Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

STROMNETZE Forschungsinitiative der Bundesregierung

U-Control

# U-Control – Recommendations for Distributed and Automated Voltage Control in Current and Future Distribution Grids


Ole Marggraf, TU Braunschweig

*7th Solar Integration Workshop in Berlin 24-25 October 2017*

Technische Universität Braunschweig · TUM Technische Universität München · FGH · RWTH AACHEN UNIVERSITY · SMA · MR · INFRAWEST · Netze BW · bayernwerk

24.10.2017

# Agenda

1 Introduction

2 Recommendations for action for distribution system operators

3 Recommendation for action for manufacturers

4 Recommendation for action for standardization committees

5 Outlook and conclusion

# Agenda

1 Introduction

2 Recommendations for action for distribution system operators

3 Recommendation for action for manufacturers

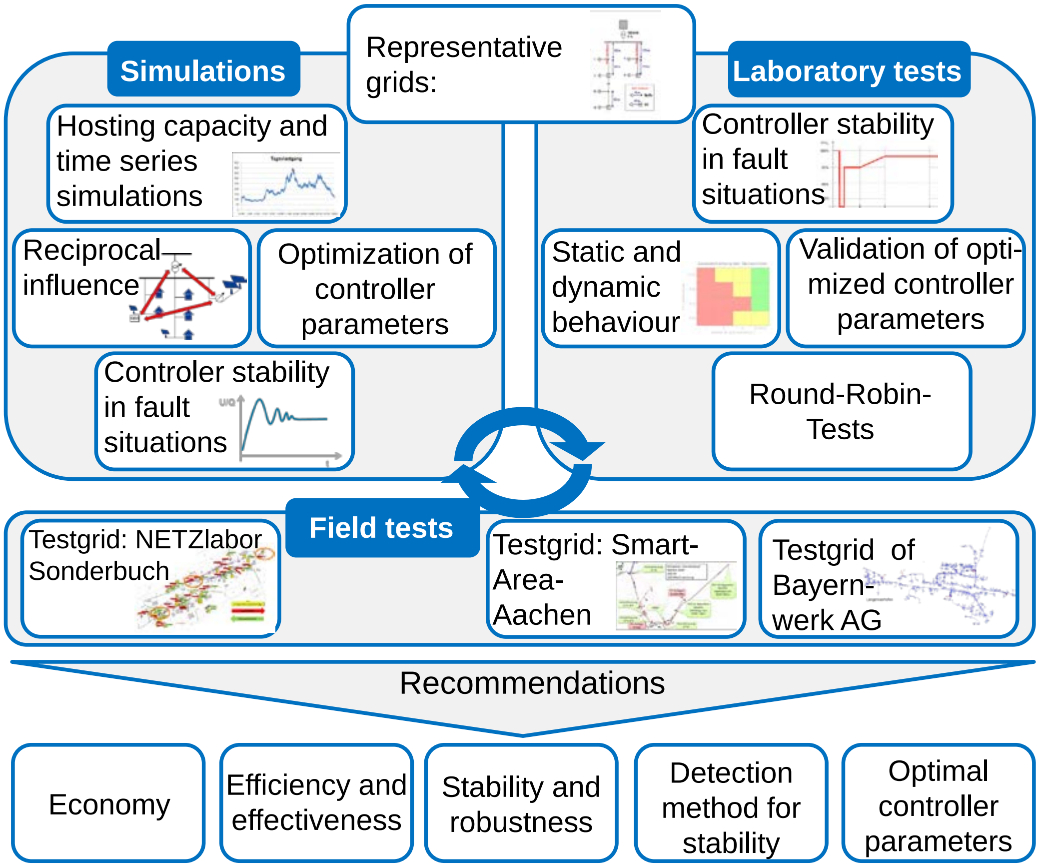
4 Recommendation for action for standardization committees

