A Simplified Method for Short Circuit Calculations in LV Radial Networks

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Abstract

This paper develops a simplified approach for the calculation of three phase short circuit current in radial low voltage LV networks. This method is based on data available at design stage, such as, voltage drop in cables and maximum design currents. It is an effective method for construction engineers in the field of electrical installation for checking the dimensions of switchgears and other equipement to withstand the thermal and dynamic effects of short circuits in site conditions.

Keywords: short circuit, low voltage, design current, voltage drop.

INTRODUCTION

IEC 60781 (and BS 7638) presents an application guide for the calculation of short circuit currents in low voltage radial systems [1, 2]. Short circuit current is an important parameter for the selection of low voltage equipment that will be capable to withstand the thermal and dynamic effects of fault condition. Short circuit parameters are defined by this guide in terms, which include the following:

a.   prospective (available) short circuit current.

b.   Peak short circuit current.

c.   Symmetrical short circuit breaking current.

d.   Steady state short circuit current.

Signficant effort has been made by engineers and acadimics to improve and simplify the short circuit current SCC methods and compile the SCC standards and guidelines to be more suitable for industrial applications [3,4].

 It is not always necessary to precisely calculate the short circuit current, and in some cases, a fast method is preferred to estimate the order of short circuit current, especially during construction activities.

In low voltage systems it is important to estimate or calculate the value of the prospective current likely to occur under short circuit conditions and to ensure that the devices provided to interrupt that current are rated to withstand and interrupt it.

There are many easy ways to calculate the short circuit current. Unfortunately as the calculating methods become easier, their accuracy gets less.

The proposed method is used to calculate the initial symmetrical three-phase short circuit current $I_k^"$, which is the rms value of the ac symmetrical component of a prospective short circuit current.

The low voltage system is a radial system, which consists of a MV/LV transformer and downstream cables and boards.

ASSUMPTIONS

The following assumptions are made in developing this method:

a.   The short circuit is far from generator and the low voltage system is supplied at one point only.

b.   The low voltage system is unmeshed.

c.   Reactances are ignored and if not ignored, the impedance of the element is the algebraic (not vectorial) sum of resistance and reactance.

d.   Contributions from motors are ignored $\sum I_{rM} \leq 0.001\, I_k^"$.

e.   Transformer tap changers are assumed to be in the main position.

THE SIMPLIFIED METHOD

 This method is based on technical data available at the design stage, and namely the percent voltage drop and the maximum design current of each section.

The method of the equivalent voltage source at the short circuit location is applied for the calculation of short circuit currents in low voltage systems [5]. In developing this method we will ignore the voltage correction factor c. This factor basically increases the voltage magnitude of the voltage source applied to the passive network by 10%. This makes the fault current at least 10% higher and sometimes leads to more conservative results [6].

For three-phase short circuit,

$$I_k^" = \frac{V_r}{\sqrt{3} Z_{sc}} \tag{1}$$

Usually, the short circuit current calculations are performed in per unit system. The per unit is the ratio of the actual to the base unit. Thus, the per unit impedance is:

$$Z_{pu} = \frac{Z_{actual}}{Z_B} \tag{2}$$

And

$$Z_B = \frac{V_B}{\sqrt{3}I_B} = \frac{V_r}{\sqrt{3}I_B} \qquad (3)$$

Where:

V_B- the base voltage, V

I_B − the base current, A.

Substituting Eq. (3) in Eq. (2), yields

$$Z_{pu} = \frac{\sqrt{3}Z_{actual} \cdot I_B}{V_r} \qquad (4)$$

Or $Z_{actual} = \frac{Z_{pu}V_r}{\sqrt{3}I_B} \qquad (4\text{-}1)$

Now, if we consider that Z_{sc} in Eq. (1), which is in ohms is Z_{actual}, then substitute Z_{actual} from Eq. (4) into Eq. (1), we obtain

$$I_k^{"} = \frac{I_B}{Z_{pu}} \qquad (5)$$

When designing low voltage networks, it is required to calculate the percent voltage drop for each cable by the following formula:

$$\Delta V_\% = \frac{\sqrt{3}I_{max}Z}{V_r}100\% \qquad (6)$$

Where:

$\Delta V_\%$ - percent voltage drop, %.

I_{max} − maximum design current, A.

