Cutting-edge integrated operation planning tool for the European power grid

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Abstract: Innovative solutions are required to help grid operators in the management of the electrical system to boost supply security while accounting for the growing percentage of renewable energy sources (RES) in order to deal with the development of the power system. The H2020 INTERPLAN project aims to support the accomplishment of the low-carbon EU targets by creating a cutting-edge tool that transmission system operators (TSOs) and distribution system operators (DSOs) can use to address the operation planning challenges of the ongoing pan-European network.

1 Introduction

The European Union (EU) energy security policy faces significant challenges as we move towards a pan-European network based on the wide diversity of energy systems among EU members. In such a context, novel solutions are needed to support the future operation, resilience and reliability of the EU electricity system in order to increase the security of supply, while also accounting for the increasing contribution of renewable energy sources (RES). The goal of the H2020 INTERPLAN project (November 2017–January 2021) is to provide an INTEgrated opeRation PLAnning tool towards the pan-European Network, with a focus on the transmission system operator (TSO)–distribution system operator (DSO) interfaces to support the EU in reaching the expected low-carbon targets, while maintaining the network security and reliability [1].

INTERPLAN project looks at the potential operation challenges which TSOs and DSOs are called to address in the 2030+ power system. In fact, the ongoing deployment of the pan-European network strongly depends on different potential scenarios related to the RES share in generation and installed capacity, as well as penetration of emerging technologies, such as storage and demand response (DR). Although these factors represent the preferential patterns to meet the EU decarbonised energy targets for 2030 and 2050, they bring new challenges for the energy system, which will outline the key operational needs of the European grid operators in the near future. In such a context, TSOs will need to evolve progressively from a 'business as usual' approach to a proactive approach in order to avoid a bottleneck effect in the future European grid, and this could be addressed through proper system operation planning. As for the distribution networks, they have been traditionally designed and treated to deliver electrical energy in one direction, i.e. from the generation units connected to the transmission system to the end-users. However, with the growing share of non-dispatchable distributed generation, customers are increasingly generating electricity themselves, and, by becoming 'prosumers', they are shifting from the end point to the centre of the power system. Therefore, DSOs will need to actively manage and operate a smarter grid through appropriate control logics, by utilising the flexibility potential in the grid, with the aim to optimise the distribution network performance. An additional critical issue is an interface between transmission and distribution systems, which is expected to evolve in the near future through mutual cooperation between TSOs and DSOs, with the aim to address operational challenges as congestion of transmission and distribution lines and at the interfaces among them, voltage support between TSOs and DSOs, and power balancing issues. The increasing complexity of the grids requires even more advanced and homogenous control and operation planning tools applied by European grid operators [1–4].

The contribution of this paper is to present an innovative integrated operation planning tool for the current and future 2030+ European power grid. The tool is integrated in the sense that all voltage levels are taken into consideration in the operation planning, and that it builds a bridge between static, long-term planning and considers operation issues by introducing controllers in the operation planning phase [4].

The tool is aimed at supporting utilising flexibility potential coming from the emerging technologies such as storage, demand response and electric vehicles for system services in all network control levels contributing to the achievement of the EU energy and climate objectives.

2 Description of INTERPLAN tool

The INTERPLAN tool is defined as a methodology consisting of a set of functions (grid equivalents, control functions) for the operation planning of the pan-European network by addressing a significant number of system operation planning challenges of the current and the future 2030+ EU power grid, from the perspective of the transmission system, the distribution system, and with a particular focus on the transmission-distribution interface. In this sense, the main goal of the tool is to achieve the operation planning of an integrated grid from the perspective of a TSO or a DSO through handling efficiently and effectively intermittent RES as well as the emerging technologies such as storage, demand response and electric vehicles. In fact, the tool supports utilising flexibility potential coming from RES, demand-side management, storage and electric vehicles for system services in all network control levels. The flowchart representing the INTERPLAN tool includes the various stages that the user (mainly TSO or DSO) can perform for the operation planning of the network under consideration, and is shown in Fig. 1.

As shown in the figure, the user, identified as a TSO or a DSO, selects the planning criteria that he/she wants to consider for the network operation planning. This selection is based on the list of planning criteria identified in the project such as maximising share of RES, assuring voltage stability, mitigating grid congestion etc. After the planning criteria selection, the following three stages are performed by the user:

- Stage 1: Simulation functionalities, key performance indicators (KPIs) and scenario selection.
- Stage 2: Grid model selection/preparation.
- Stage 3: Simulation and evaluation.