5 Outlook and conclusion

# Structure and target questions of the project

## Objective

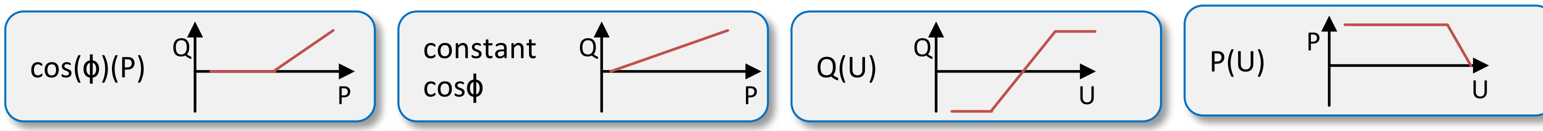
- Comparison of voltage control strategies regarding:
  - Effectiveness
  - Efficiency
  - Economics
- Analysis of stability and robustness of voltage controller in
- Ensuring of the combinability of different controller
- Point up the stability limits of voltage controller
- Optimization of the controller parameters and characteristics



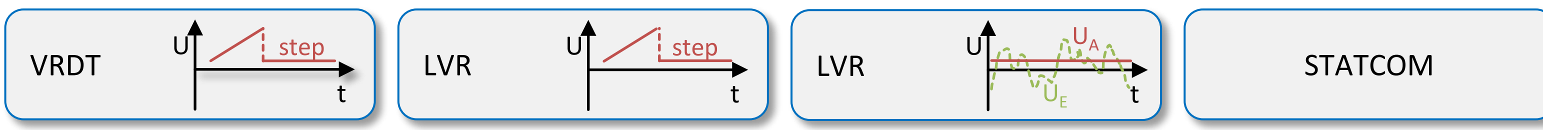

Technische Universität Braunschweig · Technische Universität München · FGH · RWTH Aachen University · SMA · MR · INFRAWEST · Netze BW · bayernwerk

# Investigated voltage control concepts

Inverter based voltage control concepts




Voltage control with smart grid equipment




VRDT

Source: MR

LVR

Source: Ruhstrat

STATCOM

Source: MR

PV-inverter

Source: SMA

Characteristics:

- Decentral
- Autonomous
- No communication

Focus on closed loop controller

# Agenda

1 Introduction

2 Recommendations for action for distribution system operators

3 Recommendation for action for manufacturers

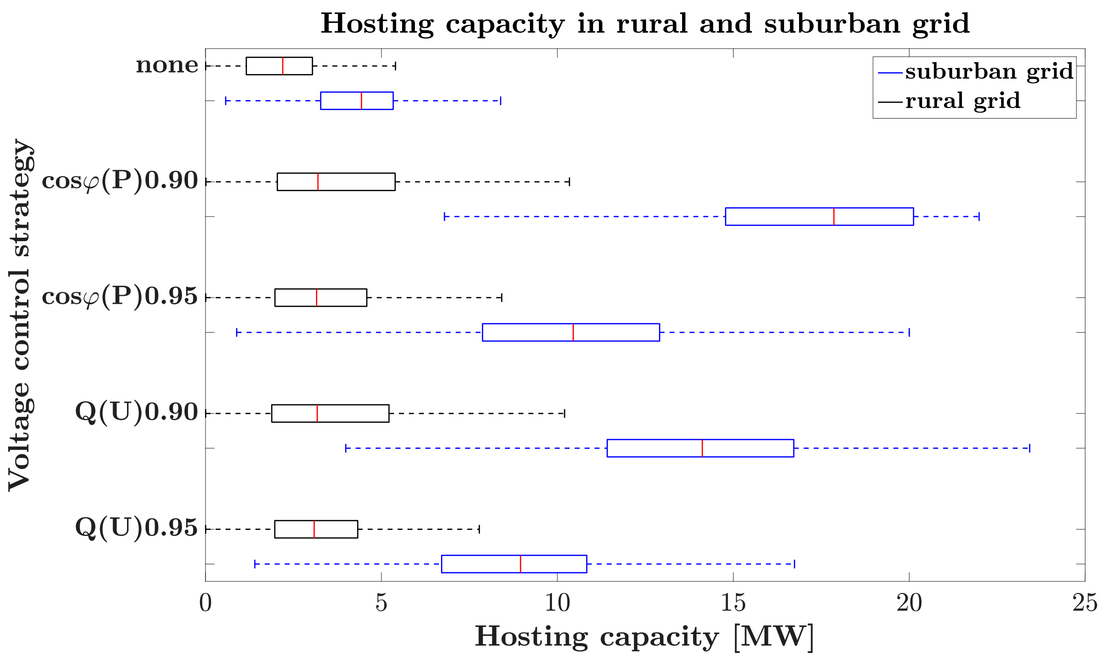
4 Recommendation for action for standardization committees

