TECHNISCHE UNIVERSITÄT WIEN

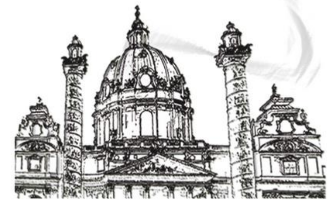
Freiheit, Gleichheit, Demokratie: Segen oder Chaos für Energiemärkte?

IEWT 2019

11. Internationale Energiewirtschaftstagung an der TU Wien

13. – 15. Februar 2019
Wien, Österreich

Tagungsort:
Campus Gußhaus / TU Wien
Gußhausstraße 25-29
1040 Wien



Veranstalter:
Energy Economics Group - Institut für Energiesysteme und Elektrische Antriebe der TU Wien
AAEE (Austrian Association for Energy Economics)

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

Daniel-Leon Schultis,
Albana Ilo

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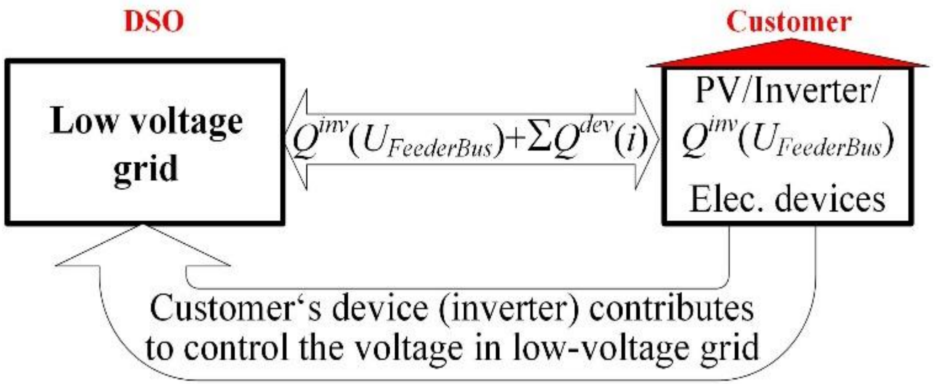
Problem statement

- The distributed generation (DG) causes violations of the upper voltage limit in low-voltage grids (LVG).

- Local Volt/var control of DG-inverters (e.g. $Q(U)$-control) is actually in discussion to eliminate the voltage limit violations.

Actual solution

In LVGs customers' plants are close to each other, and almost homogeneously connected. In this case, **the customers' smart inverters are used to support the grid operation.**



- The actual solutions intertwine the operation of LVGs and DG-inverters, although they are property of different players.

New social and technical problems

- Distributed and inverter-based local Volt/var controls lead to high and uncontrolled reactive power exchanges with the superordinate grid, making their coordination necessary.

- The coordination of customer-owned DG-inverters for LVG voltage control provokes new social and technical problems.

