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ARTIFICIAL INTELLIGENCE IN SUSTAINABLE ENERGY INDUSTRY: STATUS QUO, CHALLENGES, AND OPPORTUNITIES

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ABSTRACT

This study focuses on the future of AI in the energy sector, examining how AI can be used to improve efficiency and sustainability in the sector. The study aims to provide a realistic baseline of AI technology that can be used to compare efforts, ambitions, new applications, and challenges around the world. We covered three main topics: (i) how AI is being used in solar and hydrogen power generation; (ii) how AI is being used in supply and demand management control; and (iii) the latest advances in AI technology. In this research we explored how AI techniques outperform traditional models in controllability, energy efficiency optimization, cyber-attack prevention, IoT, big data handling, smart grid, robotics, predictive maintenance control, and computational efficiency. Our study found that AI is becoming an important tool for a new and data-intensive energy industry, which is providing a key magic tool to increase operational performance and efficiency in an increasingly cut-throat environment.

KEYWORDS: ***Artificial Intelligence; Renewable Energy; Energy Demand; Decision Making; Big Data; Energy Digitization***

1. INTRODUCTION

Computer programs now have the capacity to reason and learn. In order to prognosticate wind pets and renewable energy sources in the simplest and most effective mores, artificial intelligence is largely recommended. Real- world data can be gathered by artificial intelligence, similar as literal rainfall patterns and energy demand, which can help an association, function more effectively in society. This technology is expansive and well known for its capability to prop in the resolution of problems with scheduling, soothsaying, control, and other affiliated areas. Artificial technology, a form of contemporary technology, can help with grueling tasks. You can reuse a lot of data and make extremely accurate prognostications thanks to artificial intelligence. This enables your company to more fluently gain the information demanded for effective operation and the advancement of society. Deals prognostications can be made with its backing, and it produces accurate data that enables them to take on further strategic tasks. Making opinions using chances has become important simpler and much more accurate thanks to artificial intelligence, which will shape the future of the force chain. AI assists in prognosticating the force chain, which promotes business growth, allows for multitasking, and lessens the workload for accurate resource allocation. Artificial intelligence is veritably profitable because it takes pitfalls, works more snappily, and is accessible for diurnal operations as a digital adjunct around- the- timepiece. Artificial intelligence offers colorful types of solar technology, including solar photovoltaic, unresistant solar, solar water heating, solar process heat, concentrating solar power, etc. It principally offers real- time grid monitoring, more precise and effective power change soothsaying, and the creation of multitudinous new energy-related strategies

- The enabling technologies include: power plants flexibility, utility-scale batteries, IoT, big data and AI, blockchain, behind meter batteries, electric vehicles [3], mini-smart and renewable grids, super grids, renewable energy to hydrogen and renewable energy to heat;
- The business models include: community ownership models, peer-to-peer energy trading, energy services models, and online payment models;
- The system operation include: dynamic line rating, virtual power lines, corporation between distribution, transmission, and generation, energy forecasting, renewable power production, hydropower storage technologies and future role of utilities and system operators; and
- The energy market design includes: the different time of use tariffs, rising granularity in electricity markets, net billing schemes, the integration of the market with

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distributed resources, regional markets, innovative ancillary services, and so on[5,10-15].

1.1 Research Gap

From the literature review, it is observed that in the following specific areas attention is required:

Enhancing Reliability and Adaptability: Further research is needed to understand how AI can improve the reliability and adaptability of decentralized and decarbonized energy systems. This involves optimizing energy generation and distribution, managing renewable energy sources, and ensuring grid stability.

Addressing Data Challenges: Challenges related to data quality, availability, interoperability, and privacy need to be addressed for successful AI implementation in energy systems. Research should focus on defining data requirements, developing data collection methods, and establishing effective data management strategies.

Policies and Investment Strategies: Exploration of policies and investment strategies is necessary to promote AI adoption in the energy sector. Understanding the impact of different policy frameworks, funding mechanisms, and regulatory approaches is crucial for fostering AI innovation and deployment.

Ethical and Security Concerns: The ethical challenges, privacy considerations, and security risks associated with AI adoption in decentralized energy systems should be investigated. Developing frameworks and guidelines for responsible and secure AI implementation is important, including addressing biases, ensuring transparency, and safeguarding critical energy infrastructure.

