

# Alternative Solution To Incessant Voltage Collapse In The Nigerian Power System

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**Abstract-** *The over-centralisation of the Nigerian electricity industry made it practically impossible for electricity supply to keep pace with the growth in population and economic activities. Today, Nigeria has the biggest gap in the world between electricity demand and supply, providing its population of 150 million with roughly 3,800 megawatts of electricity. The current system relies on a single, aging national grid that is highly vulnerable to cascading failures when one component trips. Often, the load-generation mismatch, which is the frequent disparities between power demand and available supply, often exceeds the grid's stability thresholds, leading to frequency deviations beyond the critical range of system capability. To address the incessant voltage collapse of the Nigerian power system, a multi-faceted approach involving decentralisation, infrastructure modernisation, and advanced control technologies is necessary. Moreover, the incessant voltage collapse in the Nigerian power system can be addressed primarily by the factors driven by technical deficiencies, such as inadequate reactive power compensation and infrastructure decay in the aging 330kV national grid. Hence, the deployment of Flexible AC Transmission System (FACTS) devices and decentralised smart grid integration serves as a critical alternative solution to stabilise the Nigerian power network.*

**Indexed Terms-** *Ageing, Cascading Failure, Generation Mismatch, Smart Grid, Stability.*

## I. INTRODUCTION

Nigeria is situated at the heart of Africa with a population of over 150 million people. It is a vast country with a total of 356, 667 sq miles (923,768 sq km), of which 351,649 sq Miles (910,771 sq km or 98.6% of total area) is land, and it is divided into 36 states and the federal capital territory (FCT) (Sambo et al., 2010). The insurgency of electricity supply in Nigeria started way back in 1896, and the subsequent establishment of Electricity Cooperation of Nigeria (ECN) in 1951 and Niger Dam Authority (NDA) in

1962 paved the way for the advancement of electricity supply in Nigeria. In 1972, the Niger Dam Authority (NDA) and Electricity Cooperation of Nigeria (ECN) were merged to form the defunct Nigerian Electric Power Authority (NEPA), now Power Holding Company of Nigeria (PHCN), which was established to control, coordinate and effectively manage the electricity generation and supply. The establishment of NEPA to form a centralised control did not help in addressing the growing energy demand but rather resulted in incessant blackouts in the country. The over-centralisation of the Nigerian electricity industry made it practically impossible for electricity supply to keep pace with the growth in population and economic activities. Today, Nigeria has the biggest gap in the world between electricity demand and supply, providing its population of 150 million with roughly 3,800 megawatts of electricity. In contrast, South Africa generates more than 40,000 megawatts for a population of 47 million people, while Brazil generates 100,000 megawatts for its 201 million citizens (Nigeria Power Reform, n.d.). The Nigerian power system has the flexibility to meet future demands of the user in a particular area, to transmit it to the area where it will be used and then distribute it within the areas, continuously. It is designed to generate electric power in sufficient quantity to meet the consumers' present and future load demand in a particular locality. To ensure that maximum return on the large investment in the equipment, which goes to make up the power system and to keep users satisfied with reliable service, the whole system must be kept in continuous operation without any major breakdown. The investment in distribution generation will stair Nigerian to invest heavily in sustainable and renewable energy resources like gas fired micro-turbines, solar energy (photovoltaic and solar thermal) and wind energy which is in line with the federal government commitment to solve the long lasting

energy crisis in Nigeria through the adaptation of renewable energy master plan (REMP) with a target of increasing power generation capacity from 5000MW to 16000MW by the year 2015 (Dike et al., 2011). To enable Nigeria to effectively supply electrical energy continuously without breakdown, the industry has to look into the future and embrace the unique and dynamic DG to optimise electricity supply in Nigeria. Distribution generation is simply the application of a small generating plant (a few kW - 50MW) connected to the distribution network or the user's terminal (Kenneth & John, 2013).

The current Nigerian power system relies on a single, aging national grid that is highly vulnerable to cascading failures when one component trips. This paper is, therefore, objectively focused on addressing the incessant voltage collapse in the system. A multi-faceted approach is recommended that involves: grid decentralisation of the power system, infrastructure modernisation, and advanced control technologies.

