



Powering productivity: How better electricity quality and reliability can unlock MSME growth in Sierra Leone

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- Electricity is fundamental to economic growth. In low-income countries (LICs), poor power quality and reliability (PQR), manifesting as outages and voltage issues, constrain the productivity of micro, small, and medium enterprises (MSMEs) and the electricity sector as a whole.
- While the criticality of PQR for MSME and utility viability in LICs is known, policymakers lack granular data to measure and evaluate the effects of poor PQR on MSME productivity or design targeted PQR investments that unlock economic growth.
- This project addresses these gaps using nLine's energy system remote monitoring tools and data to assess the impacts of poor PQR on MSMEs in Freetown, Sierra Leone. PQR monitoring sensors were installed with 48 MSMEs across 12 communities in Freetown for nine consecutive months.
- Our data revealed that (i) 66.6% of monitored MSMEs experienced a minimum of five hours of outages daily; (ii) 50% of MSMEs spent two to six hours each day with voltage levels below the recommended operating standard and (iii) the implied \$ value of unserved energy for the distribution utility, when extrapolated to a wider population, is in the order of several hundred thousand USD.
- Our assessment draws attention to the power of real-time grid monitoring and data in addressing the operational impacts of poor PQR on MSME performance and enabling utility profitability. We conclude with policies that can be adopted to address PQR data gaps, improve grid performance, and enable broader economic resilience.

POLICY BRIEF SLE-24148

SEPTEMBER 2025

This project was funded
by IGC

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Policy motivation

Power quality is critical for MSME productivity and utility sustainability in low-income countries

For many low-income countries (LICs), the path towards sustained economic productivity, inclusive growth, and long-term development is hinged on access to reliable and high-quality electricity services. Good power quality and reliability (PQR) underpin the productivity and competitiveness of many micro, small, and medium enterprises (MSMEs) that serve as the economic backbone and deliver 80% of jobs in LICs. Despite the criticality of PQR in advancing development objectives and in achieving Sustainable Development Goal 7 (SDG7) on universal energy access, many LICs continue to face major shortfalls. On average, only 45% of the population in LICs has access to electricity. For those with access, electricity supply is often characterised by frequent outages and poor voltage quality, both of which constrain productivity and stunt economic growth (Sachs, Lafortune and Fuller, 2024).

The impact of poor PQR is particularly acute in sub-Saharan Africa (SSA), home to 22 of the world's 26 LICs. In the region, more than 70% of MSMEs report regular power outages and voltage quality issues linked to weak grid infrastructure, resulting in productivity and financial losses. Around half of these enterprises (51%) rely on diesel generators to compensate for the lack of reliable supply, further increasing costs and exposing firms to fuel price volatility (World Bank, 2025). Beyond their economic impact on MSMEs, poor PQR also undermines the financial sustainability of power utilities. Frequent outages and unserved demand reduce revenues, weaken the ability of utilities to recover operating expenses, and erode creditworthiness. This, in turn, deters private sector investment and limits access to affordable finance for grid expansion and modernisation. The result is a reinforcing cycle: underperforming grids weaken utility finances, which then restricts reinvestment in infrastructure, and ultimately perpetuates poor PQR.

To support MSME productivity, improve the financial viability of utilities and ultimately catalyse current visions of industrialisation across LICs, energy stakeholders urgently need to understand where, why, and how grids are currently failing. Unfortunately, granular, real-time measurements capturing the nature, spatial and temporal variations of PQR at the low-voltage level and their impacts on MSMEs in LICs are nonexistent. Yet, without a clear understanding of distribution grid pinch points, MSMEs in SSA's LICs will remain exposed to poor PQR that significantly constrains their ability to scale operations, attract investments, and integrate into value chains that enable broader prospects for industrialisation across SSA. Likewise, energy sector stakeholders will lack

granular data insights required to design targeted PQR interventions and energy transition investments that drive economic growth, foster industrial development, and deliver a healthy electricity sector. To address these knowledge gaps, this project deploys an innovative remote monitoring system and analytical methodology to characterise the nature, scale, and variability of PQR experienced by MSMEs in Sierra Leone. The approach provides actionable insights on two fronts: (i) the operational and financial impacts of poor PQR on MSME performance, and (ii) the implications for utility service delivery and financial sustainability.