5 Outlook and conclusion

Q(U) control in future low voltage grids

**Voltage control with distributed generators: cosφ(P) vs. Q(U)**

- Hosting capacity simulations with two grid models
- Probabilistic approach with 1000 repetitions
- Effectivity of Q(U) and cosφ(P) in rural grids quite equal
- Increase of hosting capacity of 50 % (median)
- Higher hosting capacity with cosφ limit 0,9

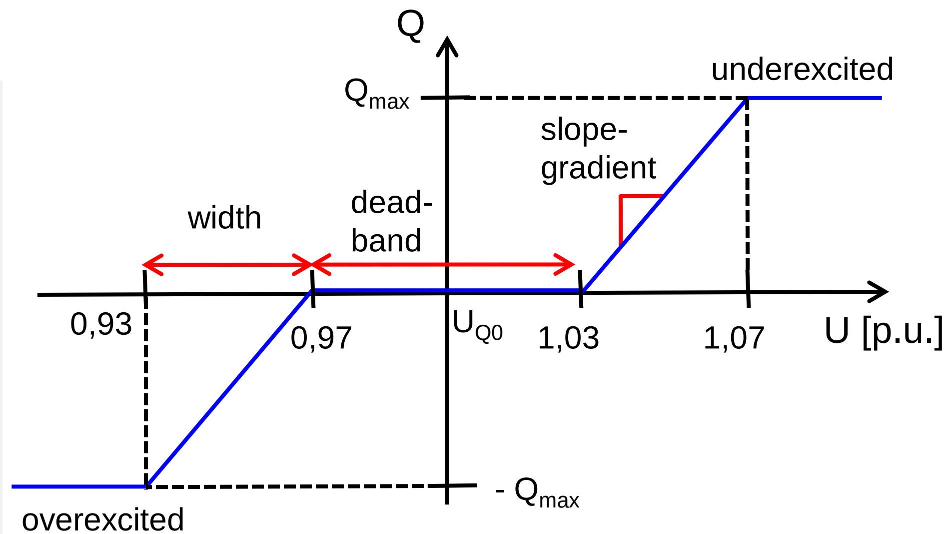


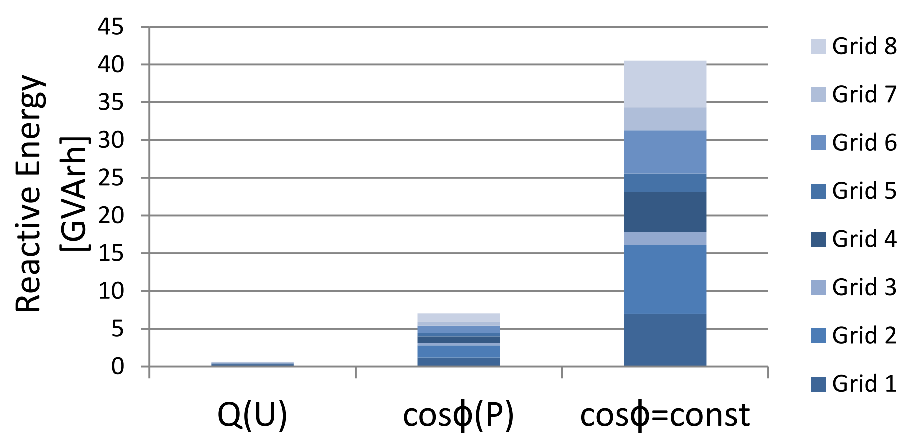

➔ **Conclusion: Q(U) and cosφ(P) lead in rural grids to equal increase of hosting capacity**

