DATA ANALYTICS IN UTILITIES

The rise of new technologies

Authors: Benjamin de Buttet (DCbrain), Thomas Lacroix (Cosmo Tech), Karl-Axel Strang (Enedis), David Szniten (Klee Group), Arthur Penserini (SNG Consulting)

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FRENCH SOLUTIONS FOR SMARTGRIDS

DATA ANALYTICS, AN ENABLER FOR THE TRANSFORMATION OF UTILITIES

The energy transition that is underway in Europe, combined with the digital revolution as a whole, is making lasting changes to the environment in which the power system operates:

- The adaptation of our production to renewable energies.
- An increasing number of players with different ways of thinking, resulting in decisions being made within very short timeframes and on the basis of criteria that go far beyond purely technical and economic considerations.
- Technical solutions for which we still do not have a comprehensive overview.
- Globalization of business models that encourage usage rather than ownership, dematerialization rather than infrastructure, intermediation rather than centralization.
- Last but not least – and an intrinsically decisive factor of the electricity system – the need for stable, not to mention decreasing, levels of power consumption.

As a result, the complexity of energy systems intensifies while at the same time the increasing amount of data available can help us to gain deeper insights into the behavior of our infrastructure and its users. Only our capacity to harness, process and interpret the data from our world will help us to move to sustainable energy systems in relation to social, technological, economic, ecological and environmental aspects.

New technologies hold great promise to help improve the planning, the efficiency and the sustainability of energy systems. Although they are not limited to the energy sector, technologies such as digital twins, blockchain, machine learning, and reinforcement learning recognize this new complexity. As part of smart grid solutions, these technologies are the new connection between the electrical engineering ecosystem on one side and the IT world on the other side.

What used to be concepts a decade ago, are now clearly described, experimented across Europe and even industrialized in some cases. The objective of this white paper is to shed light on such technologies and share case studies to help the energy community and beyond, to fully grasp their potential.

At Think Smartgrids, we are convinced that these technologies could make a massive difference to better anticipate the ongoing revolution and ensure the mandatory conditions that will yield positive impacts for all. In that way, relying on these technologies can help the energy systems to play a key role in the fight against climate change.

Olivier Grabette

Chairman of Think Smartgrids,
Member of the board of RTE

BUILDING VALUE ON DATA

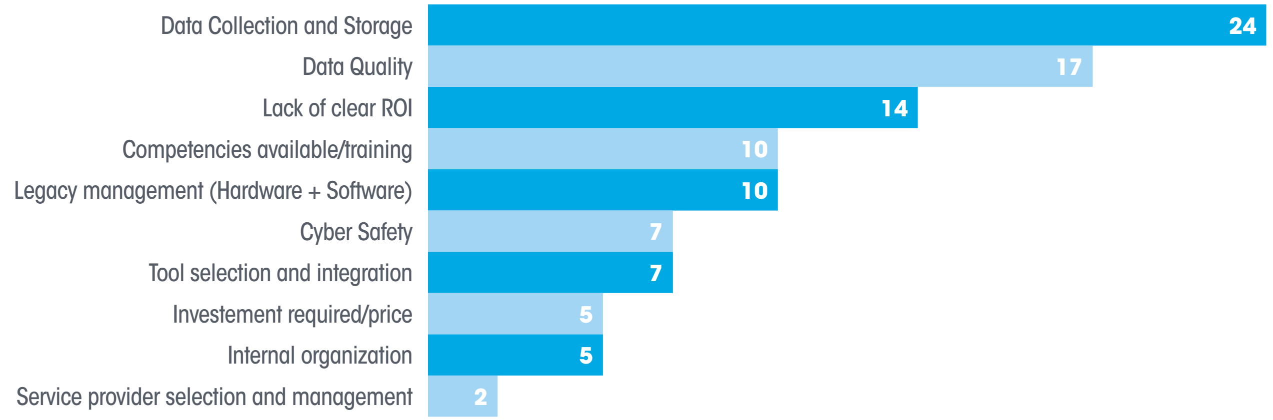
The last paper[1] published in 2018 by Think Smartgrids' Data & Digital Transformation Working group, titled The Digital Transformation of Utilities, reviewed the challenges of integrating data in smart grid operations to serve both networks and customers. Most electricity grid operators in France and Europe have initiated industrial data processing projects to improve their operational performance. However, outcomes showed that some big data projects have unclear ROI, due to the operator incapacity to address clear uses cases.

Additionally, data recovery and data quality remained operational pain points for operators, despite the implemented projects. These outcomes led us to the need for a better understanding on the enabling technologies that will accelerate the ROI on the identified use cases (asset management, flexibility, processes operations…).

3 main pain points :

- Data collection & storage (obsolescence management, diversity of assets, normalization...),
- Data quality (digitilization of historic data),
- The lack of clear Return on Investment.

Pain points preventing a higher industrialization of data use (%)[2] :



Based on those results, we have identified leading technologies, which leverage these new data layers and are either already being used or being considered by TSOs and DSOs. At this point, in the data analytics spectrum, 4 major technologies stand out for utilities companies: Machine Learning, Digital Twins, Reinforcement Learning and Blockchain.

