Cu Copper Alliance

Dynamic modeling of the performance of safety electrical circuits during a fire – case study

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Introduction

- **Safety services perform a crucial role in public buildings**

- **Their objectives are:**

  - to provide safe evacuation routes from the affected areas
  - to ensure that all services required for fighting the fire are maintained for the required time.
  - to ensure the preservation of services

What's the problem?

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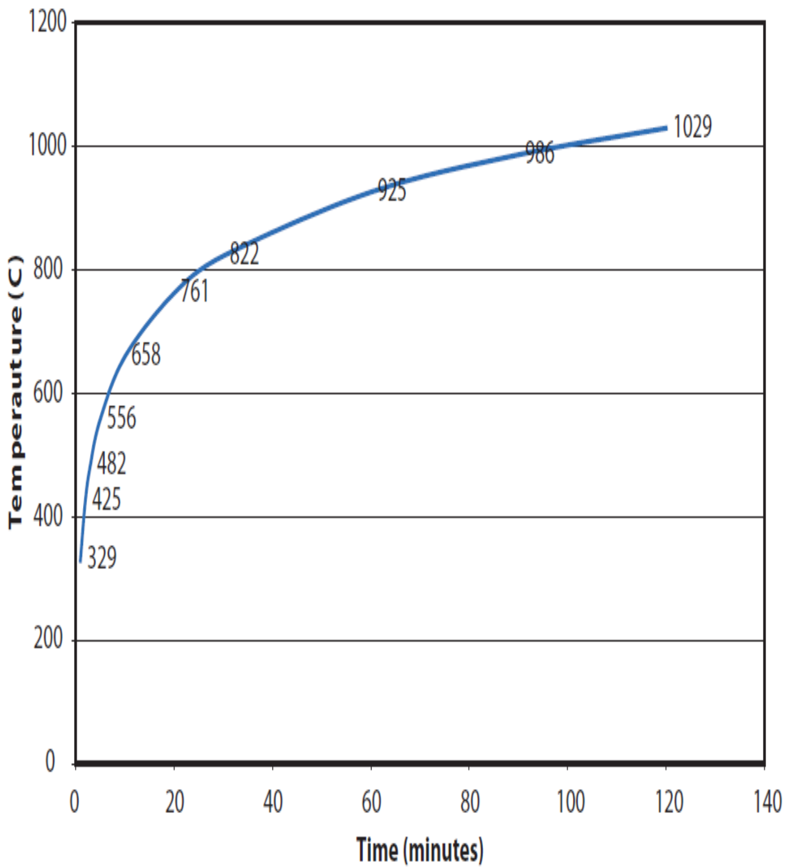

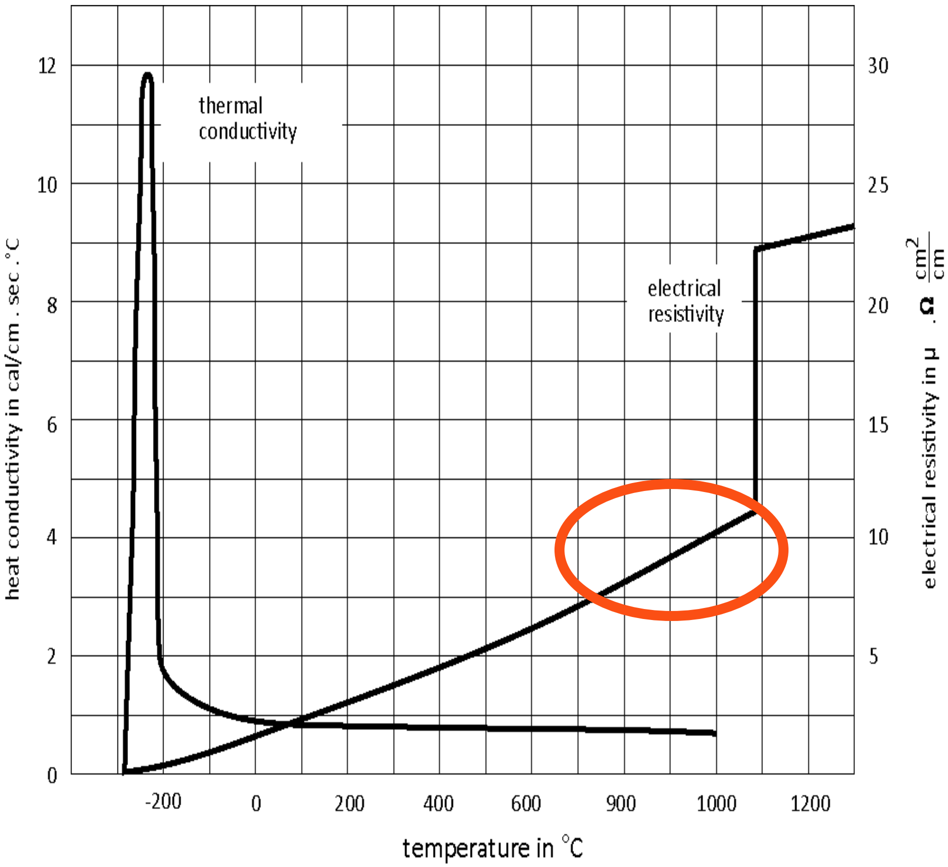

heat conductivity and electrical resistivity versus temperature, of pure copper

Aims of the study

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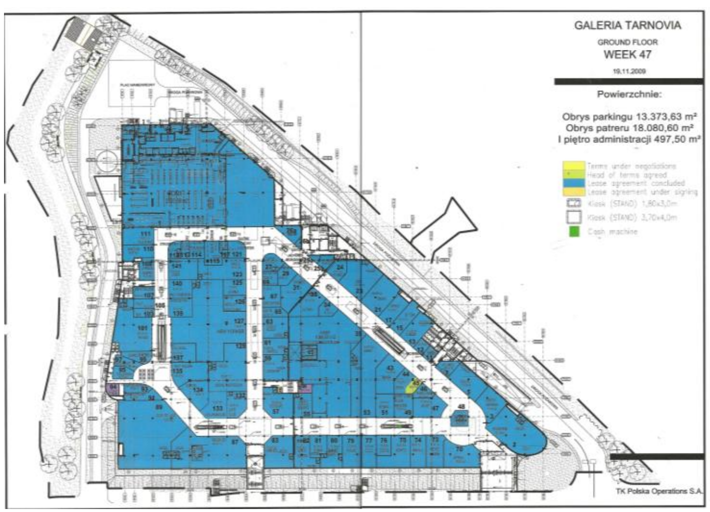
Detailed aims of this study are:

