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A particular challenge facing distribution networks (DNs) with large shares of renewable energy sources (RESs) is congestion due to reverse power flows in times of coinciding high production and low demand. While the duration of such potential bottlenecks can vary greatly due to the variable nature of RES generation, the risk of congestion itself nevertheless sets strict a limit on the expansion of renewable energy production as distribution system operators (DSOs) must ensure operation within network constraints to avoid degradation, or even permanent damage, of network components caused by thermal overloading. The use of conventional congestion management strategies for DNs, particularly grid reinforcement, is becoming increasingly ineffective in such scenarios. The typical peaked duration curve of variable RESs creates a situation where costly reinforcement measures would have to be applied to mitigate the worst-case generation conditions, however rarely occurring. Furthermore, the need to rapidly increase the number of RESs to fulfil societal and environmental goals, makes it difficult for DSOs to timely reinforce their networks. However, with large shares of connected power-electronic interfaced generators in combination with new types of controllable loads, including electric vehicles (EVs), there is a potential to operate DNs in an increasingly flexible manner.

A parallel challenge in DNs is posed by changing reactive power flows. This can be attributed to the increased RES production, as well as increased charging currents due to expanding cable networks. Also contributing to the changing flows is the rising number of consumer electronics with non-linear load characteristics. For DSOs, minimising undesired reactive power flows at the connection to the transmission system is key to meet inter-network requirements, typically set by the use of reactive power for voltage control purposes in the transmission grid.

The two challenges presented above were addressed in paper 10826, where a centralised near-real time control algorithm for flexible congestion management and reactive power control was proposed as a solution to boost network capacity quickly and safely. This can be achieved through active network management (ANM), i.e., enhanced monitoring and control of the network, which defers extensive investments in the physical grid. The algorithm was designed to include both loads and generation units as flexibility providers and allows for the use of various accompanying financial solutions, such as a local flexibility market or bilateral flexibility contracts. At each monitored bottleneck, if a constraint violation is detected, a PI controller updates the amount of flexibility required to restore operation within network limits. The controller output is then dispatched as active power set point updates to available local flexibility resources. Since the PI controller is activated at the network limit, the full line capacity is utilised. The main advantage of the setup is the high adaptability and scalability. Implementation processes, such as changing the configuration of monitored network components, and adding or removing flexibility resources, are simplified as the central feedback controller does not require a detailed network model during operation. As the total flexibility required to manage congestion at a certain location is computed, dispatching of set points to individual resources can be made through a common platform, which is independent of any specific financial arrangement for the participating flexibility providers.

The algorithm was extended to allow for control the reactive power flow at the TSO/DSO interface. The presence of converter-interfaced generation units gives the possibility to adjust converter power factors for this purpose, again using PI control and subsequent set point dispatching. With congestion management being critical for operational safety, a limit on reactive power flexibility was imposed, related to the network constraints set by the monitoring of bottlenecks.

Two key implementation aspects must be addressed before the algorithm can be deployed in a real network environment. First, it must be ensured that sufficient flexibility is available to mitigate congestion. Second, any conflicting set point updates, stemming from simultaneous monitoring of multiple network components for congestion, must be resolved. The latter issue is eliminated through a coordinated selection of setpoints in the dispatching phase, where individual resources are ultimately tasked with management of the most severe bottleneck at each time instance. The first, and perhaps the more important, issue could be managed in a planning phase ahead of deployment, involving simulations of the algorithm in a network model, using forecasted generation and demand data. A demonstration case of a full network deployment of the discussed algorithm has been conducted within the framework of the ANM4L project (EU H2020 Grant No 775970). The algorithm is there included in a digital toolbox, which includes a Python interface to network simulation software, as well as a HTTP interface for exchange of measurement data and set points with connected flexibility resources. Thus, the DSO can analyse and control flexibility in both the planning phase and in real-time operation through a single platform.

The work presented in paper 10826 indicates that flexibility can be harnessed and scaled in a modular fashion, which is suitable for rapidly evolving distribution networks with high planning uncertainty. The discussed algorithm provides a technological foundation from which further improvements can be analysed and tested. A topic highly relevant for DSOs, but not within the scope of the paper, is the minimisation of operating costs and network losses.