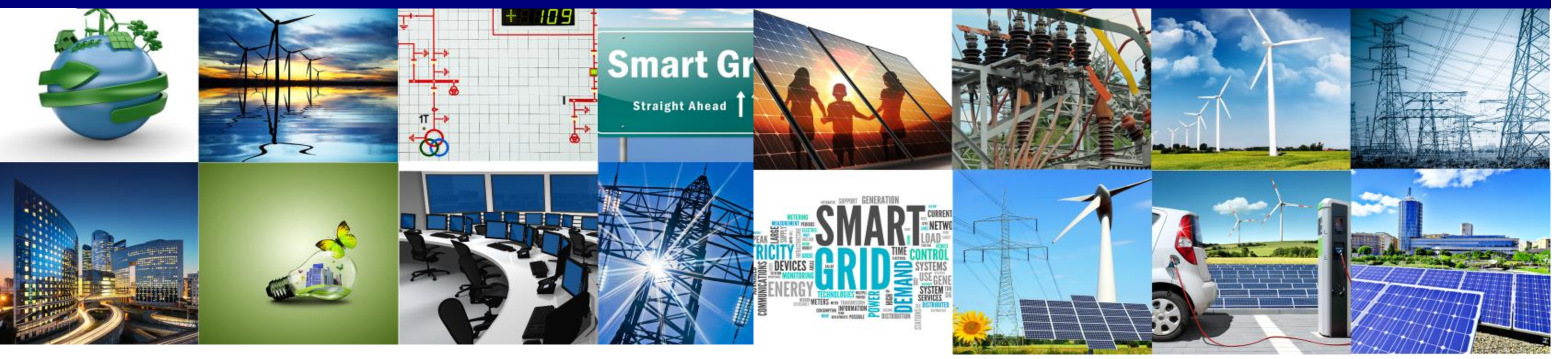
Project No. 609687

FP7-ENERGY-2013-IRP

ELECTRA

European Liaison on Electricity Committed Towards long-term Research Activities for Smart Grids



WP 12

Dissemination, Knowledge Transfer and Exploitation

Deliverable 12.4

Plan for the use and exploitation of the foreground

27/06/2018

ID&Title	**D12.4** Plan for the use and exploitation of the foreground	**Number of pages:**	86

Short description (Max. 50 words):

In this report foreground generated in ELECTRA IRP is described and potential exploitation paths are indicated.

Version	Date	Modification's nature
V0.1	09/03/2018	First Draft
V0.2	05/04/2018	Final Draft
V1.00	06/04/2018	Under review
V2.00	13/04/2018	Released
V2.01	14/05/2018	Under review after the final review meeting
V2.02	27/06/2018	Released

Accessibility

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Executive summary

In this report foreground generated by the ELECTRA IRP is described together with its foreseen potential exploitation paths.

In total, thirty-two assets have been developed. Based on their purpose and nature, those assets have been classified in three groups: i) assets mainly related to development and validation of the "Web-of-Cells" (WoC) concept, ii) assets with a more general purpose and use, and iii) assets generated by Coordination and Support Actions (CSA) activity.

It should be underlined that most of the foreground generated by the ELECTRA IRP is linked to the development and validation of the WoC concept.

According to the Description of Work (DoW), the ELECTRA project research technology development (RTD) activity was planned on a conceptual level followed by relevant experimental validations at laboratory level, thus most of the developed R&D assets are at a Technology Readiness Level (TRL) up to TRL 4. On the contrary, some of the results from the CSA activity, such as the Researchers Exchange (REX) procedure and the R&D priority questionnaire, can be considered as ”*ready for use and implementation*”, although they should be customized, depending on their specific use.

An exploitation plan articulated in three phases has been defined in order to further develop the WoC concept and bring it up to the *prototype* level, thus addressing and overcoming the existing identified gaps.

In phase 1 (2018-2021), specific aspects of the WoC concept will be investigated in the frame of national and international projects undertaken by ELECTRA partners. Activities performed in these projects will provide important elements for further development and consolidation of this control architecture, mainly at laboratory level, and can be considered as a key step to bring WoC concept up to TRL 5. In this timeframe, the European Energy Research Alliance Joint Program (EERA JP) Smart Grids will have a very important and leading role in promoting coordination and synergies among R&D projects and providing a common understanding of their results.

Phase 2 (2021-2026) is aimed at systematically investigating the WoC concept and to consolidate its maturity at TRL 5 (“Technology validated in the field”). The support from a new project to be launched in the last H2020 Calls and/or in the 9th FP programme would be very important to accomplish phase 2. This project will allow an extensive scalability analysis of the WoC concept and will support the provision of a detailed migration plan for the progressive deployment of the concept in real networks. This will require effort on device level implementation as well as on the communication interfaces and protocols. Grid operators will be directly involved in the project to take into account all constraints and necessary steps to be performed in order to obtain a realistic plan to implement and demonstrate WoC concept in a real grid portion. Again, the members of the EERA JP Smart Grids will have a key role in forming the core of the project consortium and then launching such a project and in disseminating its results.

In phase 3 the WoC control concept is implemented and demonstrated in a real grid environment. Such an Innovation Action (IA) will be led by grid operators. Its features, of course, cannot be foreseen at present. However it will represent a fundamental step to realize, by 2030, the complete migration of WoC concept from R&D organizations to industry, in view of system prototype development and demonstration.

Moreover, several assets developed within the ELECTRA IRP such as control functions, methodologies and models, will also have their own exploitation not necessarily related to WoC, i.e. they have the potential for a broader application in the short/medium term when decentralized control systems are considered. In this frame, several Partners committed to exploit ELECTRA results both in national and international projects involving grid stakeholders addressing the optimization of the operation of the existing grid.

Finally, in order to make available the results generated by the ELECTRA IRP to other users, information on ELECTRA assets are being made available to the public through the web-based EERA IP showcase.

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1. Introduction

ELECTRA IRP brings together twenty-one Research Organizations and Academic partners of the EERA Joint Programme on Smart Grids with the objective to reinforce and accelerate Europe's medium to long-term research cooperation in this area and to drive a closer integration of the research programmes of the participating organisations and of the related national programmes.

ELECTRA IRP considered both Research and Technological Development (RTD) activities and Coordination and Support Actions (CSA).

As far as RTD is concerned, ELECTRA has introduced and validated at laboratory level a new concept of grid control architecture, the so-called "Web-of-Cells" (WoC) aiming at a more decentralized control strategy and with the paradigm to solve local problems locally. According to the WoC concept [D 4.2, D 5.3], the power system is divided in cells. Cells are portion of the power grid able to maintain an agreed power exchange at their boundaries by using the internal flexibility. Cells are connected with each other through one or multiple tie-lines. In each cell, an automatic control system (the cell controller) manages voltage and balance (power-flow imports/exports) of the cell in real-time.

The cell controller is under the responsibility of a Cell System Operator role that supervises its operation and, if needed, is able to override it. The project developed in detail the various control functions to be performed by the cell controller.

It should be underlined that most of the foreground generated by the ELECTRA IRP is linked to development and validation of the WoC concept, although some assets, such as control functions, could have a more general purpose.

According to the Description of Work (DoW), the ELECTRA project RTD activity was planned on a conceptual level followed by relevant experimental validations at laboratory level, thus most of the developed R&D assets are usually at a Technology Readiness Level (TRL) up to TRL 4. On the contrary, some of the results from the CSA activity, such as the Researchers Exchange (REX) procedure and the R&D priority questionnaire, can be considered as "ready for use and implementation", although they should be customized, depending on their specific use.

2. Foreground description

In this chapter the assets developed by the ELECTRA IRP are described and classified. In total, thirty-two assets have been developed within ELECTRA. Based on their purpose and nature, those assets have been classified in three groups: i) assets mainly related to development and validation of the "Web-of-Cells" (WoC) concept, ii) assets with a more general purpose and use, and iii) assets generated by Coordination and Support Actions (CSA) activity.

The assets are listed in tables 2-4, respectively, including their classification and TRL.

For each asset indicated in Table 2-4, a standard template with a detailed description and relevant information has been prepared.

Due to its importance, the Web-of-Cells template is shown separately in Table 1, while all the other templates are reported in Annex 1, in the order as they are listed in Table 2-4.

Table 1 - Web-of-Cells distributed control concept template

Title	**Web-of-Cells distributed control concept**
Type of Asset	*System architecture*
Short description	*The Web-of-Cells distributed control concept represents a novel way to manage and restore frequency and balance the future power system in a bottom-up manner, based on local observables. It as well proposes a more active voltage management approach.*
Longer description	*The proposed Web-of-Cells control concept foresees to manage the future power system in a distributed manner, based on local observables. It proposes to organize the power system in a cellular manner, where each cell has the responsibility to provide balance and frequency restoration services based on local observables. There is no restriction in how cells are connected to each other (e.g. one or multiple tie-lines) and cells may span multiple voltage levels. The optimal sizing of a cell is determined by two parameters: 1) A cell must be large enough to have sufficient self-balancing capacity/reserves, and 2) it must be small as needed to allow secure reserves activation checking in a computational manageable time. The Web-of-Cells control concept aims to implement a 'solve local problems locally' paradigm, as an alternative to a centrally directed approach based on intensified TSO-DSO coordination and associated communication and calculation challenges.* *It depends on a slightly modified wholesale market architecture, where generation and consumption forecasts contain information that allows - as the result of the market clearing process – to determine cell import/export profiles over the (sum of) the tie-lines that connect cells to neighbouring cells. It is important to explicitly note here that it is fine for cells to import from or export energy to other cells. So, there is no requirement that it can be fully self-sustainable. The only requirement is that it has sufficient reserves capacity to correct its own aggregated generation or consumption forecast errors or small incidents, i.e. it must be able to restore its*

Title	Web-of-Cells distributed control concept
	own cell balance, which is defined as the market cleared import/export profile, by monitoring and correcting its (aggregated) tie-line power flows. *By doing so, system balance is restored in a bottom-up manner, by the aggregated effect of the restoration of all cell balances (Balance Restoration Control). This is done by deciding on activations based on local observables (tie-line power flows) in line with the solve local problems locally paradigm. As cells are physically connected to each other and sense each other's imbalance, there is a local collaboration of neighbours (whereas the decision to activate reserves is based on local observables only, the amount of activation also depends on the frequency deviation to ensure that also frequency gets restored).* *It is proposed and assumed that fast acting invertor coupled reserves can be used for the restoration (e.g. batteries or thermostatically controlled loads). This way, the balance restoration is also capable of containing frequency deviations. Nevertheless, to support the balance restoration, an adaptive frequency containment control (aFCC) is proposed) which differs from the current FCC by the fact that its activation is steered to mainly/only take place in cells that cause a deviation. This is done to avoid that FCC activations, that act on just a global frequency deviation, cause imbalances in cells and break the solve local problems locally paradigm.* *The distributed bottom-up balance restoration means that more reserves activations will be needed because the system wide imbalance netting is lost. The exact impact of this needs further analysis, but it is expected that this could be acceptable in case of the use of zero emission zero fuel cost reserves for the balancing (e.g. thermostatically controlled loads). Even so, a separate control, Balance Steering Control, has been defined to mitigate the problem, by adjusting cell balance (tie-line power flow profile) set-points in a way that two neighbouring cells can agree to not each individually restore their balance, but they do it together in a way that requires less reserves activations from each of them, while still contributing in the same manner to the system balance restoration. This can be considered as a peer to peer explicit imbalance netting approach.* *Next to balance/frequency restoration, the Web-of-Cells concept advocates a more active voltage control in cells. It proposes a Periodic Proactive recalculation of optimal voltage setpoints to ensure a robust and efficient (minimal losses) operation. This is called Post-Primary Voltage control.*
Technology Readiness Level (TRL)	*4*

Title	Web-of-Cells distributed control concept
WP of reference	*WP4, WP3*
Organisation leader	*VITO*
Contact person/ Email	*Chris Caerts (chris.caerts@vito.be)*
Second Organisation (if any)	*AIT, RSE*
Contact person/ email	*Helfried Brunner (helfried.brunner@ait.at)* *Luciano Martini (luciano.martini@rse.it)*
IPR	*EU Trademark*
IPR Status	*Request to be submitted*
References	*D5.3: WoC control concept architecture description* *D4.2: use case detailed description* *D7.1: simulation and laboratory-based validation of WoC concept* *D7.2. recommendations for further testing and validation* *L. Martini, H. Brunner, E. Rodriguez, C. Caerts, T. Strasser, G. M. Burt, Grid of the future and the need for a decentralized control architecture: the ELECTRA Web-of-Cells concept, 24th Int. Conf. on Electricity Distribution CIRED, Glasgow, 12-15 June 2017, DOI: 10.1049/oap-cired.2017.0484*
Technology keywords	*Distributed real-time control, balance restoration, frequency containment, frequency control, voltage control*
Special conditions for the access to such Asset?	*The trademark is owned in equal parts by all the ELECTRA partners. Management and exploitation of the mark will be in charge to EERA AISBL and, specifically, to EERA JP smart grids, to which all the ELECTRA partners belong. In this frame, each ELECTRA partner will have all the applicable rights to use the trademark.*

Table 2 - List of assets mainly linked to the Web-of-Cells distributed control concept

Asset classification	Asset title	TRL
	1. Post primary voltage control with ZIP loads and ELECTRA cell concept	3
	2. A novel measurand and a decentralised responsibiliszing primary frequency control	4
	3. An enhanced load frequency control framework with improved responsibilization	4
	4. Proof of concept model for integrated operation of FCC+BRC+BSC	4
	5. Proof of concept model for the operation of FCC	4
	6. Simulation files of the PVC/PPVC implementation on the CIGRE MV test network	3
	7-12. Control functions: ACPFCD, CSA, FDPD, MOC, MOD, TLC	4
Protection	13. Resilient and efficient architecture for wide-area protection	4
Security	14. Simulation model for Web-of-Cells cyber security analysis	4
Control room	15. An Enhanced Situational Awareness and Visualisation User Interface for Frequency Events	4
	16. Decision Support System Algorithms & Architecture for Frequency Control	3
	17. Design of Integration and Coordination Platform for Frequency Control Decision Support Control room functions	3
	18. Distributed Control Actor Interaction for Frequency Control Scenarios	2
	19. Control room operation for voltage control in the web-of-cells	4

Table 3 - List of assets with more general purpose and use

Asset classification	Asset title	TRL
Networks models	20. Pan-European Single Reference Power System	3
	21. "SRPS-TECRES" – Single Reference Power System for static and dynamic simulations to test ELECTRA control loops and functions	4
	22. "FLEXTEC" – Test grid model for steady-state and dynamic simulations of MV/LV distribution networks with high RES integration	4
	23. Accurate PMU latency characterisation and emulation	4
Methods and tools	24. Initialization and Synchronization of Power Hardware-in-the-Loop Simulation for Large Synchronous Power Systems	4
	25. Method for accelerated co-simulation/model exchange between MATLAB/Simulink and DIgSILENT PowerFactory	4
	26. Methodology for designing collaborative experiments and KPIs using the Smart Grid Architecture Model	4
Other	27. ELECTRA Assessment Tool for Smart Grid Interface Standard	5
	28. Procedure for validation of numerical reliability of new observables	3

Table 4 - Assets generated in CSA

Asset classification	Asset title	TRL
Data base	29. Database of DER and Smart Grids Research Infrastructure	9
Methodology	30. The ELECTRA REX methodology and scheme for researcher mobility	NA
Questionnaire	31. Questionnaire for the identification of the R&D priority and cooperation	NA

3. Exploitation plan

The WoC distributed control concept is the key asset developed by the ELECTRA IRP. Therefore, most of the exploitation plan is devoted to explain how ELECTRA partners will further develop and bring it to maturity. Moreover, several assets developed in ELECTRA have the potential for further development and application in the existing network; their exploitation in such a perspective is addressed too.

3.1 WoC control concept exploitation plan

The WoC concept and the control functions to be performed by the cell controller has been validated up to the laboratory level (ref. D7.1 and D7.2) and, therefore, can be considered at TRL 4, although some aspects could be further investigated and consolidated at lab level. More in detail, in order to drive the WoC concept to practical application in the grid, the following gaps have been identified:

1. Since corresponding proof of concept tests have been carried out with some limitations, further research and development on higher TRL levels is necessary (including more concrete rules for defining cells, corresponding test networks and benchmark criteria).
2. More validation is needed to assess stability and containment and restoration related key performance indicators (KPIs) in a many (hundreds) cells network, with a continuous stream of balance deviations in all of the cells, resulting from local generation and consumption forecast errors. Particular attention must be paid to using realistic future power system parameters (high renewable energy resources (RES) penetration, inertia, etc.), reserve resources (real-time behaviour) and the impact of actual information and communication technology (ICT) available (latencies, etc.).
3. The interactions and potential conflicts due to the implementation of the complete control solution, considering the combination of both balance and voltage control functions, have to be analysed. A more holistic approach in terms of assessing potential conflicts should include the use of all control use cases in the cell controllers, employing the same cell available resources (which will receive set-points linked to different use case objectives).
4. For increasing the TRL of the WoC concept and enabling the implementation and application in real networks, further effort is required taking into consideration the implementation of the functionalities at device level as well as on the actual communication interfaces and protocols, in order to ensure the provision of the required flexibility.
5. (Simulated) benchmarking and cost benefit analysis must be performed, e.g. quantifying the amount of additional reserves activation costs (e.g., considering cases with and without balance steering control - BSC), stability and resilience of the system, mitigated losses and congestions. The reference control concept should be a centralized one, relying on improved transmission system operator (TSO) and distribution system operator (DSO) coordination, with realistic grid parameters (e.g. inertia, integration of RES at all voltage levels, reduced central generation, large amount of reserves providing resources connected to the distribution grid).

A plan to overcome the above gaps and bring WoC concept up to the prototype level has been elaborated, see the Gantt chart in Figure 1. It consists in actions/projects to be undertaken in three subsequent phases, as explained in the following.

