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23-25 February 2025
India Expo Mart, Greater Noida, Delhi NCR, India

HARMONIZING GRIDS & SMART POWER DISTRIBUTION: EVOLVING A COLLABORATIVE APPROACH ACROSS SOUTH ASIA

Thought Leadership Paper

16th Edition ELECRAMA 2025 Powering the Future of Energy

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5th Edition

World® Utility Summit

23-25 February 2025
India Expo Mart, Greater Noida, Delhi NCR, India

Empowering Utilities:
Transforming Energy Challenges into Resilient Future

ABOUT WUS 2025

The World Utility Summit (WUS) has been at the forefront of empowering utilities to navigate the future with resilience and transformation. The 2025 edition marks the 5th iteration of this prestigious summit, which will focus on the cutting-edge technologies that will reshape the utility industry. In this Edition - Regulators, Tech Companies, Consultants, Government Officials, and Utility Leaders will all be there to share their perspectives on the challenges and opportunities that lie ahead. This gathering offers unparalleled opportunities for networking, knowledge sharing, and collaboration in

SUMMIT TRACKS:

Energizing a Greener Grid: Decarbonization Meets Distributed Solutions

This theme will explore the ongoing shift towards renewable energy sources and distributed generation models (e.g., rooftop solar) to achieve net-zero emissions. Sessions could discuss:

- Transition to Renewable energy sources & its integration
- Advancements in Energy Storage Technologies
- Policy & economic implications of decarbonization
- Innovation in Renewable Energy: advancements in solar, wind, geothermal, Hydrogen and other renewable energy technologies

Bytes & Breakers: Navigating the Digital Revolution in Utilities

This theme will delve into the impact of digital technologies on the utility industry. Sessions could address:

- Connecting to the cloud & the data landscape: Discuss how utilities can leverage cloud computing and big data for better decision-making
- Leveraging big data and analytics for optimizing grid operations and maintenance
- The changing customer experience in a digital utility environment
- Smart storage: Explore solutions for integrating energy storage into the grid to optimize renewable energy usage
- A smarter energy system: examining the risks, unlocking resilience: Explore how digitalization can build a more resilient grid
- Blockchain for Utilities amid the Energy Transition
- Big Data, Blockchain, IOT & Analytics for Grid
- Accelerated use of AI & Cloud
- Growing adoption of Modernization and Automation with Cybersecurity

Investing in Future: Building Climate Resiliency in the Energy Ecosystem

This theme will focus on strategies for building climate resilience into utility infrastructure to withstand extreme weather events like storms and floods. Sessions could explore:

- Strengthening and modernization grid infrastructure for improved resilience & to with stand extreme weather events
- Early warning systems and emergency response plans for utilities
- The role of distributed generation in enhancing grid resilience
- Adapting utility business models to account for climate risks
- Emergency preparedness and response: Developing robust plans for responding to and recovering from extreme weather events
- Expeditated the development & deployment of new technologies for managing extreme weather events
- Make Climate resilience a central part of policy framework and system planning

Harmonizing Grid Horizons: Evolving Regulatory & Policy Landscape

This theme will examine the evolving regulatory environment for the utility sector, considering the need for innovation and investment. Sessions could discuss:

- Policy frameworks for encouraging renewable energy development and distributed generation
- Regulatory reforms to promote grid modernization and digitalization
- The role of regulators in ensuring fair competition and consumer protection in the changing utility landscape
- Policy approaches for achieving national and international climate goals
- Regulation for the future: Explore how regulations can incentivize innovation in renewable energy and grid modernization
- Changing regulatory landscape: Discuss the ongoing regulatory changes impacting the utility sector

MegaWatts to MegaBytes: Confluence of Utilities and Emerging Technologies

This theme will explore the potential of emerging technologies (e.g., blockchain, Internet of Things) to revolutionize the utility sector. Sessions could address:

- Financing the Future: Unlocking the Financing for Renewable & Efficiency Projects
- Workforce Transformation: Skill & Training for Renewable Energy Economy?
- Key disruptive energy technologies: Explore technologies like small modular reactors, advanced battery storage, and hydrogen fuel cells

Session with eTECHnxt: Energy Storage – Enabling RTC Renewable Energy

- Enhancing Grid Efficiency and Reliability by Integration of Battery Storage with Renewable Energy Forecasting and Scheduling
- Role of Battery Storage in Enabling Round-the-Clock Renewable Energy Systems: Challenges, Opportunities, and Policy Implications
- Roadmap for Utilities & Industries to achieve Flexibility, Resilience, and Decarbonization

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Preamble and acknowledgement

South Asia's power sector is undergoing a transformative shift, with sustained economic growth, increased urbanization and disposable income and with new energy loads like electric vehicles (EVs) leading to a steady increase in electricity demand. At the same time, the supply side is also witnessing a change with increased penetration of clean energy and variability in the gird, while the transmission and distribution networks are aging with high loss levels and a mandate to provide affordable and reliable electricity to all. Technology can play a pivotal role in addressing these challenges and hence the focus on smart power distribution is imperative.

For adopting smart power technologies a harmonized policy framework is essential, , enhancing efficiency, and integrating renewable energy seamlessly. Clear and adaptable regulations will not only attract investments in smart power infrastructure but also provide utilities with the flexibility to adopt innovative technologies. By aligning policies across the region, governments can create a conducive environment for digitalization, automation, and demand-side management, ensuring a more resilient and sustainable power sector.

Along with policy evolution regional collaboration will be key to accelerat deployment of smart distribution applications across South Asia. A unified approach among South Asian utilities can drive shared learning, technical standardization, innovation and coordinated investments in grid modernization. Cross-border cooperation will help address common challenges such as grid reliability, financial sustainability, and cybersecurity, fostering an integrated and efficient power distribution ecosystem. By combining regulatory harmonization with strategic regional partnerships, South Asia can unlock the full potential of smart power distribution, enhancing energy security and enabling a more connected and future-ready grid.

Given this context, this thought leadership paper has been developed with the support of KPMG in India:

1. Vikas Gaba, Partner and National Lead, Power and Utilities
2. Ruchika Chawla, Associate Partner
3. Vivek Aggarwal, Associate Director
4. Abhishek Sarkar, Associate Director
5. Anand Gopalakrishnan, Associate Consultant

The paper examines the need and proposes a framework for promoting collaboration between South Asian utilities for uptake of the smart distribution applications and accelerate technology deployment to ensure delivery of reliable and affordable power to all.

It emphasizes the role of smart, agile, and resilient distribution utilities for ensuring clean energy transition and highlights the need for a collaborative approach across the region. The paper also outlines mechanisms to ensure regional collaboration on smart power distribution.

The team has developed this paper based on a comprehensive review of both primary and secondary data, as well as insightful discussions with key stakeholders. The team would like to thank the senior leadership from the power distribution sector across South Asia, industry,

and subject matter experts, for their views and insights which have helped shape this paper. We hope that this paper is informative for policymakers, technology providers, think tanks, academicians, donor organizations, and others working on expanding regional collaboration on power distribution across the South Asian region.

Table of Abbreviations

Abbreviation	Definition
4G	Fourth Generation
AC	Alternating Current
ADMS	Advanced Distribution Management System
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
APG	ASEAN Power Grid
ASEAN	Association of Southeast Asian Nations
BESS	Battery Energy Storage System
BREB	Bangladesh Rural Electrification Board
BVLOS	Beyond Visual Line of Sight
CBET	Cross-Border Electricity Trade
CEA	Central Electricity Authority
CESC	Calcutta Electric Supply Corporation
DBFOOT	Design Build Finance, Own, Operate and Transfer
DC	Direct Current
DCU	Data Concentrator Unit
DERMS	Distributed Energy Resource Management Systems
DERs	Distributed Energy Resources
DISCOMs	Distribution Companies
DSOs	Distribution System Operators
DMS	Distribution Management System
ESS	Energy Storage Systems
EV	Electric Vehicle
FDRE	Firm and Dispatchable Renewable Energy
GESI	Gender Equality and Social Inclusion
GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
HV	High Voltage
HVDC	High-Voltage Direct Current
IEC	International Electrotechnical Commission
IEDs	Intelligent Electronic Devices
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ISGF	India Smart Grid Forum
KERI	Korea Electrotechnology Research Institute
LBNL	Lawrence Berkeley National Laboratory
LIDAR	Light Detection and Ranging
MEL	Monitoring, Evaluation, and Learning
ML	Machine Learning

Abbreviation	Definition
MW	Megawatts
MWh	Megawatt-hours
NDCs	Nationally Determined Contributions
NIE	Northern Ireland Electricity
NREL	National Renewable Energy Laboratory
NSGM	National Smart Grid Mission
OMS	Outage Management System
P2P	Peer-to-Peer
PBC	Performance-Based Contracting
PG&E	Pacific Gas and Electric Company
PPP	Public-Private Partnership
PuVVNL	Purvanchal Vidyut Vitaran Nigam Limited
PV	Photovoltaic
RED II	Renewable Energy Directive II
REL	Reliance Energy Limited
R-APDRP	Restructured Accelerated Power Development and Reforms Programme
ROI	Return on Investment
SACs	South Asian Countries
SCADA	Supervisory Control and Data Acquisition
SGKC	Smart Grid Knowledge Centre
SMS	Short Message Service
SBDs	Standard Bidding Documents
SP Group	Singapore Power Group
TPDDL	Tata Power Delhi Distribution Limited
Totex	Total Expenditure
UPPCL	Uttar Pradesh Power Corporation Limited
V2G	Vehicle-to-Grid
VRE	Variable Renewable Energy

1 Introduction: South Asia's distribution challenges

1.1 Evolving Power Sector Landscape for South Asia

South Asia is transforming its power systems to meet rising electricity demand, net-zero commitments, and energy security priorities.

According to the International Energy Agency (IEA), global electricity demand is projected to increase by 2.1% annually till 2040, with developing regions contributing nearly 90% of this electricity growth. The contribution of South Asia is expected to be substantial, where the electricity demand has grown by more than 5% per annum, since start of the 21st century and is expected to more than double by 2050. Population growth, increasing urbanization and disposable incomes with increased industrialization and improved electricity access rates are the key contributors to this trend. With a per capita electricity consumption of around ~1200 kWh in 2023, which is less than half of the global average, energy demand will continue to grow as the region grows economically.

On the supply side, the region is currently dependent on fossil fuels for promoting economic growth. The region imports nearly two-thirds of its energy requirement and about 80 percent of energy production is fossil fuel based. This not only gives rise to energy security concern but has implications on the balance of payment the region, and also contributes to increase Green House Gas (GHG) emissions. The South Asian Countries have taken up clean energy targets and net zero pledges in order to meet the energy security, economic growth and environmental imperative trilemma. Figure 1 below presents the commitments made by SACs to integrate renewable energy into their power systems and meet their net-zero obligations.

