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Abstract **This document presents the final report on Task 5.7.1 – Verified results, improvement methods for modelling (task 5.1) analysis mode (task 5.5) and results display (5.6)**

Keyword List Validation

1. INTRODUCTION

This task consists of the validation of the models and the analysis methods developed. The purpose of this validation is to determine the capability of the present simulator to fulfil the end user technical requirements. The simulation results have been validated scientifically. Accuracy and speed of results have been estimated to define the range of validity of models and analysis modes. Not only, the accuracy of the single models has been tested, but also their functional behaviour as part of a complete electrical installation. The validation task has been focused on standard electrical components. In particular, lots of efforts have been done in the validation of the models of circuit breakers.

2. VALIDATION OF THE ANALYSIS METHODS

The simulator developed in this project uses different analysis methods compared to other known simulators: it allows obtaining results very near to the theoretical ones with less calculation. The first objective was to compare the results from the present simulator to the expected ones, to check if the considered approximation was good enough, and then to compare them with the results from other simulators. Simulated voltages and currents were compared with the theoretical expected results and between them. These analyses were made with different standard circuits.

Firstly, a classic RLC serie circuit is considered:

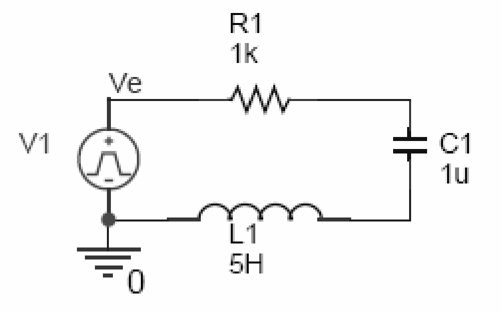

Figure 1: RLC serie circuit.

For the time domain study the voltage source considered is a square wave source. In the frequency domain simulation this square wave source is replaced with a sinusoisal one, and a sweep is made in the frequency of this signal. In the time domain analysis the voltage in the capacitor is displayed, while in the frequency domain analysis the gain curve is shown:

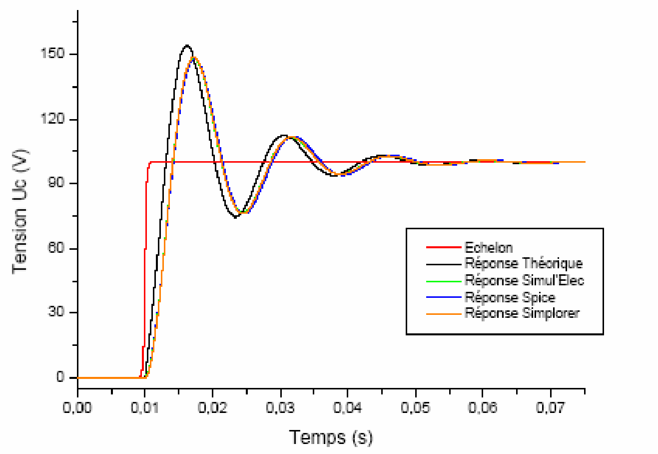

Figure 2: Step response of the RLC circuit in the time domain

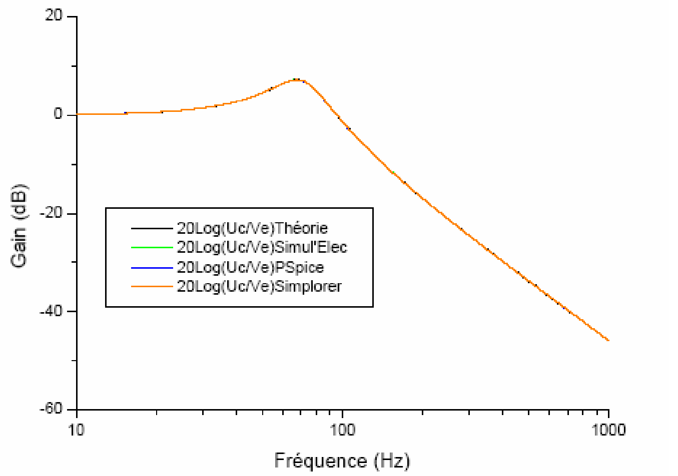

Figure 3: Response of the RLC circuit in the frequency domain.

The results obtained with the three simulators are very similar in both cases. In the time domain analysis it can be seen that the theoretical response is slightly different compared with the simulated ones.

