Smooth operator: efficiency in the electricity infrastructure

Helmut Paeschke and Dr Wulf Engl jointly discuss the motivation and concepts behind their latest project, and how it aims to support a coordinated approach to electricity grid management.

What motivated the conception of the UMBRELLA research project?

HP: Our main motivation was the development of methods capable of handling increasing uncertainties in transmission network operation; uncertainties caused by the growing share in electricity generation from intermittent renewable energy sources (RES) as well as increasing market-based cross-border flows. It shall enable transmission system operators (TSOs) to act in a coordinated European target system where regional strategies converge to ensure the best possible use of the electricity infrastructure.

Could you outline how the toolbox prototype can help support the grid security of TSOs?

WE: The toolbox prototype consists of several functional modules, for which innovative fundamental research has been carried out. Newly developed methodologies can enable TSOs to forecast and minimise risk, which they could not do before in a quantitative way. We’ve also developed and established an optimisation framework as one of the first steps to secure the grid as a combination of deterministic actions and probabilistic assessments.

How does your project address TSO challenges facing Europe? Could UMBRELLA also help tackle similar issues on a global level?

WE: It provides a much more advanced way for coping with uncertainties in system operation and system operational planning, like volatile RES and intraday market activities, outages of power plants and grid elements, as well as fluctuations in demand. These challenges do not limit themselves to Europe, so UMBRELLA methodologies are also applicable for any transmission system in the world. Of course, the larger and more densely meshed the respective transmission system and the higher the share of renewables in it, the greater the benefits of the toolbox.

In what way does your approach of combining forecasting, optimisation and risk-based assessment help stabilise the way the pan-European transmission system operates?

HP: Traditionally, system security is represented in a deterministic way that only allows for a qualitative indication of risk as ‘secure’ or ‘not secure’. UMBRELLA’s combination of the aforementioned tools and the foregone system’s uncertainty assessment provides the system operator with complete knowledge of the system’s risk. The developed security criteria account for the risk from cascading events, as well as uncertainties from RES and intraday electricity trading. This enables TSOs to optimise their system while taking into account the risk, which leads to a more stable operation of the transmission system.

Your toolbox prototype addresses several work packages at different stages. Has this approach presented any challenges and, if so, how have you overcome them?

WE: The work of the different work packages went hand in hand as planned from the timeline. Nevertheless, the real challenge was the data retrieval and processing to achieve the necessary input for the new functionalities of the toolbox in the given timeframe. As we are developing methods beyond the state of the art, the creation of operational data by TSOs needs to be extended in order to be able to use all functionalities of the toolbox properly.

As a collaboration between several institutions and universities, how do you ensure effective communication between partners?

WE: The project management team (PMT) is invited to web conferences with the work package leaders every fortnight on average. We also hold web conferences between the PMT and all beneficiaries where reasonable. In addition, internal and public workshops are taking place to gather the whole project community for discussions of scientific as well as organisational and operational project topics. The Project Management Board acts as the steering committee and meets every six months to monitor the project’s progress and offer guidance at the working level.

With the project now in its final stages of funding from the EU Seventh Framework Programme (FP7), how far have you come towards reaching your objectives? What are your hopes for the future?

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Faced with an increasingly complex job, **UMBRELLA** aims to help transmission system operators handle present and future challenges of growing uncertainty in a rapidly changing power system.

**ELECTRICITY GENERATION AND DISTRIBUTION** in the EU is becoming more and more complicated. More territories are being integrated into the EU energy market and this, coupled with a desire for clean energy from intermittent renewable energy sources (RES), presents a growing challenge for transmission system operators (TSOs) in ensuring the safe and secure operation of the European electricity infrastructure.

UMBRELLA is a large collaborative project under the EU Seventh Framework Programme (FP7) seeking to address the present and future challenges of grid operation in the pan-European context. The project team is developing an innovative prototype toolbox to support the management by TSOs of an increasingly complicated transmission system.

Coordinating the four-year project is TenneT TSO GmbH in Germany, of which Helmut Paeschke is Head of Operational Planning and Regional Coordination, together with the leaders of seven work packages, including Scientific Research and Development, Demonstration, Testing and Prototyping and Dissemination, and in collaboration with members of UMBRELLA’s project management team. Working alongside Paeschke are Dr Wulf Engl, engineering consultant at Engl-Energie, who is responsible for project management, and Rob Bootsman, Delft University of Technology, who takes care of dissemination.

**TRANSMISSION SYSTEM OPERATORS**

TSOs ensure that electricity generated from power plants is transmitted to the distribution networks or directly connected customers without incident within the framework of the agreed upon rules and according to the state of the art. The increasingly interconnected electricity network in Europe necessitates that TSOs coordinate their efforts to make the best possible use of current and future transmission capacities. For instance, this integration means there are more unscheduled cross-border flows and related physical flows to deal with.