- to verify the design of existing safety circuits,
- to verify whether the cross-section of fire safety circuits guarantee operation of equipment during fire, If not, to determine the required cross-section,
- to indicate the type of equipment most sensitive to voltage drop

The overall aim of this study is to demonstrate and emphasize the importance of selection of proper cross-section of conductors for fire safety circuits that ensure proper start-up and operation of fire safety equipment

The object of the study



Shopping Mall Galeria Tarnovia,

ul. Krakowska 149,

33-100 Tarnów, Poland

- **Area: 36.500 m2 (2 levels)**
- **Cark park area: 11.500 m2**
- **Number of shops: 115**
- **Year of opening: 2009**
- **3 fire zones separated by fire resistant walls REI60 and doors EI30**

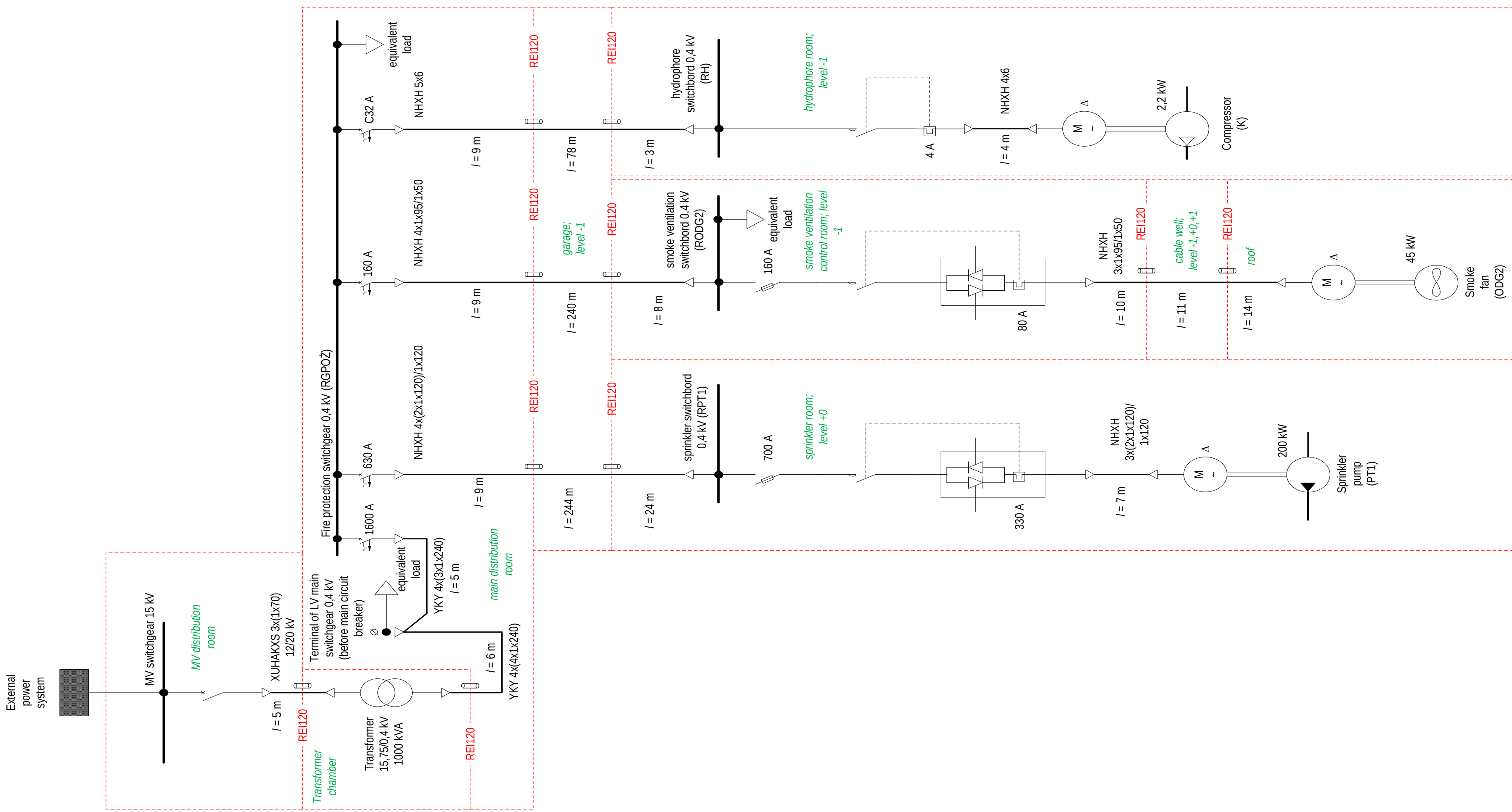
Selected fire safety circuits

Main criteria for selection of fire safety circuits used in investigations were:

- circuit significance
- relative high rated power
- circuit length

Type of fire safety device	*Rated active power*	*Supplying cable type*	*Total cable length*
Water sprinkler pump	200 kW	NHXH 4(3)x(2x1x120)/1 x120	280 m
Smoke fan	45 kW	NHXH 4(3)x(1x95)/1x50	250 m
Compressor of hydrophore reservoir	2,2 kW	NHXH (5(4)x6)	90 m

Selected fire safety circuits



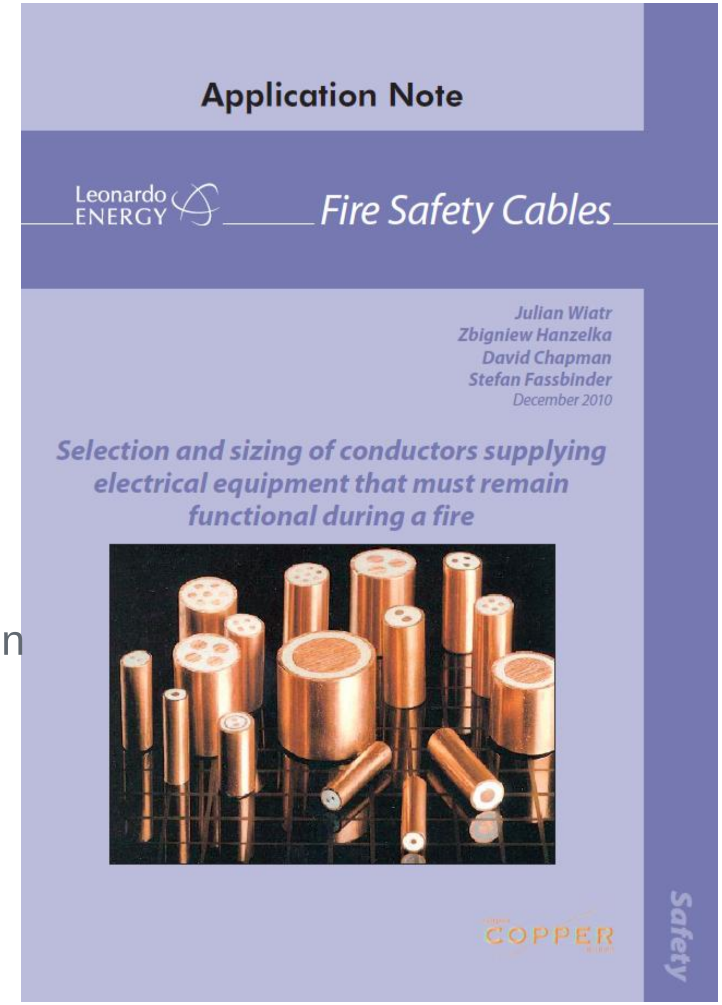
Verification of cross section of cables based on IEC 60364

Cable sizing criteria considered:

- Current rating & overload protection
- Permissible voltage drop
- Short-circuit strength
- Automatic disconnection of supply

Preliminary calculations demonstrate:

- correct cable size selection on the electrical installation design stage based on IEC 60364-4-41
- problems with the time of automatic disconnection of supply only under fire conditions
- problems with the voltage drop under fire conditions



Dynamic simulations

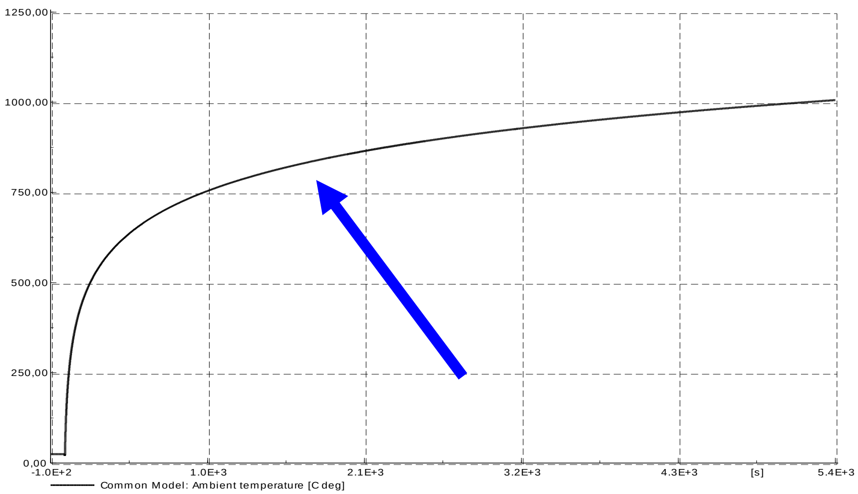
Next step of this project was to verify the performance of fire protection devices and protective relays in dynamic simulations.

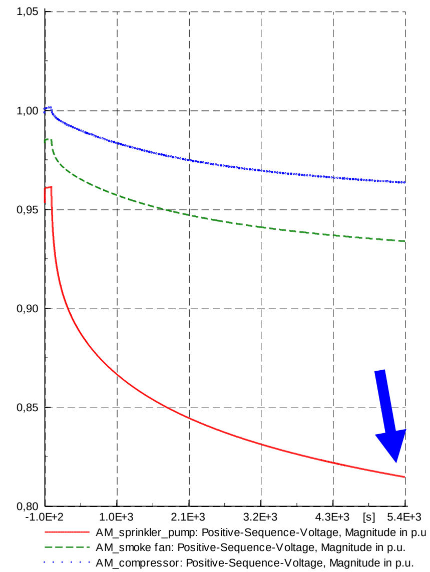
The following group of scenarios have been considered:

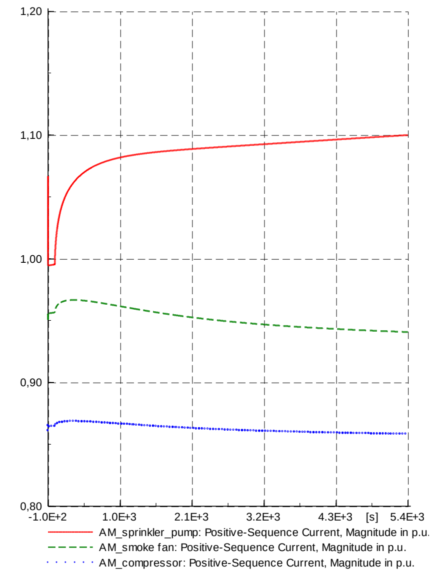
- steady state operation,
- motor starting
- single-phase fault clearing

Dynamic simulations - results

Steady-state operation







Simulation time	Resistance of cable sections located in the car park [Ohms] and [p.u]		
	Sprinkler pump circuit	Smoke fan circuit	Compressor circuit
	Length: 244 m Cross-section: 4x(2x1x120)/ 1x120 mm^2	Length: 240 m Cross-section: 4x(1x95)/ 1x50 mm^2	Length: 78 m Cross-section: (5x6) mm^2
0 s	0,0190 Ω (1,0 p.u.)	0,0236 Ω (1,0 p.u.)	0,2449 Ω (1,0 p.u.)
30 min	0,0860 Ω (4,52 p.u.)	0,1067 Ω (4,52 p.u.)	1,1075 Ω (4,52 p.u.)
60 min	0,0956 Ω (5,03 p.u.)	0,1186 Ω (5,03 p.u.)	1,2307 Ω (5,03 p.u.)
90 min	0,1013 Ω (5,33 p.u.)	0,1257 Ω (5,33 p.u.)	1,3042 Ω (5,33 p.u.)

Dynamic simulations - results

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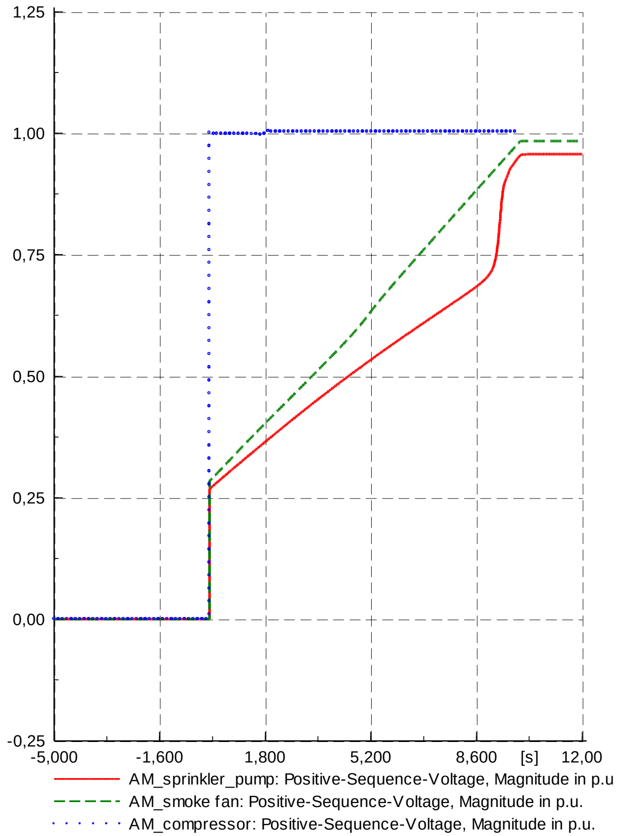
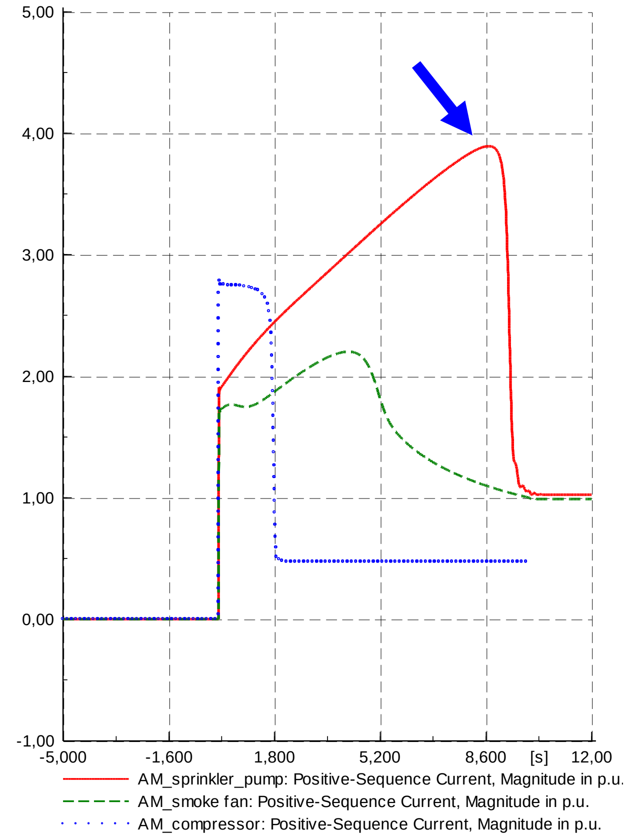
Motor starting at no-fire conditions





