No 727481 RESERVE

D6.2 v1.0

Regulatory, governance and legal issues of the transition towards 100% RES

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement no 727481.

Contractual Date of Delivery	30.09.2019
Actual Date of Delivery	30.09.2019
Authors	Dan Preotescu, Mihai Mladin, Mihai Paun (CRE),
Participant	CRE, UPB, RWTH
Work package	WP6 – Regulatory, legal issues & business models for RES
Security	PU
Nature:	Report
Version:	V1.0
Total number of pages:	23

Abstract

The increase in electricity generation from renewable sources proves to have a higher dynamic impact than estimated in the most favorable forecasts of this trend. The scenario of gradually increasing the penetration of RES (Renewable Energy Sources) in the power systems up to 100% causes several technical challenges regarding stability and, implicitly, balancing energy systems, but also regulatory challenges to sustain this new energy context in a coherent way.

The results of the project's research on the technical aspects of frequency and voltage control, with the objective of balancing energy systems, taking into account the current energy market context, implicitly lead to a resumption of key regulatory principles and further to a series of necessary changes to the regulatory framework.

This second version of the deliverable that deals with regulatory issues has as its starting point the initial proposals of the first version. These have been the subject of both advanced technical research and extensive consultations and debates with relevant stakeholders as TSOs, DSOs, national regulatory authorities, European regulatory organizations, including ENTSOE (European Network of Transmission System Operators for Electricity). Withal, interacting with European Commission representatives and reporting to the requirements and recommendations of the new energy rulebook "Clean energy for all Europeans package" was another important milestone in both the redesign of key regulatory principles and the modification and prioritization of the set of technical proposals, which are found in this final version of the deliverable.

Keyword list

Regulatory principles, Methodology, Network Codes, Technical proposals, Prioritization criteria "Clean Energy for all European Package"

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.

This deliverable focuses on the regulatory aspects of possible updates of the existing network codes and ancillary services, but also on the elaboration of new ones, with a special focus on network codes related to requirements for voltage and frequency regulation and power systems inertia. Withal, updating and defining the key regulatory principles in position to underpin the development of the future regulatory framework on the way "up to 100%" RES integration in the power system, it is also a central point of the deliverable content.

Based on an exhaustive analysis of the current context regarding network codes, existing technologies, trends, technical and legislative challenges and, last but not least, the signals sent by the European Commission, we have redefined the key regulatory principles of governance framework for the future electricity networks.

On the strength of our further project research work on the technical challenges, taking into account the above mentioned key regulatory principles and the feed-back obtained from consultations with relevant authorities and stakeholders, we have gone through the second iteration of the RESERVE proposals and have prioritized them.

The RESERVE proposals briefly mentioned in this deliverable will be the subject to more detailed descriptions in the second version of the deliverable "Definitions of Ancillary Services and Network Codes" – D6.4.

At the time of the submission of this deliverable, the final version of the RESERVE list of proposals and their prioritization are already in the attention of the relevant authorities, that are in the position to further consider them and to follow the implementation procedures.

Authors

Partner	Name	e-mail
CRE		
	Dan Preotescu	dan.preotescu@crenerg,org
	Mihai Mladin	mihai.mladin@crenerg.org
	Mihai Paun	mihai.paun@crenerg.org
UPB		
	Lucian Toma	luciantomaro@gmail.com
RWTH		
	Kai Kappner	kappner@controlling.rwth-aachen.de
	Philipp Weidinger	weidinger@controlling.rwth-aachen.de

Table of Contents

1. Introduction

The European Commission (EC) regulation defines a set of network codes. These codes are driven to harmonization, integration and efficiency of the European electricity market. On the other hand, Network Codes were developed within the period when RES target was 20%.

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.

Furthermore, according to recent targets adjustment published by the EC in the context of the strategy “Moving towards a low carbon economy”, this 20% RES threshold must be reached by next year (in 2020), and by 2030 the target proposed by the EC is 32% RES.

This dynamics and proximity to the moment when the current configuration of network codes and ancillary services will show its limits, imply a clear need for solutions to the technical challenges, mainly for frequency and voltage control, and a new perspective over the key regulatory principles of governance framework for the future electricity networks.

1.1 Objectives

This deliverable has the following two main objectives:

- To propose a set of key regulatory principles, referred to as “options”, to be considered when determining the appropriate governance framework for the future electricity networks
- To propose an updated list of technical proposals in the area of network codes and ancillary services based on the information provided by the latest tests and research in the technical area of the project, as well as on the information gathered from the consultations with relevant institutions, organizations and other stakeholders.

1.2 Outline of the deliverable

In the next chapter which follows the introduction it is included a brief presentation of the current trends and recent developments regarding the relevant technologies and network codes for the power sector, in the EU interest area, that have been considered during the project works.

The third chapter of the deliverable is presenting the redefinition of key regulatory principles identified in the project framework, to be recommended to the stakeholders, in order to enable a smooth transition toward 100% RES in the power systems while maintaining the quality of the service and the financial affordability at end-user level.

Facing the large number of technical and regulatory aspects that must be updated, according to the calculations, simulations and findings of RESERVE project, it proved useful to perform a prioritization among the proposals. Chapter 4 is dealing with this issue presenting in detail the list of criteria used for priority list identification, the prioritization methodology and the results of this methodology implementation.

Chapter 5 includes a synthesis of the results and findings of the RESERVE project from the regulatory framework point of view. This chapter can be seen also as a list of main ideas to be remembered, disseminated and exploited after the finalization of the project.

