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First Report on Project Progress

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Abstract:

This document provides an overview of the plans and progress of the RESERVE project between its start on 1st October 2016 and 31st March 2018.

Keyword list:

5G, Mobile communications, Renewable Energy Source (RES), Voltage Control, Frequency control, simulation, co-simulation, hardware in the loop, field trial.

Disclaimer:

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

Executive Summary

The RESERVE project aims to enable up to 100% RES based power generation (excluding hydro-electric power) and to propose changes to network codes and ancillary services to enable the techniques developed in the project to be deployed.

RESERVE is well on the way to achieving this objective through its development of new techniques for voltage and frequency stabilisation. RESERVE has developed two innovative research approaches, Linear Swing Dynamics (LSD) and Virtual Output Impedance (VOI), enabling the stabilisation of voltage and frequency in energy systems with little inherent inertia. The development of the techniques is supported by inter-disciplinary research on ethical business models for energy systems, based on 100% use of RES.

The new techniques will be validated in simulations and small-scale field trials in Ireland and Romania. To enable large scale co-simulation, we have created a pan-European multi-site simulation test-bed, bringing together the best simulation facilities in Europe. The testing infrastructure also includes a 5G ready mobile network as Hardware in the Loop. The changes needed to existing definitions of network codes and ancillary services to enable the use of the new techniques will be defined and if needed, new codes and services will be proposed. The structure developed by RESERVE will accompany European utilities in their challenging journey towards the complete de-carbonisation of our energy sector.

In the first 18 months of its 36 months planned duration, the RESERVE project has undertaken the definition of representative scenarios for the transition to up to 100% RES, has developed the research approach of Linear Swing Dynamics (LSD) and Virtual Output Impedance (VOI), has developed, tested and internationally deployed the software and procedures needed to enable large scale co-simulation of power networks including the use of 5G-ready hardware in the loop, has prepared a field trial in Ireland and laboratory trial in Romania and has undertaken a wide range of stakeholder interaction and general dissemination activities. Additionally, the ICT implications and the business model implications of the new techniques have been investigated and defined.

The use of the RESERVE co-simulation software and approach for the trans-Atlantic co-simulation of frequency balancing between Europe and the US was an early major success story for the RESERVE project and it attracted widespread media coverage, including TV coverage in the US.

All goals for the period were achieved and all deliverables and milestones due were delivered. Exploitation plans for project results have recently been updated.

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1. Introduction

Future energy systems will use renewable energy sources to minimise CO2 emissions. Currently large generators powered by fossil fuel turbines maintain the stability and quality of energy supplies through their inertia. The inertia of these generator-turbine groups gives providers a significant time window for reacting to network events. We urgently need to find ways to stabilise energy systems with up to 100% RES (where inertia is often lost due to power converter mediated energy transfer) to generate "RESERVEs" so that society can relax in the knowledge that it has a stable and sustainable energy supply.

The RESERVE project will enable up to 100% penetration of renewables by developing innovative approaches to system level automation based on innovative ancillary service provision with a close to market level of maturity, supported with validation of the concepts and policies using a pan-European real time simulation Infrastructure, anchoring the approach with the main sector actors in Europe and beyond.

Energy systems with high levels of RES integration will require new distributed energy and ICT system architectures and will need to integrate the use of 5G ICT into the design of ancillary services to ensure system stability. The focus of the RESERVE project is to prepare the way for new harmonised ancillary services with harmonised network codes, which are needed to operate RES based energy systems. We will do this by developing new concepts to ensure system stability and undertaking feasibility studies and trials of elements of these concepts and their implementation in 5G ICT-enhanced solutions. One example of a 5G capability which will allow increasing the stability and reliability is the creation of dedicated network slices for such critical infrastructure communication services.

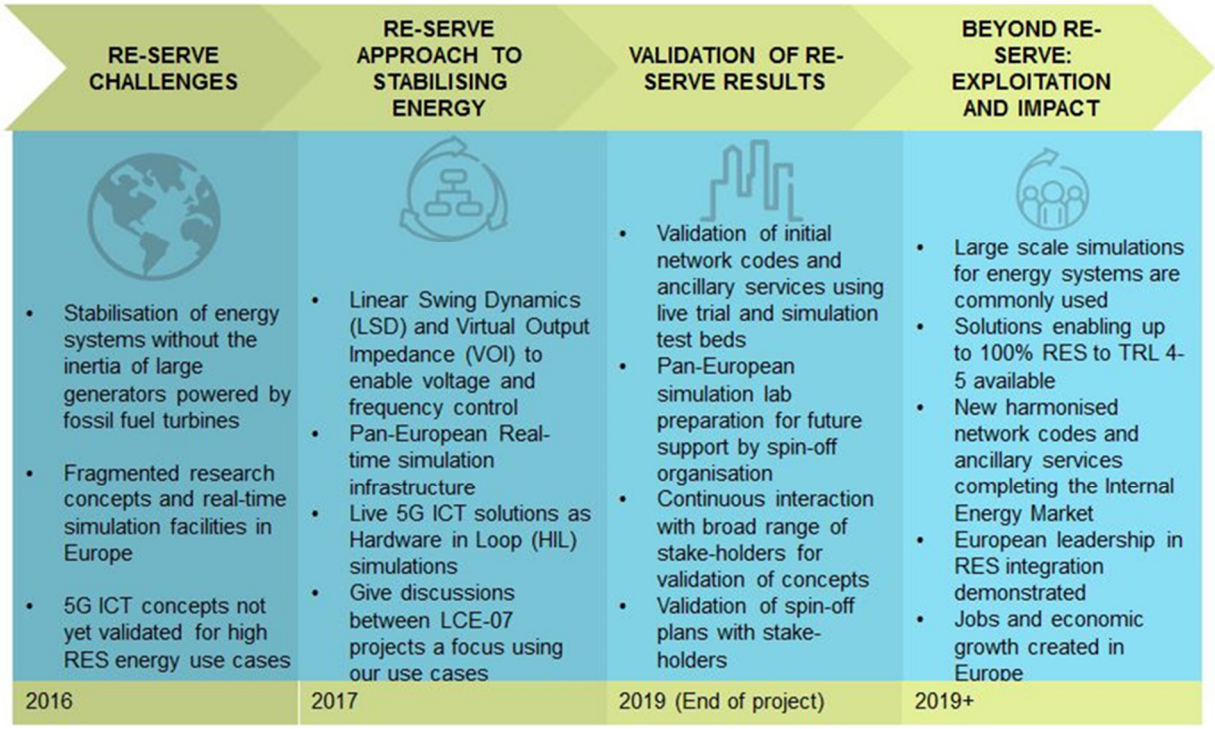

Figure 1 - From challenges through to preparing exploitation of results

1.1 The RESERVE approach to addressing the RES challenge

RESERVE will address this challenge by researching new energy system concepts, implemented as new system support services enabling distributed, multi-level control of the energy system using pan-European unified network connection codes. Near real-time control of the distributed energy network will be enabled by innovative 5G ICT. Energy system use case scenarios supplied by energy providers will form the basis of energy system models. Performance characteristics of the new control mechanisms will be investigated through integration of energy

