Reactive Power Management with Distributed Energy Resources

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EXECUTIVE SUMMARY

The increased integration of variable renewable energy sources into the power grid can, amongst others, lead to fluctuations in voltage, which may result in issues like harmonics, flicker, unbalanced loads, and power oscillations. These factors can negatively impact power quality and the ability to transfer power effectively. Therefore, effectively managing reactive power becomes crucial for stabilizing the grid, facilitating voltage control, and ensuring high power quality. In addition, distributed energy resource (DER) systems need to take over more responsibility by providing reactive power control. This improvement in power system stability plays a key role in preventing problems like load shedding and system collapse, ultimately enhancing the overall security and reliability of the power system.

Effective reactive power management of DERs becomes indeed a crucial aspect of grid operation essentially for voltage maintenance and for ensuring the stability of the grid.

There are different solutions available for managing reactive power, each tailored to specific needs. For ex-ample, fixed power factor or reactive power setpoint for PV plants, voltage-dependent reactive power provision (Q(V)), or static synchronous compensator (STATCOM) functionalities provided by DER. Unlike active power management [1], reactive management and voltage control is a rather local issue, so that they need to be tailored to the local environment and may also have adverse effects if implemented uncoordinated.

Contrastingly, due to the substantial number of involved plants, especially when also including, e.g., residential PV plants, harmonization and standardization is a must to enable grid operators efficiently include respective control functionalities and lever the possibilities this flexibility brings. For larger systems, oftentimes an inclusion in centralized (optimized) system controls may be beneficent.

Standardization of decentralized solutions for effective reactive power management are crucial for system-wide usage and application. Reactive power regulations therefore play a fundamental role in shaping power system operations amid rising renewable energy integration.

This report highlights the status and the potential of reactive power management in the presence of high renewable energy sources shares. The focus is to give an overview of reactive power regulations across several IEA PVPS Task 14 countries, including grid codes and frameworks that shape the requirements for connected distributed energy resources to provide reactive power control.

In addition, the report exemplarily examines how these regulations influence the operation of power systems with increasing integration of renewable energy sources. The report therefore discusses reactive power control support potential using DER based reactive power capabilities through different research case studies.

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• **Reactive power support potential by DERs**: The study focuses on the development and discussion of transparent performance indicators for the availability of DER reactive power support. Key performance indicators are introduced and defined. The results illustrate that Hydro and Thermal DER with fixed reactive power capability, as well as all DER types with STATCOM capability, can have significant contributions in terms of these performance indicators.

• **Forecasts for the reactive power flexibility potential of PV plants:** The main objective in this study is to forecast reactive power flexibility potential for MV PV plants. An evaluation of various PV forecasting approaches is obtained using different reactive power capabilities. A reliability indicator is introduced to evaluate the accuracy of reactive power flexibility forecasts in comparison to actual observations, emphasizing the importance of preventing overestimation. Furthermore, the study explores the use of a reactive power planning reserve to enhance the reliability of reactive power flexibility forecasts. It dis-cusses the trade-off between improved reliability and the reduction of forecasted reactive power flexibility potential. While certain methods demonstrate improvements in forecasted power values, careful con-sideration is needed to avoid overestimating exceptionally low power values, especially in specific use cases. High reliability forecast requirements will be necessary for using DER reactive power support as an ancillary service.

DERs contribute significantly to grid stability by leveraging their reactive power capabilities. Forecasting flexibility will be necessary, emphasizing the need for a delicate balance between improving forecasts and preventing overestimation to ensure DER reactive power support.

Furthermore, research examples, including use cases from three different IEA PVPS Task 14 countries, are highlighting these reactive power management applications using photovoltaics and other renewables:

• **Application-oriented reactive power management (Germany)**: The application-oriented reactive power management approach is motivated by the need of Distribution System Operators (DSOs) to control reactive power exchange at grid interfaces, supporting local voltage stability without complex infra-structure. The method focuses on controlling reactive power exchange at the 110 kV network connection point using local reactive power from DERs at the MV level. The control process involves determining target values, assessing deviations, setting reactive power set-points for controllable MV-DERs, and implementing local limitations based on extended Q(V) characteristics. In addition, the implemented solution demonstrates adaptability to different control scenarios, highlighting its flexibility in response to varying grid conditions.

• **Methods and Scenarios for Strategic Grid Planning in Distribution Networks (Austria):** The study conducted in Austrian low voltage grids aimed at a quantitative survey of the area effectiveness of future network-related measures. Aligned with European requirements, Austria mandates certain reactive power management functionalities for power electronic-based grid interfaces, such as PV inverters. However, current practices reveal limited utilization of these capabilities, with a predominant focus on cos φ = 1 during residential PV integration. The study considered various scenarios, including the impact of climate policy goals, regionalized technology rollouts, and different operating strategies related to PV, heat pumps, and e-mobility. Identified challenges include the need for a differentiated and detailed analysis of Q(V) control contributions within DSO supply areas. Discussions around reducing reactive energy demand explored options such as PV curtailments and primary substation current compounding. The study indicates a growing consideration of Q(V) as a future option among Austrian DSOs. However, a lack of capability for large-scale grid simulations emerged as barrier, hindering a comprehensive under-standing of the value of reactive power management in distribution grids.

• **Evaluation of the voltage control performance in distribution system (Japan):** In response to the growing challenge of maintaining proper voltage levels in distribution systems amid increasing PV penetration, a comprehensive project was conducted by a consortium involving TEPCO Power Grid, Tokyo Electric Power Company Holdings, Inc., and Waseda University. Supported by the New Energy and Industrial Technology Development Organization (NEDO), the project aimed to evaluate the voltage control performance under various scenarios, considering PV penetration from 2025 to 2040. While the cur-rent voltage control is conducted by fixed power factor control with different fixed values for each volt-age class, the study suggested it may be difficult to maintain an appropriate voltage due to the increase in the amount of PV interconnection in the distribution system. Based on these findings, although it continues to adopt a fixed power factor control strategy, "the power factor setting value must be changed according to the request of DSOs, with a function that allows it to be changed" was stipulated in the new grid code published in 2023.

Reactive power management is an essential aspect in achieving optimal grid performance. Various new methodologies are needed and being developed considering difference scenarios and highlighting the necessity for adaptability in response to evolving energy landscapes.

In summary, advancing reactive power management is crucial in the evolving energy landscape. Research, especially in forecasting and control algorithms, is essential for efficient power systems. Regulatory frameworks need prompt updates, necessitating strengthened collaboration between TSOs and DSOs. Exploring DER potential and leveraging information and communication technologies (ICT) for enhanced coordination are key components to ensure resilience and efficiency in power systems.