Renewables Grid Initiative

FLEXIBILITY

The need for flexibility in a climate-neutral energy system

Discussion Paper – 2020

Foreward

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Installations of renewable energy sources, mainly wind and solar, have been growing strongly for the last fifteen years. We expect that growth will accelerate as renewables are today the most economical option for providing clean energy, cutting carbon emissions and slowing down the impact of climate change. However, renewables alone will not be enough to deliver a safe and reliable electricity supply. The way to climate neutrality has to be paved by a multitude of technologies, approaches and market mechanisms. Within this mix, flexibility stands out as one of the essential features of the energy system of the future.

The current electricity system has been built up steadily over the past 100 years. The recent build-out in renewables has caused significant changes to this system. Traditionally, generation has followed demand, ready to supply any quantity at any point in time in any corner – of the developed world. As the system accrues a higher proportion of variable renewables, there is an imperative for demand to follow supply to harvest the resources provided by nature most effectively. Meaning, consumption should be focussed when power is abundant and cheap and reduced or delayed otherwise. The Californian now-infamous Duck Curve (i.e. the need for massive amounts of fossil fuels generation to be put onto the system when the sun goes down) is now a reality in many countries around the world. The approach to the issue needs to change, instead of feeding this Duck with fossil fuels, we now need to get rid of it altogether. A way to achieve this? Through flexibility.

Flexibility is a state of mind: it implies the readiness to abandon old ways of thinking and embrace new ones; for instance, by creating new market mechanisms that enable technologies such as batteries, hydrogen, and vehicle to grid to be effectively used. Flexibility is about the ability, supported by technologies, of participants to dynamically interact among themselves to maximize resources, minimize costs, as well as increasing resilience, energy security and safety.

One essential venue for flexibility deployment is the power grid. One of the main tasks of the grid operator has always been to keep the electricity system stable in balance. They have traditionally used tools such as spinning reserves which enable generation to respond quickly to changes in demand. In recent years, grid operators have added new tools and approaches to manage the increasingly challenging task of keeping the system stable. In some countries, grid operators have gone a long way to reinventing their practices, while in many others, they are still on an incremental pathway. With increasing shares of renewable in the system, flexibility services will become available at all voltage levels and involve both the demand and the generation side.

It is time for flexibility to be embedded in energy system planning and design in a meaningful way. All market and system participants need to identify and play a well-defined role in developing and contributing flexibility services through new business models if necessary. For this to happen, the electricity markets, currently designed for a fossil-fuel world, are no longer fit for purpose; they need to be reshaped to reward flexibility and dispatchability. With flexibility accounted and planned for within the system, we can accelerate the energy transition and speed up the electrification of several sectors in a cost-efficient way.

In this discussion paper, developed by RGI in close collaboration with its transmission system operators (TSOs) and NGO members, we want to focus on flexibility and the large variety of flexibility options that will be necessary while we decarbonise. As the name suggests, a discussion paper is an ongoing work and not a final one, which tries through incremental steps to find a common understanding and shared terminology and to represents different needs and approaches to flexibility. Most importantly, it also addresses the challenges of the technical complexity of flexibility. It is a first step to bring some clarity and will need to be complemented by further discussions with RGI Members and all relevant actors. In this phase of the energy transition we have to constantly learn from each other in order to find solutions.

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1. *System evolution and impacts of renewable energy sources (RES)*

1.1. Evolution of the energy system

Following the Paris Agreement, the European Union agreed to facilitate the transition away from fossil fuels towards cleaner energy to fight climate change leading to the approval of a legislative package known as "**Clean Energy for all Europeans Package**" (CEP) in May 2019. This package sets ambitious European **goals for 2030**, namely:

- **40% reduction in greenhouse gas emissions** compared to 1990;
- **32% renewable share** on gross final energy consumption;
- **32.5% reduction in primary energy consumption** compared to the baseline scenario.

At the time of writing of this paper, the above mentioned 2030 targets are under revision. Though, it has been already recognised that an increase is a necessary stepping stone towards a 2050 climate neutrality goal.

A key indication from long-term projections is that the **electricity sector holds the key for the EU's low-carbon economy**, thanks to the intrinsic efficiency of electricity and the technological maturity and increasing cost efficiency of renewables such as wind and solar. Installed capacity of renewables in EU28 has grown from **250 GW in 2008 to 496 GW in 2018**[1]**. This growth has been strongly driven by variable generation,** such as wind and solar, which have more than quadrupled their installed capacity over the last ten years, reaching **296 GW in 2018**. Preliminary data from 2019[2] show that renewables rose to a new record, supplying 35% of EU electricity with **wind and solar combined providing, for the first time, more electricity than coal.** Furthermore, according to European Commission's (EC) scenarios, this trend will continue until 2030, when wind and solar together are foreseen to reach 650 GW of installed capacity, and beyond, with variable RES capacity set to reach a value **between 1800 and 2200 GW in 2050**, according to COMBO and 1.5TECH scenarios[3]. It is important to note that not one of the EC scenarios included in the long-term projections so far is 100 % renewable by 2050.