simulations and live 5G communications. We will create a pan-European multi-site simulation test-bed, bringing together the best facilities in Europe.

RESERVE will achieve its strategic objective of enabling the integration of up to 100% penetration of renewables into the energy generation mix by

- Developing the novel research concepts of Linear Swing Dynamics (LSD) and Virtual Output Impedance (VOI),
- Validating the concepts through an innovative pan-European real time simulation infrastructure and
- Developing a set of harmonised regulations and network codes, supported by the sector actors and realised as field trials.

RESERVE is addressing the RESERVE strategic challenge through:

- Putting dynamics both for voltage and frequency control, taking into account the role and characteristics of power electronics, at the centre of our research,
- Basing work on a bottom up approach and fully decentralised approach. Such an approach follows the characteristics of the decentralised future energy system and also means that the approach can be progressively adopted supporting transitions in energy systems,
- Proposing a new way to address the transition, monitoring the evolution of the system, using advanced real-time modelling, capable of supporting future decision-making processes,
- Incorporating innovative and social responsible innovation using to a Corporate Social Responsibility approach as a complement to technical studies,
- Involving all the key-stakeholders in the process from the beginning,
- Proposes a vision of exploitation that shows clear impact well beyond the duration of the project creating new opportunity for competitivity for the energy sector in Europe, and
- Proposes the right mix of laboratory and field trial to get immediate, concrete and realistic information on the real-life implementations enabling the immediate application of the knowledge generated in the project in the day to day work of utilities.

The RESERVE concepts take the energy community from today's traditional dispatchable generation energy systems through research, simulations and field trials and the preparation of enhanced definitions of network codes and ancillary services for consideration as potential harmonised European codes and services, to an energy system based on the use of up to 100% RES generation, as illustrated in the figure below.

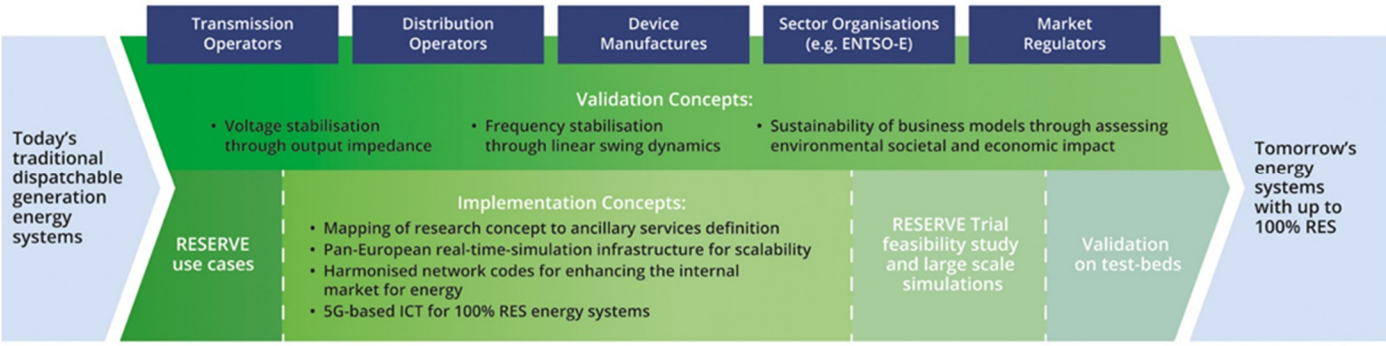

Figure 2 RESERVE concepts and approach

RESERVE has prepared a field trial of voltage control in Ireland. Tests using this infrastructure will start shortly. A laboratory trial of frequency control in Romania has started and the use of the RESERVE co-simulation software for co-simulation, including 5G-ready hardware in the loop, has

already been operational for some time. A series of tests using the infrastructure has started. The figure below illustrates the key locations preparing the field trials and testing the initial co-simulation infrastructure.

