UTILITY SMART GRID INTEGRATION // June 2026

Grid Modernization Framework for Nigerian Distribution Companies

Acknowledgement

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About Us

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ABOUT THE UTILITY SMART GRID INTEGRATION PROJECT (USGI PROJECT)

The USGI Project is funded by UK Partnering for Accelerated Climate Transitions (UK PACT) and implemented by a consortium including WEC, Greenage Technologies, and Priston Mill. The project is working with the Kano Electricity Distribution Company (KEDCO) to develop a replicable framework for grid modernization and prepare a pilot project for implementation. The project aims to reduce ATC&C losses for DisCos, improve supply for customers, and enable integration of renewable energy.

For more information, visit
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List of Acronyms

ACR	Automated Circuit Recloser
ADMS	Advanced Distribution Management System
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
ANM	Active Network Management
API	Application Programming Interface
AR	Active Response
ARRA	American Recovery and Reinvestment Act
ATC&C	Aggregate Technical, Commercial, and Collection
CAPEX	Capital Expenditure
CIS	Customer Information System
COTS	Commercial Off The Shelf
DA	Distribution Automation
DCU	Data Concentrator Unit
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DISREP	Distribution Sector Recovery Programme
DisCo	Distribution Company
DMS	Distribution Management System
DNA	Distribution Network Assessment
DOE	Department of Energy
DR	Demand Response
DRE	Distributed Renewable Energy
DRMS	Demand Response Management System
DSM	Demand Side Management
DTM	Distribution Transformer Monitor
EAM	Enterprise Asset Management
EMS	Energy Management System
EPG	Oxford Energy and Power Group
ESB	Enterprise Service Bus
EV	Electric Vehicle

FAC	Feeder Automation Controller
FAN	Field Area Network
FAT	Factory Acceptance Testing
FLISR	Fault Location, Isolation, and Service Restoration
FRTU	Feeder Remote Terminal Unit
GEDSI	Gender Equality, Disability, and Social Inclusion
GIS	Geographic Information System
GMF	Grid Modernization Framework
HAN	Home Area Network
HES	Head-End System
HSE	Health, Safety, and Environment
IDPS	Intrusion Detection/Prevention System
IEC	International Electrotechnical Commission
IED	Intelligent Electronic Device
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IREC	Interstate Renewable Energy Council
IRR	Internal Rate of Return
ISP	Internet Service Provider
IT	Information Technology
KEDCO	Kano Electricity Distribution Company
KPI	Key Performance Indicator
LBS	Load Break Switches
LCL	Low Carbon London
MDM	Meter Data Management
MDMS	Meter Data Management System
ML	Machine Learning
MoU	Memorandum of Understanding
MWMS	Mobile Workforce Management System
NAN	Neighborhood Area Network
NCC	Nigerian Communications Commission
NEMSA	Nigerian Electricity Management Services Agency
NERC	Nigerian Electricity Regulatory Commission
NIST	National Institute of Standards and Technology
NPV	Net Present Value

NSGM	National Smart Grid Mission (India)
O&M	Operations and Maintenance
OLTC	On-Load Tap Changers
OMS	Outage Management System
OPEX	Operating Expenditure
OT	Operational Technology
PKI	Public Key Infrastructure
PLC	Programmable Logic Controllers
PLCC	Power Line Carrier Communication
PMO	Project Management Office
PMU	Phasor Measurement Unit
POC	Proof of Concept
PPP	Public-Private Partnership
PQA	Power Quality Analyzer
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
REA	Rural Electrification Agency
RFI	Request for Information
RFP	Request for Proposal
ROI	Return on Investment
RTU	Remote Terminal Unit
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control And Data Acquisition
SDN	Software-Defined Networking
SFI	Small Fault Indicator
SGIG	Smart Grid Investment Grant
SIEM	Security Information and Event Management
SNS	Smarter Network Storage
SOC	Security Operations Center
SPV	Special Purpose Vehicle
UCG	Unified Communication Gateway
UK	United Kingdom
UPS	Uninterruptible Power Supplies
USGI	Utility Smart Grid Integration
VVO	Volt/VAR Optimization

Executive Summary

This Grid Modernization Framework (GMF) provides Nigerian Distribution Companies (DisCos) with a structured, evidence-based roadmap for transforming their distribution networks into modern, data-driven, and financially sustainable electricity systems. Developed by WEC Advisers under the Utility Smart Grid Integration (USGI) project, the framework responds directly to the operational, financial, and institutional challenges facing Nigeria's distribution sector, including aging infrastructure, high Aggregate Technical, Commercial, and Collection (ATC&C) losses, limited network visibility, constrained access to capital, and rising customer expectations.

Globally, utilities that have adopted systematic grid modernization – through advanced metering infrastructure, distribution automation, digital control systems, and data analytics – have achieved substantial improvements in loss reduction, reliability, operational efficiency, and customer satisfaction. These technologies have matured from experimental solutions into proven tools that deliver measurable business value, including in contexts comparable to Nigeria. For Nigerian DisCos, grid modernization is therefore not an optional technology upgrade, but a strategic imperative to restore financial viability, improve service quality, and position the utility for Nigeria's evolving power sector and clean energy transition.

Purpose and Scope of the Framework

The GMF serves as the DisCo's comprehensive guide for planning, prioritizing, financing, and implementing grid modernization investments. It moves beyond generic best-practice recommendations to provide an actionable framework grounded in the DisCo's operational realities and institutional capacity. The framework is designed to enable disciplined investment decision-making, manage implementation risk through phased deployment, and generate early financial returns that can fund subsequent stages of modernization.

The scope of the GMF spans three integrated dimensions of the DisCo's operations. The technical dimension addresses feeder-level modernization through substation automation, smart metering, network monitoring, communications infrastructure, and readiness for distributed energy resource (DER) integration. The commercial dimension focuses on revenue protection, billing and collection efficiency, customer engagement, and data-driven commercial operations. The organizational dimension emphasizes workforce capacity building, change management, cybersecurity, governance, and institutional resilience to ensure that deployed technologies can be sustainably operated and continuously improved.

Needs-Driven and Prioritized Approach

At the core of the GMF is a comprehensive needs assessment exercise which should be conducted in close collaboration with the DisCo's staff across various departments and operational functions. The assessment should identify distinct operational issue groups, which are then systematically evaluated against top strategic priorities.[1] This process reveals a concentrated set of critical challenges requiring immediate intervention, supported by a broader set of high-priority and enabling issues that can be sequenced over time. See the KEDCO Case Study in Appendix 1 for an illustrative application of this methodology.

The analysis highlights four cross-cutting strategic themes. First, revenue protection and ATC&C loss reduction are the most urgent imperatives for Nigerian DisCos, with multiple critical issues directly linked to inadequate energy accounting and collection inefficiencies. Second, the lack of operational visibility and real-time control is a foundational constraint that undermines reliability, fault response, and loss management. Third, aging physical infrastructure and weak communications networks underpin many operational failures and must be addressed early to enable digital solutions. Finally, data quality and management are identified as strategic assets that require a clear maturity pathway from basic data collection to advanced analytics and automation.

The needs assessment findings will directly inform the sequencing and design of the technical framework, ensuring that investments target demonstrated needs, respect dependencies, and deliver maximum strategic impact.

[1] In our case study of Kano Electricity Distribution Company (KEDCO), these priorities were summarized as (1) loss reduction, (2) improved reliability and energy efficiency, and (3) expanded energy access.

Feeder Modernization Blueprint

The GMF proposes a two-stage blueprint for feeder modernization applied from the 33kV feeder level. Designing the modernization blueprint at this level allows for end-to-end impact measurement and provides a modular structure that can be scaled across feeders, substations, and districts.

Stage 1 of the blueprint focuses on establishing foundational capabilities and addressing the DisCo's most critical challenges. It prioritizes comprehensive energy accounting through advanced metering; the installation of smart devices across the network; revenue protection through prepaid and remotely controllable meters; improved network visibility via basic monitoring and SCADA systems; and the deployment of a secure communications backbone. Physical infrastructure upgrades are undertaken in parallel to ensure that digital technologies operate on a reliable foundation. Stage 1 delivers immediate benefits in loss reduction, improved collections, faster fault detection, enhanced safety, and improved customer trust, while generating the cash flows necessary to support further investment.

Stage 2 builds on these foundations to enable advanced automation and optimization. This stage introduces high-resolution sensors, advanced distribution management systems, and automated fault location, isolation, and service restoration, transforming feeders into self-healing networks. It enables active technical loss reduction through volt/VAR optimization, predictive maintenance through asset health monitoring, advanced power quality management, and the introduction of demand response and customer flexibility programs. Together, these capabilities shift the DisCo from reactive operations to proactive, predictive, and optimized network management.

Progression between stages is governed by formal readiness assessments rather than fixed timelines. Advancement requires demonstrated technical performance, organizational capability, and financial validation, ensuring that complexity increases only as the DisCo's capacity to absorb and sustain new systems matures.

Geographic Expansion

Recognizing the DisCo's financial and institutional constraints, the GMF adopts a deliberate scaling philosophy for geographic expansion. Implementation begins with one or two pilot feeders, selected for high losses and commercial impact, to validate technologies, build internal capability, and demonstrate value. Successful pilots then support expansion to additional priority feeders and business districts before eventual rollout across the franchise area. This approach manages risk, preserves operational continuity, and creates a cumulative pathway toward full modernization.

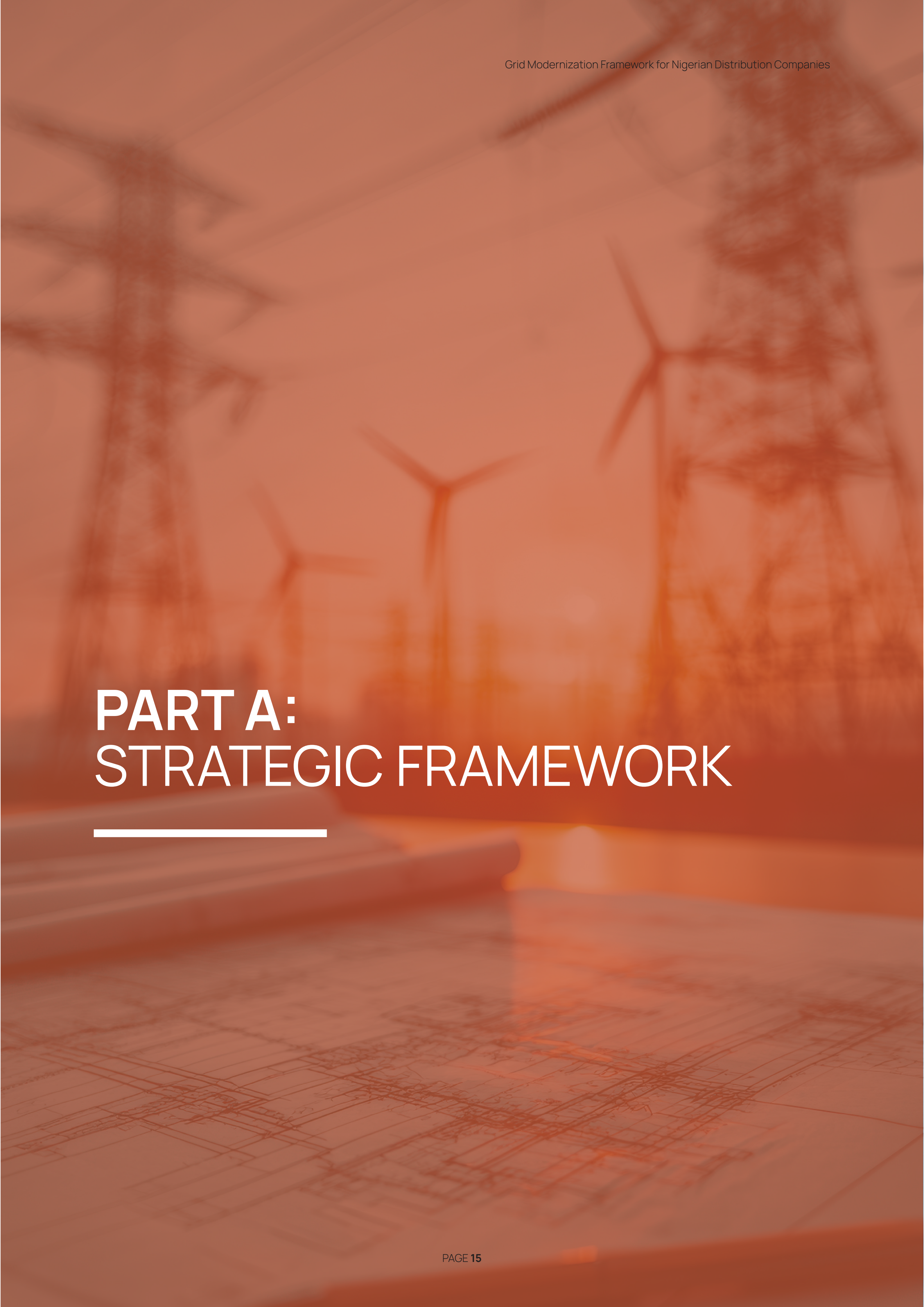
Financing Strategy, Sustainability and Risk Management

The GMF recognizes that financing is both the primary constraint and a potential enabler of transformation. It therefore proposes a blended financing strategy that combines grants and concessional loans, vendor financing, performance-based mechanisms, equity participation, DER-linked financing, and the monetization of shared infrastructure, such as fiber-optic networks. By aligning repayment with performance and leveraging early revenue gains, the framework converts modernization into a self-reinforcing investment cycle rather than a one-time capital burden.

Risk management is embedded throughout the framework, addressing key threats related to capital mobilization, institutional capacity, financial viability, cybersecurity, and technology integration. Mitigation strategies include phased financing, performance-based contracts, open standards to avoid vendor lock-in, cybersecurity-by-design, and sustained workforce development.

Conclusion

Taken together, this Grid Modernization Framework provides Nigerian DisCos with a credible, practical, and financially grounded pathway to transform their distribution operations. By anchoring technology deployment in demonstrated needs, sequencing investments through disciplined phasing, embedding capacity building, and leveraging innovative financing, the GMF positions any DisCo that applies it to achieve sustained reductions in losses, improved reliability and customer service, and long-term institutional resilience. First developed for a pilot DisCo under the USGI project, the framework is intentionally replicable, offering a scalable model for systematic grid modernization across Nigeria's electricity distribution sector.



PART A:
STRATEGIC FRAMEWORK

1. INTRODUCTION

1.1 Background and Context

Nigeria's electricity distribution sector operates in a complex and challenging environment characterized by aging infrastructure, high aggregate technical, commercial, and collection (ATC&C) losses, constrained capital availability, and evolving customer expectations. Distribution companies (DisCos) across the country face the dual imperative of improving operational performance while positioning themselves for Nigeria's clean energy transition and the integration of distributed energy resources.

The global electricity sector has undergone a significant transformation over the past two decades through the adoption of smart grid technologies, including advanced metering infrastructure (AMI), distribution automation, real-time monitoring systems, data analytics platforms, and customer engagement tools. Utilities in countries ranging from Italy and the United Kingdom to the United States and Kenya have demonstrated that systematic grid modernization can deliver measurable improvements in operational efficiency, loss reduction, reliability, and customer satisfaction. These technologies, once expensive and unproven, have matured to the point where they offer compelling business cases for utilities in developing markets, including Nigeria.

As part of the Utility Smart Grid Integration (USGI) project, WEC has developed the ***Grid Modernization Framework (GMF)*** *as a comprehensive, evidence-based roadmap to transform distribution operations through targeted technology investments, organizational capacity building, and process improvements*

Grid modernization presents DisCos with an opportunity to transform from reactive operations dependent on manual processes to proactive, data-driven management enabled by modern technologies. However, the scale of required investments demands a systematic, strategic approach that prioritizes interventions based on demonstrated needs, manages implementation risks through phasing, and generates early financial returns to fund subsequent deployments. Ad hoc technology adoption without clear strategic alignment risks wasting scarce capital on solutions that fail to address priority operational challenges or become stranded assets as the sector evolves.

As part of the Utility Smart Grid Integration (USGI) project, WEC has developed the Grid Modernization Framework (GMF) as a comprehensive, evidence-based roadmap to transform distribution operations through targeted technology investments, organizational capacity building, and process improvements. Developed through an intensive needs assessment process conducted by WEC in close collaboration with DisCo staff across relevant departments, the GMF translates operational challenges into prioritized interventions. With support from the UK PACT Clean Energy Transition programme, this framework positions DisCos to achieve their strategic priorities while contributing to Nigeria's broader clean energy and electrification goals.

The GMF methodology and structure are designed to be replicable across Nigeria's DisCo landscape, offering a model for systematic grid modernization that any utility can adapt to its unique circumstances.

This report discusses the development and implementation of the Grid Modernization Framework using Kano Electricity Distribution Company (KEDCO) as case study.

1.2 USGI's Grid Modernization Vision

In the near-term, the USGI project will operationalize a smart grid on a pilot feeder at the project's pilot DisCo, demonstrating the tangible value of grid modernization and establishing a replicable proof of concept for Nigeria's distribution sector.

In the long term, DisCos that apply this framework will build on successful pilot operationalization to modernize entire business districts into full smart grid systems, establishing national benchmarks for utility transformation and accelerating sector-wide adoption of grid modernization.

1.3 Purpose and Scope of this Framework

1.3.1 Framework Objectives

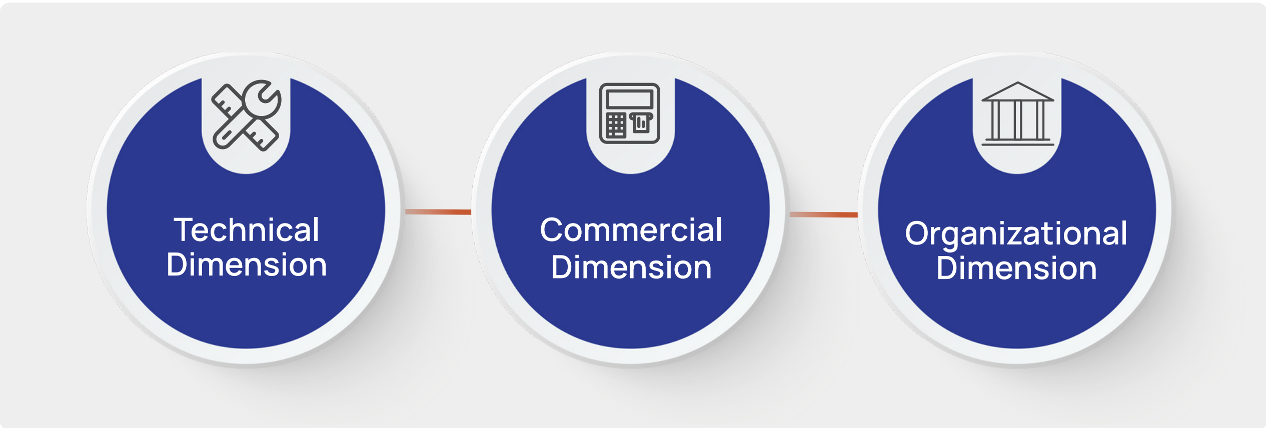
The Grid Modernization Framework serves as the Nigerian DisCo's comprehensive implementation guide for transforming distribution operations by modernizing its feeders. It does:

1. **Provide a technical framework for modernizing the DisCo's feeders** based on its specific operational needs, strategic priorities, and organizational capabilities, moving beyond generic recommendations to actionable deployment plans with expected outcomes.
2. **Enable evidence-based investment decisions** by mapping technology solutions to prioritized operational challenges identified through systematic needs assessment, ensuring scarce capital is allocated to interventions that deliver maximum strategic impact.

