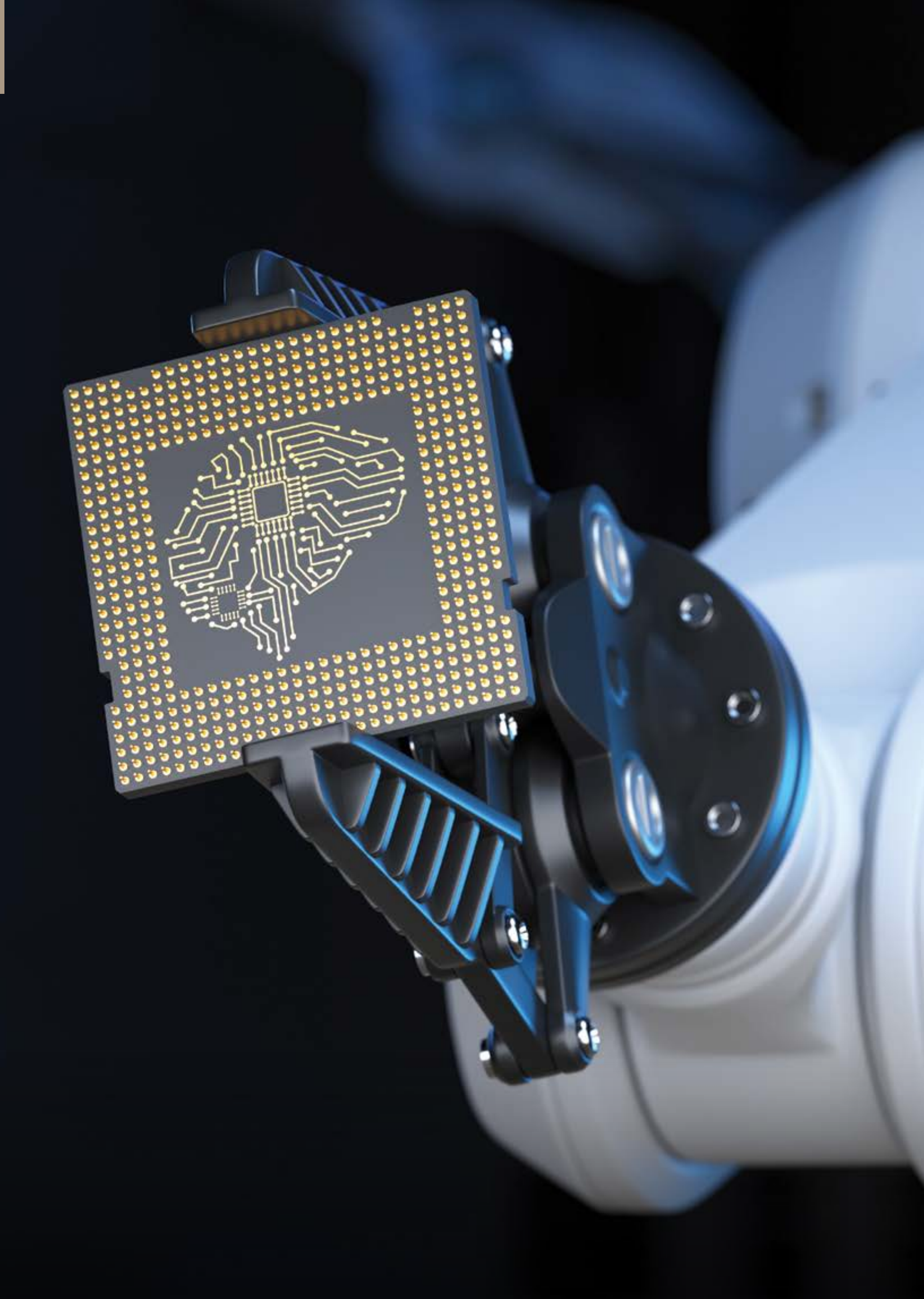

Revolutionizing electric utilities with AI

ABSTRACT

The power sector is digitizing, enabling the use of advanced computing tools such as Artificial Intelligence (AI) to achieve operational efficiency and optimality. This technological innovation is playing a significant role in the global energy transition to meet climate goals. AI is being embraced by developed countries as a critical tool for reducing energy waste, lowering costs, and accelerating the adoption of clean, renewable energy sources in power grids worldwide, as well as improving power system operation, maintenance, control, and planning. AI applications have revolutionized electric utility operations such as customer engagement, managing electrification of transportation and smart neighborhoods, electrical grid digitization, and electrical network asset digitization.

