SMART DIGITALIZATION AND REAL-TIME MANAGEMENT OF AN INCREASINGLY VOLATILE ELECTRICITY GRID

EXECUTIVE SUMMARY 01

This whitepaper discusses the challenges of managing an increasingly volatile grid, amidst uncertainties of generation and demand. The paper emphasizes the importance of real-time data in promoting a secure and reliable network. It also touches upon the modern smart grid initiatives to overcome these constraints, optimize network resources across the value chain, and help achieve grid stability and decarbonization.

It also explores the strategies to manage the grid and its assets more efficiently, using modern grid technologies, focusing on real-time network data acquisition and analysis, along with local data of weather, energy demand, behavioral trends, and energy costs.

THE STATE OF THE ELECTRICITY GRIDS TODAY 02

At any given point of the day, the amount of electricity dispatched into the grid must be able to meet the demand at the point of consumption, after accounting for line losses. If it does not, it creates grid imbalance, asset stress, higher losses, and ultimately, network breakdown and loss of supply.

Decarbonization of electricity has become one of the foremost priorities of governments worldwide. In a bid to accelerate towards **net-zero** targets, more and more renewable generation assets are added to electricity networks. Distributed Energy Resources (DERs) powered by renewables are widely accepted to play a role in replacing fossil-fuel -based power plants, within an acceptable timeline, to achieve our **grid decarbonization** and **net-zero goals** by 2050. Increased penetration of renewable generation assets into the grid has its own unique challenges, in particular those associated with intermittency, which means variability of generation due to weather changes.

In addition, **electrification of heat and transport** is essential to drive our energy transition commitments if we must meet our net-zero targets by 2050. However, electrification of district heating and transport, coupled with the growth of EV charging infrastructure, puts additional burden on the grid.

The global electricity demand is estimated to double by 2050, fuelled by rising global population, economic growth, and electrification of heat and transport. At this rate, to achieve carbon neutrality by 2050, we must aim for over 80% low carbon electricity by 2040. (https://www.iea.org/reports/net-zero-by-2050).

Many utilities have adopted a comprehensive **energy transition** and **decarbonization strategy**, by deploying more and more renewable energy (RE) into the grid, along with **carbon capture.**

Grid imbalance and overload become an increasingly likely occurrence due to load swings and supply uncertainty. Unchecked, these can result in grid instability, energy losses, deterioration in services, customer dissatisfaction, and regulatory non-compliance.

However, grid owners/operators must also be aware of the cost implications of managing their increasingly complex grids and therefore the potential financial impact upon consumers. Grid operators must effectively and efficiently adapt to real-time conditions; operators need to adopt the right strategies, along with enabling technologies, to safeguard the grid and consumers while **ensuring reliability, security, and compliance.**

An IEA study suggests that for every dollar invested in renewables, another dollar will also be needed to invest in **grid modernization**, out of which 35% should be on smart grids. Grid modernization, therefore, remains a strong focus to allow **flexible and resilient operations**, amidst growing RE penetration to achieve net-zero targets.

Global **electricity regulations, energy efficiency legislation, and emission-control policies** have ensured that the utilities modernize their electricity grids and contribute towards decarbonization and sustainability. Policy incentives and regulatory reforms are opening technology frontiers in **smart metering, distributed microgrids, grid automation,** and **grid data analytics**, to name a few, and fostering the growth of clean energy markets and net-zero campaigns.

CHALLENGES FOR NETWORK OPERATORS AND THE NEED FOR DIGITALIZATION

Network operators have a huge challenge on their hands to upgrade their networks, and to set the pace for **net-zero transition**. Smart technologies can help with reinforcement prioritization, reduction of capacity requirements, asset planning to promote grid stability, cost optimization, connection flexibility, real-time network management, and proactive customer engagement in demand response mechanisms. All these present a strong business case for DNOs to adopt digitalization to improve **network observability, asset performance, operational efficiency, fault response, and sustainability obligations**.

