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Improved Randomized Flow Model for 330kV Electric Power Transmission Network

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ABSTRACT

The study of improved randomized flow model for 330kV electric power transmission network in Nigeria focused on the Benin and Oshogbo regional 330kV network. This research is based on a randomize model and mathematical reliability assessment of the existing 330kV power transmission networks in Benin and Oshogbo regions. The network centrality values, performance characteristic, probability of failure and reliability were evaluated. With the collected data and networks information a randomized algorithm was develop, coded and implemented in MATLAB R2016a and mathematical reliability analysis to determine the critical buses as well as the reliability of the network and elements, load flow analyses in ETAP 12.6 to validate the results. The network performance for Benin region, the blackout in the network is 4.3%, overload is 43%, Computed Network Demand Load (297), Network Received Load (402) And Network Lost Load (110), The Network Service Efficiency is 1.38 and Average Betweenness Centrality (0.813). As for Oshogbo region, the blackout in the network is 6%, overload is 60%, Computed Network Demand Load (249.3), Network Received Load (266.7) And Network Lost Load (176), The Network Service Efficiency is 1.069 and Average Betweenness Centrality (0.686). All the above parameters showed that both region have unreliable, weak, over stretched network and elements. The study recommended investment in upgrading of generation and transmission capacity of the networks as well as regular maintenance of the lines.

Key words: Critical elements, Random Betweenness centrality, randomized model, reliability assessment, Voltage collapse

INTRODUCTION

In any developing and industrialized society, electricity is the backbone of its economy growth. Hence, increase in industrial and economic activities have corresponding increase for power demand. Equally, population increase is another factor that affect increase in electric power demand. For instance, our exponentially increasing population in Nigeria need corresponding increase in basic social, economic and infrastructures to meet the increasing demand which is the major events which causes critical failures of system functionality [1]. This increasing needs can only be meet by industrialized and mechanization activities which in turn requires reliable and steady power supply. The only solution to this increasing power need is the periodic and constantly review of the power supply system dynamics with proportional upgrade of power stations and existing power networks [2].

In Nigeria today, one of the major causes of frequent voltage collapse and power outage is lack of automation which has become endemic. Despite heavy investments in the power sector by the federal government in recent years, the existing generation, transmission and distribution networks are highly constrained resulting to low voltage profile, high line losses, poor reliability, low maintenance, overloading of transformers, haphazard layouts, and whimsical load connections according to [3].

In actual synthetical analysis, when the vulnerability, reliability, quality, and safety of engineering infrastructure especially power transmission infrastructure is considered, there is need to take into account the capacity and failure probability of the transmission elements and different flow routes available to them. This type of study involves a very detailed, robust and complex mechanical and physical modelling of the entire network which is practically unfeasible in respect to its development and computational procedure. Because of the above limitations, a problem solution driving approach known as random flow technique have been proposed which integrate model at different levels of details; with an objective and result-oriented modelling techniques [4].

The Benin and Oshogbo region is at the center of electric power evacuation in Nigeria, it is also at the center of the gas powered generation stations cutting across about six states in the Southern part of Nigeria. Therefore, it is crucial to consider and investigate it when analysing 330kV Nigerian Power Network because any serious disturbance to it can affect the entire Nigerian network.

The random walk technique and mathematical reliability analysis technique will be applied on at random points of the 330kV Transmission to determine the capacity of the lines and performance of the transmission network. The challenges in the Nigerian Power Transmission network may lead to:

i. Power outages/black out in the network (under investigation)
ii. Overload on the overstretched network (results into losses)
iii Network operating in maximum operation limits (resulting to instability in network)
iv Mismatches of the available power supply and needed energy demand (constraint energy balance equation)
v. More operational service cost to alternative power supply (from the consumer ends)

The specified objectives for the randomized model are contained as:

i. Collect data for the representation and modeling of the supply system for The Benin and Oshogbo regions of the 330KV transmission network.
ii. Formulate governing expression to characterize the existing problem under study.
iii. Implement collected data into formulated governing equations.
iv. Implementation of the random flow model using MATLAB tool
v. Validate results using E-TAP application tool and mathematical reliability analyses.
vi. The outcome will be used to assess the efficiency of the network and its elements.
vii. Adoption of available techniques to improve the networks under study.

this study will use the application of random power flow model and mathematical reliability techniques particularly on The Benin and Oshogbo region of the Nigeria's 330kV transmission network for improved power quality in a developing economy. The results from this study will be beneficial to power system expansion planers and operators, government, investors and the consumers.

