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SHORT-CIRCUIT CALCULATION ON A SMALL NETWORK

Abstract—In this paper will be presented the calculation of short current on a small network, using the method symmetrical components. The calculation will have in consideration the EN60909.

Index Terms—Short current, network, calculation, symmetrical components, transient components.

I. INTRODUCTION

Short circuits occurs in one power systems and cause large fall of transient currents, normally there value is much higher than the value of the load currents. These fault causes electrodynamic and thermal stresses and are potentially damaging to the power systems. A very high risk to the power systems and persons are inherent.

A complete calculation and knowledge of the short-circuit is required for design and protect the power system. The currents should be given in function of time in the short-circuit location from the beginning until the end (fig.1).

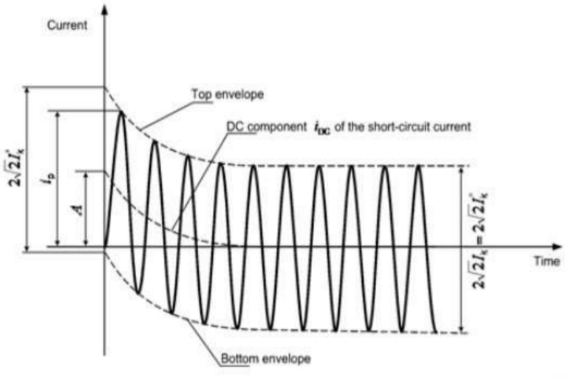

Fig. 1. Short-Circuit Current

The most used approach is given by the EN60909 [2]. This standard provides the method of calculation of RMS for the symmetrical component as well the peak value of the short-circuit current.

The knowledge of the short-circuit current in strategic points of the network is necessary to determine the breaking capacity of the protections, thermal withstand rating of the cables and the selective trip settings of the protective devices.

This paper will present the use of this approach on a small branch of power network, the calculation will be made through support of computer software.

The objective of this paper is showing the characteristic values obtained through regular tool from well know manufacturer.

II. TEST CASE

The test system is a small three-phase network of low voltage with rated voltage of 400V with two branches feeding two electrical loads (fig.2).

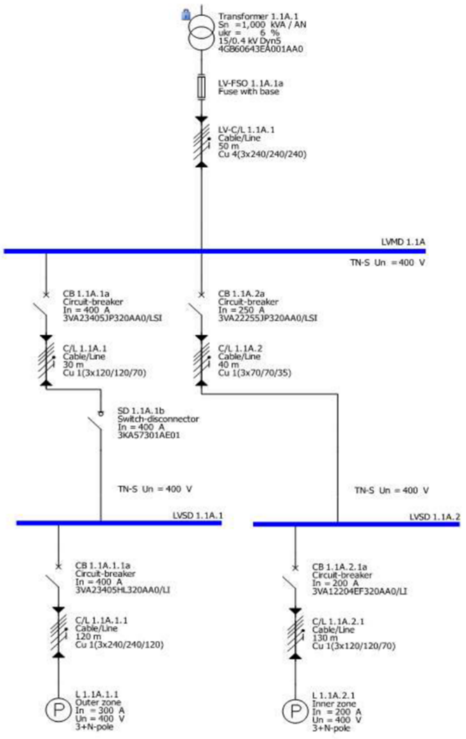

Fig. 2. Low Voltage Network

In the figure is showed the necessary data for the short-circuit calculation.

To this test has been made some assumptions such as:

1) There is no change of short-circuit type
2) There isn't any change of the network

To proceed with the calculation is necessary to input the given data of the cables and loads in the calculation software. Is also necessary to identify the type and characteristics of the main income, in our case the main incomer is know. The network will be fed by near substation. The software will define automatically the protective devices and all the settings and in the final stage all the short-current circuits will be provide.

III. NETWORK SIMULATION

The simulation is focused on the calculation of the RMS [3] values of the short-circuit currents (fig.3). During the calculation is ignored the so called electromotive [5] forces in each phase of the three phase stator armature winding. The assumption enables significant simplification and time saving computing the calculation.