1.3 How to read this document

The present document is the second version (V2) of the deliverable D6.1 which was developed and finalized in March 2018 and includes the most significant developments noticed in the interest areas, starting with above mentioned date and nowadays. However, the authors took care to include in the present deliverable all the relevant aspects so that the reader may fully understand the ideas, results, findings and proposals, without necessarily read the first version (D6.1).

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 D2.7 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 converter-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 D3.7 and D3.9.

For the specific analysis of each proposal, and the impact from the CSR, business models and policy recommendations perspectives, a determinant role has the content of the deliverables D6.6 and D6.7.

Finally, the dissemination and consultation activities carried out in WP7, and included in the D7.2 and D7.3, have helped to refine these proposals. (Fig. 1.1)

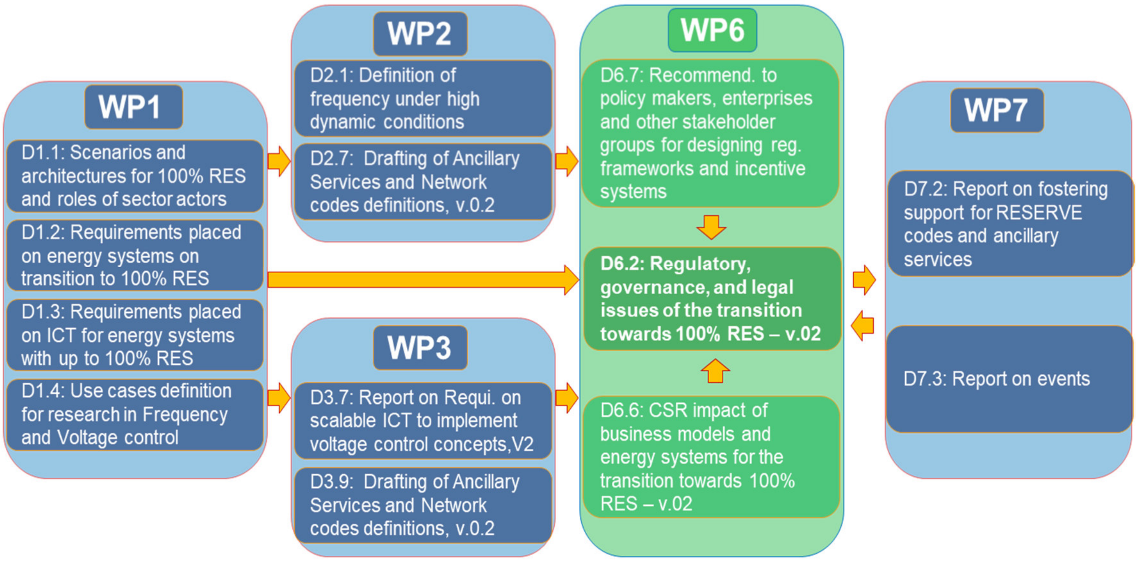

Figure 1.1 Information flow between work packages and deliverables

2. Updates on the current status and trends of Network Codes and the legislative framework

Nowadays there is a constant concern regarding the implementation of the latest technological advancements and trends in the existing regulatory framework at European level. In the following are briefly presented the trends in the technology advancements and the current status in EU legislation development, namely the so called “Winter Package”.

2.1 Trends in technology advancement

The advancement in the hardware and software technology is possible because of the significant development in the IT&C technologies. More advanced laboratories can support the development of improved solutions with the help of IT&C. While the materials science and chemistry are outside of this deliverable, we will focus of the immediate drivers that are involved in frequency and voltage control, as well as other adjacent power system applications.

The main purpose of RESERVE project is to find solutions that help maintaining the power system stable and reliable under increased share of renewable energy sources. Three main categories of technologies help achieving the RESERVE goals, i.e. energy storage systems [1], power electronics [2], and advanced information and communication technologies [3] (Figure 1). Algorithms and methodologies are then implemented to coordinate the control of frequency or voltage independently or together, while aiming at achieving the economic use of resources.