As the energy sector embraces RES, uncertainties associated with the intermittency of wind or solar power must be smoothed out by appropriate interventions from the TSOs for which modern software like the UMBRELLA toolbox under development is needed. With a growing RES presence, however, the difference between actual physical flows and forecasted load flows can be considerable. In short, there is a sizeable and increasing portion of uncertainty in the transmission system to be dealt with by the TSOs.

**UNCERTAIN PREDICTIONS**

The worst case scenario for such a large transmission system is a European-wide blackout. To avoid this and lesser calamities, it is necessary to predict energy demand and supply with a geographically high resolution. By considering factors such as the capacity of power lines and transformers, TSOs are currently able to map out possible congestions and derive countermeasures with their Day Ahead Congestion Forecast (DACF).

The current DACF process, however, can only provide limited information about possible security risks. It is based on deterministic forecasts where there is no room yet for an assessment of uncertainties. Hence, grid security can be judged only dichotomously, and it is not possible to tell how safe the system is. UMBRELLA is advancing existing forecasting methods to help generate a
clearer picture of any potential security risk. To do this, it is necessary to consider possible deviations from what is expected and also from the most likely developments. By replacing deterministic forecasts with probabilistic forecasts, the prototype toolbox is able to consider the uncertainty of infed from intermittent RES, conventional load forecasts, short-term trading activities and power plant outages.

Equally important is how these uncertain factors are modelled. To this end, the project takes into account the nonparametric characteristics of RES uncertainties and models geographic interdependences. In addition, an intraday trading model has been developed that enables TSOs to anticipate intraday trades and corresponding variations in power infed. This allows TSOs to forecast critical system states by running Monte-Carlo simulations using the assessed uncertainties and prepare adequately.

**WHAT’S THE RISK?**

Once an event is predicted, the next step is to prepare for that event. Traditionally, TSOs have the option of making topological changes or employing redispatch measures to handle congestion, but the emergence of load flow control devices has altered the decision-making process. With more options to choose from, how can TSOs be sure they are taking the best possible action?

To help ease the congestion management process, the toolbox’s creators have developed probabilistic optimisation algorithms to identify which measures can be used to maintain system security at the lowest cost. To do this, the algorithms need to be able to consider both present and future actions available to the TSO, as well as possible contingencies. By including uncertainties in the operational planning process, the toolbox can determine the best network arrangement and set points for load flow control to minimise the need for redispatch, maximise the capacity for power exchange and avoid breaching security standards.

A major element in developing this optimised decision-making process and minimising systems risk is the team’s work on methods of risk assessment. These include risk-based optimal power flow formulations and methods for probabilistic evaluation of blackout risks. As with forecasting, this is preferable to the traditional deterministic alternative, which only affords a qualitative description of system security. The risk-based assessment has the potential to optimise transmission capacities, allowing the electricity market to operate without putting the security of the system in danger.

The toolbox’s developers found that probabilistic methodology in operational planning is initially more expensive than deterministic methodology but, in the long run, proves cheaper. By considering uncertainty in the operational planning phase, TSOs can avoid high risk in real-time operation, meaning there is less need to take remedial actions and a reduced risk of losing loads in real-time. This amounts to lower operation costs and lowered risk.

Recently, these methods have been extended to take state-of-the-art load flow control devices like Flexible AC Transmission Systems (FACTS), High-voltage Direct-Current (HVDC) lines or Phase Shifting Transformers (PSTs) into account. They can be used to minimise the costs of reducing the operational risks. Again, this results in lower operational cost and reduced risk.

**TOOLBOX TESTING**

While each component of the toolbox evidently has a large part to play in the optimised operation of the electricity grid, it is the synthesis of these elements into a practicable toolbox that really matters. Key to this is getting the TSOs’ control room staff to accept the concepts of the toolbox, making it fit for them and integrating it into the actual processes of transmission system operation and operational planning.

Currently, the prototype has been subject to three test cases (three days in hourly resolution), using historic data to see how it performs when confronted with conditions such as cold spells or regionally specific high-wind infeeds. Whether actually present or taking part via web conference, each of the project’s member TSOs was able to participate in the tests.

**MEETING DEMAND FOR INNOVATION**

In this initial testing phase, the team has only been able to look at the toolbox’s deterministic functions, but even so the results have been extremely promising, particularly with regards to the optimisation possibilities and short computation times. Before the project draws to the end of its four-year run, these results will be used to provide the basis for any further improvements, particularly with regards to the operational requirements in TSO cooperation rules.

The need for an innovative approach to transmission system operation is clear. Rising complexity and uncertainty are growing challenges for TSOs, but by incorporating the probabilistic with the deterministic, UMBRELLA’s prototype toolbox expects the unexpected, assesses the risk and generates the optimal response, while lowering the risk and operational cost for a European-level transmission system operation.