C. Müller - R. Arians - C. Quester

Analysis of Influences of External Grid Disturbances on Auxiliary Power Supply Systems of Nuclear Power Plants

Relevance / Motivation

There are many events related to grid disturbance, e.g.:

- [1] IRS, IRS No. 7929, “Transition of all Dukovany NPP units to insular operation after the disconnection of several 400 kV lines of the national grid caused by a short circuit in the Sokolnice switch yard“, August 2006
- [2] IRS, IRS No. 7954, “Reactor trip due to off-site power fluctuation: NRC information notice 2008-12”, June 2007
- [3] IRS, IRS No. 8294, “Low voltage safety grade power electronics failed due to an HV over-heated line lightning overvoltage”, July 2012
- [4] IRS, IRS No. 8315, “EDG failed to start after undetected loss of two phases on 400 kV incoming offsite supply”, May 2013

→ Development of a method to analyse the effects of grid disturbances on auxiliary power systems of NPPs

Effects of External Grid Disturbances on Nuclear Power Plants – Outline of the Research Project

- Evaluation of international operating experience
  - GRS databases, e.g. event reports (e.g. IRS, ME)
- Categorization within classification scheme
  - Determination of grid disturbances with highest relevance
- Development of representative scenarios
  - 10 basic scenarios (containing only type of grid disturbance)
  - 14 combinations (containing two or three types of grid disturbances)
- Investigation of impact of scenarios on the electrical equipment of NPPs
  - Performed using a grid analysis, planning, optimization and simulation tool (commercial software)
  - In combination with procedural analysis of effects on other parts of the NPP
- Assessment of effects of the scenarios on the auxiliary power systems of NPPs

Scenarios of Grid Disturbances (1)

Scenarios containing one type of grid disturbance:

1. Undervoltage transient
2. Overvoltage transient
3. Fluctuations of reactive power and mains voltage respectively
4. Fluctuations of effective power and mains frequency respectively
5. Underfrequency transient
6. Overfrequency transient
7. Fluctuations of the load
8. Loss of offsite power without previous transient
9. One-phase asymmetry
10. Two-phases asymmetry

Scenarios of Grid Disturbances (2)

Combinations of grid disturbances, e.g.:

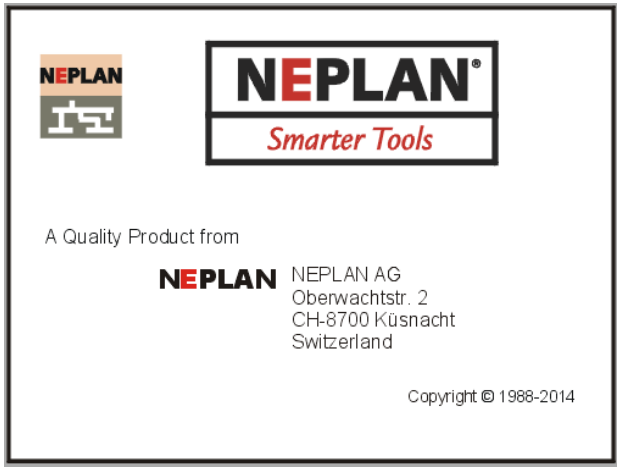
11. One-phase asymmetry and fluctuations of reactive power and mains voltage respectively
12. One-phase asymmetry and fluctuations of the load

...

