Coordinated Voltage and Reactive Power Control Strategies for Active Distribution Networks

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Abstract – The characteristics of energy supply in active distribution networks change with the presence of distributed, renewable and mobile energy sources. In order to provide alternative solutions for reinforcement and expansion of power systems, enhanced coordinated voltage regulation and management approaches are investigated. Local and remote control algorithms are established, allowing the mitigation of time-varying voltage and network congestions. The proposed solution is verified through multi-period AC power flow analysis and simulation with a benchmark distribution system.

Active Distribution Network Architecture

Several medium and low voltage benchmark distribution systems are introduced, modeled with **active system devices** and **inverter-based energy sources**. The system architecture and design **(Fig. 1**) is developed according to [1] and considers multiple feeders with different loading, lengths and feeder types. Based on **wide-area monitoring** the measured voltage signals are used as input for coordinated voltage and reactive power control strategies [2]. Downstream data processing is performed utilizing **supervisory control and data acquisition** (SCADA) systems [3].

An **energy management system** (EMS) ensures the processing of **local and remote control algorithm** to allow control of on-load-tap-changers (OLTC) and distributed energy sources, s.a. photovoltaic plants, stationary battery systems and charging infrastructures for electric vehicles.

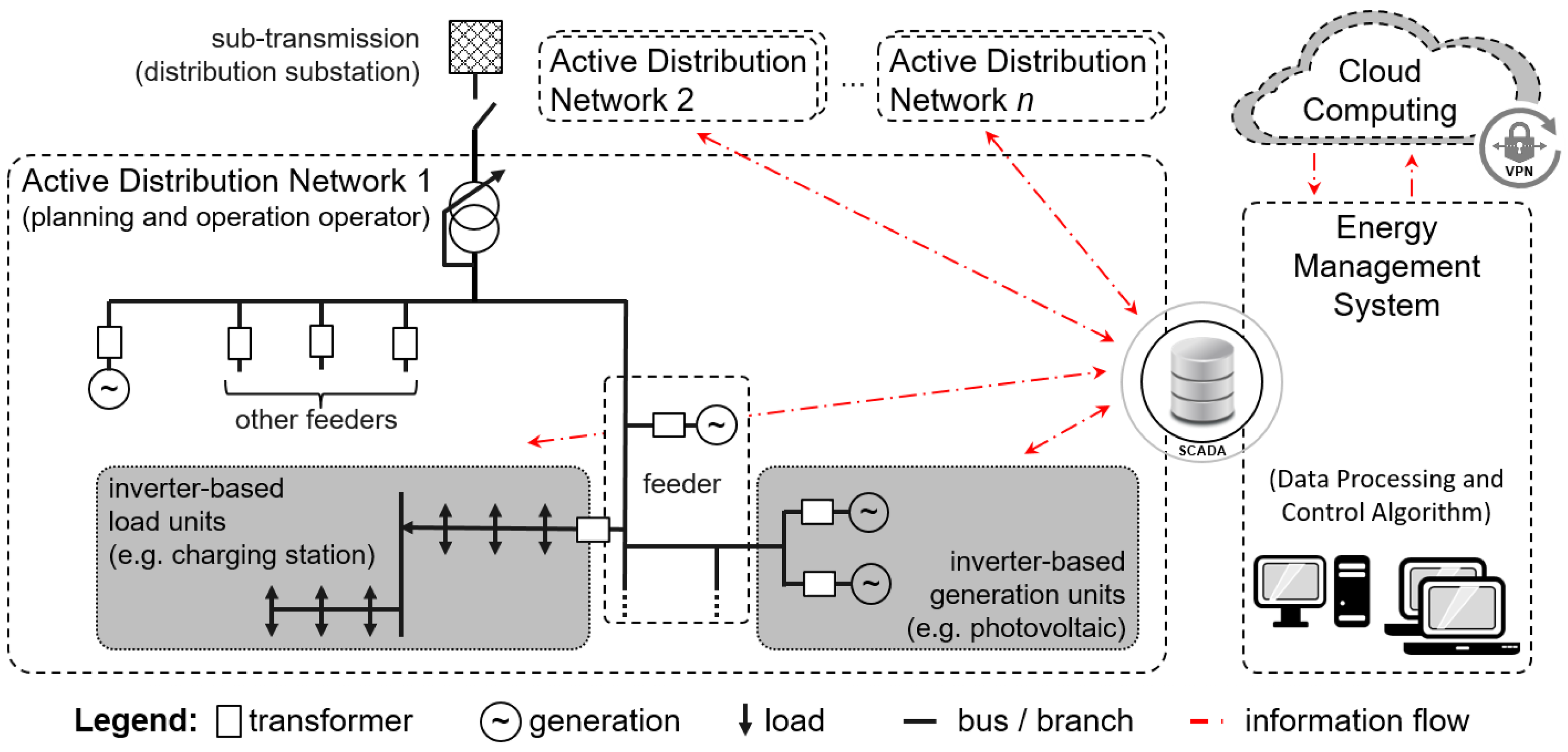

Fig. 1: System architecture and design for active distribution network based on wide-area monitoring.

Proposed Coordinated Voltage Control Algorithm for Real-world Applications

The developed control algorithms are structured in modular functions with specific input/output characteristics (**Fig. 2**). The following **influencing factors** are taken into account when determining the spatial and temporal control setting:

- R/X-ratio
- inverter position
- voltage level
- network topology
- load characteristic

A set of voltage signals $H_{\mathrm{Vctr}} = \{V_2, V_{2\mathrm{m}}^{\mathrm{sen}}, V_{2\mathrm{m}}^{\mathrm{cr}}\}$ at defined reference buses V_{ref} is used as input for:

- conventional **OLTC control schemes** and calculation of optimized **OLTC operating points**
- the **inverter control scheme** consisting of optimized operating points and linearized droop curves $H_{\mathrm{Qctr}} = \{\cos\varphi\,(P), Q(V)\}$

The underlying **mixed-integer linear programming problem** is solved by using a branch-and-cut method with simplex algorithm. Then, linearization techniques are applied to the obtained optimized operating points to create linearized droop curves applicable in real-world operations. This is achieved by defining a specific number of reference points. Finally, the control algorithms are applied and further investigated in **multi-period AC power flow analysis**. The simulation results (**Fig. 3**) compares the performance of the coordinated voltage control algorithm in different scenarios.

