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A DSO SUPPORT FRAMEWORK FOR ASSESSMENT OF FUTURE-READINESS OF DISTRIBUTION SYSTEMS: TECHNICAL, MARKET, AND POLICY PERSPECTIVES

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ABSTRACT

This paper presents the initial ideas for a framework to support the distribution system operators for assessing current status of network infrastructures, market/business models, and policies applicable to distribution systems, and thus identify future-readiness of their network. The assessment framework consists of two steps as the identification of the key indicators associated with this transition and assessing the current status by evaluation of these indicators based on inputs from distribution system operators. Case studies have been carried out for distribution system operators in three European countries, i.e., Göteborg Energi (Sweden), SOREA (France), and ENEXIS (The Netherlands). The key results have shown that presently the three distribution system operators have a small proportion of renewable power generation in their grids, but it is going to increase in the future. Hence, they need investments in flexibilities, generation and load forecasting, advanced network control, and protection strategies, etc. The results also suggest needs for development of novel business models for customers and changes in the policy and regulations. Finally, a comparative assessment of three distribution system operators is presented in the paper.

INTRODUCTION

After the transformational era of deregulation in the power industry and growing concern towards the global warming, electrical distribution systems are becoming more complex, hosting new market actors along with emerging technologies, e.g., distributed renewable generation, energy storage systems (ESSs), electric vehicles (EVs), demand resources, and information and communication technologies (ICT). The new market actors and technologies in distribution systems bring several challenges for the distribution system operators (DSOs) such as uncertainty associated with renewable energy production, network congestion, etc. Another challenge is associated with the growth rate for EVs. Increased participation of customers in intra-day or day-ahead electricity market and future concept of peer-to-peer transactions would add further complexity to the system. Cyber-security which is associated with the integration of

ICT into the systems has also been one of the concerns. All distribution systems are either going through this paradigm shift or will go through in future and thus, would be posed with challenges in managing their day-to-day operation and control strategies. DSOs need to prepare for a transition path from today's passive systems to future intelligent distribution systems by making a strategic investment in network infrastructure, upgrading monitoring and control systems, introducing novel business models, and making policy and regulation changes to enable the active participation of market actors in the overall network management. Hence, DSOs need an assessment framework to evaluate their future-readiness and consecutively identify development gaps for plausible future scenarios and eventually make themselves ready. Similar research problems are taken up by researchers in various fields and addressed by proposing different versions of assessment frameworks. For instance, in [1]-[3], performance indicators-based framework has been proposed for evaluating the performance of engineering faculty, proactive performance monitoring scheme, and, the performance of technological audit at firm's level, respectively. The authors in [4], have developed a framework for classification of smart city performance indicators and then identify technologies and actions needed for city management and planning towards urban growth. In [5], a big data framework has been developed for the assessment of electric power data quality. A framework has been used in [6], where DSO controls have been assessed in the nonbinding transactive energy market. Although several questions are raised which related with market and policy perspective, for the use of flexibility for DSO to manage embedded microgrids and islanded power systems, in [7], still a well-developed assessment tool for evaluating the future-readiness of DSOs is required. This paper presents the initial ideas for a framework through which DSOs can assess the current status or future-readiness of their network. The focus of this paper is to identify a set of such key indicators which would have major impacts on DSOs in future and then present their assessment based on inputs from DSOs. The work presented in this paper would eventually serve as input for identifying the plausible scenarios description, policy recommendations, pathways development and finally a transition plan for DSOs alongwith the identification of vital areas of development where they should focus on for a smoother transition towards future distribution grids.

FUTURE INTELLIGENT DISTRIBUTION SYSTEMS

The future intelligent distribution systems will become more complex as a cyber-physical ecosystem, which would require an integrated paradigm for energy management and control systems based on various big data resources. The intelligent distribution systems of tomorrow will be expected to be equipped with a set of advanced energy management and control systems to cope with dynamic ranges of system issues. The European Technology and Innovation Platforms (ETIPs) through Smart Networks for Energy Transition (SNET) had come up with SmartGrids Strategic Research Agenda (SRA) 2035 in March 2012 [8], where they present the following research challenges and priorities in electrical distribution systems which are necessary for their advancement towards future intelligent systems by the year 2035:

- Smart, flexible distributed demand and generation response for secure distribution system control
- Integrated distributed energy storage infrastructure planning in distribution systems
- EV integration into distribution systems
- ICT system security for distribution system operation
- Real-time network monitoring, operation, and control to avoid critical situations

FRAMEWORK DESCRIPTION FOR DISTRIBUTION SYSTEM ASSESSMENT

The framework for distribution system assessment consists of two steps, i.e., selection of key indicators and their assessment. The overall methodology for assessment framework is shown in Fig. 1.

