FlexPlan

Advanced methodology and tools taking advantage of storage and FLEXibility in transmission and distribution grid PLANning

Newsletters published twice a year

D7.3

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About FlexPlan

The FlexPlan project aims at establishing a new grid planning methodology considering the opportunity to introduce new storage and flexibility resources in electricity transmission and distribution grids as an alternative to building new grid elements. This is in line with the goals and principles of the new EC package *Clean Energy for all Europeans,* which emphasizes the potential usage of flexibility sources in the phases of grid planning and operation as alternative to grid expansion. In sight of this, FlexPlan creates a new innovative grid planning tool whose ambition is to go beyond the state of the art of planning methodologies, by including the following innovative features: integrated T&D planning, full inclusion of environmental analysis, probabilistic contingency methodologies replacing the N-1 criterion as well as optimal planning decision over several decades. However, FlexPlan is not limited to building a new tool but it also uses it to analyse six regional cases covering nearly the whole European continent, aimed at demonstrating the application of the tool on real scenarios as well as at casting a view on grid planning in Europe till 2050. In this way, the FlexPlan project tries to answer the question of which role flexibility could play and how its usage can contribute to reduce planning investments yet maintaining (at least) the current system security levels. The project ends up formulating guidelines for regulators and for the planning offices of TSOs and DSOs. The consortium includes three European TSOs, one of the most important European DSO group, several R&D companies and universities from 8 European Countries (among which the Italian RSE acting as project coordinator) and N-SIDE, the developer of the European market coupling platform EUPHEMIA.

Partners

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Executive Summary

This deliverable of the FlexPlan project includes all project newsletter issues. Six issues of the project newsletter have been published alongside the 42 months of duration of the FlexPlan project. Each newsletter issue includes a letter from the coordinating person which provides the status of the project activities as of the current date and a few articles providing a deeper insight on particular project activities.

1 Introduction

This deliverable of the FlexPlan project includes all project newsletter issues.

A newsletter issue was published every 6 months alongside the 42 months of duration of the FlexPlan project starting from month 6 (March 2020). So, by having a look at what published one can grasp the difficulties encountered by the project and the solutions put in place in order to solve them.

As it is the case for many research activities, what initially thought (ambitions, methodology, etc) had to be re-moduled in relationship with the real possibilities offered by the available technology (most notably the AWS servers, due to some intrinsic limitations and others dependent on the available project budget). Most of these simplifications could be removed in a real-world application, whenever more powerful calculation resources would be available and the high level of parallelization offered by some features of the FlexPlan methodology (in particular: Benders' decomposition and T&D decomposition) could be fully exploited.

Six newsletter issues have been published and each of them has been sent to the full list of the Advisory Board members of the project, plus a further number of persons who had subscribed to receive the newsletters through an application on the FlexPlan web. Thus, the issuing of the periodic newsletter is part of a wider comprehensive communication strategy, that encompasses the involvement of the Advisory Board into a yearly specific meeting and in a yearly round of web consultations on topics of interest for the project (last but not least, the consultation of the draft of the strategic deliverable D6.3, which brings the final regulatory guidelines concluding the overall project activities).

Each newsletter issue includes a letter from the coordinating person which provides the status of the project activities as of the current date and a few articles providing a deeper insight on particular project activities.

2 Newsletter M06 (March 2020)

2.1 Letter of the Project Coordinator

Six months have elapsed since the kick-off of the FlexPlan project. In these six months, the activities, always very tight and exciting, covered different key aspects.

There is an important on-going research activity to find the best representation for the equations of the new planning tool. Here, significant modelling efforts are requested because of the dimensionality challenges this model is subject to:

- nodal representation of very wide systems (each regional case encompasses one or several EU countries),
- hourly detail for three grid years (2030, 2040 and 2050), solved together in order to co-optimize mid- and long-term grid planning,
- large number of grid expansion candidates (each of them attached to a binary decision variable saying whether that investment is carried out or not): new lines or cables, refurbishment of existing ones, new storage units, flexible exercise of big industrial and tertiary loads,
- internalization of environmental externalities (landscape impact, air quality, CO2 lifecycle)
- holistic view of the planning procedure (transmission and distribution together): in modelling distribution grids it is important to capture the most relevant aspects while avoiding bogging into details on the huge number of lines making up the distribution system. For this reason, synthetic networks are created, so as to summarize those aspects of the real grid that are relevant for planning.

Another important subject of current investigation is the pre-processor tool, which is aimed at elaborating a nodal list of investment candidates to be proposed to the planning tool. Here the research is acting on two fronts:

- characterization of technologies and operating modalities for storage and flexibility candidates,
- creation of a robust algorithm using the results of a non-expanded minimum cost optimization to formulate lists of nodal candidates.

During the first six project months, there has also been a big effort to start elaborating data to feed both the pan-European model (ENTSO-E TYNDP scenarios and data have been taken as the basis) and the grid models of the six regional cases (based on the ENTSO-E grid model for the transmission part).

Finally, it was important also to assess the current *status quo* of EU regulation and TSO/DSO planning practice in order to build a picture of the context in which the new grid planning methodology proposed by FlexPlan is located. This analysis, produced the first technical deliverable (D6.1) which can now be downloaded from the project web site (https://flexplan-project.eu/).

The project web site is an important communication tool for FlexPlan: on it, all new achievements and all information on on-going dissemination activities is regularly posted. Everyone who is interested in grid planning issues is invited to surf it on a regular base! Presently, we have three open web consultations (https://flexplan-project.eu/consultations/): here, feedback is welcome from all EU stakeholders!

Gianluigi Migliavacca (RSE)

2.2 Why T&D grid planning needs to account for flexibility

In the light of the Covid-19 pandemic, we are observing an exceptionally low demand period due to the deceleration of economic activity. All across Europe, the average demand has decreased by approximately 20% in the period of March and April. Combined with high power generation form renewable energy sources due to favourable weather conditions, this has resulted in an increased number of negative price incidents on the day-ahead electricity market, which is a typically a sign of lacking downwards flexibility. Today's situation can be seen as scaled-down experiment of a renewable energy dominated future where the share of renewable generation is expected to be much higher than what we are observing even in this current situation. To guarantee electricity supply, the future power system needs to rely upon various sources of demand flexibility and storage on one hand, and a strong, well interconnected and flexible transmission system on the other.

Within the FlexPlan project we are in the final steps of formulating a planning model which includes flexible demand, storage and flexible transmission system models, and achieves the best trade-off between classic line and flexibility investments, tailored to the needs of the future power system. An important feature is that the model combines both transmission and distribution grid planning in order to avoid inefficiency and bottlenecks in much needed flexibility provision from and to lower voltage levels. Another important feature is that three important environmental externality factors are internalized into the model (landscape impact, air quality and CO2 lifecycle assessment). In the next coming months, we will start with the implementation of the planning model as a software tool (WP3) and demonstrate its added value in a number of regional cases (WP5). What also matters is that we are searching for planning solutions over a very long time period, encompassing the three grid years 2030, 2040 and 2050. This will allow, once applied to the European system to cast a view on the system development from the medium term till a long term where RES generation will be prevalent in the system.

Hakan Ergun (K.U. Leuven) - WP1 Leader

2.3 Flexibility resources characterization as input for network planning

The increasing participation of variable wind and solar energy production plants in the power system requires flexibility from other resources, such as fast reacting generation assets, storage and demand response. Storage, other than pumped-storage hydropower, and demand response have not been considered in traditional network planning procedures and it is the aim of FlexPlan project to revert this situation.

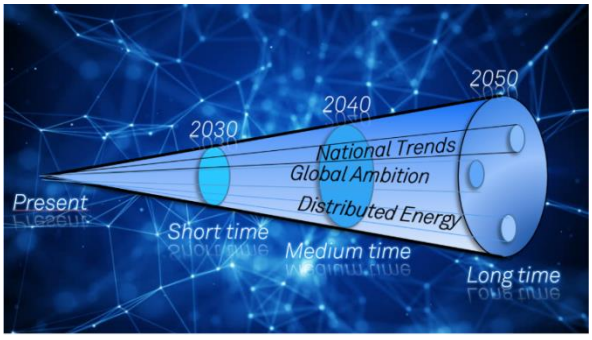
Within the FlexPlan proposed methodology, flexibility resources are presented as candidates for network planning, competing with the conventional network capacity increase approach, e.g., through new line construction. In the past months, the flexible technologies have been characterized, as a first step to consider them as input for the innovative planning tool. Two main aspects have been considered for this characterization, on the one hand techno-economical characteristics and, on the other, operational strategies in the frame of power system applications.

A list of eligible flexible resources and their main characteristics have been identified. The list includes batteries, hydrogen, electric vehicles, pumped hydro, thermal loads, compressed and liquid air, demand response… From their characteristics, attributes are being identified and two common flexibility resources models will be proposed, one for storage and another for demand response.

In addition, operation modalities for flexibility resources have been identified through the analysis of the applications of both storage and demand response strategies in the power system. Congestion support has been defined as main objective for flexibility resources and, in the next months, the research focus will be set on the development of strategies to locate and size flexibility within the network to generate candidates for the planning tool.

Raúl Rodriguez (TECNALIA) – WP2 Leader

2.4 Creating an ambitious set of pan-European scenarios



The European energy system is a highly meshed interconnected system. As FlexPlan aims at establishing a new grid planning methodology considering storage and flexibility resources for the pan-European power system, it is of great importance to extend the analysis to an area as wide as possible of the European territory. This will allow to examine a very high number of cases, which is important for the creation of the regulatory guidelines elaborated in the last phase of the project. For this reason 6 detailed regional scenarios are set up, covering each a significant portion of the European grid. However, in order to provide homogeneous border conditions to all regional cases, a pan-European scenario has to be created as well.

