European Journal of Sustainable Development (2023), **12**, 4, 589-605 ISSN: 2239-5938
Doi: 10.14207/ejsd.2023.v12n4p589

Role of Artificial Intelligence and Smart Grids in Energy Companies in the European Union Member States

By Alexandra Ioanid [1], Dan Palade [2]

ABSTRACT
Artificial intelligence has started to play a crucial part in many industries throughout the world starting in 2023. One of the sectors that stands to gain the most out of the implementation of AI-driven solutions is the power sector, especially during a time of major transitions. The purpose of this qualitative study is to identify the level at which well-established companies from the power sector are when it comes to integrating AI into their daily operations. The focus of the research is on the Romanian power sector, mainly on companies that have the largest potential for implementing AI solutions (production, transport/distribution, and suppliers and traders). To do so, the author first performs secondary research into the definition and utilization of artificial intelligence at a global level and then, conducts primary research into the state of AI deployment in the Romanian power sector. The data was collected in the summer of 2023 by conducting interviews with industry experts with an average experience of more than 30 years in the industry. The originality of the article comes from the fact that there are no academic papers meant to assess the current level of deployment of AI solutions in the Romanian power sector, and there is little literature that presents a condensed view of AI applications at a local level. The results of the study point out an early interest in implementing AI solutions. The limitations and further research paths are also presented.

Keywords: artificial intelligence, smart grids, strategy, renewable energy sources, clean energy, new technologies, decentralized power system.

1. Introduction

Over the past decades, the energy sector has seen multiple significant changes that forced companies that offered services within this sector to constantly adapt their strategies accordingly. The penetration of renewable energy technologies, the closing of nuclear power plants in many European countries after the Fukushima incident in 2011, the simplification of access of residential consumers to producing their own energy, the recent Covid-19 pandemic, and the ongoing energy crisis are just some of the changes of a technological, economic, and social nature that fueled constant challenges for the entities activating in the power sector. Now, a new change that, although not originating or being directly tied to the power sector, may force companies from the power sector to rethink their strategies for the upcoming decade. The technological developments of artificial intelligence have started to make their way within multiple sectors, among which transport, housing appliances, healthcare, banking, tourism, and telecommunications to name a few, revolutionizing them. In the context of ongoing challenges caused by increasingly

| [1] National University of Science and Technology POLITEHNICA Bucharest, Bucharest, Romania; Academy of Romanian Scientists, Bucharest, Romania;
[2] National University of Science and Technology POLITEHNICA Bucharest, Bucharest, Romania

intermittent supply, high demand, and efficiency issues, artificial intelligence may help drive the power sector toward an industrial revolution of sorts. However, whether the impact of artificial intelligence will be groundbreaking or if its benefits are marginal remains unclear.

2. Definition and business applications of AI

The term "Artificial Intelligence" (AI) evolved from being a term associated with fiction works at the beginning of the last century to be present in more and more headlines (Economist, 2023) in recent years. The term "AI" was coined in the mid-50s (McCarthy et al., 2006) by John McCarthy as being "*the science and engineering of making intelligent machines*". Earlier than that, Norbert Wiener established a new field in science named cybernetics in 1943 which he also later described (Wiener, 1985), as "*control and communication in the animal and the machine*". Nowadays, AI is commonly referred to as "*a field, which combines computer science and robust datasets, to enable problem-solving*" (IBM, 2023). AI encapsulates several concepts related to data science such as machine learning (ML) [which encapsulates natural language processing (NLP), deep learning (DL), and neural networks (NL) (Patel, 2020)], artificial neural networks (or a deep neural network when multiple hidden layers are included), and fuzzy logic (Nath & Balaji, 2014). Figure 1 indicates how the concept of artificial intelligence encapsulates elements of data science, machine learning and natural language processing.

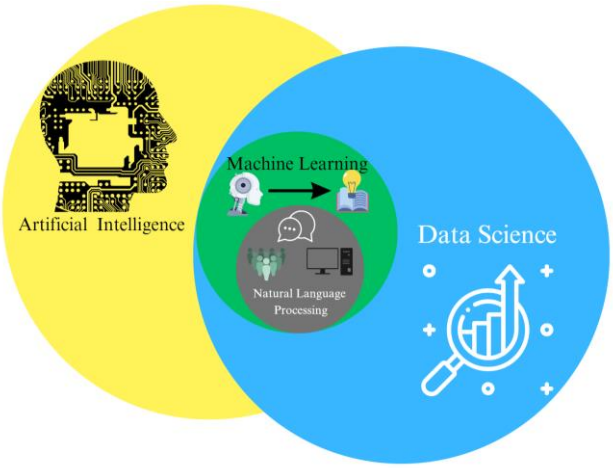

Figure 1. Relation between artificial intelligence, data science, machine learning, and NLP

Applications of artificial intelligence are becoming more and more prevalent in industries around the world, and this can be seen in the fact that the adoption of AI has more than doubled since 2017 (Chui et al., 2022). Whether it's a chatbot (Economist, 2023), the smart assistant that can be found in every smartphone, or a robot assisting doctors during surgeries (Manickam et al., 2022), self-driving vehicles, trading algorithms in finance, algorithms recommending users content based on their viewing habits, artificial intelligence has become part of our daily lives, but most of its potential remains

unexplored. The broadest uses of AI are speech recognition, customer service, computer vision, and automated stock trading (IBM, 2023).

