

RailPower

PROGRAM FOR POWER STUDIES ON
ELECTRIFIED RAILWAY LINES



Ardanuy

To compete with other modes of transport, the different railway administrations must reduce the headway between trains and increase the service speed of the line. These aims are usually achieved either with new higher-performance rolling stock or increasing the number of trains in circulation. Both factors involve a greater power demand which is met by building new electrical traction substations or increasing the power output or number of transformers in the existing ones.

Likewise, in the construction of new lines appropriate planning of the position of the different elements comprising the electrification system can translate to significant savings both economically and environmentally, both increasingly important issues when evaluating the feasibility of a railway project.

The ideal location for electrical substations and the power needed in each one of them condition the minimum headway between trains which depend on a wide variety of factors (alignment characteristics, rolling stock employed, planned train circulation graph, availability of high voltage lines and terrain, environmental impact, etc.) as a result of which making decisions requires numerous calculations for different situations which are impossible to do manually while maintaining rigour.

To resolve this problem, Ardanuy Ingeniería, S.A. has developed – as part of its R&D investment program – a complete IT tool, the **RailPower** software package which allows for electrical sizing studies to be carried out on railway lines both in alternating current (1x25 kV and 2x25 kV) and direct current, based on a simulation of real operating conditions. The results obtained facilitate decisions regarding the proper electrification of the line: location and power of electrical substations, catenary characteristics, etc., contributing to the optimisation of costs and the determination of operating limits and anticipating the emergence of critical situations.

RailPower was developed in the Windows environment which improves its ease of use, presentation and management of the results. This circumstance and its modular composition ensure that the program is open to the studies and specific needs of any operation.

● Fields of Application

RailPower is designed to be applied both in railways and in undergrounds (metros) and trams, carrying out simulations in electrification systems using alternating current (1x25 y 2x25 kV) and direct current (with different rated voltages). On railway lines it can be used with high speed trains (HSL), long-distance trains (160 km/h lines, freight), suburban rail lines, etc.. The program allows for sections with several tracks and single track sections to be processed. Likewise, it is specially programmed to study mixed circulation of trains with different composition types, locomotives, power cars and towed stock.

● Studies Derived from the Use of RailPower

The results obtained via **RailPower** are used mainly to decide the location and installed power of the substations on a new section or on a section in service for which operating conditions might change. It also allows for the proper sizing of the catenary, third rail and the backup feeders. Additionally, **RailPower** can deal with other line operation studies:

- Line times, speed and acceleration profiles, power consumed, for each type of train or gear ratio throughout the line.
- Maximum frequency of train passage.
- Timetable optimisation.
- Ideal location of the two way track switching posts.
- Percentage of power recovery on employment of trains with brake regeneration.
- Catenary power losses.
- Ideal connection of substations to the catenary: cantilever and pi circuit substations, independent track feed or parallel drives.

● Factors taken into account by RailPower

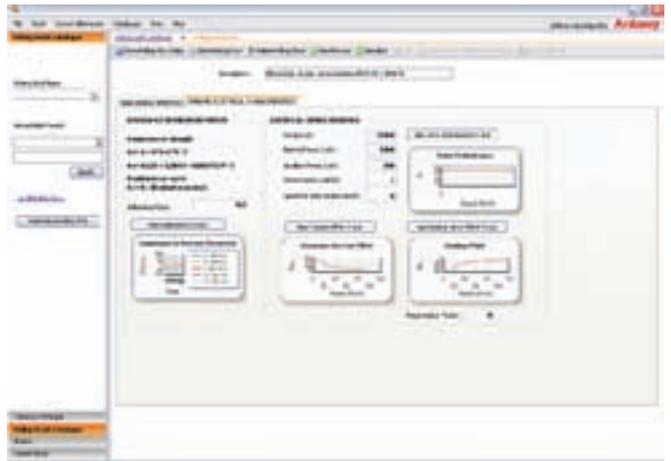
RailPower does a precise simulation of the real operating conditions bearing in mind the characteristics of the rolling stock, the parameters of the alignment (slopes, curvature radii, cants, stations and halts, tunnels, etc.), train circulation graphs, limits set via signalling and the catenary employed.

