Anforderungen an moderne Kraftwerke - Voltage Ride Through

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System Operation and Faults

System Stability

Network Codes

Testing and Simulation

IFEA – Institut für Elektrische Anlagen

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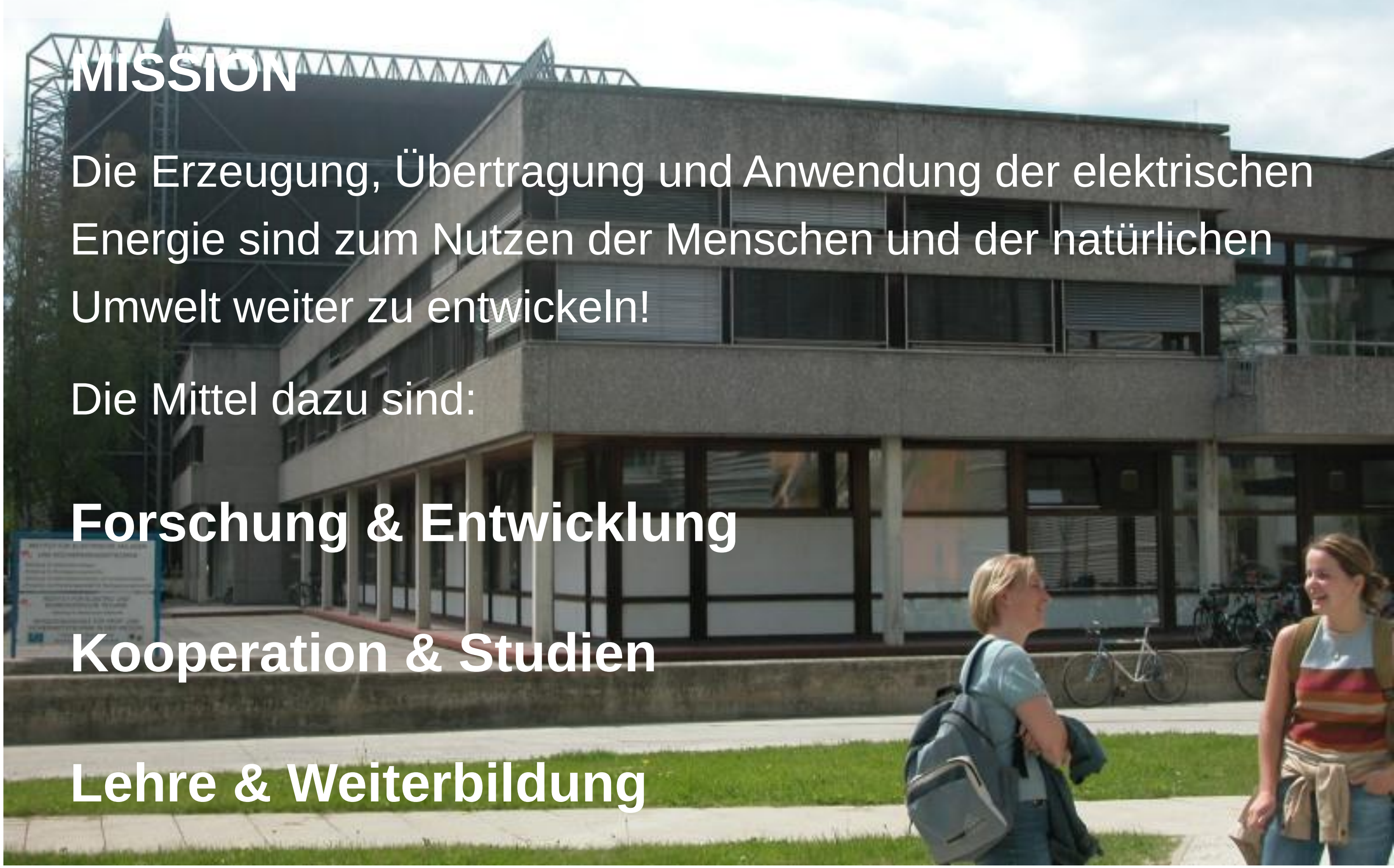

MISSION

Die Erzeugung, Übertragung und Anwendung der elektrischen Energie sind zum Nutzen der Menschen und der natürlichen Umwelt weiter zu entwickeln!

Die Mittel dazu sind:

Forschung & Entwicklung

Kooperation & Studien

Lehre & Weiterbildung

IFEA – Institut für Elektrische Anlagen

Wir verpflichten uns zu
Wahrheit,
Objektivität,
Neutralität

Univ.-Prof + Ao. Univ.-Prof + Senior Researcher		**3**
Univ.-Ass. + Univ.Projekt-Ass.	**3 + 14 =**	**16**
Studentische MitarbeiterInnen		**8**
Lektoren und Gastvortragende		**15**
Partner/ Kontakte		**105**

Elektroindustrie,
National und International (AT, EU)
Privatwirtschaft (AT, IT, DE, CZ, BLG, MKD, TR, GB, FR)
Kooperationen, …

Projekte (pro Jahr) ~ 60

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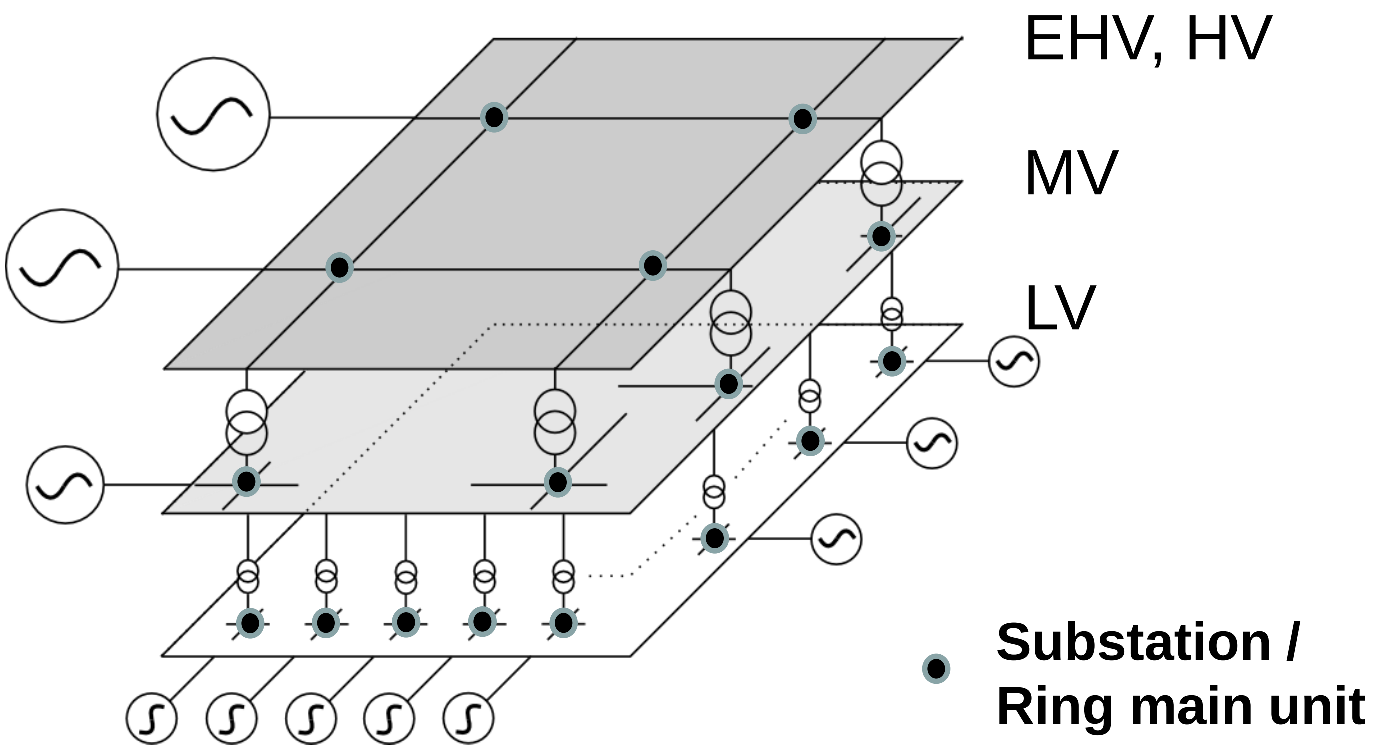
The Electrical System - Structure



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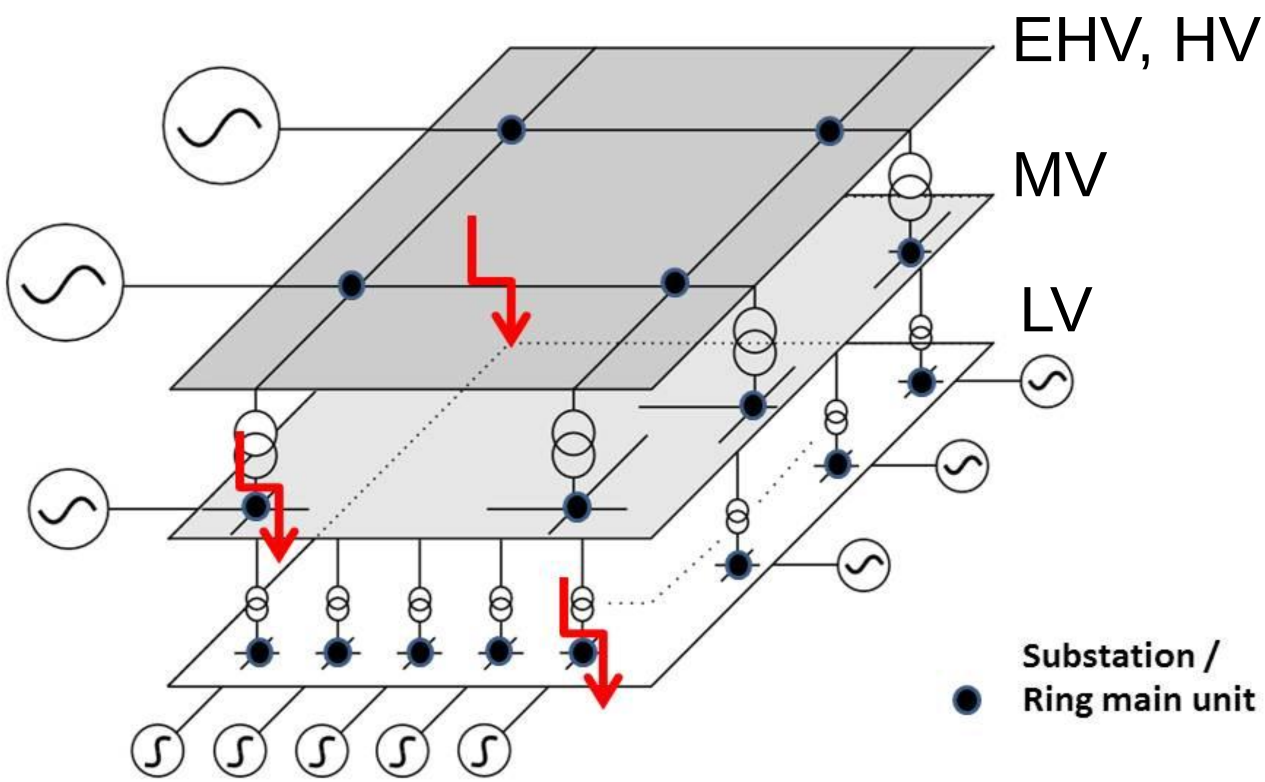
Physical behaviour