- IEA. (2019). International Energy Agency. Retrieved from https://www.iea.org/reports/world-energy-outlook-2019/electricity
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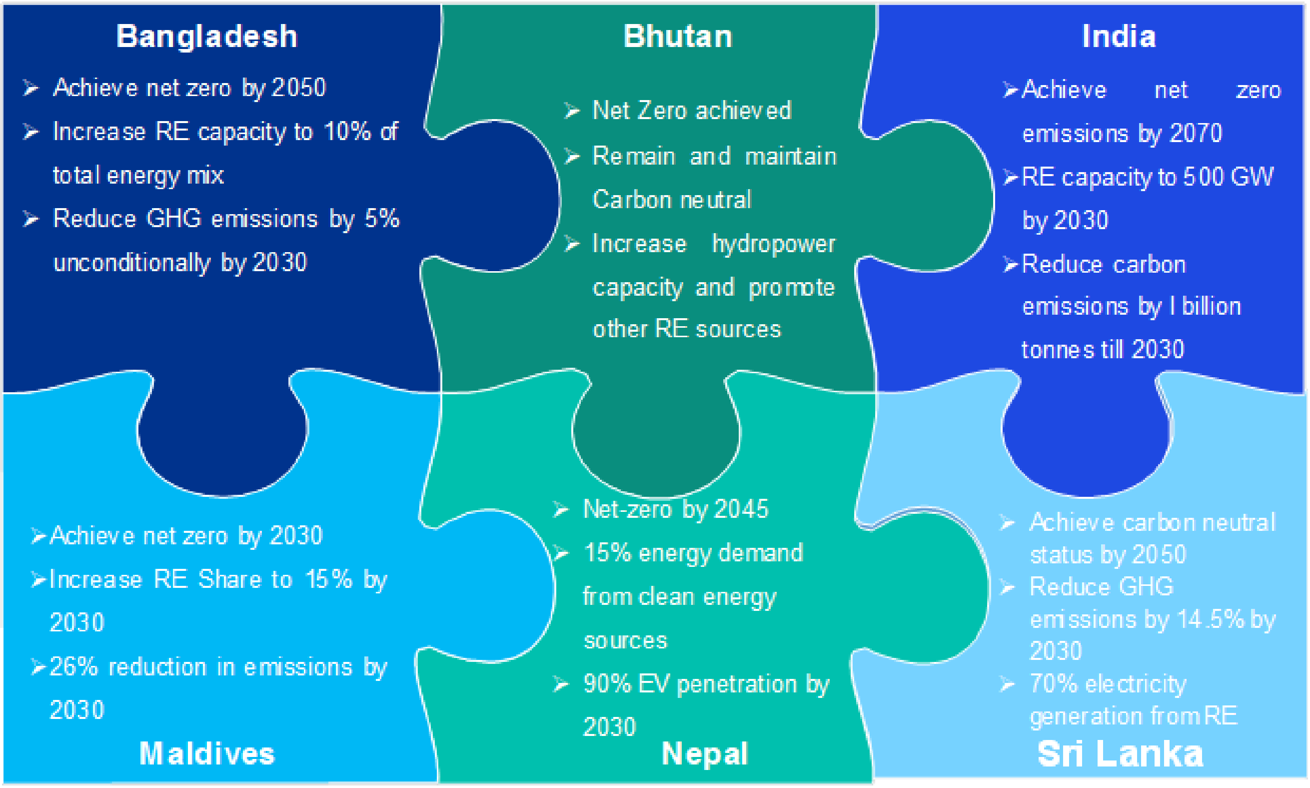


Figure 1: Climate commitments (NDCs) by South Asian countries (Source : Teri, UNFCCC, Countries government websites)

The South Asian region has set a target to more than triple its renewable energy capacity from 185 GW in 2023 to 605 GW by 2030 to meet the rising electricity demand driven by economic growth.

The evolving dynamics of electricity demand and supply has far-reaching implications on the power infrastructure in the region, which is already facing challenges such as aging and efficiency. Smart distribution applications as adopted can help South Asia utilities to meet their energy challenges effectively and efficiently. This is the focus of the current paper.

This paper discusses various smart distribution applications and presents international good practices for adoption of these applications. There is varying level of adoption of these applications in South Asia. This paper proposes a framework for promoting collboation between South Asian utilities for uptake of the smart distribution applications and accelerate deployment.

In the next sectiion we discuss common challenges faced by the South Asian distribution utilities (DISCOMs) and the role of smart distribution technologies in addressing these challenges. The section delves deeper into smart distribution technologies by illustrating internatoinal good practices adopte. The final section presents a framework for collabration in South Asia for smart distribution.

1.2 Power Distribution: Legacy and Emerging Challenges

Power distribution is a critical link in the electricity value chain as it provides the revenue stream to entire value chain. However, it remains to be the weakest across South Asia. There are several challenges that the South Asian DISCOMs, some emanating from legacy issues and some from the changing nature of the power sector. Legacy (or traditional) issues include aging infrastructure, high distribution losses and focus on ensure reliable and affordable electricity supply. The recent (early 2025) power outage in Sri Lanka consequent to a monkey coming in contact with a transformer at a substation, leading to disruption in electricity supply across the island country is a case in point of the legacy issues faced by the region's power distribution.

The emerging challenges originate from the evolving structure of the power sector, including grid integration of renewable energy, climate change and new and emerging loads. As mentioned in the previous section, the region aims to triple its renewable energy capacity and the interventions need to be planned such that the grid stability is maintained as the share of renewable energy increases. The South Asian region is one of the most vulnerable regions from a climate change perspective. For instance, the heat wave faced by the region in 2024 led to an unprecedented increase in electricity demand, and the DISCOMs struggled to meet increased electricity demand. According to Grid India (India's Power System Operator), there is a 11 percent or more increase in demand at temperatures above 30 C from demand at temperatures of 21–24 C. Moreover, heatwave derates generation capacity for renewable energy resources (solar, wind and battery storage) as well for thermal generation and there is loss of efficiency also for transmission networks.

The figure below presents these challenges in the South Asian context, highlighting the commonality of the challenges faced by the South Asian DISCOMs.

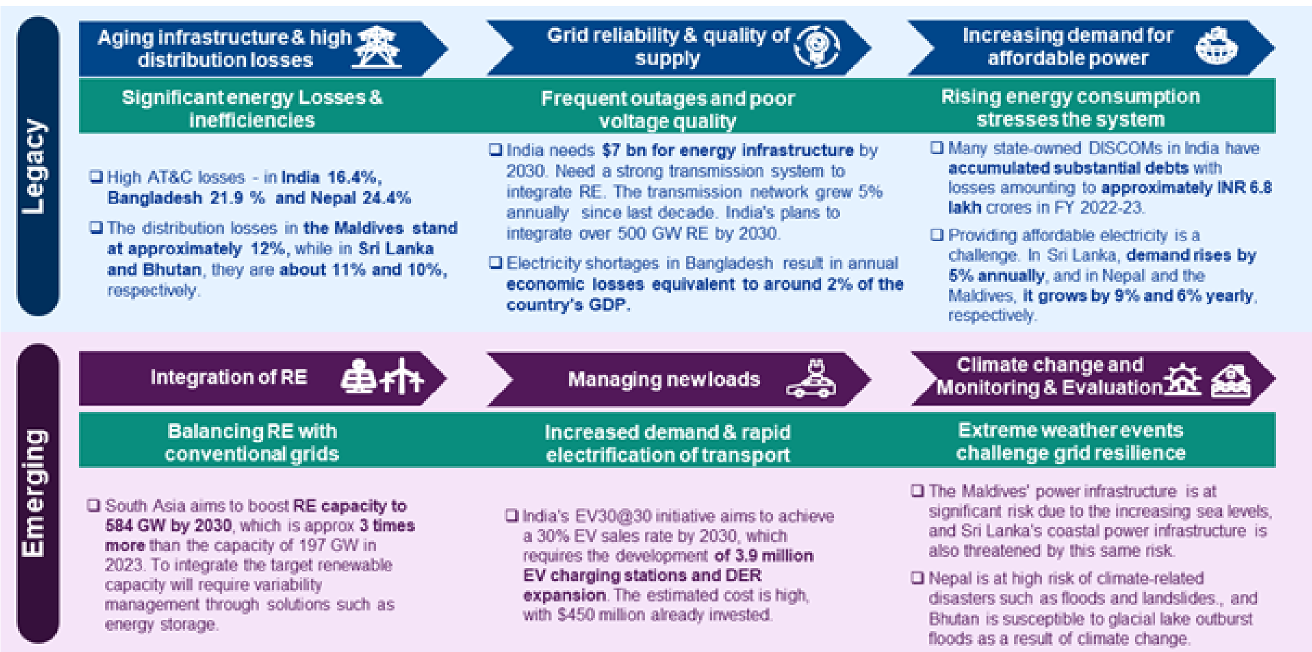


Figure 2: Legacy and emerging challenges across South Asian countries (Source: World Bank Group, ADB, CEA, PIB)

To address these legacy and emerging challenges South Asian DISCOMs are already implementing distribution modernization initiatives like smart metering, Supervisory Control & Data Acquisition (SCADA) systems, grid-scale energy storage solutions, etc., through both operational and structural measures. Figure below highlights the distribution modernization initiatives underway across South Asian DISCOMs to solve legacy and emerging challenges.

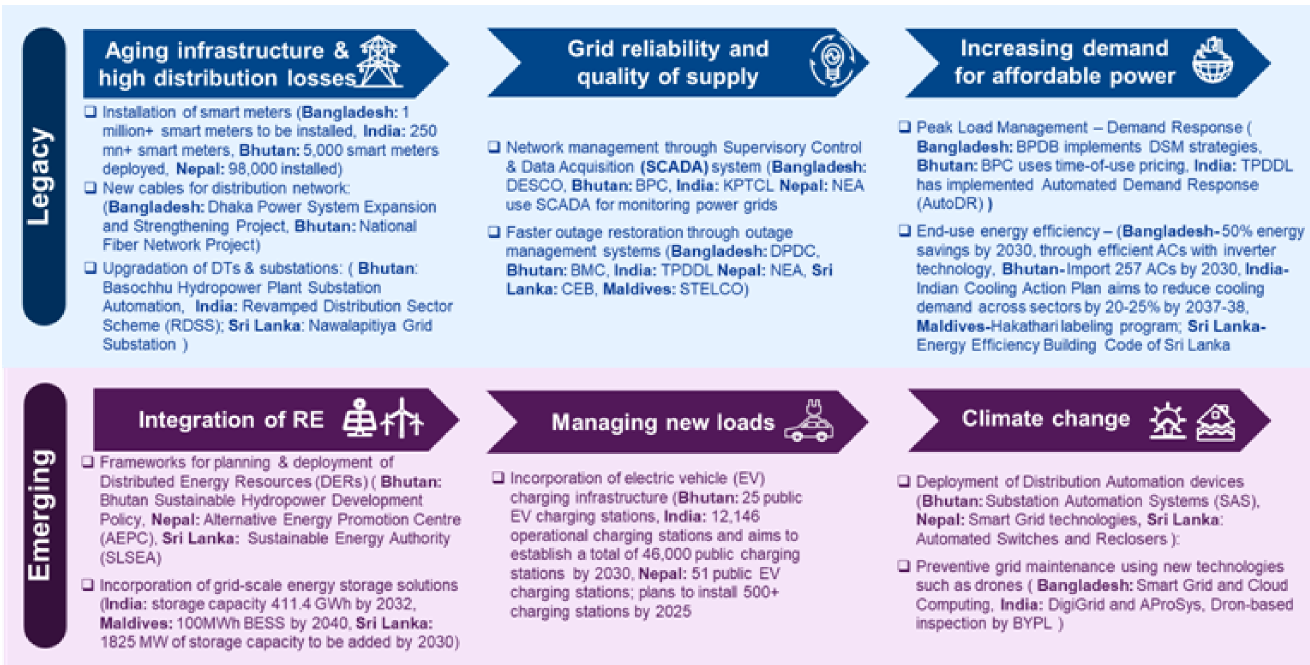
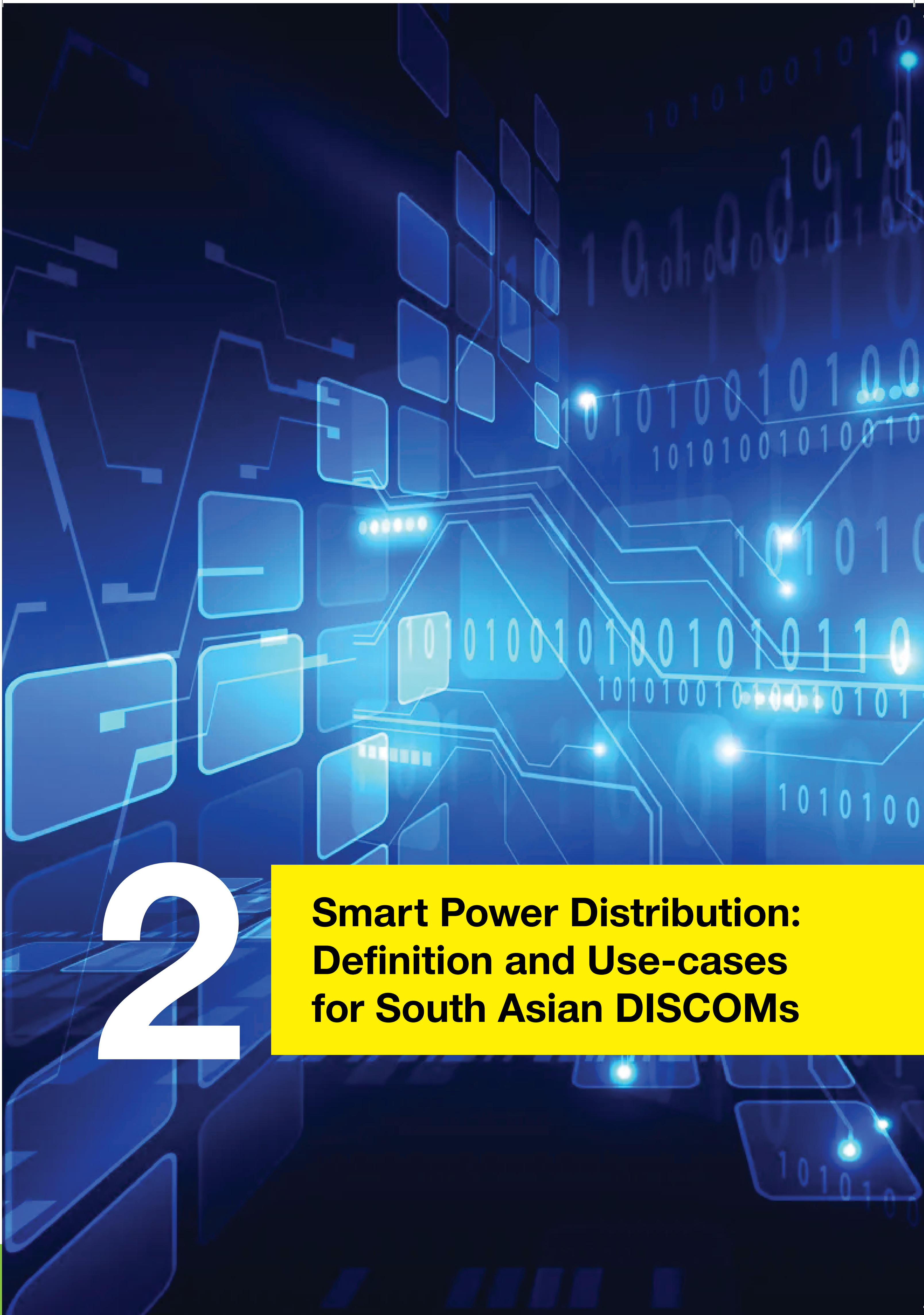