Rolling Stock

The program allows for any type of train to be defined and used. For this purpose it is necessary to specify the characteristics of the locomotive, cars or wagons, power cars and the trainset as a whole. Among the data to be entered are the weight, traction system (DC and AC type asynchronous or synchronous motors). The characteristic curves of motor car and the trainset as a whole can be entered directly or derived from the main parameters. The main parameters are:

- Drag / speed curve
- Full tractive effort / speed
- Full braking effort / speed
- Electrical – mechanical performance of the engines

On the basis of these curves the maximum accelerations and decelerations for different conditions and the tractive and braking effort intensities are calculated.



Alignment Characteristics

The alignment is defined on the basis of the following parameters: slope, curvature and cant radii, station positions, speed limit, tunnel zones, single track or double track sections, etc.. These data can be entered manually or read automatically from a spreadsheet.

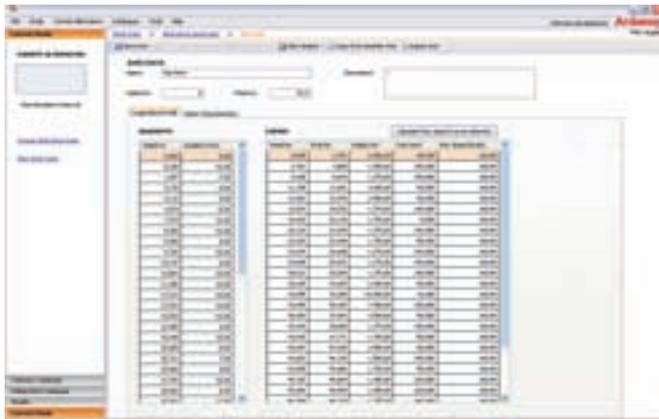
From these data, **RailPower** will divide the alignment into homogenous sections characterised by having the same value in each one of the aforementioned parameters (slope, curvature,

existence of station, etc.). The length of each section can be a range from some tens of metres to several kilometres.

Operation Parameters

The operation parameters taken into account are: maximum acceleration and deceleration, minimum safety distance between trains, station dwell time, maximum frequency between trains, etc..

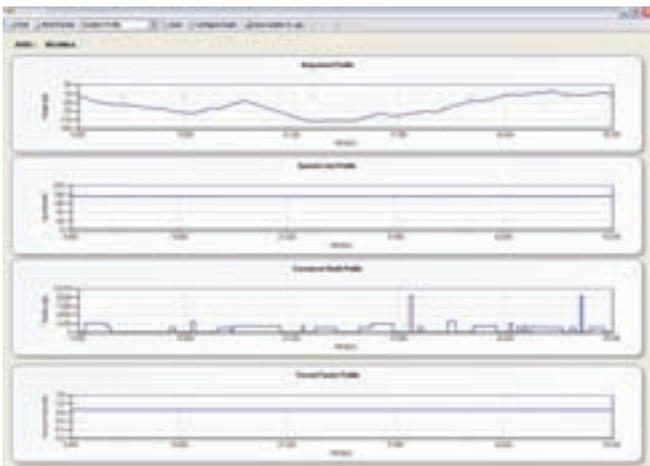
RailPower simulates the circulation of trains ensuring these requirements are met at all times. Particularly, the program verifies the distance between trains is greater than the safety distance, forcing the preceding train to brake if necessary. If the leading train has less right of way, the program allows for overtaking at the first station where possible.



Parameters of the Electrification System

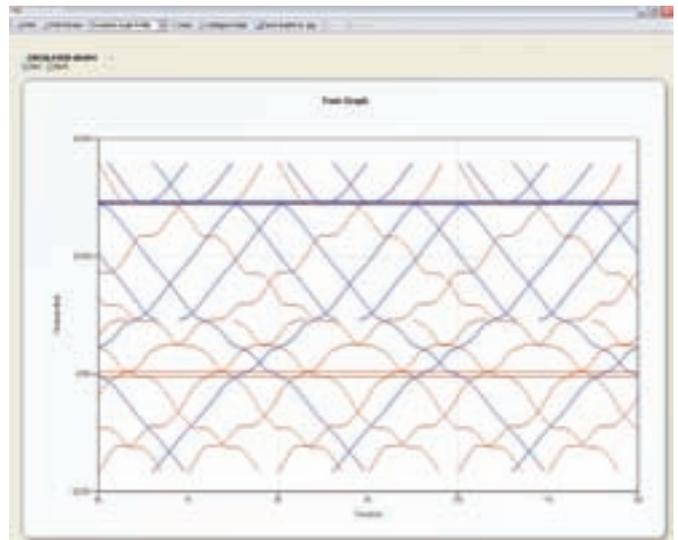
Studies can be carried out both in direct current with different levels of feed voltage (600Vdc, 750Vdc, 1500Vdc, 3000Vdc) and in alternating current (1x25 kV and 2x25 kV).

