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Study of the short-circuit currents in branches of distribution networks with trilateral power supply

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Study of the short-circuit currents in branches of distribution networks with trilateral power supply

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Abstract. The article presents the determination of the short-circuit currents in distribution networks with trilaterally power supplied branches – form a supplying substation and two decentralized energy sources. After connecting decentralized energy sources, branches with bilateral and trilateral power supply appear. This changes the network configuration and, respectively, its mode parameters, and also requires adjustments to the settings of the relay protection.

1. Introduction

Calculation of the short-circuit currents in the distribution networks with decentralized energy sources (DES) is necessary for the purpose of choosing apparatuses and current-carrying parts, as well as for correct setting of the relay protection and the means of automation [1÷3].

Following the connection of DES, sections with bilateral or trilateral supply appear in certain branches of the distribution networks, which changes the structure of the network and its mode parameters.

From the literature review it has been established that the classical methodologies for calculation of short-circuit currents in distribution networks do not take into account the presence of three power supplies in the connection branches.

The selective turning of the short circuits off requires a precise setting procedure both by the observed operational parameter and by time of action in case a number of supplying sources is available.

The aim of the present article is to describe the possibilities and the results from the implementation of an especially developed software program for calculation of the short-circuit currents in distribution networks and in branches with trilateral supply: from the power supplying substation and from two DESs. The program facilitates the correct adjustment of the protective devices in the trilaterally power supplied branches and helps to avoid unnecessary and deceptive exploits.

2. Algorithm for calculating the short-circuit currents

The compiled algorithm should be applicable to both medium-voltage and low-voltage distribution networks.

The calculation of the short-circuit currents is done taking into account the different ways of grounding of the star center of the medium voltage distribution networks in the Republic of Bulgaria [2 ÷ 5]:

- Insulated in the networks with small current of grounding connection;
- Grounded through active resistance in cable and air networks;
- Grounded through an arc-extinguishing coil in air networks;
- Combined with an arc-extinguishing coil and an active resistor, which is automatically switched on by a single-phase short-circuit breaker in air and cable lines.

The low voltage distribution network is a four-wire one with a directly grounded star center, and when compiling the zero sequence diagram for calculating unsymmetrical modes, the presence of a neutral (zero) conductor with grounding devices must be taken into account.

The size of the connected DES, included in a common connection node, affects the short-circuit currents that may exceed the permissible values. The power transformers in the transformer stations of the DES connection node in the distribution networks can be with the following connection groups: Yo/Δ, Y/Δ or Yo/Yo, and the currents for the different types of short circuits on both sides of the transformers have different values [3] [4].

In electrical networks, operating with an insulated star center, a double ground connection may occur. For the schemes for switching DES to the distribution network, the locations of the two successive ground connections are, respectively, in the connection node and in the supply node of the distribution network.

The compiled algorithm is part of the computer simulation system, described in detail in [6], and aiming at simulating the mode parameters under the following three modes: a normal mode, an emergency and tracking modes.

The input data for the compiled algorithm are actually the ones which influence the magnitude of the short-circuit currents: rated voltage, kV; effective grounding resistance of the electric pole, Ω; impedance of the first branch $R_1 + jX_1;\Omega$; impedance of the second branch $R_2 + jX_2;\Omega$; impedance of the third branch $R_3 + jX_3;\Omega$; source 1 – the power supplying sub-station; source 2 – a DES with power S_2 and $\cos\varphi_2$; source 3 – a DES with power S_3 and $\cos\varphi_3$ (Figure1).