System Reliability: The duration, frequency, system availability, and response time of outages are all monitored by reliability performance measures (RPM). In general, an interruption lasting longer than five minutes is regarded as a reliability concern, whereas an interruption lasting less than five minutes is regarded as falling within the power quality [5]. **Power Quality:** Sources of power quality challenges and problems can be categorized into load sources, power system sources and weather or environmental sources. solution of power quality problems can be achieved by good design of equipment (electrical and electronic) and electrical systems [6]. **Power System Stability:** The stability of a power transmission network is the capacity of the network to detect emergent contingencies in a function of its constitution operating parameters and in general its contingency indexing plan **Voltage Collapse:** Voltage collapse can be referred to as the process through which a number of factors, including voltage instability, cause an unnecessarily low voltages or blackout in a sizable portion of the electrical network [7]. **Artificial Intelligence in Power System:** Artificial intelligence techniques are most effective techniques for developing optimal controllers for custom power devices. It was further reviewed that the commonly used artificial intelligence controllers are Fuzzy logic controllers and ANN controllers [8]**. Randomized Model:** A simplified network called a randomized model assumes that all pathways between nodes contribute essentially to the flow to a bus. Any number of physical components in a network nodes or buses can be utilized in randomized analyses to evaluate the entire network, since its practically unfeasible to model the whole physical components in a large system like the electrical transmission network. In these types of analyses, different measures for a network link's importance will be established. These are referred to as centrality measures, which consider the various ways in that a bus can interacts with the other nodes in the network. Various randomized strategies exist, including Random Walk Decay centrality, Random Walk Closeness centrality, and Random Walk Betweenness centrality [9].

MATERIALS AND METHODS

The materials for implementing the proposed randomized power flow model and reliability techniques are:

i. Electrical Transient Analyze (ETAP software tool) for the simulation of the network and Newton Raphson method for the load flow.
ii. MATLAB R2016a software used for implementation of random flow.
iii. The line and bus parameters of the Benin and Oshogbo regions of 330kv transmission network and historical information for 2019 are used for the study.
iv. Outage historical information for 2019 Benin and Oshogbo regions of 330kv transmission network are used.

v. Single Line diagram for Benin and Oshogbo regions of 330kv transmission network.

This research work will adopt the application of Randomized flow model implemented in MATLAB R2016a as well as reliability techniques in line with integrity of reliability of probabilistic trends for determination of failure of system network and components under investigation. ETAP 12.6 simulation is used to validate results.

Description of the Network

The Nigerian transmission company provided the information for this analysis. the network of the 330kV power infrastructure in Nigeria. a 34-bus network made up mostly of both linear and non-linear components, such as generators, load terminals or buses, and transmission network are used.

Development of Randomized Flow Model Algorithm

According to [10] the various buses of the power transmission network are represented as nodes connected by undirected edges representing the transmission lines; NS nodes are power sources, NT nodes are targets (loads), and the remaining nodes are transmission nodes. The transmission network topological interconnection in a normal power network is simply modelled as a network made up of N nodes (known as vertexes) and K edges (known as lines) $N_X N$ adjacent matrix define the topological structure of the network. The randomized model gives specific consideration to the below points;

1. Each link connecting two bus is characterized by a transmission capability which cannot be exceeded;
2. Stochastically, the capability of the links are assumed to vary, to account for the disturbances inherent in their behaviour and operation.
3. The direction of the flow in output from a node is driven by the capacities of the outgoing links; the highest capacities of the outgoing links; the highest links probably channel the flow;
4. The network interconnecting links are seemingly fallible, with given probabilities values.
5. Source generation and load demands area assumed to vary in order to account for the inconsistencies inherent in the network mode of operation.

The underlying strategy to model the flow in the network is to choose a source node, connect one of the departing links to one of its neighbours, take this as a source and repeat same process until the required target is reached. The random choice of the arc to follow is based on the actual capacity of each arc departing from the node: higher capacity arcs have larger probability to be selected as flow carries. Three nested cycles of randomization make up a simplified method for the technique to assess the network's service reliability, performance characteristics, and related vulnerabilities of a power network, the fundamental components are as follows;

1. Considering the failure probabilities of each system component (bus or line), sample the network's fault configuration. Test the capacity of the arcs, the output from the supply, and the demand at the targets.
2. Create a discrete cumulative distribution function of the arc capability exiting the supply bus, then take record of the direction of flow.
3. For every supply, create the flow propagation cycle:
   i. The random walk of the flow travels along the arc sampled in accordance with the actual capacities of the rcs departing from the flow's successive nodes.
   ii. The cycle comes to an end if the flow enters a lone node with no departing connections.
   iii. A pair of nodes' flow is only taken into account once (repeated flows between the same pair of buses are rejected).
   iv. The moment the flow reaches the target node, the incoming arcs' capabilities are examined; if their sum exceeds the node's maximum capability, an overload is noted.
   v. A fresh random walk source is examine if the flow is unable to reach the desired destination. If none of the targets receive any flow, a blackout is signalled.

