ARTIFICIAL INTELLIGENCE
SERVING ELECTRICAL NETWORKS

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The Think Smartgrids association brings together an ecosystem of stakeholders who contribute to the decarbonization of electricity networks: grid operators RTE and Enedis, the main French manufacturers and equipment suppliers in the energy sector, as well as numerous French SMEs and startups at the forefront of the energy and digital technology industries, alongside the academic and research community.

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ARTIFICIAL INTELLIGENCE SERVING ELECTRICAL NETWORKS

This document from the Think Smartgrids Scientific Council presents the association's vision of the applications of artificial intelligence (AI) for the benefit of electricity networks and the major challenges associated with their deployment.

It first highlights the issues related to data and then the various characteristics expected from AI for the industry.

To illustrate the scope of AI possibilities, the text then describes a selection of use cases. For most of them, French transmission and distribution grid operators RTE and Enedis have already developed and deployed numerous solutions on an industrial scale.

Finally, two interviews with a renowned mathematician and philosopher shed light on some of the issues related to the development of AI for networks: the first one is about the strategic perspectives on AI in France; the second opens a questioning on the ethical issues that are inseparable from the generalization of AI technologies.

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KEY TAKEAWAYS FROM THE DOCUMENT:

- **AI applications for power grids**
- **Examples of AI solutions for electricity networks**
- **Technical and societal challenges**
- **The challenges of industrializing AI**
- **Data-related issues**
- **Recommendations for developing AI for networks**

What AI strategy for the energy sector in France?

Interview with Cédric Villani,
Mathematician, Fields Medal 2010, and former deputy of Essonne

For the ethics of artificial intelligence

Interview with Thierry Menissier,
Philosopher, Professor at the Université Grenoble Alpes and head of the "Ethics & AI" chair at the Multidisciplinary Institute in Artificial Intelligence of Grenoble (MIAI)

NINE RECOMMENDATIONS ARE MADE FOR THE DEVELOPMENT OF AI FOR ELECTRICITY GRIDS:

1. Put data at the heart of the approach
2. Hybridize techniques and implement multidisciplinary strategies
3. Foster transversality
4. Develop skills
5. Extend standardization
6. Aim for frugality
7. Facilitate acceptability
8. Ensure inclusion
9. Ensure the final responsibility is human

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AI, A WIDE RANGE OF APPLICATIONS FOR ELECTRIC GRIDS

Electricity networks are generating a growing amount of data, due to the deployment of smart meters and increased measurement and communication capabilities. Supported by expanding computing capabilities, **data management techniques open considerable opportunities, but also bring great challenges**.

Processing these large volumes of data, which are generally inhomogeneous, will require capacities that defy those of human operators. In this context, it seems worthwhile to look at techniques that are designed to handle such levels of complexity and benefit rather than suffer from this volume of data. We are talking here about Artificial Intelligence (AI) techniques.

These can adapt to uncertainty, linking scattered information, detecting anomalies and simplifying the modelling of complex systems, or anticipating their future state. Often based on artificial neural networks, they are able to quantify and classify data. **Obtaining relevant results depends on the availability of a large amount of quality data, high computing capacity at low cost and adequate learning algorithms**.

AI is an interdisciplinary field that combines theory and practice. It is about assisting human activities, mainly via software, and in some cases even replacing them. **AI involves the use of information systems, data with their management systems and dedicated algorithms**. There are of course solutions adapted to different types of data and problems. The available algorithms offer a wide range of technical possibilities, including implementations where the understanding of the results can be limited. One example is deep neural networks.

In addition to the end use, **several criteria determine the selection of AI methods** (type of data available, expected results, available skills, etc.). Because of their potential power (ability to maximize the use made of the available data, however varied) and their automaticity, other non-technical aspects come into play regarding these methods, one of which is user acceptability.

SOCIETAL AS WELL AS TECHNICAL OBSTACLES

Beyond the enthusiasm linked to the sometimes spectacular successes in certain fields, **AI faces a certain number of obstacles**, which are part of broader and generally transdisciplinary issues.

At the heart of AI is data, and its collection and quality represent both a strong challenge and **a set of socio-technical obstacles**. These include issues of big data and cybersecurity, but also the use made of the information collected as well as the role of intermediaries, data storage, associated costs, consent to its processing, etc.

