

Progress and Challenges on Asset Management for Future Smart Grids

**WORKING GROUP 1:
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The opinions expressed in this document are the sole responsibility of the Smart Grids European Technology Platform and do not necessarily represent the official position of the European Commission.



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Background

Electrical power systems are very complex, because of their dynamic and interconnected nature. The transmission and distribution systems are currently facing a multiplicity of changes: high penetration of distributed renewable energy generation, in combination with aging infrastructure and increasing electrical consumption. Smart grid network management technologies (e.g. On-load tap changing, reactive power compensation, automation systems coordination....) need to be compared with traditional grid reinforcement in terms of short-term and long-term benefits and costs.

In most cases, the current network infrastructure was not designed to deal with this new paradigm of distributed renewable resources whose share on the final electricity generation has been increasing in the last decade. These changes are bringing forward new challenges to the electricity system, especially in the areas related to balancing, reliability, flexibility, resilience or environmental constraints which require re-optimizing transmission and distribution networks.

Throughout the last 10 to 15 years, asset management has been adopted as the ruling paradigm for the management of electricity networks. Initially, the principles of asset management have been developed in industries that are critically dependent on the performance of physical infrastructure assets - such as water supply, transportation and energy supply.

Asset management^[1] enables an organization to understand the value of its assets in the achievement of its organizational objectives. The value itself depends on the objectives, the nature and purpose of the organization and the needs and expectations of its stakeholders.

Asset management supports the apprehension of value while balancing financial, environmental and social costs, risk, quality of service and performance related to assets.

The benefits of asset management are diverse and may include:

- a. Improved financial performance;
- b. Informed asset investment decisions;
- c. Risk management covering different aspects;
- d. Improved services and outputs;
- e. Demonstrated social responsibility;
- f. Demonstrated compliance;
- g. Enhanced reputation;
- h. Improved organizational sustainability;
- i. Improved efficiency and effectiveness;
- j. Improved EHS (environmental, health and safety);
- k. Improved quality of service;
- l. Extension of assets life span.

The following definition of asset management has been presented by the CIGRE Joint Task Force 23.18^[2]:

“The asset management of Transmission and Distribution business operating in an electricity market involves the centralization of key decision making in the network business to maximize long-term profits, whilst delivering high service levels, with acceptable and manageable risks”.

As defined in the EEGI Implementation Plan 2015-2017^[3], the R&D priorities are focused on network monitoring, control, flexibility and security. Asset management has a significant role on supporting these overall objectives, as it is transversal to all those topics.

Asset management challenges

The Smart Grid development is bringing together a new set of solutions for several network areas, including the asset management. The optimal maintenance of the network assets will offer new possibilities of providing a more safe, efficient and reliable service to the users. The progress of asset management will allow great developments on the following areas:

Network Planning

New methods of asset management will allow a more efficient network planning, e.g. through increased monitoring of the condition of network assets, allowing a better maintenance schedule and more efficient network upgrades.

Network Operation

Dynamic asset management tools will allow additional proactive measures to improve the security and resilience of the network. The monitoring and prediction of the condition of network assets will enable network operators to use the full capability of the assets, enhancing network flexibility and continuity.

Socio-Economic Impact

Innovation on asset management topics can improve the socio-economic impact of the operation and development of the network, through balancing different aspects of risk related to electricity transmission and distribution. It can contribute to the reduction of system failures, of network management and operational cost, which e.g. can give higher security of supply or lower tariffs for the end-users.

Objectives and methodology of the gap analysis

The EU work programmes identify clear classification of the ongoing RD&D efforts in line with the Integrated Roadmap. However, they do not highlight results with respect to some common issues that are fundamental for the large scale deployment (e.g.: cost benefit analysis, system integration, reliability evaluations, etc.). The evaluation of those transversal aspects represents an important input for the quantification of the contribution provided by each local demonstration towards the general targets, for the assessment of the maturity level reached by each functional demo and for the identification of the research priorities that the future research programmes should tackle in order to drive the optimal exploitation of the results of local demos towards large scale deployment.

