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METHODS FOR CALCULATING THE CURRENT TRAFFIC IN CASE OF SMALL ELECTRICAL NETWORKS

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Abstract: *Knowing the short circuit current values is particularly important in the design and choice of apparatus used in electrical systems. Experimental determination of short circuit currents is usually done on the model. Taking into account the usefulness of short circuit currents calculations and the fact that most times they must be known too precisely, are introduced certain general assumptions, to simplify calculations. In addition, the exact calculation of short circuit currents is very difficult, especially in complex systems.*

1. ASSUMPTIONS FOR CALCULATING SHORT CIRCUIT CURRENTS

In the calculation of short circuit currents are the following simplifying assumptions:

- The initial phase angle between electro motor tensions is considered zero, all electro motor voltages are in phase, thus resulting in increased short circuit current value to their real value;
- Loads are considered constant, in reality, due to changes in short-circuit voltage, some consumers, especially electric motors change their parameters, but these changes are non-essential and often lead to lower loads and therefore will not take them into account;
- Loads contribution is neglected in place of short-circuit, in reality, motors and synchronous compensators (especially those with high power, over 1 MW) contributes as additional sources in obtaining the short circuit currents, if close enough to the place of short circuit;
- Resistances are neglected, so the circuit is formed only of reactance (with the exception of cable networks and small air-section), as a result all short circuit currents are in phase (and voltages are in phase, however at the establishment of time constants is necessary to take into account resistances) because the short circuit currents result in phase, it is obtained the most important practical conclusion that they can be determined on the c.c. models;
- Arc resistance is neglected, at the beginning of short-circuit between two phases or between phase and earth, between short-circuited elements is interposed a variable resistance formed by the arc resistance and resistance of other elements interposed at short circuit place; whereas arc resistance varies depending on many parameters (short circuit current value, arc length, nominal voltage rating), it is practically difficult to determine; on the other hand, in most cases those resistances can be very small and can be neglected. In this case the short circuit is said to be metallic, metallic short-circuit calculation determines the short circuit current higher than in the non-metallic so calculation remains covering;
- Are neglected the cross-network elements, they introduce a very small current to short circuit current;
- Magnetic circuits saturation is neglected, which allows equations linearization;
- It is considered perfectly symmetrical the three-phase network, this condition is practically always fulfilled for all system elements;
- It neglects the oscillations of main generators in the short-circuit moment, this will cause to obtain short-circuit currents greater than the real ones, the assumption is valid when short-circuits takes a little time, and the considered system is strong enough, if short circuits occur in weak systems where it is question of stability, can occur important oscillation of generators even out of synchronism; so in these cases when calculating short circuit currents must be considered and the generator's oscillation. [6], [9], [10].

Existing experimental material shows that the differences between actual results and practical simplified calculations are not large. Baseline currents and voltages, calculated in practical ways, differ by ± 5-10% from the values recorded on oscillograms. If generators have not large oscillations, you can calculate the voltage and current values of undamaged branches with errors of ± 10-15%. [1], [2].

2. CONDITIONS FOR CALCULATION

1. The degree of accuracy necessary in calculating short circuit currents generally depends on the purpose of calculation. In short-circuit current calculation of marine power systems; we will limit our calculation to the approximate methods, which provide sufficient accuracy for practical purposes.
2. Using approximate methods of calculation is justified by the fact that in many cases, dates and conditions underlying the calculation is not accurate.
3. Short-circuit currents must be calculated on the assumption that all generators supplying short-circuit point are equipped with automatic voltage regulators.
4. Influence of asynchronous motors, as additional power sources are also taken into account in calculating short circuit currents.
5. If, at the terminals of asynchronous electro-motor, which is in operation, a short circuit occurs, in conformity with the inertia principle of electromagnetic induction, and if induction flow is not cut immediately, the electric motor is working briefly as a generator, feeding short circuit point.

Research has shown that the method of variation of short circuit current (Fig. 1) across an asynchronous electric motor terminals can be displayed with sufficient precision.