KEYWORDS:

Artificial Intelligence, Smart Grid, Grid Digitization, VPP, Prosumers

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Introduction

The use of renewable energy to replace fossil fuels is gaining traction as economies across the globe continue to set their carbon neutrality targets. Along with centralized renewable energy generation centers, clean electrification is also accelerating the widespread deployment of distributed generation sources. The concept of a smart grid has also transformed customers into "prosumers," allowing them to participate actively in the energy markets. Following these innovative trends in of power sector, the power grid is growing its interaction with new computing technologies such as Artificial Intelligence (AI), blockchain, and robotics.

Power grid transformation

The power grid is becoming bi-directional, allowing multiple generation sources to feed more volatile loads, such as electric vehicles as well as conventional loads. The notion of powering the grid with different resources such as base load power plants, renewables, energy storage, and electric vehicles is exciting, but it also poses certain challenges in terms of managing grid operations. To address the rising problems associated with the ongoing transformation in the power sector, utilities must embrace flexible and scalable grid management

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methodologies. The modern grid is rapidly moving towards smart grids, combining the domains of the Internet of Things (IoT) and telecommunication with the power network, transforming the power grid into an information grid. The data logged by the advanced monitoring devices in the power network enables utilities to incorporate advanced computing tools, such as AI, to effectively manage and operate the power grid through data-driven strategies. In the coming years, an increase in the proliferation of sensors and advanced smart meters in the power grid as well as advancements in behind-the-meter devices and data logging infrastructure, will enable utilities to become proactive in their services ranging from demand management and generation forecasting to predictive asset maintenance. The success of the 4th Industrial Revolution (4IR), integrating IoT and AI in industrial processes, has been the primary driver of the digital revolution in the power sector. Fig. 1 shows the developments in the power sector, comparable to 4IR, that are leading to the deployment of blockchain, AI, and IoT.

AI potential to transform electric utilities

AI is rapidly becoming the most significant tool in enabling utilities to make better pricing decisions and build stronger interactions with consumers. Utilities can use AI to increase their operational efficiency as well as to gain financial benefits in the open electricity markets. The potential use cases are as follows:

A. Predictive maintenance of assets

Time-stamped data is collected from the assets such as generation units, distribution transformers, and distribution lines via various sensors and fed into AI algorithms to predict upcoming faults to reduce downtime as well as to perform predictive maintenance. For instance, German grid operators Schleswig Holstein Nets AG and Bayernwerk Netz GmbH chose Siemens to perform an inspection of high-voltage overhead transmission lines. Siemens examined 4,000 km of transmission lines using a helicopter equipped with 19 cameras and 3D laser scanning sensors, capable of capturing 12,000 images and performing detailed 3D scanning per km. The collected data analyzed by computer vision and AI algorithms generate key insights on the asset's current condition and allow utilities to perform predictive maintenance on assets where a malfunction was likely to develop [2]. Similarly, American electric utilities such as Duke Energy and Southern California Edison (SCE) have utilized drones and AI-powered computer vision technology to conduct monitoring of transmission line assets.

B. Predicting optimal energy rates

AI can forecast the best time to sell electricity to utilities and when to store it for customers that have their generation resources, like solar power. As an example, the Adaptive Neural Fuzzy Inference System (ANFIS) has been used to forecast short-term wind patterns for power generation. This allows producers to optimize energy production and sell it back to the grid when prices are at their highest. For instance, Bidgely's AI-powered customer engagement solution is helping Electric Ireland consumers to save power costs based on the data collected through their smart meters, providing valuable insights to both consumers of electricity and utility owners [3].