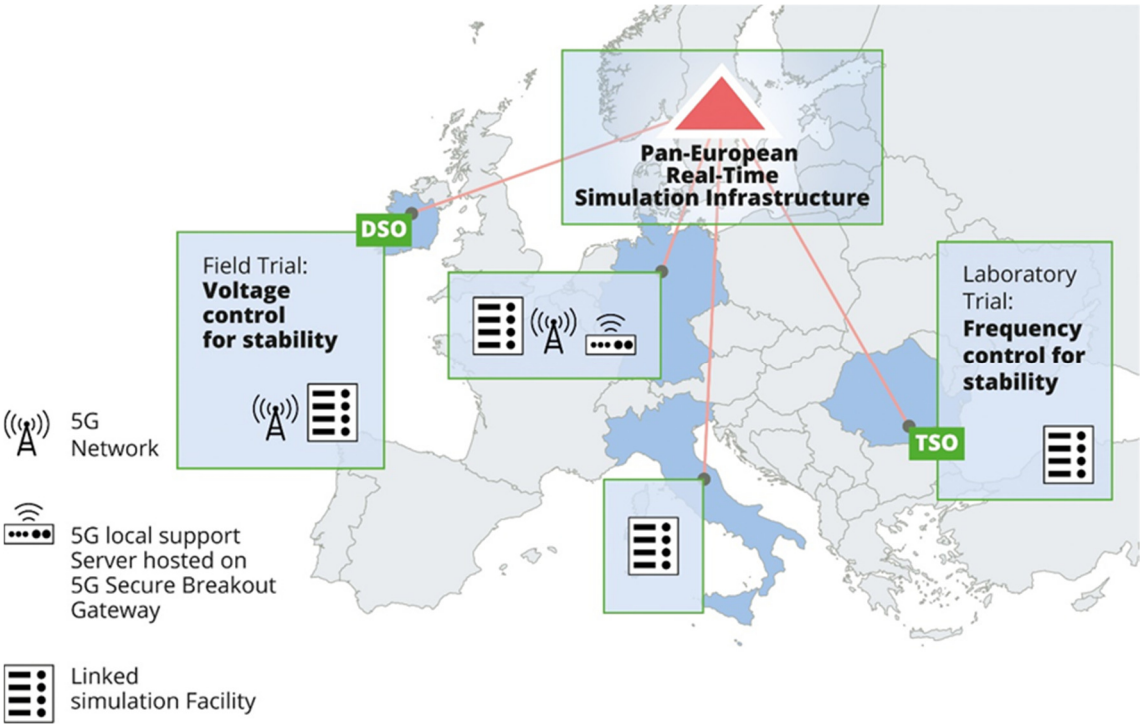

Figure 3 - RESERVE Field and Lab Trials

1.2 Work undertaken by the RESERVE project and main results achieved

RESERVE is producing a framework for stabilising energy systems with up to 100% RES integration, expressed as:

- A set of new research concepts for fast voltage and frequency control,
- New ethical business models to support 100% RES integration in today energy systems,
- A pan-European real-time simulation infrastructure, implemented as the interconnection of facilities at 4 universities, to validate the fast frequency and voltage control concepts during the project, and to support, after the end of the project, regulators and energy stakeholders in general in defining the energy transition process,
- Guidelines on the implementation of a new structure for Ancillary Services together with the corresponding measurements required to enable the European Internal Energy market to the completed,
- An adaptation and harmonisation of today's network codes to support the implementation of the new structure of Ancillary Services,
- Demonstration of fast voltage control in a live field trial on the Irish power network, which shall show increased overall distribution system utilisation, supporting an increased penetration of distributed renewable energy sources (increasing load –> reduce wind curtailment).
- Feasibility study of fast frequency control based on real time hardware in the loop experimentation, and laboratory small-scale demonstration emulating the Romanian network use-case,
- Requirements on 5G ICT for supporting energy systems with up to 100% RES integration, for promotion in standards bodies in the energy and communications sectors, and

- A spin-off company providing services and support for pan-European real-time simulation facilities.

In the period up to 31st March 2018, the RESERVE project has achieved the:

- Definition of representative scenarios for the transition to up to 100% RES,
- Development of the research approach of Linear Swing Dynamics (LSD) and Virtual Output Impedance (VOI),
- Development, testing and international deployment of the software and procedures needed to enable large scale co-simulation of power networks including the use of 5G-ready hardware in the loop,
- Preparation of the field trial in Ireland and laboratory trial in Romania,
- Undertaken a wide range of stakeholder interaction and general dissemination activities,
- Investigated the ICT and business model implications of the new techniques, and has
- Published its initial results.

All goals for the period were achieved. All deliverables and milestones due were delivered and future goals for the project are on track to be achieved by the end of the project.

1.3 Expected impact of project results

RESERVE is creating impact through the:

- RESERVE research concepts, implemented using the latest 5G ICT technologies, and promoted as ancillary service definitions to ENTSO-E/ACER and as an input to the definition of harmonised network codes will solve the energy sector issue of providing a stable power supply using RES,
- RESERVE new ancillary service definitions will enable energy providers to integrate high levels of RES to complete the European Internal Energy market as defined in the SET plan of the European Commission,
- RESERVE is providing the software needed to connect to our novel pan-European real-time simulation platform and our Dynamic Phasor solver as Open Source code creating the capability of capitalising on the availability of computational resources across Europe to create a unified virtual simulation environment, enabling much larger scale energy system simulations than are currently possible,
- RESERVE demonstrations of research results at TRL levels 4 and 5 in laboratory experiments and in field trials are creating confidence in the energy sector community that our techniques are applicable to today's and future energy systems,
- RESERVE contributions to regulations and network codes will provide the basis for scalable deployment of solutions and demonstrate European leadership in RES integration internationally,
- RESERVE results will create jobs in the service operations of the partner organisations and contribute to job creation in European based energy sector actor organisations, in the ICT and energy sectors,
- RESERVE results will unlock new markets, mostly for innovative SMEs, in implementing new energy services based on the innovative RES integration concepts and the new automation and monitoring concepts, and
- Partner organisations aim to increase their revenue streams and market shares by providing new innovative services to the energy sector which leverage the results of the RESERVE project.

The contribution RESERVE makes to society, the economy and integration, at EU level, is illustrated in the figure below.

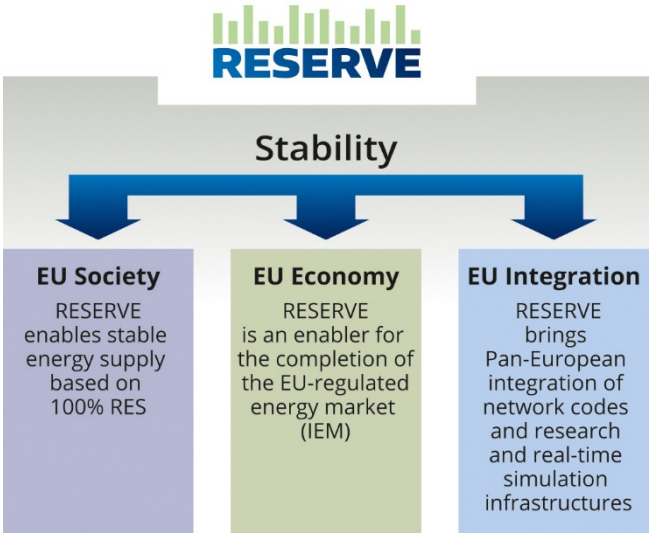

Figure 4 - The RESERVE strategic impact targets at EU level

2. Main achievements

2.1 System Level Work for RES integration

The objectives of this work are the definition of future scenarios with high level of RES penetration, enabling to highlight the most important aspects for the voltage and frequency control in the future power system. The definition of the scenarios needs the deep understanding of the features composing the scenarios, such as:

- Components
- Functions
- Information
- Communications

One of the key points arisen by drafting the scenarios was the difference between a system based only on full-converter generators, and a system based on a mix of generator technologies. Both cases are essentially based on RES, but in the former case no inertia can be guaranteed by the generators connected to the system, whereas in the latter one a mechanical inertia related to the use of hydro power plants can be taken into account.

