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(RESEARCH ARTICLE)

Electrical energy reform and its impact on power system collapse in Nigeria

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Abstract

Power system collapse has adversely affected the economic and social wellbeing of Nigerians. This paper review electricity energy reform and its impact on system collapse in Nigeria. The data on incidences of total and partial collapse in Nigeria from the year 2000 to 2020 was transformed using natural log and then modeled using ARIMA model. The model was then used to predict both total and partial collapse trend in Nigeria power system from 2022 to 2030. The trend forecast shows that the total collapse will decrease from 1.3 to 0.75 in 2030 and partial collapse will decrease from 1.4 to 0 in 2030. The ARIMA model of both the total collapse and the partial collapse show that the Value< 0.05. This value shows it is highly statistically significant which means that the trend will continue to decrease.

Keywords: Energy reform; System collapse; Total collapse; Partial collapse; ARIMA model

1 Introduction

In Nigeria, electrical power is transferred from generating stations to consumers through a transmission and distribution network known as national grid [1, 2]. The generation and transmission systems make use of a 3-phase 3-wire system while the distribution systems make use of a 3-phase or 1-phase system depending on the requirements of the energy consumers [3].

The generating station is where power is generated by a 3-phase alternator driven by turbine using mainly three sources of energy; natural gas, coal and water at 11kV or 16kV [3, 4]. This 11kV is step up by a 3-phase transformer to 330kV for the purposes of high voltage transmission to reduce copper losses and increase transmission efficiency [3]. The high voltage transmission terminates in step-down transformers in a sub-station known as receiving station where the 330kV is stepped down to 132kV [2]. This 132kV is further stepped down to 33kV and transmitted to various sub-stations in the city. This is known as secondary transmission [2]. From this point starts the primary and secondary distribution. At the sub-station the 33kV is stepped down to 415V or 11kV 3- wire for primary distribution while the 415V is further stepped down to 240V 3 phase 4 wire system for secondary distribution [3]. The power consumed or supplied is of two forms; the real and reactive powers. The real power achieves useful work while the reactive power supports the voltage and it is controlled for system stability, reliability and very important for transferring the active power through the system to the energy consumers. Power system collapse occurs when there is an increase in load or insufficient supply of reactive power. Voltage collapse or system collapse in a system refers to the inability of the said power system to maintain steady voltages at all buses in the system after being subjected to a disturbance from a given initial operating point [4]. Voltage collapse can also be defined as a process by which voltage instability leads to a very low voltage profile in a significant part of a power system. This study seeks to find out how the reform in electrical power system has impacted on power system collapse in Nigeria.

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2 Background study

Power generation in Nigeria dates back to 1886, however, the National Electric Power Authority (NEPA) was formed as result of the merger of Electricity Corporation of Nigeria (ECN) and Niger Dams Authority (NDA) in 1972 [5]. It was saddled with the responsibility of generating, transmission and distribution of electric power in Nigeria. Its operation resulted in an unstable and unreliable electric power cuts and long period of power outages and an industry characterized by lack of maintenance of power plants, low revenues, high losses, power theft and non-cost reflective tariffs and thus necessitated the reform in the sector.

The reform of the electricity sector in Nigeria began with the promulgation of the National Electric Power Policy in the 2001 with the goal of establishing an efficient electricity market in Nigeria. The overall objective of the policy is to transfer the ownership and management of the infrastructure and assets of the electricity industry to the private sector with the consequent creation of all the necessary structures required to forming and sustain an electricity market in Nigeria [5]. In 2005, the Electric Power Sector Reform (EPSR) Act was enacted and the Nigerian Electricity Regulatory commission (NERC) was established as an independent regulatory body for the electricity industry in Nigeria [6, 7]. In addition, the Power Holding Company of Nigeria (PHCN) was formed as a transitional corporation that comprises of 18 successor companies (6 generation companies, 11 distribution companies and 1 transmission company) [8]. The Nigerian Bulk Electricity Trading Plc (NBET) was established as a credible off-taker of electric power from generation companies [9]. By November 2013, the privatization of all generation and 10 distribution companies was completed with the federal government retaining the transmission company [9]. The privatization of the 11th distribution company was completed in November 2014 [10].

