NAME: Lazar Bizumic
COUNTRY: Switzerland
REGISTRATION NUMBER: 7832

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Question 2.5: While increased observability is necessary what other operational tools are needed to support increasing penetration of DER?

Energy transition towards Renewable Energy (both large-scale centralized and distributed) has altered the behavior of the power system and drastically changed the way the transmission grids are operated. To maintain reliable, safe, and secure operation of the network, system operators are forced to constantly keep their network control systems up to date and implement the newest technologies and tools which can help them achieve their targets. In addition to the ever-increasing observability of the network and operators' situational awareness achieved using the PMU data and WAMS, there is an increasing need for additional digital solutions and control room applications to help operators to efficiently control their system. The most prominently requested applications by system operators which are increasingly becoming a part of real time system control and operational planning are:

- **Optimal Power Flow (OPF) and Security Constrained Dispatch (SCD):** Fast changing system conditions require system optimization to be performed frequently, sometimes even every few minutes. OPF/SCD can help to effectively resolve voltage violation and element overloading. It can be used to limit production of DER in order to avoid line overloads. Prioritizing and keeping DER production at maximum acceptable level, but which does not cause system violation, helps maximize utilization of renewable sources.

- **Load and Generation Forecasting**: In order to efficiently plan system operation by performing look ahead studies (e.g. Congestion Forecast, Security Analysis) and optimization (e.g. OPF) it is crucial to accurately predict loading levels in the grid. In addition to traditional load forecasting tools and methods, lately AI/ML based methods are gaining traction in helping to perform short-term load forecasting more accurately. These methods are able to process large quantities of various data including inputs such as weather, social, economic information etc.

- **System Inertia Estimation**: In networks with high levels of DER penetration and extensive use of power electronics, rotating system inertia typically provided by rotating synchronous machines is significantly reduced or is hidden behind converters (Wind turbines). This makes predicting system behavior and system inertial response to the disturbances more difficult potentially putting stable system operation at risk. To overcome this, grid operators should always be aware of the actual system inertia, so that, if needed, they can react and perform necessary adjustments. For real time purpose, system inertia can be estimated by trying to take into account inertia constants of all the elements connected to the grid (including rotational and synthetic inertia). Alternately, system inertia can be estimated/measured using the advanced WAMS capabilities and by analyzing PMU data during large and small system disturbances. WAMS based inertia estimation can be active (actively inducing controlled disturbances) or passive (passively observing network and detecting disturbances once they happen).

- **Dynamic Line Ratings (DLR)**: Instead of using conservative fixed ratings (or seasonal ratings) for transmission lines, utilizing DLR makes it possible to push lines to their actual, thermal limits at every specific moment. Not only that this can help utilize the equipment more efficiently but can also help reduce the curtailment of the renewable energy due to the congestions in the transmission capacities, minimizing the need for redispatch. Use of DLR is not limited only to real time, but also forecasted line ratings for the next hours and days can be used in look-ahead studies and optimization.

- **Transient Stability Analysis (TSA)**: Due to the fast-changing operating conditions, traditional steady state security analysis of system response to contingencies might not be enough. Instead, TSA is increasingly finding its way into the control room as a part of real time and look-ahead applications (e.g. Contingency or Voltage Stability Analysis using TSA), helping system operators accurately predict the dynamic behavior of the system and avoid any unpredicted post-disturbance transient stability related surprises.

- **Load Shedding (LS) and Special Protection Schemes (SPS):** Represent the last line of defense against widespread system disturbances and blackouts. At the same time, they make it possible to safely and securely operate power system closer to its limits. Typically, these schemes are event based (e.g. underfrequency, line overload, line tripping) and predefined for limited number of events using offline studies. Lately, thanks to the advancement in capabilities of the control room solutions, these schemes and protection settings can be autonomously modified in real time to accommodate rapidly changing, but predictable grid scenarios. Depending on the required response time, LS and SPS can be executed, centrally from the control room or locally from a substation level.

In order to support increasing penetration of renewables and maximize its utilization rate, there is no single, silver bullet solution. Instead, a mix of innovative digital and hardware solutions is necessary. Here only some of them have been covered. It is evident that this list will grow in the future as new, more effective, and more advanced solutions are developed and standardized.