## II. GRID DECENTRALISATION AND REGIONAL CLUSTERS

Based on the Transmission Company of Nigeria (TCN) grid map and operational data (table 1) from the Nigerian Electricity Regulatory Commission (NERC) (Transmission Company of Nigeria, n.d.), the summary of the poor power grid performance.

Metric	2025 Performance	Early 2026 Performance (Jan–Feb)
System Stability	12 total collapses were recorded throughout the year.	2 major collapses within the first four days of the year (Jan 23 and 27).
Peak Generation	Reached a milestone of 5,543.20 MW on Feb 14, 2025.	Averaged 4,901 MW available for dispatch in January.
Plant Availability	Hovered between 38% and 40% of installed capacity.	Dropped to 32%–36% as many plants sat idle due to gas shortages.

Nigeria's power grid performance in 2025 and 2026 has been characterised by extreme instability, frequent system collapses, and low operational efficiency despite reaching record peak generation levels in early 2025, as reported by Vanguard (2026) and Intelpoint (2026). These recurrent failures are attributed to ageing transmission infrastructure, frequent line trips, and inadequate gas supply to thermal power plants. This impacts system collapse that results in near-total nationwide blackouts, with real-time generation often dropping from over 4,500 MW to nearly 0 MW during these incidents, according to reports from Punch (2026) and Vanguard (2026).

The grid decentralisation and regional clusters involve a transition from a single national grid to a system of decentralised regional or state-level grids. This ensures that a disturbance in one area does not cause a nationwide blackout. Also, embedded generation should be encouraged through Distribution Companies (DisCos) to generate and transmit their own power locally. Notably, several states are already turning to solar mini-grids and independent power projects to support local supply and reduce reliance on the national grid (Ajenikoko, G. A., & Ogunmakinde, A., 2015).

## III. ADVANCED AUTOMATION AND REAL-TIME MONITORING

Table 1: Summary of Power Grid's Performance in 2025 and 2026

Advanced automation and real-time monitoring are integrated technologies that allow systems to operate, track, and optimise themselves with minimal human intervention. While advanced automation uses artificial intelligence (AI) and machine learning (ML) to adapt to changing conditions and make autonomous decisions. Real-time monitoring provides the necessary data foundation, continuously streaming live performance metrics to identify issues the moment they occur (National Institute of Standards and Technology [NIST], 2022). To achieve the above objective, there must be full deployment of Supervisory Control and Data Acquisition (SCADA) systems for real-time monitoring and automated control. This allows the System Operator to detect precursors to collapse and intervene faster than manual processes (Hartek Group,2025).

At critical nodes of the system network, installation of Phasor Measurement Units (PMUs) will provide wide-area visibility and fast detection of grid instabilities. Thus, Strategic placement of PMUs at critical nodes, such as the Ikeja West 330kV substation, provides high-resolution, time-synchronised data that enables wide-area visibility and rapid detection of grid instabilities. Unlike traditional SCADA systems that update every few seconds, PMUs capture dynamic system responses at rates up to 120 samples per second, allowing operators to identify and mitigate precursors to cascading failures before they lead to grid collapse. (Araga, A. I., 2025).

In addition, Automatic Generation Control (AGC) have to be implemented to automatically adjust generator output every few seconds to maintain the system frequency at 50 Hz, replacing current manual adjustments (MTS Power Products, 2025).

#### IV. TECHNICAL AND INFRASTRUCTURE UPGRADES

Technically, Reactive power compensation is the management of reactive power in an AC electrical system to improve energy quality, stabilise voltage, and enhance operational efficiency. Reactive power compensation, such as static synchronous compensators (STATCOM), when installed at optimal locations with critical low voltage buses, will help to

support voltage and prevent collapse. Without adequate compensation, high levels of reactive power cause several system issues like voltage instability, increased line losses, reduced capacity and utility penalties.

Adaptive Load Shedding (ALS) is an intelligent protection strategy that uses automated Under-Frequency Load Shedding (UFLS) schemes to prevent total grid collapse. Unlike traditional static schemes that drop fixed blocks of load, adaptive systems calculate the exact amount of power to disconnect based on the Rate of Change of Frequency (RoCoF). By instantly shedding non-essential loads, the system balances generation and demand, stabilising the frequency before it reaches critical trip levels that would trigger a total blackout (Federal Energy Regulatory Commission [FERC], 2023).

