

# **CECAT® Software**

## **Electrical Overhead Catenary Calculation**

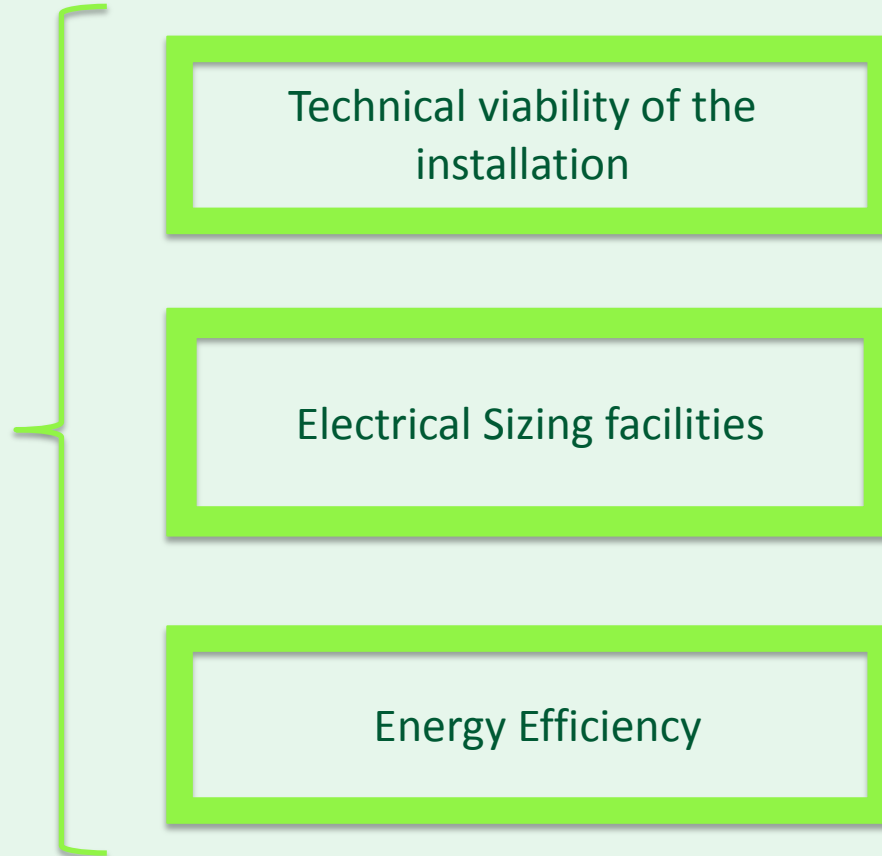


ELECTRIFICACION y  
ESTUDIOS  
FERROVIARIOS



CECAT® is a software designed and made by e2f for making studies of Railway Electrical Facilities Sizing in direct current ( 750V, 1500V, 3000V) and in alternating current ( 1x25kV y 2x25kV).

	<b>CECAT®</b> 
	<b>CÁLCULO ELÉCTRICO DE DIMENSIONAMIENTO DE CATENARIAS EN CORRIENTE CONTINUA Y CORRIENTE ALTERNA.</b>



## Electrical Sizing. Methodology

**1. RAILROAD TRACKPATH  
DESCRIPTION**

**2. TRAIN ROLLING STOCK  
INTRODUCTION**

**3. CONFIGURATION OF THE TRAINS  
TRAFFIC NETWORK**

**4. ELECTRICAL FEATURES DEFINITION**

**Plan Operation  
Analysis**

Normal situation\*

Degraded situation

\*Analysis of plant operation without regeneration and with regeneration.

