# Electric Grid Reliability: An Assessment of the Nigerian Power System Failures, Causes and Mitigations

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***Abstract:***
Quality, reliable and affordable power, is clearly sufficient as a social-economic catalyst to propel any nation's shrinking economy, increase jobs creation and reduce crime. This can be guaranteed if the power grid is stable. Grid collapse occur when the supply of electricity to some or entire regions is disrupted . Despite significant investments in the sector over the last two decades , the Nigerian electrical grid continues to be unreliable, experiencing random failures. Between 2000 and 2022, it has partially or completely collapsed 564 times, and the frequency of such incidents per year is a cause for concern. The incidents practically grounded Nigeria and its economic activity on each occasion. As a result, it is no surprise that the economy is tanking and businesses are closing up. This study identifies the limiting variables that have hampered the electricity system's viability, among which are human factors, equipment failure as a result of aging, fuel shortage and sabotage, likewise poor maintenance of transmission infrastructure . These had adverse effect on the productivity of the nation. The report also suggests mitigating strategies for avoiding blackouts in the future, include but not limit to regular proactive inspection, testing, repair of the equipment, adoption of real-time monitoring, and control system to improve grid resilience and promote grid efficiency management.
***Keywords:*** Power System Collapse, Grid Failure, Nigerian Power Grid.

## 1. Introduction

The Electrical Power System (PS) is a complex human innovation with numerous phenomena [1]. In order to deliver electricity to end users, it necessitates a high level of ability and expertise, the PS is supplied with controls that keep system parameter changes to acceptable levels well below statutory limitations. As a result of increase in load demand, environmental, and economic factors that impede the installation of more transmission lines and generating station by generating companies (GenCos). These will enable the power system network (PSN) works extremely near its stability thresholds [2]. However, most PSNs are weak, overloaded, and susceptible to voltage instability [3]. As demand increase for electric power develops, PSNs are likely to become increasingly loaded, though the construction of new transmission and generation capacity is constrained by economic and environmental considerations [4]. Between the years 2000 and 2021, the Nigerian power grid has failed 564 times, partially or completely. In view of these, the total number of system collapses per year is quite alarming and indicates that the transmission system is stressed. This has serious implications for system protection and eliminates the critical service of providing customers with reliable, continuous power.

A.Description of the Nigeria Power System

The Nigeria National Grid (NNG) is the power grid system used in Nigeria. A power grid is described as an interconnected network of transmission lines used to transport electricity from generators to load ends [5]. All networked power production systems (thermal or hydro plants) are connected to transmission substations across the country via various transmission lines (electrical conductors) [1]. Even if one generator fails, the grid system provides supply continuity, allowing for optimal consumption and efficiency [6]. The system's generators produce either 11kV or 16kV, which are then stepped up to 330kV or 132kV for transmission, a densely populated area with high electricity consumption rate, the voltages are gradually reduced. The 330 kV is stepped down to 132 kV, then to 33 kV, known as the primary distribution voltage, and then to 11 kV, which is utilized as the secondary distribution voltage. At a nominal frequency of 50Hz +/- 0.4%, this is further stepped down to 0.415kV for a line to line and 230V for a line to neutral [7].

Nigeria currently has only twenty-three operational grid-connected generators, 2 of it were hydro generators and the remaining 21 were thermal power plants. Thermal generation has an installed capacity of 8,457.6 MW (available capacity of 4,996 MW), hydropower has a total installed capacity of 1,938.4 MW (available capacity of 1,060 MW), making a total installed capacity of 10,396 MW (available capacity of 6,056 MW) [8]. The National Integrated Power Project (NIPP) includes private Producing Companies, Independent Power Producers (IPPs), and generating units [8]. They contributed to the increase in the nation’s generation capacity as well as responsible for all grid operations, monitoring, and control of transmission network. Though the network is managed by

Transmission Company of Nigeria (TCN), with its National Control Centre (NCC) (also known as Load Dispatch Centre) in Osogbo, Osun State. In Nigeria, there are eleven (11) Distribution Companies (DisCos) that span the six geopolitical zones [8]. The TCN transports electricity to the DisCos and can deliver electricity to qualifying commercial and industrial users [9]. DisCos are the intermediaries between electricity consumers and the grid. The Discos are also in charge of billing and revenue collection because of their position in the supplier value chain [10].

### B. Power Grid Collapse

When all of the power generating stations connected to either the grid shut down suddenly or simultaneously, this is referred to as a power system collapse [1]. When the grid is overloaded or transmission lines break down due to excess or under frequency, the grid has no choice but to shut down, which is exacerbated by the lack of an effective Energy Management System (EMS) [1, 5]. The grid collapse (also known as voltage collapse) causes loss of electricity supply across the environments and consumers served by the grid [11]. Voltage breakdown is uncommon in Western countries, despite their massive and complicated networks, yet it occurs frequently in Nigeria.