3. Current context of the power sector in Europe

As the European Union is fully engaged in the long-term efforts of ensuring that Europe becomes the first climate-neutral continent by 2050 (The European Commission, 2018), several mid-term and short-term goals have been set for the upcoming years. Firstly, in order to ensure climate neutrality, greenhouse gas emissions must be reduced by 55% by 2030, compared to the readings from 1990 (The European Commission, 2020).
Since the power sector is responsible for over 75% of the greenhouse gas emissions from the European Union the past decade has seen an increase in the integration of renewable energy technologies in the production mix. The target of shares of renewable energy produced in the energy mix has become more and more ambitious in recent years, with the current goal being 45% by 2030 (The European Commission, 2022).
An equally important step in reducing greenhouse gas emissions is the electrification process. Through electrification, the European Union intends to turn electricity into the main energy source and reduce its dependency on fossil fuels. To take full advantage of the positive effects of electrification, the main changes that should be brought are in heating in buildings (replacing gas consumption for heating with heat pumps) and in the transportation sector (replacing internal combustion engines with electric vehicles).
The renewable energy integration and electrification efforts are supported by two main trends:

Digitalization is taking place mainly in the distribution grid by installing smart meters, and intelligent sensors throughout the infrastructure that monitor the state of the grid, process said information, and communicate relevant information back to the distribution operator, as well as through other digital technologies intended for the network. What brings all these solutions together is the Internet of Things (IoT) integration. The IoT represents a network of objects interconnected among each other that are also connected to the Internet. The pairing of so many devices which are equipped with incorporated sensors helps provide real-time information about the physical state of the grid as well as pricing signals.

Decentralization represents an ongoing process through which the traditional framework of the power sector is shifting towards distributed generation. In practice, conventional power plants which can produce great quantities of electricity will gradually be replaced with smaller technologies such as photovoltaic panels and wind turbines. Furthermore, this new framework also involves changes in the way loads are distributed since nowadays the sector is facing an increasing number of smaller consumers as opposed to the previous industrial consumers.

Naturally, all these changes come with many challenges that the companies from the power sector, starting with producers and continuing with transmission and distribution system operators and ending with suppliers, and even consumers must prepare accordingly while

building their strategies for the upcoming decade.

The road toward reaching carbon neutrality has yielded many positive results (nowadays, more than one-third of global electricity comes from low-carbon sources, and the share of electricity produced from renewable energy sources has steadily increased from 2010 to 2020 (Ritchie & Roser, 2022), however, there are numerous threats associated with decentralization and renewable energy integration. The electricity market crisis from 2022 which arguably hasn't stabilized is an example of what can go wrong in a low-carbon energy system that hasn't been properly implemented (Venizelou et al., 2023).

To ensure an effective transition to a decentralized power sector that both integrates renewable energy sources in the energy mix and turns electricity into the main energy carrier without impacting the end consumer or the technical stability of the system, companies from the power sector have already begun to use AI in their daily operations.

4. Applications of AI in the power sector

Beginning from what the strategy of each company should be in broad terms (a long-term plan created for a company to reach the desired future state which is envisioned when the strategy is developed), it is important to understand what the specific activity of each of the participants in the power sector is.

- Producers are natural or legal people who produce electricity as their main commercial activity.
- Distribution operators - natural or legal persons who own, under any title, a distribution network and are responsible of its maintenance, exploiting it and, if necessary, expanding on it in a certain area as well as the interconnecting points with other networks in some cases, and ensuring the required long-term capacity in order to satisfy a reasonable level of energy demand;
- Transmission and system operators – any legal person who owns, under any title, a transmission network and is responsible for its maintenance, managing it, and, if necessary, expanding on it in a certain area as well as the interconnecting points with other networks in some cases, and ensuring the required long-term capacity in order to satisfy a reasonable level of energy demand;
- Suppliers represent natural and/or legal persons who sell electricity to consumers and provide it to buildings they own;
- Consumers (final clients) – natural or legal persons who buy energy for their own consumption. More recently, a new category of consumers, the prosumer, has entered the supply chain.

4.1 Electricity producers

The main areas in which artificial intelligence could be implemented by producers are forecasting and the assets responsible for power generation. With a shift towards technologies that have an intermittent production schedule (wind turbines and photovoltaic solar panels), it will become essential for producers to reach a level of predictability that is sufficiently accurate to take decisions in the future.

Wang et al. (Wang et al., 2020) present a detailed literature review of existing AI algorithms used in solar power prediction to highlight both the advantages and disadvantages of each method. The paper also includes a classification of AI subsets, such as machine learning, artificial neural networks, extreme machine learning, deep learning, etc. Similarly, AI can be used to offer a degree of predictability to wind turbine owners when making decisions. In (Zhao et al., 2022), the authors describe how AI can make use of big data to predict wind speed.

As a practical application of AI in the integration of renewable energy generation, in (Coroama & Gavrilas, 2010), the authors attempt to address the issue of the power generated by a wind power plant situated in the South-Eastern region of Romania through the use of an artificial using it comes to assets used in power generation, artificial neuronal networks can be used to solve operational problems, such as gas turbine sensor validation (Palme et al., 2011), while genetic algorithms can be used to improve the thermodynamic efficiency of gas turbines (Chaquet et al., 2012).

