A new Volt / var local control strategy in low-voltage grids in the context of the *LINK*-based holistic architecture (3)

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Background

The increasing share of distributed generation causes reverse active power flows that provoke violations of the upper voltage limit in low-voltage grids (LVG). To control the voltage in LVGs with high PV-penetration, customer-owned PV-inverters are commonly equipped with local $Q(U)$-control. This concept entails social issues in the field of cost allocation, data privacy and discrimination, and technical issues concerning cyber security, grid losses, distribution transformer loading and uncontrolled reactive power exchange between medium-voltage grid (MVG) and LVG. Furthermore, the use of numerous PV-inverters owned by different players exacerbates the Volt / var management tasks in LVG. To overcome the actual social and technical problems, a new Volt / var control strategy is proposed which arises from the *LINK*-based holistic architecture for smart power systems [1].

The rise of $L(U)$-control

The $L(U)$-control strategy arises from the *LINK*-based holistic architecture [1], which stipulates that each grid operator should primarily use his own reactive devices for voltage control.

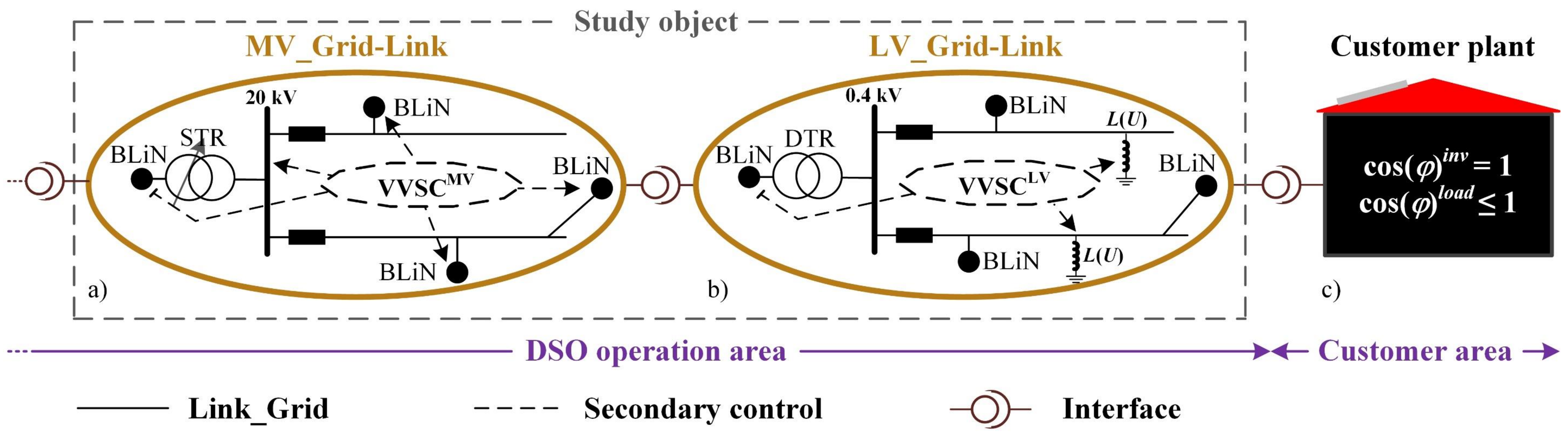

Figure 1: Schematic of the *LINK*-based Volt / var interaction chain: a) MV_Grid-Link; b) LV_Grid-Link; c) customer plant.

- $VVSC^{MV}$ calculates var set-points for the adjacent LV_Grid-Links and a voltage set-point for the MV-bus bar of the supplying transformer, while respecting static (current and voltage limits) and dynamic (var-exchange with superordinate grid) constraints.
- $VVSC^{LV}$ calculates voltage set-points for the local $L(U)$-controls, while respecting static and dynamic constraints.
- Customer plants are considered as black boxes; no data is exchanged between DSO and customers.

To control LVG voltages, inductive devices are set at the end of the violated feeders and are equipped with local $L(U)$-control.