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[1] Eurostat, 2020

[2] "The European Power Sector in 2019", Agora Energiewende

[3] COMBO: cost-efficient combination of options from 2°C scenarios, 2050; 1.5TECH: based on COMBO with more bio-energy with carbon capture and storage (BECCS), carbon capture and storage (CCS)

1.2. Understanding the impacts of RES on system operations

As RES become a larger portion of our electricity supply, it is important to understand their impacts on the functioning of the electricity system. The progressive increase of RES, which is necessary to successfully deliver the energy transition, is changing the entire architecture of the system and its operation. To be able to maintain the current high levels of security, adequacy and service quality, while avoiding excessive costs for society and minimise environmental damages, it is essential to better understand how to manage the technical challenges of running a system largely based on variable renewables.

Across Europe, the **Transmission System Operators** (TSO) have the delicate and complex task of balancing electricity production and demand in every moment, keeping the system reliable in order to ensure consumers a constant supply of electricity. Already today, with the current share of renewables, we can observe **significant impacts on the transmission grid mainly related to the technical characteristics, the variability and the location of RES.**

1.2.1 Technical characteristics of RES

RES plants usually interface with the network through power electronics, which do not provide rotating mass unlike the traditional thermal and hydro generation. Therefore, they do not have the inherent capability to support **frequency and voltage** which are **fundamental network parameters** that need to be controlled to keep the system stable. Frequency and voltage control are essential to cope with perturbations as in the case of a sudden and unexpected loss of generation, load or other grid elements.

Already today, we can observe periods where variable RES cover a significant share of electricity demand, e.g. during Christmas or Easter when consumption is low. Due to the effects of COVID-19, we have for the first time observed a prolonged period of low demand caused by a lockdown of economic activities, which is challenging in terms of electricity system operation. In fact, in its Summer Outlook 2020, National Grid points out that “managing reactive power, voltage levels, low transmission demand and high volumes of low inertia generation will continue to be challenging.” Moreover, if the summer demand for electricity remains low, more actions will be needed to balance and operate the system, actions that include the disconnection of embedded generation.[4]

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[4] https://www.nationalgrideso.com/industry-information/codes/grid-code-old/modifications/gc0143-last-resort-disconnection-embedded

With the progressive and steady displacement of thermal capacity and production, due to increasing shares of RES, the inertia of the system is also progressively decreasing *de facto* making the electricity system more vulnerable to frequency deviations. In fact, as shown in Figure 1, faced with the unexpected loss of a power generator, the frequency decreases more quickly in a system with lower inertia (System B) than in a system with more inertia (System A). In case B, frequency could drop so fast that automatic load shedding (protection system) must be activated to avoid an uncontrolled blackout.

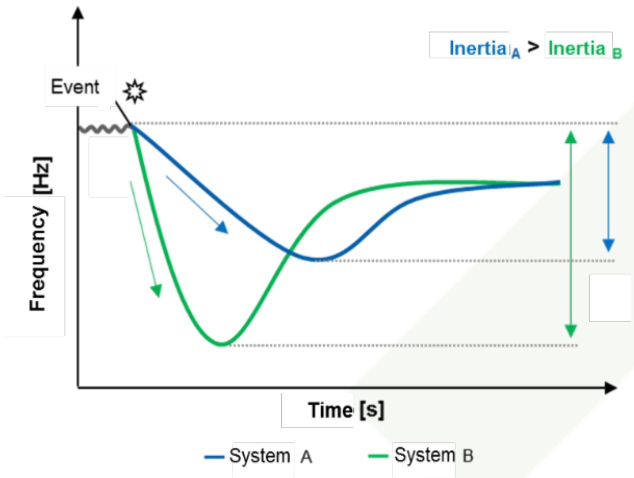

Fig 1. Qualitative behaviour of two systems with different levels of inertia - Source: Terna

The challenges to power system planning, analysis and operation brought by the massive integration of power electronics are the subject of several research programmes[5]. More joint efforts in finding innovative solutions to progressively adjust system operations to enable a high penetration of power electronics-interfaced generators is needed. However, it is also important to recognise that new technologies and power electronics can bring additional, fast-acting services to the market as illustrated in Ireland under the DS3 programme[6].