The second circuit under study is a first order low-pass filter:

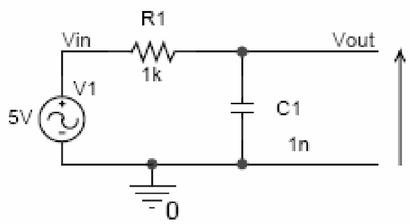

Figure 4: RC serie circuit.

This circuit was useful to compare the required time for the three simulators to obtain the characteristic curves in frequency domain analysis.

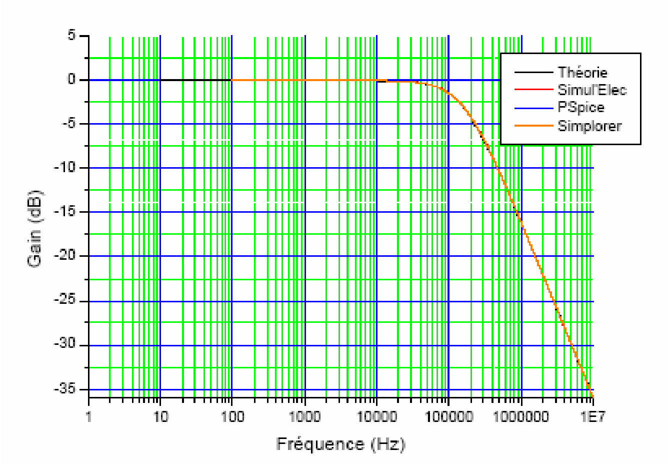

Figure 5: Response of the RC circuit in the frequency domain.

Concerning the required simulation time the following table and picture are obtained:

Number of points	**SimulÉlec (ms)**	**PSpice (ms)**	**Simplorer (ms)**
65	140	70	9603
650	1141	143	10183
6500	12341	1153	11500

Table 1: Comparison of simulation time in frequency analysis.

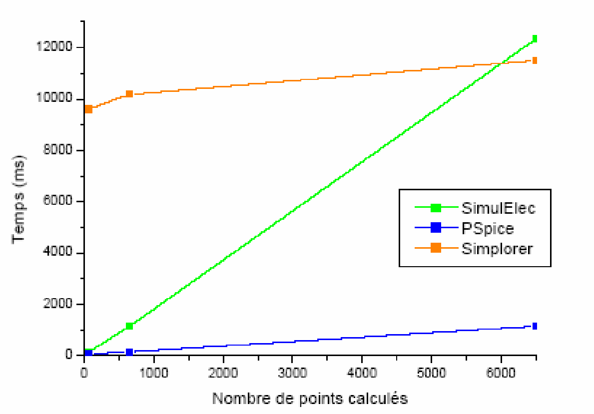

Figure 6: Simulation time in function of the required number of points.

PSpice is the fastest simulator in this type of analysis, secondly the simulator developed in this project (Simul'Elec) and finally Simplorer. Simplorer reaches Simul'Elec above 6000 points, which is a very high number of calculation points for this type of analysis.

The third circuit under study is a noisy voltage source and a low-pass filter. To simulate the noise two high frequencies sources are added to the 50Hz fundamental one:

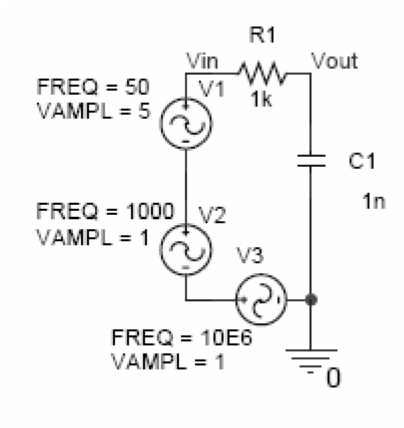

Figure 7: Noisy source and low-pass filter.

The purpose of this circuit, which involves three sources of very different frequencies, was to compare the calculation velocity of the three simulators and their accuracy level in a time domain analysis. PSpice and Simplorer do a transitory analysis and obtain the output curve point by point. Their calculation step must be based on the higher frequency signal (10MHz), but the simulation time must be based on the lower frequency one (50Hz).

Simplorer is more efficient than PSpice, it manages memory resources better, but it is still slower than Simul'Elec. Simplorer has more errors in the visualization of results when the calculation points are not enough, so it is necessary to increase the number of points and consequently the simulation time to avoid this kind of errors.