3. **Manage implementation risk through phasing** that establishes foundational capabilities first, validates technology choices through pilots before scaling, and sequences investments to align with the DisCo's financial capacity and organizational absorption capability.
4. **Generate financial sustainability** by prioritizing early-phase investments in revenue protection and loss reduction that improve cash flow and demonstrate modernization value, enabling subsequent phases to be funded through operational improvements.
5. **Build organizational capacity** through embedded workforce development, change management, and knowledge transfer that ensures the DisCo can successfully operate and sustain deployed technologies beyond vendor handover.

1.3.2 Framework Scope and Coverage

The GMF addresses the DisCo's distribution operations across three integrated dimensions:



Technical Dimension: Advanced metering infrastructure, distribution automation and control systems, network modelling, grid monitoring and sensing, communication infrastructure, power quality management, predictive maintenance, and distributed energy resource integration readiness.

Commercial Dimension: Customer information system modernization, billing and collection optimization, revenue protection and loss management, customer engagement platforms, payment flexibility, and demand-side program enablement.

Organizational Dimension: Change management, workforce capacity building, strategic planning and investment prioritization, innovation and continuous improvement, cybersecurity, and stakeholder engagement.

The framework covers all aspects of grid modernization, from strategic planning and needs assessment through risk management. It provides guidance on technology selection, vendor management, and financial structuring.

1.3.3 How to Use This Guide

This Grid Modernization Framework document is supported by two key resources, viz, key findings from the **DisCo Needs Assessment**[2] and the **Smart Grid Technology Catalogue and Cost Benchmark Report ("Smart Grid Catalogue Report")**[3]. This document references these foundational resources and should be used in conjunction with them.

It is structured to serve multiple functions:

Strategic Reference: Part A (Strategic Framework) provides the DisCo's executive management with the strategic context, needs assessment methodology, prioritization approach, and evaluation criteria for assessing grid modernization investments.

Implementation Playbook: Part B (Feeder Deployment and Scaling Framework) provides a technical framework for modernizing the DisCo's feeders, a strategy for scaling grid modernization across its franchise area, and Part C (Enabling Frameworks) provides a financial framework, procurement strategy, and the risk management perspective needed by the DisCo's project management office and implementation teams.

Reference Repository: Part D Part D (Appendices) includes case studies to support project development and decision-making and an outline for a machine learning framework applicable to DisCo grid modernization.[4]

1.3.4 Framework Development Approach

The GMF is grounded in operational reality, not theoretical best practices imposed externally. It reflects a comprehensive process of:

- Intensive needs assessment involving structured interviews, focus group discussions, and workshops with DisCo staff across key departments and operational areas.
- Ranking of Issue Groups against the DisCo's strategic priorities (e.g., loss reduction, improved reliability, and energy access).

[2] With KEDCO, WEC conducted a needs assessment exercise and developed a supporting DisCo Needs Assessment (DNA) report for the utility
[3] To download, please visit: https://wenergyconsult.com/wp/usgi/
[4] A machine learning tool for demand prediction is being developed as part of the UK PACT project

- International best practice integration drawing on case studies from utilities in Italy (Enel), United Kingdom (UK Power Networks), United States (Con Edison and SGIG projects), and India, to inform technology selection and implementation sequencing. See Appendix 2 for details of these case studies.
- Solutions mapping that matched the DisCo's prioritized needs to specific smart grid technology categories, detailed in a comprehensive Smart Grid Catalogue.
- Validation with the DisCo leadership through workshops and reviews confirming that the framework accurately reflects the utility's strategic priorities and operational constraints.

The result is a framework that balances ambition with pragmatism – positioning any DisCo that applies it as a pacesetter in grid modernization and a model for the broader distribution sector in Nigeria.

2. GOALS, PRINCIPLES, AND EVALUATION CRITERIA

Grid modernization at the DisCo is not technology adoption for its own sake, but rather a systematic transformation driven by clear strategic goals.

2.1 Overarching Goals for Grid Modernization

The DisCo's grid modernization efforts serve five interconnected goals that directly address the critical, high-priority operational challenges identified through the needs assessment process:

Table 1: Smart Grid-related Goals

Goal	Description
Goal 1: Reduce Technical and Commercial Losses to Sustainable Levels	Systematically identify, quantify, and address sources of ATC&C losses through comprehensive metering, loss analytics, network optimization, and revenue protection, targeting reductions toward regulatory benchmarks.[5]
Goal 2: Improve Reliability and Service Quality	Enhance customer experience through reduced outage frequency and duration, improved voltage quality, and proactive service delivery, achieving measurable improvements in SAIDI,[6] SAIFI,[7] and customer satisfaction.
Goal 3: Achieve Operational Visibility and Real-Time Network Control	Enable DisCo operators to monitor and control the distribution network in real-time through computerized systems, sensors, and automation devices. This will significantly reduce fault tracing time, thus reducing the heavy cost incurred in fault tracing (service downtime, human resources, fuel, vehicle maintenance, safety hazard)

[5] According to NERC's Q3 2025 Quarterly Report, "The weighted average ATC&C loss across all DisCos in 2025/Q3 was 33.27%, comprising technical and commercial loss (17.31%) and collection loss (19.30%). The ATC&C loss of 33.27% is 12.73pp higher than the 2025 MYTO target (20.54%)…"

[6] The System Average Interruption Duration Index (SAIDI) measures the average time (in minutes or hours) that the average customer is without power in a year. The formula is given as follows:

(Total duration of all customer interruptions in 1 year) / (Total number of customers)

[7] The System Average Interruption Frequency Index (SAIFI) measures the average number of interruptions each customer experiences in a year. The formula is given as follows:

(Total number of interruptions in 1 year) / (Total number of customers)

Goal	Description
Goal 4: Transform Commercial Operations and Customer Engagement	Modernize billing, collection, and customer service operations through integrated systems, accurate metering, digital engagement channels, and data-driven processes that improve efficiency and customer satisfaction.
Goal 5: Build Organizational Capacity and Institutional Resilience	Develop workforce capabilities, establish strategic planning frameworks, embed an innovative culture, manage change, and strengthen governance to ensure the DisCo can successfully implement, sustain, and continually improve its smart grid systems.

2.2 Core Principles for Grid Modernization

Seven principles guide the DisCo's approach to grid modernization, establishing how the utility will make investment decisions, sequence technology deployments, and build organizational capabilities. These key principles are derived from the experiences of international utilities, including case studies from Enel, Con Edison, UK Power Networks, and the India Smart Grid Mission, summarized in Appendix 2.

Table 2: Principles for Grid Modernization

Principle	Guideline
Principle 1: Needs-Driven and Strategically Aligned	Grid modernization investments should address demonstrated operational needs identified through systematic assessment rather than technology trends or vendor proposals. (See the KEDCO needs assessment in Appendix 1 as an illustrative example.)
Principle 2: Foundational Infrastructure First	Establish foundational capabilities before advanced systems: (1) communications backbone, (2) SCADA/DMS and basic monitoring (this must incoporate accurate network models. The right network model is the single most important foundational data needed for a functional and correct SCADA system), (3) selective automation, (4) phased AMI expansion (See US SGIG and UK Power Networks case studies). With zero existing SCADA coverage and an absent communications infrastructure, these foundational systems are prerequisites for the deployment of all downstream technologies, preventing deployment failures.

Principle	Guideline
Principle 3: Validate Framework with Pilot Projects and Scale with Financial Discipline	Technology deployments should follow Enel's phased approach: pilot on 1–3 representative feeders with baseline documentation, validate technical and financial performance, then scale systematically. Each stage should generate measurable financial returns (e.g., reduced losses, improved collections) to fund subsequent deployments,[8] with formal go/no-go gates assessing technological performance, staff readiness, and customer acceptance.[9]
Principle 4: Interoperable and Future-Proof	Technology selections should prioritize open standards, vendor-neutral architectures, and modular designs that enable integration across systems, avoid vendor lock-in, and accommodate future technology evolution. Where possible, commercial-off-the-shelf (COTS) solutions should be preferred over custom development to leverage proven capabilities and maintain upgrade paths.
Principle 5: Capacity-Building Embedded	Every technology deployment must include change management, comprehensive workforce training for both foundational strengthening and smart grid upskilling, transforming operational staff to manage digital systems (see Enel's meter reader → data analyst model). Address critical skill gaps through vendor partnerships for hands-on training and academic collaboration for advanced analytics, with explicit inclusion of women in technical programs to address workforce diversity.
Principle 6: Data-Centric and Analytics-Enabled	Grid modernization should prioritize investments in high-quality operational data (metering, sensors, monitoring systems) and establish data management foundations (integration, validation, governance) before deploying advanced analytics (as in UK Power Network's data-first approach). Data should be treated as a strategic asset that enables decision-making across all operational domains.
Principle 7: Customer-Focused and Service-Oriented	Technology investments should demonstrably improve customer experience through more accurate billing, reduced outages, proactive communication, convenient payment options, and accessible service channels. Grid modernization should enable, not complicate, customer interactions with the DisCo and actively improve transparency and trust between the two parties.

[8] For this self-funding sequence to be credible, DisCos could ring-fence the verified revenue uplift from the initial stage into a dedicated modernization reinvestment account, governed by board-level oversight and reported on quarterly. Without ring-fencing, revenue gains tend to be absorbed into general operating cash flow and cannot be reliably committed to subsequent capital deployment.

[9] Customer acceptance, in the context of this framework, refers to end-user willingness to engage with smart-meter-based visibility tools and to opt in to enhanced service offerings such as 24/7 supply tiers. It is a measure of deployment quality and customer experience, not a regulatory precondition for modernization activity. DisCos should track acceptance rates by feeder cluster and use them to flag communication or service gaps that may need remediation.

These principles inform the evaluation criteria that follow and are operationalized throughout Section 3 (technology solutions) and PART B: FEEDER DEPLOYMENT AND SCALING FRAMEWORK.

2.3 Evaluation Framework for Investment Decisions

Before approving any grid modernization investment, DisCo management should evaluate the proposal against eight mandatory assessment criteria:[10]

Mandatory Evaluation Questions

Q1 **Does the investment address the demonstrated needs from the assessment?**
The investment should map to one or more of the issues identified, with a clear explanation of how the technology resolves operational challenges and contributes to strategic priorities.

Q2 **Is there a credible cost-benefit analysis showing cost-effectiveness or reasonableness?**
Investments should include rigorous CBA with complete revenue requirements over asset life, explicit cost contingencies, sensitivity analysis, and appropriate discount rates.

Q3 **Are there clear, measurable goals with defined success metrics?**
Each investment should specify what will be achieved (e.g., "reduce SAIDI by 30% on automated feeders"), how success will be measured, and baseline/target values with timelines.

Q4 **Does the solution align with and enable DisCo's strategic priorities?**
Investments should demonstrate a positive impact on at least one strategic priority (e.g., loss reduction, reliability, or expanding energy access), ideally in a way that synergistically supports multiple priorities.

[10] Sara Baldwin, Ric O'Connell, Curt Volkmann. A Playbook for Modernizing the Distribution Grid; Volume I: Grid Modernization Goals, Principles and Plan Evaluation Checklist. IREC and GridLab. May 2020. https://irecusa. org/publications/ and https://gridlab.org/publications/

Q5 **Is the investment properly sequenced with dependencies identified?**
Proposals should acknowledge prerequisite capabilities (e.g., communication infrastructure for automation, MDMS for AMI scaling) and confirm readiness or plan for dependency resolution.

Q6 **Does the solution enable (not hinder) future DER adoption and clean energy integration?**
Investments should position the DisCo for eventual DER integration as policy evolves, avoiding technology choices that would require costly retrofit.

Q7 **Are risks (including technology obsolescence) identified and mitigated?**
Investment proposals should explicitly address implementation risks, vendor dependencies, cybersecurity vulnerabilities, and technology obsolescence, with documented mitigation strategies.

Q8 **Is there a clear implementation and monitoring plan?**
Proposals should include realistic implementation timelines, resource requirements, organizational readiness assessment, performance metrics, and monitoring/evaluation framework.

These eight questions provide an initial evaluation filter. The DisCo's Project Management Office (PMO) or Investment Committee should apply these criteria consistently to all grid modernization proposals, documenting evaluation outcomes and decision rationale to ensure transparency and accountability.

Please note that DisCos may be required to comply with NERC's Regulation on Investment in Electricity Networks in Nigeria, including securing the Commission's approval for such investments. [11]

[11] NERC (2015). Regulations for Investments In Electricity Networks in Nigeria. Nigerian Electricity Regulatory Commission website. https://nerc.gov.ng/wp-content/uploads/2015/02/NERC%20INVESTMENT%20IN%20ELECTRCICITY%20NETWORKS%20REGULATION%202015.pdf

3. OVERVIEW OF SMART GRID TECHNOLOGIES

This section offers a primer on smart grid technologies, including integration into extant grid infrastructure. It also summarizes relevant smart grid technologies and their components as extracted from the **Smart Grid Technology Catalogue and Cost Benchmarks Report.**[12]

3.1 Understanding Smart Grid Technologies

A smart grid is an intelligent electricity network that uses digital communication, automation, and advanced control systems to monitor, predict, and optimize power generation, distribution, and consumption in real time. Unlike traditional grids, which are largely one-directional and reactive, smart grids enable two-way energy and data flows, improving efficiency, reliability, and customer engagement. Smart grids combine hardware, software, and data systems to create a flexible and resilient power network capable of integrating distributed energy resources (DERs), electric vehicles (EVs), and energy storage, while reducing losses and improving service delivery.

[12] To download, please visit: https://wenergyconsult.com/wp/usgi/

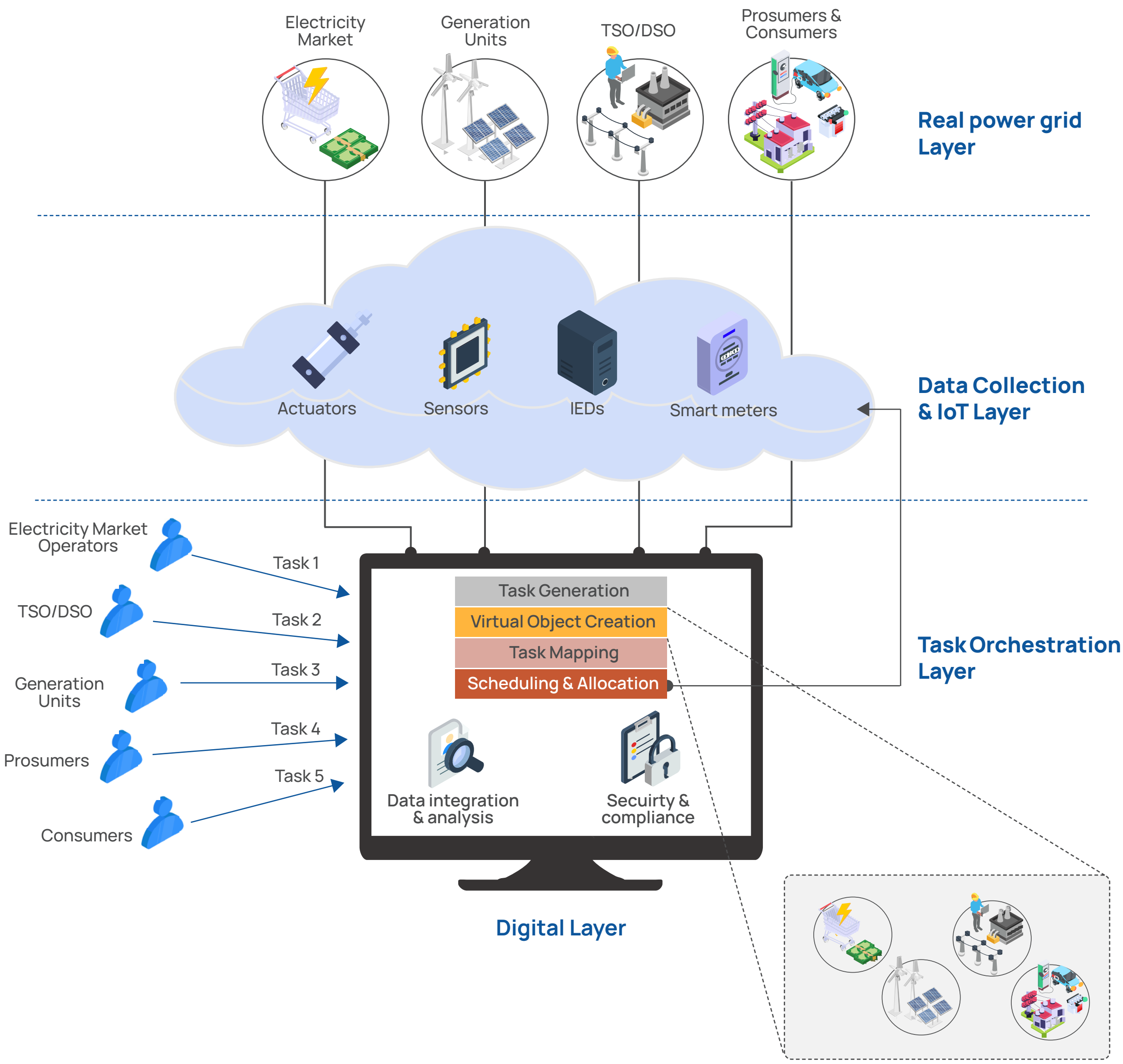


Figure 1: Digital layer of smart grid

3.2 Key Components and Functional Layers of a Smart Grid

To understand how smart grids operate, it is useful to view them as a multi-layered ecosystem, where each layer performs distinct but interconnected functions. Together, these layers transform a conventional power network into a dynamic, data-driven system capable of self-optimization and rapid response.

At the foundation, physical infrastructure delivers electricity, while upper layers enable digital monitoring, automation, and customer interaction. Communication and data form the nervous system of the grid, linking field devices to central control systems and decision-making platforms.