4.2 Transmission and distribution system operators

As could be seen while trying to define AI, there is no universally accepted definition of smart grids. The concept may vary depending on the country and industry stakeholders according to (Bossi et al., 2010). Back in 2016 smart grids were defined as "an electricity network that can intelligently integrate the actions of all users connected to it - generators, consumers, and those that do both - in order to efficiently deliver sustainable, economic, and secure electricity supplies".

This definition is nowadays used in the regulation of the Trans-European Networks for Energy (TEN-E). In order for the European Union to achieve its goal of becoming the first climate-neutral continent, wise investments must be made in the power sector. This mainly involves the integration of renewable energy technologies and phasing out of power plants that contribute to CO2 emissions. This phenomenon has been happening for the past decades, but recently, the need for consolidating the infrastructure has become more and more apparent.

The TEN-E is tasked with connecting the energy infrastructures of EU countries. To do so, Projects of Common Interest (PCIs) must be adopted. These projects are related to investments in existing infrastructure or the development of new energy infrastructure, with cross-border implications for the sustainability and security of energy supply. Since 2013 when the first PCI list was adopted, the number of projects related to smart grids increased from two to five in 2021.

In (Vasiljevska & Efthimiadis, 2022) an overview of PCI smart grid projects is included to evaluate the contribution that each of them have to accelerating the development of European cross-border energy infrastructure. To put it simply, a grid becomes a smart grid when it is equipped with IoT devices that can help multiple assets communicate with one

another and information can be relayed in real-time to grid operators in order to ensure informed decisions.

One of the main drawbacks of electrification is that power grids are being put under more and more strain. This pressure can lead to both blackouts and increased electricity prices, which must be covered by the end consumer. This pressure on the system can be alleviated by constructing more power lines and making other such investments in ensuring grid resilience. However, although these solutions are valuable, the time required for the completion of such endeavors is long and the costs associated with them are supported by the end consumer.

A potential short-term solution is represented by equipping the existing grids with energy storage systems that are powered by AI algorithms. Having AI-optimized storage systems integrated into the grid can take some pressure off the main grid, for uses such as charging electric vehicles (Yu, J., J., 2022). By having access to information in real-time such as market prices and power loads required at a residential level, an AI-driven storage system can take precise decisions related to the best time intervals for storing energy produced from renewable energy sources and the most appropriate time for offloading said energy. This solution can help grid operators to operate the grid effectively during peak hours and lower prices.

Another important role of system operators is the management of the physical infrastructure of the power grid. In order to prevent power outages or other incidents that can put the life of people in danger, grid operators can use artificial intelligence to identify defections before they can pose a serious threat. In recent years, grid assets started to be equipped with detection sensors and devices that can collect, process, and transmit valuable sets of data from the environment to command centers. These functionalities have been enabled through the Internet of Things and can help operators improve grid stability and reduce costs (Kirmani et al., 2023). The next logical step in increasing the efficiency of smart grid management is allowing AI to take decisions based on the data provided by the IoT sensors. Through constant monitoring, AI can quickly identify defections as opposed to situations when grid operators would not be aware of incidents until they are reported to them by clients. AI can assess the damage and offer solutions for addressing said incidents (V-Soft Consulting, 2020)

4.3 Suppliers

Probably the area in which AI has the biggest potential in the business of an energy supplier is represented by customer engagement. As can already be seen for large retailers (Partridge et al., 2023), companies from around the world are beginning to favor AI over human employees when it comes to interaction with their customers. AI can be used for answering customer questions and complaints through the use of virtual assistants.

Starting from the functionalities described in (Arnold, 2023) in the case of companies from the power sector, clients can make use of the following features through the use of virtual assistants:

Open support tickets that can be quickly verified and solved by the company in question;

Aid clients with setting up their accounts, uploading necessary documents, changing their contracts, and any other steps involved in the shopping process for physical products;

For loyal customers, that have chosen to extend their contracts multiple times, AI can come up with customized offers that can ensure the retention of said customers for extended periods of time;
AI chats can also assist with collecting and processing feedback from customers in order to ensure a better understanding of what is expected from the supplier and what needs aren't met.
As was discussed in the case of producers, AI can also be used for consumption forecasting, thus aiding suppliers with purchasing energy ahead of time (Mohammadigohari, 2021).

4.4 Energy security

The International Energy Agency (IEA) defines energy security as "the uninterrupted availability of energy sources at an affordable price" (International Energy Agency, 2023). When considering the time horizon, energy security refers to proper planning, investments and ensuring provision of energy in line with economic developments and environmental needs for the long-term, while for the short-term it has to do with the response the system is ready to provide while facing unexpected changes to the supply-demand balance (International Energy Agency, 2023).
While the implementation of artificial intelligence may facilitate and even optimize certain processes involved in energy security by reducing decision time and providing more accurate estimations, it can also pose a major danger to it. Back in 2017, the International Energy Agency examined the impact that digitalization and the increased level of interconnectivity of the power sector have on energy security. At the time, cyber security, privacy, data ownership, and economic disruption were the leading concerns associated to the ongoing digitalization process (International Energy Agency, 2017). However, it was stated that even if digitalization would enhance the efficiency of the power sector, it would not remove human labor for activities that involve less routine. Furthermore, at the time, cyber security attacks were few and far between.
Going back to the time horizon of energy security, artificial intelligence is expected to be more relevant for the short-term, since its implementation would help the existing human labor, not make it obsolete. Predictive AI can reduce the risk of asset failure by identifying and signaling potential issues in a timely manner (Thomas, 2023). Furthermore, AI can assist technical crews during on-site repairs by offering guidance using augmented reality. Also in the short-term horizon, AI can predict peak demand periods which put strain on the supply of energy and optimize production, supply chains, and delivery systems (Cohen, 2023).
One of the major threats associated with the premature deployment of AI solutions throughout the power sector has to do with unprotected points in the grid that may provide hackers with a backdoor to the grid or worse. In 2020, the average successful attack recorded in the energy sector resulted in damages worth 6.4 million dollars, which was, at the time, double the global average (Massachusetts Institute of Technology, 2021). Another risk of AI deployment in the power sector has to do with increasing the systematic complexity (Rhode & Wagner, 2023).
Artificial intelligence is not only a source of vulnerability that can be exploited by attackers, but also the tool used by hackers. AI-driven malware raises the threat posed by regular