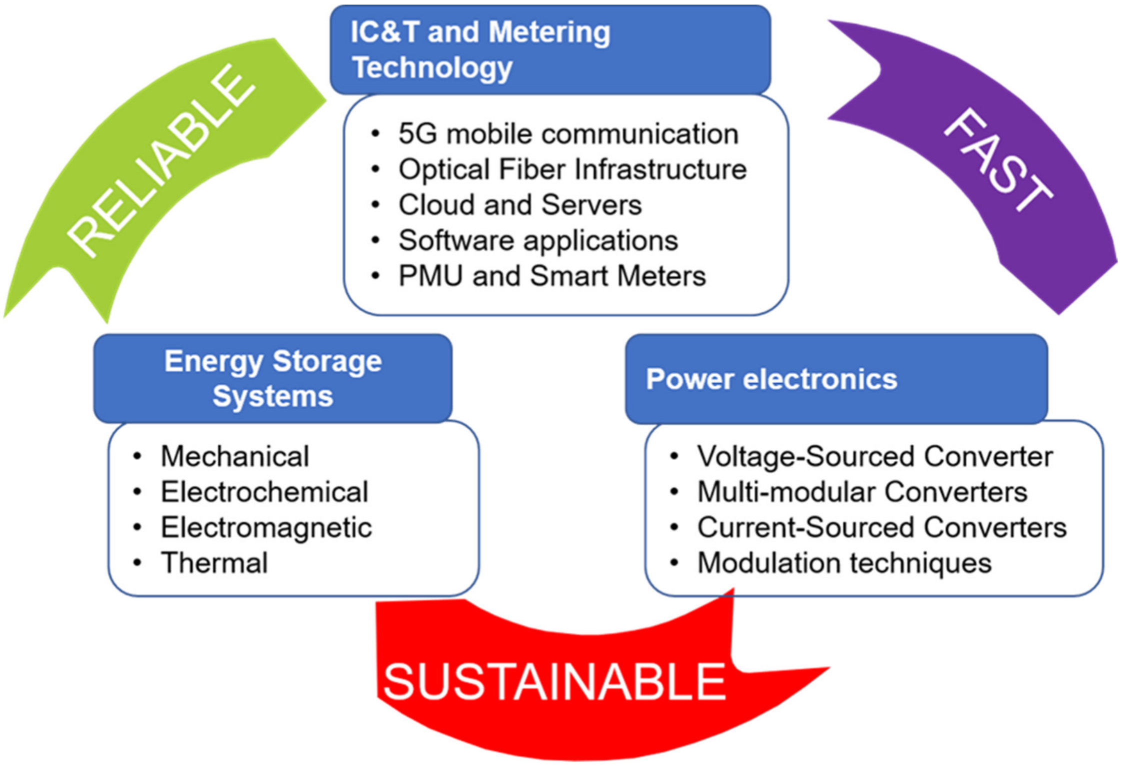

Figure 2.1 Emphasises of the most advanced technologies relevant for RESERVE project.

From the power system point of view, the effectiveness of the solutions proposed in RESERVE is qualified in terms of the quality of service based on the technical and economic requirements identified for each solution. Three direction can be defined when intended to quantify the services:

- **Fast**

Both frequency and voltage stability can be ensured by fast acting response in providing active and reactive power. Energy technologies that can respond very quickly (following detection and identification), with response time ranging from 10 ms and 100 ms are: Lithium batteries, Flow batteries, Lead-acid batteries, Super capacitors, Flywheels, HVDC, and some type of loads.

Some technologies are already mature while others need financial support to become attractive in the near future. The latest statement refers to the fact that today technology is advanced and can be successfully employed to support the theoretical solutions; the drawback comes from the high costs, which, as for most technologies, can be significantly reduced in time by incentives provided today.

The response of the energy services depends also on the signal measurement, processing and transmission. Fast detection and identification of threshold quantities are today possible by means of *PMU* devices integrated into *WAMCS*. We have shown in deliverables D5.4 and D5.5 the importance of PMU and WAMCS in identifying frequency instability conditions by analyzing multiple sets of data provided by Transelectrica.

While the transmission networks are relying on optic fiber, *5G mobile communication* is essential in handling a large number of energy resources in distribution networks, as recommended by the frequency control solutions presented in WP2 and voltage control solutions presented in WP3. The work done in WP5 of this project has proved the feasibility of the 5G technology in providing fast communication between the controlled resources and the aggregators.

- **Reliable**

In the RESERVE context, reliability refers to both the continuous / uninterrupted power supply to the customers and the stability of the power system. The first category may or may not involve network integrity. Seen from the transmission network point of view reliability may also refer to system security. However, when referring to the uninterrupted power supply to the customers we may have to understand the meaning of the system adequacy term.

Under the increased risk of natural phenomena with strong impact on the electrical networks, the philosophy of power system operation should be changed, in the sense that isolated operation of portions of the distribution grids. In order to support these ideas, besides the IC&T technologies, deployment of flexible and reliable resources is needed, such as *wall-mounted batteries*, *electrical vehicles*, *loads capable to provide demand response*, and others. In the RESERVE project we are supporting the use of *microgrid* (MG) and *virtual power plant* (VPP) as enables that support the increase of the share in the renewable energy sources (RES).

Additionally, we have briefly approached the Solid-State Transformer (SST), in support to the H2020 Storage4Grid project, to demonstrate that deployment of smart solutions can eliminate a series of technical problems, especially the frequency control. Frequency is a quantity specific to synchronous systems. The power electronic technology has significantly advanced at all levels of the distribution grids, which means that both energy sources and most of the loads are connected to the grid *via power electronic converters* (PEC). PECs are immune to a wide range of frequency variations, and the only problem in their control is the voltage. However, with appropriate voltage sources capacitors, *asynchronous microgrids* can be inhered with a strong ride-fault grid capability.

One of the solutions developed in RESERVE is the *Open Sources Inverter* (OSI), that can be customized with appropriate software tools, easy to install, for any type of control. Even if the OSI capabilities were successfully demonstrated for voltage control, implementation on various equipment intended for frequency control is also possible.

- **Sustainable**

While sustainable energy means “that the use of energy meets the needs of the present without compromising the ability of future generations to meet their own needs” [1], sustainable development of the electrical network may refer to “adopting smart solutions, in both infrastructure and control algorithms, to support large integration of renewable energy sources”. Besides the already mentioned technologies, the intelligent of the energy resources, under increased share of generation from small RES units, will be possible by using big data algorithms, cloud computing, blockchain based transactions and as such [3].