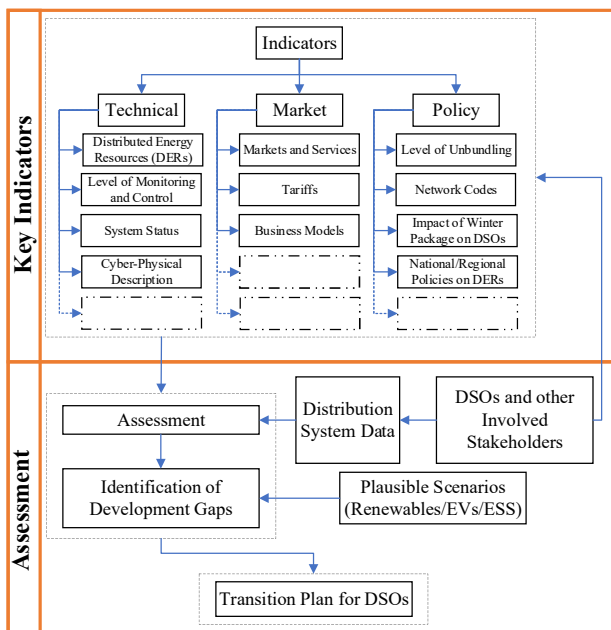


Fig. 1 Overall methodology for assessment framework

The first step is to identify the key indicators which impact

this transition. Although, the most relevant advancements are related to technical requirements for DSOs, the available market structures, policies, and regulations are also instrumental. The market and policy aspects will have a potential impact on the DSOs but are not directly controlled by them. Thus, all these aspects are interrelated, and their exclusion may limit the possible advancement in one direction or reduce the possible benefit in another. As a result, the indicators are classified as technical, market and policy. The description of these indicators and their sub-indicators is presented as follows:

Technical

These indicators mainly address the technical aspects associated with production and distribution of electricity. The selection of indicators is motivated from the issues addressed in ETIPs-SNET SRA 2035 [8] and inputs from the partner DSOs involved in UNITED-GRID project [9]. The following technical indicators are identified:

Distributed Energy Resources (DERs): It covers the aspects such as the amount of distributed renewable energy production (REP) and associated forecasting, EVs integration, heat-pumps, and district heating along with its availability for flexibility, and energy storage systems.

Level of Monitoring and Control: It covers the advancement level of DSOs with respect to monitoring and control, e.g., smart meters, advanced metering infrastructure (AMIs), and SCADA.

System Status: It covers the present infrastructure situation and operational data of the system such as loading profile and levels, existing system capacity, system configuration, quality and reliability of supply and participation in frequency control.

Cyber-physical Description: It covers the cyber-physical characteristics such as systematic architecture, structural framework for fidelity models and systems integration. It has gained importance as ICT system security has been one of the focus areas.

Market

These indicators mainly address services and markets, tariffs, financial aspects, and business models. In addition to the financial and market context set up by the DSO itself, it is important to consider how external actors/stakeholders could influence the DSOs. To capture the external influences, some indicators are related to available services from external stakeholders such as electricity retailer and service providers. The following market indicators are identified:

Markets and Services: It refers to the available markets organized by the DSO or by other actors where end users could provide their services.

Tariffs: It refers to the evaluation of the electricity charges for the end user. The tariff is divided into grid tariff and retail electricity pricing.

Business Models: It refers to the available business models provided by the DSO or other actors.

Policy

These indicators mainly address regulation and policy aspects. They become a relevant indicator especially in the changing role of the DSO. Traditionally, DSOs are highly regulated entities driven by national and European authorities because they act as natural monopolies (to have numerous competing structures would make no sense). While new policies are being drafted which will have a significant impact on DSOs, their absence may hinder the possible technology advancements. The following policy indicators are identified:

Level of Unbundling: It refers to the implementation of the unbundling. The most relevant existing European policy in this regard is the third energy package [10], which has been enacted to improve the functioning of the internal energy market and resolve structural problems.

Roll-out of Smart Meters: It refers to a cost-benefit analysis for the roll-out of smart meters and policies supporting them. It is one of the most relevant indicators for the DSO in the energy transition, as mentioned in the third energy package [10].

Network Codes: It refers to finding the key barriers for DSOs in implementation of existing network codes, which are legally binding European implementing regulations supporting the integration of national and regional electricity markets into a unified internal European market. It gains relevance as it is feared sometimes that current codes do not account the more diverse, flexible and active role that DSO need to take up in future.

Impact of Winter Package on DSO Tasks: It refers to the effect of policy aspects of winter package [11], on different tasks of DSOs. The package includes both non-legislative initiatives as well as legislative proposals. They include new rules on European Union electricity market design and a proposal for a directive on common rules for the internal electricity market and a proposal for a regulation on the internal electricity market. Many of the new principles focus on empowering consumers and the importance of the internal market.