The Random Betweenness Centrality

The average number of times a random walk beginning at s and terminating at t passes by a node I while passing between them is known as the random walk Betweenness of that node. This centrality measurement is appropriate for a network where information essentially follows random paths until it locates its objective and contains contributions from numerous such paths that are not optimal. Let Ii^{st} represent the current passing through node I from s to t. The random Betweenness centrality measure is described quantitatively as;

$$RWC_i^B = \frac{s_i}{\sum_{n=0}^{\infty}\left[\frac{s_i}{\sum_{l=1}^{N}}(n) - \frac{s_i}{\sum_{l=1}^{N} s_l}\right]\sum_{l=0}^{N} s_l} \tag{1}$$

this measure looks like a naturally logical way to express the notion that current will flow down any route from supply source to load, and nodes that are not on any such route receive a betweenness of zero. The Betweenness centrality plays a key role in the identification of critical components of complex networks according to [11].

Modelling of Random Betweenness Centrality Equation

The average number of times a random walk beginning at s (source) and terminating at t (target) passes by a node i while passing between them is known as the random walk betweenness of that node. This centrality measurement is appropriate for a network where information essentially follows random paths until it locates its objective and contains contributions from numerous such paths that are not optimal.

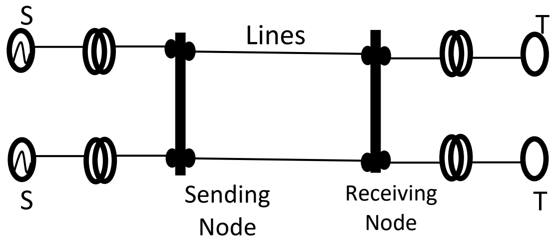

Fig. 1 Transmission System Model

Let Ii st represent the current passing through node i from s to t. The Transmission System representation to model the Random Betweenness Centrality Equation is shown below;
To model the concept of RW betweenness centrality of networks, the researcher will use the established random flow Betweenness equation;

$$b_i^{rw} \alpha \sum_{is=1}^{N} \sum_{it=1}^{is-1} \tag{2}$$

Which states the number of times that a walker starting at vis and ending at vit actually visits vi, it is based on the idea of maximum flow.

Where, vi is ith node, vj is jth node, vis is initial source node, vit is initial target node, is = i$^{th\ source}$, it= ith target. N is the number of nodes.

Consider a transmission network where current is injected from vis and drain at vit, suppose that each edge has a conductance of $A_{ij,}$ and Vi denotes the voltage at node vi. Applying Kirchhoff's current law at each vi. Kirchhoff's current law states that;

$$\sum_{i=1}^{N} I_i = \sum_{i=1}^{N} I_j \tag{3}$$

Applying the law to transmission line current flow will yield

$$\sum_{i=1}^{N} A_i j \ (\text{Vi} - \text{Vj}) = \delta_{i,is} - \delta_{i,it} \tag{4}$$

The maximum flow going from any supply i to any load j is given as $m_{ij,}$

$$m_{ij} = \left(\sum_{l=1}^{N} sl\right) \times \left(\frac{R_{jj}^{(0)}}{s_j} - \frac{R_{ii}^{(0)}}{s_i}\right) \tag{5}$$

Since from Theremin's equation, for maximum flow to occur
RL=Rth (6)
Where RL is load resistance and Rth is the Thevenin's resistance.
Equally, the maximum flow from sink j back to a source i is given as m_{ji}

$$m_{ji} = \left(\frac{R_{ij}^{(0)}}{s_j} - \frac{R_{ji}^{(0)}}{s_i} \right) \tag{7}$$

To evaluate RW centrality, we subtract Eq. (6) and Eq. (7)

$$m_{ij} - m_{ji} = \left(\sum_{l=1}^{N} sl \right) \times \left[\left(\frac{R_{jj}^{(0)}}{s_j} - \frac{R_{ii}^{(0)}}{s_i} \right) - \left(\frac{R_{ij}^{(0)}}{s_j} - \frac{R_{ji}^{(0)}}{s_i} \right) \right] \tag{8}$$