malware to unprecedented levels (Trakimavičius, 2018).
Regarding long-term energy security, the role of AI in elaborating strategies is yet to be proven, although there is much positive expectation for this time horizon (Rhode & Wagner, 2023).

5. Study

In 2022, the artificial intelligence market was globally valued at almost 125 billion euro and is expected to increase at a compound annual growth rate of 37.3% until 2030 (Grand Vision Research, 2023).
In the European Union, members of the European Parliament urge for a slowdown of the pace at which AI is being deployed, to come up with regulations that impose "restraint and responsibility" (Moller, 2023).
At a local level, since this article was initially conceptualized back in 2022, discussions regarding the use of artificial intelligence in Romania have intensified greatly. Starting with the establishment of the Romanian Committee for Artificial Intelligence (AIRomânia) and the release of a governmental memorandum in November 2022 that details an initial set of strategic initiatives in the field of AI, the Ministry of Research, Innovation, and Digitalization, means to reunite independent experts, companies, and other organizations involved in fields that are connected to AI. This indicates a real interest in Romania, as one of the few European states with no national strategy in the field of AI, at the time, to set a clear direction for the country in the following years (Ministry of Research, Innovation, and Digitalization, 2022).

5.1 Siemens survey

A study reported by Siemens in 2020 (Siemens, 2020), presents the conclusions of a survey conducted with 515 senior leaders involved in organizations from within the energy sector as well as the industrial/manufacturing, urban infrastructure, and transportation sectors, that make use or have plans to use AI. The research included respondents from North America, Latin America, Europe, the Middle East and Africa, and Asia-Pacific.
Out of the 117 energy sector respondents, all had already integrated the use of AI within their business in some capacity. Most of the companies used artificial intelligence to help with the automation of machinery and equipment (30%) while asset maintenance forecast (enabled by deep learning) and optimization of processes, machines, software, or tools came in second (28%). Other interesting applications could be found in safety monitoring/incident prevention, quality control, and the design of new products (Figure 2).

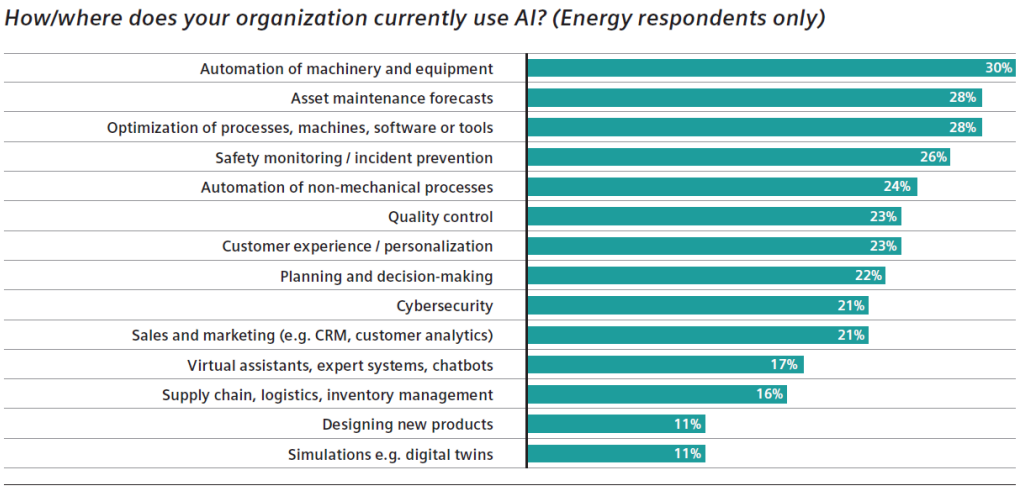

Figure 2. Applications of AI in the power sector. Source: Siemens 2020 (Siemens, 2020)

The study also revealed that industry specialists are still somewhat reluctant to fully trust AI with autonomous control of company assets.

5.2 Romanian power sector survey

Starting from this study, this paper proposes a qualitative study of the perception of industry experts from various companies in the Romanian power sector regarding the use of AI in their respective fields. Starting from the information gathered from secondary research (both academic and industry papers), which was presented in the previous chapters, the author designed a semi-structured interview aimed at experts working in the Romanian power sector (Enel România, CEZ, Electrica, Nuclearelectrica S.A.). The semi-structured interview was chosen to "*allow informants the freedom to express their views in their own terms*" (Barclay, 2018), thus reducing the need to adhere to strict terminology while trying to answer the questions.

