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SPECIAL REQUIREMENTS ON PROTECTION SYSTEMS IN ELECTROLYSIS PLANTS

The 19th IET Conference on Developments in Power System Protection

Michael Bruhns | TUD Dresden University of Technology | 02.04.2025

Agenda

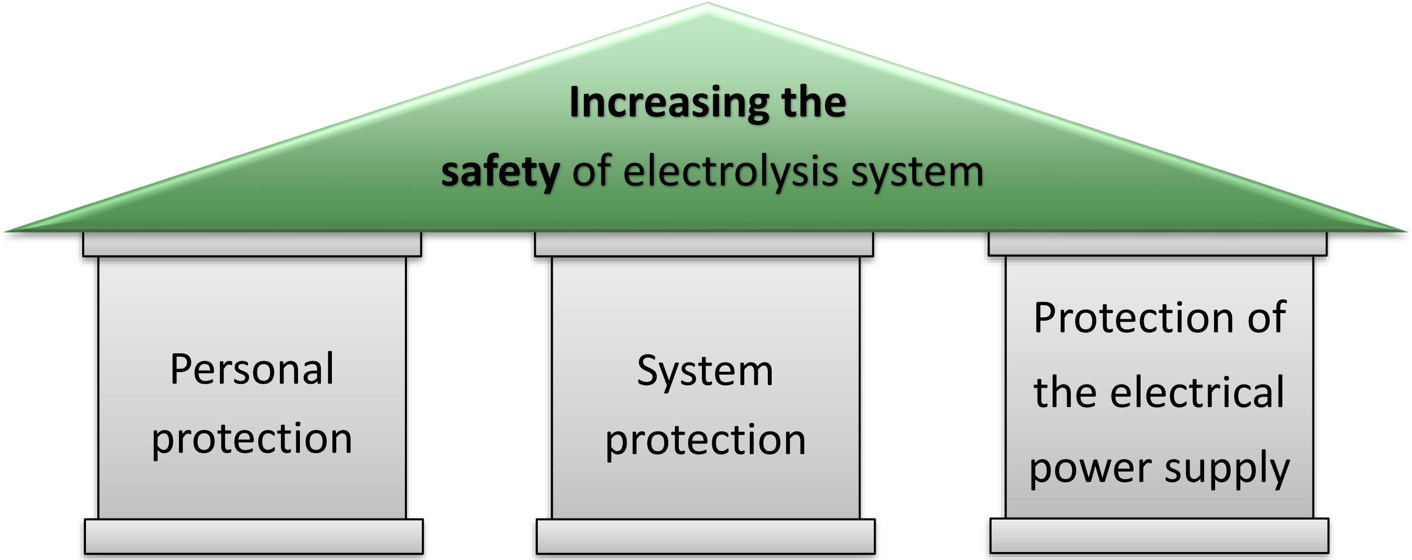
- Motivation and Introduction
- Experimental investigation on 50 kW PEM electrolyser stack at IET 4
- Summary and Outlook

Figure 1: Investigation of high-current fault arc in the Lab at TUD (fault current = 10 kA)

Motivation and Introduction

Motivation

- Overall GOAL:

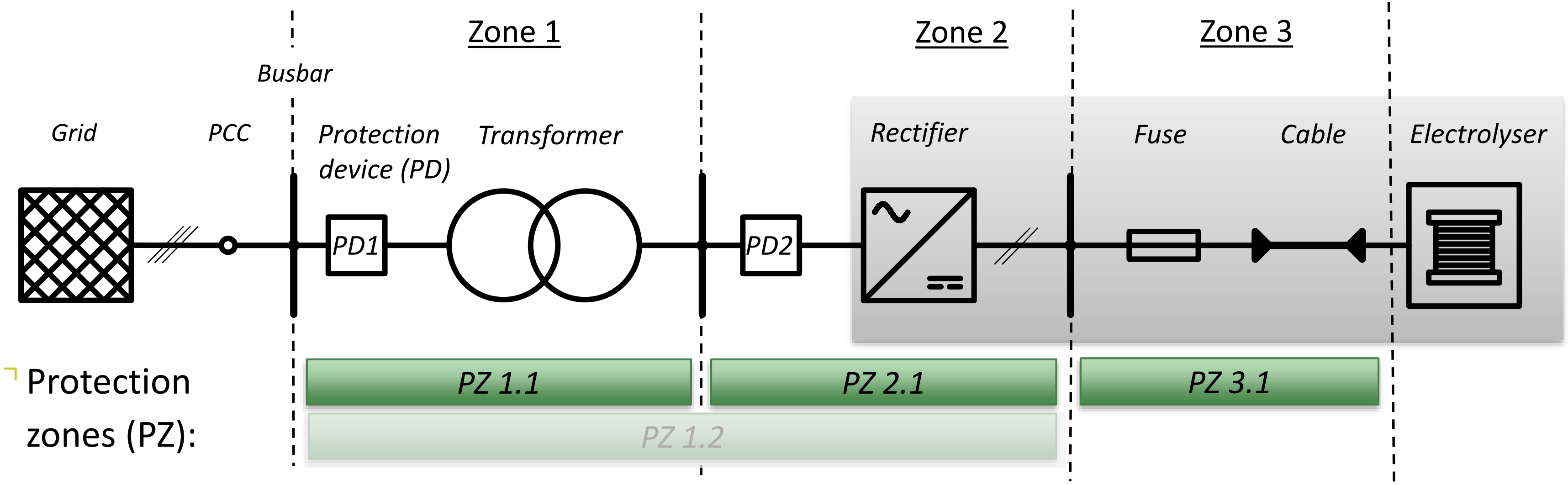


- Specific GOAL:
  - **Design of an optimal protection system for electrolysis plant (ELP)**

Motivation and Introduction

Protection system design for electrolysis plant (ELP)

- **Electrical power supply of an ELP (simplified equivalent circuit diagram):**

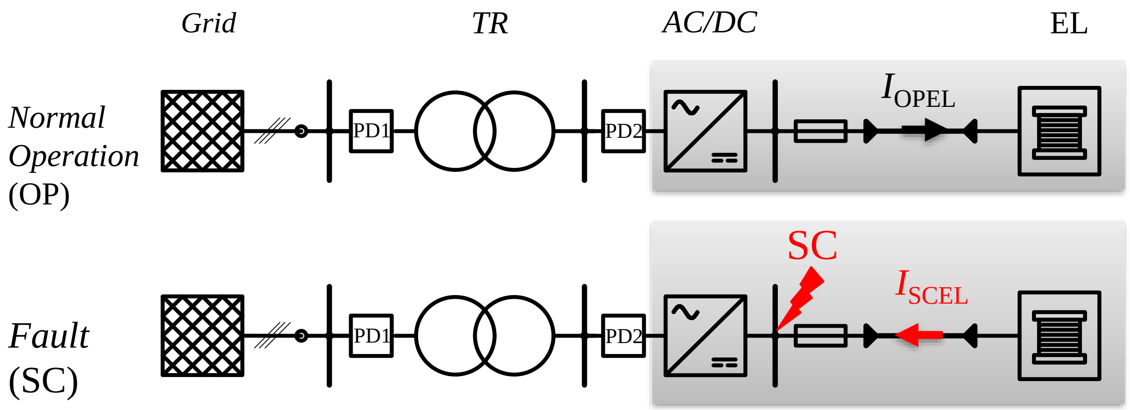


- Protection zones (PZ):

PCC … Point of common coupling

Motivation and Introduction

Behaviour of electrolysers in the event of a short circuit in the ELS



PD … protection device EL … electrolyser SC … short circuit

- Under fault conditions:
  - Voltage keeps the same sign
  - Reversal of current direction

No Information about electrical behaviour of electrolyser in literature

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Motivation and Introduction

Determination of the Short-circuit current (SCC) from electrolysers (EL)