Dynamic simulations - results

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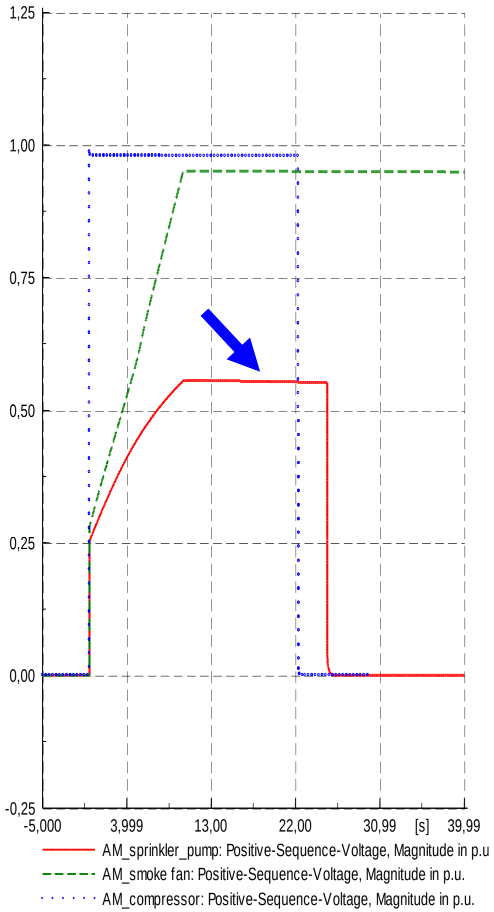
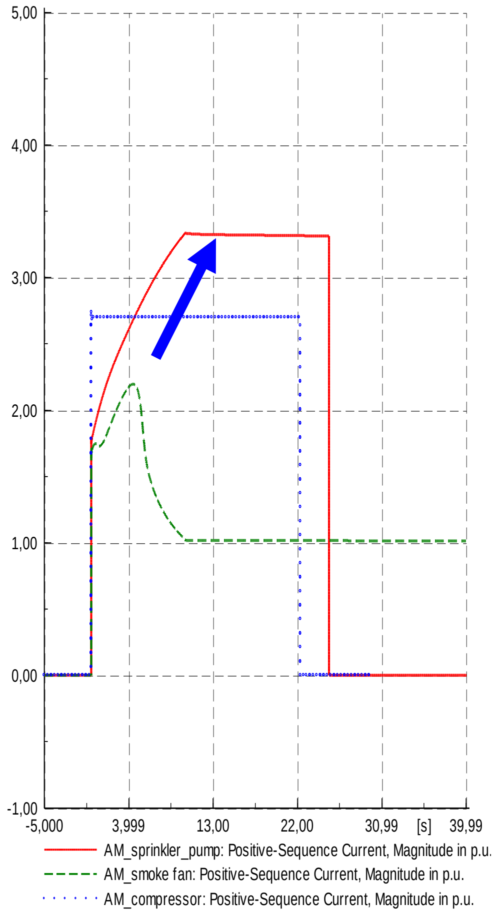
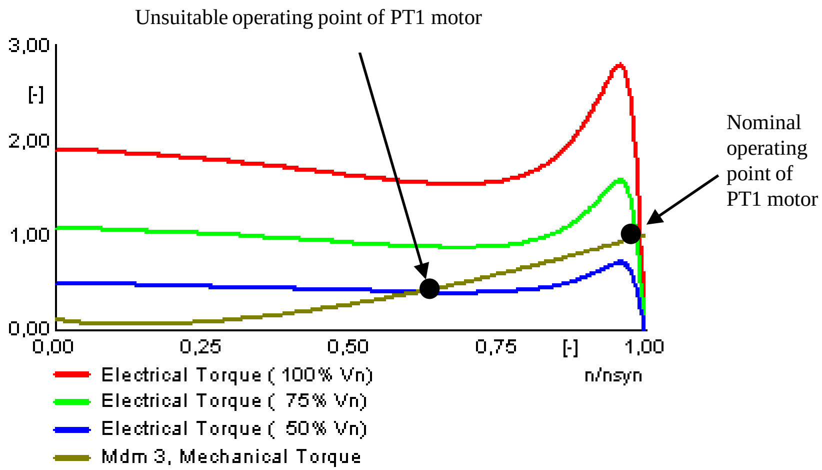
Motor starting at 90 min. fire conditions

