Power Sector

ISSUE BRIEF

DIGITALIZATION — ITS ROLE IN THE GREEN ENERGY TRANSITION

SDSN

COUNCIL OF ENGINEERS FOR THE ENERGY TRANSITION

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KEY MESSAGES

Opportunity for Digitalization in the Energy Transition

Information and communication technology such as artificial intelligence, big data, cloud computing, and blockchain can enable a 20% reduction of global CO_2 emissions by 2030, according to GeSI's SMARTer2030 report. These tools, through comprehensive data collection, processing, and analysis, can be used to increase the proportion of renewable energy generation, improve energy efficiency, promote easy operation and maintenance, and facilitate the transition to clean energy systems.

Energy Generation and Storage

The use of digital technology can improve renewable energy generation and storage through more accurate forecasting and better data analysis. For example, sensors placed in power plants and the use of artificial intelligence can improve the accuracy of energy forecasts and adjust traditional power generation according to the efficiency of generation, allowing for immediate action to correct anomalies.

Power Delivery and Utility

Digitalization improves power delivery by providing a cleaner and more efficient transportation and distribution (T&D). In gas T&D, drones can be used to track pipeline health and map leakages. In electric T&D, smart grids can better track overload and allow for the remote control of grid stations. Furthermore, establishing an intelligent controlling platform can enable more accurate and real-time management of multiple energy sources.

Challenges and Solutions of Digitalization

Digital solutions can face challenges in cybersecurity, interoperability, and data corruption. Renewable energy systems face cyber-attack threats that may compromise reliability and security, operational difficulties with coordinating and integrating different devices and systems, and data corruption, which is common due to loss of signal connection and exposure to inclement weather. Standardization could assist in security and interoperability of data, while employing data integrity tools and regular monitoring can avoid corruption.

Sustainable Digital Systems

Constructing and operating smart sensors, data centers, base stations, and networks for data collection, transmission, and analysis, however, itself requires energy consumption. Digital infrastructure can be made sustainable with a higher supply of renewable energy and with the help of cooling systems or other energy-saving technologies.

Workforce Development

A digital transformation in the renewable sector requires personnel with experience and expertise in both digital technology and energy — but there's a shortage of such engineers and experts in many regions. It is necessary to create relevant workforce development programs, such as interdisciplinary training programs in both data analysis and computer science, as well as electrical engineering and renewable energy.

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INTRODUCTION

Digital technology refers to a modern technology that utilizes digital means to convert, process, transmit, store, display, and apply information. It includes a variety of technological fields such as computers, networks, communications, digital image processing, and digital signal processing.

Digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities. It is the process of moving to a digital business.[1]

According to the Global System for Mobile Communications Association (GSMA) report titled "The Enablement Effect," the total annual greenhouse gas (GHG) emissions of the mobile sector are approximately 220 $MtCO_2$, which is about 0.4% of total global GHG emissions.[2] However, the level of avoided emissions enabled by mobile communications technologies is 10 times greater than the global carbon footprint of mobile networks themselves. In addition, a report from the Global Enabling Sustainability Initiative (GeSI) titled "SMARTer 2030" indicates that information and communications technology (ICT) can enable a 20% reduction of global CO_2e emissions by 2030.[3] Currently, the use of digital technologies in industry, especially in energy systems, is one of the most important and sustainable trends in global development. Digitalization is not only the application of technology, but also a new way of thinking and a source of new business models and consumption patterns. It provides new ways for enterprises to organize, produce, trade, innovate, and regulate. Promoting digitalization is conducive to the green energy transition via the widespread use of digital technology to avoid emissions and scale decarbonization solutions, as well as through the comprehensive circulation of business or management data within and across sectors.

Based on global experience, the energy sector can be totally transitioned with wide-spread applications of digital technologies, including, but not limited to, big data, cloud and edge computing, internet of things (IoT), artificial intelligence (AI), and blockchain. These technologies can be used to achieve comprehensive informational data collection and processing, analyze and manage renewable energy utilities to increase the proportion of renewable energy generation, promote easy operation and maintenance, improve energy efficiency for whole systems, decrease global environmental impacts, and more.