The data was collected between May and June 2023 and was obtained by interviewing industry experts with an average experience of over 30 years in the Romanian power sector. Most of the respondents occupy leadership positions in various companies from the Romanian energy supply chain (production, trading, supply). The respondents were selected based on their access to information (respondents had to occupy positions, ideally of leadership, that offered them access to concrete information regarding the state at which their company was when it came to the deployment of AI solutions), but also on the availability that the author had to reach out to the respondents. The interviews were carried out through the social networking platform, LinkedIn, and replies were received either directly through LinkedIn, e-mails or face to face discussions.

The research questions which should be answered by the study are:

RQ1: Is AI being currently used in the Romanian power sector?
RQ2: How prevalent is the deployment of AI in the Romanian power sector?

RQ3: Is the outlook for the implementation/expansion of AI in the power sector in the next five years a positive one in Romania?
RQ4: What are the leading reasons against implementing AI in the Romanian power sector, and what are the main biases against the utilization of AI in the said sector?

The interview guide for the industry experts was constructed in order to answer the research questions and the following questions were asked:

- In which part of the power sector are you working?
- Has your company implemented AI within its business?
  - ✓ If yes, at what stage is the application of said AI functionality? pilot/fully implemented)
  - ✓ If yes, what are the main uses for AI, and would you describe the impact of AI, thus far, as being a positive one?
  - ✓ If not, are there any plans of implementing AI-driven solutions in the next five years?
- What are the main reasons for not wanting to implement AI-related technologies in your business? (costs/resistance to change from higher-ups/not enough information about the benefits/reliance on the human element/cybersecurity-related threats/other)
- In 5 years do you believe companies will grant AI full control over an asset from within the company?

Table 1. Positions and companies of the respondents

No. Crt.	Sector	Position
1	Supply	General Manager
2	Production, Trading & Supply	General Manager
3	Service company (energy management, grid losses metering)	Managing Partner
4	Supply	Analyst
5	Production & Trading	Head of Energy Transactions Division
6	Supply	Director Of Operations
7	Production & Trading	Chief of Energy Services
8	Supply	Director of Regulatory Affairs and Antitrust

5.3 Results

Following the tabulation of all the responses related to the use of AI solutions in companies, and branching discussions with the interviewed parties, the insights were the following:

- Out of the 8 companies that are involved in the power sector, only two of them have implemented AI solutions in their daily processes. This correlates with the findings from the previously mentioned Siemens study in which only 39% of the respondents have successfully moved from AI pilot projects to full-scale implementations (Siemens, 2020).
- However, it was encouraging to note that of the remaining 6 companies, 4 of them have plans for implementing AI-driven solutions in the upcoming period.
- The main reasons pointed out as deterrents from implementing AI solutions in the daily processes of the companies were heavy reliance on the human factor and the Romanian regulatory framework is highly volatile. It is important to note that the recent COVID-19 pandemic as well as the energy supply crisis have only worsened the degree of volatility that the regulatory framework is subjected to. Another reason which was pointed out by one of the respondents was that it is relatively hard to make an accurate cost vs benefits estimation since it's a relatively new field and benchmarking with an appropriate degree of certainty is difficult. Finally, costs were also pointed out as a reason why AI solutions have yet to be implemented.
- Throughout the interviews, it was noticed that the main application for AI, which is planned for the upcoming years, is in production and consumption forecasting. As for the two companies that have already implemented AI solutions, the applications which were pointed out by the respondents as being either in a pilot state or fully implemented are chatbots, robot process automation elements for process automatization, and customer retention forecasting. If the first two applications are self-explanatory, the third one refers to algorithms used by AI to identify clients that are about to express their desire to change their supplier and prepare counter offers, based on their behavior. It is also worth mentioning that there are distribution companies that have purchased and equipped smart sensors in the grid, which paves the way for AI to be involved in taking both preventive and reactive measures in the future in case potential defects are identified prior to or during incidents.
- Out of all respondents, the majority have expressed that the outlook for implementing AI solutions that are completely in charge of company assets in the Romanian power sector in the upcoming five years is very positive, however, it is important to note that the human element will remain essential for the foreseeable future.

Once the study was finalized, by examining the answers which were provided, the initial research questions were answered as follows:

RA1: AI is currently implemented in the Romanian power sector, mainly by

supply companies. Judging by offers answered by specialists working in energy production and trading, there are plans for kicking off pilot projects in the following years for using AI solutions for forecasting production and consumption schedules.

RA2: Currently, the degree of deployment of AI solutions is not extensive. Only 25% of the companies from the interview have implemented AI in their daily processes, however, based on discussions with one of the respondents, this percentage has the potential to grow in the following years, as the foundation for implementing AI is already present, at least at a grid level (smart sensors and databases).

RA3: The outlook for implementing AI-driven solutions in the Romanian power sector for the following years seems to be a positive one, at least on paper, since companies that have already implemented AI in their processes describe the impact as being a positive one and further projects are in a pilot phase. At the same time, most of the companies that haven't implemented AI in their daily activities intend to do so in the following years, although there is no way to be sure that the declared commitment will be respected.

RA3: Although not many of the respondents from the interviews expressed aversion towards the concept of AI solutions being used within their companies, all of them pointed out that the volatility of the regulatory framework is the main concern when it comes to setting out to initiate complex projects of implementing AI in the daily processes. Furthermore, as it has been shown throughout this article, at a global level there are many instances of AI being used in the power sector, however, some respondents considered that the technology is far too new to properly quantify the potential benefits. Finally, as is often the case when dealing with newer technologies that involve high computational power and extensive databases, costs were pointed out as one of the reasons why AI hasn't been implemented yet.

