NIPES

Journal of Energy Technology and Environment

Journal homepage: www.nipesjournals.org.ng

Impacts of Digitization in the Technological Shift of Power Industry

Precious K. Ugboke[1]*, Jessica O. Ebimaro[2], Pelumi E. Olanrewaju[1] and Patience E. Orukpe[1]

[1]Department of Electrical/Electronic Engineering, University of Benin, Benin, Edo State, Nigeria

[2]Department of Remote Sensing and Geoscience Information System, Federal University of Technology.

Corresponding Author: precious.ugboke@eng.uniben.edu (+2348108987708)

Article information

Article History
Received 9 April 2024
Revised 24 April 2024
Accepted 1 May 2024
Available online 2 June 2024

Keywords: digitization, technology, power, energy, generation.

https://doi.org/10.5281/zenodo.11420895

https://nipes.org

Abstract

The power industry stands on the cusp of a technological revolution, driven by advancements in digitalization, renewable energy integration, and Smart grid infrastructure. One of the most significant shifts propelled by new technologies is the transition towards renewable energy sources such as solar, wind, and hydropower. Innovations in photovoltaic technology, wind turbine design, and energy storage solutions have made renewable energy more cost-effective and scalable, challenging the dominance of traditional fossil fuels. As a result, the power industry is undergoing a profound transformation, characterized by decentralized energy generation, reduced carbon emissions, and enhanced energy security. Furthermore, the proliferation of digital technologies is revolutionizing the way power systems are monitored, controlled, and optimized. Advanced sensors, Internet of Things (IoT) devices, and predictive analytics enable real-time monitoring of grid performance, facilitating proactive maintenance and fault detection. Additionally, artificial intelligence (AI) and machine learning algorithms are utilized to forecast energy demand, optimize generation schedules, and improve energy efficiency. These digital solutions not only enhance the reliability and resilience of power infrastructure but also pave the way for the emergence of smart grids capable of integrating diverse energy resources and accommodating dynamic demand patterns

1. Introduction

Power generation, like many other industries, is undergoing a significant shift towards digitalization. However, despite this trend, many companies are only beginning to explore the potential value of technology-driven initiatives and adapt their operational practices accordingly. Currently, there are no comprehensive examples of end-to-end digitization in power generation on a global scale. Even the most technologically advanced players have only implemented a limited number of isolated digital initiatives, often without clear ties to tangible business benefits.

In simpler terms, power companies are not leveraging technology to their fullest potential, resulting in higher-than-necessary operational and maintenance costs. Additionally, the pressure to reduce costs for thermal assets, such as coal and gas, is mounting due to ongoing market liberalization and

the widespread adoption of renewable energy sources like solar and wind all over the world. These market dynamics have led to consistent challenges across various markets.

2. Overview of Nigeria's Power Industry

The evolution of Nigeria's energy landscape saw the vertical unbundling of the country's power sector, resulting in the establishment of six generating companies and IPPs collectively known as GenCos [1]. The transformation commenced with the inception of the Electricity Cooperation of Nigeria (ECN) in 1951 and the Niger Dam Authority (NDA) in 1962[2]. Through Decree 24 of 197, the ECN and NDA were amalgamated to form the Nigeria Electric Power Authority (NEPA), later renamed the Power Holding Company of Nigeria (PHCN). As outlined in the factsheet released by the Nigeria Electricity Regulatory commission (NERC) containing operational performance data of grid-connected power plants for February 2024, Nigeria currently operates 26 grid-connected generating plants with a total installed capacity of 18,565MW and an available capacity of 3,957.16MW. However, the actual electricity supply falls short of the demand, with no proportional increase in electricity generation as the population grows [3]

The financial struggles within Nigeria's power sector stem from inefficiencies across its key segments: generation, transmission, and distribution. The distribution segment particularly exacerbates the liquidity crunch. High Aggregate Technical, Commercial and Collection (ATC&C) losses, along with inadequate and irregular tariff hikes are two (2) primary reasons behind Nigerian DisCos' financial troubles.