Network Codes

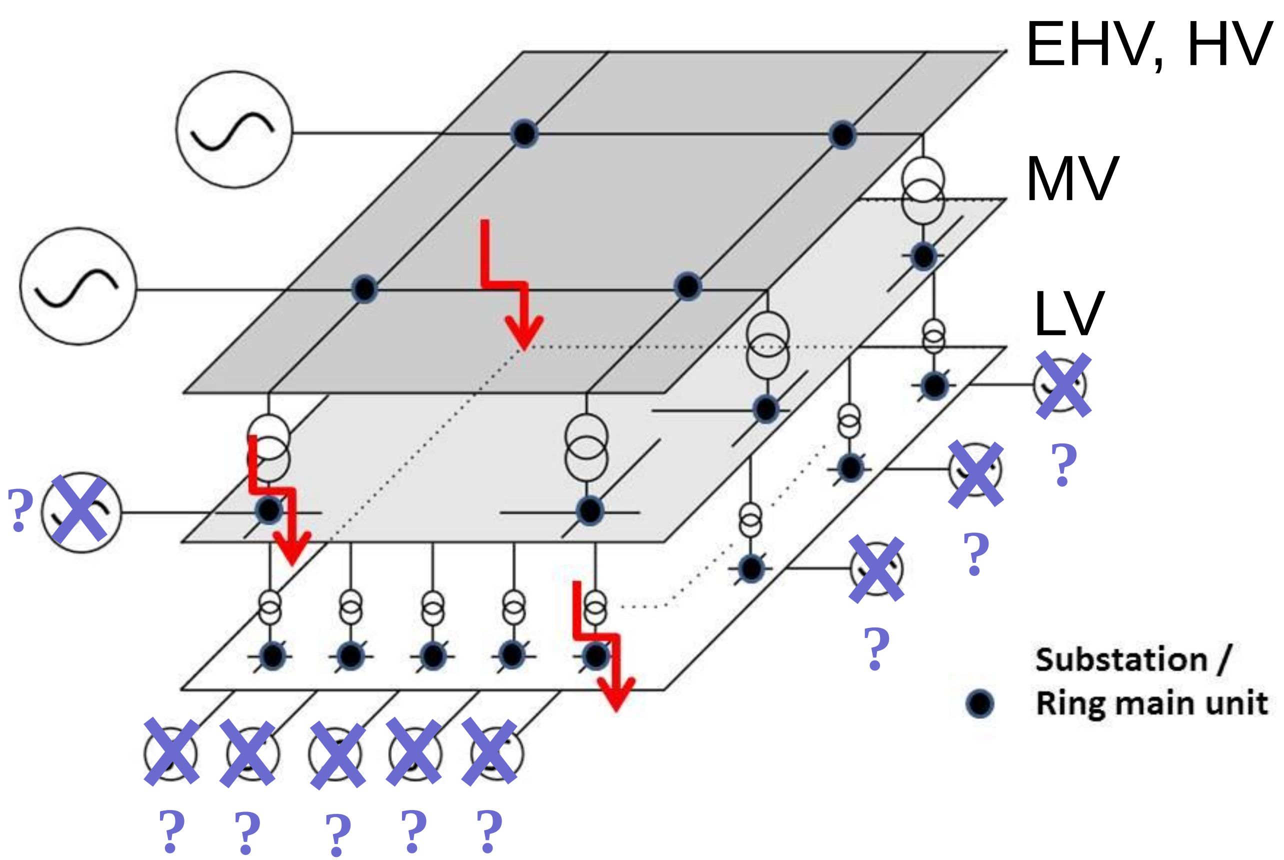
Testing

Simulation

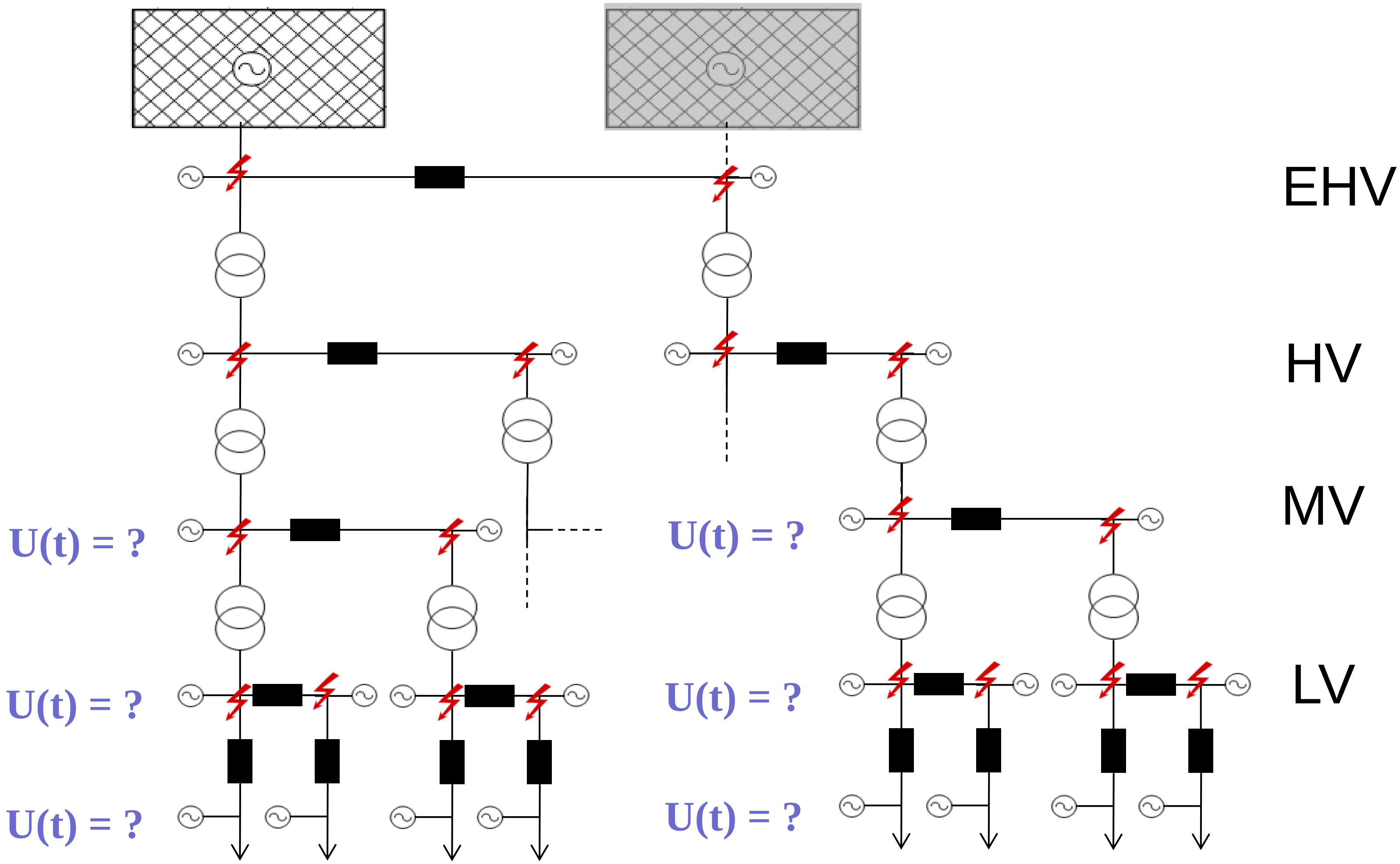
The Electrical System – Fault Behaviour (1)



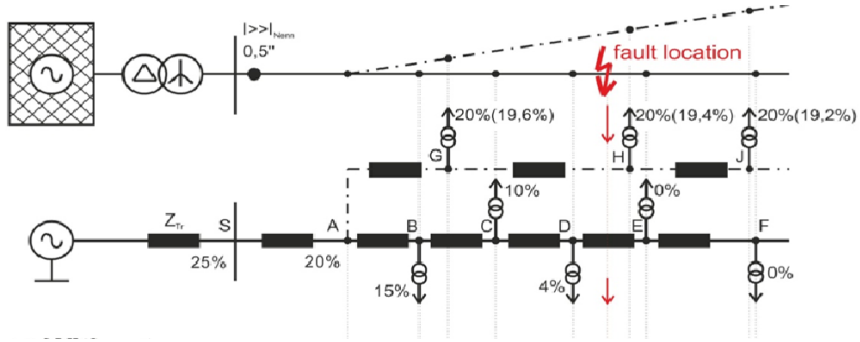
The Electrical System – Fault Behaviour (2)

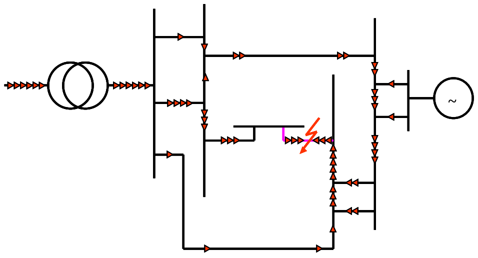


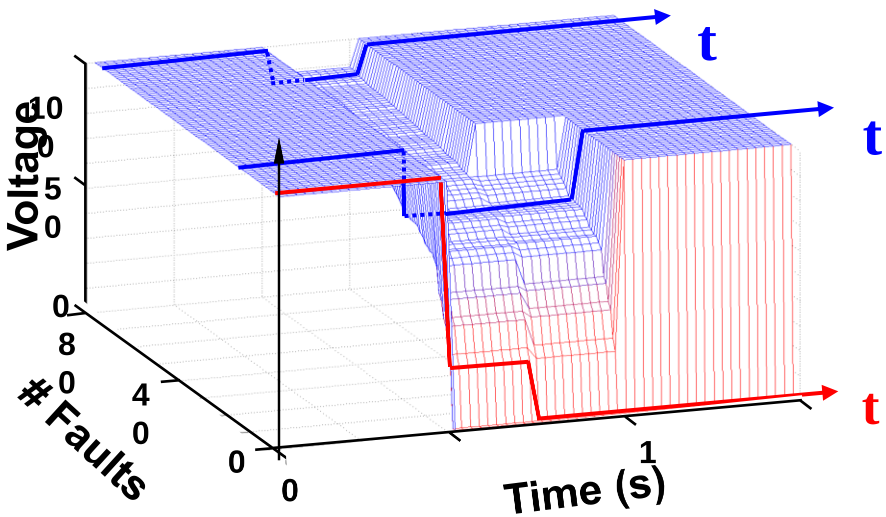
The Electrical System – Micro- / Macro-Dips

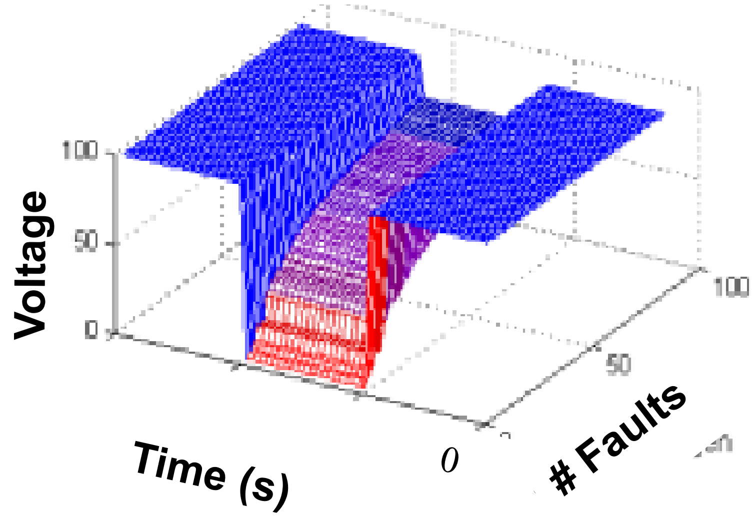


Effect of Different Protection Schemes





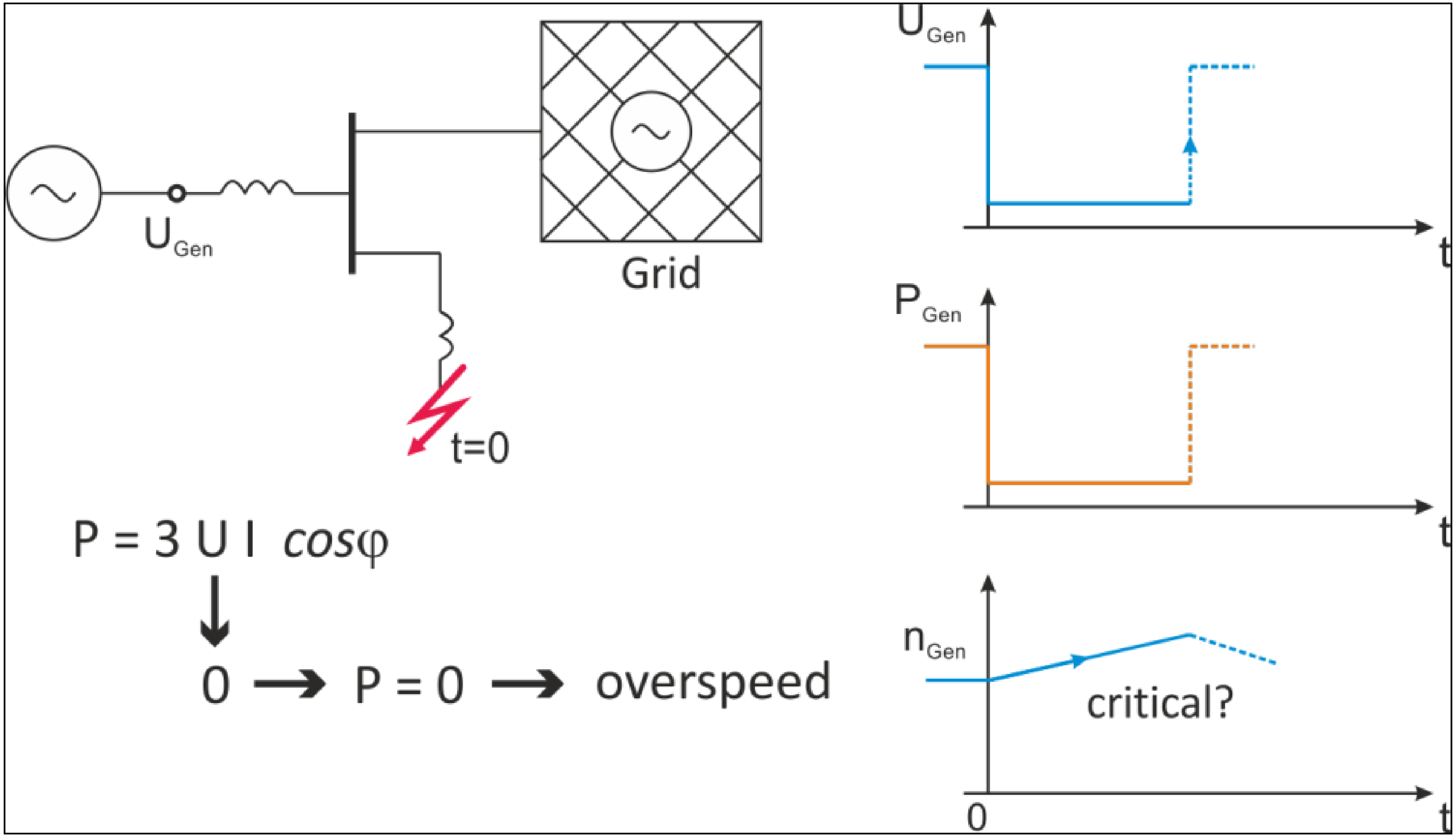




Radial System (MV + LV)

Meshed System (HV + EHV)

LVRT – Problem: Generator View



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System Stability– P(f)

W = W … Law of conservation of energy

$$W = W_{electr} + W_{mech}$$

$$\int P_{Turb} dt = \int P_{electr}\, dt + \Theta\omega_{mech}{}^2/2 \quad | \; d/\,dt$$

$$P_{Turb} = P_{electr} + \Theta\omega_{mech} * d\omega_{mech}/dt \quad | \; \omega_{mech} \sim \omega_{electr} = 2\pi f$$

$$\Theta\omega_N * d\omega/dt = P_{Turb} - P_{electr}$$

$$\Theta\omega_N{}^2/2 = P_{Turb} * H \text{ (inertia constant)}$$

$$\mathbf{d(f/f_N) \,/\, d(t/H) = \Delta p \,/2}$$

$$\Delta p = (P_{Turb} - P_{electr}) \,/\, P_{Genset}$$

Example 1 (generation mix)

f = 50 Hz H = 3 (gas tubine) …5s … 8 (steam turbine) s

→ df/dt = 5*Δp [Hz/s]

Example 2 – Overload in interconnected grid mode

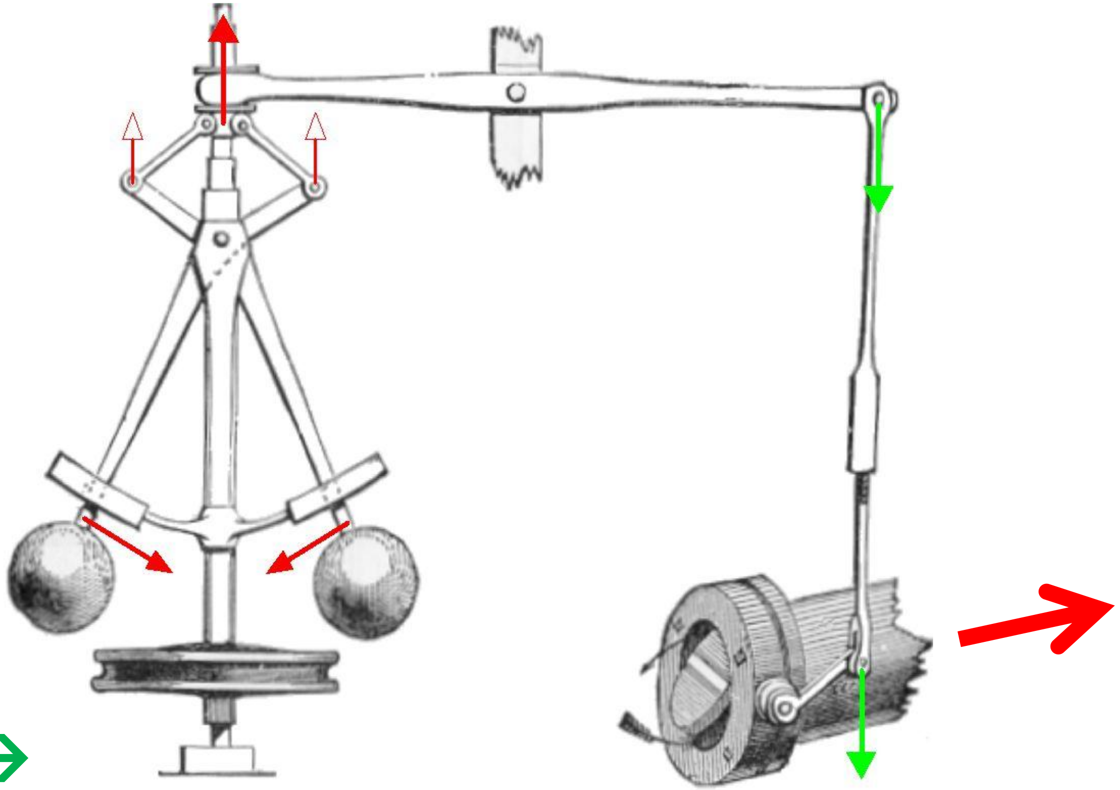
Psystem = 500’000 MW → 499’700 MW (= - 300 MW)

