

TLSim: A Software for Electrical Public Transportation Systems

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Abstract

The Laboratory of Electrical Machines of the Swiss Federal Institute of Technology (Lausanne) has developed a software (TLSim) for the simulation of electrical urban transportation systems. This program can simulate the behaviour of the power supply network (current and voltage level at any point of the topology) comprising uni- and bi-directional sub-stations. In the network the vehicles (trolleybus) may run along any defined path through different electrical supply sectors. Several models of trolleybus are available, one of these allowing for the injection of current back in the supply network. The operating schedule of the buses as well as the geographical data of the network are provided by the user. This program is a perfect tool for system planning as ascertained by its use by a Swiss transportation operator. A comparison of simulation and measurements on a real network has been performed with satisfactory results.

This software evolved from a specific study to a flexible program still being extended with new developments. The latest of such developments being the study of the influence of capacitors in helping the system to keep voltages over a specified level mainly by supplying the surge current during the acceleration of the trolleybuses.

Keywords: simulation, public transport, bus, optimization, load management

1. System to simulate

The system to simulate comprises basically 3 elements: vehicles, routes and electrical supply.

1.1. Model of vehicles

Up to now, 2 type of vehicles have been taken into account : vehicle with DC motor and vehicle with induction motor, both of them described by their traction characteristic. The second type of vehicle has another feature: the possibility to feed current back in the supply system. Introduction of new models is flexible.

The behaviour of the driver though not part of the model of the vehicle is an important parameter to take into account. The acceleration curve having a strong influence on the current supplied to the trolleybus.

1.2. Routes

Each vehicle has a predetermined route described by a set of stops; it knows its path and may easily be rerouted to another path. Routes are described by 3 features: the sequence of stops, the distance and altitude between two stops and a schedule. The program uses data provided by the operator, in particular it has make with a calculated schedule.

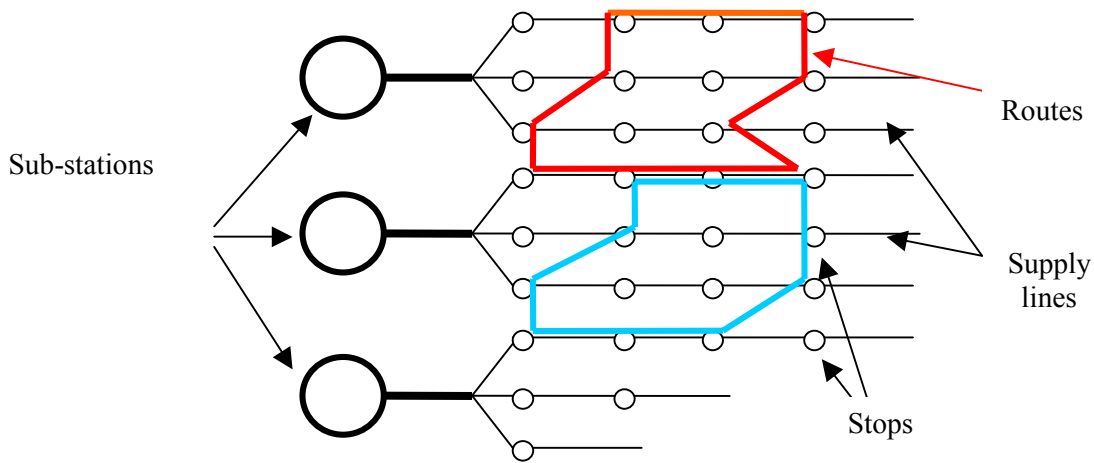


Figure 1.1: Network topology

1.3. Electrical supply

The type of model taken into account for the electrical supply is quasi-steady state, the load is always changing but transients that may briefly appear during these changes are ignored because of the complexity of the systems and the duration of simulations. This approach is moreover justified by the main objective that is essentially an analysis of the power flow. Detailed analysis of a converter with a transient simulation software allowed us to validate this approximation (fig 1.2, 1.3) [1] [3].

