AIPLAN 4EU

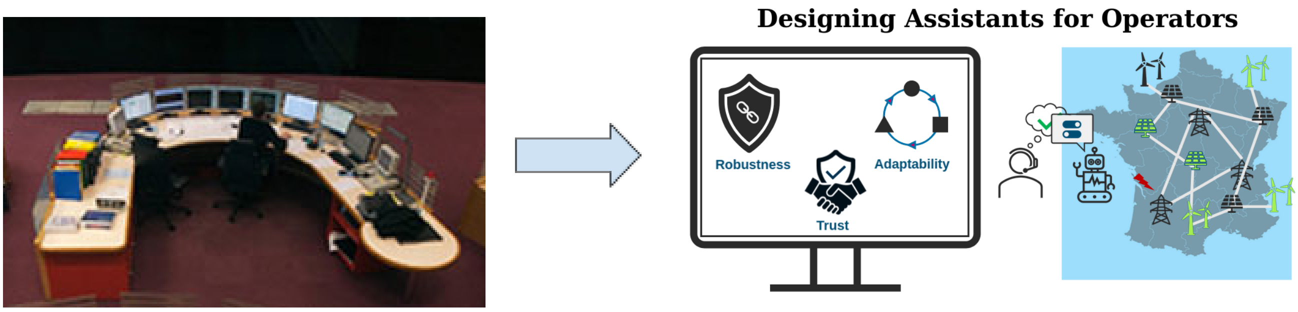
# AI-assistant for grid operation planning
06-02-2022

# Contents

# Executive summary

Please provide a short overview of the use-case and why it is relevant for the AIPlan4EU project

Power grids are critical infrastructures which are also expected to play an important role to mitigate our environmental impact, to cope with Climate Change in particular, while not sacrificing our modern economy at the same time. To succeed at the ongoing Energy Transition, grid operations in power grid control centers have to evolve and adapt rapidly with a more integrated approach for decision-making. More numerous and complex decisions have to be taken and planned with greater anticipation. AI appears as the most promising enabler for the transformation of power grid operations, a use case indeed mentioned in the AI for Climate Change COP26 report. Designing new digital assistants with near real-time planning capabilities seems like a desirable solution, which development could get accelerated through the AIPlan4EU project.




*Transforming grid operations in control centers from a fragmented multi-screen working environment to a more integrated and single interface digital assistant with smart recommandations.*

# 1. Context [~1 page]

Please describe the context of the use-case (use pictures if possible/useful to clarify the situation):

- Which is the application domain?

We are here considering the domain of power grid operations for the Energy Transition. Electrical grids are transforming as the ongoing decarbonisation changes the generation, electrifies demand, and digitises system devices. Most of these changes directly impact the control centre of power systems such as the integration of weather-based energy resources, the greater interconnection between neighboring transmission grids, more markets, active distribution networks, microgrids, and the wider availability of data. Supervision systems in control rooms have grown unreasonably to remain cognitively manageable and redesign of human machine interactions becomes necessary. Grids are also aging, and infrastructure developments are more limited but integrate more automata. Thus, the system will be pushed closer to its limits while displaying more complex dynamics. This leads to increased risk of blackouts after cascading failures of overloaded lines. See https://www.youtube.com/watch?v=A30DdnsICuw for an example of a near blackout after successive events.

AI-based solutions can help to address: (a) More numerous, complex, and coordinated decisions to make; (b) More uncertainty to consider and more anticipation needed; (c) Overcrowded and fragmented work environment with multi-screen applications and data patchwork - becoming an unmanageable supervision system (i.e., built as a big monitoring system rather than an efficient decision-making support system); (d) Human operator cognitive load would continue to increase and might saturate.

- How are the operations handled currently? Is there an established workflow?