$\Delta p = (P_{Turb} - P_{electr}) / P_{Genset}$ = - 300 / 500'000 = - 0,0006

→ df/dt = - 0,003 Hz/s

System Stability– P(f) Closed Loop Control – Overload

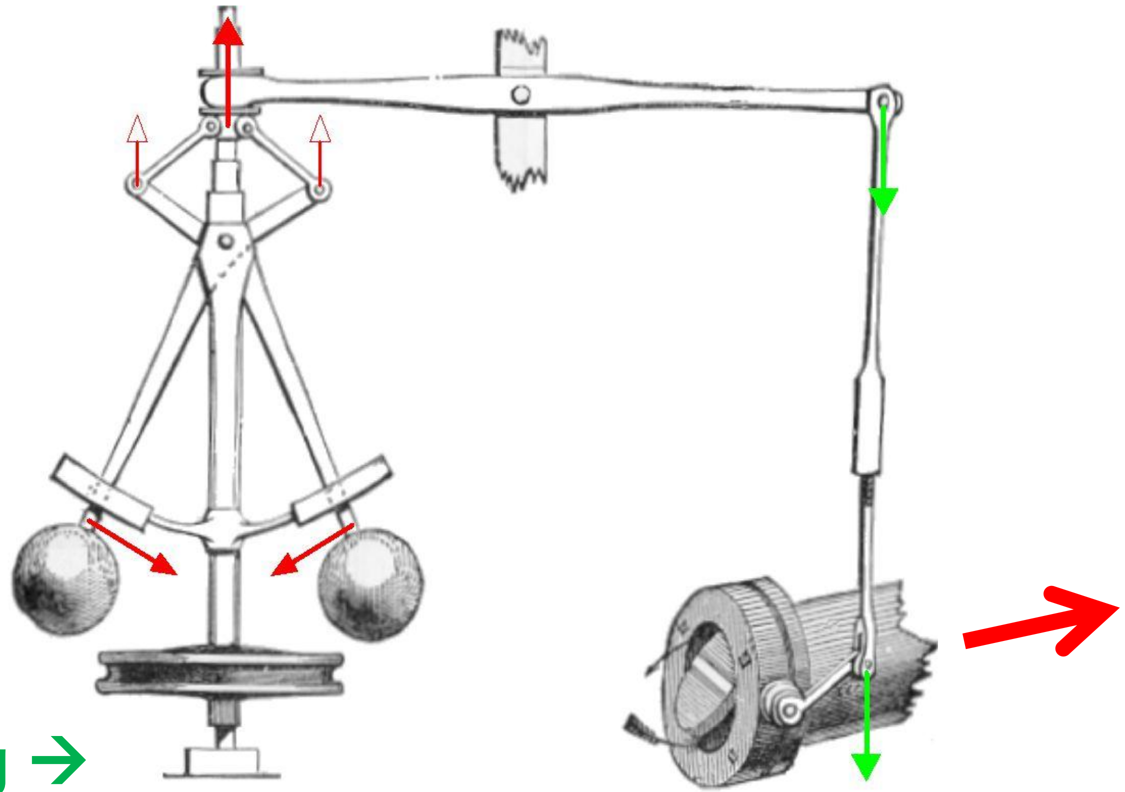
Centrifugal Pendulum



Overload →
Less frequency → Less speed → More power input →
Less Overload

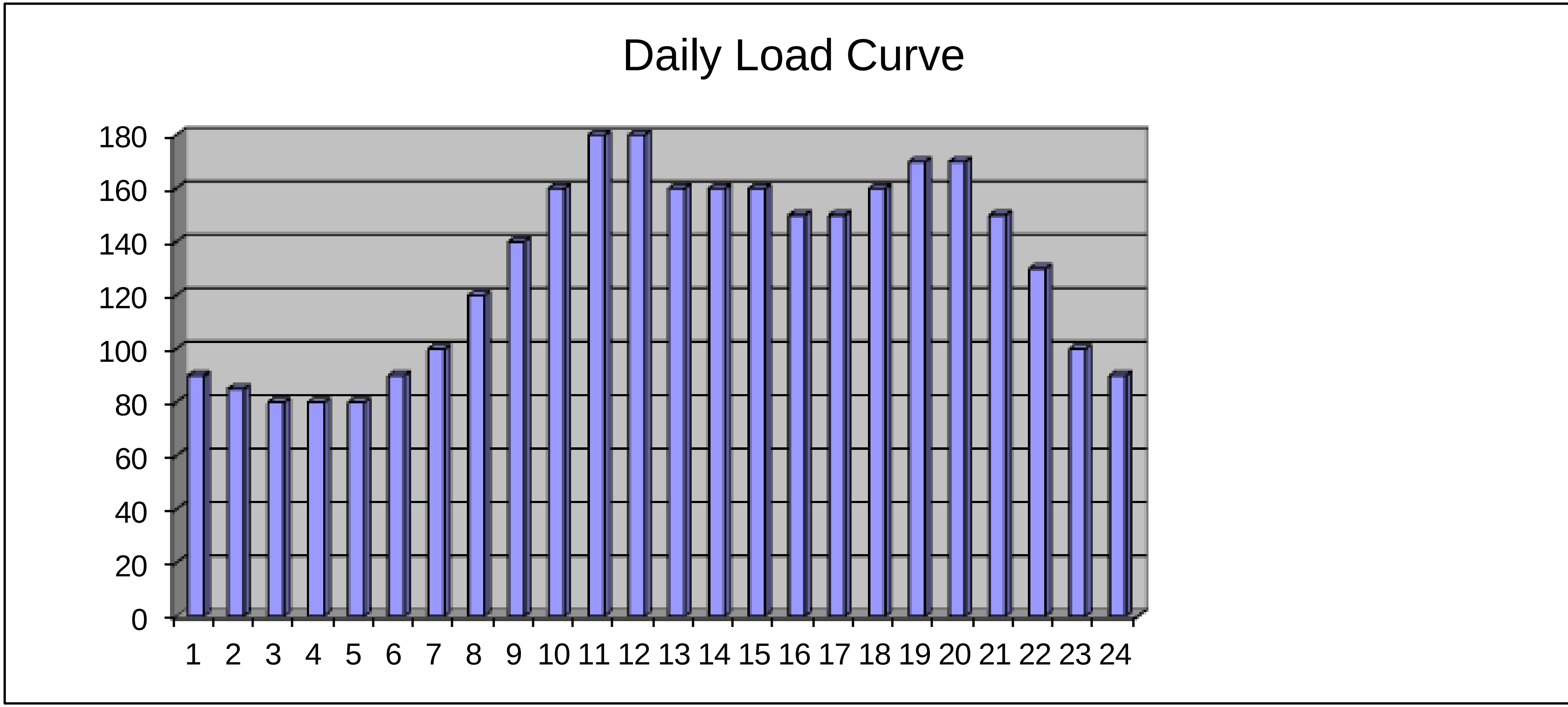
System Stability– P(f) Closed Loop Control – De-loading

Centrifugal Pendulum



De-loading →
More frequency → More speed → Less power input →
More loading

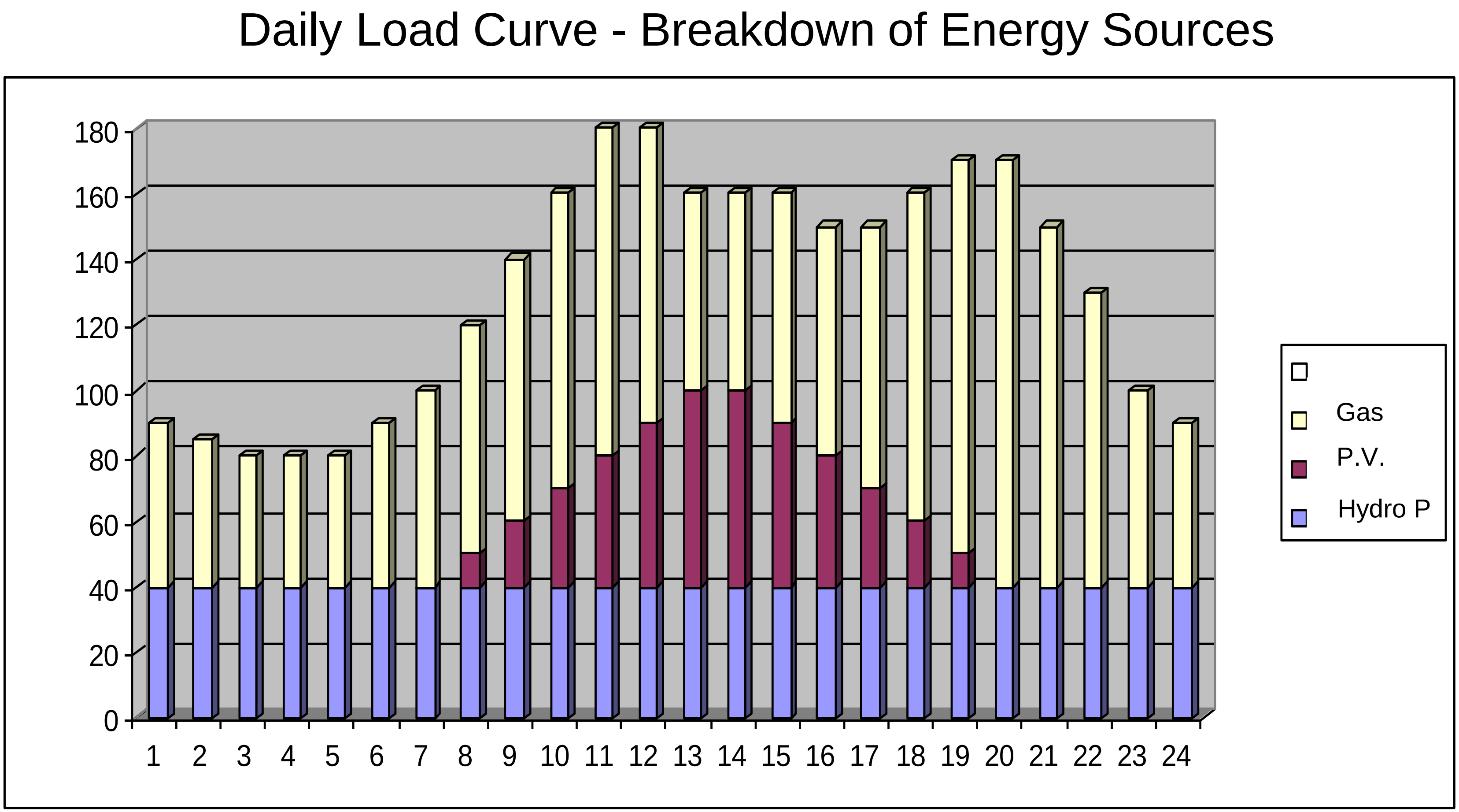
Energy Considerations



System elasticity through the adaptive (P/f-control) production of

- fossil power plants or
- nuclear power plants

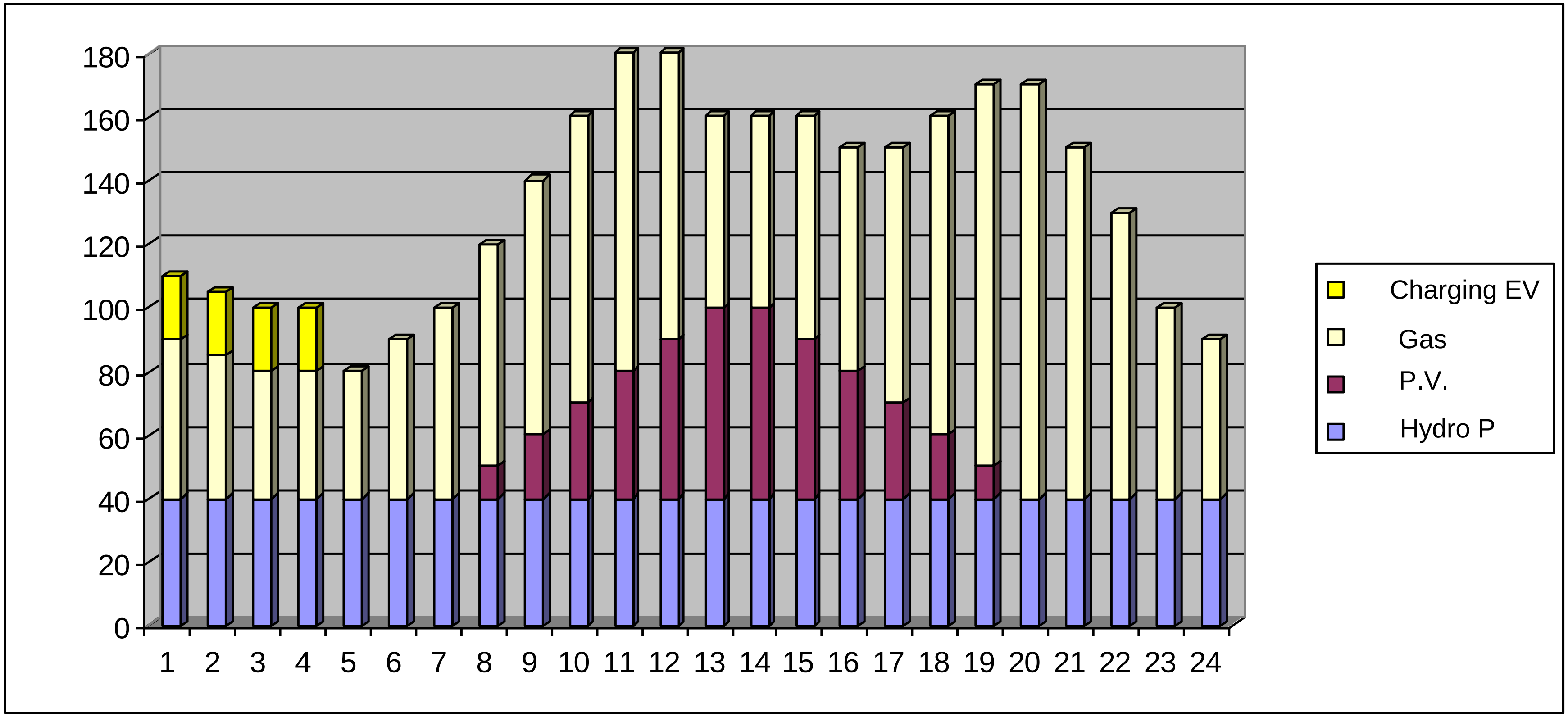
Energy Considerations



System elasticity stressed by additional fluctuating P.V. power infeed

Energy Considerations

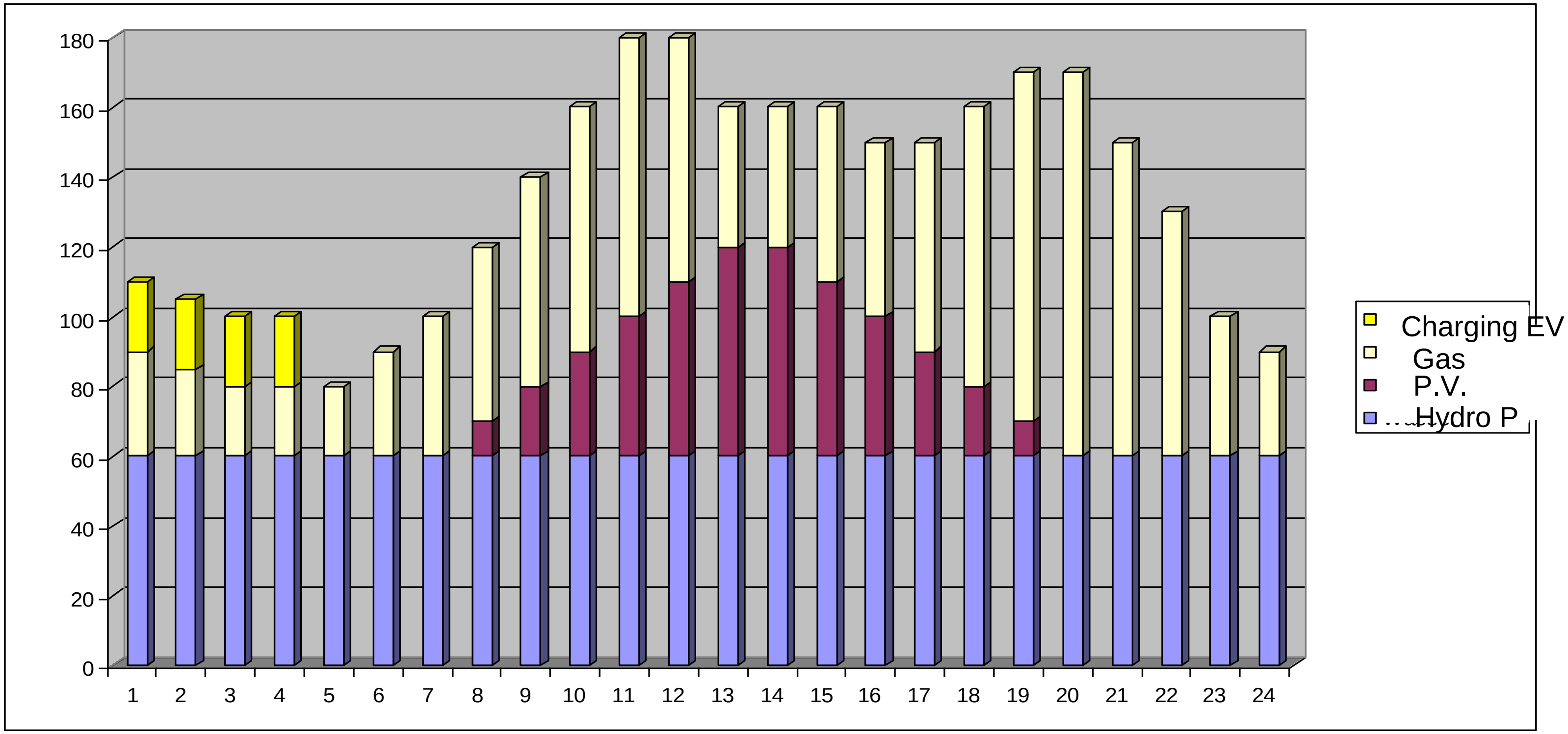
Daily Load Curve - Breakdown of Energy Sources