3 Literature review

This section reviewed related works. [8] Reviewed the power sector before and after the reform on electricity supply, reliability and Nation economy. According to them, if all identified problems NEPA are solved by the reform in the power sector, then in no distance time, Electric Power Industry can meet the energy need of the country. [9] gave a historical overview of Nigerian electricity supply and they observed that the challenges still faced by investor in the sector include, gas shortages, insecurity of power assets, high cost of operation, lack of adequate capital for consistent performance and the inactivity of some licensed firms. It recommends cost reflective tariffs, reduction in the number of unmetered electricity users, diversification of sources of power generation in the country and sustained investment in transmission infrastructure by the government. [11] Studied the voltage collapse in Nigeria Power network. It stated that the causes of voltage collapse can be categorized into two: technical and non-technical. It analysed data on system collapse in Nigeria power system from 2000 to 2020. It suggested approaches that can reduce the incidence of system collapse. They used PSAT software which makes use of Newton-Raphson iterative method to simulate the 52 bus system of Nigeria power system. The results show that the use of series compensators is the best method to reduce voltage collapse on Nigeria power system [12]. Presented a review and classification of system collapse experienced on Nigerian National Grid (NNG). Its results show that NNG is highly prone to voltage instability than other forms of disturbances.

4 Methodology

This section explains how the research was carried out. The data for the total and partial collapse in Nigeria power system from January 2000 to January 2020 was got from Ugwu et al [12]. The data was transformed using natural log and then modeled using ARIMA. The model was then used to predict both total and partial collapse in Nigeria power system from 2022 to 2030.

5 Results and discussion

Table 1 shows the total and partial collapse in Nigeria power system from January 2000 to January 2020. Figure 1 and Figure 2 show the trend analysis plot for total collapse and partial collapse respectively. Figure 3 and Figure 4 show the time series plot for total collapse and partial collapse respectively, and they show the forecast for both the total and partial collapse forecast at 95% confidence limits using ARIMA model. Table 1 shows the incidence of both total collapse and partial collapse is on a downward trend and they dropped to a very low value in 2020. The trend analysis plot for total collapse from Figure 1 shows that the trend increased in a zigzag form from 0.7 to around 1.4 and then decreased sharply to 0 in 2020. The trend forecast shows that the total collapse will decrease from 1.3 to 0.76 in 2030. The trend analysis plot for partial collapse from Figure 2 shows that the trend spiked between2002 and 2004 and thereafter decreased in a zigzag form to 0. The trend forecast shows that partial collapse will decrease from 1.4 to below 0 in 2030.

The ARIMA model of both the total collapse and the partial collapse show that the P-value < 0.05. This value shows it is highly statistically significant which means that the trend will continue to decrease.

Table 1 Total and partial collapse in Nigeria power system from Jan. 2000 to Jan 2020

Year	Total collapse	Partial collapse	Total
2000	5	6	11
2001	14	5	19
2002	9	32	41
2003	14	39	53
2004	22	30	52
2005	21	15	36
2006	20	10	30
2007	18	8	26
2008	26	16	42
2009	19	20	39
2010	22	20	42
2011	13	6	19
2012	16	8	24
2013	22	2	24
2014	9	4	13
2015	6	4	10
2016	16	6	22
2017	15	9	24
2018	12	1	13
2019	9	1	10
2020	1	0	1

Source: [12]

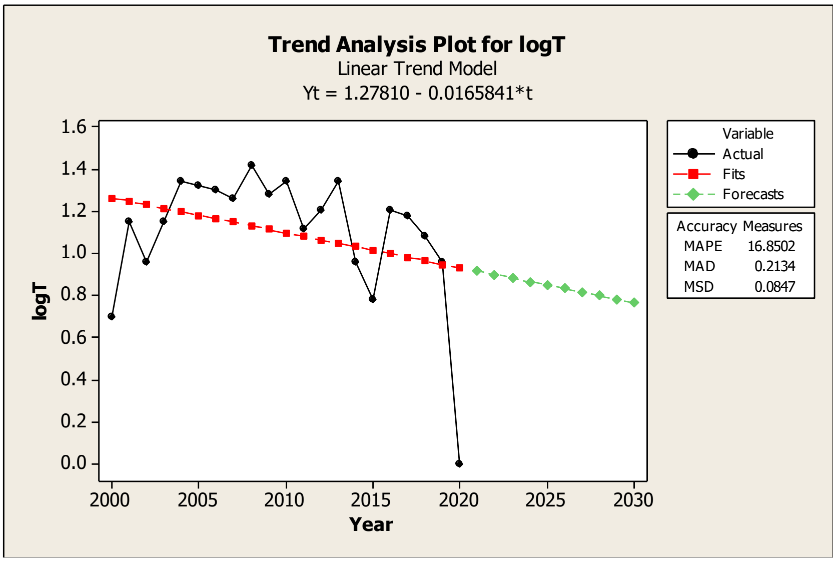

Figure 1 The trend analysis plot for total collapse

5.1 Trend Analysis for logT

Data	LogT
Length	21
NMissing	0

Fitted Trend Equation Yt = 1.27810 − 0.0165841 ∗ t

Accuracy	Measures
MAPE	16.8502
MAD	0.2134
MSD	0.0847

Forecasts	
Period	**Forecast**
2021	0.913245
2022	0.896661
2023	0.880076
2024	0.863492
2025	0.846908
2026	0.830324
2027	0.813740
2028	0.797156
2029	0.780572
2030	0.763987