<u>Technical problems:</u>

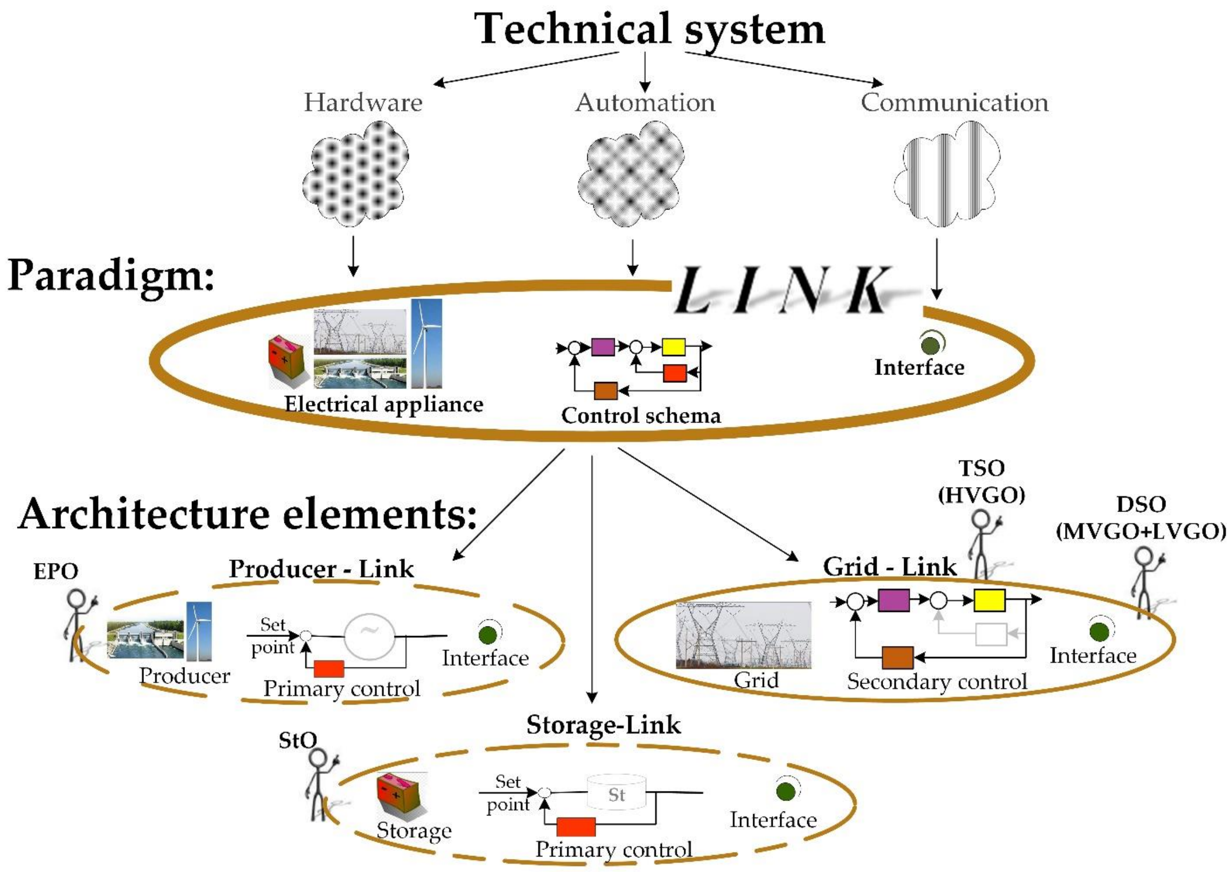
- ICT challenge / cyber security
- Complex Volt/var management in LVGs
- High *Q*-flows in all voltage levels