On top of this, advanced analytics and artificial intelligence convert data into actionable insights, driving efficiency, predictive maintenance, and smarter investment decisions.

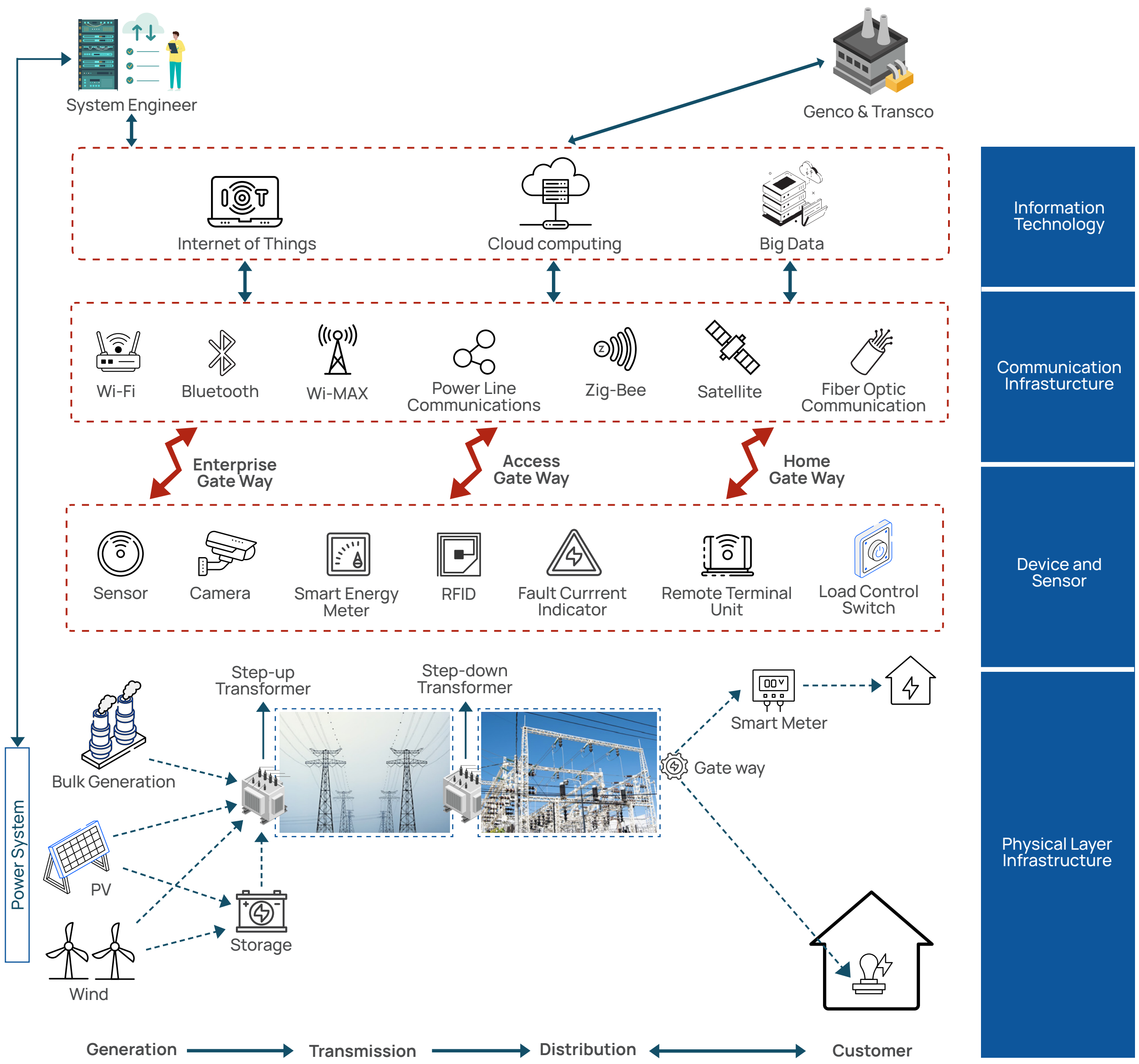


Figure 2: Architecture of the Smart Grid

Modern smart grids are therefore not single technologies, but integrated architectures combining power engineering, information technology, and cybersecurity. Each component from smart meters to distribution management systems contributes to a common goal: delivering reliable, efficient, and customer-centric electricity services.

Highlights of key smart technologies are presented in the table below:

Table 3: Smart Grid Technologies

Technology	Description	Key Components
Advanced Metering Infrastructure *For detailed functionality, installation points, and component relationships, please refer to Table 2.1 in the Smart Grid Catalogue Report.*	It represents the foundational layer of a smart grid. It comprises an integrated system of smart meters, data concentrators, communication networks, and meter data management systems that enable two-way communication between utilities and customers. Through AMI, utilities can implement time-of-use pricing, reduce losses, enhance billing accuracy, and promote customer transparency for energy tracking and demand response participation.	Smart Electricity Meters, Smart Meter Gateway (SMGW), Data Concentrator Unit (DCU), Head-End System (HES), Meter Data Management System (MDMS), Communication Network (AMI Backbone), and Consumer Interface Device (In-Home Display or App).
Grid Monitoring and Sensing Systems *For detailed functionality, installation points, and component relationships, please refer to Table 2.2 in the Smart Grid Catalogue Report.*	These provide continuous visibility of voltage, current, power quality, and asset health across the distribution network. They enable proactive fault detection, predictive maintenance, and faster restoration of power supply. Strategic placement of sensors at critical points – such as primary substations, distribution transformers, and selected feeder segments – balances resolution and coverage to deliver cost-effective network visibility.	Line Sensors (Feeder Monitors), Distribution Transformer Monitors (DTMs), Smart Fault Indicators (SFIs), Substation Monitoring Units (SMUs), Intelligent Electronic Devices (IEDs), Phasor Measurement Units (PMUs), and Environmental Sensors
Control and Automation System *For detailed functionality, installation points, and component relationships, please refer to Table 2.3 in the Smart Grid Catalogue Report.*	These constitute the decision-making backbone of a smart grid, transforming raw data from meters and sensors into actionable operational intelligence. They enable utilities to automatically detect faults, isolate affected areas, reconfigure power flows, and restore service with minimal human intervention, creating a "self-healing grid." These systems combine Intelligent Electronic Devices, SCADA, and Distribution Management Systems with automated field devices to create a fully digital control layer.	Supervisory Control and Data Acquisition (SCADA), Distribution Management System (DMS), Outage Management System (OMS), Automated Reclosers and Sectionalisers, Remote Terminal Units (RTUs), Intelligent Electronic Devices (IEDs), Automatic Voltage Regulators (AVRs), Feeder Automation Controller (FAC), Energy Management System (EMS). Global dominant international SCADA protocols for electric power systems (IEC 60870 5 101 / IEC 60870 5 104)

Technology	Description	Key Components
Communications Infrastructure *For detailed functionality, installation points, and component relationships, please refer to Table 2.4 in the Smart Grid Catalogue Report*	A robust and secure communication infrastructure underpins every aspect of the smart grid, enabling real-time visibility, situational awareness, and coordinated control across the electricity value chain. The communication network must be multi-layered, integrating wide-area networks for backbone connectivity, field area networks for feeder and distribution communication, and neighborhood/home area networks for customer-level connectivity. Each layer is characterized by different data rates, coverage, latency, and security requirements.	Wide Area Network (WAN), Field Area Network (FAN), Neighborhood Area Network (NAN), Home Area Network (HAN), Fibre Optic Network, Microwave Radio Links, Power Line Carrier Communication (PLCC), Cellular Networks (2G/3G/4G/5G/NB-IoT), RF Mesh Network, Unified Communication Gateway (UCG), Network Management System (NMS), Software-Defined Networking (SDN), Communications layer for distribution-level field devices (RS-485 ports)
Data Analytics and Software Systems *For detailed functionality, installation points, and component relationships, please refer to Table 2.5 in the Smart Grid Catalogue Report.*	The transformation to smart grids relies on the ability to collect, store, analyze, and act upon data. Data analytics and software systems enable utilities to translate raw data from smart meters, sensors, and automation devices into actionable intelligence that drives reliability, efficiency, and customer engagement. This digital intelligence layer includes Advanced Distribution Management Systems, Outage Management Systems, Geographic Information Systems, Energy Management Systems, and AI-driven analytics platforms.	Advanced Distribution Management System (ADMS), Outage Management System (OMS), Energy Management System (EMS), Asset Management System (AMS), Geographic Information System (GIS), Meter Data Management System (MDMS), Supervisory Control and Data Acquisition (SCADA), Customer Information System (CIS), Demand Response Management System (DRMS), Distributed Energy Resource Management System (DERMS), Predictive Analytics and AI Platform, Business Intelligence (BI) and Reporting, Load Forecasting System, Digital Twin / Network Simulation Platform, Mobile Workforce Management (MWM), Enterprise Service Bus (ESB) or as it is popularly referred to “Middleware”)

Technology	Description	Key Components
Cybersecurity and Data Protection *For detailed functionality, installation points, and component relationships, please refer to Table 2.6 in the Smart Grid Catalogue Report.*	As smart grids evolve into highly interconnected digital ecosystems, cybersecurity becomes a foundational pillar for their reliability and resilience. Cybersecurity extends to operational technology, including substations, control centers, and communication infrastructure. A robust framework ensures confidentiality, integrity, and availability of both operational and customer data through multi-layered security controls from device-level authentication to network encryption and real-time threat detection.	Security Information and Event Management (SIEM), Firewalls and Network Segmentation, Intrusion Detection and Prevention Systems (IDPS), Public Key Infrastructure (PKI), Endpoint Security / Antivirus Systems, Access Control and Identity Management, Data Encryption (in transit and at rest), Incident Response and Recovery Systems, Vulnerability Management and Patch Systems, Physical Security Controls for Critical Infrastructure, Cybersecurity Training and Awareness Programs
Supporting Hardware and Devices *For detailed functionality, installation points, and component relationships, please refer to Table 2.7 in the Smart Grid Catalogue Report.*	Supporting hardware and field devices provide the physical interface that connects the power network to digital control systems. These components enable measurement, switching, protection, and communication between substations, feeders, and customer premises. A reliable hardware foundation ensures that smart grid functionalities such as automation, fault detection, demand response, and data acquisition operate safely and efficiently.	Automated Circuit Reclosers (ACRs), Load Break Switches (LBS), Voltage Regulators / On-Load Tap Changers (OLTCs), Capacitor Banks (Automatic / Switched), Remote Terminal Units (RTUs), FRTUs, Programmable Logic Controllers (PLCs), Uninterruptible Power Supplies (UPS) / Backup Power Units, Power Quality Analyzers (PQAs), Surge Arresters and Protective Relays, Smart Distribution Transformers, Medium Voltage Switchgear, Low Voltage Distribution Boards

Technology	Description	Key Components
Other Software & Integration Platforms *For detailed functionality, installation points, and component relationships, please refer to Table 2.8 in the Smart Grid Catalogue Report*	Integration platforms form the "digital glue" that allows disparate systems – AMI, sensors, DMS/ADMS, communication networks, and DER interfaces – to work cohesively. These platforms include middleware, enterprise service buses, cloud-based SCADA interfaces, mobile workforce management tools, and customer engagement portals. They enable utilities to coordinate operations, implement predictive maintenance, optimize resource allocation, and deliver value-added services to consumers.	Middleware / Enterprise Service Bus (ESB), Mobile Workforce Management (MWM) Software, Enterprise Asset Management (EAM) Systems, Customer Engagement & DER Platforms, Cloud Integration Platforms / IoT Hubs, Grid Simulation & Planning Software, Geospatial Information Systems for Asset Management/Asset Mapping and Network Modelling, Cybersecurity Management Platforms, Data Visualization & Reporting Dashboards
Machine Learning Algorithm *For further details, see Appendix 3 in this report*	Leverages foundational data infrastructure from smart grid deployments to deliver actionable predictive insights that optimize energy distribution, reduce technical and commercial losses, enhance supply reliability, and facilitate distributed renewable energy (DRE) integration. By transforming operational data streams into strategic intelligence, the ML Framework enables evidence-based decisions across planning, operations, maintenance, and customer engagement.	Demand-side load forecasting capabilities, energy supply forecasting capabilities, renewable energy integration forecasting capabilities, and demand-side response framework.

PART B:
FEEDER DEPLOYMENT AND SCALING FRAMEWORK

This part provides the framework for transforming an average Nigerian DisCo's distribution network through smart grid modernization. It addresses two fundamental questions: what to deploy at the feeder level, and how to scale deployment across the franchise area.

These sections are designed to work together. While Section 4 defines what gets deployed at the feeder level, Section 5 defines the pace and sequence of expanding deployment across the franchise area.

4. FEEDER MODERNIZATION: A TWO-STAGE BLUEPRINT

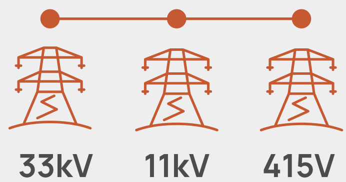
The Feeder Modernization Blueprint ("Blueprint") is a core component of the USGI Grid Modernization Framework. It defines what technologies to deploy at the feeder level, how to sequence deployment into manageable phases, and what performance standards to apply at each stage.

The Blueprint is designed to be applied across the 33kV → 11kV → 415V voltage transformation levels, ensuring that the impact of any grid modernization can be controlled and measured end-to-end. Additionally, by designing the framework for implementation from the 33kV level, the framework can easily be extended to cover entire districts/substations by simply replicating it across feeders.

In line with the Core Principles highlighted in Section 2.2 of this document, the Blueprint outlines a two-stage approach. Stage 1 addresses the DisCo's most critical operational challenges, establishing the foundational capabilities required for sustainable grid modernization. Stage 2 builds on these foundations to enable advanced automation and optimization. Progression between stages is governed by a formal readiness assessment, not a fixed timeline.

This section describes the level of smart grid functionality achieved at each stage, the smart grid technology components that are required, and the improvements over current operations.

FEEDER MODERNIZATION BLUEPRINT



...by designing the framework for implementation from the 33kV level, the framework can easily be extended to cover entire districts/substations by simply replicating it across feeders.

4.1 Stage 1: Foundation and Revenue Protection

Stage 1 of the blueprint focuses on establishing foundational capabilities that underpin all subsequent modernization activities. These include: accurate energy accounting through boundary and distribution transformer metering; revenue protection through AMI deployment and anti-tampering measures; network visibility through SCADA implementation at key feeder control points; and customer empowerment through prepaid metering and self-service platforms. Stage 1 investments are sequenced to generate measurable revenue improvements that create the financial headroom for Stage 2 capital deployment.

Stage 1 delivers transformative capabilities addressing the DisCo's critical priority issue groups identified through the needs assessment exercise. Broadly, this may include the following:

- Reduce the DisCo's ATC&C losses and improve revenue by deploying Advanced Metering Infrastructure (AMI) for accurate energy accounting, revenue protection through prepaid and remotely controllable meters, and automated meter data management.
- Upgrade the physical distribution network (switchgears i.e., feeders, replacement of undersized cables across the network, transformers, poles, conductors, etc.) to facilitate a reliable supply of electricity, reduce technical losses, and facilitate DER integration.
- Installation of smart network devices at critical points of the network to allow for data collection along the line and – in some cases – remote fault resolutions (e.g., fault passage indicators, autoreclosers, smart feeder panels, etc.)
- Leverage smart meter data to provide visibility into network conditions, enabling automatic fault/outage detection and improving power quality monitoring.
- Enable remote monitoring and control of the network by implementing a SCADA system.
- Provide customers with visibility into their consumption thereby facilitating customer demand response to reduce supply imbalances and load shedding, and
- Establishing a communication backbone for all subsequent modernization.

This stage achieves four interconnected strategic objectives. The following sections describe these objectives, outline the smart grid technology components required to achieve them, and describe how these technologies will be deployed and operated to achieve the objectives.

4.1.1 Network Visibility and Remote Network Control

Objective: Enable visibility into network conditions such as supply availability and power quality while facilitating remote control of the distribution network, thereby enabling quicker identification and resolution of faults and outages, reducing operational costs, improving staff safety, and ultimately improving customer satisfaction.

Required Smart Grid Technology Components: AMI, RTU, FRTU, GIS, SCADA, OMS, Automatic Circuit Reclosers, Load Break Switches.

Technology Deployment and Operation: This objective establishes network visibility and remote-control capability by leveraging smart meter data, deploying SCADA, and installing remotely controlled switches and reclosers at key points on the feeder. Remote Terminal Units (RTUs) at the substation monitor breaker status, transformer loading, bus voltages, and currents. OMS integrates SCADA topology data with smart meter 'last gasp' signals to automatically pinpoint fault locations when outages occur. Smart meter data also measures basic power quality data such as voltage and current magnitude, frequency, and power factor, enabling detection of power quality issues.

Remote control capability enables operators to issue commands to Automatic Circuit Reclosers and Load Break Switches at critical locations for remote sectionalizing during faults or maintenance. At the customer level, remote disconnect switches in smart meters receive commands via HES to disconnect non-paying customers.

Integrations between systems are as follows: SCADA monitors the network; OMS identifies faults using SCADA + meter data; operators use SCADA to command ACRs/LBS for isolation; HES commands meter disconnects for customer-level actions.

Benefits include the elimination of 24/7 manual substation data collection; quicker fault detection replacing customer-call-dependent awareness; rapid fault location reducing restoration time; remote switching eliminating hazardous manual operations; reduced field crew costs; improved staff safety.

Note: While Stage 1 enables remote visibility and control, automated self-healing (FLISR) is not yet possible because smart meters and basic SCADA cannot provide millisecond-resolution fault data needed for automated switching decisions – this capability requires Stage 2 updates – line sensors and enhanced automation software. Additionally, relying on smart meters to monitor power quality means that only basic power quality components can be measured, while advanced metrics such as flicker, harmonics, sag/swell waveforms cannot be measured.

4.1.2 ATC&C Loss Reduction Through Comprehensive Energy Accounting

Objective: Implement a comprehensive energy accounting system that accurately measures energy flows on the feeder to identify and minimize losses, thereby improving the DisCo's revenue collection and financial sustainability.

Required Smart Grid Technology Components: AMI[13] (Smart meters, HES, MDMS, transformer meters, Feeder meters), Customer Information System, BI Dashboards.

Technology Deployment and Operation: This objective establishes precise end-to-end energy accounting across the DisCo's network from feeder head to end customer, creating the data foundation required for all subsequent modernization interventions.

The MDMS aggregates data from all measurement points, validates readings, performs energy balance calculations (feeder input vs transformer supply vs customer consumption), and identifies discrepancies indicating losses. Analytics engines detect consumption anomalies suggesting theft or meter bypass. BI dashboards visualize loss data showing feeder-level loss rankings, transformer hotspots, and suspected theft locations, enabling targeted interventions. Customer Information System (CIS) manages prepaid customer credit balances, signaling HES to disconnect meters when the balance reaches zero, ensuring no consumption beyond payment, thereby eliminating collection losses.