When comparing the results obtained by the author with those made public by Siemens (Siemens, 2020), the following aspects are revealed:

- Romania is slightly behind when it comes to AI deployment from pilot to full-scale implementation in the power sector (25% of the companies included in this study have implemented AI in their processes as opposed to the 39% reported by Siemens (Siemens, 2020)).
- In Romania, the main areas of interest for AI applications are production and consumption forecasting (at least when it comes to future plans), and the areas in which AI has already been applied have to do with customer retention and process automation, while the Siemens study (Siemens, 2020) points out that machinery and equipment automation, asset maintenance forecasts and optimization of processes, machines, software or tools are the main focus. This can indicate that in Romania the focus is on business processes, while at a global level, the management of industry-specific physical assets is the preferred area of AI optimization.
- In terms of trusting AI, the study performed for the Romanian power sector

reveals that the majority (62%) of the interviewed experts are confident that in the following 5 years, AI can be trusted with company assets, while the Siemens study reveals that globally, industry experts have a degree of skepticism and bias when it comes to trusting AI over human experience (only 56% of the respondents would follow the AI recommendations).

6. Discussion

This article is part of a more extensive research study that aims to examine the larger implications of power aggregators in the European power sector. Through the article, the author intends to better understand the degree of acceptance of the companies that are active in the Romanian power sector towards new technologies as well as the degree to which said companies and experts are prepared to adopt new technologies and trends to be better prepared for the upcoming changes in the energy sector at a global level.

The literature that was reviewed for this paper came from both academic and industry backgrounds and covered the applications of artificial intelligence in the power sector in various parts of the world. The papers tackled issues such as proper implementation of AI solutions throughout the entities within the energy supply chain, opportunities and threats posed by AI to energy security, the perception of industry experts regarding process optimization with AI. The current paper offered a condensed view of all these aspects while also making connections between them and further used the available literature to construct a study aimed at the Romanian power sector to identify the current deployment level of AI and the perception of industry experts.

The study is relevant since there are no existing academic papers that tackle AI in the Romanian power sector which include the points of view of industry experts from across the power sector. The results can be compared to existing or future articles that cover countries in Eastern Europe.

While conducting the study, there were some inherent limitations, mainly in terms of the sample of respondents which was considered for the review. Although the author reached out to more industry experts, the responses presented in the previous chapter were the only ones that were received. Another limitation may be related to the degree of understanding that the respondents had related to the topic, since during the interviews, some respondents seemed to be unaware of the applications of AI or of the results of public studies on the subject.

For future research, a larger sample should be taken into consideration, as well as attempting to obtain the perspective of representatives from other industries in which AI has the potential of being implemented, to obtain results that indicate the degree of readiness to adopt new technologies of the Romanian power sector, not only against the global or European level but also compared to other sectors from the same country.

Furthermore, future research can also consider the answers that were received to verify if companies that plan for the implementation of AI go through with what they intend to do.

Finally, the research in question can be furthered by asking if AI represents a real solution

for the challenges that the energy sector is presently going through, or if it is just a passing trend.

7. Conclusion

After conducting interviews with experts from various companies active in the Romanian power sector, it comes across that the interest in AI solutions exists and is steadily growing. Although AI solutions have yet to be implemented in a considerable number of companies, it can be noted that most of the industry experts have a positive outlook for the implementation of AI in the upcoming years, and most of the respondents declare that their companies are planning to roll out projects of integrating AI-driven solutions in their core processes.

Companies from the Romanian power sector seem to be interested in implementing AI in business processes that deal with planning production, analyzing, and predicting customer behavior and consumption patterns.

Although there is no inherent bias against implementing AI in company processes, there are multiple barriers and limitations that prevent Romanian companies from being early adopters of AI solutions. The main issues reported by the respondents had to do with budget constraints, reliance on the human factor, and a volatile legislative framework. These deterrents coupled with recent global effects (the Covid-19 pandemic and the ongoing energy crisis) may make it difficult for companies to implement AI according to the plans that were announced.

In conclusion, by comparing industry reports (Siemens, 2020) with the results of the primary research, it can be noted that Romania is closely behind the global average in terms of AI adoption, and has overtaken the global average when it comes to making plans for implementing AI solutions. It is also interesting to remark that the main application identified, following the interviews, to be planned for implementing in the upcoming years in Romania, forecasting production and consumption, is also pointed out by industry experts as a solution to one of the biggest challenges for the future. Since forecasting is challenged by "*new variables such as energy storage, roof-top solar, electric cars, offshore wind farms, and many others*", it has become more apparent in the past decade that "*all of this makes accurate prediction much more complex – at least for human minds. AI systems, however, are well-suited to this kind of task, and are maturing at a similar pace to the growth of renewable energy*" (Siemens, 2020).

Following the research questions presented in the article, it can be noted that the companies from the Romanian power sector are at a very early stage of adopting AI in their processes. Furthermore, by comparing the results from the local study with those from a global level (Siemens, 2020) industry experts from Romania seem to be mostly aware of both the changes present at a global level and are at least willing to attempt to adopt AI technologies as a potential method to deal with upcoming challenges.