As these technologies become more mainstream, the goal of this white paper is to validate their potential added value, as well as to clearly identify their applications.

This white paper was written in collaboration with operators (TSO/DSO) or suppliers that have carried out projects using these technologies. In particular, key requirements of success are detailed, providing TSOs and DSOs with the building blocks to ensure continuous service on their energy networks.

1. https://extranet.thinksmartgrids.fr/?get_group_doc=9/1543222684-ThinkSmartgrids_report_data_nov2018.pdf
2. The digital transformation of utilities, Think Smartgrids, 2018

REINFORCEMENT LEARNING

THE POWER OF DATA ANALYTICS, WITHOUT DATA

TECHNICAL APPROACH

Reinforcement leaning is a subtechnology of the Machine Learning group. The whole idea of this technology is not to use historical data to learn / identify patterns (cfr Machine / Deep Learning) but to create data to better fine tune a winning strategy. In this sense, this technology tries to copy the "human" models based on the acquisition of knowledge through trial and error.

In order to do that, the goal is to train an "agent" so that it learns a set of game rules, and develops the ability to know when it is losing / wining:

- The rules of the game: what it can / can not do
- The opportunity to act and the consequence of this action
- A reward based on the measured success of this action and the achievement of the final goal
- The ability to restart indefinitely

Thus, the agent will always seek to maximize the reward obtained and will become more efficient at solving the problem, since it keeps in mind what it has learnt.

This technology was made popular in 2015 by Google and its "Alpha Go", which was able to beat the best Go player in the word, using Deep Reinforcement Learning capacities. Although quite new, and still very rarely industrialized, this technology is now being used in various industrial sectors, as stated by Yoshua Bengio, Turing Prize 2018, in his article "Machine Learning for Combinatorial Optimization: a Methodological Tour d'Horizon"[1].

In terms of maturity, this technology is now moving from the Proof of Concept (POC) phase to the industrialization phase.

1. Co-written with Andrea Lodi and Antoine Prouvost, Submitted on 15 Nov 2018

APPLICATIONS AND EXPECTED BENEFITS

BENEFITS

Classical Machine / Deep Learning technologies require huge amounts of clean and structured data. On the other hand, this technology is very helpful when:

- Data is not available.
- The data quality is low (unstructured data, low historical depth, few events in the datasets…)
- The environment / system is evolving too quickly.
- Through Deep Reinforcement Learning, an IT software can make better decisions with less data and align its decision processes very rapidly after the integration of a new constraint into the system.
- Thus, this technology allows control systems to be more reactive and to optimize processes.

In terms of ROI, Reinforcement Learning mainly brings the ability to automatize decision-making processes. Thus it can be used to:

- Optimize steering / exploitation processes
- Identify under-used assets
- Decrease investment plans

APPLICATIONS

Applications in the utilities sectors are as follows :

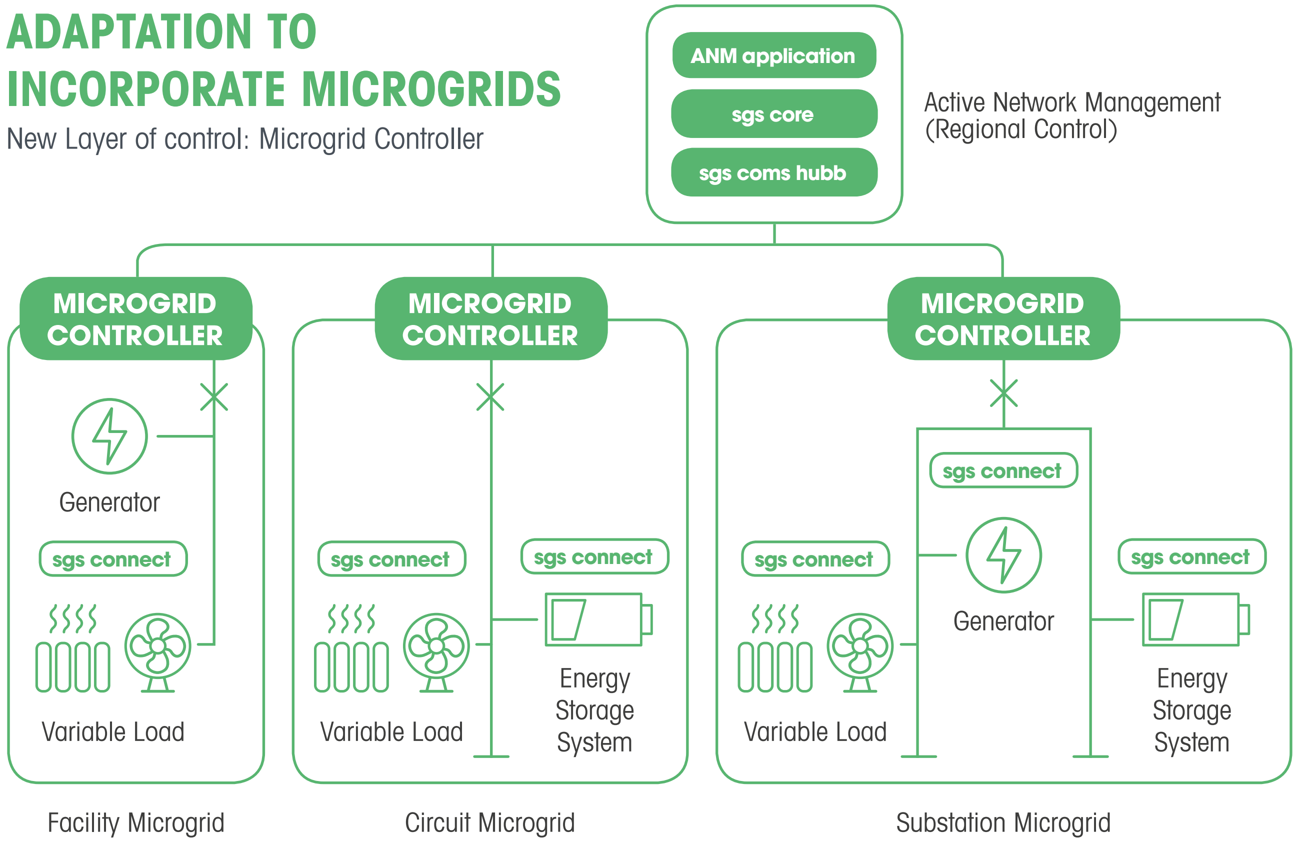
- Asset use rate optimization
- Energy management / micro grid optimization
    - Consumer management
    - Battery charging optimization
- Asset management
- Supply chain optimization