In order to overcome this limitation, the EU project GRID+^[4] introduced an additional “transversal layer” composed of a number of “maturity categories” that represent the common issues among different projects. These maturity categories represent all the activities that are required for moving fundamental research to a market uptake of an innovative smart grid solution. This methodology has been used to analyse asset management issues to identify gaps for further work.

Gap analysis on asset management progress

The overall goal of asset management is to maximize the fulfilment of company objectives through balancing performance, risks and expenditures over the life cycles of system assets.

Further development of asset management requires increased knowledge, methodologies and technologies for:

- Monitoring concepts for primary (main grid components forming the rated voltage network of interconnected equipment) and secondary (low voltage components mainly used for protection and control) components through increased use of sensors - in view of scheduling maintenance that maximizes network flexibility and reliability;
- Utilization of condition based maintenance in view of optimal utilization of network asset capabilities and further increase of network continuity;
- Development of novel maintenance methodologies for new power technologies (HVDC links, power electronics converters, underground cables, etc);
- Better understanding of how network working conditions impact the aging of critical components, e.g. through using ex-post analysis of assets that have been removed from the grid.

In transmission and distribution networks the activities included are illustrated in the figure below (although in EEGI the topics are classified differently: with a dedicated cluster composed of three functional objectives for Transmission and just one Functional Objective for Distribution, it is our strong opinion that they perfectly fit in for Distribution as well and hence we do not distinguish in this report):

- T&D A1**
Developing approaches to determine and to maximize the lifetime of critical power components for existing and future networks
- T&D A2**
Development and validation of tools which optimize asset maintenance at the system level, based on quantitative cost/benefit analysis
- T&D A3**
Demonstrations of new asset management approaches at EU level

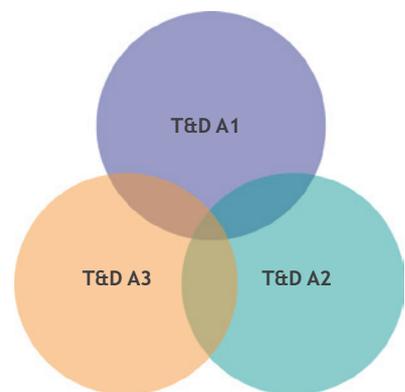


Figure 1: Transmission and Distribution R&I Activities (adapted from the EEGI Roadmap)

The technology readiness level (TRL) is a methodology adapted to measure progress made in research in judging maturity for market up-take. The Grid+ consortium adopted a more simplistic approach. The consequent ranking scheme for the analysis of projects is illustrated below together with identification to how this is related to the internationally accepted TRL system (examples of EC use and EPRI adaption in the US):

Maturity level of the innovation	Description	Colour
-1	Not relevant	Lightest yellow
0	Ready to deploy at large scale	Yellow
1	Need more demonstration or pilot project to validate the maturity	Light green
2	Need development (work with manufacturers)	Green
3	Requires more research (work with research institutions)	Dark green

Ranking scheme adopted by Grid+ for the analysis of projects

- **Maturity Level 3** indicates that the maturity category analysed is considered to be in the research stage. This level corresponds approximately to a range of TRL1 to TRL3;
- **Maturity Level 2** indicates that the maturity category analysed is in the development stage, Development is intended in this report as the set of activities needed to move from the idea that had been developed in the research stage toward the production of a prototype that works in lab conditions. This level corresponds approximately to a range of TRL4 to TRL5;

- **Maturity Level 1** indicates that the maturity category analysed is in the demonstration stage, which means that a solution has to be tested on a demonstration/pilot project in real conditions. This level corresponds approximately to a range of TRL6 to TRL7;
- **Maturity Level 0** indicates that the maturity category analysed has been tested on real conditions and it is ready for deployment. This level corresponds approximately to a range of TRL8 to TRL9.