Sierra Leone's energy context

Despite major electricity investments, including the connection of Freetown to the Côte d'Ivoire-Liberia-Sierra Leone-Guinea interconnection line, 24-hour electricity has fallen short of the expected output, and Sierra Leone's constrained grid capacity continues to impede economic productivity and the country's vision of industrialisation. "Only about a fourth of the country's population has access to gridded power, most of which lives inside the capital Freetown" (Millennium Challenge Corporation, 2021). The consequences of inadequate and unreliable electricity are wide-reaching, especially for enterprises that depend on a reliable power supply for operations. A recent World Bank survey found that 152 private firms in Sierra Leone lost, on average, 11.2% of annual revenue due to unreliable electricity—more than double the sub-Saharan African average of 5.3% (World Bank, 2020, as cited in Khan and Koo, 2024). These outages raise business operating costs, limit productivity, and deter investment, particularly in manufacturing and services.

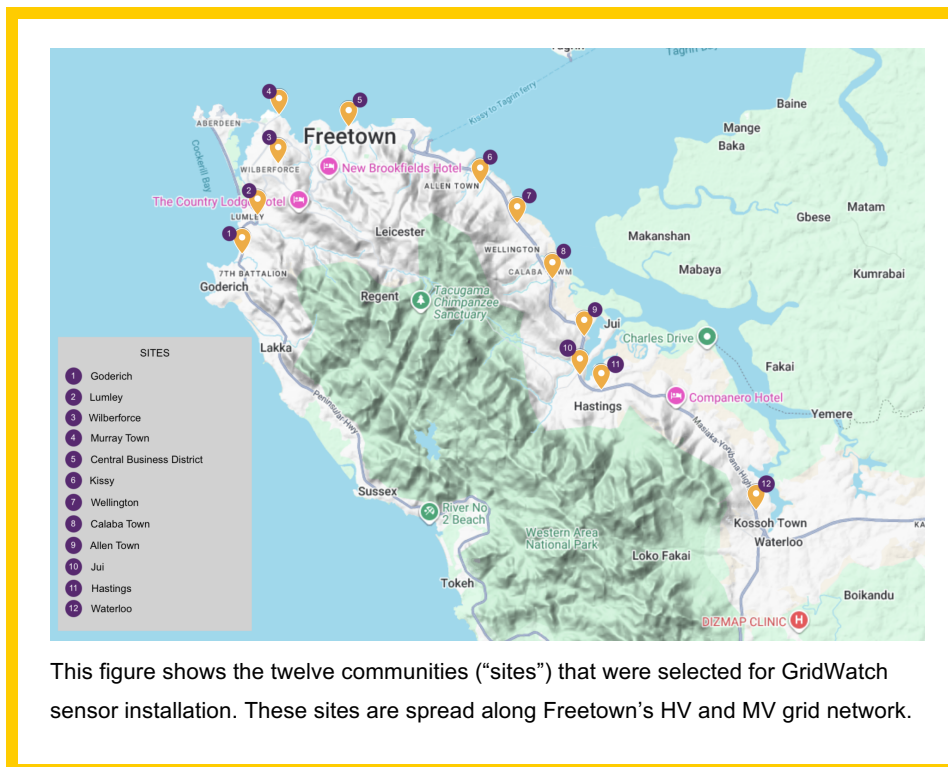
Urbanisation is accelerating, yet infrastructure and private investment lag, undermining economic opportunities. Poor PQR is unevenly distributed and disproportionately affects MSMEs, which generate over half of Sierra Leone's jobs. The country ranked 163rd of 190 in the 2020 Doing Business Report. Barriers include weak utility cost recovery, underinvestment, and governance challenges. Critically, there is little real-time, high-resolution data to assess distribution-level grid performance, limiting the ability to design effective interventions.