CONCRETE USE CASE IN PLACE

A first use case is to use Reinforcement Learning capabilities as an optimization layer integrated into an Energy Management System. In this case, the advantage of this technology is that it is capable of better adjusting its optimization calculation to behavioral changes. For example, a team from the Lisbon University[1] integrated DRL into an HVAC operating system in order to level the evolution of consumption habits. The idea being that a static control system would inevitably generate energy waste.

ADAPTATION TO INCORPORATE MICROGRIDS

New Layer of control: Microgrid Controller



Another good example in the energy sector is the ITER use case. ITER is an R&D project in the nuclear sector, endorsed by 17 countries. Launched in 2001, it is one of the largest global R&D projects and is due to be completed in 2035. Its goal is to generate energy through a fusion-based process.

The supply chain team in charge of warehousing is having issues to accurately forecast warehouse needs. Since it is a multi-lateral project with work packages evolving in time, it is hard for the team to forecast inflows and outflows. The tool used by the team, based on classical optimization techniques, was not able to adjust to this high volatility of flows. The team decided to test a Reinforcement Learning based software, provided by DCbrain, to better predict the need for warehousing capacities. The context is quite emblematic of Reinforcement Learning possibilities: ITER has a very low visibility on in & out flows and the scheduling rules evolve frequently. Thus, classical Machine and Deep Learning technologies no longer apply.

In the end, using RL capabilities, the ITER supply chain team managed to have a better vision of what they really needed in terms of warehousing capacities in the next years.

1. https://www.researchgate.net/publication/286129627_Using_reinforcement_learning_to_optimize_occupant_comfort_and_energy_usage_in_HVAC_systems

DIGITAL TWIN

A VIRTUAL REPLICA
FOR A BETTER UNDERSTANDING
OF REALITY

TECHNICAL APPROACH

As businesses embrace their digital transformations, there is a higher need to add enterprise processes before strategic and operational processes. To master the entirety of their systems and increase productivity, they create digital twins.

A digital twin is a digital replica of a process, a product, or a system. The first generation of digital twins were targeting a physical, offline representation of products. The development of telecommunications brought real-time/real-state capabilities to digital twins (such as SCADA for network control) as a second step, now extended to many objects thanks to IoT. Today, those digital twins may embrace even more than the physical assets, with the addition of an organization and their processes. The evolution of the technology allowed for the evolution of application cases, **from 2D/3D object design to system-wide prescriptive recommendations**. When more related to a business model, it could be called a Digital Twin of Organization (DTO)[1]).

All digital twins have minimal requirements, and higher-level offerings include optional characteristics.

Minimally required characteristics are:

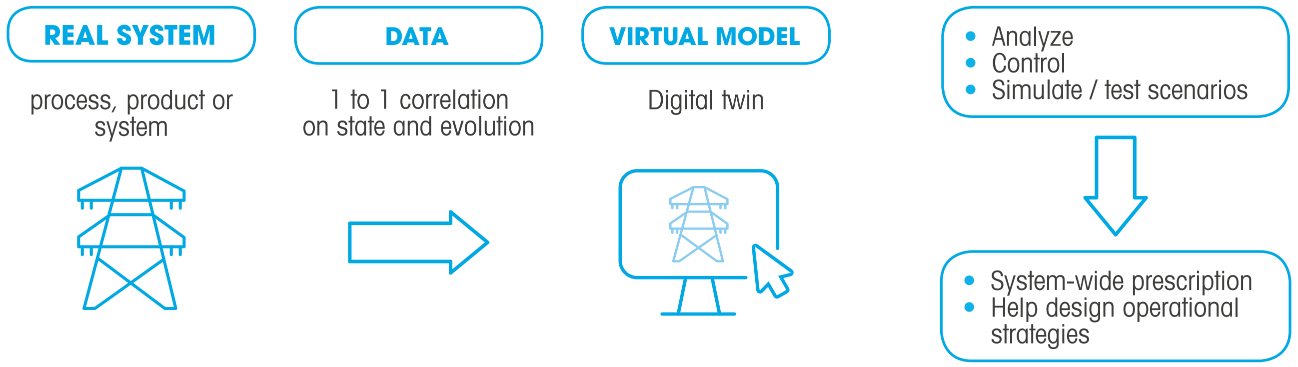
- **1-to-1 correlation** between the software and the system;
- **a physical model** (coarse or finely grained);
- **a data model**;
- **a synchronization** (possibly manual) between real and digital twins.

Optional functional elements:

- **analyze** the system to better understand and predict;
- **control** the system thanks to the increased understanding and confidence;
- **simulate** a system and test different what-if scenarios.

Digital twins allow **users to leverage predictive analytics (AI, simulations) to assess the system's behavior** in the short and long term by applying different scenarios. Users can then choose their preferred scenario and make it real in the physical world, helping industries **to manage shifts in operational strategies while improving their productivity** (also known as virtual experimentation).

The connections between the physical assets, the process and the digital twins can be achieved with **data from physical sensors, data from other software** (other digital twins, asset management tools, etc.), **as well as human expertise**. This ensures continuous monitoring and updates of the digital twin to match the real system state, which is often considered paramount to the digital twin concept.



1. https://www.gartner.com/doc/3881989/market-guide-technologies-supporting-dto

APPLICATIONS AND EXPECTED BENEFITS

BENEFITS

Digital twins provide the following benefits:

- **Faster decisions:** leverage near real time visibility on the system.
- **End-to-end decisions:** extensive data provides more granular, accurate, robust and transparent performance indicators.
- **Reduced costs of testing** new scenarios (virtual experimentation vs on field experimentation).

All in all, a digital twin acts as **a business enabler and facilitator**, allowing users to get a proper picture of their system's state and behavior without physically accessing/impacting the real system for data or trials. Extreme complex scenarios may be tested without the need for the system to actually undergo a strenuous process.

APPLICATIONS

Digital twin technologies are mature and entering mainstream use. According to Gartner, 75% of organizations implementing the IoT already use digital twins or plan to within a year[1]. In addition, digital twin technologies have been implemented in several industries.

TSO/DSO use cases

- **Network management:** the electrical network flow model may be one of the earliest large digital twins and is continuously updated to improve its representativeness, improving load balancing and dispatching decisions with faster and more precise forecast of flows.
- **Predictive Maintenance** (physical sensors + modeling) to detect problematic behavior before failure and plan appropriate action
- **Asset management:** (physical assets, organization, operational process, finance), **to improve cost/risk** decisions at the system level to optimize the whole lifecycle of assets (design, procurement, commissioning, maintenance, decommissioning/disposal)

Other use cases

- **Supply chain:** production planning optimization based on digital twins including production assets, transportation flows, inside a four-wall process, sales forecasts and product assembly.
- **Pharmaceutical industry:** digital twins allow companies to optimize production parameters for highly complex systems, accurately and proactively, without risk. This is a significant evolution in efficiency compared to the traditional approach of shifting through historical data manually to try to spot trends[2].
- **Infrastructure management:** digitalization of construction using a digital twin of that city, of the tunnels, of the metro, and the capacity to simulate how the infrastructure is operated[3].

1. https://www.gartner.com/en/newsroom/press-releases/2019-02-20-gartner-survey-reveals-digital-twins-are-entering-mai
2. https://www.mckinsey.com/business-functions/operations/our-insights/how-data-is-changing-the-pharma-operations-world
3. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/tackling-infrastructures-digital-frontier

CONCRETE USE CASE IN PLACE

THE BENEFITS OF SIMULATION IN STRATEGIC ASSET MANAGEMENT

As done for many years in the field of system operations, RTE has chosen simulation to determine their asset management strategies. Indeed, due to the many couplings at work in asset management, such as asset degradation and failures, business processes, operational (intervention grouping, HR), financial (budget, asset financial depreciation), and network constraints (outage, redundancies), it is now necessary to have a global understanding. Accordingly, the considered system may become too complex for straightforward optimization.

RTE has therefore acquired a digital twin of their electricity transmission network oriented towards "asset management", MONA, based on Cosmo Tech's asset management application. MONA is able to simulate the application of asset management strategies at whole system scale, over the short, medium and long term. It represents each asset in the network with its aging dynamics, the maintenance and renewal operations as well as the resources required to deliver the plan.

The main challenge in using MONA, which is still being worked on, was to "synchronize" the real network and its twin, notably initializing the current health status of each asset at the start of the simulation, aging dynamics with or without maintenance, actual number and individual cost of operations. To do this, RTE used statistical techniques from medical research.