The electrical supply comprises substations, cables from the substations to the supply lines and supply lines. The substations may be of 2 types: with rectifiers or current converters; the second type allows for absorbing the excess current provided by the vehicles during their braking phase. Each substation feeds a number of supply lines. As illustrated in figure 1.1, the routes and the electrical supply are both mapped on the network of stops.

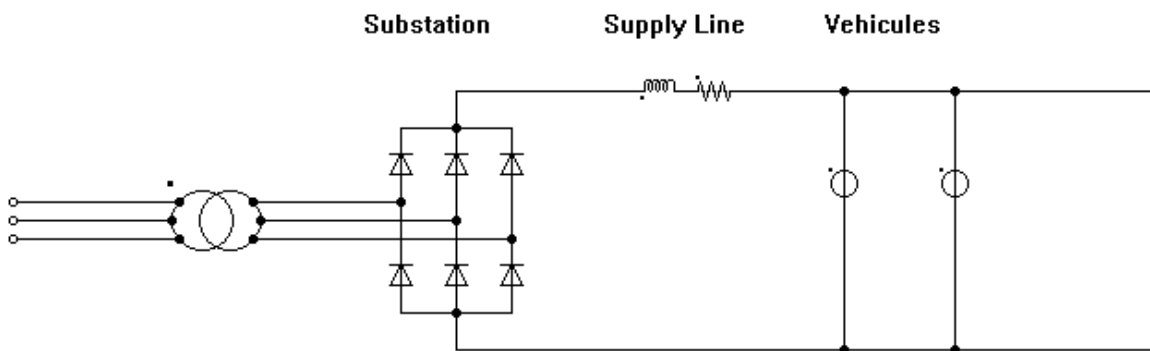


Figure 1.2: Power network, Converter, Supply line and Vehicules

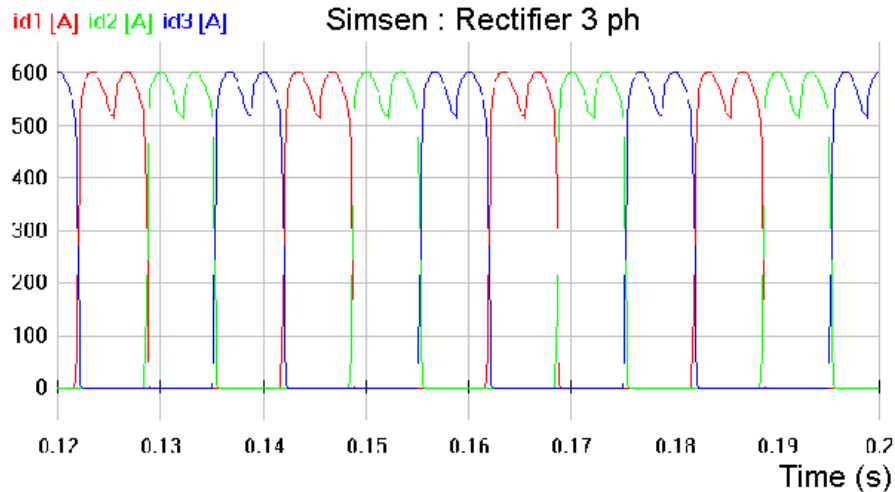


Figure 1.3: Currents on the DC side

2. Program

The program that has been developed runs on Windows. From the data provided by the user about the system and parameters of simulation the program calculates the current supplied by each sub-station and flowing in each supply line, it also calculates the voltage drop at every single stop. This last function is useful for the operator to better understand where to implement new substations or how to modify the supply lines topology to improve the system.

2.1. Structure and operation

As illustrated on figure 2.1, the program has 2 main sections: the first is the creation of the data structures using the data provided by the user, the second being the calculation for each time step of the currents and voltages. Results are displayed during the simulation and also recorded for further analysis and documentation, the user may for example gather in a spreadsheet the 5 maximal voltage drops at each bus stop.

2.2. Data

The data are of 4 types.