The main novelties of the proposed tool are described below:

- By offering the possibility to investigate all network voltage levels for operational planning purposes, the tool actually allows integrating the actions made by different stakeholders such as TSOs and DSOs considered as the primary users for the tool.
- With the current network operation planning approaches and methodologies, it is not possible to consider all existing grids (including full models) in an integrated planning tool due to computational limitations, lack of detailed models etc. Through the intrinsic grid equivalenting methodology, the tool allows simplifying certain parts of a grid while keeping the relevant characteristics. This is essential for TSO–DSO interactions, especially when utilising flexibility from distributed resources, which can be used to address operational challenges occurring at all network levels.
- Through the control functions embedded within INTERPLAN use cases (UCs) and showcases (SCs), listed below, the tool allows addressing a number of operational challenges of the current and future 2030+ power networks from the perspective of both TSOs and DSOs. In fact, INTERPLAN UCs address very specific operational challenges that grid operators may face with, in the presence of high penetration of emerging technologies. INTERPLAN UCs are [2]: (i) coordinated voltage/reactive power control; (ii) grid congestion management; (iii) coordinated TSO–DSO frequency tertiary control based on optimal power flow calculations; (iv) fast frequency restoration control; (v) power balancing at DSO level; (vi) inertia management; and (vii) optimal generation scheduling and sizing of DER for energy interruption management. On the other hand, INTERPLAN SCs address a combination of operation challenges, thereby representing typical cases that the grid operators may face with, for operation planning purposes. INTERPLAN SCs are [2] (i) low-inertia systems; (ii) effective DER operation planning through active and reactive power control; (iii) TSO–DSO coordinated power flow optimisation; (iv) active and reactive power flow optimisation at transmission and distribution networks; and (v) optimal energy interruption management.

The paper describes the INTERPLAN methodology and its main stages that allow guiding the user's choices towards the most suitable