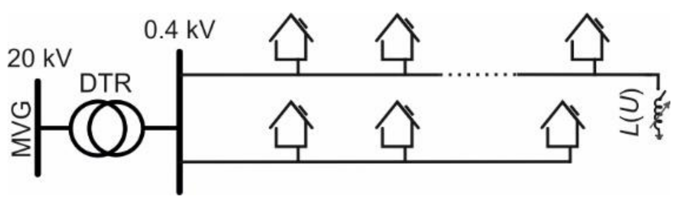

Figure 2: Schematic low-voltage grid with one $L(U)$-controlled feeder.

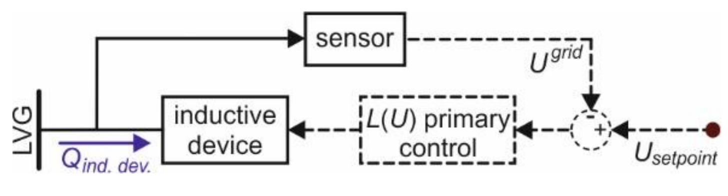

Figure 3: Basic $L(U)$ primary control loop.

Structures arising from $Q(U)$- and $L(U)$-control

The coordination of customer-owned PV-inverters entails social and technical issues in the field of **cost allocation**, **data privacy**, **cyber security** and **discrimination**.

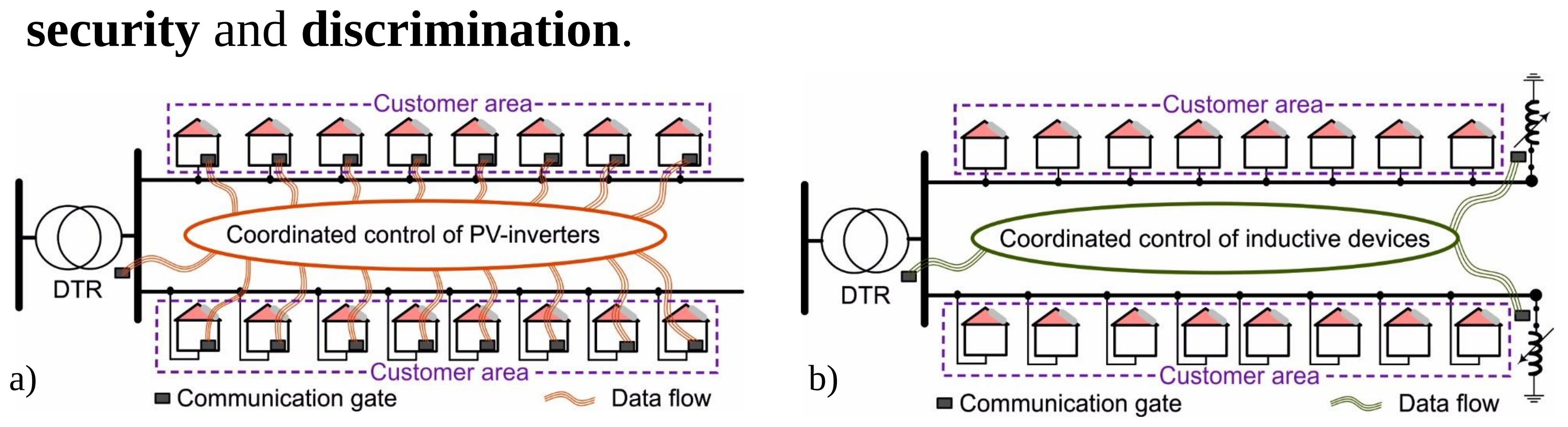

Figure 4: Structure arising from the coordination of different control devices: a) customer-owned PV-inverters; b) DSO-owned inductive devices.

The use of DSO-owned inductive devices instead of customer-owned PV-inverters solves the aforementioned issues.

Grid behavior resulting from $Q(U)$- and $L(U)$-control

The daily behavior of a real rural LVG with high PV-penetration is simulated in presence of no-, local $Q(U)$- and local $L(U)$-control strategy (fixed $Q(U)$-characteristic and voltage set-point).

