Simulation of a Real Distribution Grid with Superconducting Fault Current Limiter

A. T. Queiroz[1,2], M. Z. Fortes[1], A. Polasek[2], G. G. Sotelo[1]
1– Fluminense Federal University (UFF)
2– Electrical Energy Research Center (CEPEL)
andretqueiroz@gmail.com, mzf@vm.uff.br, polasek@cepel.br, gsotelo@id.uff.br

Abstract

The growth of generating sources connected to the power system and closer to the consumers increased the short-circuit level, due to the low impedance between the fault and the source. This means that the system may not be properly protected during a fault occurrence. One potential solution for this problem is the insertion of resistive superconducting fault current limiters SFCL (r-SFCL) in the grid. A proper study of these devices concerning how they affect the grid dynamics is necessary to correctly dimensioning and positioning them. In this context, a distribution network using data obtained from a real system of an utility was modeled using the software Alternative Transient Program (ATP). The r-SFCL was also modeled in ATP and the electrothermal analogy was used to solve the coupling between electrical and thermal phenomena that describes its behavior during a fault occurrence.

Distribution Grid Characteristics

The distribution grid is located in Rio de Janeiro city, composed by three substations (SE_1, SE_2, SE_3), as illustrated in Figure 1. The SE_1 has a power transformer of 32 MVA, primary and secondary voltages are 138-25 kV, delta-delta connection and grounded by a zig-zag transformer at secondary, The SE_2 and SE_3 have a power transformers of 3 MVA primary and secondary voltages 25-13,8 kV, delta-wye with neutral grounded. To specify the r-SFCL, the nominal current and phase voltage applied are 330 A_{rms} and 14,44 kV, respectively.