For each target year (2030, 2040 and 2050) we examine three different scenarios to model divergent political and regulatory policies, resulting in a total set of nine variants. The scenario set used in FlexPlan is in line with the latest ENTSO-E Ten Year Network Development Plan (TYNDP). While the *National Trends* scenario considers the national energy and climate targets of the member states, the other two are completely energy-based and take into account all kind of energy (not only gas and electricity). The *Global Ambition* scenario implements centralized generation reflecting the Paris Agreement target. The *Distributed Energy* scenario is in line with the target to reduce emissions to zero by 2050 by integrating the consumer into the system. Currently we are working on a methodology to finalize the detailed scenario data for 2050. In the next steps we will execute a pan-European market simulation to calculate the trans regional power exchanges. This will allow us to feed the 6 regional cases with the right border

conditions. Furthermore, we will apply a regionalization methodology in order to calculate spatially-distributed time series for load and feed-in of renewable energy sources.

Jawana Gabrielski (T.U. Dortmund) – WP4 Leader

2.5 Preliminary screening of planning practices and EU regulation

Within the activities of the FlexPlan project, a preliminary screening of current planning practices and EU regulation has recently been completed. It brought to the finalization of the deliverable "**Guideline for the compliance of network planning tool with EU overall strategies and regulatory conditions**", which is now freely downloadable from the FlexPlan project web site (https://flexplan-project.eu). This deliverable is the first in a series of three reports that are looking into regulatory aspects concerning the methodologies developed within the project. The document presents an assessment of the present pan-European regulatory framework, complemented by a reference to the existing practices at both TSO and DSO levels. The activity applied qualitative evaluation methods, based on data collected through literature screening and survey-based research. The results are structured around 17 specific thematic topics. The deliverable put forward several important remarks related to the use of flexible resources, cost-benefit analysis at both TSO and DSO levels and TSO-DSO interactions. The document concludes that there are strong regulatory signals prompting the European system operators to consider flexible resources as a new important active subject in the grid expansion planning process for system operators. Despite strong efforts from ENTSO-E to develop common methodologic principles, there are still several missing elements in the puzzle. This strengthens once again the importance and proper timing of FlexPlan project for developing and testing new innovative grid planning methodologies coping with the present and future challenges.

Andrei Morch (SINTEF) – WP6 Leader

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3 Newsletter M12 (September 2020)

3.1 Letter of the Project Coordinator

Six further months and our project has reached one year of life, which corresponds to one third of its duration. As already mentioned in the previous newsletter issue, the first project year was mainly dedicated to lay down the theoretical background. In this direction, a big progress was achieved:

- the full equation set and the corresponding data requirements have been outlined and consolidated in a thick internal report;
- the concept of flexibility has been analysed in depth from the point of view of the services that can be provided and of the most suitable technologies to provide such services, with a particular focus to congestion management, the most pertinent to the grid planning activities.

However, some important theoretical analyses are still on-going:

- investigating on the opportunity to **reduce the very demanding computational load** to solve a mixed-integer investment optimization for the entire network (transmission and distribution) at nodal level and altogether for three grid years (2030, 2040, 2050). This can be carried out by adopting advanced numerical techniques allowing to carry out a stepwise optimization process for the three grid years by realizing at each step a partial relaxation of the integer variables set. A further point consists of investigating if, again by using opportune techniques, the optimization for the transmission grid can be decoupled from that of the distribution grid.
- **creating of a small scale implementation of the equation set** and of the decomposition techniques mentioned at the previous bullet. This bears the two-fold aim to double-check that everything works well and no modeling aspect was omitted in a reduced dimensionality environment which allows an easier interpretation of the obtained results and to create a first set of results upon which the full-scale planning tool, the realization of which has already started, can be validated.
- **setting up of the methodology for the pre-processor**, which is the tool that will provide the set of candidates to the planning tool (new lines/cables, storage elements, flexible exercise of existing big loads). In turn, the planning tool carries out an optimal selection of elements from this set by minimizing the sum of OPEX plus CAPEX. So, it is essential to obtain a valid set of candidates from the pre-processor in order to allow the planning tool to perform a really optimal selection. Unfortunately, unlike the planning tool, the pre-processor can't be created on the basis of a clear-cut set of equations but a heuristic technique, based on the results of a previously calculated optimization of dispatching costs for the non-expanded system, must be set up. The true difficulty is to incorporate in this heuristics the know-how human grid planners should dispose of.

As mentioned, the **creation of the full-scale grid planning** has already started and some strategic decisions have already been taken. A first full version of it is awaited by July 2021.

In parallel, a **comprehensive data collection** is being carried out for the three grid years and for the adopted storylines (corresponding to the three described by ENTSO-E in the Ten-Year-Development-Plan 2020). This is a titanic task: a huge amount of data (full T&D grid, generation set and load characteristics) is requested in order to allow a realistic grid planning analysis at nodal grid level for 2030-2040-2050 for all six regions covered by the project simulation cases (actually, most of Europe). From the grid point of view, whereas present extra-high voltage networks (400kV and 220kV) are put available, yet in a simplified format, by ENTSO-E, data for the sub-transmission (150-130kV) and the distribution grids have to be collected from scratch. For sub-transmission, lacking direct TSO-provided data, we need to acquire (and validate) public Open Street Map data, whereas for distribution grids, whose complete dimension is clearly out-of-scope for our project, we reconstruct "synthetic" reduced-scale networks aimed at having the same characteristics as the original ones based on the collection of overall statistics from real country networks and on the analysis of some portions of real networks which are available to the consortium members. All these complex activities are now proceeding full steam and a clear timeline has been elaborated in order to complete the data collection process at least for one regional case by when planning tool and pre-processor will be ready to start their testing phase.

Gianluigi Migliavacca (RSE)

3.2 Proof-of-concept implementation for model validation

Hakan Ergun (KU Leuven) - WP1 Leader

During the last six months, the project focus has been on finalizing the mathematical foundations of the planning tool in the form of an internal deliverable and on creating the backbone of a proof-of-concept implementation of the planning model. We have created, *FlexPlan.jl,* a software package in the Julia language which will be dedicated to test the mathematical model of the planning tool. *FlexPlan.jl* allows all project partners to implement proof-of-concept models in a collaborative way. In particular, the creation of this software package aims at:

- achieving a software design where optimization solvers can be easily exchanged, allowing to test with different solvers the computational efficiency of the developed models
- extending in a flexible way the resulting model formulation
- experimenting different decomposition techniques without massive changes in the model implementation
- analyzing in depth certain modeling trade-offs by just including or excluding specific parts of the overall planning model in the optimization process. In this way, the testing can be done in a more agile way, without the need to solve a large

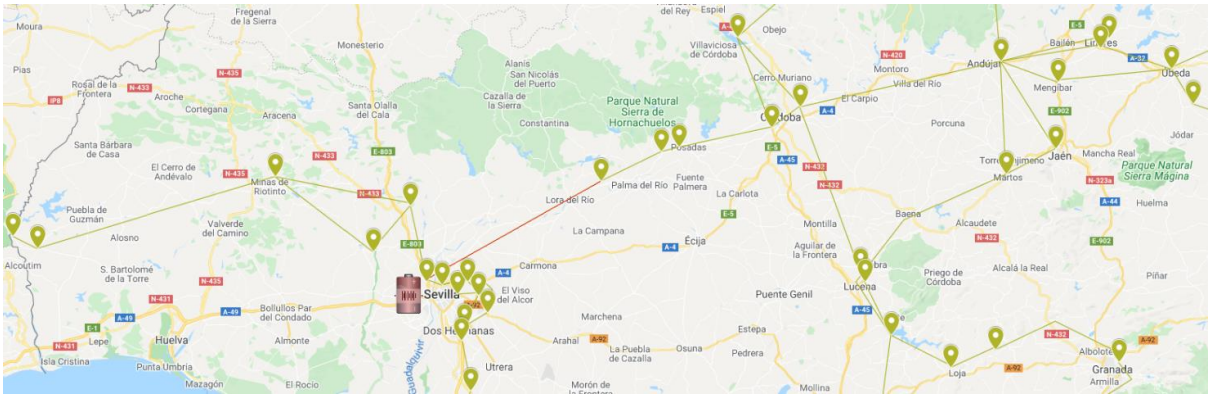
complex mathematical model during the proof-of-concept phase.

All proof-of-concept tests are being conducted on a small-sized network (see figure above), which was adapted to the Italian geography and allows to represent the environmental impact-related costs as part of the FlexPlan model. In a second phase, this network module will be replicated a high number of times in order to test possible model scaling up issues before passing to real-size test cases.

Eventually, the *FlexPlan.jl package* will also serve to provide a first validation of the planning tool, currently being implemented in parallel to the proof-of-concept tests.

3.3 A pre-processor tool to set planning candidates

Raúl Rodriguez (TECNALIA) – WP2 Leader



The increasing participation of variable wind and solar energy production plants in the power system requires flexibility from other resources, such as fast reacting generation assets, storage and demand response. Storage, other than pumped-storage hydropower, and demand response have not been considered in traditional network planning procedures and it is the aim of FlexPlan project to revert this situation, where flexibility resources are presented as candidates for network planning, competing with new line construction.

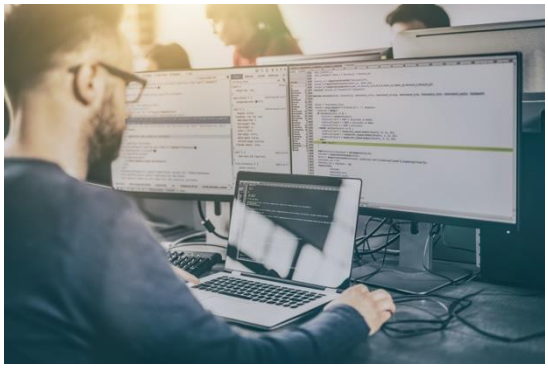
Two deliverables (D2.1 and D2.2) have been already produced on the characterization of flexible resources and on the main applications of storage and demand response for the power system, focusing on congestion support. Both are available at the link https://flexplan-project.eu/publications/. From these references, a pre-processor tool is in definition process to interact with the planning tool, as part of the planning methodology proposed in the frame of the project.

The pre-processor will receive as input both the results from an Optimal Flower Flow (OPF) executed for the non-expanded network under evaluation and the electricity network model. With this information, the tool will provide outputs back to the planning software, including a selection of locations (buses & branches) and candidates for network extension. The planning tool will then select among the candidates those that optimize the network expansion.

