

CONTENTS

FOREWORD	5
1 Scope and object.....	7
2 Normative references	8
3 Terms and definitions	8
4 Symbols	10
5 Calculation of currents during two separate simultaneous line-to-earth short circuits	12
5.1 Initial symmetrical short-circuit current	12
5.1.1 Determination of $\underline{M}_{(1)}$ and $\underline{M}_{(2)}$	12
5.1.2 Simple cases of two separate simultaneous line-to-earth short circuits.....	13
5.2 Peak short-circuit current, symmetrical short circuit breaking current and steady-state short-circuit current	13
5.3 Distribution of the currents during two separate simultaneous line-to-earth short circuits.....	14
6 Calculation of partial short-circuit currents flowing through earth in case of an unbalanced short circuit.....	14
6.1 General	14
6.2 Line-to-earth short circuit inside a station	15
6.3 Line-to-earth short circuit outside a station	16
6.4 Line-to-earth short circuit in the vicinity of a station	18
6.4.1 Earth potential \underline{U}_{ETn} at the tower n outside station B	19
6.4.2 Earth potential of station B during a line-to earth short circuit at the tower n	19
7 Reduction factor for overhead lines with earth wires	20
8 Calculation of current distribution and reduction factor in case of cables with metallic sheath or shield earthed at both ends	21
8.1 Overview	21
8.2 Three-core cable	22
8.2.1 Line-to-earth short circuit in station B	22
8.2.2 Line-to-earth short circuit on the cable between station A and station B	23
8.3 Three single-core cables	26
8.3.1 Line-to-earth short circuit in station B	26
8.3.2 Line-to-earth short circuit on the cable between station A and station B	26
Annex A (informative) Example for the calculation of two separate simultaneous line-to-earth short-circuit currents	30
Annex B (informative) Examples for the calculation of partial short-circuit currents through earth	33
Annex C (informative) Example for the calculation of the reduction factor r_1 and the current distribution through earth in case of a three-core cable	43
Annex D (informative) Example for the calculation of the reduction factor r_3 and the current distribution through earth in case of three single-core cables	48

Figure 1 – Driving point impedance \underline{Z}_P of an infinite chain, composed of the earth wire impedance $\underline{Z}_Q = \underline{Z}'_Q d_T$ and the footing resistance R_T of the towers, with equal distances d_T between the towers	9
Figure 2 – Driving point impedance \underline{Z}_{Pn} of a finite chain with n towers, composed of the earth wire impedance $\underline{Z}_Q = \underline{Z}'_Q d_T$, the footing resistance R_T of the towers, with equal distances d_T between the towers and the earthing impedance \underline{Z}_{EB} of station B from Equation (29)	10
Figure 3 – Characterisation of two separate simultaneous line-to earth short circuits and the currents I''_{KEE}	12
Figure 4 – Partial short-circuit currents in case of a line-to-earth short circuit inside station B	15
Figure 5 – Partial short-circuit currents in case of a line-to-earth short circuit at a tower T of an overhead line	16
Figure 6 – Distribution of the total current to earth \underline{I}_{ETot}	17
Figure 7 – Partial short-circuit currents in the case of a line-to-earth short circuit at a tower n of an overhead line in the vicinity of station B	18
Figure 8 – Reduction factor r for overhead lines with non-magnetic earth wires depending on soil resistivity ρ	21
Figure 9 – Reduction factor of three-core power cables	23
Figure 10 – Reduction factors for three single-core power cables	27
Figure A.1 – Two separate simultaneous line-to-earth short circuits on a single fed overhead line (see Table 1)	30
Figure B.1 – Line-to-earth short circuit inside station B – System diagram for stations A, B and C	34
Figure B.2 – Line-to-earth short circuit inside station B – Positive-, negative- and zero-sequence systems with connections at the short-circuit location F within station B	34
Figure B.3 – Line-to-earth short circuit outside stations B and C at the tower T of an overhead line – System diagram for stations A, B and C	36
Figure B.4 – Line-to-earth short circuit outside stations B and C at the tower T of an overhead line – Positive-, negative- and zero-sequence systems with connections at the short-circuit location F	37
Figure B.5 – Earth potentials $u_{ETn} = U_{Etn}/U_{ET}$ with $U_{ET} = 1,912$ kV and $u_{EBn} = U_{Ebn}/U_{EB}$ with $U_{EB} = 0,972$ kV, if the line-to-earth short circuit occurs at the towers $n = 1, 2, 3, \dots$ in the vicinity of station B	42
Figure C.1 – Example for the calculation of the cable reduction factor and the current distribution through earth in a 10-kV-network, $U_n = 10$ kV; $c = 1,1$; $f = 50$ Hz	44
Figure C.2 – Short-circuit currents and partial short-circuit currents through earth for the example in Figure C.1	45
Figure C.3 – Example for the calculation of current distribution in a 10-kV-network with a short circuit on the cable between A and B (data given in C.2.1 and Figure C.1)	46
Figure C.4 – Line-to-earth short-circuit currents, partial currents in the shield and partial currents through earth	47
Figure D.1 – Example for the calculation of the reduction factor and the current distribution in case of three single-core cables and a line-to-earth short circuit in station B	49
Figure D.2 – Positive-, negative- and zero-sequence system of the network in Figure D.1 with connections at the short-circuit location (station B)	50
Figure D.3 – Current distribution for the network in Figure D.1, depending on the length, ℓ , of the single-core cables between the stations A and B	51

Figure D.4 – Example for the calculation of the reduction factors r_3 and the current distribution in case of three single-core cables and a line-to-earth short circuit between the stations A and B	52
Figure D.5 – Positive-, negative- and zero-sequence system of the network in Figure D.4 with connections at the short-circuit location (anywhere between the stations A and B)	52
Figure D.6 – Current distribution for the cable in Figure D.4 depending on ℓ_A , $R_{EF} \rightarrow \infty$	54
Figure D.7 – Current distribution for the cable in Figure D.4 depending on ℓ_A , $R_{EF} = 5 \Omega$	56
Table 1 – Calculation of initial line-to-earth short-circuit currents in simple cases	13
Table 2 – Resistivity of the soil and equivalent earth penetration depth	20
Table C.1 – Results for the example in Figure C.1	45
Table C.2 – Results for the example in Figure C.3, $\ell = 5 \text{ km}$	47
Table C.3 – Results for the example in Figure C.3, $\ell = 10 \text{ km}$	47