One of the main benefits of the simulation has been to facilitate converging ideas between experts, asset managers and company management, by focusing the debate on assumptions and not on a priori predictions, with the possibility of accurately testing many different strategies and their effects on costs, quality of supply, security and environment on the entire system, and with a complete transparency.

MACHINE LEARNING DEEP LEARNING

COMPLEX CORRELATION BASED ON HISTORICAL DATA

TECHNICAL APPROACH

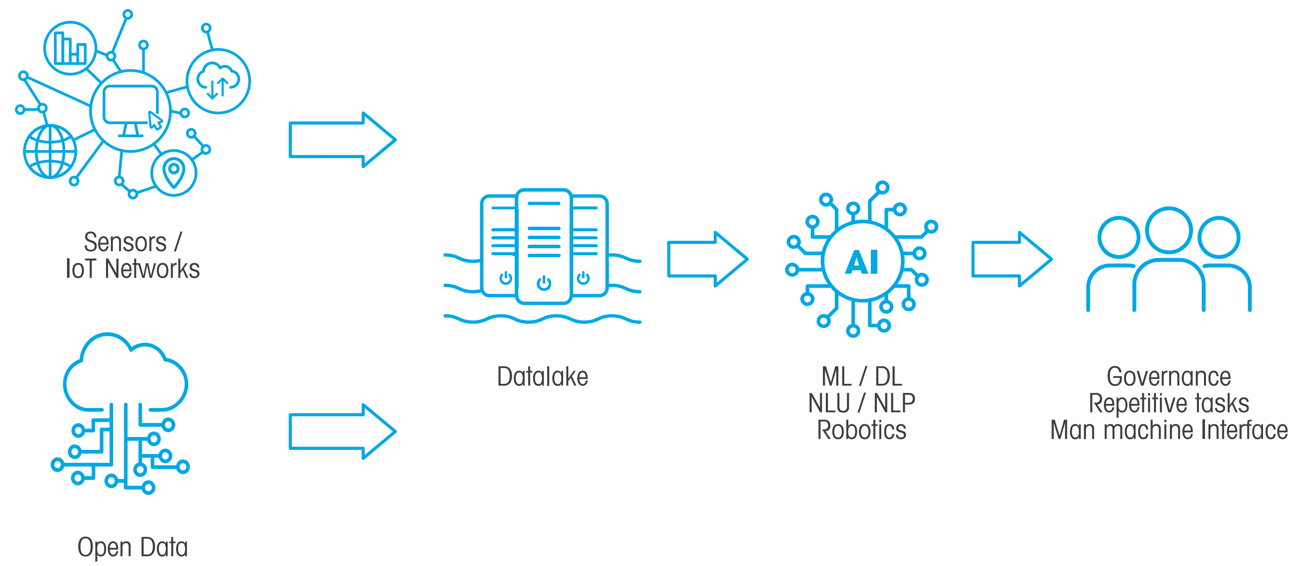
Machine Learning / Deep Learning (ML / DL) are AI technologies **enabling computers to interact independently with their environment:**

- **Understanding** situations and context (computer vision, pattern detection…)
- **Make decisions** or help humans make them (virtual assistants…)
- **Physically interacting** with the real world (robotics)

Two main assets enable these functionalities:

- **Tremendous amounts of data** (provided by the ubiquitous sensors, smartphones and other equipment and by Open Data initiatives)
- **Soaring computation power**, mostly based on dedicated hardware or even on mainstream tools like Graphics Processing Units

ML / DL allow systems to react to input data in an adaptive way, outside of human predefined rules, building on new data and producing data itself.



1. https://www.gartner.com/doc/3881989/market-guide-technologies-supporting-dto

APPLICATIONS AND EXPECTED BENEFITS

BENEFITS

- Limitation of storage cost, supply and demand prediction
- Reduction of energy consumption through optimization
- Leveraging chatbots to require fewer hotline services
- Reduced maintenance costs through predicting equipment failure
- Better grid resiliency and reliability

