VIEW POINT

THE POWER OF AI FOR RENEWABLE ENERGY GRID MANAGEMENT

Abstract

Over the last decade, renewable energy generation across the globe has seen an incredible push, as nations focus on fighting climate change and reducing their dependence on fossil fuels. International Energy Agency (IEA) has forecast that the world's renewable energy capacity addition is poised to grow at a staggering 305 GW annually between 2021 and 2026, thereby increasing the renewable portfolio targets for distribution utilities and energy retailers across the globe. Though most of the nations are looking to overshoot their capacity addition targets, grid integration of renewable energy is emerging as a key challenge. To address this, artificial intelligence (AI) offers a strong suite of solutions such as machine learning, industrial software, and other predictive capabilities.

This paper looks at existing and emerging AI technologies that are enabling electricity utility companies across the globe with more efficient forecasting and scheduling of renewable energy sources. For this paper, several pilot projects were explored to understand how AI is being utilized in smart grids, renewable energy integration, and seamless demand-side management. This paper examines the utility of AI in addressing a host of other issues such as outage management, cyber security, and fault diagnosis.

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Renewable Energy in Focus

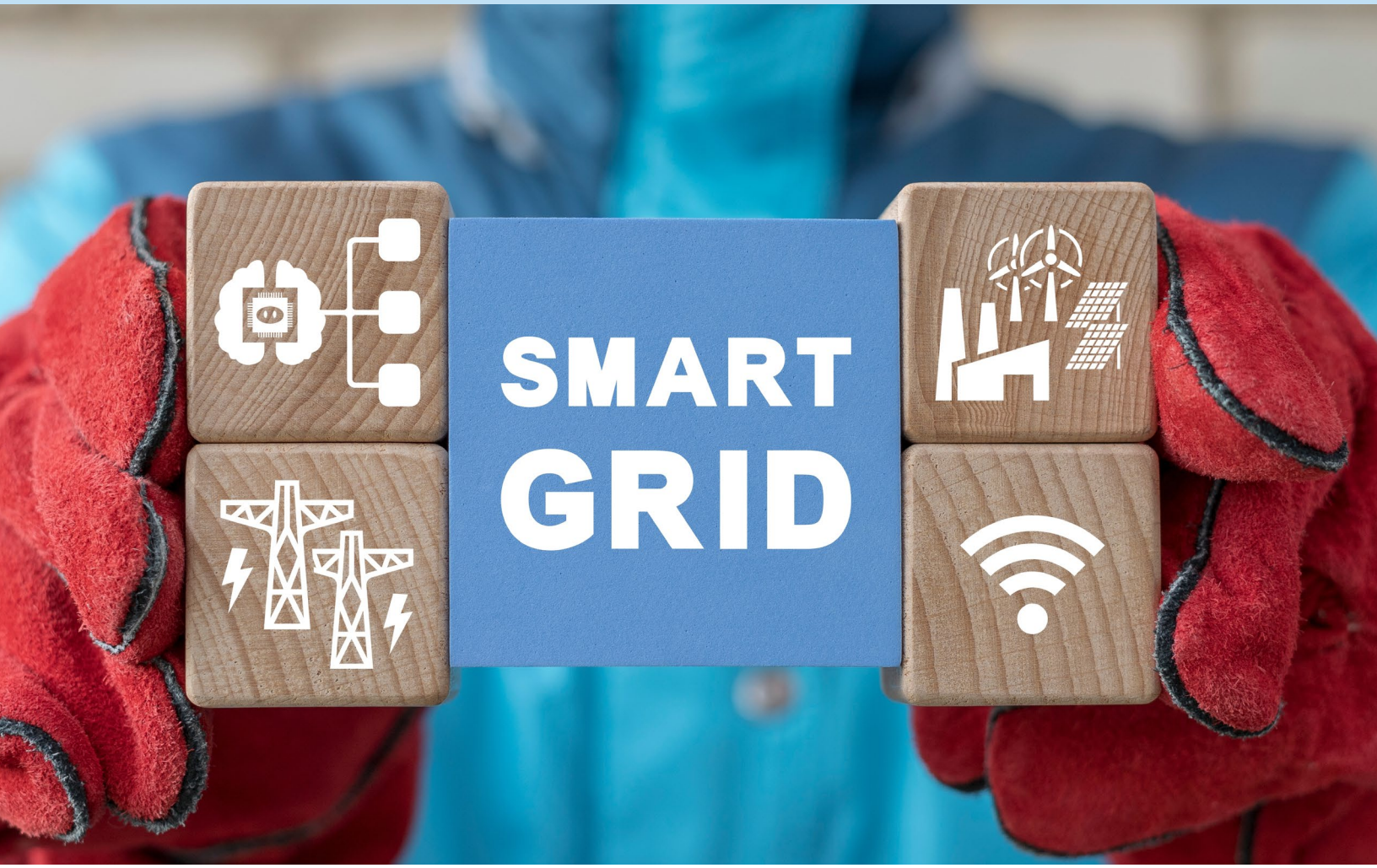
As the world looks to end its reliance on fossil fuels, electricity generation and distribution utilities across the globe are looking to invest in energy sources that are abundant in nature, produce minimal to zero greenhouse gases, do not pollute the environment, and are renewable.