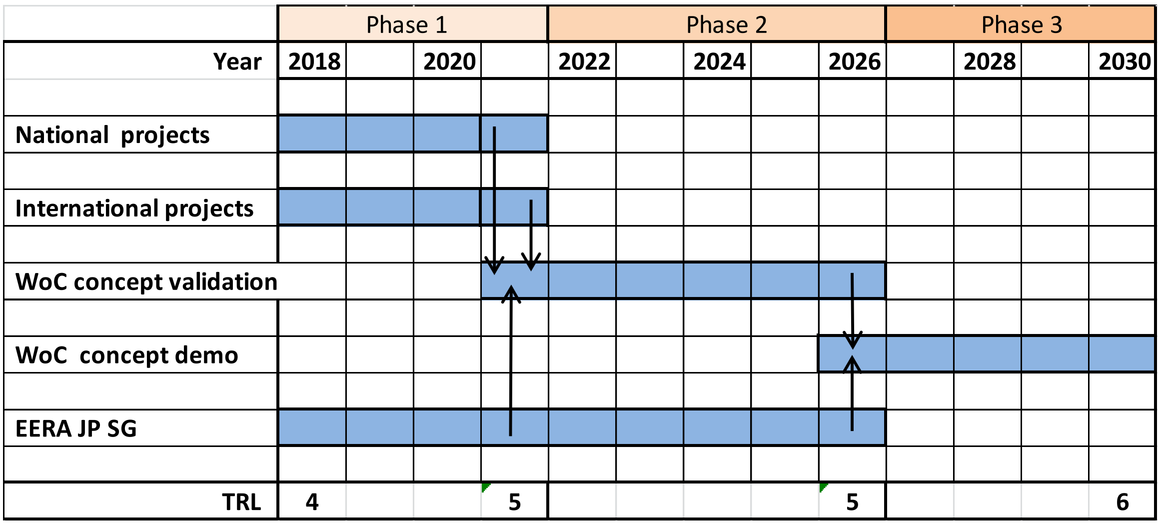


Figure 1 - Gantt chart for WoC concept exploitation and further development

Phase 1 - Short-term actions (2018 - 2021)

The short-term exploitation actions for the WoC control concept are based on three pillars:

- **National projects,** summarized in Table 5 (see pag.19), in which specific aspects of the WoC concept are investigated and further developed, mainly at laboratory level (TRL4), in order to overcome gaps indicated at page 15. These projects are usually undertaken by single partners of the ELECTRA IRP, in the period 2018 - 2021 senior researchers and PhD students from several EERA JP Smart Grids (JP SG) participants will be engaged in R&D activities on the WoC directly involving component manufacturers and national grid operators (TSOs and/or DSOs).

- **International projects,** summarized in Table 6 (see pag. 22). Again, specific aspects of the WoC concept are investigated at laboratory level (TRL4) in the 2018 - 2021period; however some activities in the field (TRL5) are also foreseen. These projects are implemented in the broader contest provided by H2020 projects such as *OSMOSE* (Innovation Action, IA www.osmose-h2020.eu/#osmose), *mySMARTLife* (IA, www.mysmartlife.eu) *ERIGrid* (R&D, www.erigrid.eu) and *FHP* (R&D) in which grid operators are fully involved. Moreover, a strong cooperation with the German project C/sells is foreseen. In fact, selected use cases as balance restoration control - BRC, post primary voltage control - PPVC, and adaptive frequency containment control - aFCC will be considered for their implementation and demonstration. Therefore, the activities performed within these projects will provide important elements for **scalability analysis** of the WoC concept and can be considered as a key intermediate step to bring it towards TRL 5.

- **International Associations and Initiatives**

  EERA JP Smart Grids, aimed at promoting synergies between the above projects and developing a common understanding of their results (in the limit of confidentiality). The EERA JP Smart Grids will have a very important and leading role in view of next steps to bring WoC concept to maturity. It is going to act as coordination platform to allow technical analyses and discussions of results, which will be collected in a common framework, in order to agree on proper strategy and suitable next steps and by promoting effective synergies among the different national and international R&D projects where the JP SG members are the core of the consortium.

As an initial step in this direction, during the 29th EERA JP SG Steering Committee meeting held in Copenhagen on 17th-18th May 2018, a specific workshop dedicated to the ELECTRA foreground *"ELECTRA IRP: activity transfer to JP SG"* and specifically devoted to identify the WoC next steps towards its use and exploitation. The meeting agenda is reported in Fig. 2.

ELECTRA IRP:
activity transfer to JP SG

Introduction - ELECTRA final review meeting outcomes **The way forward:** ➢ *The Web-of-Cells concept future development* ○ *WoC status at the end of ELECTRA - key aspects* - WoC concept for the future power system operation - Market and regulatory aspects of the WoC ○ *Open issues* - Stability analysis of a big power system organized as WoC - How operational planning changes in the WoC architecture (the cells set points) - How the cell dimension (area/power) influence the WoC operation - Smooth transition toward the WoC: mixed traditional/WoC power system? ➢ *CSA future activities* - How to make the effective collaboration possible (effective link with ETIP SNET, MI IC#1, ERANet, ISGAN, etc.) ➢ *Other open points* - ELECTRA Web-of-Cells EU trademark to be filed - ELECTRA Web-of-Cells video (animation) to be released - AOB **Conclusions** ➢ *The Web-of-Cells concept next steps within EERA JP SG* **Actions List**	ELECTRA SC members TC / WPL *40 min.* on Day 1 + *200 min.* on Day 2

Figure 2 – Agenda of the WoC workshop organized by EERA JP SG on May 18 in Copenhagen

The workshop started with the presentation about the ELECTRA final review outcomes and the present status of the WoC concept, particularly useful for the JP SG participants not directly involved in ELECTRA, namely, FOSS (Cyprus), Mines ParisTech (France), KIT and U. of Ilmenau (Germany). Afterwards, an open discussion allowed to highlight the main open issues and gaps to be addressed in order to exploit and further develop the WoC concept.

During the workshop the EERA JP SG partners presented the planned **activities to exploit the ELECTRA main results**. Table 5 and table 6 summarize the main actions foreseen within their organizations. Additionally, other JP SG members not involved in ELECTRA expressed a strong interest for the WoC approach and reported about related ongoing projects and future activities. FOSS that has been always well informed about the ELECTRA activities through the JP SG and ETIP SNET, informed about the intention to present the WoC concept to a company specialized in distributed control systems; moreover, FOSS is launching an upcoming demo project at their university campus that could serve to demonstrate a concept very similar to the WoC. Mines ParisTech representative reported on projects dealing with load and generation forecasting that could be very well integrated in the future WoC concept development and the willingness to collaborate on this very R&D interesting topics in the near future. In addition, Karlsruhe Institute of Technology (KIT) and University of Ilmenau, two new JP SG members, stated that they are performing RD&D activity on topics that are related to the WoC and its possible extension to integrated energy systems. We plan to identify possible cooperation points that will be included and exploited within the JP SG DoW.

Moreover, the ELECTRA partners agreed to file a **EU trademark application concerning WoC**. The ownership of the mark will be in charge of the EERA AISBL whereas its management and exploitation will be in charge of the EERA JP Smart Grids, to which all the ELECTRA partners belong. In this frame, each ELECTRA partner will have all the applicable rights to use the WoC trademark.

Use and exploitation of the WoC concept, as well as its further advances and consolidation, are also expected to be made in the framework of **Mission innovation, Innovation Challenge #1 Smart Grids (IC#1)**, Task *"New grid control architectures",* aiming to study and demonstrate new grid control architectures both at transmission and distribution level. This is one of the six R&D joint Tasks approved and launched by IC#1 during the last deep-dive workshop in May 2018 in Malmoe.

The 2018-2019 Program of Work of this task that is co-led by RSE and US DoE – PNNL, and involve several research organizations worldwide contributing as members of IC#1, foresees the nine sub-tasks reported in the following table. As an example of WoC-related activity, the WoC will be included as one of the available "new grid control architectures" (T5.1) and compared with other relevant approaches.

	Task Topic and Sub-Task	R	D	M	C
Task 1: STORAGE INTEGRATION					
Task 2: DEMAND RESPONSE					
Task 3: REGIONAL ELECTRICITY HIGHWAYS					
Task 4: FLEXIBILITY OPTIONS					
Task 5: NEW GRID ARCHITECTURES					
5.1	Collection of available new grid control architectures	■	■	■	
5.2	Development of a comparison tool for control architectures	■	■	■	
5.3	Enhanced new control architectures	■	■	■	
5.4	Control architecture solutions for the electric network convergence and integration with other domains	■	■	■	
5.5	Impact of new control architectures on regional grids	■			
5.6	Impact of new control architectures on distribution grids		■		
5.7	Microgrids interoperability			■	
5.8	Available new technologies for smart grids				■
5.9	ICT infrastructures				■
Task 6: POWER ELECTRONICS					

Legend:

IC#1 Sub-Challenges:

R: Regional Grid
D: Distribution Grid
M: Microgrid
C: Cross Innovation

Figure 3 – Mission Innovation IC#1: Task 5 on New Grid Control Architectures

Table 5 - Web-of-Cells (WoC) exploitation plan – National projects

Partner	Foreseen projects/actions	Funding instrument - Resources	Timeline (status)
RSE	In the frame of the RdS Project "Development and management of distribution grids" the WoC concept will be further developed and compared with microgrid approach (1) This project contributes to overcome the gap 1 (pag. 15) at TRL 4.	National funding "Ricerca di Sistema" (RdS) >1.2 M€ over the next 3-year period	2018 (running) 2019 - 2021 (to be submitted)
AIT	ABS4TSO (Advanced Balancing Services for Transmission System Operators) is going to analyse the characteristics of highly dynamic system services, supporting future system stability and security. The services include frequency stabilisation via synthetic inertia and enhanced frequency response both with a strong link to the ELECTRA use cases IRPC and FCC. Within the scope of this project a battery storage system (approx. 1MW/500 kWh) will be installed as a reference implementation at TSO level.(2) This project contributes to overcome the gap 2 and 4 at TRL 4 and 5.	National funded project within the framework Energieforschung 2017; Total costs 2.7 M€, funding 1.8 M€	May 2018 - April 2021 (3 years)

[1] RSE intends to further develop the WoC concept by applying it to distribution networks. Possible alternatives in the definition of the cell boundaries on the same network will be studied in order to define guidelines about cells dimensioning, based on scenarios of generation/load resources and flexibilities available in the grid. A configurable simulation platform will be developed aimed to facilitate the representation and the analysis of different generation /load scenarios and cell boundaries choices on the same grid. The same platform will be useful also for comparison of different control architectures applied to the same grid in order to investigates and show advantages and disadvantages of the proposed WoC concept. In particular, differences and similarities between WoC and the microgrid approach will be investigated.

[2] AIT is main partner of the national project ABS4TSO (Advanced Balancing Services for Transmission System Operators) under the lead of the transmission system operator Austrian Power Grid. ABS4TSO is going to analyse the characteristics of highly dynamic system services to be developed within the project, supporting future system stability and security. The services include frequency stabilisation via synthetic inertia and enhanced frequency response. Already in the proposal phase (end of 2017), the ELECTRA use cases IRPC and FCC have been considered. Within the scope of this project, a battery storage system (approx. 1MW/500 kWh) will be installed as a reference implementation at TSO level in order to assess the defined applications and services. Inertia and enhanced frequency response functionalities from ELECTRA are going to be further developed. The project will start in May 2018.

Partner	Foreseen projects/actions	Funding instrument - Resources	Timeline (status)
VITO	Related to WoC (-like) setpoint creation and control, VITO will work on building and Local Energy Community level production and consumption forecasting and planning – incorporating impact of market triggered flexibility activations influencing the planning – and the aggregation of these to determine cell setpoints (where cell = a local community/neighbourhood). On the control side, VITO will work on concepts and strategies related to BRC and PPVC, where building level flexibility is used to control prosumption according to provided setpoints/profiles. This project contributes to overcome the gap 3 at TRL 4.	Flemish Flux50 funding scheme (stimulating cooperation between industry, government and research institutes).(3)	2018/19 submissions
DTU	Initiate two PhD projects on distributed control schemes. The first PhD will investigate the potential benefits and drawbacks of distributed control in power Systems. The second will practically implement and test distributed control algorithms incl. WoC to get insight in the performance of such distributed control schemes. This project contributes to overcome the gap 2 at TRL 4.	Internal funding	October 2018
DTU	Initiate PhD on optimal planning of distribution networks in view of new control schemes such as WoC and market operation. This project contributes to overcome the gap 1 at TRL 4.	internal funding	October 2018

[3] Flux50 coordinates different programs to generate a common approach which facilitates the adaptation of innovative solutions and business models in order to realize the economic opportunities of the transition towards a sustainable energy system. Flux50 is organized in five innovator zones: 1) Energy Harbors, 2) **Microgrids**, 3) Multi-energy Solutions, 4) Energy Cloud Platforms and 5) Intelligent Renovation. Roadmaps, technological and legislative challenges are discussed with stakeholders from industry, research and government and a common approach resulting in demonstration projects, a supporting (low) regulated framework and about 10 M€ yearly financial support are scheduled to boost real life implementations of innovative concepts that support the energy transition via viable economic activities.

Partner	Foreseen projects/actions	Funding instrument - Resources	Timeline (status)
SINTEF Energy Research	Within framework of Centre for Intelligent Energy Distribution – CINELDI, SINTEF works on further development and adaptation of several control Use Cases from WoC to the working procedures and components at the Norwegian DSOs. Development and adaptation of PVC and PPVC Use Cases are already in process. CINELDI studies possibilities for implementation of WoC Use Cases (full or partial) in pilots within the Centre. This project contributes to overcome the gap 2 and 4 at TRL 4.	Research Council of Norway through national financing of CINELDI (8-years programme)	2018-2019 2019=>
TECNALIA	DIGITAL GRID project aimed to further develop the Web-of-Cells concept at laboratory level, focused on LV cells and involving real distribution grid equipment like MV/LV smart transformers.[(4)] This project contributes to overcome the gap 1 and 4 at TRL 4.	Basque Government through the ELKARTEK Programme.	July 2018 - Dec. 2019 (1.5 years)
TECNALIA	Use of FLEXTEC grid model to futher developed the WoC concept focused on LV cells This project contributes to overcome the gap 1 at TRL 4.	DIGITAL GRID (National Project)	2018-2019
USTRATH	National academic project to further advance the provision of decentralised grid services through the Web-of-Cells platform. This project contributes to overcome the gap 1 at TRL 4.	UKRI responsive mode programme	2018 submission
USTRATH	National industrial collaboration programmes used to further advance relevant WoC Use Cases at industry scale and utilising digital substation platforms. This project contributes to overcome the gap 1 and 4 at TRL 4 and 5.	National Network Innovation Allowance and Competition programmes	2018/19 submissions

[4] TECNALIA has submitted a proposal ("DIGITAL GRID" project) to be funded by the Basque Government through the so-called ELKARTEK Programme. The 1.5-year project will be starting in the second half of 2018 and it will be a collaboration between TECNALIA, the University of the Basque Country, the industrial manufacturer ORMAZABAL and the Basque Center for Applied Mathematics. The aim is to further develop the Web-of-Cells concept at laboratory level focused on LV cells and involving real distribution grid equipment like MV/LV smart transformers to control the LV flexibility from the substation transformer downwards. Special emphasis will be made on the post-primary voltage control, employing advanced techniques for very accurate short-term generation and load forecasts ("nowcasting"). Scalability issues and hierarchical controller conflicts will be tackled too.

Table 6 - Web-of-Cell (WoC) exploitation plan – International projects

<table>
<tr><th>Partner</th><th>Foreseen projects/actions</th><th>Funding Instrument/Resources</th><th>Timeline (status)</th></tr>
<tr><td>RSE</td><td>In the frame of a sub-transmission in-field demonstrator of Terna (Italian TSO) will be evaluated the applicability of WoC concept and selected ELECTRA UCs to the portion of the grid used for the demonstrator.[5]

This project contributes to overcome the gap 4 and 5 at TRL 5.</td><td>H2020 – GA 773406 Osmose</td><td>2018-2021 (running)</td></tr>
<tr><td>RSE</td><td>Selected UCs (i.e. BRC, PPVC, aFCC) are planned to be implemented and demonstrated within the German C/sells project in order to start to validate the WoC concept beyond laboratory environments.

This project contributes to overcome the gap 2 and 5 at TRL 4 and 5.</td><td>National funding “Ricerca di Sistema” (RdS)

>0.2 M€ over the next 2-year period</td><td>2018-2019</td></tr>
<tr><td>AIT</td><td>Usage of network and controller simulation models for validating ERIGrid testing methods and services; lessons learned and best practices for selecting laboratories for proof-of-concept validation.[6]</td><td rowspan="4">H2020 ERIGrid (GA 654113)

This project contributes to overcome the gap 2 and 3 at TRL 4.</td><td rowspan="4">2018-2020

(running)</td></tr>
<tr><td>DTU</td><td>In the frame of EriGrid develop testing methods for distributed control systems such as WoC</td></tr>
<tr><td>OFFIS</td><td>Application of ERIGrid’S holistic validation procedure to control functions designed for ELECTRA’s web of cells</td></tr>
<tr><td>TECNALIA</td><td>Use of grid models and control schemes developed in ELECTRA for validating ERIGrid testing methods and services.[7]</td></tr>
</table>

[5] In the frame of a sub-transmission in-field demonstrator of Terna (Italian TSO) the applicability of WoC concept and selected ELECTRA UCs will be evaluated in the portion of the grid used for the demonstrator. The TERNA demo aims to developing a new EMS, at regional level, for the flexibility exploitation of large industrial loads and renewable generators. This new EMS, conceived to manage network flexibilities at near real-time, could represent an ELECTRA cell controller and will take advantage from the control functions already developed within ELECTRA.

[6] For the validation of ERIGrid testing methods and services network and controller simulation models are being re-used from ELECTRA IRP. Moreover, lessons learned and best practices for selecting laboratories for proof-of-concept validation are being used in ERIGrid from the ELECTRA project.

[7] For the validation of ERIGrid testing methods and services, grid models (specially FLEXTEC) and control schemes (specially PPVC) are being re-used from ELECTRA IRP. ELECTRA control schemes will be used as use cases in ERIGrid, where its methodology will be applied to them. Besides, a centralised voltage control (similar to the PPVC function at cell level) will be implemented in the JaNDER architecture (remote control of labs for a share experiment).