1.2.2 Variability of RES

In an electricity system increasingly based on RES, which are subject to weather variations, it can become challenging to **balance production and consumption**,

[5] For instance, EU MIGRATE is a research programme running since 2016, coordinated by TenneT and involving 23 partners (TSOs, universities and manufacturers). The aim of the programme is to find solutions for the technical challenges the grid is currently and especially in the future faced with. https://www.h2020-migrate.eu/

[6] http://www.eirgridgroup.com/how-the-grid-works/ds3-programme/ds3-consultations-and-pub/index.xml

especially **during critical moments such as load peaks and steep load ramps.** The traditional flexibility options will increasingly be unavailable for these balancing tasks in a decarbonised near-future, hence new solutions need to be implemented and a shift towards a logic in which demand is able to follow generation must be supported and facilitated.

1.2.3 Location of RES

Variable renewables can be located far away from consumption centers. Therefore, the electricity generated needs to be transported over long distances to reach consumers. This can lead to **transmission network congestion** and **investment requirements in transmission network capacity and development**.

Another locational aspect is related to the voltage level. In some European countries, a significant amount of RES plants are connected to medium- and low-voltage distribution networks, which have been developed in the past to handle only electrical loads and not bi-directional flows. Therefore, **new challenges are emerging in the management of the electricity system at all voltage levels to deal for instance with voltage rise or greater needs for reactive power management.**

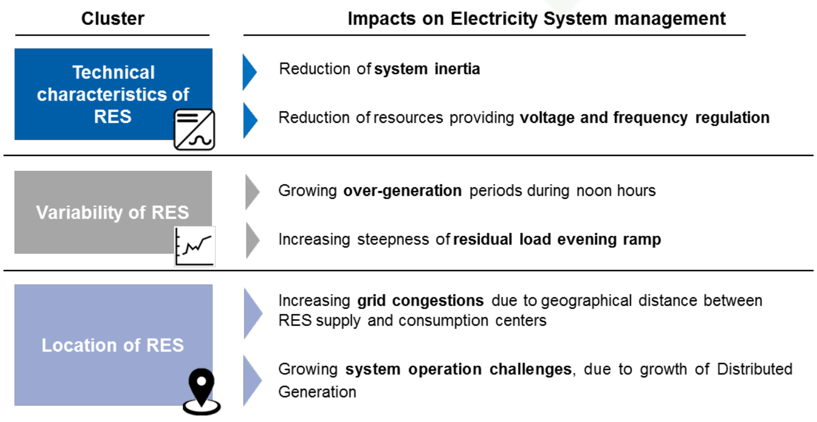

Fig 2. Impacts of Energy Transition on Electricity System Operation

1.3. Actions required to face system challenges

While we transition to a decarbonised power system, which includes reducing conventional thermal generation, and increasing RES, it is of paramount importance to implement a set of essential, coordinated and coherent actions to enable this complex transition.

Investments in necessary and sustainable electricity network infrastructure at all voltage levels will continue to be crucial, both at national level and across borders for the development of interconnection capacity between countries.

Moreover, it is possible to enable the coordination of RES deployment with the existing grid and with grid expansion plans through the introduction of geographical specifications in RES support auctions, such as already happens in Germany and Portugal. Geographical specifications can be inserted as pre-qualification criterion, restricting the development to areas which the auctioneer has pre-defined as feasible, for instance regarding the possibility of connection to the grid[7].

However, in order to keep the electricity system secure, the above-mentioned actions will need to be complemented by actions that can **increase system flexibility** and allow the **effective exploitation and management of the flexibility potential of all new resources**. System operators typically procure flexibility in dedicated ancillary service markets to perform their system management operations effectively. Consequently, a **re-design of ancillary service markets** - in terms of their procurement and remuneration rules - is an essential ingredient to support the full integration of renewables.

2. Flexibility services, resources, and their capabilities

2.1. Energy and services market

Electricity markets are typically organised in **wholesale energy markets**, where different buyers and sellers trade electricity through Forwards, Day Ahead and Intraday trading mechanisms, and **ancillary service markets**, which are characterised by a single buyer, the Electricity System Operator[8] (ESO).

Ancillary service markets are basically used to procure the necessary resources for the management and control of the electricity system up to real-time, in order to maintain a constant balance between electricity production and consumption and to keep fundamental network parameters stable.

[7] Measures to influence the geographic distribution of winning projects are only relevant for multiple-item auctions. In single-item auctions, a specific site is pre-developed by the responsible public authority, and the location of the site is thus not part of the auction result.

[8] Electricity System Operators deal with system services at global level, while, in some countries, distribution system operators (DSOs) manage local voltage control.

2.2. Market evolution and services portfolio

System operators procure **different types of services through ancillary service markets**, while other services can be mandatory. They can generally be **grouped into four categories** (see also Figure 3):

- **System Management** services ensure secure, efficient operation and monitoring of the electricity system.
- **Frequency Control** services guarantee the balance between electricity generation and consumption at any given time, in order to maintain a stable frequency through active power regulation services (e.g. frequency containment, frequency restoration, etc.).
- **Voltage Control** services maintain the voltage level in the range of permissible values through reactive power handling.
- **System Restoration** services enable grid operators to restore the electricity supply as quickly as possible after a failure affecting the whole electricity system, or part of it.