Description of the vehicles by their traction characteristic.

Schedule for each vehicle.

Description of the topology of the routes, sets of stops.

Description of the topology of the supply lines: this data must be carefully defined. The user enter sets of stops to describe each branch leaving from a feeding point.

These data are provided by the operator and let the program be quite flexible. This flexibility is illustrated in the section on the applications.

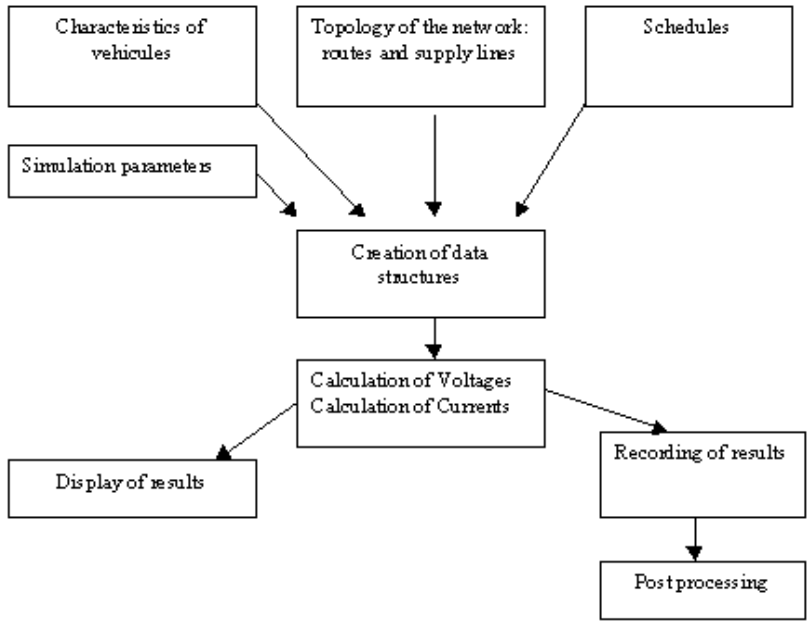


Figure 2.1: Structure of the program

2.3. User Interface

Through a graphical interface, the user controls the simulation and its parameters: what kind of vehicle to activate, start and end time. The topology of the electrical supply lines can also be modified through the interface, this allows for easily testing different cases.