- **Experimental investigation** on **50 kW PEM electrolyser (EL)** at Institute of Energy Technologies (IET 4, Forschungszentrum Jülich)
- **Experimental setup**
- **Results:**
  - **Characterization of the short-circuit current contribution from EL stack (SCCEL)**
  - **Influence of system parameters on SCCEL**

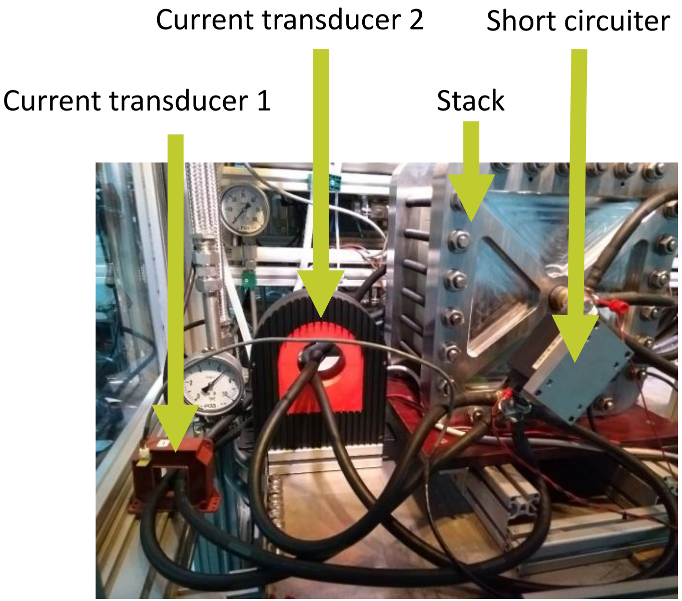

Figure 1: Test setup with 50 kW electrolysis stack at the IET 4 [4]

Experimental investigation on 50 kW PEM electrolyser (EL) at IET 4

Experimental setup

- **State 1** (S1 closed, S2 open): **Normal operation**
- **State 2** (S1 open, S2 closed): **Short circuit**