System Restoration is a last-resort service with a partially mandatory participation; for some generators with appropriate technical requirements, this obligation is expected to remain, independent of the energy mix. Hence, this paper will focus on Frequency & Voltage Control as well as System Management services.

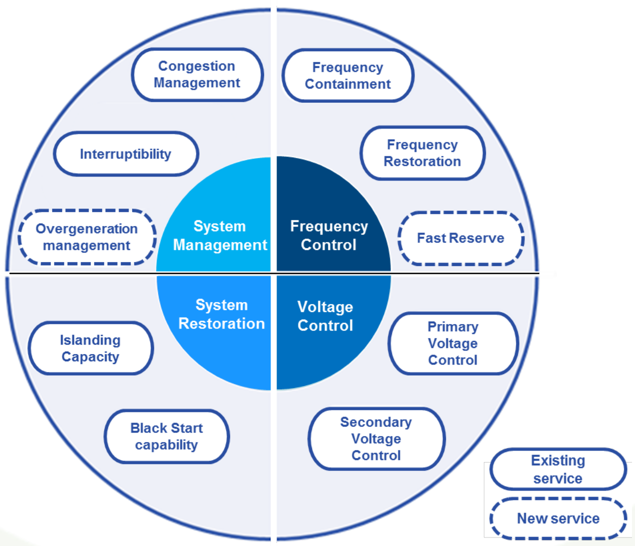

Fig 3. Classification of example ancillary services - Source: Terna

The changing resource mix triggered by the energy transition requires two major actions **in the context of re-designing ancillary service markets**:

1. **Provision of existing ancillary services from new sources** in order to adapt to the changing generation mix while guaranteeing the needed ancillary services capacity. For instance, reserves will need to be progressively provided by new sources to replace mainly conventional thermal capacity which is partly being phased out.
2. **Introduction of new services** that are required to ensure a secure system operation will emerge along with the increasing share of demand covered by variable RES. These services were previously not required, or provided implicitly by other sources, in some cases "for free" or with very low marginal costs.

New services include (not necessarily to be considered exhaustive and complete, see Figure 4):

- **Fast Reserve:** a service that delivers a very fast response (activation time < 1 second) to minimise frequency deviation from its nominal value. It should be capable of containing the rate of change of frequency (RoCoF) after a major loss, thus partly offsetting the effects of a decreasing level of system inertia.
- **Overgeneration Management:** a service capable of facing the challenge of structural over-generation from variable renewables by absorbing RES production when it exceeds demand.
- **Ramping:** additional responsibility for market participants aiming to reduce sharp schedule changes at transitions between market time periods [9]. This could help to reduce the stress of fast power fluctuations (mostly caused by high variable RES penetration) in the system. Ramping requirements may differ in central dispatch systems, however ramping products may be important to deal with RES uncertainty.

The **Fast Reserve** service is essential for managing the consequences of a decreasing level of system inertia, which measures the capability of a system to "resist" a system imbalance between generation and consumption without excessive variations of the system frequency. Today, this service is provided "for free" or with very low marginal costs by large power plants with rotating masses. Instead, the contribution of power electronics-based generation (e.g. wind and solar) to system inertia is limited or close to zero. The challenge of decreasing inertia in the electricity system can be addressed by procuring Fast Reserve explicitly via market mechanisms[10]. Its demand may differ

[9] In Ireland, for instance, Eirgrid has defined and procured a ramping margin service. http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-System-Services-Protocol-Regulated-Arrangements-v2.0.pdf

[10] The challenge of decreasing system inertia can be also be addressed by a variety of measures, e.g. additional connection requirements, extension of assets for dynamic reactive power by energy storages and the use of dedicated assets for inertia.

between different synchronous areas (e.g. Continental Europe and Great Britain) but also between highly meshed and peripheral areas (e.g. Central Europe and Italian Peninsula).

A similar argument can be made for **Overgeneration Management**. The expected growth in wind and solar production will lead to structural overgeneration at many points in time. Already in 2030, electricity production from variable RES could frequently exceed electricity demand at national level (e.g. during spring and summer in countries with a high penetration of solar), thus triggering the curtailment of electricity generated from variable renewable energy sources. It will be important to consider targeted demand side management (e.g. EV charging management) to help alleviate overgeneration. Additionally, during periods of low renewable generation dynamic demand management will be important, to ensure that demand can be managed to avoid the need to rely on fossil fuel generation for back up during low RES periods.