Socio-economic Implications: The broader socio-economic implications of AI adoption in the energy sector need to be studied. This includes analyzing the impact on employment, workforce skills, equity, accessibility, and affordability of energy services. Evaluating the potential benefits and risks for various stakeholders is crucial.

By closing these research gaps, valuable insights can be gained to effectively integrate AI in energy systems, ultimately leading to enhanced reliability, sustainability, and societal benefits.

2. WORLD ENERGY SCENARIOS

The world energy assiduity looks to primary shifts in the way it sells, generates, and distributes energy. The energy assiduity is under enormous stress to reduce carbon emigrations and to find applicable ways to manage power force- demand balance across power grids. The main ideal is to move from conventional energy coffers, similar as reactionary energy- grounded energy sources, to a new carbon-free energy source [4].

To shows the history of world energy generation and consumption by dissimilar sections between 1990 and 2017(KeyWorld) Energy Statistics 2019, 2019). Utmost of the globe's total energy consumption comes from conventional energy coffers like coal, crude oil painting, natural gas, etc., and is adding time on time. The renewable share of final world energy consumption reckoned for17.48 in 2016, which is advanced in the history. Every time the world's per capita income continues to grow. Large dependence on fossil energies for energy use and transport, global warming, and climate change are other enterprises in the recent period. The significant increase in hothouse gas house (CO2) emigrations can be looked in 2017 and is 0.22 advanced than in the 2015 financial time [2].overall demand for primary energy increased by2.3 in 2018, the largest periodic increase since 2010[5]. The United States, China, and India accumulated 70 of the world's increase in energy requisition [5]. The total share of renewable energy is presently growing from about a1/4 to about 45 in 2040(from which PV contributes 11, over from the current 2) [5]. Recent developments have been unstable and, despite proposed programs, prospects for change are also uncertain. The number of people without electricity access dropped from 980 million in 2017 to 860 million in 2018; still, Africa's lack of energy remains acute [5]. The proposed and recent enterprise give access to energy in several regions of the world; still, they aren't enough to completely exhilarate Africa by 2030[5].

There's a major problem with the power force's trust ability, e.g., voltage dips, harmonics, voltage swells, slow voltage variations, voltage imbalances, transients, frequency variations, and fast voltage variations [6], etc. furnishing high- quality electricity services to businesses and consumers are vital to profitable development. The unstable force of electricity operates as a constraint on the overall weal and profitable exertion and inhibits the power generation of a particular mileage. With these constraints, furnishing continued power inventories to consumers requires companies to deal with power force dearth's or switch to more precious and contaminating power generation options, similar as diesel creators. All options have adverse goods on firm performance and stymie competitiveness. Poor power system structure is a major cause of then on-reliability of power force in developing countries. Investment in power structure, combined with changes in the effectiveness of services, leads to a reduction in the number of outages. In cooperation with MIT- Camilla's Universal Energy Access Lab, the International Energy Agency has designed a new study to exfoliate light on the relationship between the least cost-effective electrification approach to grid trust ability and world energy access. Structure position geospatial analysis using the reference electrification model recommends Mini-grid and grid design and improves electrification planning [5]. More electrification and ultramodern smart grid structure can make the most effective use of electrical grids possible by adding renewable sources' integration as these technologies come more complex and effective.

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3. THE HISTORY AND ROLE OF AI IN THE SMART ENERGY INDUSTRY

The history of AI is grounded on demonstrations, openings, and pledges. Since the last half- century, AI advance has been erecting trial machines to perform different kinds of intelligent gets in the energy assiduity. Alan rolling is a colonist of AI. In 1950, Alan Turning proposed the "reproduction game" proposition, latterly known as the Alan Turning Test. In 1956, the term AI was chased at a regard. The List Processing program was proposed in 1964 to break and read algebra- grounded word problems. It was a cold period between 1975 and 1980 for the advancement of AI technology. This period showed a lack of interest in AI, reduced backing openings for new systems, a lack of calculating power and sense. In 1982, the proposition of artificial neural networks came popular for the first time. Between 1990 and 2015, remarkable innovations in the field of AI have been explored, similar as logistics planning for US military operations [7]. In the recent period, AI has moved from pall bias to Tensor Flow, Caffe-2, and Lite Libraries, which are used to break complex logical problems. The vacuity of these AI digital technologies will increase the energy force from further advanced wind ranch vaticinations [18], to bettered operating & conservation costs, process effectiveness and operating life of the outfit [5].

