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Load Forcast for Omelema Community in Abua/Odual Local Government Area in Rivers State

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ABSTRACT
This study identified tools, techniques and best practices required to monitor and improve network performance in Omelema Community in Abua/Odual Local Government Area in Rivers State. The method employed involved analyzing the network infrastructure, identifying bottlenecks and performance issues and implementing solutions to eliminate or mitigate them. Also, load profiling, regression analysis, mathematical model and simulation using Etap 19.1 in Newton Raphson Environment were carried out and was found that the estimated load of Omelema was 1644.8kW. The analysis of the existing circuit revealed that the existing transformers were overloaded. This was affirmed by the red and pink colours of the transformers and 415 V buses. A single-line diagram consisting of existing distribution transformers, a photovoltaic power plant, step-up/step-down transformers of required capacities and three proposed distribution transformers, were modelled in Electrical Transient Analyser Program (Etap) 19.1. When the proposed model was connected to the existing network the colours disappeared. The power flow in the single-line diagram was optimized in the network in terms of the overloading feeders, bus voltages and current fluctuations. The result further exhibited a reduction in power losses and improved voltage profile of the network. The result also shows a tremendous increase in power when compared to 2018, the total power injected into the existing network was 324.4kW, 243.2kVAr, and when the PV system was connected to the existing grid, the power rose to 624.3kW, 366.5kVAr. It was observed that the proposed distribution transformers will become marginally/critically overloaded (94-95)% in the following years as stated: T_3 with 375kW (468.8kVA) in the year 2075, T_4 with 380kW (475kVA) in the year 2086 and T_5 with 380kW (475kVA) in the year 2074, all at 0.8 power factor. A capacitor bank of 186kVAr is expected to be placed on bus 16 in 2074 for transformer T_5, 184kVAr to be placed on bus 14 for transformer T3 in 2075 and 185kVAr is expected to be placed in bus 15 for T4 in 2086; all at the same power factor 0.98. The regression model utilized was able to forecast the load profile of the community efficiently.
Keywords: Load profiling, Optimization, Omelema Community, Power Supply, Regression analysis

1. INTRODUCTION

The electricity supply and distribution are poor in the Omelema Community, compared to other parts of Abua (Ogbo-Abua) in the Abua/Odual Local Government Area of Rivers State. Each time the feeder supplying power to Omelema is energized, it trips. The feeder needs proper identification of network problems in the distribution system, estimation of the load and general optimization of the distribution system. This involved the identification of network problems, estimation of the existing load and general efficiency of the distribution system.

Improvement of existing power networks requires available information about the line, transformer(s) or substation, the type of feeder lines, primary or secondary and the line parameters (Meyur *et al.,* 2022). Furthermore, according to Roald (2023), he affirmed that "optimization under uncertainty is making optimal decisions in the presence of uncertainty". That means we must be very sure what the problems of a distribution network are before we can make concrete decisions on how to optimize the network. This means we need a better understanding of the network and the application of good methods to solve the problems hindering power supply in the network.

Idowu *et al.* (2019) carried out a study on Nigeria's Electricity Power Sector Reform: An appraisal of unresolved issues. The study explored secondary data sources to examine the issues hindering the delivery of stable power supply and smooth operation of the Sector. The authors identified capital investment, technical losses, national grid system, enabling environment politicization of the power sector etc as the obstacles impeding the actualization of the reform objectives. The authors recommended a holistic liberation of the sector by taking proactive steps to form a regulatory agency, metering customers, and good economic management policy.

Oyeleye *et al.* (2021) researched the design of effective 33/11KV injection substations using International standards. The problem the authors sought to address was voltage fluctuations in the power system. The methodology used was designing an effective 33/11KV substation and associated distribution substation elements using International codes and applicable algorithms. The authors subjected the 7.5MVA power transformer to 60% loading and added 1.25 factor for future expansion. The results they discovered were: that voltage fluctuations can cause damage to power equipment, outage of power supply and damage to substations. The 7.5MVA power transformer was designed to operate at 60% loading and can feed fifteen 500KVA transformers.

