Asset management for a Greener Grid

Executive summary

Asset Management is an essential grid operator practice that has existed for many years. New IoT technologies can today not only improve its overall efficiency of the electricity system but also contribute to the European Union Green Deal objectives. Fundamentally, this is about using less resources all over the lifecycle of the grid without increasing the risk and enabling the usage of more renewable energy generation to achieve a climate-neutral energy system.
Understanding the relation between asset management and green objectives is likely to accelerate the deployment of such advanced solutions on a wide scale that should ultimately benefit the end user.

This paper explores how a modern asset management practice contributes to a greener grid through a series of new tools driving the proper opex and capex decisions. Moreover, it outlines the financial benefits that can be triggered by efficient asset management. It then suggests the set-up of an indicator to follow the progress that would become a part of an overall smart grid monitoring process.

There are on-going projects to better assess the value of asset management initiatives led by grid operators. It would benefit the European Grid Operator to share a common view on the return on investment, and T&D Europe suppliers could help to refine it.

Introduction

Electricity grids are a strategic asset to achieve EU climate-neutral energy transition

During the COVID-19 crisis Europe's electricity grids have demonstrated their importance, strength and resilience. EU Member States and the European Commission have recognised that this has been a major achievement. EU Ministers acknowledged that the European energy system is resilient and that there is currently no risk of disruption in energy supply systems, especially for those most in need. They discussed how frontloaded infrastructure investment (together with other measures) can contribute to the fast and efficient recovery. They also discussed which activities or measures could be rapidly implemented at the EU level. The EU

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Energy Commissioner suggested "**promoting big infrastructure projects that will provide stimulus for the economy**, while making our energy system greener."[1]

The EU has committed itself to become the first climate-neutral continent by 2050. Its new growth strategy centers around the green and digital transitions. This is reflected in the bold proposals for the EU recovery plan and its long-term budget. For many years, the European Union has been committed to the reduction of carbon dioxide emissions and to increase the share of renewable energies in its energy mix. An important milestone is the adoption of the package Clean Energy for all Europeans in spring of 2019.

From 2020, we must look at how we produce, transport, distribute and use energy within the framework of the European Green Deal. Electricity networks are the backbone of Europe's energy system with electricity now an essential and critical resource in daily life for Europeans. A temporary or prolonged disruption in our electricity supply touches virtually every part of our society and economy, and the importance will further increase as additional sectors will become electrified by Smart Sector Integration. Climate change is one of the many factors putting additional stress on grid resiliency. Given its criticality, the EU has designated electricity generation and transmission as critical infrastructure[2].

Electricity Grids will require significantly increased investments

Electricity grids connect and coordinate all elements of power systems to serve their end users. Grids will play a crucial role in facilitating and enabling the energy transition to incorporate increasing levels of distributed electricity generation, changing demand patterns and the implementation of new technology and solutions. Investments in grids will have to follow the additional renewable generation capacities of the next 10-15 years (in line with grid operator investment plans).

Moreover, electricity grids are long-term investments. We expect grid components, such as transformers, switchgears, etc. to be in place, serving their purpose in good quality over several decades. Europe's electricity grids have a particular ageing structure, as they are all originating from post-World War II time. Therefore, many of their components are close to the end of their lifetime. Steady reinvestments are very important in such a situation to avoid

[1] European Commission News, Energy Council discussion confirms key position of energy sector in economic recovery, 28 April 2020 https://ec.europa.eu/info/news/energy-council-discussion-confirms-key-position-energy-sector-economic-recovery-2020-apr-28_en

[2] COUNCIL DIRECTIVE 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection

reduced reliability of supply as a result of synchronous failures of outdated equipment in future.

Clean electricity affordability can be optimised using modern Asset Monitoring principles

Investments in public grid assets are supported by end users' tariffs on the electricity produced and consumed. It is therefore crucial that the future green deal investments will enable European Regulatory Authorities for electricity grids to maintain clean energy affordability.

Traditionally, transmission and distribution asset management has consisted of placing devices in the field, then either maintaining them or replacing them after they have failed. This is still a common process for the maintenance of many distribution assets such as poles, conductors, and distribution transformers. This included periodic visual line inspections and the replacement of transformers based on manufacturer age. Operators had established periodic maintenance processes and planning cycles that ensured asset operation, though these processes were not necessarily efficient or optimal all the time, leading to system inefficiencies and costly capital and Operation & Maintenance investments.

