# Numerical Simulation of the Interactions between Low Voltage Network, Miniature Circuit Breaker and Mounting Technique

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***Abstract*—The paper proposes a simple methodology for low voltage network / miniature circuit breaker interaction analysis, based on a reduced set of measurements of the network parameters and a numerical simulation (performed in PSCAD) of the interruption transient regime. There is also highlighted the influence of DIN rail mounting technique on miniature circuit breaker performances as result of the electromagnetic fields numerical computation (performed in Infolytica MagNet). The results are validated by experimental tests and analytical solutions.**

***Index Terms*— Circuit breakers, Finite element methods, Power system simulation.**

## I. Introduction

A high-performances switching device can be invalidated by the network parameters where is to be installed and vice versa [1], [2], [3], [4]. Parameters evaluation of the low voltage electrical network upstream and downstream of the circuit breaker allows the implementation of the circuit in a power system simulation software which will offers the values of the currents and voltages which that portion of network will incur, allowing the validation of device/network interaction.

Also, a specified device can have switching parameter variations depending on the assembly mode, e.g. in electric panel made from metallic or insulated materials, on DIN rail or on mounting plate etc. In this work is analyzed the influence of the DIN rail over the electric arc displacement into the arc chamber, for miniature circuit breakers.

## II. Network / Circuit Breaker Interaction

Towards the installation point of the circuit-breaker will perform two sets of measurements: first, downstream of it, requires L-N loop impedance measurement, L-N loop resistance respectively, together with registration of the network voltage. This measurement must be performed under voltage, e.g. the authors used for this purpose a tester for electrical installations LEM NORMA UNILAP 100 XE, Fig.1. These values allow defining voltage source parameters and make corrections to element parameters R, L, C of the simulation circuit and generates short-circuit current value forecasted in that point.

Downstream of the circuit breaker are measured the resistance R, the inductance L and the capacity C values using RLC bridge. Measurements are made after visible separation of the installation.

Thus is obtained an equivalent circuit of the investigated network which is implemented in a power system simulation environment.

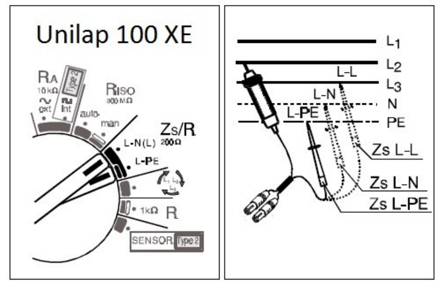


Fig. 1. UNILAP 100 XE used to measure the parameters upstream of the circuit breaker

For exemplification – validation, a low voltage line model was chosen with the following parameters: $V_S$ = 230 $V_{rms}$, $L$ = 0.2238 H, $R$ = 16.194Ω, $C$ = 1 μF and it was implemented in PSCAD, Fig. 2.

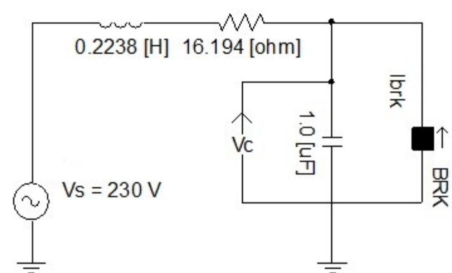


Fig. 2. The equivalent circuit simulated in PSCAD

The simulation results are illustrated in Fig. 3, which captures the disconnection made by the circuit breaker, namely the transient recovery voltage in the upper figure and the interrupted current in the figure below, very similar with the experimental measurements.

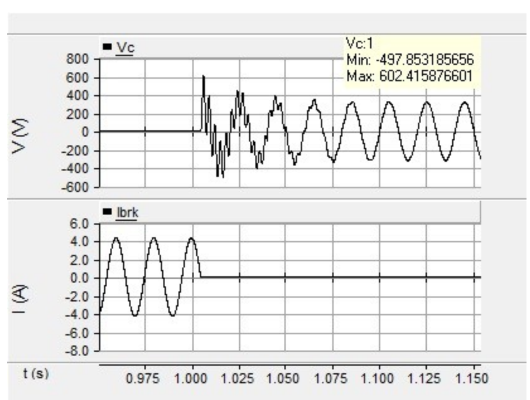


Fig. 3. Interruption oscillogram from PSCAD

From the resulted oscillogram the oscillation factor $\gamma$ is determined:

$$\gamma = \frac{V_{Cmax}}{V_S \cdot \sqrt{2}} = 1.852. \quad (1)$$

which indicates the maximum value of switching overvoltage that occurs in the system, i.e. 426 $V_{rms}$ and 602.42 $V_{peak}$ for the analyzed line.