The projects addressing Transmission & Distribution R&I activities on the topic of Asset Management (T&D A1, A2 and A3, see Figure 1) presented by Grid+^[4] are displayed by category and represented in Figure 2.

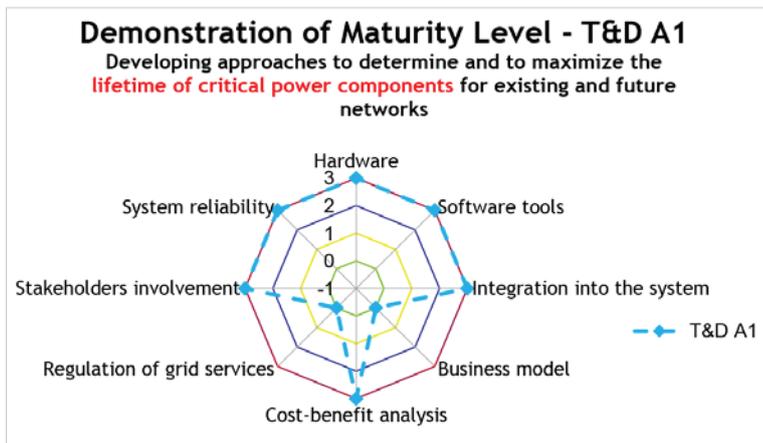
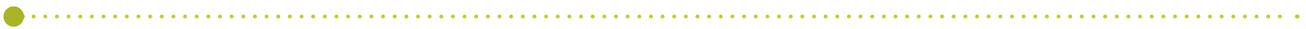
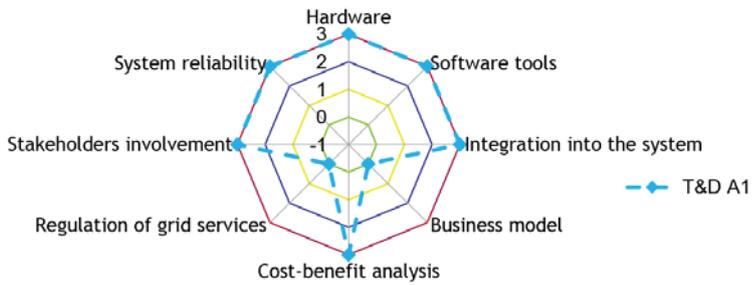


Figure 2: Transmission and Distribution R&I Projects addressing T&D Activities on Asset Management (Data from^[4])

Demonstration of Maturity Level - T&D A1

Developing approaches to determine and to maximize the lifetime of critical power components for existing and future networks



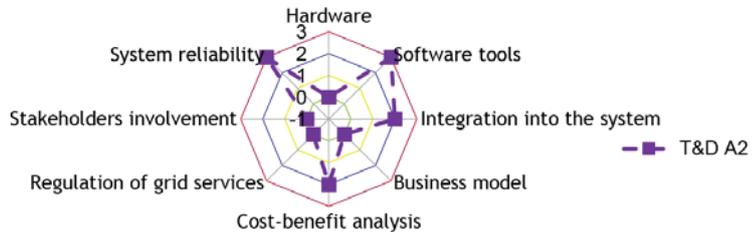
T&D A1: With the ranking scheme elaborated by the Grid+ consortium in mind, the maturity level brought by the demonstration projects is shown in the next figures. Each figure reflects the current situation and the development needs by category and T&D activities. In Figure 3, the maturity level brought by the demonstrations addressing the T&D A1 is presented.

Figure 3 shows that most of the investigation areas in T&D A1 are still in very early phase and need to be addressed.