Figure 3: Interventions across South Asian Countries (Source: ADB, Nepal Energy Forum, PIB, World Bank, Bangladesh Power Management Institute (BPIM))

As can be seen from above, technology is central to the solutions for the common challenges faced by the South Asian utilities. While some of the DISCOMs have taken up interventions, however, the rate of adoption varies across. Also, there have been technological advances, such as integration of Artificial Intelligence in solutions that are yet to be adopted DISCOMs. Interventions for adopting a customer centric approach to electricity delivery and cyber security are areas where interventions are at nascent levels. This is where is a scope of the South Asian DISCOMs to learn from international practices as well as learn from each other.

In the section we delve deeper into smart distribution, its concept relevance for the South Asian DISCOMs.

• COVID-19 impact on Indian electricity grid operations and pan-India lights out event of 5th April 2020



2

Smart Power Distribution: Definition and Use-cases for South Asian DISCOMs

2.1 About Smart Distribution Technologies

Smart distribution involves transitioning from traditional to smart and finally to a data-driven next-generation distribution grid that unlocks full potential in power infrastructure and network, delivering value, quality, and innovation to end consumers.

An Expert Group led by Central Electricity Authority (CEA) and convened by the National Smart Grid Mission (NSGM), India has defined 'Smart Distribution' as, ***"A robust electric network equipped with automation, communication and IT system enabling a two-way flow of electricity and data to ensure 24x7 reliable and quality power supply to the electricity consumers."***

In essence, the objective of Smart Distribution is to create a more efficient, reliable, and sustainable electricity grid that benefits both DISCOMs and consumers while minimizing impact on the environment (see figure below).

Figure 4: Smart Distribution Objectives (Source: KPMG Analysis)

The key benefits of Smart Distribution technologies include:

- **Flexible, reliable and resilient distribution grid:** Smart Distribution technologies enable real-time monitoring and control of network/ resources, load flow, loss computation, forecasting, predictive maintenance of network equipment etc. This helps maintaining the reliability of grid, while ensuring its flexible to absorb any demand or supply side change.
- **Improved DISCOM efficiency:** Interventions like AMI, drone-based asset management, demand response, and IoT-based asset monitoring improve operational and financial efficiency of DISCOMS by reducing network/ equipment downtime, avoiding unscheduled outages, reducing T&D losses, optimizing power purchase, and reducing Operations & Maintenance expense, etc.
- **Enhance consumer centricity:** With technologies such as P2P energy trading, demand

response, AMI-based analytics, OMS, etc. consumers can have access to real-time information on their energy use, updates on important events/ outages, notifications for safety/ protection and loading pattern. The DISCOMs can support in faster resolution of consumer concerns, enable consumer participation in power markets and/or grid support functions under Demand Response programme and provide choice to consumers, adopting a consumer centric approach.

- **Improved decision-making and management:** Smart Distribution enables real-time monitoring and control of distribution assets. With improved information flow across all levels, improved reporting and dashboarding and actionable insights, South Asian DISCOMs can better manage operations and fasten day-to-day decision-making.
- **Increase flexibility and agility for utilities of the future:** Smart distribution applications provide flexible and agile platforms to DISCOMs for fast response to different changes in the business environment including policy/ regulatory changes, change in demand or supply patterns or any other external change impacting business.
- **Improved power quality and asset/ workforce safety:** Technologies such as Automatic Power Factor Control (APFC), Static Var Generator (SVG), Active Harmonic Filters, Power Quality Monitors (PQM) and Smart Inverters help counter imbalances caused by variable clean energy and other non-linear loads. Technologies such as video surveillance, arc sensors, smoke detectors, hot spot detectors, fire control systems etc. are key for health and safety of personnel and ground assets.

• The key planning electricity body in India

As can be seen from above, there is a match between the benefits of smart distribution technologies and the interventions required to address the common challenges of South Asian DISCOMs, discussed earlier.

The Singapore case presented below is a case in point of the benefits that accrue with adoption of smart distribution interventions (See Box 1).

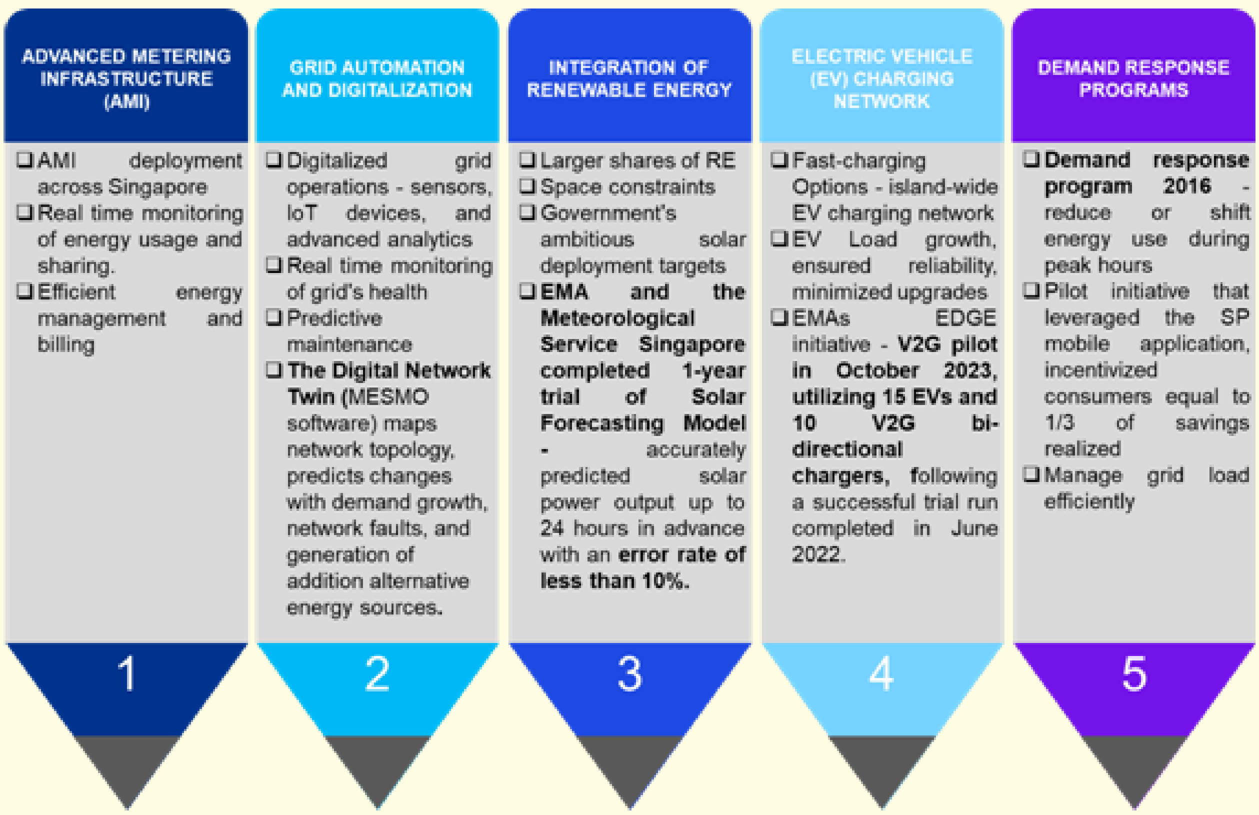
Box 1: Case Study -- Singapore Power Supply Network (Source: SP Group Official Page)

Problem Statement: Singapore Power (SP) Group has one of the most reliable and robust power systems catering to over 140,000 customers. The Group recognized the critical need for energy sustainability, efficiency, and reliability has proactively deployed smart grid technologies to enhance its power distribution network, setting a model for urban centres worldwide.

Objective: SP Group deployed smart grid technologies to:

- Enhance reliability and efficiency of electricity distribution.
- Facilitate integration of renewable energy sources into the power grid.
- Empower consumers with real-time information for better energy management.
- Support electrification of the transport sector through the expansion of EV charging infrastructure.
- Align with Singapore's climate goals by reducing the carbon footprint of the energy system.

Interventions: Singapore's SP Group has successfully leveraged smart grid technologies to enhance its power distribution network's efficiency, reliability, and sustainability. The Group's interventions serve as a model for urban centres worldwide, demonstrating how technology can transform energy systems to meet contemporary challenges while paving the way for a more sustainable future.



Outcome: SP Group's deployment of smart grid technologies achieved the following -

- Improved operational efficiency and reduced operational costs through digitization.
- Enhanced grid reliability by reducing the frequency and duration of power outages. Customers experienced an average of just 0.25 minutes of electricity interruptions. Additionally, 98% of all electricity interruptions are restored within two hours, and 90% are restored within one hour.
- Singapore's electricity production capability grew by 2% from 12,756 MW in 2022 to 13,062 MW in 2023. This growth was mainly due to the expansion of solar PV systems, which experienced a 46% rise in installed capacity, supporting sustainability objectives.
- Empowering consumers through better access to energy usage data, enabling improved energy management and conservation practices.
- Supported installing over 1,400 EV charging points, paving the way for a sustainable transportation future.

Smart Distribution technologies/ use cases have applications across all the core functions of a DISCOM, i.e., revenue management, network planning, asset health monitoring and maintenance, grid stability and operations, and customer services as well as the typical corporate functions such as finance, human resource etc. Smart distribution technologies can help resolve the South Asia DISCOMs challenges.