The use of AI and related decision-making also raises **important issues concerning explicability** (and therefore indirectly acceptability), **but also ethics**, in relation to the verification and validation of results (unbiased, non-intrusive, etc.).

Finally, the environmental footprint of AI also figures prominently in the debates it raises. The associated technical challenges are severe, especially concerning **the ability to remain relevant while being energy efficient**. For example, the increase in the volume of data and the training calculations linked to the regular updating of technical objectives are hardly compatible with energy consumption reduction targets.

DATA IS THE LIFEBLOOD OF AI

Collected, stored, exploited, transformed, data is present everywhere, especially in the field of electrical networks. An error in data processing can have serious consequences on industrial performance, security or even image and reputation.

According to a study by MIT[1], **non-quality of data results can cause an estimated loss of between 15% and 25% of a company's total turnover**. The notion of quality here describes both the characteristics of the data (accessible, complete, reliable, relevant, up-to-date, consistent, etc.) and the set of processes that ensure they are respected.

AI algorithms are programmed to learn new rules and generate a model that can solve a problem from a large and varied volume of data. **Their relevance and performance are therefore directly dependent on the availability and quality of the data**, both during the learning phase and during their exploitation.

Thus, the first two challenges to be met are data inventory and collection, which require availability, persistence and integration of data, but also compliance with the governance of the various sources and the General Data Protection Regulation (GDPR). The associated issues are wide-ranging, including **anonymization** to guarantee acceptability and trust, but also **the interoperability or genericity of management tools** that will enable the collection of data from various sources, and finally, **the issue of the maintenance of such tools**.

Next comes the analysis and exploitation of the data, which must be adapted to the problem at hand. It is then a question of d**etecting possible data quality problems and verifying their representativeness**: are they false, biased, unbalanced, inconsistent or incomplete, is there too much or too little, is their labeling appropriate, etc.? The market for data quality tools is growing rapidly due to the increasing use of AI, **and was valued at more than USD 850 million in 2019 and is expected to reach USD 3,600 million by 2028**[2].

Data is a major challenge for AI, with technical, sociological, environmental and economic barriers. It would be desirable to systematically organize discussions between the various fields concerned in order to harmonize the responses to industrial and societal issues. This harmonization effort should take place upstream of the definition of regulatory limits for AI and its uses.

1. Thomas C. Redman, "Seizing Opportunity in Data Quality", MIT Sloan, November 2017.
2. *Verified Market Research,* "Global Data Quality Tools Market Size By Data Type (Customer Data, Product Data), By Deployment Model (On-Premises, OnDemand), By Organization Size (SMEs, Large Enterprises), By End-User (Telecommunications And IT, Retail And eCommerce), By Geographic Scope And Forecast", November 2021.

WHAT AI STRATEGY FOR THE ENERGY SECTOR IN FRANCE?

INTERVIEW WITH CÉDRIC VILLANI,
MATHEMATICIAN, FIELDS MEDAL 2010 AND FORMER MP FOR ESSONNE

What is the impact of AI on the challenges of the power sector?

In general, the datafication of the world provides a fertile ground for AI, and it is also a necessary prerequisite. The world of electricity is no exception. In this field, at the crossroads of the digital and energy transitions, **the global challenges of AI are to better predict and better analyze the sector's performance objectives**. The energy transition poses a phenomenal challenge to our society! Naturally French electricity is already decarbonized, but this remains a small minority of our energy consumption, and decarbonization will require huge efforts: in this context, with a growing role for local power grids, AI will be more than welcome to improve energy savings and efficiency. Nevertheless, the relationship between AI and energy is more ambiguous than it seems. While AI is a source of opportunities and solutions, it also generates environmental risks related to the availability of the resources required for the design of computing equipment as well as to its energy consumption. **It is therefore essential to design AI solutions that are more energy and resource efficient**.

What is the place of AI in tomorrow's electricity sector?

Tomorrow's electricity system will be characterized by more diffuse and often intermittent production means, but also by more committed users wishing to reappropriate energy in a collaborative approach. As a consequence, it will have to benefit from **a real time intelligence adapted to this growing complexity**.