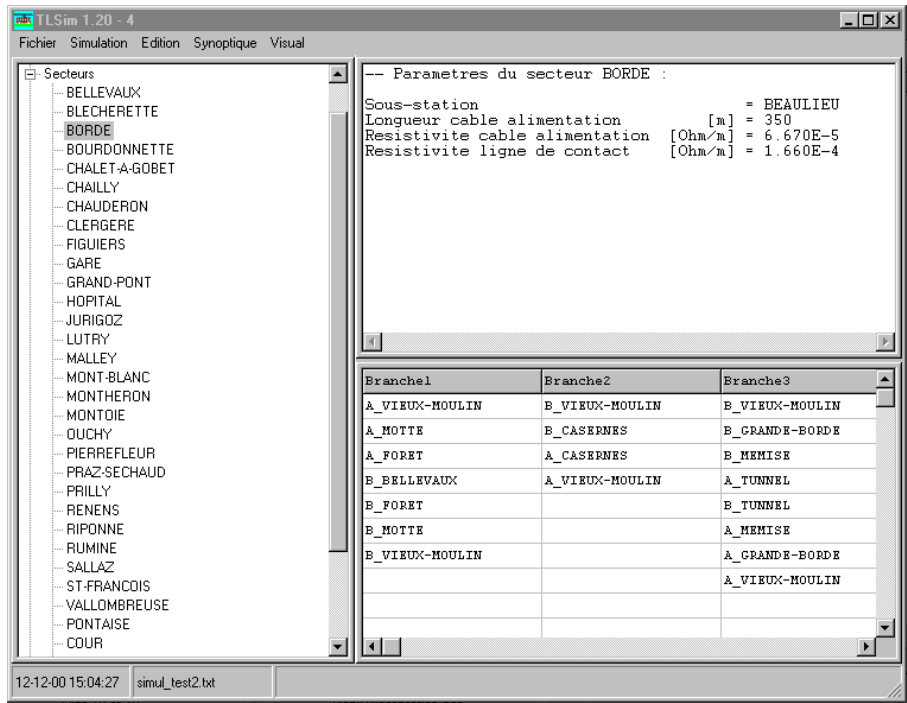


Figure 2.2: Interface

Figure 2.2 illustrates the possibility to edit the parameters of one section of the supply lines. The topology described by lists of bus stops as well as the electrical characteristics such as the resistivity of the supply line may be modified by the user.

3. Applications

Four applications are presented. Analysis of the behaviour of the network in normal operation, study of modifications to the network: placement of a new substation or/and change of the topology of the supply lines, study of the introduction of a new type of vehicle, study of new approaches to the voltage sustainment.

3.1. Analysis of the behaviour of the network

In normal operation, one wants to check the level of the voltage at each point in the supply network and the current supplied by the substations. This allows for a better understanding of the weak points in the system. This kind of analysis is regularly performed by the public transportation authority of the city of Lausanne, Switzerland (TL).

Measurements on a sector of the supply network have shown a good agreement with the results provided by the program. Below are presented some of the comparisons [2]:

3.1.1. Current at a substation comparison between measurements and calculations

Secteur Chailly
Courant mesuré au niveau de la sous-station

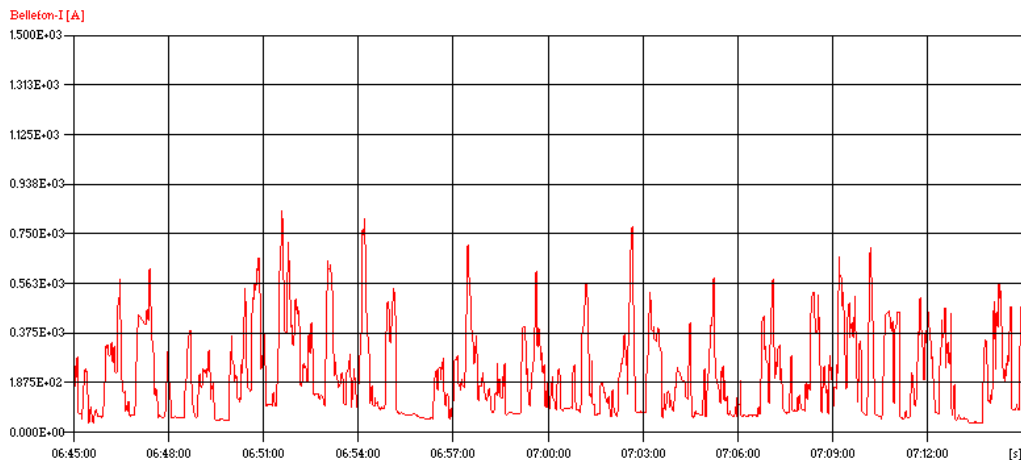


Figure 3.1: Current measured at a substation (Bellefontaine)

