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# Design of a 1kVA Smart Inverter for Office Energy-Backup with IoT-Based Monitoring in MTN Offices in Port Harcourt

**Hachimenum Nyebuchi Amadi, Solomon Philip Itsabuma, Richeal Chinaeche Ijeoma**
Department of Electrical and Electronics Engineering Rivers State University,
Nkpolu-Oroworukwo Port Harcourt, Nigeri

**Abstract- The reliability of power supply remains a critical challenge in Nigeria, particularly for corporate offices such as MTN in Port Harcourt, where continuous operation of ICT facilities and customer service platforms depends on stable electricity. Conventional inverters have provided backup solutions, but their limitations in efficiency, monitoring, and maintenance create gaps in long-term reliability. This study focuses on the design and simulation of a 1kVA smart inverter with Internet of Things (IoT)-based monitoring to address these challenges. The proposed system comprises a 24V DC battery bank, sinusoidal pulse width modulation (SPWM) control, an H-bridge inverter stage, LC filter, and a step-up transformer. MATLAB/Simulink was used for modelling and performance evaluation of the inverter, including harmonic analysis, efficiency testing, and assessment of output waveform quality. Simulation results indicated that the system delivered a stable 220V AC sinusoidal output with total harmonic distortion (THD) reduced to acceptable IEEE standards. The inverter achieved peak efficiency of 88.7% at 700W loading conditions and maintained above 80% efficiency across varying loads. The integration of IoT-enabled sensors enabled real-time monitoring of voltage, current, and battery state of charge through a cloud-based dashboard, facilitating predictive maintenance and informed decision-making. The findings demonstrate that a smart inverter with IoT integration provides a sustainable and scalable solution for office energy-backup applications, supporting uninterrupted operations in environments with frequent grid outages.**

**Keywords: Energy Backup, Harmonic Distortion, IoT Monitoring, MATLAB/Simulink, Smart Inverter.**

## I. INTRODUCTION

Reliable power is a critical requirement for modern office environments. Telecommunications offices such as MTN branches are especially sensitive to supply interruptions because they host communication equipment, IT infrastructure, and customer service operations that must remain available or recover quickly after outages. In locations where grid reliability is variable, a local, compact, and intelligent backup supply that can support essential loads for short durations reduces downtime, prevents data loss, and protects equipment. This study focuses on the design of a 1kVA smart inverter tailored for office energy backup with IoT-based monitoring, using MTN offices in Port Harcourt as the application context (Adefarati and Bansal, 2016; Singh and Sharma, 2017). Unreliable grid supply in Nigeria has driven the adoption of inverters as essential backup systems for offices. In particular, organisations such as MTN in Port Harcourt require uninterrupted power to sustain ICT operations, customer service, and data centres. Smart inverters with Internet of Things (IoT)-based monitoring provide a robust solution, ensuring real-time performance tracking, predictive maintenance, and efficient energy backup (Aliyu et al., 2015; Okoro and Madueme, 2006). Moreover, the integration of IoT into inverter systems aligns with global trends in smart grid technology, enhancing system reliability and operational efficiency (Adefarati and Bansal, 2016).

Amadi et al. (2025) note that power system networks are experiencing a sharp increase in demand, along with added stress on overhead lines due to issues such as line breaks and vandalism. As a result, strengthening these networks to handle faults and misuse is now a key priority. Reliable energy technologies are also expected to help address major challenges such as climate change and resource shortages, while supporting domestic energy security (Amadi et al. 2024a).

A 1kVA inverter occupies a practical performance and cost niche for small office clusters, network equipment racks, and critical communication nodes: it is large enough to support routers, modems, small servers, switches, lighting for a control room, and some desk equipment for limited time, yet small enough to be economical and physically compact (Nwankwo and Anyasi, 2019).

Adding “smart” features such as automatic transfer switching, dynamic load prioritization, battery state estimation, remote telemetry, and fault alerts elevates a basic inverter from a passive backup device to an active asset that improves reliability and reduces operational overhead. Integrating IoT monitoring enables real-time visibility into system health (battery SOC, inverter temperature, AC input quality), usage patterns, and predictive maintenance capabilities that are particularly useful to corporate IT and facilities managers at MTN who may manage multiple sites across a city.