<u>Social problems:</u>

- Data privacy
- Discrimination
- Cost allocation

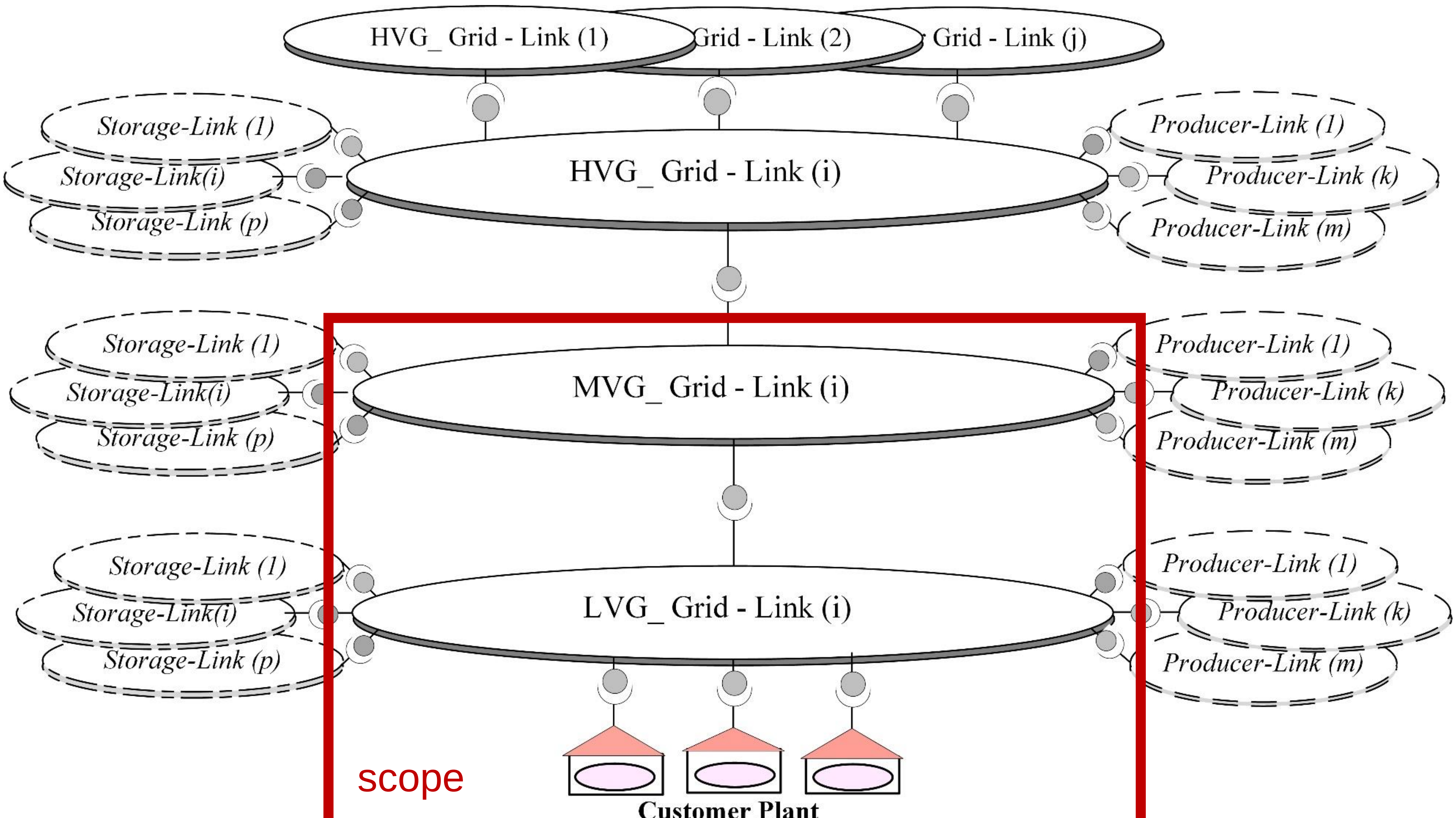
LINK-Paradigm

To solve the actual social and technical issues, the *LINK*-Paradigm and the resulting *LINK*-based holistic architecture are used.



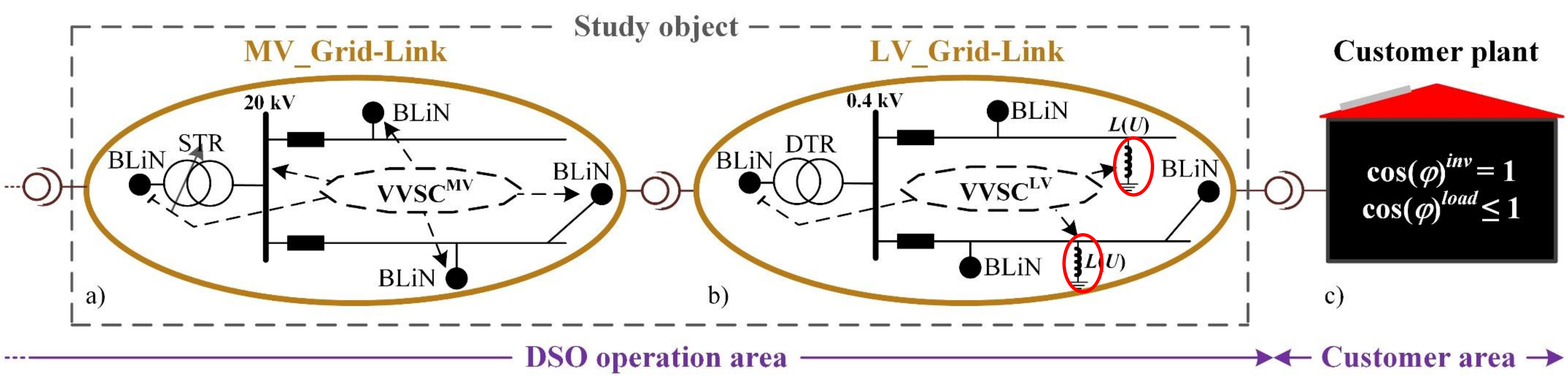
Source: A. Ilo, Link- the Smart Grid Paradigm for a Secure Decentralized Operation Architecture, EPSR, vol. 131, 2016, pp. 116-125.

LINK-based holistic architecture



Source: A. Ilo et al., Robust technical/functional operation architecture for smart power systems, CIRED Workshop 2018, Ljubljana, Slovenia.

The rise of *L*(*U*)-control



- VVSC^xx calculates var set-points for the adjacent Grid-Links and voltage set-points for internal transformers and reactive devices, while respecting static and dynamic constraints.

- Customer plants are considered as black boxes.