Integrating artificial intelligence (AI) analytics and Bayesian prediction models allows for the identification of critical nodes, such as Bus 50 in Jos, well before they hit a voltage collapse point. Unlike traditional deterministic models, Bayesian frameworks handle the inherent uncertainty of grid loads, providing a probabilistic "early warning" that enables operators to initiate preventive or reactive power injection or targeted load shedding(Omorogiuwa & Ike, 2023).

Infrastructure overhauling is also necessary to replace obsolete 50-year-old transformers, weak towers, and outdated transmission lines with higher-capacity, temperature-resistant cables. (International Energy Agency [IEA], 2023).

#### V. COMMERCIAL AND REGULATORY REFORMS

Commercial and Regulatory Reforms are the structural and legal changes designed to transform a power sector from a state-run monopoly into a competitive, efficient, and bankable market. These reforms aim to attract private investment, ensure cost recovery for utilities, and improve service delivery for consumers. The most common reform involves breaking up vertically integrated state utilities into separate entities: Generation companies (GenCos),

Transmission (TransCo). Distribution (DisCos). Also, a critical regulatory hurdle is the shift toward Multi-Year Tariff Orders (MYTO), which ensures the price consumers pay covers the actual cost of generation, transmission, and distribution, plus a reasonable profit margin for investors. As a result, it balances "affordability" for low-income citizens with "bankability" for the companies providing the electricity. (World Bank, 2023).

## VI. OUTPUT TEST OF DISTRIBUTION GENERATION (DG) IMPLEMENTATION WITH POWER SYSTEM NETWORK

Figure 1 below represents the base case voltage profiles with the final result after the integration of PV DG into the Nigerian network. Those bus voltages operating below the statutory voltage limit ( $0.95pu \leq V_i \leq 1.05pu$ ) which include: Ayede (9), Osogbo (10), New-haven (13), Onitsha (14), Gombe (16), Jos (19), Kaduna (20), Kano (22) and Makurdi (26) were all improved to normal voltage limit

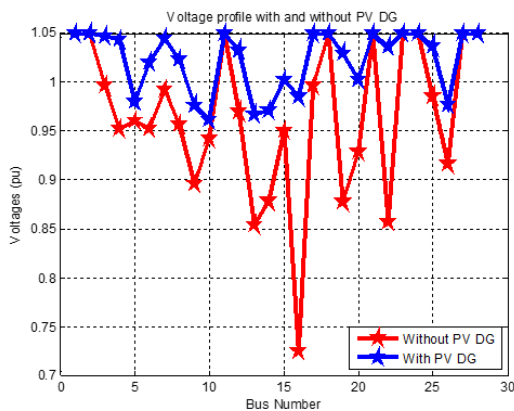


Fig 1 Voltage profile with and without DG

## VII. CONCLUSION

The test result of implementing photovoltaic distribution generation (PV DG) into the Nigerian power system shows that shifting away from a single radial national grid toward distributed generation, including large-scale solar PV and battery storage connected to the grid at an optimal position, will improve the stability of the system network. Likewise, advanced control algorithms using artificial intelligence analytics and Bayesian prediction

models can identify critical buses before they reach the voltage collapse point, and thus provide a proactive remedial solution. Also, this paper addressed the major causes of voltage collapse, which include the long and radial network, lacking the flexibility and redundancy of a ring network, which makes it highly vulnerable to cascading faults. The Load-Generation Mismatch that involves frequent disparities between power demand and available supply often exceeds the grid's stability thresholds, leading to frequency deviations beyond the critical stability limit. The continuous use of obsolete infrastructure on the grid that is over fifty years old, leading to frequent equipment failures, is highlighted in this paper. Thus, incessant voltage collapse in the Nigerian power system is primarily driven by technical deficiencies such as inadequate reactive power compensation and infrastructure decay in the aging 330kV national grid. This research emphasised the deployment of flexible AC transmission system (FACTS) devices and decentralised smart grid integration as the critical alternative solutions against incessant voltage collapse in the Nigerian power system network.

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