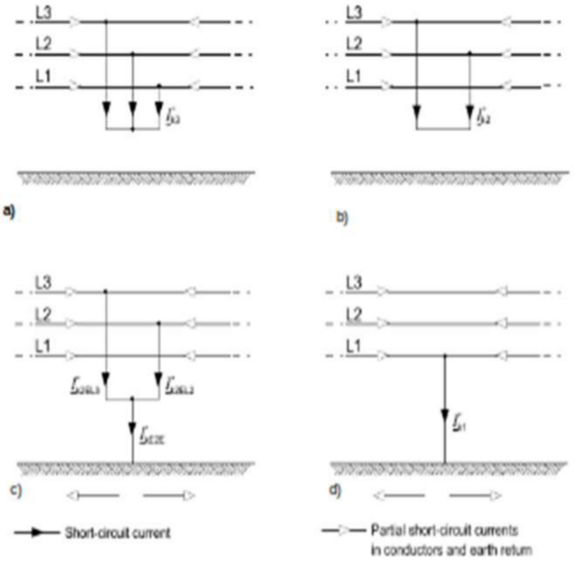

Fig. 3. Types of Short-circuit: a)Three-phase short-circuit, b)Line to line short-circuit, c)Line to line short-circuit with earth connection, d)Line to earth short circuit

In this conditions the voltages and currents of the system can change rapidly if some disturbance occurs in the network.

The RMS simulation can be done for three-phase or single-phase. This approach simplifies the calculation of the short-circuit currents by using the method of the symmetrical components, this method is widely used in the analysis of unbalanced three-phase, unsymmetrical short-circuit currents and rotating electrodynamic machinery.

A. Symmetrical components modelling

In this method the asymmetrical system is decomposed in three components.

- Positive sequence current
- Negative sequence currents
- Zero sequence current

With this method the voltages and currents, which may be unbalanced are transformed into three sets of balanced voltages and currents. The impedances presented by various power components are decoupled from each other, and transformed in independent networks from each component, this will form a balanced system, simplifying the calculations [4].

$$V_a = V_a^0 + V_a^1 + V_a^2$$

$$V_b = V_b^0 + V_b^1 + V_b^2$$

$$V_c = V_c^0 + V_c^1 + V_c^2$$

Having Ia, Ib and Ic as currents on the three lines of three-phase unsymmetrical system then we have [6]:

$$I_a = I_a^0 + I_a^1 + I_a^2$$

$$I_b = I_b^0 + I_b^1 + I_b^2$$

$$I_c = I_c^0 + I_c^1 + I_c^2$$

According to [3] the occurred fault can be simulated by adding one element, impedance, on the fault point. With the add of this element then the symmetrical component method allows the determination of the fault in a positive sequence system, adding an additional impedance Z of a certain value to the fault location depending of the fault type. That impedance's are summarized in the follow table.

TABLE I

ADDITIONAL IMPEDANCES

Fault type	Short-circuit		
	One-phase	Two-phase	Two-phase to ground
$\underline{Z}\Delta$	$\underline{Z}C2 + \underline{Z}C0$	$\underline{Z}C2$	$(\underline{Z}C2 * \underline{Z}C0)/(\underline{Z}C2 + \underline{Z}C0)$

After adding this impedances ZC on the system, is necessary to calculate there value, the calculated values represents all the impedances of the network, measured between the fault location and the ground. The indices 2 and 0 are the negative and zero sequence components.

For calculations of the impedances is necessary to create the matrices $\underline{Y}_{k2}$ and $\underline{Y}_{k0}$ for both component systems [6], the required impedance is equal to the diagonal of the short-circuit impedance matrix, obtained by inversion of the short-circuit admittance matrix $\underline{Z}_k = \underline{Y}^{-1}_{K2}$.

$$\underline{Z}_C = \underline{Z}_{ii} \tag{1}$$

Using the additional impedance $\underline{Z}_\Delta$ the positive sequence component of the voltages and currents can be easily calculated and using the substitution impedances is also possible to calculate the negative and zero sequences of the system.

B. DC components modelling

The peak and thermal equivalent short-circuit current has to be calculated to operational security and device design. Both values are related to the DC component of the short-circuit. Normally the available software's don't calculate the DC component, but because this value is calculated by the one time constant Ta, which is depending of the relations between the reactance and resistance of the substitution impedance ZC . Is possible to assume equal short-circuit impedances for the positive and negative components, for the Ta is given in the table.

TABLE II

Ta IN SECONDS FOR PARTICULAR SHORT-CIRCUIT

Short-circuit		
Three and two-phase	One-phase	Two-phase to ground
$XC1/(\omega * RC1)$	$(2XC1+XC0)/[\omega(2RC1 + RC0)]$	$(XC1+2XC0)/[\omega(R1+2RC0)]$

A simplified component can be obtained through the Thevenin equivalent, this method is very usable meshed networks.

IV. ELECTROMAGNETIC TRANSIENT

[1]Normally an power system operates in balanced state, but must be able to handle and support with over-voltages and over-currents that can occur when transient conditions occurs in the power system.

Understanding thoroughly the electromagnetic transient phenomena is one of the most important aspects in the design and operation of power system network and delivery high quality power supply.