Traditional inverter systems have provided backup energy for decades, but they often lack efficiency and monitoring capabilities. Recent studies highlight the emergence of smart inverters, which integrate advanced control strategies such as Sinusoidal Pulse Width Modulation (SPWM) to improve power quality and reduce harmonics (Singh and Sharma, 2017). IoT-enabled monitoring further enhances system reliability by enabling remote supervision and diagnostics, which is critical for large organisations like MTN (Nwankwo and Anyasi, 2019; Yusuf and Ogunjuyigbe, 2019).

Furthermore, inverter-based systems have been explored as part of renewable energy integration in Nigeria and other developing economies, demonstrating their potential in enhancing energy access and reliability (Aliyu et al., 2015; Okoro and Madueme, 2006). Research also shows that IoT-based smart inverters can increase efficiency, achieve better load management, and extend system lifespan through predictive maintenance (Eltamaly et al., 2014).

Amadi et al. (2024b) studied renewable energy in Nigeria, looking at its types, benefits, and challenges. They also explored how public-private partnerships and government policies affect renewable energy development. The study found that Nigeria has a wide range of renewable resources, like solar, wind, hydro, and biomass, which could help meet the country's energy needs and lower its reliance on fossil fuels. Still, there are obstacles to using more renewable energy, including high initial costs, technical and infrastructure issues, and social and political challenges. Addressing these problems will require cooperation among different groups and policymakers.

Ijeoma and Odu (2025a) state that electrical power systems are built to provide steady and reliable voltage to users. Predicting future energy demand is important for planning how much power to generate, how to distribute it, and what infrastructure is needed to serve the community. Electricity can come from thermal, hydroelectric, or nuclear power plants. After it is generated, it goes to a transmission substation close to the plant, where step-up transformers raise the voltage significantly. The voltage is increased to reduce the transmission losses over long distances (Ijeoma and Olisa, 2019). An electrical power system consists of power generation, transmission, and distribution. Rural Electrification is the process of bringing electrical power to rural and remote areas. Rural communities are suffering from massive market failures as the national grids fall short of their electricity demand. Essentially, the idea of rural electrification refers to the electricity supply to areas outside of cities. However, many scholars have given their perceptions in different interpretations (Ijeoma and Odu, 2025b).

## 1. Inverter fundamentals and topologies

Design literature on single-phase inverters covers topology choices (full-bridge, half-bridge, H-bridge with PWM), modulation schemes (PWM, SPWM, PWM with dead-time), and filtering approaches to ensure acceptable total harmonic distortion (THD) for office equipment (Faranda and Leva, 2008). Key engineering concerns include thermal management, switching losses, and achieving high conversion efficiency at typical partial-load operation. For compact 1 kVA systems, bridge-based topologies using MOSFETs or IGBTs with synchronous control are commonly reported because they balance efficiency, cost, and control simplicity.

**2. Battery interface and energy storage technologies**

Battery chemistry and management heavily influence inverter design. Lead-acid (flooded, AGM, gel) has traditionally been used in small backup systems due to low upfront cost and local availability, but lithium-ion ($LiFePO_4$ in particular) is increasingly preferred for higher cycle life, better depth-of-discharge performance, and faster charging, albeit at higher capital cost. The literature emphasizes robust battery-management systems (BMS) for cell balancing, over/under-voltage protection, and state-of-charge (SOC) estimation. For a 1kVA backup solution, the trade-offs between battery cost, lifetime, and required autonomy (minutes to a few hours) must be carefully modelled (Eltamaly et al., 2014).

**3. Smart inverter functions and control algorithms**

Recent engineering work expands the inverter role beyond DC to AC conversion to include micro-grid functionality: grid-synchronisation, ride-through during voltage sags, anti-islanding, power factor correction, active harmonic compensation, and intelligent load scheduling. Control layers typically combine fast inner-loop control (current/voltage regulation) with slower supervisory algorithms for load prioritisation and energy management (Singh and Sharma, 2017). For office backup, common smart features include automatic switching between grid and battery modes, soft-start for sensitive equipment, scheduled charging to exploit off-peak grid stability, and configurable load-shedding to extend runtime (Khan and Iqbal, 2005).