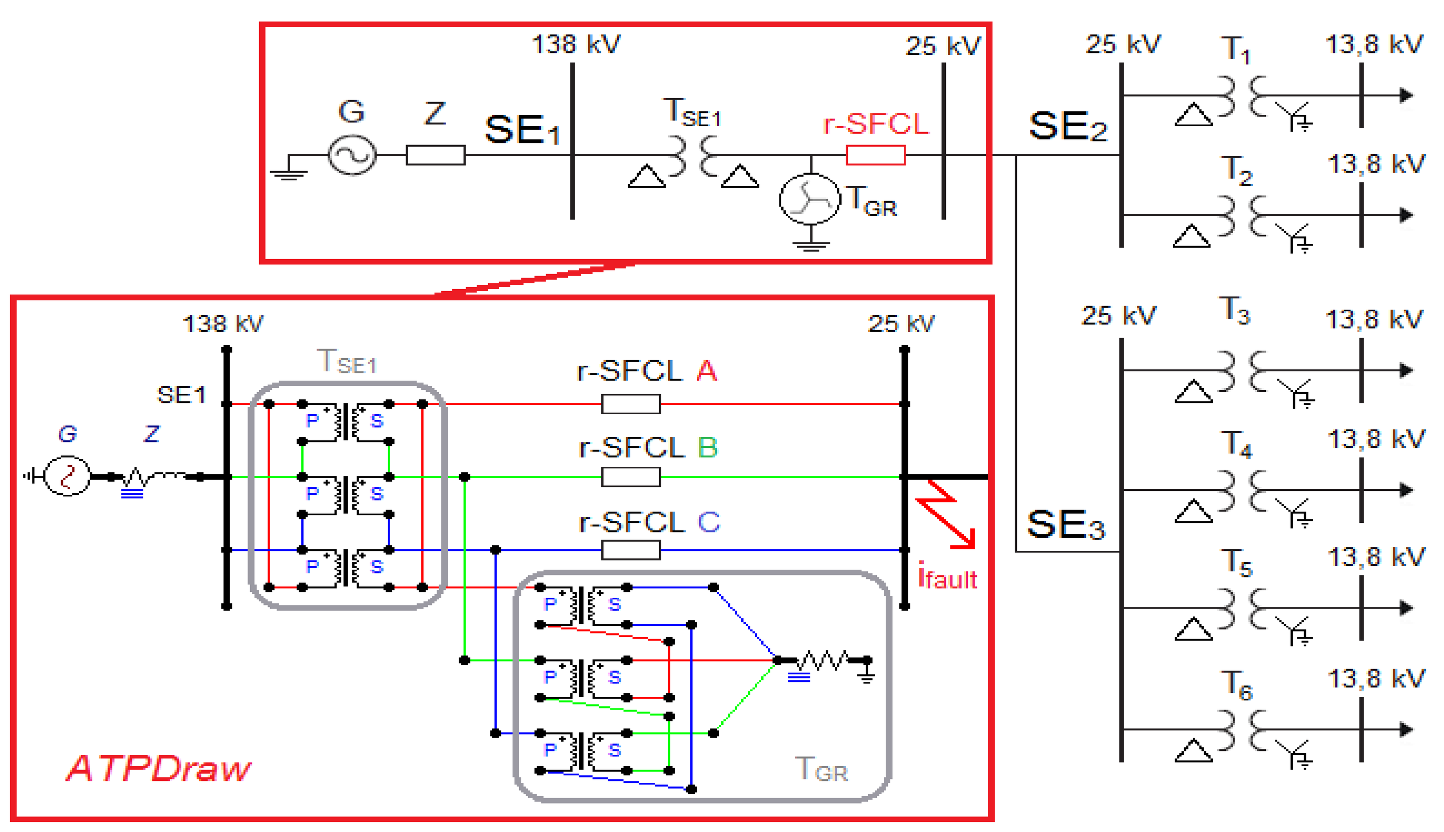

Fig.1: Single-line diagram of simulated distribution grid, by ATP.

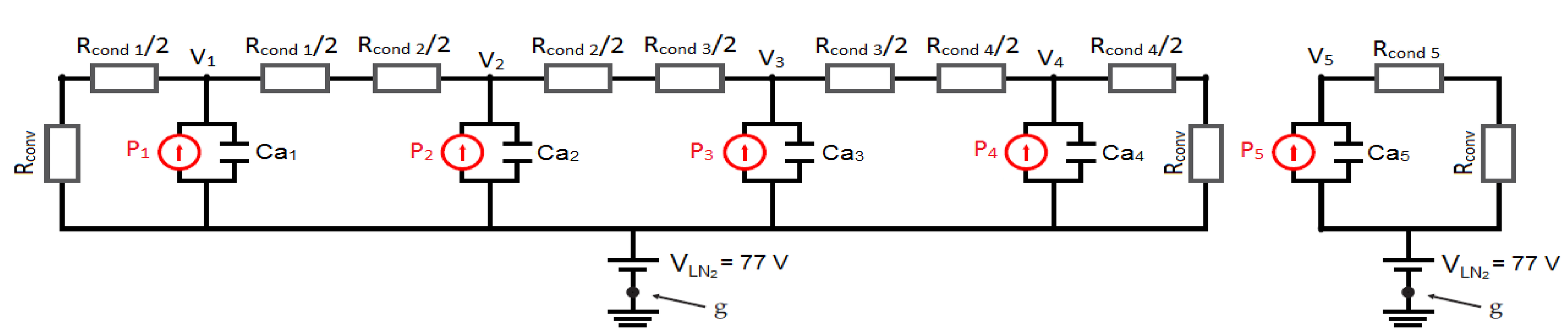

Fig. 2: Electrothermal circuit of r-SFCL.

The one-dimensional transient heat conduction equation (Eq. 1) is mathematically equivalent to the distributed transmission line equation (Eq. 2).

$$\frac{\partial T}{\partial t} = \frac{\lambda}{\gamma c} \cdot \frac{\partial^2 T}{\partial z^2} + \frac{\dot{g}}{\gamma c} \quad (1)$$

$$\frac{\partial v}{\partial t} = \frac{1}{R \cdot C} \cdot \frac{\partial^2 v}{\partial z^2} + \frac{P}{R \cdot C} \quad (2)$$

Tab. 1: r-SFCL characteristics.