# Optimal use with only one uniform Q(U) characteristic

## Optimal Q(U) characteristic

- Recommended characteristic was tested in:
  - Simulations (4 Institutes)
  - Laboratory tests (3 lab.)
  - Field tests (3 DSO)
- Wide Dead band minimize reactive energy
- Stability aspects lead to a limitation of the width to 2 %
- Characteristic is a compromise of effectivity (high hosting capacity) and efficiency (low reactive energy)
- With Q(U) reduction of reactive energy by more than 90 % compared with cosφ(P) possible
- Q(U) supports grid integration of electro mobility




➔ **Conclusion: Q(U) allows needs-based provision of reactive power for voltage control**

# Q(U) and VRDT/LVR tested together in laboratory- and field tests

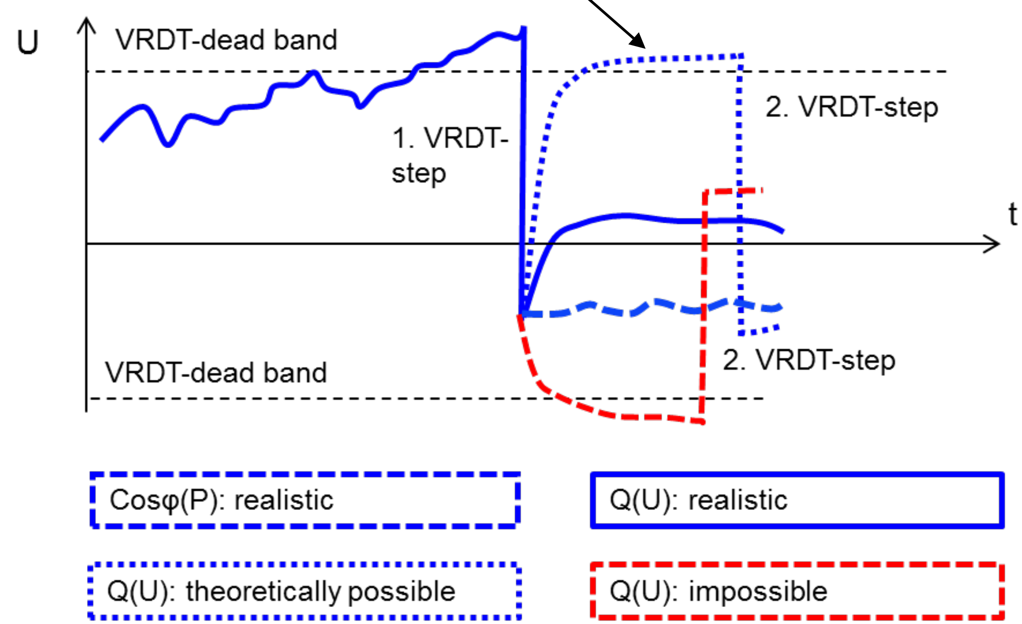
**Interplay of Q(U) with VRDT and LVR**

- VRDT and LVR act like deactivation of Q(U) control
  ➔ less reactive energy
- No oscillating controller interactions of VRDT/LVR and Q(U) possible
- Theoretically possible: Q(U) causes a second VRDT/LVR-controller step in same direction of the first
  ➔ less reactive energy
- 96 % of all VRDT steps in the field tests lead to decreased or constant reactive power from Q(U)