***LINK*-Solution stipulates that each Grid-Link operator should primarily use his own reactive devices for voltage control.**

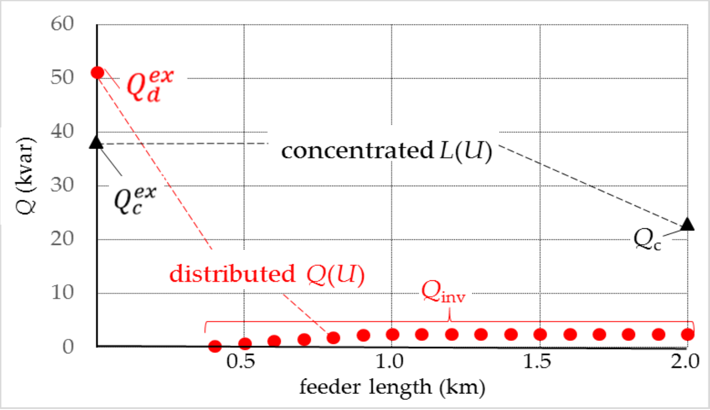
It is proposed to install DSO-owned inductive devices equipped with local *L*(*U*)-control for voltage control in LVGs.

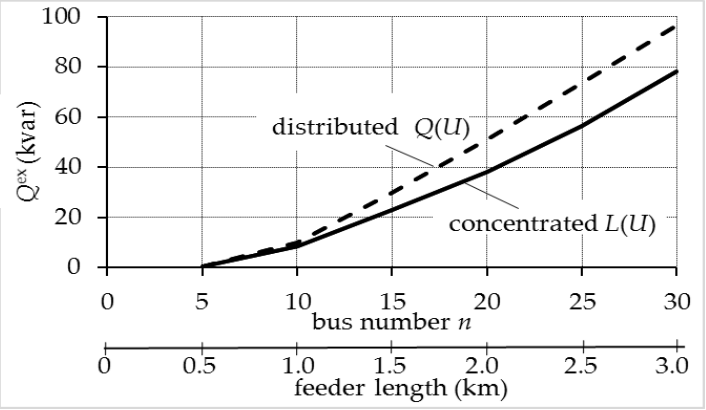
Effectiveness of distributed vs. concentrated var-sinks

Analytical investigations and numerical simulations in theoretical and real low voltage grids have shown that:

- To reach the same voltage value at the feeder end, distributed $Q(U)$-controls need to absorb more reactive power in total than the concentrated $L(U)$-control.

- The difference in reactive power absorption increases with an increasing feeder length.





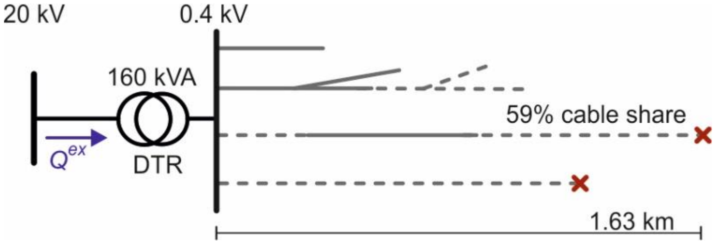
The concentrated $L(U)$-control is more effective than the distributed $Q(U)$-control.

Source: A. Ilo, D.-L. Schultis, et al., Effectiveness of Distributed vs. Concentrated Volt/Var Local Control Strategies in Low-Voltage Grids, Appl. Sci. 2018, 8(8), 1382.

Simulation models

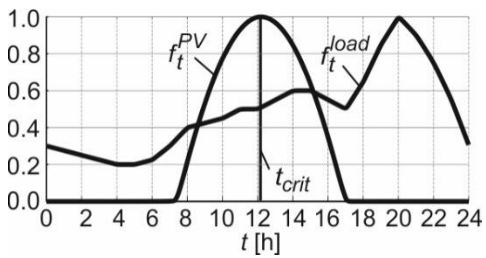
The daily behavior of a real rural LVG and a theoretical MVG is simulated in presence of no-, local $Q(U)$- and local $L(U)$-control.

LVG model:



- 61 connected (residential) customer plants
- Each customer plant includes a ZIP-load and a (5 kWp) PV-system
- Fixed $Q(U)$-characteristic and $L(U)$ voltage set-point

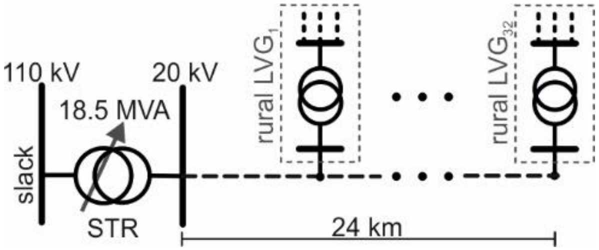
load and PV profile:



- Sampled into one minute time-steps

→ 1440 load flows per control strategy

MVG model:



