Smart Fuses for Smart Grids

Considerations about the need, potential product features and feasibility

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PRO FUDIS

IFHT | RWTH AACHEN UNIVERSITY

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Competence in Circuit Protection

- **ProFuDiS**
  The increase of decentralized energy generation leads to a lot of changes in electrical power networks and therefore also a lot of changes for the protection systems used in electrical LV- and MV-power networks.

  The ProFuDiS project has the objective to identify requirements and solutions for existing and future protection systems.

- **Cooperating partners of ProFuDiS**
  RWTH Aachen University; FGH e.V.; HTW des Saarlandes University; RWE Deutschland AG; SMA Solar Technology AG; Omicron electronics GmbH; NH/HH-Recycling e.V.; ABB AG; Schneider Electric GmbH; Siemens AG;

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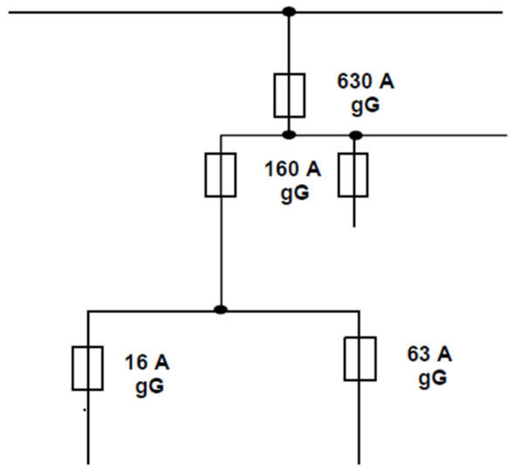
Smart Fuses for Smart Grids

- **Introduction**
- **Impact of distributed generation on low voltage grid protection**
- **Requirements and feasibility of smart fuses**

Introduction

- Electric fuses
  - Current sensing protective device
  - Independent of the current direction
- Radial low voltage (l.v.) distribution grids:
  - gG fuses widely used for protection
  - Graded for selective operation
- Increasing number of Distributed Generation (DG)
  - Influence on the power flow (normal / fault state)



⇨ Usability of „classical“ fuses needs to be checked

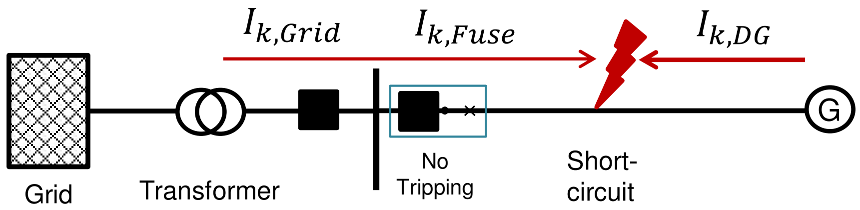
⇨ „Smart“ fuses as an alternative approach?

Impact of distributed generation on low voltage grid protection

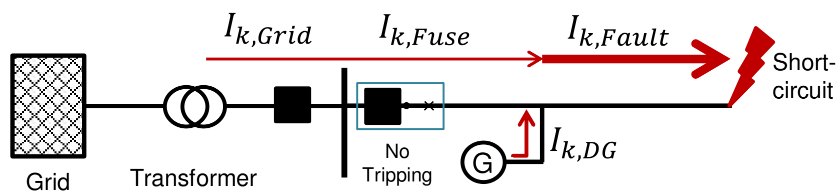
- In case of grid faults:
  - DG contribution to the fault current
  - Rise of the potential at the point of common coupling (PCC) / fault
  - Reduction of the grid's short circuit current

⇨ Increased fuse tripping time up to non-tripping

⇨ **Blinding of protection**
  - Through „backward infeed"
  - Through „intermediate infeed"



Blinding – „backward infeed"