Within the next six months, a first version of the pre-processor will be already available, and the validation process of the tool will start.

3.4 The planning tool: a complex software engineering work

Maxime Hanot (N-SIDE) – WP3 Leader



During the last three months, the FlexPlan project has undertaken one of its most challenging activities: the creation of the planning tool. This daunting task consists in designing, implementing and testing a new T&D planning tool, inclusive of Graphical User Interface (GUI), and supporting large-scale tests performed on the six regional cases. The new T&D planning model is a huge mixed-integer optimization problem, very innovative with respect to current TSO/DSO tools.

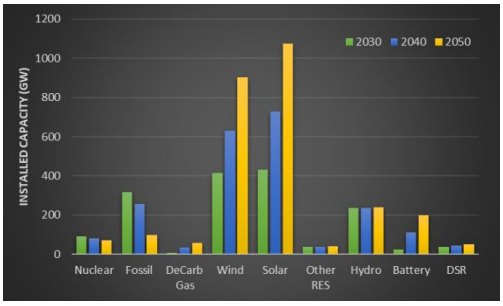
This complex software engineering work has started with a design phase. This design phase should end late October and is crucial to align the expectations of the different partners, to make sure that the developments can start smoothly and to establish a rigorous timeline. In addition, during this phase, several important questions are being answered:

- How to gather the needed data and in what format?
- How to interact with the pre-processor tool?
- What are the best technologies to develop the software?

After the design phase, the development of the tool itself will start. For this task, the FlexPlan team has decided to work in an agile way, starting from the requirements and quickly developing a Minimal Viable Product (MVP) and then improving it in terms of algorithms efficiency, GUI and other while keeping testing it. The team has therefore given itself very ambitious targets: the purpose is to get the availability of a reduced version of the tool (i.e. able to run optimal power flows) by the end of 2020 and a first complete MVP by June 2021. This MVP will then be extended by improving the efficiency of the planning algorithm, by developing an intuitive GUI and a documentation such as to ensure an easy handling by all kinds of users.

3.5 Downscaling pan-European energy scenarios to regional case level

Jawana Gabrielski (WP4 Leader); Nuno Amaro (WP5 Leader)



The FlexPlan tool will be tested and validated through six ambitious regional cases covering almost all Europe. A comprehensive set of three energy scenarios per year was created for 2030, 2040 and 2050. 2030 and 2040 scenarios are directly obtained from ENTSO-E TYNDP 2020 with minor adaptations. However, due to the absence of this data in TYNDP, 2050 scenarios are created

using a two-step methodology, validated by the consortium members and by several members of the Advisory Board, through a performed web-consultation. A first linear approach from 2030 and 2040 data in TYNDP 2020 is performed, followed by a validation of obtained results with relevant scenarios from "A Clean Planet For All" energy long term strategy from the European Commission. The created scenarios, whose methodological development and exemplary results are available in FlexPlan Deliverable 4.1 (available in: https://flexplan-project.eu/publications/), allow having a pan-European energy vision, while providing a detailed analysis at country level. The enclosed figure depicts the example of the evolution of installed capacity in Europe for the scenario "Distributed Energy". Answering to current environmental targets, fossil fuel power plants almost disappear in 2050 and the few existing ones are based on environmental friendly solutions such as decarbonized gas.

Data from these pan-EU scenarios is broken down to a regional level. As renewable energy sources depend on location and weather conditions, a regionalization methodology is applied. At first the regional distribution of the national data is calculated through statistical parameters. Based on this, regional feed-in and load time-series are determined using weather data. The process will result in a nodal distribution for each one of the simulated years. This data will be used together with the detailed grid models to fully test the functionalities of the FlexPlan tool. Regional cases grid models, currently under development, consider the existence of full geo-referenced transmission and distribution systems, existing and planned power plants and realistic load distribution. The transmission systems are based on a dataset received from ENTSO-E (extra-high-voltage grid) complemented with national level and open source data (e.g. TSO network development plans and Open Street Maps) for the sub-transmission levels. Distribution systems are built using synthetic networks, which are representative of real distribution networks around Europe. Additionally, and because FlexPlan also considers the environmental impact of grid reinforcements and thermal generation, a complementary set of data is currently being collected, allowing to have a full vision of carbon footprint and air quality around thermal power plants, which should still be operating in each one of the three target years for the FlexPlan studies. This complex and ambitious simulation process is ongoing and results will start to be delivered as of the beginning of 2021, when the first 2030 scenarios will start being simulated.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863819

4 Newsletter M18 (March 2021)

4.1 Letter of the Project Coordinator

The FlexPlan Project has now reached month 18 of its activities. This point is not only important because of the completion of the first project period, which implies administrative and technical auditing from the European Commission, but even more because it marks the halfway of the project duration. So, it is an important point to look at what has been achieved so far and what remains to be done.

For sure, one of the most brilliant aspects that have been tackled so far is the complete specification of the methodology for both the grid planning procedure and the pre-processor, the latter providing the list of the planning candidates to be examined by the planning tool.

Concerning the **methodology of the planning grid tool**, the key achievement obtained so far is not only the complete specification of the mathematical models for all system components (transmission and distribution networks AC and DC lines, phase shifter transformers, storage systems, flexible loads, etc), but also the specification of the full mathematical model for the optimization process. Regarding this latter aspect, the need to cope with unprecedentedly huge optimization systems and, thus, the need to pay particular attention to numerical tractability is very high in the project priorities. Two innovative system decoupling procedures should do the work: the former between the planning optimization of the transmission grid and the one for the distribution grids, the latter between the optimal grid dispatch problem and the candidate selection. Both these decomposition techniques have been tailored to the project needs and are now being tested on small-scale systems before they can be implemented at their full scale in the planning tool.

At the same time, also the **methodology specification for the pre-processor** has been completed and now a few small test cases are being carried out to fine-tune all aspects. For sure, the major difficulty here is that several aspects of the selection of the grid planning candidates should convey the experience of real planners into an automatic algorithm. A fine-tuning process must be carried out, trying to implement an intelligent algorithm mimicking flexibility and efficiency of typical man experience.

Meanwhile, **first partial releases of both the planning tool and the pre-processor** are available and the testing phase is progressing well. The first complete implementation of both tools should be available by June 2021.

By end of March, **the project pan-European market simulations have been finalized** for all three key years (2030, 2040, 2050) and according to all three public ENTSO-E TYNDP 2020 storylines. These simulations will allow adopting consistent border conditions for the flows exchanged between the six regional cases.

The **build-up of the six regional cases** itself is registering a very good progress, but also there the dimensionality problem is the source for important challenges: the planning tool is fed by a JSON -file, but the dimension of such file must be reduced by optimizing its structure in order not to overcome the maximum dimension that can be transmitted and read by the server.

The FlexPlan project attributes a primary importance to **dissemination**. So far, the project was represented in two 2020 conferences (UPEC and EEM), several workshops (many of which in synergy with ISGAN), journal papers (among which the very comprehensive 30-pages contribute recently published in open-access by the ENERGIES journal: https://www.mdpi.com/1996-1073/14/4/1194).

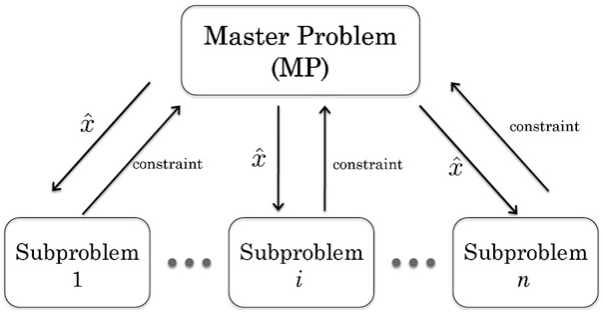
Another pillar for FlexPlan is the availability of a very competent and interested set of people following the project being members of its Advisory Board. In April 2021, a **new set of project web consultations** will be open to discuss important open issues for which the project calls for external expertise. This consultation will be not only open to the members of the Advisory Board, who are expected to provide a contribution by sharing their views, but, more in general, to whoever is following the FlexPlan project and wants to contributes with her/his expertise. As usually, non-technical two-pagers will be published for each consulted topic to introduce the open issue, along with a set of questions for which external experts are consulted. Answers will be collected through the project web site. Finally, for each topic a summary document will be posted summarizing the consultation outcome.

Stay tuned! The first half of the project has laid down a lot of good seeds, but we expect the most interesting project results to come later, in the first half of the year 2022.

Gianluigi Migliavacca (RSE)

4.2 Advanced numerical techniques to enhance computational tractability

Hakan Ergun (KU Leuven) - WP1 Leader; Marco Rossi, Dario Siface (RSE)



During the last six months, the project focus has been on the testing of the mathematical formulation of the FlexPlan model. Specific features of the planning model, such as, the modelling of flexible resources, storage modelling and joint modelling of transmission and distribution systems have been implemented in *FlexPlan.jl*, a new software package based on the Julia language. Using *FlexPlan.jl* a number of sensitivity tests have been performed on the most important modelling assumptions and the performance of scenario reduction techniques for increased computational tractability.

