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Applications of Artificial Intelligence in Clean Sustainable Energy System Support

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ABSTRACT

With increased competitiveness in energy generation industries, more resources are directed in optimizing plant operation in all aspects of the production, including fault detection and diagnosis, increase efficiency, forecasting the consumption and production. One of the most powerful tools in optimizing plant operation is artificial intelligence (AI). For the last few decades there has been major interest towards intelligent condition monitoring system (ICMS) application in power plant especially with AI development particularly in artificial neural network (ANN). It should be noted that the development of the energy industry is a step towards the development of other industries. That is why the transition to the digital industry is impossible without the digitalization and intellectualization of the energy industry. With massive possibility and room for improvement in AI, the inspiration for re-searching them are apparent, and literally, hundreds of pa-pers have been published, discussing the findings of hybrid AI for condition monitoring purposes. This paper attempts to discuss and review related work of AI and its applica-tion in energy industry. With regard to the energy indus-try, the integration of artificial intelligence in the industry will help optimize and improve efficiency in all aspects of the production, transmission and consumption of energy, fault detection and diagnosis, increase efficiency, forecast-ing the consumption and production. This note provides an overview of AI methods utilized for energy sector applica-tions, based on a systematic review of over 15 papers, 3 companies and commercial initiatives. The papers are clas-sified with regards to both the AI/ML algorithm(s) used and the application area in energy industry. We conclude the paper with a discussion of advantages and potential limitations of reviewed AI techniques for different tasks, and outlines directions for future research in this fast-growing area.

KEY WORDS: ARTIFICIAL INTELLIGENCE; DISTRIBUTED ENERGY RESOURCES, HOME ENERGY MANAGEMENT, MACHINE LEARNING.

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INTRODUCTION

The energy sector worldwide faces many challenges such as rais-ing demand, shortage of supply, environmental issue due to CO2 emis-sion. Many countries have already begun to use AI and the related technology in energy sector to allow better communication between smart grid, smart meter. AI can help improve power management effi-ciency, and use the renewable energy

sources more efficient, AI be-comes more and more important in energy industry and, indeed, it is having a great potential in future. With increased competitiveness in power generation industries, more resources are directed in optimizing plant operation, including fault detection and diagnosis. One of the most powerful tools in faults detection and diagnosis is artificial intelligence (AI). Faults should be detected early so correct mitigation measures can be taken, whilst false alarms should be eschewed to avoid un-necessary interruption and downtime. For the last few dec-ades there has been major interest towards intelligent condition moni-toring system (ICMS) application in power plant especially with AI development particularly in artificial neural network (ANN).

ANN is based on quite simple principles, but takes advantage of their mathe-matical nature, non-linear iteration to demonstrate powerful problem solving ability. With massive possibility and room for improvement in AI, the inspiration for researching them are apparent, and literally, hundreds of papers have been published, discussing the findings of hybrid AI for condition monitoring purposes. Alnaimi (2016) showed that ANNs are robust and reliable tools in energy sector application. They have been utilized to solve many operational problems, they presented a brief overview for applications of ANNs and GA for fault detection and diagnosis.

Sozontov (2019) dealt with the possibility of the implementation of artificial intelligence, which will improve the efficiency of national economy, including the energy industry. The paper presents the princi-ples of using neural networks and elements of artificial intelligence in the processes of production, transmission and consumption of electrici-ty. It has been revealed that the use of artificial intelligence in the elec-tric power industry will make it possible to minimize disruptions in power supply. It should be noted that the development of the electric power industry is a step towards the development of other industries. That is why the transition to the digital industry is impossible without the digitalization and intellectualization of the power industry. Increas-ing population worldwide demands more and more facilities, which in turn mandates the energy service providers to escalate their generation. Unfortunately, power generation globally is dominated by fossil fuels, which are the main contributor to CO2 in the atmosphere. Increasing CO2 emission threatens the world by global warming, as pointed out in the "World Energy Outlook 2019" (International Energy Agency, 2019).