**Example:**

- 630 kVA VRDT; 2.5 % step voltage
- Recommended Q(U) characteristic

➔ 1 MVA DG needed




**➔ Conclusion: Positive interplay of Q(U) control with VRDT and LVR**

# Agenda

1 Introduction

2 Recommendations for action for distribution system operators

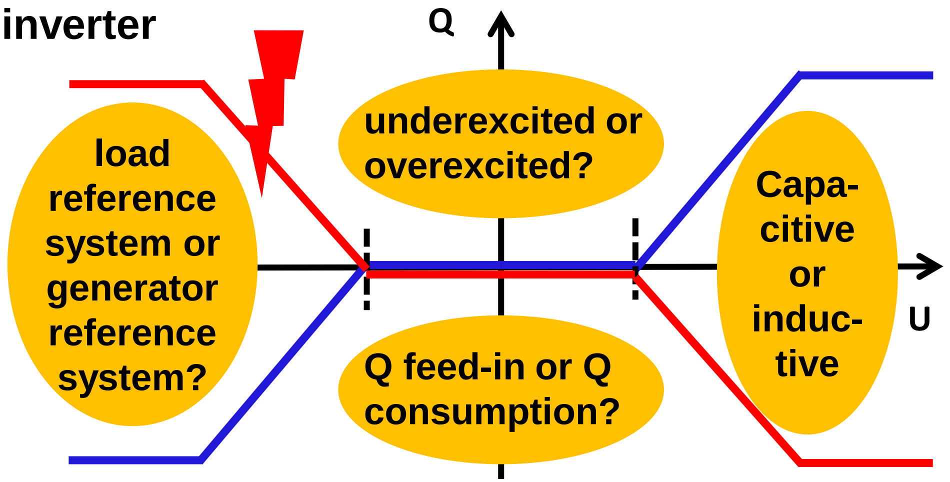
3 **Recommendation for action for manufacturers**

4 Recommendation for action for standardization committees

5 Outlook and conclusion

# Implementing Q(U) control: Minimization of failure potential

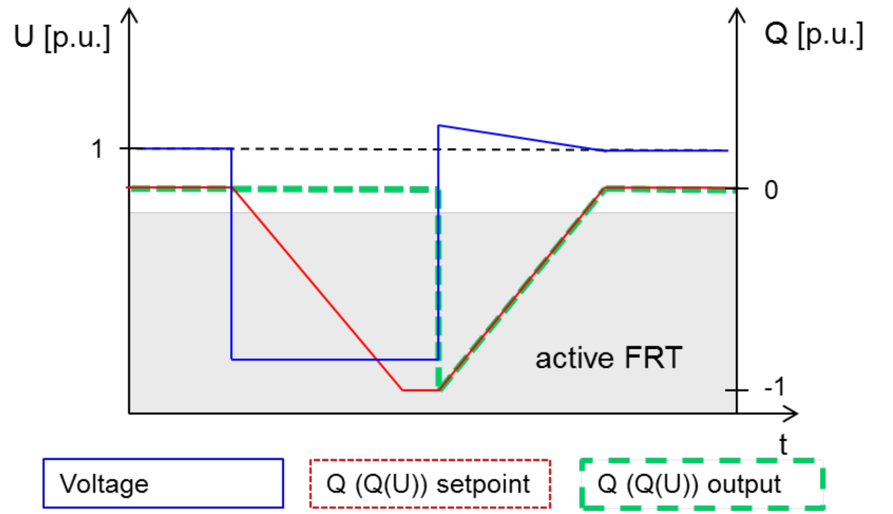
## Recommendations for manufacturers of inverter




- Set Q(U) control as default setting with recommended characteristic ➔ Less incorrect parametrization
- Give DSO the option for change characteristic
- Proof of correct parameterization of under- and overexcited operation mode

## Voltage control in fault situations

- Q(U) with ratelimiter for reactive power (possibility of interactions with anti islanding detection AID)
- Q(U) Q-set point reset when leaving FRT mode (risk of over voltage)
- VRDT and LVR in fault situations ➔ under voltage blocking function