2.2 The wide deployment of storage systems, both as individual units and as components of other entities (e.g. EV) will allow reducing the energy lost from RES as applied today by generation curtailment to meet network technical requirements. Current state on adoption and implementation of Network Codes (CRE)

Each year, the European Commission draws up an 'annual priority list' of areas to be included in the development of network codes for electricity, with input from a public consultation. The Commission, with further input from the Agency for the Cooperation of Energy Regulators (ACER) and the European Network of Transmission System Operators for Electricity (ENTSO-E), adopts proposals for network codes. The proposals for network codes are checked by an Electricity Cross-Border Committee of specialists from national energy ministries and then adopted with the approval of the Council of the European Union and the European Parliament.

Sometimes the new rules are adopted as 'guidelines' rather than 'network codes.' These are adopted under a different provision of the Electricity Regulation but they have the same status – they are both legally binding regulations.

With reference to the current state of the art, ENTSOE Member States' efforts have focused on complying with existing provisions in the context of the eight network codes adopted at European level and this process has been completed.

Having regard to the European Commission’s intention to prioritize the correct implementation of existing network codes and guidelines and to the replies to the public consultation supporting this intention, there are no plans to develop new network codes or guidelines in 2019. Therefore, the European Commission will not issue a decision establishing an annual priority list identifying areas to be included for the development of network codes in 2019. This is without prejudice to the work that the European Commission may undertake regarding the amendment of existing electricity network codes and guidelines, following the adoption of the new Electricity Regulation.

The current status on existing network codes alongside with the estimation of the impact level of RESERVE project on each of the codes (strongly or weakly influence), based on the updated RESERVE proposals, are indicated in the table below:

Table 2.1 Estimation on impact level of each of the existing codes

Network Code family	Network Codes	Status	Impact level of RESERVE project on each code
Connection codes	Requirements for Generators	Adopted	very strong
	Demand Connection	Adopted	significant
	High Voltage Direct Current	Adopted	very strong
Market codes	Capacity Allocation and Congestion Management	Adopted	significant
	Forward Capacity Allocation	Adopted	significant
	Electricity Balancing	Adopted	strong
Operation codes	Emergency and Restoration	Adopted	strong
	System Operations Guidelines	Adopted	very strong

2.3 EU legislation – “Clean energy for all Europeans package” (CRE)

The EU has agreed a comprehensive update of its energy policy framework to facilitate the transition away from fossil fuels towards cleaner energy and to deliver on the EU’s Paris Agreement commitments for reducing greenhouse gas emissions.

The completion of this new energy rulebook – called the **Clean energy for all Europeans package** - marks a significant step towards the implementation of the energy union strategy, adopted in 2015.

Based on Commission proposals published in November 2016, the Clean energy for all Europeans package consists of eight legislative acts. After political agreement by the Council and the European Parliament in 2018 and early 2019, enabling all of the new rules to be in force by mid-2019, EU countries have 1-2 years to transpose the new directives into national law.

The changes will bring considerable benefits from a consumer perspective, from an environmental perspective, and from an economic perspective. It also underlines EU leadership in tackling global warming and provides an important contribution to the EU’s long-term strategy of achieving carbon neutrality by 2050.

With a view to showing global leadership on renewables, the EU has set an ambitious, binding target of 32% for renewable energy sources in the EU’s energy mix by 2030. The recast renewable energy directive entered into force in December 2018.

The RESERVE scenario "up to 100% renewables" is getting closer in time and is increasingly part of the European Commission's concerns, and the initiative to set higher targets for RES penetration has even occurred during the implementation period of the project through this document "Clean Energy for All Europeans Package".

3. Key regulatory principles of governance framework for the future electricity networks – final definition

Achieving the ambitious goal of up to 100% RES in the European power systems will require a long period of time (probably several decades) and a lot of efforts, both intellectual and financial, but part time operation with 100% RES is not so far away. In this respect it is necessary as soon as possible, to identify a set of key principles of the governance framework to be used in the future electricity networks.

Based on the calculations and simulation performed in the frame of RESERVE project we have identified several key principles that have to be considered in designing the governance of the future configuration and operation of the power networks.

3.1 Efficiency of the investments and costs

It is well known that in the power sector all the costs are in the end included in the energy price and therefore covered by the end-user. In the same time, maintaining an affordable and sustainable electricity price on long term is a major goal for all EU members.

In these conditions it is very important to optimize the adopted technical and regulatory measures in order to achieve the maximum impact for the safety in operation of the power systems with minimum impact for financial aspects.

3.2 Collaboration at regional level

Natural resources are not equally distributed among EU members and therefore it is necessary to increase the collaboration beyond the national borders, in order to make full use of the existing capabilities. The cost for the activities necessary for the day-to-day operation of the power systems must be optimized at a regional level rather than national level as is today.

Putting in practice of this principle will require in the first place the harmonization of the regulatory and legislative framework among EU members and in the second-place development of regional structures like control and coordination centers able to provide a proper resource transfer when needed.

3.3 Transparency and predictability

One of the most important results of the unbundling was the development of many companies and firms, private or state owned, linked together in a very intricate activity. In many cases, the economic interest of these legal entities was contradictory, or they were in a direct competition for providing services or resources.

Obviously, the society interest is to support the development of those entities that are helpful for the power systems operation and to restrain the development of the entities that are only taking advantage of different administrative of regulatory mismatches, thus increasing for not good reason the electricity prices at end-users level.

Providing a transparent and predictable regulatory and legal framework will help the existing or potential investors in the power sector to develop business plans sustainable on long term and, as a result, the electricity price will be under control.

3.4 Priority

Taking into consideration the complexity of the power systems and electricity markets operation and the challenges generated by the transition from nowadays situation to up to 100% RES it is very important to accurately identify the priority scale of the necessary measures.