Partner	Foreseen projects/actions	Funding Instrument/Resources	Timeline (status)
VITO	**WoC(-like) profile planning and following by a cluster of buildings.** In the FHP project, clusters of buildings are managed to optimally plan their prosumption, possibly incorporating flex activations for various stakeholder services, and then control their prosumption in line with the agreed plan. The required modelling, forecasting, optimization and control strategies and algorithms are similar/identical to those needed for a WoC BRC control concept: each building – or each cluster of buildings – can be considered as a cell for which a setpoint is determined, that subsequently must be adhered to. Besides, the PPVC concept may be considered. This project contributes to overcome the gap 1 and 3 at TRL 4.	H2020 – GA 731231 FHP	2018-2019 (running)
VTT	mySMARTLife project focuses on harnessing renewable resources in cities. Controllability of the devices from WoC concept is further developed in the project. Smart energy management and new algorithms as well as reactive power compensation (voltage control) will be investigated. This project contributes to overcome the gap 3 at TRL 4.	Horizon 2020 on-going	2017-2020
VTT	VTT is partner in application to call “Decarbonising energy systems of geographical islands” Work is related to load based balance steering control of Electra (BSC use case). This project contributes to overcome the gap 1 at TRL 4.	Horizon 2020 call	2018-2021 (to be submitted)

Partner	Foreseen projects/actions	Funding Instrument/Resources	Timeline (status)
USTRATH	**Demonstrate smart grid measurement, control, and protection methods in partnership with Nokia** USTRATH and Nokia will collaborate on a three-year plan to demonstrate key smart grid applications, combining power systems and real-time simulation laboratory facilities at USTRATH with the extensive communications validation facilities operated by Nokia in Plano, Texas, USA. The R&D activities will include distributed frequency control, building upon the WoC frequency control use cases developed within ELECTRA. The wide-area protection methods developed within ELECTRA Task 6.3 will also be exploited and validated at a higher TRL and under a greater number of scenarios. This project contributes to overcome the gap 2 at TRL 4 and 5.	Industrial co-funding	2018-2020+ (running)
USTRATH	**Validation of distributed control concepts at scale in partnership with NTU** USTRATH and NTU will collaborate to demonstrate and validate one of the pressing issues related to distributed control concepts - the scalability of such mechanisms. Utilizing the framework of geographically distributed experimentation, and building on the WoC validation platform, an approach to demonstrating scalability will be developed. This project contributes to overcome the gap 2 at TRL 4.	International University partnership funding and ERIGrid	2018-2019 (running)
USTRATH	**Development of decision support tool for voltage control in the context of WoC concept** USTRATH and New York University (NYU) will collaborate to incorporate some responsibilization (local response to local event) techniques for voltage control with NYU, building on the WoC decision support tool developed by USTRATH. This project contributes to overcome the gap 5 at TRL 4.	International University partnership funding (Initially)	2018-2019 (running)

Phase 2 - medium term actions (2021 - 2026)

Phase 2 is characterized by the proposal of a project aimed at systematically investigating the WoC concept and bring it at TRL 5 (**technology validated in the field**). It can be seen as a necessary step in order to convince stakeholders to implement and demonstrate the WoC control concept in a real grid. However, this topic is not foreseen among the 2018-2019 H2020 Calls and any project proposal should be shifted to the 2020 call or, most probably, to the 9th FP programme. Such a project, which will take advantage from results obtained in phase 1 and will deeply involve grid operators, will have the following main features:

(i) the cell control functions (BRC, aFCC, PVC, PPVC, BSC, IRPC - ref. D4.2) are validated in a scenario of networks with high RES penetration and local imbalances due to continuous streams of distributed deviations;

(ii) a scalable simulator with a configurable control layer is developed with the aim to demonstrate a WoC control architecture applied to a real grid organised with a significant number of cells (hundreds). The user should interact with the simulator by a control room emulation as specified in D8.2.

Such a scalable simulator would allow better understanding of the global system dynamics and optimal control parameters tuning in a many cells system under normal operation conditions, characterised by continuous stream of fluctuation of RES generation and load, giving a large-scale demonstration of the advantages offered by WoC for the power system stability in a RES dominated context. The simulator will allow to evaluate future scenarios of increased RES penetration on the grid, where the existing control operation could present critical issues.

The assessment of the benefits obtained by adoption of WoC architecture on the simulated real grid will use KPIs defined by system operators and will be made by comparison with the performances of the current centralized control operation.

Moreover, for enabling the deployment of WoC architecture in real networks, effort on device level as well as on the actual communication interfaces and protocols is requested. Thus, the project will address the implementation of the functionalities (algorithms) at device level for the development of flexible and adaptive active grid components capable of efficiently delivering the services required by the WoC control functions.

This project will allow a detailed scalability analysis of the WoC concept and will support the provision of a detailed migration plan for the progressive deployment of the concept in real networks.

Again, EERA JP Smart Grids can have a key role in launching such a project and in disseminating its results.

Phase 3 - long term action (2026 - 2030)

The phase 2 project above described will put the basis for an Innovation action (IA) in which WoC control concept is implemented and demonstrated in a real grid. Such IA can be led by a grid operator (TSO or DSO). Its features, of course, cannot be foreseen at present. However, it will realize the complete migration of WoC concept from R&D organizations to industry, in view of system prototype development and demonstration.

3.2 Exploitation of ELECTRA results in the existing grid

As far as concerns the exploitation of ELECTRA results, there is an important aspect that should be stressed. Several assets developed in ELECTRA such as control functions, methodologies and models, are not necessarily related to WoC, i.e. they have the potential of a wider application in the short- medium term.

In this frame, as reported in Table 7, several partners intend to exploit ELECTRA results both in national and international projects, involving stakeholders, addressed mainly to an optimization of operation of the existing grid.

For example, SINTEF Energy works on the preparation of a proposal with a national TSO aimed to study challenges related to inertia in which results about inertia-related observables from Task 5.2 and Task 5.4 will be further developed. Similarly, wide area protection method and testing procedure developed by USTRATH in WP 6 will be further validated in communication networks in the frame of a partnership with Nokia.

Other results, such as simulation model for cyber security analysis and Hardware-in-the-Loop based validation, will be used and further developed in on-going H2020 European projects such as OSMOSE and ERIGrid.

Experiences and lesson learnt from Hardware-in-the-Loop based validation will be transferred in IEEA P2004 standardization working group.

As far as concerns assets developed in CSA, the ELECTRA REX methodology and scheme will be applied and further developed in a H2020 project (proposal submitted).

Finally, in order to make available results generated by ELECTRA to other users, selected assets identified in chapter 2, along with key deliverables illustrating project results, are being transferred to the recently developed *EERA Intellectual Property (IP) repository* and will be made available (*free access*) through the **web-based IP showcase** (*http://app.eera-set.eu/ecm/showcase*).

Table 7 - Exploitation plan of ELECTRA results/assets (other than WoC)[8]

Result / Asset	Partner	Foreseen actions	Project	Timeline
14. Simulation model for Web-of-Cells cyber security analysis	RSE	The methodology for the analysis of attacks to the WoC control architectures will be further developed to model and analyse more extended cyber kill chains in electrical control schemes for flexibility management.	National funding “Ricerca di Sistema” (RdS) H2020 IA OSMOSE (GA 773406)	2018 2018-2021

[8] The numbered items correspond to assets listed in Annex 1. The remaining items refers to more general ELECTRA results.

Result / Asset	Partner	Foreseen actions	Project	Timeline
Post Primary Voltage Control (PPVC) use case	AIT	Post Primary Voltage Control (PPVC) prototypical realization. Usage of implemented PPVC simulation-based validation in H2020 ERIGrid for validating the ERIGrid holistic validation approach as well as the validation of the AIT LabLink coupling approach	H2020 ERIGrid (GA 654113)	Q4/2017 to Q2/2018
1. Post primary voltage control with ZIP loads and Electra cell control	VTT	Simulation platform for WoC based voltage control. VTT will develop new testing laboratory to integrate developed voltage control model in actual devices.	Laboratory development (self-funded). Results will be exploited in ERIGrid project	2018-2020 (running)
2. A novel measurand and a decentralized responsabilizing primary frequency control	USTRATH	Further development of the method and its application within secondary frequency control.	Internal project	2018-2019
13. Resilient and efficient architecture for wide-area protection	USTRATH	Wide-area protection methods and testing procedures. Further validation of real-time operation over practical communications networks, and under a greater number of scenarios.	USTRATH-Nokia partnership	2018-2020+
16. Decision support System Algorithms & Architecture for Frequency Control	USTRATH	Further development to incorporate decision support for voltage control applications.	NYU-UST internal	2018-2019
23. Accurate PMU latency characterization	USTRATH	Further validation of PMU capability at distribution level, using a variety of time synchronisation technologies.	Enersyn (ESA funding)	2018-2019

Result / Asset	Partner	Foreseen actions	Project	Timeline
24. Initialization and Synchronization of Power Hardware-in-the-Loop Simulation for Large Synchronous Power Systems	USTRATH	Set-up and implementation of increasingly complex HIL experiments for the validation of decentralised smart grid controls with PNDC and TSO & DSOs at TRL5/6 and external lab users.	EFCC (UK) and follow on national projects, ERIGrid Transnational Access	2018-2020
25. Method for accelerated co-simulation/model exchange between MATLAb/Simulink and DIgSILENT Power Factory	USTRATH	Use for several other projects where the coupling between PowerFactory and Matlab is required.	EriGrid, LV Engine, MyRails	2018-2019
26. Methodology for designing collaborative experiments and KPIs using the Smart Grid Architecture Model	USTRATH	Further development of the methodology for its application to support laboratory validations	Internal project	2018-2019
30. ELECTRA REX methodology and scheme for researcher mobillity	USTRATH	USTRATH with partners will apply and further refine the mobility methodology developed within ELECTRA to support researcher mobility across the energy research domain	H2020 proposals (submitted)	2018-2021
Observables from Task 5.2 and 5.4 IRCP use case	SINTEF Energy Research	SINTEF works on preparation of project proposal towards nation TSO (Statnett SF), which will study challenges related to inertia. Results and conclusions about inertia-related observables from T5.2 and T5.4 and possibly set-up IRPC will be further studied in the project (provided that the proposal will succeed).	Norwegian TSO (Statnett SF) (under development)	2019=>
Experiences and lessons learned from Hardware-in-the-Loop based validation	AIT	Usage of best practices for various Trans-national Access (TA) projects like Smart beast Copper, 4D Power, etc.	H2020 ERIGrid (GA 654113)	2018 – 2020

Result / Asset	Partner	Foreseen actions	Project	Timeline
Experiences and lessons learned from Hardware-in-the-Loop based validation	AIT, Fraunhofer IEE, USTRATH	Provision of best practices (initialization, synchronization , time-delay compensation, etc.) as input for the IEEE P2004 standardization working group	IEEE P2004 Working Group	Q3 to Q4 2018
Multi-agent infrastructure for control	DTU	further use and development of multi-agent control infrastructure to investigate distributed systems	H2020 ERIGrid (GA 654113)	2018-2020 (running)

4. References

D4.2, “Description of the detailed functional architecture of the frequency and voltage control solution (functional and information layer)”, ELECTRA IRP WP4, January 2017.

D5.3 “The web of Cells control architecture for operating future power systems” ELECTRA IRP WP5, April 2018.

D7.1, “Report on the evaluation and validation of the ELECTRA WoC control concept”, ELECTRA IRP WP7, March 2018.

D7.2, “Lessons learned from the ELECTRA WoC control concept evaluation and recommendations for further testing and validation of 2030 integrated frequency and voltage control approaches”, ELECTRA IRP WP7, March 2018.

D8.2 “Demonstration of decision support for real time operation encompassing the identification of key threats and vulnerabilities, and the provision of assessed interventions”, ELECTRA IRP WP8, February 2018.

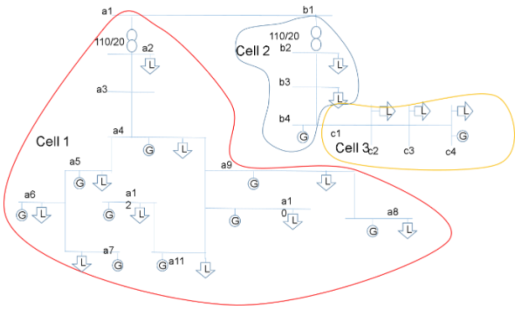
5. Disclaimer

The ELECTRA project is co-funded by the European Commission under the 7th Framework Programme 2013.

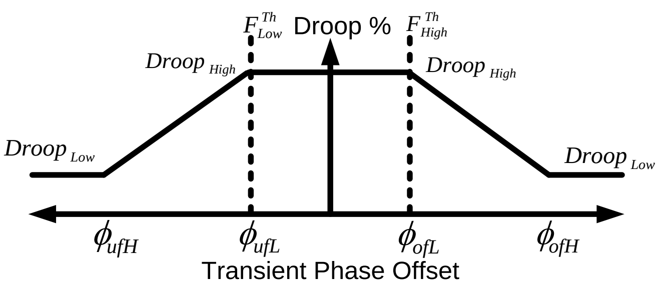
The sole responsibility for the content of this publication lies with the authors. It does not necessarily reflect the opinion of the European Commission.

The European Commission is not responsible for any use that may be made of the information contained therein.

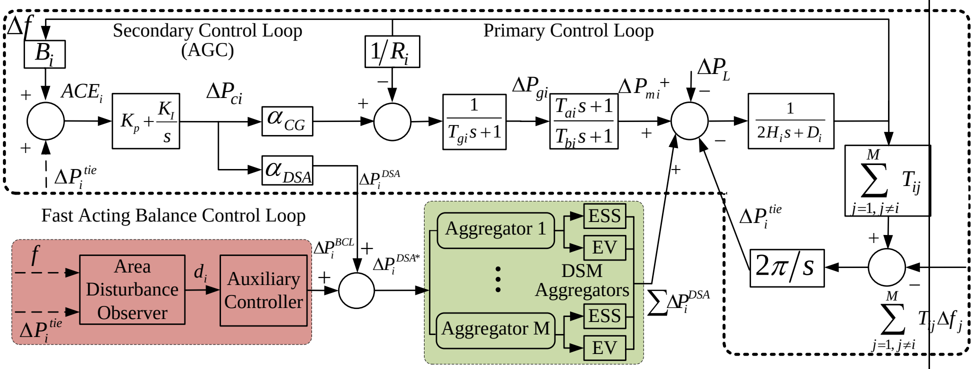
ANNEX 1 – Assets detailed description

Title	**1. Post primary voltage control with ZIP loads and Electra cell concept**
Type of Asset	*Foreground -Model*
Short description	-
Longer description	*CIGRÉ MV Benchmark grid with LV extension. Modelled as three cells according to Electra Cell concept*  Simulation environment at VTT setup for PPVC is Matlab Simulink together with Matpower package in Matlab. Grid model in Simulink made Simpower systems tool pack components and uses transient solver. The purpose of Simulink model is to act as a grid for testing. Matpower model is used for calculating optimal reactive power control and tap changer setpoints. These setpoints are given to Simulink model and results compared between different cases. As reassurance of results it was decided that Matpower calculation of power flow was used as comparison to Simulink results. System is controlled with matlab m-files and matlab is also used save the results. Some input files in CSV form are needed for the model. The development is planned to continue in projects in the same topic.
Technology Readiness Level (TRL)	*3*
WP of reference	*WP6 and WP7*
Organisation leader	*VTT Technical Research Centre of Finland*
Contact person/ Email	*riku.pasonen@vtt.fi*
Second Organisation in charge of managing the asset	
Contact person/ email	
IPR	*No IPR claims from VTT. Matpower is required tool for which comes with BSD license. Octave(GNU license) or Matlab (commercial) is required to use Matpower*
IPR Status	

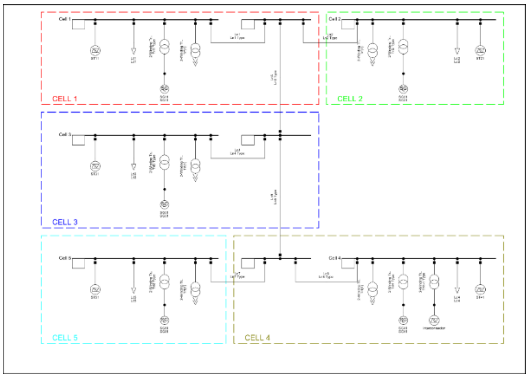
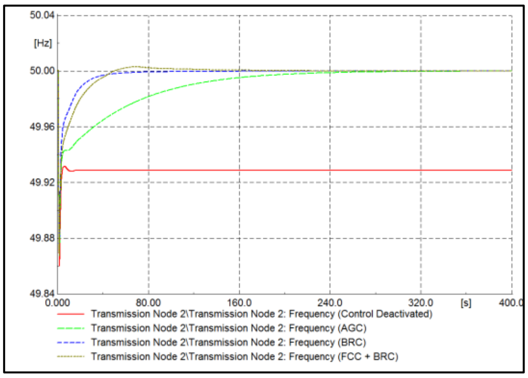
References	*ELECTRA D7.2, ELECTRA D6.2*
Technology keywords	*Optimum power flow, ZIP load model,*
Special conditions for the access to such Asset?	*Free access*

Title	**2. A novel measurand and a decentralized responsibilizing primary frequency control**
Type of Asset	*Foreground -control*
Short description	*A novel measurand, transient phase offset (TPO), is introduced to enable a novel decentralized "responsibilizing" primary frequency control based on the measurand.*
Longer description	*Upon occurrence of an event, the TPO is larger when measured geographically closer to the event than further away. Therefore, in a synchronous power system that is divided into a number of load frequency control areas, a local TPO measurement can be utilized to quickly and autonomously detect if an area should contribute more to frequency mitigation than other areas.* *The TPO has been utilized to design a novel decentralized responsibilizing primary frequency control (PFC). The droop curve for the proposed PFC is shown in Fig. 1. The design procedures and more details can be found in [1].*  *The potential advantages of the proposed control are: (i) the prioritization of local response to a local imbalance, reducing the divergence from planned system conditions and hence minimizing the operational implications of the disturbance, and (ii) supporting enhanced scalability in the future grid given the autonomy of the approach.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP7*
Organisation leader	*USTRATH*
Contact person/ Email	*Mazher Syed mazheruddin.syed@strath.ac.uk*
Second Organisation in charge of managing the asset (if any)	*N/A*
Contact person/ email	
IPR	*TBD*
IPR Status	

