The European Association of the Electricity Transmission and Distribution Equipment and Services Industry

A smartness indicator for grids:
Increasing transparency on the ability of electrical grids to support the energy transition

Proposal by T&D Europe

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1. Introduction: Why is there a need for a grid smartness indicator?

For many years the European Union has been committed to the reduction of carbon dioxide emissions and to increasing the share of renewable energies in its energy mix. The latest milestone in this long process of legislative initiatives is the package Clean Energy for all Europeans proposed by the European Commission in November 2016.

Electricity is ~~a universal form of energy – a so called secondary energy –,~~ which is used by all consumers, independent of the primary energy source, e. g. fossil fuel, nuclear power or renewable sources. Because of this decoupling of the primary energy ~~basis~~ from the appliances used by consumers, the electricity sector offers a particular opportunity to drive this transition. Renewable energy targets for this sector therefore are more ambitious than for all other sectors. The renewable energies target of 27% by 2030 translates into nearly 50% for electricity for this reason.

~~But a~~Although changing the primary energy mix in the electricity sector is easier than in any other sector, the main sources of renewable energy, i.e. solar and wind power, ~~are requiring~~require a fundamental re-thinking of how power systems are designed and operated. The new sources of energy are volatile, they may be geographically constrained, they are less controllable than conventional sources and they will result in a much more ~~distributed and fragmented~~intermittent generation ~~sector~~ than ~~in the past~~ traditional base load power stations.

Electric~~al~~ity grids ~~are connecting and coordinating~~connect and coordinate all ~~parts~~ elements of power systems to serve ~~all~~ their end users. Grids will play a crucial role in facilitating and enabling the energy transition to incorporate increasing levels of generation, changing demand patterns and the implementation of new technology and solutions. As we move on from traditional energy systems, ~~But they will not be the same as in the past. N~~new, smarter solutions will be required in order to manage the changing generation mix, ~~deal with fragmentation and volatility of power generation~~ whil~~e~~st maintaining affordability and ensuring ~~of electricity and~~ security of supply. This means that not only the generation sector will have to undergo a fundamental transformation, but also the grids will have to change and develop ~~be adapted and developed~~ accordingly in order to ensure value for money, a successful transition and to deliver value and quality of supply to consumers~~make the energy transition a success~~.

Today's regulation does not reflect this need for transformation. Regulation is primarily or in many cases even exclusively focusing on cost-efficiency of the grids, but not on their active contribution to a successful (including cost-efficient) energy transition. There is a need to broaden this regulatory view on electricity grids. We therefore propose the introduction of a grid smartness indicator or a grid smartness monitoring process. This new methodology would create transparency on the transition to smarter grids in Europe, increase the awareness of

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smart technologies and their potential and promote the use of best practices. By doing so it is expected to help Member States investing to reach their emissions reduction and energy efficiency targets while incentivising investments in innovative technologies.

Introducing such an indicator or process requires using the knowledge of all relevant stakeholder groups. T&D Europe therefore has drafted a first set of ideas on how such an indicator could be created. This is presented by this paper, which we propose to serve as a starting point for a development process to be launched by the European Commission and involving the relevant stakeholder groups.

2. What should a Grid Smartness Indicator address and what does this mean?

2.1 Objective of a Grid Smartness Indicator

The Grid Smartness Indicator or Monitoring Process should provide information on the ability of a grid to serve its purpose. Traditionally there has been a triangle of expectations on power systems and on grids as an integral part of them. They should ensure cost-efficient, reliable and sustainable provision of electrical energy.

These three expectations are still in place, but they are applied in a different environment today.

The smartness indicator should therefore reflect the ability of the grid to enable the entire power system to ensure cost-effectiveness whilst supporting the energy transition and security of supply as well as the participation for all users known today and in the future (e.g. generators, consumers, prosumers, aggregators, etc.).

2.2 Breakdown of the objective and ~~of~~ the expectation on grids

Although expectations on power systems and grids seem to be the same as in the past from an end user point of view, the conclusions may be ~~be~~ different in the context of the energy transition. This chapter therefore discusses the different elements of the objective more in detail.

Cost-effectiveness, **support of the energy transition and security of supply** are representing the traditional triangle of requirements, with the energy transition covering sustainability and security of supply addressing reliability and resilience.