Today grid operators operate in real-time from control rooms to optimize the power flows, handle maintenance or new equipment integration on the grid, and most importantly avoid blackouts because of congestion. They are highly trained engineers as their job requires studies, planning and adaptable decision making rather than simply reproducing pre-established event management scenarios. They operate based on simulation tools, real-time and forecasted data, but yet with little decision-making support tools such as assistants. When they feel it is needed, they mostly manually explore solutions and validate their decision in their simulation tool. They can modify the topology configuration of the grid, redispatch some production, curtail some renewable production, use some load shedding or even some battery storage nowadays to change the power flows on the grid. This is a large set of possible flexibilities among which they have to identify the effective ones in a given context. Day-ahead planning services give some insights on the upcoming trends and possible actions to start considering. There then exists an intra-day established workflow with 5-minute times step forecast resolution over a few hours horizons. But this requires a lot of supervision and a lot of manual entries and manual simulations. They operate mainly with experience to determine relevant remedial actions when needed. But as the variability on the grid is increasing a lot with shifting dynamics and behaviors even within the course of a year now given the energy transition, usual solutions might not work anymore in all or new contexts. Operators will have to adapt more quickly and get some assistance. Also while some flexibility and actions can be done curatively once a problem occurs, it can be the case that actions have to be taken preventively before it is too late to implement them given operational constraints, in particular when considering using batteries or redispatching.
Several operators also act on the same interconnected grid at the same time and this requires some coordination that is not always easily achieved despite common grid files.

- What are the drawbacks of the current solution (if any)?

The current « supervise everything » approach on dozens of screens cannot scale anymore to take critical decisions as the complexity rises given the Energy Transition: operators become overwhelmed by information without much indication on what to do and any recommendations for it. There is a need to help operators identify and prioritize

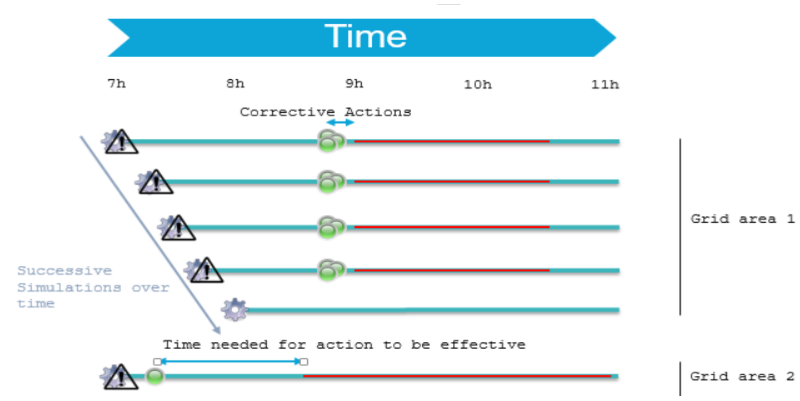
tasks while displaying relevant information and recommendations only for those tasks, with ideally a single interface assistant. In particular, current approaches don't leverage very much the available data with new data-driven approaches. They don't integrate operator experience and preferred style.
Also current workflow only considers snapshot based solutions and not sequential decisions over a time horizon, thus putting the burden of the anticipation and evaluation of the long term consequences of the actions to the human operator alone. But as the grid gets pushed towards its limits, decisions become more numerous and a lot more interdependent. Solutions should not only be effective at one given time but over a larger time-horizon given other possible actions and events. Solutions should also be implemented with the right anticipation given their effective activation time. So solutions will need to indeed consider the full underlying planning problem of power grid operations. Better near real-time operation planning could also help anticipate the workload and level it up across operators in a given control room.

## 2. Planning Application [~1 page]

Planning is a technology that helps you in automating or optimizing some decisions given a predictive model of a system / situation. Here we need to clearly identify the key decisions that should be automated/optimized in the use-case. Also, a storyboard of how planning is used within the workflow shall be presented.

- What are the key problems that you plan to address with planning technology?
    - Highlight which kind of decisions shall be automated or optimized