On this matter, the profusion of data, as well as the increase in computing power and its pragmatic nature require AI. AI models, driven by data, can embrace great complexity by including numerous data from diverse sources and are not constrained by human understanding of the physical system.

To consider new uses and innovative optimizations of the power system, **reinforcement learning** could be appropriate. Similarly to what was done in AlphaGo[1], previously unthought-of solutions could emerge for the short to medium-term management of the electrical system.

However, every medal has its reverse side. AI models can violate physical laws and the lack of causality in their mechanisms makes them difficult to interpret. These limitations **make AI a powerful tool for information analysis and decision support, but a second line tool for medium- and long-term issues** (management forecasting, planning, etc.). Clearly, we must not believe that AI will free us from heavy choices based above all on physics and involving the entire model of society.

What are the obstacles to the deployment of AI in the electricity sector?

Developments over the last ten years have enabled the implementation of increasingly complex AI techniques that use more and more data. Paradoxically, the current, let alone future, profusion of data raises tricky issues. Beyond the issues of size, accessibility and quality of data, the hard part is **the sharing of data and the necessary mutual trust that the different stakeholders must have**. In the field of health, this is very striking, in the field of electricity, similar effects must be anticipated. If the players in the electricity system enjoy an enviable situation with regard to the availability of data, they will have to agree on how to make the best use of shared data blocks.

1. https://deepmind.com/research/case-studies/alphago-the-story-so-far

A FEW EXAMPLES OF AI SOLUTIONS FOR ELECTRICITY NETWORKS

Due to the amount of data available and the abundance of use cases, the energy sector offers many opportunities for AI: real-time operation, maintenance, planning, optimization, etc. AI-based solutions are already contributing effectively to the performance of power grids, while still presenting broad development prospects.

GRID MANAGEMENT, OPERATION AND PLANNINGU

The energy transition is characterized in particular by increasingly diffuse and intermittent energy production systems. The French law on the energy transition for green growth has set a target of 40% of renewable electric energy in national production by 2030. **Managing these additional variability elements increases the complexity of the control and operation of distribution and transmission networks**. New techniques are required to deal with them, notably AI-based techniques.

Voltage management

On the network, the voltage varies continuously. It is impacted by slow variations linked to seasonal, weekly and daily consumption cycles. It is also subject to rapid variations linked to multiple hazards: random fluctuations in loads, changes in network topology, tripping of thermal generation units, variations in RE production, etc.

However, the voltage must be maintained within a range that ensures the proper functioning of the power system and guarantees the safety of the system, its equipment and its users. For this, **adapted and coordinated control solutions are necessary**. At the interface between the transmission and distribution networks in France, 2,300 primary substations impose a set voltage that guarantees the proper functioning of the system.

To date, this set point voltage is fixed for each primary station and should only be changed in the event of major work in the sector. With the increase of RE production, it is no longer possible to find a fixed set point voltage applicable all year round. **The solution is to switch to a dynamic voltage that would adapt several times a day to the real state of consumption and production**. To do this, it is necessary to have a real time image of the voltage on the network. This is provided by a sample of the 800,000 MV-LV substations that cover the territory.

Knowledge of the voltage on these substations is the key to a dynamic management of the grid. As soon as a voltage anomaly is detected, for example an energy input from photovoltaic panels, a second algorithm is set in motion to instantly recalculate the new setpoint voltage to be applied to the source station. Considering the volume of data to be processed, classical optimization algorithms are no longer adapted to this task. **Deep learning algorithms have demonstrated significant performance gains in this area**, both in terms of speed and accuracy. After the training phase, this type of algorithm can take into account real time data and adapt its variables to the changes observed on the network. This tool will be deployed progressively.

Anticipating the impact of new uses on power quality

The development of uses containing power electronics generates parasitic currents that can impact the quality of the power supplied. This is particularly the case for electric vehicles, photovoltaic panels and heat pumps. **Estimating the risk of harmonic disturbances on the network using conventional approaches would require decades of simulations**. Indeed, for each of the 800,000 distribution substations, there are about 30 parameters to consider, which must then be compared with the hypotheses of the progression of the deployment of these different infrastructures until through 2035.