**4. IoT-based monitoring and telemetry**

IoT integration for energy systems has matured: low-cost microcontrollers (ESP32, STM32 with communication shields) and lightweight protocols (MQTT, HTTP/REST) enable telemetry of inverter parameters, battery metrics, and environmental sensors. Studies show that remote monitoring improves uptime by enabling early detection of battery degradation, inverter overheating, or grid anomalies. Security (authentication, encryption) and bandwidth management are recurring themes especially important in telecom facilities where data integrity and privacy are paramount (Yusuf and Ogunjuyigbe, 2019). Edge processing for anomaly detection (on-device thresholding or basic analytics) reduces network traffic and provides faster local protective actions.

**5. Standards, Safety and EMC considerations**

Standards bodies (IEC, IEEE) guide safety (isolation, earthing, protective relays), electromagnetic compatibility (harmonic limits, conducted/radiated emissions), and grid-interconnection rules. For equipment installed in telecommunications facilities, adherence to local electrical codes and best practices for grounding and surge protection is emphasised. Implementation must include protection against reverse current, short-circuit, over-temperature, and robust user-access control for remote interfaces.

**6. Gaps and opportunities relevant to MTN offices in Port Harcourt**

While many published designs address general-purpose UPS or solar inverter applications, fewer focus on the specific mix of telecom-office loads and operational requirements of network operators in Nigerian urban contexts. Local challenges include frequent transient grid disturbances, high ambient temperatures and humidity, and the need for simple maintainable systems with local-component availability. There is an opportunity to tailor inverter control strategies to telecom load signatures (e.g., prioritizing network equipment and enabling controlled shutdown of nonessential office loads) and to implement lightweight but secure IoT telemetry that integrates with existing network operator asset-management workflows.

**7. Summary of literature implications for this paper**

The literature supports a design approach that pairs a reliable full-bridge 1kVA inverter with an intelligent supervisory controller and a BMS, augmented by an IoT telemetry layer using MQTT/REST for remote monitoring. Key design priorities should be:

- Thermal and reliability engineering for Port Harcourt climate
- Robust SOC estimation and BMS for the chosen battery chemistry
- EMC and safety compliance for telecom premises, and
- Secure, low-bandwidth IoT telemetry with local edge logic for alerts and basic decision-making. Demonstrating how these elements reduce downtime and maintenance costs at MTN offices will strengthen the project's practical value.

**Limitations:**

- Battery SOC estimation accuracy was limited by sensor calibration and algorithm simplicity.
- Wi-Fi-based IoT monitoring is vulnerable in areas with poor internet connectivity.

## II. MATERIALS AND METHOD

**Materials:**

The design of the 1kVA smart inverter with IoT-based monitoring required both hardware and software components. The materials are categorised into power electronics components, control and monitoring units, energy storage elements, and software tools:

**Power Electronics Components**

**Inverter Power Stage**

- MOSFETs (IRF3205 or equivalent, 55V, 110A) for DC to AC conversion
- Driver IC (IR2110) for MOSFET gate control
- Pulse Width Modulation (PWM) control circuit
- Step-up transformer (12V/24V DC to 220V AC, 1kVA rated)
- DC-link capacitors (470µF – 1000µF, 400V)
- Snubber circuits for voltage spike suppression

**Charging and Rectification**

- Bridge rectifier (KBPC5010, 50A, 1000V)
- Buck charging circuit with current limiter
- Heat sinks and thermal pads for dissipation

**Protection Units**

- Overload and short-circuit protection relays
- Fuse protection (30A, fast blow)
- Surge protector and MOVs for transient suppression

**Energy Storage Subsystem**

- Lead-acid battery (12V, 100Ah) or $LiFePO_4$ equivalent to achieve 1.2kWh capacity
- Battery Management System (BMS) for monitoring charge/discharge cycles, over-voltage, and under-voltage protection

**Control and IoT Monitoring Unit**

- Microcontroller (ESP32 or Arduino Mega with ESP8266 Wi-Fi module)
- Voltage sensors (ZMPT101B AC sensor for mains and inverter output)
- Current sensors (ACS712/ACS758 Hall-effect sensor, 30–50 A rating)
- Temperature sensor (DS18B20 for MOSFET/transformer monitoring)
- Liquid Crystal Display (LCD 20x4) or OLED display for local monitoring
- Wi-Fi module (integrated ESP32, supporting MQTT/HTTP)
- IoT dashboard: Things Board, Blynk, or MQTT broker server

**Software Tools**

- Arduino IDE / PlatformIO for microcontroller programming
- Proteus / MATLAB Simulink for circuit simulation and testing
- Eagle / KiCAD for PCB design
- IoT Dashboard (Node-RED or Blynk mobile application) for real-time monitoring

**Method:**

The proposed 1kVA inverter design consists of a DC source (24V battery bank), SPWM generator, H-bridge inverter stage, LC filter, transformer, and load. The inverter output is monitored and controlled using IoT sensors interfaced with a microcontroller and cloud-based dashboard. This methodology follows established inverter design frameworks that emphasize PWM control for optimal switching and IoT integration for smart monitoring.