We aim at developing a recommendation assistant for operators to suggest relevant and timely actions for congestion management, that is to avoid overloads that can lead to blackouts. Overloads can happen because power lines have capacity limits that power flows can exceed. Power flows then need to be rerouted without creating new overloads. Power flows are stochastic and changing all day long because of varying productions and consumptions as well as maintenance activities. Loads are forecasted at national level, producers bid on markets to supply those consumers from one day ahead up to one hour ahead of real-time. Outages are planned ahead but can be delayed or canceled. Also assets such as power lines could get unpredictably disconnected because of lightning or other incidents, and grid operations need to be robust and be able to react to those possible contingencies.
Planning is meant here to either help take preventive actions ahead of time, or be ready to quickly implement curative actions if some impactful incident occurs. Not well thought or coordinated actions can quickly degrade the grid and lead to a blackout. Actions need to be carefully evaluated over a time horizon  to safely operate under this stochastic environment .
In case an operator waits for an incident to occur before doing a curative action, he only has about 5 minutes to confirm and implement its action. He hence needs to be quite prepared for it. Or get supported by an assistant to quickly help him find a good enough solution.
As it is expected that the number of impactful events will at least double as the system gets pushed towards its limits under the Energy Transition, an assistant would also relieve the operator from achieving twice as much work.




*A simple scenario where incidents are forecasted in multiple parts of a grid, and several corrective actions with different start-up time are possible. Forecast are refreshed as we get closer to real-time. Green dots each represent an available remedial actions, and the blue arrows the time it needs to be effective. For instance, starting a nuclear power plant takes longer than applying topological grid changes, and would have a longer blue arrow. The former would need to be applied preventively, while the latter can be applied curatively if the incident really occurs.*

<u>Detailed Storyboard description:</u>

An operator starts monitoring a grid composed of two smaller areas at 7:00am. Forecasts show 2 issues:

- An incident in area 1 could happen around 9:00am and would lead to some overloads, with three available corrective actions after simulations, each being able to be executed just before 9:00am.
- Another such incident in area 2 could happen around 7:30am with only one preventive action available. This leaves only a couple of minutes to execute it or not.

*A couple of questions arises to decide on the best planning strategy:*

- *Which decisions have priority ? It seems that a preventive action on area 2 should be urgently taken, but maybe the forecast isn't that reliable yet.*
- *When should we implement actions ? We can see that waiting for the last simulation at 8:00am in area 1 shows that the forecasted incident would not lead to problems anymore which would be the best option.*
- *How does applying a preventive action on area 2 reflect on area 1 ? Would it lead to a less secure grid state ? What coordination is required ? Maybe there's a new outage operation in this area that isn't yet taken into account by the simulation.*
- *Which of the three corrective actions in area 1 should be taken ? The operator has to mediate between economical, practical and safety arguments, each with a degree of uncertainty over an activation horizon.*

- How do you measure the quality of such decision/automation? Why is the status quo not satisfactory?

Statu quo will lead to rapidly increasing operational cost while we are integrating more renewables as it is currently the case in Germany: operational cost was multiplied by 2.5 and rose by 1 Billion. There is also a higher risk of blackouts at times of transition in a statu quo. We might also not reduce CO2 emissions significantly for several years in the end as we would eventually rely on old CO2 intensive power plants being turned on for congestion management if no advanced planning lets us use flexibilities better.
Measures for the quality of decisions here are first assessed on the ability not  mainly assessed over the operational cost and the CO2 emitted. At a second stage, the stability of decisions over time should also be considered as a sign of robustness. Counterfactual analysis can be simulated against a “*do nothing*” policy to highlight the value of actions. Finally the amount of renewable integration, which is favored by how much flexibility grid operations offers, is also considered in the mid-term.

- Which kind of data is relevant for taking the decisions to be automated /optimized?
    - Highlight what is “constant” (i.e., it does not change between successive decisions) and what is “contingent” (i.e., non-predictable data that is important to take an informed decision)

The topology of the grid revolves around reference configurations. Forecasts of productions, consumptions and outages change rather smoothly every 5 minutes. Those can be considered approximately constant between decisions.
Unexpected line disconnections, delayed outage schedule or sudden wind storms that would quickly change wind production are contingent events.

- How often is planning invoked? Which actor/software/rule invokes the planning?
    - E.g., planning is done once a day to decide the shift activities
    - E.g., planning is triggered when a discrepancy is observed w.r.t. the planned course

Planning is done from the day before and revised every hour up to few minutes before real-time by a continuous forecasting and simulation process. It is also triggered when a large discrepancy or contingency occurs.

# 3. Impact [~ 1 page]

## 3.1. Business Impacts

- What are the business impacts of automating/optimizing the decisions?