ATC&C losses comprise two elements: technical and commercial. Technical losses, resulting from electricity flow in transmission and distribution (T&D) networks, are inevitable. While developed economies typically experience T&D losses ranging from 6-8 percent, Nigeria's losses stand at approximately 16 percent due to deficiencies in distribution system planning (as reported in [4]
According to the January 2024 factsheet report on the metering and customer service standards published by the Nigeria Electricity Regulatory Commission (NERC), it can be deduced that the DisCos still has a lot to do in terms of metering of customers. The Tables 1 and 2 show published details. Figure 1 shows the various types of complaints received by DisCos as at January 2024][5,6].

Table 1: Metering performance by DisCos

METERING	
Total registered customers	**Customers metered in December 2023**
13,231,807	**42,961**
Total metered customers'	**Metering rate**
5,885,687	**44.48%**

Table 2: Customer complaints from Discos

CUSTOMER COMPLAINTS	
Complaints received	**Service Interruption**
98,502	**7.93%**
Metering	**Billing**

63.03%	**9.70%**

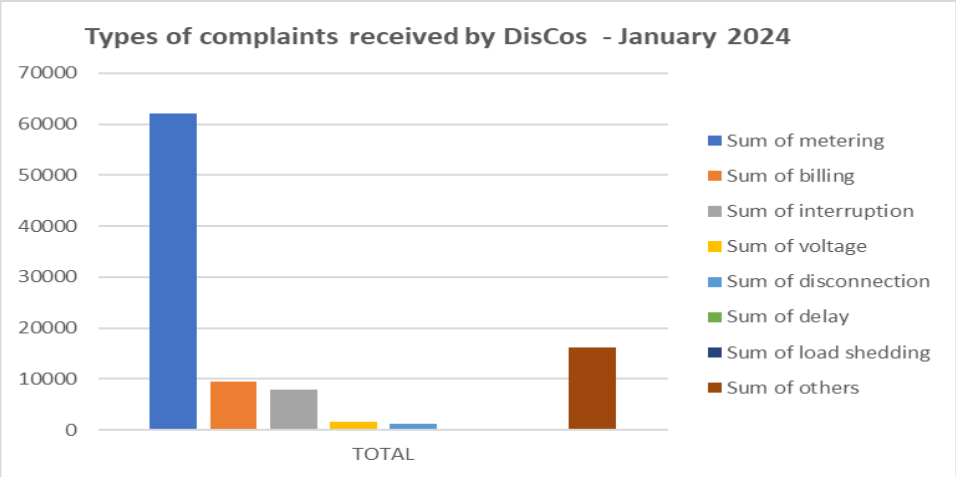

Figure 1: Types of complaints received by Discos derived from Metering and Customer Service Standards published by NERC, January 2024.

To achieve financial viability in the distribution segment requires minimizing Aggregate Technical, Commercial, and Collection (ATC&C) losses. This can be accomplished by upgrading outdated transmission and distribution (T&D) infrastructure, ensuring 100 percent metering of customers, implementing fintech solutions for electricity payments, and leveraging information technology to combat electricity theft.

3. Challenges Faced by Power Industry Towards Digitization

Digital transformations in the power industry hold tremendous promise for enhancing efficiency, reliability, and sustainability. However, they also encounter common pitfalls that can hinder their success and impact. This section explores some of the key challenges faced by power industry, digital transformations and strategies to overcome them. The challenges are [7]:

1. Complexity of existing infrastructure and legacy systems: Many power companies operate with outdated equipment and siloed IT systems, making integration and interoperability a daunting task. As a result, implementing digital solutions often requires significant upfront investment in infrastructure upgrades and system modernization. Moreover, the shift towards digital technologies has the potential to disrupt current workflows and procedures, resulting in resistance from employees and stakeholders who are accustomed to conventional practices.
2. Lack of comprehensive data management and analytics capabilities: While power companies generate vast amounts of data from sensors, meters, and other sources, harnessing this data to derive actionable insights remains a challenge. Inadequate data quality, governance, and analytics capabilities hinder the ability to extract value from data and make informed decisions. To address this challenge, power companies must invest in data infrastructure, analytics tools, and talent development to build a data-driven culture and leverage data as a strategic asset.
3. Regulatory and compliance requirements: This poses significant hurdles to digital transformation initiatives in the power industry. The regulatory landscape is complex and constantly evolving, with stringent standards and guidelines governing various aspects of power generation, transmission, and distribution. Navigating these regulatory requirements while implementing digital solutions requires careful planning, coordination, and compliance measures to ensure adherence to industry standards and regulations.

