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Definitions of ancillary services and network codes

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Abstract

This is the first version of the deliverable regarding the definition of ancillary services and network codes. The proposals described are representing the result of the analysis and consultations conducted so far in the RESERVE project, having as a starting point the generation structure developed in WP1 and the computation and analysis performed so far in the WPs 2 and 3, in relation to frequency and voltage control. The results of the WP6 regulatory review and prioritization, as well as stakeholder consultations in WP7, have also been important milestones in the delivery process of this version.

For a better understanding of the context, the proposals are accompanied by a short description of the current situation in the power systems.

This deliverable analyzes the environmental, economic and corporate social responsibility (CSR) aspects for each of the proposals, and the estimated impact from this perspective.

This is a continuous process. Further information from the research work carried out in the RESERVE will be used for the final version of the deliverable due month 36 (D6.4 v1.0).

Keyword list

Network Codes, Ancillary Services, CSR

Disclaimer

All information provided reflects the status of the RESERVE project at the time of writing and may be subject to change.

Executive Summary

Integration of renewable generation represents a key pillar of the European Commission's broader energy and climate objectives in reducing greenhouse gas emissions, improving the security of the energy supply, diversifying energy supplies and improving Europe's industrial competitiveness.

In recent years, there has been a stronger focus of both the European Commission and the EU electricity industry, as well as the national and international regulatory authorities, on the context of increasing penetration of the supply of electricity from renewable energy sources (RES).

Most of the research work has been focused on a time perspective up to 2020, and on the implication of RES at transmission network level. However, it is widely accepted that much of the growth of renewables beyond 2020, and up to 100%, may be based on decentralized generation. So far, no thorough analysis was done beyond transmission level, which means that the distributions networks are at the current state insufficiently analyzed and tested, which may result in additional future challenges through unidentified behavior.

The proposed scenario "up to 100% RES in the energy system" implies a series of critical changes and adaptations, from a technical point of view (as frequency and voltage control) to support the stability, safety and optimal operation of the energy system. Also, in this context, it is very important to consider energy storage capacities and regulatory implications.

Therefore, it is mandatory to understand how the impacts from alternative future developments in generation, transmission, distribution and storage interact with each other, and what are the resulting implications in respect to the regulatory framework, as well as the CSR impact.

Based on the work performed in the WP 1, WP 2 and WP 3 in RESERVE, 19 technical proposals for new regulations or updates of the existing regulations have been developed. These proposals have undergone a process of analysis, prioritization and completion in D6.1 and MS15, adding the definition of a new network code related to the storage. In the frame of WP7, these 19+1 proposals were passed through the filter of consultations with stakeholders and national and international regulatory authorities, and the obtained feedback is incorporated in the next stages of the project, leading to the final definition of these technical proposals.

Starting from the above-mentioned technical proposals, in this deliverable the authors will present:

- the initial definition of three new ancillary services,
- two changes of existing ancillary services,
- basics of one new network code.

For each of the proposals, a compact description of the existing situation, the foreseen changes generated by the operation of the power systems with up to 100% RES, and the potential positive impact of the proposals in facilitating the transition from present situation to future one are provided.

Moreover, these changes will substantially concern the environment and society. For each of the proposals the CSR perspective and impact assessment are important elements that have been considered, analyzed and included in this deliverable.

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1. Introduction

The European Commission (EC) regulation defines a set of network codes. These codes have two goals: the first one is to drive the completion of the internal energy marked, and the second one is to reach the target of 20% renewable integration.

Therefore, this initial target of 20% renewable energy sources (RES) target was the basis for the definitions of the current set of network codes, and the existing design components of the ancillary services are meeting the same criteria.

Currently large generators powered by fossil fuels maintain the power system stability and quality of energy supplies through their mechanical inertia. While replacing the large generators with small and low inertia or inertia less units, there will be a reduction of the total inertia in the energy system with an impact on the increase of its instability risk.

On the way toward 100% RES goal, several technical and regulatory challenges need to be considered, and amendments to the existing network codes and ancillary services are necessary. Starting from the analysis of the regulatory framework and the prioritization of the 19+1 proposals from D6.1, and the CSR analysis framework and evaluation methodology developed in the D6.5, this deliverable comes with a more detailed definition of the necessary changes in the context of ancillary services and network codes. In the same time, it provides an overview of environmental, economic and societal aspects in relation to the above-mentioned potential changes.

1.1 Objectives and outline of the deliverable

Objectives

- To provide initial definitions of ancillary services and network codes, that are relevant for supporting the transition up to 100% RES, while meeting the requirements and responding to the challenges of the new context;
- To analyze environmental, economic and societal aspects of different potential energy systems design, with specific reference to the proposed amendments and definitions of ancillary services and network codes.

Outline of the deliverable

The first chapter of the deliverable includes the necessary information for understanding the statements and rationale presented in this work, and the relationship between the content of this deliverable and the results of the activities performed in other WP's of RESERVE.

Within the second chapter, we identified and defined six proposals of new or updated ancillary services and network codes. They rely on the information on regulatory and CSR aspects from the deliverables D6.1 and D6.5, based on the assumptions and analysis from WPs 1, 2, 3 as a starting point, and at the same time passing through the filter of WP7 consultations.

In Chapter 3, the above-mentioned proposals go through a CSR analysis, and Chapter 4 provides a series of additional information on the proposals for new or changed power network codes definitions.

1.2 How to read this document

The content of this deliverable leans on the results and findings of the activity performed in several work packages of the RESERVE project. Thus, for fully understanding the statements, the proposals and the rationale supporting them, it is necessary to acknowledge the information included in several other deliverables.

The first step of the project was to develop significant scenarios for power system operation with up to 100% RES. Different scenarios, from both studies of EC and other projects in which the RESERVE consortium organizations or experts are involved, have been compared and discussed to find the adequate characteristics. To fully understand the issues mentioned in this deliverable, related to the scenarios, it is necessary to access the WP1 deliverables, mainly the D1.1.

The current definition of frequency is accurate for current power systems where synchronous machines are still representing a high share of the total system generation. The rationale behind is that power plants based on synchronous machines intrinsically respond to local frequency deviations through their inertia. However, this scenario is rapidly changing with the increasing penetration of converter-based generators since they have very low or no inertia. Therefore, as the share of RES increases, the overall system inertia decreases, resulting in larger frequency deviations after a power imbalance. Therefore, the assumption that only minor differences exist between different frequency measurement locations can be incorrect.