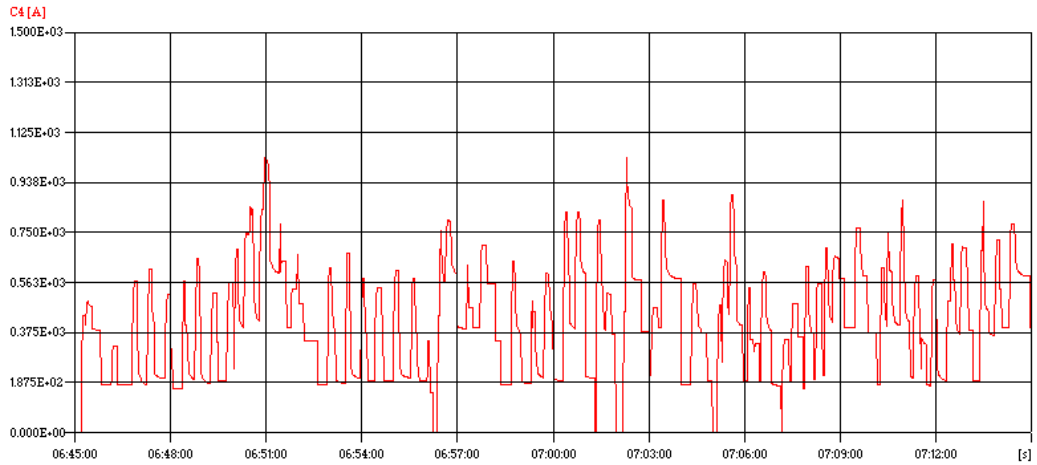


Figure 3.2: Current calculated at a substation (Bellefontaine)

3.1.2. Voltage drop at a bus stop comparison between measurement and calculation

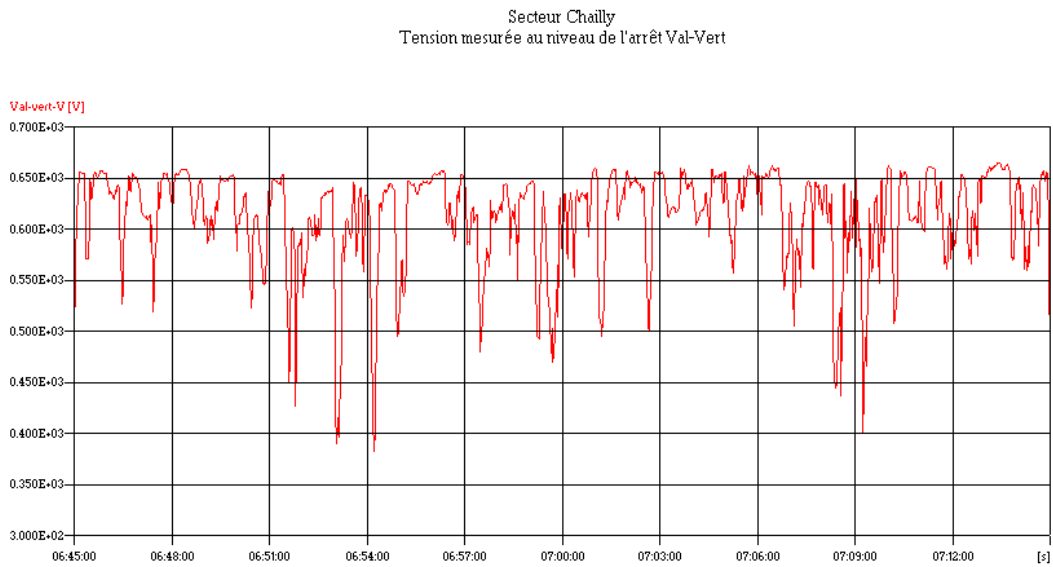


Figure 3.3: Voltage measured at a bus stop (Valvert)

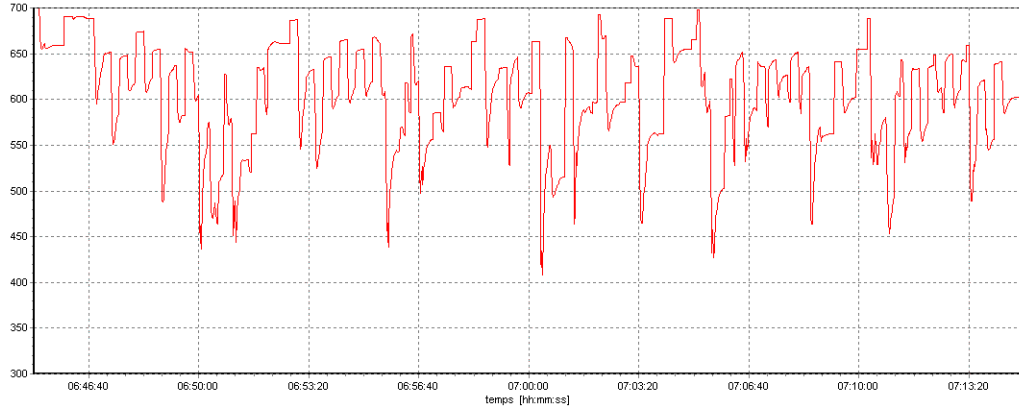


Figure 3.4: Voltage calculated at a bus stop (Valvert)