V_r − rated voltage, V.

dividing Eq. (4) 0n Eq. (6), yields

$$\frac{Z_{pu}}{\Delta V_\%} = \frac{I_B}{I_{max} \cdot 100\%}$$

Or $Z_{pu} = \frac{\Delta V_\%}{100} \frac{I_B}{I_{max}} \qquad (7)$

Thus, the per unit impedance of a radial section consists of the per unit impedance of the transformer and the cables. Based on equation (7), the per unit impedance of the transformer is:

$$Z_{pu} = \frac{Z_\%}{100} \frac{I_B}{I_{rT}} \qquad (8)$$

Where:

$Z_\%$ - percent voltage impedance of transformer, %.

I_{rT} − rated current of transformer, A.

And for the cable is:

$$Z_{pu} = \frac{\Delta V_\%}{100} \frac{I_B}{I_{max}} \qquad (9)$$

Substitute Eqs. (8) and (9) in Eq. (5), we get

$$I_k^{"} = \frac{100}{\frac{\Delta v_\%}{I_{max}} + \frac{Z_\%}{I_{rT}}} \qquad (10)$$

Where:

I_{max} − maximum design current of the cable, A.

If the LV network consists of more than one cable, then Eq. (10) becomes:

$$I_k^{"} = \frac{100}{\sum \frac{\Delta V_\%}{I_{max}} + \frac{Z_\%}{I_{rT}}} \qquad (11)$$

In an LV network the active resistance of the cables is known (or may be calculated), therefore the active component of the voltage drop may be calculated by the following formula:

$$\Delta V_{a\%} = \frac{\sqrt{3}I_{max}Z \cos\varphi}{V_r}100\% \qquad (12)$$

By dividing Eq. (6) 0n Eq. (12), we obtain:

$$K_1 = \frac{\Delta V_\%}{\Delta V_{a\%}} = \frac{Z}{Z \cos\varphi} = \frac{1}{\cos\varphi} \qquad (13)$$

Where:

Z− impedance of the cable.

$\cos\varphi$− power factor.

In equation (13), K_1 depends only on the power factor $\cos\varphi$;

Finally, we have

$$I_k^{"} = \frac{100}{\sum \frac{K_1\Delta V_{a\%}}{I_{max}} + \frac{Z_\%}{I_{rT}}} \qquad (14)$$

Once $I_K^{"}$ is known, then the following criteria must be considered for the short circuit strength of LV systems [7,8]:

$$I_{cn} \geq I_k^{"} \qquad (15)$$

$$I_{cm} = cI_{cn} = k\sqrt{2}I_{cn} \qquad (16)$$

Where:

I_{cn} − the rated ultimate short circuit breaking current (breaking capacity).

I_{cm} − the rated short circuit making capacity (making capacity).

VRIFICATION OF THE METHOD

A simple radial section of a LV network is selected to verify the correctness of the proposed method. The section consists of MV/LV transformer, 185 mm^2, 100 m cable, and 70 mm^2, 50 m cable connecting a 100 KW motor to sub-distribution board (Fig. 1).
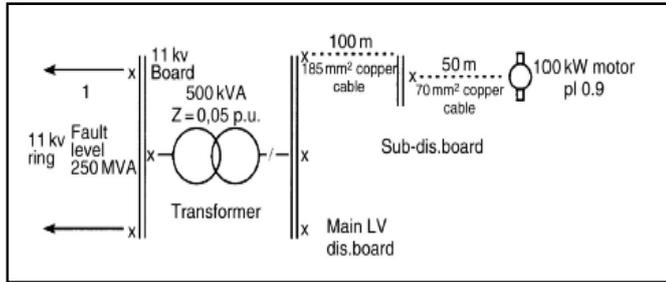

Figure 1

The calculations of three-phase short-circuit currents were performed by traditional equivalent voltage source and the proposed simplified method. The results of calculations are shown in table 1.

Table 1. Results of short circuit current calculations

$I_k^{''}$ (A)	Voltage source method	Simplified method	Error, %
Main board	7429	7214	3
Sub-dis.board	4839	4576	5.7

It is obvious from the table that errors resulting from using this method is acceptable from engineering point of view.

CONCLUSION

It is important to note that the intention of this paper was to present a simplified method for the calculation of short circuit current in radial network, and to provide engineers who are designing LV network with a simple and easy tool to check the suitability of selected equipment in terms of switchgear dimensions and protection setting.

The essence of the method is to use data that are available at design stage such as voltage drop, maximum design current with transformer parameters such as voltage impedance and rated current.

The errors resulting from using this method are acceptable from engineering point of view.

ACKNOLEDGEMENT

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