The definition of different types of electrification throughout the same alignment is allowed (conventional catenary, rigid catenary, third rail, etc.), introducing the parameters of the conductors comprising the catenary system and their geometric distribution on the line. On the basis of these data the program calculates the equivalent impedance of the whole system.



Train Circulation Graphs

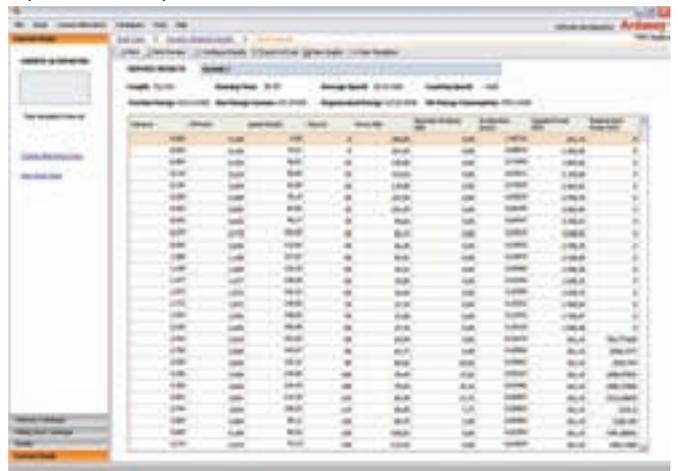
RailPower allows for the definition of as many train circulation graphs as needed. The graphs to be studied are introduced establishing the passing sequence of the trains during the desired interval. For each train the moment in which the journey begins is specified, the initial speed, right of way with regards to the rest of the trains, stations and halts in which each train must stop and the dwell time in each of them.



● Methodology and Calculation

RailPower carries out calculations based on a real simulation of operating conditions on the basis of the aforementioned parameters. To carry out the calculations a time is digitalised in intervals defined by the user. For each moment of time the values of the different variables to be calculated are obtained, bearing in mind the results of the preceding moment of time. This allows the user to obtain the results with the precision required for each study.

The program is executed sequentially, following the modules in which it was developed. In this way the output of a module is used as input for subsequent modules.



Dynamic Simulation Module

Once the characteristics of the rolling stock or of the alignment under study are entered, the program calculates the top speed that each train can have at each point on the line to meet the speed limits established for each section.

Isolated circulation is calculated by the line of each one of the trains: the train accelerates, brakes, coasts, stops at stations, etc.. The calculations obtained through this simulation allows for a first approximation of the circulation times and speed profiles for a train as well as the line capacity and the powers needed for this composition.

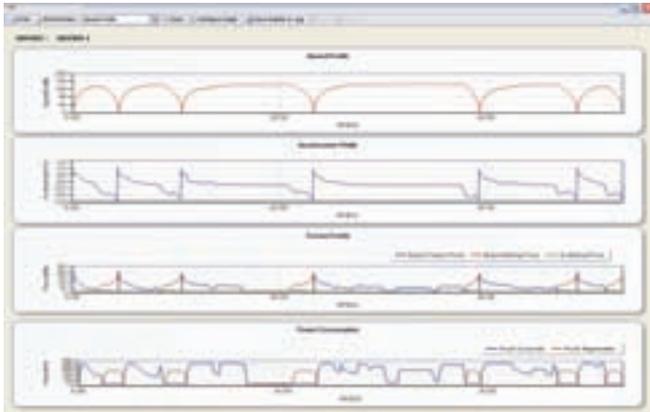
Simulation of the Train Circulation Graph

Once the train circulation graph is chosen a simulation is done of the combined running of all of the trains, resolving (through braking and overtaking) excessive closeness between trains. As a result, the power consumed by each train at each moment and point in the line as well

as the train speed are obtained. The maximum and average consumption for each track area and in the complete section under study.