To cope with global warming due to increasing CO2 emission from the traditional power system, governments around the world are encouraging renewable electric energy sources. For example, contrib-uting the green energy, motivated by declining capital costs and the government tax benefits, the United States added 72 gigawatts (GW) of new wind and solar (photovoltaic) capacity between 2018 and 2021 (U.S. Energy Information Administration, 2019). Similar renewable sources addition is carrying out across the globe today.

Recently, Serban and Lytras (2020) have reported that the synergy between renewable energy (RE) and AI will change the energy sector and improve sustainability at national and global level. Using AI could increase the efficiency of the RE sector by detecting and predicting patterns, by performing specific tasks without explicit instruction from human, by optimizing the supply and enhancing decision-making. It will provide better insights on processes due to speed forecasting and smart links between vital components as result of rapid development of technologies incorporating AI, (Lytras, 2017; Lytras, 2018; Visvizi, 2016). AI methods can be used to tackle various challenges, ranging from selecting the optimal set of consumers to respond, learning their attributes and preferences, dynamic pricing, scheduling and control of devices, learning how to incentivize participants in the DR schemes and how to reward them in a fair and economically efficient way (Antono-poulos, 2020).

As nuclear power plants around the world reach their natural end-of-life, decommissioning plants – including Sellafield in Cumbria, Chernobyl in the Ukraine and Fukushima in Japan – offers a market opportunity for bespoke AI-enabled robots. Recent disaster situations such as Fukushima have shown the crucial importance of robotics tech-nology for clean-up and decommissioning of nuclear waste, monitoring and intervention, which is missing up to date, this is making AI work even more vital for energy sector (University of Lincoln, 2018). The application of AI technologies, particularly expert systems, to control room activities in a nuclear power plant can reduce operator error and improve plant safety and reliability. They constitute only a small fraction of those being developed, although few systems are actually in use in nuclear plants today.

RESULT AND DISCUSSION

There is no universally accepted definition for artificial intelli-gence, in this regard, by artificial intelligence we mean a machine sys-tem capable of learning, using objective knowledge and experience, solving creative problems like the human brain and inventive tasks without going through options, build strategies and apply abstract concepts (Losev, 2018). Figure 1 shows the concept of AI where it is a main branch of computer science that aims to create intelligent ma-chine. AI has become an essential part of technology industry. Ma-chine learning (ML) is a core of AI. ML uses data to train algorithms and gives computer system the ability to take decision and improve performance. Support vector machine (SVM), computer vision (CV) is type of ML. Deep learning (DL) is the most advance type of machine learning, Artificial Neural Network (ANN) is type of deep machine learning. In these days, AI has become an essential part in industry and life: Technology, manufacturing, banking, power station, electricity, energy, etc.

Figure 1: AI Approaches

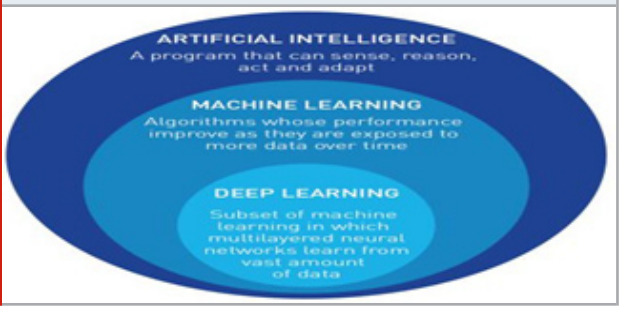
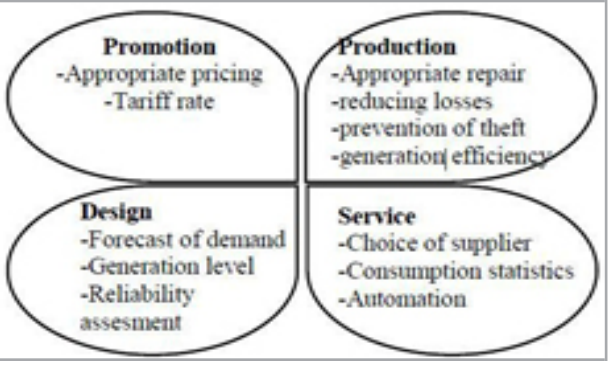


