Smart Grid Indicators – The case for observability

A Technical Discussion Paper by DSO ENTITY's Task Force Digitalisation of the Energy System (DRAFT) |
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Preface and disclaimer

This technical discussion paper is the product of DSO Entity's Task Force Digitalisation of the Energy System (TF DESAP), comprising approximately 28 experts from 16 different member states. The paper presents the latest conclusions drawn by TF DESAP on the topic of Smart Grid Indicators (SGI) as introduced in the Digitalising the energy system - EU action plan (COM/2022/552). This paper serves as a supportive document to DSO Entity's messages to the Energy Infrastructure Forum 2024.

The findings and recommendations outlined herein result from an exhaustive literature review and a series of workshops. These workshops engaged various stakeholders, including representatives from the DG ENER, ACER, CEER, and ENTSO-E, among others.

This document serves as a technical discussion paper. The content is intended for discussion and does not necessarily reflect the final position of DSO Entity. All conclusions drawn and recommendations made herein are solely those of TF DESAP and do not represent the views or policies of the above-mentioned stakeholders unless explicitly stated.

Executive summary

- Along with a description of the key principles for the establishment of Smart Grid Indicators (SGIs), this technical report aims at shedding some light on the first area for Smart Grids performance Indicators identified, "Observability". This paper analyses the different needs for DSOs within a selection of use cases for observability and shows a concrete initial example of SGIs. This paper cannot be regarded as a final input from DSO Entity on the SGIs, but as a working paper that will be further developed with additional SGIs.
- Observability is of central importance on our path to a sustainable energy future. It is a pre-requisite for DSOs to cope with their operational needs and to efficiently manage an increasingly complex power system.
- While observability is recognized at EU level as a vital part of a broader concept to handle congestion management, voltage control, active participation of customers and system integration, it is needed for nearly all aspects of the distribution business.
- The higher complexity and extensive nature of distribution networks, compared to transmission grids, make achieving the appropriate level of observability particularly critical, especially for LV grids. There can be different needs for observability depending on the use cases, ranging from real time vs batch processing and at different grid areas and voltage levels.
- The case for observability shall be assessed based on the various use-cases, since real-time and close to real-time data acquisition and processing time increases the overall complexity and associated costs.
- Reaching a proper level of observability does not mean 100% deployment for all grids' assets (substations, devices, sensors, etc.). Every DSO should decide upon its observability strategy. Drawing upon a detailed knowledge of the system in question, the definition of the baseline depends as well on the targeted use-case in the grid area considered in accordance with economical parameters and national regulatory and policy framework in place.

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1. Introduction

The Electricity Directive (Directive (EU) 2019/944), namely in the Article 59.1 (l), tasks the National Regulatory Authorities (NRAs) to develop a new methodology that can help monitor the necessary infrastructure upgrade through the use of smart grids, focusing on energy efficiency and integration of energy from renewable sources.

What is more, the Electricity Directive also states that regulatory authorities should ensure that TSOs and DSOs take appropriate measures to make their network more resilient and flexible. It impales that regulators should monitor those operators' performance based on indicators such as the capability of transmission system operators and distribution system operators to operate lines under dynamic line rating, the development of remote monitoring and real-time control of substations, the reduction of grid losses and the frequency and duration of power interruptions.

In particular, and as foreseen in the Digitalising the Energy System – EU action plan issued by the European Commission in October 2022, the European Commission (EC) will support the European Union Agency for the Cooperation of Energy Regulators (ACER) and the national regulatory authorities (NRAs) in their work to define common smart grid indicators (SGIs), as well as objectives for these indicators, so NRAs can monitor smart and digital investments in the electricity grid annually as of 2023 and measure progress towards the creation of the digital twin. ENTSO-E and DSO Entity have been invited to jointly support the development of those SGIs, by presenting a common DSO and TSO perspective.

These indicators can be split in two different categories, one category focusing on the solutions deployed ("input indicators"), and the second focusing on the benefit that can be derived from implementing smart solutions ("output indicators"). Hence, the definitions below are applied:

- **Input indicators:** describe attributes that are built in support of a Smart Grid (e.g., percentage of substations using automation).
- **Output indicators:** describe the value that may derive from achieving a Smart Grid. These KPIs ensure technological neutrality.