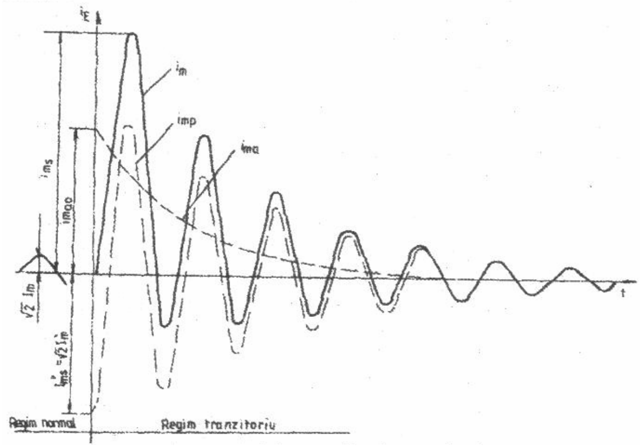

Fig. 1 A variation of short circuit currents.

$\mathbf{i_m}$ - short circuit current; $\mathbf{i_{mp}}$ – periodical component (symmetrical) of short circuit current;
$\mathbf{i_{ma}}$ – a-periodical component (symmetrical) of short circuit current; $\sqrt{2}I_m$ - current amplitude before short circuit; $\mathbf{i_{mş}}$ - shock short circuit current; $\mathbf{i_{mao}}$ - baseline (maximum) a-periodical component of short circuit current; I''_{mp} - baseline (maximum) of periodical component of short circuit current; I''_m - effective value of initial periodic component of short circuit current.

1. in determining the short circuit current to be taken into account influence of asynchronous motors with the following values (current values in relation to $\mathbf{I_{me}}$, where the $\mathbf{I_{me}}$ shall be the sum of nominal currents of all asynchronous motors in operation at a moment which is made the calculation):
- instantly short-circuit... 6.25 $\mathbf{I_{me}}$
- at **T** time, ie a period after the appearance of short-circuit ($\omega t = 2\pi$) .... 2.5 $\mathbf{I_{me}}$
- at **2T** time, so after two periods of short-circuit occurrence ($\omega t = 4\pi$) .... $\mathbf{I_{me}}$
- to determine the shock short-circuit current (at **T/2**) is recommended .... 8 $\mathbf{I_{me}}$.

2. To determine the short-circuit currents will be produced a scheme of calculation.

The calculation scheme will highlight all the elements which contribute to setting the short circuit values, and those that must be checked to determine electrodynamics' and thermal (generators, transformers, auto-switches, cables, bars, current transformers etc.).

3. Degree of accuracy of short circuit calculations will depend on the data made available by suppliers for each element involved in stabilizing of short-circuit current value or which must be checked for the electrodynamics' and thermal stability. For it will consider the following:

a. For the generator:
$\mathbf{S_n}$ **($\mathbf{P_n}$)** - rated power;
$\mathbf{U_n}$ - rated voltage between phases;
$\mathbf{X_d}$ - synchronous longitudinal reactance;
X'_d - longitudinal transient reactance;
X''_d - longitudinal over-transient reactance;
$\mathbf{R_g}$ - internal resistance of the generator;
$\mathbf{i_{cm}}$ - the maximum excitation current with voltage regulator, excitation winding at nominal temperature;
$\mathbf{i_{co}}$- the value of unload excitation current when at nominal voltage, windings are at room temperature;
$\mathbf{K_c}$ - short circuit ratio - the ratio of excitation current corresponding to the induced armature nominal voltage in un-load function and excitation current corresponding to induced armature rated current $\mathbf{I_g}$ in the stabilized three-phase short-circuit, machine rotating at the rated speed. [8], [11].

b. For the electro-motor:
$\mathbf{P_n}$ - rated power;
$\mathbf{U_n}$ - nominal voltage between phases;
X'_d - transient reactance;
$\mathbf{R_m}$ – electro-motor internal resistance.

c. For the transformer:
$\mathbf{P_n}$ – nominal power;
$\mathbf{U_1}$ - primary nominal voltage;
$\mathbf{U_2}$ - secondary nominal voltage;
$\mathbf{R_t}$ - resistance or $\mathbf{r_t\%}$ - percentage resistance;
$\mathbf{X_t}$ - reactance or $\mathbf{x_t\%}$ - percentage reactance;
$\mathbf{u_k}$ - short circuit voltage.

d. for connection and protection devices:
$\mathbf{X_a}$ – reactance;
$\mathbf{R_a}$ - resistance;
$\mathbf{I_m}$ - rated breaking current;
$\mathbf{I_n}$ - confinement current;
$\mathbf{I_d}$ - the dynamic current limit;
$\mathbf{I_t}$ – the thermal current limit.

e. for the cable:
$\mathbf{R_0}$ - specific resistance;
X - specific reactance.

f. for coils with reactance:
$\mathbf{I_{nbr}}$ - rated current;
$\mathbf{U_{nbr}}$ - nominal voltage;
$\mathbf{X_{br}\%}$ - percentage reactance;
$I_t\sqrt{t}$ - feature value for thermal stability;
$\mathbf{L_n}$ - nominal induction.

g. For the current transformer:
X – transformer's reactance;
$\mathbf{I_n}$ - primary rated current;
$\mathbf{K_t}$ - thermal coefficient;
$\mathbf{I_t}$ **[KA]** - thermal current limit;
$\mathbf{K_d}$ - dynamic coefficient;
$\mathbf{I_d}$ **[KA]** - dynamic current limit.