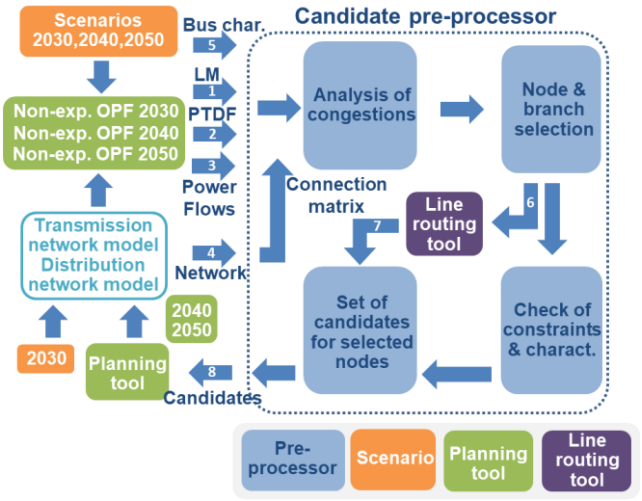
An important milestone of the project has been reached with the publication of the project deliverable "Probabilistic optimization of T&D systems planning with high grid flexibility and its scalability" (*https://flexplan-project.eu/wp- content/uploads/2021/03/D1.2_20210325_V1.0.pdf*). This comprehensive deliverable describes the full mathematical model, details of the implementation within *FlexPlan.jl* and

detailed results showcasing the performance of the developed model. The deliverable further discusses advanced model decomposition techniques to further increase the computational tractability which are currently being implemented within *FlexPlan.jl*. One of the most important features in that respect is the decomposed transmission and distribution system modelling, where distribution grid expansion strategies are provided as potential expansion candidates for the transmission system, allowing to represent a large number of distribution grids in the planning problem. This decomposition technique on one side reduces the dimensionality of the optimization problems, thus helping to preserve numerical tractability, on the other side notwithstanding the implementation of an integrated transmission-distribution grid planning approach, the actions to be carried out by the two system operators are decoupled and this could favour the practical application of the methodology. Secondly, a novel decomposition technique has been formulated to iteratively solve the planning and operational problems, while preserving the stochastic nature of the planning problem. This decomposition, while separating the solution of the investment problem from the calculation of the optimal dispatch, also allows to easily integrate different variants of load and RES generation timeseries into one only investment decision process.

We are also very happy to announce that *FlexPlan.jl* will be made available to the research community as an open-source software package in the months to come.

4.3 A complex methodology to provide the best planning candidates

Raúl Rodriguez (TECNALIA) – WP2 Leader



The increasing integration of variable wind and solar generation in the power system requires getting flexibility from other resources, such as storage and demand. Storage, other than pumped-storage hydropower, and demand response have not been considered in traditional network planning procedures and it is the aim of FlexPlan project to revert this situation, where flexibility resources are presented as candidates for network planning, competing with new line construction.

To help the planning tool in the candidate selection process, a pre-processor tool methodology has been defined during the last six months and the first version of this software has been produced. The pre-processor software receives as input:

- the results from an Optimal Power Flow (OPF) run on the non-expanded network model;
- the network model and scenario;
- a characterization for network nodes (useful to decide which technologies can be hosted in each place);

- a set of pre-defined network candidates provided by the user (especially useful for new grid expansion corridors).

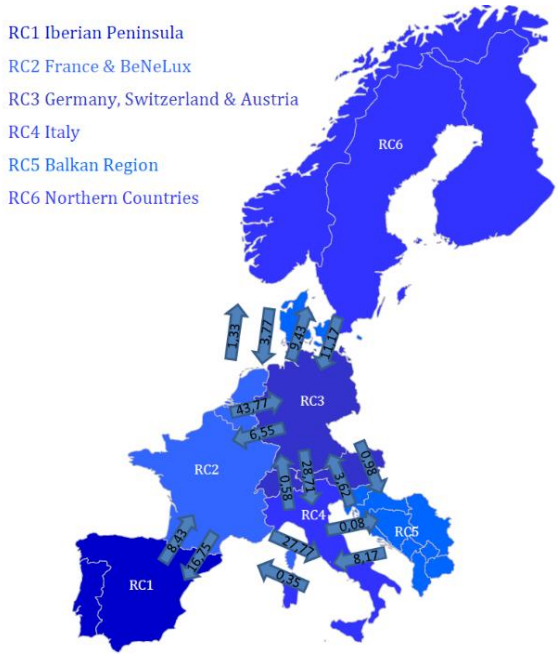
With these inputs, the pre-processor tool is able to locate congestions in the network and select a preferred bus for the installation of flexible resources. For each of the identified locations, it proposes a set of candidate technologies, such as storage and demand response, but also conventional grid expansion solutions, such as lines and Phase Shifting Transformers (PST). As last step, for each of the proposed technologies, a size and cost is provided.

Then, this set of locations and candidates is provided to the planning tool, which will select among the candidates those that minimize total network expansion costs (CAPEX + OPEX).

Within the next six months, the current version of the pre-processor will be tested and tuned, through the analysis of Regional Use Cases. Another aspect to be fulfilled is the adequate integration between the pre-processor and both the planning tool and a line routing software, which will provide line technology and cost inputs to evaluate AC and DC branches as network expansion options.

4.4 Pan-European market simulations for three storylines at 2030-2040-2050

Jawana Gabrielski (Technische Universität Dortmund) – WP4 Leader



The innovative FlexPlan grid planning tool will be validated and applied to run six regional cases, covering almost all Europe. As the European energy system is a meshed interconnected system, cross border effects between the different regions have to be considered. For this, a set of pan-European simulations is carried out, providing coherent border conditions as a common ground for the following regional cases.

Data for 2030 and 2040 drawn from the three scenarios described by ENTSO-E in the "Ten-Year Network Development Plan 2020" was further elaborated and extended to 2050 during a complex data collection and processing activity. The pan-European simulations set-up followed a two-step approach. First, hourly renewable energy sources injection as well as load time series were determined on a regional level, in order to feed the regional cases with nodal information that is coherent with the overall scenario. Based on this, in a second step, market simulations were carried out, running an integrated unit commitment and dispatch model, which determines power plant and storage schedules, as well as hourly cross border exchanges between European countries. The underlying optimization took into account different constraints as the reserve power to be maintained, available transmission capacities between the different countries and the time coupling restrictions of generation units and storages.

More details on the methodology as well as some exemplary results are presented in FlexPlan Deliverable 4.2 (*https://flexplan-project.eu/wp-content/uploads/2021/03/D4.2_20210326_V1.0.pdf*).

4.5 New ideas for the dissemination of the project results

Stefania Ballauco *(WP7 Leader)*

The 2030 and 2050 targets for full decarbonization are closer than they seem.

The FlexPlan project, whose scope is in line with the goals and principles of the new EC package *Clean Energy for all Europeans,* is now at the halfway point, after 18 months of intense activity. Now the purpose is to address the effort also in the direction of dissemination, communication and exploitation of FlexPlan objectives and in sight of the next important project results.

The website https://flexplan-project.eu/ is an important and useful showcase and it will continue to be used for every update. Web users can find here project news and inspiration to foster discussion on current topics on the energy world. We aim to make it a hub of useful updates for all our audiences.

Fortunately, we a have a lot of traditional and digital channels and tools we can use to communicate our results and to create awareness among all stakeholders and the general public. Social networks are one of the most popular ones. We are going to focus on LinkedIn, where FlexPlan has its official page and where dynamic interaction and debate can give wide visibility to the project, through a sharing activity by our followers, who can use the @Flexplan project TAG.

Events are also a very important opportunity to stimulate the exchange of opinions, gather inputs and present the project outcomes. In addition to the organization of the final project workshop and of the six regional workshops to illustrate the final project results, we will take part to the most relevant international conferences, webinar or meeting where our goals and expected outcomes can be shared.

Next to the ongoing scientific outputs, such as publications of papers on hight impact scientific journals, we will plan press releases, articles and interviews on national press and magazines in order to involve journalists on our project activity and, at the same time, to speak to our heterogeneous audience, taking care to adapt the language and the message to the different targets: scientists, decision makers, press&media, interested people. We will also be promoters of editorial initiatives, to collect and to comment the results of our research activity.

Communication and storytelling are challenges that we can win and what we can do is explained in an Emily Dickinson quote: “I know nothing in the world that has as much power as a word. Sometimes I write one, and I look at it, until it begins to shine”. So, let’s make our words shine!

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 863819

5 Newsletter M24 (September 2021)

5.1 Letter of the Project Coordinator

The last six months of activities of the FlexPlan project have been marked by a progress on the simulation activities and by some reflections on the modelling side.

On the side of the simulations, the 6 regional cases have made good progress and the input data for running the non-expanded OPFs at 2030 (distribution network still excluded) are now ready. This should be the first step, allowing the pre-processor to analyze reinforcement needs (both grid and flexibility resources) so as to feed the new planning tool.

However, the run of these OPFs was possible only for one month of time due to memory limitations of the Amazon WEB Service (AWS) on which the simulation is run. One-year-long simulations would be necessary instead. That opened the debate on which measure could be more opportune to implement. The most obvious solutions would be either to widen the AWS memory setting, possible, yet with increasing hiring costs, or delocalizing the simulation by exploiting local servers. The former solution would however imply a very significant increase of the resources (AWS resources, unlike real servers don't manage memory swap: as soon as the memory demand overcomes the available one, the simulation crashes), whereas the latter would request a HW endowment which most regional case leaders don't dispose of. So, a modelling refection was initiated too. As the detailed analysis of storage and DSM resources prevents the simulations to adopt a rougher granularity than 1 hour, the preferred solution would be to find a way to split the yearly OPF calculation into independent monthly simulations that can be run independently. That opportunity will be explored by pre-solving the problem of the allocation of water among the year months, possibly by adopting techniques based on "water value" methodologies, well known in the Nordic Countries, where important seasonal reservoirs are managed. So, these techniques, that were already to be applied for the Nordic regional case, will be extended to all "big" reservoirs of the other regional cases. For small reservoirs, a simpler hypothesis could be applied: that those reservoirs manage every month only the water of that very month, so that the level at the end of the month is the same as the begin.

Beyond what has been mentioned so far, during the last 6 months, a significant progress has been realized on the side of the set up of the synthetic distribution networks on the basis of statistics collected on real networks.

The testing of the Benders decomposition techniques applied to the FlexPlan problem is continuing and the results seem encouraging.

Finally, the development of the planning tool is also proceeding and a Graphic User Interface layout has been also laid down and presented to the consortium TSOs for discussion. The aim of this is to create

an experience that can facilitate as much as possible the adoption by the European System Operators in their future planning analyses.