System elasticity stressed by additional fluctuating P.V. power infeed
additional EV charging

Energy Considerations

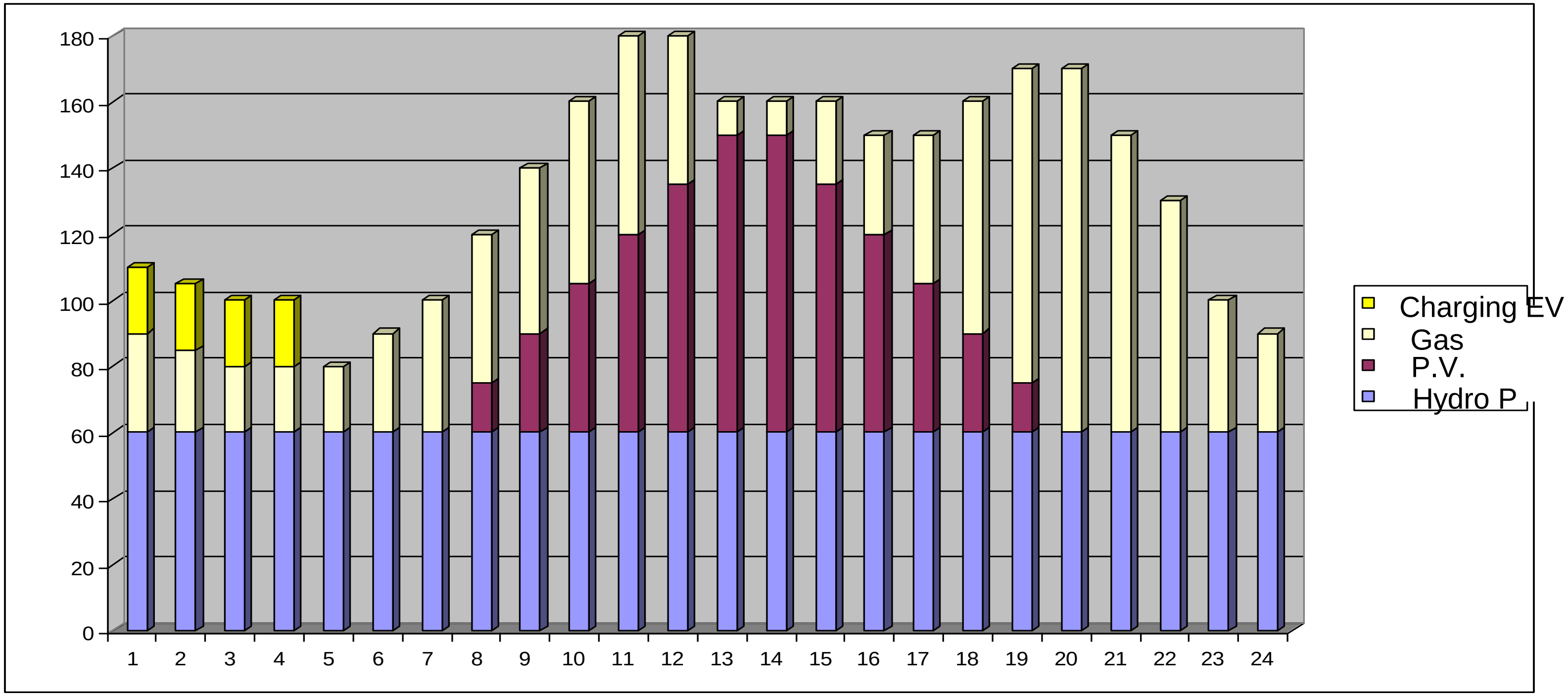
Daily Load Curve - Breakdown of Energy Sources



System elasticity stressed by additional fluctuating P.V. power infeed
additional EV charging
increased hydropower generation

Energy Considerations

Daily Load Curve - Breakdown of Energy Sources



System elasticity stressed by increased fluctuating P.V. power infeed

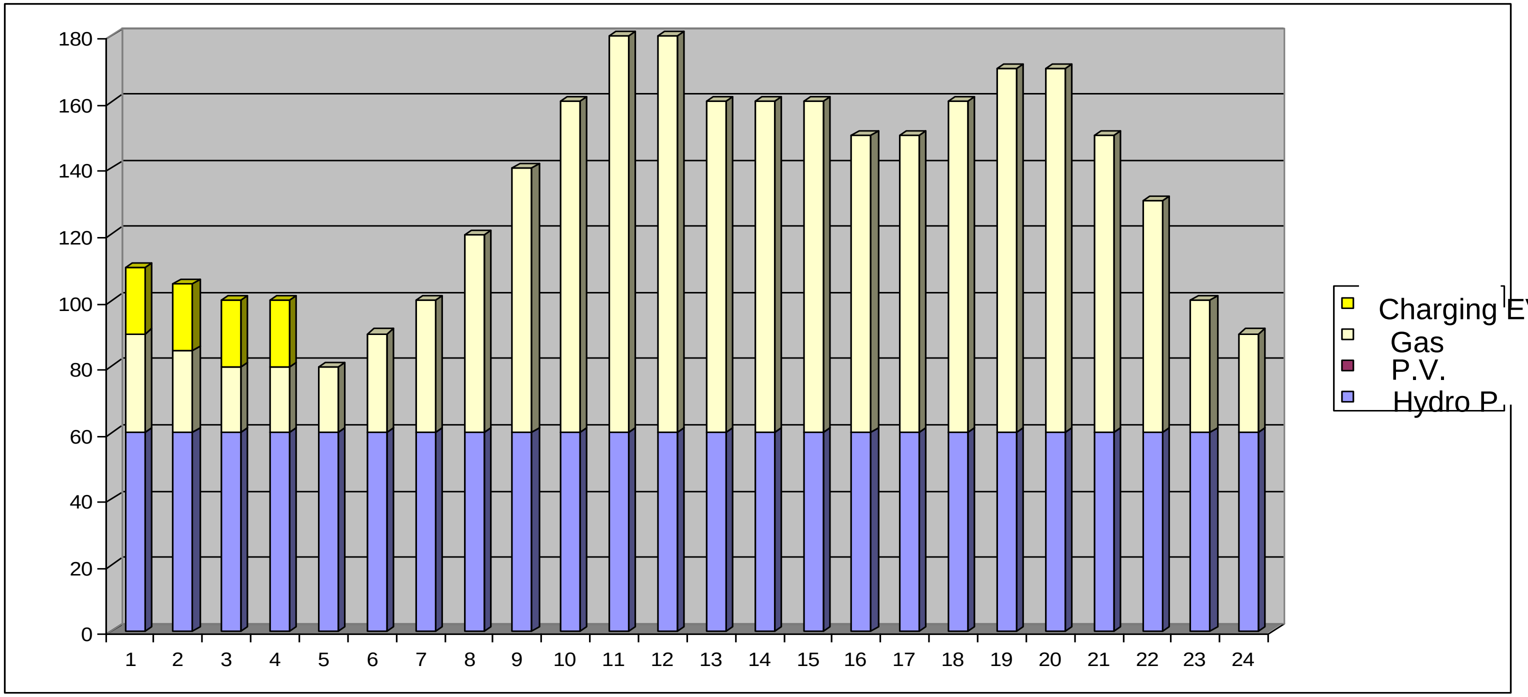
additional EV charging

increased Hydropower generation

Energy Considerations

Daily Load Curve - Breakdown of Energy Sources

Challenge: optimization of the power plant park



System elasticity stressed by additional EV charging

increased Hydropower generation

sunless day

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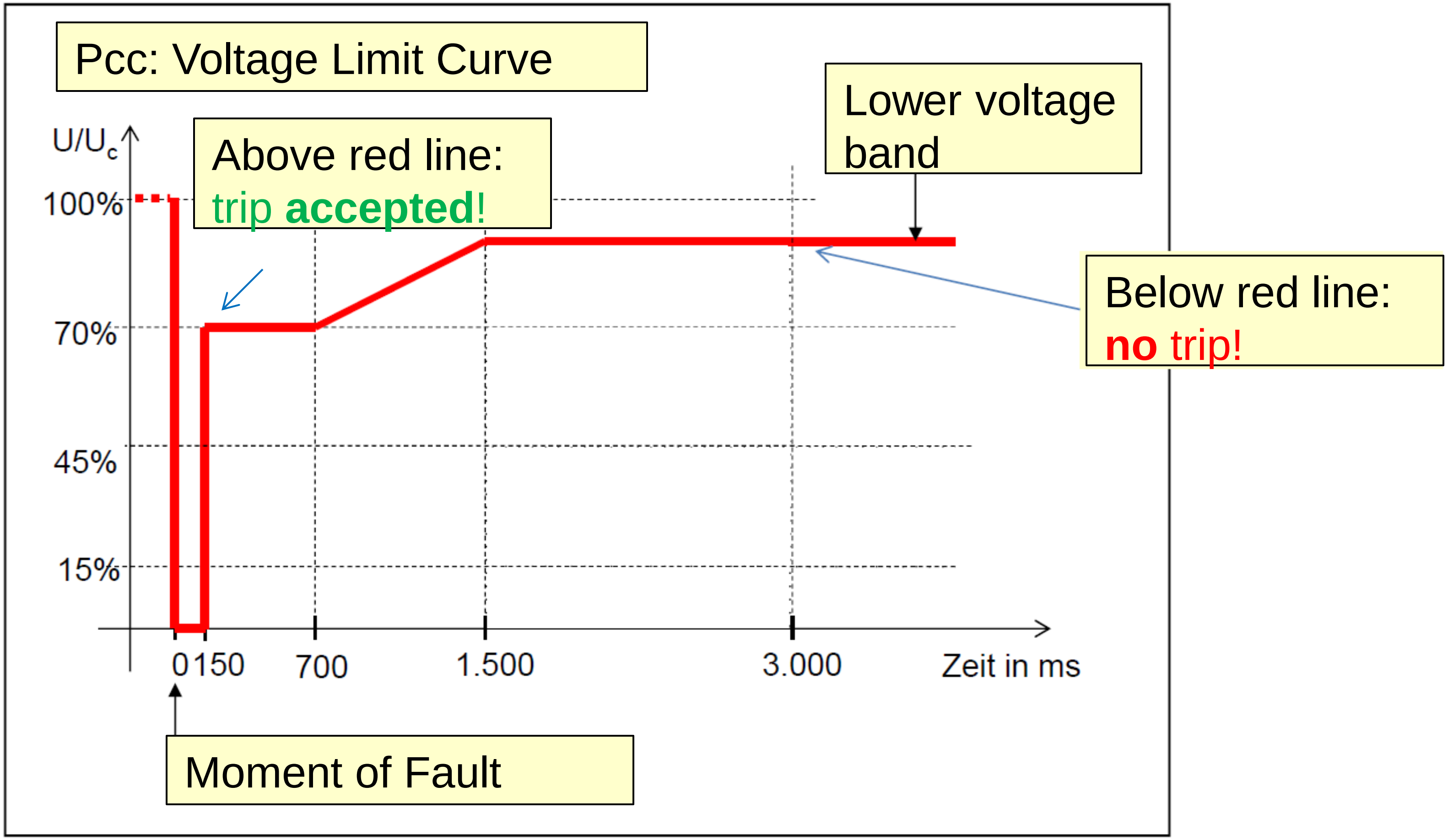
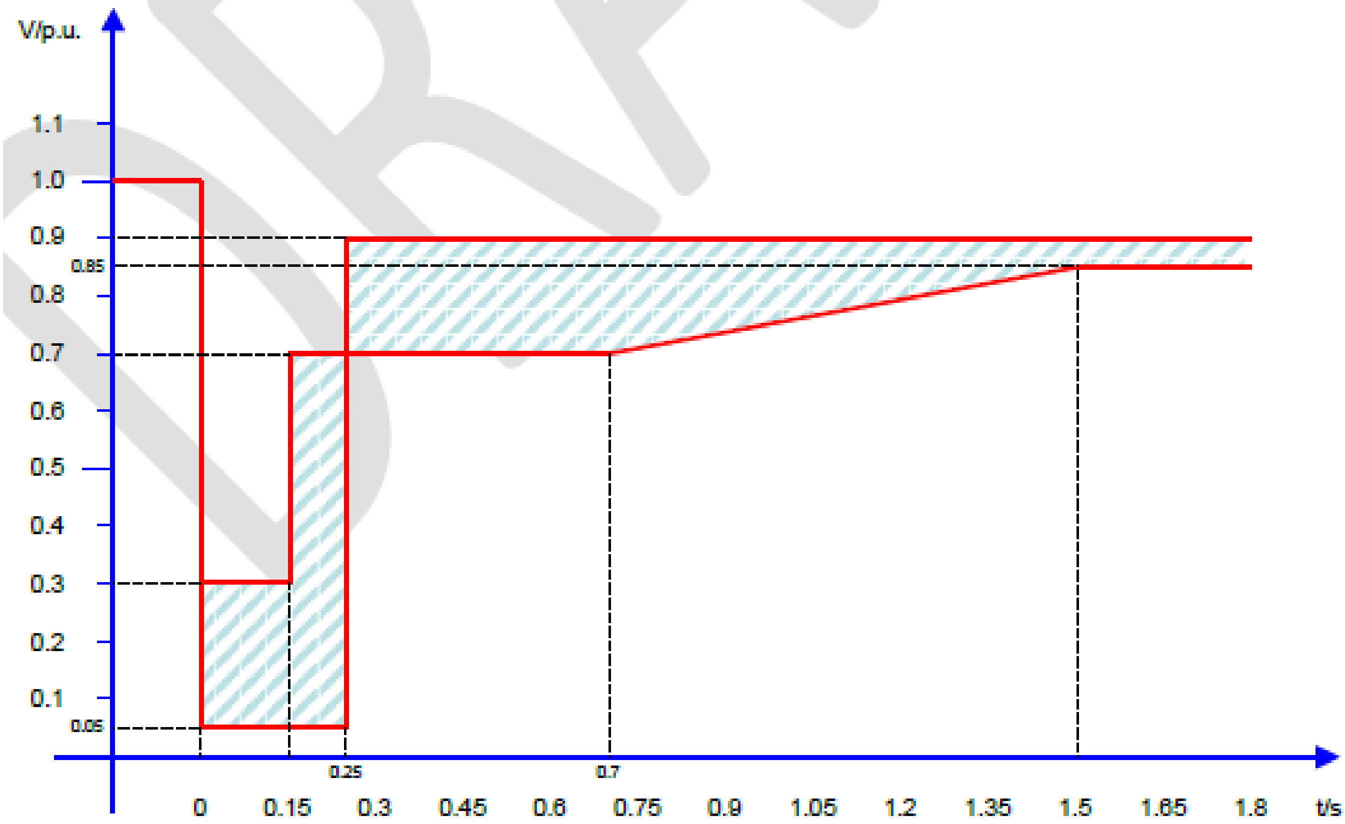
LVRT – Basic Requirements