24. Overfrequency transient and fluctuations of the load and an one-phase asymmetry

Simulation and Analysis Tool

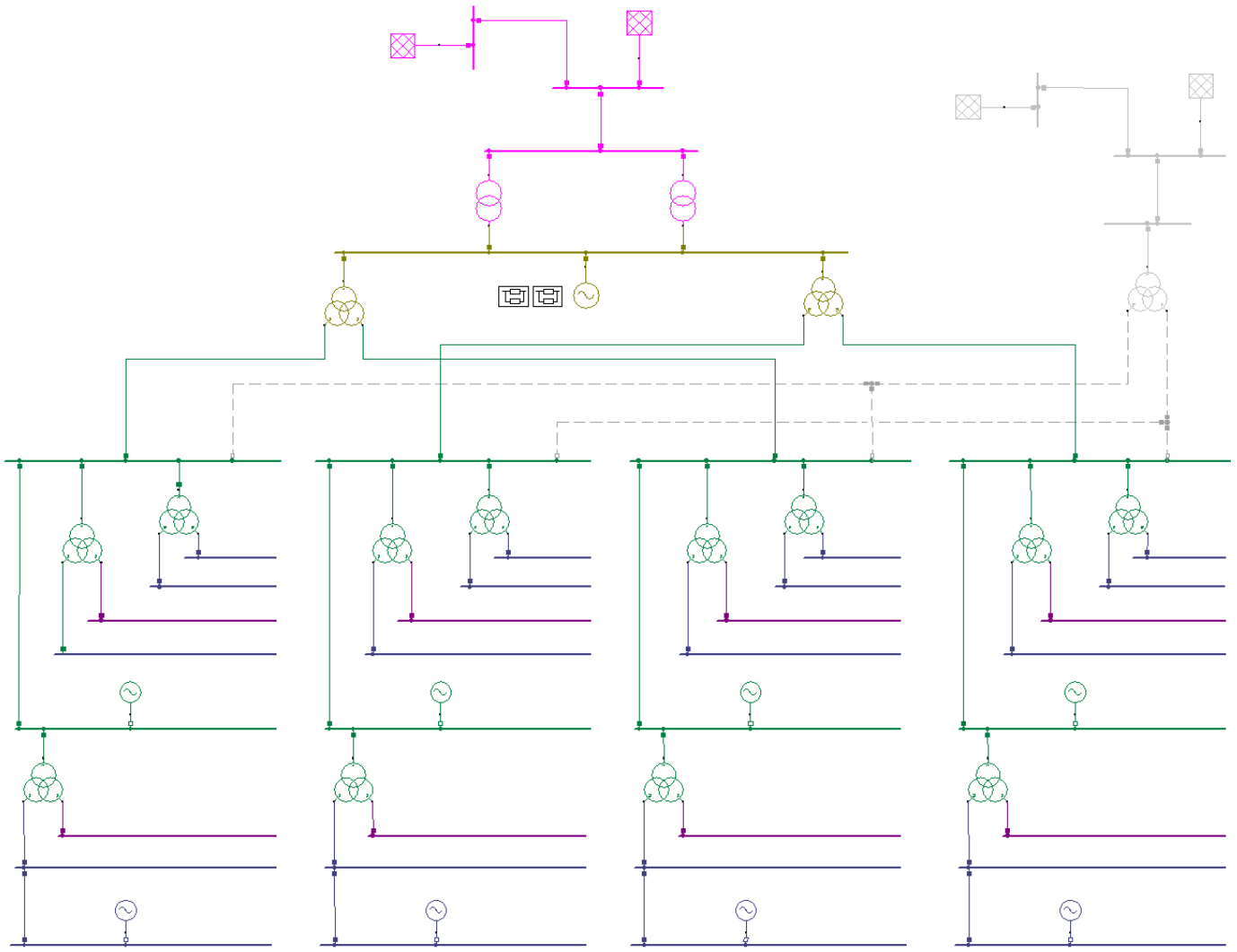
- Load flow / contingency analysis
- Short circuit analysis
- Harmonic analysis
- Dynamic simulation
- Flash-arc calculation
- Overhead line / cable parameter calculation
- Cable sizing
- ...
- Component libraries
  - D-A-CH
    - D – Deutschland – Germany
    - A – Österreich – Austria
    - CH – Schweiz - Switzerland