Gianluigi Migliavacca (RSE)

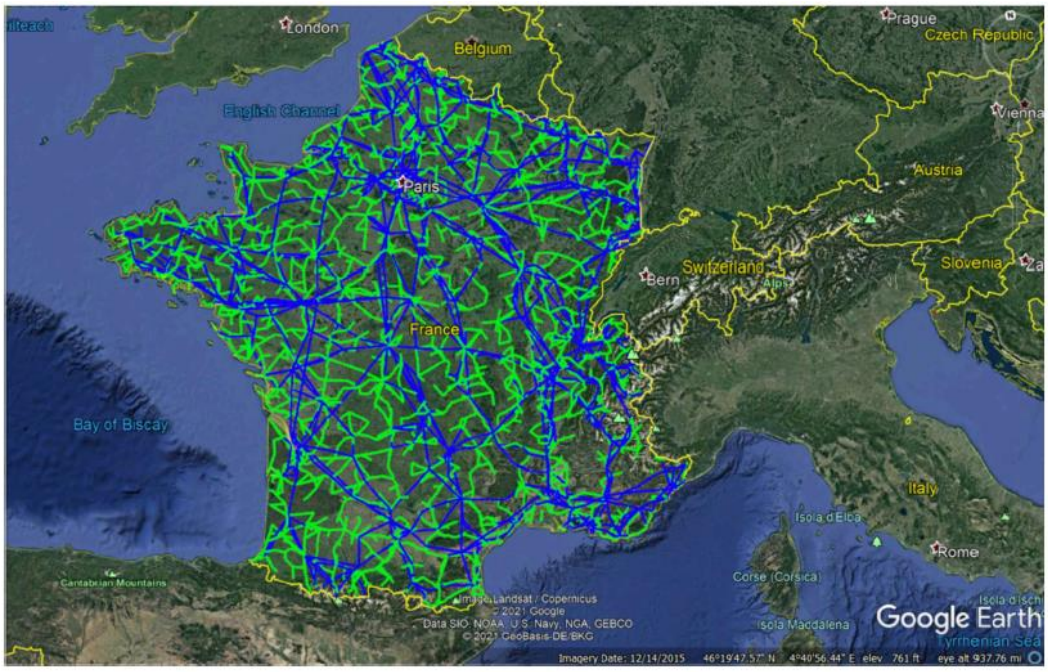
5.2 Progress in the regional cases set-up

Nuno Amaro (WP5 Leader) – R&D NESTER

The FlexPlan innovative grid planning tool is fully tested within the scope of the project by simulating network expansion plans in six ambitious regional cases. In previous editions of our newsletter we described energy scenarios to be used, up to 2050, as well as some preliminary results of pan-European market simulations. While the former constitute the basis of our simulations and provide different vision of the European Energy system in 2030, 2040 and 2050, the latter contributes to the definition and simulation of the regional cases by establishing coherent and univocal cross border flows between these. During the last six months, sound progress has been made in the setup of these six regional cases. The main activities can be summarized as follows.

Adaptation of energetic scenarios to grid nodal level. The energy scenarios created in the scope of FlexPlan start from data collected from TYNDP 2020, which reports installed capacities and load values aggregated at national level. For this reason, a methodology was created to adapt these to grid nodal level, starting from the regional level time series obtained in the scope of the pan-European simulations performed previously. This activity is currently in the last step and very soon these load and generation time series will be ready to simulate all energy scenarios considered in FlexPlan. These are complemented by the already obtained market results which provide time series data for cross border flows.

Development of grid models for transmission and distribution systems. The FlexPlan team defined and completed a very ambitious goal of having realistic regional case grid models (which add up to nearly the European grid) for both transmission and distribution systems. Transmission systems models are completed and consist of the transmission networks of countries involved in the regional cases. These models started from a data shared by ENTSO-E (grid model used in TYNDP 2018 studies), which are complemented by an extensive set of data including the full sub-transmission grid models and full geographical identification of grid nodes. This represented a comprehensive and complex data collection and validation task which now allows us to be confident on having complete and realistic transmission grid models. In the following picture, you can perceive the executed activity for the creation of the French Transmission Network model. In blue, you can see the data that was shared by ENTSO-E, already complemented with the geographical location of the different grid nodes, and in green the sub-transmission grid model, fully created by the FlexPlan team, resulting in a complete system model for the French transmission system.



Distribution systems are represented using synthetic network models. As there is no data available to cover the full extent of the distribution systems, which is the target of FlexPlan, the team resorted to a novel methodology to create synthetic networks. These are created based on statistics extracted from real distribution systems, which are representative of the different countries and geographical conditions. A detailed explanation of this modelling approach is given in the next section of this newsletter.

Collection of additional data sources. In order to simulate realistic conditions, another workflow was dedicated to the collection of data related to generation and load. On the side of generation, a full characterization of generation units is performed, including the identification of their geographical location, and technical characterization (installed capacity, fuel type, etc). Additionally, pollutant emissions data was also collected to allow performing environmental impact studies. From the load side, flexibility related data was gathered, in order to characterize and use flexibility provision from the load side as well as the identification of the geographical location of industrial loads. This data collection process is already finished for all regional cases, providing a complete characterization of load and generation, according to the requirements of the FlexPlan project.

The three activities here described can be considered as the main building blocks of the FlexPlan regional cases, allowing the grid expansion simulation toolchain to take place. In order to allow the user to quickly execute the simulation process, a dedicated methodology was also created to combine and place this datasets into a single structured input data file (using JSON format) which is then uploaded to the cloud based environment of the FlexPlan grid planning tool. At this stage, this data collection process is almost finished and the different regional cases are ready to start the simulation within the next few months. Stay tuned with us for more news.

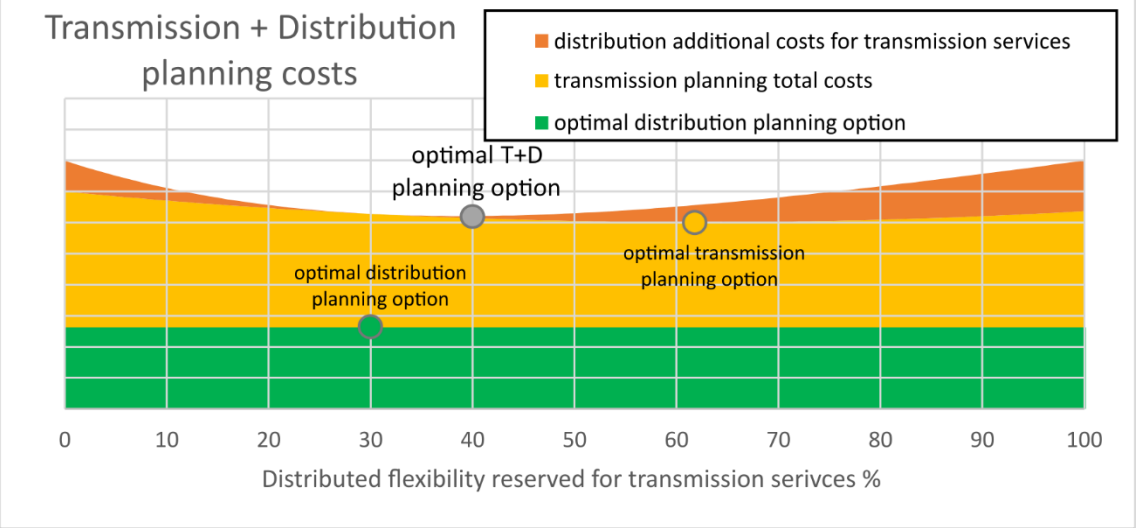
5.3 The complex procedure for setting up synthetic distribution networks

Marco Rossi - RSE

Distribution networks are increasingly important within the planning and operation of the electricity system, especially considering the volume of flexibility reserve that is connected to the lowest voltage levels which can contribute to services for both transmission and distribution networks. For this reason, a faithful representation of the distribution system over the European regions covered by the project FlexPlan is crucial for the identification of the flexibility potential in terms of grid planning (at any voltage level).

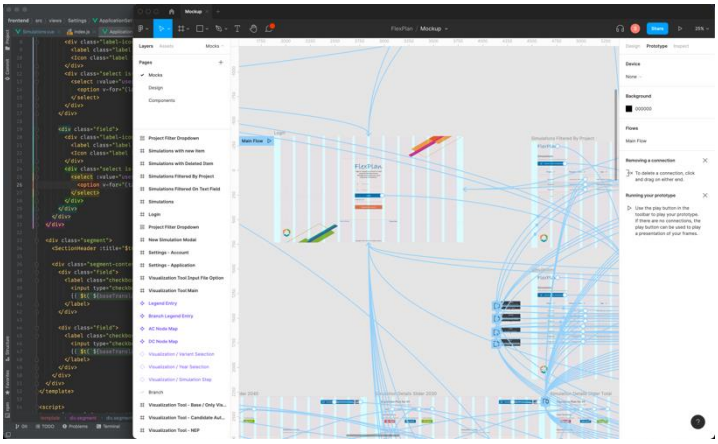
In general, a distribution system model covering the entire territory of a country is rarely available and it needs to be developed by resorting to electrical network synthesis. Literature reports many methods for the realization of synthetic grids and RSE has developed a method capable of providing a set of randomly generated networks which feature the same topological and electrical characteristics of real distribution systems (collected from public data/reports and dedicated interviews with system operators).

For each considered country, the synthetized distribution system counts hundreds of thousands of nodes and (flexible) devices that increases the complexity of the integrated transmission-distribution planning problem. The challenging dimension of the model is expected to be out of the capabilities of state-of-the-art solvers, so that the optimization of the planning measures can be obtained by adopting a decoupled (but still cooperative) transmission and distribution planning approach. FlexPlan dedicated significant resources to the development of an innovative methodology (recently published and presented at the CIRED 2021, see: https://flexplan-project.eu/wp-content/uploads/2021/09/Planning-of-distribution-networks-considering-flexibility-of-local-resources-CIRED-2021.pdf) based on the reservation of a TSO-DSO agreed distribution flexibility portion for transmission services. As in the graph shown below, an optimal compromise is calculated between a minimum cost optimal plan for distribution-only and an optimal plan maximizing the availability of resources able to provide services for the transmission system. On top of the advantages in terms of computational tractability, the decoupled planning approach brings benefits in terms of TSO-DSO coordination simplification.