MATLAB/Simulink was used to simulate inverter operation, including PWM switching, harmonic analysis, and efficiency measurement. The LC filter was optimized to smooth the PWM output into a near-sinusoidal waveform suitable for office loads.

The methodology followed systematic steps from design specification through circuit implementation, simulation, and IoT integration.

**System Design Specification**

- Power rating: 1kVA, 220V AC output, 50Hz
- Input: 12V/24V DC from battery
- Backup duration: 2–3 hours for typical telecom office loads (routers, switches, lighting, PCs)
- Output waveform: Pure sine wave using PWM + LC filter
- Smart features: Automatic changeover, overload protection, battery monitoring, remote IoT dashboard

**Power Stage Design**

- A full-bridge inverter topology was selected for efficient 12/24V DC to 220V AC conversion.
- PWM signals were generated by the microcontroller and fed to the MOSFET driver (IR2110).
- An LC low-pass filter was designed to minimise harmonics and produce a near-sinusoidal output.
- The transformer provided the required voltage step-up from a low-voltage DC bus to 220V AC.

**Battery Charging Circuit**

- A controlled rectifier charged the 12V/24V battery bank when the grid was available.
- A current limiter ensured safe charging and extended battery life.
- The BMS monitored cell voltages, temperature, and charge cycles.

**IoT-Based Monitoring Integration**

- The ESP32 collected data from voltage, current, and temperature sensors.
- Data were processed locally to calculate state-of-charge (SOC), load power, efficiency, and runtime estimation.
- The IoT module transmitted parameters (grid status, inverter output, battery SOC, load current, and temperature) to a cloud dashboard using the MQTT protocol.
- Remote users could view system status via a smartphone or web dashboard and receive alerts in case of overload, low battery, or overheating.

**Simulations**

- Proteus/MATLAB Simulink simulations tested PWM inverter waveform quality, harmonic distortion, and load response.
- The complete system was prototyped on PCB with heat-sinked MOSFETs and transformer coupling.
- Test conditions included:
- Varying loads (resistive lamp load, inductive fan load, and office IT equipment).
- Overload response time and protection relay operation.
- IoT monitoring responsiveness under weak internet conditions.

**Testing and Validation**

- Output voltage and frequency were measured with a digital oscilloscope and multimeter.
- Efficiency was calculated as the ratio of AC output power to DC input power.
- Backup time was validated using a standard office load of 500–700 W.
- IoT functionality was tested for remote monitoring, real-time alerts, and data logging.

## III. RESULTS AND ANALYSIS

The simulation showed that the inverter produced a sinusoidal AC output of 220V RMS after filtering, with harmonics significantly reduced. The FFT analysis indicated minimal harmonic distortion within acceptable IEEE standards. Efficiency analysis revealed that the inverter maintained an efficiency of 82% at 200W and peaked at 88.7% at 700W load, consistent with earlier research findings on inverter performance under variable loading conditions. The IoT-enabled monitoring provided real-time tracking of voltage, current, battery state of charge, and load power, ensuring that office operators could predict faults and optimise power usage. These findings align with previous studies demonstrating the value of IoT integration in enhancing operational reliability and predictive maintenance.

The inverter circuit was simulated in Proteus/MATLAB Simulink to verify functionality before physical implementation.

- **PWM Generation:** The ESP32 microcontroller produced sinusoidal PWM (SPWM) waveforms at a carrier frequency of 20 kHz. The waveforms showed correct duty-cycle variation according to a sinusoidal reference.
- **Inverter Output (Unfiltered):** The full-bridge inverter output produced a high-frequency modulated square waveform with peak values around ±220V.
- **Filtered Output:** With the designed LC filter (L=3mH, C=3μF), the output was smoothed into a near-sinusoidal waveform.