Based on the above points, two scenarios for the frequency control have been defined, called SF_A (Mixed Mechanical-Synthetic Inertia) and SF_B (Full Synthetic Inertia).

New functionalities investigated in SF_A are RoCoF control, with the participation of converter-based plants (not existing today) and the extended control, with the participation of Virtual Power Plants (VPPs) in the secondary frequency regulation (introducing new second level hierarchy).

New functionalities investigated in SF_B are the converters in grid forming mode (instead of currently used grid following mode) and the application of Linear Swing Dynamics (LSD) concept (instead of non-linear swing dynamics), for reaching the linear dynamic of the system.

For the voltage scenarios, the main electricity infrastructure under consideration is the Low Voltage (LV) network: however, the two voltage scenarios address two different issues, i.e., the Dynamic Voltage Stability (in SV_A) and the implementation of an Active Voltage Management system (in SV_B). Both these topics arose from the increasing penetration of RES at LV level, and the exploitation of the potentials of the inverters connected to the network for acting the proper control. However, in the first case the stability of the voltage is studied dynamically, whereas in the latter one in steady state.

Traditionally, frequency control is executed by the transmission system operators (TSO). The RESERVE project has shown that it is useful to decentralize the frequency control to local power generation units and energy storage systems in both transmission and distribution networks. The inverters, or voltage-sourced controllers, will be extended by sensors and actuators for measuring frequencies and other data, and they can control the frequency levels at their connection point in the electric grid. Even for voltage control, the inverters in the distribution networks play a vital role in measuring impedances and adapting the voltage to the needed levels.

In transmission networks, the large distances and small number of communicating devices lends itself to using optical fiber or powerline communications. In distribution networks, however, the typical distances to be bridged are much smaller and the number of devices is much bigger, so that it will be by far more beneficial to deploy the entire communications system using 4G and 5G mobile networks.

The main achievements on this topic are summarised here:

- Definition of four scenarios, two for voltage and two for frequency control, assuming a high share of renewable energy sources (up to 100%)
- Description of the components and functions to be implemented for all scenarios, including innovative visualization tools such as SGAM

- First study of the ICT requirements for all scenarios, identifying use cases and benefits of 5G-based communication solutions in future smart grids
- Thanks to the modularity of the four scenarios, updated definitions of component, functions, information and communication is guaranteed by collecting feedback from the simulation and the field trials

More information is available in Deliverables D1.2, D1.3 and D1.5, which are provided on the web page www.re-serve.eu.

2.2 Frequency Stability by design

The objective of this work is to define, through measures and proof-of-concept simulations, the frequency control that can be achieved through renewable and power converter-based distributed energy resources (DERs). With the proper communication system, it is expected that DERs will be able to provide a faster control and possibly a more stable system than the current asset based on conventional power plants.

In the first year and a half of the project, the focus has been on technical aspects related to the frequency estimation, frequency control and the communication system required to implement novel frequency control strategies involving non-synchronous devices. The last nine months of the work have been mainly dedicated to draft network code requirements for frequency control of DERs in distribution networks.

A general expression, called Frequency Divider Formula (FDF), to estimate frequency variations during the transient of electric power systems has been proposed. Such an expression is derived based on standard assumptions of power system models for transient stability analysis and can be readily implemented in power system software tools for transient stability analysis. The formula is aimed at improving the accuracy of the estimation of bus frequency and/or rotor speed deviations as well as the rate of change of frequency (RoCoF) in power systems with inclusion of inertia. The FDF can be also utilized to define the accuracy of current available devices that measure bus frequency deviations, such as the phase-locked loops.

A review of relevance of current techniques to advanced frequency control has been carried out in parallel with the definition of the FDF. This work led to a comprehensive overview of the actual frequency control techniques in power systems. The emphasis is on the specific characteristics of the primary control level and the architecture and characteristics of the secondary control level. The overview considers technical and economic implications at all control levels with the increasing share of generation from non-synchronous energy sources are discussed in detail. A special focus is on battery energy storage systems which are anticipated to play a crucial role in future power system with low or no inertia.

Following the review of current frequency control practices and the impact of non-synchronous generation in the frequency control, a novel control approach for power electronic converters, namely, the Linear Swing Dynamic (LSD) has been proposed and validated. In particular, the LSD-based Improved Virtual Synchronous Generator (LSD-VSG) has been developed to exploit the advantages of conventional Synchronous Generators (SG), such as generation-system synchronization and inertial response, and tackle its disadvantages represented by the nonlinear characteristics and nonlinear swing dynamics. The proposed LSD-VSG aims at providing system synchronization and coherency and is thus expected to function adequately in the 100% non-synchronous scenario.

Part of the work has focused on the definition of ICT requirements based on the developed concepts of frequency estimation and control. Different communication architectures for primary frequency control of distribution systems have been defined and preliminary tests carried out. These include decentralized, centralised and distributed approaches to collect and transmit frequency measures for primary frequency control of DERs in distribution networks. The ICT requirements for a secondary frequency control of the DERs included in a distribution networks have also been prepared.

The work on network code requirements for frequency control has focused on distribution system operators and their interaction with transmission system operators. First a review of white papers

and existing recommendations under review by system operators has been carried out. Based on this review, several aspects that are not currently covered in the existing network codes have been identified. These refer to ancillary services for the provision of RoCoF, primary and secondary frequency control in system with either low inertia or no inertia at all. It is anticipated that the high penetration of power electronic converters will reduce or even remove the current time-scale difference between RoCoF and primary frequency control. Moreover, power converters of all device involved in the frequency control, namely, DERs, energy storage and microgrids, need to satisfy a set of constraints to be adequate for frequency control. Finally, the communication system, when required, for example for receiving/sending frequency measurements to relevant device controllers or to implement secondary frequency control of DERs need to satisfy given constraints, e.g., maximum latency. All the issues above are collected in a set of network code requirements. Whenever necessary, appropriate simulation tests and field trials have been defined to provide a quantitative evaluation of the proposed network code requirements.