After developing a learning base representative of the types of distribution substations and reducing the list of parameters to those that have a real impact on harmonics, **Machine Learning algorithms are used to model the behavior of the network as a function of the equipment penetration rate.** The result is a "map of France of harmonic risk" where the state of each point of the network appears according to a color code characterizing the risk. This map can be enhanced and work is underway to improve the modeling of the behavior of new uses, in particular electric vehicles. **Over time, this map will allow us to adjust the location and timing of investments to reinforce the network**.

Network development studies

Digitization and the increasing complexity of the electrical system are a major challenge. This has led to a growing need for stability studies, changes in business lines, new asset management policies to be implemented, etc. This ever-increasing need for analysis is due to the multiplication of uncertainties and decision criteria to be taken into account (connection of RE, heritage constraints, environmental footprint, etc.).

AI has the qualities required **to facilitate the realization of network development studies**, while offering designers **the possibility of integrating more constraints**, such as wear and tear on equipment or environmental constraints linked to a specific geographical area, thus guaranteeing a more robust forecasting of the evolution of the electrical network.

For their design, analysis and understanding of multi-situation power system planning studies, network engineers can also rely on data from a power system simulation tool and on AI. Upstream of a network development forecasting study, a block based on natural language processing allows research managers not only **to analyze the economic or environmental context** of a given territory, but also **to identify the projects in progress in this geographical area** through a unified database and to capitalize on previous studies. Another block will **facilitate the understanding of increasingly voluminous simulation data**, by helping to explore it and using advanced data analysis algorithms, in order **to allow the re-evaluation of decisions taken to adapt infrastructures**.

FROM PREVENTIVE MAINTENANCE TO PREDICTIVE MAINTENANCE

The learning capacity of AI and more particularly of **data mining** allows us in some cases to move from a preventive maintenance logic, based on the respect of manufacturer recommendations and/or on operator feedback, to a predictive maintenance logic taking into account a large number of available information or measurements related to the equipment installed on the network.

In this context, task automation enables asset management which, coupled with AI techniques, significantly i**ncreases the availability of equipment and opens up prospects for cost reduction**, bet it economic or environmental.

In low voltage, for example, France has two million electricity outlets. Based on the history of replacements, but also on a number of exogenous variables (humidity, work in the vicinity, etc.), **a machine learning algorithm can calculate the probability of a cable's failure according to its characteristics and environment**. Similar applications are being developed for medium voltage cables and transformers in substations.

AI techniques of another kind are also used on overhead cables. This is the case, for example, for overhead lines inspected every year by helicopter or drone. **In this case, image recognition is used to optimize the scheduling of the renovation of technical equipment**. Instead of spotting defects using the naked eye and expertise of field agents, the programmed renovation of networks is now triggered by automatic diagnostics based on image analysis. This work is carried out in France by an AI supported by nearly half a million integrated photos.

CUSTOMER EXPERIENCE AND EMPLOYEE SUPPORT

AI is transforming the day-to-day operations and tasks performed on the power grid. It is augmenting certain capabilities and is now **able to support operations and maintenance technicians, customer advisors, support function employees and even customers**.

In the field, for example, deep learning tools, combined with image analysis, are capable of **recognizing equipment** and **providing technicians with all the characteristics they need for their work**.

Combined with other IT tools, such as geolocation, these solutions **make it easier and more reliable to collect and qualify asset data** during visits to the 2,300 primary substations and 800,000 MV-LV substations. Over time, they could even detect faults and provide an initial analysis to help technicians make the right choices. The most recent developments have made it possible to take the ergonomics of these tools a step further by reducing their computer footprint, thus making them available in Edge mode on a telephone or tablet.

On the other side of the network, for customer advisors, AI technologies **improve customer reception and complaint processing**. Based on the fine semantic analysis of verbatims, AI solutions can automatically categorize and synthesize complaints. These complaints can then be directed to the appropriate departments, which can also be supported by an AI capable of suggesting answers. Thus, the average time for processing complaints is reduced and employees can focus more on customer relations. Innovative deep learning methods could also **analyze the content of complaints and quickly detect the emergence of new sources of dissatisfaction**. This detection would then enable the rapid implementation of a response policy adapted to new situations.

