7.996	6.059
								TOMMY BUS	8.730	6.584
								Bus-2	-16.725	-12.643
JERE BUS	33	87.149	-3.8	0	0	9.377	7.033	Bus3	-9.377	-7.033
MADALLA BUS	11	89.268	-4.3	0	0	2.915	2.186	SULEJA TOWN BUS	-2.915	-2.186
MAIN BUS	132	100	0	33.342	28.339	0	0	Bus3	16.587	14.375
								Bus-2	8.377	6.982
								Bus-2	8.377	6.982
RAFINSANYI BUS	11	89.165	-4.4	0	0	3.151	2.363	SULEJA TOWN BUS	-3.151	-2.363
SULEJA TOWN BUS	33	90.503	-3.4	0	0	0	0	Bus3	-6.075	-4.718
								RAFINSANYI BUS	3.156	2.454
								MADALLA BUS	2.919	2.264
TOMMY BUS	33	94.767	-2.9	0	0	8.624	6.468	Bus4	-8.624	-6.468

Table 7: Branch losses summary report before compensation

CKT/Branch	From-To Bus Flow		To-From Bus Flow		Losses	
ID	MW	Mvar	MW	Mvar	kW	kvar
ABUJA STEEL LINE	-7.817	-5.863	7.996	6.059	178.4	196.0
TR2	16.755	13.964	-16.725	-12.643	29.4	1321.1
JERE LINE	10.155	7.887	-9.377	-7.033	777.9	854.6
SULEJA TOWN LINE	6.371	5.043	-6.075	-4.718	295.9	325.1
TR1	-16.526	-12.931	16.587	14.375	60.9	1444.0
TOMMY LINE	8.730	6.584	-8.624	-6.468	106.0	116.4
T4	-2.915	-2.186	2.919	2.264	4.2	77.7
T3	-3.151	-2.363	3.156	2.454	4.9	90.9
					1457.5	**4425.8**

Table 8: Load flow report after compensation

Bus		Voltage		Generation		Load		Load Flow		
ID	kV	%Mag	Ang			MW	Mvar	ID	MW	Mvar
ABUJA STEEL BUS	33	97.634	-3.7	0	0	8.500	0.655	Bus4	-8.500	-0.655
Bus-2	132	100	0.0	0	0	0	0	Bus4	18.000	2.960
								MAIN BUS	-9.000	-1.480
								MAIN BUS	-9.000	-1.480
Bus3	33	102.299	-3.6	0	0	0	0	JERE BUS	12.755	-3.350
								SULEJA TOWN BUS	8.099	-6.039
								MAIN BUS	-20.855	9.389
Bus4	33	99.192	-2.9	0	0	0	0	ABUJA STEEL BUS	8.625	0.793
								TOMMY BUS	9.355	1.243
								Bus-2	-17.979	-2.036
JERE BUS	33	98.754	-7.8	0	0	12.041	-4.135	Bus3	-12.041	4.135
MADALLA BUS	11	100.498	-7.9	0	0	3.695	2.771	SULEJA TOWN BUS	-3.695	-2.771
MAIN BUS	132	100	0	33.342	28.339	0	0	Bus3	20.918	-7.890
								Bus-2	9.000	1.480
								Bus-2	9.000	1.480
RAFINSANYI BUS	11	100.382	-7.9	0	0	3.994	2.995	SULEJA TOWN BUS	-3.994	-2.995
SULEJA TOWN BUS	33	101.888	-6.9	0	0	0.000	-12.457	Bus3	-7.700	6.477
								RAFINSANYI BUS	4.000	3.110
								MADALLA BUS	3.700	2.870
TOMMY BUS	33	98.310	-3.3	0	0	9.281	1.162	Bus4	-9.281	-1.162

Table 9: Voltage profile of buses before/after compensation

Bus ID	Before Compensation		After Compensation	
	Voltage (%)	Angle (deg)	Voltage (%)	Angle (deg)
ABUJA STEEL BUS	93.631	-3.0	**97.634**	**-3.7**
Bus-2	100	0.0	100	0
Bus3	95.602	-2.9	**102.299**	**-3.6**
Bus4	96.127	-2.7	**99.192**	**-2.9**
JERE BUS	87.149	-3.8	**98.754**	**-7.8**
MADALLA BUS	89.268	-4.3	**100.498**	**-7.9**
MAIN BUS	100	0.0	100	0
RAFINSANYI BUS	89.165	-4.4	**100.382**	**-7.9**
SULEJA TOWN BUS	90.503	-3.4	**101.888**	**-6.9**
TOMMY BUS	94.767	-2.9	**98.310**	**-3.3**