DSO Entity is especially focused on the definition of input indicators and aims to propose, within this paper, SGIs that are specific for observability. The focus on observability results from an analysis from the DSO Entity on the main challenges DSOs are facing, which can be accommodated with digital and smart solutions and can be differentiated between:

1. **Drivers**: These are external factors that necessitate action from DSOs to act, including electrification, decentralization, ageing network, growing consumer expectations, climate change and environmental concerns, and cyber threats.
2. **Responses**: These are strategies to manage the drivers, allowing DSOs to effectively fulfill their responsibilities. These include enabling direct involvement of customers; ensuring network power quality; supporting better planning for grid investments; ensuring better resilience to cope with natural and cyber threats; enhancing active system management; enabling active asset management; unlocking flexibility; and facilitating/providing online services, interfaces and data access for consumers and third-party applications.

These challenges should be viewed as the guiding objectives for the development and investment in distribution networks. Therefore, the establishment of SGIs that can monitor the measures implemented to address these challenges is crucial. Horizontal to these challenges is the need to increase the observability of the networks, which is seen as a prerequisite for the identification of the exact needs from DSOs, supporting the initial focus on observability and on SGIs that monitor the level of observability from the DSOs. It is important to highlight that this paper is not intended to represent the final stance of DSOs on the SGIs, but rather serves as a working document that will be further developed to build a toolbox for the establishment of SGIs in Europe.

2. Definition and benefits

2.1. Definition of observability

Observability is recognized at EU level, as a vital part of a broader concept to handle congestion management, voltage control, active participation of customers, development of demand response and integration of renewables. It can be defined as temporal, geospatial, and topological awareness of grid variables and assets. This is done mainly by measuring current, voltage and other variables, i.e., status, temperature, etc. Hence, it can be understood as the ability to differentiate the conditions throughout the different locations in the network.

Increased observability provides better knowledge about the grid and its behavior, thus, supporting not only the operation of networks, but also the decision-making process for investments[1].

It is referenced under the EU regulation in the following terms:

- **The Network Code on Demand Response** provides a definition for a DSO Observability area: *"DSO observability areas' means the area constituted by the grid elements, grid users that might significantly affect existing or forecasted **congestion issues or voltage issues** in the DSO network. One DSO observability area may cover parts of the grids from other systems operators, and overlap with other DSO observability areas linked to different issues."*[2]
- The **revised Electricity Market Design Regulation** states that *"enabling the use of data from dedicated measurement devices for observability and settlement should facilitate the **active participation of the final customers** in the market and the development of their **demand response**".*

2.2. Benefits of observability

Grid observability provides substantial advantages to DSOs by improving numerous facets of grid management and customer engagement, namely:

- **Technical grid flexibility is enhanced** through precise voltage control and effective congestion management, ensuring stable and **efficient power delivery**, reducing the risk of outages and bottlenecks.
- Observability enables seamless **system integration**, facilitating the harmonious operation of diverse energy sources and technologies.
- **In terms of long-term planning**, the detailed insights derived from observability data assist DSOs in forecasting future infrastructure requirements. This ensures efficient investment and prevents unnecessary grid expansion by planning the grid using real data from LV level. It also enables grid analyses and simulations with real measurement data, thereby increasing planning reliability.

[1] *"The roadmap on Go4Flex - Grid observability for flexibility", E.DSO*

[2] Art 2.48 SOGL: "*observability area means a TSO's transmission system and the relevant parts of distribution systems and neighboring TSOs' transmission systems, on which the TSO implements real-time monitoring and modelling to maintain operational security in its control area including interconnectors". But no specific definition given for DSOs.*

- Observability also contributes to reducing the duration of the grid connection processes by allowing a more accurate determination of the available capacity for new connections.

In **operational planning**, the use of real-time data enables more accurate forecasting and responsive adjustments to daily grid operations. Continuous monitoring aids in identifying and rectifying issues such as voltage sags, swells, and harmonics, maintaining compliance with regulatory standards.