Project overview

The study focused on Western Urban and Western Rural districts in Freetown, selecting areas with high concentrations of grid-connected MSMEs. A purposive sampling strategy aimed to capture variation in voltage and outage performance across the EDSA grid. Twelve communities were identified for GridWatch sensor installation, covering diverse parts of the grid network from Goderich in the west to Waterloo in the east. In each community, one distribution transformer was

chosen that served at least 15 MSMEs, and sensors were randomly installed with a subset of four MSMEs connected to the same transformer.

Figure 1: Location of monitored MSMEs and GridWatch sensor installation in Freetown.



To measure PQR continuously at the 48 MSMEs, we leveraged Gridwatch, a remote measurement approach that combines quickly deployable wall outlet sensors with cloud algorithms to aggregate sensor data into key performance indicators (KPIs) of energy system quality and reliability (Klugman, 2021). Over a period of nine months (November 2024 to July 2025), real-time sensor data were collected on power outages (frequency and duration), voltage and frequency levels at each MSME and aggregated to the distribution transformer level to generate community-level KPIs. These businesses were strictly powered by EDSA electricity.

Table 1: Summary of key performance indicators (KPIs) measured by GridWatch.

Key Performance Indicator	Definition [units]
System Average Interruption Duration Index (SAIDI)	Average cumulative outage time experienced by a customer [hours]
System Average Interruption Frequency Index (SAIFI)	Average number of outages experienced by a customer [number of interruptions]
Customer Average Interruption Duration Index (CAIDI)	Average duration of any single outage experienced by a customer [hours]

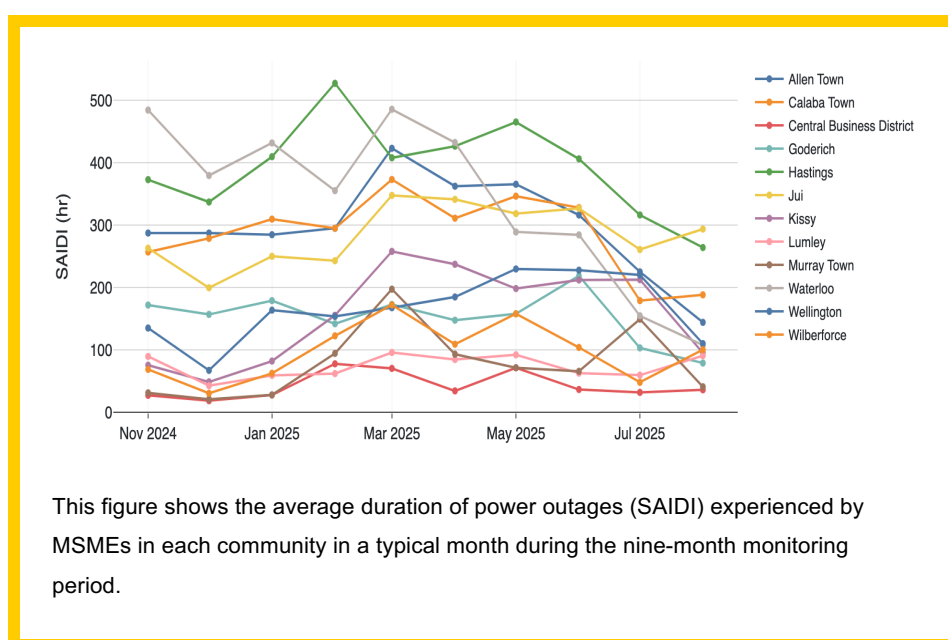
Average Voltage	Average voltage delivered to customer [Vrms]
Hours Undervoltage	Average time customer experiences very low voltage [hours]
Minutes Overvoltage	Average time customer experiences very high voltage [minutes]

Alongside sensor installation, surveys gathered information on business operations, electricity satisfaction, and coping strategies. These qualitative insights complemented sensor data, helping to explain socio-economic and operational impacts of PQR variation. Given the sample size (12 transformers), the analysis emphasised descriptive statistics and correlations, treating results as exploratory.