Strategic Fit with the World Bank's DISREP program
The energy accounting, analytics, and revenue protection capabilities described above align directly with Nigeria's broader distribution sector reform programme, which provides a complementary financing channel for the investments set out in this section. Through the World Bank's Distribution Sector Recovery Programme (DISREP), implementation funding is committed against the same intervention categories addressed here: customer enumeration and metering, management information system deployment, and network rehabilitation. **Appendix 4: ATC&C Loss Reduction Pathway and DISREP Financing Alignment** sets out a sequenced three-phase implementation model covering data infrastructure stabilization, revenue assurance, and network modernization, and maps each phase against DISREP's funded components. DisCos applying this Framework should consult the Appendix when scoping the financing structure for their Stage 1 ATC&C loss reduction investments, particularly where DISREP eligibility is already confirmed through an approved Performance Improvement Plan.

4.1.3 Infrastructure Modernization and DER Readiness

Objective: Modernize physical distribution network infrastructure to facilitate reliable supply of electricity to customers, reduce equipment failure and maintenance costs, and position the distribution network to integrate additional supply from DERs.

[13] MI specifications should be compliant with the requirements detailed in the Nigerian Electricity Smart Metering Regulation v01 (2015): https://nerc.gov.ng/wp-content/uploads/2017/01/NESMR_EMM.pdf, in addition to bi-directional capabilities, a key factor in NERC's Draft Net Billing Regulation (2025): https://nerc.gov.ng/wp-content/uploads/2025/09/Draft-Net-Billing-Regulations.pdf

Required Smart Grid Technology Components: None (This objective focuses on upgrading or refurbishing the traditional distribution network infrastructure to enable the successful integration of smart grid technology).

Technology Deployment and Operation: It addresses critical aging infrastructure through strategic physical upgrades, enabling deployed smart technologies to function on a reliable foundation. Key equipment, such as transformers, protection switches, breakers, etc. are refurbished or replaced to ensure they are all in good working condition and capable of supplying reliable electricity to customers.

While DER integration is not a required part of the framework, these infrastructure upgrades also support the integration of distributed energy resources (DERs) by ensuring the distribution network can safely and reliably receive and transmit additional supply. To integrate DERs, Current Transformers, Voltage Transformers, and grid-forming inverters can be installed to enable safe and effective DER interconnection, synchronization of supply from the bulk grid and DERs, and islanding during bulk grid outages.

These physical improvements ensure smart grid technologies operate effectively in the following ways: smart meters require a reliable supply for communication; SCADA requires functional breakers for remote control; automation requires maintained conductors to minimize faults.

Note: While Stage 1 physical upgrades deliver immediate reliability improvement through the elimination of equipment failure-driven outages, it does not deliver comprehensive asset health monitoring and predictive maintenance, which will be incorporated in Stage 2.

4.1.4 Data Management and Customer Empowerment

Objective: Establish the communication backbone and data management systems that underpin smart grid deployment. This includes enabling secure and reliable communication between smart grid equipment on the distribution network, analyzing data to derive useful insights that can guide action, and using data to engage and empower customers to make decisions on their electricity usage.

Required Smart Grid Technology Components: Communication infrastructure (fiber optic networks, cellular networks, Power Line Carrier Communication, etc.), Artificial Intelligence (AI) and Machine Learning (ML) Analytics Tools, Cybersecurity Software.

Technology Deployment and Operation: Selection of the appropriate communication infrastructure for the feeder depends on the geographic context and feeder topology (e.g., fiber networks for substations requiring low latency, cellular networks for dispersed areas, RF mesh for medium-density zones, PLCC for high-density residential areas). The final design of the communications infrastructure for each feeder should optimize cost-effectiveness while ensuring reliable communications for the smart grid system. Additionally, a comprehensive cybersecurity infrastructure with encrypted channels and access controls protecting operational systems is required to ensure that information relayed over the network is secure from external interference.

Customer consumption data is fed to AI and ML analytics tools to identify patterns in customer energy consumption, enabling the DisCo to forecast customer demand (see Appendix 3). Additionally, this stage enables modern customer interaction through a customer engagement platform (web portal and mobile application), facilitating real-time consumption monitoring, payment management, and service requests. Customers are empowered to make informed decisions on their energy usage as they will be able to view details of their electricity consumption in real-time through the customer engagement platform. These capabilities transform customer experience from passive service recipients to engaged energy managers, improving satisfaction.

Data management platforms integrate deployed technologies in the following ways: HES manages meter communications; MDMS stores and analyzes meter data; CIS manages customer accounts and billing; BI tools provide executive dashboards; all systems interconnect via secure middleware, enabling data flow. This integrated architecture establishes a scalable platform that supports Stage 1 deployments and provides a foundation for advanced analytics and automation in Stage 2.

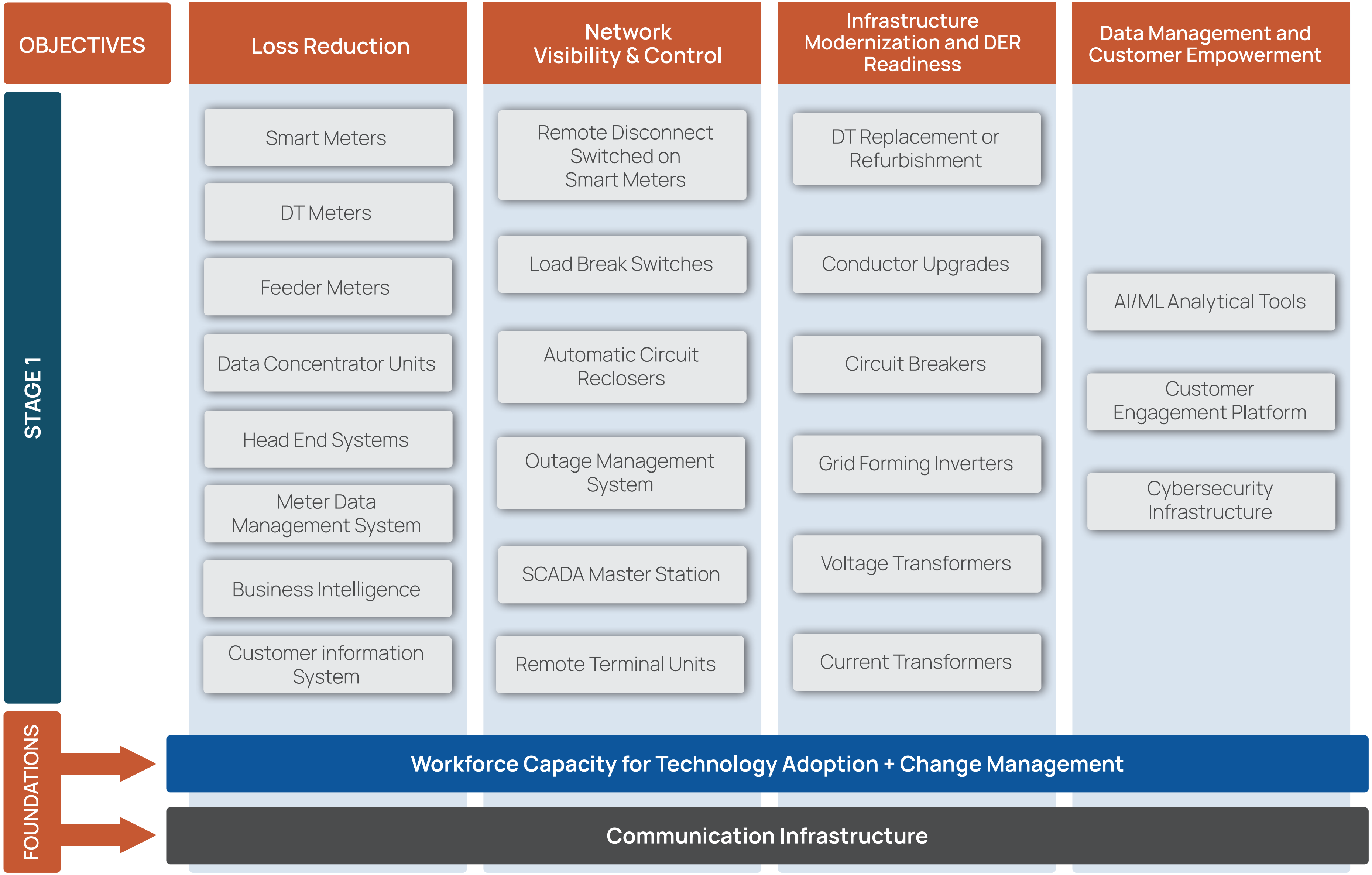


Figure 3: Stage 1 – Implementation schematic showing key objectives and relevant technologies

4.2 Stage 2: Advanced Automation and Optimization

Stage 2 builds on the foundations established by Stage 1 to advance operational capabilities by transforming the grid from a passive, manually-operated network into an active, self-optimizing system. This stage is unlocked only when Stage 1 readiness criteria have been met.

Stage 2 transforms feeders from foundational visibility to intelligent, self-optimizing operations by achieving four strategic outcomes that drive operational excellence.

4.2.1 Active Technical Loss Reduction Through Network Optimization

Objective: Advance beyond measuring and manually rectifying technical losses to actively reducing technical losses through voltage and reactive power optimization, further reducing ATC&C losses.

Required Smart Grid Technology Components: Line sensors, ADMS with VVO capabilities, Smart Inverters, Capacitor Banks.

Technology Deployment and Operation: This objective deploys intelligent optimization infrastructure that actively reduces technical losses rather than simply measuring them. Line sensors provide continuous real-time measurements of voltage, current, phase angle, and power quality at strategic feeder locations. This granular data feeds ADMS, which uses its VVO module to analyze network state and calculate optimal voltage profiles and reactive power flows, minimizing losses while maintaining voltage within acceptable limits.

ADMS issues automated control commands to smart inverters and capacitor banks at select locations, dynamically adjusting reactive power injection and absorption. Voltage regulators at the substation receive setpoint adjustments, optimizing the voltage profile across feeders. This closed-loop optimization operates continuously - sensors measure, ADMS analyzes, devices adjust - minimizing reactive losses in conductors.

The new technology components introduced in Stage 2 work in conjunction with Stage 1 systems: MDMS provides historical load patterns that inform VVO algorithms; SCADA topology data enables ADMS to understand the network configuration; smart meter voltage measurements validate optimization effectiveness at customer endpoints.

Progression from Stage 1: While Stage 1 measures losses enabling identification and targeted manual rectification, Stage 2 actively reduces losses in real-time through intelligent control.

4.2.2 Self-Healing Networks Through Automated Fault Response

Objective: Enable automated self-healing and active power quality management, significantly improving network reliability and reducing operational costs.

Required Smart Grid Technology Components: Line sensors, Smart Fault Indicators (SFIs), ADMS with FLISR capabilities, Power Quality Analyzers (PQAs), Smart Inverters.

Technology Deployment and Operation: This builds on Stage 1 by implementing automated fault response, enabling self-healing networks. The FLISR system comprises three integrated components: fault detection through line sensors and fault indicators (devices providing millisecond fault location data that could not be delivered by smart meters in Stage 1). The fault-isolation logic in the FLISR software analyzes fault location and automatically commands the upstream ACR to open. Service restoration logic identifies alternate feed paths and commands switches to reroute power to unaffected customers. This entire sequence completes within 30-60 seconds without operator intervention.

Stage 2 deploys additional ACRs and additional LBS at strategic locations on the feeder, providing sufficient sectionalizing points for effective automation. Enhanced SCADA integration with FLISR provides operators with visibility into automated actions with manual override capability for complex situations.

Additionally, the deployment of PQAs and line sensors enables real-time monitoring of advanced power quality elements. If a power quality issue (e.g., harmonic distortion from a factory) is detected, the ADMS can command Smart Inverters on the network to inject compensating current to cancel out the distortion and stabilize voltage.

Progression from Stage 1: Stage 1 provides visibility (SCADA) and remote control (ACRs/LBS) but lacks automation because basic metering/SCADA cannot detect faults with the sub-second precision needed for safe automated switching. Stage 2 line sensors/fault indicators provide the required millisecond fault detection, enabling FLISR automation. The operator role evolves: in Stage 1, operators manually interpret SCADA data and issue control commands. However, in Stage 2, automation handles routine faults while operators supervise, intervene for complex scenarios, and focus on network optimization. This results in SAIDI/SAIFI improvement on automated feeders as restoration time is reduced from hours to seconds, thereby improving customer satisfaction in addition to operational efficiency, enabling staff to handle growing network complexity.

Additionally, the introduction of PQAs and line sensors facilitates measurement of advanced power quality metrics such as flicker, harmonics, sag/swell waveforms which is not possible with smart meters in Stage 1. ADMS and smart meters enable active power quality management.

4.2.3 Predictive Maintenance and Asset Intelligence

Objective: Transition from reactive to predictive maintenance thereby optimizing the use of existing hardware, extending asset life and reducing equipment replacement costs, and preventing catastrophic failures.

Required Smart Grid Technology Components: Asset health monitoring sensors (e.g., Distribution Transformer Monitors (DTMs), Dynamic Line Rating (DLR) Sensors), ADMS.

Technology Deployment and Operation: Asset health monitoring sensors (on critical assets, including transformers, primary breakers, and critical cables) continuously monitor operating conditions such as transformer temperature, loading, oil quality indicators, cable partial discharge, indicating insulation deterioration, breaker operation counts, and timing. An advanced analytics platform within the ADMS processes sensor data using AI/ML algorithms to identify patterns indicating impending failures. The system generates predictive maintenance alerts, enabling condition-based interventions before failures occur.

Progression from Stage 1: Asset life extension through timely interventions and reduced emergency repairs and associated costs. It helps prevent service disruptions, optimize maintenance budgets by targeting equipment that needs attention rather than fixed schedules, and improve safety through early identification of developing hazards. Integration with Stage 1 data will enable SCADA to provide operational context, and MDMS to show loading patterns. This combined data will enable sophisticated analytics to correlate operating conditions with asset health, continuously improving predictive models.

4.2.4 Customer Experience Transformation and Demand Response

Objective: Transform the customer experience by providing AI-driven advanced analytics and enabling voluntary demand response programs; helping to avoid involuntary disconnections while engaging customers as active participants.

Required Smart Grid Technology Components: Demand Response Management System (DRMS).

Technology Deployment and Operation: This objective deploys modern customer interaction platforms, transforming the DisCo-customer relationship from one-directional billing to a two-way engagement model with real-time information exchange, self-service capabilities, and demand flexibility programs.

DRMS establishes voluntary load reduction programs in which customers receive incentives to reduce consumption during peak periods or when supply constraints occur. In addition to customer-managed demand response, customers can sign up for automatic demand response, where the DRMS automatically adjusts customer consumption (e.g., temporarily turning off non-essential equipment such as water heaters) during peak times. DRMS integrates with MDMS (consumption data), ADMS (network constraints), and the customer portal (notifications and incentives). During high-demand periods, DRMS identifies enrolled customers, sends load-reduction requests via the portal/SMS, tracks compliance, and calculates incentives. It engages customers as active participants in grid management, providing demand-side flexibility and reducing the need for involuntary load shedding.

This results in improved customer satisfaction through transparency and engagement, reduced call center burden through self-service channels, and new revenue opportunities from demand response and flexible tariff structures — while building the social license required for sustained investment.

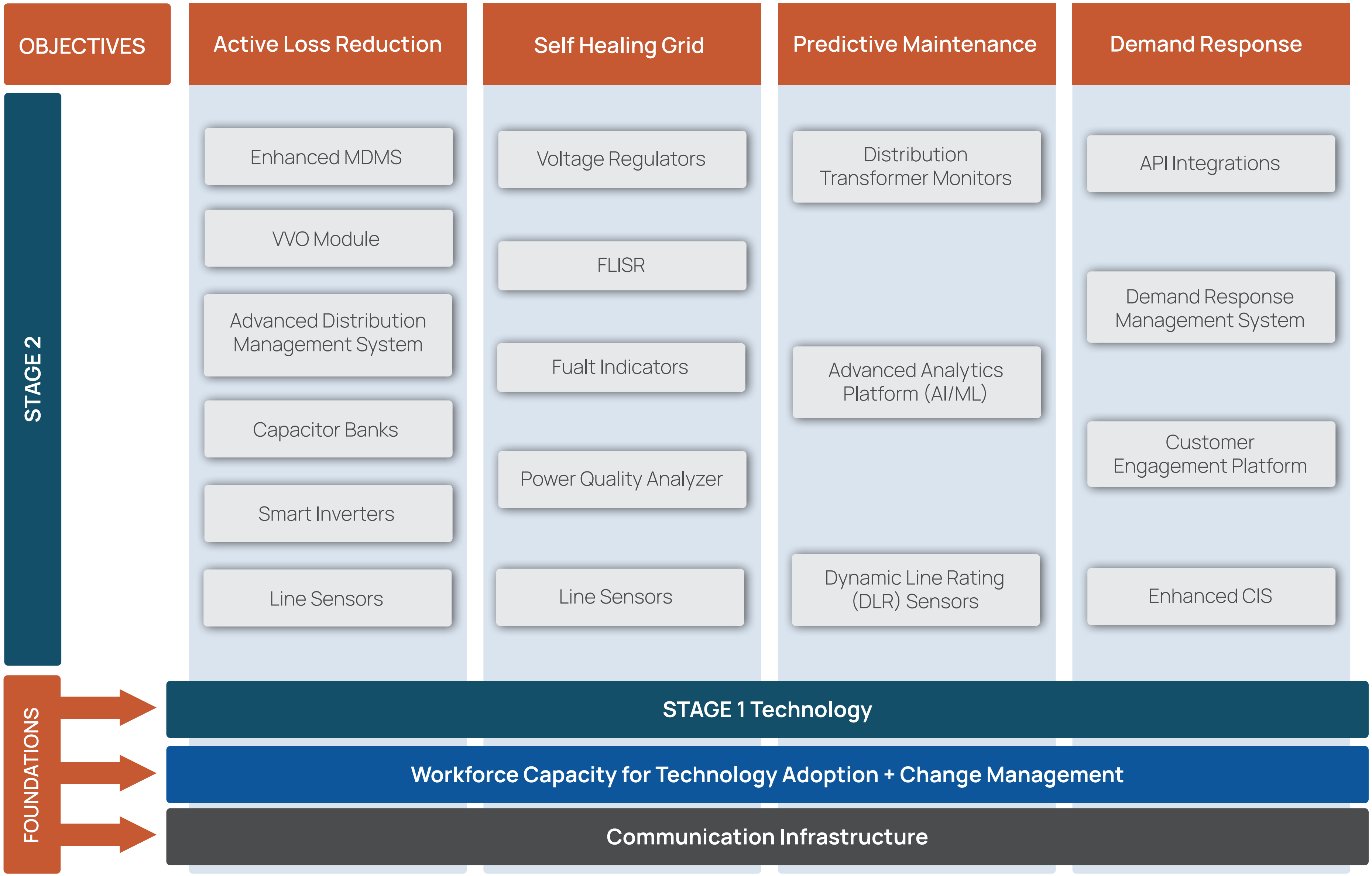


Figure 4: Stage 2 – Implementation schematic showing key objectives and relevant technologies

4.3 Implementation Process

This section discusses the process for implementing the Blueprint, including parallel efforts at the organizational level, evaluation criteria for measuring success, and the progression logic for moving from Stage 1 to Stage 2.