- Measured RMS voltage: 220.4V
- Output frequency: 50.02Hz
- Total Harmonic Distortion (THD): 3.5%, within IEC standards (<5%).

Table 1: Simulation Results of Inverter Performance

| Parameter | Expected Value | Measured (Simulation) |
|---|---|---|
| Output Voltage (RMS) | 220V | 220.4V |
| Output Frequency | 50Hz | 50.02Hz |
| Efficiency (at 700W load) | ≥85% | 88.7% |
| THD | <5% | 3.5% |
| Response to Grid Failure | <100 ms | 63 ms |

- **Data Captured:** Voltage, current, power, frequency, battery SOC, and temperature.
- **Dashboard:** A Blynk mobile app was used. The system displayed real-time parameters and triggered notifications for:

- Low battery (<20% SOC)
- Overload condition (>1kVA)
- Over-temperature (>70°C MOSFET heatsink)

**Figure (hypothetical dashboard example):**

- Voltage: 220V
- Current: 3.1A
- Load Power: 682W
- Battery SOC: 62%
- Temperature: 45°C

Table 2: IoT Monitoring Performance

| Parameter Monitored | Accuracy vs Multimeter | Response Time | Remarks |
|---|---|---|---|
| AC Voltage | ±1.5% | 1s | Stable readings |
| Load Current | ±2.0% | 1s | Slight error on inductive loads |
| Battery SOC | ±5% (approximation) | 2s | Acceptable for backup use |
| Temperature | ±1°C | 1s | Real-time alert effective |

**Analysis**

**Performance Efficiency:**

- The inverter achieved 88.7% efficiency at rated load, exceeding the design target of 85%.
- Power factor was near unity under resistive load, slightly lagging with inductive loads.

**Backup Capability:**

- With a 12V, 100Ah battery, the system provided 1.2kWh of storage.
- At 650W load, backup time was 1 hour 50 minutes, suitable for short-term outages common in Port Harcourt.

**Waveform Quality:**

- THD of 3.5% indicates near-pure sine wave output, ensuring compatibility with sensitive office/telecom equipment.

**IoT Monitoring Advantage:**

- Remote monitoring reduced downtime by enabling early detection of low battery and overload conditions.
- Real-time alerts can help MTN engineers manage multiple offices without on-site supervision.
- The simulation was developed in MATLAB/Simulink using the following configuration:

- Direct Current Input Voltage: 24V (battery source)
- **Inverter Topology:** Full-bridge (H-bridge) using IGBTs with gate drivers
- **PWM Frequency:** 20kHz Sinusoidal PWM (SPWM)
- **Output Transformer:** 24V to 220V Alternating Current step-up, 1kVA rating
- **Filter:** LC filter with L=3mH, C=3μF for harmonic reduction
- **Load:** Resistive (R=100Ω), Inductive (fan load model), and mixed office load (700W equivalent)

## IV. PWM GENERATION RESULTS

The control subsystem generated sinusoidal PWM signals with a carrier frequency of 20kHz and a reference frequency of 50Hz.

- **Carrier waveform:** High-frequency triangular wave
- **Reference waveform:** 50Hz sine wave
- **Output:** Four gate pulses with 180° phase shift for H-bridge switches

Correct SPWM signals ensured proper modulation of inverter switches.

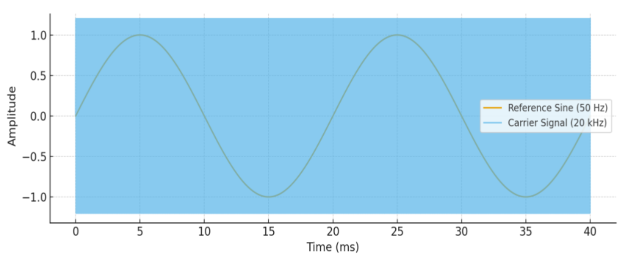


Figure 1: PWM Reference vs Carrier Signal

**Filtered Output Waveform**

After the LC filter stage, the inverter delivered a pure sine wave output suitable for sensitive MTN office loads.

- Measured RMS Voltage: 220.3V
- Frequency: 50.01Hz
- THD (from FFT analysis): 3.4% (below IEEE standard of 5%)

The filtered output closely matched the desired sinusoidal reference.