Key findings

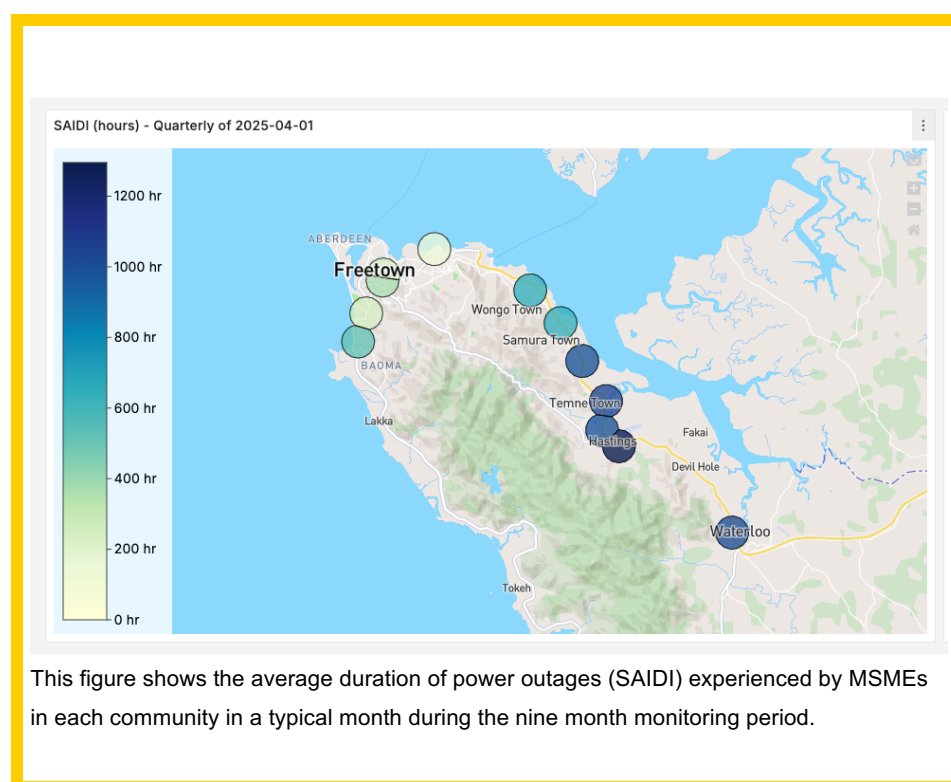
Outages are pervasive and spatially uneven across Freetown. All 48 MSMEs in our sample experienced outages daily, and we recorded a total of 6,195 outage interruptions over the course of the nine-month monitoring period. In addition, we found significant spatial variations in PQR across Freetown, with MSMEs in the eastern part of the grid disproportionately affected by large-scale outages and voltage quality issues. MSMEs in eastern Freetown experienced nearly seven times higher daily duration of outages than those recorded in western Freetown. In terms of outage duration, MSMEs across 12 monitored communities experienced between 150 and 500 hours of outages per month.

Figure 2: Average monthly duration of power outages (hours) per monitored community.



The presence of large-scale outages in one section of the grid suggests broader governance and equity issues. Probing deeper into the east-west divide observed in the data, we found that outage disruptions are not random but rather consistently affect the same two groups of sampled communities: five sites in western Freetown (Goderich, Lumley, Wilberforce, the CBD, and Murray Town) and six sites in eastern Freetown (Hastings, Jui, Allen Town, Calaba Town, Wellington, and Kissy). This repeated clustering indicates that communities within each group share critical grid infrastructure such as substations, feeders, or transmission lines. The implication is that outages in these areas are driven by systemic vulnerabilities rather than isolated local failures. The pattern also raises concerns around service equity. Concentrated vulnerabilities mean that certain communities—and by extension MSMEs—are disproportionately exposed to repeated disruptions, which undermines fairness in energy access.