The main achievements on this topic are summarised here:

- Definition of the Frequency Divider Formula (FDF) and validation through RTDS and hardware-in-the-loop. This work has led to the following contributions:
    - Proposal of a new definition of the frequency to substitute the definition provided in the ENTSO-E Commission Regulation (EU) 2016/631 of 14 April 2016.
    - Definition of new efficient dynamic state-estimation technique.
    - Comparison of different techniques for the estimation of local frequency deviations and their impact on the dynamic behavior of distribution systems.
- Statistical dynamic analysis of the impact of power generation from wind power plants, photovoltaic systems and microgrids for the frequency control of the system.
- Development and validation of the LSD concept for future power systems with up to 100% generation from converter-based DERs.
- List of requirement on scalable ICT to implement primary and secondary frequency control concepts in distribution systems with DERs, energy storage and microgrids.
- Draft of network code requirements for RoCoF, primary and secondary frequency control of DSO with inclusion of DERs, energy storage and microgrids.

The work carried out so far has led to the publication of 6 journal papers and 10 conference papers.

More information is available in Deliverables 2.1-2.6, which are provided on the web page www.re-serve.eu

2.3 Voltage Stability by design

The main objectives of the work are to define system level decentralised voltage control and monitoring for futuristic low voltage (LV) distribution grids.

The first year of the project was spent to identify the challenges associated with large penetration of RES. Dynamic problems such as interaction among converters due to impedance overlap, parallel resonances and constant power loads were identified as key challenges. Steady state problems such as over or under voltage and voltage unbalance were identified as key challenges.

Effort was spent to formulate a suitable stability criterion for determination of system stability margins. The generalised Nyquist criterion (GNC), an extension of Middlebrook theory was adopted and validated for an exemplary LV feeder. In the second half of year 1, the Dynamic Voltage Stability Monitoring (DVSM) algorithm, was formulated as a decentralised approach utilising ICT architecture. The DVSM algorithm helps maintain the dynamic stability of the LV grid. The wideband system identification (WSI) tool is proposed to measure the unknown grid impedance.

For handling of steady state problems in the LV grid such over or under voltage and voltage unbalance, effort was spent reviewing various techniques and the active voltage management (AVM) is proposed. The algorithm determines active power and reactive power setpoints of every RES inverter to maintain voltage within limits and minimise power losses and voltage unbalance. In this context, the concept of volt-var curves was validated.

The work progress in voltage stability by design leads one towards a new class of inverters with new behaviours. Effort has been spent formulating the impact on current network codes and possible formulation of new network codes.

The proposed voltage stability by design concept combines the algorithms developed in the power systems and the ICT architecture to formulate a decentralised and robust control paradigm. In RESERVE, the futuristic scenario of having substantial number of power electronics in power systems is seen not as a challenge but rather as degrees of freedom for control and automation.

The main achievements on this topic are summarised here:

- Impedance based stability criteria for power electronic interfaced multi-source system was defined. The GNC methodology was proposed to determine stability margins at every bus.
- For guaranteeing dynamic stability margins of futuristic LV grids, the DVSM algorithm is proposed. The algorithm is envisioned to operated ideally with 5G communication given that the goal is to increase the number of DVSM cycles per hour.
- For steady state voltage control, the AVM technique is proposed. The proposed AVM technique maintains the grid voltage at every bus within specified upper and lower limits and in the process also minimises the steady state voltage unbalance and power losses in the grid.
- The ICT requirements for the new techniques has been identified.
- The implications of the new techniques on network codes/ancillary service definitions are defined.

More information is available in Deliverables D3.1 and D3.2, which are provided on the web page www.re-serve.eu

2.4 Pan-European real time simulation infrastructure and live 5G testing platform

The vision of the Energy Union requires a scientific framework of support to validate solutions and concepts in a realistic manner before implementation. The idea is to create a network of laboratories that, using real time simulation, can support all the stakeholders in defining the next step in the evolution of the grid infrastructure. Such a lab system could support both market regulation and network code definition.

Therefore, a lab interface is required which connects simulation sites through the internet with minimal latency to be able to support real-time experiments. Apart from the interconnection challenge, a scalable solver for simulation based on a dynamic phasor solver is to be implemented in RESERVE. The idea is to make this solver available as open source to all the laboratories that are willing to join in the future. Each laboratory could then expand locally the computational effort thanks to off-the-shelf commercial solutions such as RTDS or OPAL-RT.

Within RESERVE, it is planned to run tests with the aforementioned components, the interface and the solver, and for this reason deploy them to all simulation sites that participate in the project.

Since 5G network supports many functions that would be beneficial for the operation of smart grids such as local distributed data processing and network management capabilities, the project includes the adaption of these functions for grid applications. Control algorithms and the communication stack required in typical grid applications are implemented on a Distributed Cloud System (DCS) from Ericsson which is situated in the RWTH laboratory. Furthermore, the DCS is

integrated with the real-time simulation infrastructure of RWTH to test the grid applications implemented on the DCS.

The main achievements on this topic are summarised here:

- The laboratory interface, called VILLASframework, for the pan-European co-simulation has been implemented.
    - It includes VILLASnode, which interconnects laboratories, and two web based applications.
    - VILLASweb, which allows visualizing data exchanged between simulation sites in real-time, and
    - Pintura, which can be used to visualize and edit IEC61970 CIM based grid data.
- VILLASnode instances were deployed to RWTH, WIT, UPB and POLITO. Besides, the quality of the connection was measured and a first distributed simulation test was executed using the simulation infrastructure in RWTH and WIT.
- The VILLASframework was the backbone of the RT-SUPER LAB demo, interconnecting several real-time simulation sites across the US and Europe.

  The dynamic phasor open source solver developed in the frame of RESERVE was employed for the previously mentioned distributed simulation example between RWTH and WIT. It has several interfaces such as VILLASnode for co-simulation, an adapter to be able to use IEC61970 CIM as data format for describing the simulated grid and Python as an easy means to script simulations and visualize results.
- The Ericsson communication network facilities have been integrated into the real-time simulation infrastructure of RWTH.
- It was evaluated which frequency and voltage control concepts developed by the partners in RESERVE could be deployed to a DCS and what technology would be used for communication between power system equipment and the DCS and for managing several grid applications in the DCS.
- The distributed edge cloud functionality development has progressed over this period, with adaptor updates being made to open FMB, a framework for grid edge interoperability, and the integration of IEC61850 started.