## Inputs/ Results

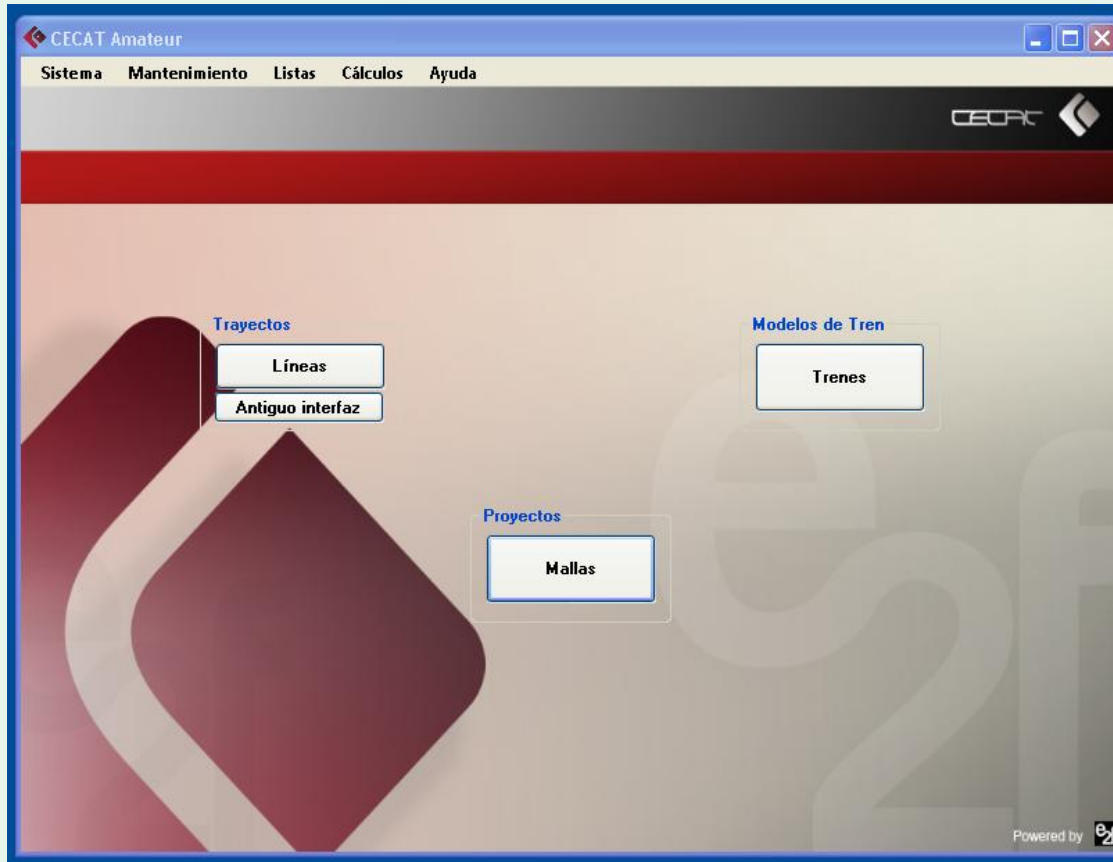
### Inputs:

- Profile and line layout
- Curves, slopes and cambers.
- Maximum speeds and limitations.
- Overhead contact line composition
- Features of return circuit
- Location and composition substations
- Train features
- Train traffic
- Other features

### Results:

- Pantograph voltage of each of the trains
- Power in Substations
- Shorts calculations
- Conductors intensity
- Conductors weather
- Regenerative energy
- Efficiency energy at installing

## Input Data



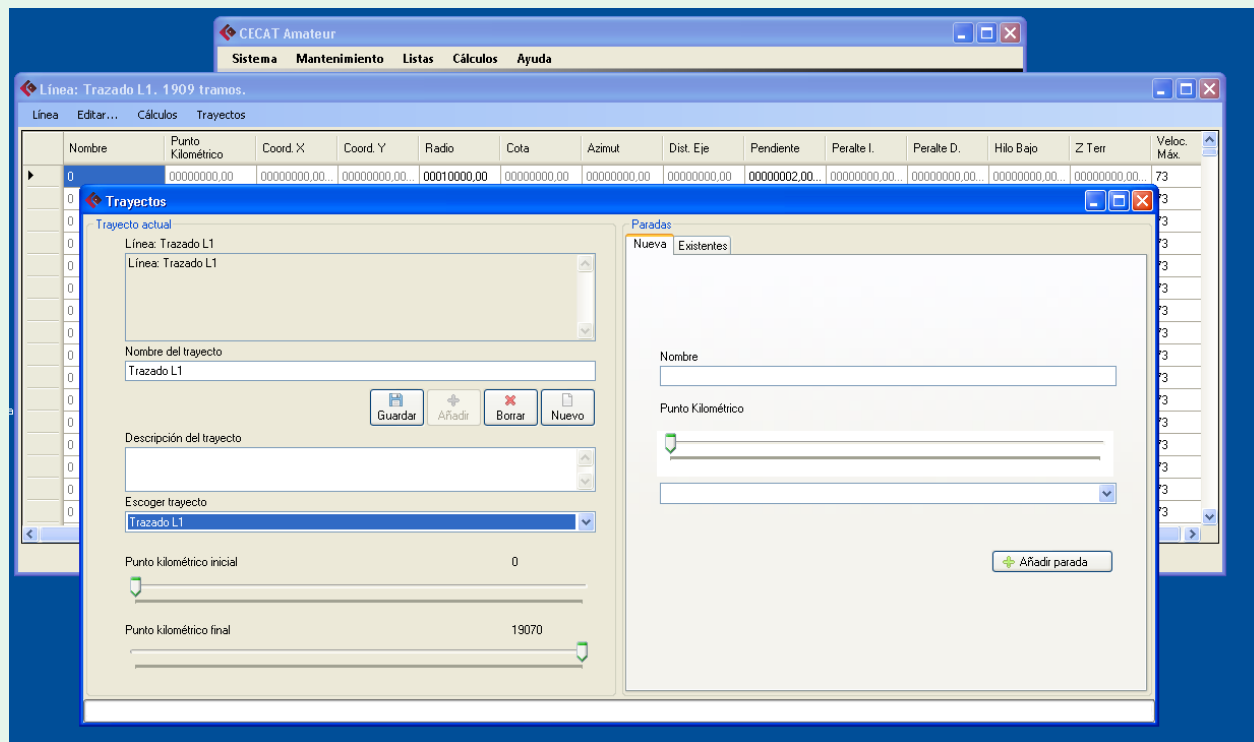
CECAT® is divided in three modules :