According to Heydarzadeh and Tabatabaei (2016), to reduce active and reactive power losses and to improve the voltage margin of the total distribution network; the authors carried out research and recommended distributed generation (DG) and capacitor bank installation. The combined approach was to reduce power loss and improve the voltage margin, the authors used sensitivity analysis to optimize the DGs placement directly on the candidate buses to reduce the search space and provide more effect on the voltage profile improvement. The researchers further used a plant growth simulation algorithm to optimize the DG magnitude and ETAP software was also used to optimally link the capacitor banks into the network to enhance the voltage margins and reduce branch losses. The results obtained from the33–bb IEEE test network were effective. Researchers are not relenting on efficient ways to reduce power losses (real power). Rajaram *et al.* (2015) researched on minimization of power losses and improved voltage profile, by using a modified plant growth simulation algorithm. The results indicated that real power loss was reduced. The algorithm was tested for 33 bus radial distribution system and the results indicated that the algorithm was efficient.

Shakil *et al.* (2020) researched power flow analysis and Optimization in the Ring Distribution Network of Bahawalpur using the Newton-Raphson method.

They used Newton Raphson and the Fast Decoupled Method to minimize the cost of electricity. They studied the effect of optimum active and reactive powers, without affecting the voltage regulation. Power flow algorithms were applied to solve the problem of efficient power generation, supply and distribution of electricity in different regions of Bahawalpur. The result they got was that there was an optimum flow of power along the lines with voltage values among different regions of Bahawalpur and that the results from both algorithms successfully converged and there was an absolute match to validate the accuracy.

Suyono and Hasanah (2016) presented a study on the influence of penetration level and concentration of distributed generation on power losses in the network. Steady-state power flow analysis was used to examine the power loss variation for a variety of distributed generation penetrations using existing potential power plants. The results showed an improved voltage profile and a reduction in power losses in the system.

This paper proposes the loading pattern for the distribution transformers based on the design of the network and uses a mathematical model (least square regression method) to forecast when the distribution transformers will be overloaded for further improvement. According to Dudex (2023), long-term forecasting in a power system involves predicting electricity demand several years in advance. Sometimes the way and manner data are collated from a source for experimental purposes and research work affects the overall result in a distribution network. Claeys *et al* (2021) and Ekeriance *et al* (2024) declared that mathematical optimization is a key technology in modelling electrical distribution systems and can be used for efficient management of the network system, for optimal results.

The main objectives of this study are :

i. To profile the loads of the Omelema Community
ii. To determine the projected loading of the proposed relief transformers using least square regression analysis

2. MATERIALS AND METHOD

2.1 Materials

The materials needed for this work include the following:

Concrete pole length 10.32m/18.54m, mixed steel/wooden cross arm length – 1.8m, span length-45/50m, conductor size 100mm^{2}AAC, planting depth – 1.8/1.2m, 33/11kV pin insulators and disc insulators, D-Iron and shackle insulators for TDN 0/H lines. Other materials are R. M. U with two extensions, lighting arresters, earthing material, drop-out fuses, line isolators, transformers, a photovoltaic power plant and a laptop.

2.1.1 Data Source and Collection

The data was obtained through the load profile of the Omelema community and a secondary source from Port Harcourt Electricity Distribution (PHED) staff. The load profile data and the secondary source data were subjected to least square regression analysis. This is shown in Table 1.T_3, T_4 and T_5 are the yearly expected load of the transformers.

2.2 Method

The load of the Omelema community was profiled and a total load of 1644.8kW was gotten. A single-line diagram was designed and assembled. Regression analysis was adopted to analyse the load increment per year. The comprehensive single-line diagram was assembled and simulated using the Newton-Raphson method embedded in (ETAP 19.1) to analyse the power flow in the network.

2.2.1 Load Survey and Analysis

The community consists mainly of residential buildings; small-scale and agro-allied industries and anticipated individual development. Maximum demand will occur in the evening when all types of equipment are in operation. The basic loads were divided into the following groups:

i. Dwelling houses
ii. Offices, repairs outlets/workshops
iii. Commercial (Electric motors and other electric tools).