Electrical Simulation Module

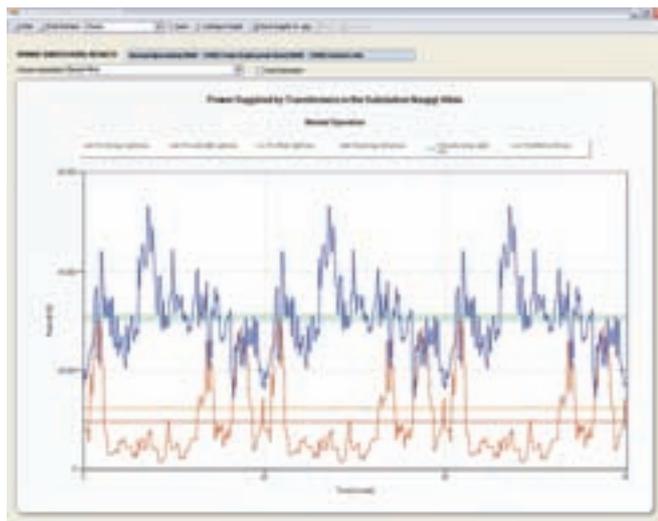
On the basis of the catenary data on the location of the elements comprising the electrical schematic (substations, auto-transformers, sectionings and neutral zones, parallel drives, etc.) of the position of the trains and the power demanded by them at each moment the program resolves the electrical circuit in each sector through iterations. As a result the outgoing current of each substation and the voltage and current running through each train will be obtained.



The power of each substation is obtained from the aforementioned results. On the basis of the instantaneous values the average and maximum power required in the interval in question is calculated.

Thus, the pantograph voltages of each train at each point of the line can be obtained. In this way, the maximum and minimum voltage drops throughout the line are seen, which allows for verification of whether the chosen location for the electrical substations is appropriate.

The program allows for calculations to be made taking into account or discarding power regeneration on braking. With these results, the lowest needed power levels for that circulation graph are revealed. These same calculations carried out for other operating conditions allow for ideal placement to be determined as well as the required substation power levels.



Results Generated by the Program

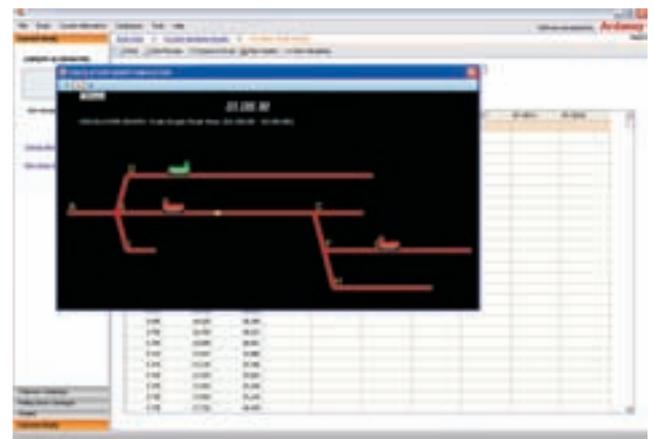
The results of all of the calculations can be observed on screen (or printed) in the form of tables or colour graphs for their interpretation and analysis. The program provides instantaneous and global values for the factors affecting the decisions. From among the results obtained the following are of particular note:

- Instantaneous and average power of the transformers in each electrical traction substation for the different distributions and train circulation graphs under study.
- Pantograph voltage of the trains in circulation at each moment and position.
- Substation power and pantograph voltage of the trains in the event of failure of a substation or transformer.
- Recovery of energy through braking regeneration.
- Disipated electrical power in the catenary and in the rails.
- Full and partial line times, speed and acceleration, tractive effort and consumed power at each point on the line for the different trains under study.
- Power balance (consumed by traction, by auxiliary services, regenerated and net) in the travel along the line for each type of simulated train.
- Position and consumption at each moment of the trains on the circulation graph.
- Intensity of the substation feeders.

Analysis of the results

In the definitive selection of the substation locations numerous factors come together which must be considered: availability of terrains or space, proximity to high voltage lines and power availability on the part of electrical companies, environmental impact, etc. For this reason it is necessary to test different electrical substation distributions throughout the line.

In summary, this is a valuable tool for making decisions in electrification installation projects (electrical substations and catenary to install) which can never replace an evaluation and analysis by qualified personnel.



RailPower software has been used to carry out over 100 electrification projects for diverse Railway Administrations (Ministry of Public Works, ADIF, FEVE, Andalusian Government Railways,

EuskoTren, TMB, GISA, FGC, SFM, Tenerife Metro) and in different countries (India, Vietnam, Morocco, Algeria, South Africa, Ireland, Portugal, Bulgaria, Lithuania, Chile, etc.) executed by both Ardanuy Ingeniería S.A. and other companies in the field.

The results obtained with the program have been successfully contrasted on various occasions, such as on Delhi Metro Rail Corporation Line I.