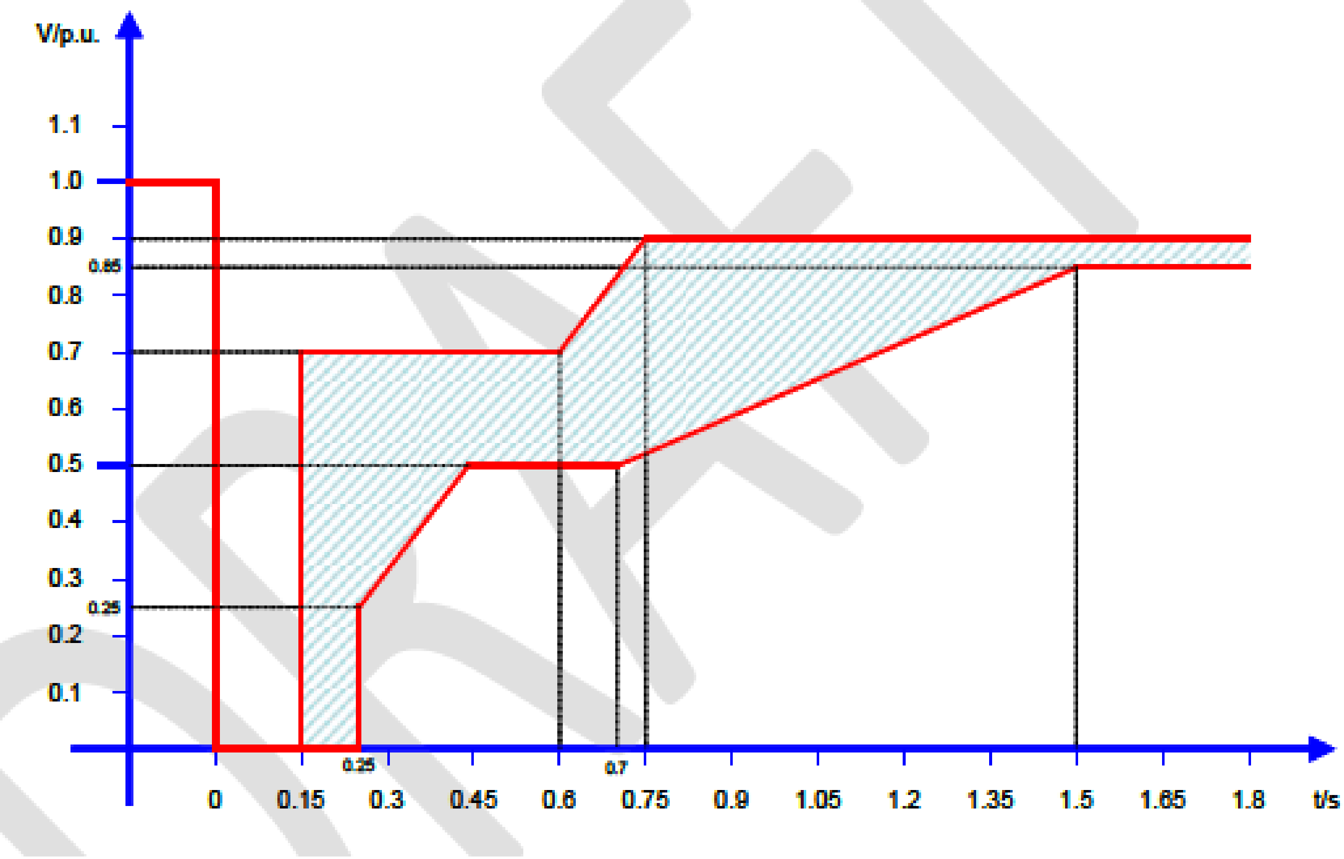
LVRT – Specific Requirements: Single Generator (1)

Low Voltage Fault Ride Through (LVRT – Synchroneous Generator, Typ B)



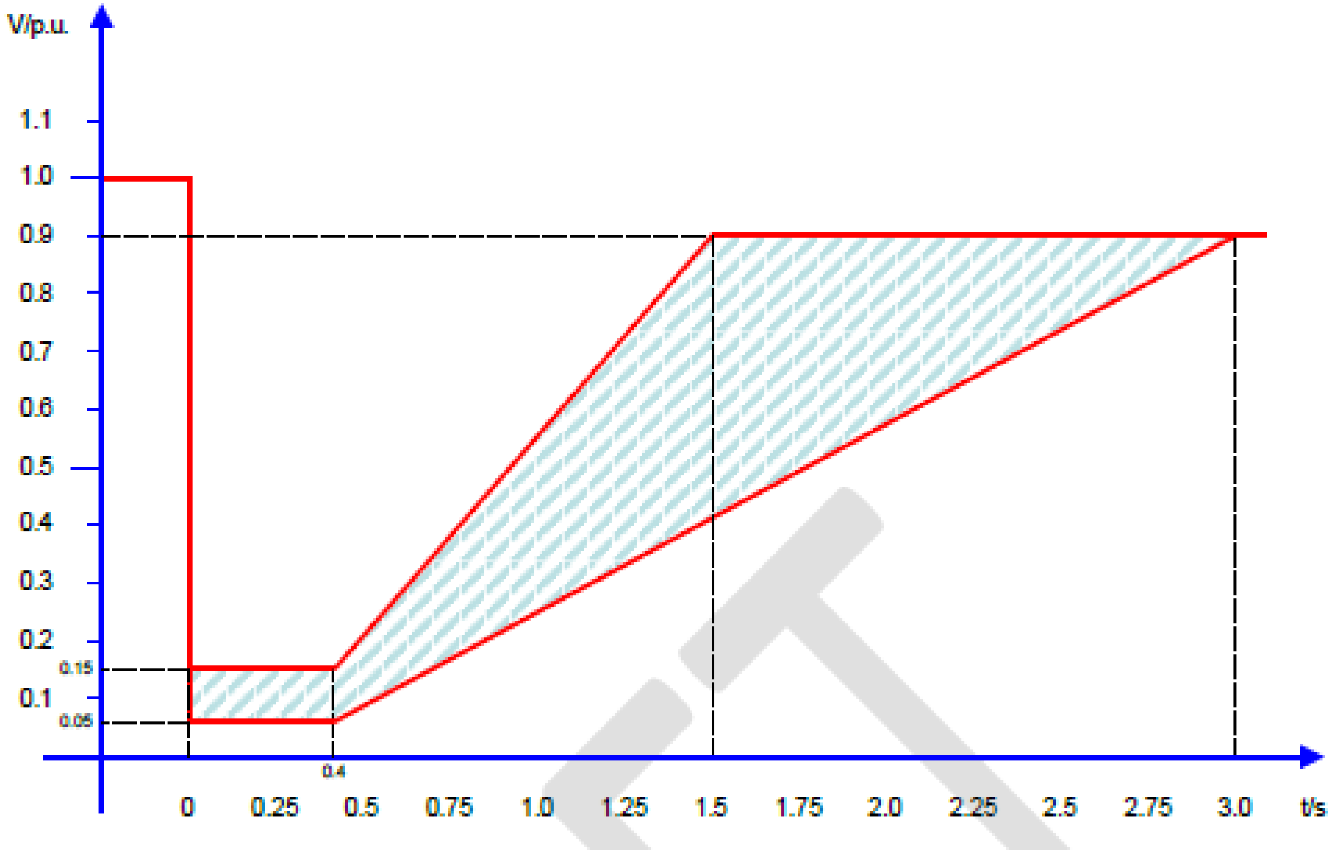
LVRT – Specific Requirements: Single Generator (2)

Low Voltage Fault Ride Through (LVRT – Synchroneous Generator, Typ C)



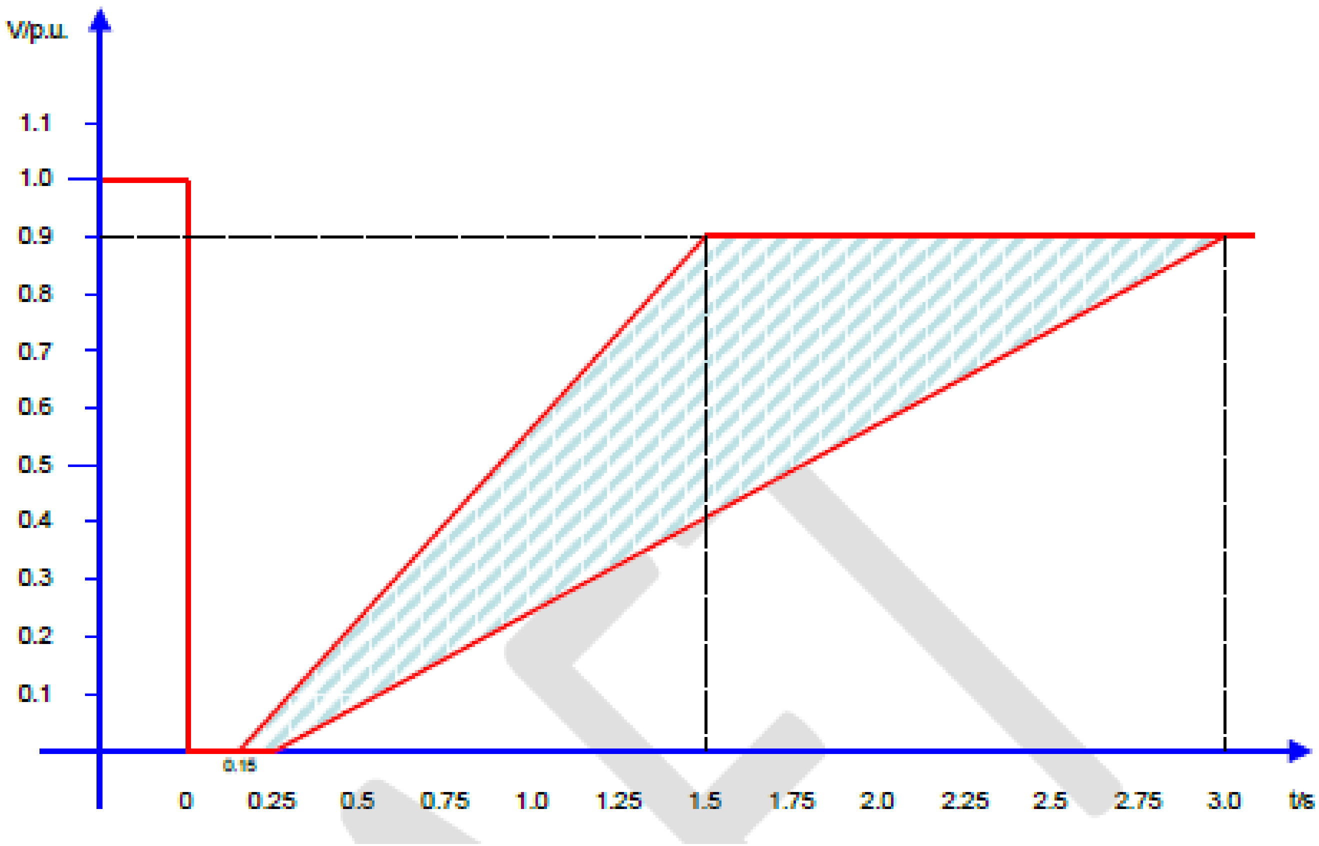
LVRT – Specific Requirements: Power Plant Park (1)

Low Voltage Fault Ride Through (LVRT – Synchroneous Generators, Typ B)

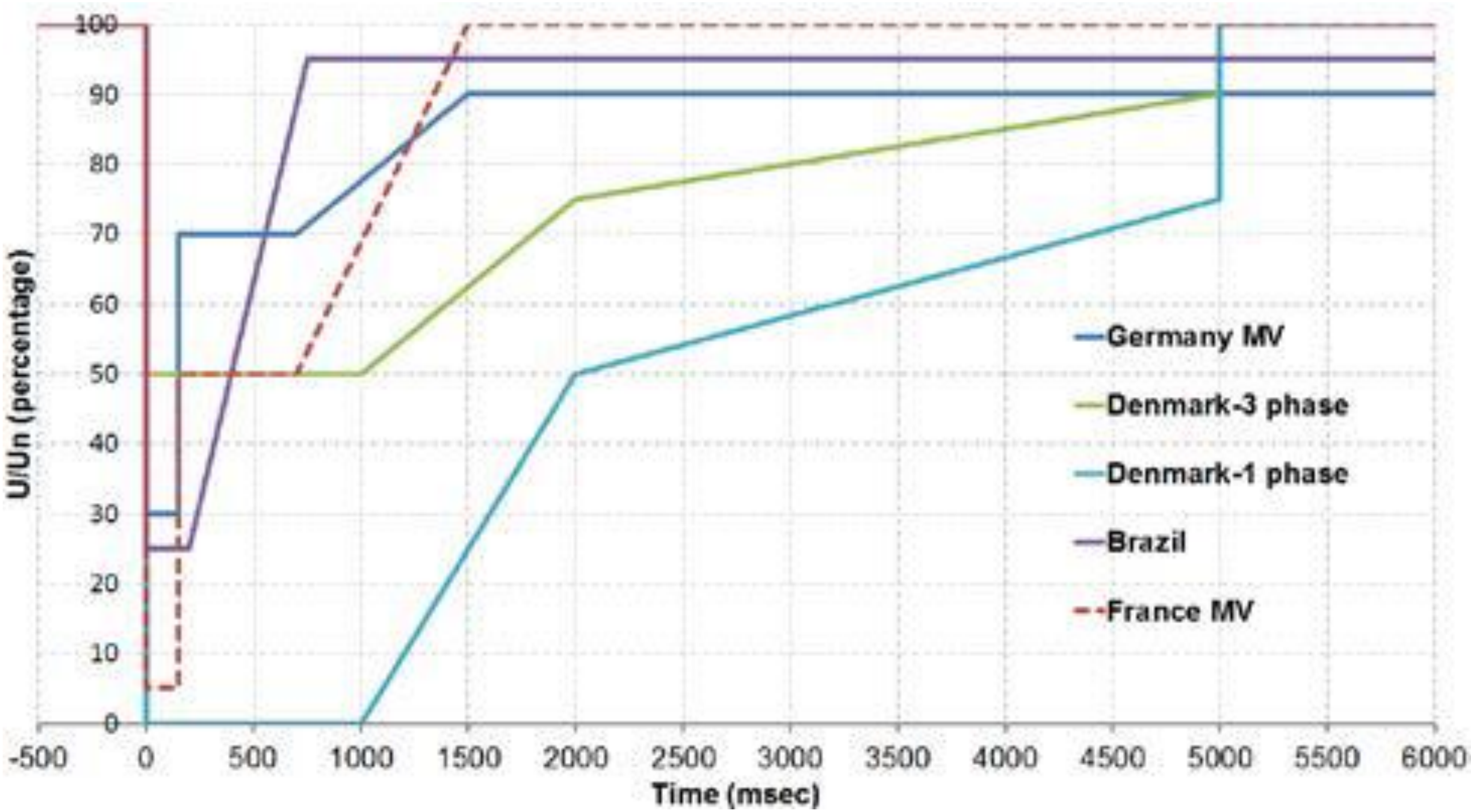


LVRT – Specific Requirements: Power Plant Park (2)