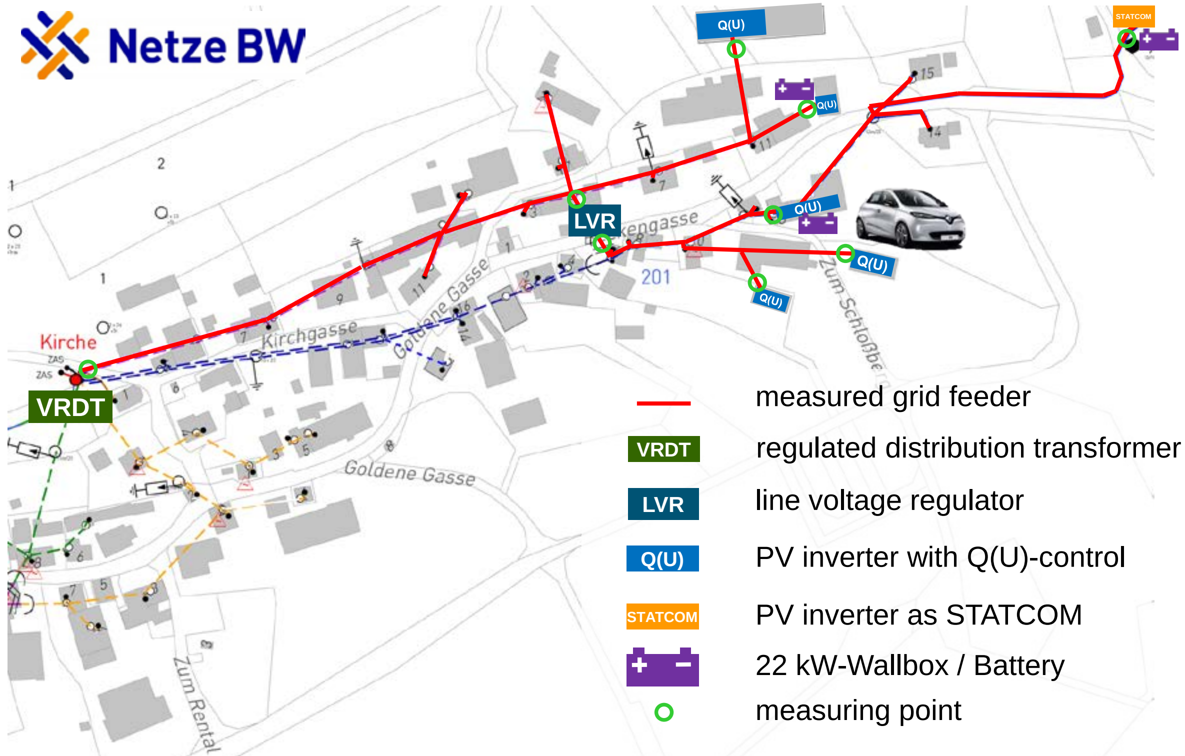
µ-Control

# Agenda

1. Introduction
2. Recommendations for action for distribution system operators
3. Recommendation for action for manufacturers
4. **Recommendation for action for standardization committees**
5. Outlook and conclusion

# Q(U) control tested in simulations, laboratory- and field tests

- Three field tests:
  - NETZlabor Sonderbuch (Netze BW)
  - Bayernwerk
  - Infrawest
- Tested controllers: VRDT, LVR, Q(U) and STATCOM (alone and in combination)
- Tests of different controller parameters





**➔ Investigations regarding effectivity, efficiency and stability recommend the Q(U)**

# Amendment of the German standard VDE-AR-N 4105 and VDE 0124-100

**Q(U) as default setting for voltage control**

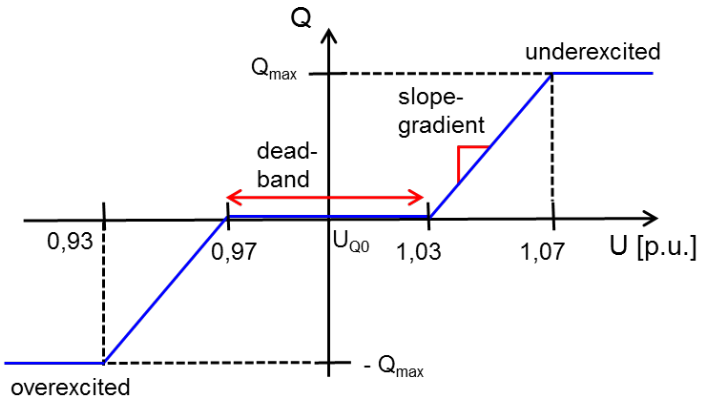
- need-oriented voltage control with reactive power
- Many DSO without voltage control problems
- Less incorrect parametrization
- Less reactive energy for voltage control