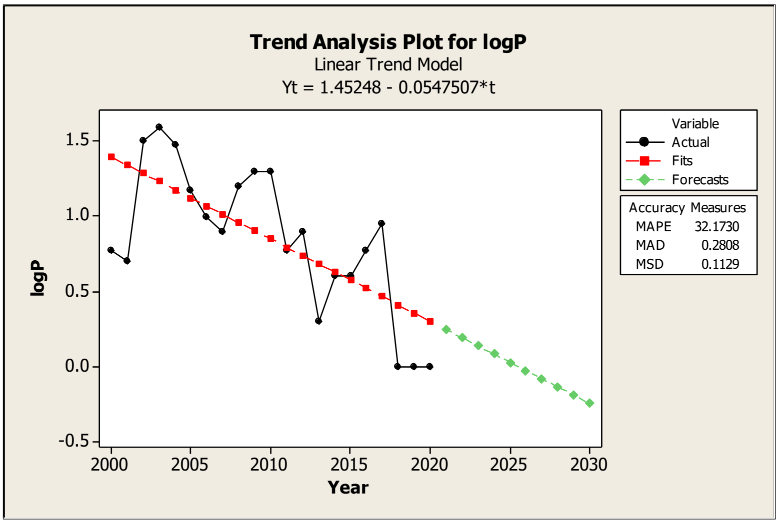

Figure 2 The trend analysis plot for partial collapse

5.2 Trend Analysis for logP

Data	LogT
Length	21
NMissing	0

Fitted Trend Equation $Yt = 1.45248 - 0.0547507 * t$

Accuracy	Measures
MAPE	32.1730
MAD	0.2808
MSD	0.1129

Forecasts	
Period	**Forecast**
2021	0.247961
2022	0.193211
2023	0.138460
2024	0.083709
2025	0.028958
2026	-0.025792
2027	-0.080543
2028	-0.135294
2029	-0.190044
2030	-0.244795

5.3 ARIMA Model: logT

Estimates at each iteration

	Iteration	SSE	Parameters
0.	2.10829	0.100	1.076
1.	1.89149	0.250	0.868
2.	1.75732	0.400	0.669
3.	1.67890	0.550	0.479
4.	1.64777	0.662	0.341
5.	1.64098	0.710	0.280
6.	1.63962	0.732	0.253
7.	1.63935	0.742	0.241
8.	1.63930	0.747	0.236
9.	1.63929	0.234	0.234

10.	1.63929	0.750	0.232
11.	1.63928	0.750	0.232

Relative change in each estimate less than 0.0010

Final Estimates of Parameters				
Type	**Coef**	**SECoef**	**T**	**P**
AR 1	0.7505	0.3121	2.40	0.027
Constant	0.23195	0.08975	2.58	0.018
Mean	0.9296	0.3597		

Number of observations: 21
Residuals: SS = 1.62620 (backforecasts excluded)
MS = 0.08559 DF = 19

Modified Box-Pierce (Ljung-Box) Chi-Square statistic				
Lag	12	24	36	48
Chi-Square	4.6	*	*	*
DF	10	*	*	*
P-Value	0.918	*	*	*

Forecasts from period 21

95 Percent Limits			
Period Forecast	**Lower**	**Upper**	**Actual**
22	0.23195	-0.34158	0.80548
23	0.40603	-0.31105	1.12310
24	0.53666	-0.24981	1.32314
25	0.63471	-0.18828	1.45769
26	0.70829	-0.13457	1.55114
27	0.76350	-0.09034	1.61735
28	0.80495	-0.05502	1.66491
29	0.83605	-0.02735	1.69945
30	0.85939	-0.00594	1.72471
31	0.87690	0.01049	1.74331