4.3.1 Organizational Readiness and GEDSI Integration

Success in implementing the Blueprint requires parallel workforce development in change management and in ensuring the DisCo's staff operate and sustain deployed technologies effectively.

Consistent with UK PACT GEDSI objectives, training programs actively recruit and support women and underrepresented groups, establishing targets for female participation in technical roles. The Project Management Office with dedicated staff manages the transformation portfolio, coordinates vendor activities, tracks implementation progress, and ensures integration across departments.

4.3.2 Success Criteria for Stage 1 and Readiness Assessment for Stage 2

Moving feeders from Stage 1 to Stage 2 requires success in Stage 1 across technical, organizational, and financial dimensions. Advancement is contingent on a formal stage-gate review.

Mandatory prerequisites verified through formal gate review include:

- **Technical readiness:** Stage 1 AMI infrastructure is operational with 95%+ meter reporting rates; SCADA is providing real-time visibility on the feeder with 99% availability; communication backbone proven reliable with 95%+ uptime; and data management systems (HES, MDMS, CIS) are fully integrated and stable.

- **Operational performance:** Demonstrated ATC&C loss reduction toward the set target; validated collection efficiency improvement on the feeder; remote operations (disconnect/reconnect) functioning reliably; and SCADA-based fault response showing measurable restoration time improvement.

- **Organizational capacity:** Workforce competent in operating Stage 1 technologies with minimal vendor support; operational processes and data governance procedures documented and embedded.

- **Financial validation:** Stage 1 is measurably improving financial performance on the feeder; business case validated through actual performance; investment returns justifying Stage 2 commitment; funding sources secured or committed for Stage 2 deployment.

Formal stage-gate reviews verify prerequisite capabilities before progression, ensuring the DisCo maintains a solid foundation throughout the modernization journey.

4.3.3 Managing Dependencies

Grid modernization technologies exist within interconnected ecosystems where capabilities build upon one another in logical sequences. The two-stage implementation explicitly manages critical dependencies:

- **Communication infrastructure as foundation:** Stage 1 establishes a communication backbone enabling all subsequent deployments since AMI, SCADA, and automation all depend on robust, secure communications.

- **Data before analytics:** Stage 2 automation requires comprehensive Stage 1 metering data and SCADA telemetry – attempting advanced analytics without foundational data infrastructure would fail.

- **Organizational readiness and GEDSI integration:** Each stage includes parallel workforce development, ensuring staff possess skills to operate new technologies, with targeted inclusion of women and underrepresented groups in technical training programs consistent with UK PACT GEDSI objectives - deploying systems without human capacity creates unsustainable implementations.

4.3.4 Technology Evolution and Future Developments

Grid modernization is a continuous journey rather than a finite project. While Stages 1 and 2 establish comprehensive smart grid foundations, the technology landscape and the DisCo's operational needs will continue to evolve.

- Advanced DER integration enabling net billing and bidirectional power flow management, supporting the clean energy transition.
- Electric vehicle infrastructure readiness as EV adoption grows, requiring smart charging management and grid impact mitigation

- Energy storage integration supporting renewable energy and grid stability
- Further automation advancement incorporating AI/ML for autonomous network optimization.

Technology refresh planning ensures deployed systems remain current. For instance, smart meters have 10 – 15-year lifespans requiring eventual replacement with next-generation technologies; SCADA and software platforms require periodic upgrades; communication infrastructure evolves with 5G and beyond.

The DisCo maintains its technology monitoring function, tracking sector developments, evaluating emerging capabilities, and planning strategic upgrades as part of its continuous improvement programme.

5. GEOGRAPHIC EXPANSION: PHASED ROLLOUT ACROSS THE UTILITY

The geographic expansion or scaling philosophy for the GMF follows a systematic approach that balances ambition with pragmatism. Rather than attempting to modernize the entire franchise area simultaneously, the GMF adopts a phased rollout that allows the DisCo to build institutional capacity, validate technology choices, and generate early financial returns that fund subsequent expansion.

The phasing strategy serves four critical purposes:

1. Managing implementation risk by validating technologies before wide-scale deployment.
2. Generating early financial returns from initial investments.
3. Aligning investment pace with the DisCo's organizational capacity and workforce development
4. Maintaining operational continuity by avoiding disruptive implementations.

Geographic deployment prioritizes high-loss feeders for maximum impact demonstration, commercial and industrial zones where accurate metering yields the fastest revenue recovery, and areas with existing communications infrastructure to reduce deployment costs. The three-phase rollout is structured as follows:

The GMF defines three implementation phases:

Phase 1

Pilot Feeders

The DisCo implements pilot projects on one or two priority feeders to test the framework, build institutional capacity for implementation, and demonstrate measurable results to internal and external stakeholders.

Phase 2

Priority Feeder Expansion and Business District Coverage

The DisCo expands implementation beyond the selected pilot feeder(s) to other high-priority feeders, targeting those with high losses and commercial load concentration.

Phase 3

Expansion across Franchise Area

Building on the previous phases, the DisCo progressively expands the grid modernization framework across its franchise area using fit-for-purpose configurations for different customer segments.

5.1 Phase 1: Pilot Feeders

Phase 1 represents the entry point for the DisCo's grid modernization journey and is deliberately designed as a learning-intensive, risk-managed process that validates the modernization approach before committing to larger-scale deployment.

Scope and Activities

Pilot feeders are selected based on a combination of high ATC&C losses, significant commercial load concentration, recurring outage history, and proximity to existing communications infrastructure. Selection criteria are applied consistently to ensure that pilot results are representative of the DisCo's broader modernization opportunity.

Beyond technology deployment, Phase 1 emphasizes institutional and operational readiness, including:

- Establishment of project governance structures and workflows
- Intensive workforce training and change-management programs are embedded alongside implementation
- Development of standard operating procedures for data-driven operations
- Customer sensitization and engagement on pilot feeders to build trust and acceptance, particularly around smart metering

Progression to Phase 2

Progression through Phase 1 is not timeline-based but is contingent on a formal review against clearly defined success criteria. Progression is approved only when the DisCo demonstrates readiness across technical, commercial, and organizational dimensions.

- Technical performance of deployed systems under real network conditions.
- Reliability and uptime of the communication infrastructure.
- Accuracy and usability of data for operational and commercial decision-making.
- Staff capability to operate systems with decreasing reliance on vendors.
- Realized financial impacts, particularly improvements in collection efficiency and loss reduction.

Formal reviews assess whether performance targets outlined in Section 4.3.2 have been met and whether lessons learned have been captured, documented, and incorporated into the rollout plan for subsequent phases.

Expected Benefits

Phase 1 delivers immediate and visible benefits on the pilot feeders, including:

- Measurable ATC&C loss reduction
- Faster fault detection and reduced restoration times
- Improved billing accuracy and customer trust
- Demonstrated proof of value for smart grid investments
- Creation of internal champions and skilled teams capable of supporting scale-up

Crucially, Phase 1 generates credible technical, financial, and organizational evidence that de-risks future investment and underpins financing discussions for expansion.

5.2 Phase 2: Priority Feeder Expansion

Phase 2 transitions the DisCo from piloting to targeted scaling, expanding grid modernization to multiple priority feeders while advancing Stage 2 capabilities on proven pilot feeders.

Scope and Activities

This phase involves two parallel tracks. Firstly, building on pilot success, the DisCo upgrades the original Phase 1 pilot feeder(s) to Stage 2 capabilities where readiness criteria have been met. Secondly, Stage 1 deployment is extended to additional high-priority feeders.

In parallel, the DisCo extends implementation to additional feeders, prioritizing high-loss and high-revenue feeders, particularly those serving commercial and industrial loads.

Eventually, within this phase, implementation is extended to selected substations where feeder-level deployments can be aggregated into a business district-level smart grid.

During Phase 2, the DisCo:

- Replicates and standardizes Phase 1 technical architectures to reduce unit costs and implementation complexity.
- Introduces Stage 2 capabilities, including advanced sensors, feeder automation, and ADMS-enabled functions such as FLISR, volt/VAR optimization, and predictive maintenance.
- Strengthens data analytics capabilities, moving from descriptive reporting to optimization-oriented decision support.
- Expands customer engagement tools and pilots demand-side interventions where appropriate.

Progression to Phase 3

Progression from Phase 2 to Phase 3 is incremental and linked to performance. Expansion occurs feeder-by-feeder and district-by-district, with continuous validation of:

- Financial sustainability of deployments.
- Operational stability as system complexity increases.
- Workforce absorption capacity.
- Customer response and service quality improvements.

Phase 2 also serves as the point where the DisCo begins to institutionalize grid modernization – shifting from a project mindset to a continuous improvement programme, with dedicated internal teams, data governance frameworks, and regular performance reviews.

5.3 Phase 3: Expansion Across Franchise Area

Phase 3 represents the long-term transformation phase in which grid modernization becomes business-as-usual across the DisCo's entire franchise area.

Scope and Activities

In Phase 3, the DisCo progressively extends smart grid deployment to the remaining feeders across urban, peri-urban, and selected rural areas.

Key characteristics of Phase 3 include:

- High levels of standardization in equipment specifications, system architecture, and operating procedures.
- Economies of scale in procurement and implementation.
- Integration of grid modernization into routine capital planning, asset management, and operational budgeting.

- Advanced use of analytics for network planning, investment prioritization, and DER integration readiness.

Progression Logic

Expansion across the franchise area is paced according to:

- Financial performance and cash-flow availability.
- Regulatory and tariff evolution.
- Maturity of internal capabilities.
- Differentiated service strategies (e.g., prioritizing higher-density or economically strategic areas first).

Importantly, Phase 3 does not imply uniform deployment everywhere. The DisCo retains flexibility to apply fit-for-purpose configurations based on customer segment, load profile, revenue potential, and infrastructure readiness.

5.4 Integrating Feeder Modernization and Scaling

To further clarify the relationship between the deepening technological maturity of feeder deployment and the expanding footprint of phased scaling, the following matrix demonstrates how the Stages and Phases of this technical framework interact.

Table 4: Staging and Phasing of the Technical Framework

	Pilot Phase (Phase 1)	**Priority Expansion (Phase 2)**	**Full Franchise (Phase 3)**
Number of Feeders	*1 to 2 feeders*	*10 to 20 feeders or 1 business district*	*Progressive expansion across the franchise*
Stage 1 Activities	Deploy complete Stage 1 on pilot feeders; validate; build capacity	Replicate Stage 1 on new priority feeders	Continue Stage 1 deployment on the remaining feeders
Stage 2 Activities	*After set period, upgrade pilot feeders to Stage 2 if readiness criteria are met*	Upgrade early Phase 2 feeders to Stage 2 once they complete Stage 1	Progressive Stage 2 upgrades as feeders mature
Primary Goals	*Prove technology; build skills; demonstrate value*	*Scale proven solutions; maintain quality*	*Achieve full modernization; sustain operations*

PART C:
ENABLING FRAMEWORKS

This part addresses the supporting or enabling frameworks that underpin the DisCo's transformation. It covers how to finance the required investments, how to source technology and implementation partners, and how to manage the risks inherent in large-scale grid modernization.

6. FINANCING STRATEGY

DisCos across Nigeria operate under severe financial constraints, creating a fundamental paradox: the utility needs grid modernization to improve revenue and reduce costs, but constrained cash flows limit its ability to finance the upfront capital investment. The GMF addresses this paradox through a blended financing strategy that combines multiple funding sources and structures to match the specific risk-return profiles of different investors and financiers.

It promotes a single or blended approach, leveraging the framework's exceptional economics through a combination of the following complementary financing models:

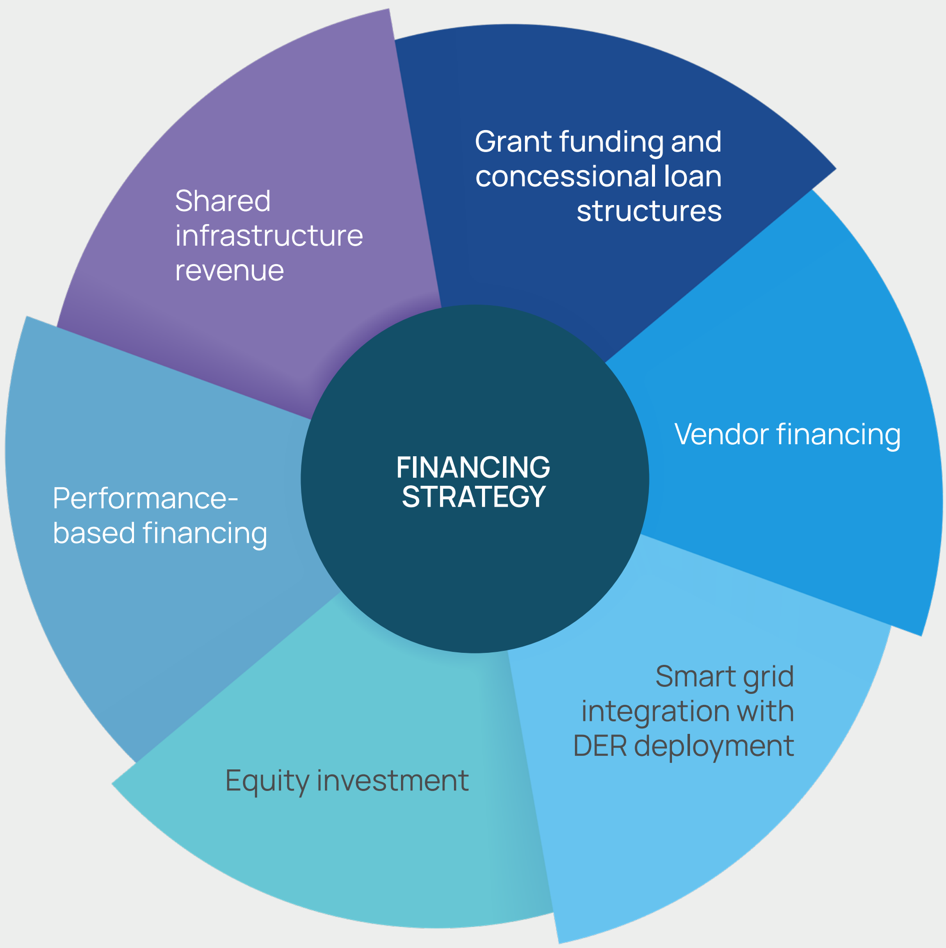


Figure 5: Financing Strategy

6.1 Financing Models

6.1.1 Grant Funding/Concessional Loan Structures

Grant funding from the REA and international development partners addresses the capital-intensive nature of foundational smart grid infrastructure, particularly for components with long payback periods or where commercial risk is too high for private finance alone. [14 15 16]

While commercial interest rates would be unsustainable given most DisCos' current financial positions, concessional loans at lower interest rates and longer tenors can fund larger-scale grid modernization tranches where the revenue improvement case is demonstrated but commercial finance remains constrained. The World Bank's DISREP programme is a model of this (please see Appendix 4 for more information).

The combination of grants covering foundational infrastructure and concessional loans funding revenue-generating assets creates a capital structure appropriate for establishing operational capability and demonstrating financial viability, thereby attracting commercial financing.

6.1.2 Vendor Financing: Aligning Supplier and Utility Interests

VVendor/supplier financing is another key pillar of the DisCo's financing strategy, reducing upfront cash requirements and aligning equipment supplier success with grid modernization outcomes. Vendors extend credit on equipment supply and installation, with repayment structured as a share of verified revenue improvements or over an agreed multi-year period.

Major smart grid equipment manufacturers now routinely offer vendor financing programs specifically designed for emerging market utilities. These programs typically structure payment terms with an initial deposit and acceptance testing, with the outstanding payment deferred/spread over manageable installments tied to project milestones and performance verification.

The performance linkage in vendor financing agreements creates powerful incentive alignment. Payment schedules are tied to specific, measurable operational outcomes such as metering coverage rates, loss reduction milestones, or billing collection improvements.[17]

For the DisCo applying Stage 1 of the Blueprint, vendor financing may target the procurement of metering, communications, and distribution automation equipment. This approach is particularly

[14] World Bank Group. Nigeria Distributed Access through Renewable Energy Scale-up Project. World Bank Document
[15] African Development Bank. Nigeria: African Development Bank Group loans $500 million to support economic governance and energy transition. AFDB website. https://www.afdb.org/en/news-and-events/press-releases/nigeria-african-development-bank-group-loans-500-million-support-economic-governance-and-energy-transition-88948
[16] AFD. Nigeria, EU and AFD Join Forces to Strengthen the Electricity Grid in the North-West of Nigeria. AFD website. https://www.afd.fr/en/actualites/communique-de-presse/nigeria-eu-afd-strengthen-electricity-grid-north-west-nigeria
[17] Asthana A, Booth A, Green J (2010). Best Practices in the Deployment of Smart Grid Technologies. McKinsey & Company. https://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/epng/pdfs/mck%20on%20smart%20grids/mosg_bestpractices_vf.pdf

effective for Advanced Metering Infrastructure (AMI) deployment, where the revenue recovery from loss reduction typically covers repayment obligations within a two-to-four-year period.

6.1.3 Smart grid bundling with DER deployment

This financing option leverages the rapid growth of Distributed Energy Resource (DER) projects within the DisCo's franchise area to co-finance grid modernization investments.

Under this financing model, DER developers provide capital expenditure funding for grid modernization investments required to enable their projects, effectively cross-subsidizing distribution network upgrades with private energy sector capital. The smart grid bundling approach can be implemented through different contractual and operational structures, reflecting the diversity of DER business models operating in the Nigerian market.

In DER models where the developer supplies electricity to the DisCo rather than taking over distribution operations (e.g., embedded generation or mini-grid interconnection), a revenue-sharing or cost-recovery mechanism compensates the developer for grid modernization capex.

6.1.4 Equity Investment: Patient Capital with Strategic Value

This financing pillar secures patient, long-term capital through strategic equity investment that brings both funding and operational expertise. Strategic investors include international development finance institutions (DFIs), infrastructure funds, and strategic utility investors with experience in emerging market grid modernization.