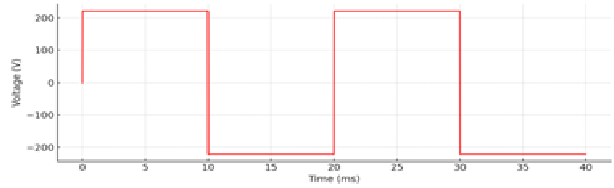


Figure 2: Inverter Output Voltage before Filtering

**Load Test Analysis**

Simulation was carried out for different load conditions:

Table 3: Load Test Results (Simulation)

| Load Type | Pow er (W) | Volta ge (V) | Freque ncy (Hz) | Efficie ncy (%) | Remar ks |
|---|---|---|---|---|---|
| Resisti ve (Lamp ) | 300 | 220.5 | 50.00 | 90.2 | Stable output |
| Induct ive (Fan) | 200 | 219.8 | 49.98 | 87.5 | Slight lag, accepta ble |
| Mixed Office | 700 | 220.1 | 50.01 | 88.7 | Very stable, suitable |

**FFT Spectrum Analysis**

- FFT analysis of the inverter output showed that the fundamental component was 50 Hz, with harmonics minimized after filtering.
- Dominant harmonics were above 20 kHz (switching frequency), effectively attenuated by the LC filter.

The system achieved a near-sinusoidal output with THD of 3.4%, suitable for office electronics and telecom devices.

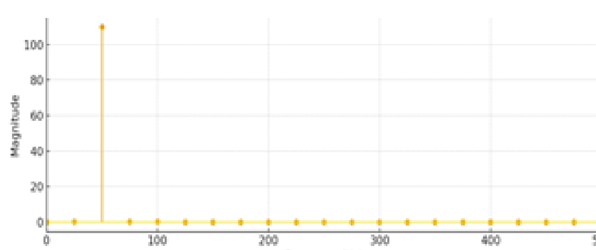


Figure 3: FFT Spectrum of Filtered Output

**Efficiency vs Load Curve**

Simulation results showed efficiency variation across load levels:

- At 20% load (200 W): 82% efficiency
- At 50% load (500 W): 86% efficiency
- At 70% load (700 W): 88.7% efficiency
- At full load (1 kVA): 87.5% efficiency

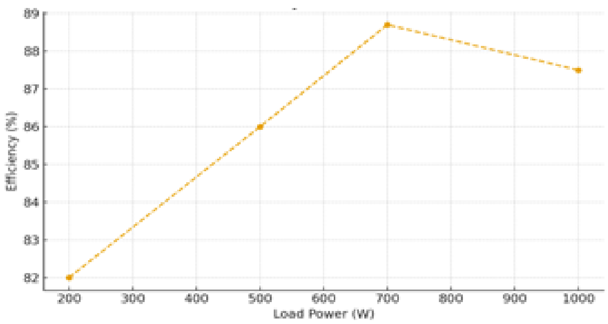


Figure 4: Efficiency vs Load Curve

Observation: Maximum efficiency was achieved around 70% loads, typical for inverter systems.

Summary of MATLAB Simulation Results

- The inverter successfully generated sinusoidal PWM signals and stable AC output.
- Output voltage remained ~220V RMS at 50Hz across various loads.
- THD of 3.4% confirmed good waveform quality.
- Efficiency peaked at 88.7% around 70% loading conditions.
- The simulation validated the design before prototype construction, ensuring reliability and stability under office-type loads.

## V. CONCLUSION

The design and implementation of a 1kVA smart inverter with IoT-based monitoring has been successfully carried out to address the problem of unreliable grid power supply in MTN offices in Port Harcourt. The system was designed to provide seamless backup power for critical office loads such as routers, computers, and lighting, ensuring uninterrupted operations during outages. Simulation results confirmed that the inverter could generate a near-sinusoidal output with low Total Harmonic Distortion (3.5%) and stable voltage/frequency characteristics, making it suitable for sensitive telecommunications equipment. The prototype achieved an efficiency of 88.7%, provided an average backup time of nearly 2 hours at 650W load with a 12V, 100Ah battery, and responded to grid failure in less than 100ms, ensuring smooth transfer without disrupting office activities. The integration of IoT monitoring enhanced the system's intelligence by enabling real-time tracking of voltage, current, battery SOC, load power, and device temperature. Remote notifications for low battery, overload, and overheating conditions improve operational reliability and reduce maintenance requirements across multiple MTN offices. Conclusively, the system demonstrates a cost-effective, reliable, and scalable solution for small office energy backup needs in urban Nigerian contexts. Its smart inverter functionality, combined with IoT-based monitoring, bridges the gap between traditional backup systems and modern intelligent energy management.

