

EES-UETP Course “Protection of Future Networks with Distributed Generation”

Impacts of DER on Distribution System Protection

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Outline

Impacts of Distributed Energy Resources (DER) on Distribution System Protection

1. Introduction
 - a) Distributed Generation
 - b) New framework conditions for network protection and control
2. Classification of impacts of DER
3. Discussion of selected challenges
 - a) Sympathetic tripping
 - b) Difficulties with direction determination
 - c) Intermediate infeeds / “Blinding” of protection
 - d) Intermittent infeed and source impedance
 - e) Anti islanding / Loss of mains protection
 - f) Coordination concerning automatic reclosing
4. Weaknesses of conventional protection and control
5. Outlook – Concepts for future distribution networks
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1. Introduction

a) Distributed Generation

The term “Distributed Generation”
involves many different types of
Distributed Energy Resources (DER)
like e.g.:



PV system



Wind turbine



Marine current turbine

Source: Marine Current Turbines Ltd

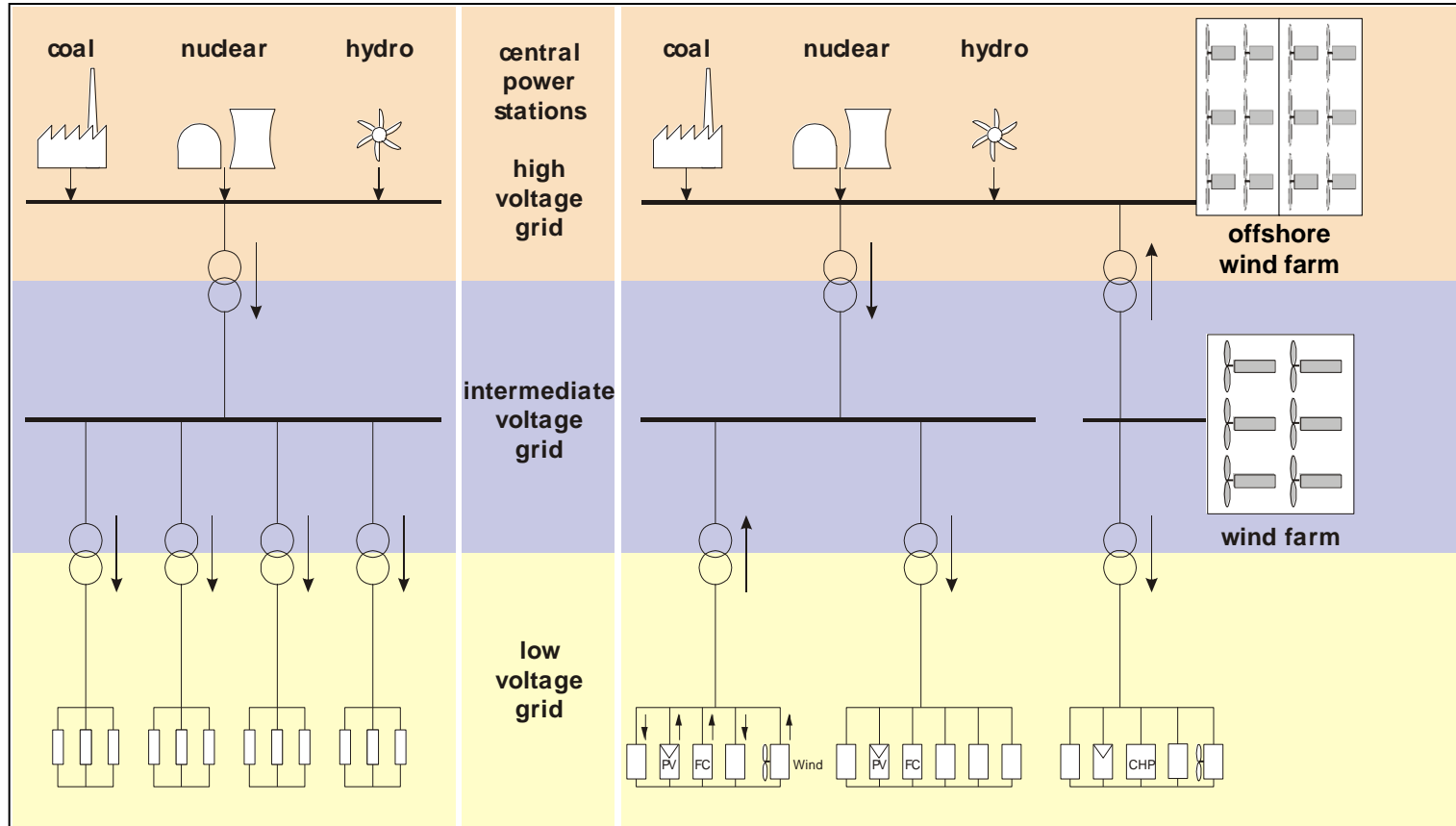


Biomass power plant / CHP



1. Introduction

a) Distributed Generation



Centralized versus decentralized supply structure

Source: T. Degner, J. Schmid, P. Strauss (Editors): DISPOWER – Final Public Report, 2006



1. Introduction

b) New framework conditions for network protection and control

An increasing number of DER is installed all over the distribution level

- Bi-directional power flow
 - normal operating conditions: DER contributing to load currents
 - fault conditions: DER contributing to SC currents

A large variety of DER technologies has to be considered

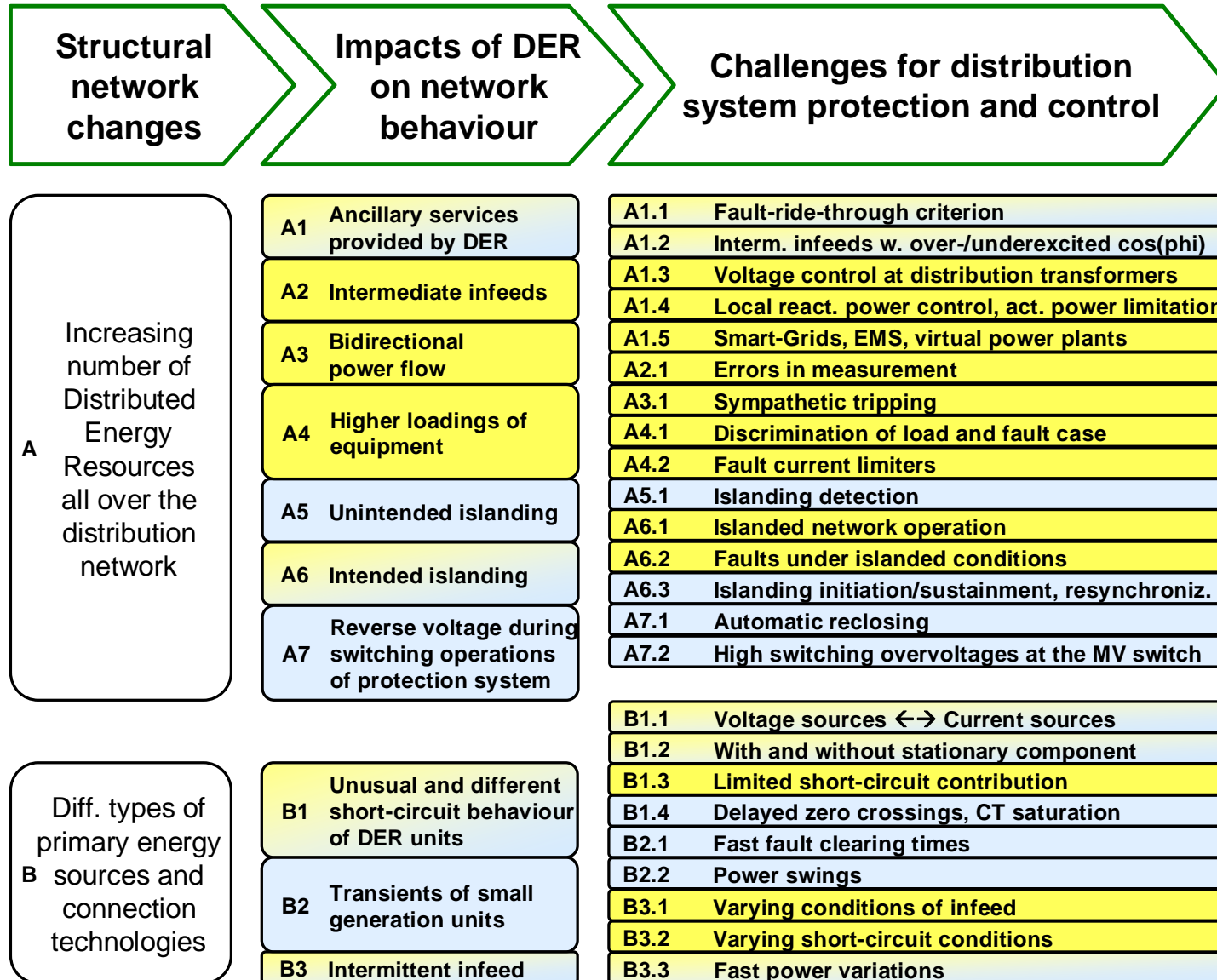
- Different types of DER technologies
 - primary energy source (intermittent/steady, un-/controllable)
 - principle of generation (SM, ASM, DFIG, PV, fuel cells, ...)
- Different DER connection technologies
 - directly coupled, converter coupled, ...