Table 10: System losses summary before/after compensation

System Losses			
Before Compensation		After Compensation	
kW	kvar	kW	kvar
1457.5	4425.8	1408.4	4078.6

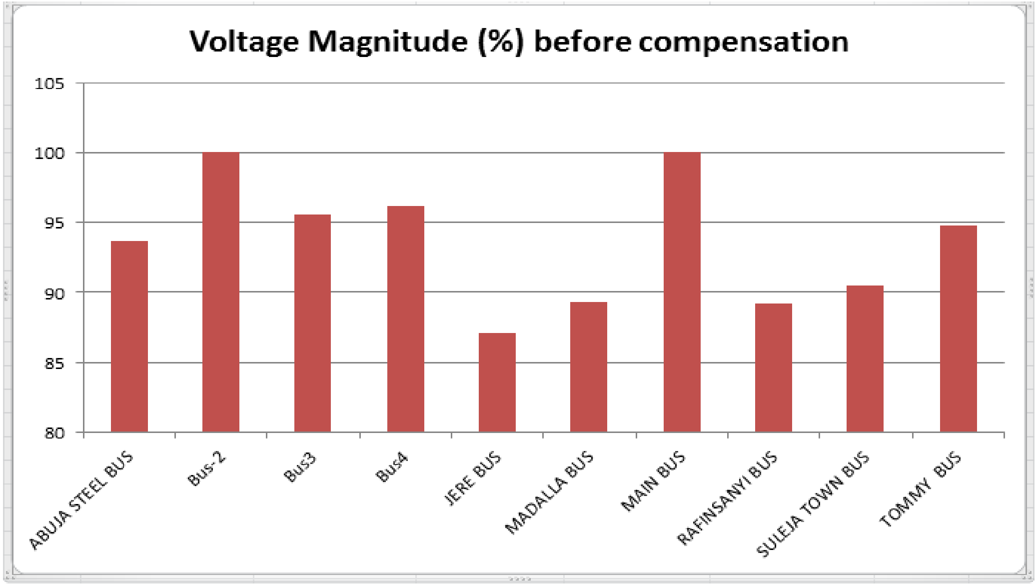

Figure 3: Voltage magnitude before compensation

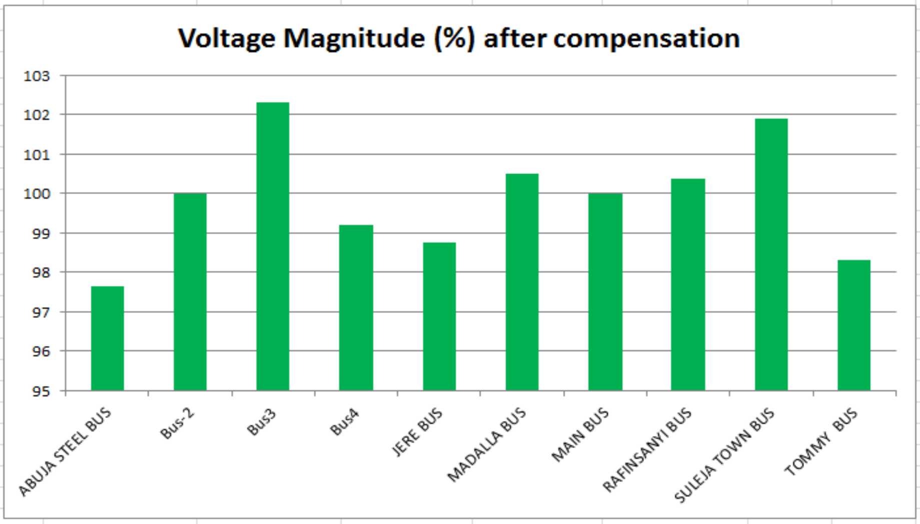

Figure 4: Voltage magnitude after compensation

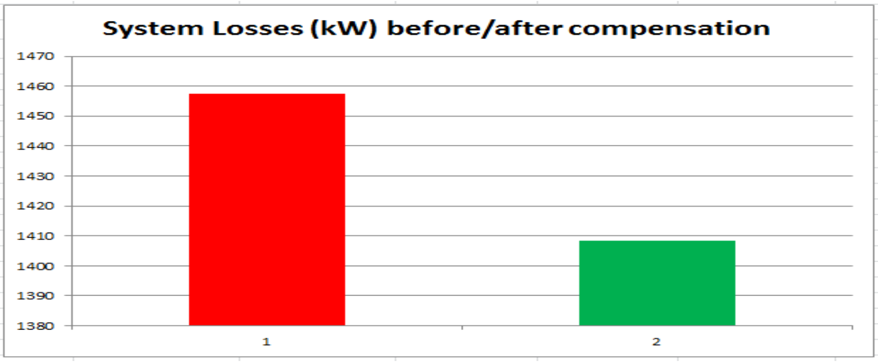

Figure 5: System losses before/after compensation

VI. Discussion

Fig. 5 is the simulated model of the single line diagram of the Suleja substation in ETAP environment while the load flow result is presented in Table 6. The results indicate voltage violations at Abuja steel bus, Jere bus, Madalla bus, Rafinsanyi bus, Suleja town bus and Tommy bus with percentage magnitudes of 93.631%, 87.149%, 89.268%, 89.165%, 90.503% and 94.767 % respectively. The normal range of bus voltages is assumed to be 95-105 %. Jere bus has the highest voltage violation.

Table 7 shows a summary of the branch losses associated with the network before compensation. The result clearly shows that Jere line and transformer T4 has the highest and lowest branch losses of 777.9 kW and 4.2 kW respectively. An overall system loss of 1457.5 kW and 4425.8 kVAr was experienced by the network.

The load flow result presented in Table 8 represents the report obtained after compensation is made. The compensation is achieved through optimal sizing and placement of capacitor banks at affected buses. This compensation led to an overall improvement of the voltage profile of buses in the system network. The graphical representation of the bus voltages before and after compensation is depicted in Figures 3 and 4 respectively.

Table 9 presents the voltage profile of buses before and after compensation with the indication of improvement in the voltage magnitude of all the buses that hitherto fell outside the acceptable value limit of 0.95£V£1.05. Table 10 is a representation of the summary of system losses before and after compensation. Reduction in the overall system loss was observed to be from 1457.5 kW to 1408.4 kW for active power loss and from 4425 kVAr to 4078.6 kVAr for the reactive power loss.

VII. Conclusion