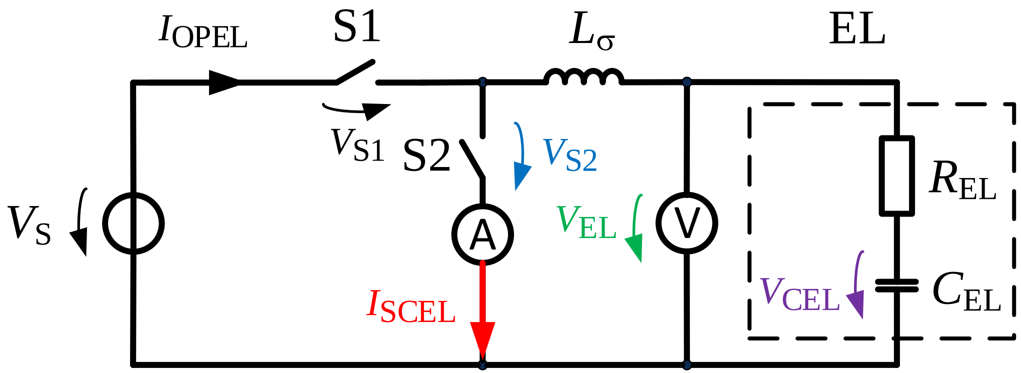

Figure 1: Equivalent circuit diagram of test setup at the IET 4

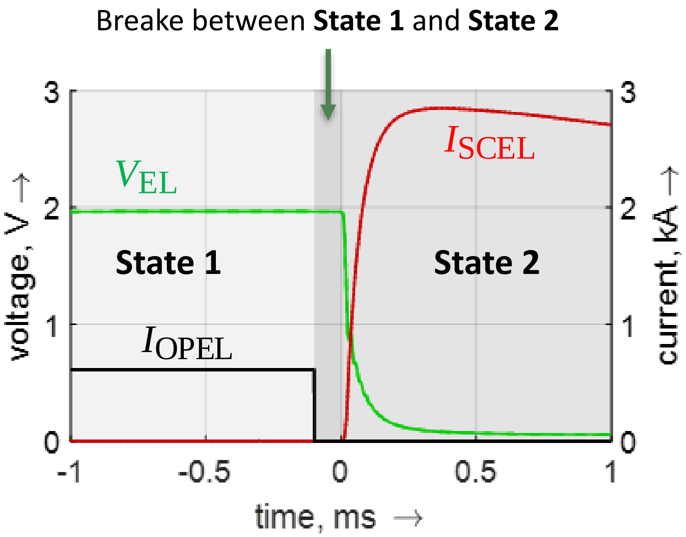

Figure 2: cell voltage and current during experiment

Experimental investigation on 50 kW PEM electrolyser (EL) at IET 4

Characterisation of the short-circuit current

- Steep rise in current after fault occurrence
- After reaching maximum: exponential drop in short-circuit current (with single time constant)

- **Peak of I_{SCEL} is up to five times the rated current I_{OPEL}**
- **No fuel cell operation visible**
- **Short circuit behaviour similar to capacity**

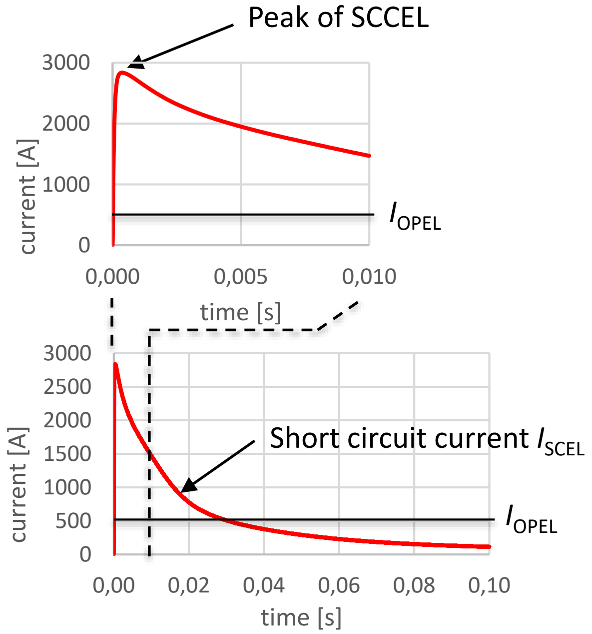

Figure 1: Time curve of the short-circuit current with peak value from a 50 kW electrolysis stack with an external short circuit [4]

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Experimental investigation on 50 kW PEM electrolyser at IET 4

Influence of system parameters

- *Investigation of the dependency of the SCCEL parameters on the system parameters*
- Definition of SCCEL parameters