For undirected networks, Substituting values of S_I and R^o balance out to

$$s_i p_{ij}(n) = s_i \sum_{l_1, l_2, \ldots, l_{n-1} = 1}^{N} \frac{A_{il_1}}{s_i} \frac{A_{l_1 l_2}}{s_{l_1}} \times \frac{A_{il1}}{s_{ln\text{-}1}} \tag{9}$$

$$\frac{R_{ij}^{(0)}}{s_j} = \frac{\sum_{n=0}^{\infty} \left[p_{ji}(n) - \frac{s_i}{\sum_{l=1}^{N} s_l} \right]}{s_i} = \frac{R_{ji}^{(0)}}{s_i} \tag{10}$$

$$m_{ij} - m_{ji} = C_{rw}(j)^{-1} - C_{rw}(i)^{-1}, \tag{11}$$

Where

C_{rw} is the random walk centrality value given as

$$C_{rw}(i) \equiv \frac{s_i}{R_{II}^{(0)} \sum_{l=1}^{N} s_l} \tag{12}$$

$$C_{rw}(i) = \frac{s_i}{\sum_{n=0}^{\infty} \left[p_{ii}(n) - \frac{s_i}{\sum_{l=1}^{N} s_l} \right] \sum_{l=1}^{N} s_l} \tag{13}$$

From the eq, above, Substituting values of P_{ij} into eq. (13) gives

$$RWC_i^B = \frac{s_i}{\sum_{n=0}^{\infty} \left[\frac{s_i}{\sum_{l=1}^{N}} (n) - \frac{s_i}{\sum_{l=1}^{N} s_l} \right] \sum_{l=0}^{N} s_l} \tag{14}$$

Where node current is n.
Eq. (3.20) is the random Betweenness centrality for power network

System Performance Indicators and Elements Measurements

The Performance of a power system in this analytical evaluation is with respect to the following indictors for randomized power flow is as:

i. Blackouts and overload problems are computed considering the average value of the flow which did not reach the load or is above the rating capability of the power transmission network, respectively.

ii. The network demanded load is the addition of all average power generated from all supply, $S_i, i = 1, 2, 3, \ldots N_g$ Hence,

$$\text{NDL} = \sum_{i=1}^{N_{si}} S_i \tag{15}$$

where; ND_L: Network demand load

S_i : summation of sources of generation

Ns_i : Number of electrical energy generated from all the supply sources

iii. The network received load is addition of all average power flow reaching the target

$l_i, i = 1, 2, 3, \ldots N_i$:

$$NRL = \sum_{i=1}^{Ni} t_1 \tag{16}$$

iv. the network lost load is calculated as the difference between network demand and network received load:

$$NLL = NDL - NRL \tag{17}$$

v. The network service efficiency is calculated as the ration between network received load and network demand loads; that is

$$NSE = \frac{NRL}{NDL} \tag{18}$$

2.6 Benin Region of Nigerian 330kV Transmission Network

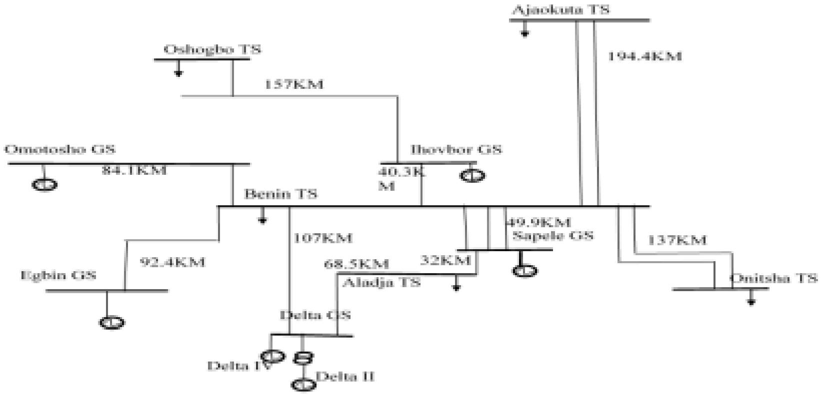

Fig. 2 Single line diagram of 330kV Benin region network

Source: Extract from Transmission Company of Nigeria (2020) 330kV Nigerian Transmission Network

Transmission Company of Nigeria (TCN) has Ten transmission regions, namely: Shiroro, Kaduna, Kano, Bauchi, Oshogbo, Benin, Enugu, Port Harcourt, Abuja and Lagos. The Benin region has four work stations, namely: Benin, Ajaokuta, Sapele and Delta. Equally, The Benin sub-region has Seven generation stations: Sapele i, Sapele ii, Delta ii, Delta iii, Delta iv, Ihovbor and Egbin, and Nineteen circuits according to TCN annual report, 2019. Randomized and mathematical reliability techniques will be employed to investigate the load flow scenario of the study case and suggest improvement to the network. the single line diagram for the study case is as presented in figure below;