The contents of the D 2.1, D 2.2, D2.3 and D2.6 are the basis for the proposals concerning the frequency control.

Regarding the voltage control, two concepts were developed within WP 3, that make best use of inverter-based RES units. The concepts operate on different time scales and fulfil different objectives. To enable further demonstration on physical hardware and the deployment of the techniques in a field-trial environment both voltage control scenarios warrant extensive experimentation for verification, development and as proof-of-concept.

One of the major challenges in active distribution grids is the harmonic stability issue. Impedances at the power electronic interface were mapped in determining harmonic voltage stability. On this basis, there is a requirement for DSOs to have the impedance information to perform stability analysis of the network. The fundamentals for the proposals concerning the voltage control are part of the deliverables D3.2 and D3.3.

The next step for identification and definition of the necessary new ancillary services and network codes was to establish the key regulatory principles for facilitating the transition between the present RES penetration percentage in the power systems up to 100 %. Deliverable 6.1 presents the set of key regulatory principles, a methodology for putting these principles in practice and the resulted priority list of proposals (so called Top 5) based on the entire list of proposals (presented in detail in MS 15). Accessing D6.1 it is necessary to understand the link between the technical proposals documented in MS 15 and the list of new ancillary services and network codes presented in the present deliverable.

For the specific analysis of each proposal and the impact from the CSR perspective, a determinant role had the content of the deliverable D6.5.

Finally, the dissemination and consultation activities carried out in WP7, and included in the D7.2, have helped to refine these proposals. (Fig. 1.1)

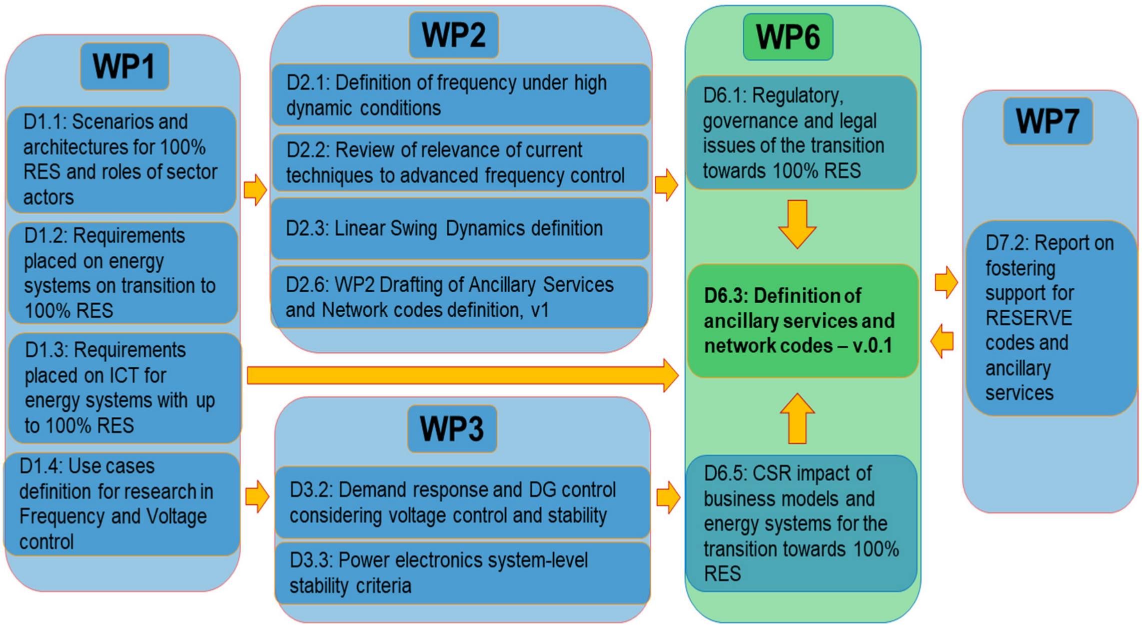

Figure 1.1 Flows of information between work packages and deliverables

1.3 Transition from present situation up to 100% RES in power systems

Increasing the share of RES in the power systems up to 100% raises various types of challenges: technical, financial, social acceptance, etc. One of these challenges is correctly understand how the transition from the actual situation to the expected one will take place: which are the significant steps, how fast the process will be, how the challenges are changing from one stage to the next one and those that will follow.

One important aspect of the power system operation is that the generation structure is different from hour to hour in accordance with the electricity market conditions. In these conditions, in terms of the meteorological conditions, day time, fuel price and others, the generation structure may be very different from the structure identified using the annual average values.

The Romanian Power System operates strongly interconnected with the neighboring systems and the yearly electricity produced from RES (not including large hydro units) is currently around 20%. Nevertheless the hourly measurement performed for 2017 by the Romanian TSO Transelectrica (source: www.transelectrica.ro) have proved a distribution of RES generation among the other generation sources as showed below:

- The most often percentage: 13%;
- The maximum percentage: >40%;
- The number of hours when RES percentage is more than 40%: 12 hours per year.

In other words, although the Romanian Power System usually has a RES penetration of 13%, there are significant hour intervals when this percentage goes up to 40%.

Recently the EU Parliament and EU Commission come to the agreement for a new target for RES penetration in the power systems: 32% until 2030. Based on this target, extrapolating the above-mentioned measurements from 2017, and taking into account the evolution foreseen for the Romanian Power System until 2030, we estimate the following values:

- The most often percentage: 26%;
- The maximum percentage: >75%;
- The number of hours when RES percentage is more than 75%: 139 hours.

According to these assessments, the Romanian Power System will already operate in 2030 with more than 75% RES penetration (which is in fact the maximum for the Romanian Power System considering the large hydro units) for a duration of around 6 days per year.

The main conclusions of Romanian case study are:

- The power systems have to be ready to operate at different RES percentages in close times.
- Times with high RES percentages will be significantly increased in number and duration (meaning that curtailment solution will no longer be applicable without prejudices) in the near future (up to 10 years).

2. New Definition of Ancillary Services and Network Codes Toward 100% RES

The calculations and analyses performed in WP 2 and 3 of the RESERVE project have proven the necessity for upgrades of some existing network codes and for the development of new ones in order to properly deal with the increasing complexity in the power systems operation while the share of RES generation will reach up to 100%.

As presented in D 6.1 – Regulatory, governance and legal issues of the transition towards 100% RES and in the documentation of MS 15 – Initial definition of ancillary services and network codes, a list of 19 technical proposals for updating the existing network codes and one proposal for a new network code have been developed so far. Not all the RESERVE technical proposals require new ancillary services or changes in the existing ancillary services.