APPLICATIONS

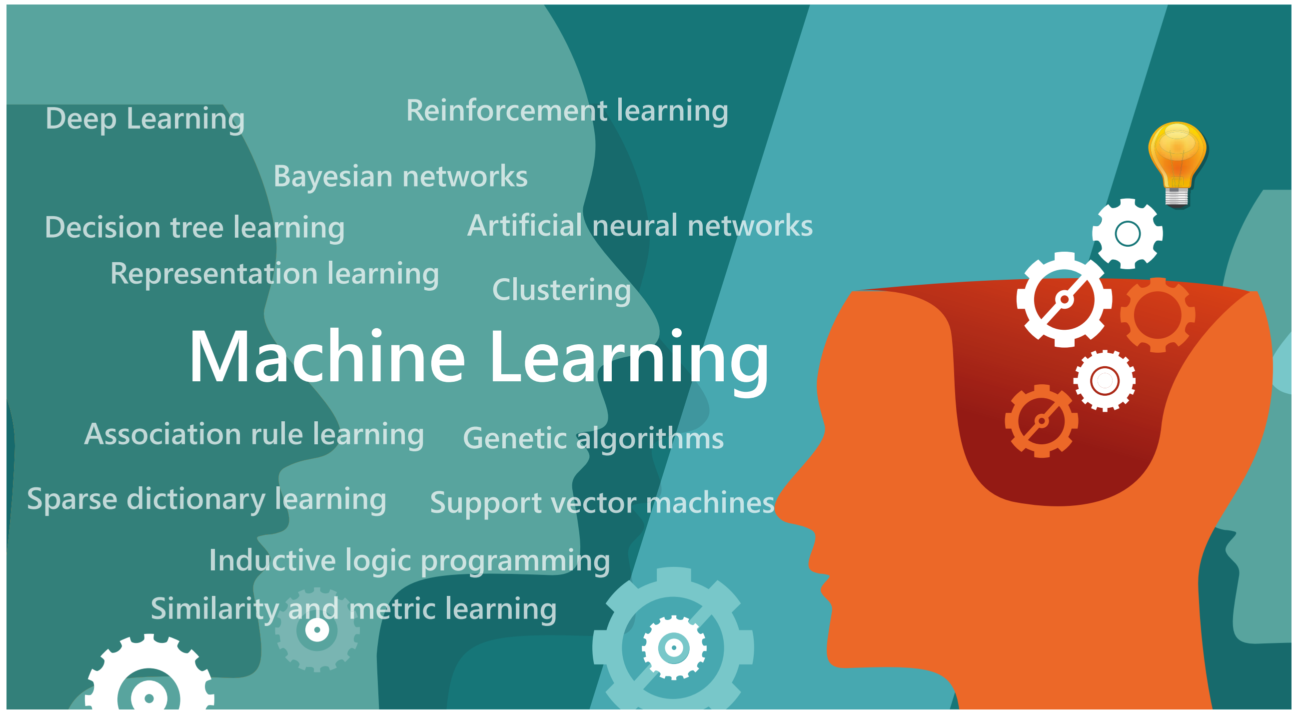
Machine learning is already operational in some use cases, such as anomaly or pattern detection on data provided by power consumption sensors. Autonomous management for smart grids based on ML / DL is still in development.

- **Prediction:** power outage prediction and recommended outage reactions
- **Optimization:** energy storage and energy production optimization
- **Data classification:** filtering and prioritizing maintenance operations
- **Fraud detection:** detecting unusual or out of bounds usage
- **Singularities detection:** understanding grid use patterns
- **Man machine interface** (chatbots, personal assistants…): enhancing users experience

1. https://www.gartner.com/en/newsroom/press-releases/2019-02-20-gartner-survey-reveals-digital-twins-are-entering-mai
2. https://www.mckinsey.com/business-functions/operations/our-insights/how-data-is-changing-the-pharma-operations-world
3. https://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/tackling-infrastructures-digital-frontier

CONCRETE USE CASE IN PLACE

- **Adaptation to user demand (Distribution Utility):** Through ML / DL, smart systems are able to adapt energy storage and distribution according to user consumption. Storing unused solar energy during the day in adapted batteries and distributing it to users through the night, anticipating weather change and storing to make it available in case of temperature drop…
- **Maximizing Power Usage Effectiveness (Cloud Datacenter Operator):** Cooling computers and infrastructure in data centers is a major consumption and cost concern. Using AI, and especially Deep Learning, cloud operators are able to optimize power consumption and reduce data center cooling costs by 40%. AI technologies are used in this case to be able to understand non-linear interactions between heterogeneous equipment in data centers and to build an optimized cooling model.
- **Energy Resources Detection (Oil / Gas Company):** Using Machine Learning and Deep Learning algorithms, companies optimize underground exploration to find resources, through Computer Vision analyzing underground imaging, through pattern detection etc.



BLOCKCHAIN

A NEW WAY TO ENSURE INFORMATION EXCHANGE

TECHNICAL APPROACH

The term blockchain encompasses a family of technologies centred on a ledger which:

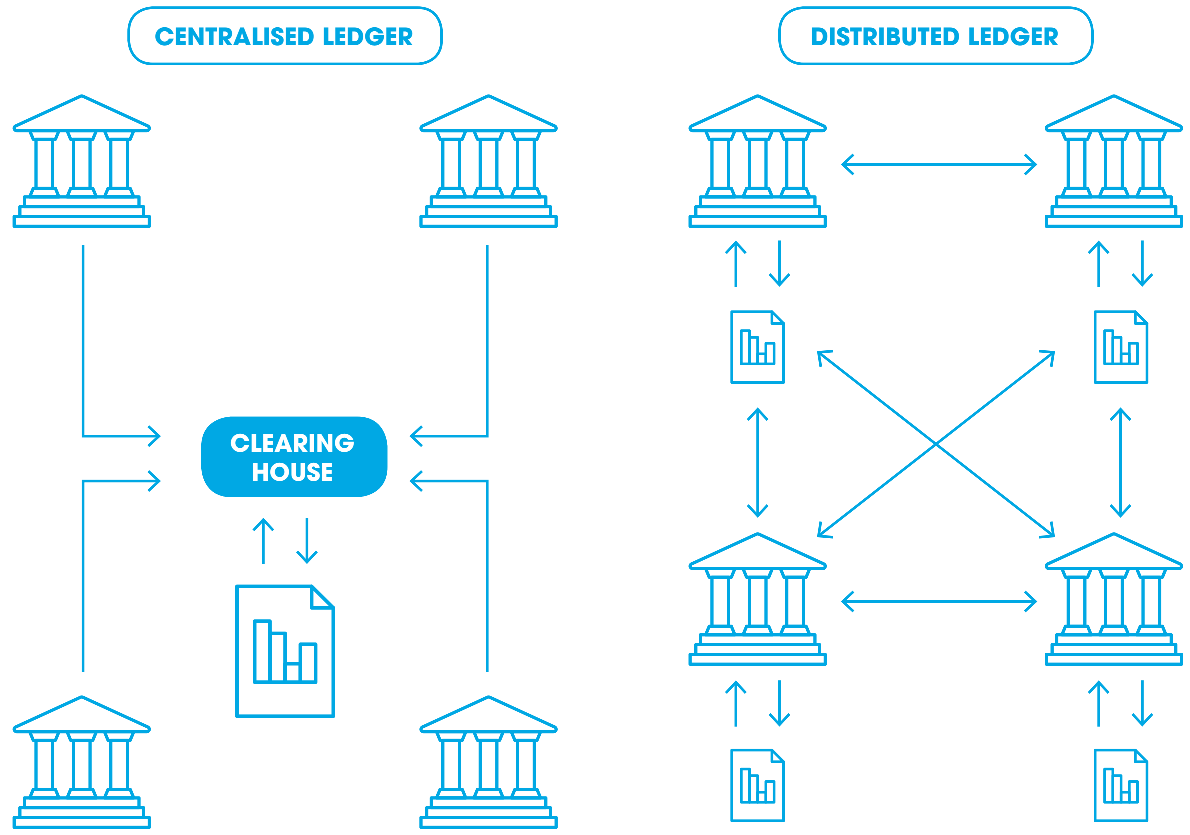
- Stores information on transactions between participants and adds them incrementally,
- Secures this information through timestamps and cryptographic means
- Is distributed between participants with synchronized copies across several nodes held by different stakeholders of the network.

The various blockchain technologies can be differentiated according to three main characteristics:

- A blockchain can be either public, consortium or private, depending on the desired governance and level of accessibility
- A distributed ledger technology can be enhanced or not by autonomous programs, called smart contracts, to fit specific applications
- Blockchains rely on a consensus. Very different ones exist, each with its own technical characteristics and its governance model

EMBEDDING DISTRIBUTED LEDGER TECHNOLOGY

A distributed ledger is a network that records ownership through a shared registry



APPLICATIONS AND EXPECTED BENEFITS

BENEFITS

The main benefits identified for this family of technologies are:

- Improving **trust** between stakeholders
- Improving **transparency** through shared meta-data between stakeholders
- Improving **data security and integrity**

APPLICATIONS

As of today, the main commercial applications of blockchains revolve around peer-to-peer transactions (financial sector) and traceability of assets and supply chains (logistics). But, blockchain applications are starting to be integrated in several services in the energy sector:

- **guarantees of origin of electricity** produced from renewable energy sources
- **charging of electric vehicles**
- **ledgers in energy trading platforms**

However, most applications remain at the experimental phase, as blockchain technologies still need to prove their medium-term ROI relative to conventional IT solutions with proven track records.

CONCRETE USE CASE IN PLACE

A blockchain-based service must manage energy exchanges according to the rules set by energy communities. It harnesses the available smart metering infrastructure installed by the DSO and acts as the trusted party for energy data to the energy stakeholders, so that the service stays focused on the governance of the energy community.

SELF-CONSUMPTION COMMUNITY

Energy consumption and production are measured through smart meters. The production is virtually allocated to the consumers. A virtual network is implemented, tracking the transaction between the parties. At each time interval (10, 15 or 30 min e.g.), the energy generated is aggregated and divided between the different participants, according to their actual consumption and predefined rules.

The difference between consumption and allocated production is transmitted to the participant's own usual electricity provider.

Energy measurements of the smart meter are integrated on a blockchain via IoT modules. Trusted programs running on the blockchain compute the proper allocation of the produced energy according to rules enshrined in the blockchain. The sharing is secured, certified by the blockchain consensus, and auditable. The developed architecture is a tokenless blockchain where the validators are part of the operation. The implemented consensus mechanism requires light calculation and provides a certification of the energy allocation. Data is restricted to the participating actors, governance is assured by designated actors, and the chosen scope is then the one of a consortium blockchain.