5.4 Building a Graphical User Interface for the FlexPlan new planning tool: a rigorous and methodical process

Maxime Hanot (WP3 Leader), Samuel Monroe – N-SIDE



Early July marked the beginning of our work on the graphical user interface, part of the WP3. In order to build the right product for our partners, we are following a full process of UX/UI design prior to the development phase.

The process started by reviewing the requirements acquired during the customer consultations and summarizing the major features the interface should propose to the users.

From these features, we established a list of user flows to describe how the user would access and use these features on the application, and a map of the different pages and how they would be linked in the application.

The next step in the process was to start designing the wireframes of the application. Wireframes consist of a high-level and abstract representation of the future application, designed with a monochrome palette, simple black boxed elements and no typography.

Our goal at this stage was to rapidly have a raw representation of the future application, and be able to discuss among the team if we were going in the right direction with the way we designed the features.

Most importantly, we were able to prototype these wireframes by adding interactions in the design and simulate a real application flow. This prototyped wireframe helped us gather feedback from our partners and detect what we were missing and immediately adjust our design accordingly.

Last step before starting the implementation was to design a high-fidelity mockup of the user interface, taking our last iteration of the wireframes and applying design, typography and a color palette.

Again, this mockup was prototyped, iterated internally and reviewed with the partners, in particular the system operators members of the FlexPlan consortium with whom we organized several ad hoc meetings, to obtain feedback and make adjustments before reaching the implementation phase.

These processes allowed us to quickly come up with a solution in accordance with the future user needs and their inputs, and we are now tackling the implementation of the product with more ease and confidence in what we will deliver.

This implementation phase is also iterative, divided by main feature of the application, and supported by the mockup which helps us focus on the business logic rather than visual concerns.

5.5 A thick dissemination calendar for the fall season

Gianluigi Migliavacca - RSE

Dissemination is a precise duty for all Horizon2020 projects: public funded research results must be shared with all European stakeholders and constitute an experience to build upon for future industrial application.

The FlexPlan project takes very seriously this mandate and makes big efforts to bring the acquired know-how on all possible tables, yet taking into account the different expectations of the different public the project addresses to (scientific word, system operators, regulators, European stakeholders,…).

On this pathway, autumn 2021 will bring several events of interest.

FlexPlan will take an active part in the new edition of the CIRED conference (https://www.cired2021.org/), held in virtual form on 20-23 September 2021. Two important contributions will be provided:

- Presentation of the paper "*Planning of distribution networks considering flexibility of local resources: how to deal with transmission system services*". This paper outlines a new methodology, set up by FlexPlan, to perform an integrated grid planning between transmission and distribution grid by means of a TSO-DSO cooperative approach which allows to maintain a separation between the two processes and limit the amount of data to be exchanged. At the same time, this approach makes it possible to considerably reduce the computational complexity that an integrated TSO-DSO grid planning approach would entail. The FlexPlan paper will be presented by its main author, Marco Rossi (RSE), in **Session MS5.3 (22nd September – h14.30)**.

- **Participation in Round Table 20 "*The worth of flexibility in distribution planning and operation*" (22nd September – h16.30)** by Gianluigi Migliavacca (RSE), FlexPlan project coordinating person. He will carry out a presentation ("*What about the competition for flexibility between TSO and DSO? Is it possible to perform integrated planning?*") and participate in the subsequent debate.

Later in the year, FlexPlan will take part in the IEEE PES ISGT EUROPE 2021 virtual conference (18-21 October 2021), an important debate forum for smart grids, with a special session dedicated to goals and achievements of FlexPlan. Such session (Session 7A: PANEL 1) is scheduled for 18th October h16:45-18:30 CET. Last but not least, in occasion of the semestral project meeting, a new edition of the project Advisory Board will be held in the afternoon of November 24th. The invited list includes 60 people from the most important European stakeholders, with whom we would like to debate the project results of the last year.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863819

6 Newsletter M30 (March 2022)

6.1 Letter of the Project Coordinator

Research projects, like FlexPlan, which aim at assessing the potential of radically innovative methodologies, must be ambitious at the beginning, but also able to re-tune the efforts for ensuring the applicability of the assessed methodologies to realistic study cases. In the case of transmission and distribution grid planning studies, big cases encompassing at least one single country (actually, more than one in most FlexPlan regional cases) and able to reproduce in detail the entire transmission grid plus a portion of distribution grids should be able to solve optimization cases encompassing thousands of nodes. As we want to be able to assess the optimal investment mix by considering a high number of candidates, the simulation models we have to solve are mixed-integer optimizations with a high number of integer variables (one for each investment candidate). Considering the temporal axis, we have to calculate the optimal investment pathway till the long term by taking into account investments for three decades (2030, 2040 and 2050) in one single simulation. However, as we have to consider the potential role of storage and demand side management, we can't afford a time resolution wider than one hour.

How to maintain numerical treatability by putting together a so high number of challenges? That was the problem that we coped with during the last six project months.

In the last newsletter, I reported about a split of each optimal power flow simulation into separate months by imposing a hydro reservoir level at the beginning and at the end of every month. That was not sufficient and our monthly simulations were hardly able to tackle one month's simulation in one shot (at least with the AWS ICT endowment that we have available). So, we decided to adopt some extra simplifications to reduce the complexity of the problem that the solver has to solve plus other initiatives able to improve the operation of the six regional case Leaders (RCLs). Here the list of the adopted initiatives:

- **AWS availability improvement:** the number of AWS servers was increased from 1 to 3 to allow the RCLs to work in parallel. At the same time it was decided to implement a "start-stop" feature, which will allow, once operative, to pay AWS servers only when active and not on idle time. Once the "start-stop" feature is available, the memory endowment for each AWS will be increased to the maximum amount compatible with the FlexPlan budget
- **Modelling simplifications:** the models for storage devices and flexible loads have been simplified, reducing the number of integral constraints, yet maintaining a very high realism. Integral constraints are very complex for the solver because they tie together different simulation times. At the same time, the T&D decomposition has also been simplified: it will consider just 1 candidate per distribution network to be assessed together with the transmission grid candidates.

- **Reduction of the horizon of each single simulation:** the simulation will be carried out week per week and not any longer per month. Additionally, not all 52 yearly weeks will be simulated but only 12 "representative weeks" per year. Each of these weeks, through a representativeness coefficient will be considered as representative for a given number of weeks. Finally, only 2 climatic variants will be considered per scenario (initially, we though of considering 5 of them).

The first results coming from the expetimentation of the new "lighter" simulation framework are encouraging: within a short time, all RCLs were able to succesfully run their optimization for one week of 2030. Staring from this, the new challege is, from now on, to accelerate the deployment of the simulation studies: they should be all concluded within September 2022 in order allow us to spend the last 6 project months for drawing a picture on the degree of support storage and DSM can assure to grid planning in the medium-long term throughout Europe. Such picture will bring to the elaboration of regulatory guidelines suggesting the European authorities, as well as the national regulatory authorities, what pathways to put in place in order to stimulate the optimal deployment of the electric transmission and distribution grids.

The three short articles that follow this intrioduction will provide a more in-depth picture of the simplifications that I have just listed above.

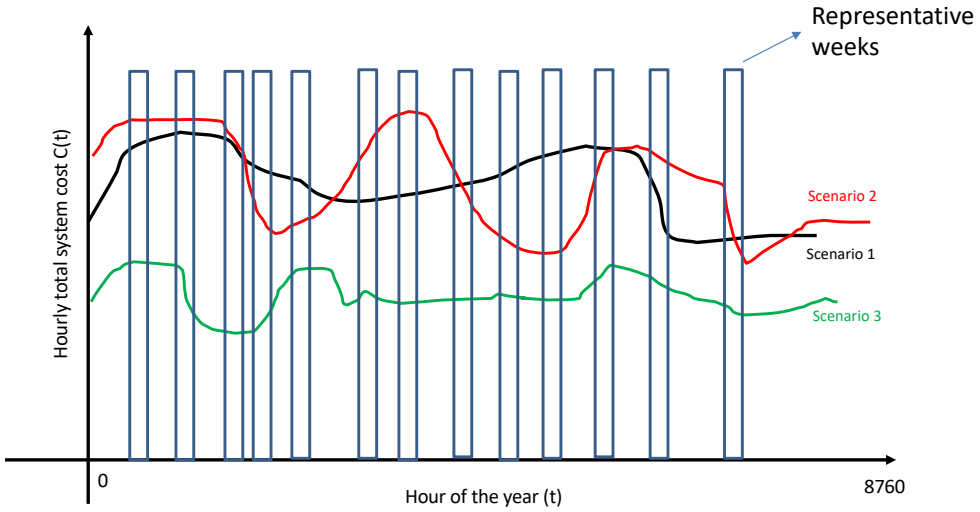
Gianluigi Migliavacca (RSE)

6.2 Simplification of the modelling framework to improve computational efficiency

Hakan Ergun (WP1 Leader) – KU Leuven

With the regional case studies being performed, we needed to bring a few computational improvements to the optimization model in order to reduce problem size and complexity and, consequently, reduce the overall computation time. First, a temporal decomposition of the optimization problem was carried out by adopting time series clustering. This allowed to use a few representative weeks instead of full planning years, hence reducing size and complexity of the model. In order to preserve the accuracy of the storage model, initial and final storage values for the representative weeks were obtained from the time series data of the pan-European model.

Second, both storage and demand flexibility models were simplified, in particular with respect to the relaxation of some integrality constraints which are in reality hardly binding, such as maximum energy absorption over an entire planning year for hydro storage or yearly bounds on not consumed energy for demand flexibility. The relaxation of such constraints increased the computational speed of the model without significantly affecting results accuracy.



Finally, to minimize the number of optimization variables in the problem, generators have been defined as two separate sets: dispatchable and non-dispatchable generators. Non-dispatchable generators are treated as parameters in the problem. This brings to further reduce the computational requirements.