Reliability Analyses Using Mathematical Techniques

From the above data, using mathematical techniques, the failure rate and probability of failure is computed as shown in table 1 below.

$$Failure\ \text{Rate}\ \delta = \frac{\text{Fault Frequency}}{Duration\ \text{of Fault}} \tag{19}$$

and the probability of failure is given as:

$$q_{ij} = 1 - e^{-\lambda ijT} \tag{20}$$

From eq. (20), Failure rates for Benin region are

$$Failure\ \text{Rate}\ \delta = \frac{28}{77} = 0.36$$

and Probability of failure, $q_{ij} = 1 - e^{-0.36x1} = 0.3023237$

Table 1: Transmission line, Failure rate and Betweenness centrality for Benin region

S/N	From	To	Frequency of Fault	Total Outages forr 2019 (Hrs)	Failure Rate	Probability of Failure	Betweenness Centrality
I	Benin	Onitsha (BIT)	28	77	0.36	0.3023237	1.5624
2	Benin	Onitsha (B2T)	18	203	0.09	0.0860688	2.6740
3	Benin	Omotosho (B5M)	25	83	0.30	0.2591818	1.2247
4	Ihovbor	Oshogbo (V7H)	59	446	0.13	0.1219046	0.6123
5	Ihovbor	Benin (V7B)	34	167	0.20	0.1812692	0.3674
6	Sapele	Benin (S3B)	50	308	0.16	0.1478562	0.2449

7	Delta	Benin (D3B)	37	112	0.33	0.2810763	0.1750
8	Benin	Ajaokuta (B11J)	45	151	0.30	0.2591818	0.1312
9	Benin	Ajaokuta (B12J)	46	94	0.49	0.3873736	0.1021
10	Benin	Egbin (B6E)	29	75	0.39	0.3229431	0.9816
11	Sapele	Benin (S4B)	32	118	0.27	0.2366205	0.1668
12	Sapele	Benin (S5B)	43	435	0.09	0.0860688	1.0557
13	Sapele	Aladja (S4A))	22	250	0.09	0.0860688	1.0471
14	Delta	Aladja (D4A))	20	123	0.16	0.1478562	1.0404
	TOTAL		488	2642			

Source: TCN 2019

Table 1 shows that for the Benin region, the Benin-Ajaokuta line (B12J) has the highest failure rate, followed by Benin-Egbin (B6E). The Sapele-Benin Line (S5B) and Sapele-Aladija (S4A) has the lowest failure rate. Table 1 shows that the network with the highest failure rate has the highest probability of failure. Table1 also shows the Benin region, Benin-Onitsha line2 (B2T) has the highest centrality value followed by Benin-Onitsha line1 (B1T). The Sapele-Benin lines (S4B) and Benin-Ajaokuta line (B12J) has the lowest centrality values.

Implementation of the Random Flow Model

From the equation quantitatively random Betweenness centrality measurement as expressed, working with the Benin Region data in Table 1 above, and with the development, coding and implementation of the random flow algorithm in MATLAB R2016a,. Centrality values can also be evaluated as shown below;

$$RWC_i^B = \frac{s_i}{\sum_{n=0}^{\infty}\left[\frac{s_i}{\sum_{l=1}^{N}}(n) - \frac{s_i}{\sum_{l=1}^{N} s_l}\right]\sum_{l=0}^{N} s_l} \quad (21)$$

$$RWC_i^B = \frac{185}{\sum_{n=0}^{\infty}\left[\frac{185}{\sum_{l=1}^{N}}(0.00272) - \frac{185}{185}\right]185}$$

