Review

Artificial Intelligence's Evolution and Impact: From the Birth of Intelligent Agents to Navigating Sustainable and Renewable Energy in the Digital Era

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Review

Artificial Intelligence's Evolution and Impact: From the Birth of Intelligent Agents to Navigating Sustainable and Renewable Energy in the Digital Era

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Abstract: AI applications are transforming the technology and digital sector, seamlessly integrating into the daily interactions of individuals with the digital world. Key entry points to the internet, such as search engines, are now complemented by recommendation systems that curate content on social networks, streaming platforms, and online marketplaces. Additionally, virtual assistants have become ubiquitous across various platforms. While these groundbreaking changes are gradually extending to several industries, there remains significant untapped potential for the application of artificial intelligence in diverse domains. The renewable energy sector, in particular, continually reinvents itself through research and innovation to meet the escalating demand. Positioned at the forefront of technological evolution, this industry is well-placed to effectively adopt and tailor the innovations of artificial intelligence to its specific needs. Presently, both emerging and established tools leverage elements of AI to enhance processes and introduce functionalities that were previously unattainable. If the current trajectory persists, AI-enhanced tools have the potential to assume a role as crucial to the future of engineering as computer-aided design (CAD) software is in contemporary times.

Keywords: artificial intelligence; machine learning; sustainable development; and renewable energy

Introduction

The incorporation of artificial intelligence (AI) technology is causing a substantial revolution in the renewable energy industry, with the capacity to significantly enhance efficiency and decision-making procedures [1–4]. This article examines the impact of AI on the industry, resulting in greater functionality and performance. With the increasing urgency to shift towards sustainable energy sources worldwide, AI is emerging as a crucial factor in renewable energy [1,2,5–8]. It holds the potential to completely transform the way electricity is generated, distributed, and consumed, paving the way for a more environmentally friendly and sustainable future [9–12].

Amidst a formidable energy crisis in Europe, characterized by a significant spike in energy costs, the global community is experiencing the far-reaching consequences [13,14]. The World Bank predicts that global economic growth would decrease from 5.7 percent in 2021, a year impacted by COVID-19, to 2.9 percent in 2022 [15]. Given the occurrence of major floods in Pakistan due to climate change and the record-breaking hot summer seen in Europe in 2022, there is an increasingly pressing need for renewable energy sources to reduce carbon emissions [16,17].

Despite attempts to utilize renewable sources such as wind, water, and solar power for a sustainable future, their overall contribution to the total energy output remains relatively insignificant [18–20]. The main reasons for this are cost and unpredictability considerations [21,22]. The incorporation of artificial intelligence, a nascent discipline, into the renewable energy industry has the capacity to tackle these obstacles and beyond [23,24]. While AI's involvement in the energy sector is now limited, substantial expansion and advancement are expected as it becomes a more essential component of the business.

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Implementation of AI in Different Sectors

AI in the Renewable Energy Sector

AI encapsulates a diverse array of methodologies, spanning machine learning, neural networks, optimization, statistics, and logic systems [25]. Through the strategic utilization of these cutting-edge technologies, the renewable energy sector stands poised to achieve automation, elevated decision-making capabilities, and an overall augmentation of functionality. The integration of AI contributes significantly to enhancing the efficiency of power generation and delivery processes, thereby systematically reducing the environmental footprint associated with renewable energy operations [1]. This multifaceted application of AI underscores its transformative potential, positioning it as a key driver in advancing the sustainability and effectiveness of the renewable energy landscape [26,27].

Importance of AI in Automated Decision-Making

A noteworthy advantage attributed to AI within the renewable energy sector is its ability to expedite complex tasks more expeditiously than traditional methods. The implementation of automated decision-making processes, facilitated by AI, serves to streamline an array of operations, resulting in a notable elevation of overall efficiency and productivity [28]. As an illustrative instance, AI algorithms demonstrate the capability to automate scheduling for preventive maintenance, effectively mitigating the risk of system failures and significantly diminishing costly downtime [29–31]. This exemplifies the transformative impact of AI in optimizing processes and fortifying the reliability of renewable energy systems.

AI in Assisted Decision-Making

AI also supports assisted decision-making, amalgamating human intelligence with insights from AI [32,33]. In the realm of renewable energy, this approach empowers experts to make informed decisions by incorporating data-driven analyses provided by AI algorithms. For instance, AI can aid in conducting environmental impact analyses for renewable energy projects, evaluating factors such as wildlife preservation, carbon footprint, and land use, thereby assisting stakeholders in making sustainable and informed choices [34,35].

Use of AI in Management of Power Supply and Flow

AI and machine learning algorithms assume a pivotal role in the intricate management of power supply and flow within renewable energy systems [36]. These sophisticated technologies systematically analyze real-time data, guaranteeing the optimal utilization of resources and the seamless integration of renewable energy into existing power grids [37,38]. Through a continuous process of monitoring and adjusting power flow dynamics, AI ensures a harmonious alignment of energy generation with demand, thereby minimizing waste and maximizing overall efficiency [39,40]. The intricate orchestration of AI and machine learning in this context underscores their transformative impact in bolstering the precision and sustainability of renewable energy operations [5,19].

