CONTROLLED SWITCHING PROBABILITY DISTRIBUTION EVALUATION

Ciprian NEMEŞ[1*], *Florin MUNTEANU[2*], Dumitru IVAS[3*]

A general overview of controlled switching probability, depending the disconnecting moment of the circuit breaker from electric power systems is presented. The controlled switching benefits include enhancements of circuit breaker performance, reduction and control of switching transients, improvement of power quality, extension of equipment life and increase in time intervals between interrupter maintenance, etc.

Keywords: controlled switching, circuit breakers, switching transients, switchgear.

1. Introduction

A transient occurs in the power system when the network changes from one steady into another. Switching operations in power networks are a common cause of transient disturbances. It is not necessary that after every changes of state, such as after a switching action, transient oscillations occurs in a network, but, in the practice, however, this rarely happens, and after switching actions, transient oscillations appear in an electrical network. Depending on the network configuration and the characteristics of the switching loads, these transients can cause undesirable effects, not only on the switched loads, but also on the entire network.

Controlled switching is applied to limit the consequences of a switching event on the switched equipment, on the circuit breaker, and/or on the power system. Controlled switching, especially the controlled opening, can also offer an alternative in cases where the short-circuit fault requirements are increasing. The short-circuit current is a wide-spread fault of an electrical system, when the electrical current is drastically increased, as compared with the operation conditions and dropped after a short time. This current induces significant stress in circuit breaker [1], so it is recommended that disconnecting moment to be when the current zero crossing. The ideal switching changes from close to open position instantaneously, and the sinusoidal current is always interrupted at current zero.

In this paper a probabilistic approach is presented, based on the probability distribution function of the disconnecting moment. The basic principle is the calculation of the current expressions in parametric form, as functions of the switching parameters and their probability distribution functions.

[1] Lecturer, PhD, Power Engineering Department, University “Gh. Asachi” Iasi, Romania
[2] Prof, PhD, Power Engineering Department, University “Gh. Asachi” Iasi, Romania
[3] Prof, PhD, Power Engineering Department, University “Gh. Asachi” Iasi, Romania

2. Characteristic of the short-circuit current

The short-circuit current is one of the most important factors influencing the design of the electrical equipments. In circuit analysis, the term short circuit is used by analogy to designate a zero-impedance connection between two nodes. In an ideal short circuit, this means there is no resistance and no voltage drop across the short. In real circuits, the result is a connection of nearly zero impedance, and almost no resistance. In such a case, the current drawn is limited by the rest of the circuit.

When the time constant of the supply circuit L/T is rather high, which in the case for short-circuit faults close to the generator terminals, the transient and subtransient reactance of the synchronous generator cause an extra-high first peak of the short-circuit current, see the figure 1a.

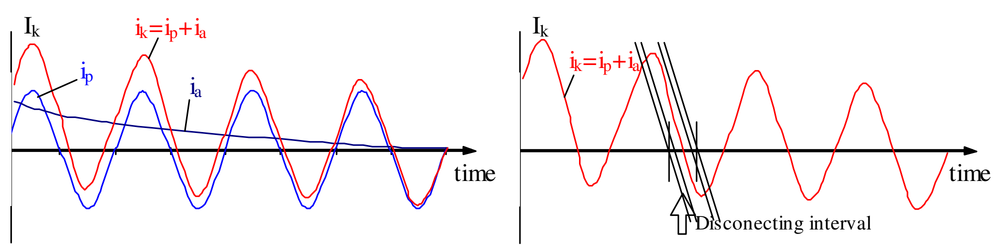

Fig. 1. The evolution of short circuit current in time (a), the disconnecting interval (b).

The evolution in time of the short circuit current is described by the following equation:

$$i_k = I_{pm} \sin(\omega t + \alpha - \varphi_k) + [I_m \sin(\alpha - \varphi) - I_{pm} \sin(\alpha - \varphi_k)]e^{-t/T_a} \qquad (1)$$

The controlled switching considers the effect of the interrupted current frequency, 100 times zero crossing during a second. The objective is to estimate the disconnecting intervals, which have as effect the reduced current magnitudes, such is presented in figure 1b.

3. Probabilistic approach

The short circuit expression depends by the following variables (t - time, α – initial phase of voltage, φ - difference phase current-voltage and I_m- load current). The last parameters (φ and I_m) depend by the type of load, but the time t and angle α can take any values in the disconnecting process.

In the paper it is analysed the manner in that the variable α, depending by the disconnecting moment t, influence the probability that in the disconnecting moment [2], the current pass to zero.

Ideally is that the disconnecting interval of the circuit-breaker operations to be tight, the moment of disconnecting is necessary being precisely know, nearly by the current wave crossing zero. In practice, the moment of disconnect will be placed into interval (t^*-Δt, t^*+Δt), the distance of interval Δt is affected by circuit-breaker characteristics such as mechanical scatter, electrical scatter, speed and energy of the contacts and deviations of timing due to interval between subsequent operations. Two cases will be compared in the paper.