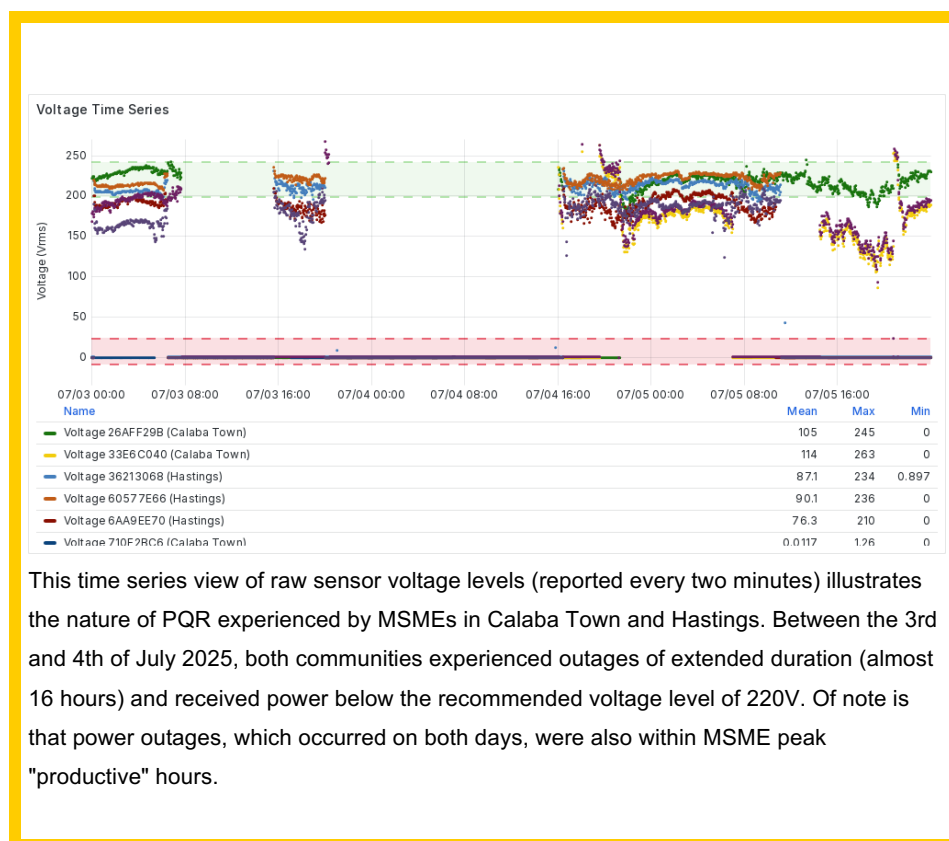
Figure 3: A map overview of the East-West divide in SAIDI.



Outages tell a new story about electricity consumption per capita. Sierra Leone's per capita electricity consumption remains among the lowest globally, but as shown in Figure 3, this lack of consumption cannot entirely be attributed to a lack of willingness to consume electricity. Instead, we see how frequent outages, particularly during the most productive hours of the day (8 a.m. to 6 p.m.), mean that both businesses and households are unable to utilise electricity consistently, even when they have the capacity and need to do so. Consequently, official figures on per capita electricity consumption present a distorted picture,

capturing only actual use rather than the much higher latent demand. This gap between potential and actual consumption underscores the extent of suppressed demand, suggesting that a more reliable electricity supply could unlock significant economic and social benefits for the country.

Figure 4: A long power outage during productive hours in Hastings and Calaba Town.