4. Absence of clearly defined vision and delineation of new roles: Many companies spanning various industries struggle to articulate a concise vision for their digital transformations. Consequently, employees are often left uncertain about how digital tools and analytics can enhance their daily responsibilities, with some perceiving the transformation as a potential threat rather than an opportunity. For instance, they may be afraid that automation will render their positions obsolete. Illustrating the impact of digitization on various roles within a power plant, helps employees understand that successful digital transformations will leverage on data and streamline processes to prioritize performance enhancements. Thus, the transition to digital technologies will result in the evolution of roles, rather than reduction in workforce.
5. Organizational culture and change management: This presents substantial barriers to successful digital transformations. Resistance to change, lack of buy-in from leaders, and inadequate training and communication can impede the adoption and acceptance of digital technologies within the organization. Addressing cultural barriers and fostering a culture of innovation, collaboration, and continuous learning are essential for driving successful digital transformation initiatives in the power industry.

4. How Technologies Can Help in Reducing Electricity Costs.

Humans have evolved from the first industrial revolution where power was generated from coal, to the second industrial revolution generating power from petroleum, to the third industrial revolution of nuclear energy and now the ongoing fourth industrial revolution that is still being explored. Each new stage sought to make things easier, faster and life better.

Technology, particularly advancements characteristics of the fourth industrial revolution, holds significant potential for mitigating Aggregate Technical, Commercial, and Collection (ATC&C) losses[8]. Developed nations are leveraging technology to enhance efficiency and productivity within the power sector. However, Nigerian power sector entities are falling behind in adopting these new technologies.

By effectively implementing the technologies and solutions outlined in section 4.1, power producers must shift their operations and maintenance practices from traditional to digitally enabled approaches. Distribution Companies (DisCos) should aim to reduce their ATC&C losses, enhance customer satisfaction, and bolster their financial sustainability.

4.1 How Technologies can Help Generation Companies (Gencos)

Technology can help generation companies in the following ways:
1. Operations: Technologies can help transition a power plant from focusing on safe and reliable operation with major effort on manual work for reporting, issue resolution, and control walks into implementing real-time monitoring and control systems to optimize plant performance, adjust generation schedules, and minimize downtime supported by automated reporting, guided issue resolution, and digitized control walks.
2. Maintenance: The use of predictive maintenance techniques, leveraging data analytics, and IoT sensors to detect and rectify equipment malfunctions proactively, thereby minimizing downtime and maintenance expenditures. Real-time, advance analytics can monitor equipment, reducing reliance on time-based maintenance and facilitating predictive maintenance. Furthermore, the integration of smart sensors feeding the digital twin offers enhanced insights into plant condition. Implement digital control towers to monitor the status of both scheduled and unscheduled outages in real-time. Utilize drones for inspections during outages to access challenging-to-reach areas like cooling towers and boiler walls, thus diminishing the necessity for scaffolding.

3. Energy Efficiency: Instead of regularly analyzing heat-rate losses by performance engineers based on performance reports created manually, GenCos can invest in energy management systems and smart grid technologies to optimize energy usage, reduce waste, and maximize the efficiency of power generation processes. The heat-rate losses and root causes can be visualized in real time, triggering immediate actions to resolve issues as quickly as possible.
4. Health, Safety, Security, and Environment: Integrate digital solutions for risk assessment, emergency response planning, and environmental monitoring to enhance safety compliance, minimize environmental impact, and mitigate operational risks.

4.2 How Technologies can Help Transmission and Distribution Companies (Discos)

Technologies can help transmission and distribution companies in the following ways:
1. Prepaid Smart Meters: Implementing prepaid smart meters enable electricity consumers to monitor and manage their energy usage more effectively. These meters provide real-time data on consumption, allowing consumers to track their usage patterns and adjust their behavior accordingly (Orukpe and Agbontaen, 2013). Additionally, prepaid functionality eliminates issues of non-payment and revenue loss for distribution companies, ensuring a more reliable revenue stream and improved financial sustainability. Figure 2 shows a typical smart prepared meter.