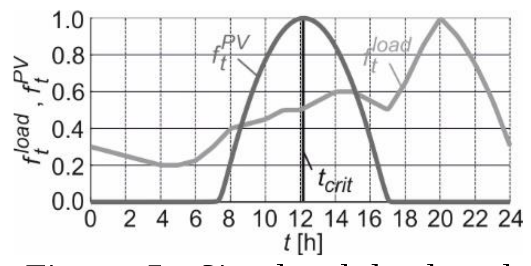

Figure 5: Simulated load and PV-production profile.

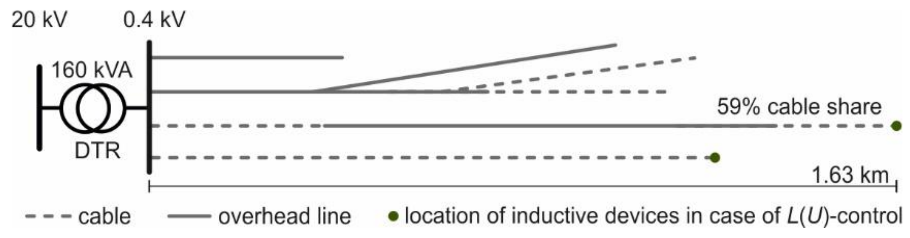

Figure 6: Schematic presentation of the simulated rural low-voltage grid.

Results show that the use of $Q(U)$-control eliminates the violations of the upper voltage limit. Simultaneously, it provokes high additional Q-flows within the LVG increasing significantly **grid losses**, **distribution transformer loading** and ***Q*-exchange between LVG and MVG**. The use of $L(U)$-control also eliminates all voltage limit violations. It improves the LVG behavior compared to the $Q(U)$-control case.

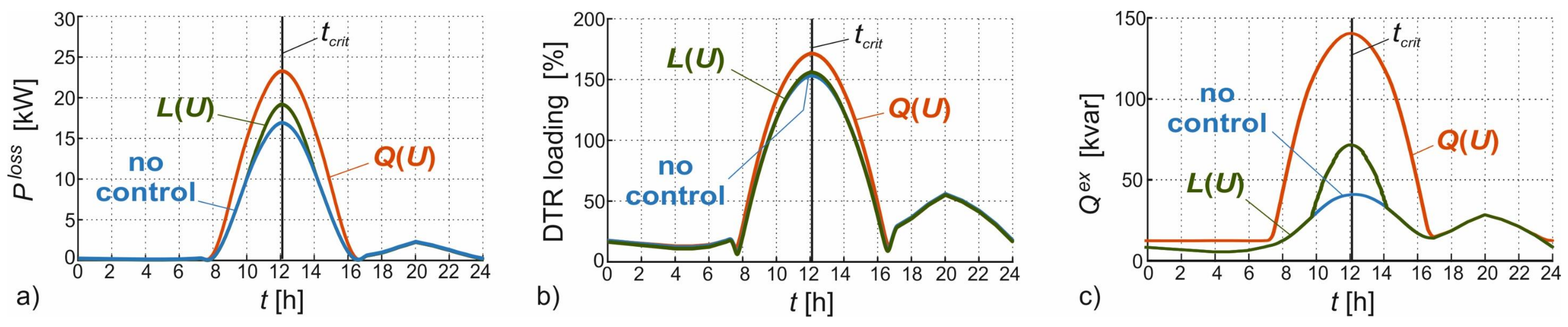

Figure 7: Daily behavior of the rural LVG for no-control and different control strategies: a) grid losses; b) distribution transformer loading; c) Q-exchange between low- and medium-voltage grid.

32 of the rural low-voltage grids are connected to a medium-voltage feeder and simulated for the most critical time-point (t=12h).