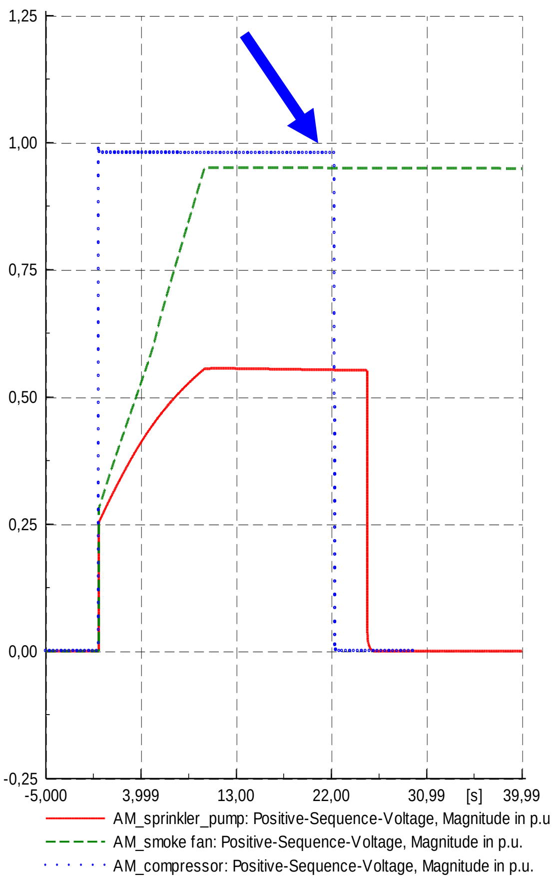


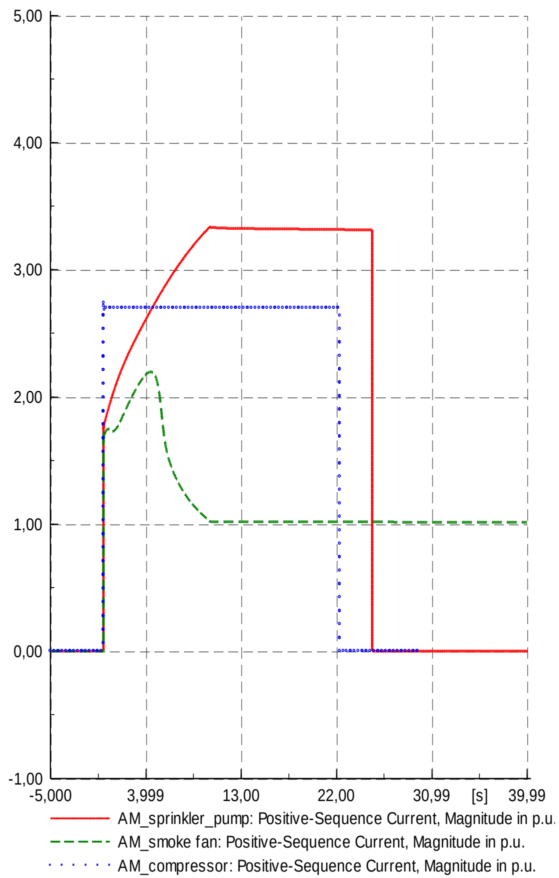


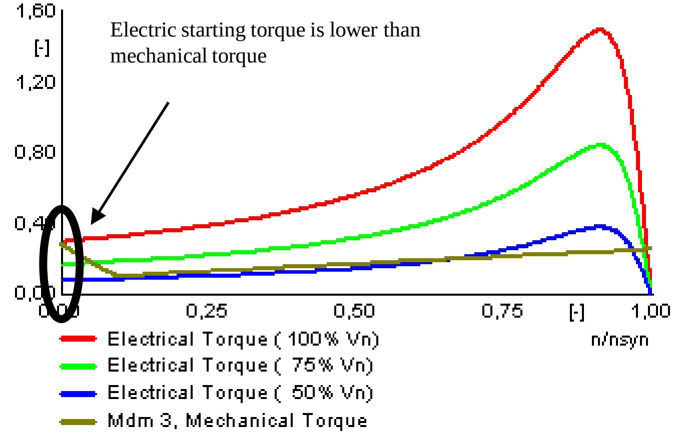


Dynamic simulations - results

Motor starting at 90 min. fire conditions

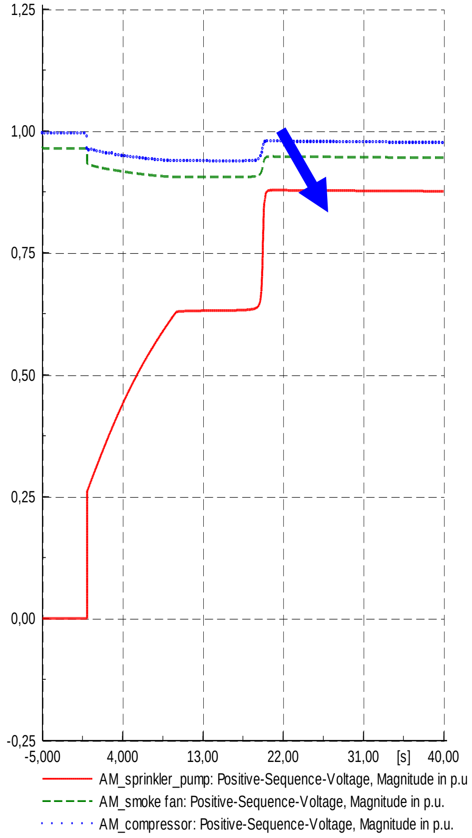


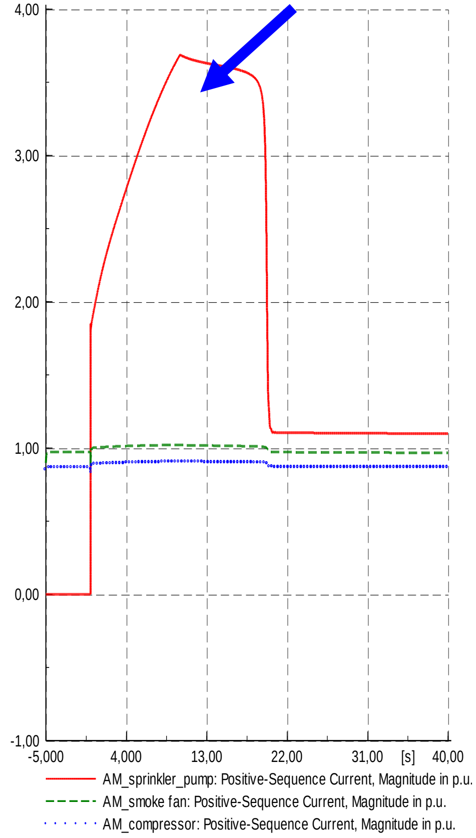


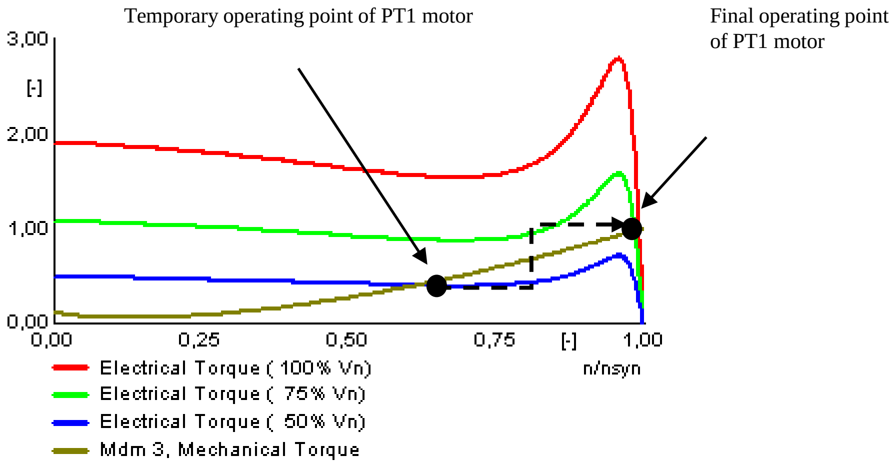


Dynamic simulations - results

<u>Motor starting at 90 min. fire conditions:</u> the cable cross-section has been increased from 2x120 mm2 to 3x120 mm2

