Applicability of calculation methods of minimum and maximum short circuit currents in grid with voltage up to 1 kV

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***Abstract*— The values of minimum and maximum short-circuit currents are calculated at the designing of power supply systems for selecting equipment and protection systems. By means of Matlab/Simulink modeling the farthest location of the motor load is defined for which the motor feed to the fault at substation should be considered. The article provides a comparison of different methods for accounting of the arc.**

Keywords— fault current feed, mathematical model, Matlab/Simulink, arc fault, arc resistance.

I. Introduction

In the power supply system at a voltage level of 0.4 kV short circuits are calculated in order to select equipment and build circuit protection. Thus, it is required to calculate the value of the maximum and minimum short-circuit current. The calculation process of the highest possible short-circuit current value usually considers both the feed from the motor load and the arc-free direct nature of the short circuit. The minimum current gives an arc short-circuits, which can often occur in confined spaces: busbars shields, at the terminals of the apparatus, input boxes of electric motors, various detachable connections, etc. The settings for the operation of the protection systems are selected by the value of the current of the single-phase arc short circuits in the end of protected line. In this regard, it becomes very important to calculate the values of the arc current.

II. Problem Statement

The calculation of the highest short-circuit current values should account for the contribution from the asynchronous and synchronous motor loads directly connected to the short circuit place at arbitrary time instants including initial and contact opening instants. But in these grids there are a lot of motors. Therefore, the question arises - what power of the motor load and at how long the distance from the busbsrs should be taken into account when calculating the highest possible direct short circuit current?

When determining the minimum short-circuit current, it is recommended to take into account an increasing in the active resistance of the conductors due to their heating by the short-circuit current (thermal decline of the short-circuit current) by the disconnection time of the circuit. It is introduced temperature coefficient $K_{\vartheta t}$, depending on the material and temperature of the conductor.

It is recommended to take into account the arc at the short-circuit place by introducing into the design scheme the active resistance of the arc Ra, which is determined on the base of the probabilistic characteristics of the influence of a stable arc on the short-circuit current. The paper posed the task of determining the arc resistance and short-circuit current in accordance with various existing techniques for the same initial conditions.

III. Results Of Numerical Experiment At Calculating Maximum Short-Circuit Currents

It is believed that the feed current from the motor load may be considered insufficient if less than 1% of the fault current drawn from the grid [1,2].

$$\sum \mathrm{I_{ratIM}} \le 0.01 \cdot I_{\mathrm{SC}}^{(3)} \qquad (1)$$

Using this equation, the maximum motor load current can be defined that is negligible in short-circuit. Additionally, corresponding surge current of the motor load can be calculated.

$$\mathrm{P_{IM}} \le 0.01 \cdot I_{\mathrm{SC}}^{(3)} \cdot \cos\varphi \cdot \eta \cdot \mathrm{U_{rat}} \cdot \sqrt{3} \qquad (2)$$

The currents of direct short-circuit currents for many typical substations, on the low voltage buses of the transformer are easy to determine, because the resistance of the entire circuit is known. Based on this, there were obtained motor loads, which feed surge current should be taken into account at calculations [3,4]. Also, by means of math modeling in the Matlab / Simulink program, the values of the distance of the motor load from the busbars were obtained, when the influence of this load can be ignored [5,6]. The plots describing the variation of feed currents of the motor loads vs cable length are presented in Fig. 1.

IV. Calculation Of Single-Phase Arc Short Circuits

There are many literary sources that determine the methods of calculating short circuit arc currents [1,2]. The electric arc usually can be taken into account at the short-circuits by several methods: introducing the arc active resistance Ra into the design scheme, determined using the formula; using the decreasing coefficient; and using a fixed tabular or plot-determined value of the arc resistance for typical design conditions [1,2,7-10]. However, various literature sources have other recommendations for taking into account the electric arc when calculating the minimum short-circuit current. The results of comparing of the calculation methods of the active arc resistance and the arc single-phase short circuit current are presented in the table 1 [1,2,7-10]. It can be noted that many sources are similar in determining the

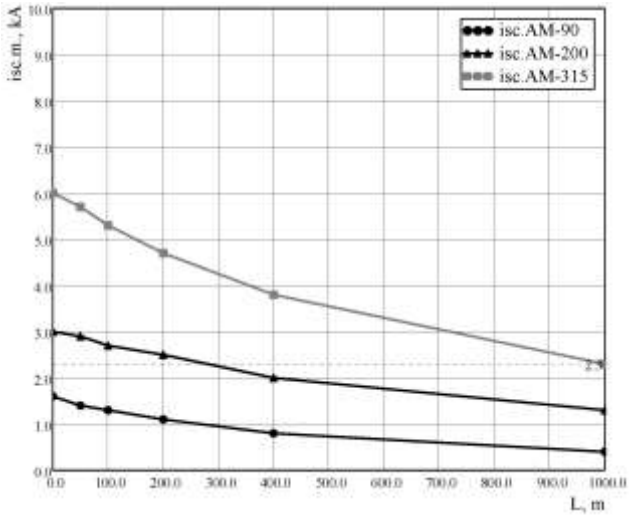

Fig. 1. Variation of feed currents from the motor loads vs cable length for the 1000 kVA 10/0.4 kV transformer.

parameters of the arc, but there are also those that are completely different. Also present are those where experimental data were taken as the base.

TABLE I. COMPARISON OF VARIOUS LITERATURE SOURCES

Source	R_a, mΩ	$I^{(1)}_a$, kA
M.A. Shisha	17	5.5
B.N. Neklepaev	29	4.4
I.L. Nebrat	17	5.5
A.B. Belyaev	15	5.7
Y.G. Baribin	20	5.2
V. Terzija, H.-J. Koglin	13	6.0

The values of the arc resistance obtained from various sources for the same conditions differ by more than 2 times, the calculated values of the currents differ by 1.4 times. This suggests that in the calculation, short-circuit currents in the distribution network Ra is relatively large in relation to the total resistance of the short-circuit, and therefore, the reliability of the calculated values of the short-circuit currents will depend on the accuracy of the used value Ra.

V. CONCLUSION

For the correct configuration of the power supply system and the choice of conductors and apparatuses the values of the maximum and minimum possible short-circuit currents are of especially importance. However, to determine the active resistance of an arc, existing calculation methods often either require knowledge of the full source data, and do not suggest great accuracy, or they recommend using tabular values of the arc resistance, which have a large spread of values. There are very large discrepancies in the matter of calculating of arc resistance. The calculation results according to different methods often differ several times. An arc, like a short circuit, is a random event, the set of parameters of which forms a set of probability parameters. Perhaps, it should be guided by other methods for determining the arc fault, when configuring protections and choosing settings in low-voltage grids. For example, the appearance of harmonics in the network that are characteristic for single-phase faults and for arc faults. There is data that single-phase short-circuits are characterized by a high level of third harmonic of current in the neutral wire. That is also characteristic of stable arc. The development of the arc short circuit gives characteristic even harmonics of the current.

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