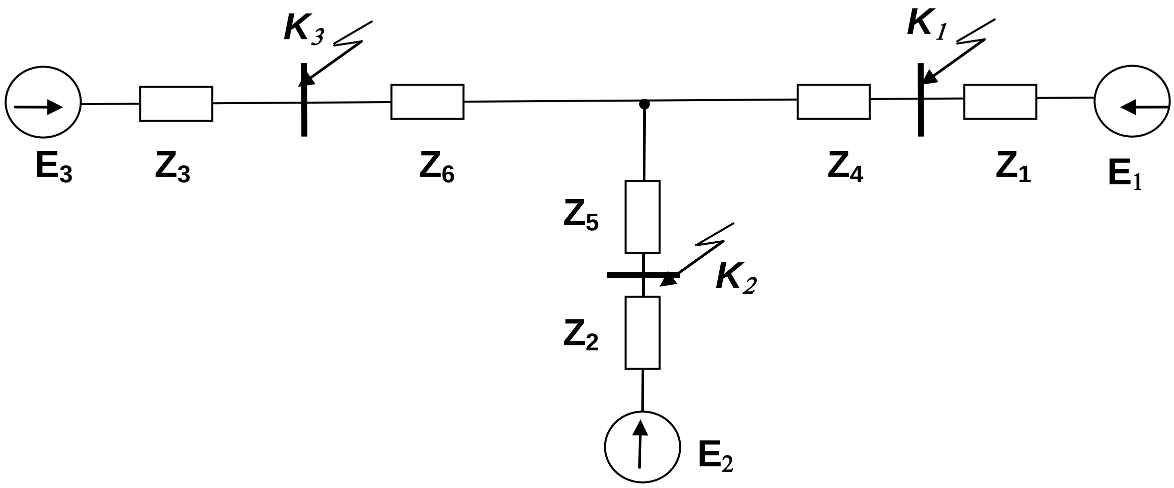

Figure1. Replacement scheme of the distribution network

The sequence of the calculations is as it follows:

Step 1 – the input data are introduced and the place of the short circuit is chosen.

Step 2 – the impedance of the connected in short circuit is calculated.

The following three cases are considered at this step**,** depending on the place, where the short circuit occurs:

- *Case 1 – short circuit in point K1 (Figure 1).*

Calculation unit 1:

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$$Z_7 = Z_2 + Z_5\,; Z_8 = Z_3 + Z_6\,; \tag{1}$$

$$E_4 = E_2 // E_3 = \frac{E_3.Z_7 + E_2.Z_8}{Z_7 + Z_8}\,; Z_9 = \frac{Z_7 Z_8}{Z_7 + Z_8}\,; \tag{2}$$

$$Z_{10} = Z_9 + Z_4\,; \quad E_{екв1} = E_4 // E_1 = \frac{E_4.Z_1 + E_1.Z_{10}}{Z_1 + Z_{10}}\,; \quad Z_{екв1} = Z_1 // Z_{10}\,. \tag{3}$$

where Z_1 and Z_2 are the impedances of DES 1 and 2; Z_3 – the impedance for connection to the supplying network; Z4, Z5, Z6 – the impedances of the power lines; E1, E2, E3 – the e.m.f. of the generating sources.

- *Case 2: short circuit in point K2 (Figure1):*

Calculation unit 2:

$$Z_8 = Z_3 + Z_6\,;\; Z_{11} = Z_4 + Z_1\,; \tag{4}$$

$$E_5 = E_3 // E_1 = \frac{E_3.Z_{11} + E_1.Z_8}{Z_{11} + Z_8}\,;\; Z_{12} = Z_8 // Z_{11}\,; \tag{5}$$

$$Z_{13} = Z_{12} + Z_5\,; \quad E_{екв2} = E_5 // E_2 = \frac{E_5.Z_2 + E_2.Z_{13}}{Z_2 + Z_{13}}\,; \quad Z_{екв2} = Z_{13} // Z_2\,. \tag{6}$$

- *Case 3: short circuit in point K3 (Figure1):*

Calculation unit 3:

$$Z_{11} = Z_4 + Z_1\,; Z_7 = Z_2 + Z_5\,; \tag{7}$$

$$Z_{14} = Z_2 // Z_{11}\,; E_6 = E_1 // E_2 = \frac{E_1.Z_2 + E_2.Z_{11}}{Z_2 + Z_{11}}\,; \tag{8}$$

$$Z_{15} = Z_6 + Z_{14}\,; \quad E_{екв3} = E_3 // E_6 = \frac{E_3.Z_{15} + E_6.Z_3}{Z_3 + Z_{15}}\,; \quad Z_{екв3} = Z_3 // Z_{15}\,. \tag{9}$$

Step 3 – the short-circuit currents (three-phase, two-phase, and single-phase short-circuit, ground connection, double coupling) are calculated using the traditional approach and the classical methods [1,7].

Step 4 – the procedure is repeated after changing some of the influencing factors and the obtained results are visualized.

Following the developed algorithm, a software program, based on the calculating capabilities of Excel, has been compiled, which performs the described procedures and is part of the computerized system for calculating the mode parameters in the electrical networks of EPF-Sliven [6].

3. Numerical experiment

The calculations are performed at the following input data: rated voltage 20 kV; effective grounding resistance of the electric pole 4Ω; impedance of the first branch $R_1 + jX_1;\Omega$; impedance of the second branch $R_2 + jX_2;\Omega$; impedance of the third branch $R_3 + jX_3;\Omega$.

The voltage of the supplying sub-station (source 1) is 110/20 kV; source 2 – a DES with power S_2 and $\cos\varphi_2$; source 3 – DES with power S_3 and $\cos\varphi_3$.

The results from the conducted experiments are presented in Figures 2, 3, 4 and 5.