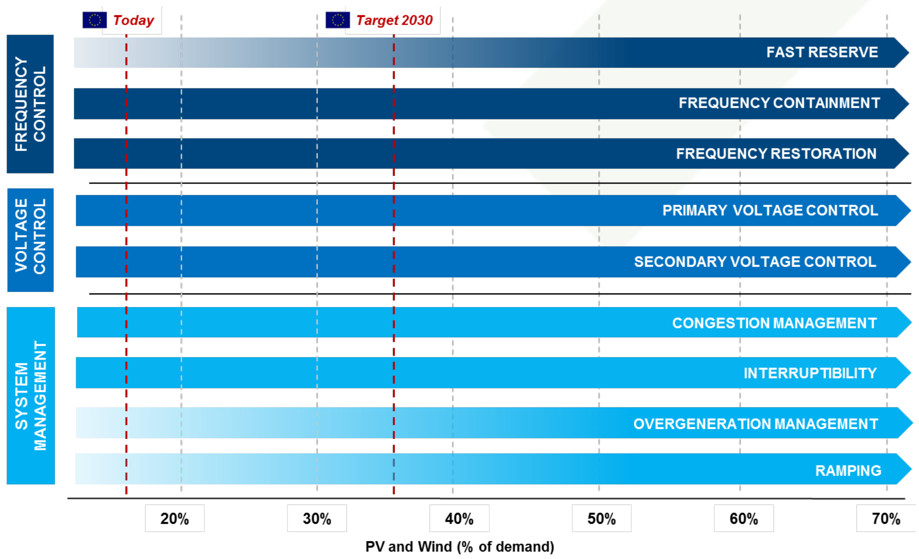

Fig 4. Qualitative representation showing how the need for ancillary services evolves as shares of variable RES grow – Source: Terna

2.3. Unlock the potential of new flexibility resources

Historically, **conventional thermal power plants together with hydro plants** have been, and still are, a **key source of ancillary services** for congestion management and frequency/voltage control. This flexibility can also be easily provided by **renewable thermal power plants,** such as **geothermal** and **biogas plants**.

During the last decade, we have witnessed **a constant decrease in the available thermal capacity** and consequently **in the availability of resources that so far have**

been fundamental in the provision of ancillary services. Furthermore, with increasing shares of variable RES in the system, the hydro and thermal capacity still in the system will be used increasingly as backup to step in during times of low wind and solar production. This means that less and less conventional fossil resources will be dispatched and therefore be ready to provide grid services.

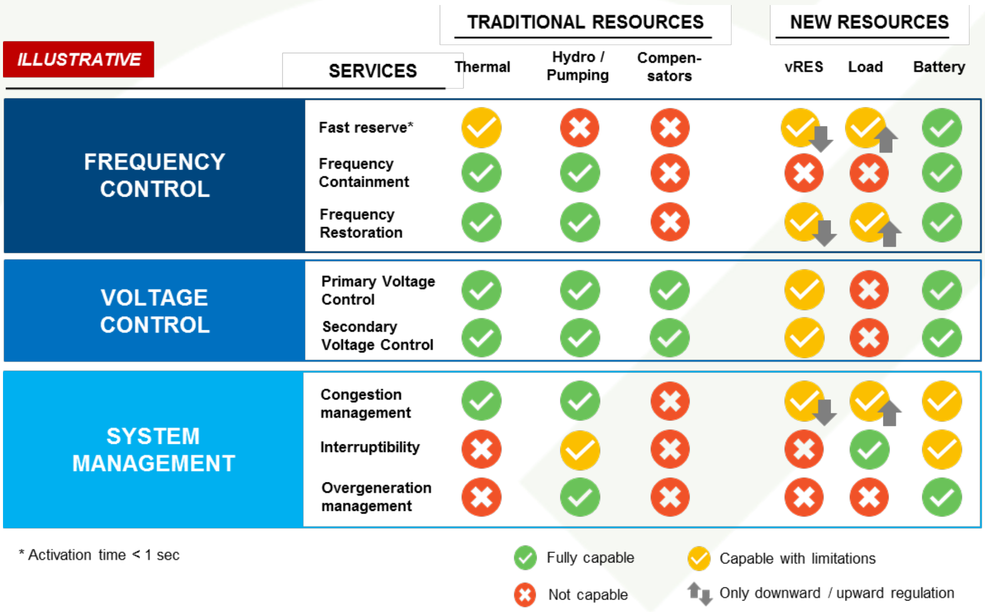

Fig 5. Grid Services and technologies (illustrative) – Source: Terna

While this graph may represent the current status, there is work underway to unlock fast acting services from demand and technologies such as EV charging management.

Among the **traditional flexibility** providers are the following resources:

- **Thermal** (conventional power plants, especially those with steam turbines) can provide high levels of thermo-mechanical inertia to the electricity system and are by design perfect for providing Fast Reserve services. But these services are available only during normal operation: in the absence of operating conventional power plants, their contribution to system services must be replaced with other sources.
- **Hydro plants** have to date been, together with thermal plants, key ancillary services providers due to their ability to easily and quickly regulate their power production, which is linked to a water flow from a reservoir. Hydro plants are indeed capable of performing **all the grid services usually required** and those with a reservoir linked to a pumping mechanism could hold the potential to store electricity.