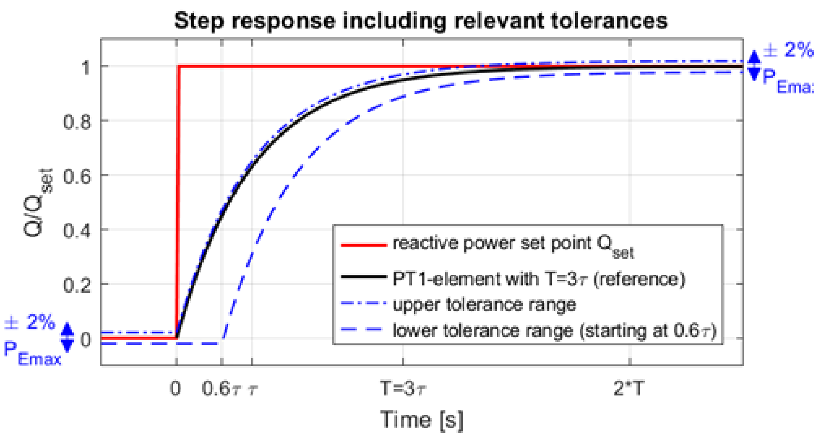
**Uniform default Q(U) characteristic**

- Only small profit with individual optimized characteristics
- Possibility to set a DSO-specific characteristic should be given

**Verify dynamic behavior of Q(U) control**

- PT1 behavior of the Q(U) control (T = 3 - 60 s)
- Dynamic and static behavior of Q(U) control should be proofed in type tests




➔ **VDE and 'U-Control' consortium together develop the future of voltage control**

# Agenda

1 Introduction

2 Recommendations for action for distribution system operators

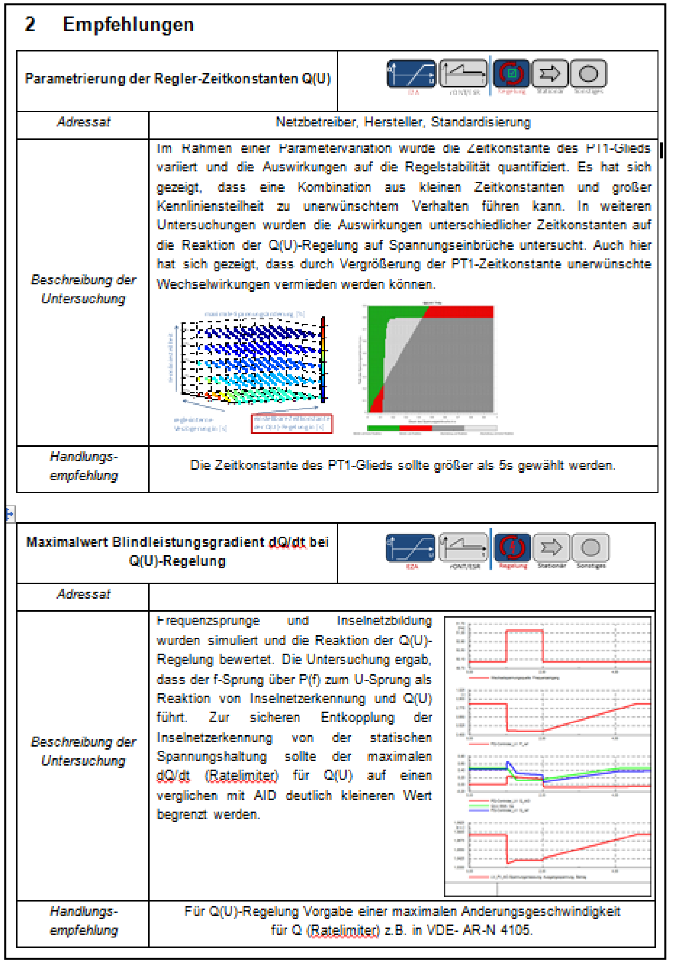
3 Recommendation for action for manufacturers