KEY CONSIDERATIONS FOR THE DIGITALIZATION IN THE DECARBONIZATION OF ENERGY

Energy Generation

Renewables: To improve the accuracy of capacity forecasting, it is logical to apply big data and AI technologies to collect and analyze large amounts of data. Taking advantage of cloud and edge computing technologies can improve data correlation and provide more dependable and predictable renewable energy generation.

Emission monitoring in fossil energy: Sensors installed in exhaust channels of fossil fuel or biofuel-based power plants can relay data on the chemical composition and thermal properties of the exhaust gas. This allows the current efficiency of the power plant to be calculated, and it allows for immediate action to correct any anomalies and bring the efficiency back to optimized conditions. Efficiency of power plants directly impacts the amount of fossil fuel or biofuel used, and hence the carbon emissions produced accordingly.

1. Gartner, "Gartner Information Technology Glossary."
2. GSMA, "Mobile Technologies Enabling Huge Carbon Reductions in Response to Climate Emergency."
3. GeSI, "Digital with Purpose: Delivering a SMARTer2030."

Distributed energy resources*:* Distributed energy supply systems, such as renewable energy (in some applications) and electric vehicles (behind the meter), can also be integrated well via digital technology. This controls them in smart ways to decrease the system's environmental impacts (i.e., the concept of a virtual power plant (VPP)).

Maintenance of power plants: Drones and Lidar can offer situational awareness, improve operational efficiency, perform system diagnostics to detect defects early on, enable performance-based maintenance, and perform prognostics to improve future power supply availability. Digital maintenance platforms could help with remote monitoring so as to improve the maintenance efficiency of power plants.

Power Delivery

System operation and maintenance: Digital twin technology which maps virtual and real systems could improve the reliability of the whole transmission system, avoid system congestion, reduce loss, and improve fault identification, location, and isolation.

Transportation and Distribution (T&D): In gas T&D, drones can be used to measure transmission pipeline health, especially mapping leakages. This is usually done with special methane sensitive sensors on the drones. Similarly, methane sensor equipped vans are run within cities to track methane leakages in underground pipelines, which can then be repaired. In electricity T&D, smart grids allow better monitoring of grid health, including transformer and line overload, and remote control of individual grid stations, transformers, billing areas, etc. At the same time, the precise location of where electricity theft is taking place can be identified.

Energy Storage

Digital technology can improve the real time verification and prediction of the state of the energy storage equipment's health. This ensures the safety and reliability of energy storage systems and reduces operating costs via peak shaving (i.e., allowing batteries to be used during peak hours).

Energy Utilization

Digital technology can be used to significantly increase the penetration level of renewable energy in any application, such as in manufacturing, buildings, and transport. This can be achieved by establishing an intelligent controlling platform based on the infrastructure of the energy system to achieve quick responses from the demand side to control different energy sources, while considering GHG emissions through the Security Constrained Economic Dispatch (SCED) optimization process to meet electricity demand at the lowest cost. Furthermore, establishing a VPP platform can transform consumers into prosumers, individuals who both consume and produce, to further ensure reliability and efficiency. In addition, blockchain technology can be adopted to promote security transactions for energy trading.

Building management systems, industrial management systems, home automation, demand management, and energy monitoring systems usually promise up to 30% savings in energy demand. This is usually because of greater awareness of energy demand in real time, rather than by receiving a bill one month later. Energy monitoring allows irregular events to trigger an alarm and wasteful behavior to be identified, allowing end-users to make immediate changes and reduce energy demand.

Certainly, we cannot ignore challenges, such as technical barriers, cross platform information exchange and integration, qualified personnel, and policy and regulations when applying digital technology in energy systems. Policy makers, developers, power system operators, IT developers, and academic experts should work together to develop solutions to mitigate potential challenges. For example, developing best practices and standardizing workflows that are replicable and unified will be necessary for implementing new digital technologies in existing energy systems.

The following sections are structured as follows: description of the challenge, existing solutions, benefits analysis, successful replicable experiences, and key references.

