

R&I NEEDS AND CHALLENGES FOR A FUTURE RELIABLE, ECONOMIC AND EFFICIENT SMART GRID SYSTEM TAKING INTO ACCOUNT MICROGRID AND LOCAL ENERGY COMMUNITIES TO SUPPORT THE EU ENERGY TRANSITION

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ABSTRACT

In its Research and Innovation Roadmap, targeting a 10-year period from 2017 to 2026, the European Technology and Innovation Platform for Smart Networks for the Energy Transition (ETIP SNET) defines long-term priorities for investment in Research and Innovation (R&I) activities within the European energy sector. Priorities are established having in mind the EU energy strategy and the expected future challenges of different stakeholders in the energy value chain. Complementarily, the ETIP SNET prioritizes the R&I activities with an Implementation Plan (IP), based on the R&I Roadmap, for the short-term, in which a 3-year period, from 2017 to 2020, is considered.

This paper will focus on the microgrid and local energy communities' aspects that are tackled in the ETIP-SNET Roadmap and Implementation Plan.

INTRODUCTION

The ETIP SNET has the mission to guide research and innovation activities to support Europe's energy transition. The ETIP SNET is elaborating a vision, Roadmaps and the associated Implementation Plans for R&I activities for smart networks, storage and other sources of flexibility and integrated energy systems. This work is being completed by engaging all stakeholders. This exercise represents the continuation of the activities performed in the framework of the EEGI and ETP platforms [1].

More specifically, The ETIP SNET mission is mainly to:

- Set-out a vision for R&I for Smart Networks for Energy Transition

- Prepare and update the Strategic Research and Innovation Roadmap, which specifies the long-term R&I targets; the latest version addresses the challenges for years 2017 - 2026 [2]
- Prepare and update the Implementation Plan (IP) which specifies the short-term R&I needs [3]
- Report and interact with stakeholders on the implementation of R&I activities at European, National/regional and industrial levels and identify innovation barriers.

The activities of ETIP SNET are organized in five working groups (WG), that address horizontal aspects of the energy system. In particular, the working group on Reliable, Economic and Efficient Smart Grid System (WG1) addresses the mid and long-term business and technology trends contributing to the overall energy system optimization at affordable investment and operational costs. WG1 is focused on overall system aspects, addressing the main functionalities, quality and efficiency of the electricity system as such and considering the benefits of its integration with the other energy vectors.

NEEDS & CHALLENGES ADDRESSED

Shifting from predictable demand and supply patterns towards a more decentralized and volatile power system, eventually with fully dynamic power flows involving microgrids and local energy communities [4], will drastically change the shape of the electricity networks and impact at both transmission and distribution levels. To address the challenges that this will present, enhanced observability and controllability are required at all voltage levels to be able to manage the increasing

variability and uncertainty of operational conditions in a cost-effective way. More accurate information on the network operational state are required and measurements with higher time granularity and requirements for communication infrastructure are to be addressed. Operational principles of the system need to be revised, too. Microgrids, energy communities and the increasing amount of all types of controllable small-scale resources (distributed generation, electric vehicles, storages, controllable loads etc.) shift the data transfer and control architectures towards more decentralized solutions.

The use of local energy storage systems provides an additional resource, fostering a more efficient development and operation of electricity networks. This will require a transformation of the traditional business models to meet the growing integration of existing and emerging energy systems actors and expectations of customers. Interoperable and integrated platforms enabled by new energy generation models such as microgrids and local energy communities within the existing electricity system require new R&I needs to address the resulting emerging challenges and opportunities.