Figure 2: Smart prepaid meter

2. Supervisory Control and Data Acquisition (SCADA): SCADA systems enable real-time monitoring and control of electricity transmission and distribution networks. By remotely monitoring substations, transformers, and other critical infrastructure, operators can detect faults, optimize grid performance, and respond to emergencies promptly. Figure 3 shows a typical power plant control room using SCADA.

Figure 3: Control room of a power plant using SCADA

The process entails receiving data from Programmable Logic Controllers (PLCs), which primarily gather information from sensors or manually inputted values. This data is then visualized on Human Machine Interfaces (HMIs), enabling operators to remotely oversee and manage the devices.
SCADA (Supervisory Control and Data Acquisition) offers numerous advantages in the power distribution sector. Many Distribution Companies (DisCos) currently rely on manual labor to

monitor current flow, line voltage, and circuit breaker operations. With SCADA, these processes can be fully automated, resulting in reduced labor costs and improved efficiency. For instance, SCADA systems can swiftly identify fault locations and prompt operators with alarms to rectify them. Ultimately, SCADA plays a crucial role in helping DisCos enhance the quality and reliability of power supply.

3. Geographical Information System (GIS): The significance of utilizing electricity as a catalyst for the socio-economic advancement of the nation cannot be overstated. Therefore, maintaining a comprehensive and precise inventory of physical assets and their spatial locations is crucial for routine service provision, network expansion, and maintenance, utilizing geospatial techniques. GIS, an emerging technology, functions as a software application designed for generating and presenting cartographic data. Its five key components - software, data, procedures, hardware, and personnel - collaborate to capture, store, retrieve, analyze, and showcase geographically referenced information. Additionally, GIS possesses the capability to analyze spatial data, conducting attribute and location analysis, as well as spatial modeling [9]. Figure 4 illustrates a typical geographical information system.

Figure 4: Geographic information system

By consistently monitoring and updating the GIS mapping of both the consumer database and electrical network, planning can be greatly improved, load can be managed more efficiently, losses can be reduced, revenue can be increased, and the management standard of the distribution network can be elevated. Additionally, GIS technology can help foster stronger consumer relationships. The implementation of GIS in the sector has revolutionized transmission and distribution planning, as it allows for precise alignment of transmission line routes and geospatial management of electricity distribution facilities. GIS have become a vital technology in the utility sector, significantly enhancing traditional practices.

GIS-based electrical network mapping and consumer indexing ultimately facilitate better management of the network, control electricity theft, recovery of dues, etc. Overall, integration of GIS with other platforms such as Customer Relationship Management (CRM), SCADA, Outage Management System (OMS), etc., would foster a more efficient distribution network for stakeholders in the power sector.

4. Outage Management System (OMS): A power outages is a frequent occurrence in Nigeria, with significant economic repercussions. According to Eco Fin Agency, Nigeria incurs losses of approximately US$ 29.3 billion, equivalent to nearly 7 percent of its GDP, as a result of power outages and inadequate distribution systems (https://www.ecofinagency.com/public-management/2904-39984-nigeria-loses-29-3-bln-yearly-to-power-outages-and-poor-energy-distribution-gencos).

Distribution companies utilize Outage Management Systems (OMS), a type of network management software, to monitor and efficiently restore power within the grid (Phoenix Energy,

2018). It helps utilities efficiently manage power outages by quickly identifying affected areas, dispatching repair crews, and providing real-time updates to customers. By streamlining outage response processes and minimizing downtime, OMS enhances customer satisfaction and reduces revenue losses associated with service interruptions. Figure 5 presents a typical flow of an outage management system.