SFCL	2G Tape (YBCO)
Lenght [cm]	430
Critical current [A_{rms}]	299,38
Shunt resistor material	stainless steel

Results

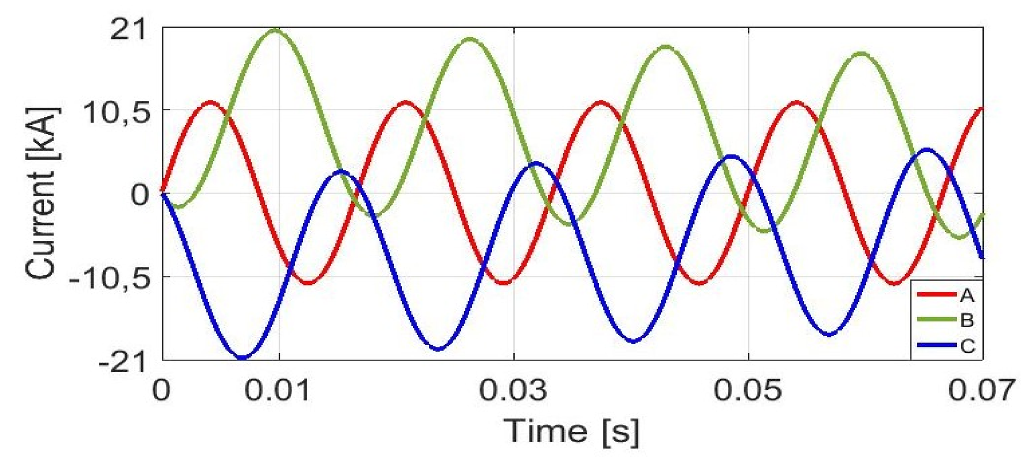

Fig. 3: Three-phase fault current.

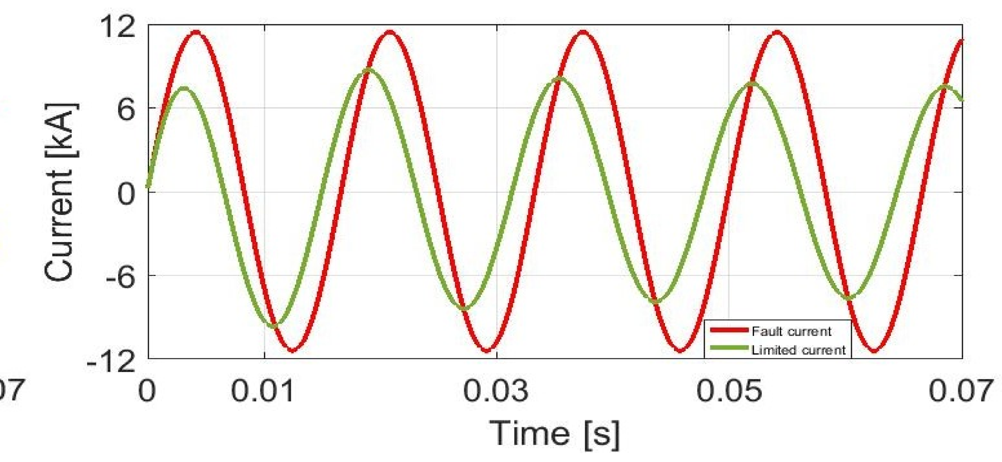

Fig. 4: "A" phase current.