Figure 3: Demonstrations Maturity Level on T&D A1 (Data from [4])

Demonstration of Maturity Level - T&D A2

Development and validation of tools which optimize asset maintenance at the system level, based on quantitative cost/benefit analysis



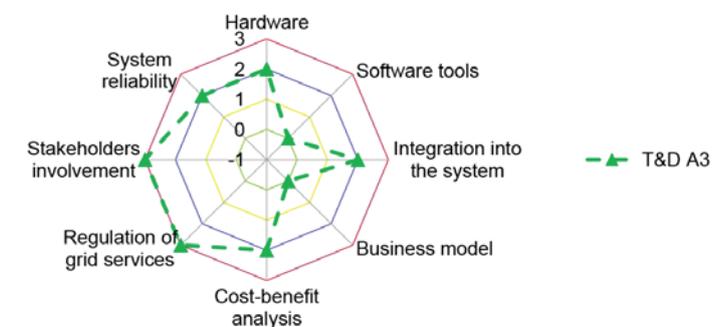
T&D A2 received several contributions from the demonstrations project in half of the research topics, however there is still the need for further development on the remaining ones.

The maturity level from demonstrations addressing the T&D A3 is revealed in Figure 4.

Figure 4: Demonstrations Maturity Level on T&D A2 (Data from [4])

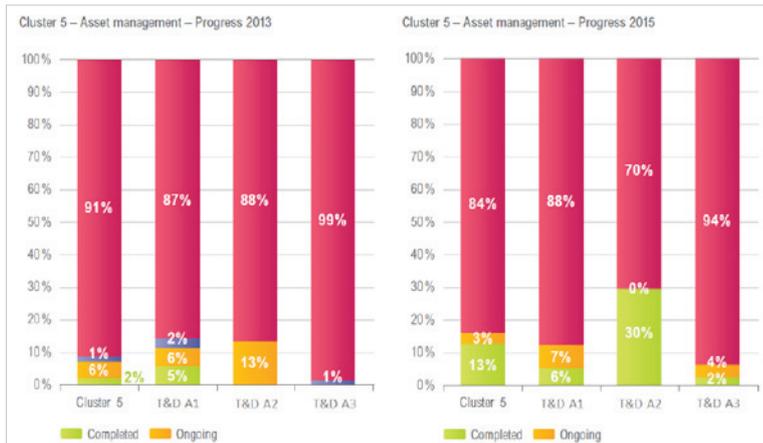
Demonstrations Maturity Level - T&D A3

Demonstrations of new asset management approaches at EU level



T&D A3 also received major contributions from the demonstration projects, but some of the developments are in fundamental stages and most of the research effort is still to be done.

Figure 5: Demonstrations Maturity Level on T&D A3 (Data from [4])



ENTSO-E R&D: According to latest ENTSO-E R&D Monitoring Report 2015 ^[5], which considers a specific cluster 5 dedicated to the subject of Asset management, most of the R&D effort is still to be done, as it is evident in Figure 6.

Figure 6: Achievement Progress on the Asset Management Cluster and A1, A2 and A3 clusters (as defined above) but with developments as in transmission reported by ENTSO-E ^[5]

Regarding DSOs and according to EDSO4SG information presented in their last Implementation plans to EEGI, low activity on this area has been done. “Asset management” was, included in cluster 4 of DSOs, as a new functional objective at 2013. No specific projects have been developed at European level, since then: only minor lateral contributions about economics to A2, but nothing about A1 or A3.

Further developments on asset management

The research and development of new tools and methodologies for improved asset management is a key subject for the management of existing network infrastructure, while in addition coping with expansion and integration of smart grids.