$$RWC_i^B = \frac{185}{118} = 1.5624$$

Simulation of Benin Region of 330kV Transmission Networks Using ETAP

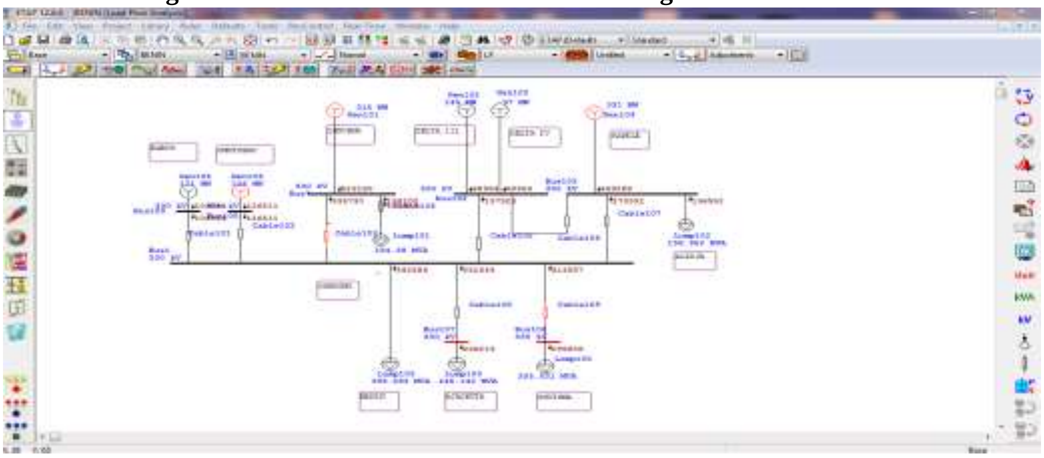

Fig. 3 Violations in Benin region network

Simulation of Benin Region of 330kV Transmission Networks.

Figure 3 shows the violations in Benin region network, Benin-Onitsha (B2T) and Benin-Ihovbor (B7V) lines are overloaded. It is also shown that the Generation station at Sapele, Omotosho and Ihovbor are overloaded. Ajaokuta and Onitsha buses have under-voltage issues

Study Case 2: Oshogbo Region of Nigerian 330kV Transmission Network

The Oshogbo region have Four generation station; namely, Jabba, Ihavbor, Olorunshogo and Egbin. It also has four load centers; namely, Ayade, Ganmo, Oshogbo and Papalanto.

the single line diagram for the study case is as presented in figure below;

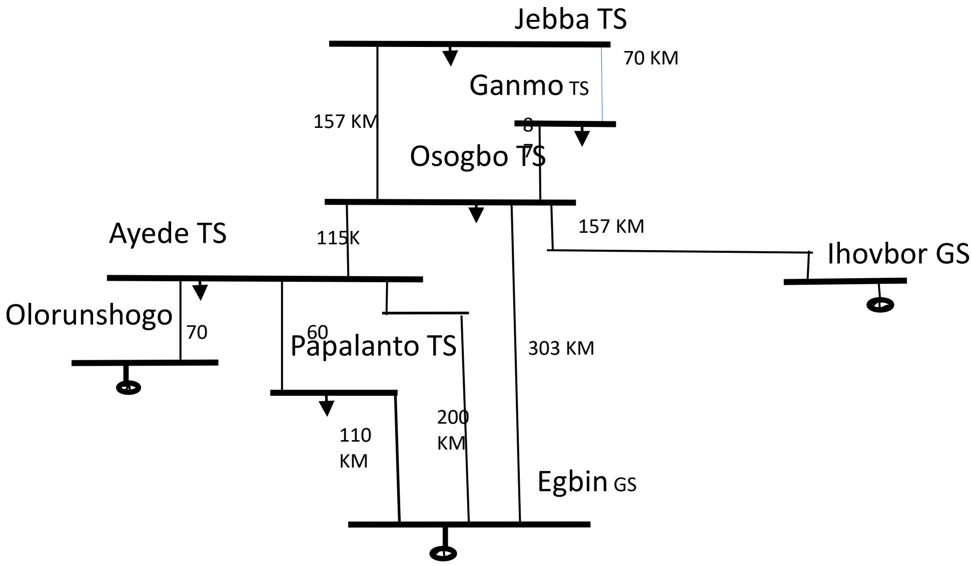

Fig. 4 Single-Line Diagram of Oshogbo Region of 330kV Network

Mathematical Techniques Using Reliability Analyses

From the above data, using mathematical techniques, the failure rate and probability of failure is computed as shown in table 2.

$$Failure\ \text{Rate}\ \delta = \frac{\text{Fault Frequency}}{Duration\ \text{of Fault}} \quad (22)$$

And the probability of failure is given as:

q_{ij} = 1- e$^{-\lambda ijT}$ (23)

From eq. (29), Failure rates for Benin region are

$$Failure\ \text{Rate}\ \delta = \frac{72}{200} = 0.36$$

Probability of failure, q_{ij} =1-e$^{-0.36x1}$ = 0.3023237

Implementation of the Random Flow Model

Random Betweenness centrality measurement as expressed, working with the Oshogbo Region data and the development, coding and implementation of the random flow algorithm in MATLAB R201

$$RWC_i^B = \frac{s_i}{\sum_{n=0}^{\infty}\left[\frac{s_i}{\sum_{l=1}^{N}}(n) - \frac{s_i}{\sum_{l=1}^{N} s_l}\right]\sum_{l=0}^{N} s_l} \quad (24)$$

Centrality values can also be evaluated as shown below;

Table 2: Transmission Line and Failure Rate, Betweenness Centrality for Oshogbo region