As per the annual study conducted by IEA[1], renewable energy generation contributed to 29% of the globe's total electricity generation in 2021, up from 7478 TWh in 2020 to 8000 TWh in 2021. It is exciting to see that renewable energy is booming. At the same time, conventional electricity generation has started to decline, and new projects are few and far between. This decline in the use of fossil fuel and growth in renewable energy-based electricity generation is poised to continue in future. Optimistic estimates see renewable energy contributing about 43% of total electricity generation in the world by 2030, and about 65% by 2050.

As always, there are caveats to these statistics with numerous challenges on the path to meeting renewable energy targets. According to various sources, due to a massive growth in wind turbine and solar photovoltaic (SPV) cell installations over the past few years, many nations will overshoot their renewable energy generation targets. If they are proved right, such predictions mean that integration of renewable energy into the grid is going to be the biggest challenge as well as opportunity for electricity utilities in the coming years.

How do we plan to manage a grid that receives the bulk of its electricity from renewable energy sources? Will the current state of electricity grids across the globe be enough to deal with such excessive volumes of renewable energy? If not, what can we do to ensure that these grids can scale and manage the growing amount of renewable energy-based electricity generation?

Artificial intelligence (AI) and machine learning (ML) may well be the answer to these and more questions as the world moves toward renewable energy.



[1] World Energy Outlook 2022 by International Energy Agency https://iea.blob.core.windows.net/assets/830fe099-5530-48f2-a7c1-11f35d510983/WorldEnergyOutlook2022.pdf

Artificial Intelligence for Renewable Energy Grids

Electricity grids are designed to balance supply and demand of electricity in real time, as large-scale electricity storage is not economically viable with the technology available today. Therefore, grid operators are required to predict or forecast electricity availability on a day-ahead or term-ahead basis. Most widely used renewable energy sources such as solar power and wind are intermittent in nature and unpredictable due to the dependency on the weather. This poses a significant challenge for grid operators as they must perform complex electricity scheduling and dispatch operations in real time and even a simple miscommunication by the generators/distributors/transmitters could lead to blackouts.

While advancements in electricity storage are needed to resolve such intermittency, issues related to renewable energy, advancement in electricity grid technology is also pivotal. Grid management is critical to ensure efficient electricity scheduling and dispatch, autonomous control of renewable energy generating stations, and transmission line fault detection. AI and ML will play a key role in providing predictive analysis to grid operators for efficient management of all the stakeholders in the electricity sector.

Table 1 shows some of the AI technologies currently being employed by electricity grid operators.