In summary it can be said that, in contrast to the frequency domain analysis, the three simulators work in a different manner in time domain, so the results will be more or less accurate depending on the simulation time. The fastest simulator is Simul'Elec, which gives acceptable results in a short time. PSpice gives good results too, but it is not possible to fix the time interval between two consecutive calculation points and the simulation time is quite long. Simplorer has an intermediate simulation time, but its results sometimes are misleading depending of the number of calculation points or required precision.

3. VALIDATION OF MODELS OF CIRCUIT-BREAKERS

A protection selectivity low voltage test bench was used to do some experimental tests with real circuit-breakers and to compare the results with the theoretically calculated and the simulated ones. This test bench is able to reproduce the conditions of a short-circuit in safe conditions.

Its purpose is to check the general behaviour of the circuit-breakers in function of the test bench and the type of selectivity. With the use of a current probe and a digital oscilloscope it is possible to measure the current and the opening time of the circuit breakers.

The circuit-breakers under test are used in different test benches. Configurations with more than one circuit-breaker allow us to probe the principle of selectivity. Different types of selectivity can be distinguished: total selectivity is achieved when the curves time/current of the dispositives do not overlap, partial selectivity occurs when the curves partially overlap. The system will work properly if the short-circuit current is lower than the cross point of the two curves. There is no selectivity in the zones when the curves are overlapped.

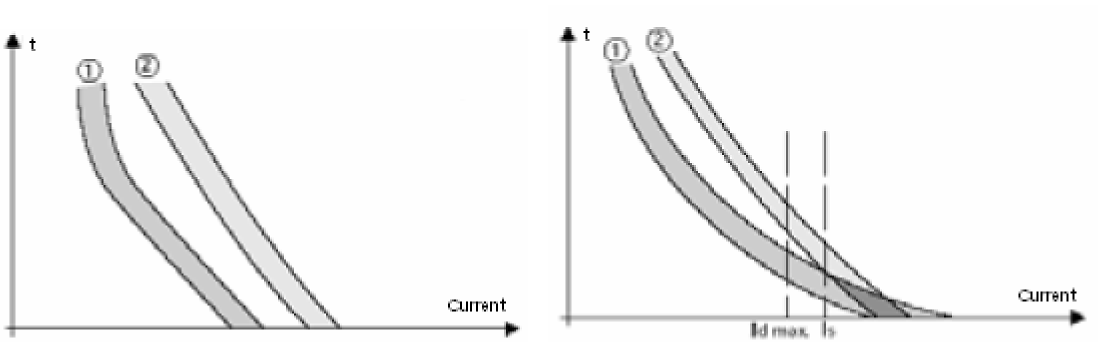

Figure 8: Total and partial selectivity.

There can be differences between the theoretical values, the simulations and the measures in three main aspects: the short-circuit current, the opening time of the circuit breakers and the selectivity. A difference in the short-circuit current will produce a diferrence in the opening time, and this could lead to a difference in the selectivity.

The results obtained show there are little differences between the simulations and the measures concerning the short-circuit currents and their opening times. However, in some cases more important differences are observed between the opening times of the circuit-breakers. A small difference in the short-circuit current could involve important divergence between the opening times if the current is in the zone almost vertical of the activation curve of the circuit-breaker. It is important to remark that in most cases simulation gave a better approximation to the experimental values than calculations.

Concerning selectivity, the simulator gives correct results when there is total selectivity. However, when the circuit-breakers under study involve a partial selectivity, the simulator sometimes gives different results than the measured one, where it is not the expected circuit-breaker the one which become active. To improve these results thermal inertia of circuit-breakers could be considered in cases where the activation is almost simultaneous. In addition, in cases where the activation of circuit-breakers is very quick, the peak value of the short-circuit current coud be taken into account, not only the effective value, which is only appropriate when there are several cycles of a periodic signal.

As well as working with the protection selectivity low voltage test bench, a second test bench was used to validate the proper working of some component models of the simulator, like circuit-breakers, relays, wires. This second test bench is complementary to the previous one and allow us to work with different levels of DC or AC currents.

The voltage drop in some long wires was tested. When the wires are long enough and the current is high there is a difference of potential between their extremes that cannot be neglected in order to design a good protection system for the circuit.

With a more accurate model of the wire simulated results are expected to be nearer to experimental ones.