6.3 Measures to simplify simulations computational impact on the basis of the experience of the RC simulations

Nuno Amaro (R&D NESTER – WP5 Leader) and Maxime Hanot (N-SIDE – WP3 Leader)

The execution of FlexPlan Regional Cases (RC) simulations is a highly complex process, requiring significant computational resources. In order to decrease the computational effort, a set of simplifications was put into place. These simplifications answer to a two-fold objective: on one side to significantly reduce the required simulation time (as a measure of computational effort required), on the other side to preserve a high level of accuracy and correctness of the results. The latter objective is of upmost importance as the RC are not only aimed at testing the FlexPlan Tool, but also at providing realistic results that can shed light on the role of storage and other flexibility solutions in grid planning, feeding the subsequent elaboration of regulatory guidelines.

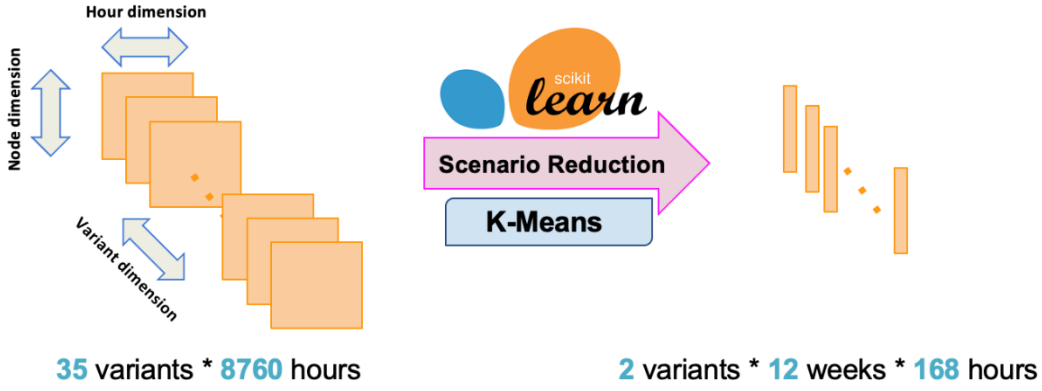
The simplification measures, designed and validated by RC, do not include significant reductions in the level of detail of the power systems to be simulated (such as simplifying the transmission networks). Instead, the implemented simplifications are focused on the following two aspects:

- Simplification of the modelling framework, consisting mainly of simplifications on some of the models used in the toolchain (see previous article).
- Reduction of the time-series dimension of the simulated scenarios, as explained below.

FlexPlan considers the simulation of three different energy scenarios for the three target years (2030, 2040, 2050). A Monte Carlo methodology was implemented to take into consideration different climatic conditions for each one of these scenarios. One of the implemented simplifications corresponds to the selection of two different variants for each scenario (while previously we had a target of five variants). In

addition to this, the simulation of the time series of each variant considers now the possibility to simulate a certain number of "representative" weeks (typically 12 per year) instead of simulating all 7860h of each year.

In order to help RC to simulate a set of representative weeks, a scenario reduction methodology was considered, allowing to identify and cluster weeks throughout the year according to their similarity. RC are now aiming at simulating a set of 12 weeks per year, which are representative of the whole year in order to retain the seasonal variability of different energy resources.



The simplifications mentioned above are the result of a joint collaboration between the RC leaders, the FlexPlan modelling team and tool developers. They aim at contributing not only to an easier execution of the project simulations, but also to an easier tool usage from future end-users.

Finally, one last important required improvement was to be able to parallelize the simulations. Indeed, the project was initially only using one single server which was too limiting for the execution of all the regional cases. It was therefore decided to start using two new servers to be able to run three simulations in parallel (one server for two regional cases). In order to ensure an adequate use of the project budget, the development team will also implement a new feature ensuring that servers are up and running only when they are executing a simulation and are stopped whenever they are not used.

6.4 The T&D decomposition methodology

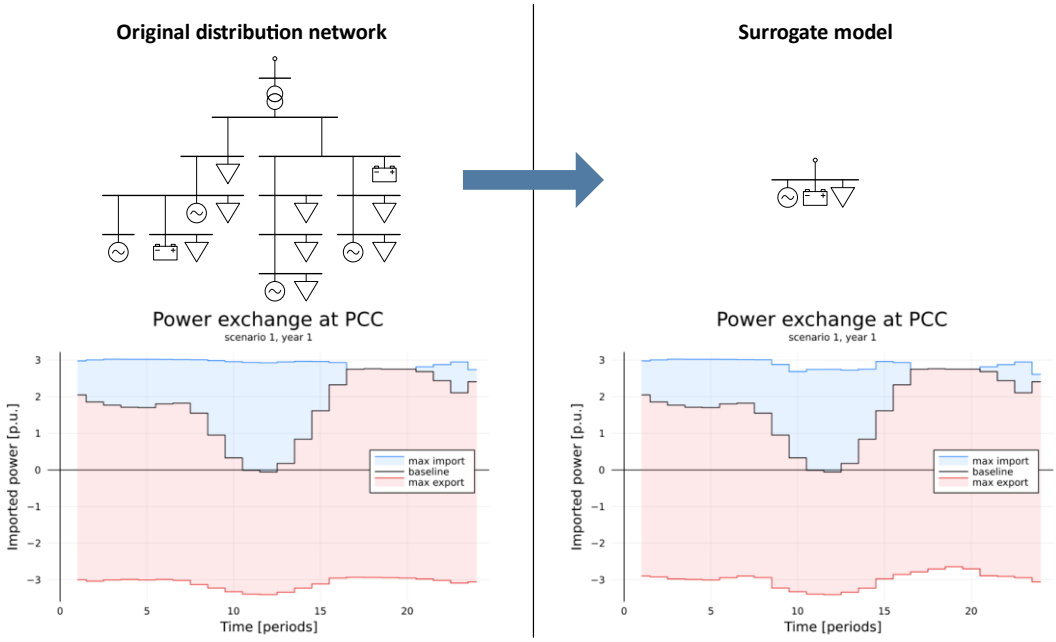
Matteo Rossini and Marco Rossi (RSE)

Solving a transmission network planning problem with the size of the FlexPlan regional cases and with the granularity of one hour is a computational challenge. If we add the many connected distribution networks, the problem is very likely to become computationally intractable – hence the need for a decomposition aimed at decoupling transmission and distribution networks.

Starting from the observation that, in a distribution network, congestion can only be solved by acting locally, the approach we have experimented consists in first deciding the investments in each distribution network to cover the flexibility needs of the network itself; then making the remaining flexibility available to the transmission network.

However, this approach still requires solving a transmission planning problem taking into account the flexibility provided by distribution networks. This is still a very challenging numeric problem: simplifications are necessary. For this purpose, we calculate a surrogate model for each distribution network and we include it into the transmission network. In this way, we are able to reduce the complexity of the solving process. In doing that, the trickiest issue is to create an extremely simple surrogate model – what we devised consists merely of one generator, one storage device and one flexible load – but nevertheless able to capture as many distribution network constraints as possible, including bus voltage bounds that often limit the amount of power that can be provided by distributed resources. In fact, it is essential that the planning obtained with the surrogate model remains feasible even when applied to the original model.

After the planning of the transmission network has been calculated considering the flexibility provided by distribution networks through their surrogate models, the last step of the procedure is to fix the power exchange at the Points of Common Coupling (PCCs) between transmission and distribution and calculate the planning on each non-simplified distribution network, so as to be able to account for the right dispatching costs.



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 863819

7 Newsletter M36 (September 2022)

7.1 Letter of the Project Coordinator

The final months of activity are difficult for all research projects and FlexPlan is no exception.

The two tools that are part of the innovative grid planning suite by FlexPlan (pre-processor and grid-expansion engine) are both completely debugged and finalized. A demo version of the grid-expansion engine will soon be available, ready to be distributed upon request by Eurpean stakeholders.

On top of FlexPlan grid planning suite, two comprehensive open access libraries, created on top of the contractual obligations, can already be freely downloaded from GitHub (an feedback after using these packages is welcome!):

- OptimalTransmissionRouting.jl, a Julia/JuMP package to determine the **optimal transmission system route** considering spatial information. Such package has been published as an open access license toolbox and can be found on: https://github.com/Electa-Git/OptimalTransmissionRouting.jl
- FlexPlan.jl, a Julia/JuMP **package to carry out transmission and distribution network planning** considering AC and DC technology, storage and demand flexibility as possible expansion candidates. A mixed-integer linear problem is constructed to be solved with any commercial or open-source MILP solver. Installation instructions, information regarding problem types and network formulations are provided in the package documentation (https://electa-git.github.io/FlexPlan.jl/dev/).

The 6 Regional Cases are now in the running phase. This phase is very time-consuming and for this reason, 6 Amazon Web Servers have been booked for two months in order to give a virtual meachine available to each Regonal Case. The investments for the three decades of interest (2030, 2040 and 2050) are being assessed in sequence and the final results should be available by end of November 2022.

Meanwhile, the activities of the "regulatory" work package (WP6) have been resumed. They feature three important goals to be achieved during the last 6 months of project activities:

- Analyze the results of the 6 Regional Cases in order to understand what can be genralized, what depends on the input assumptions and what highlights an evident trend for the mid-long term. The important question to be answered is: "To what extent the deployment of flexibility (storage and DSM) can support grid planning?"
- Analyze the prospects of scalability and replicability of the FlexPlan grid-planning suite in order to understand possible barriers to the adoption by TSOs and DSOs across Europe.

- Analyze the evolution during the last years of the EU regulation on storage and demand-side management as well as the provisions adopted by the national governments in the different European regions covered by the 6 Regional Cases. The final goal is to single out regulatory barriers to storage and DSM deployment and efficient ways to remove them. All this activity will be finally distilled into synthetic regulatory guidelines, which will constitute the final result of the FlexPlan project.

Final activities will be those analysing the prospects for exploitaton of the main project results and the impact assessment of the regulatory provisions individuated by FlexPlan.

A "booklet" featuring a summary of all project results will be published as deliverable D8.2. Additionally, a similar booklet will be published as an ISGAN WG6 report, this latter adding the result of a questionnaire that should add the extra-EU wiepoint on the topics of analysis of FlexPlan.

Last but not least, the last months of the FlexPlan poject will see important dissemination events: a final workshop to be physically held in Brussels on 14th February 2023 and 6 national events to disseminate the results of the 6 Regional Cases to the relvant national stakeholders.