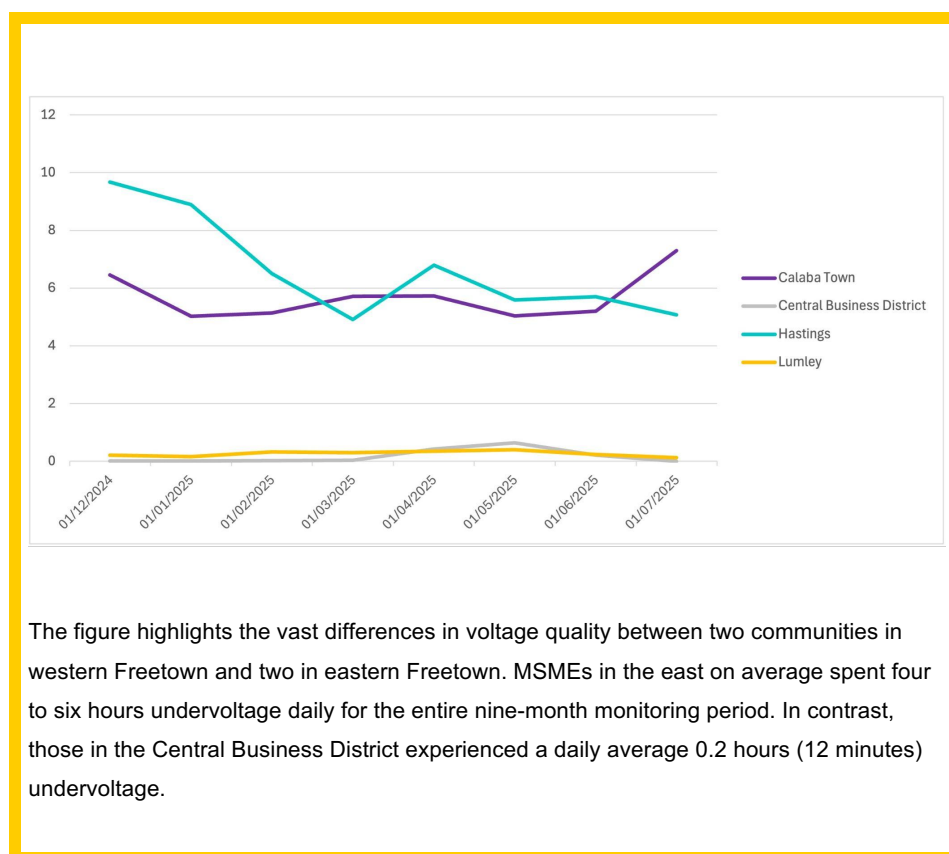


Extreme voltage events are frequent and damaging to MSME appliances.

As observed with outages, sampled MSMEs in western Freetown (i.e., Wellington, Lumley, and Murray Town) receive voltage levels close to the nominal 230V standard with minimal undervoltage exposure (e.g. less than 37 minutes per day in Murray Town). In contrast, MSMEs in eastern Freetown experienced severe voltage quality issues (e.g. the four MSMEs in Hastings received only 190V on average and experienced an average of 6.6 hours of undervoltage daily). Looking deeper, we found smaller excursions/very low readings (below 190V), and larger excursions that inconvenience appliances and lead to improper operations (below 100V). Voltage sags below 100V render electricity unusable and will likely cripple MSMEs' operational capabilities. The effects of these sags are also cumulative as they draw higher current from compressors or motors of appliances like refrigerators that are commonly owned by MSMEs. In addition to sags, we found very high spikes (exceeding 300V) that result in rapid appliance failure and violate IEEE/IEC voltage thresholds. Replacement or repair costs for

affected appliances were reported to exceed several hundred Leones (SLE) per incident, representing a disproportionate financial burden for MSMEs operating with limited liquidity.

Figure 5: Average monthly hours of undervoltage across the two best PQR sites in western Freetown and the worst two PQR sites in eastern Freetown.



The cost of inaction is high for EDSA. The monetary costs of outages for the Electricity Distribution and Supply Authority (EDSA) are substantial once scaled across a broader sample of MSMEs. As shown in Figure 2, the average business in eastern Freetown experiences around 300 hours of outages each month, which has implications for both actual unserved energies, suppressed demand, and utility revenue. For the utility, 300 hours of unserved energy translates into thousands of kilowatt-hours of electricity that could have been sold but was not. For example, if an MSME were to use 20 kWh per day, 300 hours of outage would equate to 250 kWh of suppressed demand per business per month—demand that never appears on the utility’s revenue books. When scaled to just 1,000 MSMEs, this represents approximately 250,000 kWh of suppressed demand every month, or about USD 62,500 in lost revenue for the utility at the current tariff of \$0.25 per kWh. More importantly, since many of EDSA’s costs (distribution infrastructure and equipment, maintenance, and salaries) are fixed, selling less electricity makes cost recovery harder and can push tariffs up for customers. Beyond the direct financial loss, this situation distorts the utility’s

performance metrics, as official consumption data significantly understate the true size of the market.

Policy recommendations

Overall, our findings indicate a significant opportunity to reduce grid outages and voltage quality issues experienced by MSMEs in Freetown. These brief highlights policies that can be adopted to address current PQR challenges in Freetown and, by extension, in Sierra Leone. Below, we focus on four recommendations that can improve grid network performance and enable the design of incentives that promote productive and equitable use of electricity in Sierra Leone and derisk the sector at large.