- Railroad trackpath
- Train models
- Projects / Networks

## Modules: Trackpath

The path can be defined with the following parameters:

- Kilometric point
- Coordinates x and y
- Curvature radius
- Elevation
- Azimuth
- Wheel base
- Slope
- Camber
- Maximum speed



This module allows creating different paths indicating the start and the end. It can be also defined the particular stations.

## Module: Train models

Each train model is defined with the following characteristics:

- Weight, power
- Specific aerodynamic coefficients
- Acceleration/Deceleration
- Maximum uncompensated acceleration
- Friction coefficient
- Stress curves
- Braking curves
- Potency from rheostat
- Regenerative braking potency
- Electrical braking speed

The screenshot displays the 'Trenes' software interface. The main window is titled 'Indefomable' and contains various configuration parameters for a train model. The parameters are organized into several sections:

- Masa total:** 202.0 t
- Velocidad:** 0 km/h
- Fuerza resistente:** 140.33 daN
- Valores de resistencia al avance. Coeficientes específicos:**
  - A: 1.100000000000 daN/t
  - B: 0.010000000000 daN/(km/h)
  - C: 0.000180000000 daN/(km/h)<sup>2</sup>
- Valores absolutos:**
  - 140.3325 daN
  - 1.27575 daN/(km/h)
  - 0.0229635 daN/(km/h)<sup>2</sup>
- Potencia:** 1320 kW
- Consumo Aux.:** 150 kW
- Longitud:** 90 m
- Rendimiento del Tren:** 1.000
- Interoperable:**
- Coef. de Adherencia:** 0.250
- Potencia Reóstato:** 750 kW
- Coef. de almacenamiento:** 1.000000 m/s<sup>2</sup>
- Deceleración:** 1.000000 m/s<sup>2</sup>
- Acel. máx. no compensada:** 0.650000 m/s<sup>2</sup>
- Masa de la carga:** 74 t
- Potencia Frenado Regenerativo:** 1500 kW
- Masa giratorias:** 5.0 %
- Masa en vacío:** 122 t
- Velocidad Fren. Elect.:** 5 km/h
- Cap. de almacenamiento:** 0.000 kWh
- Coseno φ:** 1.000