Opening the markets to the flexibility resources provided by microgrids and local energy communities is crucial to boost their own development. Energy communities can act as both generator and demand facility, therefore the access and use of this potential flexibility should be addressed starting by the resource quantification. New market design should integrate resources with specific duration, timeframes, and volumes offered by these new players who compete with conventional generation e.g. in balancing markets at a level playing field. Furthermore, synergies between electricity and heat systems, or synergies between electricity and gas and/or hydrogen systems, fostering the integration between different energy networks will also increase energy efficiency and facilitate the decarbonization of buildings' energy consumption. Microgrids and local energy communities might provide a suitable environment for the provision of this interaction between electrical and non-electrical energy networks. For example, storing liquid fuels, gas, hydrogen or thermal energy allows to store energy not only within a day (short term) but also between seasons (long term), whereas storing electricity in batteries for shorter periods may be complementary. Above topics require new R&I activities.

Evaluated aspects for R&I

The priorities of R&I that shall be tackled in the next 10 years with the aim to achieve the overarching goals set by the SET Plan as illustrated in the ETIP SNET Roadmap. The description of the R&I activities has been organized with a two-level, tree-like structure; the first level of the tree-like structure consisted of Clusters (C) and the second level of functional objectives (FO, then D

for distribution and T for transmission functional objectives). Clusters corresponded more or less to the main activities of the network operators, i.e. network operations, asset management, planning and market designs. Each cluster is composed of a list of FO that are a family of functions that must be addressed by network operators (and other stakeholders of the power system when needed) and where R&I is needed.

The ETIP SNET delivered a new Implementation Plan specifying R&I topics to be addressed in the short-term, building upon the R&I activities listed in the current 10-year R&I roadmap. Compared to the previous IP, topics that were addressed by recently started or ongoing projects have been excluded from the new IP (see ① in Fig. 1). Topics that were not addressed by projects, or only partially addressed, have been duplicated in the new IP, unless their relative level of urgency or importance decreased, as represented by ② in Fig. 1. Also, the changing context in the energy system and the evolving status of ongoing R&I activities allowed the definition of new R&I priorities for the upcoming years. These new priorities have been identified amongst the list of topics listed in the 10-year roadmap (see ③ in Fig 1). Finally, the high-level vision from the ETIP-SNET working groups are considered when updating the R&I priorities for the upcoming years. The main criteria to be considered should be:

- Urgency: the agenda of integration challenges faced by energy system stakeholders;
- Timeliness for availability: the needed time for achieving full system integration;
- System impact: the expected impact on system planning, operation and maintenance once system integration has been successfully implemented.

Following the same process as the previous versions, the new Implementation Plan was submitted to stakeholders' consultations.

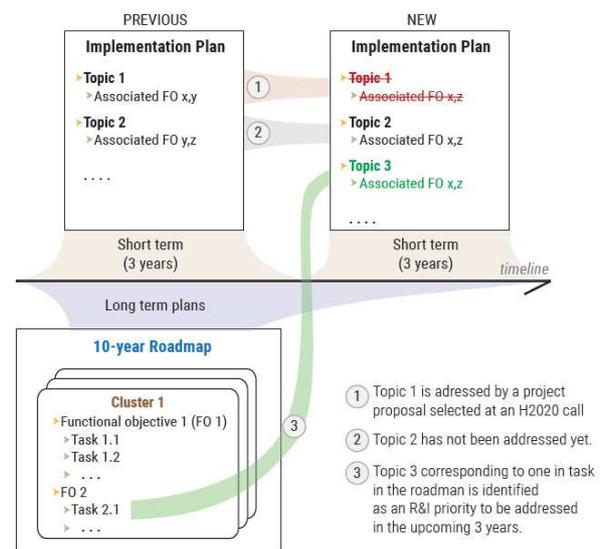


Fig. 1 - General process to prioritize topics in the Implementation Plans (IPs)

FOCUS ON MICROGRIDS R&I

Microgrids and energy communities represent a significant innovation that occurs in several Clusters and Functional Objectives of the Roadmap. Several research and innovation challenges shall be addressed in order to enable the large-scale deployment of these technologies in Europe. Microgrids affect both the transmission and the distribution systems, as well as the market design, and are, therefore, included in the functional objectives of both.