It is well known that a good rule may have bad results if it issued to early or may have no results if it is issued to late (or something in between) so the timing of the regulations is of outmost importance.

A proper identification of the priority and sometimes urgency of a measure will bring benefits from both: time point of view (by reducing the overall duration of the process) and financial point of view (by effectively supporting the next steps and thus reducing the costs of the whole process).

3.5 Long Term Continuity

The transition process from the existing situation (20% RES penetration in the power systems) to up to 100% RES must be designed as a whole. Taking into account the long period of time foreseen to accomplish this goal it is necessary to make sure that measures taken in the first stages, although apparently useful at the moment, are not hindering the implementation of future stages by becoming obstacles that must be removed.

In this way of thinking, every step must be coordinated with the existing and future conditions and necessities so that both to be answered properly.

3.6 Societal acceptance and involvement

According to the understanding of the RESERVE project working team, this is the most important principle that must be followed in order to achieve a successfully and smooth transition process up to 100% RES in the power systems.

Acceptance and involvement of the population must not be approached separately because they are intrinsic connected. Acceptance will bring more involvement and more involvement will bring more acceptance supporting in this way the process development.

Based on the experience gained so far in implementation of the RES into the power systems one can easily see that the above-mentioned principles are not independent of each other and also, they are connected in a hierarchical structure, as presented in Fig. 2.

The most important principle proved to be “Societal acceptance and involvement”. Failing to follow this principle will, most likely, lead to significant difficulties in implementing the necessary measures, no matter how sound they justified from the technical and economical point of view. On the contrary, the action plans developed according to this principle proved to be much more easily and even cheaper to be put in practice.

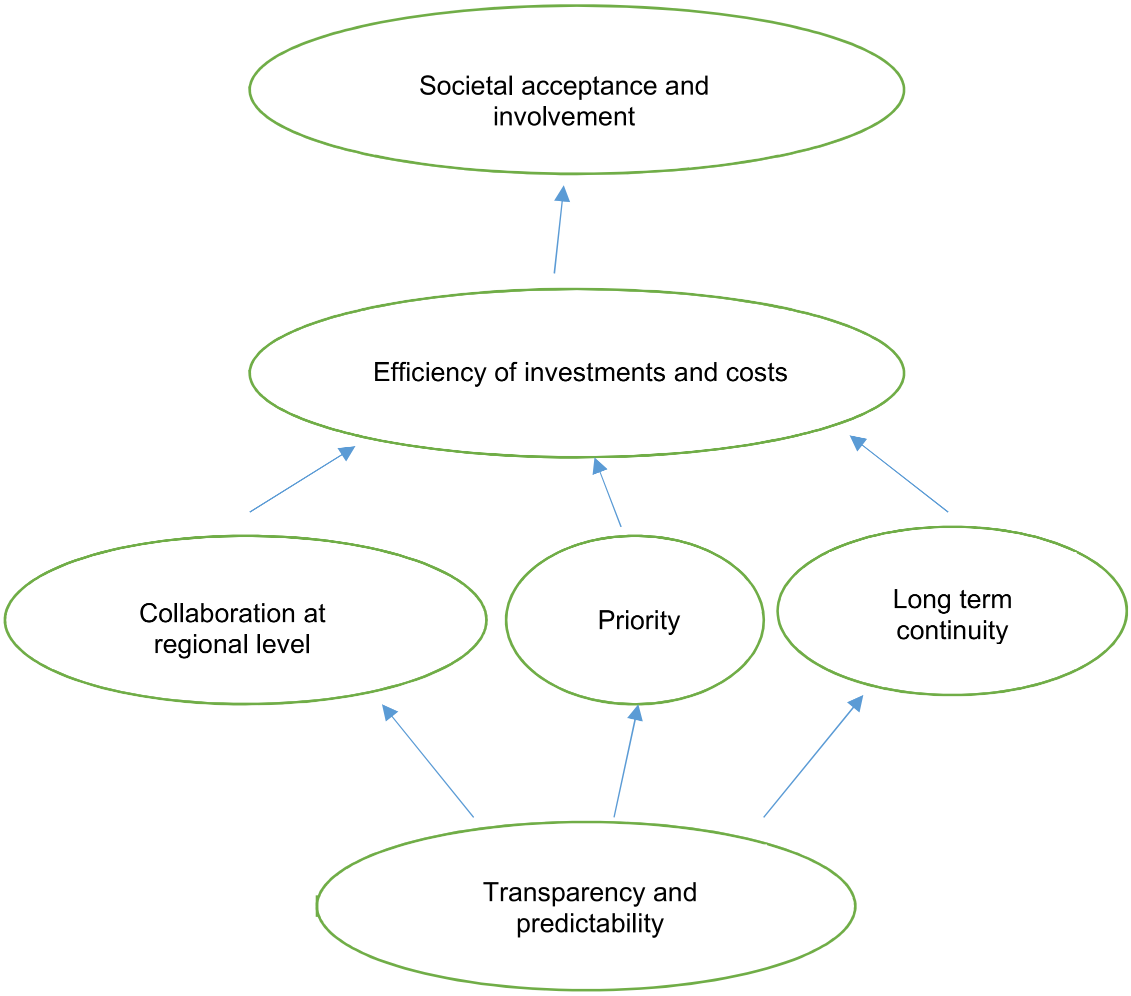

Figure 3.1 Hierarchical structure of the key regulatory framework principles

4. RESERVE proposals evaluation and prioritization

Based on the calculations and analyses performed in the first part of the project, the initial list of proposals has been developed and included in the D6.1. Continuing from that point, in the second half of the project implementation new proposals where added and new improvements have been performed to some of the previous proposals, up to the final list included in this deliverable.