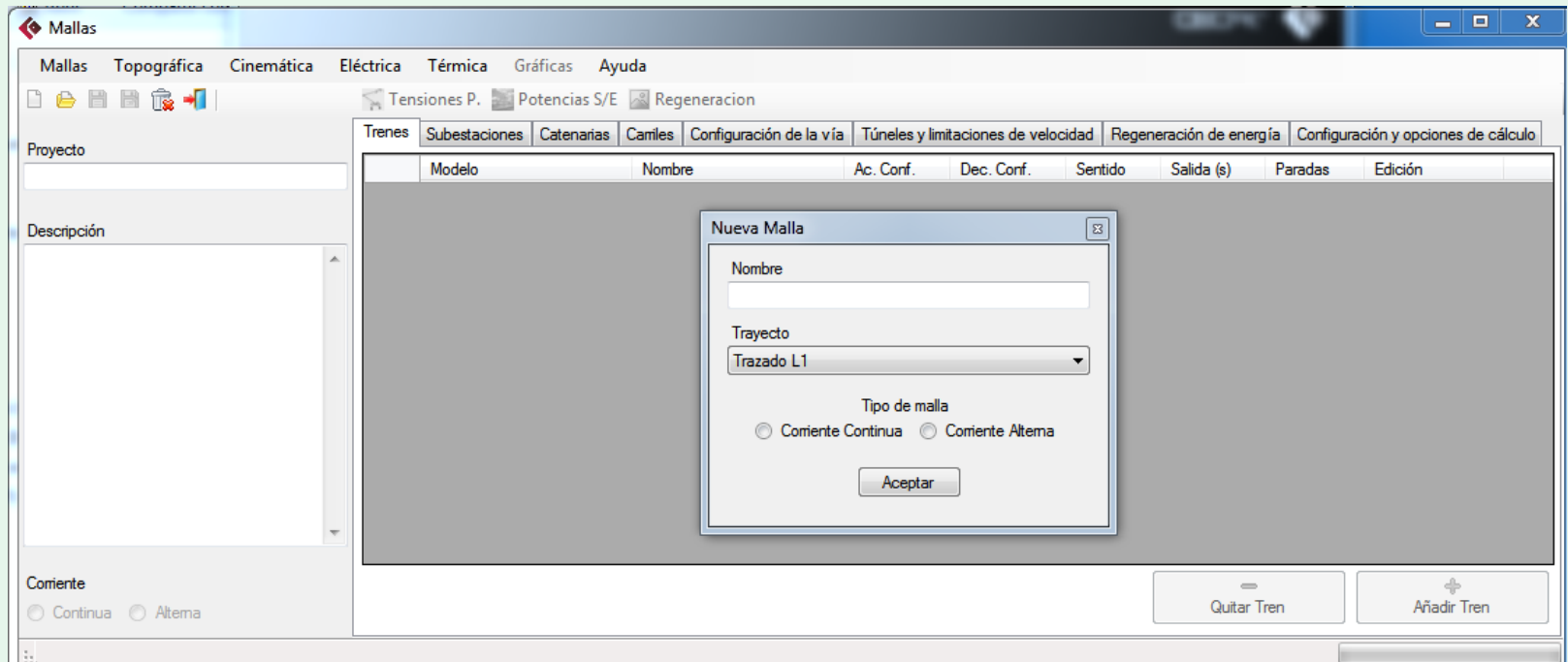
Below the main configuration window, there is a 'Curva de tracción' window showing a graph of 'U/T Metrorrey 3 V esfuerzo'. The graph plots 'Esfuerzo (kN)' on the y-axis (0 to 250) against 'Velocidad (km/h)' on the x-axis (0 to 90). The curve shows a constant effort of 201.3 kN from 0 to 30 km/h, followed by a decreasing effort as speed increases, reaching 61.11 kN at 70 km/h. A table below the graph provides the data points:

Velocidad (km/h)	Fuerza (kN)
0	201.3
30	201.3
35	173.7
40	153.12
45	136.68
50	123.21
55	99.78
60	83.25
65	70.74
70	61.11



## Module: Projects

When a new project is started, it must be defined if the installation is **direct current** (750 V, 1500 V y 3500 V) or **alternating current** (1x25 kV o 2x25 kV)



## Module: Projects

To define the project is necessary introduce:

- Trains
- Substations
- Autotransformer center\*
- Overhead contact line
- Rail configuration
- Tunnels and speed limits
- Railroad

\*Only for 2x25 kV AC system

The screenshot shows the 'Mallas' window in the CECAT Amateur software. The window title is 'Mallas' and it has a menu bar with 'Mallas' and 'Gráficas'. Below the menu bar is a toolbar with icons for file operations. The main area is a table with columns: 'Modelo', 'Nombre', 'Ac. Conf.', 'Dec. Conf.', 'Sentido', 'Salida (s)', 'Paradas', and 'Edición'. The table contains 11 rows of data for 'U/T Monterrey 3V' trains, with various configurations and directions. At the bottom of the window, there are buttons for 'Quitar Tren' and 'Añadir Tren', and a status bar indicating '5 min cargado correctamente'.

Modelo	Nombre	Ac. Conf.	Dec. Conf.	Sentido	Salida (s)	Paradas	Edición
U/T Monterrey 3V	U/T Monterrey 3V vuelta	0.575	0.5	Vuelta	0	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V ida	0.879	0.5	Ida	2390	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a	0.575	0.5	Vuelta	300	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a a	0.575	0.5	Vuelta	600	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a b	0.575	0.5	Vuelta	900	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a c	0.575	0.5	Vuelta	1200	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a d	0.575	0.5	Vuelta	1500	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a e	0.575	0.5	Vuelta	1800	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a f	0.575	0.5	Vuelta	2100	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a g	0.575	0.5	Vuelta	2400	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a h	0.575	0.5	Vuelta	2700	19	Editar
U/T Monterrey 3V	U/T Monterrey 3V vuelta a i	0.575	0.5	Vuelta	3000	19	Editar

Blocks

Trenes Subestaciones Catenarias Camiles Configuración de la vía Túneles y limitaciones de velocidad

# Section: Trains

The introduction of trains in the models will be performed:

- Name of project
- Model train selection
- Running direction
- Comfort acceleration/deceleration
- Stops
- Time-out and stop