This phenomena can be provoked due internal or external disturbances in the power system such: Lightning strikes, par- tial discharges due defects of electrical equipment, switching. This disturbances involve a range of frequencies from DC to MHz. The transient phenomena is a combination of travelling waves in the elements of the power system.

Generally, single event can cause several effects such: Over-voltages, over-currents, distorted waveforms or electromechan- ical oscillations (fig.4).

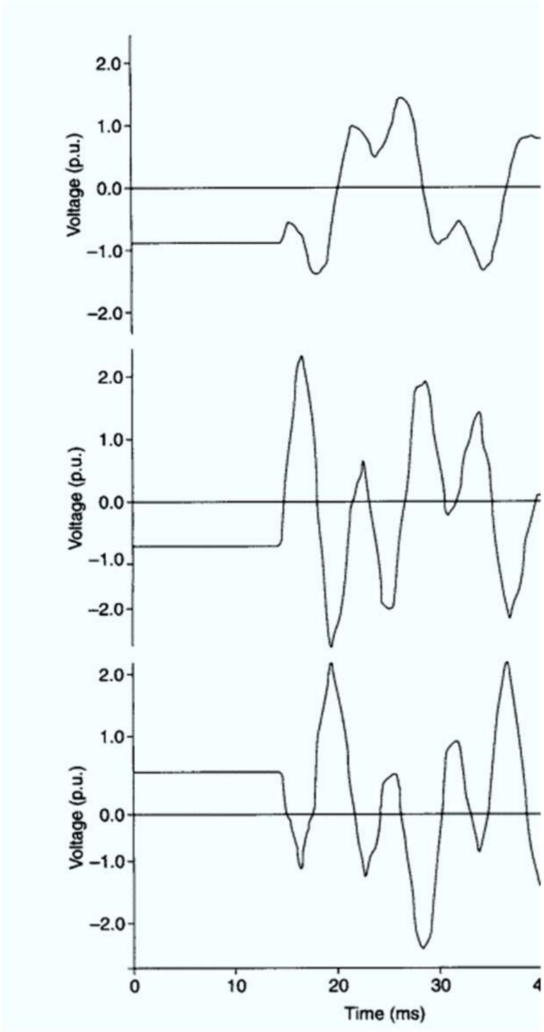

Fig. 4. Example of waveform distortion for switching operation

Generally the lightning strokes is the phenomena that produces the highest voltages surges (fig.5).

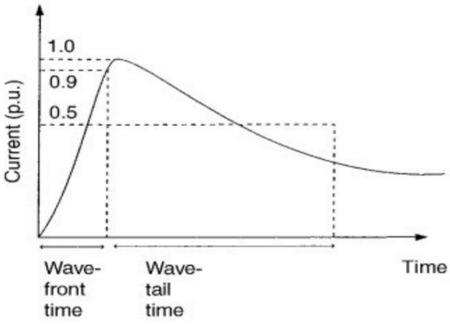

Fig. 5. Typical waveform due lightning strike

A. Classification of electromagnetic transients

The waveforms of the electromagnetic transients have one or more oscillatory components and this can be characterized by the frequencies of these oscillations. During the simulation process, the accurate determination of the oscillations are related to the equivalent circuits used to represent the system components. The component model isn't the appropriate for all types of transient analysis and must be worked to fit in the scope of the study.

It is more appropriate to classify the transients by the time range of the study related to the phenomena under investigation. The main issue in the analysis of the transients is selecting the model for each component that realistically represents the system over the time frame.

For example the lightning strike is the fastest-acting disturbance and the simulation requires to be on the region of nano to micro-seconds, during this time the variation of the frequency, voltage and current will be negligible, on the other hand the capacitance and inductance of the system will exercise the biggest influence.

For the case of switching the timescale is in micro to milliseconds concerning the insulation, and the simulation time goes into cycles, if the system recovery from the disturbance needs to be investigated.

The power system components can be divided in two types, characterised essential by the lumped parameters, such as electrical machines capacitor or reactor banks, and those with distributed parameters, where are included overhead lines and underground or submarine cables. After a switching event these circuit elements are subjected to voltages and currents involving frequencies between 50 Hz and 100 kHz. Within such a vast range the values of the component parameters and of the earth path will vary with frequency. The simulation process must be able of reproducing the frequency variation of both the lumped and distributed parameters.

This simulation needs also to represent such non-linearities as magnetic saturation, surge diverted characteristics and circuit-breaker arcs. The most important, if not more, as the method of solution is the availability of reliable data and the variation of the system components with frequency, the fast transient model including stray parameters followed by one based on simpler equivalent circuits.