S/N	From	To	Frequency of Fault	Total Outages For 2019 (Hrs)	Failure Rate	Probability of Failure	Betweeness Centrality
1	Osogbo	Ayede TS (O1A)	72	200	0.32	0.3023	0.1634
2	Osogbo TS	Ganmo TS (O2G)	49	150	0.22	0.1975	2.0542
3	Ayade TS	Papalanta TS (A1P)	19	86	0.22	0.1975	0.3424
4	Egbin GS	Osogbo TS (O3E)	102	200	0.46	0.3687	0.6847
5	Egbin GS	Ayede TS (A2E)	91	220	0.41	0.3363	0.2054
6	Egbin GS	Papalanta TS (E2P)	58	144	0.40	0.3297	0.1369
7	Jabba TS	Osogbo TS (O4J)	82	219	0.37	0.3093	0.1978
8	Jabba TS	Ganmo TS (J1G)	26	99	0.26	0.2289	1.1734
9	Olorunshogo G.S	Ayede TS (A2X)	17	152	0.11	0.1042	1.1571
10	Ihovbor GS	Osogbo TS (O5I)	59	448	0.13	0.1219	0.1456
	Total		575	1,918			

Source: TCN 2019

Table 2 shows that for Oshogbo region, the Egbin to Oshogbo line has the highest failure rate, followed by by Egbin to Papalanta. The Olorunshogo to Ayade line and Oshogbo to Ihavbor lines have the lowest failure rate. It also shows that the network with the highest failure rate have the highest failure probability, Table also shows the

Oshogbo region, Oshogbo -Ganmo (O2G) has the highest centrality value followed by Ayade- Olurunshogo line (A2X). The Egbin-Papalanto lines (E2P) and Oshogbo -Ayade line (O1A) has the lowest centrality.

2.11: Simulation of Oshogbo Region of 330kV Transmission Networks Using ETAB

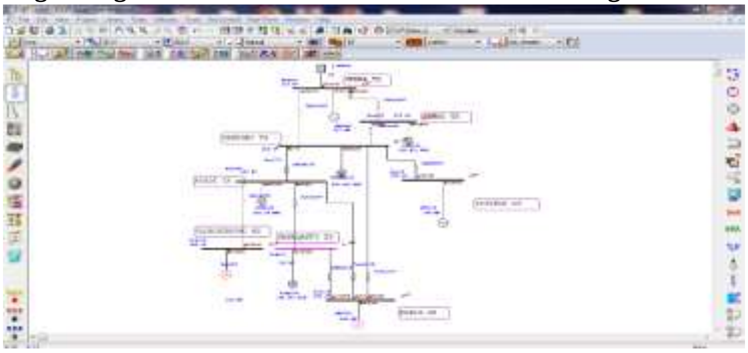

Fig. 5 ETAP 12.6 Simulation Single-Line Diagram of Oshogbo Region

Figure 5 shows the violations in Oshogbo region, Ayade -Olurunshogo line and Jabba-Ganmo lines are overloaded. It is also shows that the Generation station at Olurunshogo and Egbin are overloaded, whereas, Papentanto Bus has under-voltage issues.

2.12: Evaluation of Network Performance Parameters

the network performance parameters can be evaluated as;

i. The Network Demand Load (NDL);

$$NDL = \sum_{i=1}^{N_{si}} S_i$$

For Benin region,

$$NDL = \frac{1785}{6} = 292\text{MW}$$

For Oshogbo Region,

$$NDL = \frac{997}{4} = 249.3\text{MW}$$

ii. Network Receive Load (NRL);

$$NRL = \sum_{i=1}^{Ni} t_1$$

For Benin region,

$$NRL = \frac{2013.1}{5} = 402.\text{MW}$$

$$NRL = \frac{1067}{4} = 266.7\text{MW}$$

iii. Network Loss Load (NLL);

$$NLL = NDL - NRL$$

For Benin region NLL= 292 – 402 = - 110MW
Oshogbo region, NLL=249.3–266.7= -17.4MW

(iv) Network Service Efficiency (NSE);

$$NSE = \frac{NRL}{NDL}$$

For Benin region,

$$NSE = \frac{402}{292} = 1.38$$

For Oshogbo region, $NSE = \frac{266.7}{249.3}$ = 1.069

The network lost load is negative in both regions which means deficit in power supply as a result of insufficient power generation to meet load demand.

Methods Adopted to Improve Benin and Oshogbo Regional Networks

In order to improve the identified violations in the networks as shown in the above MATLAB implementation and ETAP Simulations, the following actions were taking;

i. New lines (Double) introduced to the networks for sections with overload.
ii. Regulation of power flow and voltage drop by installation of capacitor banks.
iii. Upgrade of capacity of overloaded generation stations.