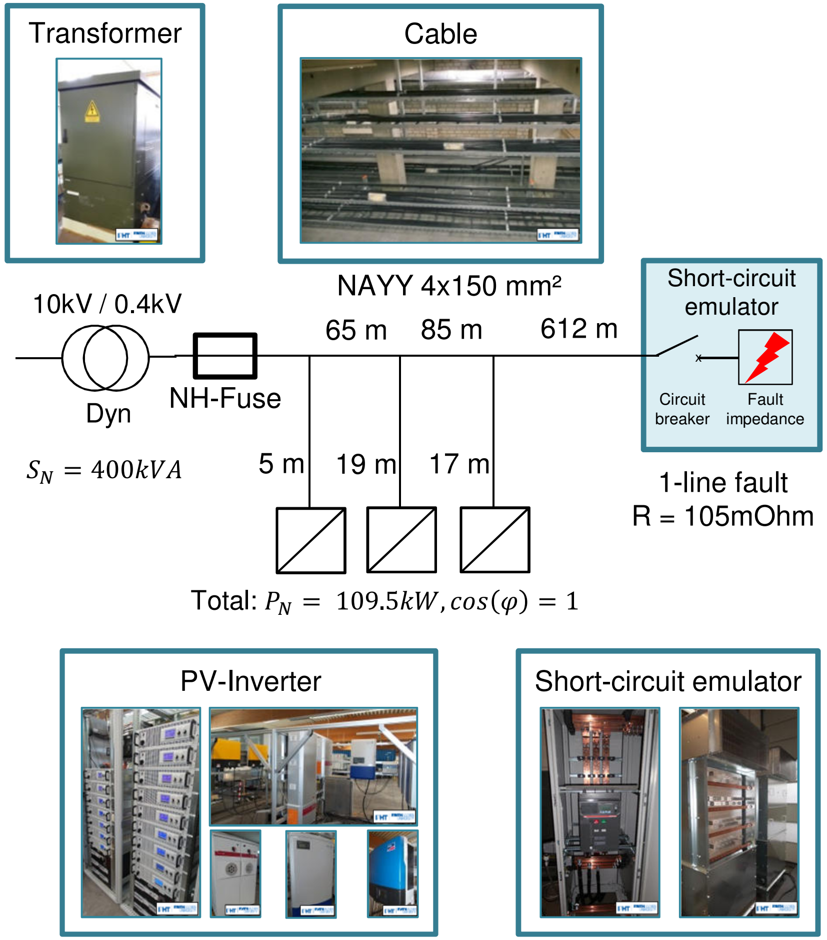


Blinding – „intermediate infeed"

Impact of distributed generation on low voltage grid protection

Blinding through "intermediate infeed"

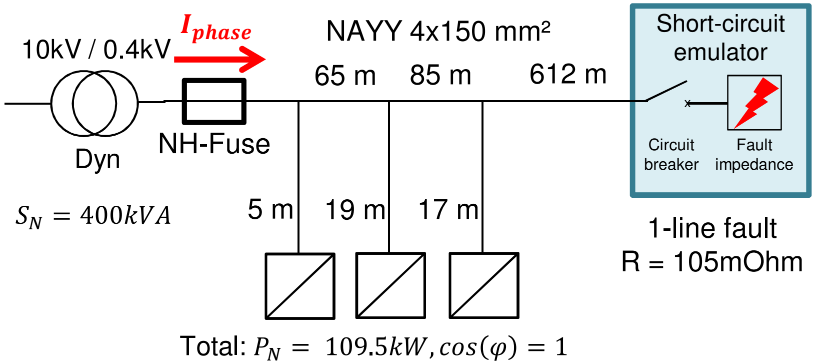
- Laboratory test in the IFHT testing center
  - Supply
    - 400kVA, 10kV/0,4kV Dyn5 transformer
  - Cable
    - 762m NAYY 4x150mm²
  - Infeed
    - Photovoltaik inverters ($P_N = 109{,}5kW$, $\cos(\varphi) = 1$, parametrization acc. to ARN4105)
    - Connected at 3 „residential service lines" NAYY4x35mm², $L_{max} = 19m$
  - Fault
    - L1-Ground fault, $R_{Fault} = 105m\Omega$

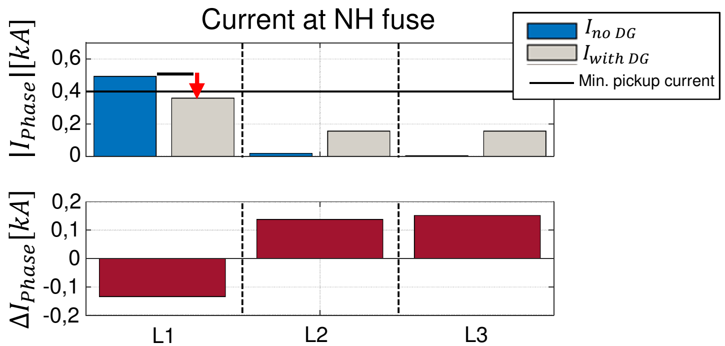


Impact of distributed generation on low voltage grid protection

Blinding through “intermediate infeed”

- Laboratory test in the IFHT testing center
  - Short-Circuit experiments:
    - 1. without PV-inverters
    - 2. with PV-inverters
  - Evaluation:
    - Fault-current at NH-Fuse (beginning of the line)
    - 250A NH2 gG fuse
    - Conventional fusing current: $1{,}6 \cdot I_N = 400A$
  - Results:
    - $I_{phase,with\ DG} = 359A < 400A = 1{,}6 \cdot I_N$
    - Fuse-tripping time increased up to a non-tripping





➡ Blinding with PV-inverters in l.v. grids is possible

Definition of a smart fuse

- A smart fuse (or actor fuse) in this context means a fuse able to act on the command of a fault detecting device and to interrupt currents below its intrinsic time-current characteristic.
- Fault detecting devices may either be integral function of the fuse or external sophisticated grid control units as required for smart grids.