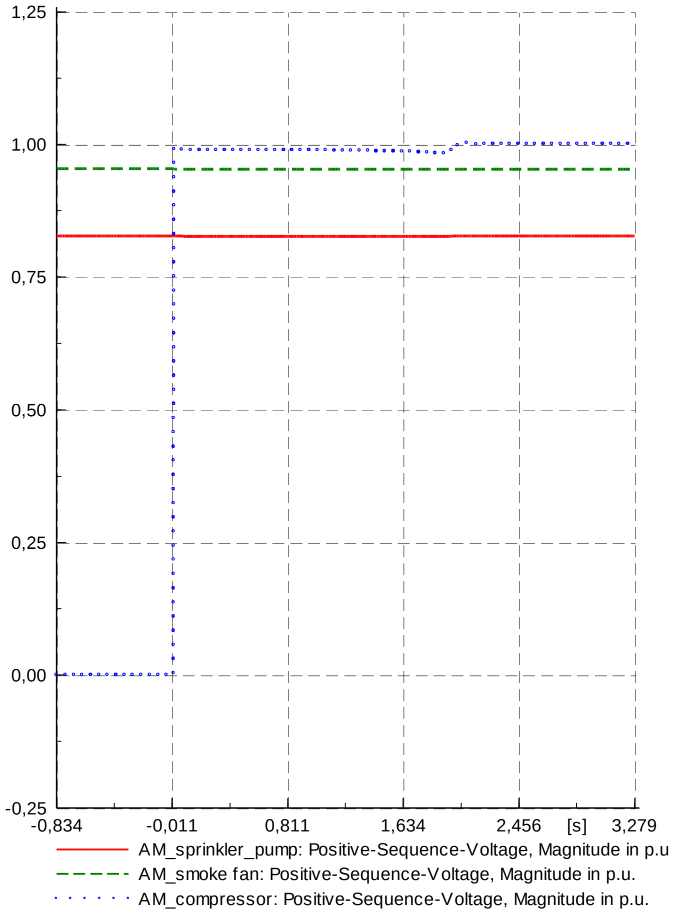


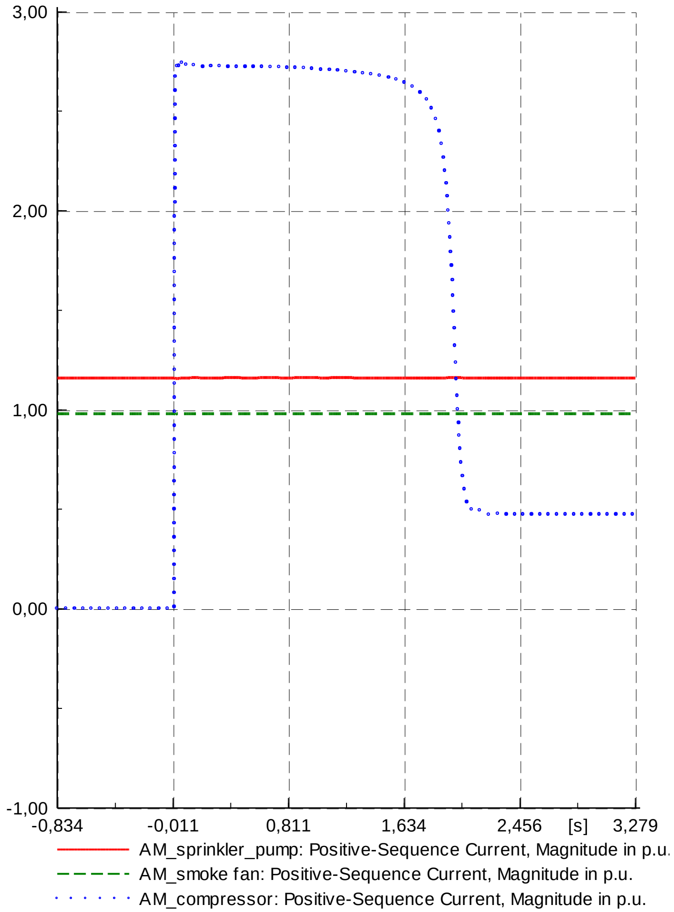




Dynamic simulations - results

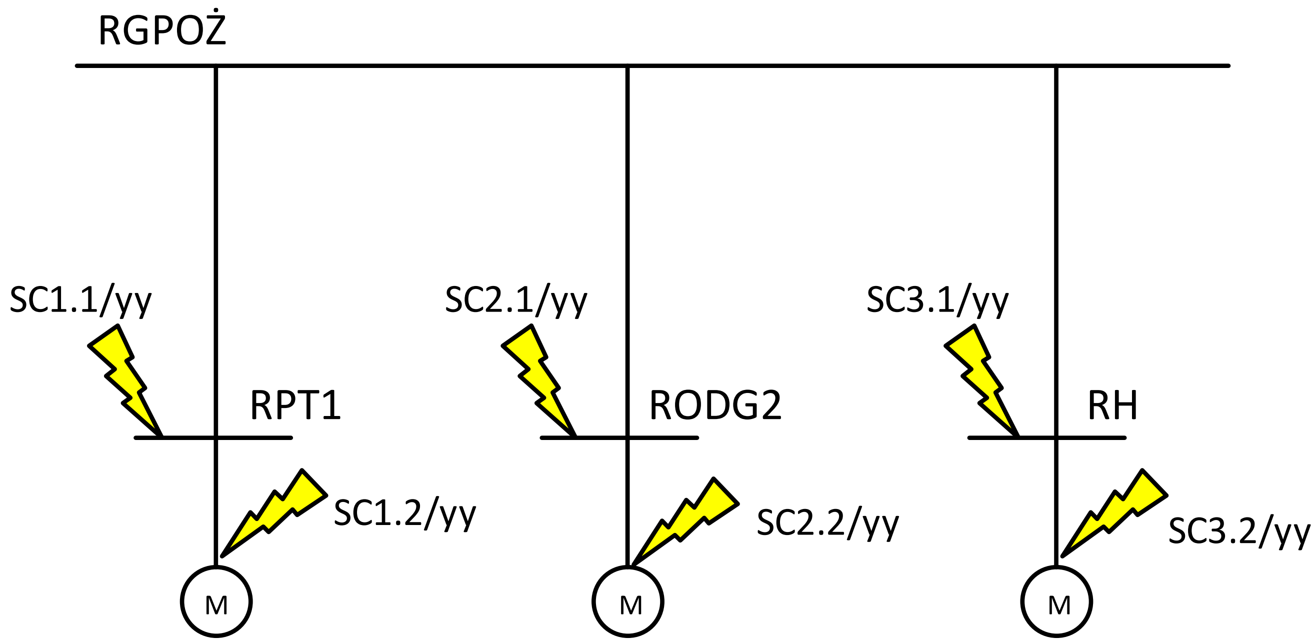
Motor starting at 90 min. fire conditions





Dynamic simulations - results

Single phase-to-ground faults



Dynamic simulations - results

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Single phase-to-ground faults

Scenario	Total clearing time	Required supply disconnection time	Activated fault protection device
SC1.1/0	0,070 s	5 s	Electromagnetic release in CB (RGPOŻ – PT1 circuit)
SC1.2/0	0,047 s	0,4 s	Electromagnetic release in CB (RGPOŻ – PT1 circuit)
SC2.1/0	0,007 s	5 s	Electromagnetic release in CB (RGPOŻ– ODG2 circuit)
SC2.2/0	0,008 s	0,4 s	Electromagnetic release in CB (RGPOŻ– ODG2 circuit)
SC3.1/0	0,003 s	5 s	Electromagnetic release in CB (RGPOŻ– K circuit)
SC3.2/0	0,003 s	0,4 s	Electromagnetic release in CB (RGPOŻ– K circuit)
SC1.1/90	32,707 s	5 s	Thermal release in CB (RGPOŻ – PT1 circuit)
SC1.2/90	12,588 s	0,4 s	Thermal relay in the contactor (RPT1)
SC2.1/90	3,988 s	5 s	Thermal release in CB (RGPOŻ – ODG2 circuit)
SC2.2/90	0,38 s	0,4 s	Thermal relay in the contactor (RODG2)
SC3.1/90	6,246 s	5 s	Thermal release in CB (RGPOŻ – K circuit)
SC3.2/90	2,980 s	0,4 s	Thermal relay in the contactor (RH)

Dynamic simulations - results

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Single phase-to-ground faults – increased cross-section

Considered scenario	Cable cross-section [mm^2]	Time of disconnection obtained from simulation	Required supply disconnection time	Activated fault protection device
SC1.1/90	4x(2x1x120)/1x120 (existing)	32,707 s	5 s	Thermal release in CB (RGPOŻ – PT1 circuit)
SC1.1/90	4x(2x1x120)/(2x1x120) (new)	11,846 s	5 s	Thermal release in CB (RGPOŻ – PT1 circuit)
SC1.1/90	4x(3x1x120)/(2x1x120) (new)	0,106 s	5 s	Thermal release in CB (RGPOŻ – PT1 circuit)