Table 1: AI technologies being used in electricity grid management

Ref	Objective Function	Techniques Used	Limitation
Darab et al	Lightning strike detection, fault location detection, and islanding	Traveling wave method, impedance-based method, ANN, support vector machine, fuzzy logic, genetic algorithm	Extra load due to islanding DG unit may reduce reliability on other DERs
Blake et al	Optimization of DERs, load forecasting	ANN, Levenberg–Marquardt training algorithm	Optimal sizing of ESS, operation of a CHP unit in a site with varying load, and control of charging/ discharging of ESS need further elaboration
Javaid et al	Economical energy management with RES integration	Binary PSO, GA, cuckoo search algorithm	Consumers trade their consumption priorities for cheaper electricity
Elkazaz et al	Online optimal operation of DG for residential applications	Genetic Algorithm (GA)	Considers only a small number of houses; consumption behavior varies across residential consumers
Jaramillo et al	Optimal scheduling of DERs	Mixed Integer Linear Programming (MILP)	Peak power cost is not considered in the objective function
Melham et al	Integration of RESs in SG for residential energy management	MILP	Residential consumer with DR program not considered
Al-Alawi et al	Minimizing fuel dependency, engine wear and tear, and greenhouse gas emission	Artificial Neural Network (ANN)	Integration of DERs is not considered

Source: "State-of-the-Art Artificial Intelligence Techniques for Distributed Smart Grids: A Review" by Syed Saqib Ali and Bong Jun Choi

Although AI is being used in grid management in the areas mentioned in Table 1, the technology is still nascent and not widespread. Grid management is the key to unlocking the full potential of AI in the integration of renewable energy with the electricity grid. Some crucial areas where AI can be very helpful are discussed below.

Application of AI in Grid Management

The power of artificial intelligence and machine learning can be leveraged in several ways across the entire energy generation, storage, and transmission channels.

Electricity scheduling

An AI-based scheduling system can easily examine several generating stations, transmission and distribution grids, economic feasibility, infrastructure viability, merit order dispatch, and similar sets of information in real-time. Using this data, it is feasible to develop practically viable and efficient power scheduling models that grid operators can rely upon for scheduling. As a matter of fact, the electricity grid is more about data than electricity.