T&D Europe's Asset Management Task Force has worked on an overview of these novelties and their financial and environmental impacts, as well as a dedicated proposition for an "Asset Green Index", which can assist energy regulators to monitor the development towards smarter transmission and distribution grids, as prescribed by the new Electricity Directive.3 This is presented by this paper, which we propose to serve as a starting point for a discussion process with relevant stakeholders, including grid operators, grid users (generators and consumers) and regulators.

How to make the grid greener?

A greener grid will be achieved by reducing the physical resources across the grid lifecycle and enabling the usage of cleaner resources in terms of generation and loads. More specifically the following actions are recommended:

- Optimise resource usage for the maintenance of the grid: this is about asset lifetime extension based on asset health and not only age avoiding manufacturing of new

[3] T&D Europe has developed a Grid Smartness Monitoring process[3] proposed in the context of the Clean Energy Package, in which the Asset Green Index can be integrated. Read more: https://tdeurope.eu/latest-news/39:tracking-progress-towards-smarter-grids-a-proposal-for-the-implementation-of-the-revised-electricity-directive.html .

devices, reduction of the maintenance interventions avoiding crew dispatch thanks to predictive and reliability centered maintenance, and optimised crisis management. For instance, avoidance of dirty power generation to substitute the loss of main generation or links to the main generation. It is anticipated that the manpower optimisation will allow to deal with the grid development.

- Reduce resource usage for the operation of the grid: this is about energy efficiency.[4] This shall be complemented by the non-technical losses' detection, the contribution of the grid to the overall sector coupling optimisation and the integration of the grid edge resources such as renewable generation into the operation optimisation.

- Better coordinate the above operation and maintenance activities, having the risk management optimisation integrating the climate impact on the decision criteria. This is likely to change the result of traditional arbitrages. Green criteria could for instance privilege the usage of assets that follow a circular economy process.

- Reduce resource usage to cope with the evolution of the grid requirements, during the planning phase. A typical example is to support climate-neutrality thanks to an easy integration of renewable generation and Electrical Vehicles:

  - this starts by having a clear model of the grid hosting capacity and grid edge Distributed Energy Resources (generation, storage, displaceable loads), typically reflected into a GIS (Geographical Information System) tool,

  - it is then about facilitating the decision between adding lines or additional grid automation to maximise the usage of existing resources,

  - additionally, it is also about optimising the product selection criteria to integrate the full life-cycle cost, aimed at developing a circular economy.

Standardising the measurement and/or quantification of each of the above topics would be a way to help identify progress areas and integration into the smart grid indicator. This would be achieved through (new) IEC or CEN/CENELEC works.

[4] T&D Europe is planning the publication of a dedicated paper on energy efficiency in June/July 2020?

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Asset management as a key component to define the investments

Asset management (AM) is simply defined as the coordinated activity of an organisation in realising value from its assets for a given risk level. From an electrical networks point of view this covers both operations and maintenance, having to consider assets over their complete life-cycle, their efficient operation and optimised maintenance practices, so as to provide constant service, integration of new technologies for interconnection and digitalisation.
AM activities have always been done, performed by asset managers who have a lot of experience and knowledge in the field. Indeed, operators have in place in-house developed AM systems based on traditional data collection methods. However, today the operators are transforming the way in which this is carried out through digitalisation.

Three main components for a modern asset management practice

Asset management starts by properly managing the list of assets and associated attributes. This is the basis for establishing models whether electrotechnical or economical that can help drive optimised decision making for maintenance, operation, and investments – also known as the grid digital twin. From a geographical point of view, grid assets are extremely distributed, as much as one to two orders of magnitude higher than that found in other industries. For instance, EDP is claiming 10^7 assets[5] while large industrial plants would be in the range of $10.^5$ Geographical Information Systems (GIS) offer the necessary platform to support this, importing and synchronising datasets from other databases, simulation and operational tools for grid and grid edge needs. More generally, asset management implementation requires the integration of multiple software existing in the grid operator centers (Grid Management, Smart Meter Management, Customer Information Management, etc.).