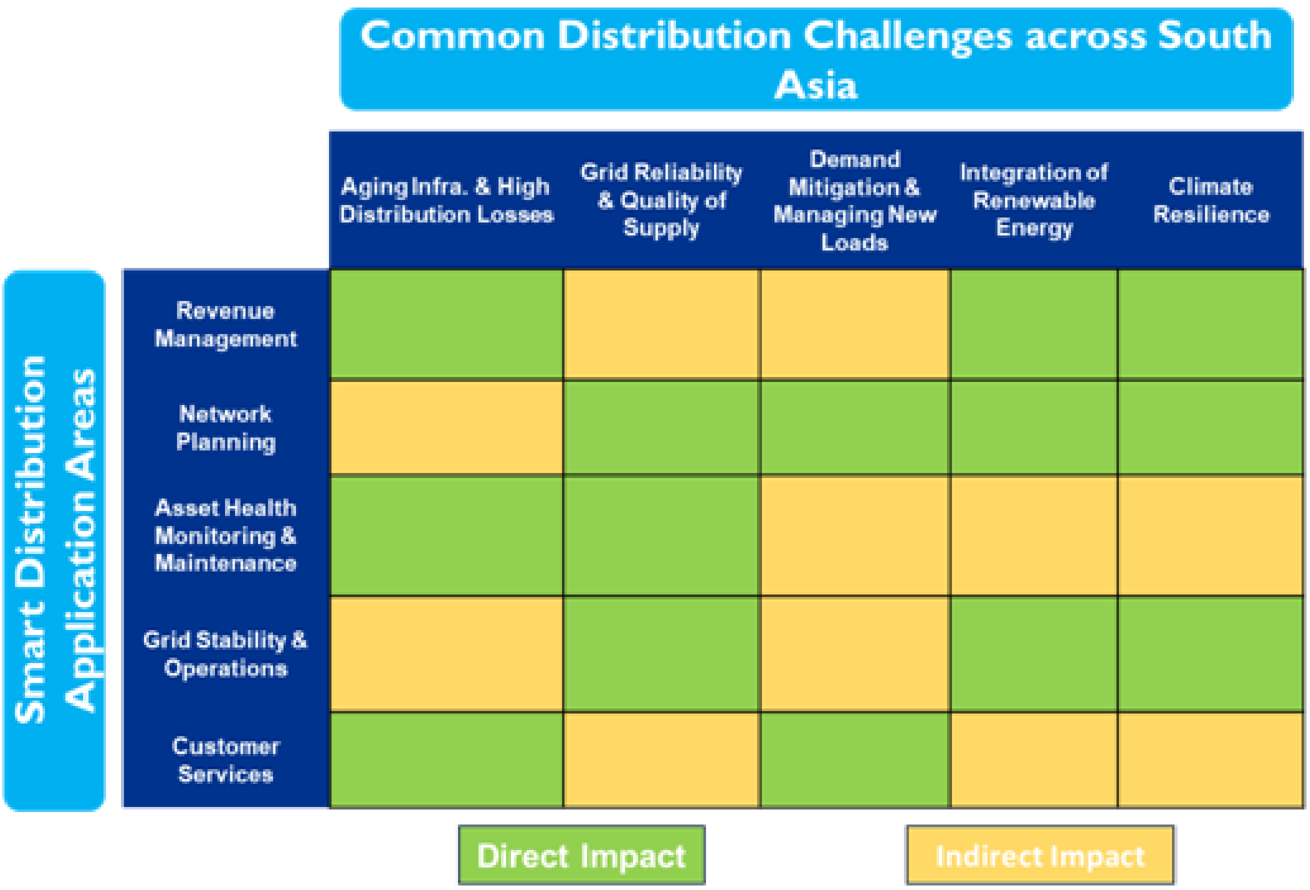


Figure 5: Core functions mapping to common priorities in South Asian Countries (Sources: KPMG Analysis)

Building on the above, in the subsequent section, we discuss the rationale for regional cooperation/ collaboration on developing and deploying smart distribution technologies and their use cases within the South Asia region.

2.2 Regional collaboration to accelerate adoption of smart distribution technologies

To re-emphasise, South Asian DISCOMs face common challenges and common goals to deliver reliable, quality, affordable, and clean power to all. The experience these DISCOMs have with implementing distribution modernization initiatives varies, with most being in the early stages of their transition towards a clean and smart energy future. Therefore, collaboration across South Asian DISCOMs, in planning and implementing future smart distribution initiatives could foster innovation, efficiency, and shared resources, leading to smooth and seamless implementation and improved outcomes. By collaborating on resources, expertise, and technological prowess, South Asian DISCOMs can develop a resilient electricity system that operates efficiently and achieves common regional goals.
So far, regional energy collaboration in South Asia has been limited to Cross-Border Electricity Trade (CBET). Smart distribution technologies present an opportunity for the region to expand regional cooperation beyond CBET. While the detailed framework for regional cooperation in smart technologies is discussed in detail subsequently, in principle, such a collaboration will be built on harmonisation of priorities, expanding the scope from (energy) consumption to capacity creation and developing innovation led business models. Regional collaboration can play a catalytic role in making smart distribution transformation faster and more efficient.

In the subsequent section, we will discuss in detail the potential areas of collaboration and specific smart distribution technologies/use cases that can be planned and deployed through regional collaboration.

2.3 Potential Areas of Collaboration

The array of technologies driving ‘smart’ functionalities in power distribution networks is expansive. These technologies equip utilities to navigate challenges and capitalize on opportunities with unprecedented agility and insight. It requires discoms to understand these technologies and prioritise based on their specific context.

As illustrated in the figure below for utilities, the modernization landscape is broad, covering core operational technologies such as SCADA, load forecasting, and substation automation to strategic corporate functions like performance management and vendor analysis. It spans pivotal areas, including energy portfolio management, smart energy storage, vehicle-to-grid (V2G) technologies, and cutting-edge solutions like AI-powered chatbots and drone-based asset management.
The smart distribution solution framework in the figure below offers a structured approach through 8 fundamental technology functions, encompassing core operational and corporate support functions, further branching into specific technology use cases. The framework addresses not only core utility functions but also incorporates corporate functions, demonstrating its expansive scope.

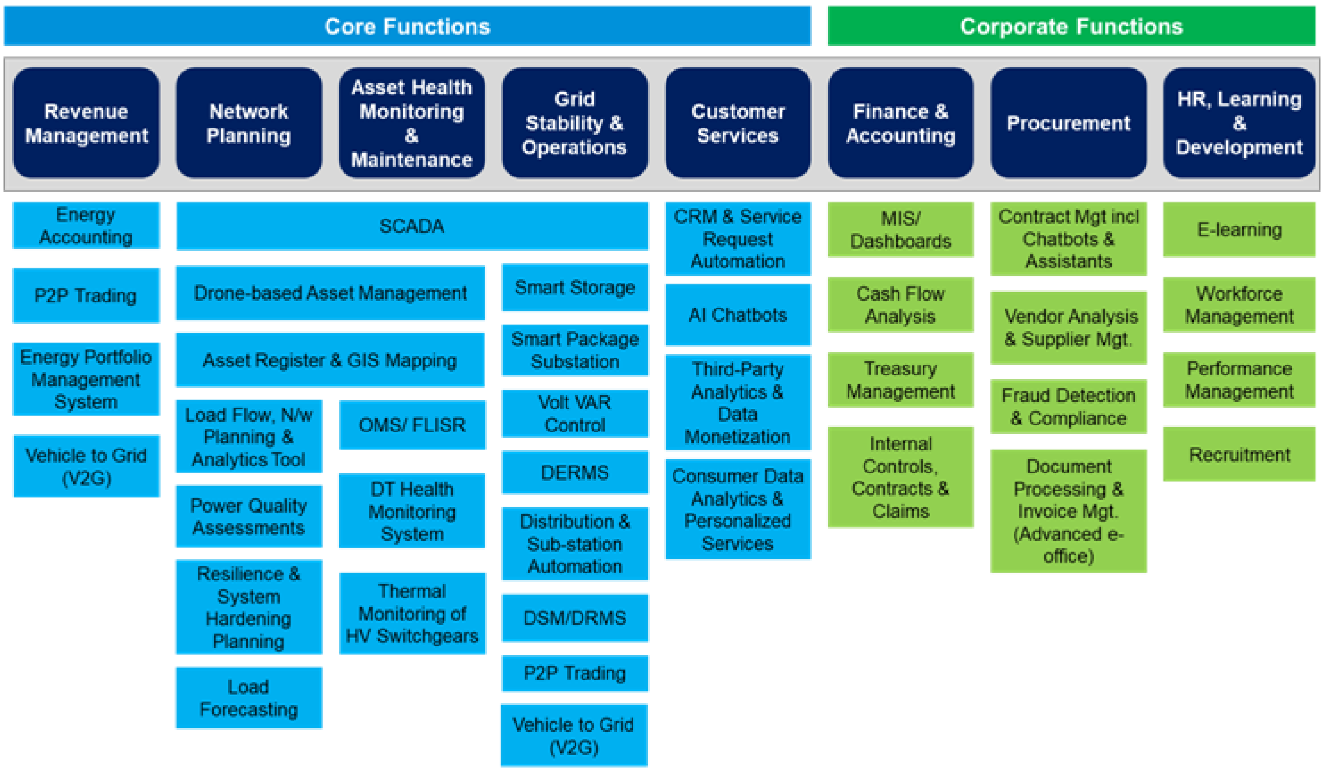


Figure 6: Framework of Smart Distribution Technology/Use cases.

These address many core utility functions such as revenue management, network planning, asset health monitoring and maintenance, grid stability and operations and customer services. Additionally, it integrates corporate functions like finance and accounting, procurement, HR, and learning and development.

2.4 Technologies Enabling Smart Power Distribution

This section introduces a spectrum of smart distribution technologies that enable distribution modernization, underscoring their potential to revolutionize DISCOM operations through improved efficiency and sustainability. These transformative technologies are essential not only as tools for advancement but also as avenues for collaboration. By embracing these technologies and pooling expertise, utilities in South Asian countries can capitalize on their collective strengths to meet regional energy objectives and catalyse innovation in power distribution.

2.4.1 Grid management and automation system

a) About the technology options

SCADA, DMS, and OMS represent pivotal technologies for modern utilities, each serving a critical function in enhancing power distribution efficiency. SCADA facilitates real-time monitoring and control, DMS leverages advanced analytics to optimize grid operations, and OMS improves outage detection, response, and restoration. Additionally, substation automation employs intelligent electronic devices for remote operations, significantly reducing the need for manual intervention and boosting system reliability. These technologies collectively form the backbone of intelligent power distribution networks, enhancing operational efficiency, reliability, and system resilience.

For South Asian DISCOMs, these technologies are particularly vital. They enable predictive maintenance, automated fault detection, and efficient load management—key capabilities given the region's escalating electricity demand and ageing infrastructure. By minimizing power losses, enhancing reliability, and facilitating the integration of renewable energy, these systems markedly improve the operational landscape of power utilities.

Moreover, these technological implementations enrich network planning with refined load forecasting, optimize asset health monitoring, and ensure grid stability. They also enhance customer satisfaction by reducing service interruptions.

b) Implementation Examples:

Few examples of implementation of grid management and automation system both globally and in South Asia have been provided in table 1 below.

Table 1: Implementation examples of grid management and automation system

Region	Entities	Implementation Details
Global (Guatemala	Energuate, the electricity company in Guatemala and the largest in Central America	• The first cloud-hosted SCADA system globally implemented in collaboration with Energuate in 2023 • It enabled advanced operation and monitoring of Guatemala's national electricity grid, catering to over 2.2 million customers across nearly 50,000 miles of power grid. • Incorporated best user experience practices and advanced analytical capabilities, the new PRISM SCADA system significantly improves incident resolution times and decision-making. • Cloud deployment facilitates automatic resource allocation, shifting from fixed to consumption-based variable costs, cutting initial investment and infrastructure update expenses by up to 50%. • Minimized installation-related onsite activities and supports scalable grid architectures.
South Asia (Bhutan)	Bhutan Power Corporation Limited	• SCADA systems installed and commissioned at Jemina, Gedu, and Gomtu substations. • These advancements significantly enhance control, monitoring, and data analysis capabilities, improving efficiency and reliability across the power grid.