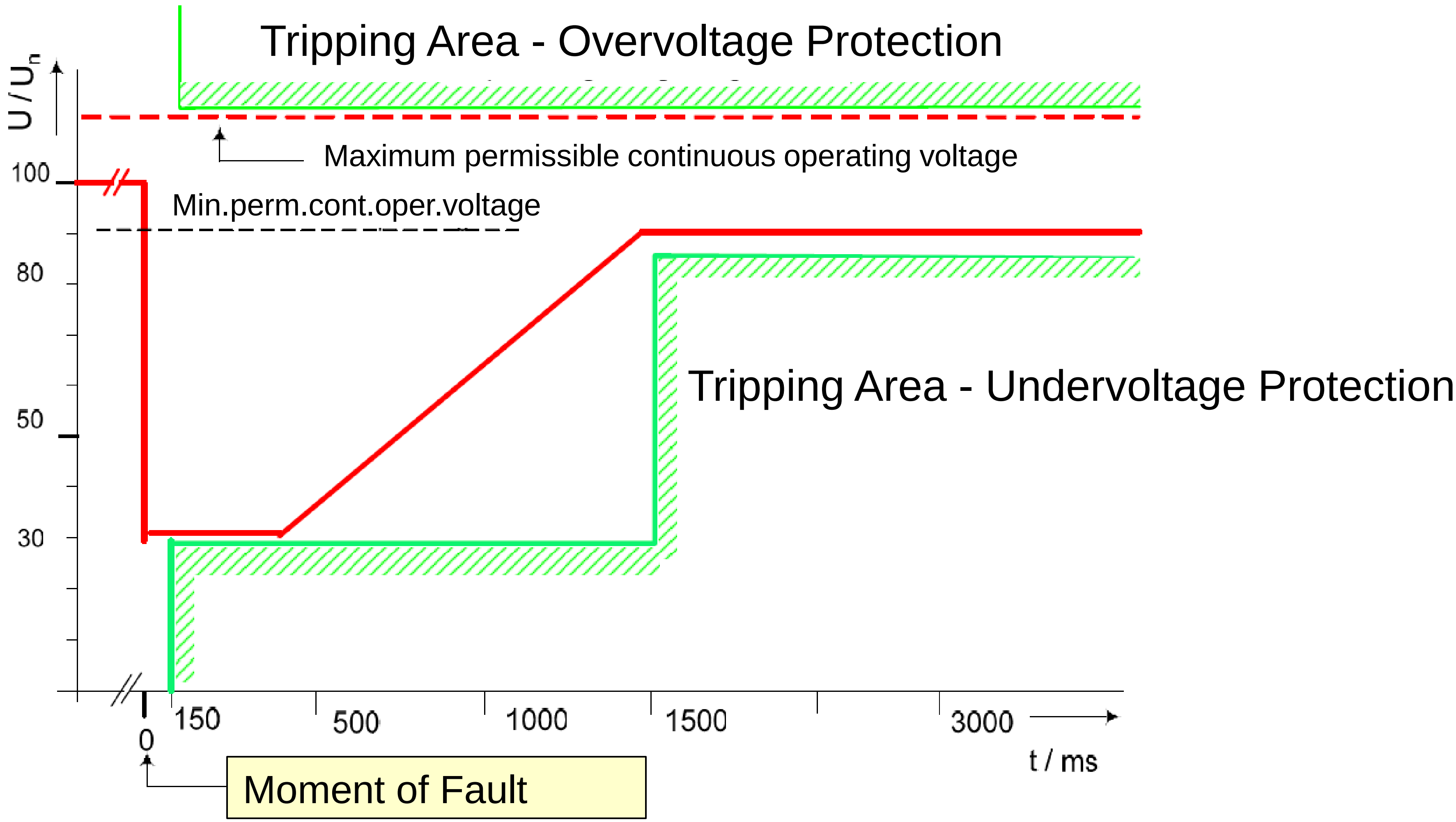
Low Voltage Fault Ride Through (LVRT – Synchroneous Generators, Typ C)



Network Codes in different Countries



LVRT – Under-/Oververvoltage Protection Requirements (2)



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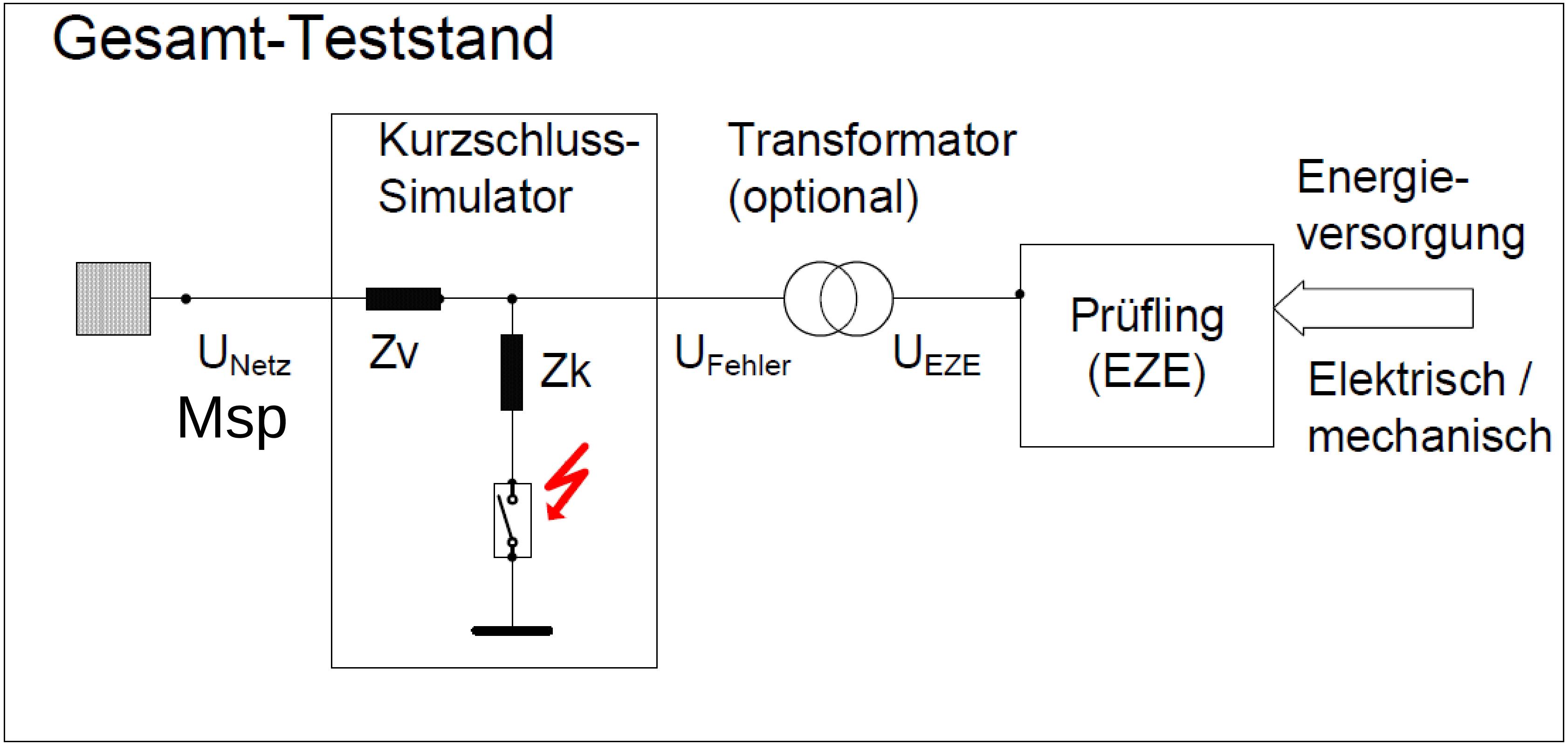
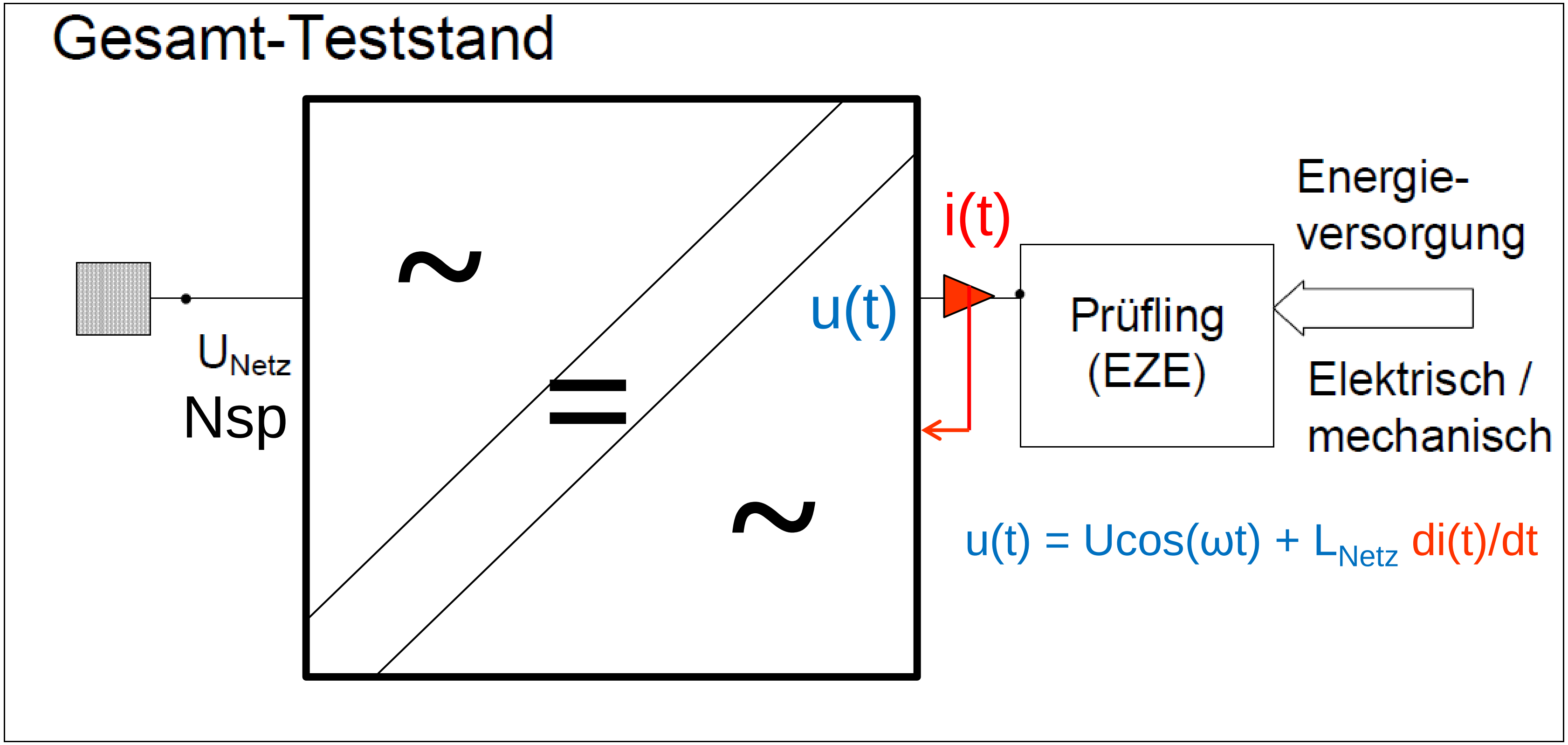
LVRT – Test Simulation

Schematic Diagram of a transformatorbased Test Set-up

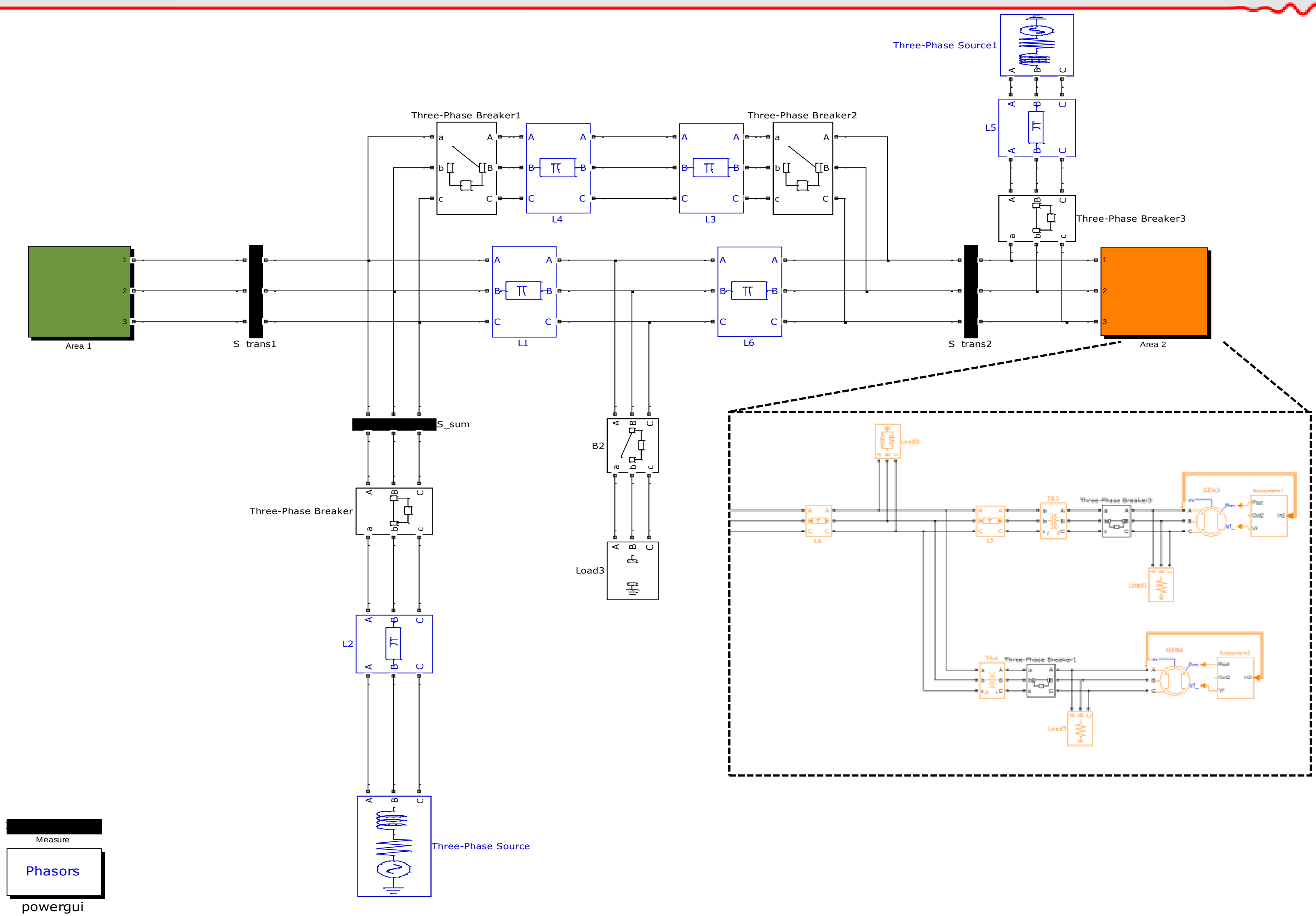


LVRT – Test Simulation

Schematic Diagram of a transformatorbased Test Set-up

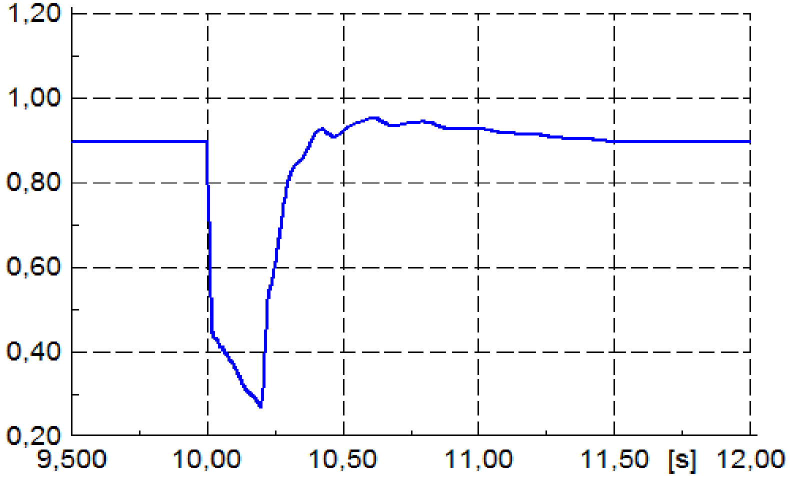


Simulation LVRT – Modell (2)