Currently, in the power systems there are three categories of ancillary services [10]:

- Related to frequency control;
- Related to voltage control;
- Related to emergency and restoration plans.

Frequency and restoration are exclusively in the transmission area of interest and therefore they are included only in the transmission codes. The voltage related issues are included in both TSO's and DSO's codes.

2.1 Definition of new network code: Requirements for power converter-based Energy Storage Systems (ESSs) connected to the electricity grid.

As mentioned before, the transition from the present situation of the RES penetration in the power systems to shares up to 100% RES rises many new technical challenges. These are caused by the increasing complexity generated by the increasing number of small and unpredictable generation units, including data handling, control coordination, system services provision etc.

One significant aspect is related to the reduction of the synchronously connected generators in terms of number and capacity and their replacement with converter-based generators. This process is not sustainable for high shares of RES unless it is supported by a significant increase in storage capacities. Therefore, storage facilities, irrespective of the technology they are using (hydro pump storage, batteries, flywheels, super capacitors, etc.), will become a crucial pillar of the power systems operation.

Currently, the aspects related to the storage facilities are addressed in five different existing network codes:

- Requirements for Generators – for the aspects related to the generation mode;
- High Voltage Direct Current Connections – for the converter-based storage facilities;
- Demand Connection Code – for the aspects related to the consumption mode;
- System Operations – for operational aspects in both generator and consumer mode;
- Emergency and Restoration – for aspects related to the participation to the restoration process in generator mode.

By definition, a network code is a collection of rules and regulations (if the case) related to a certain technical activity. The main purpose of a code is to facilitate the understanding of the main legal requirements for operating an activity in that sector. In this context, the present situation for storage, being covered by five different codes, is obviously not favorable.

The main reason for the present approach is that storage was not considered to be significant for the power system operation and it was of an electricity market aspect.

The findings of RESERVE project, presented in D6.1 and MS15, proved that storage facilities will play a critical role in the power systems with up to 100% RES providing several very important ancillary services using several different technologies in the process.

Considering the above arguments, new proposals for networks codes concerning storage facilities are necessary

2.2 New approach for "Frequency Containment Reserve (FCR)"

Currently, in all European countries it is mandatory for all the generators connected to the national power systems to provide Frequency Containment Reserve (previously known as Primary Reserve). Two approaches for reimbursement exist: some of the countries (like Spain or U.K.) are paying a regulated fee for this service, while in the rest of them (like Eastern Europe countries) the service is not reimbursed at all.

The main reason for this situation is leans on the synchronous generators technical characteristics. In case of an imbalance between generation and load in the power system, the rotating masses of the synchronous generators are reacting naturally (accelerating if the generation is bigger than load and vice versa) and the process is very fast. The only concern in this situation is to avoid trespassing the limits of the machine.

The above-mentioned behavior is similar for all synchronous generators irrespective of their primary energy source, rated power, rated voltage, voltage connection level etc. It is therefore natural to mandate all the generation units to provide FCR proportional to their rated power. Nowadays the idea that this service must be reimbursed with a (regulated) fee is more and more accepted.

The replacement of the synchronously connected generators with converter-based generators for RES shares up to 100% has produced two major changes in the existing situation:

a. Converter-based generators do not react naturally to the power system imbalances:

Because of this technical characteristic, the converter-based generators need supplementary investments to become capable to detect the imbalance and react properly. Moreover, the unpredictability of the primary energy source level makes it very difficult from a technical point of view. Therefore, it is very costly to assess and set the appropriate margin for capacity availability dedicated to FCR.

b. The rated power is not relevant for the efficiency of the generation:

From the electricity generation efficiency point of view 10 photovoltaic panels are practically at the same level with 1000 photovoltaic panels. This characteristic made possible the massive development of so-called "roof top" photovoltaic power plants built on different types of buildings in different European countries and raised the issue of the distributed generation.

Considering the above-mentioned facts, one can easily understand that the smaller the photovoltaic park is the more difficult it will be from the financial point of view to perform supplementary investments for providing extremely small amounts of FCR.

The proposal resulted in the RESERVE project is to create the possibility for the small generators to purchase the FCR service from the bigger ones. The procedure for operating this service may be market oriented or fully regulated according to the state policy in this respect.

Moreover, in this new context, the DSO will actively participate with the TSO for frequency control, and will assume competencies and extensive involvement in ensuring the stability and functioning of the network (Fig. 2.1).

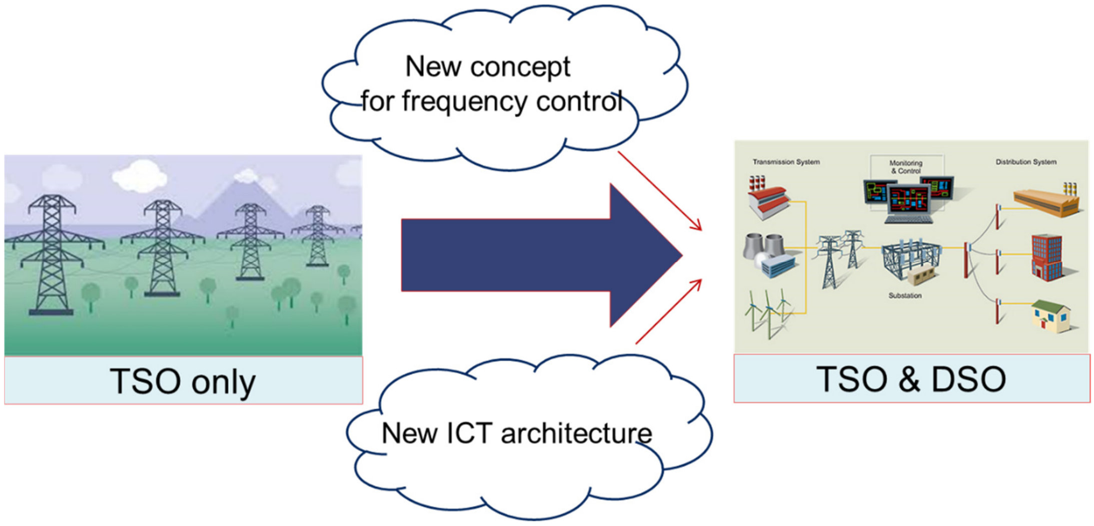

Figure 2.1 Impact of the new Frequency Control concept

2.3 New ancillary service: “Specifications and requirements for linear behavior in swing dynamics”

The future power systems with up to 100% generation from converter-based generators will experience radical changes in system dynamics, control and automation architecture. The replacement of classical synchronous generators with converter-based generators will result in a very low inertia in the power systems with very fast and complex dynamics. This in turn, poses critical challenges in system control, stability and dynamic performance. In this context, new advancements and innovative concepts are required to analyse future system dynamics and tackle with the above-mentioned challenges in order to facilitate a smooth transition towards power systems with up to 100% RES while maintaining a well-controlled, stable and reliable power systems operation.