Through suitable digital interventions using smart grid technologies and real-time network monitoring, it is possible to overcome the inherent challenges of decentralized and intermittent generation, network capacity planning, constraint management, grid balancing, and power systems reliability.

By adopting **smart grid strategies**, grid owners/operators can address the issues of RE availability, weather impact, demand fluctuations, and load constraints. With **smart digitalization**, the grid can be made more **adaptive and resilient**, so that it responds quickly to supply and demand constraints, in a cost-effective and sustainable way.

Increased application of **data-driven strategies** will be crucial in managing generation uncertainties, demand response, and optimizing grid operations. The grid topology and specifications will have to be designed to deliver **flexibility services**, despite the variability of distributed generation, energy demand, load incidents, weather events, and energy consumption patterns. **Grid digitalization,** with the adoption of data-driven technologies, will play a significant role in **managing generation uncertainties, accelerating demand response**, and **optimizing grid operations.**

THE ROLE OF DATA IN SMART GRID TECHNOLOGIES

The proliferation of RE systems and the advent of new energy sources such as hydrogen, storage systems, electric vehicles (EVs), and demand response (DR) systems are transforming the electricity grids. The adoption of enabling technologies with advanced sensors, communication and data systems forms an essential part of our global strategy to manage, plan, and operate our grid and its connected energy systems optimally, and with reduced constraints.

Smart grid technologies are at the forefront of **grid modernization** and **digital transformation**. They provide **two-way communication** between the controller and the electricity grid for **real-time data monitoring, visualization, and analytics.** The Office of Gas and Electricity Markets (Ofgem) in the UK has recommended that DNOs identify the priorities and create an enabling framework for smart grid technologies to improve **grid resilience, network stability, security of supply, and customer services**.

Smart grids are an example of **IT-OT integration**, involving seamless interaction with SCADA, EAM, OMS, GIS, and sensors, to provide **situational awareness** of the grid and **network state estimation**, and to **manage risks and compliance**. A modern smart grid implementation uses load flow analysis application to facilitate grid planning, network design, loss calculations, contingency analysis, protection coordination, and vulnerability assessment. It uses data from **Automated Metering Infrastructure (AMI) and Meter Data Management (MDM)** systems to provide time-series measurement and analysis of voltage, current, load and energy profile, frequency, and power quality.

Acquiring the right data of the dynamic grid ecosystem at the right time is crucial in digitally transforming the grid into an **interactive, fault-tolerant, adaptive, and self-healing** entity. Smart grid applications use this data to help detect inefficiencies in the network, identify faults and alert the grid operators to take proactive action to reduce breakdowns, technical losses, asset failures, and revenue losses. They also protect utilities against service-level violations, regulatory non-compliance, and carbon burden in grid operations.

DATA-LED GRID TRANSFORMATION AND DECARBONIZATION

Commitment to net-zero goals, decarbonization action plan, and carbon footprint measurements remain the key focus of grid transformation using smart grid technologies, which provide a two-way communication with the electricity network, for **real-time monitoring, visualization, and analytics**.

Data-led grid digitalization ensures its **reliability, stability, and protection** during fast-changing RE connections and other decarbonization initiatives. Data-driven strategies supported by **SCADA, EAM, OMS, GIS, IoT, and instrumentation**, provide status check, health, and compliance of the electricity network.

Pragmatic selection and use of data-driven smart grid initiatives can help detect inefficiencies in the network and alert the grid operators to take **proactive action** to reduce breakdowns, technical losses, asset deterioration, and revenue loss. Moreover, these initiatives protect utilities against service-level violations, regulatory non-compliance, and added carbon footprint in grid operations, thus promoting sustainability.

Smart grid technologies to transform network operations is now an accepted mandate due to strict imposition of electricity regulations, which requires electricity utilities to adhere to grid discipline, maintain generation and dispatch schedules, bridge the supply-demand gap, and ensure power quality, reliability, grid stability, and service standards.