## II. COLLAPSES OF THE NIGERIAN NATIONAL GRID

The system collapse phenomenon is common on the Nigerian national grid, and it frequently results in either a partial or complete systemic failure (blackout), severely impeding the country's socioeconomic development and industrialization. Most areas of the network have low voltage profiles, particularly in the north, extremely high transmission losses, a radial and weak grid network, inadequate dispatch and control infrastructures, and regular system breakdown [12]. Table 1 displays statistics on partial (p/c) and entire (t/c) grid collapses of the Nigerian National Grid from January 2000 to December 2022 [11, 13, 14, 15, and 16]. Over a period of eighteen years, the grid alarmingly fell both partially and very almost two and a half times per month on average [11]. In reality, in January 2018 there were six (6) grid collapses in eight days. [17, 18]. The grid had collapsed six times by 8 April 2022. The most recent collapse was caused by vandalism of a transmission tower between the states of Akwa Ibom and Cross Rivers, resulting in a sudden loss of about 4000MW of generation, while the previous ones were caused by system failures Fig. 1 is a chart of the grid collapses on the NNG from 2000 to 2022[19] [20].

## III. CAUSES OF POWER GRID COLLAPSES IN NIGERIA

There are many technical and non-technical variables cause power system failures. A common occurrence in PSs is generator outages, which can result in voltage collapse. The failure of generators carrying a large load causes PS instability, and if no countermeasures are put in place, there could be a system collapse [6]. Line tripping is a phenomenon in which a PS line is pulled out of service.

TABLE I
NIGERIAN NATIONAL GRID COLLAPSES FROM 2000 TO 2022

| Year | Partial Collapse | Complete Collapse | Total |
|---|---|---|---|
| **2000** | 6 | 5 | 11 |
| **2001** | 5 | 14 | 19 |
| **2002** | 32 | 9 | 41 |
| **2003** | 39 | 14 | 53 |
| **2004** | 30 | 22 | 52 |
| **2005** | 15 | 21 | 36 |
| **2006** | 10 | 20 | 30 |
| **2007** | 8 | 18 | 26 |
| **2008** | 16 | 26 | 42 |
| **2009** | 20 | 19 | 39 |
| **2010** | 20 | 22 | 42 |
| **2011** | 6 | 13 | 19 |
| **2012** | 8 | 16 | 24 |
| **2013** | 2 | 22 | 24 |
| **2014** | 4 | 9 | 13 |
| **2015** | 4 | 6 | 10 |
| **2016** | 6 | 22 | 28 |
| **2017** | 9 | 15 | 24 |
| **2018** | 1 | 12 | 13 |
| **2019** | 4 | 7 | 10 |
| **2020** | 1 | 3 | 4 |
| **2021** | 2 | 2 | 4 |
| **2022** | 2 | 6 | 8 |

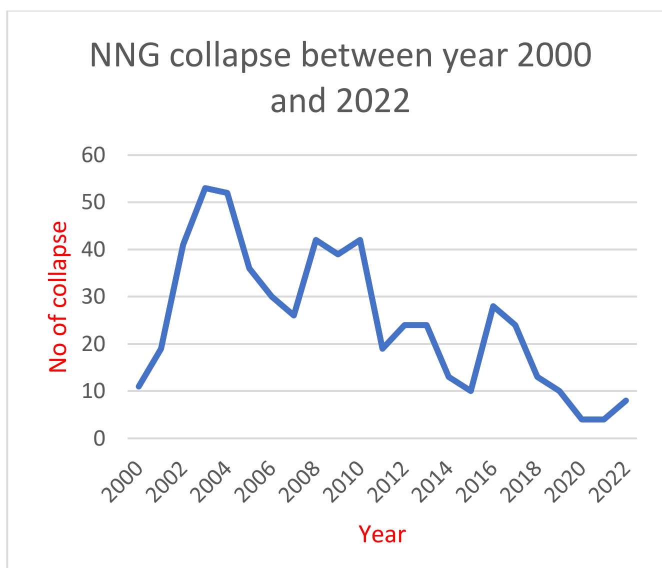


Fig. 1. Chart Showing NNG collapses from 2000 to 2021.

This is as a result of physical incident or a technological failure on the connection which sometimes cause line tripping. If this occurs on a line carrying a heavy load, the system could collapse [6]. The high rate of grid collapses is attributed to the NNG's lack of flexibility [13, 21], as it is long, radial, weak, and severely stressed in form, and any increase in load might trigger voltage collapse in the PS. When a consumer's load demand exceeds the system's available power, the system is stressed beyond its capacity, causing some of the system's parameters to shift, which can result in the PS collapsing [6]. Collapses can also happen as a result of sudden load drops or load rejections at the distribution end without bringing the system operation in focus, vandalism of transmission infrastructures, and equipment short-circuiting, or any action that puts operational pressures on the generator far beyond its designed capability, one of which is when the operating frequency deviates from the nominal operating frequency designed for the generator [1].