CHALLENGES TO DIGITALIZATION IN THE GREEN ENERGY TRANSITION

Utilization Challenges

Cybersecurity and privacy: Cyber-attack threats could compromise the reliability and security of the grid and lead to potential power outages or equipment damages. In addition, cyber attacks can also threaten the privacy of millions of households, whether targeting local grids and utilities, or domestic solar PV Engineering Procurement Construction (EPC) companies and energy monitoring solution providers.

Interoperability: Various digital solutions and technologies may operate on different platforms and use different protocols. This may present challenges for integrating and coordinating different systems and devices. The rapid increase in the variety and quantity of sensors and IoT devices (input) and connected terminals (output) creates the need for greater and faster scalability, higher data processing ability, and lower response latency.

Data corruption, loss, and intermittent data*:* Wind and solar energy production data through Supervisory Control And Data Acquisition (SCADA) systems and other tools is often prone to data corruption and loss. There is frequent loss of signal connection, leading to intermittent data, as well. Many renewable energy projects are also installed in inaccessible terrains, such as rugged and offshore locations that may be more exposed to inclement weather. For example, wind projects, even onshore, may be prone to higher winds, while solar projects are often in locations with higher sun and dust, such as deserts. All of these factors can lead to unreliable data transmission or garbled data.

Data outliers and identification of actions*:* Dealing with data outliers and accurately interpreting and analyzing data can pose significant challenges. Outliers can significantly distort statistical figures such as mean and standard deviation, leading to misinterpretations and wrong conclusions. There are various statistical methods to detect outliers, but choosing an appropriate method and setting the selection criterion can be challenging. Many real-world phenomena involve complex interactions and correlations. It is challenging to select the right models to capture these relationships, provide complete and thorough interpretations, and take correct and timely actions.

Digital Systems Challenges

When digitizing renewable energy systems, or any existing system, it is important to ensure that the software and hardware of the new digital system does not threaten the security and reliability of the existing energy system. In addition, the use of digital devices, such as sensors and servers, and the setting up of data centers, networks, and base stations for data collection, transformation, analysis and controls, also leads to an increased energy demand.

Workforce Development Challenges for Different Regions

Digital transformation in the renewable sector requires personnel with experience and expertise in digital technology as well as green energy. Currently, there is a shortage of such engineers and experts in many regions and countries. There is also a need for engineering students to learn digitalization techniques adherent to climate change constraints. This presents challenges to create relevant workforce development programs to train qualified personnel to design, construct, operate, and maintain digitalized renewable energy systems.

Policy and Regulatory Challenges

Digital transformation requires regulatory changes and the creation of standards to deal with cybersecurity, data management, privacy, and other challenges. Policies and regulatory frameworks must also keep up with the pace of technological advancement.

SOLUTIONS FOR THE DIGITAL TRANSFORMATION OF GREEN ENERGY

Utilization of Digital Technology

Access and cybersecurity: For monitoring and control, standardization of regulations could help to solve the challenges in interoperability to ensure all the systems can be connected with seamless data transfer/exchange. Moreover, sensors, smart meters, and other mechanisms enable real-time monitoring and control of systems, allowing for greater operational efficiency and better decision-making. For predictive maintenance and performance-based maintenance, digital technologies can be used to perform diagnostics and prognostics of systems.

Detection of data corruption, outliers, and intermittent data: Since they are normally buried under large amounts of data, corrupted/outlier data can be challenging to detect, identify, diagnose, and resolve. The most common methods to detect these problems are: (1) calculating checksums or cryptographic hashes of files or data sets; (2) using data integrity tools to check for possible corruption; and (3) performing a reasonability check to spot potential corrupted or outlier data. It is important to approach the problem systematically and to be patient in efforts to identify and rectify the underlying cause. Though it comes with a higher cost, redundancy can be a good solution for critical infrastructure.

Achieving secure, reliable, and low-carbon digitalization systems*:* More secure and reliable digital systems are needed in renewable energy to ensure security and reliability. The application of advanced digital infrastructure such as green data centers, telecommunication rooms, and higher-efficiency base stations can help to decrease the energy consumption/carbon footprint of a digitalization system. Higher percentages of renewable energy supply, energy-saving ICT technologies, power feeding systems, cooling systems, etc., allow for higher energy efficiency and GHG emission management in digital systems at different levels. In addition, these technologies can be used to balance between performance and power consumption for front-end sensors, data sampling rates, data processing, edge computing, etc.