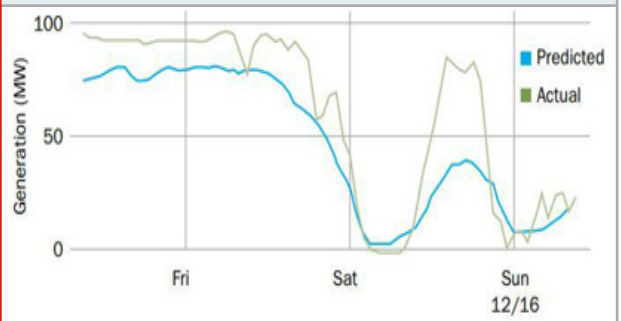
Figure 2: Tasks of artificial intelligence in Energy industry



The main tasks solved by artificial intelligence are presented in Figure 2.

At the design level, issues are being addressed to improve en-ergy demand fore-casting, as well as generation level, assessment of the reliability of power generating equipment, automation of relay protection systems and automation with increasing load on power plants. While at the production level, optimization of pre-ventive maintenance of equipment, increase of efficiency of gen-eration, reduction of losses and prevention of thefts of energy re-sources. For the promotion level, optimization of price depending on the time of year and day, and the tariff dynamics is also determined and justified.

Figure 3: Example of DeepMind Predictions vs. Actual in De-cember 2018. Source: Witherspoon, Sims and Will Fadrhonc. 2019. "Machine Learning Can Boost the Value of Wind Energy."



From the aspect of the service level, questions are solved on the automatic selection of the most prof-itable supplier, detailed statistics on energy consumption and en-ergy re-sources are provided, automated customer service is pro-vided, and energy consumption issues are optimized taking into account customer habits and behavior. Figure 3 shows the DeepMind System predicts energy output 36 hours ahead using neural networks, and recommends how to create optimal com-mitment on the grid, At General Motors, using artificial intelli-gence algorithms made it possible to increase the efficiency of wind turbines by 5%, while maintenance costs were reduced by 20% (Losev, 2019).

An interesting application of artificial intelligence methods was reported by the German company Schleswig-Holstein Netz AG, which operates electrical networks in the federal state of Schleswig-Holstein. Here, the self-learning network is used to determine the locations of the alleged damage. As initial data, this network uses information on per-formance of components of electrical networks and the repairs carried out, as well as information on loads and weather conditions. The Amer-ican company Air Fusion, which uses unmanned aerial vehicles to study the state of high-voltage power lines and wind turbines, uses software with artificial intelligence algorithms to process monitoring results.

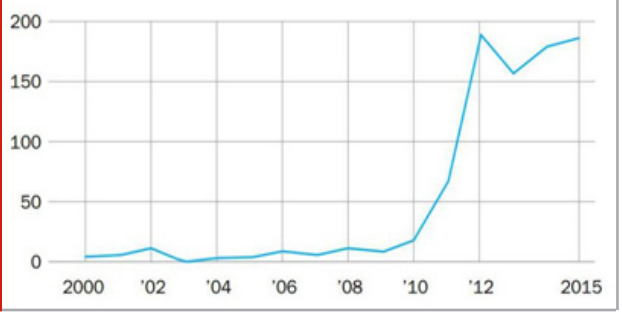
The neural network helps to solve the pattern recognition problem, for which thousands of images of damaged wind turbines are loaded into the program during the training process. Nuclear energy, which is one of the high-tech industries where developed countries retain its leading position. If we consider the introduction of artificial intelligence in this industry, then it will help solve a number of problems (Table 1).Any Artificial Intelligence is only as smart as its data. This is one of the biggest sticking points. The topics of data protection and data security are some of the greatest weak points for the use of Artificial Intelligence (Figure 4). Those who are connected digitally and intelligently reveal a lot about themselves and the system be-comes vulnerable to cyberattacks.