2.4.2 Advanced Metering Infrastructure (AMI) & Data Analytics

a) About the technology

Advanced Metering Infrastructure (AMI) and data analytics are pivotal in elevating power distribution systems. Smart meters, sophisticated communication networks, and data management systems enable precise real-time monitoring, accurate billing, and improved demand management. AMI notably helps in mitigating power theft losses and fosters energy conservation, enhancing grid efficiency overall. Furthermore, consumers gain access to detailed energy usage information, encouraging better consumption habits.

Data analytics, enriched with artificial intelligence and machine learning, further refines grid operations. This technology supports predictive maintenance strategies by identifying potential equipment failures before they occur, reducing downtime and minimizing operational costs.

b) Implementation Examples

Few examples of implementation of AMI and data analytics both globally and in South Asia have been provided in table 2 below.

Table 2: Implementation examples of AMI & data analytics

Region	Entities	Implementation Details
Global (United States of America)	U.S. electric utilities	• In 2022 , U.S. electric utilities had about 119 million advanced (smart) metering infrastructure (AMI) installations, equal to 72% of total electric meter installations. Residential customers accounted for about 88% of total AMI installations, and about 73% of total residential electric meters were AMI. • AMI includes meters that measure and record electricity usage at a minimum of hourly intervals and provide the data to the utility and the utility customer at least once a day. AMI installations range from basic hourly intervals to real-time meters with built-in two-way communication capable of recording and transmitting instantaneous data.
Global (European Union)	European utilities	• Aimed for 20% reductions in GHG emissions and primary energy use and 20% renewable energy penetration by 2020, driving the deployment of nearly 200 million smart meters. • Establishes common rules for an internal electricity market, promoting smart grids, distributed generation, energy efficiency, and innovative pricing schemes. • Varying success among DSOs; some countries like Sweden and Italy completed smart meter rollouts, while others like Belgium and Germany struggled due to a lack of incentives. • Europe stands out as a leading region in AMI adoption, having installed approximately 155 million smart meters across various countries. • The region boasts a completion rate of about 70%, demonstrating robust regional commitment and a well-coordinated approach towards smart grid and AMI deployment. • European countries were among the early adopters of AMI, initially enhancing traditional metering systems by integrating communicating meter infrastructures.

South Asia (Bangladesh)	Bangladesh Rural Electrification Board (BREB)	• BREB is installing 500,000 smart prepayment meters with AMI solutions to modernize Bangladesh's power distribution system. • Enables automated meter reading, accurate billing, reduced system losses, and access to detailed energy usage information and time-of-use tariffs. • Enhances grid resilience, connects smart home devices, and optimizes infrastructure investments with advanced data analytics. • Aimed to improve customer service with timely issue resolution, better communication, and greater transparency, addressing daily electricity shortages
South Asia (Nepal)	Nepal Electricity Authority	• Implemented a pilot on smart pre-paid meters in two Micro Hydro Projects (MHPs) in Solukhumbu and Okhaldhunga, installing 1,308 meters to ensure timely revenue collection. • MHPs are vital for electrifying remote areas in Nepal, where extending the national grid is difficult, and traditional energy sources are still in use. • Addressed issues like overloads and inefficient tariff collection with an SMS-based recharge system, ensuring timely revenue and improved sustainability. • Enhanced efficiency, reduced complaints, and better power quality improved working conditions for operators and managers.

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2.4.3 GIS Mapping

a) About the technology

GIS mapping integrates geographic and electrical network data into a single platform, providing utilities with a comprehensive view of their infrastructure. This technology enhances planning, asset management, and network reliability while reducing downtime. The GIS mapping facilitates efficient transmission/ distribution line and substation planning, leading to faster service response and improved customer service.

Utilities can optimize equipment placement, anticipate issues, and enhance grid stability by modelling and analysing scenarios. Ultimately, GIS mapping strengthens power networks by improving reliability, efficiency, and response times, making it a critical tool for effective network management.

b) Implementation Examples:

Few examples of implementation of GIS mapping both globally and in South Asia have been provided in table 3 below.

Table 3: Implementation examples of GIS mapping

Region	Entities	Implementation Details
Global (United States of America)	U.S. Electric and Gas utility	• Ameren , an electric and gas utility in Saint Louis, Missouri, serves 2.4 million and 900,000 natural gas customers across Missouri and Illinois. • Faced issues with outdated field mapping solutions and integrated epoch field, a cross-platform mobile mapping solution, to provide real-time GIS and work management data to over 4,000 field users. • The GIS implementation has improved efficiency with automatic daily data updates, overcoming deployment challenges during the pandemic, and aimed to equip over 4,000 mobile workers with up-to-date asset information by 2022.
Global (Australia)	Australian Power Distribution Utility – Queensland	• Energy Queensland , operating one of the world's largest energy networks in north-eastern Australia, faces extreme weather conditions and the need to provide stable, low-cost energy while transitioning to 50% renewable energy by the end of the decade. • Implemented GIS technology to create a 3D digital twin of its network, improving asset management, resilience, and customer communication while integrating diverse energy sources, including thermal, hydro, wind, and solar. • Enhanced network resilience and efficiency, better prediction and response to weather events, and inspired other utilities globally to adopt similar transformations and collaborate on achieving net zero emissions.

South Asian (India)	Reliance Energy Limited (REL) – power distribution operations	• Reliance Energy Limited (REL) , India's leading private power utility, needed to improve service quality, asset management, and outage response for its 25 million customers across 124,300 square kilometres. • Implemented a GIS-based system using Esri ArcGIS platform, integrating GIS with traditional power distribution to enhance asset mapping, real-time alerts, and geospatial analysis. • Achieved quicker detection of faulty lines, faster action, improved asset management, and better network planning, supporting the success of R-APDRP projects.

2.4.4 Advanced Technologies for Distribution Infrastructure Health Management

a) About technology options:

- Drone-based Asset Monitoring: Drone-based Asset Monitoring utilizes drones with advanced sensors (cameras, thermal imaging, LiDAR) to capture real-time data on network assets in inaccessible areas. Data is analysed using AI and ML technologies to identify faults and weak links, providing cost-effective visual inspections, improving safety, reducing outage times, and lowering maintenance costs.

- DT Health Monitoring: It uses sensors to capture real-time physical and electrical data from transformers, which are analysed centrally with predictive maintenance techniques. Involves electrical and non-electrical sensors, a DCU, a 4-G Gateway, AI/ML-based analytics software, and middleware for alerts, enabling early detection of asset degradation, reducing downtime, and lowering maintenance costs.

- Thermal Monitoring of HV Switchgear: Monitors real-time physical and electrical data of transformers using a combination of sensors, with data sent to a central system for analysis using AI/ML-based predictive maintenance. Utilizes middleware for alerts and a 4-G Gateway, with thermal sensors alerting unsafe temperatures, preventing outages, and extending switchgear life through proactive maintenance.

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b) Implementation Examples:

Few examples of implementation of advanced technologies for distribution infrastructure health management both globally and in South Asia have been provided in table 4 below.

Table 4: Implementation examples of distribution infrastructure health management

Region	Entities	Implementation Details
Global (United States of America)	U.S. electric utilities	• Duke Energy aimed to improve power reliability and strengthen the electric grid in Boone and Hamilton counties. • Used drone inspections operated by licensed pilots to safely and efficiently inspect overhead power lines, substations, and transformers, capturing visual and GPS data. • Enhanced safety and efficiency in inspections, improved identification and repair of equipment issues, and ongoing inspections in multiple locations.
Global (United Kingdom)	UK National Grid	• UK's National Grid needed a safer, more efficient, cost-effective method to inspect power lines and substations across England and Wales. • Deployed advanced drones with high-tech sensors (thermal cameras, LiDAR) to capture data and generate 3D models, enabling precise maintenance planning and collaborating with the UK Civil Aviation Authority for Beyond Visual Line of Sight (BVLOS) flights. • Enhanced safety and efficiency in inspections, improved identification and repair of equipment issues, and readiness for large-scale deployment with AI integration for further efficiency improvements.
South Asian (India)	Tata Power-DDL Utility (Power Distribution Utility	• Tata Power-DDL aimed to improve service quality and reduce downtime in maintaining power lines, poles, and towers. • Deployed micro drones equipped with Integrated Thermal Vision cameras, LIDAR, high-resolution cameras, and GPS-enabled Autopilot Systems to capture detailed imagery for electrical asset inspection, monitoring, and mapping. • Enhanced defect detection, improved decision-making, minimized downtime during maintenance, and broader application potential for future projects, leading to better consumer service.

2.4.5 Distribution Health Monitoring

a) About the technology

Utilities use sensors to monitor transformers by capturing real-time physical and electrical data, which is analysed in a central system using predictive maintenance techniques. This process integrates electrical and non-electrical sensors, a DCU, a 4G Gateway, AI/ML-based analytics software, and middleware for alerts.

Collecting real-time asset usage and performance data enables early detection of asset degradation, minimizing downtime and maintenance costs. This is especially beneficial for utilities in the region, where budget constraints often limit maintenance efforts, ensuring more efficient resource allocation and improved grid reliability.

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b) Implementation Examples

Few examples of implementation of distribution health monitoring both globally and in South Asia have been provided in table 5 below.

Table 5: Implementation examples of distribution health monitoring

Region	Entities	Implementation Details
Global (Italy)	Enel's Infrastructure and Networks division (power distribution utility)	• Enel was required to enhance grid reliability and service quality by tracking transformer health • Deployed digital power transformer programme equipping power transformers with advanced data-driven capabilities for real-time analytics and virtual site management, starting with a pilot phase in Cortina D'Ampezzo, Italy. It allows continuous transformer performance monitoring, predicting potential failures, and optimizing maintenance schedules. • This has improved grid reliability, extended transformer life, and reduced operational costs. It has minimized the downtime, ensuring a stable and efficient electricity supply.
South Asia (Bangladesh)	Dhaka Electric Supply Company Limited (DESCO)	• DESCO plans to install a Distribution Transformer Monitoring System in Bangladesh, which is expected to begin in July 2025.
South Asia (India)	Tata Power-DDL Utility	• Tata Power Delhi - DDL needed to improve service quality and reduce downtime in its low-voltage distribution network, which faced increasing customer complaints and long restoration times. • Implemented IoT-based automation across 300 substations, integrating IoT devices with ADMS, field force automation, and SAP IS-U systems for real-time outage alerts, monitoring, and automated response. • Reduced customer complaints and restoration times, improved network management and planning, and enhanced service quality, with plans to scale up the project to benefit an additional 640,000 customers.

2.4.6 Thermal monitoring of HV switchgear

a) About the technology

IoT-based thermal monitoring enables real-time tracking of key parameters in high-voltage switchgear, including temperature, current, and humidity. Temperature sensors detect overheating at vulnerable contact joints caused by age, resistance, or loose connections, while ambient temperature and humidity sensors assess environmental conditions. Partial discharge sensors analyse acoustic and electromagnetic emissions to identify insulation issues.

Sensor data is wirelessly transmitted to a centralized system, where predictive software and dashboards generate alerts for deviations. This proactive approach prevents unplanned outages, enhances reliability, and extends switchgear life by enabling timely maintenance interventions based on real-time thermal data and predictive diagnostics.

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b) Implementation Examples:

An example of implementation of thermal monitoring of HV switchgear globally has been provided in table 6 below.