References	*[1] Syed, MH, Guillo-Sansano, E, Blair, SM, Roscoe, AJ & Burt, GM 2018, 'A novel decentralized responsibilizing primary frequency control'* IEEE Transactions on Power Systems. *DOI: https://doi.org/10.1109/TPWRS.2018.2799483*
Technology keywords	*Responsibilization, primary frequency control, decentralized control.*
Special conditions for the access to such Asset?	*TBD*

Title	**3. An enhanced load frequency control framework with improved responsibilization**
Type of Asset	*Foreground- control*
Short description	*A novel secondary frequency control, referred to as the enhanced load frequency control framework, is proposed.*
Longer description	*The developed Balanced Restoration Control (BRC) method called Enhanced Load Frequency Control (ELFC) framework is presented below. The framework incorporates a fast acting balance control loop (BCL), in addition to the primary and secondary control loop. The key features are:* • *Fast and autonomous identification of disturbance location, ensuring unilateral activation of reserves allowing for faster response speeds.* • *Use of area power imbalance over conventionally utilized area control error (ACE) as control input.* • *Employs only fast acting demand side resources, eliminating any restriction on speed of response due to ramp-rate constraints.*  *The potential advantages of the proposed control are: (i) the prioritization of local response to a local imbalance, reducing the divergence from planned system conditions and hence minimizing the operational implications of the disturbance, and (ii) supporting enhanced scalability in the future grid given the autonomy of the approach.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP7*
Organisation leader	*USTRATH*
Contact person/ Email	*Mazher Syed* mazheruddin.syed@strath.ac.uk
Second Organisation in charge of managing the asset (if any)	*N/A*
Contact person/ email	
IPR	*TBD*
IPR Status	
References	

Technology keywords	*Responsibilization, secondary frequency control, decentralized control.*
Special conditions for the access to such Asset?	*TBD*

Title	**4. Proof of concept model for integrated operation of FCC+BRC+BSC**
Type of Asset	*foreground -control*
Short description	*Models have been created and simulations carried out which show the successful integration of ELECTRA FCC and BRC controllers in a power system model, and their operation during a scenario involving BSC actions.*
Longer description	*The simulations are performed on a reduced test system representing the GB transmission system, including lower voltage distribution system models based on the University of Strathclyde PNDC test system. The model is composed of five "cells" as defined by the web-of-cells concept within the ELECTRA IRP. Each cell contains controller models which act independently of one another, with the objective of solving active power imbalances locally by providing reserve activations when the imbalance event occurs within the local cell.*  **Figure 1 - The GB-based transmission system model, characterised by five "cells"**  **Figure 2 - Frequency response of controller combinations to imbalance event.** *The FCC controller successfully localises the droop response by curtailing it in external cells and enlarging it in the problem cell. The BRC controller improves on present-day secondary frequency AGC-based load-frequency control by activating fast-acting active power reserves only in the problem cell through an algorithm which can identify the location of the imbalance event. The result of the combined controller case is a quick recovery of frequency to the nominal value after an imbalance event, while achieving localisation of reserve activation through tailored droop contributions and no fast-acting reserve activations in non-problem cells.*

The successful operation of these controllers (FCC and BRC) is also tested for a scripted BSC operation scenario and are shown to operate as expected.

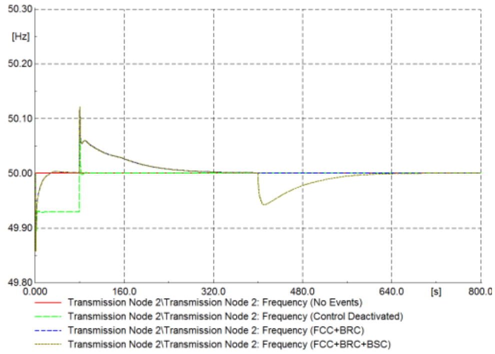
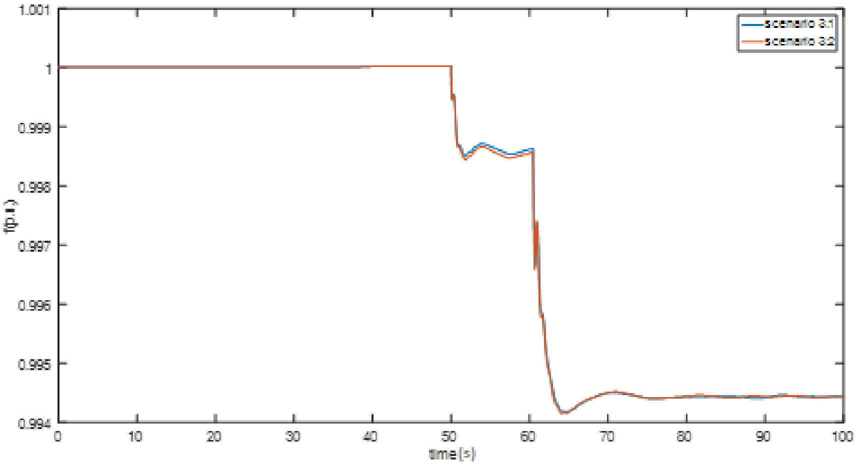


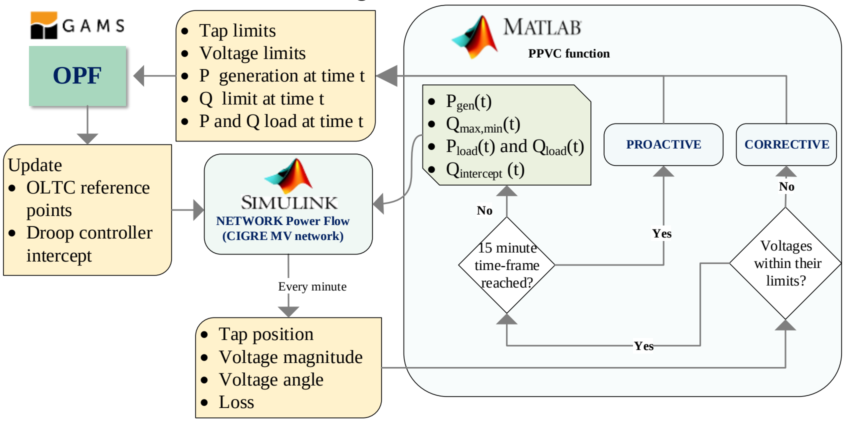
Figure 3 - Frequency response of scripted BSC scenario.

The BSC scenario uses imbalance netting when two equal-but-opposite imbalance events occur in neighbouring cells. After the secondary reserves have been fully deployed in each cell, the boundary power flow setpoints of the secondary controller is changed to a value which allows the reserves to be returned to their pre-event dispatch. This maintains system frequency, while allowing generators to return to pre-fault levels, as long as it is operationally secure to alter the inter-cell power flows. The simulation demonstrates that there is no conflict between the FCC+BRC controllers and the operation of BSC.

Technology Readiness Level (TRL)	*4*
WP of reference	*WP7*
Organisation leader	*USTRATH*
Contact person/ Email	*Kevin Johnstone (kevin.johnstone@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	*CRES*
Contact person/ email	*Evangelos Rikos (vrikos@cres.gr)*
IPR	*TBD*
IPR Status	
References	
Technology keywords	*Simulation, Control*
Special conditions for the access to such Asset?	*TBD*

Title	**5. Proof of concept model for the operation of FCC**
Type of Asset	*foreground -control*
Short description	*Simulation of the FCC function, developed within ELECTRA, in a MV grid.*
Longer description	*The selected variant of FCC aims at locally observing and responding to frequency changes by modifying active power within a time scale of less than 30sec in order to support the containment of frequency under normal operation or after incidents. To this end, this variant assumes a frequency dead-band which makes the response configurable depending on the magnitude of the imbalance, thereby achieving an optimal performance of the decentralised controllers under both system states. When the steady state is reached, the CPFC may be adjusted (based on the cell's imbalance error signal) if the incident that lead to the FCC activation occurred in another cell; if the incident occurred in a certain cell, the CPFC of this cell would be its previous value:* $$CPFC = \begin{cases} CPFC, & \text{disturbance occured in this cell} \\ 0, & \text{disturbance occured in another cell} \end{cases}$$ *An example is provided in figure 1, where the frequency had a second drop, after the steady state is reached, due to the new values of the CPFC in the cells where the problem did not occur. In this situation, only the cell with the problem has to contribute to its mitigation.*  **Figure 1 - Frequency of the system** *This adjustment can be regarded as an intermediate step between the traditional primary and secondary frequency control (i.e. FCC and BRC, respectively).* *The core idea of this control scheme originates from the classic droop control function of synchronous generators with dead-band which can be extended and applied to various other resources, including DER and loads. Regardless of the underlying technology of the device that is used for the provision of FCC (which is beyond the scope of this analysis), the controller should always interact with*

	higher level functions at cell level for contributing and managing the overall cell's power frequency response (CPFC), which in this specific variant is determined by the web-of-cells requirement (NPFC).
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6*
Organisation leader	*INESC TEC*
Contact person/ Email	*Filipe Soares (filipe.j.soares@inesctec.pt);* *António Coelho (amcoelho@inesctec.pt)*
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	
IPR	*TBD*
IPR Status	
References	*D6.1 - Functional specification of the control functions for the control of flexibility across the different control boundaries* *D6.3 – Core functions of the Web-of-Cells control scheme* *A. Coelho, F. Soares, B. Silva, C. Moreira, "Primary Frequency Control in Future Power Systems - The ELECTRA Project Approach under the Web-of-Cells Concept", IREP 2017, Espinho, Portugal*
Technology keywords	*Simulation, primary frequency control, Web-of-Cells*
Special conditions for the access to such Asset?	*TBD*

Title	**6. Simulation files of the PVC/PPVC implementation on the CIGRE MV test network**
Type of Asset	*foreground -control*
Short description	*Simulation files developed for the implementation of Post Primary Voltage Control (PPVC)*
Longer description	*The simulation files of the implementation of the post-primary voltage control on the CIGRE MV electrical network is provided. The PPVC is implemented using Matlab Simulink and the OPF is written using the General Algebraic Modelling System (GAMS). The objective in the OPF formulation is loss minimization and the OLTC and converter droop controller parameters are included in the constraint. As the tap setting is integer variable, the loss minimizing OPF is Mixed Integer Nonlinear Programming (MINLP) problem. As shown in figure below the PPVC process starts as the Simulink based network model starts running.* 
Technology Readiness Level (TRL)	*3*
WP of reference	*7*
Organisation leader	*SINTEF Energy Research*
Contact person/ Email	*Merkebu Zenebe Degefa* MerkebuZenebe.Degefa@sintef.no
Second Organisation in charge of managing the asset (if any)	*NA*
Contact person/ email	*NA*
IPR	*The PPVC system for the CIGRE MV test grid model implemented in Matlab Simulink and the OPF is written using the General Algebraic Modeling System (GAMS)*
IPR Status	*The model can be used freely for research/educational purposes*
References	*[1] Merkebu Z. Degefa, Salvatore D'Arco, Andrei Morch and Atsede G. Endegnanew. "Power Hardware-In-the-Loop Validation of Post-Primary Voltage Control Scheme" The 1st IEEE Conference on Energy Internet and Energy System Integration. NOV 26-28, 2017 Beijing China*

Technology keywords	*Power systems model; Voltage Control; Web-of-Cells;*
Special conditions for the access to such Asset?	*The model can be used freely for research/educational purposes*

Title	**7. Adaptive Cell Power-Frequency Characteristic Determination (ACPFCD)**
Type of Asset	*foreground – control function*
Short description	*The Adaptive Cell Power-Frequency Characteristic Determination function uses fuzzy logic in order to obtain an on-line adjustment of a CPFC based on the imbalance and frequency deviation values*
Longer description	*The basic concept of this approach is the following: when an imbalance incident happens in one cell, the frequency initially increases/decreases based on the imbalance sign and, by the same token, the tie-line error aggregate follows an opposite, to the frequency course. Thus, by detecting the combined signs as well as sizes of the two errors, it is possible to adjust the droop slope of the cell when the incident takes place outside the cell or maintain its maximum value whenever the incident concerns the specific cell.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6-Controllable Flexibility*
Organisation leader	*CRES-Centre for Renewable Energy Sources and Saving*
Contact person/ Email	*Evangelos Rikos/vrikos@cres.gr*
Second Organisation in charge of managing the asset	*VITO*
Contact person/ email	*Chris Caerts/chris.caerts@vito.be*
IPR	*Not applicable*
IPR Status	*Not applicable*
References	*[1] D6.3- Core functions of the Web-of-Cells control scheme* *[2] E. Rikos, C. Caerts, M. Cabiati, M. Syed, G. Burt, "Adaptive Fuzzy Control for Power-Frequency Characteristic Regulation in High-RES Power Systems", Energies 2017, 10, 982 (http://www.mdpi.com/1996-1073/10/7/982)*
Technology keywords	*Control function*
Special conditions for the access to such Asset?	*Ref [1] and [2] need to be cited.*

Title	**8. Cell Set-point Adjusting (CSA)**
Type of Asset	*foreground – control function*
Short description	*The Cell Set-point Adjusting function detects imbalances exceeding a specific threshold in a cell and negotiates with its peers the possibility of adjusting the set-point of the tie-lines.*
Longer description	*The function performs a number of actions including the detection of imbalances, the estimation of the imbalance size, the calculation of remaining available capacity for each tie-line, the issuing of request for set-point adjustment to neighbouring cells, the response to a similar request from another cell, and the final assessment of imbalance with the final acceptance of the adjustment.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6-Controllable Flexibility*
Organisation leader	*CRES-Centre for Renewable Energy Sources and Saving*
Contact person/ Email	*Evangelos Rikos/vrikos@cres.gr*
Second Organisation in charge of managing the asset	*VITO*
Contact person/ email	*Chris Caerts/chris.caerts@vito.be*
IPR	*Not applicable*
IPR Status	*Not applicable*
References	*D6.3- Core functions of the Web-of-Cells control scheme*
Technology keywords	*Control function*
Special conditions for the access to such Asset?	*Reference to the ELECTRA IRP D 6.3*

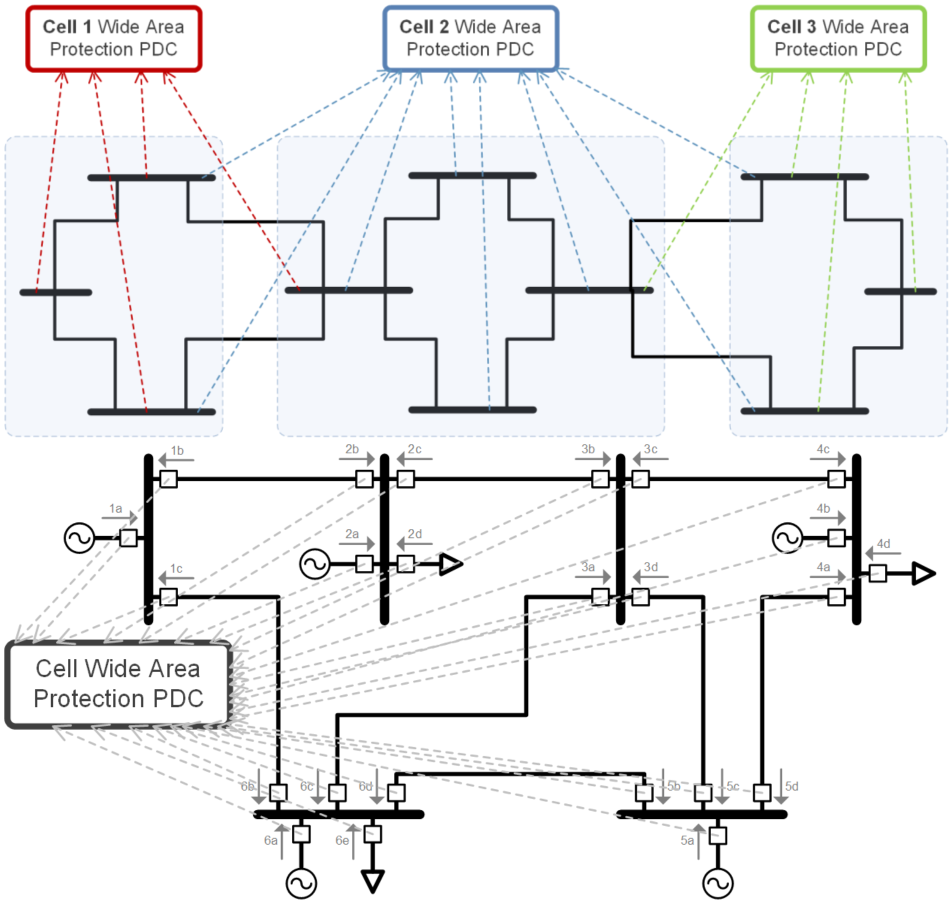
Title	**9. Frequency Droop Parameter Determination (FDPD)**
Type of Asset	*foreground –control function*
Short description	*The Frequency Droop Parameter Determination function implements a strategy in order to divide all available FCC reserves into frequency slots in order to obtain a scalable activation through frequency deadband values for each reserve*
Longer description	*The function prioritises the cheapest reserves so that they can be used first for the very small and more frequent imbalances, and if these deviations exceed specific limits more and more reserves are activated. More analytically, FDPD receives two input signals, namely one Cell Power-Frequency Characteristic (CPFC) value that is used as a set-point at the beginning of the process and a table of values (as a second input) which corresponds to the final (optimised) Merit Order list of all acceptable reserves. The output of this procedure is another table containing droop slopes as well as frequency values (activation thresholds) for the selected Frequency Containment Control reserves.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6-Controllable Flexibility*
Organisation leader	*CRES-Centre for Renewable Energy Sources and Saving*
Contact person/ Email	*Evangelos Rikos/vrikos@cres.gr*
Second Organisation in charge of managing the asset (if any)	*VITO*
Contact person/ email	*Chris Caerts/chris.caerts@vito.be*
IPR	*Not applicable*
IPR Status	*Not applicable*
References	*D6.3- Core functions of the Web-of-Cells control scheme*
Technology keywords	*Control function*
Special conditions for the access to such Asset?	*Reference to the ELECTRA IRP D 6.3*