Also, instead of using PSCad for circuit simulation, a simplified analytic determination of the oscillation factor, according to [5], can be applied for a faster transient recovery voltage parameters determination. From notations:

$$\delta = \frac{R}{2L} = 6.62 s^{-1}; \ \omega_0 = \frac{1}{\sqrt{LC}} = 2133.83 s^{-1}. \quad (2)$$

and:

$$\omega_e = \sqrt{\omega_0^2 - \delta^2}. \quad (3)$$

results:

$$\gamma = 1 + e^{-\delta \frac{\pi}{\omega_e}} = 1.99. \quad (4)$$

The generated error by simplified analytical calculation is 7.45%.

## III. DIN Rail Mounting Technique

The mounting technique of the miniature circuit breaker may be an important component that affects its performances. The ferromagnetic and / or conductive materials lied in proximity of the breaker determine variations of the electrodynamic forces that act on the electric arc generating its movement from initial position, denoted 1 in Fig. 4, to the arc chamber.

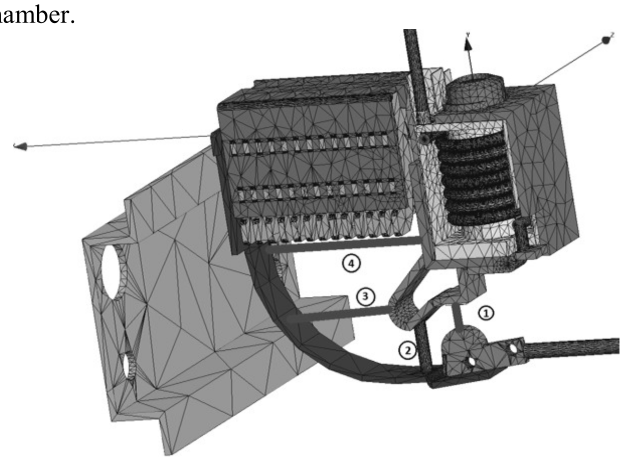


Fig. 4. Miniature circuit breaker in MagNet

For miniature circuit breaker the standard assembly is by DIN rail. The influence of this mounting technique is analyzed using Finite Element Method to compute the electrodynamic forces, [6], [7], [8], [9], with and without DIN rail.

The forces exerted on electric arc column are determined for all four position of the arc inside the breaker: 1, 2, 3, 4 in Fig. 4.

In Table I are shown the variations of the forces generated by the DIN rail, negative values meaning the reducing of the force in the DIN rail presence. Bolded cells represent the most important component of the forces for arc displacement.

TABLE I
VARIATIONS OF THE ELECTRODYNAMIC FORCE ON ELECTRIC ARC WITH TOWARDS WITHOUT DIN RAIL

| Position of the electric arc | Force [%] | | | |
|---|---|---|---|---|
| | F(x) | F(y) | F(z) | Mag(F) |
| **1** | **1.13** | 0.62 | 0.52 | 1.13 |
| **2** | **1.30** | 0.60 | 1.54 | 1.30 |
| **3** | 2.99 | **3.37** | -10.59 | 3.33 |
| **4** | 2.90 | **1.39** | -8.07 | 1.33 |

For the arc chamber and DIN rail geometrical configuration specified in Fig. 4 the influence of mounting technique is positive. The increasing in electrodynamic force that leads the arc into chamber is up to 3.37%.

For different geometries, as in [10], electric panels or various electrical equipments proximity, the analyses are performed in the same way focused on the electrodynamic forces on electric arc variations.

## IV. Conclusions

Accordingly to the presented methodology, the behavior of the miniature circuit breaker in terms of the electric network and the mounting technique becomes easy determinable based on electromagnetic field computation. The inputted data are the breaker, network and assembly parameters. All these are available on technical sheets except the network variables which can be measured using basic methods.

Thus, any regimes, rating or faults, can be evaluated in a virtual environment certifying the breaker and its arrangement choosing, also avoiding on site testing

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