The Linear Swing Dynamic-based Improved Virtual Synchronous Generator (LSD-VSG) has been developed to take the advantages of conventional synchronous generators, such as generation-system synchronization and inertial response, and tackle its disadvantages represented by the nonlinear characteristics and nonlinear swing dynamics. One of the main results of the implementation of this concept will be a new generation of protection and automation more accurate, faster, more reliable.

The LSD concept consists in linearizing the nonlinear (sinusoidal) power-angle characteristic, which in turn, describes system swing dynamics during power disturbances. The respective LSD control adopts the new (linear) power-angle characteristics and formulation, to be implemented and embedded in the control of RES-tied converters.

These aspects, along with the importance of system frequency dynamics and limits are yet to be carefully investigated, from system dynamics and performance point of view. In this regard, there are different solutions proposed in the literature to achieve a secure and stable integration of RES in low-inertia power systems, such as Synchronverter and Virtual Synchronous Generator.

The Synchronverter (SV) is a converter with a specific embedded control algorithm that mimics the operation of a synchronous generator. The model of a SV derived from the model of a three-phase round-rotor SG as it behaves in the same way, mathematically. The SV has the capability to provide frequency and voltage control through the control of its active and reactive power, respectively. The SV achieves the synchronization with the power grid without a dedicated synchronization unit which is an identical feature of SG. The Synchronverter is composed of two parts: power electronics and control.

The Virtual Synchronous Generator (VSG) is proposed in literature to emulate the SG and provide virtual inertia for system frequency support. It is composed of power and control parts, similar to the SV.

Irrespective of the technical solution used, the linearization of the swing behavior of the system requires a collaboration between the system operator and the converter interfaced generator owner and this collaboration will have the characteristics of an ancillary service. The details of this collaboration will be defined in the next stages of the project and will be presented in deliverable D6.4.

2.4 New ancillary service: “Providing Synthetic Inertia”

The replacement of the rotating masses based synchronous generators with inverter-based generators has many technical consequences and one of the most important of those is the reduction of the power system inertia.

Nowadays the power system inertia is provided by the kinetic inertia stored in the rotors of the synchronous generators. In case of a perturbation (a short circuit for example) the system uses a part of this stored energy (by reducing the speed of the rotors accordingly) from all the synchronous generators connected to the grid in that instant, proportionally with their rated power and electrical distance from the generator to the perturbation location. This wide distribution of efforts helps each of them to maintain the synchronism during the perturbation and after the outage by the protection systems.

The converter-based generators do not have this technical characteristic. Wind turbines have a rotating part but with low speed and reduced mass, and moreover the connection to the grid is performed using a converter so there will be no natural reaction to any perturbation in the electricity network. The photovoltaic sources do not have any moving parts at all so there is no subject for discussions from this point of view.

In these conditions, it is obvious that each replacement of a synchronous generator with a converter-based generator will reduce the kinetic energy stored in the power system. Thus will increase the efforts for each synchronous generator still connected to the grid making more and more difficult for them to maintain the synchronous operation after large outages (this effect is called: reduction of power system inertia).

The synchronous generators operating in power systems with low inertia are in danger of losing their stability after an outage. To prevent this, the synthetic inertia needs to be provided by storage facilities and the stability of the synchronous generators will be restored again (Fig. 2.2)

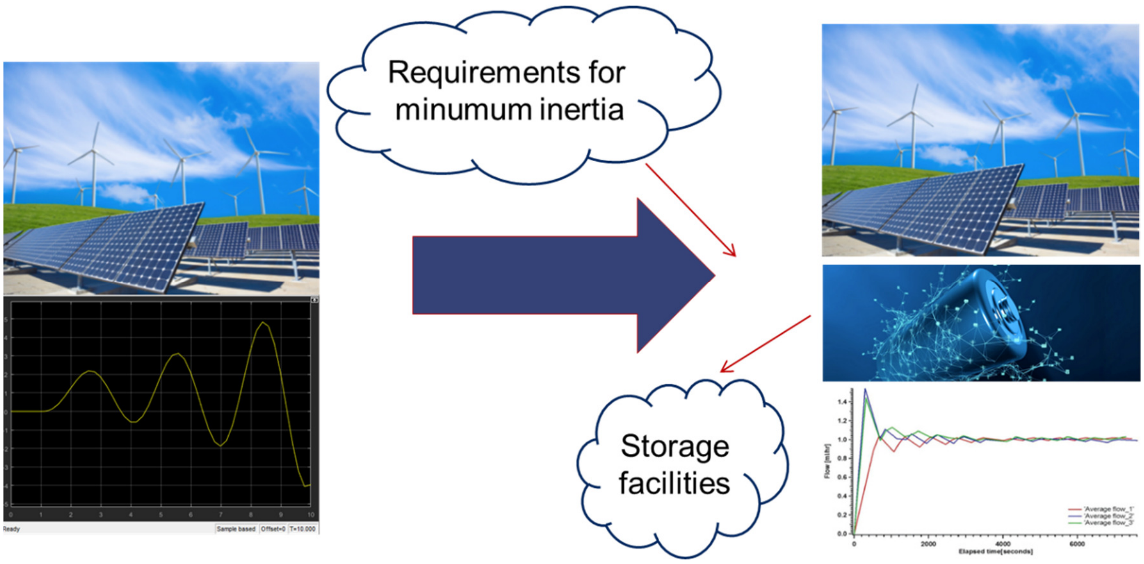

Figure 2.2 Impact of the Synthetic Inertia concept

Simulations and analyses performed in RESERVE have proved that operating the power system with up to 100% RES is practically impossible if it is not maintained with a certain limit of inertia. In order to maintain this limit, the only technical possibility is to require some of the power system actors (usually generators but not only) to provide certain amount of synthetic inertia as an ancillary service.

2.5 New approach for "Voltage Control"

The approach for this ancillary service is well harmonized among European countries as compared with other existing ancillary services.