In terms of customer experience, let's not forget to mention **chatbots**, which can **personalize customer relations by considerably improving the accessibility of information**. Advances in text mining, machine learning and the power of machines have enabled chatbots to make enormous progress in **natural language recognition**. They are able to handle digressions and lack of information. In particular, they can ask questions to obtain details. Customers can then "converse" with chatbots, which are real search engines, and thus become autonomous in solving problems and simple or frequent requests[1].

1. "Les humains derrière l'Intelligence Artificielle - Innovations & besoins de compétences", White Paper, Michael Page, Technology, 2021

THE CHALLENGES OF INDUSTRIALIZING AI

INTEGRATION INTO THE IS AND PROCESSES

The industrialization of AI solutions is confronted with the usual problems in the information system (IS), such as data availability, performance, lack of instability, security or maintenance, sometimes even aggravating them.

Companies in which AI is integrated are often confronted with an **abundance of experiments** and have difficulty making the transition from experimentation, or proof of concept, to an AI tool integrated into the company's business IS, in other words, the transition to scale. Accelerating the industrialization of AI processing and its integration into core information systems has now become one of the major challenges facing companies, particularly in the electrical system.

Moreover, the inclusion of AI solutions necessarily influences the governance of business processes, which must be adapted to take into account the life cycle of such solutions. **Initial validation functions must often be rethought and the control of AI algorithm performance requires special attention and dedicated monitoring tools**.

IMPACT ON COMPUTING RESOURCES

In addition, one of the challenges of AI is to manage to capture and **process large volumes of heterogeneous data, some of which are technical in nature, others more functional**. The amount of data and the complexity of the algorithms involved **push computer systems to their limits**, whether in terms of data storage and access or in terms of computing power. For example, the execution of certain algorithms is facilitated by the use of specific processors such as GPUs (Graphic Processing Units), optimized for parallel computing. These new technologies evolve really fast requiring recurrent and important levels of investment.

NEED FOR NEW SKILLS

Finally, AI technologies are complex and **require specific and rare skills**. The explosion in the deployment of this type of technology in companies has created a recruitment bottleneck that is not finding enough candidates and, as a result, is holding back the adoption of AI. In 2021, **57% of European companies cite the difficulty of recruiting profiles with the right skills, 45% cite the lack of in-house skills**.

A REGULATORY FRAMEWORK IN PREPARATION

AI techniques cover issues that go far beyond the conventional technical framework. Its developments will eventually have to be subject to precise standardization and operational constraints, on a scale that goes beyond the national framework. In early 2020, the European Commission published a white paper to define the priorities for the future framework of artificial intelligence[1]. This led to the drafting of a regulation t**o guarantee a "Trustworthy AI", which is expected to come into force in 2023**[2]. This new legal framework will aim **to protect the fundamental rights of users, define the safety of AI use and the responsibility of stakeholders**, with a number of requirements in terms of transparency, robustness, fairness and environmental impact. Energy production and distribution are among the use cases identified as critical by the Commission and strong financial penalties will apply in case of non-compliance with these requirements. In parallel, **the ISO and IEC standardization bodies are also preparing a specific framework**.

1. EUROPEAN COMMISSION, WHITE PAPER "Artificial Intelligence: a European approach to excellence and trust", 02 19 2020
2. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1623335154975&uri=CELEX%3A52021PC0206

For the ethics of artificial intelligence

INTERVIEW WITH THIERRY MENISSIER
Philosopher and university lecturer and researcher at Grenoble-Alpes University

Does AI raise new ethical questions or is it just a new way of looking at issues already raised by other technical systems?

We must indeed consider the persistence of ethical questions raised by technical systems as they develop. **AI**, like other technical systems before it, **redefines the boundaries of exclusive human intervention**. However, the strong entanglement of computing in all sectors of our society and its ability to deal with problems that are too large and complex for humans (even experts) to handle, significantly accentuates the ethical issues surrounding AI.

What fears are linked to AI?

The main fear linked to AI stems on the one hand from its capacity to imitate human behavior to a certain extent, and on the other hand **to appropriate the implicit knowledge** contained in the data sets it processes.

The term "artificial intelligence" is a symptom of the fear it generates. It conveys the idea of an autonomous entity, which could potentially become superior to human beings, whereas **"augmented computing" or "expert systems" would have been both closer to reality and less anxiety-provoking**.