Moreover, grid observability **promotes direct customer involvement** by unlocking the necessary data for consumers to make informed decisions about their energy consumption. It fosters **customer participation in flexibility markets** by offering insights for demand response, where consumers can adjust their consumption based on grid conditions and price signals. This engagement is further enhanced through online services, interfaces, and data access for consumers and third-party applications, cultivating a more interactive and dynamic energy ecosystem. Apart from this, observability also equips DSOs with more data to better quantify their flexibility needs and define the flexibility products and services they want to buy from the market.

Active asset and system management are also improved, as observability enables predictive maintenance and optimized performance of grid components, ensuring a reliable supply even as demand escalates. It also allows quicker detection and rectification of faults.

Collectively, these enhancements result in **substantial overall benefits** for the energy system and society. Higher grid **resilience** is attained, ensuring continuity of service amidst varying conditions and potential disruptions. More involved consumers contribute to a more responsive and efficient grid, while better utilization of investments ensures that the total costs of infrastructure upkeep are affordable to the end consumer.

Grid observability could be called the key to reliability, resilience, efficiency and operational excellence in modern distribution grids[3].

2.3. Challenges in grid observability

To increase the observability of the distribution networks it is important to fully grasp the main challenges associated with it. These challenges can be of a technical nature, particularly associated with the complexity of the network, and of a more generic nature, including regulatory, investment needs and skills.

Technological challenges

Observability for the distribution networks inherently poses more intricate challenges compared to the transmission networks. This complexity primarily stems from the **higher granularity, increased variability** at lower voltage levels and a larger number of directly connected assets and customers.

Unlike the more centralized transmission grid, the distribution grid encompasses a **vast network of low voltage (LV) lines**, serving numerous and diverse end-users, each with **distinct consumption patterns** that are currently more volatile due to the increased penetration of distributed energy resources. This renders the economics of observability at the low voltage level difficult to justify as both investment and operating costs can be significantly high.

[3] *"Observability, the key to reliability, resiliency and operational excellence in modern distribution grids", PSI Energy*

Additionally, the **age of the network** introduces further challenges, as it comprises of various ages, particularly in the LV grid, which has evolved over an extended period, incorporating a diverse mix of outdated and modern equipment, **making it harder to manage**.

This complexity is enhanced by the increasing penetration of DERs, which can introduce bidirectional power flows.

At present, **LV networks are characterized by low observability**, lacking the adequate sampling rate and data analytics capabilities that are more common in high voltage systems.

General challenges

Addressing these challenges requires **significant investments not only towards smart grid infrastructure, but also advanced monitoring technologies, data analytics and new competences** to transform the distribution grid into a more transparent, manageable, and responsive network. There could be additional obstacles across different DSOs in Europe, such as:

- **Regulatory frameworks** may impose limitations for investment on the deployment of monitoring and control technologies in distribution grids, for example, through excessively restrictive rules that limit investment or even due to non-supporting regulation. These can affect the level of observability achieved by DSOs.
- As the new Eurelectric study *"Grid for Speed"* indicates, **massive investments are needed**, therefore budgetary constraints and resource limitations may also impact DSOs' ability to invest in advanced monitoring infrastructure. Eurelectric estimates that, out of the €67b yearly investments needed until 2050, €4b a year will be needed for automation and digitalization in addition to €4b a year for smart meters roll-out.
- The **increasing amount of data requires additional skills** than the ones available today to grid operators for data storage handling, data modelling and analytics, computational power and data management systems.
- The **current age of grid components** makes it sometimes inefficient or not possible to equip with observability capabilities – the grid components first need to be upgraded.

3. Use cases and different levels of observability

A variety of technologies can be utilized to enhance observability. These include smart metering devices; telemetric meters for large clients (non-domestic); remote measurements in substations; power quality sensors (voltage and current); SCADA; DLR; etc. The application of these technologies can be tailored to suit specific use cases and needs.

As a guiding principle, observability should be linked to the phenomenon we seek to monitor, rather than perceiving the network as a static element. Several use cases for observability can be identified, such as: grid observability for flexibility resources management, grid observability for the efficient use of the network, grid observability for technical local substation balancing, grid observability for distribution development planning, grid observability for voltage control at LV level, among others.