Technical requirements for smart fuses

- Smart fuses shall be able to operate upon a signal of a fault detecting device.
- Smart fuses shall be able to interrupt fault currents below their minimum melting current.
- Smart fuses shall be able to interrupt over-currents faster than given by their intrinsic time-current characteristic.
- Smart fuses shall provide selectivity of protection beyond standard selectivity rules.
- Smart fuses shall operate according to their intrinsic characteristic unless triggered by an external signal.

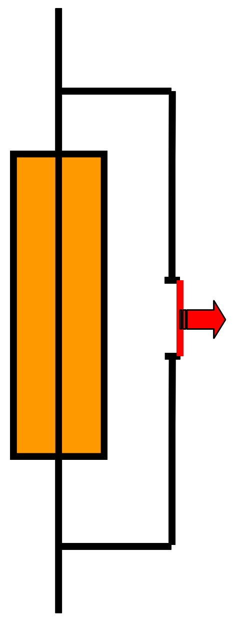
Expected features of smart fuses

- Smart fuses interrupt fault currents equal to or below normal operating currents.
- Smart fuses overcome blinding problems in l.v. distribution grids.
- Smart fuses reduce hazards of impedance limited arc flash (see presentation H. Schau).
- Smart fuses are able to interrupt longitudinal arcs and thus to reduce the risk of fire.
- Smart fuses provide fail-safe overcurrent protection.
- Smart fuses fit existing fuse-bases in l.v. distribution systems.

Potential solutions

Bypass solution

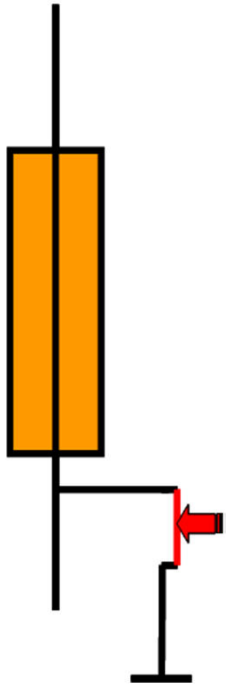
- Well known for m.v. applications
- Difficult to realize for l.v. circuits
- No fail-safe protection



Potential solutions

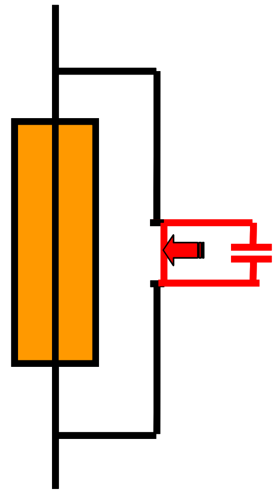
Solid grounding

- Common solution for arc fault energy limitation
- Limited selectivity of protection
- Fail-safe circuit protection



Potential solutions

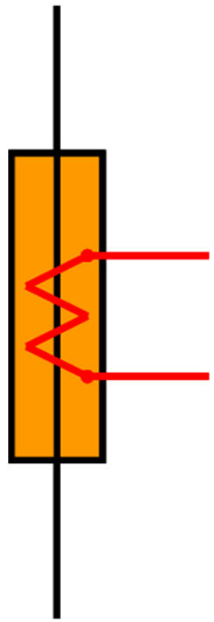
Electric pulse added



- Opening of restrictions by high I^2t injection
- Limited by surge voltage level
- Fail-safe circuit protection

Potential solutions

Heat pulse added



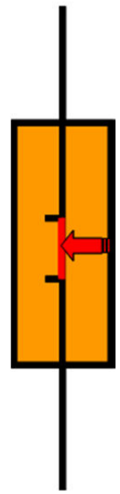
- Additional electric heat supports M-effect
- Reactive substance boosts temperature-rise
- T/C characteristic is shifted to the left by external heat injection
- Fail-safe circuit protection

Smart Fuses for Smart Grids

Potential solutions

Mechanical break

- Realized on h.v. fuse-links
- Mechanical break in fuse-elements interrupts low fault currents
- Fail-safe circuit protection



Conclusions

- Distributed generation in l.v. grids is challenging traditional system protection.
- Smart fuses will be able to cope with future requirements for l.v. grid protection.
- Smart fuses offer more safety features than just overcurrent protection.
- Fuse technology may be at the rim of a new fuse generation!

Thank you for your attention

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