Target investors span three categories, each bringing distinct value propositions:

- **Infrastructure funds** with emerging market experience actively seek utility transformation opportunities offering relatively high returns with clear modernization pathways. These funds manage billions in Africa-focused infrastructure capital requiring deployment in transformational projects.
- **Impact investors** focused on energy access and climate outcomes increasingly target utility modernization as addressing multiple sustainable development goals: reliable electricity access, climate change mitigation through loss reduction, and economic development through improved power supply.
- **Strategic utility investors** seeking Nigerian market entry could view the DisCo as providing operational experience, market knowledge, and a platform for broader regional engagement.
- **Federal and state government investment vehicles** such as the Ministry of Finance Incorporated (MOFI) or the various state investment promotion agencies in Nigeria could provide equity investments as part of efforts to improve the performance of Nigeria's electricity distribution sector.

The proposed investment structure establishes a Grid Modernization Special Purpose Vehicle (SPV) as a distinct legal entity dedicated to ring-fencing grid modernization assets and cash flows, providing investors with security and transparency separate from the DisCo's broader balance sheet. [18]

6.1.5 Performance-Based Financing: Aligning Payment with Results

Another financing pillar employs performance-based financing structures that align payment obligations with verified operational results. This approach is particularly well-suited to grid modernization where revenue improvements are measurable and attributable to specific technology deployments.

Commercial performance contracts employ the Energy Service Company (ESCO) model, where specialized third-party implementers deploy, operate, and maintain smart grid technologies in exchange for a contractually defined share of the verified savings or revenue improvements generated.

Please Note: Since the Electricity Act 2023 [19] *restricts distribution utilities to activities authorized under their electricity distribution and supply licenses, we propose that the DisCo explore an SPV structure in monetizing the communications infrastructure. This approach will establish a clear legal and regulatory separation between the licensed electricity distribution business and the provision of telecommunications services. While the DisCo remains regulated by NERC and restricted to authorized activities, the SPV operates as an independent telecommunications entity licensed by the Nigerian Communications Commission (NCC). The DisCo's role is limited to the commercial leasing of passive infrastructure assets, such as poles and rights-of-way, to the SPV on an arm's-length basis, thereby ensuring regulatory compliance, financial ring-fencing, and preventing cross-subsidization between regulated electricity tariffs and unregulated telecommunications revenues.*

[18] NERC (2020). Guideline on Distribution Franchising in the Nigerian Electricity Supply Industry. Nigerian Electricity Regulatory Commission (NERC) website. https://nerc.gov.ng/wp-content/uploads/2020/07/Guidelines%20on%20Distribution%20Franchasing%20in%20the%20NESI0001.pdf
[19] Electricity Act 2023. NEMSA website. https://nemsa.gov.ng/wp-content/uploads/2024/05/ELECTRICITY-ACT-2023.pdf

6.2 Highlights of Financing Models

Below are summaries of relevant terms, benefits, and risk mitigation for each financing option

Table 5: Financing Highlights

Source	Key Terms	Primary Benefits	Risk Mitigation
Grant Funding and Concessional Loans	• Grants: 0% interest, no repayment • Concessional loans: single-digit interest, a more extended grace period, and a longer loan tenor. • Milestone-based disbursement • Ex: World Bank DISREP US$500M committed financing for DisCo PIPs, >90% aligned to ATC&C loss reduction interventions. See Appendix 4.	• Covers part of Phase 1 costs • Enables deployment in underserved areas • No immediate repayment burden • Technical assistance included • Builds creditworthiness for commercial finance	• REA/DARES mandate alignment • Development partner track record • Government commitment to utility sector reform • Performance-based disbursement triggers
Vendor Financing	• 3-5 years repayment period • 20-30% upfront, 70-80% deferred • Performance-linked milestones • Equipment-secured obligations • Integrated with O&M contracts	• Reduces upfront cash • Aligns supplier success with DisCo results • Embedded technical support • Future preferential terms • Technology transfer included	• Escrow accounts from revenues • Tariff cost recovery commitment • Equipment performance bonds • Liquidated damages provisions
DER Deployment Bundling	• Up to 20-year repayment terms (linked to DER contract) • Up to 100% developer-funded	• Reduces the DisCo's upfront costs • Allocates risk to parties with a direct commercial interest in network reliability • Enables faster rollout • Ensures that DER-driven grid upgrades are compliant with GMF standards	• Contracts should clearly define asset ownership, maintenance responsibilities, data-sharing arrangements • Reintegration conditions should be clearly outlined in the contract
Equity Investment	• Up to 10-year investment horizon • Minority ownership stake • Quarterly dividend distributions • Board representation rights • Put/call exit options	• Patient capital, no near-term repayment • Strategic operational expertise • Global best practice access • Governance improvements • Credibility signal to other financiers	• SPV ring-fencing of revenues • MIGA political risk insurance • Step-in rights for missed targets • Minority investor protections • Independent board directors

Source	Key Terms	Primary Benefits	Risk Mitigation
Performance-Based Financing	• Payment upon verified results • Independent verification agents • Milestone-based disbursement • Up to 10-year ESCO contracts • Savings share	• Zero payment if systems fail • Transfers implementation risk • Validates Framework effectiveness • Aligned incentives • Proven development partner model	• Independent verification protocols • Baseline performance documentation • Contract dispute arbitration • Phased payment triggers

6.3 Transforming Constraint into Opportunity

The DisCo's financial constraints are surmountable through strategic financing that leverages the Grid Modernization Framework's exceptional economics and self-funding characteristics. The blended approach – combining grant funding, vendor financing, equity investment, performance-based financing, and shared infrastructure revenue – creates a resilient capital structure in which each source addresses specific needs while collectively reducing dependence on a single source.

The critical insight is that the DisCo's most significant barrier (i.e., limited financial capacity) becomes an enabler through strategic design. Initial investments generate cash flows to support expansion. Infrastructure serves dual purposes, generating multiple revenue streams that attract additional capital on improved terms. Rather than viewing financing as a constraint, this strategy positions it as the accelerator, converting the DisCo's transformation vision into operational reality and establishing a sustainable model that supports decades of operational excellence.

7. STRATEGIC SOURCING

Successful implementation of the Grid Modernization Framework requires a sourcing approach that balances technical rigor with commercial pragmatism and embeds local capacity development throughout the procurement process.

7.1 Procurement Principles

Consistent with the foundational principles for grid modernization (see Section 2.2), five secondary procurement principles govern the sourcing strategy:

1. **Value-Based Selection:** Procurement decisions prioritize life-cycle cost optimization over the lowest initial price. Evaluation considers the total cost of ownership, including equipment, installation, commissioning, training, ongoing maintenance, technical support, and system upgrades over the technology's operational lifespan. This approach ensures sustainable, long-term value rather than short-term cost minimization, which often leads to higher operational expenses and premature replacement.
2. **Technical Fitness and Interoperability:** All procured technologies must directly address operational gaps identified in the DisCo's needs assessment, operate effectively in Nigerian grid conditions, and comply with NERC technical standards.[20]
3. **Local Capacity Development:** Following Principle 5 (Capacity-Building Embedded), procurement specifications include mandatory knowledge transfer, training programmes, and local content requirements to build the DisCo's internal technical capability.
4. **Transparency and Compliance:** All procurement processes follow competitive, auditable methodologies with clear, published evaluation criteria aligned with the investment evaluation framework (Section 2.3). Procurement activities align with Nigerian Electricity Regulatory Commission (NERC) requirements and follow regulatory approval protocols where applicable. Documentation requirements ensure full traceability from needs identification through vendor selection, contracting, and implementation.

[20] This is compliant with NERC's Nigerian Electricity Supply and Installation Standards (NESIS) Regulations v 02 (2025) which mandates the adoption of IEC 61850 and related standards in the construction and operations of virtual power plants, digital substations, SCADA systems, virtual power plants, intelligent electronic devices, protection systems, PMUs, RTUs, amongst others. https://nerc.gov.ng/wp-content/uploads/2025/10/Grid-Code-and-NESIS-Regulations.zip

5. **Inclusion and Equity (GEDSI Integration):** Consistent with the DisCo's commitment to Gender Equality, Disability, and Social Inclusion (GEDSI), procurement processes actively encourage participation of women-owned and minority-owned enterprises, and technology deployments consider the needs of vulnerable customer groups.

7.2 Procurement Approaches

The DisCo's procurement strategy employs differentiated approaches tailored to technology maturity, implementation complexity, and strategic importance.

Phased Procurement Strategy: The procurement strategy follows a three-phase approach aligned with Principle 3 (Pilot-Validate-Scale) and the implementation timeline:

- **Pilot Deployment Phase:** Limited competitive selection of partners for pilot sites focusing on proof-of-concept, technology validation, and evidence generation. Partner selection emphasizes vendor technical support, knowledge transfer commitments, and flexibility for pilot adjustments based on operational learning.
- **Expansion to Priority Commercial Feeders:** Framework agreements are based on pilot performance, enabling preferential procurement from proven vendors while maintaining competition through periodic market testing. Procurement specifications are standardized based on pilot learnings, reducing customization costs.
- **Broader Expansion:** Volume procurement supports leveraging of demonstrated success, establishes vendor relationships, and standardizes specifications. There is potential for multi-DisCo aggregated procurement to achieve economies of scale and support sector-wide modernization as framework replicability is demonstrated.

Procurement Principles

- Value-Based Selection
- Technical Fitness and Interoperability
- Local Capacity Development
- Transparency & Compliance
- Inclusion & Equity (GEDSI Integration)

Package Structuring: Procurement is organized into three complementary package categories that recognize the distinct nature of equipment supply, service delivery, and long-term partnership arrangements:

- **Technology Packages:** Equipment supply including smart meters, grid sensors, communication infrastructure, automation devices (reclosers, switches), and software platforms. Procured through competitive bidding with technical specifications derived from the **Smart Grid Technology Catalogue.**
- **Service Packages:** Installation, system integration, commissioning, testing, and warranty support. They may be bundled with technology packages for turnkey delivery or procured separately to leverage local installation capacity and build domestic expertise
- **Partnership Packages:** Long-term operations and maintenance, technical capacity building, distributed renewable energy (DRE) development support, and shared infrastructure monetization are structured as strategic partnership packages requiring experienced, financially robust partners.

Establishing Procurement Modalities: Different technology categories require tailored procurement approaches that reflect market structure, technical complexity, and risk allocation:

- **Direct Procurement:** Suitable for standardized equipment with established specifications such as smart meters, communication modules, and grid sensors. Competitive bidding emphasizes compliance with technical standards, local support capabilities, and delivery timelines.
- **Design-Build-Operate:** Applied to complex integrated systems, including SCADA platforms, Meter Data Management Systems (MDMS), and enterprise software requiring customization and long-term support. Vendors assume greater implementation responsibility in exchange for multi-year operational contracts that align incentives with performance.

Implementing Market Engagement: Effective market engagement ensures competitive, realistic procurement outcomes by establishing dialogue with potential vendors before formal tender processes:

- Pre-procurement supplier consultations validate technology catalogue specifications, confirm local market capacity, and refine requirements based on vendor feedback on the Nigerian operating environment.
- Request for Information (RFI) processes gather market intelligence on available technologies, indicative pricing ranges, implementation timelines, and local support infrastructure before issuing formal tenders.

- Mandatory site visits for prospective bidders ensure that proposals are realistic and based on actual DisCo operating conditions, with vendor qualifications assessed against Nigeria-specific grid environment requirements.
- Clarification workshops provide bidders with the opportunity for technical questions during the tender response periods; reducing ambiguities, minimizing bid variations, and improving overall proposal quality.

7.3 Vendor Qualification and Selection

The DisCo's vendor selection process employs a two-stage approach: initial pre-qualification to establish minimum capability thresholds, followed by detailed technical and commercial evaluation of shortlisted vendors.

Setting Pre-Qualification Criteria: Vendors must demonstrate minimum qualifications before their bids enter detailed evaluation. Pre-qualification criteria establish capability thresholds without yet scoring competitive differentiation:

- Technical capability with documented track record of comparable smart grid deployments in similar operational contexts (developing markets, high-loss networks, constrained capital environments).
- Financial stability with adequate bonding capacity to support contract obligations, verified through audited financial statements and credit references.
- Local presence through direct Nigerian operations or established partnerships with local distributors, system integrators, and maintenance service providers.
- Demonstrated commitment to GEDSI principles and Health, Safety, and Environment (HSE) compliance, evidenced through corporate policies and implementation examples from previous projects.

Developing Evaluation Framework: Pre-qualified vendors are evaluated using weighted criteria that balance technical merit, commercial competitiveness, implementation capacity, and strategic value addition. The evaluation framework applies consistently across all procurement packages while allowing technology-specific technical criteria. Below is an example:

- **Technical Merit (40%):** Compliance with specifications, innovative features, system interoperability, scalability potential, technology roadmap, quality of proposed solution architecture, alignment with open standards, and – in the case of electricity meters and metering equipment – evidence of NEMSA type test certification.[21] Assessment includes technical proposal review, reference system inspections, and vendor presentations.
- **Commercial Terms (30%):** Life-cycle costs including initial capital, installation, commissioning, training, maintenance, and eventual replacement or upgrade. The evaluation considers payment flexibility, warranty provisions, spare parts availability, pricing transparency, and cost escalation protections for multi-year contracts.
- **Implementation Capacity (20%):** Proposed delivery timeline, project management approach, local partnerships and resource mobilization plans, installation expertise, commissioning methodology, and risk mitigation strategies. Emphasizes the vendor's demonstrated ability to deliver in the Nigerian operating environment.
- **Value Addition (10%):** Training programs with specific curricula and gender inclusion commitments, knowledge transfer plans, GEDSI integration proposals, local content sourcing plans, and community engagement approaches.

Due Diligence Process: Preliminary selected vendors undergo comprehensive verification before final contract award to validate claims made during proposal evaluation:

Reference checks from previous clients in comparable projects, validating claimed performance, on-time delivery, technical support quality, and post-installation responsiveness.

- Reference checks from previous clients in comparable projects, validating claimed performance, on-time delivery, technical support quality, and post-installation responsiveness.
- Factory or facility visits for critical equipment to verify manufacturing standards, quality control processes, testing procedures, and production capacity to meet delivery schedules.
- Financial health assessment ensuring vendor stability throughout contract duration, including review of current obligations, credit ratings, and insurance coverage.
- Compliance verification covering NERC and NEMSA requirements, environmental standards, labor practices, and social safeguards, with particular attention to GEDSI commitments.

[21] Compliance with NERC's metering code v02, requires that "all electricity meters and metering equipment used in Nigeria shall be certified to the required accuracy and standards specified in [the Metering], code by an approved Metering Test Station". https://nerc.gov.ng/wp-content/uploads/2014/11/MeteringCode_V02_03112014.pdf

Contract Management: Effective contract execution ensures vendor accountability and performance throughout technology deployment and operational handovers:

- Performance-based milestone payments tied to verified deliverables and acceptance criteria, with holdbacks released only after successful commissioning and initial operational period.
- Service level agreements with defined penalties for non-performance (delayed delivery, substandard quality, inadequate support) and incentives for exceeding targets (early completion, superior performance metrics).
- Clear dispute resolution mechanisms, including escalation protocols, mediation procedures, and arbitration provisions that provide efficient conflict resolution without litigation delays.
- Technology refresh and upgrade provisions ensuring systems remain current throughout operational life, with clearly defined responsibilities for firmware updates, security patches, and eventual hardware replacement as technology evolves.

This procurement strategy establishes the foundation for transparent, value-driven technology acquisition, positioning the DisCo for sustainable grid modernization.

8. RISK MANAGEMENT

This section focuses on the critical and high-priority risks that could significantly impact the utility's success with the grid modernization project. Risk prioritization was conducted using a hybrid framework that evaluates likelihood and impact across five dimensions: technological, financial, operational/institutional, policy, and environmental factors. The analysis prioritizes risks most relevant to the DisCo management and directly addresses concerns around institutional capacity, financial viability, cybersecurity, technology integration, and regulatory uncertainty – areas where mitigation is essential for project sustainability and bankability.

8.1 Project Funding & Capital Mobilization Risk

DisCos face the fundamental challenge of securing sufficient upfront capital to fund smart grid modernization investments. The risk mitigation strategy combines multiple funding source diversification with phased deployment sequencing.

Impact Analysis: Failure to mobilize adequate project capital would result in project delays or complete inability to commence implementation; forced reductions in project scope that compromise the integrated smart grid vision; loss of momentum and stakeholder confidence in the modernization agenda; missed opportunities as technology costs evolve or financing windows close; and continued operational inefficiencies that perpetuate the utility's financial challenges.

Mitigation Strategy includes:

- **Prioritizing Concessional and Blended Finance from Developmental Finance Institutions (DFIs):** Maximize grant funding from government sources and development partners for technical assistance, capacity building, and revenue/non-revenue generating components. Access low-interest, long-tenor concessional loans from DFIs with grace periods aligned with revenue realization timelines. Utilize credit enhancement mechanisms (guarantees, first-loss capital, political risk insurance) to de-risk commercial financing and improve access to affordable debt.
- **Phased Implementation Approach:** By breaking the project into discrete, independently financeable phases, with each phase delivering measurable value. Start with quick-win, lower-cost interventions (e.g., prepaid meters) that generate early revenue

improvements to create internal cash flow. Structure financing in tranches with release of subsequent funding conditional on achieving predefined milestones, reducing upfront capital requirements, and demonstrating responsible use of funds before securing larger investments.

- **Exploring Third-Party Ownership and Vendor-Financing Model:** Engage private sector partners to finance, build, and operate smart grid infrastructure (especially AMI) under a concession or lease arrangement, reducing the DisCo's capital exposure while maintaining operational oversight.

8.2 DisCo Institutional Capacity & Sustainability Risk

DisCos typically possess insufficient technical and financial capacity to effectively deploy, operate, and sustain smart grid investments on their own. The mitigation strategy focuses on structured capacity transfer through vendor contracts and strategic partnerships.

Ownership or management turnover at the DisCo may lead to changing priorities and weakened commitment to grid modernization. Also, regulatory non-compliance of proposed projects may result in operational disruptions, heavy fines and eventual abandonment of these projects.

Impact Analysis: The project faces significant risks, including premature technology failure due to inadequate maintenance; inability to extract value from data and analytics platforms; reversion to manual processes despite available automation; staff turnover leading to knowledge loss; and ultimately, stranded investments that fail to deliver anticipated benefits. This would undermine stakeholder confidence, jeopardize future funding, and reinforce the cycle of underinvestment in Nigerian distribution infrastructure.