Table 6: Implementation example of thermal monitoring of HV switchgear

Region	Entities	Implementation Details
Global (Ireland)	Northern Ireland Electricity Networks	• Northern Ireland Electricity Networks was required to manage age-related failures in their 2,300-mile-long high-voltage underground cables, switchgears and prioritize their replacement. • Installed three monitoring systems at substations to monitor 72, 11-kV cables and categorized cable status as green, amber, or red based on significance and condition. • It has resulted in improved network performance and reduced maintenance costs. Prevented critical voltage transformer failure and enhanced reliability and safety of the electricity network.

2.4.7 Blockchain Technology (Use case – Peer-2-Peer networks)

a) About the use case

P2P energy trading allows grid-connected users to buy and sell energy within a local area through a secure platform managed by DISCOMs, which charge a fee to regulate network constraints. Prosumers trade excess energy, while consumers purchase it, enabling multi-directional transactions across varying quantities, timescales, and spatial scales.

Blockchain technology with smart contracts ensures secure, transparent, and real-time billing, enhancing revenue management. This decentralized model reduces dependency on centralized power procurement, optimizes energy flow, minimizes peak load stress, and fosters community-driven energy sharing. The transparency of blockchain further ensures trust, security, and reliability in the energy exchange process.

b) Implementation Examples:

Few examples of implementation of blockchain technology both globally and in South Asia have been provided in table 7 below

Table 7: Implementation examples of blockchain technology

Region	Entities	Implementation Details
Global (European Union)	European Utility	• Create a marketplace for generators and buyers of renewable energy, disrupting traditional energy sector models. • Launched Piclo , the UK's first peer-to-peer energy platform, in collaboration with Open Utility and Good Energy, matching demand with supply every half hour and balancing surplus and shortfalls. • Signed up hydro, solar, and wind generation sites across England, Scotland, and Wales, including National Trust properties, and placed consumers at the heart of the energy process, promoting decentralization of energy generation.
Global (European Union)	European Utility	• Energie Steiermark needed a solution to manage surplus solar electricity and enable prosumers to share clean energy efficiently. • Launched the smart community platform in July 2023, in collaboration with Powerledger, to facilitate secure and transparent peer-to-peer (P2P) energy transactions, featuring energy monitoring, P2P trading, pricing control, and billing integration. • Enhanced flexibility and control for participants, improved ROI on renewable assets, better risk management, and ongoing innovation contributing to Austria's renewable energy targets.

South Asia (India)	Indian Utilities	• Demonstrated technical feasibility and user acceptance of P2P trading of rooftop solar energy in India under the "Regulatory Sandbox Approach" with no money transactions, only shadow bills. • Implemented three pilot projects with UPPCL (Uttar Pradesh), Tata Power Delhi Distribution Ltd (TPDDL), and CESC (Kolkata), integrating smart meter data with blockchain platforms to generate shadow bills and test various trading scenarios. • Achieved price discovery, incentivized rooftop PV uptake, developed business models for P2P trading, and submitted recommendations to regulators, demonstrating benefits over traditional Feed-in-Tariffs.

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2.4.8 Distributed Energy Resource Management Systems (DERMS)

a) About the technology

Implementing DERMS in South Asia is essential for enhancing grid resilience, optimizing distributed energy resources (DERs) like solar, wind, batteries, and EVs, and ensuring a stable, flexible, and sustainable energy future. DERMS integrates energy management platforms, grid software, demand forecasting, and cybersecurity to balance supply and demand dynamically, reducing outages and operational costs.

By supporting demand response and renewable energy integration, DERMS enables efficient resource management amid growing solar and battery adoption, ensuring reliability and sustainability while strengthening the region's power infrastructure.

b) Implementation Examples:

Few examples of implementation of DERMS globally have been provided in table 8 below.

Table 8: Implementation examples of DERMS

Region	Entities	Implementation Details
Global (United States of America)	U.S. electric utilities	• Pacific Gas and Electric Company (PG&E) needed to maintain grid reliability and accelerate customer adoption of DER amidst extreme weather and increasing electricity demand. • Deployed DERMS to provide real-time visibility and control of DER, enhancing situational awareness and grid management. • Improved grid reliability and resilience, increased DER capacity, and supported the integration of three million EVs by 2030, establishing a new utility-industry standard for integrating DER at scale.
Global (Singapore)	Singapore Energy Utility	• Ensure Singapore's grid infrastructure can support integrating and deploying cleaner energy sources like solar generation systems, battery Energy Storage Systems (ESS), and Electric Vehicles (EVs). • Developed DERMS to optimize the management of small-scale DERs, conducted a proof-of-concept in 2021, and focused on solar forecasting and EV adoption in the next phase. • Enhanced real-time information and control capabilities for network operators, supported sustainable integration of solar and EV-related DERs, and improved management of reliability and system costs.

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• Electric, S. (2023). Battery Energy Storage as Flexible Grid Resources. Retrieved from https://www.se.com/us/en/about-us/newsroom/news/press-releases/schneider-electric-and-pg-e-announce-solution-on-microsoft-azure-to-maximize-value-of-evs-solar-and-battery-energy-storage-as-flexible-grid-resources-64b83491df41d00f070feaef

• SP Group. (n.d.). Retrieved from https://www.spgroup.com.sg/our-services/network/our-smart-energy-network

2.4.9 Battery Storage Systems

a) About the technology

Implementing intelligent energy storage systems in South Asia is vital for stabilizing the grid, enhancing renewable energy integration, and ensuring reliable power supply. These systems utilize real-time monitoring, predictive analytics, and automation to optimize energy storage, distribution, and consumption. At their core, they consist of a battery pack managed by a battery management system that tracks key parameters, while an inverter facilitates power conversion between DC and AC.

The energy management system coordinates dispatch activities, balancing supply and demand, reducing dependence on peaking plants, and providing backup during outages, ultimately improving energy availability and grid reliability.

b) Implementation Examples:

Few examples of implementation of battery storage systems both globally and in South Asia have been provided in table 9 below.

Table 9: Implementation examples of battery storage systems

Region	Entities	Implementation Details
Global (Australia)	Australian Utility	• Neoen is a renewable energy company specializing in innovative and large-scale projects, including the Hornsdale Power Reserve, the world's largest lithium-ion battery. • The company aimed to expand the Hornsdale Power Reserve to enhance grid stability, reduce blackout risks, and support a higher penetration of renewable energy. • The expansion increased the battery's capacity to 150 MW and 193.5 MWh, delivered $150 million in savings for South Australian energy consumers, created 158 jobs, and generated over $300 million in economic benefits.
Global (Europe)	European Utility	• Address potential frequency variations on the electric grid in Italy due to the decommissioning of coal plants and support Italy's climate goals and EU 2030 targets. • Fluence delivered two Gridstack™ energy storage systems totalling 40 MW for Terna , providing Fast Reserve grid services with advanced, fast-response capabilities. • Enhanced grid resiliency and stability, building on Fluence's extensive experience in delivering large-scale storage solutions in 13 European countries.

South Asia (India)	Indian Utility	• Energy storage is expected to be a key intervention for grid management in India. • Demand driven capacity tender model for firm and dispatchable renewable energy (FDRE) has been introduced, combining energy storage with renewable energy to provide firm power to the DISCOMs. • By February 2025, an aggregate of 28.6 GW of FDRE power was bid out, of which for about 10 GW LOAs had been issued. • From a DISCOM perspective, this helps them meet their renewable energy target, while ensuring grid stability.
South Asia (Nepal)	Nepal Electricity Authority	• Nepal's national power grid is strained due to the surge in electric vehicle demand, and government push for induction stoves, leading to frequent outages. • The Grid Resilience through Intelligent Photovoltaic Storage (GRIPS) project, led by Gham Power and partners, introduced a smart storage system that switches between grid, battery, and solar power during outages, promoting clean energy and reducing reliance on polluting sources. • Expected to reduce outages, enhance grid reliability, support sustainable development, and address increasing energy demand in Nepal while emphasizing Gender Equality and Social Inclusion (GESI) policies.

• ARENA. (2020). South Australian battery grows bigger and better. Retrieved from ARENAWIRE: https://arena.gov.au/blog/south-australian-battery-grows-bigger-and-better/

• Mickey, A. (2021). Fluence, a Siemens and AES company. Retrieved from https://blog.fluenceenergy.com/enel-x-taps-fluence-gridstack-storage-product-to-deliver-fast-reserve-services-in-italy

2.4.10 Smart Charging Stations (V2G)

a) Description

Implementing Vehicle-to-Grid (V2G) technology in South Asia can transform EVs into distributed energy assets, reducing grid strain during peak demand, optimizing power distribution, and generating additional revenue. V2G enables bi-directional energy flow, allowing EV batteries to supply power when the grid needs support and recharge when demand is low.

This enhances grid stability, minimizes costly peak power purchases, and incentivizes EV adoption through dynamic pricing. Integrating V2G with smart metering, SCADA, and advanced analytics strengthens grid resilience, aligning with South Asia's modernization efforts for a more sustainable and efficient energy ecosystem.

b) Implementation Examples:

Few examples of implementation of smart charging stations both globally and in South Asia have been provided in table 10 below.

Table 10: Implementation examples of smart charging stations

Region	Entities	Implementation Details
Global (Europe)	European utility	• Develop an AC-based V2G system with 22 chargers for a city car-sharing scheme and solar power integration in Lombok, Netherlands , addressing grid constraint management, balancing, and congestion management. • Implemented 22 AC 22 kW chargers for 22 Renault Zoe vehicles with V2G services. • Enhanced grid reliability and stability through smart energy distribution, efficient use of idle EVs for grid stabilization and trading and promoted renewable energy integration with scalability potential.
Global (United States of America)	American Utilities	• Utilize the idle time of electric school buses to stabilize the power grid through bidirectional charging (V2G) . • Implement V2G projects in Beverly, Massachusetts; Southern California's Cajon Valley; and New York City, using school buses with 220 kWh batteries to feed energy back into the grid. • Enhanced grid stability, provided enough energy to power 100 single-family homes for a day in Beverly, and offered economic incentives such as USD 2 per kWh for V2G participants in Southern California.
South Asia (India)	Tata Power Utility	• Reduce carbon emissions in the transportation and energy sectors by exploring the potential of EVs to provide essential grid services. • TPDDL and India Smart Grid Forum (ISGF) are demonstrating V2G technology to show how EVs interact with the grid, provide frequency and voltage support, serve as backup power sources, and participate in the power market by storing and selling electricity. • Enhanced grid stability, economic benefits from optimized energy costs, and a contribution to reducing carbon emissions through the use of green electricity.

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2.5 Implementation Spectrum

The technologies enabling smart distribution are expansive and versatile, applicable to various components from consumer meters to substations and networks. Implementation varies based on budget and utility requirements. For instance, GIS technology can create a digital twin of physical assets and networks, enhancing resilience and optimizing maintenance times. Combining GIS technology with AMI data further reduces customer response times and enhances reliability. Additionally, IoT-based smart grids use sensors and communication technologies to monitor and manage electricity distribution, improving efficiency and integrating renewable energy sources. Drone-based asset monitoring provides cost-effective visual inspections of infrastructure, identifying potential hazards and reducing outage times. AMI enables automated meter reading, accurate billing, and detailed energy usage information, while thermal monitoring of high-voltage switchgear prevents outages by alerting unsafe temperatures.

However, not all technologies can be implemented in one go, and there is a prioritization required in terms of utility and investments, taking into account the country priorities and the state of utility distribution network. Prioritizing technologies that offer the most significant benefits regarding reliability, efficiency, and customer service will ensure that investments are strategic and impactful. Deploying a single technology may be straightforward and provide some benefits, but the true potential lies in combining multiple technologies. This integrated approach can create a greater and more far-reaching impact on the power distribution system. For example, while GIS technology alone can enhance asset management, combining it with AMI data can significantly improve customer response times and reliability. Similarly, integrating IoT-based smart grids, drone-based asset monitoring, and thermal monitoring can collectively optimize efficiency, safety, and maintenance. The table maps different smart distribution technologies for specific problem areas and possible benefits that can be derived from the technology implementation.