The proposals resulted from RESERVE project may be grouped in the following categories:

- New network codes;
- New ancillary services;
- Changings in the definition of existing ancillary services;
- New definitions to be included in the network codes.

4.1 Updated list of the proposals in the scenario "up to 100% RES"

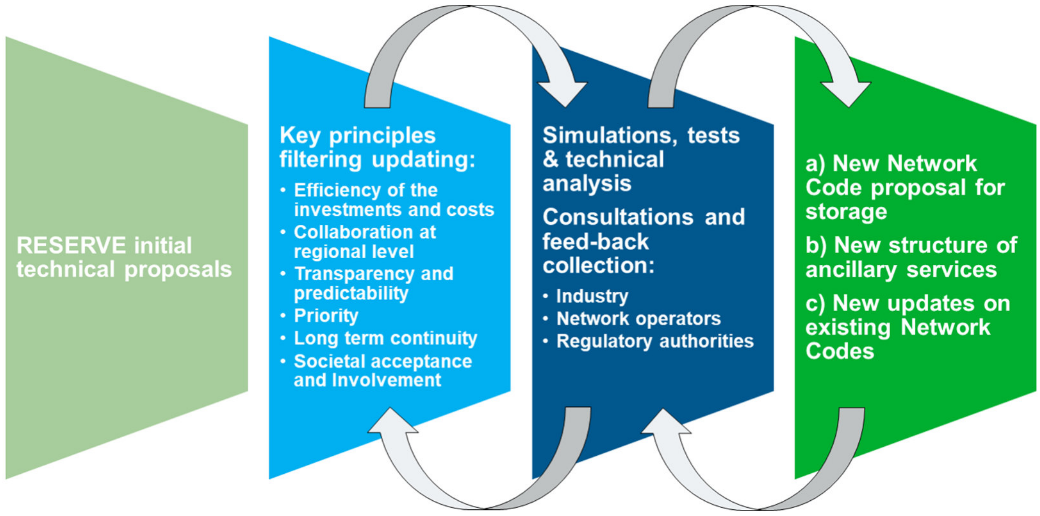

Figure 4.1 Initial technical proposal

The list of proposals is the following:

- New transmission network code (eventually new chapter in the distribution codes): Requirements for Energy Storage Systems (ESSs) connected to the transmission grid.
- New approach for frequency containment reserve.
- New approach for voltage control.
- New approach for defense service.
- New approach for restoration service.
- New ancillary service: requirements for linear behavior in swing dynamics.
- New ancillary service: providing RoCoF control.
- New ancillary service: providing automatic frequency control reserves.
- New ancillary service: providing system flexibility.
- New ancillary service: providing reactive power for voltage control.
- New ancillary service: providing active power for voltage control.
- New ancillary service: providing input signal for frequency controllers.
- Update of existing network codes: adoption of reference scenarios.
- Update of existing network codes: distributed frequency control.
- Update of existing network codes: distributed voltage control.
- Update of existing network codes: requirements of minimum system inertia.
- Update of existing network codes: system swing dynamics.
- Update of existing network codes: expanding the frequency control strategy to allow using small-sized and/or intermittent energy resources.

- Update of existing network codes: recommended settings for the controlled units.
- Update of existing network codes: new requirements for the perturbations injected from RES converters.
- Update of existing network codes: ICT chapter.
- Update of existing network codes: new requirements for frequency measurement.
- Update of existing network codes: RoCoP definition.

A detailed presentation of the proposals and the related rationales are included in D6.3 and D6.4, developed in the framework of this project.

4.2 Methodology and evaluation criteria (CRE and RWTH)

Increasing the RES penetration up to 100%, in the Power Systems is an ambitious goal and as it is shown in the previous chapter requires many changes and updates of the existing regulatory framework in order to properly implement the technical characteristics of the new technologies. In these conditions it is only natural to establish a priority order among these proposals.

In the first stage of the prioritization process it was defined a set of criteria, as follows:

- **RES implementation effectiveness**.
  All proposals are meant to support the increase of RES in the power systems but some of them are more effective than others, from this point of view and this criterion has the purpose to mark the differences if any, between the proposals.
- **Cost effectiveness**
  It is well known that in the power sector all the costs are covered by the end-users, therefore it is very important to assess accurately the economic impact of the measures proposed based on technical reasons and rationales. In case the implementation costs of a proposal are higher than economic benefits generated by the respective proposal (could be many reasons for that situation, for example if the necessary technologies are not mature enough and others) it is advisable to postpone the implementation of to search for another approach.
- **Urgency of implementation**
  Nowadays the generators based on RES are using convertors to connect to the grid, except hydro-generators. This technical characteristic made them difficult to operate in parallel with classical, synchronous rotating machines, generators because of the technological differences. The increase of the convertor-based generator up to significant levels requires implementation of new regulations and techniques. Obviously, some of these new approaches are required also at lower levels of RES penetration, some of them are required only at higher levels, therefore this criterion differentiate the proposals from this point of view.
- **Long term efficiency**
  This criterion has the scope to identify which proposals are more effective on long term, in the sense that their implementation is actually a basis for the new steps and not only a specific solution for short term. Also, an important aspect is to identify the (if any) the proposals that are useful at a moment but they might become a burden in the future, at higher levels of RES penetration. This criterion is based on the general principle that is easier (and/or cheaper) to prevent than to correct.