An AI Era of Forecasting Renewable Power Output

The precision in forecasting renewable power output holds paramount importance in the realm of efficient grid management and strategic planning. AI algorithms play a pivotal role in this context by leveraging an intricate analysis of historical data, weather patterns, and pertinent variables, resulting in highly accurate power output predictions [41,42]. These forecasts, meticulously generated by AI, serve as invaluable tools empowering grid operators and energy market participants. Informed decisions pertaining to power purchase agreements, demand response programs, and grid stability are facilitated, thereby mitigating uncertainties and optimizing the seamless integration of renewable energy into the preexisting energy infrastructure [43]. This

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sophisticated utilization of AI underscores its transformative impact on bolstering the reliability and adaptability of the energy landscape [44].

AI in Transportation System

AI exerts a substantial influence on contemporary transportation systems, addressing critical issues prevalent in the sector [45,46]. A primary concern involves inadequacies in vehicle operation, frequent accidents, and suboptimal roadway pavement design and construction [47,48]. AI interventions significantly enhance vehicle driving capabilities by employing object detection mechanisms, benefitting drivers across diverse age groups [49,50]. Moreover, AI contributes to the refinement of pavement design through the incorporation of appropriate material characteristics, resulting in the creation of efficient roadways accessible to all drivers [51]. Furthermore, AI facilitates a comprehensive assessment of the impact of temperature and rainfall patterns on pavement conditions, utilizing statistical data and advanced methodologies [52,53]. In summation, the pervasive influence of AI significantly contributes to the establishment and maintenance of a secure and effective transportation system.

Use of AI in Optimizing Plant Availability

Ensuring the sustained optimal availability of plants emerges as a pivotal necessity in the relentless pursuit of maximizing the output of renewable energy systems. The integration of cutting-edge AI technologies plays a pivotal role in this mission [54], providing invaluable support in forecasting and forestalling potential failures through the meticulous analysis of real-time performance data and the identification of anomalies [35,55]. The orchestration of proactive maintenance management by AI-driven systems stands as a linchpin, proficiently curbing downtime and guaranteeing that renewable energy plants consistently operate at their zenith performance levels [56]. This strategic approach significantly augments overall availability and productivity, exemplifying the transformative impact of AI in fortifying the reliability and efficiency of renewable energy infrastructure [57].

Importance of AI in Risk and Opportunity Assessment

Image recognition, a subset of artificial intelligence (AI), assumes a crucial role in data validation [58,59]. Investors and developers can leverage image recognition and other algorithms to assess potential risks and opportunities associated with a project [60,61]. Utilizing these algorithms, preliminary cash-flow models can be generated, offering developers insights into a project's viability. By automating the project modeling process, AI tools swiftly identify lucrative projects, enabling teams to focus on efficiently closing deals [62,63].

Supply and Flow Management AI era

AI and machine learning empower electricity companies and grid operators to forecast generation, schedule maintenance, and manage power flows [64,65]. Concurrently, consumers can access real-time information about supply to better manage consumption, distributed generation, and storage, consequently reducing energy bills [66]. The proliferation of smart meters generates valuable data that AI algorithms utilize to predict demand and network load, optimizing consumption from solar and battery systems [67].

AI use in Power Output Prediction

AI systems harness the predictive power of wind speeds and irradiance forecasts, enabling them to generate short-term projections of renewable power output within minutes, a remarkable improvement over traditional forecasting spanning several days [6,68]. This capability contributes substantially to bolstering grid stability and streamlining the dispatching process, ultimately optimizing plant availability [69]. Additionally, this advanced technology facilitates the seamless execution of scheduled maintenance activities, ensuring the continuous and efficient operation of

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renewable energy plants [5,70]. The rapid and precise predictions afforded by AI significantly elevate the responsiveness and reliability of renewable power generation systems, marking a significant advancement in the field of sustainable energy management [6,12].

Economic Optimization by AI

AI programs integrate machine learning weather models, historical datasets, real-time information from local weather stations, satellite imagery, cameras, and sensor networks [71–73]. This comprehensive approach to forecasting enables more efficient management of conventional generators, reducing the costs associated with starting and shutting down units [72,73]. It optimizes plant usage by adapting output to changing weather conditions, thereby decreasing the cost of solar power curtailment [74]. Automation in green manufacturing powered by AI helps cut down on resource consumption and waste, which in turn promotes eco-friendly production practices that are good for the economy [28,75–77]. Sustainable farming is improved by AI-powered precision agriculture, which gives farmers a bigger advantage by optimizing crop yield while minimizing resource usage [78–80]. On top of that, AI boosts the efficiency of carbon dioxide capture systems that rely on adsorption, which in turn helps fight climate change by lowering operational costs and improving capture procedures [81,82]. More precise forecasting of renewable output enables generators and energy traders to participate in wholesale and balancing markets with increased accuracy [83–86].

Conclusion

There is a strong connection between the notion of artificial intelligence (AI) and the beginning of the field of computer science's development. Researchers have been trying to imitate human cognitive processes ever since the field was in its infancy. Their ultimate goal is to give computers the appearance of intelligence. At the moment, the definition of artificial intelligence that is generally recognized describes it as the study of "intelligent agents," which are systems that are able to perceive their environment and respond in order to achieve certain objectives.

A thermostat is a simple example of an intelligent agent that may be used in several situations. It is able to detect the temperature in a room, which is referred to as its environment, and then it utilizes its aims to attain a temperature that has been specified. In spite of the fact that the environment in this scenario represents a material component of the real world, it is possible that this may not apply to all intelligent agents in every situation. In addition, the efficiency of such systems is dependent on the utilization of relatively plain logic when the purpose is to accomplish uncomplicated goals in an environment that is less complicated. On the other hand, when the amount of complexity of the environment or the objectives rises, it becomes necessary to employ more advanced reasoning.

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