Title	**10. Merit Order Collection (MOC)**
Type of Asset	*foreground -control*
Short description	*The Merit Order Collection function collates all available reserves' status in a list sorted by cost and size*
Longer description	*The Merit Order Collection function implements an algorithm in order to collect all available reserves' status, collate them in a list initially ranked based on the European Article Number (EAN, a unique identity number for each unit) of each reserve and, consequently, sort twice the list based first and foremost on cost/W (ascending order with cheapest reserves first) and then based on the size of the reserve.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6-Controllable Flexibility*
Organisation leader	*CRES-Centre for Renewable Energy Sources and Saving*
Contact person/ Email	*Evangelos Rikos/vrikos@cres.gr*
Second Organisation in charge of managing the asset	*VITO*
Contact person/ email	*Chris Caerts/chris.caerts@vito.be*
IPR	*Not applicable*
IPR Status	*Not applicable*
References	*D6.3- Core functions of the Web-of-Cells control scheme*
Technology keywords	*Control function*
Special conditions for the access to such Asset?	*Reference to the ELECTRA IRP D 6.3*

Title	**11. Merit Order Decision (MOD)**
Type of Asset	*foreground –control function*
Short description	*The Merit Order Decision is a function that uses the initial merit order list produced by the Merit Order Collection function in order to refine it by selecting only the reserves that have no negative impact on the grid*
Longer description	*The function includes a load flow analysis, in which it calculates the voltages of all buses, under the assumption of a steady state with the reserves activated to their full, i.e. they can reach either their Pmax or their Pmin since both are the worst case scenarios in terms of reserves activation. In this process if some of the nodes' voltages are above or below a maximum allowable limit or the line currents exceed the maximum capacity of the line, the reserves at the relevant bus are excluded.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6-Controllable Flexibility*
Organisation leader	*CRES-Centre for Renewable Energy Sources and Saving*
Contact person/ Email	*Evangelos Rikos/vrikos@cres.gr*
Second Organisation in charge of managing the asset (if any)	*VITO*
Contact person/ email	*Chris Caerts/chris.caerts@vito.be*
IPR	*Not applicable*
IPR Status	*Not applicable*
References	*D6.3- Core functions of the Web-of-Cells control scheme*
Technology keywords	*Control function*
Special conditions for the access to such Asset?	*Reference to the ELECTRA IRP D 6.3*

Title	**12. Tie-line Limits Calculation (TLC)**
Type of Asset	*foreground – control function*
Short description	*The Tie-line Limits Calculation function performs a calculation of the remaining available capacity of the tie-lines in order to inform the Cell Set-point Adjuster function of the capability of change in case of imbalance*
Longer description	*The function performs a number of actions including the following:* *-It receives the values of power schedules of the tie-lines corresponding to the beginning of the selected timeframe* *-It retrieves the static information regarding the maximum power limits of the tie-lines* *-It subtracts the scheduled powers from the maximum ones to calculate the difference (allowable power changes)* *-It issues the vector of allowed change to the Cell Set-point Adjuster together with the identity of each tie-line.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6-Controllable Flexibility*
Organisation leader	*CRES-Centre for Renewable Energy Sources and Saving*
Contact person/ Email	*Evangelos Rikos (vrikos@cres.gr)*
Second Organisation in charge of managing the asset	*VITO*
Contact person/ email	*Chris Caerts (chris.caerts@vito.be)*
IPR	*Not applicable*
IPR Status	*Not applicable*
References	*D6.3- Core functions of the Web-of-Cells control scheme*
Technology keywords	*Control function*
Special conditions for the access to such Asset?	*Reference to the ELECTRA IRP D 6.3*

<table>
<tr><td>Title</td><td>13. Resilient and efficient architecture for Wide Area Protection</td></tr>
<tr><td>Type of Asset</td><td>Foreground - protection</td></tr>
<tr><td>Short description</td><td>A new architecture has been defined for wide area protection for power systems operating under the web-of-cells paradigm. This approach leverages the wealth of measurements in future power systems to provide correct and timely supervisory protection functionality, including during degraded states where some real-time information is missing.</td></tr>
<tr><td>Longer description</td><td>The following figures illustrate the multi-cell wide area protection architecture:

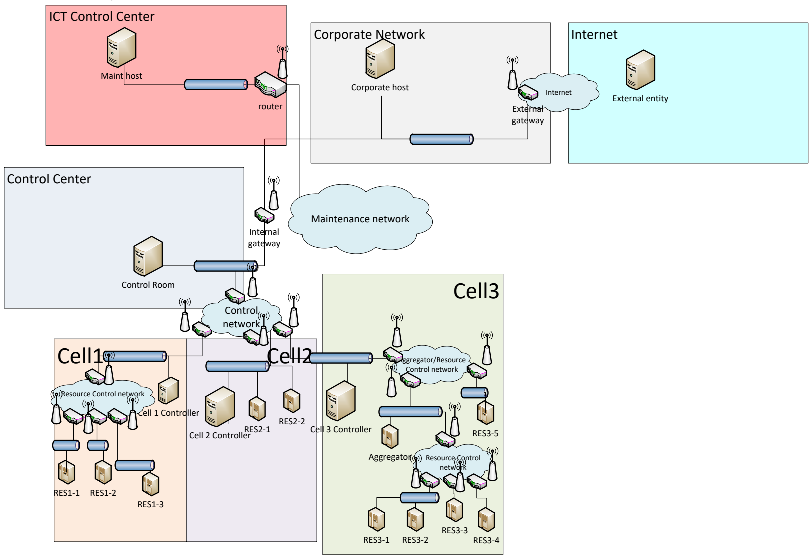


A cell Phasor Data Concentrator (PDC) receives voltage and current measurements from multiple Phasor Measurement Units (PMUs) – ideally at each feeder in the cell. Each cell applies a wide area protection algorithm on the PMU measurements to detect and locate faulted circuit sections. The key characteristics of the proposed approach are:

Resiliency to missing measurements.
Adaptability to varying system conditions, such as changes in topology, changes in generation and demand, and changes in inter-cell tie-line flows. No circuit impedance data is required.
Scalability to a large number of measurement locations due to efficient computational design.
</td></tr>
<tr><td>Technology Readiness Level (TRL)</td><td>4-5</td></tr>
<tr><td>WP of reference</td><td>WP6</td></tr>
</table>

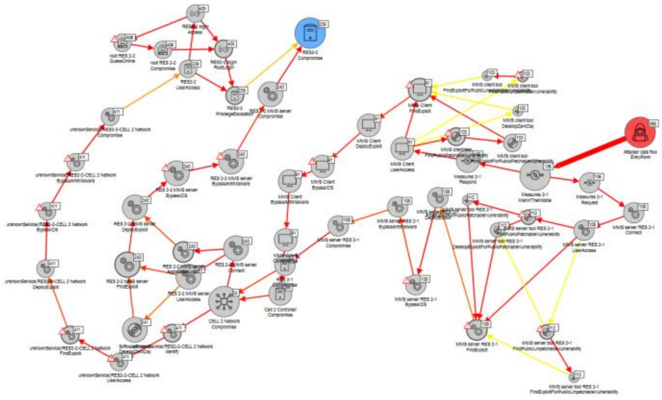
Organisation leader	*USTRATH*
Contact person/ Email	*Steven Blair (steven.m.blair@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	*N/A*
Contact person/ email	*N/A*
IPR	
IPR Status	
References	*ELECTRA Deliverable D6.2* *"Minimising the impact of disturbances in future highly-distributed power systems", Steven M. Blair, Graeme Burt, A. Lof, S. Hänninen, B. Kedra, M. Kosmecki, J. Merino, F.R. Belloni, D. Pala, M. Valov, B. Lüers, A. Temiz, CIGRE B5 Symposium, Auckland, New Zealand, 2017.*
Technology keywords	*Wide area protection, communications, Phasor Measurement Units (PMUs)*
Special conditions for the access to such Asset?	

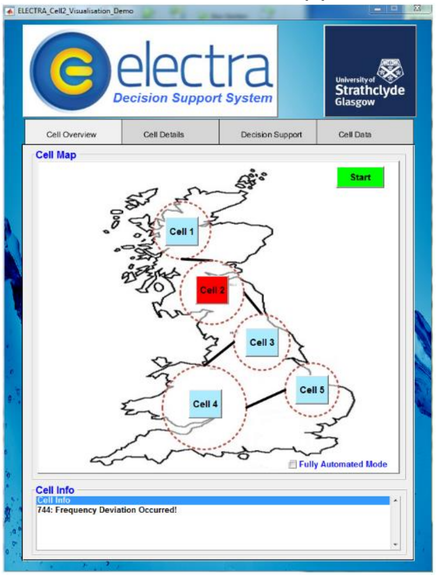
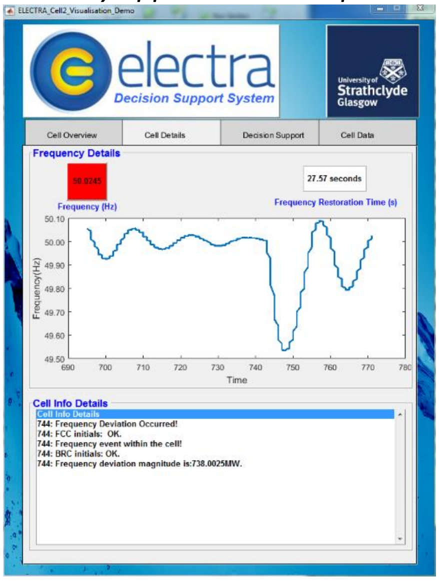
<table>
<tr><td>Title</td><td>14. Simulation model for Web-of-Cells cyber security analysis</td></tr>
<tr><td>Type of Asset</td><td>Foreground -security</td></tr>
<tr><td>Short description</td><td>A model of the Information and Communication Technology (ICT) architecture comprising different topological solutions underlying the Web-of-Cells (WoC) concept, extended with security features and measures, for the analysis of possible attack paths and their success likelihood.</td></tr>
<tr><td>Longer description</td><td>A securiCAD[9] model of the Information and Communication Technology (ICT) architecture deployed for the execution of the Web-of-Cells (WoC) control strategies. The model addresses several WoC-specific ICT topologies with different hardware and software assets. The following picture shows the general ICT architecture of the WoC represented in the securiCAD model.

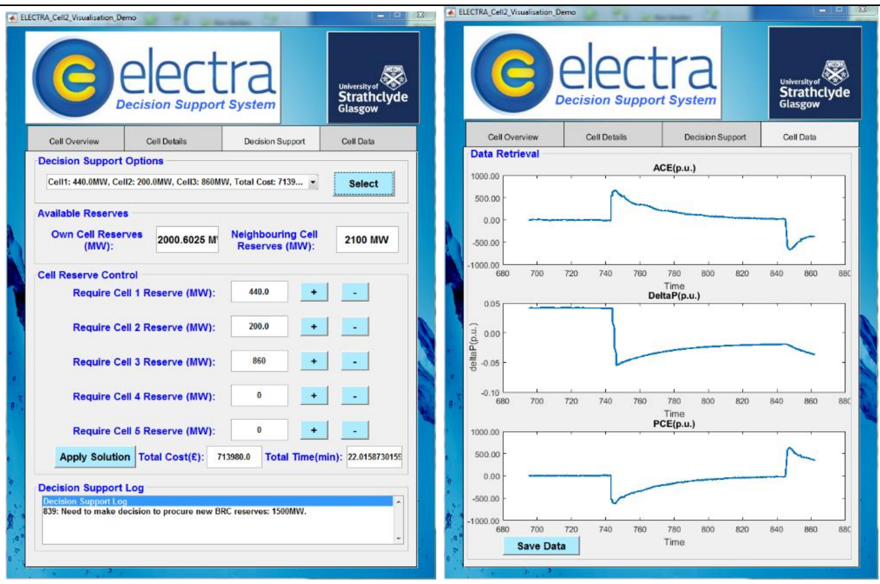


The model allows to estimate the threat likelihoods in relation to architecture variants in terms of asset features and cyber security measures. Once cyber security countermeasures are included into the model, with securiCAD it is possible to evaluate their effectiveness considering the attack paths automatically generated by the tool. The following figure presents an attack graph including the most frequently traversed and least resilient attack paths in the securiCAD simulations from the model of the previous WoC architecture. The source is the attacker (red circle) and the target (blue circle) is the attack step of compromising a cell resource. The attacker performs a “Man In The Middle” attack to the data flow between the cell 2 controller and the resource 2-2 in the Cell 2 architecture. The attack graph involves different assets and weaknesses that the attacker may exploit in order to progress with the attack process. The evaluation of the TTC values depends on the analysis of the whole attack graph.</td></tr>
</table>

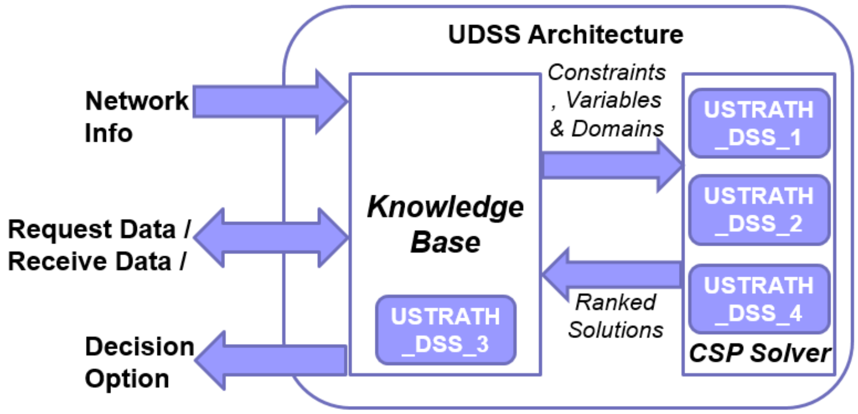
9 securiCAD is a tool developed by foreseeti, see http://www.electrairp.eu

	 *From the analysis of the model it is possible to obtain the steps of the main attack paths and evaluate the Time To Compromise (TTC) for the more critical assets. The model simulations support the selection of suitable security countermeasures and the evaluation of their effectiveness through a sensitivity analysis of the TTC values.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP 4*
Organisation leader	*RSE*
Contact person/ Email	*Roberta Terruggia (roberta.terruggia@rse-web.it)*
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	
IPR	
IPR Status	
References	*ELECTRA Deliverable D4.4*
Technology keywords	*Cyber Security, Smart Grid, Web-of-Cells*
Special conditions for the access to such Asset?	*Free access*

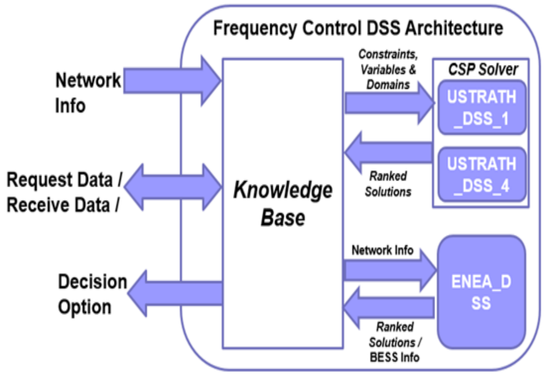
Title	**15. An Enhanced Situational Awareness and Visualisation User Interface for Frequency Events**
Type of Asset	*foreground – control room*
Short description	*USTRATH generated foreground IP in the form of an enhanced situational awareness and visualisation user interface for frequency events. The developed visualisation allows the operator to observe the system state at a glance and understand the situation quickly. The user interface integrates the developed decision support systems that can guide an operator with available actions to take and their expected outcomes.*
Longer description	*The user interface provides a high-level view of the controlled systems, visualising for the operator all of the cells and their status. A detailed view can only be accessed for the cells that the operator has responsibility for. The detailed view of the cell provides frequency status combined with a coloured indicator (green means normal condition and red means frequency deviation). When a frequency deviation occurs, it provides the time to restore the frequency. In addition, the visualisation offers other information within the cell, including available reserves in its own cell, reserves of neighbouring cells, area control error, and power control error. The integrated decision support system will list the suggested actions to take when the operator needs to make a decision. The decision support system will give the operator a certain window of time to override the decision support in such a case after which, if no response has been received, the decision support automatically applies the best option.*  

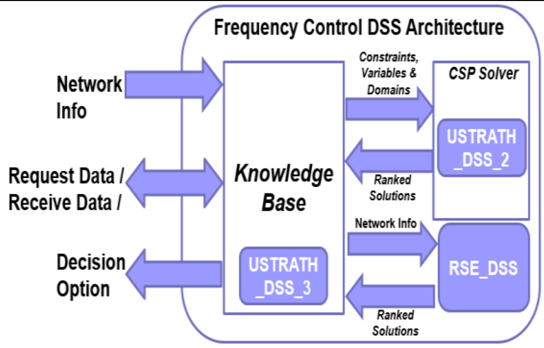


Technology Readiness Level (TRL)	*4*
WP of reference	*WP8*
Organisation leader	*USTRATH*
Contact person/ Email	*Minjiang Chen (minjiang.chen@strath.ac.uk) and Stephen McArthur (s.mcarthur@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	
IPR	
IPR Status	
References	*ELECTRA IRP D8.3 - Recommendations on Future Development of Decision Support Systems*
Technology keywords	*Visualisation, Situational Awareness, Decision Support System, Frequency Control*
Special conditions for the access to such Asset?	*TBD*