However, **cost-effectiveness** in the context of the energy transition translates into other challenges and solutions than in traditional power systems. Wind and solar power as well as new types of load, in particular EV charging infrastructures, are rapidly evolving and are

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challenging the grids with high and rare peaks. Traditional design of the grid based on the peak load would result in decreasing ~~utilization~~ utilisation due to changing demand patterns and project increases in peak demand affected directly by consumer charging behaviour. ~~of the installed capacity and therefore decrease also overall cost-efficiency.~~ Deferring investments in primary equipment and reinforcement by smarter operation of the grids therefore gains importance.

Some eExamples of ~~approaching this new task~~smarter operation are:

a) Dynamic loading of components

b) Increased ability to accommodate DER by dynamic voltage control

c) Reasonable curtailment of rare peaks of RES feed-in or load – Such as Active Network Management

d) Advanced asset health management

e) Minimization of fuel and carbon cost of conventional generation by maximizing accommodation of renewables – Increasing network capacity and headroom using smart techniques such as reactive power compensation

Examples for equipping and using the grids for supporting **sustainability and the energy transition** are:

a) Loss reduction by increasing energy-efficiency of the grids

b) ~~Maximum accommodation of renewables~~Accommodating increasing levels of renewable generation

c) Support of electrification of new sectors, e.g. Electric Vehicles (EV) Charging and heat

d) Optimization of the grid load at all voltage levels including phase balancing, to increase the ~~support the increasing~~ energy efficiency of the grid

Ensuring **security and quality of supply as well as resilience** of the system has become a quite different and much more challenging task in an environment with much more stochastic, volatile processes and significantly increased complexity due to highly distributed, active resources both on generation and consumption side.

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Examples for approaches for the grid to ~~deal with this situation~~more effectively manage this are:

a) Advanced planning procedures and tools, reflecting distributed resources and new loads, in particular EV charging infrastructures, and consideration of operational measures (e.g. peak shaving) when assessing and planning the infrastructure.

b) Advanced asset management, reflecting condition and importance of assets and ensuring that critical components are identified and prioritised: Such approaches are becoming more relevant in a rapidly evolving environment, in which grid enforcements and extension have to be implemented much faster than in the traditional, quite stable European environment. Prioritization of limited investment and maintenance resources is a key success factor under such circumstances.

c) Real-time dynamic security assessment on transmission level: Historically, the European interconnected power system has been engineered ~~primarily has been built~~ to share reserves and to allow portfolio optimisation in a regionally balanced power system. Additionally the majority of generation was provided by large rotating machines, stabilizing the grid by their mechanically inertia. Today, with increasing regional imbalances caused by geographically constrained sources of renewable energy mainly connected via power electronics, the pan-European transmission grids are facing a fundamentally different task. The traditional way of operating the systems with strong focus on preventing emergencies and much less attention on curing such efficiently, which resulted in high reserve capacities in the transmission grid, is not adequate for this task any more. Instead, more real-time monitoring and network management ~~needs to~~should be applied to ensure best utilisation of the infrastructure, while at the same time maintaining ~~the high level of~~ security of supply. In doing so, also new grid elements based on power electronics need to be considered.

d) Self-healing or re-configuring distribution networks: Rapidly changing load situations caused by volatile distributed generation are requiring more operational flexibility even in the secondary distribution level, which traditionally has not been controlled or monitored.

e) Fast outage clearing: Reliability of supply can be improved not only by avoiding outages, but also by shortening the time of interruption of supply. Increased application of remote control and monitoring can support this and at the same time even lower costs.

f) Increased resilience provided by on-grid micro- or nanogrids: Distributed generation, if equipped with adequate microgrid controllers, can run independent from the grid in case of regional or system-wide blackouts. Using this opportunity given by distributed generation would reduce the negative impacts of such blackouts significantly.

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g) Demand response programmes helping to avoid critical situations: Such programmes may help to balance load and generation, they may help accommodating renewable generation, but they may also my give relief to the grids in critical situation, and help the grid to manage changing demand patters and increasing connected loads in a more effective and efficient way. tin that way help the system to withstand the crisis.

h) Cyber security assessments: All the items above imply the use of more digital control and communication technologies. Moreover, integrating and coordinating highly distributed resources means a quantitatively much broader exposure of the system to cyber crime. Cyber security and cyber security assessments are therefore crucial for ensuring security of supply in future power systems.