Problem areas		Enabling Smart Distribution Technologies (Illustrative)	Outcome Indicators
1	Aging infrastructure, voltage fluctuations, voltage sags	• Smart-metering and advanceddata analytics • Consumer indexing • GIS mapping • Advanced technologies for asset health management • SCADA/DMS • Substation Digitalization • RTDAS • Feeder automation • Cybersecurity • Battery storage systems	• Reduced outages- feeder tripping, DTR failures • Improved SAIDI, SAIFI and other reliability indicators • Reduced accidental risks • Reduced Energy Not Served • Improved quality of work

2	High transmission and distribution losses, inefficient load management, and outdated equipment	• Smart-metering and advanced data analytics • Consumer indexing • GIS mapping • Advanced technologies for asset health management • Automated Energy Accounting	• Reduced AT&C losses • Reduced ACS-ARR gap • Improved billing efficiency • Improved collection efficiency • Improved Tariff cycle timelines
3	Lack of real-time data access, poor customer communication, and limited consumer engagement	• Smart metering and advanced analytics • Prosumers • Battery Swapping stations • Smart homes • Smart charging stations • Demand response programs • Grid interactive buildings • DERMS • Vehicle to Grid (V2G) • OMS	• Better renewables integration • Higher consumer satisfaction • Increased share of value-added services (VAS) revenue for distribution utilities • Better asset utilization • Increased EV adoption • Better consumer participation • Improved Energy Efficiency Adoption • CAIFI
4	Insufficient data analytics, lack of integrated planning tools, and inadequate forecasting methods	• SCADA/ DMS • Demand forecasting • Energy portfolio management • OMS • Demand Side Management (DSM)	• Better asset utilization • Reduced power procurement costs • Reduced Energy Not Served
5	Rigid infrastructure, limited integration of renewable energy sources, and lack of adaptive technologies	• Smart-metering and advanced data analytics • Enterprise architecture and Interoperability • Cybersecurity • DERMS • Battery storage systems • Microgrid • Demand Response (DR)	• Increased Renewable adoption • Improved Sustainability Index • Better Adoption of Energy Efficiency measures • Adaptive Tariff structure and regimes i.e. Critical peak pricing (CPP) etc.

The table gives a quick snapshot of the various smart grid technologies and their benefits. These smart distribution technologies/use cases that can be planned and deployed through regional collaboration. In the subsequent section, we discuss these collaborative approaches for deploying Smart Distribution technologies in the South Asian region.

3 Collaborative approach to accelerate the adoption of smart distribution technologies across South Asia

The typical process for implementing a Smart Distribution technology involves five (5) stages, as presented in the figure below. The process is relevant for national as well as regional adoption of these technologies. At the regional level, this process helps define the touch points where collaboration can happen to facilitate adoption. Right from developing suitable policy environment, to building business models taking advantage of the economies of scale and driving innovation, collaboration can be built in every step. Regional collaboration also creates a market for aggregation of demand for the various smart distribution technologies. This aggregation can help bring-in economies of scale in the procurement and also be able to access a larger set of investors/sellers. The aggregation of demand also, creates a conducive environment to focus on local manufacturing of the equipment as well as building the technology led solution, which in turn enhances the skill base in South Asia and also creates employment opportunities in an emerging area of business.

These specific strategies foster adoption of smart distribution technologies across South Asian DISCOMs and are discussed next.

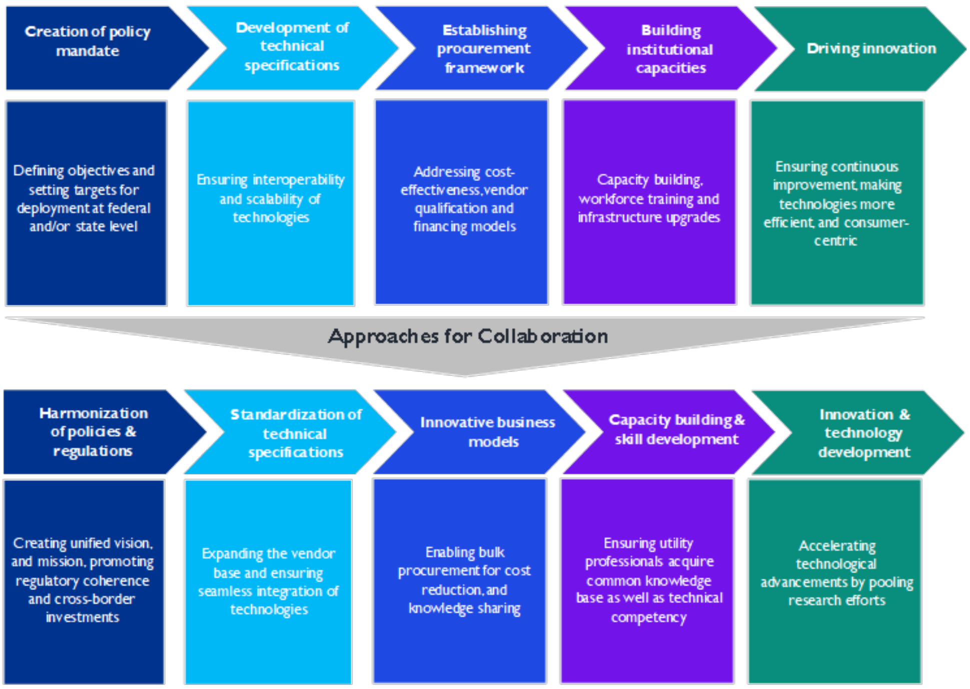

Figure 7: Lifecycle of Smart Distribution technology and corresponding collaboration approaches

3.1 Harmonization of policies and regulations

Regional collaboration on smart power distribution requires policy alignment to establish a unified vision for Smart Distribution, ensuring regulatory coherence and promoting cross-border investments. This involves harmonizing policies, regulations, and financial incentives across South Asian DISCOMs to create an integrated and resilient power distribution ecosystem. For example, harmonizing energy policies in the European Union has facilitated integration of renewable energy sources and enhanced grid security . Harmonization of policies can be through following illustrative structures:

- **Establish a Regional Smart Distribution Framework** that defines common goals like reducing losses, improving reliability, enabling renewable energy integration, etc. and identifying regional priorities like cybersecurity, grid resilience, affordability, energy access improvements, etc.

This framework would set clear targets and roadmaps for deployment of Smart Distribution technologies to achieve common goals and regional priorities.

- **Alignment of regulatory frameworks** governing aspects like tariffs philosophies, net metering, data privacy, demand-side management, etc. This alignment would also entail standardization of quality of service (QoS) norms for power supply reliability, voltage stability, and outage management as well as grid code alignment to ensure compatibility in operational protocols for power distribution operations across SACs.
- **Investment centric policies and incentives** to facilitate cross-border investments. These policies could include tax incentives/ exemptions, waiver of customs/ import duties, risk guarantees, and public-private partnerships (PPPs) for Smart Distribution projects. The policy provides the ground on which procurement structures and innovative financing models can be built.
- **Data privacy and cybersecurity policies:** A plethora of data is generated consequent to implementation of smart distribution technologies. Here developing policies to safeguard privacy of the consumer data, as well as to safeguard the DISCOMs from cyber-attacks is imperative. This will ensure secure and ethical use of data generated. At the regional level, establishing guidelines for consumer data protection and privacy in Smart Distribution deployments. Minimum cybersecurity requirements for smart distribution networks, including encryption, authentication, and intrusion detection will need to be defined.

Potential activities/ tasks to facilitate such collaboration may include:

- **Regional working groups/ policy forums:** Formation of a joint task force comprising policymakers, regulators, and utilities to draft a shared Smart Distribution vision. This task force would organize regional regulatory convergence dialogues to align national electricity regulations. They can also develop model regulations for smart distribution technologies as well as policy blueprint outlining key milestones, technology adoption strategies, and regulatory support mechanisms that South Asian DISCOMs can adopt.
- **Policy pilots:** Roll out regional pilot projects for innovative tariff mechanisms and data-sharing frameworks to facilitate Smart Distribution technology adoption. A sandbox approach to policy making, as adopted by India for tests P2P trading model can be considered.
- **Cybersecurity standardization for Smart Distribution** – Develop encryption and access control standards for AMI, SCADA, and cloud-based grid analytics. Conduct regional cybersecurity drills to test resilience.
- **Secure data-sharing frameworks** – Establish data exchange rules between DISCOMs while ensuring consumer data privacy.

The ASEAN power grid initiative case presented in box 2 below highlights how harmonization of policies and regulations facilitated enhance cross -border electricity trade.

Box 2: Case Study – The ASEAN Power Grid (APG) Initiative (Source: ASEAN Energy Outlook)

The APG initiative is a regional effort by the Association of Southeast Asian Nations (ASEAN) to interconnect member states' electricity grids, enhancing energy security, sustainability, and economic efficiency. Launched in the late 1990s, it facilitates cross-border electricity trading by harmonizing technical standards, regulatory frameworks, and market rules. Key harmonization measures include:

- **Grid code alignment:** Ensuring compatibility in voltage levels and operational protocols.
- **Policy coordination:** Streamlining tariffs, licensing, and dispute resolution.
- **Market mechanisms:** Establishing platforms for bilateral/multilateral power trade.

This integration optimizes resource use, reducing reliance on fossil fuels and avoiding redundant infrastructure. The APG saves an estimated $6 billion annually in energy costs by improving grid efficiency and enabling cheaper renewable energy sharing.

3.2 Standardization of technical specifications

Standardizing technical specifications for Smart Distribution technologies is crucial for ensuring efficiency, scalability, and interoperability across utilities, vendors, and grid infrastructure. A unified approach to technical standards facilitates seamless integration, cost reduction, vendor neutrality, and improved grid resilience. For example, the International Electrotechnical Commission (IEC) standards, like IEC 61850, have played a crucial role in facilitating the global adoption and interoperability of smart grid technologies. These standards provide a framework for integrating various digital technologies, ensuring that different systems and devices can work together seamlessly . Implementing standardization requires coordinated actions across multiple domains, including equipment, grid automation, communication protocols, cybersecurity, and data management as discussed below:

- **Equipment standards:** Define minimum technical and functional specifications for smart meters, transformers, batteries, inverters, and other DER components, including aspects such as accuracy, communication protocols, etc. Standardize technology architecture to ensure compatibility across different vendors and communication networks. Establish data management standards for handling consumer energy data securely and efficiently.
- **Establish uniform grid automation standards:** Standardize Distribution Automation Systems (DAS) to enable remote monitoring and control of grid assets. Develop Fault Detection, Isolation, and Restoration (FDIR) protocols to improve outage response. Ensure interoperability of SCADA systems across different DISCOMs.
- **Harmonization of communication protocols:** Standardize communication protocols like DLMS/COSEM, IEC 61850, etc. for seamless data exchange between smart meters, control centres, and distributed energy resources. Ensure compatibility between wired (fibre, powerline communication) and wireless (RF mesh, NB-IoT) communication technologies. Create common Application Programming Interfaces (APIs) to integrate new Smart Distribution applications with existing utility software.
- **Standardized energy management and Demand Response solutions:** Define technical standards for Demand Response programs, enabling real-time load control across multiple utilities. Standardize DER integration, ensuring that solar, wind, and battery storage systems can be seamlessly incorporated into distribution grids. Ensure compatibility of smart inverters and home energy management systems (HEMS) with regional grid standards. Here again pilots can be tested for implementation of DR solutions. Taking advantage of the
- **Regional testing and certification ecosystems:** Create regional testing and certification centres for smart grid equipment. Ensure compliance with international standards (IEC, IEEE, ISO) while adapting them for regional needs. Encourage mutual recognition of certifications

across different regulatory jurisdiction.