So, naturally, this fear crystallizes around employment. What would happen if, for reasons of profitability, humans were replaced by machines for increasingly complex tasks? **Projecting ourselves into a post-employment world generates anxiety, because we do not have a thought pattern ready to accept such a situation**. Work channels a good proportion of human aggressiveness while allowing a classification by merit among other things.

What is the place of artificial intelligence in a human/machine pairing?

When we talk about humans, we think of freedom and free will. AI is beginning to affect the conduct of our societies, leading to considerations about ethical use. Many applications seek to replace the "organizer" (as is the case in smart cities). **The socio-political dimension is thus replaced by a pragmatic management in the organizational sense**. Yet it is the a priori free confrontation of ideas that, according to some, is a vector of freedom. But this is not the paradigm of an AI, which will seek an optimum according to defined rules.

Freedom would therefore evolve following the integration of AI techniques in the same way as it did during the Renaissance with the invention of printing and the first generalization of access to synthetic knowledge which completely revolutionized the society of the time.

Finally, while AI can imitate human behavior, to a certain extent, and surpass some of our brain capacities, it is not able to create. **Human intelligence remains the original creative intelligence and, in this respect, remains in control**.

The challenge is therefore to remember the basis of our ethics and t**o apply to AI the principles that humans have already established in the past**. Just as the law defines a framework for human intelligence, the latter defines a framework for artificial intelligence.

RECOMMENDATIONS FOR DEVELOPING AI FOR NETWORKS

PUT DATA AT THE HEART OF THE APPROACH

For each tool using AI technologies, in-depth work needs to be carried out on the data involved and its quality must be guaranteed. A number of questions relating to organization and technical solutions must be asked upstream of the project. Is dedicated governance required? How to manage data ownership, beyond data collection? **A clear definition of roles and responsibilities is essential**. Data Lake or Data Warehouse types of data architectures can be relevant solutions, but will not be suitable for all stakeholders or all use cases. In addition, **feedback and evaluation are still needed for more recent approaches such as Data Mesh**.

HYBRIDIZE TECHNIQUES AND IMPLEMENT MULTIDISCIPLINARY APPROACHES

Deriving intelligible knowledge from heterogeneous and unstructured data requires **hybridizing AI techniques between themselves** or with more traditional methods. The implementation of multidisciplinary approaches should also **enable progress to be made in terms of performance as well as acceptability and inclusiveness**.

FOSTER TRANSVERSALITY

Collaboration between smart grid stakeholders is essential to overcome the current scientific barriers, both on technical issues and on societal and ethical issues.

DEVELOP SKILLS

All the sector's stakeholders must be given the opportunity to develop their skills **by adapting training courses** in schools and universities and b**y deploying a system** to help companies at all levels to become familiar with these issues.

EXTEND STANDARDIZATION

The development of standards would facilitate the design and industrial deployment of AI-based solutions. Standardization should cover the field of data as well as AI models and control references. This standardization should extend to the processes of data storage, information exchange (in particular between all the stakeholders of electrical systems - grid operators, producers, consumers, energy market players, service providers), but also to the analysis and perpetuation of data. Finally, **the management of user consent should be the subject of specific treatment**.

AIM FOR FRUGALITY

The use of AI techniques can have a significant environmental footprint. **Optimizing the complexity of models** (or hybridizing them), as well as **the frequency of their re-training** and **the volume of data collected**, is now a necessity, to be considered upstream of projects. The choice of hosting infrastructures based on environmental criteria is also fundamental.

FACILITATE ACCEPTABILITY

The level of explicability, which allows an understanding of which elements have been considered by the AI system to obtain results, must be improved **to help deal with training biases,** allow for greater objectivity, and ultimately **facilitate acceptability**.

ENSURE INCLUSION

Care must be taken to ensure that AI does not lead to **an increase in the digital divide** within the population.

ENSURE THE FINAL RESPONSIBILITY IS HUMAN

It is essential to ensure that AI remains **at the service of humans**, by guaranteeing the respect of ethical values and principles, but also the robustness of the AI techniques used. And no matter how efficient and reliable the decision support tool may be, the end responsibility must remain human.