The second layer aims at optimising the maintenance of the assets. This is about the different substation components (transformers, circuit breaker, Intelligent Electronic Devices), their associated connection points (to busbar and feeders) and their interconnection assets (overhead lines and associated poles, underground cables, and junction boxes). Several drivers are accelerating asset degradation compared to the situation ten years ago: the effect of climate change, with storms and floods overstressing the assets especially between the substations; the assets digitalisation with cybersecurity rules requiring more frequent updates within a substation; and the usage of Distributed Energy Resources leading to new voltage and current profile stressing the overall chain. The national regulatory authority is responsible for incentivising/enabling operators to invest in the relevant asset management technologies, systematically integrating the carbon impact on the scenario considered.

Asset performance management platforms help to optimise the maintenance of assets. They collect asset condition data regularly to assess Grid Asset Health by monitoring diagnostic,

[5] "Machine learning and AI at EDP", Grid Analytics Europe 2018

prognostic and prescriptive analysis identifying the premature aging due to stress conditions and then suggest more accurate inspection, maintenance or replacement recommendations to support the decision-making process. Recommendations are transformed to work actions that must be evaluated in terms of cost and urgency and finally optimised in a multiyear plan. Generally, a what-if analysis is done to evaluate the benefit/cost ratio for a Transmission or Distribution Utility to perform these work actions. Note that the increasing dynamic nature of the grid linked to a growing number of Distributed Energy Resources is going to reduce the operational margins and thus enforce the interest of the predictive maintenance.

Investment planning is the third essential aspect of asset management. This ranges from the simple asset modernisation or renewal, that from now on should be done in the spirit of a circular economy approach, to the grid evolution with new solutions enabled by distributed automation (compared to the traditional addition of lines and substations) with DER bringing new electrotechnical constraints and solution opportunities. New investment options and selection criteria (Opex/Capex, flexibility, etc.) are quickly emerging, requiring new tools to make sure that the investments are properly balancing the different dimensions.

This can leverage international standard and European developments

Existing AM systems are generally proprietary and there is little or no common standard or framework used across different operators. However, many network operators are looking to recent developments in asset management best practices. Various Asset Management frameworks are being used, most notably the more generic ISO 55000 standard, and the more specific CNAIM (common network asset index methodology) developed by the UK DSOs.
The essence of ISO 55000 is value realisation from assets. This means that the right things are being done correctly, and that any action taken will support an organisation's strategic objectives. It is a generic framework applicable in many industries, but several network operators are implementing this with the specific goals of aligning AM practices with their business strategy.

CNAIM is a common methodology for assessing condition-based risk for electricity distribution assets and sets out the overall process as well as the parameters, values, and conditions to be used. It is very specific to the UK but does provide a common base measure among the different operators. The resulting outputs, namely Probability of Failure (related to Health) and Consequences of Failure (including environmental and societal implications), expressed in monetary terms, are used to generate a risk matrix. This methodology does provide a common quantitative score of asset failure risk for comparison across different operators and different manufacturers, there is an additional part of this method which is qualitative and open to interpretation.

The development of a standard would need to consider the existing capabilities and methods of data acquisition of the many different international operators.

Implementation is still at an early stage

Independent from framework or method, many operators have an AM in place which typically produces 'basic' risk matrices. The development and introduction of newer methods using machine learning (ML) and artificial intelligence (AI) is giving the operators more insight into their assets and empowering them to move from simple monitoring to diagnostics and further to prognostics. Expert systems are helping automate repetitive analytical tasks based on expert rules, leveraged by ML to provide 'standard' reports. Statistical methods and rules provide insight into assets where large sets of historical data are available, which are constantly updated. It is worth noting that many operators still collate relevant data through manual inspection, as has been the case for historical datasets, and that in certain circumstances this may not change. AI and neural network methods are being used for analytical tasks, again where large historical datasets are available, in this case for generating and training models, and whose rules are 'hidden' within the neural net.

Many system operators are still at the stage[6] of evaluating the value of these new methods and how to appropriately use them - not necessarily independently. Although some limited projects to date provide some limited validation, the use of these methods in other applications and industries have proven successful, providing strong support to their integration into current practice.