A grade from 1-5 is applied with *expert view* for each criterion:

- 1: not relevant or low impact
- 5: highly relevant or high impact

It can quote 2 or more different proposals with the same grade if it is considered appropriate.

The evaluation process is done in a filter way, each layer includes one criterion. In order to pass to the next layer, an average grade should be higher the 5. And the final layer of urgency of implementation is to show when it should happen.

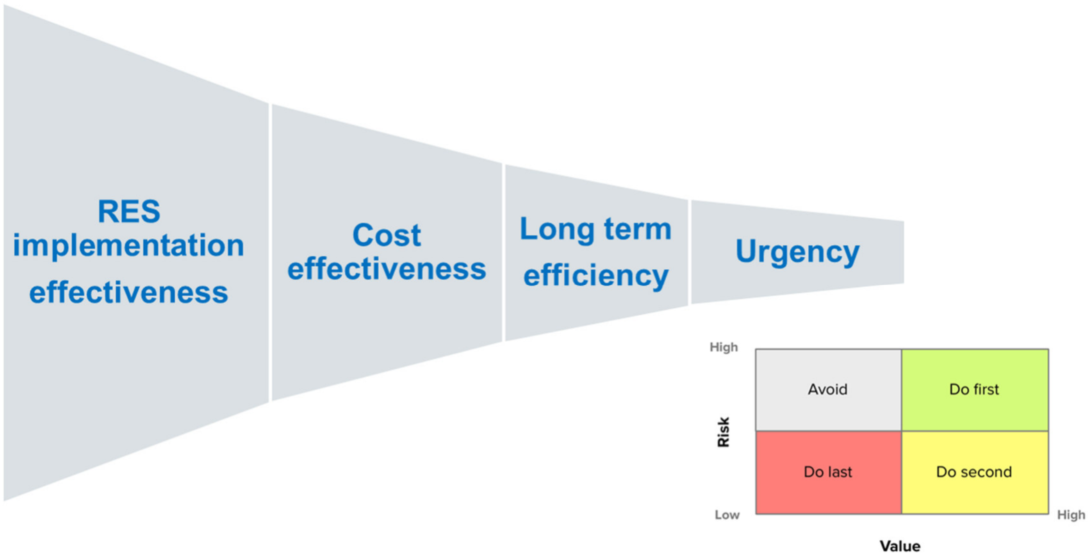

Figure 4.2 Evaluation process of Priority List

The prioritisation is done by a group of experts representing work packages from 1 to 6 of the RESERVE project. According to his or her justification, the experts will give grades for each proposed item.

The results are average grades which experts give.

4.3 New set of priorities

The methodology presented in the previous paragraphs was put in application on the list of proposals developed in RESERVE project. The representatives of all Consortium members were required to assign a mark between 1 and 5, for each proposal. Number 5 signifies high priority and importance and 1 signifies the lowest priority and importance.

The results of this process are presented in Annex 1 – "Prioritization results".

Obviously, the analysis was performed separately for each proposal's category:

- New network codes,
- New or updated ancillary services,
- New or updated definitions in the existing network codes.

The first category includes only one proposal so prioritization is not possible but the marks received by the proposal (3.79 – see Annex1) proved that this proposal it is considered both important and urgent by all participants in the prioritization process.

In the first rank of the ancillary services category is the proposal for a new approach for Frequency Containment Reserves (FCR). This result seems logical because:

- It is easy to implement: no need for supplementary equipment just regulatory changes,
- It may be performed in the near future,
- Facilitates the development of the distributed generation.

Providing synthetic inertia is in the second rank of this category. The main reasons for this high rank position are the following:

- In order to be implemented it will require a new generation of converters, able to provide that service fast, accurate and by remote control.
- Without synthetic inertia it will be simply not possible to increase the penetration of converter-based generation (as is the case for most of the significant RES powered generators) because of the power systems stability limitations.

In the third rank it is an existing ancillary service that has to be approach differently in order to become a really strong facilitator of the distributed generation. The massive development of the prosumers will make the voltage control, as it is performed nowadays, to become increasingly not effective. In these conditions a new approach it is needed and in the RESERVE project few solutions were developed.

The proposal in the fourth rank shows the necessity for expanding the existing power system reserves structure in order to overcome the foreseen large variations on the generation side, as a result of large amount of wind and photovoltaic powered generation.

The positions starting with fifth rank are all necessary and strong facilitators for up to 100% RES, the lower marks received are reflecting the timing issue: they are becoming effective with higher RES penetration percentages than existing nowadays and therefore can be implemented in later stages.

The high marks received by the proposals from the “Update of the existing network codes” category proves that almost all of them were considered by the specialists involved in the prioritization process, both significant and urgent.

The top priorities are dealing with similar issues as the ancillary services category: synthetic inertia, distributed generation with impact on the frequency and voltage control, perturbation containment etc.

The simulations and tests performed in the framework of RESERVE project have proved that in the power systems with high level of RES penetration the speed of the physical phenomenon it is significantly increased. Also, the frequency, which is nowadays used for almost all the monitoring, alarming, protection and automatization systems, will no longer be in the position to provide proper signals. In these conditions, new approaches must be considered and RoCoP it is one the available solutions.