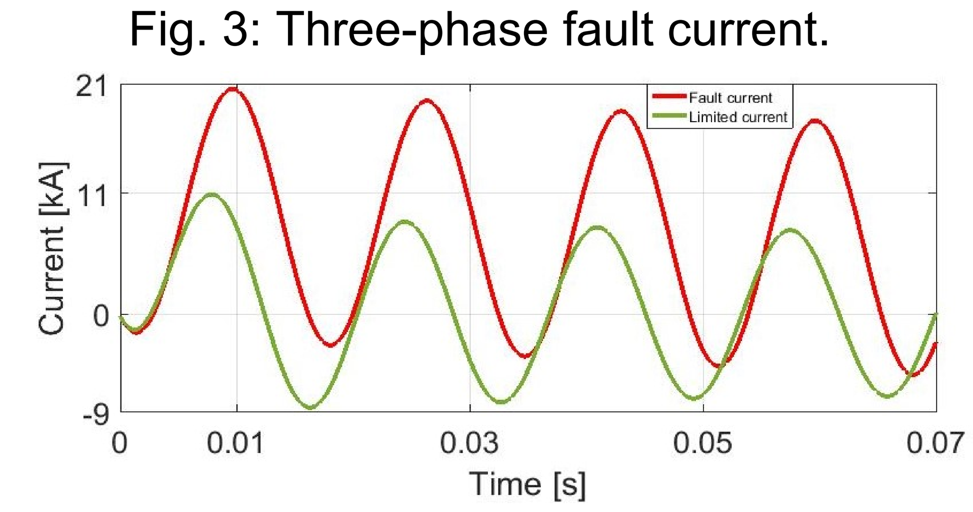

Fig. 5: "B" phase current.

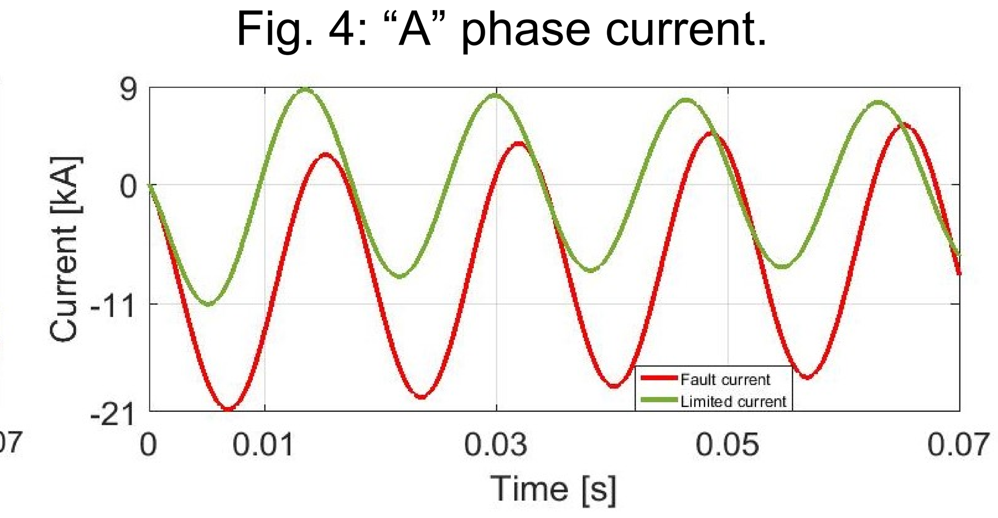

Fig. 6: "C" phase current.

Tab. 2: Values of fault currents by ATP simulation.

Fault Type	I_{fault} [kA_{peak}] Fault current	Limited Current	Reduction [%]	I_{fault} [kA_{rms}] Fault current	Limited Current	Reduction [%]	Phase(s)
Three-phase	11,43	7,42	35,1	11,40	7,27	36,2	A
	20,51	10,90	46,9	11,41	7,26	36,4	B
	20,78	11,08	46,7	11,46	7,28	36,5	C
Line-to-line	14,47	9,21	36,4	9,98	6,46	35,3	AB
	19,24	10,51	45,4	10,03	7,24	27,8	BC
	14,72	8,59	41,6	10,02	7,17	28,4	AC
Double line-to-ground	15,36	10,28	33,1	10,48	7,29	30,4	AB
	19,56	10,55	46,1	10,51	7,56	28,1	BC
	16,74	9,49	43,3	10,52	6,78	35,6	AC
Line-to-ground	7,03	4,81	31,6	6,68	4,36	34,7	A
	10,73	7,59	29,3	6,69	5,42	19,0	B
	10,82	7,55	30,2	6,70	5,47	18,4	C

Conclusions

The simulation results of the distribution system show that the SFCL is able to reduce short-circuit currents in the first half-cycle, which makes possible to evaluate its performance for real applications in the power systems and their future installation by the utilities, to limiting the currents values below the interrupting capacity of existing circuit breakers.