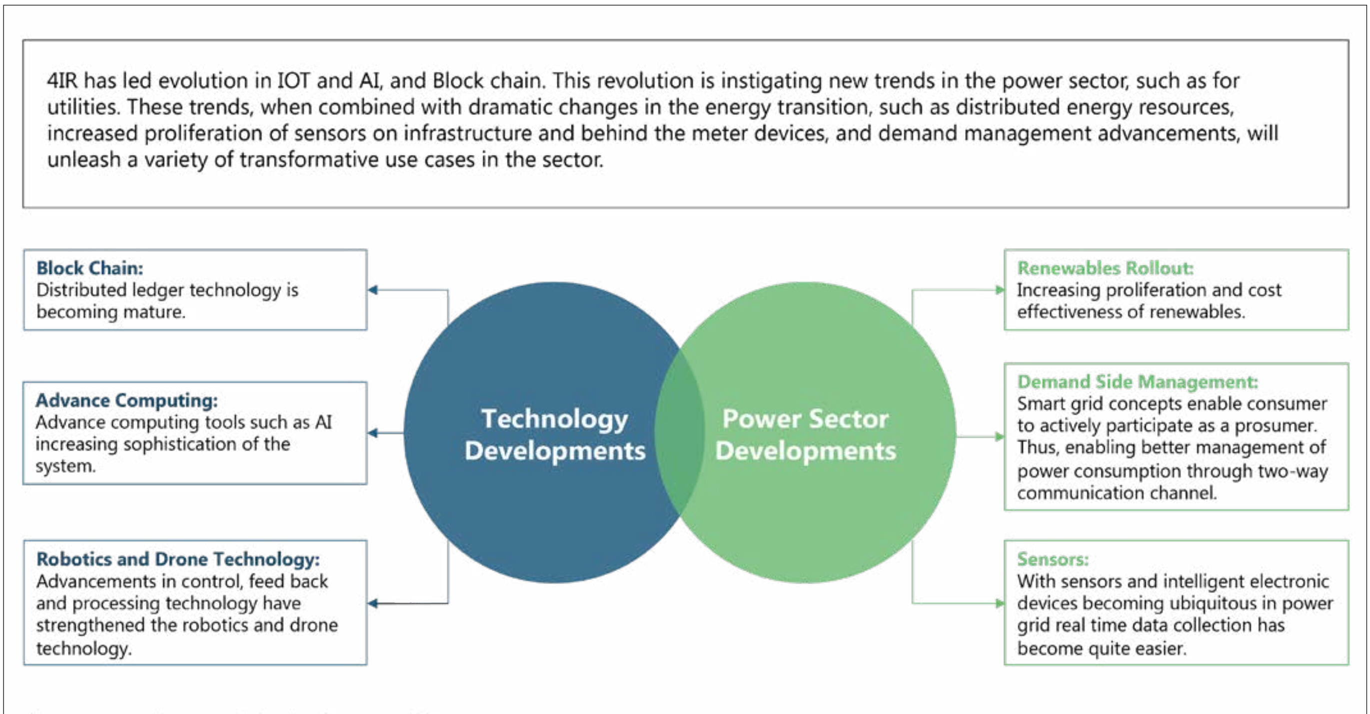

Figure 1. 4IR and new trends in electric power grid [1]

C. Predicting accurate energy demand

Accurately predicting customers' energy needs is of vital importance for any electric utility. There are currently no adequate options for bulk energy storage, which implies that energy must be delivered and consumed as soon as it is generated. Here, AI can play an important role by predicting future energy demand based on historical real-time data such as weather conditions, consumer usage, time of the year, etc. This way, AI can prevent the ducker scenario by timely predicting both load and renewable generation. For example, Asia-Pacific Energy's company CLP Holdings implemented AI-powered distributed energy resources management system to optimize energy generation and managed to reduce peak energy consumption by 7 % through optimal integration of batteries and renewable energy assets [4].

D. Identifying better trading options

The electricity tariff plays a major role in the open electricity market, where consumers are free to purchase electricity from the provider of their choice. To remain competitive, utility companies may utilize AI to determine the optimal time span to acquire electricity at the lowest price. For example, NextEra Energy services wanted to help its commercial and industrial customers to lower their energy costs during periods of energy peaks or high wholesale electricity prices. In this line, NextEra Energy deployed AutoGrid's ControlComm, an AI-powered demand response platform, that allowed customers to develop intelligent curtailment plans and monetize their energy flexibility without affecting power grid operations [5]. Through this program, NextEra Energy's customers voluntarily enrolled themselves in electricity consumption reduction programs based on AI predictions about higher electricity prices and peak load scenarios in exchange for monetary benefits.

E. Reducing customer churn (electricity switching rate)

Churn rates in the energy business can reach more than 20 % (the percentage of customers who discontinue using a service in a given year). It is critical to accurately predict and prevent customer churn. In this line, AI can be incorporated by utilities to predict when a customer is getting ready to churn out. By analyzing historical usage data, AI can help utilities to identify key indicators that can predict when a customer is going to churn. Electric utilities in the UK faced a massive churn out of customers as electricity tariffs increased after the end of the Covid lockdown.

Customer churn is a major challenge for utilities across the globe due to the rising prices of electricity. To deal with this, TEPCO, a Japanese electric utility, launched an annual home energy reports program powered by Bidgely's AI-powered solution (UtilityAITM) [6]. The utility provided energy reports, generated through AI, to their customers on contract renewal as a novel strategy to promote increased customer retention. These reports are generated using AI on the consumer data to disaggregate energy use down to the appliance level, allowing consumers to reduce their electricity consumption and hence cut their electricity bills.