Impact of New Network Codes and Guidelines: It refers to expected effects of new network codes and guidelines as mentioned in the winter package [10]. The package not just proposes a new set of network codes and guidelines but also specifies the way the DSOs will be involved in their development.

National/Regional Policies on DERs: It refers to

identifying other national policies that can have an impact on the distribution system, for instance, incentives for certain types of renewable energy or legislation/lack of legislation on aggregators.

The second step is to assess the current status, i.e., future-readiness of DSOs. The qualitative assessment is done based on the DSOs response on the proposed indicators. The DSOs along with other involved stakeholders will provide inputs in the form of system data, market/business models, regulatory policies, etc. The output of the proposed assessment framework would serve as an input for identification of the development gaps, i.e., the progress needed, within each area, i.e., technical, market, or policy, for the transition toward a future intelligent distribution system. Finally, with the identified development gaps and plausible scenarios (Renewables/EVs/ESSs, etc.), a suggestion for DSO transition plan will be delivered.

CASE STUDIES AND THEIR ASSESSMENT

The developed framework has been used to assess the current status of three distribution systems in Sweden, France, and the Netherlands. The presented case studies could be used as an example of how to use the framework and how the results may look like. The DSOs included in the case study are:

- **Göteborg Energi (Sweden):** Göteborg Energi is a Swedish municipality owned energy company. The grid has nearly 262 000 customers and 4.4 *TWh* of annual energy consumption.
- **SOREA (France):** SOREA is a small distribution network company in France. It is active in electricity production and distribution and operates its grid mainly with hydro- and PV-based production. The grid has nearly 14 000 customers and 140 *GWh* of annual energy consumption.
- **ENEXIS (The Netherlands):** ENEXIS is a Dutch DSO supplying electricity to around 2.8 million customers. The annual energy consumption is 34.5 *TWh*. Their distribution system covers both urban and rural areas.

The three involved DSOs have filled the proposed indicators list and the assessment has been done based on their responses. A summary of their current status assessment is presented in Table 1.

Table 1 Indicators based Current Status Assessment for DSOs in Sweden, France, and The Netherlands

Indicator Category	Indicator Name	Göteborg Energi (Sweden)	SOREA (France)	ENEXIS (The Netherlands)
Technical	Distributed Energy Resources	Limited local REP, forecasting of REP is not currently available, charging infrastructure for EVs is being built up, heat-pumps and district heating is widespread today, although, currently not used for flexibility, utility-scale energy storages are not in place.	Limited local REP, solutions for REP forecasting has been recently installed at demo-site, a few EVs are present, high district heating demand, however, currently not used for flexibility, the network does not have any energy storages but expected soon.	Limited local REP, forecasting of REP is not available. However, one of the ENEXIS's demo-site, i.e., Strijp-S has high REP level. Currently, the network does not have any EVs and heating demand, network presently has a very small amount of energy storages.

Indicator Category	Indicator Name	Göteborg Energi (Sweden)	SOREA (France)	ENEXIS (The Netherlands)
	Level of Monitoring and Control	AMIs cover almost 100% of the customers. Also, a new roll-out is planned. The standard SCADA is presently in use for grids from 10 kV up to 130 kV.	No AMIs are installed now but are expected soon. However, substations are equipped with automation systems.	High number of smart meters along with automation systems for substations.
	System Status	The system has underground cables (100%) with moderate loading, the network is designed as a meshed system but operated radially, high level of reliability for supply, and no participation in frequency control.	The system has both underground and overhead cables; Network is designed as a meshed system, a high level of reliability for supply, and no participation in frequency control.	The system has mainly cables; network is designed and operated as a radial network, very high level of reliability for supply, and no participation in frequency control.
	Cyber-Physical Description	No information available.	No information available.	A new standard was implemented in 2017 for gas and electricity grid security which assists in setting up security architectures, training employees and detecting security incidents in a structured way. Also, the security management system is integrated with the risk management system.
Market	Markets and Services	Electricity prices are open to competition and traded at the Nord pool stock exchange. Customers can choose to pay either spot market price or fixed prices offered by energy retailers. Currently, limited number of actors are providing ancillary services.	Limited information is available, although wholesale electricity supply is open to competition.	No information available.
	Tariffs	Grid tariffs are based on fixed cost and energy charge with separate power tariff for a commercial customer.	Grid tariffs are based on a fixed cost based on subscribed power and energy charge.	Tariffs are based on fixed cost based on subscribed power and energy charge.
	Business Models	No information available.	Feed-in tariffs for PV and hydro generation.	Feed-in tariffs for PV and hydro generation.
Policy	Level of Unbundling	Fully unbundled at both wholesale and retail levels.	Exemption for small DSOs.	Fully unbundled, mostly DSOs are fully independent and owned by provincial or local government.
	Roll-out of Smart Meters	100% roll-out.	Full deployment expected by the end of 2024.	Estimated 72% coverage by 2020 based on current national roll-out plans.
	Network Codes	No information available.	National regulator (CRE) are aligned to achieve the European objectives.	No information available.
	Impact of Winter Package on DSO Tasks	Development of technologies to use flexibility services for increased efficiency of operation and planning of the distribution network.	Deployment of digitalization of technologies to allow self-consumption and dynamic pricing to the consumers.	Development of market management provisions for balancing peak power demand resulting in cost saving.
	Impact of New Network Codes and Guidelines	New grid tariffs to be introduced in local networks which leads to the risk that DSOs will have limited possibilities to design their own grid tariff.	Expected impact on grid tariffs depending on the season.	No information available.
	National/Regional Policies on DERs	Discussions at the national level regarding new functional requirements for new generation of smart meters, energy storages, and local energy communities.	Expected impact on guidance related to storage (chemical and hydrogen)	Commitment towards reducing greenhouse gas emissions by 16% till 2020, increasing energy consumption from sustainable sources by 14% till 2020, and annual energy savings of 1.5%.