1. The first case of the random switching, the disconnecting moment being uniformly distributed.
   In case of the circuit breaker, without controlled switching, the disconnecting moment to be approximately t=0.15s after fault moment. In that interval, the moment of disconnect may be uniform distribute, in the 0-0.15 s interval, with the same probability to disconnect. If the disconnecting moment is uniform distributed, the current amplitude interrupted is distributed as in the figure 2. The extreme values of the current amplitude interrupted will present the maximum probability to appearance that is most great that the probability to disconnecting then the current pass to zero.

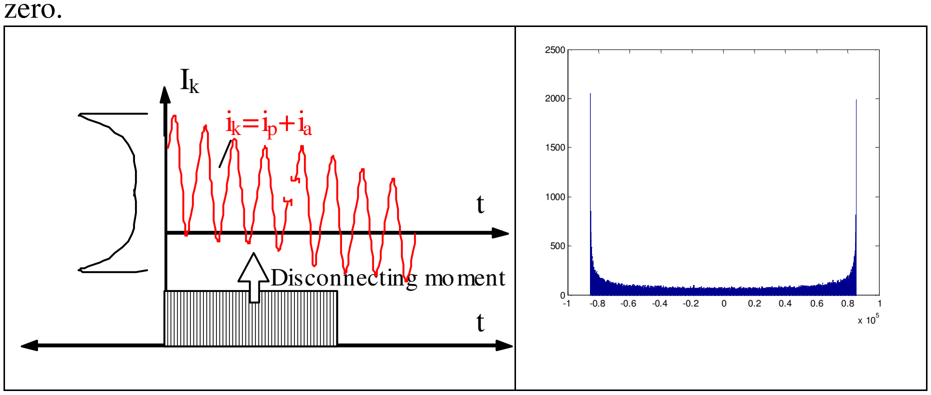

Fig. 2. Probability distribution for the random switching.

The second case of the controlled switching, the disconnecting moment having a distribution of controlled operations around a target point on the current wave. All this factors are most or less controllable, all this having a normal distribution. If the disconnecting moment is normal distributed around of the current zero crossing, the probability to disconnect to zero magnitudes current is described by the following figure. So, the probabilities to disconnecting then the current pass to zero are greater that in the previously case and the extreme values of the current interrupted has a negligible probability.

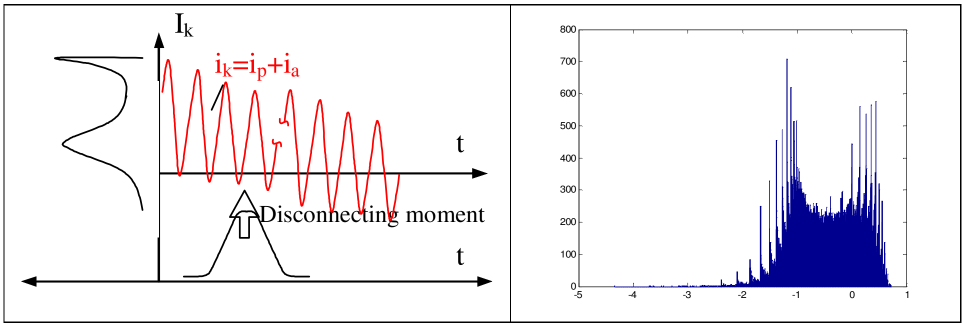

Fig. 3. Probability distribution for the controlled switching.

4. Conclusions

From the probability distribution function of the current disconnected results that the probability to disconnect the zero crossing current is smaller that the probability to disconnect the extreme values current. These involve the necessity of the controlled switching, focus to the disconnecting moment, with the main benefits that result from that: extension of circuit breaker life and increase in time intervals between interrupter maintenance (scheduled maintenance is based on a simple relation between the interrupted current and a maximum number of operations); added value associated with circuit breaker performance enhancement during current interruption in the thermal or in the dielectric region.

REFERENCES

1. *C. Nemeş, D. Ivas, Fl. Munteanu* Modelarea fiabilităţii contactelor întreruptoarelor electrice bazată pe fizica electroeroziunii. *CIEM 2003, 22-25 octombrie 2003, Bucureşti. Vol. I, pag. 2.16 – 2.20. ISBN 973-27-1032-2.*
2. Ciprian M.NEMEŞ, Dumitru IVAS, *Aspecte privind influenţa sistemului electroenergetic asupra fiabilităţii întreruptoarelor*, Al XIX - lea Simpozion Naţional "Siguranţă în Funcţionare a Sistemului Energetic" SINAIA, 28 - 30 septembrie 2005. ISBN 973-87456-0-8. Pag. 165-169.