- **Compensators** are devices that can be used to adjust voltage levels at the connection points of the power network, either by injecting or absorbing reactive power. Two main groups of compensator devices can be distinguished: rotating and static (commonly referred to as 'STATCOM'). The former, by rotating, also contributes to system inertia, while the latter can inject/absorb reactive power at a fast rate, but does not provide inertia because no moving parts are involved. Compensators are typically deployed in areas that lack other options for voltage control. Studies and research are ongoing as to what can be achieved with synthetic inertia or grid forming controls. In addition, static compensators can be equipped with storage devices in order to provide inertia using grid-forming control principles, which is equivalent to inertia provided by rotating machines and can be gradually designed for the desired contribution.

In view of the radically changing energy mix and in order to continue operating the electricity system safely, it will be **necessary to exploit new flexibility resources** and, consequently, to **build a framework that can ensure their development and market participation, while taking into account the different capabilities of each technology** (see Figure 5):

- **Today variable RES** (vRES, mainly wind and PV)[11], due to their intrinsic characteristics, are perhaps not required to provide rapid frequency response or frequency containment services. However trials in Ireland and Northern Ireland have demonstrated the capability of RES to provide faster frequency services (DS3 [12]). Additionally, such technologies can provide the system with **other services** (e.g. **frequency restoration** and **congestion management**) by reducing and/or increasing their power output,

  - When vRES are used to provide these active power flexibility services, **their power output is necessarily reduced**. In order to be able to provide upward frequency control, today vRES must be operated structurally with a reduced power output thus reducing their total production. When providing downward frequency control, vRES can maximise their power output and reduce it only when requested by the grid operator, thus impacting total generation much less. **Within current market structures, vRES are not yet best placed to provide downward regulation services**. With technology advancements or in combination with batteries, vRES **may also become able to react at a faster and programmable rate**, making them potentially suitable for the

[11] Variable renewable energy sources (vRES) are renewable energy sources that are non-dispatchable due to their dependency on weather conditions (e.g. wind and solar power), as opposed to a dispatchable renewable energy sources such as hydro with storage, or biomass, or a relatively constant source such as geothermal power.

[12] http://www.eirgridgroup.com/site-files/library/EirGrid/DS3-System-Services-Qualification-Trials-Process-Outcomes-and-Learnings-2017.pdf

provision of Fast Reserve services, ideally only in downward direction in order to not having to reduce their power output. It is worth mentioning that newer installations of vRES are also technically capable of **contributing to voltage control**, as already happens in some European countries, in line with the general requirements for all generators. Potentially, vRES will play a more active role in frequency and voltage regulation using **grid forming technologies**. These technologies enable power electronics-based plants like wind and solar plants to mimic the behaviour of thermo-mechanical assets, adapting their active and reactive power output automatically, making it possible for them to support the system stability. With or without grid forming technologies, providing system services comes at the cost of having to operate structurally with a reduced power output. In the short-term, grid forming can play an important role only for isolated systems with high vRES share and lack of interconnections (i.e. islands); in the long-term, it could be important for the whole system with 100% RES share in the electricity system.[13]

- **Electricity demand,** like vRES, **as of today** is not usually contracted for fast reserve or frequency containment services but used for interruptibility services (which simply require to interrupt load but not to follow a signal such as the frequency error). In the future, this might change with new converter-based load such as electric vehicles. Still, demand response (DR) can be extremely useful in providing **frequency restoration** and **congestion management services.** In this case, DR is a natural fit to provide **upward regulation by reducing energy consumption, thus complementing vRES, provided that the service is not procured symmetrically**. With further technology advancements or in combination with batteries, DR may be able to modify the vRES load at a faster and programmable rate, thus enabling provision of Fast Reserve services. Driven by cost/opportunity reasons, so far this service has typically mainly been carried out by large energy consumers, such as industrial plants, even if potentially any energy consumer, of any size, can contribute to the system regulation. As more energy demand is electrified, such as that from the heating or the transportation sectors, the potential of demand-side regulation massively increases (e.g. electric vehicles, hybrid heat pumps or load coupled to batteries). Smart meters and digital control tools can enable this. In addition, wider sector coupling i.e. the integration of gas and electricity systems, for example Power-to-X (using **electrolysers and hydrogen**) can help maximise

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[13] The before mentioned MIGRATE research programme has shown that grid forming control will be a key enabler for the massive integration of power electronics into today's power systems and for running a 100% power electronics and climate-neutral power system.

the use of renewables and maintain flexibility. Essentially, these devices consume electricity to generate gas through a relatively flexible process, thereby providing ESOs with programmable demand that can be used to avoid overgeneration.