ONGOING PROOF OF CONCEPT IN FRANCE

The solution has been deployed on a small energy community with 2 producers and 3 consumers. At each measured time interval, power production is mutualized and shared through the public network. Enedis, the main DSO in France, is part of first pilot projects, to test the interface with Enedis and its smart metering system. The architecture connects IoT devices to a port on the smart meter which transmits energy data at a 2-second interval to the device connected to the blockchain network. The blockchain network calculates the ratios of electricity self-consumed and provided by the respective retailer for each consumer of the community at each time.

In turn, Enedis uses its smart metering infrastructure to upload the respective load and production curves, communicates with the blockchain network to recover the allocation coefficients and combines the data to calculate each consumers' energy quantities to be accounted as self-consumption or energy provided by the retailer. The quantities are transmitted to the energy community, respective retailers and balancing group entities. The DSO and its metering infrastructure remain the trusted party, for energy data transmitted to the stakeholders, while the blockchain certifies that the energy allocation respects the governance decided by the community. This can be replicated for any other similar project, provided that a smart metering infrastructure has been installed and that the data exchange protocol with the DSO has been properly defined.

TOP 8 DATA ANALYTICS PREREQUISITES FOR SUCCESS

The analysis of the selected analytics technologies has highlighted their unique capacity and value proposition to address TSO and DSO use cases. In the upcoming years, the working group foresees an acceleration of the adoption of those technologies, for the benefits of TSO/DSO performance. This latter could improve by almost 25% through Big Data Use, as stated by the McKInsey Institute, in its "Big Data: the next frontier for innovation, competition and productivity".

However, it is important to note that selecting and implementing technologies within an organization requires guidelines to follow. The integration of data analytics into daily processes is not straightforward. 8 major points have been identified.

1. Availability / quality of data: analytics technologies require data to operate. Hence the right organization (including IT architecture, processes, competences,…) is essential to ensure the highest quality of data and the necessary frequency of uploads.

2. Competencies: integrating analytics technologies and manipulating the necessary data is new for most energy companies. These organizations need to integrate new people (data scientists, data owners, data architects, business modelers) that will have the ability to extract value.

3. Transparency & auditability: to be trusted, analytics technologies must avoid leveraging black box algorithms to make sure decisions can be justified. In particular, collaborators need to trust the models and therefore understand them.

4. Scalability: to allow companies to extract maximum value, the analytics technologies must provide scalability on 3 axes: horizontal (across the entire infrastructure), vertical (from strategy to operation), temporal: short, medium and long term. In order to do so, analytics projects must be structured in a strategic plan, to avoid small scale operations, with no / few impacts on value.

5. Upgradability: during the lifecycle of the technology, both analytics and data update processes must be aligned, especially for automatic updates. However, the main challenge is to ensure, when human contributors are needed, they are aware of their responsibilities and keep the data up-to-date.

6. Integrability: implementation within the company legacy information system can be very challenging. Most of the time, this legacy system was not designed to store / clean / aggerate and analyze data. Before launching an industrialization project, companies need to anticipate any impact on the legacy system.

7. Security: working with data can generate fear, especially when it is done with external providers. Most of time, people are worried that it might lead to loss of competence. On a strategic level, top management might be afraid of a competitive advantage decrease. With Big Data, the topic of cyber security is gaining importance and is now becoming a strategic topic for organizations.

8. Confidentiality: of course, whether you want to better understand customers or optimize processes, data processing must be done in compliance with legislation, especially when it comes to individual data.

DATA & DIGITAL TRANSFORMATION WORKING GROUP

Created in 2015 as part of the government's Smart Grid Plan, Think Smartgrids federates and represents the French smart grid ecosystem. The association is chaired by Olivier Grabette, member of the board of RTE (French TSO).

To meet the needs of the sector, Think Smartgrids relies on a Scientific Council and several Commissions and Working Groups, chaired by well-known personalities in the French smart grids ecosystem.

The Data & Digital Transformation working group was initiated in 2017 by two members of Think Smartgrids, Cosmo Tech and DCbrain, with contributions from more than 20 members.

The objective of this working group is to provide answers to the operational issues of grid operators regarding digital projects: Data Use, Value, industrialization of data projects, operational paint points…

A study based on more than twenty interviews with key European players was published in November 2018 and is availiable on Think Smartgrids' website at https://extranet.thinksmartgrids.fr/?get_group_doc=9/1543222684-ThinkSmartgrids_report_data_nov2018.pdf

Benjamin de Buttet, co-founder of DCbrain, and Thomas Lacroix, Chief Technical Officer at Cosmo Tech, are the two co-leads of the Data and Digital transformation working group.

OBSERVING MEMBERS

ASSOCIATED MEMBERS

PARTNER MEMBERS

Schools, research centers and labs

This study was conducted by the Data & Digital Transformation working group of the association Think Smartgrids.

Think Smartgrids federates and represents the French smart grid ecosystem, with a hundred members, from startups to large groups, research laboratories, universities, professional associations and clusters, covering the entire smart grid value chain: electronic engineering, utilities, automation, telecommunication equipment and information systems, business models, training, and regulation.

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Think Smartgrids – Tél : +33 1 42 06 52 50 – contact@thinksmartgrids.
www.thinksmartgrids.fr - @ThinkSmartgrids

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