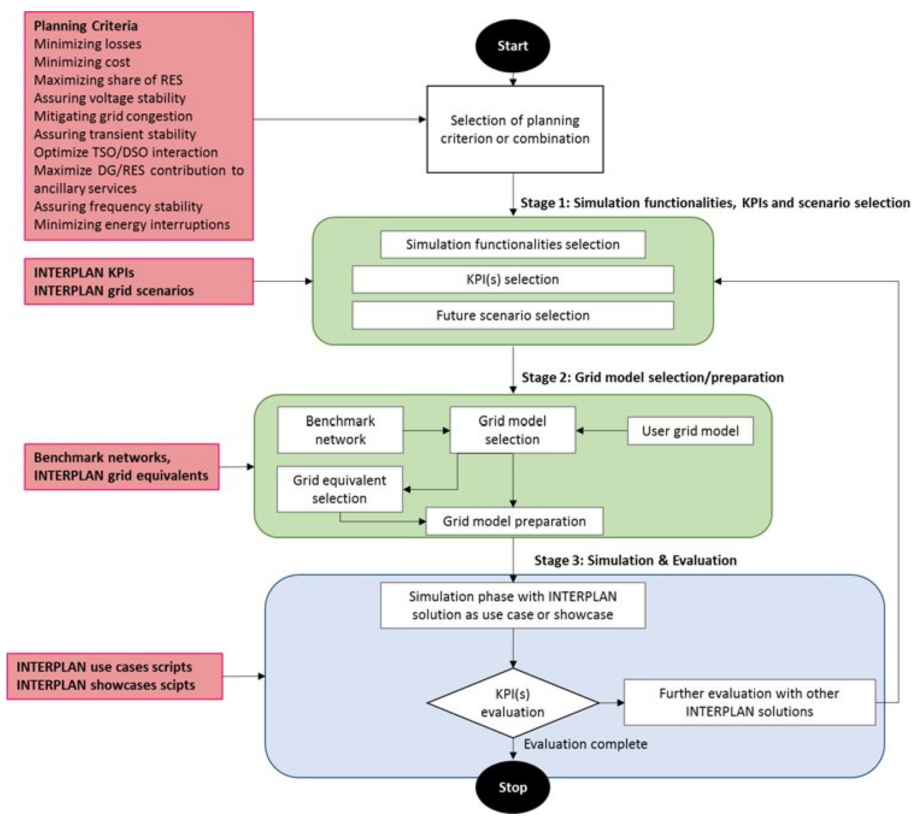

Fig. 1 *Scheme of the INTERPLAN tool*

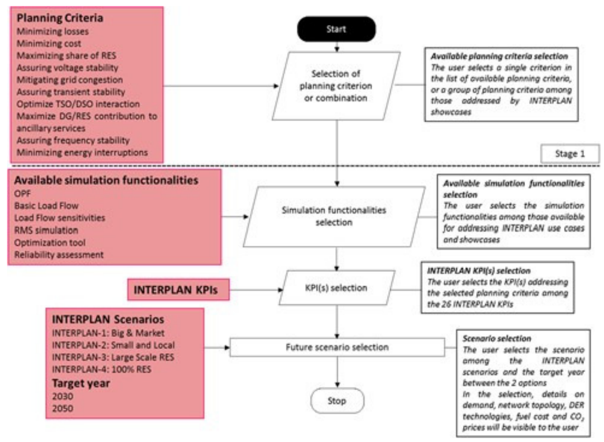

Fig. 2 *Stage 1 of INTERPLAN tool*

INTERPLAN solution, namely the UC- and SC-related control functions, to apply in the function of the operation challenge that the user wants to investigate in a specific network as part of the distribution system, the transmission system or the transmission–distribution system.

From the practical point of view, the INTERPLAN methodology can be transformed into a Python-based toolbox interfacing with DIgSILENT PowerFactory, consisting of grid equivalents and control functions for UCs and SCs for addressing the related operational challenges under the selected scenario and operation planning criteria.

3 INTERPLAN tool composing stages

Assuming that the user (TSO or DSO) knows from the beginning the operational challenge that requires investigation, the tool will guide the user towards the most suitable INTERPLAN solution (UC and SC-related control functions). Indeed, the three composing stages have been structured to guide the user selecting the most proper control function to apply according to the operation challenge the user wants to investigate in a specific network. According to this approach, all the possible selections enabled will be known to the user in advance through the INTERPLAN user manual.

Under stage 1 'Simulation functionalities, Key Performance Indicators (KPIs) and scenario selection', the user selects the simulation functionality, the KPIs and the operating future scenario. The scheme of stage 1 is shown in Fig. 2.

The simulation functionality can be selected from the list of simulation functionalities used for the INTERPLAN UCs and SCs. Similarly, the KPIs selection can be done from the list of INTERPLAN KPIs and the operating scenario can be selected among the four INTERPLAN scenarios [4]. These types of choices can be done according to pre-defined schemes consisting of the possible combinations enabled to the user that are UCs- and SCs-oriented. As an example, consider the user selects 'Minimize losses' as a planning criterion. There are four UCs that address this planning criterion, i.e.:

- UC1: Coordinated grid voltage/reactive power control.
- UC3: TSO-DSO coordinated frequency tertiary control based on optimal power flow.
- UC5: Power balancing at DSO level.
- UC7: Energy interruption management.

Each of these UCs needs a specific simulation functionality to be selected. For instance, UC3 needs load flow (LF) and optimal power flow (OPF) with the objective of loss minimisation, whereas UC5 only needs LF. Similarly, each of the combination 'planning criterion + use case' leads to the specific KPI(s) selection. For instance, the combination 'Minimizing losses + UC3: Coordinated TSO–DSO frequency tertiary control based on optimal power flow calculations' leads to the selection of two KPIs, i.e., level of losses in transmission and distribution networks and power losses.