- 32 equidistantly connected rural LVGs

LVG losses, DTR loading, and *Q*-exchange

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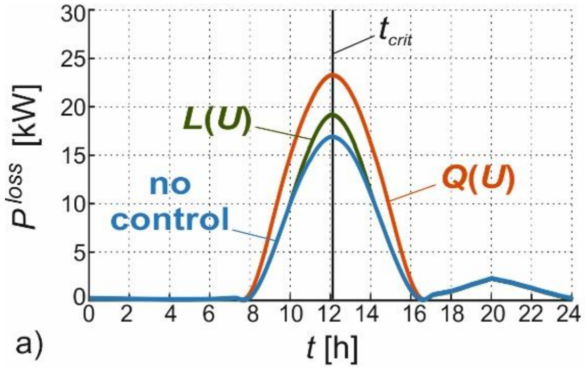
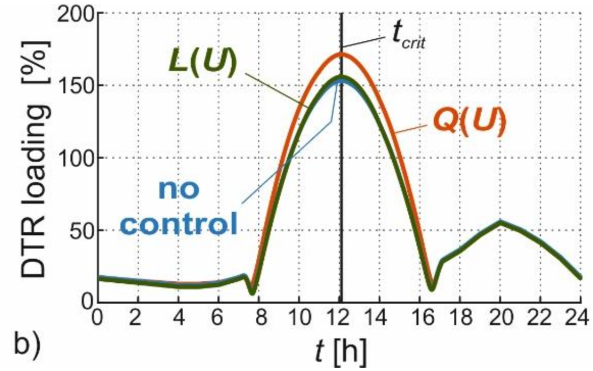
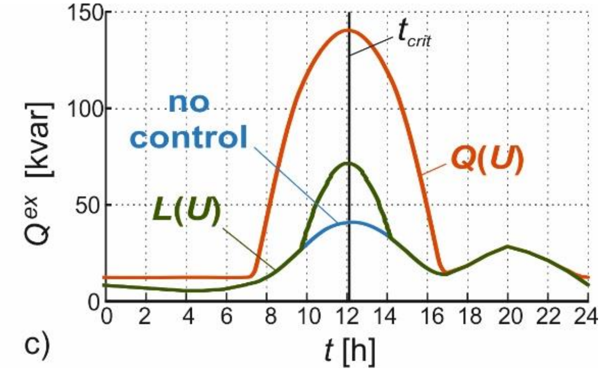
Grid losses:



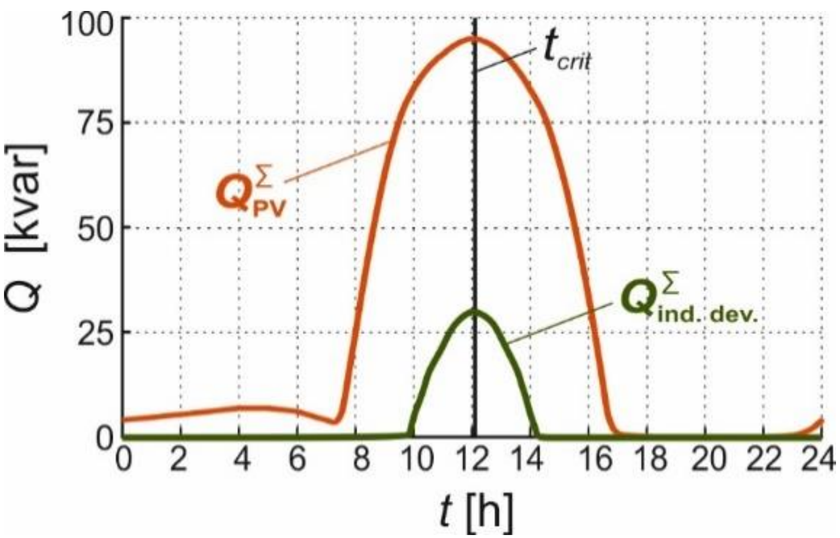
DTR loading:



***Q*-exchange:**



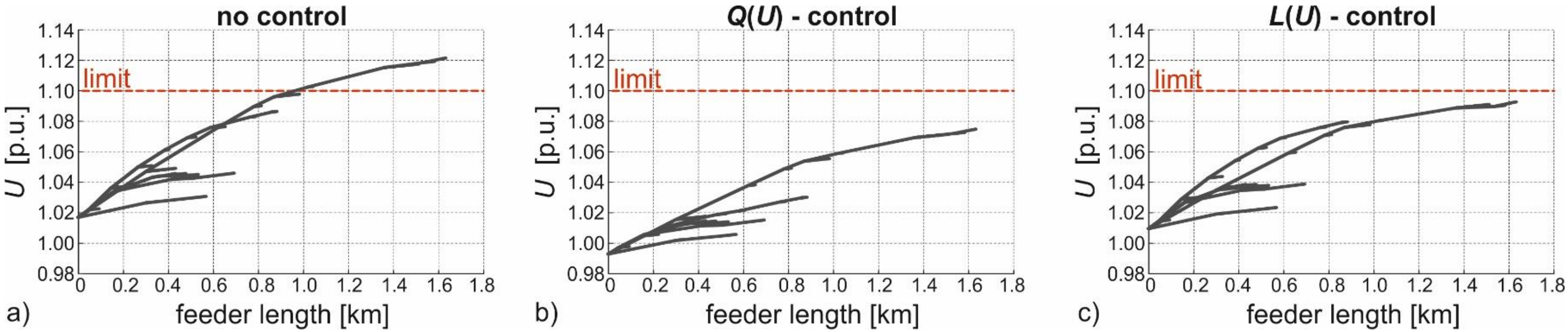
***Q*-consumption of control devices:**



Q(*U*)-controlled PV-inverters absorb more reactive power in total than *L*(*U*)-controlled inductive devices, leading to:

- High grid losses
- High DTR loading
- High *Q*-exchange

LVG voltage profiles at t_{crit}

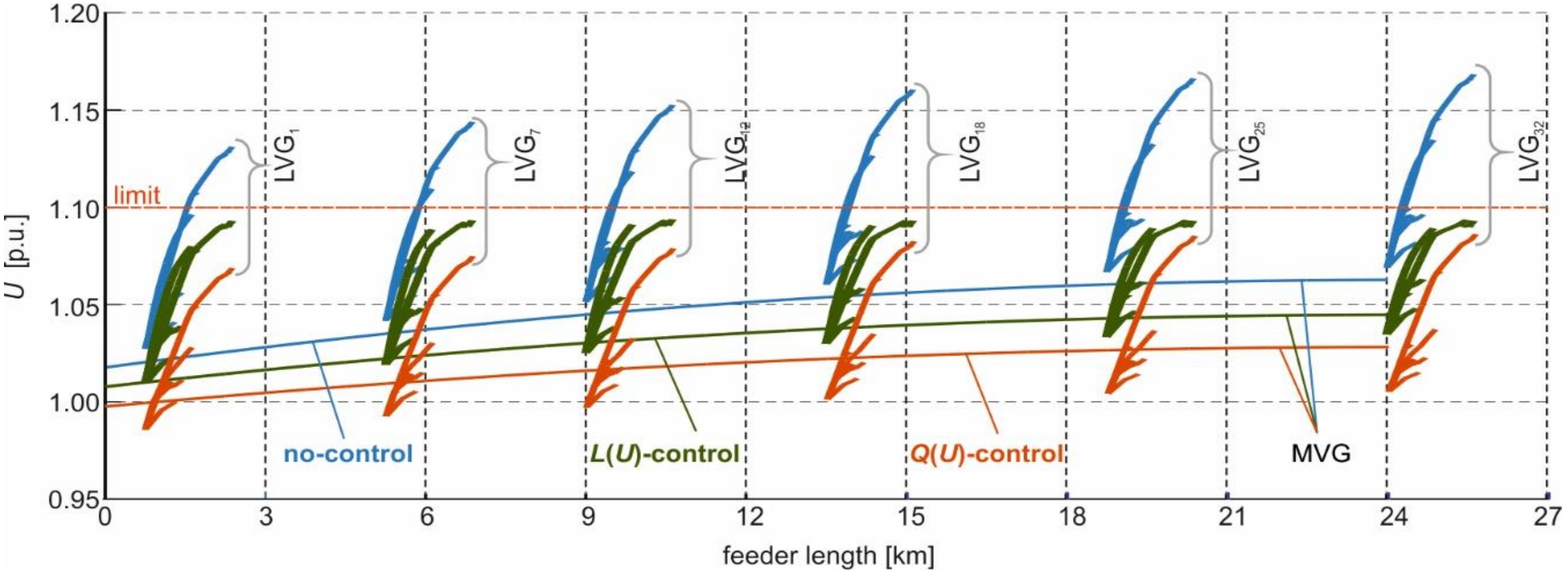


No-control → violations of the upper voltage limit appear.