Microgrids are a fundamental aspect of the transmission system Cluster C2 “Security and system stability” of European transmission networks. In particular, microgrids are seen as important assets that can contribute to enhancing the reliability and resilience of the European grids when developed in synergy with expanding energy infrastructures.

As specified in FO T8, research is needed to develop new power system restoration planning methodologies that may incorporate interactive graphics and optimization algorithms; these should account for new users that provide emergency services to the grids. This can be achieved thanks to Renewable Energy Sources (RES) and Distributed Energy Resources (DER) management supplied by customers, by using domestic intelligent electrical appliances that can detect changes in network frequency and respond according to the order of priority set by the user. Simulation tools for detecting weak points in the pan-European system are needed, together with operational guidelines that include acceptable reconnection scenarios. The customer could also participate in defense plans (e.g., selective load shedding). Regarding the priority of improvement of defense and restoration plans and enhancing TSOs role, new approaches and technologies aiming at reducing the probability of failure should be developed. These tools should utilize probabilistic approaches, which embrace new stochastic models incorporating all trading floors: day-ahead, intraday, balancing markets, as well as markets in connected energy vectors, such as heat markets etc. The aims of this challenge are to assess the potential contributions of RES, DER, storage and microgrid to defense plans (black-start capabilities, islanding capabilities) and to develop a joint TSO/DSO approach for defense plans involving DER and microgrid.

Microgrids are also mentioned in the ETIP SNET roadmap as an important asset that can provide flexibility to the distribution grids, in cooperation with other controllable resources such as storage systems and micro generation units. Microgrids and energy communities are important in the distribution system clusters C1 “Integration of smart customers and buildings, C2 “Integration of decentralised generation, demand, storage and networks” and C3 “Network operations”.

The FO D1 “Active demand response”, addresses microgrid and energy communities’ related R&I needs. Active demand response must play a fundamental role in ensuring a reliable operation of decentralized energy concepts, such as the case of microgrid. Also, research is needed in order to develop more efficient solutions and planning methods for integrating small and medium sized DER, storage, electric vehicles and decentralised thermal generation units to the distribution networks (FO D3, D4, D5, D6, D7, D14).

Integration of different size and type generation units to distribution networks is analysed in functional objectives D3 “DSO integration of small DER”, D4 “System integration of medium DER”. Several R&I challenges related to microgrids and energy communities have been identified:

- Energy management solutions for local generation-load balancing (including energy storage, demand response, etc.) need to be developed. These solutions have to take into account power quality, grid losses reduction, improved asset management, reliability and islanding. Microgrids are one possible solution when developing such systems.
- Market mechanisms for the participation of end users and DER units in electricity markets need to be developed. Specific attention should be put on the role and interactions between the different market players and studies of local energy markets need to be included. Energy communities can be used to implement the local markets.

FO D5 analyses the issue of integration of storage in network management. In particular, an assessment of the added value to be brought by storage to MV/LV networks for the control of power flows, voltage profiles, power quality, as well as islanding and micro-grid applications, including black start capabilities are required. This analysis requires the development of:

- Simulation tools to better appraise the cycling profiles associated to the envisaged applications and business models;
- CBA tools to compare storage with other flexibility means including environmental and social aspects;
- ICT infrastructure for connecting (monitoring and possibly remote controlling by different actors) all storage devices to the network and/or energy and/or customers management platforms of the different actors (DSOs, retailers, aggregators, etc.).
- Standardized communication protocols between storage devices and inverters, but also between storage devices and remote storage management platforms to meet requirements from network operators, retailers and aggregators (including cybersecurity).

Also, micro grids and local energy communities can have a relevant role in terms of sector coupling and integration of energy systems (like mobility, heat and cooling, gas, hydrogen and their interface). In particular, distributed storage provided by EVs (Vehicle to Grid) is addressed in FO D6 “Infrastructure to host EV/PHEV – Electrification of Transport” and thermal storage in heating and cooling systems and the gas grids is addressed in FO D7 “Integration with other energy networks”.