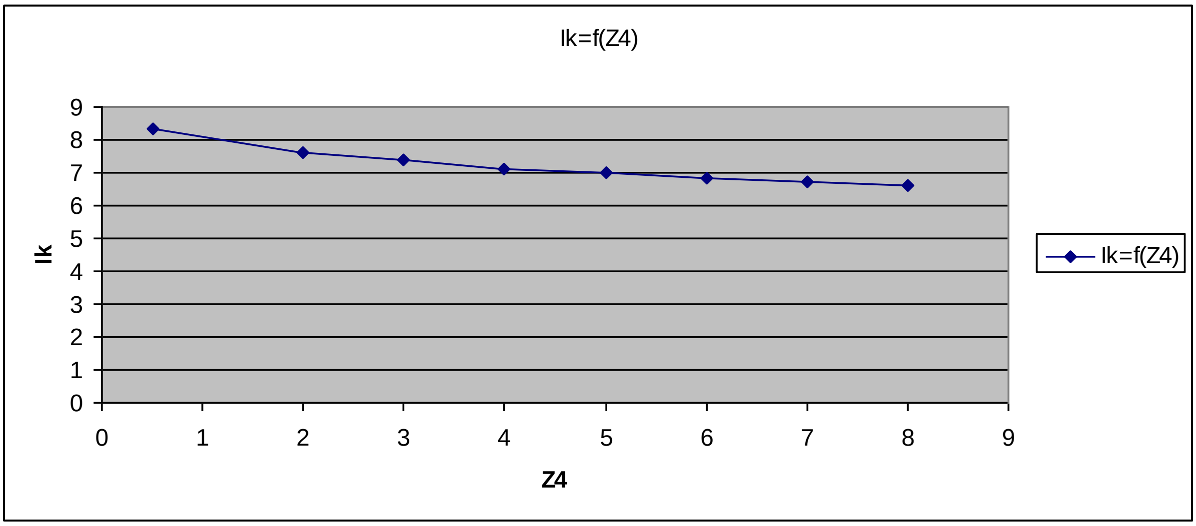

Figure 2. Short-circuit current at changing Z4

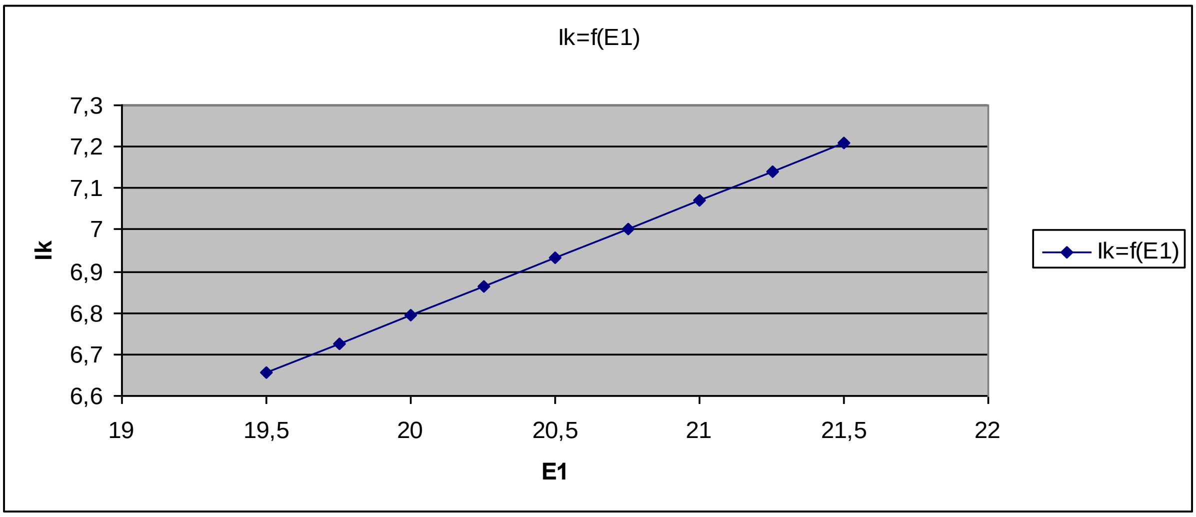

Figure 3. Short-circuit current at changing E1

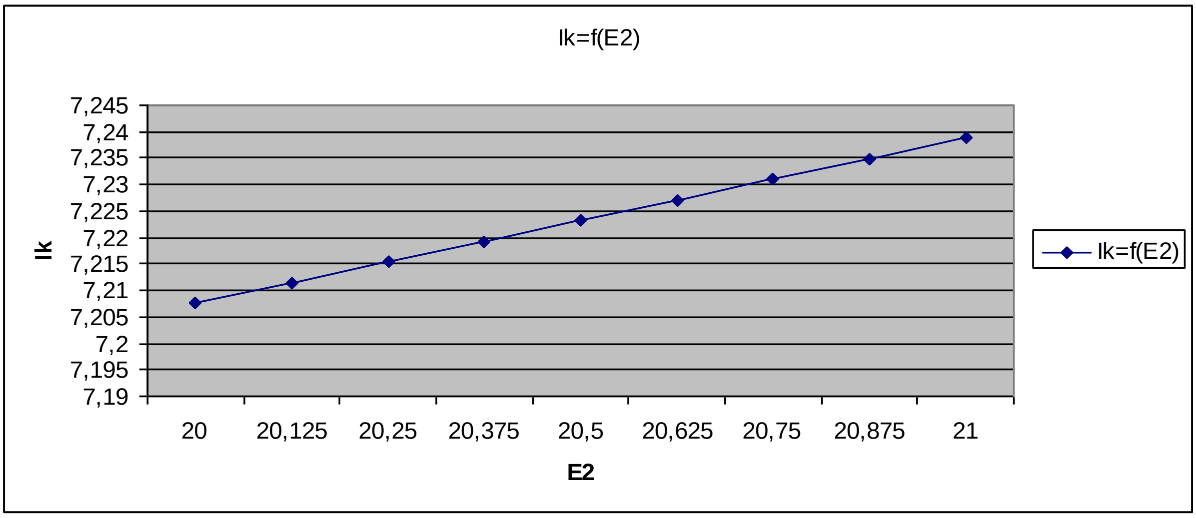

Figure 4. Short-circuit current at changing E2

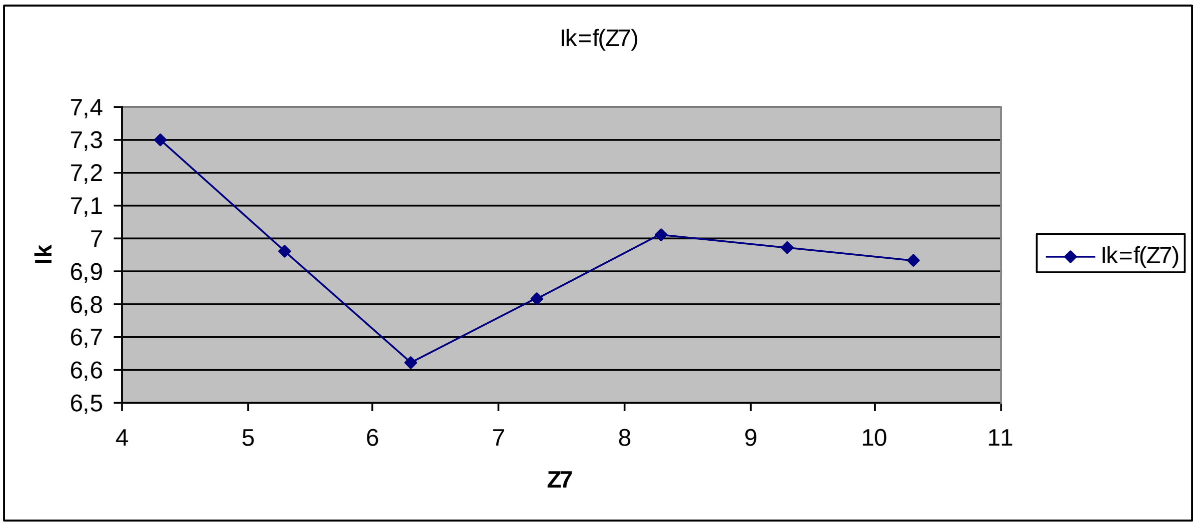

Figure 5. Short-circuit current at changing Z7

4. Summary

By means of the possibilities, offered by the algorithm and by the performed calculations, the magnitude of the short-circuit currents in the branches of distribution networks with power supply from three sources can be found.

5. Conclusions

- The compiled algorithm allows for defining the short-circuit currents in different points of the branches in distribution networks in case they are power supplied by three sources.
- The algorithm allows to change the factors, influencing the magnitude of the short-circuit currents and obtain results for their most unfavorable combinations.
- The obtained results are useful for the relay protection settings, which makes it possible to avoid unnecessary and false outages and interruptions in the power supply, which, in turn, results in more reliable operation of the electrical network.
- The results from the calculations are useful for selecting the apparatuses and the current-carrying parts both at the design stage and during the exploitation of electrical networks with associated DESs.

6. References

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