More information is available in Deliverables 4.1, 4.2, 4.4 and 4.5, which are provided on the web page www.re-serve.eu.

2.5 Test-beds for validation of research results

The primary objective of this Work Package is to validate, evaluate, demonstrate and enhance the concepts developed in this project for both voltage and frequency control in real life scenario.

The focus during the first 18 months of the project has been on permitting, procuring and constructing the trial sites for voltage control in Ireland and developing network models and collating associated system data for the simulation based frequency control trials in Romania and other partner countries.

In order to allow for the validation of both voltage and frequency control scenarios utilising the pan-European real time simulation infrastructure and live 5G testing platform, detailed implementation and test plans have been developed.

The main achievements on this topic are summarised here:

- The research concepts developed in Work Packages 2 and 3 have been successfully mapped to specific trial site locations, technologies and communications configurations.
- A phased deployment of trial site validation of the SV_A algorithm has been scoped with electrical installation works to accommodate the trial designed at Burnwood 38 kV Station in Co. Laois, Ireland. Design of the power inverter required to initiate noise injection and

grid impedance data calculation at this trial site has been completed and assembly of the inverter has commenced in RWTH Aachen.

- The development of SV_B validaiton trial sites in Ireland is substantially complete with;
    - 7 kW Ground Mounted Solar PV Array with Smart Inverter control has been Constructed and Commissioned in Portlaoise Ireland.
    - Ireland's first Vehicle to Grid (V2G) Charger was installed in Leopardstown, Ireland.
    - A total of four 'behind the meter' battery installations have been completed across locations in counties Cork and Dublin.
- The first battery trial site has successfully tested the provision of on-demand reactive voltage support to the distribution network. The integration of parallel communications with and control of this installation alongside a commercial aggregator has been successfully tested.
- The SV_B Algorithm has been tuned and resultant Volt-VAR curves produced for two of the trial sites. Site specific tuning of the algorithm for the remaining trial sites is ongoing.
- With regard to the trials of frequency control; network models of the Romanian Power System along with corresponding databases were prepared for simulation. In addition, relevant frequency and ROCOF data records of system performance have been collected and frequency analysis matched to significant system events has commenced. These data, as well as other new data, together with network and frequency control models developed in WP2 and WP3, will be used in the second half of the project period to validate the various network codes proposals.
- A methodology for implementing the simulation scenarios of voltage and frequency control utilising network data on the co-simulation platform developed in WP4 has been defined.
- A test plan to allow for the investigation of the performance of 5G communication networks in the implementation of both Frequency and Voltage control scenarios has been developed.

More information is available in Deliverables 5.1 and 5.4, which are provided on the web page www.re-serve.eu

2.6 Regulatory and legal issues

The development of harmonized network codes will bring economies of scale to markets for renewable energy products and will play an important role in making the profitable provisioning of sustainable energy services a reality as roadmaps for RES introduction are implemented. The process used by RESERVE is illustrated in the figure below.

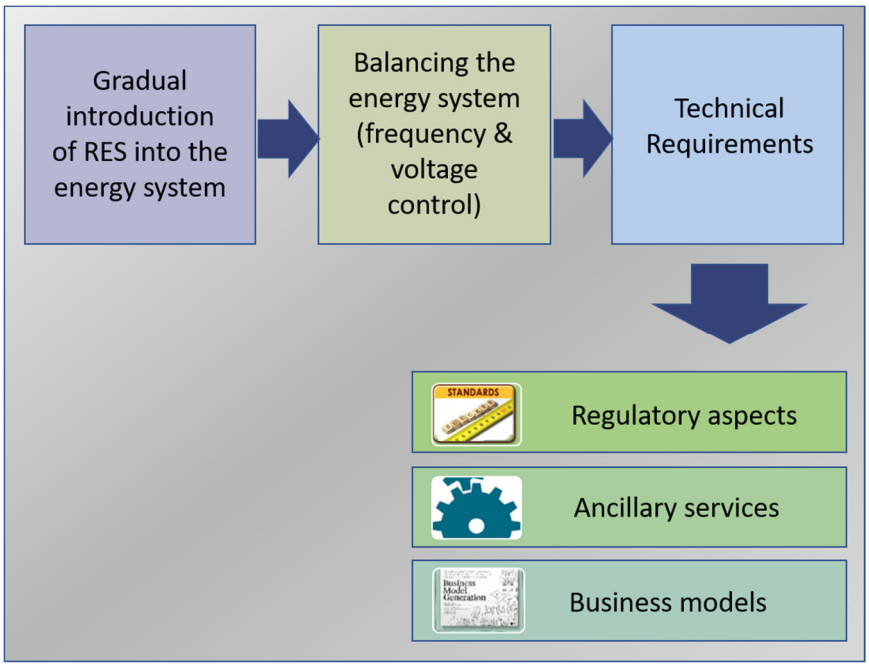

Figure 5 – The RESERVE approach to regulatory and legal issues

Harmonised network codes will be developed with staggered deployment related to the roadmaps for RES deployment. The critical path towards the expected work and results of the WP6 will follow the scenarios of gradually introducing RES into the energy system, balancing it from the frequency and voltage control perspective, generating technical requirements with impact on the following:

- Regulatory aspects (Network codes & Standards)
- Ancillary services (system services)
- Potential business models.

Objectives

- To propose major adaptations of existing network codes and/or new network codes, based on draft inputs form work packages (WP) 1-6 and promote their adoption internationally
- 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 (beyond 2040)

It will address the regulatory aspects of possibly updating existing network codes and elaboration of new ones, based on the voltage and frequency issues of network codes, and on the input coming from WP1-5. The deliverable addressing "Regulatory and legal issues" has two versions: 1st version is released in March 2018 and the 2nd version is released in September 2019.

In order to increase the percentage of RES penetration up to 100% several technical challenges are foreseen, and in the work packages 1 to 5 several technical solutions are developed and tested.