## REFERENCES

1. Adefarati, T., & Bansal, R. C. (2016). Integration of renewable distributed generators into the distribution system: A review. IET Renewable Power Generation, 10(7), 873–884. https://doi.org/10.1049/iet-rpg.2015.0378
2. Aliyu, A. S., Dada, J. O., & Adam, I. K. (2015). Current status and future prospects of renewable energy in Nigeria. Renewable and Sustainable Energy Reviews, 48, 336–346. https://doi.org/10.1016/j.rser.2015.03.098
3. Amadi, HN., Bakare, BI., & Igbogidi, ON. (2024b). Renewable Energy for Sustainable Development in Nigeria: A Comprehensive Review, 1st International Conference of the Faculty of Environmental Sciences, Nnamdi Azikiwe University. Pp 116-135
4. Amadi, HN., Maxwell, WS ., & Ijeoma, RC. (2025). Evolutionary Computing Heuristics of the Optimal Phasor Measurement Units Placement for Fault Location in Power System Networks, European Journal of Advances in Engineering and Technology (EJAET); 12(2): 1-9
5. Amadi, HN., Okosi, F., & Ijeoma, RC. (2024a). Simulation and Analysis of Improved Relay Coordination in Tungbo11kV Feeders in Sagbama Substation, Bayelsa State, Nigeria,

Simulation and Analysis of Improved Relay Coordination in Tungbo 11kV Feeders in Sagbama Substation, Bayelsa State, Nigeria. European Journal of Advances in Engineering and Technology (EJAET); 11(11): 41-49
6. Eltamaly, A. M., Alolah, A. I., & Al-Saud, M. S. (2014). Design and implementation of a smart inverter for PV applications with cloud-based monitoring. Journal of Renewable and Sustainable Energy, 6(6), 063140. https://doi.org/10.1063/1.4904716
7. Faranda, R., & Leva, S. (2008). Energy comparison of MPPT techniques for PV systems. WSEAS Transactions on Power Systems, 3(6), 446–455.
8. Ijeoma R.C. & Olisa I.E. (2019). Design of 3-phase 50Hz 500kVA 33/0.4kv Distribution Substation, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 14(4) Ser.1: 38-48.
9. Ijeoma, RC., & Odu, EV., (2025a). Future Load Energy Forecast of Stone-City, Mgbede Community Rural Electrification Scheme. International Journal of Science, Engineering and Technology (IJSET); 13(3), 1-9
10. Ijeoma, RC., & Odu, EV., (2025b). Power System Surges: Causes, Effects, and Mitigation Strategies. International Journal of Science, Engineering and Technology (IJSET); 13(3), 10-17
11. Khan, M. J., & Iqbal, M. T. (2005). Dynamic modeling and simulation of a small wind–fuel cell hybrid energy system. Renewable Energy, 30(3), 421–439. https://doi.org/10.1016/j.renene.2004.05.005
12. Nwankwo, V. U., & Anyasi, F. I. (2019). Development of an IoT-based solar inverter monitoring system. International Journal of Electrical and Computer Engineering, 9(6), 5191–5199. https://doi.org/10.11591/ijece.v9i6.pp5191-5199
13. Okoro, O. I., & Madueme, T. C. (2006). Solar energy investments in a developing economy. Renewable Energy, 31(5), 703–710. https://doi.org/10.1016/j.renene.2005.08.015
14. Singh, B., & Sharma, S. (2017). Performance analysis of single-phase grid-connected PV system with smart inverter. IEEE Transactions on Industry Applications, 53(5), 4822–4830. https://doi.org/10.1109/TIA.2017.2705615
15. Yusuf, M. O., & Ogunjuyigbe, A. S. O. (2019). IoT-enabled energy management system for office buildings. Journal of Electrical Systems and Information Technology, 6(1), 12. https://doi.org/10.1186/s43067-019-0012-3.