New network operating conditions must be considered

- Interconnected and islanded operation
- Reconnection / Synchronism restoration of
 - single DER units
 - grid sections
- Coordination concerning automatic reclosing



2. Classification of impacts of DER



2. Classification of impacts of DER

A: Increasing number of DER all over the distribution network

A1	Ancillary services provided by DER	A1.1	Fault-ride-through criterion
A2	Intermediate infeeds	A1.2	Interm. infeeds w. over-/underexcited $\cos(\phi)$
A3	Bidirectional power flow	A1.3	Voltage control at distribution transformers
A4	Higher loadings of equipment	A1.4	Local react. power control, act. power limitation
A5	Unintended islanding	A1.5	Smart-Grids, EMS, virtual power plants
A6	Intended islanding	A2.1	Errors in measurement
A7	Reverse voltage during switching operations of protection system	A3.1	Sympathetic tripping
		A4.1	Discrimination of load and fault case
		A4.2	Fault current limiters
		A5.1	Islanding detection
		A6.1	Islanded network operation
		A6.2	Faults under islanded conditions
		A6.3	Islanding initiation/sustainment, resynchroniz.
		A7.1	Automatic reclosing
		A7.2	High switching overvoltages at the MV switch

Color code: Impacts on steady-state (yellow) and transient (blue) network behavior

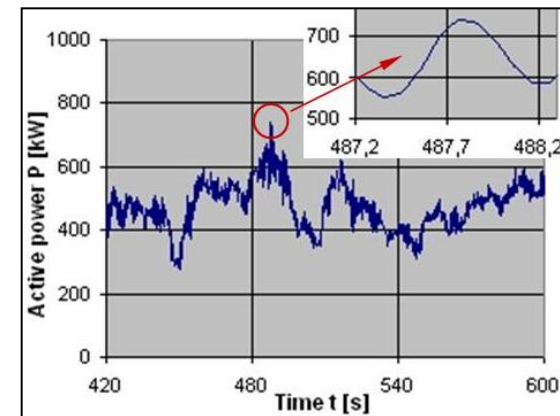
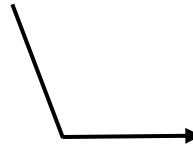


2. Classification of impacts of DER

B: Different types of primary energy sources and connection technologies

B1	Unusual and different short-circuit behaviour of DER units
B2	Transients of small generation units
B3	Intermittent infeed

B1.1	Voltage sources \leftrightarrow Current sources
B1.2	With and without stationary component
B1.3	Limited short-circuit contribution
B1.4	Delayed zero crossings, CT saturation
B2.1	Fast fault clearing times
B2.2	Power swings
B3.1	Varying conditions of infeed
B3.2	Varying short-circuit conditions
B3.3	Fast power variations



Wind turbine (600 kW)

Color code:

Impacts on steady-state (yellow)
and transient (blue) network behavior

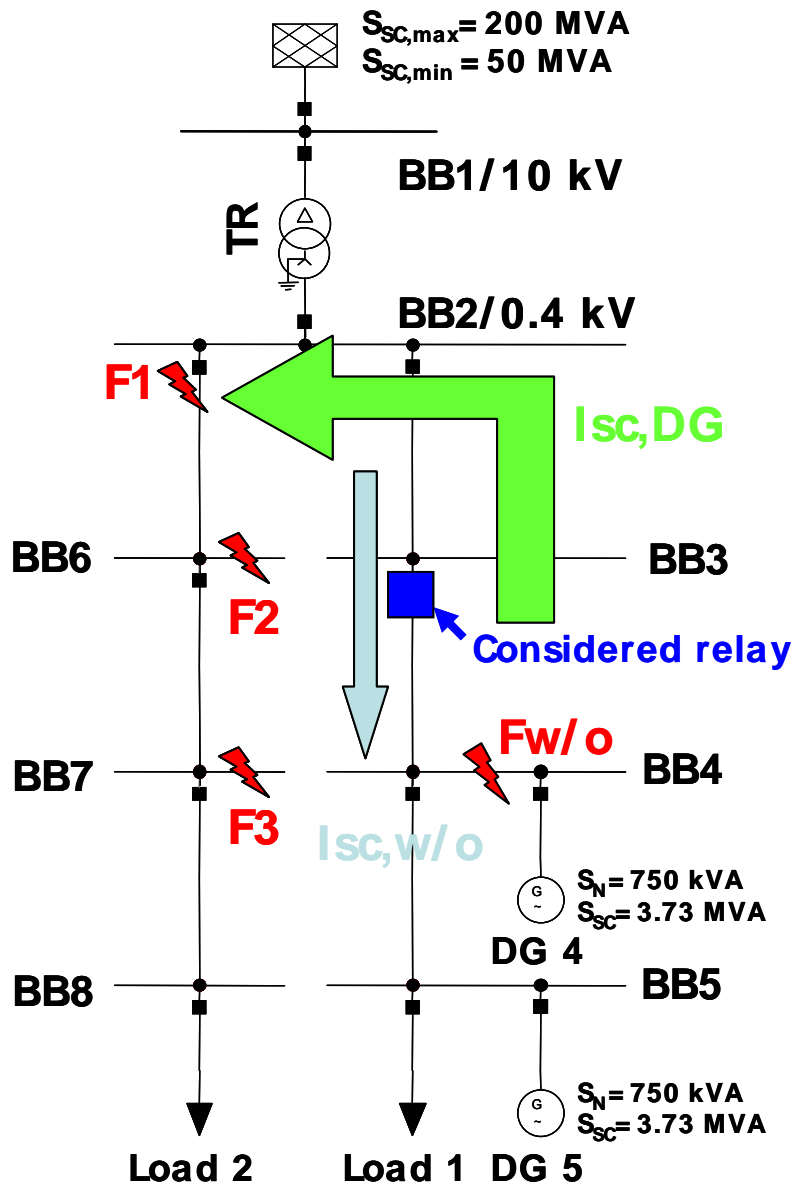


3. Discussion of selected challenges

a) Sympathetic tripping

Case study:
Sympathetic tripping of a relay
at an adjacent "healthy" feeder

Different fault scenarios
F1, F2 and F3



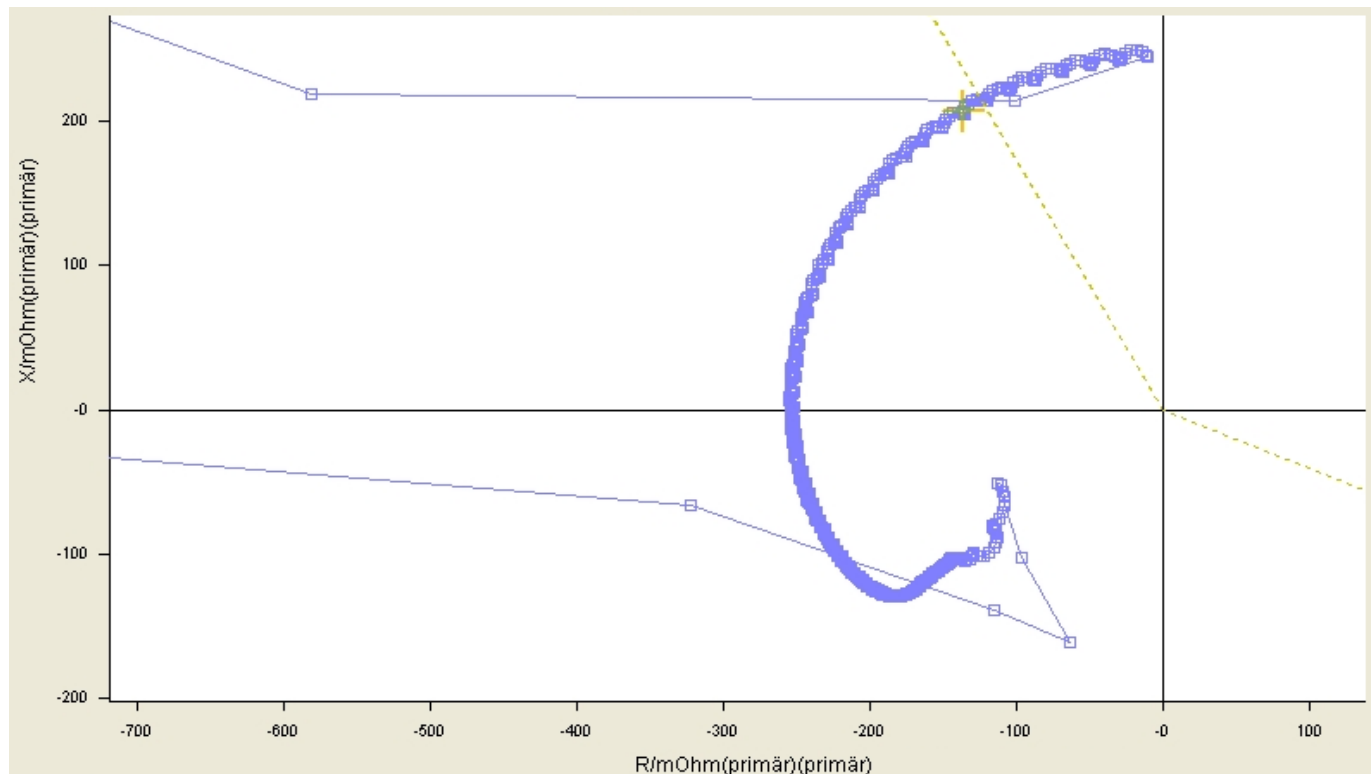
→ Direction determination required!

3. Discussion of selected challenges

b) Difficulties with direction determination

Example: 3-ph fault in a 20 kV network with DER (synchronous generator)

- High grading times, low stored energy constant
- Generator accelerates and transient load angle increases
- Measured impedance moves from backward to forward zone



→ Wrong direction determination!