Empowerment of all types of users of the grids and letting them participate more actively is a new, additional requirement complementing the traditional triangle. An important pre-requisite for such participation is transparency of the user's influence on the service received and on the system, both for the user himself and for service providers–. Examples for implementation are:

a) Smart metering infrastructure and services providing information to users and grid operators

b) Time of use tariffs

c) Facilitation of participation of all players - even very small ones - in markets by efficient and functional regulations for registration, qualification and settlement.

d) Allowance for the grid operator to use reasonable curtailment of rare peaks as an alternative to grid extension based on economical decisions.

There are two more elements in the objective summarised earlier, which suggest a broadening of the traditional triangle of requirements and a need for different solutions in future than in the past: The first is the requirement to serve all types of users of the grids. In addition to the classical users – bulk power plants and passive consumers – this addresses for instance distributed generators, prosumers and new service providers, such as aggregators. The second is to be accessible to all of these new users known already today, but also to those that may evolve in future and are not known yet. This accessibility requires concepts that are capable of evolution and adaptation. Digitalisation, if properly applied, can be expected to be a key enabler to address this requirement.

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3. First ideas on the Grid Smartness Indicator

3.1 The general concept

~~One could expect that a~~A Grid Smartness Indicator addressing the objective as outlined in the previous chapter would ideally be a figure clearly measuring the contribution of a particular grid to the energy transition, e. g. by quantifying accommodated renewable generation, utilisation of assets, reliability of supply or curtailed generation from renewables. However, these outcomes will not only depend on the smartness of the grid, but at least as much on its structure inherited from the past, the situation of load and generation and many other factors.

Therefore we propose another view on the indicator: The Grid Smartness Indicator should reflect the feasibility that a grid is prepared to support the objective defined above. It should not be a precise measurement of what a particular grid is delivering by using smart technologies and solutions. Therefore it may be sufficient to accumulate obviously supportive technologies weighted based on their role out in the grid or availability to the grid user, without the need for quantifying their contribution in a particular grid. This makes the indicator simple, robust – and will always allow the addition of new solutions in the future.

It should also be noted that there is not a one and only smart grid. Different combinations of technologies and solutions may result in grids equally serving the requirements, although being quite differently equipped. This also means that some of the solutions proposed to be monitored under a Smartness Indicator may be overlapping, defining more a menu of alternatives than one consistent set of complementary solutions. This implies that not all monitored solutions need to be in place in a certain grid to make it smart.

Looking at technologies and solutions to be monitored, we propose to structure them in three technological groups:

I. **Smart grid infrastructure** (field devices, remote monitoring and control):
Assuming that a common denominator of most, if not all smart solutions is to operate grids in a more precise and adaptive manner, getting information from the field and being able to control the grid remotely is ~~an obvious~~a pre-requisite for increased smartness. This would be reflected by this first group. ~~A S~~smart grid infrastructure that supports cost-efficiency as well as reliability and - by increasing the capability to accommodate RES generation - sustainability

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II. **Smart grid functions** (operational features on network level, software):
Using information provided by the infrastructure addressed by the first group is the second building block of smart grids. ~~Here we are talking~~P ~~p~~rimarily ~~about~~ software functions applied on network level – either ~~in~~ on parts of a network, such as overhead lines connected to a secondary distribution substation, or to entire grids.

III. **Smart actuators** - new non-conventional components to operate the network:
Combining the first two groups means to operate conventionally equipped grids with more monitoring and remote control more smartly. This is an important first step towards smart grids. However, there are more opportunities if non-conventional elements are added, allowing faster adaptation of the grid to new situations and by that to increase utilisation without reducing reliability of supply. Such solutions are ~~very ofte~~frequently in based on power electronics.

3.2 Technologies and solutions contributing to the three areas of smartening grids

3.2.1 Smart grid infrastructure

Examples for technologies and solutions representing the smart grid infrastructure are listed in the following table. Some of them are ~~more~~ relevant for the transmission level, others for the distribution level and some for both. This is indicated in the two right columns of the table.

Examples	Transm.	Distr.
Percentage of substations remotely monitored and controlled in real-time, itemised as transmission, HV/MV and MV/LV substations	•	•
Percentage of substations ready for predictive maintenance, itemised as before	•	•
Percentage of energy efficient transformers	(•)	•
Percentage of smart meters with building automation gateways installed		•
Percentage of the grid connected to smart buildings (according to the Smartness indicator for buildings)		•
…		
…		

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3.2.2 Smart grid functions

Smart grid functions are complementary modules to the smart grid infrastructure, these help to manageing grid planning, operation and maintenance more effectively and efficiently.