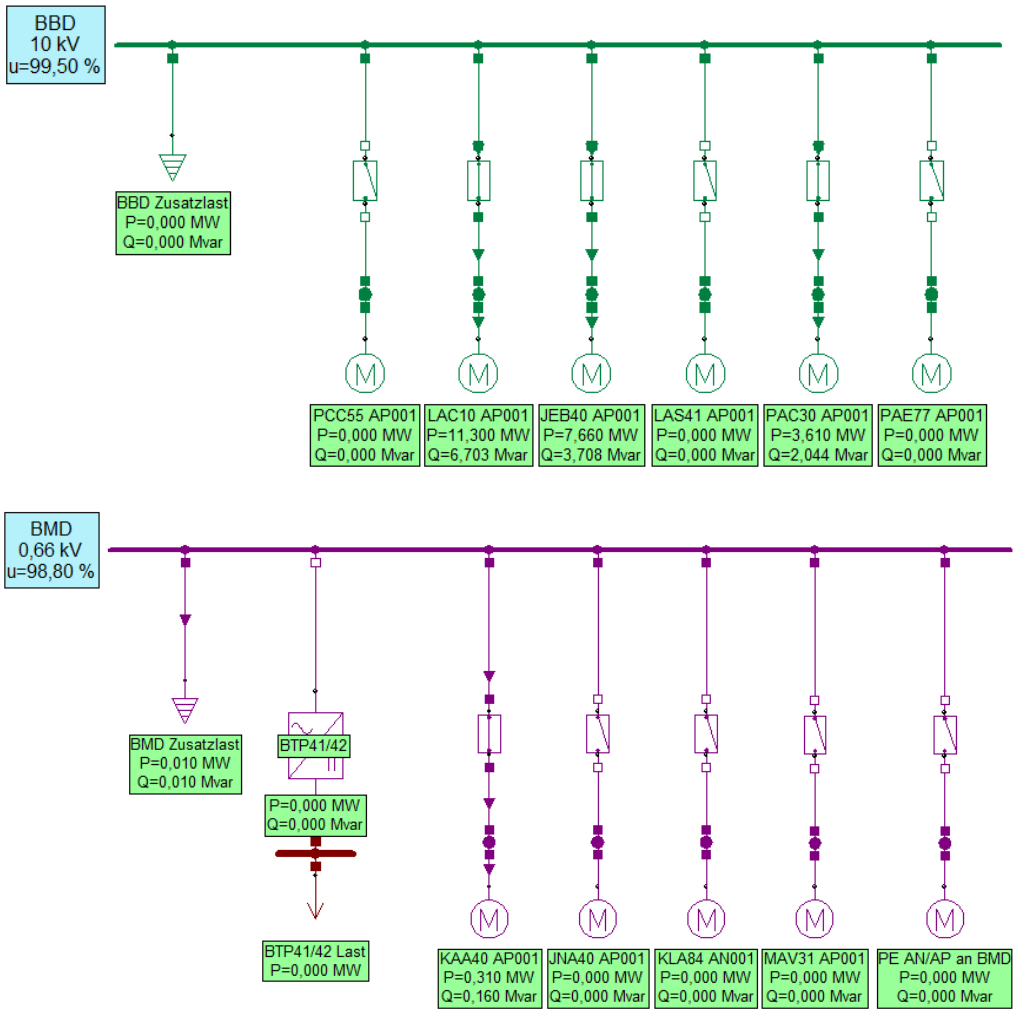
Implementation of a Model of an Auxiliary Power System

- Based on German NPPs of the type Konvoi
- Considers the following details:
  - Generator
  - Transformers
  - Busbars (AC and DC)
  - Important actuators
  - Connecting cables
  - Emergency diesel generators (EDGs)
  - External grids
  - ...