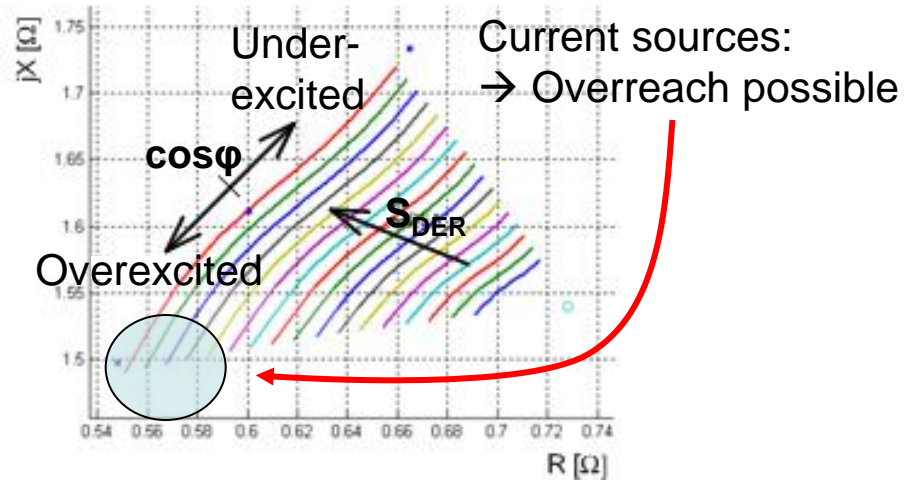
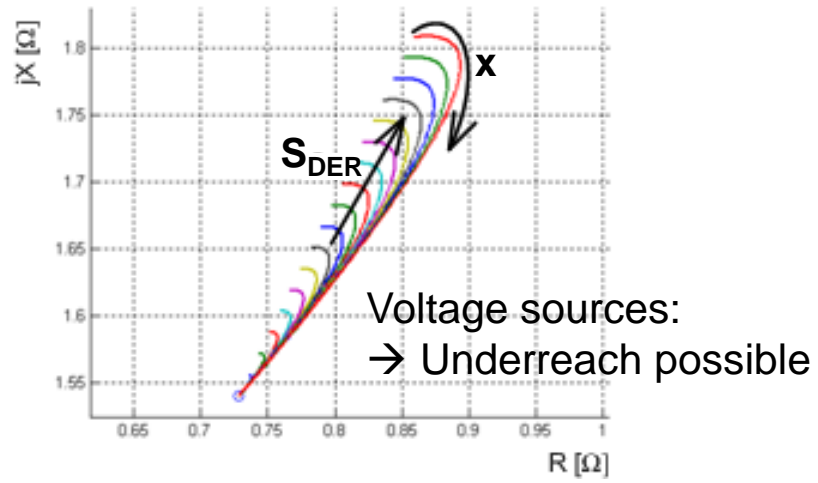
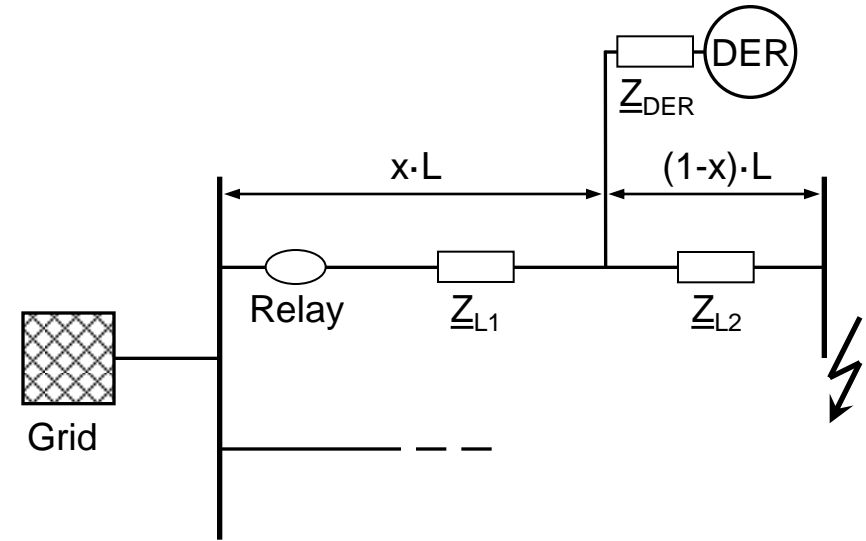


3. Discussion of selected challenges

c) Intermediate infeeds / "Blinding" of protection

$$\underline{Z}_{Relay} = \frac{V_{ph-ph}}{I_{ph-ph}} =$$

$$\underline{Z}_{Relay} = \underline{Z}_{L1} + \underline{Z}_{L2} + \underbrace{\frac{I_{DER}}{I_{ph-ph}} \cdot \underline{Z}_{L2}}_{error}$$



→ Errors in measurement due to intermediate infeeds!