A sudden shutdown can occur because of a planned action as part of routine operating procedures or because of protective measures taken by protective relays in response to any potentially detrimental operational development within the power plant or the concerned generator [1]. Poor or insufficient investment (Expansions, Upgrades, and a lack of an organized maintenance schedule) plagued Nigeria's national grid for decades until its progressive openness in 2005 and final privatization in 2013. The anticipated investment, particularly in the downstream, is missing [1]. The voltage profile of the PS is also affected by the activity of tap changing transformers. The voltage profile varies drastically when transformer tap changers are swapped, especially if the transformer is supporting a substantial load [22]. On the Nigerian system, line tripping is a common occurrence. When a line carrying a lot of power drops, it can generate imbalances in the PS and, resulting in system's instability [6]. Weather is responsible for a portion of power disruptions. Transmission lines can trip due to some reasons, including if trees hit the power lines it can cause a short circuit. Additionally, the line could trip due to a fault to ground or an open circuit [6]. Severe weather has the potential to destroy vital power infrastructure, resulting in outages that might last for days, weeks, or even months [6].

## IV. EFFECTS OF GRID COLLAPSES ON THE NIGERIAN SOCIETY

Power system failure causes a great deal of inconvenience and financial loss to both home and industrial clients [6]. Numerous businesses that depend heavily on an adequate power supply have suffered because of the frequent PS breakdowns due to the high cost of operating diesel generators [6, 23]. The poor performance of the power industry has an equal impact on small enterprises and heavy machinery manufacturers. Citizens are often affected socially, psychologically, and physically because of insufficient and unreliable electricity supply (21). As a result of frequent collapses witnessed over a long period, the Nigerian electricity system cannot be regarded to be extremely reliable [24]. Overall, the NNG failures have played a significant role in the Nigerian economy's stagnation. Due to poor service, most industrial clients and individuals have been forced to install power generators, incurring significant costs for both themselves and the Nigerian economy. [23].

## V. APPROACHES TO POWER SYSTEM RESILIENCE AND RELIABILITY

The capacity of a PS to provide appropriate services almost continuously with minimal disruptions spanning a considerable amount of time has been defined as reliability [24]. Many interventions in the Nigerian power networks have occurred, including load shedding, privatization of the distribution sector, and so on. This section discusses some methods for ensuring the NNG's stability and reliability.

### A. Load Shedding

The Nigerian Power Industry has used load shedding as a technique of avoiding system-wide voltage collapse. This strategy is considered only after all other viable options for averting collapse have been exhausted [4]. Depending on the rate of voltage reduction, the load can be shed manually or automatically. This approach has been employed as an effective solution for a variety of scenarios, particularly when the collapse occurs in a short period and the load characteristics preclude efficient load reduction via transformer load taps changer control [4].

### B. Newer Equipment and Facilities

Traditional planning and engineering power delivery tools are not effective in dealing with current issues such as older technology, dated system designs, and contemporary unregulated loading levels [5]. Increased maintenance expenditures and additional repair/restoration charges are associated with older assets and facilities. As a result, they must be altered. In addition, more generating stations should be created in order to match the consumer's power demand. The expansion and reform of these three elements of the PS will improve the system's overall protection during any disruptions [1]. Older areas need a substantial amount of additional substation sites and rights of way, which are unavailable in the current area, forcing them to rely on inadequate facilities [5]. The use of flexible AC Transmission system (FACTs) devices on transmission lines will enhance reliable and efficient power grid. It reduces the risk of grid collapse by control the power flow and maintain a stable voltage profile of the transmission lines [25-26].

### C. Decentralization of the Power Transmission/Distribution System

This is critical to the system's success and dependability. Because the system is currently reliant on a small number of power stations, breakdowns can have a significant impact. Electricity could be better controlled and distributed, as well as more efficient, when paired with Smart Grid technology [5]. An integrated network of micro grids and distributed generation connected by cutting-edge smart grid technologies that incorporates automated fault detections, and network self-healing is one of the alternatives suggested to prevent another significant outage.

### D.Power System Automation

Planned outages, load forecasting, analysis of potential outcomes, generating units scheduling, market settlements, and other benefits are available when automation is combined with an Energy Management System (EMS) [11]. Contingencies are sensed, viewed, and mitigating steps conducted are sufficient to return the PS to normalcy and stable power system via reliable technologies like SCADA. The control center will use the information gathered to make informed and timely decisions.

## VI. CONCLUSION

Over time, it has become clear that a system-wide SCADA system, as well as an extensive EMS, may enhance system operations, raise power system dependability, increase PS efficiency, automate billing, and thereby improve utility health. Digital monitoring and data input would be able to foresee issues before they arise with the integration of Artificial Intelligence (AI) technology into SCADA. Additionally, the technology might offer suggestions or instructions on how to address a problem before it becomes worse or work more effectively. The Nigerian government should focus on ensuring the country's national security because it is related to energy security.

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