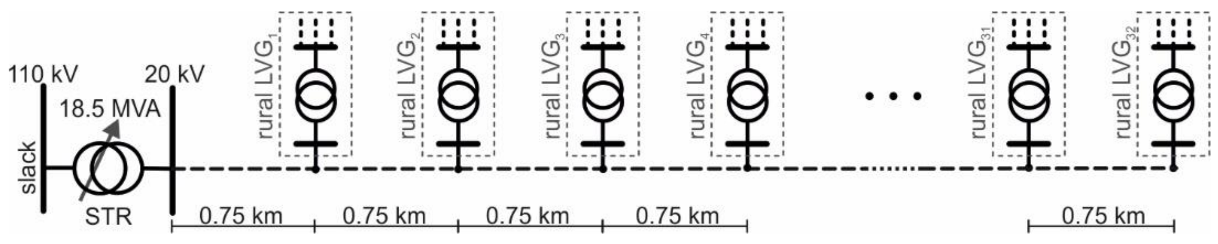

Figure 7: Schematic presentation of the simulated medium-voltage feeder.

The use of local $Q(U)$-control significantly impacts the voltages within the superordinate MVG. They are decreased more than necessary to eliminate the limit violations. In comparison, MVG voltages are less suppressed if local $L(U)$-controls are used.

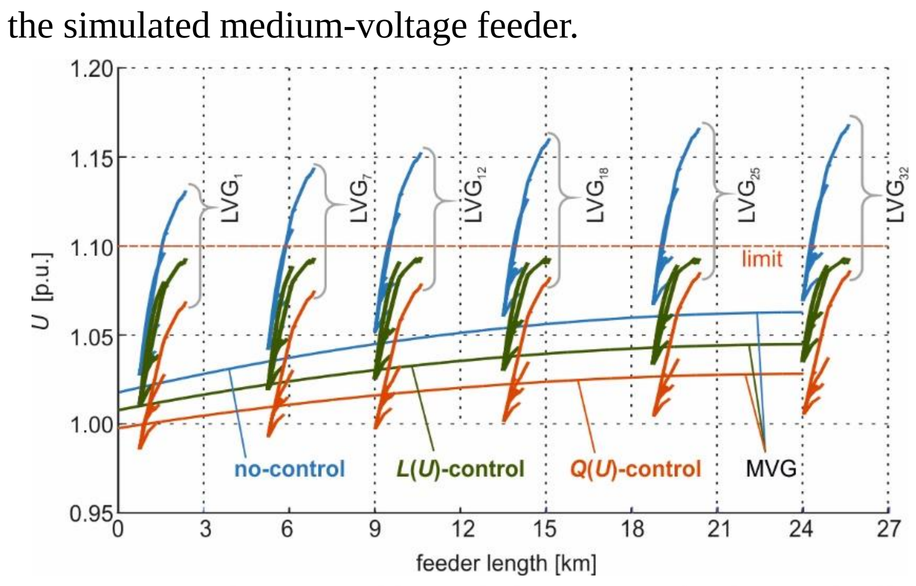

Figure 8: Voltage profiles of the MVG feeder and all feeders of selected rural LVGs at t_{crit} for no-control and different control strategies.

Conclusion

The proposed $L(U)$-control strategy shows substantial benefits compared to the $Q(U)$-control of PV-inverters:

Social benefits:

- Cancels out the need for customers to invest in Volt / var controllers.
- Discrimination of customers is impossible in principle.
- Data privacy is guaranteed.

Technical benefits:

- Eliminates all violations of the upper voltage limit.
- Less suppresses MVG voltages.
- Reduces threat to cyber attacks / ICT challenge. **→ cost reduction**
- Simplifies Volt / var management tasks in LVGs. **→ cost reduction**
- Reduces grid losses, DTR loading and Q-exchange. **→ cost reduction**

Additional expenditures:

- Installation and operation of local $L(U)$-controls. **→ cost increase**

[1] A. Ilo, "Link" - The smart grid paradigm for a secure decentralized operation architecture, *Electric Power Systems Research*, vol.131, pp. 116-125, 2016, doi: 10.1016/j.epsr.2015.10.001.