Only the network operators are the providers for this service: TSO's and DSO's are the only ones reimbursed for it. The payment is fully regulated and it is in fact a fixed amount included in the transmission and distribution tariff assessed by the national regulatory body in order to cover the costs generated by the provision of the service.

The network operators are in charge to maintain the voltage within certain margins (values of the margins are different for some regions like: U.K., Continental Europe, NordPool, etc.). In case they are not compliant, the national regulatory body will charge them with penalties proportional with limits breaches.

The generators are other participants to this service but for them the participation it is more like a penalty. The system operator is establishing a maximum level of reactive energy that it can be provided during an established period (usually per month but it is possible for shorter periods). If the generator provides more reactive power than the maximum allowed it will pay a certain fee per each kVarh over the limit.

Obviously, this system is not appealing at all for both parties: network operators on one side and the other actors of the power system on the other side.

The significant development of the distributed generation makes the prosumers a major player in the voltage control of the power systems with up to 100% RES, changing the present responsibilities of the DSO's (see Fig. 2.3).

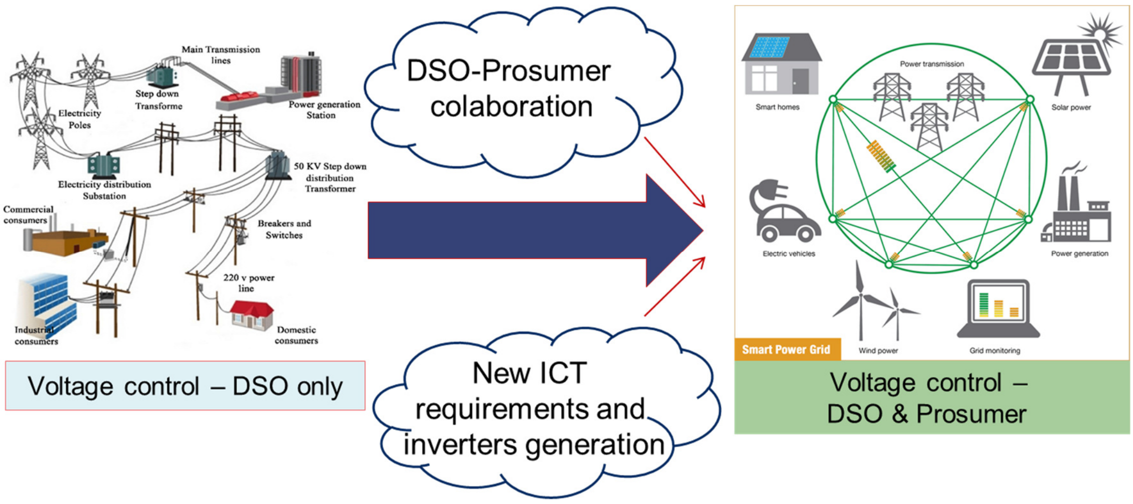

Figure 2.3 DSO-Prosumer collaboration on Voltage control

In the framework of the RESERVE project, two innovative approaches like Dynamic Voltage Stability Monitoring and Active Voltage Management were developed, analyzed and they will be tested in field trials. These new points of view are based with the common idea that in a power system with up to 100% RES there will be a lot of distributed generation at low voltage level and this situation generates new opportunities from the point of view of voltage control.

Basically, RESERVE proposals are creating the basis for a new type of collaboration between the so called "prosumers" (energy user capable of production & consumption) and the Distribution Operators directly or using an aggregator.

According to the national policy, a new market may be organized for this service or it may be a new fully regulated ancillary service.

2.6 New ancillary service: “Providing System Flexibility”

One of the main characteristics of the existing power systems is the full predictability of the generation. Corroborated with small unpredictability of the consumption, one may reasonably consider that the only significant unbalances may occur because of a large generation or consumption outages. Based on this particular aspect, the three-level reserve system was developed: Frequency Containment Reserve (FCR), Frequency Restoration Reserve (FRR) and Replacement Reserves (RR). For Continental Europe, this system is designed to cover an outage of 3000 MW, considered the largest installed generation loss possible following a single cause outage (a single bus bar).

In case of the power systems with up to 100% RES this basic characteristic is about to change dramatically.

The power systems with 15.000 MW or more installed power in RES may face variation in generation going to 5.000÷7.000 MW in a duration of 6hours or less, in normal operational conditions (no outages), because of the weather changes. Not to mention that in case of photovoltaic parks there is a natural variation of about 100% of the installed power, from midday to evening, every day.

It is obvious that in order to increase the percentage of RES penetration it is necessary to increase the capacity of the power system to manage these large and relatively fast variations without reducing the quality of supply.

As a solution for the problem presented above, in the frame of RESERVE project it is proposed to define a new ancillary service: flexibility reserve which will be added to the existing reserve system.

This type of reserve will be activated on longer terms than RR, probably in between 3÷6 hours and it needs to involve large amounts of installed power, much larger than the biggest outage with single cause, possible in the system.

3. Environmental, Economic and Societal CSR Aspects of Different Potential Energy Systems Design

Corporate Social Responsibility is defined by the EU as “a concept whereby companies integrate social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis” [11]. This means firstly that the CSR approach is always the point of view of a company.

Second, CSR means creating some value for aspects the companies are not forced by law. This generates more time and effort. Implementing CSR in the daily business of a company as well as in the behavior of its employees can be seen as a process of sensitization to take into account also the needs of the stakeholder.

3.1 Implementation of CSR in the network codes

CSR is built on three pillars that are Ethics, Environment, and Economy, which focuses on the stakeholder value. Enterprises are challenged to quantify these characteristics. Creating impact on one of these three pillars does not mean to have a visual outcome at the common KPIs of an enterprise.

The change in energy transition towards low mechanical inertia energy systems affects not only the technical part of the energy supply to the people. We are living in a situation of ground-breaking changes. The standard by which the supply of electrical energy is measured by the society and the politics is changing. The 100% security of supply is assumed to be self-evident.

In addition to a low price, there is now a focus on sustainability and environmental compatibility in the power supply sector.

The upcoming energy transition will make disruptive changes in the energy system. Some entities will arise while some must redefine their work. The network codes are giving the fundamental rules for the new architecture of the electricity market. To ensure sustainable growth and socially acceptable changes RESERVE is cross checking the network codes with CSR standards.