Q(*U*)-control → eliminates limit violations.
→ decreases LVG voltages more than necessary.

L(*U*)-control → eliminates limit violations.
→ decreases LVG voltages as required.

MVG & LVG voltage profiles at t_{crit}



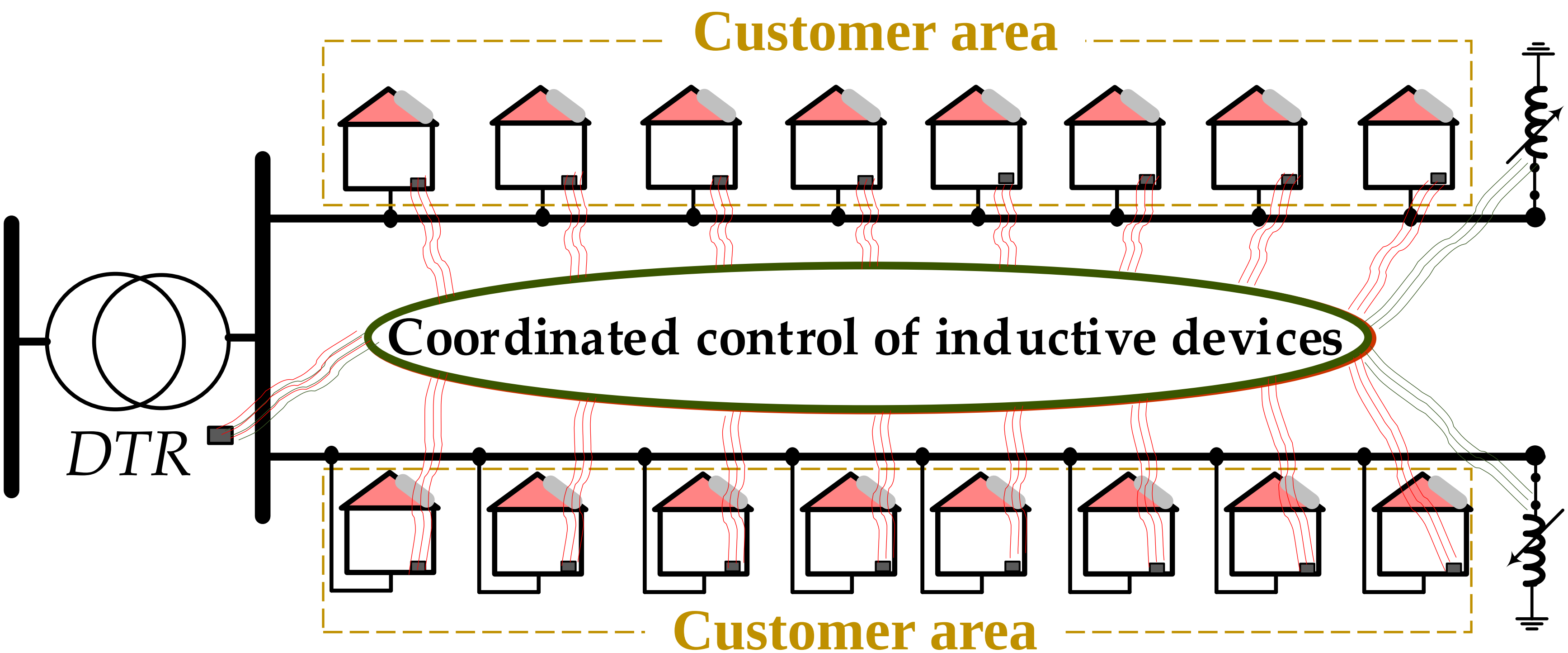
- No-control → violations of the upper voltage limit appear in all LVGs.

- *Q*(*U*)-control → eliminates limit violations.
  → decreases MVG and LVG voltages more than necessary.
  → provokes relative large voltage drops in DTRs.