Stay tuned!

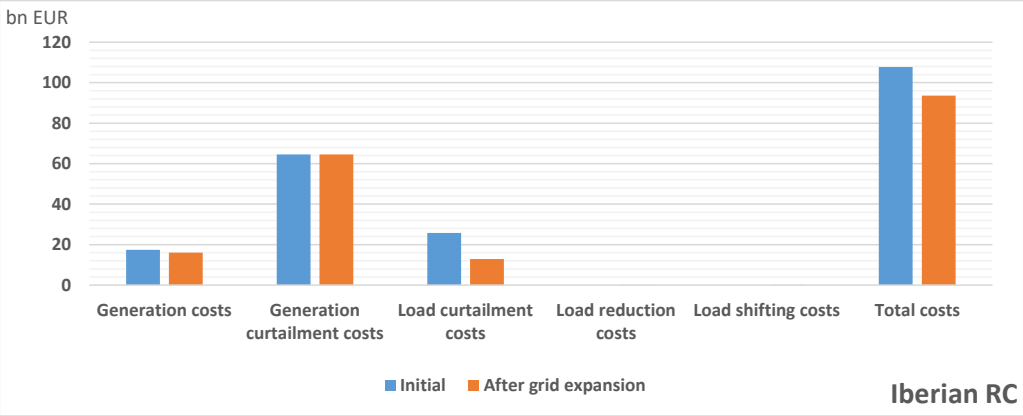
Gianluigi Migliavacca (RSE)

7.2 The 6 Regional Cases: results for 2030

Aleksandr Egorov (WP5 Leader) – R&D NESTER

The six Regional Cases are simulated using realistic geo-referenced models of the corresponding transmission and sub-transmission systems. In order to ensure a coherent approach for all cases, it was decided to use a common base dataset for the networks. An important activity to complement the existing grid models was dedicated to the collection of data related to generation units and distributed load time-series on higher voltage levels of transmission substations. Based on this input data and to account for the variability of RES generation and load conditions, a probabilistic cost minimization Optimal Power Flow is performed to identify existing congestion and other relevant results (e.g., costs related to system operation including load and generation curtailment costs) and to replace the traditional N-1 criterion. Congestion is identified through the existence of non-zero Lagrange Multipliers (LM) associated with branch flow constraints, which leads to proposing a list of grid expansion candidates to solve the grid expansion problem. In order to demonstrate the robustness and applicability of the proposed methodology, two out of the six Regional Cases results for solving the grid expansion problem in 2030 are herein shortly described.

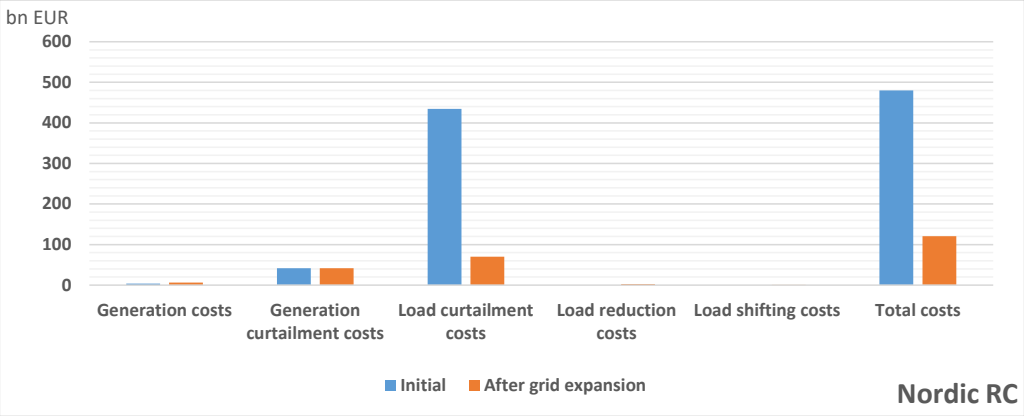
For Iberian Regional Case, 4 candidates were proposed in transmission network, 54 in distribution network, 8 storages and 34 flexibility loads. A small number of candidates in the transmission network is due to a strong mashed transmission network in Iberian Peninsula, which led to not very big number of congestions (291 congestion, 120 of which are in transmission network). From 100 candidates in total 47 were approved, which includes 3 AC branches in transmission network, 31 AC branches and 2 transformers in distribution network, 2 hydrogen storages and 9 flexibility loads. These grid expansion decisions decreased the total costs by 13% of the initial costs.



It can be seen, that even though there is a small increase in generation curtailment costs, the significant reduction of the total costs is due to the reduction of the load curtailment costs (almost 50% reduction) and generation costs (8%).

For Nordic Regional Case, in addition to 100 automatically generated candidates, 14 more manually added were considered. 13 candidates were proposed in transmission network, 95 in distribution network, 3 storages and 3 flexibility loads. The network in Nordic Regional Case is more elongated, comparing to Iberian Regional Case, which leads to significantly higher number of congestions (approx.

56 000 of congestions, approx. 7 000 of which are in transmission network) and also includes two of the three transmission corridors into the area of interest in Norway. From 114 candidates in total 73 were approved, which includes 7 AC branches in transmission network, 63 AC branches and in distribution network and all 3 flexibility loads. These grid expansion decisions decreased the total costs by 75% of the initial costs.



Such a significant reduction in initial costs was made possible by a very significant reduction in the load curtailment costs (reduction of almost 84%).

By end of November 2022 results will be obtained for all remaining Regional Cases.

7.3 Analysis of Regional Cases results and elaboration of regulatory guidelines: a delicate activity for the last 6 months of project activities

Andrei Morch (SINTEF ENERGI – WP6 Leader) and Dario Siface (RSE – Leader of tasks T6.2-T6.3)

The opening activity of the workpackage dedicated to "Regulatory Analysis" was conducted in 2019, during the first six months of FlexPlan project, and consisted in creating a comprehansive overview of the regulatory landscape to feed the main activities of the project. This activity brought to the conclusion that there were strong regulatory signals prompting European system operators to consider flexible resources as a new important active subject in the grid expansion planning process. The activity also highlighted the main limitations and shortcomings, which were presented in a dedicated public report: "Guideline for the compliance of network planning tool with EU overall strategies and regulatory conditions".

After two and a half challenging FlexPlan years the projects has recently resumed the activities for the workpackage "Regulatory Analysis". The plan is to derive the main lessons learned from the six regional cases, where the network planning tool was deployed and tested. Already in November 2021 the Consortium made the first steps towards these goals at a dedicated internal workshop in Trondheim (NO), when the project groups carried out a brainstorming to single out the main priorities and points of attention for the concluding activities.

Considering the importance to consider flexibility in grid planning practices, an assessment will be carried out to analyse the scalability and replicability potential of the FlexPlan methodology and tools, to identify the possible barriers and consider possible ways to overcome these in order to ensure the future exploitation of the project's outcomes.

Another parallel activity focuses on the regulatory challenges and policy lessons learned analysis of the gep between the planning methodology and tools proposed by FlexPlan and the present network planning practice and regulation. The activity has already initiated an online survey among the stakeholders to get the latest status for the planning practices.

Finally, following the intentions of EU Directive 2019/944 on Internal Elerctricity Market, the European Regulators (ACER) have recently issued the "Framework Guideline" for the forthcoming Network Code for Demand Response. FlexPlan project recognises the significance of this document for the succesfull delpoyment of outcomes from FlexPlan and thus intends to follow closely its development and align its conclusions to the main highlighted topics.

7.4 The Project Final Workshop and many other dissemination events for the last project months

Gianluigi Migliavacca (RSE)

The FlexPlan **final workshop** will take place in **Brussels on 14th February 2023** to disseminate the most important achievements of the FlexPlan project. The event will be held at the L42 business center (https://www.l42.be/portfolio-item/live/) with the following programme:

- Draft event programme (from 9.00 till 16.30 / lunch break 12.00 - 13.30):
  - Overview of FlexPlan aim and methodology (45 minutes including Q&A)
  - Showcase of FlexPlan pre-processor and planning tool (45 minutes including Q&A)
  - Results of the pan-European model and of the 6 regional cases (2 hours 45 minutes including Q&A)
  - Preview of the final regulatory reflections and guidelines (45 minutes including Q&A)
  - General debate on possible up-scalability of the FlexPlan methodologies and tools and about real takeaway for the European stakeholders (1 hour)

For registering to the event, please provide your request through the web page: https://flexplan-project.eu/contacts/. Possibly, it will also be possible to follow the event in remote, even if, the physical participation will allow a better participation in the discussions.

In addition to the Final Workshop, 6 regional events will be held to inform about the project FlexPlan achievements with highlight to the results of the local Regional Case. Each of these events will be held preferably by using the local language.

The Italian event will take place in Milan as a physical event on 25th January 2023.

In parallel, the other 5 regional cases will all organize an on-line event between January and February 2023.

Regional Case	Date	Language	Mail for registration
Italy	25/01/2023	Italian	Please provide your request through: https://flexplan-project.eu/contacts/
Germany, Austria and Switzerland	28/02/2023	German	flexplan.ie3@gmail.com
Iberian Peninsula	17/02/2023	English	Registration will be done at TECNALIA's web site. Please, check https://www.tecnalia.com/en/agenda from the 15th of January on.
Nordic Countries	20 February, 2023 13:00-	Norwegian	flexplan.ie6@gmail.com

	15:00		
Balkan region		Serbian	Date still to be finalized within first week of February 2023
France and BeNeLux	01/02/2023	English	flexplan.ie2@gmail.com

Finally, two webinars will be organized too, one in the framework of the BRIDGE initiative and another organized by the alliance of the European Energy Research Alliance (EERA). Information will be timely published on the FlexPlan web site.

I take the opportunity to signal two recent paper publications presented at the CIGRE Session 2022 and at the SEST Conference in Eindhoven. They can be downloaded from the project web site: https://flexplan-project.eu/

Last but not least: end November 2022, you can find the FlexPlan project in the EU Zone of the ENLIT conference in Frankfurt am Main (https://www.enlit-europe.com/).

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