4. Short-circuit current calculation will be made for projects of ships with generators rated current, simultaneously coupled on bars, exceeds 1000 A, in order to verify the electro-dynamic and thermal stability of generators to connect, bars and wire. [1], [6].

The calculation is done at the most difficult operating mode of the power plant.

3. SHORT CIRCUIT CALCULATION FOR FINITE POWER SOURCES

If short circuit occurs near a power plant, we can not consider generators as having a constant voltage, therefore, no periodic component of short circuit current no longer maintain a constant actual value. To determine the periodic component of interest moment, can use the calculation curves method or impedance method. [3], [4].

If the sources of the scheme are similar and in identical conditions with respect to short-circuit point, (assuming that the periodic component has the same of variation law), they can be replaced by a general source. Consider the example in Fig. 2.a, with the equivalent scheme (Fig. 2.b), in relative units (S_b = 100 MVA, U_b = 121 kV). [4], [10].

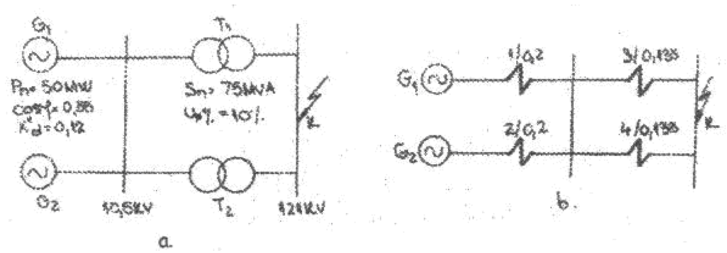

Fig. 2.a Design scheme and equivalent one.

Since generators are of the same power [13], same type and in the identical conditions relative to the short circuit point, we replace them by an equivalent generator of **S= S₁ + S₂** power and $x_5 = \frac{x_1 x_2}{x_1 + x_2}$ reactance. [10], [11], [12].

Figure 2.b then becomes Figure 3. Further all reactance are grouped in relation to the point of short circuit, leading to the final scheme (Fig. 4), in which one the equivalent generator is connected to a short-circuit point through an equivalent reactance.

$$x_\Sigma = x_5 + \frac{x_3 x_4}{x_3 + x_4} \quad (3.1)$$

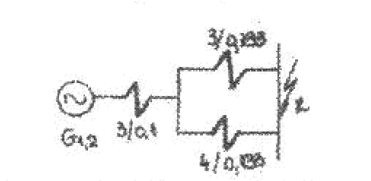

Fig. 3 Equivalent scheme.

Fig. 4 Final equivalent scheme.

Reactance calculation is then determined by the relationship:

$$x_{calc} = x_\Sigma \cdot \frac{S}{S_b} \quad (3.2)$$

From this last relation result that calculation reactance is expressed in relative nominal units (by multiplying $\mathbf{x_\Sigma}$ - relative basis reactance – with the ratio $\mathbf{S/S_b}$ will returns to the nominal conditions). [5].

Depending on the calculation reactance calculated from the last relation, from the calculation curves is found periodic short-circuit current in relative nominal units, at times we are interested. Knowing the relatively nominal current is then determined absolute current (in A):

$$I_{k(t)} = I^*_{k(t)} \cdot I_n \quad (3.3)$$

where:

$I^*_{k(t)}$ - the periodic current in nominal relative units at **t** moment;

$\mathbf{I_n}$ - rated current of the equivalent generator, calculated using the relationship:

$$I_n = \frac{S}{\sqrt{3} \cdot U_{med}} \quad (3.4)$$

CONCLUSIONS

Reducing short-circuits current and consequently the demands caused by it, determine the choice of circuit elements less oversized to normal operation conditions. Efficiency of practical methods to reduce short-circuit currents result from the difference between the reduction of investment in primary circuit elements due to short-circuit current reduction and investment determined due to elements that are inserted after the current reduction. [7].

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