4. CHALLENGES OF AI RELINQUISHMENT IN THE SMART ENERGY ASSIDUITY

There are different types of tailback challenges to espousing AI in the smart energy sector, similar as data quality and lack of data, AI network parameters tuning, specialized structure difficulties, lack of good experts, integration challenges, pitfalls, or compliance issues and legal enterprises. Discovery and opinion of faults are also complex challenges for erecting energy systems [8]. Different inquiries fete that data instability and deficient information are some of the major challenges facing energy systems [17]. The poor quality of regulators, detectors, and controlled bias for energy system operation and data estimation affects the system's trust ability and performance. The complex correlations and strong coupling of the power grid, the high data dimensionality, including the massive complexity of large- scale simulation grid data, face new challenges in the energy request [9]. The use of AI to integrate renewable energy, similar as wind and solar, is also complex and delicate for grid operations [19].

Presently, different IT companies have demonstrated amount computing, one of the most effective supercomputers. While quantum technology improves AI- grounded ML ways and increases system processing capabilities, it also increases playing pets. While AI development is an effective and promising development of sustainability, perpetration produces an enormous quantum of carbon footmark, reflecting a direct answer effect. A Single AI learning algorithm can release CO2 emigrations level to five buses [16]. AI ways calculate heavily on different types of energy data, therefore contributing laterally/ directly to the universal carbon footmark of data technology (IT) [1]. Other crucial energy- related AI challenges include

- Non-theoretical history: One reason for AI's decelerating growth in the energy sector is the lack of crucial AI chops among decision makers. Utmost associations warrant the technological background to understand how they would profit from AI operations.
- Lack of practical moxie: There are numerous professionals with in- depth specialized aspects. still, it is extremely delicate to find good professionals to make dependable AI-powered operations with real practical benefits. Although power companies cover and maintain data, digitizing with advanced operation software is problematic. Data loss, poor configuration, device malfunction and unauthorized access are related pitfalls. Because the cost of mistake in the energy sector is high, numerous companies are reticent to consider trying new strategies with little moxie.
- Outdated power system structure: An outdated structure is the topmost handicap to the modernization of the energy sector. At current, mileage companies are trapped in a lot of data they produce; they've no idea how and when to deal with it. Although the assiduity has further data than anyone differently, the data is also dispersed, disorganized, spread across different formats and stored locally. While the assiduity has huge gains, it also suffers from the vulnerabilities of outdated systems.
- Profitable pressure: The integration of innovative advanced energy technologies may be the right object to do, although it isn't cheap. It takes a long time and plutocrat to find a well-established software provider, make and configure software, qualify, maintain, and manage it. Either, this deployment of energy technology will affect developing, conforming, and controlling software that needs a great deal of backing and coffers.
- Decentralization and diversification: Decentralization and diversification of energy force, together with the development of arising AI technologies and adding demand trends, produce complex problems for energy product, energy transmission, energy distribution, and cargo consumption in all countries of the world.
- Cellular technologies: Cellular technology dependence limits the significance of AI in numerous developing husbandries, particularly low- income countries, pastoral and other underserved areas. The adding trouble of cyber attacks is getting decreasingly popular, and a major concern, substantially as automated control and smart metering account for nearly 10 of global grid investment, which is original to$ 30 billion a time for installing digital structure [19].
- Black: boxes AI- grounded operations are black boxes for consumers, utmost of whom don't fete their internal functions or how they've been created, which constitute a implicit trouble. And, given that the current ways are far from perfection, the protections will be productive as they are integrated into the power systems.

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5. CONCLUSION

In conclusion, decentralization, decarbonization, and digitization are causing a rapid shift in the energy sector. AI proves to be a useful tool for improving the reliability and adaptability of the electricity system. With applications ranging from big data analytics to intelligent robotics and cyber attack prevention, the vast capabilities of AI can be divided into assessment, inference, and response. Effective data analysis, machine learning, and AI application depend on high-quality data sets. Governments from all around the world are embracing various AI policies, concentrating on their own advantages and societal demands. The construction of AI ecosystems and clusters, as well as strategic investments in AI research and development, can promote innovation in both the private and public energy sectors. To maximize the advantages of AI while minimizing any potential negatives, ethical issues, data privacy, and security are being addressed. Overall, AI has the ability to alter the energy industry, propel future growth, and manage and navigate new energy systems.

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