The proposal to include a chapter or section (if necessary) in the existing and future network codes, dedicated to the ICT aspects it is ranked on the third positions. This proposal is in accordance with the latest and foreseen for the near future evolutions from the power systems and it is a very strong facilitator for the distributed generation and so called “smart grid” actions.

Like the ancillary services category, the proposals not included in the so called “top five” must also be considered as significant but probably more effective in future stages of the RES powered generation development.

5. Conclusions

The increase of the electricity generators powered by RES (considering that with few exceptions this type of generators are converter-based machines), penetration up to 100% rises a large number of challenges, in all significant aspects of the power systems operation: technical, regulatory, economic etc.

RESERVE project has focused on two of the most important technical aspects of the power systems: frequency and voltage control; identifying all the impacts generated by this evolution (up to 100% RES in power systems), proposing technical solutions, checking the economic sustainability and identifying the necessary updates of the regulatory framework in this respect.

As presented in the paragraph 1.3 – “How to read the document”, the present report is a continuation of D6.1 and includes the findings, details and conclusions developed in the frame of the project, from the beginning till the end.

First of all, a set of key principles necessary for supporting up to 100 % RES penetration, were identified and presented in the Chapter 3.

The simulations, tests and analyses performed in RESERVE project have showed that frequency control strategy need to change significantly along with the massive increase of the converter-based electricity generators.

In the same context, voltage control must find new solutions to properly face the foreseen large development of the distributed generation connected at medium and low voltage.

The large number of necessary updates (see paragraph 4.1) of the existing regulatory framework took the specialists involved in RESERVE, to the conclusion that it is difficult to implement all in the same time, therefore a prioritization is necessary. Chapter 4 of this report is presenting the methodology used for prioritization and the results of the its application on the list of proposals developed in RESERVE.

The proposals may be grouped in 3 main categories, as follows:

- New network codes,
- New or updated ancillary services,
- New or updated definitions included in the existing network codes.

The prioritisation methodology results were analyzed separately for each category. Obviously, in case of the new network codes, being only one proposal, no prioritisation is possible. Never the less the marks received by the proposal are providing that the specialists working in RESERVE project consider this proposal both important and urgent.

Achieving the goal of up to 100% RES in power systems requires significant changes in the regulatory framework: 11 proposals for new or updated existing ancillary services and 11 proposals for updating the existing network codes have been developed in RESERVE.

Considering the ancillary services category, new approaches for Frequency Containment Reserves and Voltage Control, and a new ancillary service: Providing Synthetic Inertia have been considered as the most important and urgent measures needed to facilitate the increase of RES penetration up to 100% in the power systems, in the near future.

Synthetic inertia issues, ICT requirements and problems related to the distributed generation (regarding frequency and perturbations) are in the “top five” of the proposals for the updating the existing network codes.

Taking into consideration all the aspects presented in Chapter 4 of this report, the specialists involved in RESERVE project concluded that in the near future a new generation of converter must be put in operation. The new converters must be able to handle more technical aspects than the present one, like: providing synthetic inertia, voltage control, frequency control and others; also, they have to be able to do that faster and following remote control.

6. List of Figures

7. References

[1] Regulation (EC) No 714/2009: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009R0714&from=EN

[2] https://ec.europa.eu/energy/en/topics/wholesale-market/electricity-network-codes

[3] IEA - Global EV Outlook 2017, on-line: https://www.iea.org/publications/freepublications/publication/GlobalEVOutlook2017.pdf Accessed September 2017

[4] IEC 61851-1:2017 - Electric vehicle conductive charging system - Part 1: General requirements

[5] Integration of Renewable Energy in Europe – 9011-700 – 12 June 2014: https://ec.europa.eu/energy/sites/ener/files/documents/201406_report_renewables_integration_europe.pdf

[6] C.-C. Liu, S. McArthur, S.-J. Lee, *Smart Grid Handbook*, Wiley & Sons, 2016.

[7] Blockchain – an opportunity for energy producers and consumers?, PwC, https://www.pwc.com/gx/en/industries/assets/pwc-blockchain-opportunity-for-energy-producers-and-consumers.pdf

[8] http://eur-lex.europa.eu/resource.html?uri=cellar:fa6ea15b-b7b0-11e6-9e3c-01aa75ed71a1.0001.02/DOC_1&format=PDF

[9] Integrating Renewable Electricity on the Grid – American Physical Society – R eport by APS panel on Public Affairs: https://www.aps.org/policy/reports/popa-reports/upload/integratingelec.pdf

[10] ENTSO-E website

[11] COMMUNICATION FROM THE COMMISSION concerning Corporate Social Responsibility: A business contribution to Sustainable Development, Commission of the European Communities, Brussels, 2nd July 2002.

[11] European Commission, “Clean Energy for all Europeans package”, May 2019: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans

[1L] X. Li, S. Wang, A Review on Energy Management, Operation Control and Application Methods for Grid Battery Energy Storage Systems, CSEE Journal of Power and Energy Systems, Electronic ISSN: 2096-0042, pp.1-15, 13 June 2019.

[2L] R. Teodorescu, M. Liserre, R. Pedro, Grid Converters for Photovoltaic and Wind Power Systems, Wiley, 2010.

[3L] C.-C. Liu, S. McArthur, S.-J. Lee, *Smart Grid Handbook*, Wiley & Sons, 2016.

[4L] https://ec.europa.eu/eurostat/statistics-explained/index.php/Archive:Monitoring_sustainable_development_in_the_European_Union

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