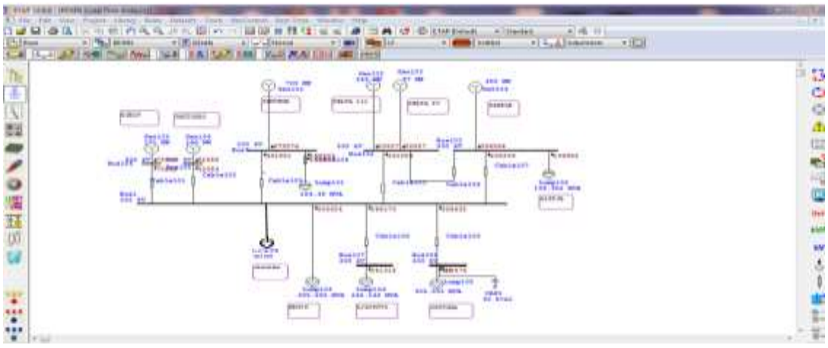

Fig. 6 ETAP 12.6 Simulation Single-Line Diagram of improved Network.

Figure 6 shows how the violations in Benin region network have been mitigated. Overloading in Benin-Onitsha (B2T) and Benin-Ihovbor (B7V) lines, Overloading in Generation station at Sapele, Omotosho, Ihovbor and under-voltage issues in Ajaokuta and Oshogbo buses are all mitigated.

RESULTS AND DISCUSSION

Table 3: Network Performance of Benin and Oshogbo Region

S/N	Network Performance Indicators	Benin	Oshogbo
1	Blackout (%)	4.3%	6%
2	Overload (%)	43%	60%
3	Network Demand Load (NDL)	292	249.3
4	Network Received Load (NRL)	402	266.7
5	Network Lost Load (NLL)	-110	-17.6
6	Network Service Efficiency	1.38	1.069
7	Average Betweeness Centrality	0.813	0.686

Table 3 show that both regions of investigation have unreliable, weak, over stretched network and elements, but comparatively, the Oshogbo region is weaker than Benin region. Most of the basics for performance assessment are higher in the Oshogbo, blackout, overload and Probability of failure are higher in Oshogbo. Random centrality value is that need high ones are lower in Oshogbo.

Results of Improved Benin and Oshogbo 330kV Network

Table 4: Network Performance Characteristics of Benin and Oshogbo Region After improvement

S/N	Network Performance Indicators	Benin	Oshogbo
1	Blackout (%)	0.3%	0.5%
2	Overload (%)	3%	5%
3	Network Demand Load (NDL)	420	312.5
4	Network Received Load (NRL)	402	266.7
5	Network Lost Load (NLL)	18.6	75.8
6	Network Service Efficiency	0.95	0.77
7	Average Betweeness Centrality	0.813	0.686

Table 4 explicitly shows the improvement in network performance characteristics values. the network demanded load have improved for both region, for the network lost load values after improvement, there is surplus power of 18.5MW in the Benin region network and 75.8MW in the Oshogbo region network. The percentage blackout has reduced 4.3% to 0.3% for Benin region and from 6% to 0.5% for Oshogbo region, the percentage overload has reduced from reduced 43% to 3% for Benin region and from 60% to 5% for Oshogbo region. Equally, Network Service Efficiency reduced 1.38 to 0.95for Benin region and from 6% to 0.5% for Oshogbo region, the percentage overload has reduced from reduced 43% to 3% for Benin region and from 1.069 to 0.77 for Oshogbo region.

CONCLUSION

The randomized model and reliability analysis of a power system network does not only provide numerical indices for the effect of random component failure on the network, it can also act as a technique for ranking the performance of power system networks and components. In this research work, centrality and reliability analysis of the Benin and Oshogbo region of Nigeria 330kV line were examined making use of mathematical reliability techniques and Randomized flow model implemented in MATLAB R2016a, using ETAB 12.6 simulation to validate the results. Results of the two region are compared, which shows that both region have unreliable, weak, over stretched network and elements, but comparatively, the Oshogbo region is weaker than Benin region as shown by the centrality and failure probability values.

Comparing of results from mathematical reliability analysis, randomized model implemental in MATLAB and ETAP 12.6 simulation prove that all techniques are effective. In ranking the various networks of investigation, for the Benin region, the Benin- Ajaokuta line is more critical while for the Oshogbo region, the Egbin- Papenlanto line is more critical. This fact is correct for all the techniques used. Possible improvement of the study case networks was simulated in ETAP 12.6. Randomized centrality concept is about how much effect a particular bus has on the grid. The concept is very important for power sector planning, as its values will give an idea on buses to reinforce, reconfigure and upgrade.

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