- **Batteries** (including those installed in electric vehicles) have the potential to offer a very wide range of services including **power-intensive services**, such as **fast reserve**, making them particularly valuable in a system to cope with imbalances or even to compensate partly the decreasing level of inertia. In fact, batteries, being a pure electrochemical technology, are characterised by a **reaction time quicker than conventional thermal and hydro plants**.

It is evident that the **new flexibility resources are very different from traditional flexibility providers**, e.g. in terms of cost structure, number of installations, typical size and geographical distribution. Providing ancillary services is a natural side-business for large power plants, because they are intrinsically designed to modulate their active/reactive power output depending on the request from the grid. The same cannot be said for demand response or distributed energy resources, because the involved devices are, as of today, designed to provide a specific service which implicitly defines power exchange with the grid (e.g. heating, cooling, mobility) and in many countries lack real-time telemetry and remote management systems.

In this context, it is helpful **to distinguish between being available ("reserve") and real-time activation ("balancing")** and how to remunerate these two aspects. For most new flexibility resources, activation costs can be rather high because of significant opportunity costs (e.g. for demand side service providers, it can be the interrupted production process of an industrial consumer). High activation costs typically imply low activation probability and consequently low or at least unpredictable cash flows. At the same time, fixed costs have to be borne by flexibility providers in order to participate in ancillary service markets (e.g. live metering, telemetry, trading). Therefore, it is **essential to explicitly remunerate availability of flexibility services** in order to reduce the investment risks and facilitate the deployment and participation of new resources.

Finally, a **progressive effort is needed to digitalise the electricity system** in order to **observe, control and monitor the ever-increasing number of resources** that actively interface with the grid, reduce the connection/activation costs and make it easier for small prosumers to contribute. For example, observing and controlling the behaviour of millions of electric vehicles or heat pumps, each one providing a very little share of the procured service, is far more challenging than observing a few hundred large thermal plants connected to the high-voltage grid. Retail market changes and consumer behaviour may also drive digitalisation requirements.

3. Coordination between TSOs and DSOs

Coordination between transmission and distribution grid operators **is essential for a secure, reliable and affordable power system**. This is an important, comprehensive and complex topic that deserves a stand-alone discussion. In the context of this paper, we focus on high-level aspects of TSO-DSO coordination.

In areas such as quality of supply and system restoration, coordination and cooperation between TSOs and DSOs has long been established. With the on-going energy transition, new challenges are arising and with them new areas of potential coordination also emerge. Among these, at least two are worth mentioning in the context of flexibility and system operation: (1) data exchange between TSOs and DSOs and (2) procurement of flexibility services from distributed energy resources.

With the rise of distributed energy resources (DER) such as rooftop solar and household batteries, the share of installed capacity located in low- and medium-voltage networks has dramatically increased in the last decade and will continue to grow in the future. Electricity system operators typically lack real-time telemetry of DER, which makes it more difficult to forecast the system state, identify critical events early enough and correctly manage the instantaneous balance between generation and consumption in the electricity system.

For this reason, it is essential to define and implement a **structured and reliable process of – standardised – data exchange**, where DSOs and/or operators of DER communicate real-time data to the corresponding TSO. This ensures that the total DER production and the resulting power flows in each substation of the transmission network can be estimated, and so the security analysis of the transmission network, and the balancing actions in the electricity system can be carried out in an efficient and secure manner.

A second opportunity of coordination is linked to the **procurement of flexibility services from resources located in distribution grids**. A significant share of the new flexibility resources is expected to be small-scale assets, such as DER, residential batteries, heat pumps or electric vehicles, and will thus be developed in low- and medium-voltage grids. As aforementioned, it will be fundamental for a secure system operation to be able to take into account these new flexibility resources. Just like traditional assets, these new resources could pre-qualify for global ancillary service markets managed by the corresponding TSO, present offers[14] for upward and downward regulation and eventually be activated. A key difference compared to traditional resources is that TSOs have little visibility on the impact of their activation, because these assets are not located in transmission grids. For example, it could

[14] Unlike traditional resources, DER are unlikely to present offers individually, but instead through an aggregator.

happen that the activation of thousands of electric vehicles at once causes congestion in the distribution grid.

For this reason, it is necessary that **TSOs coordinate with DSOs**. The coordination between TSOs and DSOs is a complex topic and depends on regional circumstances. Examples of coordination platforms include DA/RE ("DAta exchange/REdispatch") an IT platform developed by TransnetBW and NetzeBW in Germany, and the GOPACS platform developed by TenneT and the Dutch DSOs. Generally, a **traffic light system** is one of a number of examples that **can be used for coordination** (see Figure 6). Under this scheme, certain distributed resources could be allowed (green light), limited (yellow light) or even prevented (red light) from participating in global ancillary service markets under certain conditions, for example when their activation would cause congestion. In a static traffic light approach, this would happen already in the pre-qualification phase,[15] whereas in a dynamic approach, limitations could be defined for each time interval (session) of the ancillary service market. Moreover, such a coordination mechanism would be a pre-requisite for running local ancillary service markets (e.g. DSOs procuring voltage control locally to manage their grid) to avoid contradictory dispatch orders or enable activations that resolve a critical situation for the distribution grid.