Based on the list of the proposed technical solutions, a part of the work within WP6 (D.6.1) is focusing on a list of modification and/or new regulations, that will be developed and promoted to the relevant parties.

In the process of elaboration of the above-mentioned methodology a workshop was organized in November last year and the result were intensively used in the next steps.

In order to define a set of harmonized network codes, a wish list is identified, combining top-down and bottom-~~p~~up approaches:

- Top-down:
  - Starting from the existing list of current network codes, an analysis will be made, in order to see which codes are strongly influenced by the results of the RESERVE project scenarios
  - Extract from the existing and proposed legislations at the EU level, for instance the Clean Energy Package 2017, to see which new network codes are requested to be harmonized
  - Key drivers and trend from technology development, e.g. storage, electric vehicle, block chain, fifth generation (5G) of the communication technology development, etc
- Bottom-up:
  - Outcomes in terms of new findings or requirements in WPs 1- 5 related to the voltage and frequency issue on the way toward 100% RES will require additional network codes Further will be identified which current network codes should be adapted and which new network codes should be considered to be harmonized.

The bottom-up approach will represent the main input of this deliverable and the results of the top-down approach will be considered as the basic premises, in order to connect with the new findings or requirements in WP1, 2, 3 and 6.

The main achievements on this topic are summarised here:

- Proposal for a new network code regarding the storage.
- Proposals for new ancillary services.
- Proposals for changes of several existing regulations.
- It was developed and applied a new methodology for prioritisation of the proposals.
- Based on the list of proposals a TOP 5 priority list was developed
  - Requirements for new behavior of RES inverters
  - Distribution system - frequency control
  - System swing dynamics
  - Dynamic stability margins
  - Requirements of minimum system inertia
- .A stakeholder's consultation workshop was organized in Bucharest in June 2017, and another workshop following the methodology on Network Codes prioritization was organised in Cork, in November 2017.

More information is available in Deliverable 6.1 and 6.5, which are provided on the web page www.re-serve.eu

2.7 Business Models for RES

The objectives of this work are the definition of future scenarios towards 100% RES penetration. T6.2 analyses the most important aspects for the market changes and upcoming business models in the future power system, in respect of corporate social responsibility and the approach of sustainability. The definition of the scenarios needs the deep understanding of the features composing the scenarios, such as:

- Stakeholders
- Sector actors

- Market structures
- Corporate social responsibility and the approach of sustainability
- Existing network codes

The new energy system designs will result in societal, economic and environmental consequences which need to be thoroughly measured and assessed. Based on the analysis of these consequences, T6.2 will provide the first version of the CSR guidelines for the development of business models and energy system designs by taking inherent trade-offs into account.

For defining stakeholders an initial workshop was held in January 2017. Market structures and involved sector actors were discussed at an organised conference in Bucharest in June 2017. A survey – executed during the conference – confirmed the results of the discussions. The developed results were continuously validated with the different project partners and further consolidated in a second workshop in January 2018.

Main challenges of T6.2 are defining a basis market model which illustrates the various market structures in Europe, especially in the LV grid, and finding a way integrating sustainable KPIs in business models. Even though these challenges needed to be fixed, there are no changes of the results of T6.2 needed to the half time of the project.

One of the outcomes of T6.2 is to recognise the need for customer participation to ensure a successful and sustainable development towards 100% RES. This also follows the idea of a bottom-up market model in the future. Involving society means setting a framework for customer participation as well as taking into account the social and environmental advantages and risks the energy transition will create.

The main achievements on this topic are summarised here:

- T6.2 evaluates challenges and threats from the three pillars of corporate social responsibility (CSR) – the economic, environmental and social perspective –stemming from the energy transition for existing and upcoming players.
- Using examples of the changing roles of TSOs and DSOs, the canvas business model is extended to all three perspectives.
- These business models are also analysed by using the sustainability balanced scorecard to identify strategic and operational objectives exemplary for TSOs and DSOs in the future.
- T6.2 assesses the network codes proposed in this project with regard to the requirements of CSR and of sustainability.
- T6.2 provides the first version of the CSR guidelines for the development of business models and energy system designs.

More information is available in Deliverables D6.1 and D6.5, which will be provided on the web page www.re-serve.eu after submission.

2.8 Generating Impact with RESERVE

The overarching objective of this work is to maximize the scientific, industrial and societal impact of the project by creating awareness of the technologies and the innovation activities within the project but also channelizing guiding feedback from the public that will be incorporated in the strategic orientation of the project.

The first step consisted in working out the marketing objectives and the special targets for the RESERVE project derived from the strategic goals. Taking into consideration that the target groups are very heterogeneous, an open design was chosen which could give us the opportunity to attract a wide range of groups. The current design and the key slogan, "*Fast, Safe, Sustainable*", were chosen because they reflect the vision of the RESERVE project to support our increasingly ICT-enhanced life styles with a stable and safe power eco-system maximizing the use of renewable sources of energy. By using a mix of pure technical pictures and colours combined with highlights, the idea is to give the viewers a good feeling of safety and ecological sensibility. A project website was also directly established and linked with RESERVE main social

media channels (LinkedIn and Twitter) with the aim to inform the public about all project and related activities and to get immediate feedback from the interested communities regarding further updates and possible cooperation.

Numerous actions were taken in the reporting period in order to collect relevant information about the ongoing work with a clear focus on the harmonization of network codes. These included for example networking activities with TSOs and DSOs members with the purpose of creating a group of experts with whom to exchange on our expected results and in this way prepare the way for the future exploitation of the RESERVE outcomes. Furthermore, we have identified a group of Standard Development Organizations (SDOs) and we plan, as soon as we will have convincing figures and arguments coming from the research activity of the other WPs, to have direct discussions with them in order to get straightforward feedbacks about the possibility and way to include our suggestions into the existing standards.

The main events that have been organized in this context were the 1st Stakeholder Meeting (Bucharest, 23 June 2017) and the 1st Advisory Board meeting (Brussels, 23 January 2018). Objectives of these assemblies, counting among their participants TSOs and DSOs members as well as well-known academics, were for one side to receive a feedback on the RESERVE ongoing work (methodology and results achieved so far on the work on network codes), and on the other to get inputs useful for the definition of the new network codes, taking into account the future applicability of the methodology, convincing show cases, and a clear and significant impact.