Different observability applications may necessitate varying degrees of data granularity and accuracy. Therefore, when evaluating the required level of observability, i**t is crucial to consider the use cases for**

which observability will be needed and the unique characteristics of the distribution network and area under consideration.

Additionally, **time requirements for data communication can also differ, and these should be distinguished from data granularity.** For instance, granular smart meter measurements are surely relevant to achieve more accurate forecasts. For this use case in particular, it is not required to have near real-time communication of these data, since granularity is what is most relevant. However, for active system management, near real-time data is needed, so that the DSO is capable of acting swiftly.

Several key characteristics should be taken into account when determining the needed level of observability:

- Observability of the distribution grid can be achieved through **various means using different technologies.** The **right combination of technologies** to reach a certain desired level of observability is a key dimension of the observability strategy and its definition is the responsibility of the DSO.
- The **required level of observability can vary between different use cases, and minimum observability levels can be defined for each use case.**
- **The level of observability needed can differ among different LV grids of the same DSO, since LV grids with high penetration of RES and/or e-mobility may require a more comprehensive observability than grids with simple loads.**
- **The required level of observability is not static and will evolve over time.**
- Observability needs vary based on at least two **characteristics**: data temporality and voltage levels.
- **Higher ambition levels correlate with increased costs.**
- Given the rapidly evolving technology landscape and the growing integration of renewable energy, **observability solutions should be future proof** to adapt to changing requirements and remain relevant in the long term.

Considering these characteristics, it's important to note that developing <u>a single standard</u> applicable to all observability needs is a significant challenge that may not necessarily have an economic rationale for implementation. In fact, solutions designed to evaluate the level and requirements of observability should be grounded in the principle of optimizing the balance between achieving the highest overall efficiency and minimizing total costs for all stakeholders involved. This includes grid operators and different types of grid users, while also considering the uncertainties surrounding future needs.

In the following sections we will explore three specific use cases for observability, illustrating the varying needs of observability or methods that can be considered. Note that these use cases are mere examples that portray the importance of tailor-made observability strategies to meet different needs from DSOs and that several approaches to observability can be used. Although the use cases selected are more specific to the LV level, given the lack of observability DSOs have for this voltage range, other use cases could be distinguished, especially at MV level, but were not further analyzed within this report.

3.1. Use-case: Consumption load estimation

With the increasing penetration of DERs, network management is becoming significantly more complex. Therefore, it's crucial to accurately estimate load in a way that captures the diverse dynamics from consumers and their changing demand patterns. Note that this use case is related to the individual load estimation, there are less granular means of estimating loads, namely resorting to substation data, however, these are not here described. The following methods provide various approaches to tackle this challenge, each with its own level of accuracy, data requirements and granularity, and cost implications:

- **Method 1: Load estimation through yearly data**
  This method involves collecting data on each customer's annual electricity consumption. The data is then statistically aggregated to estimate the grid's maximum load. This approach provides a broad estimate based on annual usage patterns, offering a low-cost but less accurate measure for the load.
- **Method 2: Standardized load profiles through yearly data**
  In this method, the yearly consumption data of customers is converted into standardized load profiles, which depict typical consumption patterns over time. These profiles are then aggregated to estimate the load. This method provides a more detailed estimation than Method 1 by accounting for consumption variations throughout the year.
- **Method 3**: **Standardized load profiles through smart meter data**
  This method is similar to Method 2 but is enhanced by incorporating readings from smart meters where available. Smart meters provide more granular data, enabling more accurate load profiles.
- **Method 4: Direct usage of smart meter data**
  This method exclusively relies on smart meter data, aggregating hourly (or 15-minute values) consumption readings from all customers equipped with smart meters. This approach offers a high level of accuracy in load estimation by using more granular data, but it also incurs higher costs due to the more complex computational requirements. Additionally, a large proportion of consumers must have smart meter data available.
- **Method 5: Merge of smart meter data and historical measurements**
  This approach merges historical measurements with Methods 3 and 4. By leveraging historical data alongside current smart meter readings, this method enhances load estimation accuracy through trend analysis and the identification of consumption patterns over time. It strikes a balance between the use of historical insights and granular smart meter data for a comprehensive estimation.
- **Method 6: Real-time measurements[4]**
  The most accurate and expensive method involves the use of real-time measurements from the grid. This method employs advanced sensors and communication infrastructure to provide continuous, real-time data on consumption and load. It allows for the most precise estimation of grid loading, enabling immediate response to demand variations and improving grid management.