**Tren Proyecto**

Descripción: Media distancia S-449 i1, Tiempo de Salida: 900 s

Modelo: Media distancia S-449

Descripción del modelo: [Empty field]

Parámetros de confort y aceleración:

- Sentido:  Ida  Vuelta
- Accl. de confort: 0.600 m/s<sup>2</sup>, Decel. de confort: 0.600 m/s<sup>2</sup>
- Interoperable:
- Longitud: 99 m, Eficiencia: 1.000, Vel. Máx.: 160 Km/H
- Peso Carga: 200.6t, Peso Vicio: 172t, Carga por eje: 1t
- Resistencia al avance:  $M = [1.17 + 0.00329 \cdot V] + (0.000462 \cdot V^3)$
- Coficiente de Adherencia: 0.25
- Energía regenerativa: Rendimiento sistema: 0, Capacidad batería: 0, Resistencia de control: 0, Capacidad condensador: 0

Datos Peralte:

- Uglet o Soplolese: -26 mm
- Insuficiencia de Peralte: 115 mm

Gráficas: Gráfica de Esfuerzo Tracción, Gráfica de Esfuerzo Frenado

Parada	Tiempo de Parada (s)	Origen	Destino
EST.1	1	<input checked="" type="checkbox"/>	<input type="checkbox"/>
EST.2	45	<input type="checkbox"/>	<input type="checkbox"/>
EST.3	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.4	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.5	45	<input type="checkbox"/>	<input type="checkbox"/>
EST.6	45	<input type="checkbox"/>	<input type="checkbox"/>
EST.7	45	<input type="checkbox"/>	<input type="checkbox"/>
EST.8	1	<input type="checkbox"/>	<input checked="" type="checkbox"/>

Aplicar: 0 segundos a todas las paradas.

**Añadir Tren Proyecto**

Modelo: Alvia S-130, Nombre del Tren: Alvia S-130

Salida: 0 segundos

Paradas:

Parada	Tiempo de Parada (s)	Origen	Destino
EST.1	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.2	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.3	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.4	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.5	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.6	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.7	0	<input type="checkbox"/>	<input type="checkbox"/>
EST.8	0	<input type="checkbox"/>	<input type="checkbox"/>

Aplicar: 0 segundos a todas las paradas.

**Mallas**

Tensiones P., Potencias S/E, Regeneración

Trenes	Subestaciones	Catenarias	Carries	Configuración de la vía	Túneles y limitaciones de velocidad	Regeneración de energía	Configuración y opciones de cálculo
Media distancia S-449	Media distancia S-449 i1	0.6	0.6	Ida	900	6	Editar
Media distancia S-449	Media distancia S-449 i2	0.6	0.6	Ida	4500	7	Editar
Media distancia S-449	Media distancia S-449 i3	0.6	0.6	Ida	7920	5	Editar
Media distancia S-449	Media distancia S-449 v1	0.6	0.6	Vuelta	0	5	Editar
Media distancia S-449	Media distancia S-449 v3	0.6	0.6	Vuelta	5640	7	Editar
Alvia S-130	Alvia S-130 ida 2	0.6	0.6	Ida	5880	3	Editar
Alvia S-130	Alvia S-130 vuelta 1	0.6	0.6	Vuelta	10200	3	Editar
Media distancia S-449	Media distancia S-449 v2	0.6	0.6	Vuelta	2040	6	Editar
Alvia S-130	Alvia S-130 ida 1	0.6	0.6	Ida	9000	3	Editar
Alvia S-130	Alvia S-130 vuelta 2	0.6	0.6	Vuelta	1800	3	Editar

Botones: Quitar Tren, Añadir Tren

## Section: Substations in DC projects

The substations will be defined according to the following parameters:

- Kilometer point
- Normal operation or out of service
- Reference voltage\*
- Internal impedance
- Earth resistance
- Lead feeders
- Losses at the transformer

Trenes	Subestaciones	Catenarias	Cariles	Configuración de la vía	Túneles y limitaciones de velocidad	Regeneración de energía	Configuración y opciones de cálculo	
	Nombre	Punto Kilométrico	Funcionamiento	Voltaje	Impedancia Interna	Resistencia Tierra	Pérdidas en Vacío	Feeders de Alimentación
	SER F1	-1000	Normal	1500	1000	0.8	0	
	SER Exposición	380	Normal	1500	0,086898	0,8	5	
	SER Y Griega	3460	Normal	1500	0,080638	0,8	5	
	SER Cuauhtemoc	7290	Normal	1500	0,078338	0,8	5	
	SER Mitras	11660	Normal	1500	0,075748	0,8	5	
	SER Aztlan	15140	Normal	1500	0,076238	0,8	5	
	SER Talleres	18980	Normal	1500	0,081668	0,8	5	
	SER F2	20070	Normal	1500	1000	0.8	0	

min cargado correctamente 20

\* The reference voltage in the substations can be defined with different values from the nominal values