B. Transient simulators

From all tools used in the past for the simulation of power system transients are the electronic analogue computer, the transient network analyzer (TNA) and the HVDC simulator. The electronic analogue computer basically solved ordinary differential equations by means of several units designed to perform specific functions, such as adders, multipliers and integrator as well as signal generators and a multichannel cathode ray oscilloscope.

V. SIMULATION

In this section it will be focused how the simulation was made and present the results of short-circuit calculation made with help of the software Simaris. The software makes the calculation of short-circuit, load flow and energy balance, the calculation is made with base of the EN 60909 aside other relevant standards. The Simaris don't calculate the transient components, this components have to be calculated with the methods indicated on section IV-B.

Initially all the calculations have been made with help of other software with more capability than Simaris but the impossibility of access to this software was necessary to use similar software but providing the same results for fault currents.

The network used as test is a small part of one real distribution from a design project to onshore LNG plant (Ka˚lstø) in Norway, this plant is the main pipeline that feeds one bigger LNG (Ka˚rstø) located East from Ka˚lstø.

The project was a refurbishing of that power system with more than 25 years of operation reaching the end lifetime cycle and because the existing main building were was all the main panel and other distribution boards, wasn't hermetic and been inside of one area with risk of explosion due the nature of hydrocarbon in circulation in that area, was necessary to remove the old main building and re-install all the electrical components in an new main building outside of the area with risk of explosion.

The fig.2 on page 1 shows the small part of the power system analyzed, the network is connected to main grid from Haugalandkraft through a substation with transformer of 1000kVA 15/0,4kV.

To be able proceed with the calculations is necessary to input some parameters on the software, all necessary parameters for the calculation are presented in fig.2 on page 1 and on the table III.

TABLE III

CABLES DATA

Cables Data				
Designation	**Cross-section [mm2]**	**Ib[A]**	**Iz [A]**	**Length[m]**
LV-C/L 1.1A.1	3 ∗ 240 + 240 + 240	500	1612	50
C/L 1.1A.1	3 ∗ 120 + 120 + 70	300	346	30
C/L 1.1A.2	3 ∗ 70 + 70 + 35	200	246	40
C/L 1.1A.1.1	3 ∗ 240 + 240 + 120	300	324	120
C/L 1.1A.2.1	3 ∗ 120 + 120 + 70	200	223	130

After introduction of all necessary parameters the software proceeds with all the calculations providing an optimization for the cables, protective devices and the given the fault currents on the bus bar's and electrical loads, the values for the minimum fault currents are presented on the table IV. The minimum fault current is very important to define the settings of the protective devices.

TABLE IV

MINIMUM FAULT CURRENTS CALCULATED

Minimum fault currents calculated				
Designation	P htoN [kA]	P htoP E[kA]	P htoP h[kA]	3P h[kA]
LVMD 1.1A	18,47	18,47	17,50	20,18
LVMD 1.1A.1	18,47	18,47	17,50	20,18
LVSD 1.1A.1	10,08	9,06	12,42	14,34
L 1.1A.1.1	4,34	3,53	6,40	7,40
LVSD 1.1A.2	6,40	4,78	9,18	10,60
L 1.1A.2.1	2,53	1,95	4,08	4,71

The full calculation of the fault current isn't finished without the results for the maximum values for the fault currents on the power system. This value is also very important because defines the capacity or rating of the protective devices.

The maximum fault current calculated is presented under on the table V.

TABLE V

MAXIMUM FAULT CURRENTS CALCULATED

Maximum fault currents calculated			
Designation	P htoN [kA]	P htoP E[kA]	3P h[kA]
LVMD 1.1A	21,62	21,62	23,50
LVMD 1.1A.1	21,62	21,62	23,50
LVSD 1.1A.1	12,64	11,60	17,31
L 1.1A.1.1	5,60	4,70	9,20
LVSD 1.1A.2	8,50	6,60	13,48
L 1.1A.2.1	3,43	2,70	6,25

VI. CONCLUSION

This work presents a study and calculation of the short-circuit in one small power system. This study was made with base of EN60909 and the support of software from Siemens, Simaris.

The method in study was the symmetrical components so it can be simpler the calculation with base of two assumptions made in section II in page 1.

All the results obtained through this method didn't show any discrepancy compared with the EN60909 and were expected thus values.

Wasn't possible to present the study or results for the transient components due the difficult access to software able to proceed with the calculation and verification of this components.

This study shows the importance of the calculation of the short-circuit currents during the design phase of one project allowing sizing properly all the equipment's, which should support the efforts caused by these currents, or still the evaluation of existing equipment when there is an expansion of the system that can raise the short-circuit power.

It will be proposed for the next study proceed with the full calculation with another software, so it can be verified the transient components as well calculate the asymmetrical components of the system. It can be possible to present graphics showing the evolution of the currents through the short-circuit.

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