Mitigation Strategy includes:

- **Comprehensive Capacity Development Program:** this includes developing role-specific training programs covering technical operations (e.g., SCADA/DMS operation, AMI data management), commercial operations (e.g., revenue assurance with data analytics), and cybersecurity awareness, and practical workshops/simulation exercises.
- **Performance-Based Financing Mechanisms:** Tie a portion of project financing to achievement of operational milestones (e.g., system uptime targets, loss reduction percentages) to create accountability and ensure capacity building translates into performance improvement.

- **Technical Assistance and Mentorship:** This could entail pairing the DisCo's staff with experienced utility professionals through twinning arrangements, embedding WEC technical advisors during the critical early deployment phases, and establishing peer-learning networks with DisCos that have successfully implemented grid modernization.
- **Sustainable O&M Funding Models:** Work with the financing strategy to ensure dedicated O&M budgets, through ring-fenced tariff components specifically for technology maintenance and staff development, and establishing depreciation reserves for technology refresh cycles.
- **Secure Support/Buy-In of the Key Stakeholders:** Conduct compliance testing for relevant projects and implement necessary modifications to meet regulatory requirements. Also, secure input of industry governing authorities and stakeholders (e.g., NERC, REA) in implementing the modernization framework.

8.3 Financial Viability & Cost Recovery Risk

The utility faces the fundamental challenge of recovering smart grid investments through tariffs in an environment limited by cost-reflective tariff shortfalls, high ATC&C losses, and competing capital priorities across all operational needs.

Impact Analysis: Failure to achieve financial viability would result in inability to meet debt service obligations, leading to default risk; deterioration of newly deployed assets due to inadequate O&M funding; reversion to manual operations as automated systems fail; erosion of investor confidence,m preventing future infrastructure investments; and potential abandonment of the modernization pathway. This would not only waste the initial investment but also reinforce the perception that Nigerian DisCos cannot successfully implement and sustain advanced technologies.

Mitigation Strategy includes:

- **Phased Tariff Adjustments Linked to Service Improvements:** This would entail communicating transparently with customers about the relationship between investments, service quality, and tariff requirements. Furthermore, the DisCo advocates with NERC for targeted tariff structures that allow high-value customers (Band A, commercial/industrial) to pay cost-reflective rates while maintaining cross-subsidy mechanisms for residential customers.
- **Prioritizing Revenue Assurance Systems in its Phased Implementation Approach:** By deploying smart grid technologies specifically designed to improve revenue collection (see Section 3.2 for details of these technologies)

- **Blended Finance to Reduce Tariff Pressure:** Leverage the financing strategy to access concessional financing (grants, low-interest loans) from development partners (UK PACT, AFD, GIZ, World Bank) to reduce the upfront capital burden, results-based financing that provides payments upon achievement of performance targets, technical assistance grants to offset costs of capacity building and institutional strengthening, and credit enhancement mechanisms (guarantees, first-loss capital) to improve access to commercial financing on favorable terms.

8.4 Cybersecurity & Data Protection Risk

With the deployment of interconnected digital systems, the utility's cyber-attack surface expands dramatically. Legacy systems may harbor unpatched vulnerabilities, and staff may lack sufficient cybersecurity awareness training. The risk of cyber-attacks, data breaches, ransomware, unauthorized system access, and manipulation of operational technology (OT) systems poses existential threats to grid operations and customer trust.

Impact Analysis: A successful cyber-attack could result in widespread service disruptions affecting thousands of customers; financial losses from operational disruption; regulatory penalties; and loss of customer and investor confidence.

Mitigation Strategy includes:

- **Security-by-Design Approach:** Integrating cybersecurity requirements into all technology procurement specifications, mandating that all systems comply with international standards (i.e., NIST Cybersecurity Framework, IEC 62351, ISO 27001) and requiring vendors to provide security certifications and conduct security audits as part of commissioning.
- **Security Operations Center (SOC) Establishment:** Deploying a Security Information and Event Management (SIEM) system[22] to aggregate and analyze logs from IT and OT systems, establish 24/7 monitoring capabilities (which can be outsourced initially to specialized providers), and develop incident response protocols and escalation procedures.
- **Network Segmentation and Access Controls:** Separating Separating IT and OT networks using firewalls and intrusion detection/prevention systems (IDPS),[23] implementing role-based access controls and multi-factor authentication for all critical systems, and deploying Public Key Infrastructure (p) for device authentication and encryption.

[22] A cybersecurity solution that centrally collects and analyzes data from across the organization's IT environment to detect, analyze, and respond to threats in real time. **See Smart Grid Technology Catalogue** for further details.

[23] Focused detectors/blockers that could work with SIEMS to monitor networks and systems for malicious activity, policy violations, or suspicious patterns, providing alerts (IDS) and, in the case of IPS, taking automated actions like blocking threats in real-time to prevent breaches. See **Smart Grid Technology Catalogue** for further details.

- **Staff Training and Awareness Programs:** Conducting regular cybersecurity awareness training for all staff, and providing specialized training for IT/OT personnel on threat detection, incident response, and security best practices.

8.5 Technology Integration & Interoperability Risk

The risk of incompatibility between new and legacy systems, vendor lock-in, proprietary data formats, and inadequate system integration testing could result in stranded investments in non-interoperable technologies; inability to achieve end-to-end visibility and control; performance degradation; cost escalations for custom integration work; and dependence on single vendors for ongoing support and upgrades.

Impact Analysis: Poor technology integration would undermine the core value proposition of smart grid integration and grid modernization – the ability to leverage data from multiple sources for holistic operational decision-making. This would result in technology "islands" that cannot communicate, redundant manual data entry processes, an inability to implement advanced analytics, and, ultimately, a failure to deliver the anticipated efficiency gains and operational improvements.

Mitigation Strategy includes:

- **Open Standards Adoption:** Mandating the use of industry-standard protocols (for instance, IEC 61850 [commonly deployed for substation automation], IEC 60870-5-104 [or IEC-104, mostly used in central SCADA deployment] and DNP3) in all technology procurements, specifying data format standards to ensure semantic interoperability, and requiring vendor support for open APIs to enable third-party integration.
- **Phased Integration Approach:** Pilot integration with limited scope (e.g., single feeder, one substation) before full-scale deployment. In addition, conducting factory acceptance testing (FAT) and site acceptance testing (SAT) with explicit integration validation criteria. Finally, developing integration test plans that verify data flows across system boundaries.
- **Rigorous Testing Protocols:** Performing load and stress testing to ensure systems can handle peak data volumes.
- **Multi-Vendor Strategy:** Avoiding single-vendor lock-in by maintaining competitive procurement processes and negotiating contracts that include knowledge transfer, source code escrow, and technology transfer provisions. It is vital to also build in-house technical expertise to reduce dependence on vendor-specific knowledge.

8.6 Risk Governance, Monitoring & Adaptive Management

Effective risk management requires robust governance structures and continuous monitoring. The DisCo will establish:

Risk Register and Dashboard: A living document that captures all identified risks, their current status, mitigation actions, and responsible owners. The risk register will be reviewed quarterly and updated as new risks emerge or existing risks evolve.

Quarterly Risk Reviews: Project steering committee meetings will include formal risk reviews with assessment of risk status changes; effectiveness of mitigation measures; new or emerging risks; and decisions on risk response strategies (accept, avoid, mitigate, transfer).

Escalation and Decision Protocols: Clear escalation pathways for risks that exceed established thresholds, with defined decision-making authority at different organizational levels to ensure timely risk response.

Continuous Learning and Adaptation: Post-implementation reviews and lessons learned sessions to capture insights from risk events, refine mitigation strategies, and build institutional knowledge for future projects.

Through disciplined risk management focused on the highest-priority threats to project success, the DisCo can navigate the challenges of grid modernization and build the institutional resilience needed for long-term transformation.

PART D: APPENDIX

APPENDIX 1: KEDCO CASE STUDY

A1.1 DisCo Background: Kano Electricity Distribution Company (KEDCO)

KEDCO is one of eleven privatized electricity distribution companies (DisCos) in Nigeria, serving the north-western states of Kano, Katsina, and Jigawa. It is the pilot DisCo for the USGI project, selected for its scale, the severity of its operational challenges, and its leadership's willingness to embrace grid modernization. KEDCO's experience illustrates the conditions that the GMF is designed to address and provides an evidence base that other Nigerian DisCos can draw on when applying the framework to their own contexts.

The franchise area covers a large, predominantly urban and peri-urban population with a significant commercial and industrial load base, but also serves areas with limited grid access. Infrastructure is generally outdated, with many components operating beyond their design life. The reactive maintenance approach that results from this aging asset base is a systemic constraint on reliability and operational efficiency.

A1.2 Needs Assessment: Process and Findings

WEC conducted a comprehensive needs assessment of KEDCO as part of the USGI project, in close collaboration with KEDCO staff and management. The assessment followed a four-stage process:

- Pre-assessment preparation: alignment with KEDCO leadership, identification of key stakeholders, and questionnaire design
- Data collection: focus group discussions and individual interviews with staff across 15 operational areas and 4 organizational levels, supported by field observations
- Data validation and analysis: verification of findings using public sources and analysis of interview data
- Needs ranking and solution mapping: prioritization of identified gaps against KEDCO's three strategic priorities using a structured 1-to-5 scoring methodology

The assessment identified approximately 140 distinct operational issues, which were consolidated into 32 Issue Groups. Each Issue Group was evaluated against KEDCO's three strategic priorities and assigned a composite score from 1 (low impact) to 5 (critical impact). The composite score reflects the maximum score across the three priorities, ensuring that issues critical to any one strategic objective receive appropriate prominence.

KEDCO's Three Strategic Priorities

- P1 – Improve Overall Energy Efficiency and Reliability: addressing frequent equipment failures, extended outages, aging infrastructure, and reactive maintenance
- P2 – Reduce ATC&C Losses: tackling the prevailing ATC&C loss rate against a NERC-mandated target for the utility
- P3 – Improve Energy Access to Underserved Areas: expanding reliable grid supply in a country where approximately 43% of the population lacks access

A1.3 Critical Priority Issue Groups

The needs assessment identified eight critical priority issues required to address KEDCO's strategic priorities. These critical priorities cluster around three interconnected operational themes:

Revenue Protection and Loss Management.

KEDCO's ATC&C loss rate represents billions in lost revenue annually. Collection losses are the single largest component, exceeding technical and commercial losses combined. The four critical issues in this cluster are:

- Inability to Monitor and Attribute ATC&C Losses: No feeder-level visibility exists to determine whether losses are predominantly technical or commercial.
- Network Design Contributing to High Losses: Network architecture has design characteristics that facilitate theft even with good metering. Reconfiguration to address this requires detailed loss data that KEDCO currently cannot generate.
- Inadequate Metering and Anti-Theft Infrastructure: Need for additional meters, anti-theft applications, and tamper-detection features.
- Poor Collection Performance: Manual processes for managing overdue accounts, payment plans, and disconnections limit responsiveness and the effectiveness of credit control.

Operational Visibility and Control

KEDCO operates without real-time network visibility; all data collection is manual. The absence of SCADA means there is no remote alarm, no automated control, and no real-time data acquisition. The two critical issues in this cluster are:

- Absence of Real-Time Network Visibility: No SCADA or automated data acquisition. Fault detection relies on customer calls. Restoration times vary by area, driven by manual isolation and switching.
- Manual Fault Management: Without automated switching or recloser deployment, every fault requires physical crew dispatch. The utility operates entirely reactively, with no predictive or proactive capability.

Foundational Infrastructure and Workforce Capacity

These issues represent preconditions for all other modernization investments. They are:

- Aging Assets and Reactive Maintenance Approach: Assets average are often beyond design life. No condition-based monitoring or predictive maintenance capability exists. Failure rates are high, and the utility lacks the asset management systems to prioritize replacement effectively.
- Workforce Skills Gaps: Significant skills deficits exist in automation, data analytics, DER integration, and smart grid operations. Without workforce development running in parallel with technology deployment, even well-designed systems will underperform.

A1.4 High Priority Issue Groups

The 7 High Priority Issue Groups build on critical needs and cluster around four enabling themes:

- Lack of Automation and Optimization: Limited deployment of smart grid technologies prevents proactive operations. Without real-time visibility, automated grid devices, and dynamic load management, KEDCO cannot optimize network performance.
- Constrained Data and Analytics Capabilities: Fragmented and manually maintained data systems – with Google Sheets as the primary platform – prevent integrated decision-making. No ERP system exists; technical, commercial, customer, and financial data reside in separate, unconnected systems.
- Need for Future-Readiness: Limited smart meter deployment, absence of a structured smart grid roadmap, and inadequate planning frameworks leave the utility unprepared for DER integration and technology evolution.
- Limited Organizational Capacity and Governance: Absence of strategic investment prioritization frameworks, decision support tools, and systematic performance management limits the utility's ability to plan and sequence modernization investments.

A1.5 Cross-Cutting Strategic Themes

Analysis of the above prioritized needs reveals four themes that are consistent with the GMF's framework-level analysis and are likely to recur in other Nigerian DisCos:

- **Revenue protection dominance:** Four of the eight critical needs directly relate to loss management and revenue protection, confirming that ATC&C loss reduction is the primary financial imperative. Success in this area generates cash flow that funds subsequent modernization phases.

- **Operational visibility as systemic constraint:** Approximately six of the top fifteen needs relate to operational visibility and real-time monitoring. Lack of network visibility is both an independent operational problem and a multiplier that limits the value of all other investments.
- **Data as a foundational gap:** The absence of integrated, reliable operational data is a cross-cutting constraint. KEDCO's reliance on Google Sheets for operational data capture and the lack of API integration across systems is representative of conditions across the Nigerian DisCo sector.
- **Workforce capacity as a binding dependency:** Technology investments will only deliver their intended value if the workforce can operate and sustain deployed systems. Skills development is not a separate workstream — it is a prerequisite that must run in parallel from the earliest phase.

A1.6 Application of the GMF to KEDCO

The GMF was adapted for KEDCO, and its structure directly reflects the findings of the needs assessment summarized above and WEC is working with KEDCO to design and implement a pilot project to test Stage 1 of the Grid Modernization Framework.

The following maps KEDCO's critical and high-priority issues to the GMF components that address them.

GMF Response to KEDCO's Priority Needs

Stage 1 of the Feeder Modernization Blueprint (Section 4) was specifically designed to address KEDCO's Critical Priority Issues

- ATC&C Loss Monitoring and Metering: Addressed through deployment of AMI including smart meters, transformer meters, feeder meters, and a Meter Data Management System (MDMS), establishing end-to-end energy accounting from substation to customer.
- Operational Visibility: Addressed through SCADA deployment enabling real-time monitoring, remote switching, and automated fault detection – replacing the current reliance on manual data collection and customer-reported faults.
- Infrastructure and Workforce Capacity: Addressed through physical network rehabilitation running in parallel with Stage 1 technology deployment, and a mandatory workforce development programme embedded throughout implementation.

Stage 2 of the Blueprint addresses KEDCO's High Priority Issues, building on the foundations established in Stage 1

- Automation and Optimization: Distribution automation, fault passage indicators, and an Advanced Distribution Management System (ADMS) for proactive, data-driven network management.
- Data and Analytics: Integration of operational and commercial data systems, moving from fragmented manual platforms to a unified data architecture supporting evidence-based decision-making.
- Future-Readiness and Organizational Capacity: Structured capacity-building programme, strategic planning framework, and technology monitoring function to manage the utility's long-term modernization roadmap.

APPENDIX 2: INTERNATIONAL CASE STUDIES

A2.1 Case Study 1: Enel (Italy)

Project Title	**Telegestore: National Smart Meter Rollout**
Scope/ Modernization Objectives	Replace 30 million traditional meters with smart meters nationwide and establish remote management capability. World's first full-scale national Advanced Metering Infrastructure (AMI) deployment.
Country/City	Italy (Nationwide)
Time Period	2001 – 2006 (5 years)
Intervention	• **Technology Deployment:** Smart meters with Power Line Communication modules, LV concentrators at substations, dual-channel communication network (PLC and GSM backbone), Meter Data Management (MDM) integrated with Outage Management System (OMS) and billing systems. **Strategy:** Full-scale national rollout enabling bidirectional energy measurement, remote connection/disconnection, real-time consumption tracking, automated billing accuracy, and rapid fault detection and power quality monitoring.
Implementation Model	• **In-house system development:** Enel developed proprietary meters and communication protocols, ensuring interoperability and full control over costs • **Phased rollout:** Started with regional pilots before scaling nationally • **Integration with customer service:** Enabled remote operations, reducing field visits and manual billing • **Workforce transformation:** Re-trained meter technicians as network data analysts and field responders
Financing Approach	Approximately €2.1 billion total investment (around €70 per meter, including communications and IT systems). Internal utility investment.
Outcome/ Results	• Meter reading cost: €1 per reading → €0.05 per remote reading (i.e., 95% reduction) • Billing accuracy: ‹90% → ›99% • Connection/disconnection time: Days → ‹1 hour • Non-technical losses: ~7% → ‹3% • Customer service time: Average 5 days → ‹1 day Overall, these improvements translated into enhanced revenue protection, Improved customer satisfaction and gains in operational efficiency
Critical Success Factors	• In-house technology development reduced dependency and costs • Standardized PLC + GSM hybrid communication enhanced reliability • Phased pilot-before-scale approach • Early regulatory coordination with AEEG (Italian regulatory authority) • Integration of smart meters with customer service and prepayment systems

Lessons Learned	• Partner with local assemblers to build technical capacity and reduce import costs (applicable in Nigerian DisCo context) • Adopt hybrid communication (PLC for urban, GSM/4G for peri-urban/rural) • Pilot a limited number of meters before full rollout • Link smart meters to service requests and prepayment systems • Co-design pilots with the regulator for tariff, data, and privacy frameworks
References (weblinks)	https://www.smart-energy.com/regional-news/europe-uk/enel-telegestore-project-is-on-track/ https://unece.org/fileadmin/DAM/energy/se/pp/adhoc/adhoc8May06/2_Rogai.pdf

A2.2 Case Study 2: UK Power Networks (UK)

Project Title	**Active Response & Low Carbon London**
Scope/ Modernization Objectives	Demonstrate how smart grid technologies enable distributed energy integration, dynamic load management, and real-time flexibility markets. Comprised of multiple innovation programmes such as: • **Low Carbon London (LCL):** Demonstrate how smart grids support decarbonization through demand-side response, time-of-use tariffs, and EV integration, • **Active Response (AR):** Develop software and control systems for real-time network reconfiguration, enabling flexible power flows and deferred network reinforcement, and • **Smarter Network Storage (SNS):** Deploy large-scale batteries to assess commercial and operational benefits of storage for grid balancing.
Country/City	United Kingdom (London, South East, and East of England)
Time Period	2011 – 2023 Primary phases: LCL: 2011 – 2014; AR: 2018 – 2023; SNS: 2013 – 2017)
Intervention	• **Technology Deployment:** Smart meters, LV monitoring sensors, substation data loggers, Active Network Management (ANM) systems, Dynamic Power Flow Controllers, Advanced Distribution Management System (ADMS), GIS integration, Piclo Flex flexibility platform, market interface APIs, smart tariffs, EV time-shifting, demand response portals. • **Strategy:** Layered system integrating data visibility, automation, and market participation. Active Response introduced "smart distribution brain" algorithms for automatic power flow rerouting. Focus on demand-side response, time-of-use tariffs, EV integration, real-time network reconfiguration, and deferred network reinforcement through flexible control.