**Feeders**

Par Derecha | Par Izquierda | Impar Derecha | Impar Izquierda

Resistencia:  Ω

Sección:  mm<sup>2</sup>

Número de hilos:

Longitud (m):  m

Material:

Aluminio

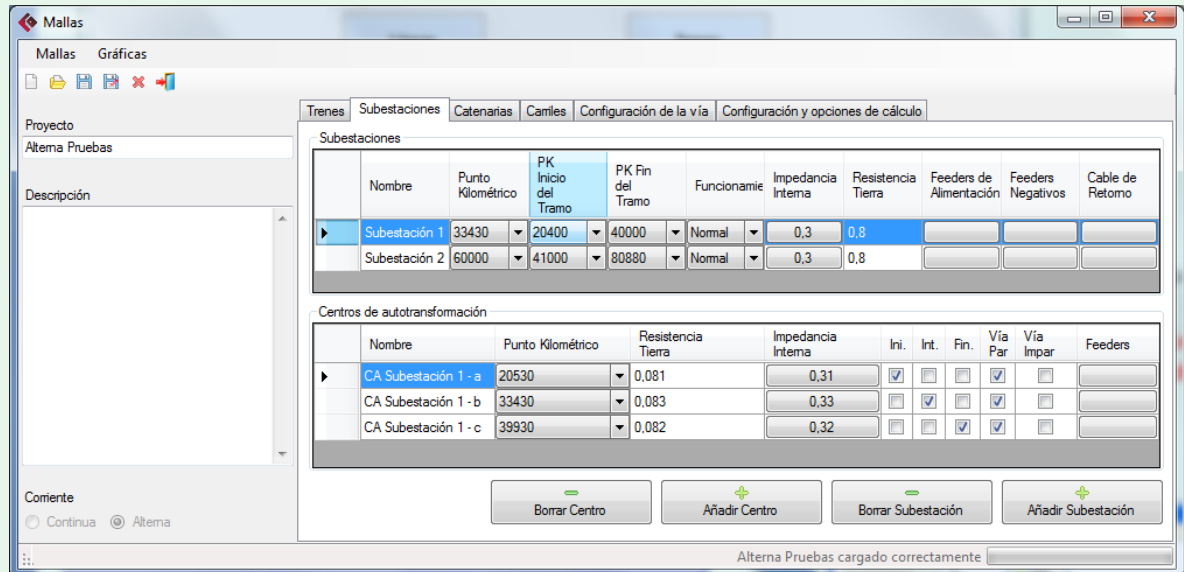
Cobre

## Section: Substations in AC projects

In AC projects is necessary to define substations but we also must specify the autotransformer centers, only for 2x25KV AC systems.

The autotransformer centers are defined by the following parameters:

- Name
- Kilometer point
- Internal impedance
- Lead Feeders



The screenshot shows the 'Mallas' software interface with the 'Subestaciones' tab selected. The 'Subestaciones' table lists two substations, and the 'Centros de autotransformación' table lists three autotransformer centers for Subestación 1.

Nombre	Punto Kilométrico	PK Inicio del Tramo	PK Fin del Tramo	Funcionamiento	Impedancia Interna	Resistencia Tierra	Feeders de Alimentación	Feeders Negativos	Cable de Retorno
Subestación 1	33430	20400	40000	Normal	0,3	0,8			
Subestación 2	60000	41000	80880	Normal	0,3	0,8			

Nombre	Punto Kilométrico	Resistencia Tierra	Impedancia Interna	Ini.	Int.	Fin.	Vía Par	Vía Impar	Feeders
CA Subestación 1 - a	20530	0,081	0,31	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
CA Subestación 1 - b	33430	0,083	0,33	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	
CA Subestación 1 - c	39930	0,082	0,32	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	