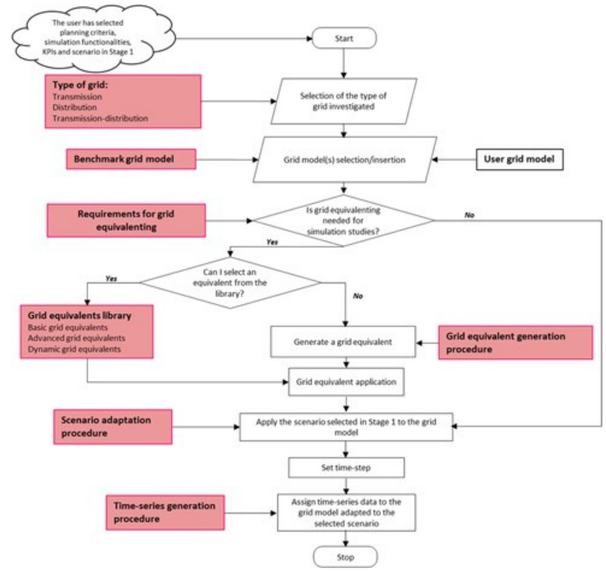

Fig. 3 *Stage 2 of INTERPLAN tool*

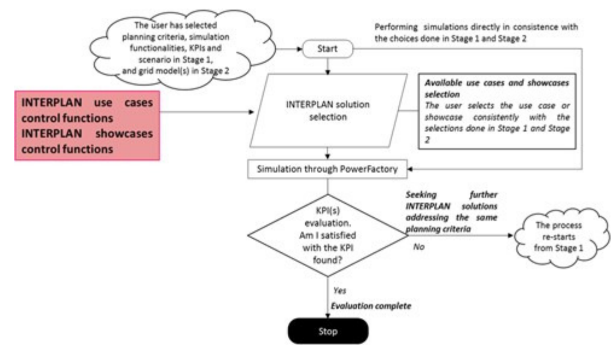

Fig. 4 *Stage 3 of INTERPLAN tool*

Finally, for each UC, there is a specific INTERPLAN scenario suggested, which is in this case, INTERPLAN 2-small and local, for all these four UCs. The user also selects the target year, i.e., 2030 or 2050. In the selection, details on demand, network topology, emerging technologies (storage, electric vehicles, flexible demand), fuel cost and CO_2 prices will be visible to the user to guide the selection.

Under stage 2 'Grid model selection/preparation', the user selects the grid model for the simulation phase in the next stage, and it is then adapted to the INTERPLAN scenario selected under the previous stage. The scheme of stage 2 is shown in Fig. 3.

In detail, under stage 2 the user can use his own grid model and/or a benchmark grid model. Then, if a grid equivalent model is required for the simulation phase – based on pre-defined requirements for grid equivalenting – the user can select it from the grid equivalents library consisting of a list of pre-defined grid equivalents. In case any of the grid equivalents present in the library is not suitable for the studies that the user wants to conduct, the user can generate a grid equivalent model through the grid equivalent generation procedure developed in the project. When the grid model is decided, it is then adapted to the scenario selected under stage 1 through a procedure developed in the project [5]. Note that in the evaluation phase if a grid equivalent is required or not, the user is guided by the user manual showing when a grid equivalent is required. In fact, similar to stage 1, the enabled choices are UC and SC oriented according to pre-defined schemes.

For instance, in case the user wants to investigate the coordinated voltage/reactive power control, namely UC1, through the manual, he/she knows that (i) the grids investigated for control belong to both transmission and distribution levels; (ii) grid equivalenting is required; (iii) this UC needs two grid equivalents: one modelling transmission grid and the other modelling distribution grid, meaning that while studying transmission grid, distribution grid should be placed as an equivalent grid and vice versa; and (iv) the type of grid equivalents required is 'basic', i.e., simplified grid models with aggregated values for active and reactive power.

Finally, stage 3 of INTERPLAN tool is dedicated to the simulation and evaluation phase. Under this stage, shown in Fig. 4, the user performs the simulation either directly without selecting any of the INTERPLAN solutions (UC- and SC-related control functions) for creating an own reference case, or by using one of the INTERPLAN solutions according to the operation challenge that the user wants to investigate and the choices done in the previous stages.

The evaluation phase follows simulation one. In detail, here, the user makes his evaluation through the KPIs values found in the simulation phase. If the user is satisfied with the KPI(s) found, the evaluation is complete and the process stops. Otherwise, the user can decide to investigate further INTERPLAN solutions (namely further control functions) addressing the same operation challenge under the same planning criteria. In this latter case, the process re-starts from stage 1. Therefore, the entire tool continues iteratively, until the user is satisfied with KPI(s) values found in the simulation phase.

4 Conclusions and key findings

This paper presents a summary of the methodology devised within the INTERPLAN project, aimed at facilitating and improving power system operation planning in a short-to-medium timeframe, with a special focus on high RES penetration both in the TSO and DSO grids. The INTERPLAN tool consists of three main stages, which allow the simulation functionalities, KPIs and scenario selection, the grid model selection and preparation and the simulation and evaluation. Through the embedded control functions operating at different network voltage levels, the tool allows grid operators to address a number of operational challenges of the current and future 2030+ power networks. The possibility to investigate all network voltage levels in an integrated manner is made possible thanks to the intrinsic grid equivalenting methodology, which simplifies certain parts of a grid while keeping the relevant characteristics. This is essential for TSO–DSO interactions, especially when utilising flexibility from distributed resources which can be used to address operational challenges occurring at all network levels.

The INTERPLAN methodology described in this paper can be transformed into a Python-based toolbox interfacing with DIgSILENT PowerFactory in the simulation phase in stage 3, consisting of grid equivalents and control functions for UCs and SCs for addressing the related operational challenges under the selected scenario and operation planning criteria.

In future work, the proof-of-concept of the tool will be verified through investigating a specific grid operation challenge and by going 'manually' throughout all the steps of the methodology.

5 References

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