Time Series Plot for logT

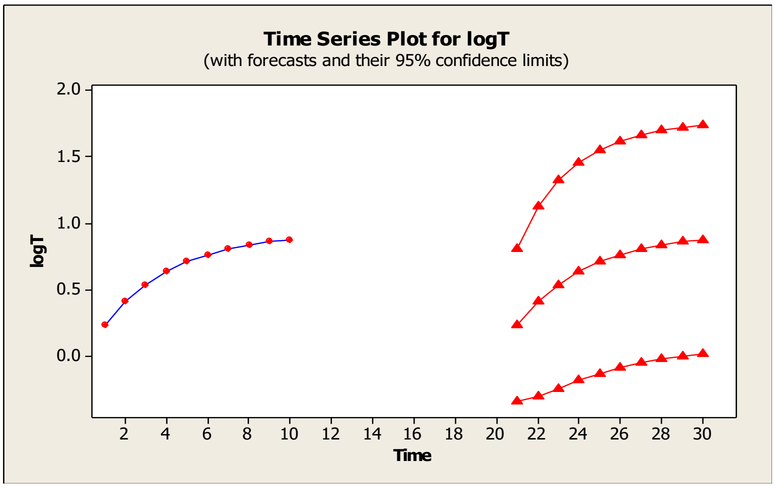

Figure 3 The time series plot for total collapse

5.4 ARIMA Model: logP

Estimates at each iteration

	Iteration	SSE	Parameters
0.	4.30656	0.100	0.855
1.	3.54248	0.250	0.702
2.	2.97031	0.400	0.549
3.	2.58990	0.550	0.397
4.	2.40146	0.700	0.248
5.	2.37771	0.761	0.181
6.	2.37726	0.763	0.176
7.	2.37725	0.763	0.176
8.	2.37725	0.763	0.176

Relative change in each estimate less than 0.0010

Final Estimates of Parameters				
Type	**Coef**	**SECoef**	**T**	**P**
AR 1	0.7633	0.1783	4.28	0.000
Constant	0.17558	0.08140	2.16	0.044
Mean	0.7419	0.3439		

Number of observations: 21
Residuals: SS = 2.37693 (back forecasts excluded)
MS = 0.12510 DF = 19

Modified Box-Pierce (Ljung-Box) Chi-Square statistic				
Lag	12	24	36	48
Chi-Square	11.2	*	*	*
DF	10	*	*	*
P-Value	0.340	*	*	*

Forecasts from period 21

95 Percent Limits			
Period Forecast	**Lower**	**Upper**	**Actual**
22	0.17558	-0.51781	0.86897
23	0.30960	-0.56271	1.18191
24	0.41191	-0.54942	1.37323
25	0.49000	-0.51958	1.49958
26	0.54961	-0.48706	1.58627
27	0.59511	-0.45701	1.64722
28	0.62984	-0.43118	1.69086
29	0.65635	-0.40983	1.72252
30	0.67659	-0.39258	1.74575
31	0.69203	-0.37887	1.76294

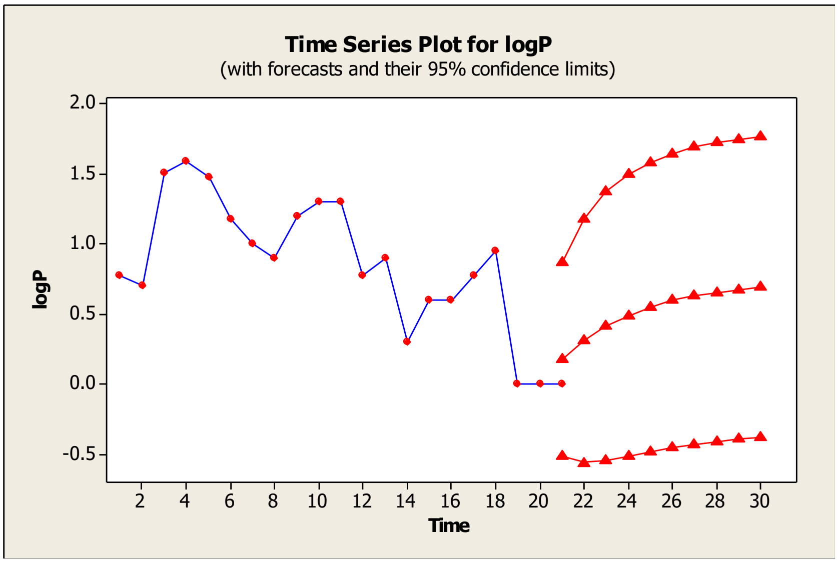

Figure 4 The time series plot for partial collapse

6 Conclusion

This paper explained how electric power is transferred from power station through transmission and distribution network to energy consumers. It also gave the background on power sector and reforms in the power sector in Nigeria. It analyzed the statistical data of both total collapse and partial collapse in Nigeria from 2000 to 2020. The results show that the trend of total and partial collapse decreased from the year 2000 to 2020 and the forecast show that both total and partial collapse will continue to decrease till 2030.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors whose names are listed immediately below certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers bureaus; membership, employment, consultancies, stock ownership or other equity interest; and expert testimony or patent-licensing arrangement) or non-financial interest (such as personal or professional relationship, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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