Buttons: Borrar Centro, Añadir Centro, Borrar Subestación, Añadir Subestación

Project: Alterna Pruebas

Comente:  Continua  Alterna

Status: Alterna Pruebas cargado correctamente

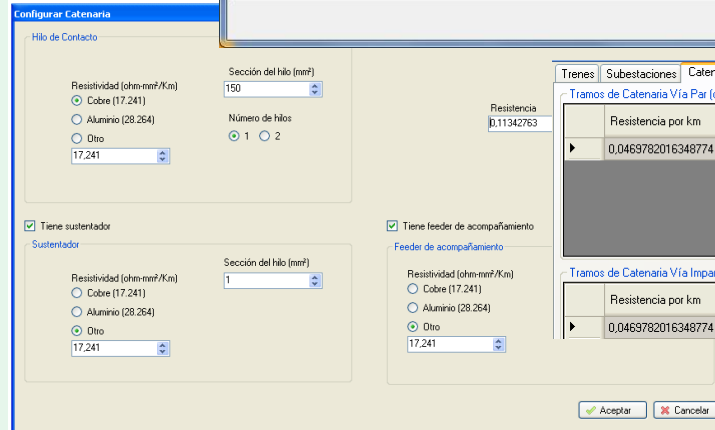
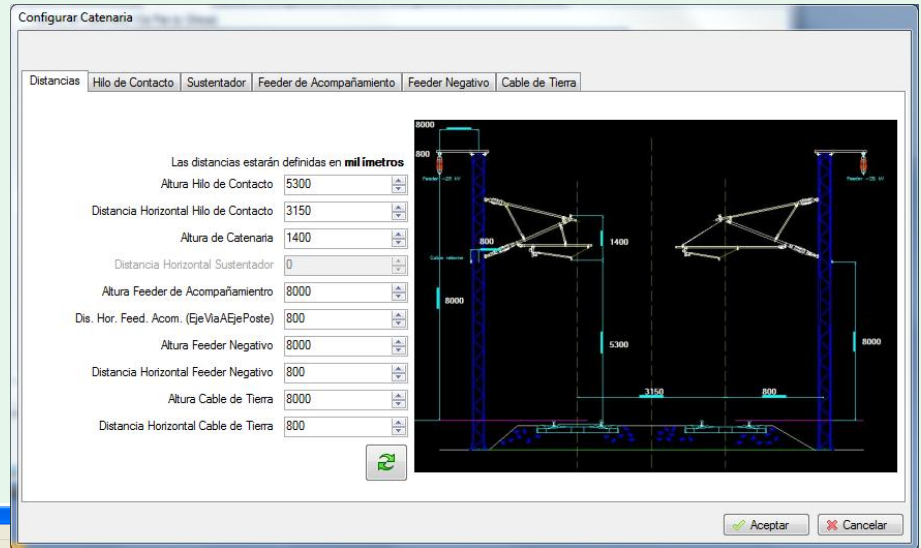
## Section: Overhead contact line

The catenary composition will be defined by the following parameters:

- Overhead contact line wire
- Messenger wire
- Reinforcement feeder \*
- Negative feeder \*\*
- Ground wire\*\*

\* DC only in direct current

\*\* 2x25kV AC alternating current only



Trenes | Subestaciones | Catenarias | Cariles | Tipo de vía | Configuración y opciones de cálculo

Tramos de Catenaria Vía Par (o Única)

Resistencia por km	P.K. Inicial	P.K. Final	Cálculo R.
0.0469782016348774	10	2000	

Tramos de Catenaria Vía Impar

Resistencia por km	P.K. Inicial	P.K. Final	Cálculo R.
0.0469782016348774	10	1500	

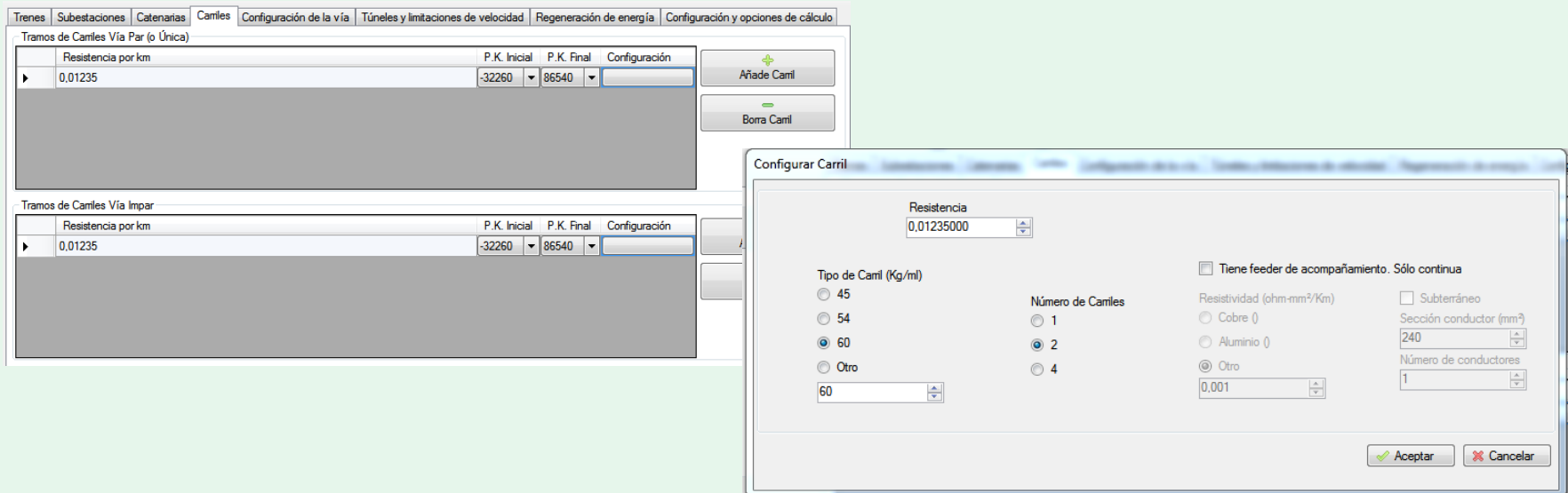
It's possible to simulate all kinds of overhead contact line: flexible, rigid y third rail