Operators will not be replaced any time soon and will still be responsible for operating the grid. The planning process aims at making recommendations much like Google did for their data center cooling operators in the first place. Operators will benefit from these new decision-support tools to adapt themselves to the evolving system conditions. They will need some training using them. The process overall implementation will nonetheless not have to change much, as the recommendations would be made on top but outside of existing Energy Management Systems through an Interface such as OperatorFabric ([https://opfab.github.io/](https://opfab.github.io/) ). For Google data-center cooling, this was for instance first done just by sending emails.
At the same time, the Energy Transition needs to happen at a steady pace  which requires rapid adaptation in terms of operations and which would be more quickly achieved with advanced software for augmented decision-making.

- How does the quality measure defined in the previous section map to the business? E.g.:
  - by automating the picking from shelves, we can reduce the operational costs by …
  - by optimizing the management of agricultural practices, we can reduce soil compaction that is bad because…)

By optimizing the existing grid flexibilities , costly and uncertain new investments such as building new lines to increase grid capacity would be avoided. This will also limit the grid's environmental footprint. Eventually this would allow for greater renewable energy penetration and reduced CO2 emissions towards a carbon-neutral target by 2050.

- How do you define a satisfactory measurement from the business perspective? (e.g., we aim at reducing soil compaction by 10% because…)

We aim at limiting the increase of operational cost to 20% in the coming years.
We aim at maintaining a similar “equivalent outage time” of 3 minutes over a year while avoiding large blackouts.
We aim at integrating an overall renewable energy mix of 30% by 2030 with a steady and regular increase year by year.
We ambition to use at least twice as much grid flexibility as it is used today with a more diverse set of plans and actions.

## 1.2. Other Impacts

- Is there any other impact besides business? E.g. environmental, societal…

As mentioned, the Energy Transition and associated environmental considerations are a huge driver of the necessary evolution of grid operations. Transmission grid companies should also not discriminate between any consumer and should provide electricity to all. An overall social welfare is to be considered but without discriminating between end users. Finally power grid reliability and cost-effectiveness can give a competitive edge to European attractivity for industries.

# 4. Measures of Success [˜1 page]

Describe how, concretely, one can measure the success of a planning integration in this use-case.

- KPIs: what are key indicators and their thresholds?

We will look at the operational cost and ensure it does not increase by more than 20% on average, while the rate of renewable penetration at least doubles. $CO_2$ emissions should at the same time reduce at least by the rate of renewable penetration. These indicators will reflect how much we succeed at the Energy Transition both on economical and environmental aspects. However, more grid flexibility usage should not lead to more than twice as many actions as today to allow operators to gradually adapt. The new decision-support system should also allow operators to take at least twice as fast decisions when no obvious solution exists in the first place. It should finally reduce the number of coordination issues, that is undesired side-effects on neighboring areas.

- Expected performance: computational speed, solution quality…

For a given power line contingency, the recommendation system should be able to make a recommendation for a one-hour time horizon in a few seconds. When considering the full set of impactful contingencies, it should provide a full set of new recommandations in less than 10 minutes. When refreshing those recommandations every 5 to 10 minutes as the forecasts are refreshed closer to real-time, this should not take more than a minute. Similarly when one unforeseen event happens.
Considering solution quality, the objective is to use more flexibility than today, hence to be better at exploring the space of solutions, possible topological changes in particular, and combine them in sequence when needed, to eventually better exploit them. Solutions should use little costly and non-environmental friendly production redispatching, avoid load shedding on customers, and prioritize the use of on grid assets. While minimizing energy losses on the grid could also be a criteria, the most important one in times of Energy Transition is for the grid to be robust and secure. There could exist several good enough solutions most of the time, the main challenge being to find at least one in time.

- How can one make these measures?

These measures (operational costs, $CO_2$ emissions, number of actions) can be derived from the observed states of the power grid, energy price and power plants characteristics. These measures are often already publicly available for historical data in a commitment to transparency to the overall public. Open-data services have been made available over the recent years.
One can also make those measures in simulated environments for any new decision-support system.
At a second stage, one can do some fine grained parallel-run in control rooms with operators to make real-time comparison on which recommandations an operator would have preferred between the established and the newly proposed decision-support system.