A holistic approach should be taken to asset management, linking measurements to objectives specified by companies' strategy[7]. Sensorisation of the network needs to be carried out accordingly, taking into account asset population, cost and the selection of the correct measurement regime for each asset and scenario. It is important to note that once installed in the field, the sensors themselves becomes assets. The vast range of sensors available today for measurement in the field is increasing, having smaller footprints, lower energy demands and increased connectivity, all of this leveraged by available IoT platforms.
Examples of measurements currently carried out include:

- Temperature, Pressure and Humidity measurements (ambient, critical points in primary circuits)
- Operational measurements (position, number of operations, operation times, etc.)

[6] « Asset management: a risk based approach. Energy & Resources Benchmark Study", Deloitte, 2013: this is showing that only 38% of the respondents have a systematic approach (maturity level 4 out of 5), that more than 80% of them only partially integrate the life-cycle costing for their strategy, and 19% of some predictive analytics

[7] "Financially optimized maintenance planning using asset performance management», Gartner report, 2018 is stating than less than 5% of asset intensive organization are leveraging financially optimized maintenance planning

- Oil quality measurements (dissolved gas analysis, moisture content)
- Insulation quality measurements (partial discharge)

These measurements coupled with available electrical data provides data, supported by IoT technologies, to the different platforms available, be they at edge-, fog-, or cloud-level.

Asset management should become a tool to drive toward a greener grid

The following table is crossing the ideas developed in the last two sections. It shows a very interesting match between asset management families and the capability to contribute to a greener grid.

While asset management is a current practice nowadays, enabling resource saving for the green objective is likely to request some initial investments:

- Sensors: they are needed to improve the asset condition assessment. This ranges from satellite images (typically to observe the vegetation evolution) to temperature sensor analysing junction between conductors.

- Analytic: they are needed to interpret the new series of data, with processing ranging from off-line (for instance for asset replacement advice) to real-time on-line (for instance for non-wire alternative automation). Non-wire alternatives will typically involve distribution automation between substations, or between a substation and a prosumer, and is not necessarily linked to a local energy market, thus not constrained by the regulation.

- Modeling: the grid, especially the distribution one, is increasingly influenced by the grid edge DER resources, acting as real or virtual generators and storage devices, todays managed asynchronously from the grid resources.

Asset Mgt Family		Asset Information Management	Asset Performance Management	Asset Investment Planning
Key technology		Databases for asset modeling and lifecycle management	Sensors and analytics for maintenance optimisation and asset usage optimisation	Analytics comparing different scenario on multiple criteria
Sustainability family	Sustainability family topic			
Reduce resource usage for the maintenance of the grid	Lifetime extension		X	
	Workforce reduction		X	
	Crisis management			X
Reduce resource usage for the operation of the grid	Energy efficiency		Indirect	
	Non-technical losses		Indirect	
	Sector coupling			x
	Grid edge resources	x		
Better coordinate the above operation and maintenance activities	Traditional		x	
	Adding green criteria	x	x	
Reduce resource usage to cope with evolution of the grid requirements	Renewable gen.			X
	Electrical Vehicles			X
	Non-Wire alternative	x		x

Benefits quantification - examples[8]

One of North America's largest transmission system operators, whose network extends across 11 states with 5.4 million consumers in the southern and eastern USA, with approximately 65,000 km of transmission lines and 345,000 km of distribution lines, has therefore decided to implement an integrated resource management system.
With the support of an independent external consultant, savings of approximately $14.8 million in the first year of operation have been identified as a result of avoiding serious system disruptions due to equipment failures, $1.2 million as a result of reducing unplanned outages, $2 million as a result of more efficient execution of planned shutdowns, and $1.6 million as a

[8] Kreusel, J.; Saliba, S.
Digitalisierung am Rande der Netze – Voraussetzung für eine erfolgreiche Dezentralisierung der Energiewende. (Digitalisation at the edge of the grids – pre-requisite for a successful decentralisation of the energy transition.)
Realisierung Utility 4.0, vol. 1, Springer Vieweg, 2020, ISBN 978-3-658-25331-8, pp. 331-350

result of optimised use of manpower and capital. Overall, the savings in the first year were almost twice the investment for the integrated system solution.
Another example in Qatar[9], has shown the following benefits: more than 50% in reduction of asset failures, 182% net benefits generated against the overall costs.