Potential activities/ tasks to facilitate such collaboration may include:

- **Regional standards committee:** Create a body with utility representatives to draft minimum technical and functional specifications for various smart distribution technologies like smart meters, inverters, batteries, transformers, etc.
- **Regional Communication Standards Task Force:** Align smart distribution communication protocols across countries. Conduct cross-utility testing of different communication technologies to determine the best fit. Bring together technology providers to define open standards for data interoperability. Publish technical guidelines for seamless connectivity between Smart Distribution technologies, utility control centres, and consumer interfaces.
- **Harmonized DER integration protocols:** Ensure seamless connection of rooftop solar and battery systems with distribution grids by defining regional requirements for voltage and frequency support in smart inverters.
- **Knowledge sharing:** Partner with global organizations like IEC and Institute of Electrical and Electronics Engineers (IEEE) to draw technical expertise to formulate common technical specifications.
- **Testing and certification processes:** Create regional testing and certification centres for Smart Distribution equipment. Ensuring compliance with international standards (IEC, IEEE, ISO) while adapting them for regional needs. Encourage mutual recognition of certifications across different regulatory jurisdictions

- The 6th ASEAN Energy Outlook -; Published in November 2020; Accessed on 27 January 2025
- iec_2022_how-we-contribute_smart_grids_0.pdf; Accessed on 27 January 2025

The European Union's standardization of DER components case presented in box 3 below highlights how standardization of technical specifications strengthened regional manufacturing capabilities and supply chains.

Box 3: Case Study – European Union's (EU's) standardization of DER components (Source: EU Commission)

The EU's standardization of DER components like solar inverters, battery interfaces, smart meters etc. has streamlined manufacturing, installation, and grid integration. By harmonizing technical specifications (e.g., voltage levels, communication protocols) via regulations like the EU Renewable Energy Directive (RED II) and Ecodesign Directive, the bloc reduced costs through economies of scale, simplified compliance, and minimized customization. Key initiatives include:

- **Interoperability standards:** Ensuring DER components (e.g., inverters, storage systems) work seamlessly across borders and grid systems.
- **Smart Grid codes:** Facilitating plug-and-play integration of solar and storage systems.
- **Market harmonization:** Reducing administrative barriers through unified certification (e.g., EU-wide product labelling).

Standardized components lowered solar PV and storage system costs by 15–20% between 2015–2020, driven by reduced R&D duplication and bulk production efficiencies.

3.3 Innovative business models and procurement frameworks

Implementing new business models and collaborative procurement strategies can reduce technology costs and attract private-sector investments, thereby driving the adoption of smart technologies. For example, joint procurement of high-voltage direct current (HVDC) cables and transformers for cross-border interconnectors like NordLink between Germany and Norway reduced costs by 15-20% as compared to individual procurement . The focus areas may involve the following:

- **Performance-based Contracting (PBC):** PBCs incentivize suppliers to improve efficiency, innovate and reduce costs as their payment is tied to performance metrics like reliability, availability, and total cost of ownership. For example, in both Kenya and Georgia, performance-based management contracts were used to improve the efficiency of power utilities .
- **Demand aggregation:** Pooling demand across South Asian DISCOMs can achieve economies of scale in procurement by lowering costs and improving supply chain efficiency.
- **Private sector participation:** Encouraging private investment through public-private partnership models like Design Build Finance, Own, Operate and Transfer (DBFOOT) and innovative financing models like Total Expenditure (Totex) model/ Hybrid model have proven to accelerate the deployment of smart technologies in South Asia.

- Clean energy for all Europeans package; Accessed on 27 January 2025
- NordLink Interconnector; Accessed on 31 January 2025
- Best Practices for Performance-Based Management Contracts for the Power Sector; Published in September 2018; Accessed on 31 January 2025

Potential activities/ tasks to facilitate such collaboration may include:

- **Regional procurement portal:** Launch an online platform for collective tendering.
- **Model Standard Bidding Documents (SBDs) and PPP contracting frameworks:** Create templates for SBDs and PPP agreements for joint procurement of smart distribution technologies.
- **Joint funding mechanisms:** Leverage funding from multilateral agencies like the World Bank and Asian Development Bank to finance cross-border smart distribution projects.

The Indian smart metering market transformation case presented in box 4 below highlights how aggregation can help bring-in economies of scale in procurement and enhance private sector participation.

Box 4: Case Study – Smart Metering Market Transformation in India (Source: Ministry of Power, GoI)

India's smart metering program is globally the largest smart metering procurement on a PPP model. Starting small with few pilots and players, India's smart metering market has gradually transformed into a full-scale national rollout with a large group of developers, private equity firms, manufacturers and equipment providers. A few highlights from the transformation include:

- Tenders for **132 million** smart meters were awarded. Contracts awarded to large project developers like Adani, Intellismart, Genus Power, NCC, Polaris, etc.

- Private equity firms like I Squared Capital, Singapore's sovereign wealth fund GIC, etc., are invested in the market.
- More than 100 smart metering players across the value chain, with 59 entities already empanelled as Advanced Metering Infrastructure Service Providers.

3.4 Capacity building and skill development

Capacity building ensures stakeholders are equipped to implement and manage smart distribution technologies. As technology in smart distribution is fast evolving, continuous upskilling of the stakeholders is key to ensure DISCOMs and other stakeholder are at the top of the technology curve. Enhancing the skills and knowledge of utility personnel and other stakeholders through targeted training in areas like DER management, cybersecurity, grid analytics, etc. is essential for effective implementation. Collaborative capacity-building efforts can create a skilled workforce and improve decision-making. For example, The ASEAN Centre for Energy's capacity-building initiatives have enhanced regional expertise in energy management. The focus areas may involve the following:

- **Joint training programs:** Regional training programs on advanced technologies and best practices in smart distribution, developed in close coordination with power distribution stakeholders in SACs, can enhance the skills and knowledge of utility personnel and other stakeholders.
- **Decision-making tools:** Creating common tools like cost-benefit analysis frameworks, power procurement cost optimization models, data analytic frameworks, project management tools, etc., can support informed decision-making, better investments, and efficient project execution.
- **Regional platforms for knowledge sharing:** Creating dedicated regional networks for cooperation on smart distribution initiatives. For example, ELECREMA, which is flagship showcase of the Indian Electrical Industry ecosystem. Under its banner, it has multiple platforms, most notable being the World Utility Summit (WUS), which is one of the largest congregations of global utility representative and related stakeholders including government and regulators. The platform deliberates on the most recent and upcoming issues impacting utilities worldwide.

Potential activities/ tasks to facilitate such collaboration may include:

- **South Asia Smart Distribution Academy:** Establish a dedicated centre for advanced training for regional utility professionals and other relevant stakeholders.
- **Certification programmes:** Introduce common certification coursework for specialized skills in smart distribution technologies and solutions.
- **Training Consortia:** Partner with global research institutions like the National Renewable Energy Laboratory (NREL), Lawrence Berkeley National Laboratory (LBNL), etc. to deliver workshops on smart distribution.

• Case-Study-on-Smart-Metering-Market-Transformation-in-India_23Jan25.pdf; Published in January 2025; Accessed on 31 January 2025

The World Utility Summit case presented in box 5 below highlights how it has empowered utilities to navigate the future with resilience and transformation by providing a common platform to together regulators, tech companies, consultants, government officials, and utility leaders and helping them share their views.

Box 5: Case Study – The World Utility Summit (Source: IEEMA, ELECRAMA)
Case Study: The World Utility Summit

The World Utility Summit (WUS), an international platform developed under the ELCREMA banner has delivered strategic engagement programmes through conferences and roundtables on power utility sector focusing on transformation and sustainable infrastructure. The initiative organized focused sessions and networking events to equip utilities globally with insights into grid modernization digital transformation and resource management. Through 4 successful editions, WUS has attracted over 400 delegates from 40 countries, with more than 250 organizations participating in the Summit. WUS collaborated with industry leaders and technology innovators to ensure knowledge transfer and practical implementation, building international partnerships for sustainable solutions. For its 5th edition, WUS focuses on “Empowering Utilities: Transforming Energy Challenges into Resilient Future”, emphasizing smart distribution solutions for tomorrow’s utility sector.

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3.5 Innovation and technology development

Innovation is expected to drive the development of cost-effective solutions tailored to South Asia’s unique challenges. Promoting research and innovation through collaborative R&D initiatives and incubation support for startups can foster localized technologies for distribution modernization. For example, the Korea Electrotechnology Research Institute (KERI) and LBNL have been working together on smart grid R&D, exploring automated demand response technologies, energy efficiency strategies, and the development of open smart grid standards The focus areas may involve the following:

- **Joint R&D Labs:** Establishing joint R&D labs to foster innovation in smart distribution technologies. Joint R&D efforts can accelerate the development of new solutions like AI-based predictive maintenance tools, advanced grid management systems, etc. Developing solutions linked closely to the local requirement of the South Asian DISCOMs, will make the solutions not only more relevant but also resilient.
- **Startup incubators:** Promoting and supporting startups in the region focused on developing cutting-edge solutions for smart grids like microgrids and battery systems. The support would

involve providing resources and mentorship to innovative startups. Regional incubators will help hone the local talent and also give these start-ups a larger regional market to explore.

- **Pilot Projects:** Implementing innovative solutions in selected distribution zones in South Asian DISCOMs for testing and scalability.

Potential activities/ tasks to facilitate such collaboration may include:

- **South Asia smart grid innovation network:** Establish a regional platform to fund and coordinate R&D activities with support from power distribution stakeholders in South Asian countries.
- **Challenge grants:** Provide seed funding for startups addressing regional power distribution issues and developing smart distribution technologies and solutions.
- **Innovation hubs:** Set up innovation hubs in major South Asian cities like in Colombo, Delhi, Dhaka, Kathmandu, etc., to collaborate with academia and industry. For example, the Smart Grid Knowledge Centre (SGKC) in Manesar, Haryana, India, houses a smart grid innovation hub.

• Korea Electrotechnology Research Institute and Berkeley Lab Will Work Together on Smart Grid R&D | Energy Technologies Area; Accessed on 31 January 2025

The Nordic Green Grid Innovation Hub case presented in box 6 below highlights how regional energy challenges can be addressed through collaboration on innovative enterprises.

Box 6: Case Study – Nordic Green Grid Innovation Hub (Source: HiQ)

The Nordic Green Grid Innovation Hub is a collaborative initiative among Nordic countries to enhance their power grids' efficiency and reliability. Key objectives include:

- Grid optimization: Implement AI-driven solutions to enhance the performance and stability of the power grid.
- Downtime reduction: Minimize grid downtime through predictive maintenance and real-time monitoring.
- Sustainability: Support the integration of renewable energy sources into the grid.

Implementing AI tools has led to a 25% reduction in grid downtime, enhancing the reliability of the power supply.

3.6 Conclusion

While the process lays down various steps, it is not sequential in nature. South Asian DISCOMs can focus on the low-hanging fruits such as working through a platform like the World Utility Summit to build capacity and learn and adopt from each other's experience. This will help build a case in point that can then be leveraged to bring in harmonisation and collaboration in other areas such as policies and business models.

Building collaboration is akin to building blocks. South Asian DISCOMs may start small, focusing on one business unit with a select smart distribution technology. For instance, using drones to support asset management, where select DISCOMs may get involve to start with. As the experience gets build, the learnings can be leveraged for a wider adoption of the drone technology as well other smart distribution technologies may be adopted based on the past experience. From business unit, the collaboration can expand to multiple business units and from select DISCOMs to many. As DISCOMs build the collaboration, other stakeholders can also be engaged to widen the scope and moving from pilot to policies and from anecdotal collaboration to structured approach for implementing smart distribution across South Asian DISCOMs.

"In the long history of humankind, those who learned to collaborate and improvise most effectively have prevailed"

- Charles Darwin

• AI Adoption in Nordic Energy and Manufacturing - HiQ; Accessed on 31 January 2025

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STRATEGIC PARTNERS

IEEMA is the first ISO certified industry association in India, with 950 + member organizations encompassing the complete value chain in power generation, transmission and distribution equipment. Its membership base ranges from public sector enterprises, multinational companies to small, medium and large companies. IEEMA members have contributed to more than 95% of the power equipment installed in India.
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