LVRT – Influence of Fault Clearing Time (1)

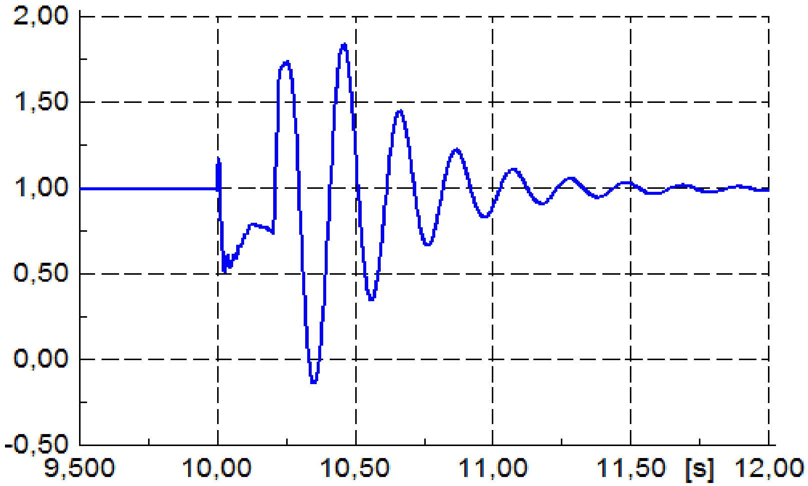
Terminal voltage



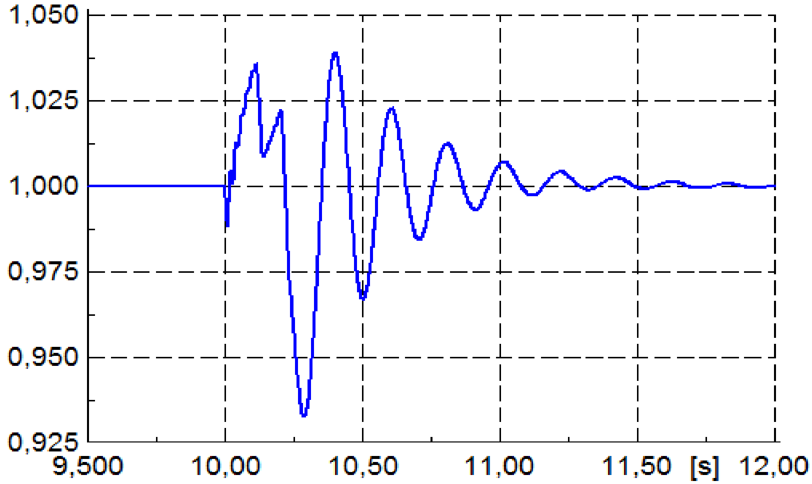
Inertia constant H = 0.32 s

Fault clearing time t_{clear} = 200 ms

Active Power

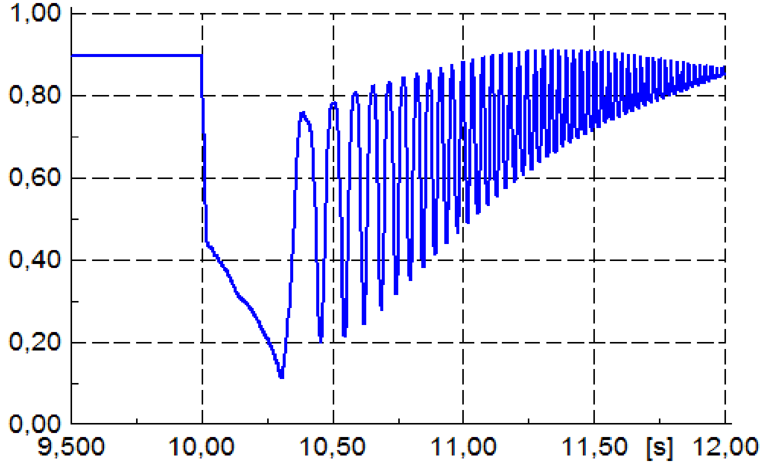


Rotational speed



LVRT – Influence of Fault Clearing Time (2)

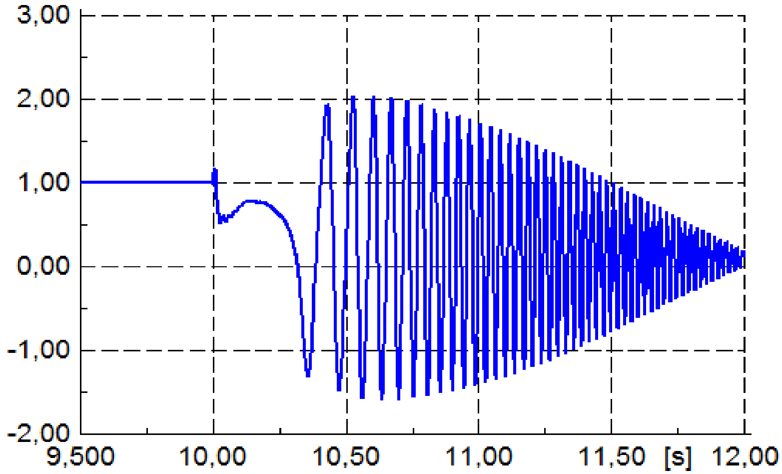
Terminal voltage



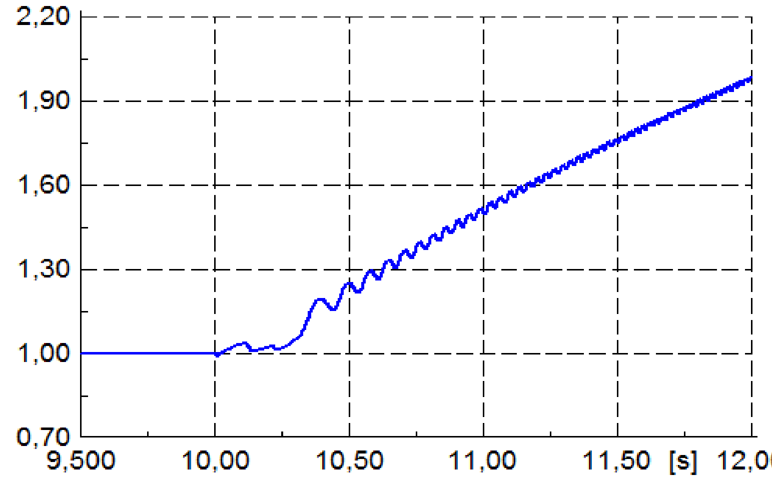
Inertia constant H = 0.32 s

Fault clearing time t_{clear} = 300 ms

Active power

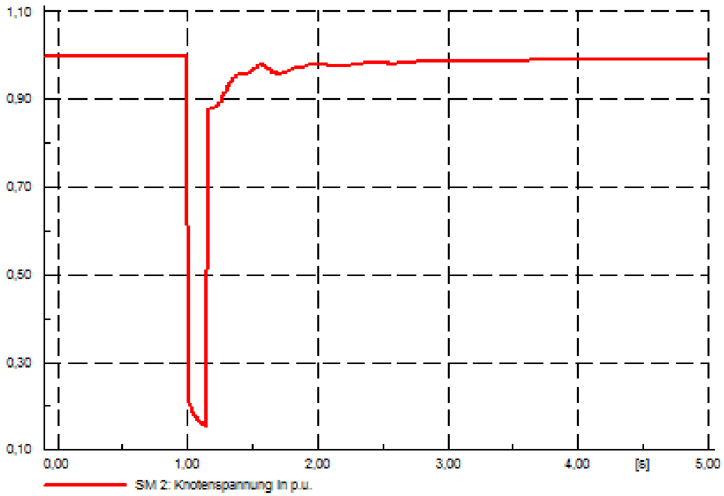


Rotational speed



LVRT – Test Simulation (3)

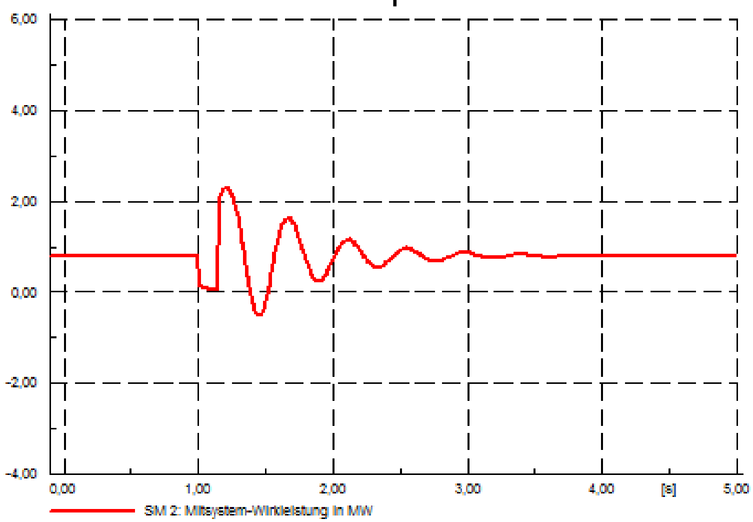
Voltage



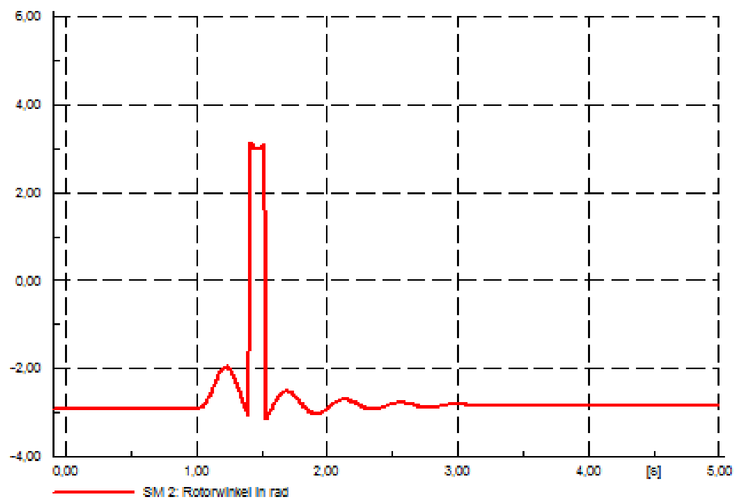
Inertia constant H = 2,5 s

Fault clearing time t_{clear} = 150 ms

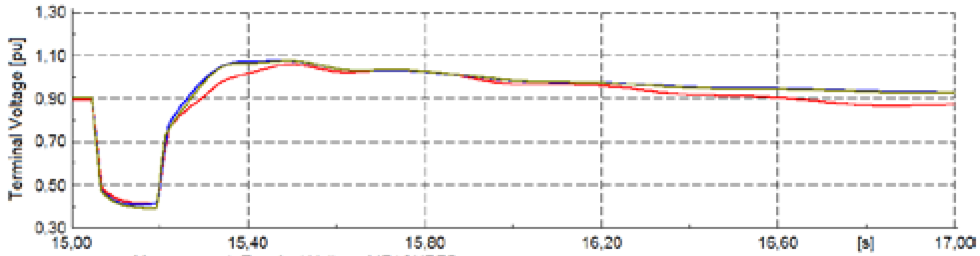
Active power

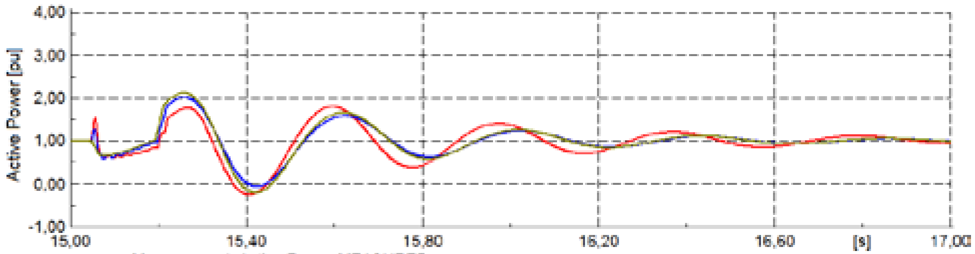


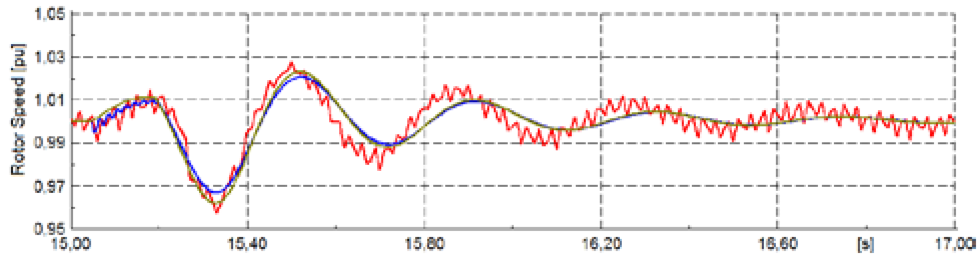
Rotor angle



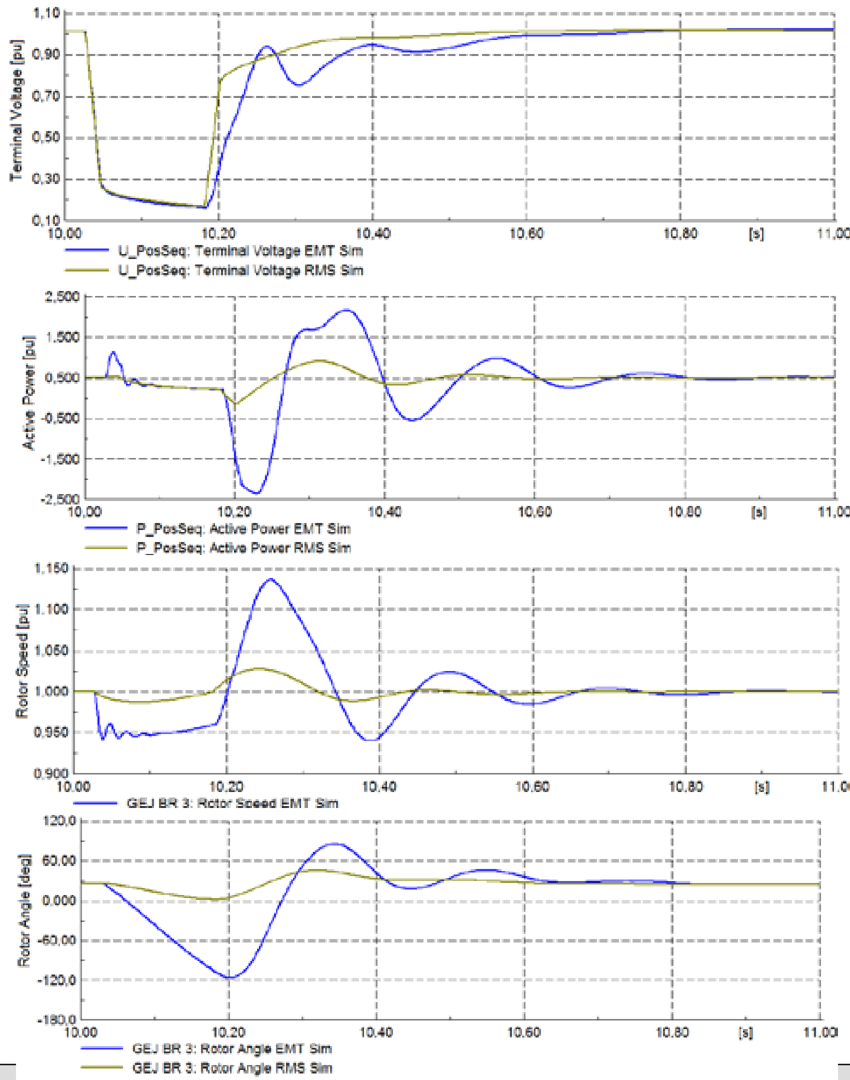
LVRT: 5.5 MVA / 10.5 kV gas-engine-driven generator; dip = 150 ms