A comparative assessment with the proposed indicators of the three DSOs is presented in Table 2. Although, the three DSOs having relatively different sizes and number of customers (hence power demand), as well as different market rules and policies at national level, but it would be beneficial for them as well as for other DSOs in Europe to look at the comparative assessment between them. This may also act as a motivation for a transition towards future

intelligent distribution systems.

The investigated DSOs have shown diversity in terms of technology, policy and market readiness. The DSOs need to be prepared themselves for the following:

- Needs for investments in flexibilities
- Needs for advanced forecasting and monitoring
- Needs for advanced system automation and protection

- Needs for incentives schemes and business models
- Needs for changes in the role of DSOs which can own and/or procure certain resources and services.

Table 2 Comparative Assessment of the three DSOs

Indicators Name	Comparative Assessment
Distributed Energy Resources	Limited local renewable energy production in all DSOs. The EVs demand is not high in all the networks, but the infrastructure is being built. Only ENEXIS has a small amount of energy storages provisions. Although, none of the networks has provision for flexibility today.
Level of Monitoring and Control	The level assessed by AMLs and automation systems varies from high (Göteborg Energi and ENEXIS) to low (SOREA).
System Status	The power distribution is mainly done by underground cables in all DSOs. Also, all have a high level of reliability of supply while frequency control is done at the TSO level.
Cyber-Physical Description	As of today, not much information is available for Göteborg Energi and SOREA. But ENEXIS has implemented some standards for improved risk and security management.
Markets and Services	Currently, not much information is available for SOREA and ENEXIS, whereas Göteborg Energi has some advanced provisions for competitive electricity prices are available through different market mechanisms.
Tariffs	Grid tariffs are mainly based on fixed costs with provisions of subscribed power and energy charge in case of all three DSOs.
Business Models	Currently, not much information is available for Göteborg Energi, while SOREA and ENEXIS have feed-in tariff models available for PV- and hydro-power.
Level of Unbundling	The level of unbundling varies from partial unbundling (SOREA) to total unbundling (Göteborg Energi and ENEXIS).
Roll-out of Smart Meters	Roll-out varied from currently 100% in Göteborg Energi to expected 72% by 2020 in ENEXIS and expected 100% by 2024 in SOREA.
Network Codes	Currently, not much information is available for Göteborg Energi and ENEXIS, while SOREA is aligning themselves to achieve objectives.
Impact of Winter Package on DSO Tasks	Currently, not much information is available for SOREA and ENEXIS, while Göteborg Energi has possibilities of new tariffs being introduced at a local level.
National/Regional Policies on DERs	All DSOs are committed towards the national legislation for the reduction in greenhouse gas emissions, increased renewable generation, energy savings, advanced metering and setup of local energy storage and communities.

CONCLUSIONS

This paper presents a framework with a list of technical, market and policy indicators for DSOs, to assess their current status or future-readiness. To demonstrate the use of the developed framework, case-studies for DSOs in Sweden, France, and the Netherlands have been carried out. A comparative assessment between the DSOs is also presented along with the identification of areas of preparedness required for the transition. The key takeaways from the case-studies are that DSOs currently have a limited amount of renewable energy production in

their grids, but the share will be increased. As part of future studies, the assessment results from this framework will serve as input for developing a transition plan for DSOs to facilitate a smoother transition towards the future. The assessment results would also help in identifying plausible scenarios, policy recommendations, and pathways development, all of which also serve inputs for transition plan for DSOs. Most importantly, the proposed framework can be used by other DSOs to assess their future-readiness.

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