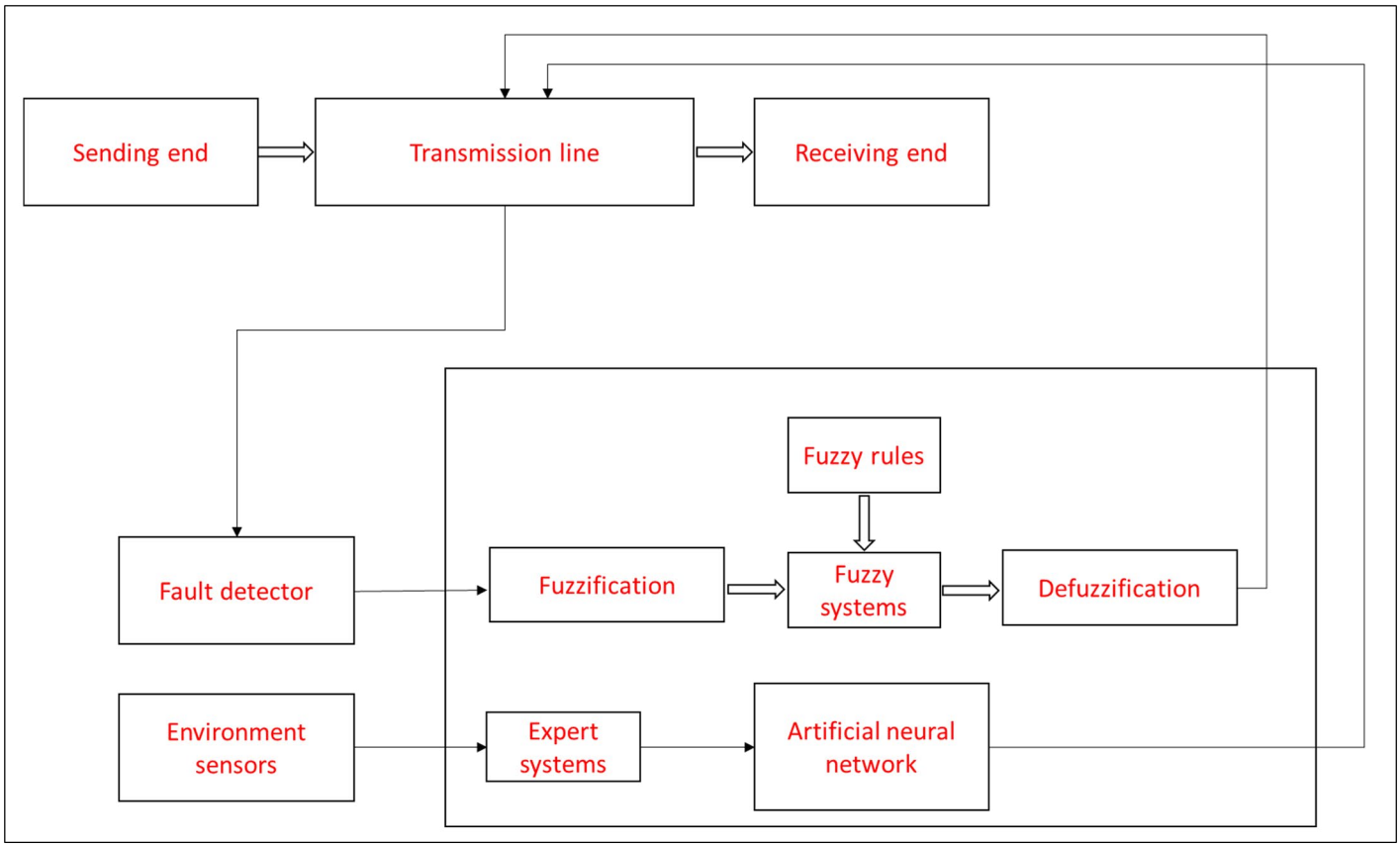
Merit order dispatch

AI can provide accurate predictions on power usage patterns and trends for households and commercial spaces in normal and extreme weather situations. In addition, AI can also be used to predict, in real-time, the regions where loss of power would result in drastic infrastructure and human loss. This ability enables grid operators to dispatch electricity to such regions on priority.

Operation and control

At present, AI is already being utilized in multiple countries for various operation and control measures to ensure an efficient and reliable grid. Some of the operations currently being performed by AI and ML software in electricity grids include load flow, frequency control, voltage monitoring and control, fault diagnosis, and cyber security. Figure 1 depicts how a potential AI-based fault detection system for transmission lines may look.

Figure 1: AI-based fault detection system for transmission lines



Source: "Artificial Intelligence in Power Systems" by R. Pasupathi Nath, V. Nishanth Balaji

Conclusion

Artificial intelligence is a game-changer for the integration of renewable energy with the electricity grid. We are at a critical juncture of this millennium as both renewable energy and AI are entering advanced stages in their technology cycle and their amalgamation is bound to happen. With growing concerns around fossil fuel-based energy generation and climate change, use of renewable energy is bound to grow rapidly. An AI-controlled grid will not only be adaptable to renewable energy generation but will also be resilient and more secure.

This means that electricity sector stakeholders such as utilities, grid operators, and generators need to investigate the application of AI in their specific areas and plan AI-enabled renewable energy grids. To achieve this, all stakeholders will require significant support from organizations that excel in AI technology and industrial software. In coming years, a significant amount of research and investment is needed to ensure the advancement of both AI and renewable energy.

About the Author

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Anamika, a consultant with Infosys Consulting, India, has over 6 years of work experience in the energy and utilities industry. She has supported various North American and European utilities in the areas of energy trading and risk management, electricity outage management, and field service management. She is passionate about grid modernization and enablement of AI in energy grids across the world.

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