Auxiliary Power System

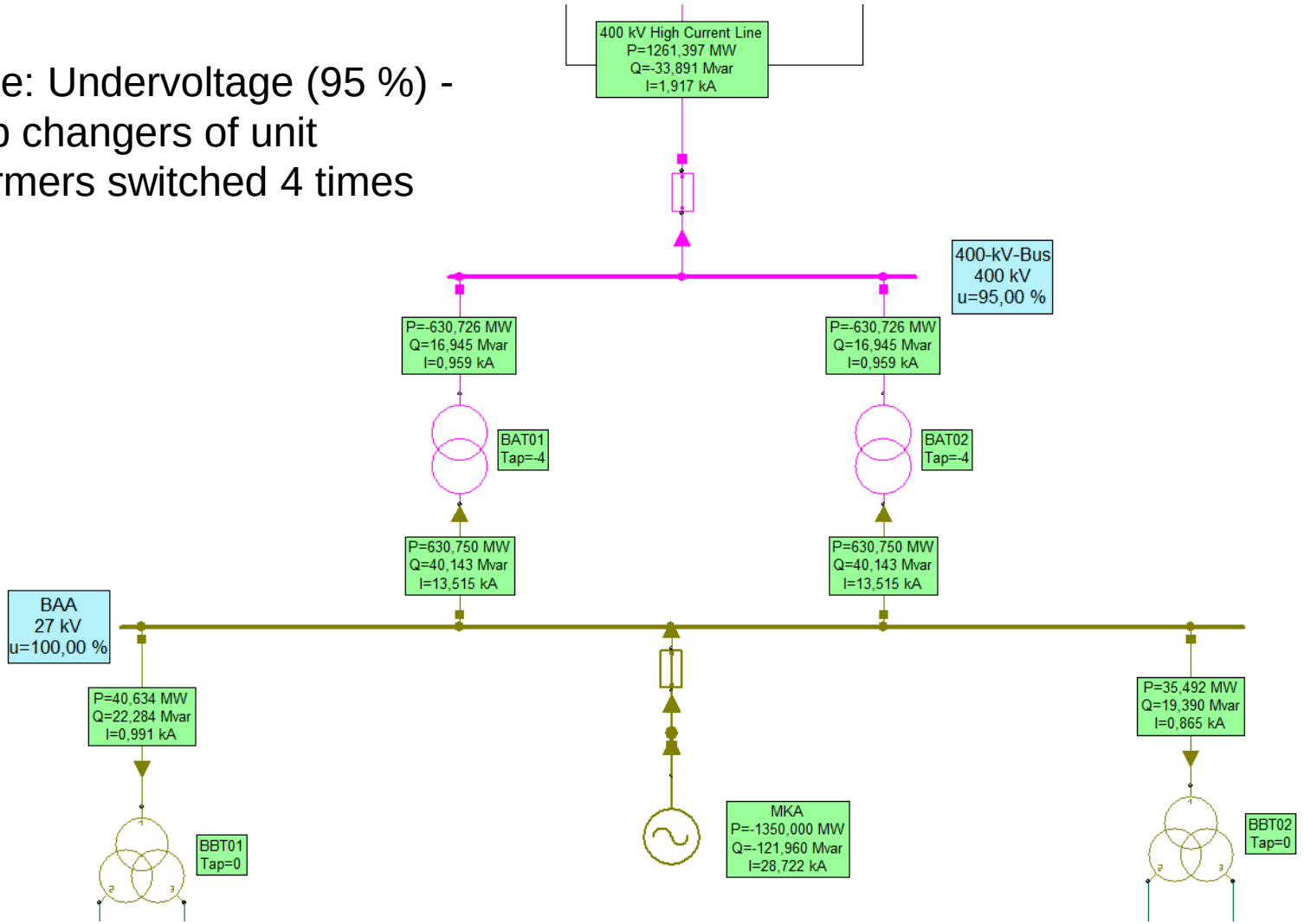


Auxiliary Power System



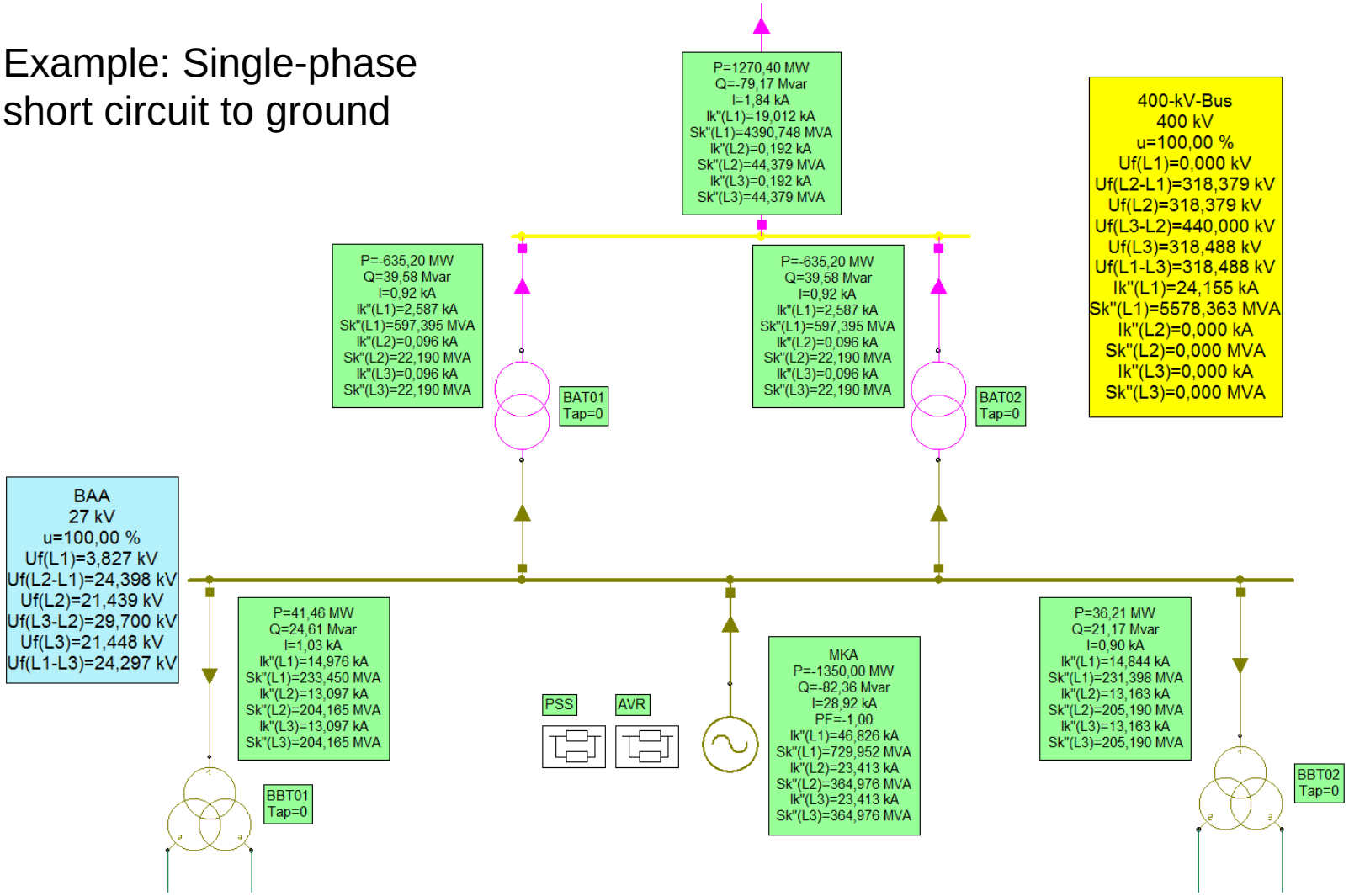
Load Flow Analysis

Example: Undervoltage (95 %) - load tap changers of unit transformers switched 4 times