Defining indicators to follow how asset management contributes to a greener grid

Transmission and distribution network operators typically load their strategy definition and configuration into an Asset Management system. It is then translated as objective functions that will be used by the optimiser engine, such as:

- minimise asset risks
- maximise Grid asset reliability
- minimise planned costs
- maximise Asset Health Index

The proposition is to use a set of indicators to establish a current baseline on how Asset Management contributes to Green and define targets for the coming years. Targets could be reevaluated every year depending on network operator's environment or regulation constraints.

Commonly, environmental impacts and consequences of failure are defined criteria in asset risk index scope. Network operators define rules to determine risk score including environmental criteria weight. Given that Asset Risk model is linked to Asset Health model, when asset health condition decreases then asset risk score increases, and so environmental criteria risk score increases. As a consequence, a decision maker can follow how asset failures effect on environment by defining an accurate and exhaustive list of environmental criteria, setting proper environment criteria weight impact and a strategy to minimise failures impact to *Green*.

Scheduled (usually periodic) maintenance has a cost. Cyclic maintenances require human resources, spare parts, and tools at a precise location during a specific period. Planned outages are also required and may stress assets making them aging faster. Reducing the number of cyclic maintenances by means of a condition and predictive maintenance strategy can help to reduce environmental and climate impacts and thus make the grid greener. Regulators could define a maximum number of cyclic maintenance targets over the next 10 years period that could be followed by the Utilities as per as their Asset Management strategy.

[9] "Asset Performance Management for Power Grids", World Engineers Summit – Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference, WES-CUE 2017, 19–21 July 2017, Singapore

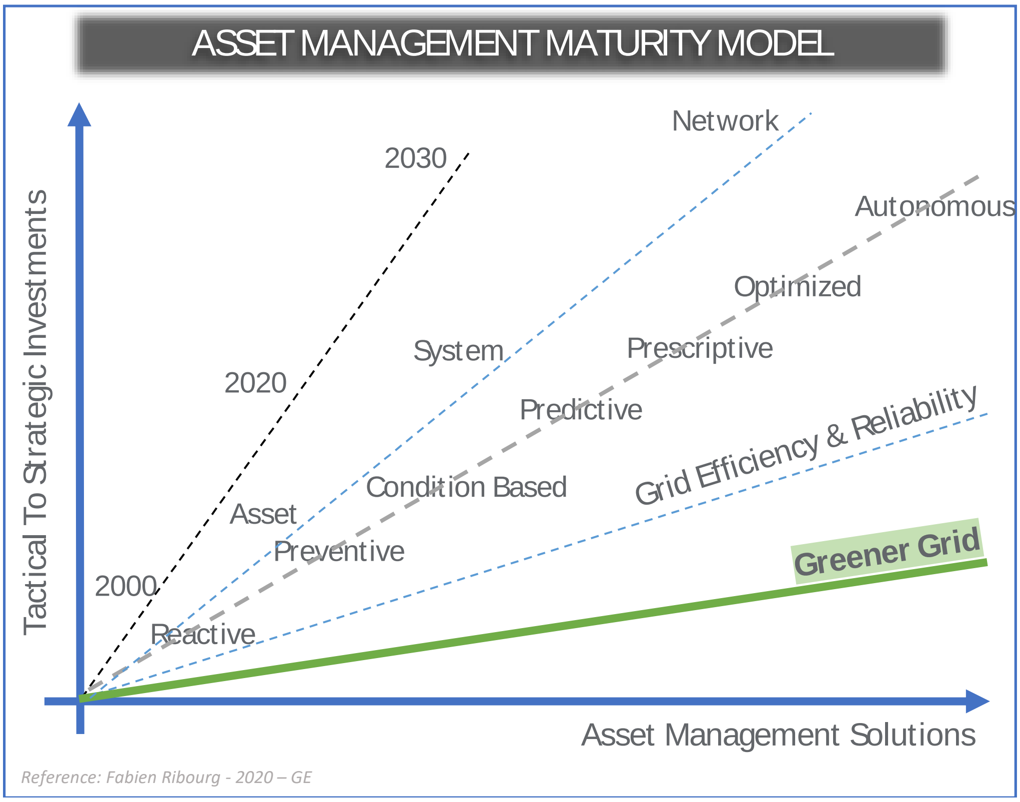
Replacement has a cost. An asset replacement is an important investment for a Transmission and Distribution Operator. It requires coordination between multiple departments as investment, operation, maintenance, and outage plans shall converge to an optimised plan. Regularly, Grid assets can continue to operate in a degraded operation mode to extend their life. Maximising asset life has a positive impact on circular economy and helps to reduce number plan outages, necessary spare parts, decommissioning and recycling efforts, inventory management and supply chain by following asset operation efficiency parameters linked to asset Health Index.