This first proposal “New approach for Frequency Containment Reserve (FCR)” has economic and social implications. In addition to the introduction of a new market (that for FCR), this will improve opportunities for small and especially private units to actively participate in the energy market. This is an act of democratization. The possibility to purchase FCR services reduces barriers to market entry. And vice versa, on the new market, energy communities consisting of several small units can also act as suppliers and sell FCRs in the consumer-consumer trade.

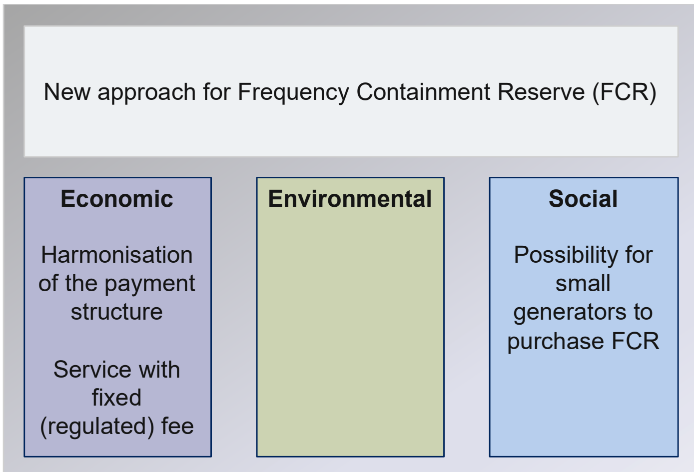

Figure 3.1: CSR aspects on FCR

3.2 CSR aspects related to "Swing Dynamics Linearization" ancillary service

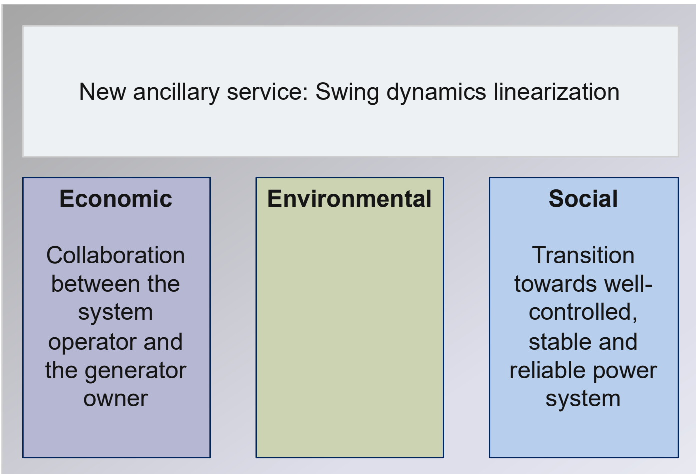

Figure 3.2: CSR aspects to SDL

The second proposal "New ancillary service: Swing dynamics linearization" also has an influence in the economic and social areas. A particularly sensitive area of this proposal is the bringing together of system operators with the private operators of converter-based generators. This step is necessary from both a technical and an economic point of view. Nevertheless, further elaboration should take account of consumer protection. This concerns both an appropriate remuneration for services provided and adequate protection of data security.

CSR in terms of "swing dynamics linearization" covers the aspects of communication between different actors in the energy supply chain. This, of course, has to follow rules, which are set in this network code. Also, the collaboration between energy generator and system operator is helping to make the grid more reliable and stable.

3.3 CSR aspects related to "Providing synthetic inertia" ancillary service

The third proposal "New ancillary service: providing synthetic inertia" has mainly an economic impact. With the introduction of a further ancillary service, another (sub)market is created. This step is indispensable for the economy as a whole. It must be clarified in a further design how such services are to be remunerated and who pays for the costs incurred in this way. The constant expansion of the market to include additional ancillary services must not lead to a financial (over)burden for private consumers. From an environmental point of view, the enabling of up to 100% RES is basically very positive. However, to catch negative effects of a lack of inertia multiple storage facilities are needed. It is needed to consider that the production and recycling of batteries might have also negative consequences to the environment. The goal is to achieve an overall positive impact. This must be considered in regulatory terms.

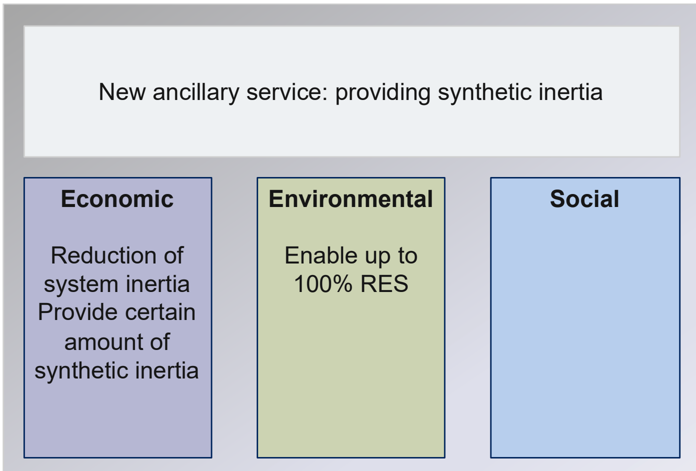

Figure 3.3: CSR aspects to new ancillary services

3.5 CSR aspects related to “Voltage control” ancillary service

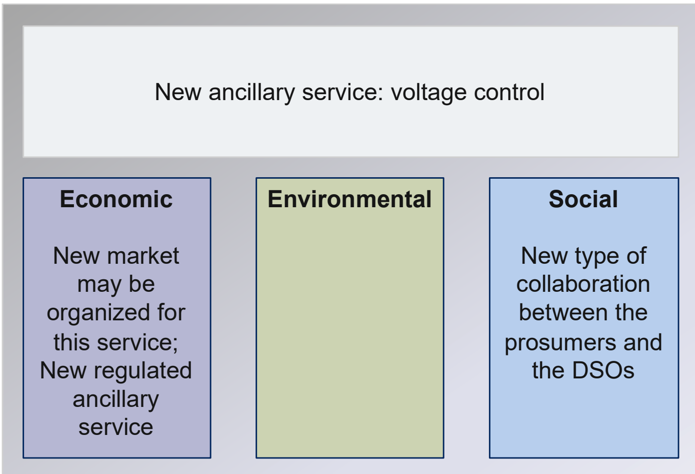

Figure 3.4: CSR aspects to VC

The fourth proposal “New approach for voltage control” has an economic and social impact. Again, it is about a new ancillary service, which is bought on the market. Another positive factor is the greater involvement of private individuals in the market. In principle, they can also benefit from improvements and the containment of T&D losses. Nevertheless, the aspects of consumer protection already mentioned in NC#2 must be taken into account at this point. In particular, the access rights of the DSO must be clearly defined. Clear rules must also be established on the possibility of consumer representation.