4 Recommendation for action for standardization committees

5 **Outlook and conclusion**

# Outlook

- Only a small extract from the whole results and recommendations were be given
- Catalogue with concrete recommendations for action is under preparation
- Detailed results and recommendations regarding the hosting capacity and the economics will follow (simulations in progress)
- Project will be finished by end of Feb. 2018



## 2 Empfehlungen

| Parametrierung der Regler-Zeitkonstanten Q(U) | |
|---|---|
| *Adressat* | Netzbetreiber, Hersteller, Standardisierung |
| *Beschreibung der Untersuchung* | Im Rahmen einer Parametervariation wurde die Zeitkonstante des PT1-Glieds variiert und die Auswirkungen auf die Regelstabilität quantifiziert. Es hat sich gezeigt, dass eine Kombination aus kleinen Zeitkonstanten und großer Kennliniensteilheit zu unerwünschtem Verhalten führen kann. In weiteren Untersuchungen wurden die Auswirkungen unterschiedlicher Zeitkonstanten auf die Reaktion der Q(U)-Regelung auf Spannungseinbrüche untersucht. Auch hier hat sich gezeigt, dass durch Vergrößerung der PT1-Zeitkonstante unerwünschte Wechselwirkungen vermieden werden können. |
| *Handlungs-empfehlung* | Die Zeitkonstante des PT1-Glieds sollte größer als 5s gewählt werden. |

| Maximalwert Blindleistungsgradient dQ/dt bei Q(U)-Regelung | |
|---|---|
| *Adressat* | |
| *Beschreibung der Untersuchung* | Frequenzsprunge und Inselnetzbildung wurden simuliert und die Reaktion der Q(U)-Regelung bewertet. Die Untersuchung ergab, dass der f-Sprung über P(f) zum U-Sprung als Reaktion von Inselnetzerkennung und Q(U) führt. Zur sicheren Entkopplung der Inselnetzerkennung von der statischen Spannungshaltung sollte der maximalen dQ/dt (Ratelimiter) für Q(U) auf einen verglichen mit AID deutlich kleineren Wert begrenzt werden. |
| *Handlungs-empfehlung* | Für Q(U)-Regelung Vorgabe einer maximalen Anderungsgeschwindigkeit für Q (Ratelimiter) z.B. in VDE- AR-N 4105. |

# Conclusion

- Simulations of four research institutes, tests in three laboratories and three field tests lead to recommendations for action

- The following stakeholder are addressed with the recommendations:
  - Distribution system operators
  - Manufacturers of DG and voltage control equipment
  - Standardization committees

- Future distribution grids with numerous decentralized and autonomous voltage controllers can be managed stable and secure

- Therefore it is necessary to implement the given recommendations regarding:
  - Stable and secure controller parameters
  - Controller performance
  - Characteristics and
  - Test procedures and test setups

# Thank you for your attention


Ole Marggraf
Technische Universität Braunschweig
Institut für Hochspannungstechnik und Elektrische Energieanlagen – elenia
Tel: +49 (0) 531 391 9718
Mobil: +49 (0) 15773452032
Email: o.marggraf@tu-braunschweig.de

Institut für Hochspannungstechnik und Elektrische Energieanlagen

**Authors:**

Ole Marggraf, Stefan Laudahn, Bernd Engel, Marco Lindner, Christian Aigner, Rolf Witzmann, M. Schoeneberger, Sören Patzack, H. Vennegeerts, Michael Cremer, Marian Meyer, Armin Schnettler, Thorsten Bülo, Franco Pizzutto, Robert Frings, Imen Ghourabi, Andre Großhans, Frank Wirtz, Johannes Brantl

Technische Universität Braunschweig

Technische Universität München

24.10.2017