SC1.2/90	4x(2x1x120)/1x120 (existing)	12,588 s	0,4 s	Thermal relay in the contactor (RPT1)
SC1.2/90	4x(2x1x120)/(2x1x120) (new)	9,561 s	0,4 s	Thermal relay in the contactor (RPT1)
SC1.2/90	4x(3x1x120)/(2x1x120) (new)	0,358 s	0,4 s	Thermal relay in the contactor (RPT1)
SC3.1/90	(5x6) (existing)	6,246 s	5 s	Thermal release in CB (RGPOŻ – K circuit)
SC3.1/90	(5x10) (new)	3,049 s	5 s	Thermal release in CB (RGPOŻ – K circuit)
SC3.1/90	(5x16) (new)	1,531 s	5 s	Thermal release in CB (RGPOŻ – K circuit)
SC3.2/90	(5x6) (existing)	2,980 s	0,4 s	Thermal relay in the contactor (RH)
SC3.2/90	(5x10) (new)	2,941 s	0,4 s	Thermal relay in the contactor (RH)
SC3.2/90	(5x16) (new)	0,047 s	0,4 s	Electromagnetic release in CB (RGPOŻ– K circuit)

Conclusions

- The initial verification shows the problems with exceeding allowable times of automatic disconnection of supply as well as maximum levels of voltage drop along the circuits when a fire occurs

- The dynamic simulations confirm the problems found out at the initial verification. Additionally the motors start-up problems have been observed.

- Cable size verification method described in LE guidelines may be used as a technical knowledge source for electrical engineers designing electrical installations including fire safety circuits.

- It is essential to increase cross-section of conductors to decrease both voltage and phase-to-ground impedance and ensure sufficiently fast automatic disconnection of supply.

Conclusions

The overall conclusion and recommendation of this study is that it is necessary to develop and evaluate standards and recommendations for fire safety circuits to include clear cable sizing criteria for specific fire conditions.

Thank you

For more information please contact
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