F. Predict merit order of energy prices

Utility providers have many alternatives from where they acquire their energy, ranging from renewables like wind and solar to fossil fuels and nuclear. When it's time to sell the power, these various sources are grouped into a price-based merit order. This influences the sequence in which the various sources of electric power are sold.

AI algorithms are also better at predicting an ideal merit order by taking into consideration all of the different elements that influence the price

AI algorithms are also better at predicting an ideal merit order by taking into consideration all of the different elements that influence the price, including weather, demand, how much energy is available from various sources, previous usage, and so on. For example, Schneider's microgrid technology implemented at a microgrid operated by Oncor allows for cost-effective cloud-based economic dispatching of the generation resources to meet the demand for electricity [7].

Bottlenecks to AI adoption in the power sector

The above discussion indicates that AI has the potential to significantly improve the entire power sector ranging from power generation to transmission, distribution, and consumption. However, there are numerous challenges in both emerging markets and advanced economies, impacting the adoption of AI in the power sector. The major challenges are as follows:

1. The integrity of the electrical grid is critical. As there is always the chance of a loophole that hackers might exploit, AI-powered services may jeopardize the security of the power sector.
2. The lack of regulations and policies to ensure the effective digital transformation of the traditional power sector is hindering the widespread deployment of AI-powered grid services.
3. The outdated power grid is one of the major bottlenecks to the modernization of the power sector. Furthermore, implementing modern smart technology and sensors is not a cheap solution and will require significant investment.
4. There are only a limited number of solution providers that have sufficient technical knowledge of both AI technology and the power sector. Furthermore, cautious stakeholders would rather continue with time-tested processes and technologies than risk the power network by attempting anything new.

Mapping of AI applications in grid services

AI has been driving the information revolution not only in the electric utilities but also throughout the power sector as a whole. The digitization of the electric power generation, electricity market, transmission, distribution, and retail sectors, has enabled the implementation of AI-powered applications, boosting the efficiency of each sector. The power generation sector uses AI to study the possibilities of new energy resources, including wind, solar, and geothermal power based

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on historical geographical data. Plus, AI is also utilized by power generation companies to improve power plant efficiency and implement predictive maintenance. To cope with the increasing complexity of the power sector due to decarbonization and decentralization, electric utilities are deploying AI-powered grid flexibility services. AI is also considered to be a potential tool to increase the pace of electric vehicle adoption by providing smart charging and charging management solutions. The adoption of smart meters has paved the way for a range of AI-powered applications, from demand response to customer interaction, as well as helping consumers to participate as active stakeholders in the electricity market