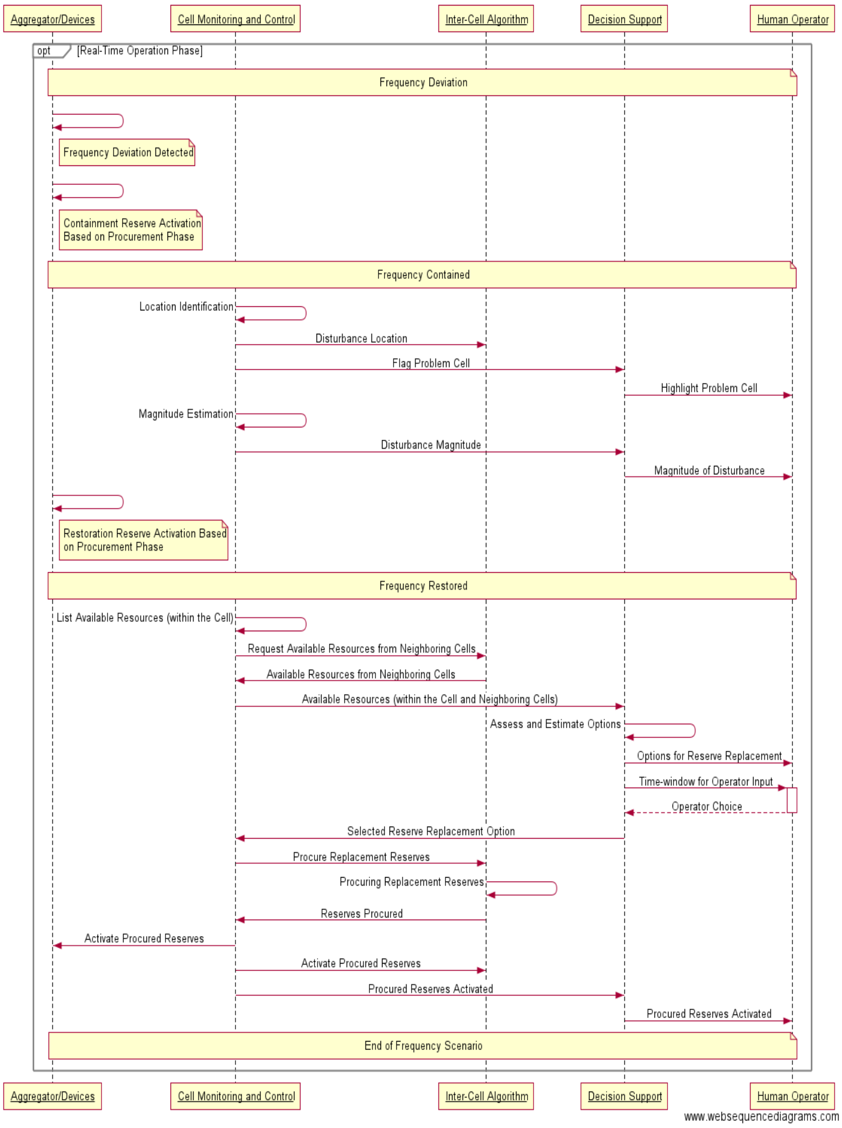
Title	**16. Decision Support System Algorithms & Architecture for Frequency Control**
Type of Asset	*foreground – control room*
Short description	*USTRATH generated foreground IP in the form of decision support algorithms and an architecture for frequency control. The algorithms and architecture can identify decision points and provide ranked solutions for the human operator during the frequency event through the use of, and integration of, knowledge based system techniques and a constraint satisfaction problem algorithm.*
Longer description	*A prototype decision support system for frequency control was developed that gathers cell information and provides the knowledge and optimization tools to support proactive decision making. It has knowledge about decision points and what data is required for each decision point. Once a decision point is identified, it provides the option(s) based on its knowledge or optimised solutions by interacting with its optimisation tool. The selected optimisation method is constraint programming, which is applied to the frequency problem being cast as a Constraint Satisfaction Problem (CSP). Therefore, the system is composed of a Knowledge Base (KB) and a CSP solver. In some cases, the KB has the knowledge to directly provide the decision plan based on its knowledge without using the CSP solver. For many problems, there may be more than one set of variable assignments that satisfy all declared constraints. In such cases, the CSP solver can be configured to return either a user-defined number of solutions in a best-first manner or to search for all possible solutions.* 
Technology Readiness Level (TRL)	*3*
WP of reference	*WP8*
Organisation leader	*USTRATH*
Contact person/ Email	*Minjiang Chen (minjiang.chen@strath.ac.uk) and Stephen McArthur (s.mcarthur@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	

Contact person/ email	
IPR	
IPR Status	
References	*ELECTRA IRP D8.2 - Demonstration of Decision Support for Real Time Operation*
Technology keywords	*Decision Support System, Frequency Control, Knowledge Base, Optimisation*
Special conditions for the access to such Asset?	*TBD*

Title	**17. Design of Integration and Coordination Platform for Frequency Control Decision Support**
Type of Asset	*foreground*
Short description	*USTRATH, ENEA and RSE generated foreground IP relating to decision support system coordination for frequency control. There are several decision support tools that have been developed for frequency events. A design for the platform that combines and co-ordinates the operation and outcomes from the developed decision support tools has been created. This details how they react to decision points under two different frequency events.*
Longer description	*The developed decision support tools can be integrated into a decision support system architecture for frequency control developed by USTRATH. The first decision support coordination is between USTRATH and ENEA and delivers three automated decisions after a single frequency event has been restored. ENEA_DSS is triggered first to bring the state of charge of a Battery Energy Storage System (BESS) into its safe energy range and also provides available capacity of BESS for USTRATH_DSS_1. While ENEA_DSS is undertaking its processing and analysis, USTRATH_DSS_1 can start in parallel to procure available reserves for Balance Restoration Control (BRC) as soon as possible, based on available BESS capacities received from ENEA_DSS and other available reserves. Finally, USTRATH_DSS_4 is triggered to replace BRC deployed reserves with less expensive options.*  *The second decision support coordination is between USTRATH and RSE and this delivers three automated decisions during a two frequency event. If the frequency deviation occurred due to loss of a tie-line, RSE_DSS is triggered to respond and restore frequency. The triggering of the RSE_DSS is performed when specific protection functions are able to properly identify and isolate a faulty section. When this protection detects a fault on the tie-lines the RSE_DSS is triggered. If the frequency deviation occurred due to a loss of generation larger than the BRC reserves can handle, it needs USTRATH_DSS_2 and USTRATH_DSS_3 to restore frequency by its own available reserves or to negotiate with neighbouring cells.*

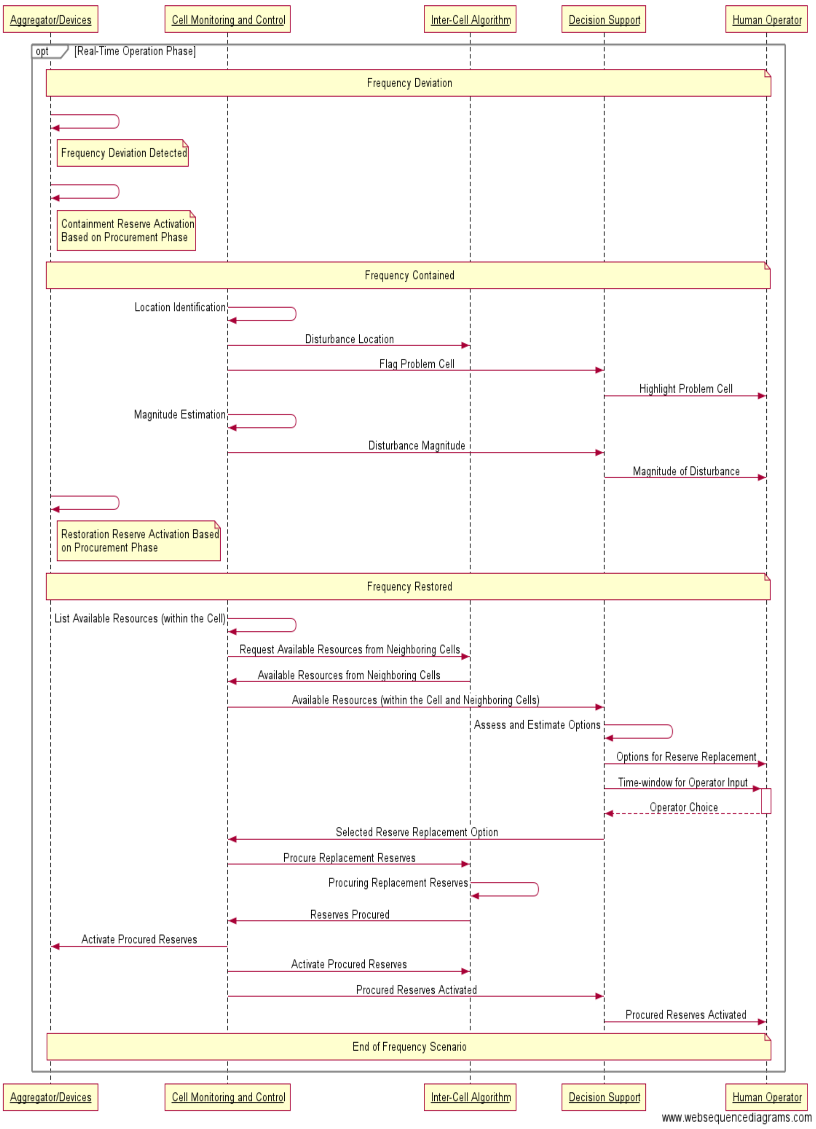
	
Technology Readiness Level (TRL)	*3*
WP of reference	*WP8*
Organisation leader	*USTRATH*
Contact person/ Email	*Minjiang Chen (minjiang.chen@strath.ac.uk) and Stephen McArthur (s.mcarthur@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	*ENEA, RSE*
Contact person/ email	*Marialaura Disomma (marialaura.disomma@enea.it) and Roberto Zuelli (roberto.zuelli@rse-web.it)*
IPR	
IPR Status	
References	*ELECTRA IRP D8.3 - Recommendations on Future Development of Decision Support Systems*
Technology keywords	*Decision Support System, Frequency Control, Decision Support Coordination*
Special conditions for the access to such Asset?	*TBD*

<table>
<tr><td>Title</td><td>18. Distributed Control Actor Interaction for Frequency Control Scenarios</td></tr>
<tr><td>Type of Asset</td><td>foreground – control room</td></tr>
<tr><td>Short description</td><td>USTRATH generated foreground IP that defines the interactions taking place between the different system actors when a single frequency event and two frequency event occur.</td></tr>
<tr><td>Longer description</td><td>For a single frequency event, frequency control algorithms developed in ELECTRA can automatically handle that event within a cell. That is, the deployment of the procured reserves can fully restore the frequency within operational limits, and there is no requirement for a human operator to take action. However, even if the system is automatically resolving the single event, key information must still be relayed to the operator so that they are kept well informed of what is happening within the network and how any particular incident is being dealt with. The information and messaging between actors has been designed.



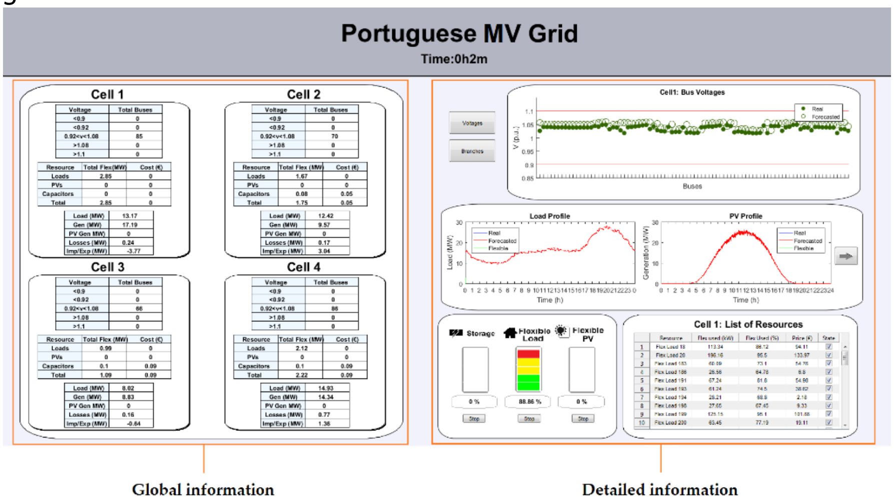
Two frequency events occur within the same cell. The second frequency event occurs almost instantly after the first frequency deviation. Within this situation, it is assumed that the procured restoration reserves are not</td></tr>
</table>

	sufficient to mitigate both events, meaning that the balance restoration control cannot restore the frequency to within normal operational levels purely by implementing the plan from the procurement phase. Therefore, all spare capacity from local devices and neighbouring cells should be determined. The decision support system of the problem cell will prioritise the combination of reserves that mitigate this frequency event. The speed of response will be more important than cost, due to the emergency situation. The communication between the problem cell and neighbours in order to assess and procure emergency support has been designed.



Technology Readiness Level (TRL)	*2*
WP of reference	*WP8*
Organisation leader	*USTRATH*
Contact person/ Email	*Minjiang Chen (minjiang.chen@strath.ac.uk) and Stephen McArthur (s.mcarthur@strath.ac.uk)*
Second Organisation in charge of	

managing the asset (if any)	
Contact person/ email	
IPR	
IPR Status	
References	*ELECTRA IRP D8.1 Demonstration of visualization techniques for the control room engineer in 2030*
Technology keywords	*Frequency Control; Automatic Control; Decision Support System*
Special conditions for the access to such Asset?	*TBD*

<table>
<tr><td>Title</td><td>19. Control room operation for voltage control in the web-of-cells</td></tr>
<tr><td>Type of Asset</td><td>foreground –control room</td></tr>
<tr><td>Short description</td><td>Integration of the pro-active voltage control (PPVC) in an operating tool for the cell operators</td></tr>
<tr><td>Longer description</td><td>The pro-active voltage control (PPVC) approach developed in Task 6.2 was integrated in an operating tool for cell operators. The operating tool allows for an enhancement of observability and provides all the relevant data in a friendly way to the cell operators, which makes it a good complement to visualize the voltage control strategy in the cells.
The PPVC runs a proactive algorithm each 15 minutes to calculate the optimal set points of the reserves and a corrective mechanism to overcome unexpected grid events or load/generation forecasting errors that would ultimately lead to voltage limits' violations.
The operating tool for cell operators, which has a user interface (figure below), presents updated cell information divided into two parts: the global information and the detailed information. The global information is always visible for the operator and represents information of the cells under the responsibility of the Cell Operator and neighbouring cells, while the detailed information is only visible when the operator decides to have an in depth visualization of a given cell.


The operating tool presented in the figure above also enables cell operators to control the flexible resources available in the cell remotely and to modify the solution provided by the PPVC algorithm with the guarantee that no technical problem will occur in the cell.
The information presented to cell operators is the following:
• Highlight voltage violations
• Present operator solutions from PPVC (D8.2, Fig. 3.18) ⍰ by colouring affected buses according to the expected voltage levels
• The information provided in the "Global information" section is</td></tr>
</table>

	the number of buses that are in each range of voltage ("emergency situation", "abnormal situation", "normal situation"), the total flexibility that it is being used by each type of resource and its costs and the global cell status indicating the total load, generation, PV generation, losses and energy imports/exports of the cell. • *The information provided in the "Detailed information" section is the buses voltage, the branches loading, the load profile, the PV profile, the losses profile, the imports/exports profiles and the state of the flexible resources.* *The actions that the operators can implement for the user interface are summarized in the following bullets:* • *Visualize detailed information about a specific cell;* • *Visualize the voltages in the buses or the power flows in the branches;* • *Stop or start the utilization of the flexibility provided by an individual resource;* • *Stop or start the utilization of the flexibility provided by an aggregated set of resources (flexible load, PV or storage).*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP8*
Organisation leader	*INESC TEC*
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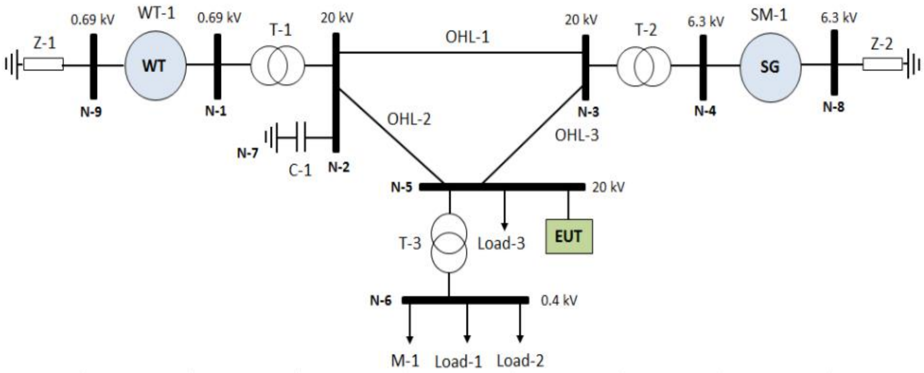
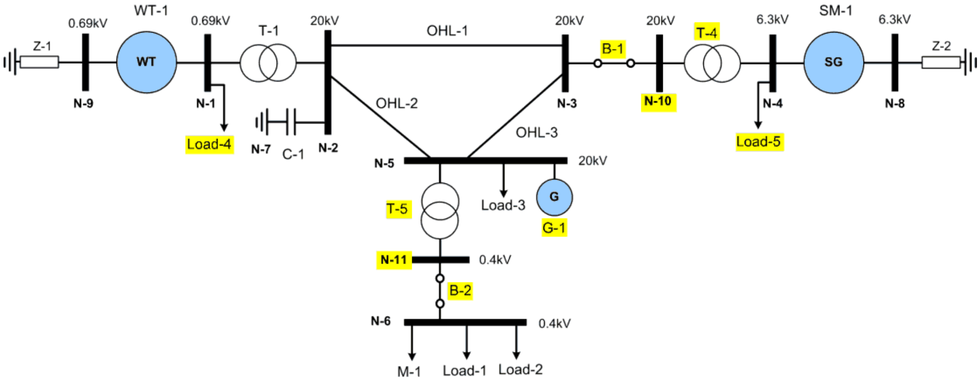
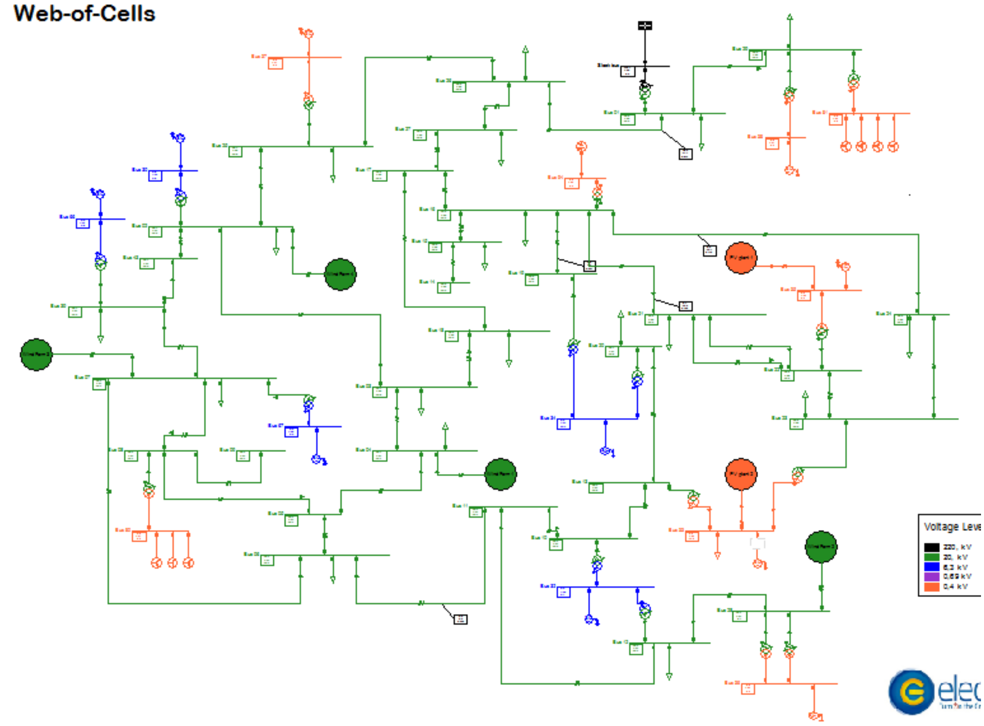
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	
IPR	*TBD*
IPR Status	
References	*D8.2 - Demonstration of decision support for real time operation* *D8.3 - Recommendations on future development of decision support systems*
Technology keywords	*Simulation, control room, voltage control, cell operator*
Special conditions for the access to such Asset?	*TBD*