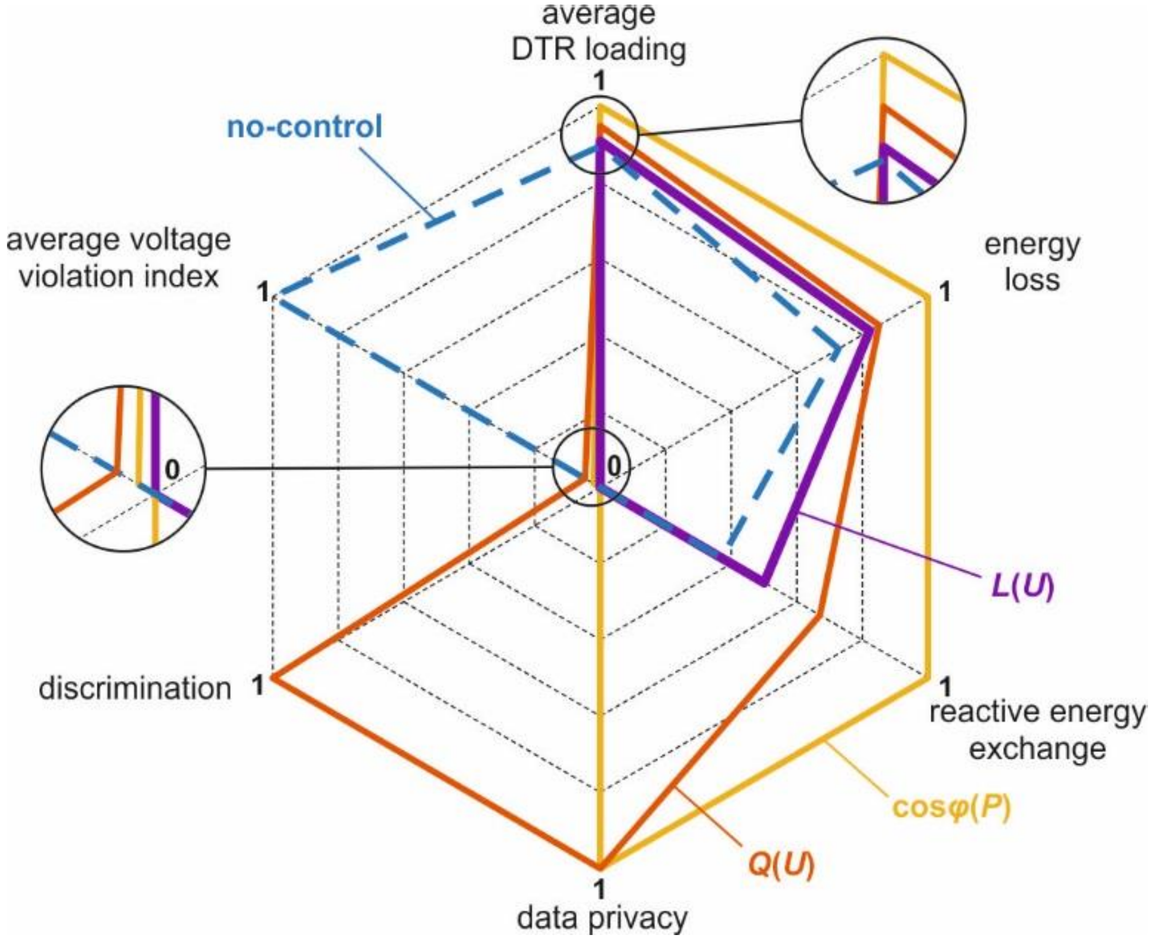
- *L*(*U*)-control → eliminates limit violations.
  → decreases MVG and LVG voltages as required.
  → provokes relative small voltage drops in DTRs

Actual solution
ICT challenge and data privacy violation

LINK-Solution
Neither ICT challenge nor data privacy violation



Overall performance evaluation of reactive power control strategies in low-voltage grids



Source: D.-L. Schultis, A. Ilo, et al., Overall performance evaluation of reactive power control strategies in low voltage grids with high prosumer share, EPSR. 2019, vol. 168, pp. 336-349.

Conclusions

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

Social benefits:

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

Technical/economical benefits:

- All violations of the upper voltage limit are eliminated.
- MVG voltages are less suppressed.
- ICT challenge / threat to cyber attacks is reduced. → **cost reduction**
- Volt / var management tasks in LVGs are simplified. → **cost reduction**
- Grid losses, DTR loading and Q-exchange are reduced. → **cost reduction**

Additional expenditures:

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

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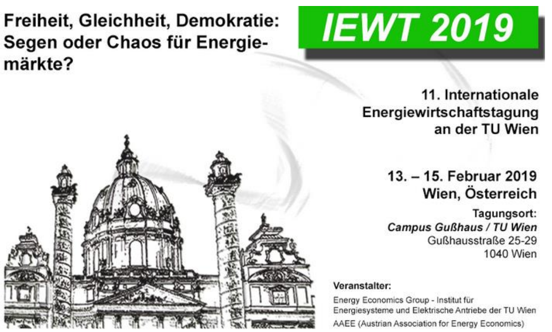

Thank you for your attention

Daniel-Leon Schultis, Albana Ilo