Funding: The publication of this article has been funded by the National University of Science and Technology POLITEHNICA Bucharest (UPB).

References

Alan Mathison Turing. (1950). The Imitation Game. COMPUTING MACHINERY AND INTELLIGENCE, LIX(October 1950), 436-460.

Arnold, V. (2023, February 21). AI chats for better customer retention. (Neuroflash) Retrieved May 2023, from Neuroflash: https://neuroflash.com/ai-chats-for-better-customer-retention/

Barclay, C. (2018, March). Semi-Structured Interviews. Retrieved May 2023, from KnowHow: https://know.fife.scot/__data/assets/pdf_file/0028/177607/KnowHow-Semistructured-interviews.pdf

Bossi C.; Ciapessoni E.; Cirio D.; L'Abbate A.; Martini L..; Mauri G.; Moneta D.; Tornelli C. (2010). Smart Grid: tecnologie, funzionalità ed iniziative di dimostrazione in corso in Europa. Contributo ERSE al Piano di Azione Tecnologica del Major Economies Forum.

Bossi, C., E., C., Cirio, D., L'Abbate, A., Martini, L., Mauri, G., . . . Tornelli, C. (2010). Smart Grid: tecnologie, funzionalità ed iniziative di dimostrazione in corso in Europa. Contributo ERSE al Piano di Azione Tecnologica del Major Economies Forum. ERSE.

Chaquet, J. M., Carmona, E. J., & Corral, R. (2012). Using genetic algorithms to improve the thermodynamic efficiency of gas turbines designed by traditional methods. Applied Soft Computing, 12(11), 3627–3635. https://doi.org/https://doi.org/10.1016/j.asoc.2012.06.009

Chui, M., Hall, B., Mayhew, H., Singla, A., & Sukharvsky, A. (2022, December 6). The state of AI in 2022—and a half decade in review. Retrieved from McKinsey: https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2022-and-a-half-decade-in-review

Cohen, A. (2023, June 29). The Promise and Peril of AI in the Energy Sector. Retrieved from Forbes: https://www.forbes.com/sites/arielcohen/2023/06/29/the-promise-and-peril-of-ai-in-energy/?sh=2520941633b9

Coroama, I., & Gavrilas, M. (2010). A Study on Wind Energy Generation Forecasting Using Connectionist Models. 12th International Conference on Optimization of Electrical and Electronic Equipment (pp. 1257-1262). Braşov: Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/OPTIM.2010.5510508

Economist. (2023, April 20). How to worry wisely about artificial intelligence.

Grand Vision Research. (2023). Artificial Intelligence Market Size, Share & Trends Analysis Report By Solution, By Technology (Deep Learning, Machine Learning), By End-use, By Region, And Segment Forecasts, 2023 - 2030. Grand Vision Research.

IBM. (2023). What is artificial intelligence (AI)? (IBM) Retrieved from https://www.ibm.com/topics/artificial-intelligence

International Energy Agency. (2017). Digitalization & Energy. International Energy Agency .

International Energy Agency. (2023, August 3). Emergency response and energy security: Ensuring the uninterrupted availability of energy sources at an affordable price. Retrieved from International Energy Agency: https://www.iea.org/about/emergency-response-and-energy-security

John McCarthy, Marvin L. Minsky, Nathaniel Rochester, and Claude E. Shannon. (2006, August 31). A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence. AI Magazine, 27(4), 12-14.

Kirmani, S., Mazid, A., Khan, I. A., & Abid, M. (2023, December 31). A Survey on IoT-Enabled Smart Grids: Technologies, Architectures, Applications, and Challenges. Sustainability, 15, 1-26. https://doi.org/https://doi.org/10.3390/su15010717

Manickam, P., Mariappan, S., Murugesan, S., Hansda, S., Kaushik, A., Shinde, R., & Thipperudraswamy, S. (2022, July 25). Artificial Intelligence (AI) and Internet of Medical Things (IoMT) Assisted Biomedical Systems for Intelligent Healthcare. Biosensors, 12, 1-29. https://doi.org/https://doi.org/10.3390/bios12080562

Manickam, P.; Mariappan, S.A.; Murugesan, S.M.; Hansda, S.; Kaushik, A.; Shinde, R.; Thipperudraswamy, S.P. (2022, July 25). Artificial Intelligence (AI) and Internet of Medical Things (IoMT) Assisted Biomedical Systems for Intelligent Healthcare. Biosensors, pp. 1-29.

Massachusetts Institute of Technology. (2021). Transforming the energy industry with AI. MIT Technology Review Insights.

McCarthy, J., Minsky, M. L., Rochester, N., & Shannon, C. E. (2006, August 31). A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence. AI Magazine, 27(4), 12-14. https://doi.org/https://doi.org/10.1609/aimag.v27i4.1904

Michael Chui, Bryce Hall, Helen Mayhew, Alex Singla and Alex Sukharvsky. (2022, Decemvber 6). The state of AI in 2022—and a half decade in review. Retrieved from McKinsey: https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2022-and-a-half-decade-in-review

Ministry of Research, Innovation, and Digitalization. (2022, November 11). AIRomânia. Retrieved May 2023, from https://ai.gov.ro/

Mohammadigohari, M. (2021). Energy consumption forecasting using machine learning. Rochester: Rochester Institute of Technology.