Data collection has a cost. Network operators have gathered for years a lot of data in their Operation & Maintenance departments historian systems. They may also have invested massively in equipping assets with sensors or real time Condition Monitoring Systems from different manufacturer that generated big data volume and variety. Data shall be retrieved and sent at different velocity to different databases provided by industrial or IT providers. However, most of the health models are based on condition parameters that are not so useful as principal components to analyse asset health. Also, it is often complex to assess data quality score to a condition data. Is the asset health index highly reliable? Data Science can help network operators to determine condition parameters that directly add value to their operations. Additionally, to enhance sensors accuracy for given condition parameter data and overall data quality can be a profitable investment. Investments in networks can be better prioritised and focused by capturing process and store only required condition parameter data.

A new Asset Green Index (AGI) can be used to quantify and combine all factors that contribute to *Green* where 0% represents high *Green* impacts and 100% represented very low *Green* impacts. National regulatory authorities have an opportunity to include such an indicator in the limited set of indicators they need to establish under the new EU Electricity Directive.[10] Decision makers of network operating companies and regulators can follow regularly AGI evolution. If AGI rate of decrease is high or if AGI is below a defined limit, this should be a warning signal and trigger a risk re-evaluation.

Network operating companies can be inspired by asset management maturity models to better position themselves among others to set their future Asset Management strategy and investments target with the objective to make a greener grid. Usually, maturity models are based on how efficiently and consistently a utility company manage their asset fleet and take decisions on asset related issues following the knowledge and understanding of given situations. Commonly, the less mature utilities mostly perform on failure reactive maintenances whereas the most mature network utilities by anticipating failure using prediction, optimising their OPEX/CAPEX based on strategy and autonomously plan work orders. The journey toward predictive, optimised and autonomous decision making requires investment in asset management tools to equip users and support business processes. See below chart as a synthesis of Asset Management Maturity Model.

[10] Article 59(1)(l), https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019L0944



Network operating companies can regularly perform a self-assessment and evaluate their progress. These studies could help decision makers of network operating companies and regulators to lead new objectives or adjust the strategy. Regulators could also observe the network operating companies' distribution per maturity level so that they can focus recommendations.

A regulation policy can be proposed adding/applying systematically

1. Environmental criteria that network operators shall include in their asset risk model involving circular economy, inappropriate back-up generation, unoptimised operations cost consequences.

2. Environmental objective function parameter to minimise environmental risk of a given work plan based on recommendations.

3. Condition and predictive based maintenance strategy.

4. Asset and energy operation efficiency parameter linked to asset health index.

5. Use Data Science to reduce the number collected condition data, optimising sensors accuracy and data quality.

6. AGI objective function parameter to minimise overall *Green* impact of a given work plan based on recommendations.

7. Asset Management maturity level assessment of utilities to recommend process and tool enhancements to avoid failure, making the grid more reliable and ultimately generate growth.

The right balance between short term cost optimisations and *Green* will always depend on the individual network operator's situation, with directions provided by the regulators. However, a strategical investment for becoming greener in asset management product will help both network operators and regulators to realise the Green Deal.

Conclusion

Asset management is the foundation for a modern risk management system that will ultimately be reflected into the grid cost optimisation for the consumer.

Asset management is a major instrument to drive toward a greener grid target, maximising the usage of existing resources, avoiding interruptions and optimising investment for new resources.

Asset management is today at different levels of maturity among the utilities, with significant new benefits that could be expected from the new IoT technologies. It is thus recommended to set up an incentive for the grid operator accordingly.

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