Microgrids and energy communities also significantly affect distribution network monitoring and control functionalities: research is needed on developing both LV and MV network operations (functional objectives D8 and D9) both in normal operational conditions to e.g. increase the network hosting capacity and in fault situations where islanding operation of microgrids can be used temporarily. Restoring main energy supply and synchronisation to the grid deserves particular attention.

The FO D14 calls for the analysis of the potential for integration of flexible decentralised thermal power generation units, which could provide such synchronisation. The R&I challenges are:

- To optimise the connection, control and management of the generation units, including those coordinated as "virtual power plants", and providing flexibility to the power system.
- To demonstrate contribution of small and micro-CHP to “virtual power plant” configurations.
- To integrate small-scale and micro-CHPs, energy storage and demand response for optimal balancing of supply and demand, while maintaining high efficiency operation of the CHP system.
- To demonstrate the complementarity between small- and micro-CHP installations and heat pumps at the district level.

These investigations shall help provide flexibility options to the DSOs at different time scales (from operations to planning activities) in coordination with the balancing responsible party and/or TSOs.

The different FO addressing microgrids and local energy communities aspects are summarised in the following table:

Functional Objectives	Short-term Priority (IP)	Medium/long-term Priority (R&I Roadmap)
D1 - Active demand response		✓
D3 - System integration of small DER	✓	✓
D4 - System integration of medium DER	✓	✓
D5 - Integration of storage in network management	✓	✓
D6 - Infrastructure to host EV/PHEV – Electrification of transport	✓	✓
D7 - Integration with other energy networks	✓	✓
D8 - Monitoring and control of LV network	✓	✓
D9 - Automation and control of MV network	✓	✓
D14 - Flexible decentralised thermal power generation	✓	✓
T8 - Reliability and resilience		✓

Tab. 2 - Short-term and long-term functional objectives priorities, targeting μ grids and local energy communities topics, by ETIP-SNET

Finally, the experts of WG1 of ETIP SNET have also identified R&I topics related to microgrids and local energy communities that shall be addressed by future research programs, also in line with the Clean Energy Package [5], as follows:

- Designing the optimal set of technical policy measures ensuring the EU energy transitions towards new low-carbon technologies, renewable energy, energy efficiency, and grid infrastructure emissions to fulfil Europe's 2050 energy targets. For example, integrating new market players providing system services at a local level; defining the information exchange between local energy communities, microgrids and the grid operator, and the coordination schemes to enable the use of flexibility; including the roles that will be played by data hubs (if any) as facilitators.
- Evaluating impacts of peer to peer energy exchange models facilitated or enabled by microgrids and local communities towards coordinated energy ecosystem.
- The introduction of smart energy contracts and blockchain technology to keep track of renewable-energy certificates or allow producers to trade energy peer-to-peer with customers.
- The application of big data approaches processing high volume of information with the artificial intelligence approaches for the design, estimation, fault diagnostics and fault-tolerant control.

CONCLUSIONS

The needs identified in the 10-year ETIP SNET Roadmap and 3-year Implementation Plan are based on a gap analysis of the already completed R&I projects. Short and mid-term R&I needs were identified in the 2017-2020 ETIP SNET Implementation Plan for the whole

value chain of the electricity system (transmission and distribution networks, storage, distributed generation, etc).

Piloting and demonstration activities are needed to test and define grid services and the related business and economic models for future smart distribution and transmission networks as well as smart connections to other energy vectors, such as heat, gas and mobility. These services may include activities of the network value chain, such as network development, operation and maintenance, metering, billing, customer services, data management, grid balancing and others, including testing of collective self-consumption schemes and microgrids services. Results obtained in the implementations shall be coupled with scalability and replicability and cost benefit analyses to pave the way towards large scale deployment of the most promising solutions.

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