Table 1: Yearly Expected Load

YEAR	**EXPECTED LOAD (KW)**		
	T_3	T_4	T_5
2018	42	35	28
2019	52	40	33
2020	58	45	38
2021	60	50	48
2022	67	55	52

These values were validated by records from PHED staff which compares significantly.

The expected loads for T_3, T_4 and T_5 were analyzed using the least square regression equation y=a+bx, for each transformer to determine the load growth pattern and when each transformer will be due for improvement replacement, or relief of the entire circuit transformers

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CASE 1: Transformer T_3

Table 2: Yearly Expected Load

Year	X	Expected load ykw	XY	X^2
2018	-2	42	84	4
2019	-1	52	-52	1
2020	0	58	0	0
2021	1	60	60	1
2022	2	67	134	4
	Σx=0	Σy=279	Σxy = 58	Σx^2=10

$$y=a+bx \quad (1)$$

$$b=\frac{n\Sigma xy-\Sigma x\,\Sigma y}{n\Sigma\times 2-(\Sigma\, x)2} \quad (2)$$

n= 5

$$\frac{5(58)}{5(10)}-\frac{0\,(279)\,0}{(0)2}$$

b = 5.8

$$a=\frac{\Sigma y}{n}-\frac{\Sigma x}{n}$$

$$=\frac{279}{5}-\frac{5.8\,(0)0}{5}$$

= 55.8

a = 55.8

b = 5.8

The regression equation y = 55.8 + 5.8 x (3)

The regression analysis was represented in a flow chart using the regression equation for transformers T_3, T_4 and T_5 as shown in Figure 1.