3.2. Supply network modification

In this example the user wants to study the modification of a sector. This kind of study is important for the planification when the operator looks for the implementation of a new substation or for the best way to divide a supply line in subparts. In figure 3.5, the sector is initially only supplied at position A, it is then cut in 2 parts, the second part beginning at position B. This is a very common planning study. The problem is to have the data structure matching correctly the modification of topology.

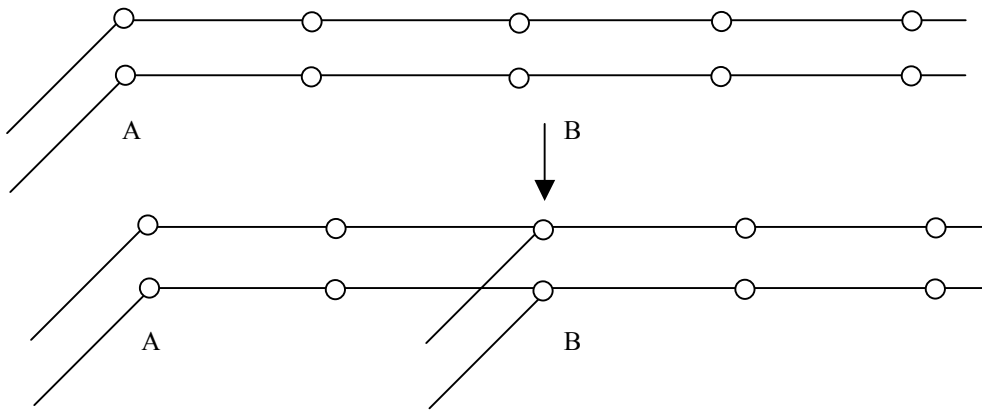


Figure 3.5: Modification of topology

3.3 Introduction of a new type of trolleybus

This example illustrates another important domain: the introduction of a new type of vehicle. In this particular case, the new vehicle had a novel characteristic, the possibility to feed back current in the supply network. The operator wanted to analyse the behaviour of the network when these vehicles are in operation, and in particular how energy may be transferred from current supplying to current absorbing trolleybuses and this with a network supplied by two kinds of substations: current converter or simple rectifier. Figure 3.7 illustrates the calculation of the current supplied to this type of bus when going through the profile and schedule described in figure 3.6. As explained in section 1.1 the behaviour of the driver has a strong influence on the current supplied to the vehicle.