Environmental consequences can be positive if the total energy to be generated can be reduced through the reheating of T&D losses indirectly. Voltage control helps not only to improve the market towards a customer centric service model, it also has impact to the balance sheet of DSOs. A better controlling of the voltage can save penalty costs.

CSR in “Voltage Control” helps to make the grid more efficient in terms of energy losses as well as giving the chance to the customer to participate in the stabilization process and lower his own costs in the future.

3.6 CSR aspects related to “Providing system flexibility” ancillary service

The fifth proposal “New ancillary service: providing system flexibility” has an economic and social impact. The basic points of the introduction of an aid remain the same as in the NCs previously discussed. Apart from the above-mentioned advantages and the absolute economic necessity of a functioning and reliable power supply, there are some consequences that need to be assessed. Thus, the build-up of extensive reserves as described above can lead to a large extent of overcapacities. This would then affect both the economic and environmental areas. Economically, a large amount of capital would be tied up in assets.

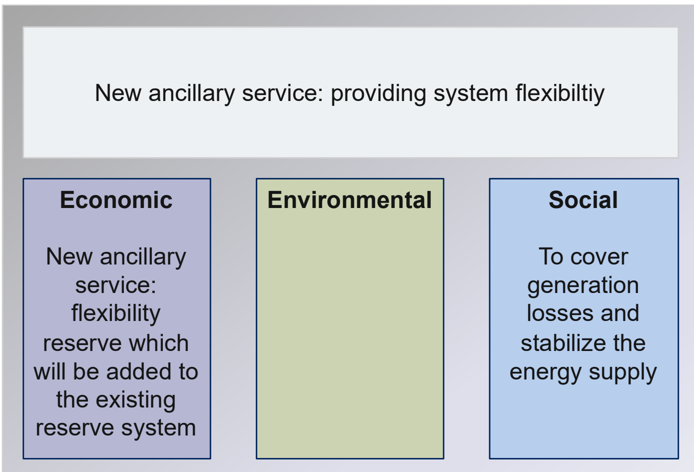

Figure 3.5: CSR aspects to system flexibility

In addition, this overcapacity would have a strong environmental impact in terms of generation, transmission and storage. System flexibility is also important to enhance actors in the energy market to have faster and more efficient trading sequences to avoid penalty fees and re-dispatch costs.

CSR in “Providing system flexibility” covers the consideration of the changes from today’s energy system to a system with a lower share of inertia. But system flexibility means also to connect Europe into one grid system for balancing over capacities and demands for a better reliability.

3.7 Overview of the proposed ancillary services and network codes from CSR perspective

	# of economic impacts	# of environmental impacts	# of social impacts
New approach for (FCR)	++		+
New ancillary service: Swing dynamics linearization	+		+
New ancillary service: providing synthetic inertia	++	+	
New ancillary service: voltage control	++		+
New ancillary service: providing system flexibiltiy	+		+
	Total: 8	Total: 1	Total: 4

Figure 3.6: Overview of the proposed network codes from CSR perspective

Fehler! Verweisquelle konnte nicht gefunden werden. shows the classification of the different aspects of the proposed network codes in RESERVE, which are referring immediately to one of the pillars. Of course, most of the actions are linked to other consequences indirectly. However, if there is no overshadowing outcome of the proposed network code, here is only considered the first implication. As mentioned, Corporate Social Responsibility is clustered in three pillars of economy, environment and society. CSR means the consideration of all aspects equally. It is well known, that the measurement of environmental as well as social aspects is much harder than the financial evaluation of a process.

Taking this into account, RESERVE is controlling the energy transition not only from environmental and social aspects. Up to 100% RES is only achievable if there is also a financial revenue for the actors.

Following this, the low amount of environmental impacts in the graphic is only the primary impact, the suggested network codes have. For instance, RESERVE suggests the implementation of Swing Dynamics Linearization. First, this has an impact on the economic part of entities. Because voltage control will become easier to control and needs less power electronics. Second, this enables a reliable and stable grid in the future. But this has also indirect consequences on the environment. The new technology enables the energy generation on local level. Transmission losses will be reduced, and the energy efficiency will rise.

In addition, RESERVE proposes network codes on a Pan-European level. Harmonization will generate economies of scale and enable a new market structure for energy in general and for ancillary services in particular.

RESERVE ensures the sustainable growth of the energy sector and a transition towards 100% RES which involves stakeholder of the supply chain of electrical energy. The proposed network codes are cross-checked with the CSR strategy of the project.

4. Proposals for changed network codes definitions

- Adoption of reference Scenarios;

Initial definition: In the frame of RESERVE project four different scenarios were developed. Network codes could "adopt" them as reference scenarios, i.e. ending points of the evolution of the European system by specifying the year at which 100% RES-electricity is expected.

- Distribution system - frequency control;

Initial definition: Frequency scenarios focus more on HV and MV networks

i. Different architectures of communications have been suggested in this project, for inertial, primary and secondary control. One of the aspects to be clarified is if distribution system will help the frequency control or not. If not, (as in case of decentralised control managed by TSO), there is no necessity to define VPP (Virtual Power Plant) or micro grids as potential actors.

ii. From the point 3.a.i, the different actors participating in the control should be deeply described, in terms of technical and market requirements

iii. Importance of data integrity, for avoiding lack of information

iv. Indication where and how to install the metering units, control units and so on (also highlighting problems due to intentional attacks to the system)

- Distribution system - voltage control;

Initial definition: Voltage scenarios developed in RESERVE project focus essentially on LV networks. Within Deliverable 1.3 (within the Appendix on page 78) there is the mention of the EC Article 29.1 Network codes and the ranges note for HV: the ranges mentioned are 0.90 pu to 1.118 pu for connection points between 110 kV and 300 kV stations and for connections between 300 kV and 400 kV the range is 0.90 pu to 1.05 pu.

- Requirements of minimum system inertia;

Initial definition: In the special circumstances of up to 100% RES, from regulatory authorities must be an assignment to the hydro power plants to allow maintaining a higher inertia in operation. For the power system operator, recommended practice for maintaining mechanical inertia into the system is advisable.