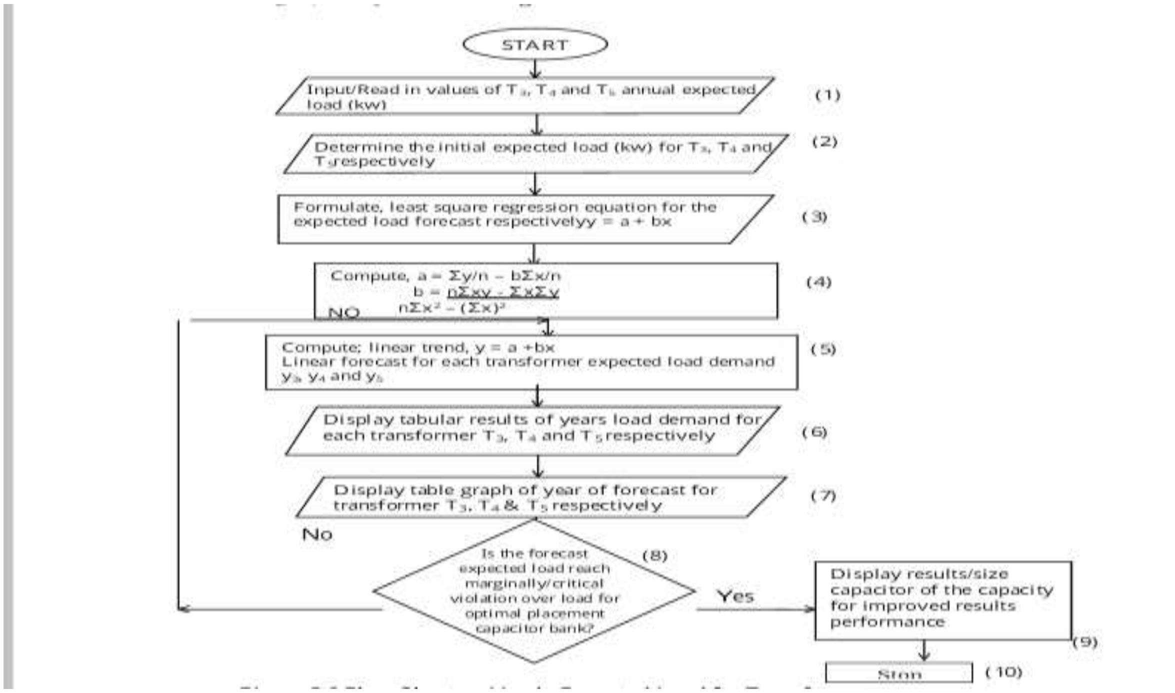

Figure 1: Flow Chart on Yearly Expected Loads on Transformers

Capacitor Bank Calculation

$$Q_c = P[\tan\cos^{-1}(pf_1) - \tan\cos^{-1}(pf_2)] \quad (4)$$

Where

P: injected active power

Pf_1: Initial power factor

Pf_2: Desired power factor

Parameters For Bus 14, T_3 in the year 2075

P = 335.9kW

Pf_1=0.8

Pf_2=0.98

$$Q_c = 335.9 * [\tan\cos^{-1}(0.8) - \tan\cos^{-1}(0.98)]$$

$$Q_c = 335.9 * [\tan 36.870 - \tan 11.478]$$

$$Q_c = 335.9 * (0.75 - 0.203)$$

$$Q_c = 335.9 * (0.547)$$

$$Q_c = 183.74kvar$$

Parameters For Bus 15, T_4 in year 2086

P = 337.7kW

Pf_1=0.8

Pf_2=0.98

$$Q_c = 337.7 * [\tan\cos^{-1}(0.8) - \tan\cos^{-1}(0.98)]$$

$$Q_c = 337.7 * [\tan 36.870 - \tan 11.478]$$

$$Q_c = 337.7 * (0.75 - 0.203)$$

$$Q_c = 337.7 * (0.547)$$

$$Q_c = 184.72kvar$$

Parameters For Bus 16, T_5 in the year 2074

P = 240.2kW

Pf_1=0.8

Pf_2=0.98

$$Q_c = 240.2 * [\tan\cos^{-1}(0.8) - \tan\cos^{-1}(0.98)]$$

$$Q_c = 240.2 * [\tan 36.870 - \tan 11.478]$$

$$Q_c = 240.2 * (0.75 - 0.203)$$

$$Q_c = 240.2 * (0.547)$$

$$Q_c = 186.1kVAr$$

3. RESULTS AND DISCUSSION

3.1. Results of the Profiled Loads of Omelema Community

The simulation result as shown in Figure 2 represents the existing grid of Omelema Community with initial 2NOS. 300KVA, 33/0.415KV transformers. The transformers were loaded up to 280KV (224KW) each of them with a power factor of 0.8. When 0.8 power was applied into the network in a simulation exercise using Newton Raphson method imbedded in (ETAP 19.1) to analyse the power flow in the network, the real and reactive powers observed at the output of transformer T_1 and T_2 were 209KW, 156.7kVAr in each of the transformers. The transformers' symbols T_1 and T_2 were showing red colours, while the buses were showing pink colours. The colours shown were an indication of network violation. The transformers were overloaded by 93% as against 70 – 80% as recommended. The same applies to the bus bars. Similarly, the result of the mathematical model revealed that the total load for the Omelema Community was far above the existing network transformer hence the existing transformers were overloaded and thus need relief transformers or network improvement.