The ETP Smart Grids considers the following aspects highly relevant. They need to be addressed by more intensified R&D efforts:

- Periodic preventive actions based on the reliability performance of the network assets which are more and more required due to the variability of the power sources and the operational integration of day-ahead and intraday-market schedules. Taking these parameters into account will support the decision of the network operators and improve the overall electric system flexibility and reliability. This can contribute to a higher level of integration of renewable energy sources and demand-side response features;
- The development of new approaches describing the ageing process of network assets according to the type of use would be quite important, as it is transversal to all the network levels. Besides the ageing, the probability of failure is a very important KPI for asset management. The implementation of predictive maintenance strategies based on more accurate life expectancy estimations can result in huge improvements on both transmission and distribution levels, resorting to probabilistic approaches to manage the network risk;
- Real-time monitoring of the power flow in the network and the condition of networks assets, can contribute to significantly improved decisions basis for asset management. This requires efficient handling of a massive quantity of data coming from the smart grid monitoring sensors which “digitize” the system. In parallel with this progress, big data and data mining tools should follow in order to bring maximum value to the asset management system by true integration. For a more complete assessment on digitalization of the energy system, we refer to our upcoming report ‘The digital smart energy system 4.0’, available in May 2016 on www.smartgrids.eu;

- The implementation of integrated asset management systems by the use of new techniques which can take advantage of new infrastructures like “smart substations”, “advanced LV and MV monitoring systems for secondary substations” and embedded ICT to monitor in real-time each of the network assets at the same time. For instance, weather conditions have significant influence on transmission/distribution line ratings and consequently on their life time. A weather forecasting tool should be a standard “software tool” for both real time monitoring and power system operational planning. Recently, weather forecasting tools are improving continuously, so the TSOs and DSOs could rely on them (Dynamic Line Rating-DLR is considered seriously in some regions instead of new line construction);
- Asset maintenance for the maximization of the lifetime of critical network components for existing and future networks. This includes improved understanding of material characteristics and degradation mechanisms for electricity network components;
- Strategic long-term asset management mechanisms for optimal control of network assets, including robust long-term financial plans for maximum network asset;
- Extensive network asset condition assessment based on historical data and multiple attributes and new planning tools based on this information;
- More efficiently utilised data source for decision support to DSOs and TSOs concerning investments, reinvestments, maintenance optimization, etc. This requires R&D concerning methodologies for big data handling - e.g. data mining, pattern recognition, etc;
- Adequate cyber security measures, as the electricity grid is considered to be a critical infrastructure;
- Electricity distribution and transmission systems are a critical infrastructure for modern society, and will play an even more crucial role in the environmentally friendly energy systems of the future - representing the core of making new renewable energy sources available. To a large degree the primary components of electricity networks are based on existing technology, but there is still a potential to improve the technological solutions with regards to e.g. capacity, reliability and environmental impact;
- Validation of the added value of individual asset’s lifetime assessment compared with the common approach based on generic parameters with similar components and with alternative solutions considering new approaches (reinforcement vs local voltage control etc). Through the individual assessment of assets combined with the possibility of partially renewing small components or adding new protective layers to extend its lifespan may lead to an improved efficiency on the investments. The development of a new methodology and tools that evaluate the viability of each component to be partially repaired or renewed or replaced for an alternative solution and new ways of detecting component failure based on failure models are of crucial importance;
- New tools for dynamic management of outage planning and optimal maintenance schedule are critical to guarantee security of supply and network response;
- New techniques for assets inspection, resorting to UAVs and robotics that allow to check the asset’s condition and intervene in hostile environments without direct human intervention, avoiding the risk of human accident.

Asset Managers: insights provided from the eyes of experts

About 30 invitations were issued to utility asset managers and utility innovation managers with a request for interview covering the current state of the art on asset management and main trends. As result, the views on key topics that require further research and development in the various subdomains of asset management were established.