Workforce Development Solutions

It is necessary to identify workforce needs, develop training programs such as in data analysis, invest in education, support workers in transition, promote diversity and inclusion, foster innovation, and collaborate with the industry to promote workforce development for energy transitions. Curriculum for workforce development on digitalization and renewable energy may include technology re-tooling, codes as well as standards, best practice learning on renewable energy, etc.

Policy and Regulation Development Solutions:

It is important to create supportive policy and regulatory frameworks to encourage the adoption, innovation, and integration of digital technologies in the energy sector. Developing robust digital infrastructure, standardizing data exchange and communication protocols, promoting technology neutral policy, establishing cybersecurity and privacy regulation, and providing market incentives are key policy and regulatory measures that can help facilitate the digital transformation of the energy sector.

BENEFITS OF DIGITALIZING THE ENERGY SECTOR

- Improving situation awareness and operation efficiency, performing diagnostic functions for early fault detection, executing performance-based maintenance, and executing prognostics to prevent unplanned outages and schedule repairs/replacements to minimize downtime will improve the reliability and resilience of the system.

- Providing detailed information on performance, energy consumption, and carbon footprint down to the device level creates the baseline of the system and offers the possibility of pin-point accuracy of improvements.

- Since energy storage systems may have different characteristics and power/energy density, digitalization can provide better coordination and improve overall performance of the energy storage systems. With better information and coordination, digitalization can create better interoperability, a more efficient demand response program, and improve energy efficiency and system resilience and reliability.

- Providing better understanding/estimation of the health condition and state of charge (SOC) of the battery storage system will enable the participation of the battery storage system in the ancillary service market and/or energy service market in both real-time and day-ahead markets.

- Since data is collected and transferred through communication networks, reducing the need for physical activities can largely reduce power consumption and GHG emissions.

- To improve forecasting, improve the capacity forecasting green power supply and make the unit commitment scheduling more efficient. With accurate forecasting, utilities will better manage their systems to avoid possible congestions.

- Well established standards and regulations can promote investment and innovation and ensure safe and efficient operation of green energy systems. It can also prevent political conflict among countries with interconnected systems.

SUCCESSFUL REPLICABLE EXPERIENCES

Wind capacity forecasting: The Electric Reliability Council of Texas (ERCOT) is responsible for managing the power grid in Texas. Wind power is a significant source of energy in the ERCOT grid, with over 30 GW of installed wind capacity. Wind capacity forecasting is essential for the efficient and reliable integration of wind power into the ERCOT grid. ERCOT performs an Intra-Hour Wind Power Forecast (IHWPF) by wind region that provides a rolling two-hour, five-minute forecast of ERCOT-wide wind production potential. This report is posted every 5 minutes and includes system-wide and geographic regional 5-minute averaged solar power production for a rolling historical 60-minute period.[4]

Smart controlling platform solution in cement: The Conch Cement company in China constructed a green energy system controlled by a digital platform that integrates PV, wind, biomass fuel, as well as storage to promote the green energy transition. In 2021, this platform helped use 1.28 million kWh of wind power, 164 million kWh of photovoltaic power, and 22,000 tons of biomass fuel, achieving carbon reductions of 741 tons, 95,300 tons, and 24,000 tons, respectively.[5]

Smart energy solution in wind: 5G and cloud technology help the Zhegu wind power station in Tibet achieve remote monitoring, auto inspection, disposal, and individual operations. 5G technology was applied to provide exclusive user plane function (UPF) network services, which promote low latency, high reliability, and data security network capabilities to meet diverse application scenarios of the wind turbine system. The system also used cloud and edge technology to improve data collection efficiency and security. Remote monitoring applications, with low latency and fast speed through the 5G network, mainly help experts and maintenance staff obtain efficient remote guidance in real time and improve troubleshooting efficiency.