Title	**20. Pan-European Single Reference Power System**
Type of Asset	*foreground –networks models*
Short description	*Pan European system includes the models of several standard cells that can be representative of the different HV cell topologies. The models is realized in both DIgSILENT Powerfactory and Matlab-Simulink SimPowerSystems*
Longer description	*The model is an extension of the CIGRE's European HV Benchmark network. The model combines AC and DC transmission systems at multiple voltage levels, with ranges from 20kV to 400kV in the AC system and a nominal voltage of the 725kV for the DC one. The cells inside contain diverse DERs: batteries, PWM inverter driven resources. Complete grid information can be found in the official ELECTRA deliverable D5.4 [1] as well as in the referenced UPEC publication [2]. Both publications need to be cited when using the grid model.*
Technology Readiness Level (TRL)	*3*
WP of reference	*5*
Organisation leader	*DTU - Technical University of Denmark*
Contact person/ Email	*Mattia Marinelli; matm@elektro.dtu.dk*
Second Organisation in charge of managing the asset (if any)	*IEN – Institute of Power Engineering (Poland) for Matlab-Simulink (SimPowerSystems) version*
Contact person/ email	*Michał Kosmecki; m.kosmecki@ien.gda.pl*
IPR	*Test grid model implemented in DigSilent PowerFactory v15.2 and Matlab-Simulink (SimPowerSystem toolbox)*
IPR Status	*The model can be used freely for research/educational purposes*
References	*[1] M. Marinelli, et al., "Functional description of the monitoring and observability detailed concepts for the Pan-European Control Schemes," ELECTRA Deliverable D5.4. WP5: Increased Observability. Mar. 2017* *[2] M. Marinelli, M. Pertl, M. Rezkalla, M. Kosmecki, S. Canevese, A. Obushevs, A. Morch, "The Pan-European Reference Grid Developed in the ELECTRA Project for Deriving Innovative Observability Concepts in the Web-of-Cells Framework," Universities Power Engineering Conference (UPEC), 2016 Proceedings of the 51st International, pp. 1-6, Coimbra, 6-9 Sep. 2016.*
Technology keywords	*Power systems model; Voltage and Frequency control; Web-of-Cells; Transient Analysis*
Special conditions for the access to such Asset?	*The model can be used freely for research/educational purposes. Ref [1] and [2] need to be cited.*

Title	21. "SRPS-TECRES" – Single Reference Power System for static and dynamic simulations to test ELECTRA control loops and functions.
Type of Asset	*Foreground – networks models*
Short description	*This small power system was specially designed for testing the ELECTRA control loops and functions in the framework of WP5. It is composed by two generators, (one representing a synchronous conventional group plus one full-converter coupled generator representing a renewable/intermittent generation) and some loads. With this simple design, it is able to reproduce many different grid conditions.*
Longer description	*The SRPS-TEC test grid basic model is intended to keep the tradeoff between simplicity and usefulness for testing ELECTRA control loops and functions in WP5. These functions are the basic step for the further implementation of the voltage and balance ELECTRA UCs, such as the adaptive NPFC determination or the PPVC controlling. Due to this, this first mockup model can be used for the validation of the loops/functions, minimizing the inaccuracies related to the modeling/simulation itself. A general overview of the test grid is shown in Figure 1. Conventional (synchronous generator SM-1) and non-conventional generator (Wind turbine WT-1) models have been included. This way, simple adjustments over this base model allow facing different non-dispatchable/dispatchable scenarios as well as diverse percentages of real/virtual inertia. A free connection point has been assigned to N-5 bus for individual testing of different control systems in different devices, named as EUT (Equipment Under Test). A capacitor bank (C-1) has been included to compensate the power factor in the wind power plant terminals. To complete the system, also 3 passive and 1 dynamic load have been included.*  **Figure 1 - General overview of the SRPS-TEC basic model** *Next, the main elements of the grid as well as its name tag in previously shown Figure 1 are detailed:* • *1 Wind turbine (WT-1)* • *1 Synchronous generator (SM-1)* • *1 Capacitor bank (C-1)* • *2 grounding impedances of the generators (Z-1 and Z-2)* • *3 Passive loads (Load-X)* • *1 Asynchronous motor (M-1)* • *3 Overhead lines (OHL-X)* • *3 Transformers (T-X)*

	In addition to the above described basic model, an extension of it has been devised in order to emphasize the operation of Balance Control use cases. The specific extension is shown in Figure 2 below. In this diagram all extra to the original model components are highlighted in yellow:  **Figure 2 - SRPS-TECRES: extension of the basic model (i.e. SRPS-TEC) used in the Balance Control validation**
Technology Readiness Level (TRL)	*4*
WP of reference	*WP5 – Increased observability*
Organisation leader	*TECNALIA*
Contact person/ Email	*Julia Merino (julia.merino@tecnalia.com)* *Emilio Rodríguez (jemilio.rodriguez@tecnalia.com)*
Second Organisation in charge of managing the asset)	*CRES*
Contact person/ email	*Evangelos Rikos (vrikos@cres.gr)*
IPR	*Other: Test grid model implemented in Matlab/Simpowersystems*
IPR Status	*NA*
References	*D5.2. Functional description of the monitoring and observability detailed concepts for the Distributed Local Control Schemes.* *Annex 3.4.: Define small test grid in SRPS*
Technology keywords	*Test grid model, Single Reference Power System (SRPS)*
Special conditions for the access to such Asset?	*Restricted access: only for educational and research purposes; reference to ELECTRA IRP must be explicitly done.*

Title	**22. "FLEXTEC" – Test grid model for steady-state and dynamic simulations of MV/LV distribution networks with high RES integration**
Type of Asset	*Foreground* **–** *networks models*
Short description	*Test MV/LV grid model with multiple renewable energy sources and conventional generation designed within the ELECTRA IRP project. It is intended to serve as a flexible resource for the testing and validation of control algorithms and grid operation methods in scenarios with a high penetration ratio of distributed renewable energy sources.*
Longer description	*It is accepted that the current grids are evolving towards new topologies where the presence of renewable energy sources is going to be remarkable. In addition, research institutes, universities or even industries are continuously developing new algorithms and methods that need to be simulated for their validation in highly accurate test grids, such as new protection schemes, congestion management algorithms or novel controls for distributed energy resources, among others. In the development of ELECTRA IRP project, it has been found a lack of accessible and open source test grids that could precisely represent the future grid conditions.* *The most commonly used benchmarks, such as the IEEE, are mainly high voltage grids with synchronous generation while some others very known, as the CIGRE benchmarks (MV and LV grids) only have data valid for steady-state studies, lacking dynamic controls. Due to this, it has been considered of interest the development of a MV/LV distribution grid model with a high penetration of distributed resources and the corresponding controls for the generation sources, that could faithfully represent the web-of-cells (WoC) control architecture and future grid scenarios developed in ELECTRA. It is also intended to serve as a flexible basis for further developments. The high number of distributed energy resources, many of them coming from renewable energy sources, also allow the testing of a wide range of scenarios and the analysis of the added-value of resource flexibility.* *The test grid presents a meshed configuration in the MV levels and a radial structure typically representative of the LV feeders. The connection to the transmission network is done through a 255 MVA 220 kV/20 kV transformer. The MV distribution grid voltage is 20 kV. The conventional generation generates at 6.3 kV. The wind generators voltage is 690 V and the PV panels are connected to the 400 V LV grid. A general overview of the grid is shown in Figure 1. In a first WoC approach, the grid has been divided into three main cells although the flexible structure of the grid and its size it is enough to easily divide it into a bigger number of cells. In the framework of ELECTRA, up to 9 cells have been considered.*

	 **Figure 1 - Test grid model scheme** *The generation placed in the grid includes:* ● *10 conventional renewable and non-renewable distributed energy sources (3 diesel groups + 5 hydraulic units + 2 gas generators) with rated powers between 2.7 MW and 10 MW.* ● *20 wind turbines of 2.5 MW grouped into four big wind power plants.* ● *7 medium power wind turbines of 240 kW each one.* ● *27 PV systems with rated powers between 2.1 kW and 4.1 kW.* *The loads have been modeled as constant PQ loads with variable profiles of around 10% variation over their scheduled program. It has also been added to the profile the typical uncertainty that is characteristic of the very-short term techniques (15 min to 1 h ahead), 1% [1]. The same procedure has been followed for the definition of the generation profiles, considering that the uncertainty in generation forecasting is bigger compared to the uncertainty in the load (up to 5%) [2].* *References* *[1] J. W. Taylor. "An evaluation of methods for very short-term load forecasting using minute-by-minute British data," International Journal of Forecasting, vol. 24, no. 4, pp, 645-658, Dec 2008.* *[2] Anemos. plus Project. D1.2 - "Advanced Tools for the Management of Electricity Grids with Large-Scale Wind Generation", Jan 2011.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP7 - Integration and Lab Testing for Proof of Concept*
Organisation leader	*TECNALIA*

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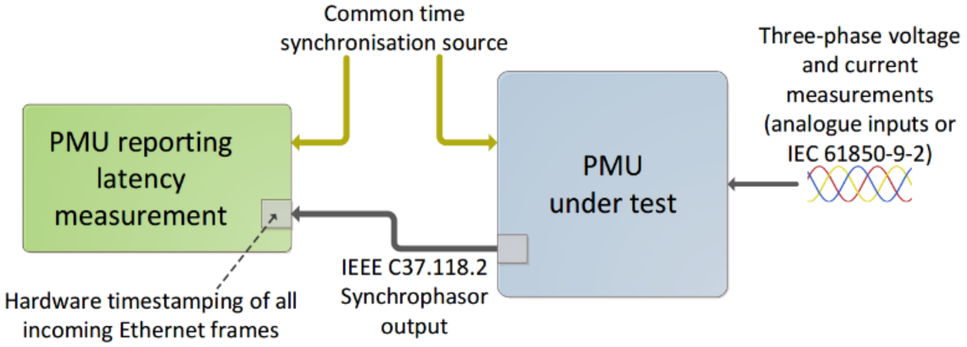
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	
IPR	*Other:* *Test grid model implemented in PowerFactory (DIgSILENT)*
IPR Status	*NA*
References	*D7.1, Report on the evaluation and validation of the ELECTRA WoC control concept.* *D7.2, Lessons learned from the ELECTRA WoC control concept evaluation and recommendations for further testing and validation of 2030 integrated frequency and voltage control approaches.*
Technology keywords	*Grid model, power system simulation, dynamic simulation.*
Special conditions for the access to such Asset?	*Restricted access: only for educational and research purposes; reference to ELECTRA IRP must be explicitly done.*

Title	**23. Accurate PMU latency characterisation and emulation**
Type of Asset	*Foreground –networks models*
Short description	*A new method has been developed to very accurately and conveniently characterise the latency performance of Phasor Measurement Unit (PMU) data. This technique can also be used to emulate measurement and communications latencies in offline and real-time simulations, which enables the realistic validation of decentralised control methods.*
Longer description	*Wide-area phasor measurement unit (PMU) monitoring schemes are being increasingly utilised to enable new system functions, such as decentralised frequency control paradigms.* *The reporting latency of a PMU is the time difference between the time of transmission of the first bit of a PMU report message and the timestamp contained in the report. This means that a device with an Ethernet interface which supports hardware timestamping (according to IEEE 1588v2), and the accompanying software stack, can be used to very precisely measure the reporting latency of a PMU, according to this definition. The following figure illustrates the measurement method:*  *This approach can also be extended to measuring the total latency perceived when communicating PMU data over wide area networks (WANs) i.e. between substations. Capturing this information is important for understanding dynamic system behaviour, and can be used for realistically emulating communications delays within complex power system simulations. This method can also be applied to achieve real-time communications emulation within laboratory experiments, which may also include power hardware, multiple controllers, and real-time power system simulation.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP6*
Organisation leader	*USTRATH*
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Second Organisation in charge of managing the asset (if any)	*N/A*

Contact person/ email	*N/A*
IPR	*N/A*
IPR Status	
References	*ELECTRA Deliverable D6.2, open source software repository: https://doi.org/10.5281/zenodo.400934*
Technology keywords	*Wide area protection, communications, Phasor Measurement Units (PMUs)*
Special conditions for the access to such Asset?	*TBD*

Title	**24. Initialization and Synchronization of Power Hardware-in-the-Loop Simulation for Large Synchronous Power Systems**
Type of Asset	*foreground –methods and tools*
Short description	*A Power Hardware-in-the-Loop (PHIL) initialization technique has been developed for experiments where the hardware under test (HUT) represents an important area of the network which underpins the stability of the simulation. The real-time simulation is unable to initialize without the HUT, therefore a method for initializing the simulation without the HUT (this being critical for the stability of the simulation) has been developed.*
Longer description	*The issues associated with initialization and synchronization of a PHIL simulation, where the HUT represents a larger portion of the test network, arise under two circumstances: (i) where the test network to be represented by the HUT is critical for initialization of the DRTS simulation and (ii) where the test network to be represented by the HUT affects the voltage and frequency of the DRTS simulation. The example for the first circumstance is when the HUT is to represent a large portion of generation without which the test network cannot maintain its stability. The example of the second situation is when the HUT represents a portion of load or generation without which the DRTS simulation can start but the frequency and voltage would be off the nominal value (due to the missing load or generation).* *AC Controlled Current Source: for the emulation of power transfer behaviour at the PCC, a controlled current source allows for easiest implementation and high accuracy for achieving the required active and reactive power set points. This implementation will only require the measured voltage and the P and Q set points at the PCC for generating the current signals as:* $$I_d = \frac{P_{ref}V_d - Q_{ref}V_q}{V_d^2+V_q^2} \quad (1)$$ $$I_q = \frac{P_{ref}V_q + Q_{ref}V_d}{V_d^2+V_q^2} \quad (2)$$ *where* $\boldsymbol{I_d}$ *is the direct axis current,* $\boldsymbol{I_q}$ *is the quadrature axis current,* $\boldsymbol{P_{ref}}$ *and* $\boldsymbol{Q_{ref}}$ *are the reference active and reactive*

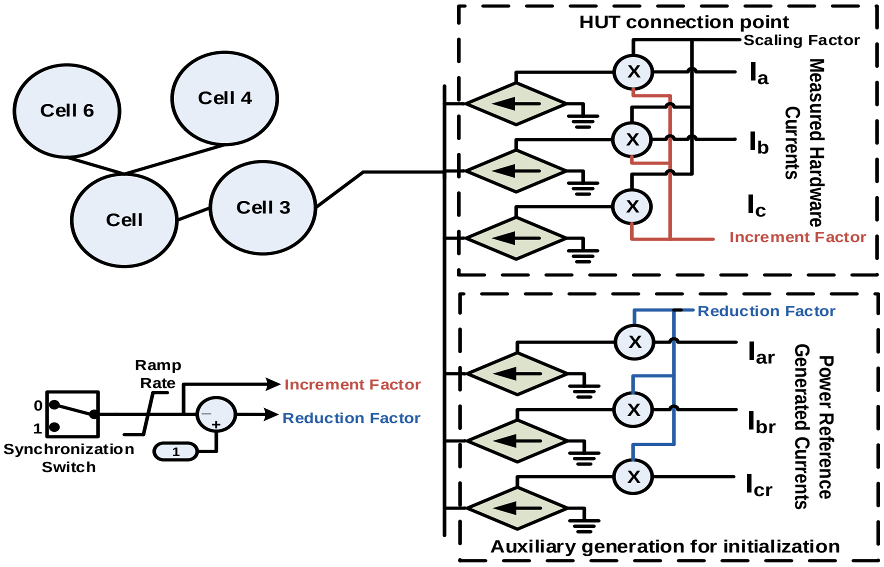


Figure 1 - PHIL initialization and synchronization.

powers to be injected at the PCC respectively, V_d is the direct axis voltage at PCC and V_q is the quadrature axis voltage at PCC. The direct and quadrature axis voltages required can be obtained with Park's transformation as

$$\begin{bmatrix} V_d \\ V_q \\ V_0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos(\theta) & \cos(\theta - 2\pi/3) & \cos(\theta + 2\pi/3) \\ -\sin(\theta) & -\sin(\theta - 2\pi/3) & -\sin(\theta + 2\pi/3) \\ 1/2 & 1/2 & 1/2 \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \quad (3)$$

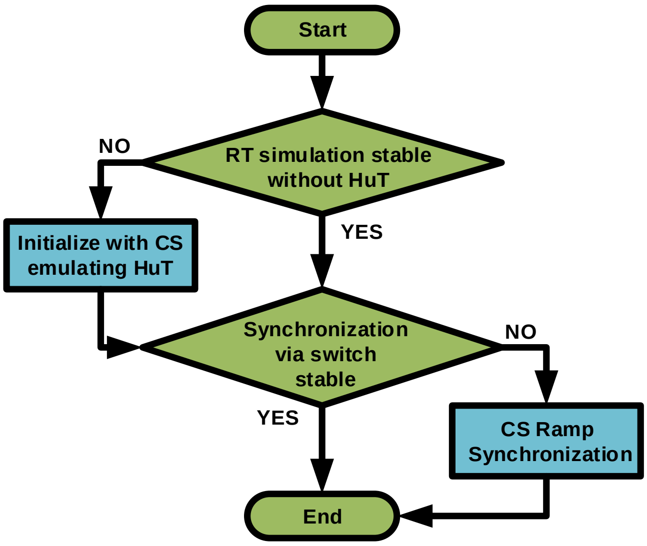
The three phase currents required for current controlled source can be obtained from the quadrature and direct currents using inverse Park's transformation as

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} \cos(\theta) & -\sin(\theta) & 1 \\ \cos(\theta - 2\pi/3) & -\sin(\theta - 2\pi/3) & 1 \\ \cos(\theta + 2\pi/3) & -\sin(\theta + 2\pi/3) & 1 \end{bmatrix} \begin{bmatrix} I_d \\ I_q \\ I_0 \end{bmatrix} \quad (4)$$

In this manner, the initialization is straightforward and accurate when the power transfers at the PCC are known. A schematic of this configuration is shown in Fig. 1 on the auxiliary generation for initialization block, this will serve for a six-area power system to be initialized when divided into four-areas being simulated (Cell 3-6) and the other two areas (Cell 1-2) being critical for stability of the simulated areas and therefore emulated by the current sources.