Moller, C. (2023, April 25). Europe gets a bit more concerned about AI. Retrieved from UK5G: https://uk5g.org/updates/read-articles/europe-gets-a-bit-more-concerned-about-ai/

Nath, R. P., & Balaji, V. N. (2014). Artificial Intelligence in Power Systems. National Electronic Conference On Communication And Networking. Chennai. https://doi.org/10.23883/ijrter.2018.4234.eywih

Norbert Wiener. (1985). Cybernetics or control a nd communication in the animal and the machine (second edition ed.). Massachusetts: The M.I.T. Press.

Palme, T., Fast, M., & Thern, M. (2011). Gas turbine sensor validation through classification with artificial neural networks. Applied energy, 88(11), 3898-3904. https://doi.org/https://doi.org/10.1016/j.apenergy.2011.03.047

Partridge, J., Inman, P., Lawson, A., Jolly, J., Partington, R., Tophman, G., . . . Butler, S. (2023, February 18). From Retail to transport: how ai is changing every corner of the economy. (From retail to transport: how AI is changing every corner of the economy) Retrieved from The Guardian: https://www.theguardian.com/technology/2023/feb/18/from-retail-to-transport-how-ai-is-changing-every-corner-of-the-economy

Patel, S. (2020, February 3). Hype and Hope: Artificial Intelligence's Role in the Power Sector. Retrieved from Power Magazine: https://www.powermag.com/hype-and-hope-artificial-intelligences-role-in-the-power-sector/

POWER. (2020, February 3). Hype and Hope: Artificial Intelligence's Role in the Power Sector.

R.Pasupathi Nath, V.Nishanth Balaji. (2014). Artificial Intelligence in Power Systems. Journal of Computer Engineering.

Rhode, F., & Wagner, j. (2023, April 6). The Opportunities and Risks of AI in Energy Supply. Retrieved from Algorithm Watch: https://algorithmwatch.org/en/ai_in_energy_supply/

Ritchie, H., & Roser, M. (2022). Electricity Mix. Retrieved from Our World in Data: https://ourworldindata.org/electricity-mix#citation

Siemens. (2020). Next-Gen Industrial AI Energy Sector. Siemens.

The Economist. (2023, April 22). Large, creative AI models will transform lives and labour markets. Retrieved from The Economist: https://www.economist.com/interactive/science-and-technology/2023/04/22/large-creative-ai-models-will-transform-how-we-live-and-work

The European Commission. (2018). A Clean Planet for all. Brussels.

The European Commission. (2020). Stepping up Europe's 2030 climate ambition. Brussels.

The European Commission. (2022). REPowerEU Plan. Brussels.

Thomas, E. (2023, September 8). Predictive AI offers energy security amid changing industry. Retrieved from Energy Monitor: https://www.energymonitor.ai/news/predictive-ai-offers-energy-security-amid-changing-industry/?cf-view

Trakimavičius, L. (2018, December 4). The threat of AI to energy security. Retrieved from Atlantic COuncil: https://www.atlanticcouncil.org/blogs/new-atlanticist/the-threat-of-ai-to-energy-security/

Turing, A., M. (1950). The Imitation Game. COMPUTING MACHINERY AND INTELLIGENCE, 59(October 1950), 436-460.

Vasiljevska, J., & Efthimiadis, T. (2022, March 6). Selection of Smart Grids Projects of Common Interest—Past Experiences and Future Perspectives. Energies, 15(5). https://doi.org/https://doi.org/10.3390/en15051915

Venizelou, V., Tsolakis, A., Evagorou, D., Patsonakis, C., Koskinas, I., Therapontos, P., . . . Georghiou, G. E. (2023, March 17). DSO-Aggregator Demand Response Cooperation Framework towards Reliable,

Fair and Secure Flexibility Dispatch. Energies, 16. https://doi.org/https://doi.org/10.3390/en16062815

V-Soft Consulting. (2020). Secure and Maintain Power Grids Effectively with Artificial Intelligence. (V-Soft Consulting) Retrieved from V-Soft Consulting: https://blog.vsoftconsulting.com/blog/secure-and-maintain-power-grids-with-artificial-intelligence

Wang, H., Liu, Y., Zhou, B., Li, C., Cao, G., Voropai, N., & Barakhtenko, E. (2020, June 15). Taxonomy research of artificial intelligence for deterministic solar power forecasting. Energy Conversion and Management, pp. 1-17. https://doi.org/https://doi.org/10.1016/j.enconman.2020.112909

Wiener, N. (1985). Cybernetics or control and communication in the animal and the machine (second edition ed.). Massachusetts: The M.I.T. Press.

Yu, J., J. (2022, September 15). Artificial Intelligence Can Bring Real Solutions To The Power Grid Crisis. Retrieved from Forbes: https://www.forbes.com/sites/sk/2022/09/15/artificial-intelligence-can-bring-real-solutions-to-the-power-grid-crisis/?sh=1131c86326cc

Zhao, E., Sun, S., & Wang, S. (2022, June). New developments in wind energy forecasting with artificial intelligence and big data: a scientometric insight. Data Science and Management, 5(2), 84-95. https://doi.org/https://doi.org/10.1016/j.dsm.2022.05.002

LIST OF ABREVIATIONS:
AI – Artificial Intelligence
ANNs – Artificial Neural Networks
DL – Deep Learning
DNN – Deep Neural Networks
IoT – Internet of Things
ML – Machine Learning
NLP – Natural Language Processing
NN – Neural Networks
PCIs – Projects of Common Interest