Hydropower modernization: The Brazilian planning authority estimates that 11 GW of additional capacity could be added by repowering and modernizing just 51 power plants of its existing fleet, which would translate to reductions of marginal expansion costs of up to 10%. Moreover, a study of projects that were already modernized in

4. ERCOT, “Combined Wind and Solar.”
5. Baidu, “Conch Cement focuses on low-carbon development.”

Brazil showed actual gains in efficiency of between 1.5% and 5%, which translated to additional generation. Modernization projects financed by the Inter-American Development Bank (IDB) in the region have also demonstrated gains in energy availability, reduction in operation and maintenance costs, and increased installed capacity, all of which translated to economic benefits and increased lifetimes of the power plants.[6]

ITU-T L.1380 series of recommendations on smart energy solutions: By facilitating the adoption of clean energy, regional customization, network communication, and IoT, energy utilities in urban areas can be improved and optimized. Smart energy solutions can also promote conversion to all kinds of renewable energy sources such as solar, wind power, electric power, and chemical power, increase the uptake of clean energy for electric power generation, optimize energy feeding structure, and improve overall energy efficiency. Distinguished by their specific functions, smart energy solutions, such as those recommended by the International Telecommunication Union Telecommunication Standardization Sector (ITU-T), can be applied to five key domains of a city: the business district, community, industrial park, electric transportation network, and municipal area.[7]

AI prediction in solar generation: With AI prediction tools based on weather forecasting in solar generation, clients are able to report capacity predictions within 5% error to the grid, improving the integration of renewable energy into the grid, while reducing their prediction penalties. Using AI can help in renewable generation forecasts and help grid operators match generation and demand patterns well in advance to avoid curtailment of renewable energy sources.

Energy management software application: Solar generation, utility demand, and battery management software that can keep track of PV modules, inverter and battery health, while tagging irregular events for action. The software tracks weather forecasts to be prepared for decreased production or potential power breakdowns/loadshedding. The battery charge and discharge keep in mind the regular patterns of loadshedding in that location, so that storage is available too for these times. It also takes into account off-peak and peak rates for the best bill savings for the customer.

24/7 carbon-free energy at Google Data Centers: By analyzing granular energy data, Google can measure how a given data center's hourly electricity use coincides with hourly carbon-free electricity supply on the regional grid. The carbon footprint of a data center is minimized when its hourly energy use is fully matched by regional carbon-free generation, either from Google-contracted renewables or the broader grid mix. Google has become the world's largest corporate buyer of renewable energy. In 2017 alone, it purchased more than seven billion kilowatt-hours of electricity from solar and wind farms that were built specifically for Google. This enabled Google to match 100% of its annual electricity consumption through direct purchases of renewable energy.[8]

24/7 carbon free energy using hybrid Battery Energy Storage System (BESS): A MW scale hybrid BESS has been commissioned with solar to supply 24/7 energy in Gurugram, India. This hybrid BESS is comprised of LFP & Tubular Gel Batteries to reduce the capital investment by 40% with a 100% flicker free response to the electricity demand from multiple resources. This H-BESS has replaced diesel generators, completely offsetting the carbon footprint. The preventive, predictive artificial intelligence-machine learning model embedded in the battery management system & energy management system (EMS) analyzes the cell level data to predict 15 days in advance the anomalies at the system and cell levels.

6. Folly de Aguiar, Et. Al, "*Expansão da Geração*."
7. International Telecommunication Union, "*Series L: Environment and ICTS*."
8. Google Sustainability, "Tracking Our Carbon-Free Energy Progress."

The AI-EMS also forecasts the solar production for the day, including the grid export and solar utilization, for better and efficient energy management.

Green base station solutions: Based on the renewable energy resources, China Mobile builds wind and photovoltaic renewable energy power generation systems in their base stations.

China Mobile has more than 10,000 zero carbon/ low-carbon base station sites with their own renewable energy systems. In addition, they promote the application of energy saving technology to continuously reduce the power consumption of different subsystems and equipment, and improve energy efficiency through new designs, materials, technologies and indicators.[9]

9. Waitang, "Carbon Neutrality Action in China Mobile."

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