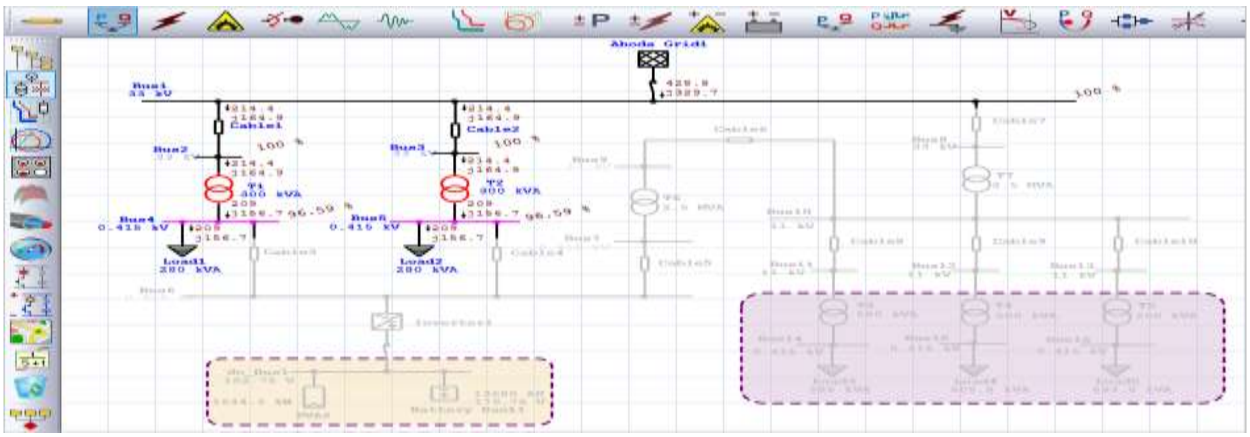

Figure 2: Simulation Result of Existing 2Nos. 300kVA, 33/0.415kV Network in Omelema Community

3.2. Results of the Determined Projected Loading of the Proposed Relief Transformers via Regression Model

The simulation exercise continued as shown in Figure 3, this was done in some selected years 2023, 2048, 2063, 2048 and 2076. It was observed that the network showed violations in some of the years and T_4 but showed no violations in T_3 and T_5 in the year 2076. Each of the simulation processes has its own projected value of load for T_3, T_4 and T_5 and the corresponding respective injected voltages in each year. When the existing network was stimulated it showed the usual red colours on the transformers symbols but when the existing network was connected to the designed model, there was no violation.

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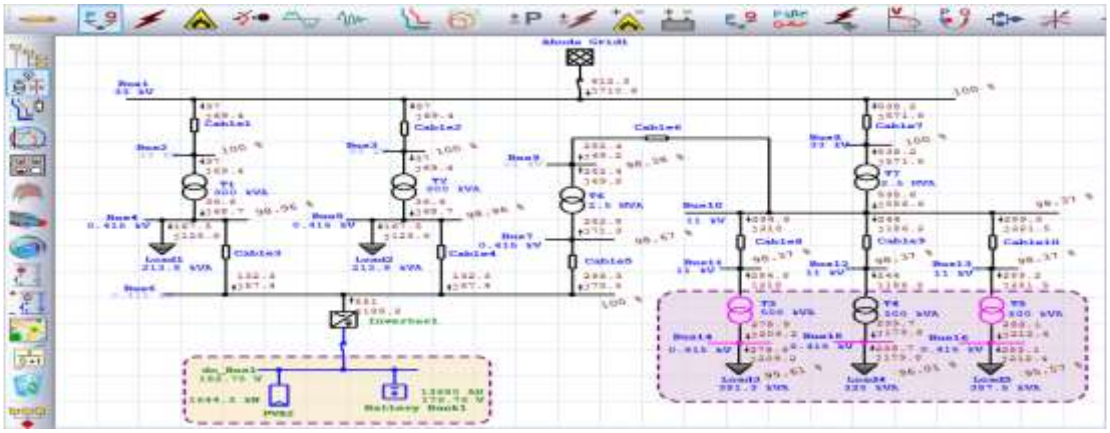

Figure 3: Simulation Result Showing Projected Load for T_3, T_4 and T_5 in year 2076