The Load flow modeling and performance analysis of Suleja 132 kV sub-transmission station using ETAP are presented in this paper. A detailed mathematical model of the Newton-Rahson (polar coordinate) for load flow solution is discussed. Also, presented are the results of simulation of the modeled network of the case study, which include bus voltage magnitudes, phase angles, the power flow and losses of the station. The initial results of the load flow analysis showed that six (6) buses had their voltage magnitudes fell outside the specified statutory limit of $0.95 \leq V \leq 1.05$ p.u. These buses include Abuja steel bus, Jere bus, Madalla bus, Rafinsanyi bus, Suleja town bus and Tommy bus with magnitudes of 0.936 p. u, 0.871 p.u, 0.892 p.u, 0.891 p.u, 0.905 p.u and 0.947 p.u. respectively. Since the quality of power supply for any given system depends on the voltage at the buses and transmission power, it is highly imperative to keep the bus voltage within the specified statutory limit and reduce the active power loss to a minimum. Thus, the need for compensation through optimal sizing and placement of capacitor banks at the affected buses. The compensation led to overall performance improvement in voltage profile of all the buses that hitherto fell outside the acceptable value limit of $0.95 \leq V \leq 1.05$ p.u. and reduction in system power loss.

The application of a compensating device on the six (6) buses of the Suleja 132 kV sub-transmission network whose voltage value fell outside the statutory limit showed improvement on voltage magnitudes of the buses to 1.0 p.u. and also reduced the total active power loss from 1457.5 kW to 1408.4 kW, indicating a 3.36% reduction in the total active power loss for the system. Hence, the results of this paper suggest that the load flow of a power system can be performed using Newton-Raphson technique on sub-transmission station and the application of a compensating device as adopted can improve voltage and power profile of the power system.

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Onah, C. O, et. al. "Load Flow Modeling and Performance Analysis of Suleja 132/33 kV Sub-transmission Station." *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 16(4), (2021): pp. 38-48.