Design targeted and spatially responsive network efficiency investments.

Feeders located in eastern Freetown are “poor power quality hotspots” and should be prioritised for more granular power quality monitoring and targeted upgrades. Given the stark disparity in power quality between the eastern and western grids of Freetown, the eastern feeders should be formally designated as a "Poor Power Quality Hotspot." This prioritisation will allow Sierra Leone's Electricity and Water Regulatory Commission (EWRC) and EDSA to allocate monitoring and investment resources and attention where they are most needed. To provide more granularity, the Ministry of Energy (MoE), EDSA, or other energy-sector investors could deploy additional power-quality sensors on feeders in the east to identify the most overloaded segments and enable EDSA's rapid-response crew to conduct emergency repairs and reconductoring. Fast-tracking upgrades on these feeders and introducing structural fixes such as transformer replacements or capacitor banks will reduce outages, improve voltage stability, and directly support local businesses that are most adversely affected. Beyond the eastern corridor of the grid, the MoE, and EDSA could also expand feeder-level monitoring infrastructure across Freetown to continuously capture voltage and outage data. Such citywide monitoring would ensure that electricity investments deliver the maximum social and economic benefit per dollar spent.

Energy sector stakeholders must deploy power-quality monitoring tools to enable data-driven grid governance. As shown from our analysis, effective poor PQR mitigation requires precise, real-time data that enables the regulator (EWRC) to not only identify SAIDI and SAIFI hotspots but also capture the severity of voltage fluctuations that damage appliances or equipment. PQR monitoring ensures that issues are identified before they escalate into prolonged outages or widespread equipment damage. Over time, the collected data can also guide predictive maintenance programs, reducing costs, and improving grid

reliability across the eastern network. Beyond its reactive benefits of faster fault isolation and restoration, such data also enables the regulator to establish new regulatory innovations around network performance improvements. For instance, with access to real-time monitoring, EWRC could (i) institute a PQR monitoring mandate for feeders serving significant commercial clusters and (ii) establish a compensation/liability framework for verified appliance damage due to utility-side PQR failures, or even establish performance-based incentives that reward EDSA for reducing unserved energy and voltage excursions. Such regulatory innovations would not only incentivise EDSA to actively manage power quality but also empower businesses, investors, and EWRC to monitor trends and ensure compliance.

Revise existing institutional logics around grid operations and regulations in a way that centres MSME productivity to ensure that both EDSA MSMEs profit from efficiency improvements.

MSMEs must be protected via appliance-damage mitigation measures to foster economic equity. MSMEs in high-outage areas are disproportionately impacted by voltage fluctuations, leading to equipment damage and financial loss. To address this, the Government of Sierra Leone, Small and Medium Enterprise Agency (SMEDA), and EWRC could adopt mitigation strategies such as a utility-administered compensation fund, funded by a modest tariff surcharge, to reimburse businesses for verified utility-driven voltage-related appliance damages, or a subsidy program for surge protectors, voltage regulators, and backup solutions. Such programs should be supported with training for MSMEs on managing PQR risks and investing in energy-efficient appliances. EWRC could also empower MSMEs to report power-quality issues and establish a streamlined reporting channel for appliance damage, allowing businesses to quickly document losses and request support on comparative models like India's state Compensation Plan for Temporary Damages scheme. These measures will provide immediate relief to MSMEs, encourage investment in protective equipment, and help build trust between the utility and the business community.

Unserved-energy cost must be integrated into grid investment prioritisation and planning. Future grid investments should be guided by a clear economic rationale that considers reliability, quality, and economic impacts. As a starting point, the MoE and EDSA could leverage sensor-generated data on the economic costs of unserved energy to prioritise feeders for upgrades. In this scenario, every candidate feeder or asset investment is ranked by the expected unserved-energy cost avoided per dollar invested. This ensures that limited resources are directed toward projects that yield the highest return in terms of service reliability and economic benefit. Over time, such a systematic approach will optimise grid performance, enable cost-reflective tariff allocation, reduce business losses due

to outages, and create a transparent decision-making framework that regulators, investors, and stakeholders can understand and support.

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