3. Discussion of selected challenges

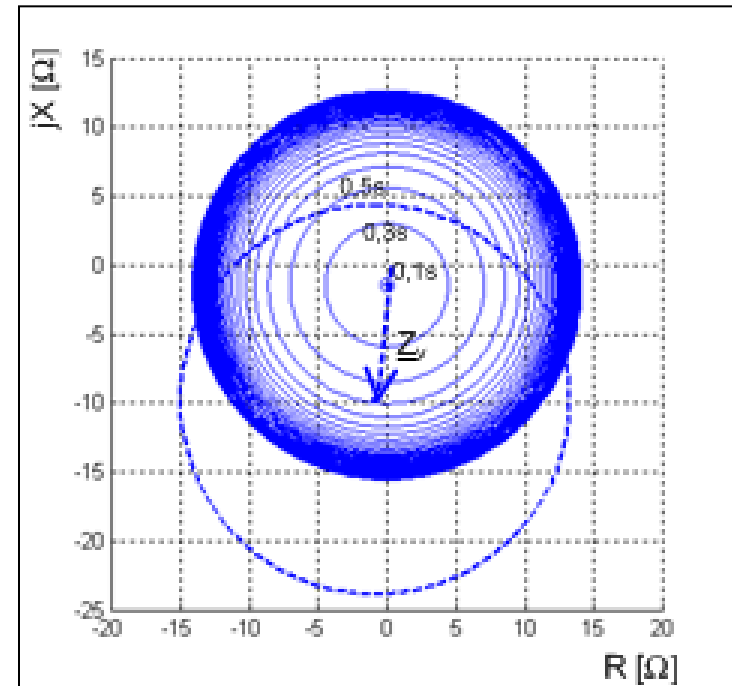
d) Intermittent infeeds and source impedance

Protection based on current criteria:

- Consideration in the impedance plane
- Pick-up circle depends on source impedance

Problem:

- Intermittent infeed of DER
- Intermittent source impedance
- No defined / fixed pick-up area
- No clear pick-up conditions!



Pick-up zones in the R/X-plane

→ Dependence on source impedance!

3. Discussion of selected challenges

e) Anti islanding / Loss of mains protection

	Method	Realization	Reliability	Compatibility
passive	Under/over voltage, Under/ over frequency, Rate of change of frequency or voltage	low cost, easy	quite unreliable	very good
	Voltage vector shift, phase displacement	difficult definition of limits	moderate	very good
	Monitoring of harmonics	difficult definition of limits	moderate	very good
active	Impedance measurement	quite easy	good, not reli- able in mass deployment	good
	Frequency shift / Voltage shift	easy	effective	negative influence on output power
	Injection of a pilot signal	quite easy	effective	good
.	DMS / Enhanced communication options	high effort	very effective	very good

→ **Reliable and fast anti islanding protection required!**

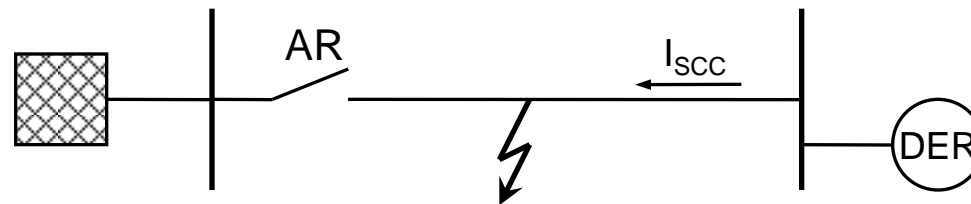


3. Discussion of selected challenges

f) Coordination concerning automatic reclosing

Possible challenges when applying automatic reclosing (AR)

- During dead time the DER unit may feed the electric arc
- No deionization → automatic reclosing not successful!
- Mechanical damage of DER possible (asynchronous reclosing)



→ Fast disconnection at both sides required!



4. Weaknesses of conventional protection and control

When connecting DER to the power system not only calculations regarding voltage control, power quality etc. have to be carried out.

Reliable distribution system operation also requires careful consideration of the following weaknesses of conventional protection...

- High / graded tripping times
- Missing or wrong direction determination
- Measuring error due to intermediate infeed
- Dependence on source impedance (for current criteria)
- Fast LoM protection / tripping at both sides (automatic reclosing) required

...and control concepts:

- Ancillary services provided by DER
- LoM protection and automatic reclosing
- Communication infrastructure



5. Outlook – Concepts for future distribution networks

- Further development of the distance protection technology regarding direction determination and islanding detection
- Analysis of the time overcurrent function regarding compensation/elimination of the source impedance and application of optimization procedures
- Application of further communication and information technologies / Coupling with the distribution management system → Smart Grids
- Extended application of differential protection systems
- Utilization of adaptive network protection technologies
- ...



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Thank you for your attention!

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