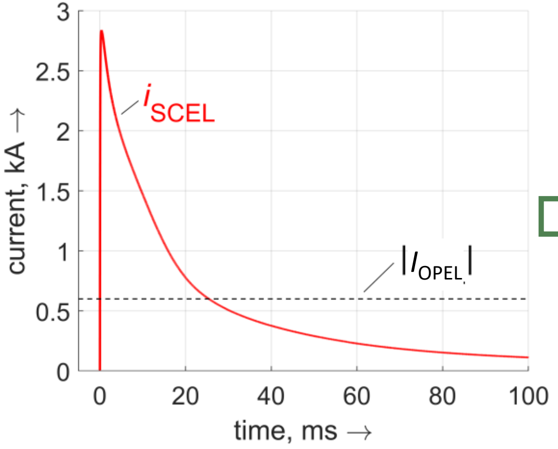

Figure 1: Time curve of SCCEL

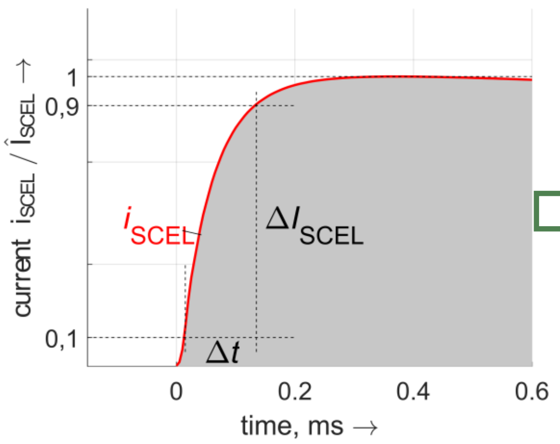

Figure 2: SCCEL parameters

SCCEL parameters
Maximum Value $\hat{\imath}_{\mathrm{SCEL}}$
Gradient $\frac{\Delta I_{\mathrm{SCEL}}}{\Delta t}$
Rise time Δt
Current-time area $\int_{t_0}^{t_1} i_{\mathrm{SCEL}}^2 \mathrm{d}t$

Experimental investigation on 50 kW PEM electrolyser at IET 4

Influence of system parameters on SCCEL

System parameter	*Change in values*
Thickness of membrane, µm	**51 → 178**
Catalyst (loading: δ_{IrO2}, δ_{Pt})	**Low → high**
EL technology	**PEM → AEL**
Operating current, A	26 → 614
Operating temperature, °C	50 → 80
Operating pressure, bar	0 → 9.5

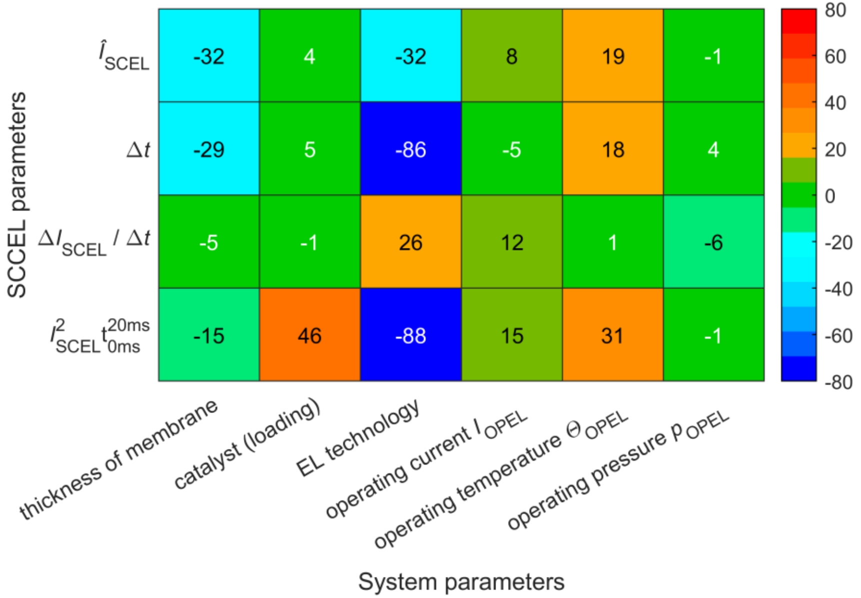

Figure 1: Overview of influence of EL stack parameters on SCCEL Parameters

- **Parameters of stack** have <u>higher</u> influence than the operating conditions

Summary and Outlook

- **EL significantly contributes to the SCC** in case of DC faults in ELPs
- **SCCEL must be taken into account** when designing the protection systems of ELP
- The **SCCEL of systems with real performance characteristics and dimensions** is unknown
- **Dependency** between the **essential characteristics of an EL** (technology, MEA, number and active area of cells) **and the relevant SCCEL parameters** should be investigated further

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Thank you for your attention!

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References

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[2] Clemens, H.; Rothe, K.: *Schutztechnik in Elektroenergiesystemen*. 3. Auflage, Berlin: Verl. Technik, 1991.

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[4] Institute of Energy and Climate Research, Electrochemical Process Engineering (IEK-14), Forschungszentrum Jülich within a project cooperation with SMA Solar Technology AG.

[5] IEC 61660-1, Short-circuit currents in d.c. auxiliary installations in power plants and substations - Part 1: Calculation of short-circuit currents, 1997.