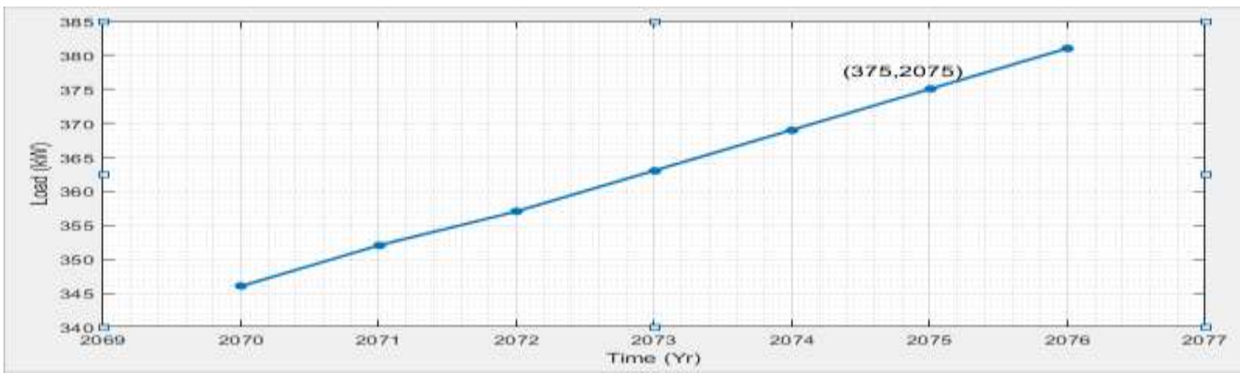

Figure 4: Graph of Load v year for T4

Figure 4 shows the relationship between load KW vs Time (yr) for the projected loading capacity of T_4. The observation shows that linearity exists among the three transformers; it specified the maximum load and year of overload for capacitor bank placement. Table 3 shows the summary of data for the relief transformers proposed and the photovoltaic plant. Further projected loads were imputed into the proposed transformer T_3, T_4 and T_5 and simulated in year 2078, 2089 as shown in Figure 5, the networks were not healthy in each of the simulation for transformers T_3, T_4 and T_5. Their buses showed red and pink colours respectively. Transformer T_5 and its bus showed red and pink colours respectively. Network violations means that transformers loading, voltages and current are either below or extremely above minimum level of operation. It means the network performance was poor and needs improvement for those years specified.

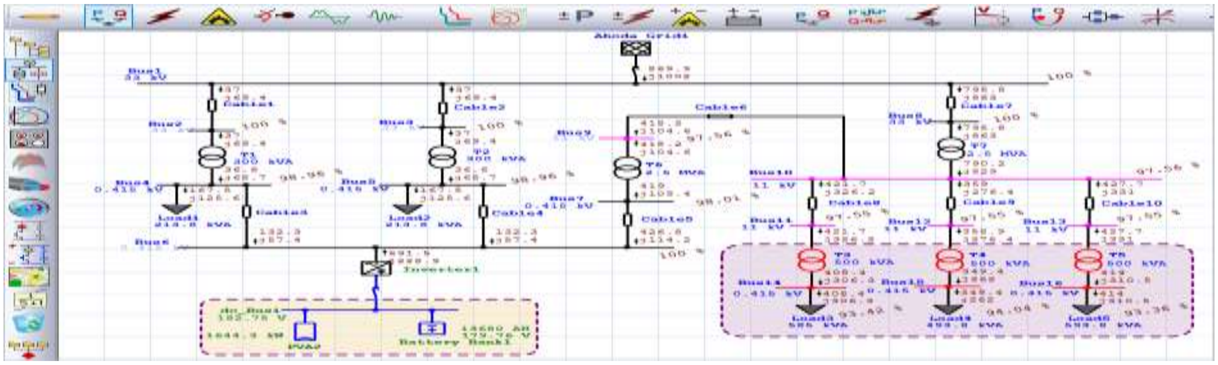

Figure 5: Expected Load in Year 2089 (T3: 106.6%, T4: 90.6% & T5: 108.2%)

Table 3: Simulation Results Data for T_3, T_4 T_5 and PV

Transformer/ PV	Kw	Kvar	MaX.load	Year	Remarks
T_3	335.9	251.5	468.8	2075	94-95% Overloaded
PV	615.9	206.6		2075	
Total power	951.8	458.1		2075	94-95% Overloaded
T_4	337.7	253.2	475	2086	
PV	674.6	223.9		2086	
Total power	1,012.3 477.1				
T_5	340.2	255.2	475	2074	94-95% Overloaded
PV	610.7	2051		2074	
Total power	950.9	460.3		2074	

When historical data are available, some proven statistical forecast can be developed in a distribution network. Forecasting about the future performance of a power network saves equipment breakdown due to faults and thus saves cost of repair as shown in Table 4 (Manukyan *et al*., 2020).