The synchronization process is begun by means of a synchronization switch that inversely ramps up and down both controlled current sources. The ramp rate can be chosen such that it doesn't create any oscillations or transients on the system, once the currents from the auxiliary generation are reduced to zero and the currents from the HUT are fully connected to the simulation, the system is synchronized.

A flowchart of the process for performing the initialization and synchronization is shown in Fig.3. This process assumes that the PHIL

	simulation is stable for the proposed interface algorithm chosen. This should be ensured before the PHIL simulation initialization and synchronization procedure is begun.  **Figure 2 - Initialization and synchronization flowchart.**
Technology Readiness Level (TRL)	*4*
WP of reference	*WP7*
Organisation leader	*USTRATH*
Contact person/ Email	*Efren Guillo-Sansano (Efren.guillo-sansano@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	
IPR	*TBD*
IPR Status	
References	
Technology keywords	*Methodology, PHIL, initialization*
Special conditions for the access to such Asset?	*TBD*

Title	**25. Method for accelerated co-simulation/model exchange between MATLAB/Simulink and DIgSILENT PowerFactory**
Type of Asset	*foreground – methods and tools*
Short description	*A method has been developed which greatly reduces the simulation time overhead when integrating MATLAB/Simulink controller models into DIgSILENT PowerFactory power system simulation models. This method reduces simulation times by a factor of over 500.*
Longer description	*DIgSILENT PowerFactory allows the integration of controller models, which have been designed in the MATLAB/Simulink design environment, into power system models developed in PowerFactory. The method is cumbersome, and, crucially for the analyst, causes extremely long simulation run times. This is due to the method employed by the software, which requires a Simulink model to be continually re-opened and executed for each individual time step in the simulation.* *Alternatively, the analyst may choose to re-implement the controller within the DIgSILENT PowerFactory internal controller design suite, named DSL. This process is time consuming for the analyst and may introduce errors in the re-implementation process, defeating the purpose of having the controller originally developed in Simulink. However, when a controller model is developed in PowerFactory, the analyst is able to derive a .dll file (compiled model) from the original model. It is the use of this .dll file which opens the opportunity to have PowerFactory run a model which has been developed originally in Simulink as if it had been developed as DSL within PowerFactory.* *This result is achieved by converting the Simulink model first into C-code and then a .dll file which is in the same format as a .dll file which has been derived from a native PowerFactory controller, and running the .dll internally within PowerFactory. When the conversion process has been properly performed, simulation results are identical to those found through the original, slow co-simulation approach as outlined in the DIgSILENT PowerFactory User Manual, but the simulation time is reduced by a factor of at least 500.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP7*
Organisation leader	*USTRATH*
Contact person/ Email	*Kevin Johnstone (kevin.johnstone@strath.ac.uk)*
Second Organisation in charge of managing the asset (if any)	
Contact person/ email	

IPR	*TBD*
IPR Status	
References	*"A co-simulation approach using powerfactory and matlab/simulink to enable validation of distributed control concepts within future power systems", K. Johnstone, Steven M. Blair, M.H. Syed, Graeme Burt, T.I. Strasser, CIRED, Glasgow, UK, 2017.*
Technology keywords	*Methodology, Co-simulation, Model Exchange*
Special conditions for the access to such Asset?	*TBD*

Title	**26. Methodology for designing collaborative experiments and KPIs using the Smart Grid Architecture Model**
Type of Asset	*foreground – methods and tools*
Short description	*Methodology for collaboratively designing laboratory experiments and developing key performance indicators for the testing and validation of novel power system control architectures in multiple laboratory environments.*
Longer description	*This foreground covers a methodology for collaboratively designing laboratory experiments and developing key performance indicators for the testing and validation of novel power system control architectures in multiple laboratory environments. The contribution makes use of the smart grid architecture model (SGAM) as it facilitates the integration of individually developed control functions into a consolidated solution for laboratory validation and testing. The experimental results obtained across multiple laboratories can be efficiently compared, when the proposed methodology is adopted and thus the method offers means of support for improved cooperation in smart grid validation and round robin testing.*
Technology Readiness Level (TRL)	*4*
WP of reference	*WP7*
Organisation leader	*USTRATH*
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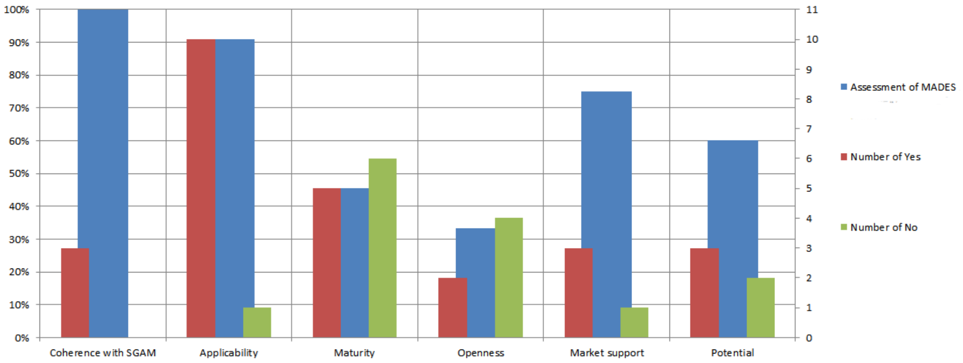
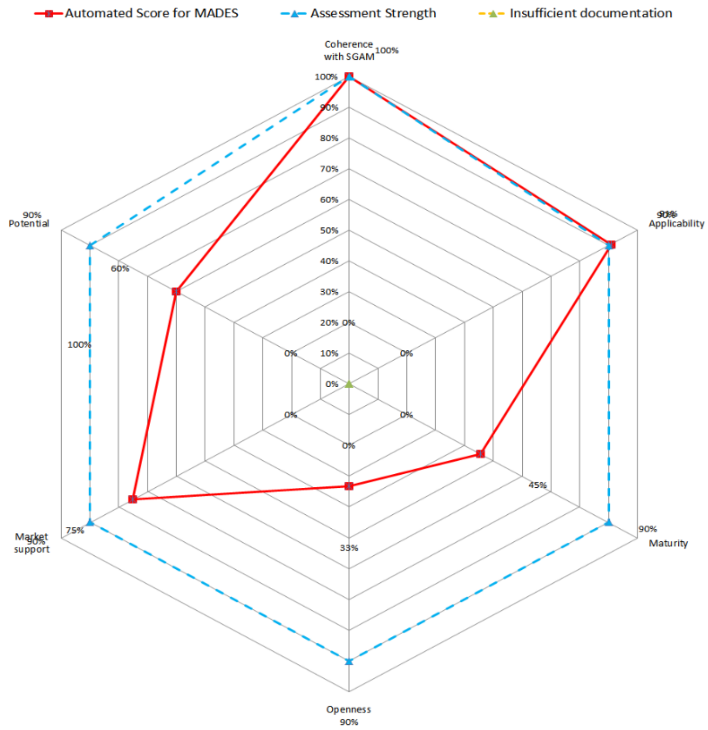
Second Organisation in charge of managing the asset (if any)	*USTRATH, VTT, DERlab, DTU, TECNALIA*
Contact person/ email	
IPR	
IPR Status	
References	*Reference to the ELECTRA IRP deliverables and publications (mainly D7.1, D7.2 and R7.1)* *"Laboratory infrastructure driven key performance indicator development using the Smart Grid Architecture Model", M.H. Syed, E. Guillo, Steven M. Blair, Graeme Burt, T.I. Strasser, H. Brunner, O. Gehrke, J. E. Rodriguez-Seco, CIRED, Glasgow, UK, 2017.*
Technology keywords	*Methodology*
Special conditions for the access to such Asset?	*TBD*

Title	**27. Electra Assessment Tool for Smart Grid Interface Standard (EAT-SGIS)**
Type of Asset	*foreground*
Short description	*A reference method and a related tool for assessing and classifying the ICT interoperability standards and specifications for Smart Grid interfaces*
Longer description	*EAT-SGIS define a methodology and the related tool for assessment of and information collection about SG interface standards. The final result of the application of EAT-SGIS to a specific standard is a rich schedule, summarizing and evaluating its features, which could be "extracted" from the tool and stored. This stored data can be further used, for example, in documents or databases.* *The figure below represents an example of the output of the tool.*  
Technology Readiness Level (TRL)	*5*
WP of reference	*4*
Organisation leader	*ENEA*

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Second Organisation in charge of managing the asset (if any)	*IEN, RSE, CRES, TUBITAK, OFFIS*
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IPR	*NA*
IPR Status	
References	*Deliverable 4.3* *PAPER:* *Angelo Frascella, Jacek Swiderski, Gianluigi Proserpio, Evangelos Rikos, Armağan Temiz, Aleksander Babs, Mathias Uslar, Samuele Branchetti, Giorgio Graditi, "Looking for the unified classification and evaluation approach of SG interface standards for the purposes of ELECTRA IRP" - USB Proceedings 2015 International Symposium on Smart Electric Distribution Systems and Tech ISBN: 978-1-4799-7735-2/15*
Technology keywords	*Interoperability Standards, SGAM, Smart Grid*
Special conditions for the access to such Asset?	*Free access*

Title	**28. Procedure for validation of numerical reliability of new observables**
Type of Asset	*Foreground - Methodology*
Short description	*The procedure answers the following questions:* ***1.*** *Does the analytical model always converge to a unique solution?* ***2.*** *Does the unique solution represent the observable that we have in mind to a high degree?* ***3.*** *Is the model as it runs in Simulink accurate enough?*
Longer description	*Question number one is really a question about the existence and uniqueness of the underlying ODEs, and can be answered using the Picard–Lindelöf theorem.* *Question number two can be answered by looking at the qualitative behaviour of the ODEs describing the model dynamics. One technique that can be applied to autonomous, second-order ODEs is to analyse the phase portrait of the system.* *Question number three can be answered by selecting a numerical solver, e.g. the popular 4th order Runge–Kutta method and then doing numerical experiments to determine when the solution breaks down. Another possibility is to apply backward error analysis, i.e. to analyse another system of ODEs, which has the numerical solution of the original ODEs as exact solution. This is a very powerful concept for error analysis. This question ends up with a recommendation for time step length.* *The methodology is applied to the Akagi PLL, giving a step-length recommendation.*
Technology Readiness Level (TRL)	*3*
WP of reference	*WP5*
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IPR	NA
IPR Status	NA
References	D5.2
Technology keywords	
Special conditions for the access to such Asset?	Free access

Title	29. DERlab Database of DER and Smart Grids Research Infrastructure
Type of Asset	*foreground*
Short description	*Database of DER and Smart Grid Research Infrastructure - the database contains details on Smart Grid and DER laboratories, testing facilities and similar competencies, clustering all relevant information and the labs' profiles systematically.*
Longer description	*For connecting existing labs with researchers and customers, a Database of DER and Smart Grid Research Infrastructure was developed – free accessible via http://infrastructure.der-lab.net/. Developed and maintained by DERlab since 2012, the database contains details on Smart Grid and DER laboratories, testing facilities and similar competencies, clustering all relevant information and the labs' profiles systematically.* *In September 2016, the database version 2.0 was launched, appearing in a completely renewed design and offering new extensive search and filtering options. Currently, the directory includes more than 50 institutes from Europe and the US, presenting more than 200 labs, testing capabilities and services. Each institute has the chance to present all relevant information about their facilities in order to inform their customers on the most important details, such as:* • *Static and mobile equipment of the facility* • *Power range* • *Simulation and optimisation tools* • *Offered testing services within the laboratory* • *Quality management and standards compliance of the offered testing services* *Examples of research infrastructure listed in the database cover a broad range from PV system labs, PHIL simulation environments or Microgrid configurations.* *For offering an up-to-date overview on the existing research infrastructure, DERlab aims at constantly expanding its database, encouraging all institutes active in the field of DER and Smart Grids, to submit information on their laboratories and facilities – they will be a gainful extension to the current content. Adding infrastructure to the database is very easy and free: An embedded online form on http://infrastructure.der-lab.net/add-your-ri-database/ allows new entries and updates.* *Institutes with facilities in the DERlab database clearly benefit from DERlab's core business - Its network and dissemination activities:* • *The database is accessed by our broad international network, which coincides with the institutes' targeted customers* • *Institutes gain visibility in the field of DER and Smart Grids* • *With the enhanced search functions in the database, possible new customers can easily find the services offered by the institute*
Technology Readiness Level (TRL)	*9*
WP of reference	*WP2*

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Contact person/ email	*N/A*
IPR	*Database*
IPR Status	*N/A*
References	*key ELECTRA deliverables and papers.*
Technology keywords	*Research infrastructure, database, smart grids, DER, research,*
Special conditions for the access to such Asset?	*Free access to the on line data base*

Title	**30. The ELECTRA REX methodology and scheme for researcher mobility**
Type of Asset	*Foreground -methodology*
Short description	*The ELECTRA REX Mobility scheme proposes a methodology for the operation of a researcher exchange programme, incorporating scheduled calls for applications, online application submission, exchange selection, commissioning, reporting and review.*
Longer description	*The ELECTRA REX scheme offers assistance to support transnational and international researcher exchanges to or from the research project partners and EERA Joint Programme members, that complements and enhances the collaborative smart grids research undertaken within the joint programme. Through a series of managed REX Calls, applications are invited for one of three types of exchange: Global Exchange, European Exchange, Intra-ELECTRA Exchange. The successfully selected applicants are provided funding for the additional costs of travel, accommodation, and subsistence associated with the exchange visit, and support for participation in an international ELECTRA REX workshop aligned with a technical conference. These workshops provide an opportunity for exchange researchers to share experiences of mobility as well as disseminate their results through their international co-authored papers.* *The call-based methodology supports an iterative process of call preparation and issuing, application review and commissioning, and reporting and evaluation, with the latter supporting feedback into the subsequent calls. The combination of targeted joint publications and the web-hosted abstracts as exchange deliverables provides a useful focus on seeking valuable results in the collaboration between researcher and host. Furthermore, the implementation of host and researcher questionnaires provides valuable oversight and learning from each of the exchange calls, with collated lessons learned incorporated into subsequent calls.*
Technology Readiness Level (TRL)	*N/A*
WP of reference	*WP9*
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IPR	*N/A*
IPR Status	*N/A*
References	*A significant number of joint papers have been published from the exchange teams following successful exchanges. Each has the exchange researcher and their hosts as co-authors.*

Technology keywords	*Researcher mobility; researcher exchange; international collaboration.*
Special conditions for the access to such Asset?	*Free access to reuse the methodology provided appropriate acknowledgement included.*

Title	**31. Questionnaire for the identification of the R&D priorities on smart grids**
Type of Asset	*foreground - questionnaire*
Short description	*The questionnaire aims to identify the top R&D priorities in the smart grids field and the related actions targeted to implement International Cooperation (INCO).*
Longer description	*In order to have a more homogeneous concept of smart grids at worldwide level, a questionnaire aimed to identify the most interesting topics on smart grids and to geographically prioritize them has been developed.* *In particular, eight categories, are defined:* *1. network operation;* *2. power system management;* *3. smart grid ICT and control systems interoperability;* *4. electrical storage integration;* *5. transmission networks;* *6. research infrastructure, lab facilities and testing;* *7. other topics;* *8. suggested other topics.* *For each category, specific topics are outlined, allowing to further detail the activity. Furthermore, for each topic, nine type of actions the responders may be available to implement are listed:* *1. workshops;* *2. conference side events;* *3. research exchanges;* *4. international collaboration;* *5. joint proposals;* *6. joint projects;* *7. summer schools;* *8. joint publications;* *9. joint use of international research infrastructure.* *The responders are asked to identify and rank the ten topics of highest interest and to express their availability to implement specific actions.* *Hence, the elaboration of all the replies allows to identify the R&D topics on smart grids of highest interest for the responders and the related actions they are available to take. The outcomes of this process can lead to the definition of an action plan to be implemented at global level in the smart grids field by means of International Cooperation.* *The questionnaire was taken as reference for the identification and the launch of the R&D activities within Mission Innovation Challenge #1 on Smart Grids.*
Technology Readiness Level (TRL)	*N.A*
WP of reference	*10*
Organisation leader	*RSE*

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IPR	
IPR Status	
References	*ELECTRA D10.2, D10.3*
Technology keywords	*Smart grids, R&D priorities, questionnaire*
Special conditions for the access to such Asset?	*Free access*