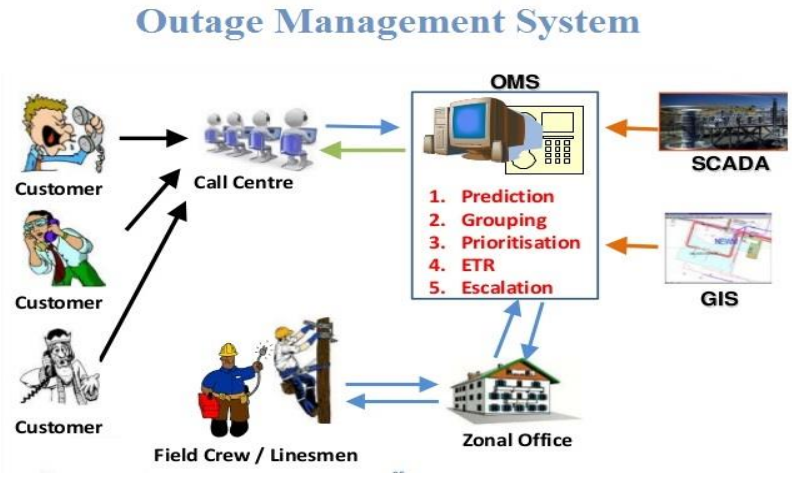

Figure 5: Flow of outage management system

5. Online Payment of Electricity Bills: Offering online payment options enables consumers to conveniently pay their electricity bills from anywhere, reducing the need for physical payment centers and improving overall customer satisfaction. Online payment systems also enhance revenue collection efficiency for distribution companies, reducing instances of non-payment and revenue leakage. In 2020, the federal government gave a directive stopping the collection of cash for payment of electricity bills (https://www.businessamlive.com/fg-orders-Discos-to-stop-the-use-of-cash-payments-for-electricity-bills/).

6. Applicability of Data Protection in Power Sector: Power companies will have access to personal data of power consumers with the implementation of smart meters. These companies will be required to process such personal data in accordance with the rules of the extant provisions of the law.

In Nigeria, data protection is governed by the Nigerian Data Protection Regulation, (NDPR), 2019. The NDPR requires all persons who process the data of individuals to put in place measures for safeguarding and ensuring the proper use of personal data in their possession or under their control.

4.3 Other Challenges

However, alongside the opportunities presented by new technologies, the power industry also faces challenges related to cybersecurity, interoperability, and regulatory frameworks. As power systems become more interconnected and dependent on digital infrastructure, they also become more vulnerable to cyber threats and vulnerabilities. Addressing these challenges require robust cybersecurity measures, standardized communication protocols, and collaborative efforts between stakeholders to ensure the resilience and security of critical energy infrastructure.

5. Conclusion

In conclusion, the role of digitization in the power industry is transformative, driving innovation, efficiency, and sustainability across the entire value chain. By embracing digitalization, renewable energy integration, and smart grid solutions, the power sector can navigate the complexities of a

rapidly evolving energy landscape and transition towards a more resilient, flexible, and sustainable future.

References

[1] Babatunde O., Buraimoh E., Tinuoye O., Ayegbusi C., Davidson I. and Ighravwe D. E. (2023). Electricity sector assessment in Nigeria: the post-liberation era. Cogent Engineering, Vol. 10, Issue 1, https://doi.org/1.1080/23311916.2022.2157536.

[2] Ihiabe Y.A, (October 2015). Application of GIS in Electrical Distribution Network System. European International Journal of Science and Technology, Vol 4 No. 8, 81-82.

[3] Kaisa Huhta (2020) Smartening up while keeping safe/ Advances in smart metering and data protection under EU law, Journal of Energy & Natural Resources Law, 38:1, 5-22

[4] Okakwu I. K, Oluwasogo E. S. and Orukpe P. E. (2022). Performance evaluation of hydropower stations in Nigeria. International J. Renew. Energ & Environ, Vol. 2 (1), pp. 1-12.

[5] Oni A. (2021) "The Nigerian Electricity Market: Understanding the transaction, legal, and policy issues. Legal Naija Publisher.

[6] Orukpe P. E. and Agbontaen F. O. (2013). Prepaid meter in Nigeria: the story so far and the way forward. Advanced Materials Research, Vol. 824, pp. 114-119.

[7] Phoenix Energy, (2018) 'An Overview of Outage Management Systems' Phoenix Energy https://www.phoenixenergygroup.com/blog/an-overview-of-outage-management-systems (Accessed on 7 December 2023)

[8] Vidya Muthukrishnan 'SCADA System: What is it? (Supervisory Control and Data Acquisition)' Electrical4U November 22, 2020: https//www.electrical4u.com/scada-system/ (Accessed December 1, 2020)

[9] Kalluri Srinivasa Rao, S Ramana Kumar Joga, V. Hari Shankar Dinesh, S. Mounika, B. Musili Naidu, M. Sai. "Innovative Digital Energy Meter with Overload Indication and Power Theft Monitoring", 2023 4th International Conference for Emerging Technology (INCET), 2023