BETWEEN RISKS AND OPPORTUNITIES, THE PROSPECTS FOR THE DEVELOPMENT OF AI FOR ELECTRICITY NETWORKS

AI techniques are already regularly used in French electricity networks, whether for transmission or distribution. Combined with historical business knowledge, **they have proven their effectiveness and are a valuable addition to the tools used by grid operators**. The issues covered are varied, involving the entire spectrum from operational to long-term planning, asset management and user experience. In order to go even further, a **growing number of research projects are attempting to overcome the scientific and technical barriers identified**, and the prospects for development are significant.

RISKS AND CONCERNS

As with any technical system, the prospects of AI are linked to scientific and societal issues.

The collection, quality and ownership of data remain important issues at the heart of any AI-related development. On these aspects, **there are technical barriers on the measurement, exchange, storage, analysis and durability of data, but also socio-economic barriers** on ownership, consent to dissemination and possible remuneration.

Because of its complexity, **AI remains difficult to understand and explain**. Often perceived as a "black box", it sometimes arouses a certain amount of mistrust. In this context, decision making, which could be biased or be perceived as unacceptable depending on the culture, represents a considerable challenge and carries ethical implications.

On a related note, **AI raises issues of inclusivity**, directly exposing the existence of digital divides in the population. To benefit from AI, people must have access to digital tools and be able to understand how they are used and how they work.

Finally, there are ecological issues. Calculations linked to data analysis are costly in terms of energy, but also in terms of raw materials, due to the need for powerful calculation resources and large data storage capacities. In this context, the issues of centralization/decentralization of intelligence take on their full meaning. The end of life of this equipment also raises questions. We still need to find a compromise between the use, security, costs and environmental impacts of AI techniques.

BENEFITS OF AI FOR ELECTRICITY NETWORKS

The challenges of AI can be measured by the opportunities it offers.

The major advantage of AI techniques is **to embrace the complexity of systems that could not otherwise be understood**. This ability to aggregate large volumes of data can facilitate decision making, whether in the planning phase or for operational management, but also to better manage the user experience for customers or employees.

The ability of AI to aggregate historical data also creates links between scattered, exogenous and endogenous information, in order to better forecast the evolution of a system. Prediction is one of the major capabilities of AI for networks, whether for renewable production or for consumption. The classification capacity of AI also greatly **facilitates the detection of anomalies**, by detecting anything out of the ordinary.

OUTLOOK

In the longer term, AI techniques could become commonplace in the modeling of complex systems and go beyond the analysis of historical data. Coupled with numerical models, reinforcement learning will be able **to perform millions of simulations of a system**, and thus potentially **generate new solutions**. The proportion of expert systems in AI techniques should also grow, proving **an improved combination of good knowledge of the system and its automated learning**.

Currently, the majority of data processing is done centrally in data centers. The increase in use cases and the number of data processed by AI techniques generates a risk of bandwidth saturation. "**Edge AI**", which integrates processing as near as possible to sensors or connected objects, makes it possible to overcome this risk and should develop widely in an industry whose geographical footprint, covering that of electrical networks, is particularly extensive.

Industrial robotics will also soon be able to benefit from the progress of AI. In particular "cobotics", or collaborative robotics, which aims to develop robotic technologies that interact continuously with humans. Equipped with AI, the cobot would then be able to analyze its environment and adapt in real time to the situation.

Thanks to the power provided by **quantum computing**, it will become possible to train machine learning models on huge databases much faster. Today, some language processing algorithms have nearly 200 billion parameters[1]. Thanks to quantum computing, we could go even further, which would make it possible to **identify, for example, any correlations that were previously impossible to discern in noisy data**.

All these perspectives still require a lot of research work and their generalization will not be without difficulties. Moreover, whatever developments are envisaged, it is essential to maintain a degree of human intervention in the processes. AI makes it possible to integrate more variables into the simulations and to broaden the possibilities, but it remains a tool and complements human intelligence rather than competing with it. In this configuration, **human work** will have less value in execution but **will keep a privileged place in ideation, verification and validation**. Employees will have to be trained to assimilate these new technical requirements and to develop new skills.

1. GPT-3, L'intelligence artificielle qui écrit des articles (presque) seule - Les Numériques (lesnumeriques.com)

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