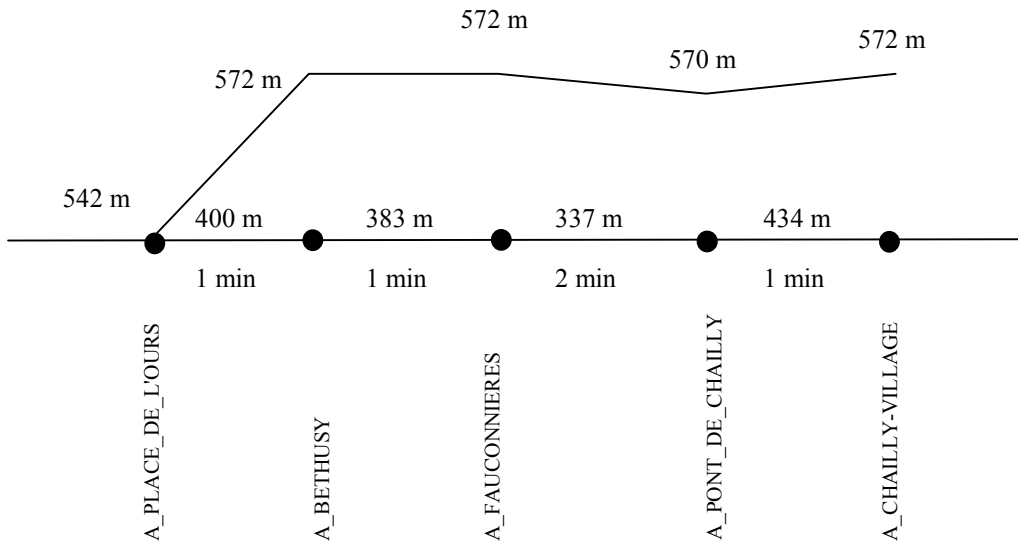


Figure 3.6 Topology and schedule of the bus path

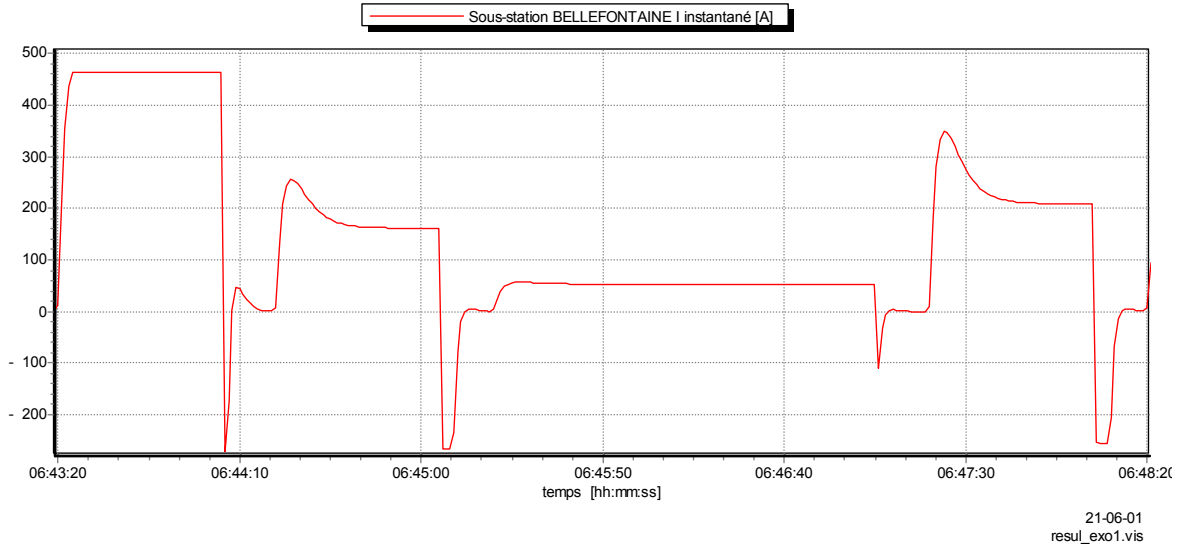


Figure 3.7 Current supplied to the bus

3.4. Voltage support on line-ending

This application has shown the use of the program in the study of a novel approach to voltage support. In some supply sectors, when several vehicles start simultaneously, voltage at the end of the supply line may drop to a level about half as in a normal state. To correct this problem two of the possible solutions are either adding a new sub-station or implementing a local voltage support (batteries of capacitors, flywheel energy storage). The simulation program TlSim provided a helpful support in assessing the interest of the solution with capacitors.

4. Conclusion

The program TlSim has proved its usefulness through its use by the transportation authority of Lausanne (Switzerland), in the analysis of the operation as well as in the planification. At the Laboratory of Electrical Machines of the Swiss Federal Institute of Technology (LEME), it has been helpful in the study of new approaches to the voltage maintenance at the end of supply lines. Several developments are under consideration; among them the extension to tramway and subway networks.

5. References

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