The exploitation path for the project outcomes is resumed in the following scheme.

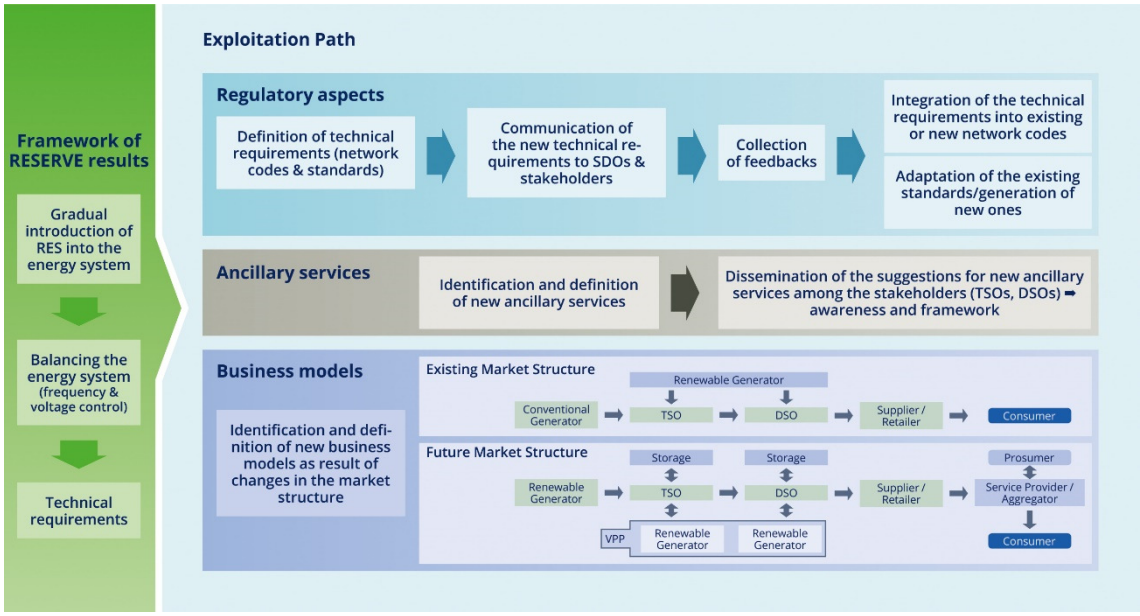

Figure 6 - Exploitation of Results

The main achievements on this topic are summarised here:

- RESERVE has designed and implemented the necessary communication and dissemination tools and interfaces to bring about opportunities for constructive communication between project and the public.
- RESERVE has successfully started fostering the support for RESERVE ancillary services and network codes by sharing the ongoing work and achieved results, as well as collecting feedbacks and inputs from Stakeholders and Advisory Board members during the organization of dedicated events.
- RESERVE has created awareness of the project work and disseminated the results through the organization and participation in numerous targeted events (workshops, conferences, exhibition fairs etc.) and has planned even more aiming at pushing ahead

the sharing of knowledge and ideas and at driving the dialog with the different target audiences.

- RESERVE has developed the concept for the training programmes that will be implemented in the second half of the project and that are aimed at creating impact on the educational needs on the energy sector.

More information is available in Deliverable D7.1, which is provided on the web page www.re-serve.eu

3. Conclusions

The strategic objective of the RESERVE project is:

To enable up to 100% penetration of renewables by developing innovative approaches to system level automation based on innovative ancillary service provision with a close to market level of maturity, supported with validation of the concepts and policies using a pan- European real-time simulation Infrastructure, anchoring the approach with the main sector actors in Europe and beyond."

After 18 months of operation, RESERVE has researched innovative approaches to system level automation based on innovative ancillary service provision and has developed the pan-European real-time simulation infrastructure. Initial proposals for new and enhanced network codes and ancillary service definitions have been developed by the project.

Bringing the new approaches to a close to market level of maturity by experimenting with the approach to voltage control in field trials and the approach to frequency control using simulations has started. The further investigation of the proposed network code and ancillary service definitions and the generation of impact with the project results are in focus in the second half of the project.

The RESERVE project has achieved its interim objectives in the first 18 months of operation and is on target to achieve the project goals as planned during the second half of the project.

4. List of Abbreviations

B2B	Business to Business
BMS	Building management system
CAPEX	CAPital EXpenditure
CENELEC	European Committee for Electro technical Standardization
CEP	Complex Event Processing
COTS	Commercial off-the-shelf
CPMS	Charge Point Management System
CSA	Cloud Security Alliance
EMS	Decentralised energy management system
DER	Distributed Energy Resources
DMS	Distribution Management System
DMTF	Distributed Management Taskforce
DSE	Domain Specific Enabler
EAC	Exploitation Activities Coordinator
ERP	Enterprise Resource Planning
ESB	Electricity Supply Board
ESCO	Energy Service Companies
ESO	European Standardisation Organisations
ETP	European Technology Platform
ETSI	European Telecommunications Standards Institute
GE	Generic Enabler
HEMS	Home Energy Management System
HV	High Voltage
I2ND	Interfaces to the Network and Devices
ICT	Information and Communication Technology
IEC	International Electro-technical Commission
IoT	Internet of Things
KPI	Key Performance Indicator
LV	Low Voltage
M2M	Machine to Machine
MPLS	Multiprotocol Label Switching

MV	Medium Voltage
NaN	Neighbourhood Area Network
NIST	National Institute of Standards and Technology
O&M	Operations and maintenance
OPEX	OPerational EXpenditure
PM	Project Manager
PMT	Project Management Team
PPP	Public Private Partnership
QEG	Quality Evaluation Group
S3C	Service Capacity; Capability; Connectivity
SCADA	Supervisory Control and Data Acquisition
SDH	Synchronous Digital Hierarchy
SDN	Software defined Networks
SDOs	Standards Development Organisations
SET	Strategic Energy Technology
SET	Strategic Energy Technology
SG-CG	Smart Grid Coordination Group
SGSG	Smart Grid Stakeholders Group
SME	Small & Medium Enterprise
SoA	State of the Art
SON	Self Organizing Network
SS	Secondary Substation
TL	Task Leader
TM	Technical Manager
VPP	Virtual Power Plant
WP	Work Package
WPL	Work Package Leader