[4] The term real-time measurements is associated to the time which the data is communicated to the systems of the DSO. In this case, the measurements are communicated in near real-time.

3.2. Use case: observability of secondary substations

This use case focuses on enhancing the observability of secondary substations. With the increased penetration of DER, it's also crucial to have a comprehensive view of the power flows at the lower and medium voltage levels. This is particularly relevant for managing the effects of self-consumption, including addressing potential reverse power flows, and the impact of EV penetration. The following methods propose different approaches to achieve this, each with its own level of complexity, data requirements, and potential benefits:

- **Method 1: Analog secondary substation**
  This method involves the use of analog short-circuit indicators (MV) in secondary substations, which are locally readable and facilitate the identification of outages locations. It also involves the use of analog "Schleppzeiger" (drag/trailing pointer) for measuring the peak load of transformers. These indicators are typically read and reset manually once a year, providing one value per year without detailed profiles or information about the timing of peak load.
- **Method 2: Remote measurements without substation upgrades**
  This method involves the digitalization of the "Schleppzeiger" (LV) (drag/trailing pointer). Measurements of the load-curve of the transformer are remotely read (e.g., daily) to provide information about utilization and to verify the consumption/generation balance of connected customers (smart meter readings). This is complemented with granular data from smart meters, grid monitoring devices or integrated sensors of voltage, current, active/reactive power, harmonics, etc., to provide data for grid operation/planning purposes in the required granularity (e.g., 5 min, 1 min). Additional options include measurements of the transformer-oil temperature, air temperature and door-control (safety).
- **Method 3: Intelligent secondary substation (MV)**
  This method involves the use of smart-grid-ready MV switchgear with remotely readable short circuit indicators (MV) and remotely controllable circuit breakers to optimize recovery times after outages. Integrated measurements of MV-feeders (voltage, current, active/reactive power, etc.) increase the observability level in the MV grid. In every new and renewed (end of lifecycle) secondary substation, a smart-grid-ready MV switchgear is installed. Based on analysis of the grid topology and other criteria, "important" substations are identified (the criteria might change over time) and prioritized in the renewal strategy. Eventually, at least the "important" intelligent secondary substations are connected with ICT (activation of intelligence).

3.3. Use case: Observability for flexibility

This use case focuses on enhancing network observability for flexibility needs, in what regards to explicit flexibility only, meaning that implicit flexibility through dynamic tariffing schemes is not covered, not excluding their relevance for DSOs. As the complexity of power grid operations increases, it's crucial to have real-time data and advanced technologies to identify network congestion issues and to manage and activate available flexibility resources. The following methods propose different approaches to achieve this, each with its own level of complexity, data requirements, and potential benefits:

- **Method 1: Use of near real-time data**
  Near real-time data is crucial for operational activities, which involve identifying network congestion problems and activating available flexibility resources in due time. SCADA systems, in

conjunction with field measurements and communication infrastructure enable near real-time monitoring and control of power grid operations. They collect data from numerous measurement points and allow DSOs to control its operation. However, for flexibility procurement, it's important to have Advanced Metering Infrastructure (AMI) in place, which includes the smart meter devices and communication systems, to collect and analyze granular energy consumption data.

- **Method 2: Deployment of IoT sensors**
  Another level of network observability involves the deployment of IoT sensors at strategic locations across the network. These sensors can monitor various parameters, such as voltage, current, temperature, humidity, and other relevant indicators. Devices installed by the user (behind the meter) that enhance network observability for flexibility could also be considered. However, this is not a required element and should only be used for informative purposes to the consumer, especially since the data is achieved through devices not owned nor controlled by the DSOs.
- **Method 3: Systems for data visualization**
  Network observability for flexibility needs, both for determining flexibility needs and for managing and procuring flexibility resources, should be supported by systems that enable **data visualization** and analysis across various timeframes and configurations. Near real-time observability is needed to promptly detect or predict interruptions, while longitudinal observability is necessary to locate possible/future congestion issues within the network.