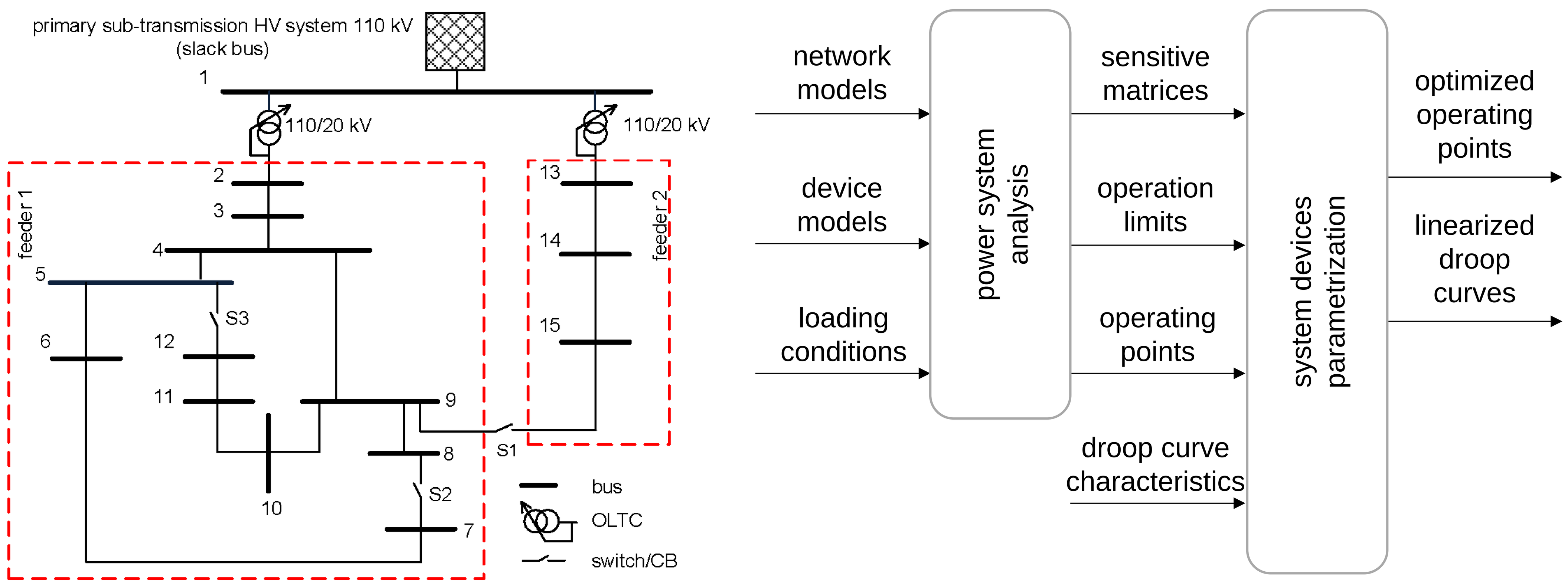

Fig. 2: Network topology CIGRE 20kV distribution network benchmark (left) and input/output characteristic of proposed reactive power control algorithm (right).

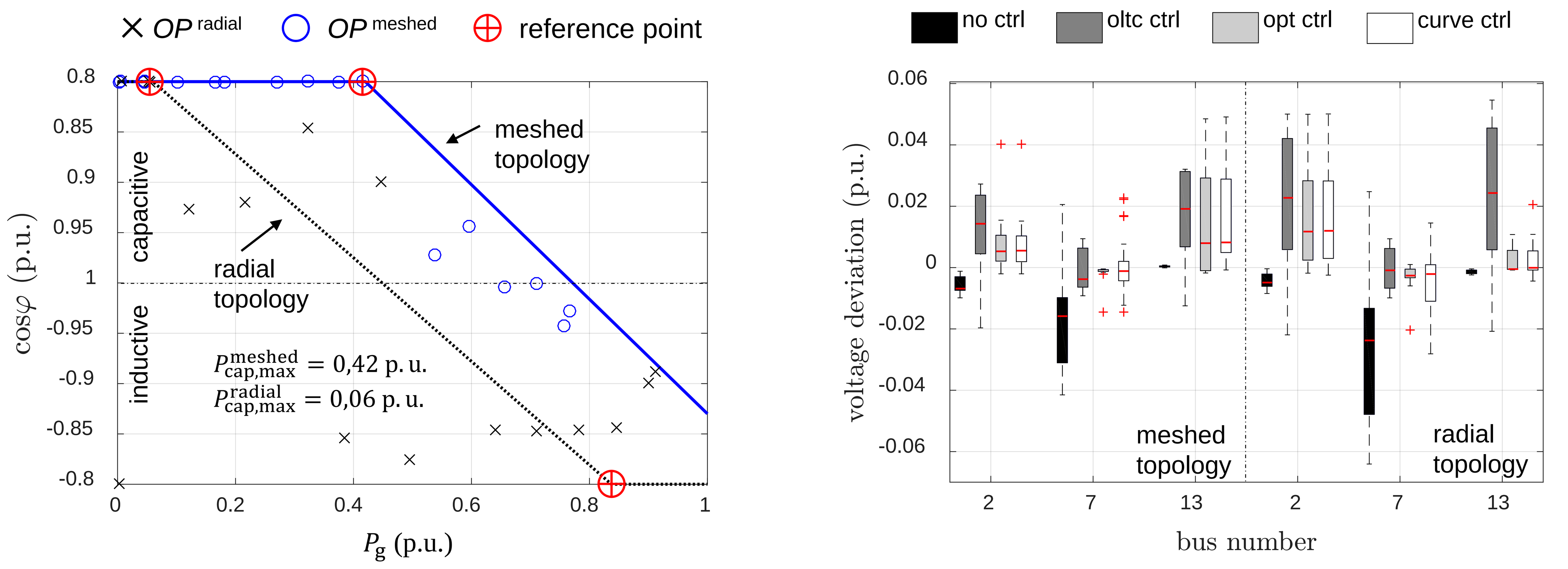

Fig. 3: Exemplary optimized operating points and linearized droop curves (left) and comparison of applied control schemes in terms of observed voltage variations (right).

Conclusion and Outlook

The proposed coordinated voltage and reactive power control strategies exploit the temporal and spatial flexibilities of active system devices and inverter-based energy sources. The simulation results indicate the potential and effectiveness when applying the control schemes to provide a comprehensive set of additional power system services. The implementation in existing active distribution networks is part of future investigations.

References

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