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Editorial

Monitoring and Automation of Complex Power Systems

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Overview of Challenges and Contributions

This Special Issue aims at collecting new research contributions and perspectives on the topic of the monitoring and automation of modern power systems. Monitoring and automation of the electric grid, down to the low voltage of the system, are today essential to deal with the challenges and complexity associated with the new generation of power systems. As an example, the growing number of small-scale generation units based on renewable energy sources, which are directly connected to the distribution network, brings the risks of reverse power flow and overvoltages in the distribution system, together with the highly intermittent and unpredictable operating conditions of the grid. In the near future, volatility and unpredictability may be further exacerbated by the ongoing electrification of the heating and mobility sectors, which will lead to unknown power consumption patterns and the possibility to have, at different times of the day, unexpected peaks of either generation or power consumption.

In this highly dynamic scenario, grid operators are called to promptly react to possible issues or emergency conditions, in order to always ensure a reliable delivery of the power supply to the final customers, with the expected levels of power quality. For this purpose, the real-time monitoring of the grid operating conditions is key to provide a clear and accurate view of the current situation, as well as its evolution over time. Beyond providing system awareness to human operators, the system states computed via the monitoring tools represent the essential input for any subsequent grid optimization, management, or control application. Given the multitude of distributed energy resources to be coordinated, the velocity with which the system conditions may change, and the massive increase of heterogeneous data to be processed, grid operators increasingly need to be supported in their tasks by fully (or semi-) automated grid management processes.

For the successful and reliable implementation of the needed power system automation functionalities, it is of paramount importance that all the elements of the entire automation chain are properly designed and characterized. In short, the overall automation chain includes:

- *Sensors and measurements*: These are the field components that sense and measure the electrical quantities of interest, so that it is possible to infer the operating conditions of the grid. Since measurements are always affected by uncertainties, it is important to have a proper understanding of the metrological performance of the deployed instruments, so that this can be duly taken into account in the subsequent steps of the automation chain.
- *Communication*: The communication channel is used to transmit the measurements from the field to the control center or to the computational nodes where the grid intelligence runs. The latency, robustness, and security of the communication are some of the aspects that may be relevant to consider for setting up the desired automation functionalities.

- *Monitoring tools*: This refers to the specific techniques adopted to process the measurement data and to derive from them the most likely operating conditions of the grid at a given instant of time. Different techniques, each one with specific pros and cons, can be adopted for this purpose, and different challenges may be present depending on the considered level and characteristics of the grid to be monitored.
- *Automation functions*: This includes both the core algorithms designed to deal with a specific optimization or management functionality and the sequence of steps put in place to send the corresponding actuation commands to the controllable field components. In this case also, different automation functionalities and grid characteristics may require devising ad hoc solutions.
- *IT architecture*: As a transversal layer, different features of the IT architecture (e.g., hierarchical vs. decentralized, on premises vs. cloud-based, etc.) may affect the overall implementation of the desired automation schemes.

This Special Issue includes five articles, authored by international research teams from different countries, which focus on specific aspects of the above-mentioned automation chain.

The works presented in [1,2] deal with the measurement layer of the automation chain. In [1], a low-cost measurement instrumentation setup is proposed for the characterization of the metrological performance of voltage instrument transformers (VTs) up to the first resonance frequency. This allows understanding the behavior of VTs over a broad frequency range, thus providing relevant information to determine how the accuracy performance may be affected by the possible presence of harmonics and other power quality issues in the measured signal. This contribution is particularly relevant since, above all, at the distribution level, sensors are potentially required to work in an increasingly polluted (from a power quality perspective) environment. The characterization of metrological performance is also the focus of [2]. Here, a stand-alone merging unit is presented together with the procedure for its accuracy characterization in a hardware-in-the-loop setup that includes both sensors and measurement units. The proposed methodology allows replicating the whole measurement chain within a digital substation and characterizing the behavior of merging units or other synchronized measurement units with typical laboratory instrumentation.

The proposals in [3,4] cover a different layer of the automation chain and address issues related to the monitoring of distribution grids. In [3], a distribution system state estimation algorithm based on an extended Kalman filter (EKF) is proposed for the accurate tracking of the grid operating conditions over time. This work proposes an alternative way to model the EKF-based estimator and a novel methodology for the prior estimation of the power injections used as the input to the estimator. Moreover, an in-depth analysis is provided to show the accuracy performance of the estimator depending on the number of available phasor measurement units in the system. In [4], the addressed challenge is the partition of large grids into smaller areas for the implementation of a coordinated multi-area state estimation algorithm. For this purpose, independent physics-aware neural networks are used to provide the estimation of different sub-areas. Beyond providing a distributed implementation of the state estimation problem, the proposed data-driven methodology allows coping with the problem of the unobservability of the distribution grids, which comes from the poor coverage of measurements typically present in distribution system scenarios.

Finally, [5] proposes a multi-objective framework for the optimal planning of a power system where design costs, reliability, and generation performance indexes are taken into account. The proposed solution relies on a hybrid meta-heuristic method that combines the bat algorithm and the generalized evolutionary walk algorithm.

Overall, the contributions to this Special Issue offer some novel approaches and further progress in particular for the characterization of the measurement chain and for the following implementation of monitoring algorithms. Both of these aspects unlock better visibility of the operating conditions of distribution systems while helping to identify the confidence level of the monitoring results, which is of utmost importance for the proper and reliable implementation of the subsequent automation schemes.

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References

1. Crotti, G.; D'Avanzo, G.; Giordano, D.; Letizia, P.S.; Luiso, M. Extended SINDICOMP: Characterizing MV Voltage Transformers with Sine Waves. *Energies* **2021**, *14*, 1715. [CrossRef]
2. Mingotti, A.; Costa, F.; Peretto, L.; Tinarelli, R. Characterization Procedure for Stand-Alone Merging Units Based on Hardware-in-the-Loop Technology. *Energies* **2021**, *14*, 1993. [CrossRef]
3. Macii, D.; Fontanelli, D.; Barchi, G. A Distribution System State Estimator Based on an Extended Kalman Filter Enhanced with a Prior Evaluation of Power Injections at Unmonitored Buses. *Energies* **2020**, *13*, 6054. [CrossRef]
4. Tran, M.Q.; Zamzam, A.S.; Nguyen, P.H.; Pemen, G. Multi-Area Distribution System State Estimation Using Decentralized Physics-Aware Neural Networks. *Energies* **2021**, *14*, 3025. [CrossRef]
5. Guerraiche, K.; Dekhici, L.; Chatelet, E.; Zeblah, A. Multi-Objective Electrical Power System Design Optimization Using a Modified Bat Algorithm. *Energies* **2021**, *14*, 3956. [CrossRef]