4. Input indicators for observability

As previously mentioned, the measures implemented to increase observability, as well as the degree of observability required, depends on the specific use cases. Therefore, the SGIs to be implemented should align with the priority use cases for the respective Member State and the level of observability should consider the operational reality of the DSO, namely network topology and technologies in place. A summary of the main key principles based on which the SGIs should be set, is provided in Annex B.

Taking into account the example use cases identified and the various methods and approaches described, DSO Entity proposes the following indicators:

- Grid elements with real-time or close to real-time measurements – refer to the percentage of grid elements (e.g., transformers, overhead and underground lines, circuit breakers and disconnectors) with real-time or close to real-time measurements divided by the total number of grid elements.
- Secondary substations with remote measurements and control – refer to the percentage of secondary substations with remote measurements and control divided by the total amount of secondary substations.
- Roll-out of smart meters – refer to the percentage number of smart meters deployed divided by the total number of connected customers.

These indicators are only examples of potential input indicators that can be adopted by DSOs to monitor the degree of observability. Note that the extent to which these indicators are implemented, namely, the grid elements considered, and the measurements accounted should be defined at national or DSO level, since their need is dependent on the network topology and the devices in place. For instance, with a high deployment rate of AMI, the necessity for remote measurement and control at secondary substation level may not be so high as opposed to a situation with low AMI deployment rate. Additionally, when implemented at the national level, there should be complete clarity on what is being monitored (e.g., grid elements, variables measured…).

These indicators can then be linked with the use cases identified. The latter can easily be associated with potential societal benefits, which are marked in the table below as examples.

Use Case	Input indicators			Benefit from the use case
	Grid elements with real-time or close to real-time measurements	*Secondary substations with remote measurements and control*	*Roll-out of smart meters*	
Consumption load estimation		X	X	Power quality; Energy restoration during outages
Observability of secondary substations	X	X		Power quality; Grid utilization; Energy restoration during outages
Observability for flexibility	X	X	X	Deferred investments; Energy contracted in flexibility markets; Percentage reduction in energy not supplied from DER, %; Hosting capacity for DER

Note that the linkage between benefits and use cases/input indicators is merely qualitative, and the degree to which an input indicator generates a specific benefit is not directly quantifiable, since it is influenced by several other variables.

Through the linkage between the benefits and the use cases, and the identification of the input indicators for each use case, it is possible to match input indicators with possible output indicators (measure the benefit) through the matrix below, with one input indicator being able to influence (qualitatively) several output indicators. Note that both the input indicators, the use cases and benefits consist of a non-exhaustive and example list, it shall be adapted according to the national needs.

Objectives	Output indicator	Observability		
		% of assets with real-time or close to real-time measurements	*% of secondary substations with remote measurements and control*	*% roll-out of smart meters*
High degree of resilience and security of supply	*Power quality*	X	X	X
	Energy restoration during outages	X	X	
	Percentage reduction in	X		X

Transition towards a sustainable low carbon energy system	*energy not supplied from DER, %*			
	Hosting capacity for DER	X		X
Energy efficiency: reducing energy consumption and consume energy when it is most abundant and cheapest	*Network losses*			
	Grid utilization		X	
Active participation and flexibility including DR and storage	*Energy contracted in flexibility markets*	X		X
	Deferred investments	X		X

5. Conclusion and recommendations

The diverse methods presented in the use cases represent a progression from broad, cost-effective estimates to highly accurate, near real-time data collection with varying granularity, each tailored to distinct operational needs and resource availability. Depending on the level of ambition and the stipulated requirements for planning or real time operation, all the solutions could be viable options.