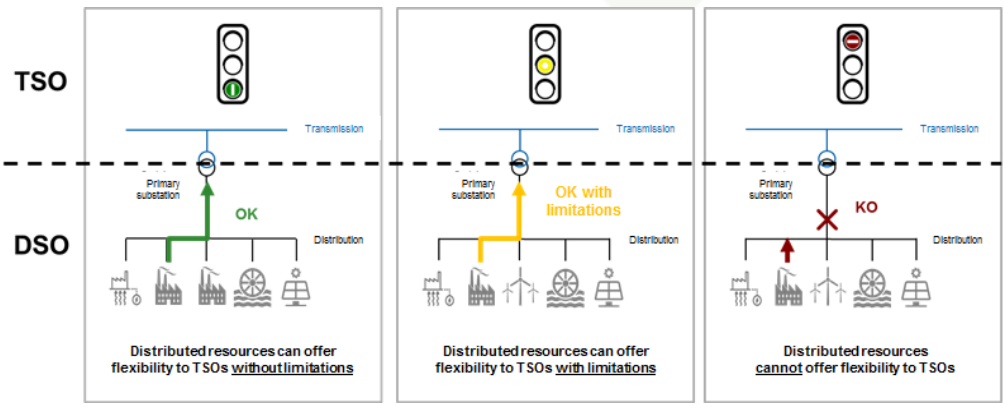

Fig 6. Example of coordination between TSO and DSOs through traffic lights – Source: Terna

[15] This approach has already been implemented in Italy for the so-called UVAM pilot project that aims at facilitating the participation of distributed flexibility resources in the ancillary services market run by Terna.

4. Recommendations

A full integration of renewables into the electricity system can only be achieved by implementing a set of essential, coordinated and coherent measures. Investments in electricity network infrastructures will continue to be crucial. This includes national network development, interconnections in the case of highly congested cross-border connections and also compensators. In general, a well-meshed grid connecting regions with different characteristics (PV-dominant, hydro-dominant, wind-dominant, areas with different consumption patterns or in different time-zones), along with better RES location, more observability and more measurements can reduce the need for flexibility and make the process of integration of RES more efficient.

Still, in order to maximise the use of renewables and new distributed resources, **flexibility should become a key priority by pursuing the following actions:**

1. Review of grid services market design

The changing resource mix triggered by the energy transition will require system operators (1) to procure existing grid services from new resources and (2) to **introduce new grid services,** in order to ensure a secure system operation. **Investments in new assets to provide flexibility to the electricity system will be necessary** (e.g. in power-intensive batteries) and should be supported by multi-annual contracts between electricity system operators and flexibility providers, following a competitive bidding process. In addition, it should be acknowledged that **remunerating the availability of flexibility resources greatly facilitates the participation of demand response and distributed energy resources in grid services markets, because this provides a more predictable cash flow**.

2. Dynamic regulation to facilitate flexibility

Strong regulatory support will be key to enabling TSOs and DSOs to maximise the benefits of new technologies and service capability. Innovative developments can be assisted by a dynamic approach to regulation – where regulators are able to examine new market and operational models that look holistically at consumer, network and market issues and facilitate trials of new services among others. It will be important to share learning from progressive regulatory environments that have enabled new service development. This would deliver useful insights to the wider TSO/DSO community and the regulatory sector as to how regulators can help transition towards more flexible systems and greater consumer participation.

3. Progressive efforts towards digitalisation and standardisation

Real-time telemetry and remote-control capability require measurement and communication devices as well as software. We are currently observing an exploration phase in which different technology solutions are being developed. Competition for ideas is key for coming up with innovative solutions. At the same time, standardisation has a value and should consider at least two aspects. First, increasing demand-side response should be enabled by **cross-border compatibility**, e.g. that electric cars bought in Denmark should be able to participate in the German or Spanish ancillary service markets. Secondly, there is a **benefit in deploying ready-to-pool devices, from the moment of purchase**. Millions of small-scale connectable devices will be sold in the coming decade; it would be a missed opportunity if these devices were not ready-to-pool or required additional installations by a technician. For this reason, **standardisation should be pursued with priority and in an open and collaborative way.**

4. Fostering TSO-DSO coordination

Flexibility will be needed across different voltage levels, be it in transmission or distribution networks. First and foremost, a process of standardised data exchange and real-time communication between TSOs and DSOs is needed and should be further explored via pilot projects.