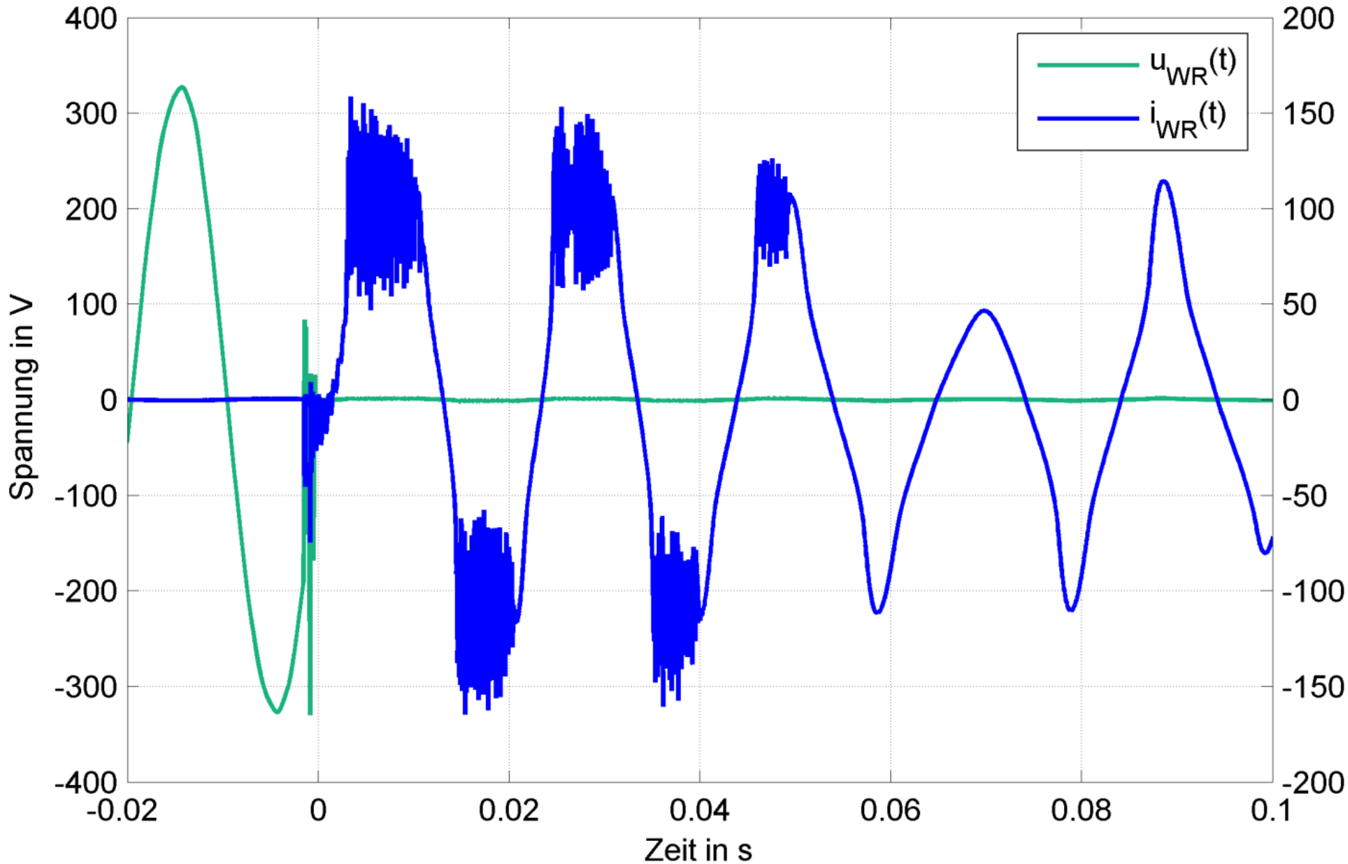




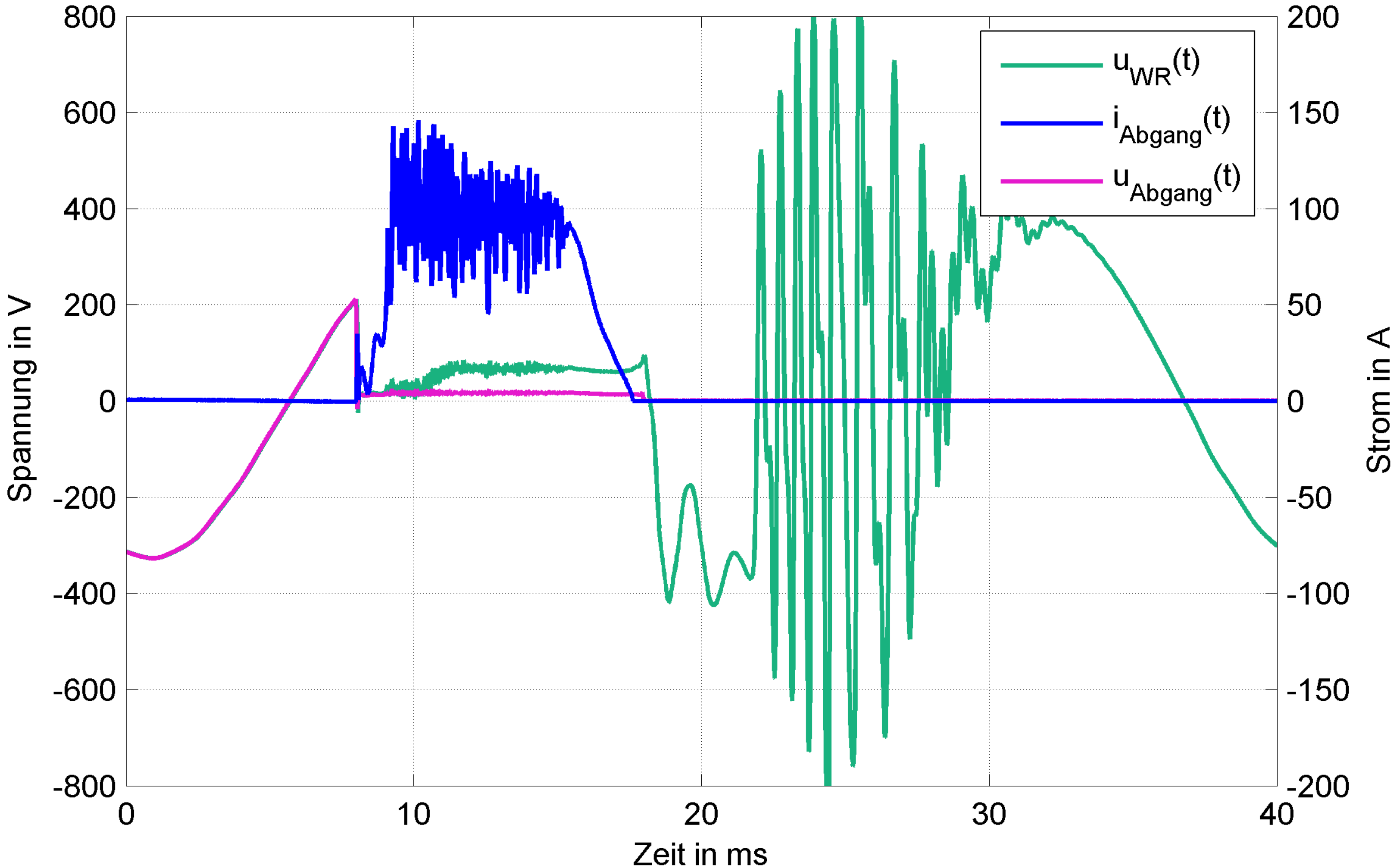
LVRT: 0.78 MVA / 0.4 kV gas-engine-driven generator; dip = 150 ms



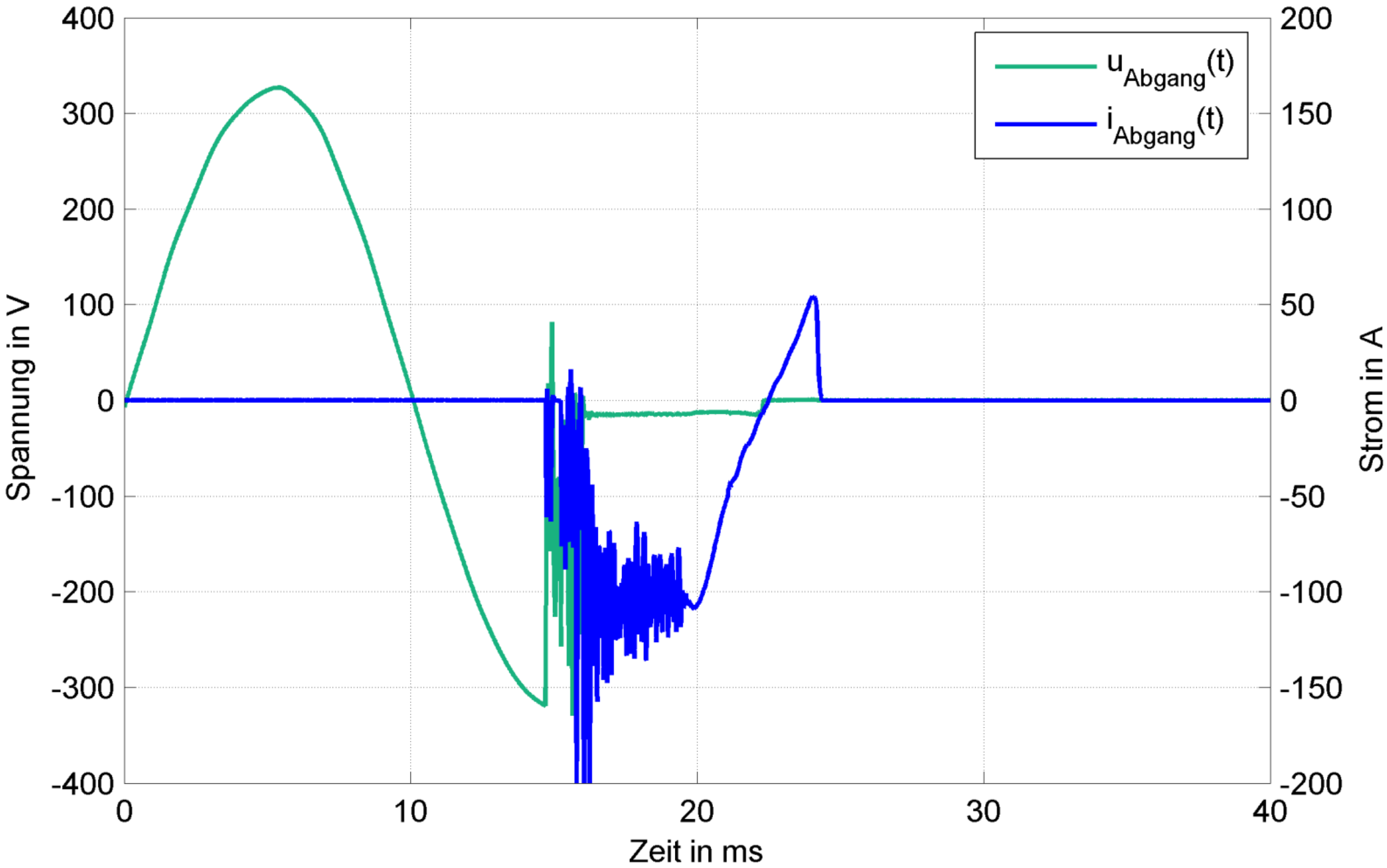
LVRT – Inverter Behaviour (1)



LVRT – Inverter Behaviour (2)

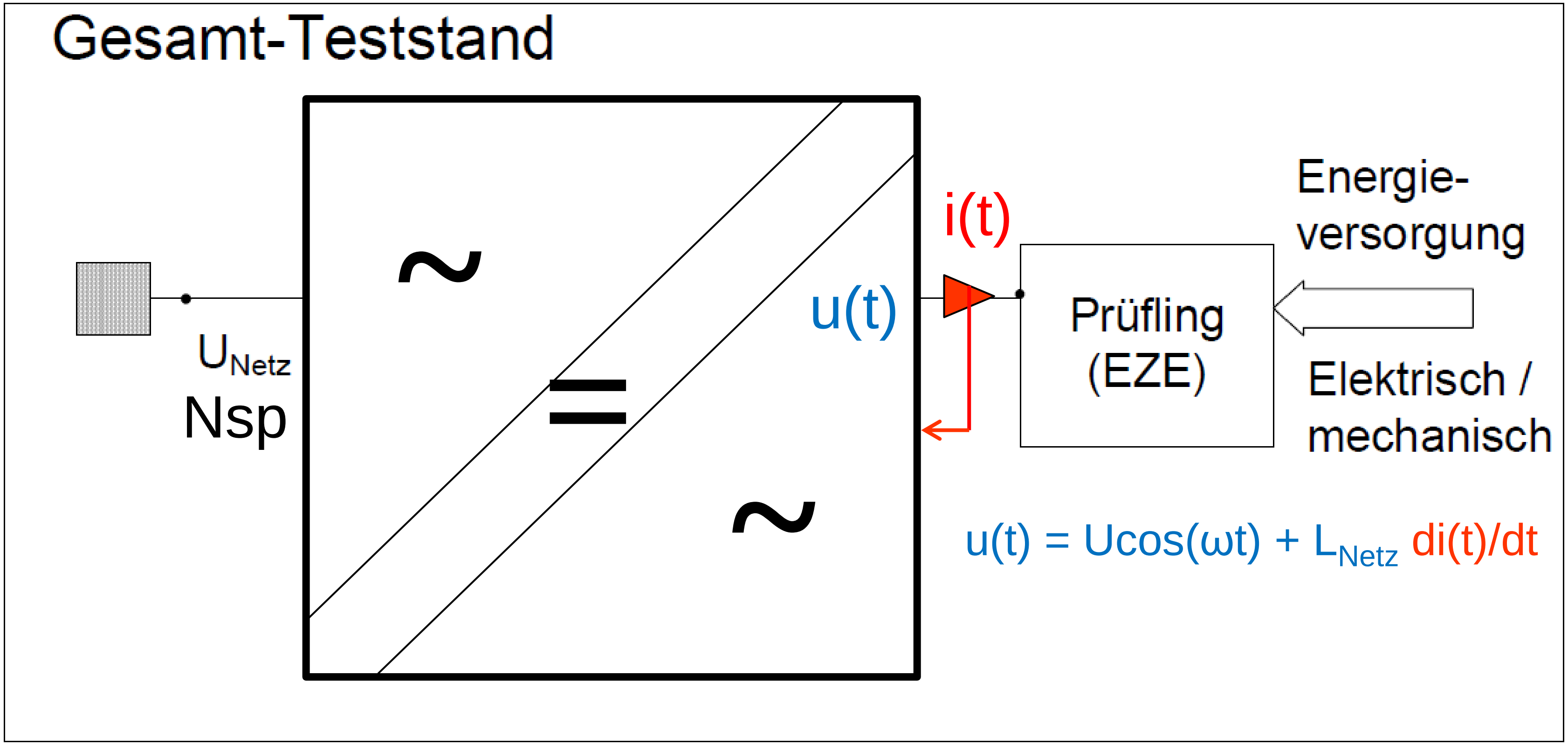


LVRT – Inverter Behaviour (3)



LVRT – Test Simulation

Schematic Diagram of a transformatorbased Test Set-up



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