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Grid operators are being called on to apply innovative concepts to help ensure a successful energy-policy transition by facilitating the integration of volatile, decentralised energy sources, storage systems and other innovative assets coupled with the increased streams of data stemming from various parts of the grid they control and the electrification of automobility and the heating sector. At the same time, lowering revenue caps is creating added pressure to keep improving operational efficiency.

This is prompting grid operators to adapt to a new role requiring a high level of digitalisation. One possible approach for tackling this exists in the form of AI/ML methods, which build on the use of existing data volumes.

The data can be used to optimise grid planning and operations, as well as associated grid-operator tasks. Decision-support and -making processes need to consider a number of factors, often almost in real time, in order to react to fluctuations in generation and consumption, while at the same time not compromising grid stability. Here, AI/ML can be very effective in terms of quickly analysing and assessing large volumes of data with the high accuracy. The underlying issue with the system-wide and sometimes inert embracing of the new data-based technologies, such as AI/ML is, on one hand, the fact that operating power system means running a huge optimization apparatus with thousands of system variables; and on the other, that power system represents the critical infrastructure and the backbone of the society, which in turn means that any ill-handling can be very impactful and expensive. The fact that AI models and solutions are often attributed as “black-box systems” does not help policy and decision makers of the electrical utilities to press full-speed on implementation of these systems.

Due to their ability to generate outputs such as content, predictions, recommendations, or decisions, AI offers many opportunities for system operators (SO). Here, we will focus on three PS applications.

To start, AI are applied for more accurate load forecasting. The advantage of applying AI in the load forecasting system is two-fold. First, AI-based programs are able to include changes in the meteorological, social or economic context in their prediction models, resulting in more accurate short-term load forecasting, used by SOs for net balancing. Second, AI can improve long-term load forecasting, used by SOs to identify future bottlenecks and thus investment opportunities in the electricity grid, by analysing and “testing” the effectiveness of different investments before they are implemented, using digital twins.

The second application of AI for SOs lies in simplified or even automated management of flexibility assets (EV, BESS). SOs could make use of these technologies to support net balancing: when there is an oversupply of electricity on the grid, SOs could signal the flexibility assets to charge; with an undersupply, SOs could signal to discharge. With their ability to give precise, local overviews of the flexibility capacity available, AI-based programs could support SOs’ manual flexibility management. Alternatively, flexibility management could be automated: AI could be applied to balance the electricity net autonomously without human involvement.

Third, AI can be applied to support or carry out electricity market activities, creating a highly automated electricity market. AI-based programs can estimate electricity prices on the basis of the prediction of electricity supply and demand. Although this can be used to improve human decision-making on the electricity market, the great opportunity of AI lies in automated, near-real-time electricity trade. AI could predict fluctuations in the electricity market prices and manage its flexibility assets accordingly. When electricity prices fluctuate (for example, rise due to an undersupply), AI-based programs can react (by discharging electricity from their flexibility assets, and selling this electricity for a higher price) and in doing so, re-balance the grid.

The availability of an AI-based tool alone does not automatically mean it will be used by staff. The probabilistic approach adopted by AI in particular is initially an unfamiliar concept and can result in minimal uptake. When introducing an AI system, therefore, all affected parties must be involved and properly trained right from the outset.

The first concern regards the lack of transparency, which could lead to accountability issues. Although the electricity system has always been complex, the application of AI intensifies this. SOs frequently purchase AI technology (or service) from IT companies and startups. SOs use the program but are often no experts in how the program operates; it is a black box. Such a situation is already happening in some micro-grids. This can result in SOs making decisions (regarding balancing or investments) based on models that they do not understand or control, leading to questions regarding accountability for public spending, high electricity prices or network downtime. For accountability purposes and to prevent automation bias or “overtrusting” the program, it should be clear on what basis data and data-analyses decisions are made.

Second, the application of AI might limit human autonomy. Using AI for automated flexibility asset management instead of supporting SOs “manual” flexibility management leaves SOs with limited or no options regarding flexibility management and obstructs SOs in differentiating from the pre-programmed path. Overriding of the program can be necessary in case of bias or cyberattacks. It can, however, be challenging for SOs to adjust the AI-based program in use, as it might not be owned or developed by them.

The third risk concerns cybersecurity. The increase of renewable energy and electrification leads to more devices connected to the grid and, via their AI program, connected to the internet. AI programs require two-way communication: the program gathers data (such as electricity consumption) and sends commands (for example, a signal to an electric vehicle to charge). These open networks are more vulnerable to non-authorized access or other types of disruption (such as false data injection) than one-way communication systems.

The fourth risk regards price manipulation on the electricity market. Due to the complexity of AI, it is often unknown on what basis AI programs operate, and the programs can be used by a variety of actors for different goals. SOs cannot monitor what data the AI uses to make decisions about the electricity market. This could result in multiple AI programs conflicting with each other or with the goal of the SOs to create a reliable, affordable and sustainable electricity network.

These risks and potential shortcomings hinder the system-wide adoption of these systems. These issues should be thoughtfully addressed before employment of AI/ML systems for decision-making in PS domain.