Table 4 : Summary of Transformers Yearly Expected Load

Year	X	T_3	T_4	T_5	Remark
2018	-2	44.2	35	27.20	
2019	-1	50.00	40	33.50	
2020	0	55.80	45	39.80	
2021	1	61.60	50	46.10	
2022	2	67.40	55	52.40	
2023	3	73.20	60	58.70	
2024	4	79.00	65	65.00	
2025	5	73.20	70	71.30	
2026	6	79.00	75	77.60	
2027	7	96.60	80	83.90	
2028	8	102.20	85	90.20	
2029	9	108.00	90	96.50	
2030	10	113.80	95	102.80	
2031	11	119.6	100	109.1	
2032	12	125.4	105	115.4	

2033	13	131.2	110	121.7	
2034	14	137.00	115	128	
2035	15	142.8	120	134.3	
2036	16	148.6	125	140.6	
2037	17	154.4	130	146.9	
2038	18	160.2	135	153.2	
2039	19	166.0	140	159.5	
2040	20	171.8	145	1695.8	
2041	21	177.6	150	172.1	
2042	22	183.40	155	178.4	
2043	23	189.2	160	184.7	
2044	24	195.5	165	191	
2045	25	200.8	170	197.3	
2046	26	206.6	175	203.6	
2047	27	212.4	180	209.9	
2048	28	218.2	185	216.2	
2049	29	224	190	222.5	
2050	30	229.8	195	228.8	
2051	31	235.6	200	235.1	
2052	32	241.4	205	241.4	
2053	33	247.2	210	247.7	
2054	34	253	215	254	
2055	35	258.8	220	260.3	
2056	36	264.6	225	266.6	
2057	37	270.4	230	272.9	
2058	38	276.2	235	279.2	
2059	39	282	240	285.5	
2060	40	287.8	245	291.8	
2061	41	293.6	250	298.1	
2062	42	299.4	255	304.4	
2063	43	305.2	260	310.7	
2064	44	311	265	317	
2065	45	316.8	270	323.3	
2066	46	322.6	275	329.6	
2067	47	328.4	280	335.9	
2068	48	334.2	285	342.2	
2069	49	340	290	348.5	
2070	50	345.8	295	354.8	
2071	51	351.6	300	361.1	
2072	52	357.4	305	367.4	
2073	53	363.2	315	373.7	
2074	54	369	320	380	T^5 95% Marginally overloaded
2075	55	374.8	325	386.3	T^3 95% Marginally overloaded
2076	56	380.6	330	392.6	
2077	57	386.4	335	405.2	
2078	58	392.2	340	411.5	
2079	59	398	345	417.8	
2080	60	403.8	350	424.1	
2081	61	409.6	355	430.4	

2082	62	415.4	360	436.7	
2083	63	421.2	365	443	
2084	64	427	370	449.3	
2085	65	432.8	375	455.6	
2086	66	438.6	380	461.9	T^4 95% Marginally overloaded
2087	67	444.4	385	461.9	
2088	68	461.8	390	468.2	
2089	69	467.6	395	474.5	
2090	70	473.4	400		
2091	71		405		
2092	72		410		
2093	73		415		
2094	74		420		
2095	75		425		
2096	76		430		
2097	77		435		
2099	78		450		
20100	79		455		
20101	80		460		
20102	81		465		
20103	82		470		
20104	83		475		

4. CONCLUSION

The research identified tools, techniques and best practices needed to check and thus, enhance network performance in Omelema Community in Abua/Odual Local Government Area in Rivers State. The model employed involved analyzing the network infrastructure, identifying bottlenecks and performance issues and implementing solutions to eliminate or mitigate them. From the study, the loadings of the transformers T_3, T_4, & T_5 from 2018 to 2090, are analyzed. T_3 will be overloaded maximally at 95% with 375kW(468.83kVA) of load in 2075, T_4 will be overloaded in the year 2086 when x = 86 with 380kW (475kVA) and T_5 will be overloaded at 380kW (474.9kVA) 95% marginally when x = 69 in the year 2089.

Over the years, development has taken place in the community due to oil companies' activities. The new housing estate was proposed which attract investors and company staff who need accommodation. At present, the load has increased from 600kVA to 1456kVA giving rise to a load of 2,056kVA. Thus, the existing load of 300kVA and 33/11kVA transformers which are overloaded, are to be relieved by 3Nos 500kVA,11/0.415kV transformers. To achieve this, 2.5MVA, 33/11kV transformers were installed to step down the 33kV line to the 11kV line so that the relief transformers could be installed.

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