In 2018, the German Federal Office for Security (BSI) observed that the number of cyberattacks on critical infrastructure tripled in comparison to the previous year. Energy supply and the entire energy system are part of this critical infrastructure. This is why cyberse-curity is becoming more and more important today and in the future in order to protect the highly networked power grid from attacks and data theft from the outside. There are already strict security require-ments for participants in the electricity market in the area of data protection and data security, though. Contrary to the widespread opinion that AI makes the power grid less secure, AI can make an important contribution in the fight against cyberattacks. It can quick-ly check large amounts of data and thus detect deviations. AI can also draw conclusions from past cyberattacks. Machine Learning has already achieved great success in this area, for example in the detec-tion and defense of Trojans.

Table 1. The main results of the use of artificial intelligence in atomic energy.

No	Task	Task
1	Reactor safety	Identification location of defects
2	Nuclear power plant	Quick data flow analysis
3	Catastrophic risk management	Preventive emergency situations, reducing danger
4	Creating digital models of nuclear power plants	Ensuring the safety of nuclear power plants, the collection of all technical, technological and operational information
5	Artificial Intelligence and Automated Process Control System (APCS)	Appropriate resource allocation, increasing production efficiency Reduced development cycle,
6	Optimization of design processes	cost reduction. Solving complex problems
7	Advancement of science	Fast processing of data from scientific experiments and their further application
8	Technological process	Accelerate the pace of innovation and productivity
9	Cybersecurity	Finding vulnerabilities, writing codes and machine algorithms

Figure 4: Cyber Vulnerabilities. Source: Kaspersky Labs. Fickling, David. 2019. "Cyberattacks Make Smart Grids Look Pretty Dumb." Bloomberg.com, June 17, 2019. https://www.bloomberg.com/opinion/articles/2019-06-17/argentina-blaming-hackers-for-outage-makes-smart-grids-look-dumb



Many end users are critical of Artificial Intelligence, especially in relation to smart home technologies. This is understandable, because the data of the most private space that reveals a lot about its users is collected. Studies have shown that the biggest obstacle to the ac-ceptance of smart meters is fear of revealing private information without knowing exactly how it is used. These fears are justified, as there is still no regulation on how to handle this sensitive data, which is important for the electricity system of the future. Germany and the EU are trying to curb data access by private companies, as is hap-pening in the USA and China, for example. The EU Commission has therefore developed four basic ethical principles for AIs: AI should respect human autonomy, avoid social harm, be fair, and be explain-able. In order to give the energy industry and in particular end con-sumers more confidence in the AI, AI offers a multitude of suitable application scenarios that will support the energy transition and a climate-friendly energy system. It will be crucial, however, to protect user data and make the use of AI transparent and comprehensible (Vähäkainu, 2019).

CONCLUSION AND FUTURE WORK

With regard to the energy industry, the integration of artificial intelli-gence in the industry will help optimize and improve efficiency in all aspects of the production, transmission and consumption of energy, fault detection and diagnosis, increase efficiency, forecasting the con-sumption and production. It should be noted that the development of the energy industry is a step towards the development of other indus-tries. That is why the transition to the digital industry is impossible without the digitalization and intellectualization of the energy industry. It has been revealed that the use of artificial intelligence in the energy industry will make it possible to minimize disruptions in power supply. The topics of data protection and data security are some of the greatest weak points for the use of Artificial Intelligence. It is clear that the fu-ture lies in AI and furthermore, the capability of AI to revolutionize the energy sector must also not be doubted. AI can increase the efficiency, speed and security of energy consumption and generation and could lead the constant transitions in this sector to meet the changing climate needs.

But it also goes without saying that even this "intelligent tech-nology" has its own shortcomings which needs to be taken care of be-fore we can embrace it with open hands. For those looking to make a difference in shaping the future of society, the interface between AI and energy is a great place to start. Technological innovation is drastically changing the way we think about these two industries and their integration is in its early stages. Their synergy may change the world like we never knew it, and they are primed for innovative thinkers to make their mark. The future work depends of recharging new algorithms of AI which booster the efficiency of energy industry: production, distribution, marketing etc. Also it is important to take care of personality securing: more investment, time should be devoted to the aspect of cyber-attack related to big data and AI. Security, risk assignment, and hazard management of AI application in energy sector should be taken very serious. These topics should take a big part in future research at different levels.

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