Here area few examples of how smart technologies are helping transform the grid ecosystem and offering multiple benefits in energy optimization and decarbonization:

- The evolution of the **intelligent microgrid** has led to the creation of **flexible networks**, powered by renewable energies (solar, wind, geothermal, biomass, or battery energy storage, etc.) with both the capacity and the capability to export clean power into the grid during peak periods, serving an excellent source of decarbonized electricity.

  Monash University, Melbourne in its bid to achieve net zero by 2030, has started sourcing most of its electricity needs from renewable sources, gradually eliminating its dependence on coal-based energy. It has set up a microgrid system comprising solar PV and battery energy storage system (BESS) which stores excess electricity from renewable sources for future use. During peak times, when the grid is stressed, the campus load is automatically switched to the microgrid system, thus reducing demand on the grid.

- A combination of decentralized, distributed RE systems can be logically woven into a **virtual power plant (VPP)** offering clean generation, on a merit order basis, regulating supply versus demand in real time and minimizing grid constraints.

  The French electricity generating company CNR uses a VPP platform for logical aggregation of its remote wind and solar energy systems, real-time monitoring, and controlling generation based on price signals from electricity markets. Using the platform, the company operates an economically viable and environmentally sustainable RE portfolio, automatically ramping up and down generation as per market demand and reducing volatility.

Distributed energy resources management system (DERMS) is an application that manages diverse and multi-location RE systems from a common platform to deliver clean electricity into the grid.

UK Power Networks provides power to nearly one-third of the UK's population via its three regulated electricity distribution networks - London Power Networks, Eastern Power Networks, and South-Eastern Power Networks. As part of their vision to be a leading DSO, they have implemented DERMS with ANM (Active Network Management) capability to deliver a range of services, such as flexible generation, flexible connections, and flexible market services.

Advanced distributed management system (ADMS) is an application that embeds real-time load and frequency measurements with demand response systems to improve energy efficiency and resiliency in grid operations.

The National Renewable Energy Laboratory (NREL), US has partnered with the Pacific Northwest National Laboratory to build an open-source platform to deliver ADMS, aimed to improve network efficiency, reliability, and resilience. The ADMS application has the capability of managing distributed generation, real-time DER dispatch, demand forecasts, network flexibility, and DSO (distribution system operator) planning.

Electrical vehicle (EV) charging infrastructure, powered by renewable energy, is a potential, sustainable energy resource, with the capability to import electricity from the grid for charging and export clean power back into the grid during emergencies or demand peaks, using vehicle-to-grid (V2G) technology.

A collaborative V2G program began in April 2018 between OVO Energy, Kaluza, Nissan, and Indra Renewable Technology, supported by the Office for Zero Emission Vehicles (OZEV) and the Department for Business, Energy, and Industrial Strategy (BEIS). The algorithm uses artificial intelligence (AI) to combine wholesale electricity price feeds, weather, and grid data to automatically charge grid-connected EVs when prices and carbon levels are low, and export energy to the local grid when it needs support.

CONCLUSION 07

Grid capacity, availability, generation volatility, weather factors, fluctuating demand, and load constraints all have direct impact on grid stability, security, and reliability. By adopting **smart grid technologies**, we can address some of these challenges on our **path to decarbonization**. Smart digitalization helps in creating an interactive, adaptive, and self-healing grid, cutting down on energy losses and accelerating net-zero goals.

Electricity regulations governing the grid have become stricter and electrical utilities are expected to adhere to the grid discipline, maintain generation and dispatch schedules equitably, and ensure power quality, reliability, and service standards.

There is a strong business case for grid owners and operators to accelerate digitalization with the aim to improve **real-time network visibility**, become more **responsive to electricity** customers and be more responsible towards the environment. A planned and holistic approach is therefore needed for **grid transformation**, supported by **digital innovations**, for better **network visualization, building grid tolerance, efficiency improvement**, and **accelerating decarbonization and sustainability**.

FURTHER READINGS

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