From the set of interviews that were conducted, the following topics were highlighted at multiple occasions as the main concerns and research needs according to the asset managers:

- Asset planning tools (e.g. risk and reliability related) are to be accommodated with techno-economical models of new energy infrastructure (renewables, storage) and need to take into account “digital grids”: grids which combine energy infrastructure with ICT-based monitoring and control supporting to new approaches in investment strategies for asset management;
- Decision-aid tools supporting the expert knowledge of asset managers, since the utilities are coping not only with ageing infrastructure assets but also with an ageing (personal) field force. As these employees are retiring, knowhow gets lost. In addition, in some cases utilities are considering outsourcing activities that will further accelerate the knowhow drain. It is though well understood that irrespective of the decision, with decision-aid-tools that can be made available the core of the expertise for managing assets should be harnessed internally, forming the required core expertise for managing effectively assets;
- Collection of grid status information at lower voltage levels can create value for the asset management and operations provided this can be done economically and collected data can be translated into useful information/intelligence for numerous management processes;
- Organizational redesign: third party stakeholder management becomes more important since network design and investments are to be tailored to the local context, leveraging synergies of initiatives taken by local industry, cities or end-users. This requires the asset management department to attract new roles such as business development;
- Long-term asset management should take a holistic approach, considering common applications with multiple energy carriers (electricity, gas, heat).

The major areas of development identified in this gap analysis and in the survey on asset managers are described below:

METHODS FOR MORE COST-EFFECTIVE ASSET MANAGEMENT:

Development of novel cost-benefit analysis that could be applied European wide to evaluate the effects of condition assessment and to evaluate the need for network reinforcements. These methods need to be approved by regulators e.g. in the grid operation guidelines, to avoid loss of insurance coverage when extending the maintenance cycle;

OPTIMAL UTILISATION OF ASSET LIFE:

New approaches for describing and monitoring the aging process of network assets and maximizing the useful lifetime of critical network components is crucial for the optimal use of existing and future networks;

REAL-TIME MONITORING OF THE POWER FLOW AND ASSET CONDITION:

New approaches for improving system reliability through the exploitation of the smart grid potential for monitoring and long term condition assessment;

NEW TECHNIQUES FOR USING REMOTE SURVEILLANCE IN ASSET MANAGEMENT:

New techniques for the inspection of network assets resorting to use of UAVs and robotics, avoiding the risk of human injuries;

OPTIMAL OUTAGE AND MAINTENANCE PLANNING:

New tools for dynamic management of outage planning and optimal maintenance schedule are critical to guarantee security of supply and competent network response;

NEW BUSINESS MODELS FOR ASSET MANAGEMENT:

New approaches for business development considering different approaches on asset management, including third party stakeholder management tailored to the local network conditions, creating the capability of taking advantage of synergies between system players (local generation, aggregators or prosumers);

HANDLING OF LARGE AMOUNTS OF ASSET CONDITION DATA:

Development of capabilities for the management of large amounts of data (Big Data) acquired from the network assets to generate useful and valuable information for an improved management and operation of the network, leading to circumstances that can be potentiated by the network digitalization.

References

- [1] International Standard Organization, ISO 55000: Asset Management - Overview, principles and terminology, 2014.
- [2] S. Bartlett et al, on behalf of the CIGRE Joint Task Force 23.18 and Australian Working Groups, "Optimal Asset Management in a de-regulated environment", Paris: CIGRE, 2002.
- [3] EEGI-European technology platform for the electricity networks of the future, [Online]. Available: <http://www.gridplus.eu/Documents/EEGI%20Implementation%20Plan%202015-2017.pdf>.
- [4] GRID+, Supporting the Development of the European Electricity Grids Initiative (EEGI), "D 1.2 Map of initiatives and gap analysis," www.gridplus.eu.
- [5] ENTSO-E, "R&D Monitoring Report 2015 - Research & Development Roadmap 2013 - 2022," ENTSO-E AISBL, Brussels, Belgium, 2016.

Acronyms

DSO:	Distribution System Operator
EEGI:	European Electricity Grid Initiative
EPRI:	Electric Power Research Institute
ICT:	Information and Communication Technology
R&D:	Research and Development
RES:	Renewable Energy Sources
TRL:	Technology Readiness Level
TSO:	Transmission System Operator
UAV:	Unmanned Aerial Vehicle