Examples	Transm.	Distr.
Percentage of the number of lines operated under dynamic line ratings	•	
Asset health monitoring, supporting controlled, temporary overloading	•	•
Percentage of networks prepared by local automation for remote reconfiguration through advanced distribution management systems		•
Number of micro- or nanogrids being able to operate autonomously during grid outages		•
Use of real-time dynamic security assessment on transmission level	•	
Flow-based allocation of interconnector capacity in market processes	•	
Share of load under demand response programmes	•	•
…		
…		

3.2.3 Smart actuators - new non-conventional components to operate the network

Traditional grid operation is focusing focusses primarily on prevention of critical situations rather than curing them. As a consequence most of the active grid elements, such as transformers, are not prepared to influence load-flow quickly, resulting in the need of reserving significant grid capacity as reserve for emergency situations. In truly smart grids this approach needs to be challenged. Non-conventional (but in many cases already proven) components can support this.

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Examples	Transm.	Distr.
HVDC lines embedded into the AC grid being able to influence load flow	•	
Fast (i.e. power electronics based) FACTS, optionally including storage capabilities	•	(•)
Smart distribution transformers with actuators or other equipment for distribution voltage control (e.g. line voltage regulators)		•
…		
…		

3.3 Contribution of smart technologies and solutions to enabling grids to serve their purpose

Smart technologies and solution have been grouped using technical categories in the previous sections in order to reflect the technical structure of a grid. Doing so ensured that each solution could be counted only once. However, eventually it is also important to understand, to which of the objectives of a grid discussed in the chapter before the different solutions can contribute. The following table therefore maps solutions to objectives.

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Smart technology or solution	Cost-effec-tiveness	Energy transition	Security of supply	Empower-ment
Smart grid infrastructure				
Percentage of substations remotely monitored and controlled in real-time, itemised as transmission, HV/MV and MV/LV substations	•	•	•	
Percentage of substations ready for predictive maintenance, itemised as before	•			
Percentage of energy efficient transformers	•	•		
Percentage of smart meters with building automation gateways installed		•		•
Percentage of the grid connected to smart buildings (according to the Smartness indicator for buildings)	•	•		•
Smart grid functions				
Percentage of number of lines operated under dynamic line ratings		•		
Asset health monitoring, supporting controlled, temporary overloading		•		
Percentage of networks prepared by local automation for remote reconfiguration through advanced distribution management systems		•		
Number of micro- or nanogrids being able to operate autonomously during grid outages			•	•
Use of real-time dynamic security assessment on transmission level	•	•	•	
Flow-based allocation of interconnector capacity	•	•		
Share of load under demand response programmes	•	•		•
Smart actuators				
HVDC lines embedded into the AC grid being able to influence load flow		•	•	
Fast (i.e. power electronics based) FACTS, optionally including storage capabilities		•	•	
Smart distribution transformers with actuators or other equipment for distribution voltage control (e.g. line voltage regulators)	•			

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4. Link between smart grids and smart buildings

In the Energy Performance of Buildings Directive (EPBD) the European Commission has proposed to develop a Smartness Indicator for Buildings. Such indicator shall reflect the ability of buildings to

a) Adjust to the needs of the user and empower building occupants providing information on operational energy consumption (complementing the energy performance information provided in the EPCs);

b) Ensure efficient and comfortable building operation, signal when systems need maintenance or repair; and

c) Readiness of the building to participate in demand response, charge electric vehicles and host energy storage systems.

~~Especially~~ In particular the first and the third bullet points address ~~are addressing~~ topics related to electricity consumption. ~~They~~ These need to be reflected and supported by the grid infrastructure accordingly. There is a fundamental link between smart buildings and the grid they are connected to. Smart buildings can only deploy their potential if they are connected to a smart grid to ensure the building and its residents participate in the energy flexibility~~.~~ such as DSR, time of use tariffs and the new energy services.

The smartness indicator for buildings, as currently being developed in the framework of the revision of the Energy Performance of Buildings Directive, therefore needs to be consistent with the Grid Smartness Indicator proposed in this paper. We believe the connection to a grid with (smart) digital functionalities should form an integral part of the buildings indicator. In the same spirit, the existence of smart buildings connected to the grid is reflected by our proposal of a grid smartness indicator, as buildings play an important role as load and energy resources for the grid.

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