Implementation Model	• **Pilot-first strategy:** Each innovation project tested in live network areas (Brixton, London City, East England) with full customer participation • **Regulatory sandboxing:** Collaboration with Ofgem allowed experimentation with dynamic tariffs and flexibility markets under controlled conditions • **Data interoperability:** Systems built on open protocols to integrate third-party analytics, EV charging data, and DER controllers • **Capacity building:** UKPN trained internal staff and partnered with universities (Imperial College London, University of Bath) for advanced modeling and analysis
Financing Approach	Ofgem's Innovation Funding Incentive & Network Innovation Competition. £43 million total innovation funding leveraged into >£250 million in avoided network investments.
Outcome/ Results	• **Network reinforcement deferral:** 10 – 20% savings through flexible control • **Voltage compliance:** >98% through dynamic reconfiguration • **Customer flexibility participation:** 3,000+ customers enrolled in Demand Side Response (DSR) and time-of-use tariff pilots • **Carbon reduction:** Estimated 13,000 tonnes of CO_2 avoided per year (LCL phase) • **Investment efficiency:** £43M funding → >£250M avoided network investments • Demonstrated digital control can replace physical reinforcement • Improved service quality and reduced customer interruptions • Validated customers as active grid participants • Direct contribution to the UK's Net Zero goals • Strong business case for smart investments
Critical Success Factors	• Innovation Directorate under Ofgem provided governance structure • Regulatory sandbox enabled tariff flexibility • Engaged consumers as active grid participants • Digital-first approach before hardware expansion • Integrated GIS, metering, and load sensors for data-driven planning • Customer flexibility participation through demand side response and time-of-use tariff pilots
Lessons Learned	• Establish Smart Grid Innovation Unit to manage pilots, data, and partnerships (applicable to DisCos in similar contexts) • Begin with SCADA/DMS upgrades before large-scale AMI rollout • Build digital twin using GIS and AMI data for predictive maintenance • Integrate prepaid system and test "flexibility communities" • Use phased, data-first integration approach progressing from visibility to automation to flexibility
References (weblinks)	https://d1oyzg0jo3ox9g.cloudfront.net/app/uploads/2023/10/Summary-Report.pdf

A2.3 Case study 3: U.S. Utilities (Con Edison, SGIG Projects)

Project Title	**U.S. Smart Grid Investment Grant (SGIG) Program – Distribution Automation & Self-Healing Networks (Con Edison as flagship urban deployment)**
Scope/ Modernization Objectives	Enhance grid reliability and resilience through real-time visibility and autonomous control. Multiple utilities participated, viz: Con Edison Smart Grid Demonstration, CenterPoint Energy SGIG Project, Southern Company Smart Grid Demonstration, PG&E Smart Grid Deployment Plan. Core objectives included deploying intelligent devices to improve outage detection, reduce restoration time, enhance situational awareness, roll out AMI and Distribution Automation (DA), integrate renewables, deploy Volt/VAR optimization, and integrate DERs into system operations.
Country/City	United States (Multiple utilities; Con Edison focused on urban New York, 3.4M customers)
Time Period	2009 – 2015 (some utilities continuing beyond 2015, e.g., PG&E 2011– present)
Intervention	• **Technology Deployment:** Automated reclosers, remote fault indicators, smart switches, voltage regulators, secure fiber and wireless networks, AMI mesh, SCADA upgrades, Distribution Management System (DMS), Outage Management System (OMS), Energy Management System (EMS), AMI portals, demand response systems, time-of-use tariffs, NIST-compliant cybersecurity architecture, multi-level authentication, encryption. **Strategy:** Multi-tiered architecture integrating field devices, control systems, and analytics platforms. Self-healing network approach with automated switches isolating faults and rerouting power within seconds. Focus on Fault Location, Isolation & Service Restoration (FLISR) systems and advanced outage management.
Implementation Model	• **Federal–Utility Partnership:** Each utility contributed 50% co-funding with U.S. Department of Energy (DOE) providing remainder under SGIG • **Phased Deployment:** Utilities first modernized control rooms (SCADA, DMS) before rolling out field automation and AMI • **Technology Standardization:** Adoption of open standards (IEC 61850, DNP3) ensured interoperability between vendors • **Data-Driven Decision-Making:** Predictive analytics tools for fault prediction, asset health monitoring, and energy forecasting • **Cybersecurity-by-design:** NIST standards guided cybersecurity integration from inception

Financing Approach	Funded under the American Recovery and Reinvestment Act (ARRA). Public-private funding model: 50% utility contribution, 50% U.S. Department of Energy (DOE) grant funding through SGIG program.
Outcome/ Results	• **Reliability (SAIDI/SAIFI):** 30-40% reduction in average outage durations in automated feeders • **Restoration time:** Power rerouted within 60 seconds on self-healing networks • **Customer engagement:** 65 million AMI meters installed nationwide • **Energy efficiency:** 1-2% system loss reduction via Volt/VAR optimization • **Carbon and cost savings:** Estimated $2 billion in avoided outage and fuel costs • **Cyber resilience:** Zero major cybersecurity incidents across SGIG projects • Demonstrated tangible reliability improvements • Showed automation impact for critical feeders • Created digital interface between customers and utilities • Enhanced operational efficiency and energy savings • Reinforced financial sustainability of smart grid investment • Validated the importance of early cybersecurity integration
Critical Success Factors	• Public-private funding partnership (SGIG) • Layered control-center-first investment approach • Open standards reduced vendor lock-in • Predictive analytics for asset management • Automated reclosers reduced outages • Cybersecurity embedded from day one • Federal-utility coordination and strong funding support
Lessons Learned	• Leverage donor co-funding (applicable to KEDCO with bilateral and multilateral agencies) • Prioritize feeder automation at critical substations • Adopt NIST-aligned cybersecurity framework early • Require open protocols for all procurements to avoid vendor lock-in • Begin with SCADA/DMS modernization before large-scale AMI rollout • Use phased deployment starting with control room modernization • Build digital twin using GIS and AMI data for predictive maintenance
References (weblinks)	https://www.energy.gov/sites/prod/files/2016/11/f34/Distribution%20Automation%20Summary%20Report_09-29-16.pdf https://research.protocol.ai/publications/smart-grid-pilot-projects/hammersley2018b.pdf

A2.4 Case Study 4: India Smart Grid Mission

Project Title	**Smart Grid Pilot Project, Puducherry / Puducherry Smart Grid Demonstration Project**
Scope/ Modernization Objectives	Implement comprehensive smart grid functionalities in Distribution Division-I: Advanced Metering Infrastructure, Peak Load Management, Outage Management System, Power Quality Management, Renewable Energy Integration, and Energy Storage. Aimed to reduce high AT&C losses (India 23.65% vs global 9.8%), improve billing efficiency, enhance IT infrastructure for 34,000 domestic consumers, enable real-time monitoring, and serve as proof of concept for nationwide implementation. Expected expansion to include water management, gas, e-medical, e-education, and e-transportation.
Country/City	India, Puducherry (Union Territory, ~1 million population, 96% literacy rate)
Time Period	Sanctioned October 2012; Milestones: December 2017 (1st completed), June 2018 (hardware/software installed), August 2018 (planned completion, delayed), declared "go live" July 2019
Intervention	• **Technology Deployment:** Smart meters with two-way communication for 34,000+ consumers, Data Concentration Units (DCUs), Meter Data Management System (MDMS), Head-End System, multiple communication technologies (RF-2.4GHz, RF-865 MHz, GPRS), SCADA/ Distribution Management System, Control Centre equipment, Outage Management System, Peak Load Management, Power Quality Management tools, renewable energy integration systems, variable tariff support, microgeneration capability. • **Strategy:** Real-time consumption visibility, remote meter reading, time-of-use pricing, bidirectional utility-consumer communication, automated billing, demand-side management, integration with RAPDRP modules.
Implementation Model	Public-private partnership: jointly developed by Power Grid Corporation of India Ltd (POWERGRID) and Puducherry Electricity Department (PED). Implemented by Dongfang Electronics Company Limited. Milestone-based approach with staged payments. Factory Acceptance Tests (FAT) for meters and DCUs before deployment. Systems integrated with existing R-APDRP [24] infrastructure. Consumer portals developed for real-time data access. Open collaboration framework for knowledge sharing across utilities.

[24] R-APDRP was a power sector scheme aimed at reducing ATC&C losses through grid modernization and related interventions. https://www.pib.gov.in/newsite/PrintRelease.aspx?relid=112254&reg=3&lang=2#

Financing Approach	50% funding from Ministry of Power (Government of India) as grant; 50% from utility/state government. 1st Milestone triggered Rs. 4.44 Crores release (January 2017). Part of 14 smart grid pilots with total cost Rs 2.9 billion (including Rs 1.3 billion government funding). Government-utility cost-sharing model designed for resource-constrained utilities.
Outcome/ Results	34,000 consumers targeted with smart meters. Control Centre established with real-time monitoring. All hardware/software commissioned by June 2018. Consumer portals were developed and shared. Integration with RAPDRP modules achieved. AT&C losses reduced close to targets. Potential 7% electricity cost reduction for consumers. Served as demonstration site for regulators and policymakers nationwide, enabling knowledge transfer to other distribution utilities.
Challenges	Unexpected public opposition to smart meter installation disrupted field work (August 2018). ~5,000 installations were pending due to community resistance. Matter escalated to the Public Accounts Committee and Estimates Committee requiring legislative intervention. Social and political barriers requiring stakeholder management. Broader Indian context challenges: interoperability between systems/ vendors, cybersecurity concerns, communication technology reliability issues, integration complexity with legacy IT systems, high costs vs. sanctioned amounts, specification changes for NSGM compliance, staff skill development needs, limited IT implementation agency support.
Critical Success Factors	Strong central government support through Ministry of Power funding. Public-private partnership sharing expertise and risk. Joint development by POWERGRID (technical) and local electricity department (operational). Milestone-based quality checks (Bureau of India Standards (BIS) certification, FAT). Comprehensive scope across multiple smart grid functionalities. Integration with existing R-APDRP infrastructure. Consumer engagement platforms from inception. Real-time monitoring and data-driven decision focus. High-literacy service territory (96%) potentially easing adoption. Part of National Smart Grid Mission providing policy framework and standards.

Lessons Learned	Public opposition can significantly delay implementation; proactive community engagement and education are essential from project start. Political and social acceptance are as important as technical readiness. Clear messaging about smart meter benefits (accurate billing, better service, consumer empowerment) needed to overcome resistance. Milestone-based implementation with certification ensures quality before large-scale deployment. Legacy system integration requires careful planning; R-APDRP integration demonstrated interoperable systems value. 50-50 central-state funding enables projects while ensuring local ownership. Pilot projects serve dual purpose: deployment and nationwide learning demonstration. Consumer portals providing real-time data access enhance acceptance. Technical standards and BIS certification critical for interoperability and quality. Techno-economic analysis before nationwide rollout optimizes investment and sets realistic expectations.
References (weblinks)	https://www.iitk.ac.in/npsc/Papers/NPSC2014/1569993451.pdf https://www.nsgm.gov.in/en/sg-pilot https://electricity.py.gov.in/sites/default/files/smart-grid-pilot-project-status.pdf https://www.researchgate.net/publication/303356161_Smart_grid_implementation_in_India_-_A_case_study_of_Puducherry_pilot_project https://pmc.ncbi.nlm.nih.gov/articles/PMC11586363/ https://electricity.py.gov.in/smart-grid

APPENDIX 3: ATC&C LOSS REDUCTION PATHWAY AND DISREP FINANCING ALIGNMENT

The content that follows in this Appendix was contributed as part of the Grid Modernization Framework stakeholder review process. It sets out a three-phase ATC&C loss-reduction pathway and maps DISREP's funded components to each phase, providing a practical bridge between the Stage 1 technology architecture described in Part B of this Framework and the financing structure available through DISREP for DisCos with approved PIPs.

The World Bank's Distribution Sector Recovery Programme (DISREP), Project P172891, is a multi-year financing programme that supports the implementation of DisCo Performance Improvement Plans (PIPs) developed under Nigeria's Power Sector Recovery Programme (PSRP). DISREP combines two financing instruments: a Programme-for-Results (PforR) component administered through the Bureau of Public Enterprises (BPE), which is the Federal Government's 40 percent shareholder in all eleven DisCos, and an Investment Project Financing (IPF) component administered through the Transmission Company of Nigeria (TCN) for bulk metering and data acquisition platform procurement. Funds are allocated against PIPs that have been reviewed and approved by the Nigerian Electricity Regulatory Commission (NERC), with disbursement triggered by performance against Disbursement Linked Indicators (DLIs) covering metering coverage, customer connections, loss reduction, and operational reliability. The programme directly addresses the same set of distribution sector failures that this Grid Modernization Framework targets: aggregate technical, commercial, and collection (ATC&C) losses estimated at 36 percent in 2017, average DisCo remittance to Nigerian Bulk Electricity Trading (NBET) of 29 percent in 2018, and constrained internal financing capacity that prevents DisCos from funding modernization from balance sheet alone. [25] [26]

[25] World Bank (January 13, 2021). Program Appraisal Document on a Proposed Loan in the amount of US$500 million to the Federal Republic of Nigeria for the Nigeria Distribution Sector Recovery Program.
[26] World Bank (February 4, 2021). Restructuring paper on a Proposed Program Restructuring of the Nigeria Distribution Sector Recovery Program.

Table 6: DISREP Financing Structure

Component	Amount (US$M)	Key Activities
IPF Component 1: Smart Meters & MDMS	233.0	3.2M smart meters, Head-End Systems, MDMS
IPF Component 3: Owner's Engineer	1.5	Supervision of meter supply & installation
IPF Technical Assistance	15.5	Implementation support, capacity building
PforR DLI1: Network Rehabilitation	150.0	MV/LV line rehab, transformer capacity
PforR DLI2: MIS Implementation	100.0	CMS, OMS, ERP, GIS, customer mapping
TOTAL DISREP ENVELOPE	**500.0**	

Phase 1: Stabilization & Visibility

This phase establishes the foundational data infrastructure required for all subsequent loss reduction interventions:

1. Customer Enumeration & GIS Mapping: Validate the entire customer base and map every meter to a specific transformer. This stops "ghost" consumption and creates the asset registry required for accurate energy accounting.
2. Boundary Metering: Install meters at 100% of the distribution transformers and feeders to pinpoint high-loss clusters immediately. This enables feeder-level loss calculation and targeted intervention.
3. Billing System Audit: Clean up the legacy billing database to eliminate estimated billing errors and non-existent accounts. This ensures that the customer information system (CIS / CMS) accurately reflects the physical customer base

Table 7: Phase 1 Activities + DISREP Funding

Strategy Activity	DISREP Funding Source	Amount (US$M)	Status
Customer Enumeration	DLI2(ii): Customer mapping for GIS	37.0	**Funded**
GIS Mapping	DLI2(ii): Field campaigns	Included in Table 6	**Funded**
Boundary Metering	IPF1: Smart meters (portion)	Part of 233.0	**Funded**
Billing System Audit	DLI2: CMS implementation		**Funded**

Phase 2: Revenue Assurance & Commercial Recovery

It focuses on eliminating commercial and collection losses, the largest components of ATC&C losses in high-loss environments:

1. Mass Metering Rollout: Aggressive deployment of prepaid meters for all residential and small business customers to eliminate collection losses. Prepaid metering ensures that revenue is collected before energy is consumed.
2. Smart Meters for Maximum Demand (MD): Ensure 100% smart metering for industrial and high-value commercial users with remote monitoring to prevent tampering. These meters provide real-time consumption data and remote disconnect capability.
3. Revenue Protection Teams: Establish dedicated units to monitor boundary meter data and conduct targeted raids on areas where "energy sent" does not match "energy billed." Analytics engines detect consumption anomalies suggesting theft or meter bypass, while BI dashboards visualize loss data showing feeder-level loss rankings, transformer hotspots, and suspected theft locations.

Table 8: Phase 2 Activities + DISREP Funding

Strategy Activity	DISREP Funding Source	Amount (US$M)	Status
Mass Metering Rollout	IPF1: 3.2M smart meters (ICB Ph 1 & 2 + Domestic)	Part of 233.0	**Funded**
MD Smart Meters	IPF1: Included in 3.2M meters	Included in Table 6	**Funded**
MDMS Deployment	IPF1: Meter Data Management Systems	20.0	**Funded**
Revenue Protection Teams	TA: Capacity building	5.5 (partial)	**Partial**

Phase 3: Network Modernization

This phase addresses technical losses through infrastructure upgrades, funded by the improved cash flows from Phases 1 and 2:

1. ABC Re-conductoring: Replace bare conductors with Aerial Bunched Cables in high-theft areas. ABC cables are theft-resistant and reduce technical losses through improved conductor efficiency.
2. Network Optimization and Load Balancing: Reconfiguring network topology, Implementing capacitor banks for reactive power compensation, Balancing load across phases for feeders and transformers
3. Management Information System Integration: Fully integrate the distribution management system (i.e, OMS, CIS/CMS, ERP, & GIS) to automate fault detection and load balancing. This enables real-time network optimization and reduces outage-related revenue losses.

Table 9: Phase 3 Activities + DISREP Funding

Strategy Activity	DISREP Funding Source	Amount (US$M)	Status
MV Line Rehabilitation	DLI1: MV/LV distribution lines	150	**Funded**
Transformer Rehabilitation	DLI1: Transformer capacity increase	Included in Table 6	**Funded**
ABC Re-conductoring	Not explicitly covered	-	**Gap**
Network Optimization and Load Balancing	Not in DISREP scope	-	**Gap**
MIS Integration	DLI2: CIS/CMS, ERP, GIS, and OMS		**Partial**

The DISREP program provides substantial financial support for the ATC&C Loss Reduction Strategy, with US$478 million (96% of total DISREP envelope) directly aligned to the three-phase approach. Key funded areas include:

- Smart meters with MDMS, DT Meters (US$233M)
- Network rehabilitation - MV/LV lines and transformers (US$150M)
- MIS implementation - CMS, OMS, ERP, GIS (US$100M)

The remaining gap areas (ABC re-conductoring, full SCADA, Network Optimization and Load Balancing, revenue protection operations) represent opportunities for complementary financing through the Grid Modernization Framework's blended financing strategy, including vendor financing, performance-based contracts, and shared infrastructure revenue.

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