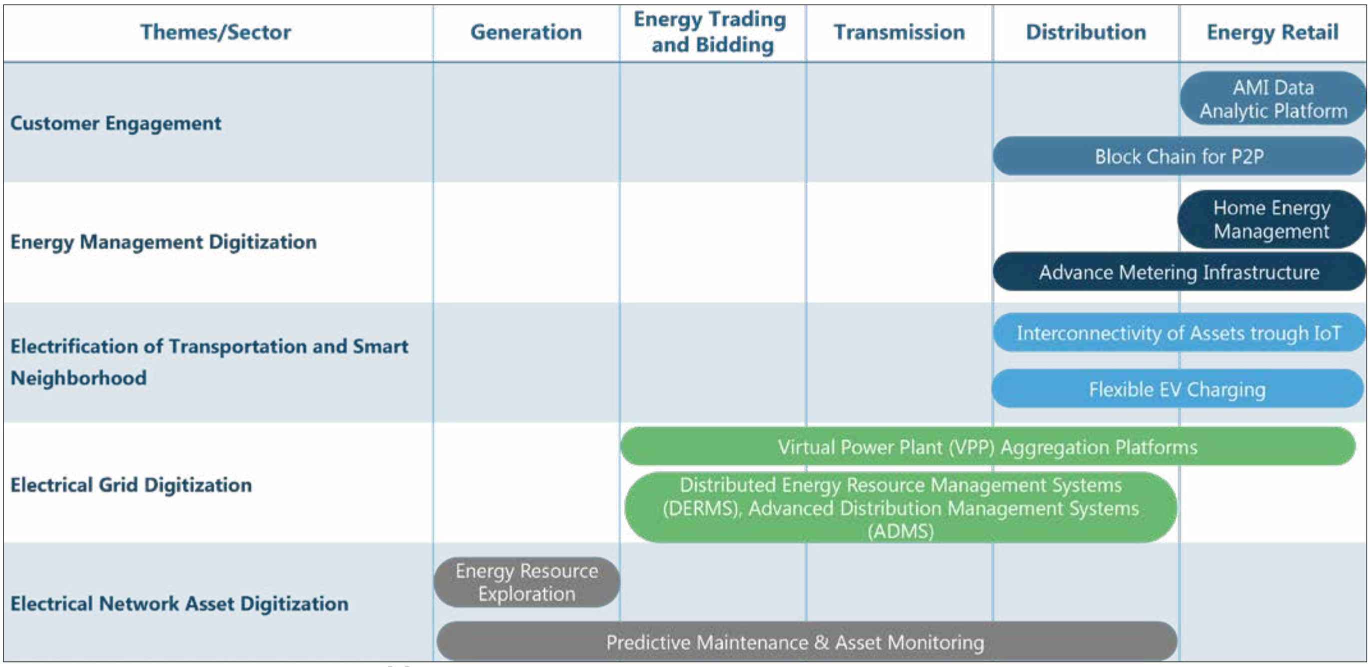

Figure 2. AI applications in Grid Services [1]

Theme	AI - Powered Grid Services	Major Electric Utilities	Service Providers
Customer Engagement /Energy Management Digitization	• Home Energy Management • Building Energy Management System • Advance Metering Infrastructure (AMI)	AEP, AEP - Public Service Company of Oklahoma (PSO), Ameren, APS, BPA,BRPL, City of Palo Alto Utilities, Con Edison, Duquesne Light Company, Electric Ireland, Eversource Energy, Knoxville Utilities, Madison Gas and Electric, NESCO, NextEra Energy, NRGi, NV Energy, NYPA, Pacific Power, SMUD, TEPCO, VSE	Oracle, C3.AI, Bridgely, AutoGrid, Landis+ Gyr, Honeywell, Siemens, Schneider Electric
Electrification of Transportation and Smart Neighborhood	• Smart Grid • Cloud Services for Grid operations • EV Smart Charging Platform	BGE, DEWA, E.ON, Eneco Group, Exelon	Oracle, ABB, AutoGrid, C3.AI, Driivz, Fortum Charge & Drive, Virta, Microsoft AWS, Itron
Electrical Grid Digitization	• Virtual Power Plant (VPP) Aggregation Platforms • Distributed Energy Resource Management Systems (DERMS) • Advanced Distribution Management Systems (ADMS)	ActewAGL, APS, AVANGRID, CenterPoint Energy, CLP HOLDINGS, Counties Energy, CPS Energy, DEWA, DTE, Duke Energy, Enel, Eversource Energy, Florida Power & Light (FPL), Knoxville Utilities, LADWP, National Grid, NIE Networks, Northern Powergrid, ONCOR, Portland General Electric, PSEG IL, Puget Sound Energy (PSE), SAPN, SCE, SDEM	GE Digital, Oracle, Schneider Electric, AutoGrid, Generac Grid Services/Enbala, AutoGrid, ABB, Next Kraftwerke
Electrical Network Asset Digitization	• Predictive Maintenance & Asset Monitoring	Duke Energy, Enel, Florida Power & Light (FPL), National Grid, SMECO, SCE, Xcel Energy, UK Power Networks	Siemens, Hitachi ABB Power Grids, Itron, Schneider Electric GE Digital, AutoGrid, Oracle

Figure 3. Major electric utilities and solution providers enabling AI in the power sector [1]

In the coming years, AI will be assisting utilities in optimizing electricity prices through better trading, reducing customer churn, and predicting the likelihood of winning customers

by enabling two-way communication and the flow of electricity. The aforementioned AI-powered grid services, along with their area of deployment, are shown in Fig. 2.

Utilities moving ahead toward the information grid

The major electric utilities in the USA, Europe, and Australia are actively participating in the collection of data through smart meters and assisting their customers in optimizing their electricity usage with the help of AI algorithms. AI-power grid services cater to all sectors of the electric power network, including customer engagement programs, asset planning, digitization of distribution and transmission networks, optimal IoT-based interoperability, energy resource management, and resource forecasting. Fig. 3 depicts prominent AI-powered grid solution providers as electric utilities employing a variety of AI-powered grid services such as customer engagement activities, smart EV charging, grid flexibility services, and predictive maintenance and monitoring of critical power sector assets.

Looking forward

These advancements indicate how AI is enabling utilities to improve their efficiency and reliability, but it is still in the early stages of deployment. In the coming years, AI will be assisting utilities in optimizing electricity prices through better trading, reducing customer churn, and predicting the likelihood of winning customers. The United States, Europe, and Australia account for the majority of AI-powered grid service deployments, and it is envisaged that as the number of renewable energy developments, electrification of transportation, and digitization of metering infrastructure increases, AI will gain even more traction in the utility sector.

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