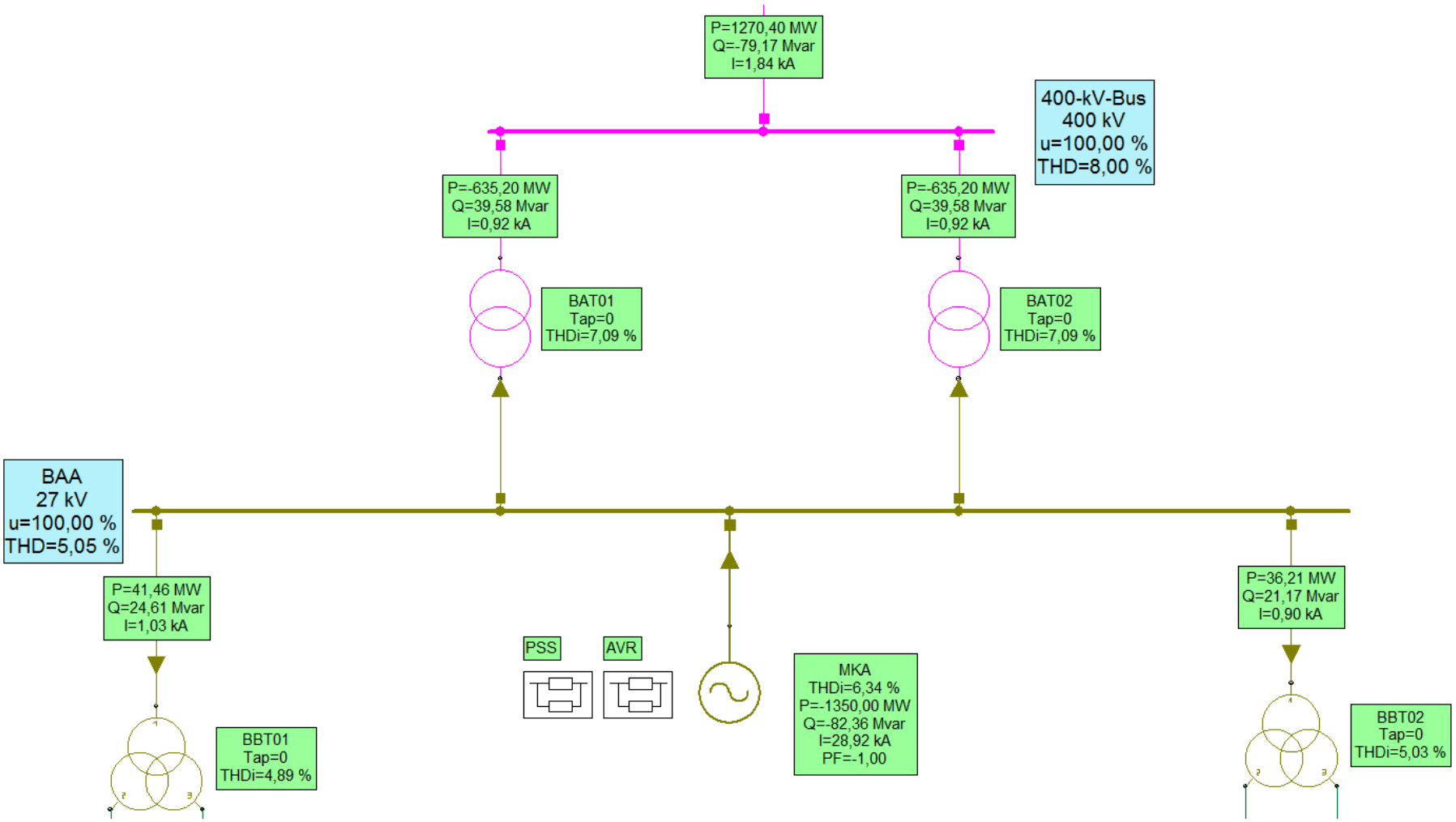


Short Circuit Analysis

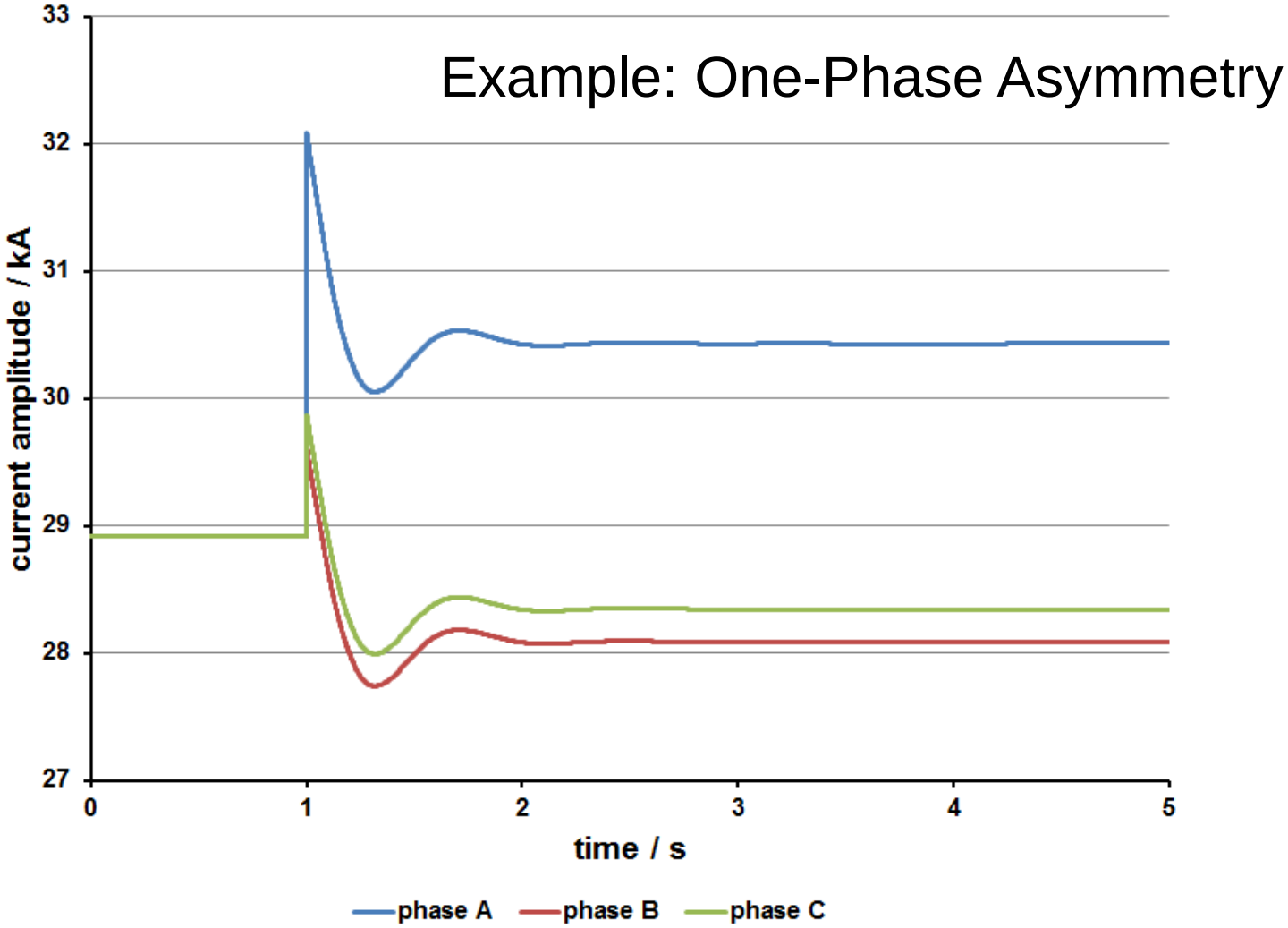
Example: Single-phase short circuit to ground



Harmonic Analysis



Dynamic Simulation



Investigations Carried Out

Simulations for all scenarios

- at full load
- in shutdown operation

taking into account

- fast transients
- slow transients

Results

- 6 scenarios are explicitly covered by the original design of the auxiliary power system
- the simulations/calculations do not indicate any need for action for 8 scenarios
- the simulations indicate a need for action for 10 scenarios, but it is sufficient if the recommendations of the Reactor Safety Commission (RSK-„Reaktor-Sicherheitskommission“) from 2014 concerning phase asymmetry are taken into account

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