Furthermore, if the combination of observable and estimated parameter output closely aligns with real-life measurements and does not yield additional value by increasing the number of observable points, adding more observable points will only marginally enhance overall accuracy. Therefore, it is crucial to assess whether installing additional devices to enhance observability **will significantly contribute to achieving the intended goal**. For instance, if a single balancing smart meter at a substation provides all the necessary data for monitoring energy flows (transformer overload), it indicates that the observability of the transformer is at the highest level, ensuring the **observability objective function**. The same observation can be made upon deciding to build a new digital substation, since in some cases, a retrofit to the existing substations might be enough.

In each scenario, an evaluation of operational needs, associated risk levels, regulatory or customer service quality requirements, and costs is essential to determine the appropriate level of observability. **Generally, a higher level of ambition and accuracy will lead to increased costs.** These costs are not only associated to investments in smart grid infrastructure but also to investments in advanced systems, analytics and skills, covering both CAPEX and OPEX**.** This points to the need to strategically invest in observability, based on the individual needs, since **there is no one-size-fits-all strategy for observability.**

Additionally, there are limits to observability, influenced by cost/benefit analysis, privacy concerns and cybersecurity risks, that might differ among MSs. Therefore, it is imperative to define a goal for which the information will be collected, identify the required data to achieve that goal, and ascertain the technical solutions needed to obtain the necessary data. Fulfilling all the identified technical needs ensures full observability of the defined as a goal.

Annex A - List of use cases (non-exhaustive)

The paper focuses on particular use cases for observability that were selected with the purpose of proving the different needs and applications of observability from the perspective of the DSO. However, there are several additional use cases that can be defined. The list below presents a non-exhaustive list of use cases for observability.

1. Fault Detection and Localization (quickly detecting and localizing faults)
2. Load Monitoring and Balancing (continuous monitoring of load patterns and fluctuations)
3. Voltage Regulation (different voltage levels allows for monitoring voltage fluctuations)
4. Renewable Energy Integration (manage their variability and intermittency)
5. Demand Response Management (to enable real time demand response)
6. Power Quality Monitoring (other power quality observation)
7. Distributed Energy Resource Management (automatic activation and redispatching)
8. Electric Vehicle Charging Infrastructure control[5]
9. Real time grid availability indication for flexibility activation
10. State estimation: Due to growing grids´ complexity, helpful to rely more on state measurement and less on state estimation in the distribution case whenever it is possible to arrange for the necessary instrumentation.
11. Detect and respond to cybersecurity threats[6]
12. Grid Planning and Expansion (to estimate available capacity, peak loads, etc.)
13. Asset Management and Maintenance (to enable predictive maintenance)
14. Unauthorized electricity consumption
15. Flexibility needs assessment & evaluation
16. Assessment of activated/procured flexibility
17. Customer electricity consumption visibility
18. Monitor grid congestions

[5] This use case is not applicable to all DSOs, since not all control this activity, being regarded as a commercial activity.

[6] Although the present technical report doesn't focus on cybersecurity, a higher degree of observability can have a strong influence on cybersecurity, both positive (detection capability) and negative (higher exposure) and should be carefully assessed.

Annex B – Key principles for SGIs

To understand the current smart grid landscape, DSO Entity did a state-of-the-art analysis on the implementation of SGIs throughout Europe based on a comprehensive data collection from EU countries complemented by an in-depth desktop research.

Based on the inputs collated, main key principal blocks were defined, which should set the basis for the adoption of SGIs in the MSs:

- The process of defining SGIs requires a constant dialogue between system operators (SOs) and National Regulatory Authorities (NRAs) and collaboration on both input and output indicators;
- Prerequisites such as observability and data management in all cases will have to be present in order to achieve objectives;
- It's important to limit the scope of the SGIs to the regulated activities of the SOs;
- Given the different grid topologies and operational reality, it is anticipated that sharing of knowledge and best practices will add more value than direct benchmarking;
- Developing SGIs is not a one-time event, but a continuous improvement loop enabling to capture the digital maturity of the solutions deployed as well as the dynamic evolution of challenges;
- The SGIs should be adaptive when monitoring over long regulatory periods;
- Grid smartification is complementary to grid expansion efforts;
- Data must be available and collectable with reasonable effort for the SO to meet reporting obligations;
- Clarification of definitions and feasibility to compute the different indicators are a must;
- The SGIs should be technology neutral.