- System swing dynamics;

Initial definition: In the frame of RESERVE project it is studied the concept of Linear Swing Dynamics (LSD) that will result in a linear dynamical system with new requirements and roles in RES-tied converters' control and frequency regulation. The nonlinear swing equation is an intrinsic form that represents the mechanical dynamics of synchronous generators. This form interprets the nonlinear swing dynamics caused by the electromechanical oscillations in a synchronous generator. Also, it is used in the control design, frequency regulation and stability analysis. However, in systems with up to 100% non-synchronous generation, new style of system swing dynamics will appear. This is not discussed in the ENTSO-E existing network codes.

- Expanding the frequency control strategy to allow using small-sized and/or intermittent energy resources;

Initial definition: Two types of control procedures are currently defined: the decentralized control specific to the primary frequency control, and the centralized control specific to the secondary frequency control. In the future, a diversity of control procedures may be required. For example, the distributed control is introduced. The distributed control refers to the coordinated control within a regional network, including both generation sources and loads, as a low level control in the centralized scheme. This control strategy refers to the Virtual Power Plant and Micro grid concepts.

The implementation of these concepts will require standardization of their operation in relation to the network operator in the grid codes, such as: communication type; reserve monitoring; QoS monitoring and coordination.

- Requirements for the HVDC systems;

Initial definition: In the power systems with up to 100% RES the HVDC systems will have new requirements that respect the technical constraints and specifications of each AC network. Furthermore, HVDC systems should provide synthetic inertia to the disturbed AC network without compromising the frequency stability of other HVDC-connected AC networks. These activities will definitely consider the coordination between HVDC system owners and the respective TSO.

- Recommended settings for the controlled units;

Initial definition: Recommendation regarding the coordination between inverters characteristics for frequency control and droop values is advisable. This is important to achieve coherency into the interconnected power system.

- Requirements for new behaviour of RES inverters;

Initial definition: In the context of decentralised control, the control command received from a tertiary level or from a Micro grid operator might be set points for real and reactive power in a conventional sense. However, the methods developed in RESERVE project, envisions a case where the higher level might modify the behavioural of inverter. By behavioural we mean the control parameters themselves.

The examples used in this project to support the above mentioned statements are the following:

  - The Dynamic Voltage Stability Monitoring (DVSM) (SV_A) functionality which resides in the SSAU would send control commands back to the VOI controller, which will in turn modify the control parameters of the inverter to achieve the set-point impedance. Hence, the behavioural of inverters are modified here and since the SSAU sends these commands, the DSO grid codes must allow it.
  - The Active Voltage Management (AVM) (SV_B) technique modifies the Volt-VAr curves of the RES inverter. Hence the concept of Volt-VAr curve definition for house RES inverters must be included into the grid codes.

- New requirements for the perturbations injected from RES inverters;

Initial definition: Grid codes should be formed related to the injection of white noise signal into the grid voltage for a short duration. The white noise signals, otherwise known as Pseudo Random Binary Sequence (PRBS) is generated in the control loop of the inverter, where the duty cycle or current/voltage reference are perturbed. This induces perturbations on the output voltage and current of the inverter for impedance measurement. In the frame of RESERVE project, we will determine magnitude of perturbation required for accurate determination of impedance and injection time period that is required for the noise injection and propose them for new grid codes.

- Dynamic Stability margins;

Initial definition: Hence for the futuristic grids, we propose the inclusion of dynamic stability margin definitions. Additionally, we envision through our work to determine minimum dynamic stability margin limits or thresholds that the system must possess.

- ITC chapter in network codes;

Initial definition: The ITC issues are spread among the network codes text and a dedicated chapter will allow a better understanding of the requirements. Along with the increasing of the RES penetration in the power systems the operation of these systems will become more and more complex and therefore the requirements for ITC will become more and more detailed and difficult to coordinate.

5. Conclusions

It is already known that the process of increasing the RES penetration in the power systems up to 100% raises a lot of technical challenges for operation while keeping the same level, or even better, quality of services.

RESERVE project focuses on the challenges related to the frequency and voltage control in this context, pointing out not only the technical aspects but also regulatory, environmental and corporate social responsibility.

The modeling and simulations performed so far in the project have supported the general conclusion that increasing the share of the converter-based generators and while reducing the share of the synchronous generators (as a counterpart) will cause stronger dynamics occurring in the power system with more complex control actions.

To properly handle the above-mentioned challenges and facilitate the transition between the existing situations to the targeted one, the most important mean to be considered is the necessary new regulations and ancillary services or the updates required by the existing ones.

Based on the work developed in the project at this stage 6 proposal where developed, as follows:

- Definition of one new network code related to storage;
- Updating the definition for two existing ancillary services: frequency containment reserves and voltage control;
- Three new ancillary services: swing dynamics linearization, providing synthetic inertia and providing power system flexibility.

Initial definition, the most significant substation aspects and brief description of each proposal are presented in the Chapter 2 of this document.

Based on the aspects presented in this document one may draw two other important conclusions:

- A new generation of converters will be needed in the near future: smarter, faster and more flexible in operation.
- The relationship between TSO's and DSO's will have to adapt to the effects of the distributed generation generalization.

From CSR perspective, RESERVE is helping to make the grid more efficient and reliable. The network codes cover the most important aspects of the changes in the energy transition, after evaluation of the consortium. Thereby it is important to check all network codes if they do not affect any counterproductive consequence of the energy transition. Like it can be seen above, all suggested network codes are covering at least one aspect of sustainable growth directly. Furthermore, no stand out negative consequence could be identified. Of course, energy transition is bringing up a lot of changes. Some of them are disruptive. The clustered needs written down in network codes assure a sustainable growth respecting the needs of the society first.

6. List of Figures

7. References

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8. List of abbreviations

TSO	Transmission System Operator
DSO	Distribution System Operator
EC	European Commission
RES	Renewable Energy Systems
WP	Work package
D	Deliverable
MS	Milestone
CSR	Corporate Social Responsibility
ESSs	Energy Storage Systems
FCR	Frequency Containment Reserves
AC	Alternative current
DC	Direct current
EU	European Union
LSD	Linear Swing Dynamic
SG	Synchronous Generator
VSG	Virtual Synchronous Generator
LDS-VSG	Linear Swing Dynamic-based Improved Synchronous Generator
SV	Synchronverter
FRR	Frequency Restauration Reserves
RR	Replacement Reserves
ENTSO-E	European Network on Transmission System Operator in Electricity
GW	Gigawatt
HV	High voltage
MV	Medium voltage
KPI	Key Performance Indices
NC	Network Code
T&D	Transmission and Distribution Losses