## Section: Rails

To calculate the resistance of the rails is necessary to know:

- Type of Rail
- Rail number

In the case of alternating current, a special section exists to recalculate the electrical impedance considering the geometric effects of grounding.



The screenshot shows the 'Configurar Carril' dialog box in a software application. The dialog box is titled 'Configurar Carril' and contains the following fields and options:

- Resistencia:** 0.01235000
- Tipo de Carril (Kg/ml):** 60 (selected)
- Número de Carriles:** 2 (selected)
- Resistividad (ohm-mm²/Km):** 0.001
- Sección conductor (mm²):** 240
- Número de conductores:** 1
- Tiene feeder de acompañamiento. Sólo continua
- Subterráneo

Buttons for 'Aceptar' and 'Cancelar' are visible at the bottom right of the dialog box.

## Section: Rail configuration

Trenes Subestaciones Catenarias Camiles Configuración de la vía Túneles y limitaciones de velocidad Regeneración de energía Configuración y opciones de cálculo

Tipos de vía

	P.K. Inicial	P.K. Final	Par	Impar	Tipo de vía
▶	-4000	1280	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Doble ▼
	1280	9495	<input checked="" type="checkbox"/>	<input type="checkbox"/>	Única ▼

## Section: Tunnels and speed limits



Trenes Subestaciones Catenarias Camiles Configuración de la vía Túneles y limitaciones de velocidad Regeneración de energía Configuración y opciones de cálculo

Túneles

	P.K. Inicial	P.K. Final	Vía
*			Ambas ▼

Limitaciones de velocidad

	P.K. Inicial	P.K. Final	Velocidad Máxima	Vía
▶	-32260	-320	200	Ambas ▼
	-320	200	140	Ambas ▼
	200	1720	160	Ambas ▼
	1720	86540	200	Ambas ▼
*				Ambas ▼

Aplicar  Recargar 



# Pantograph Voltage. With/Without regeneration

The screenshot displays the 'Cálculos en Corriente Continua A15' software interface, which is used for calculating continuous current in railway electrification systems. The interface is divided into several panels:

- Opciones gráficas:** Includes options for limiting tensions (7000 V), showing tensions (Ambas, Pantógrafo, Accesibles), and scale (Común, Propia). It also allows for not calculating regenerative power during deceleration and setting the title and background color.
- Curvas de Trenes:** A list of train segments with checkboxes for 'Tensión pantógrafo' and 'Tensión accesible'. The segments include media distancia S-449 (1, 2, 3) and Alvia S-130 (ida 2, vuelta 1).
- Opciones cálculos:** Includes options for smoothing velocity (30 s), calculating regenerative power, and sampling frequency (1 muestra = 1 s). It also has buttons for 'Generación de mallas de circulación' and 'Cálculos Cortocircuito'.
- Interoperabilidad:** A section for setting interoperability parameters, including nominal, minimum, and maximum tensions, auxiliary current, and maximum current. It also includes a 'Punto de acumulación de energía' section with fields for P.K., power, and energy.
- Cálculo:** A section for selecting a train (Media distancia S-449:1) and setting calculation parameters like Cos φ, Coef. Efic, and Intensidad Máx. (888.89 A). It also includes a 'Pestaña actual' dropdown and a 'Calcular' button.

# Substations voltage. With/Without regeneration

**Subestaciones**

Subestación	Instantáneo	Eficaz
Ficticia 1	60993D	176093
	7D1A62	CBFFD0
Dos Hermanas	F5DB70	10409E
Utrera	EA044C	A8A70E
	783939	E77ABF
Las Alcantarillas	E41026	55FCB9
Lebrija	C1F328	FF69B2
	432035	E3CC4F

**Feeders**

Feeder	Instantáneo	Eficaz
Ficticia 1 Izq.	6AA843	6AA837
Ficticia 1 Izq.	528246	6E8246
Ficticia 1 Der.	737A49	73B849
Ficticia 1 Der.	78732E	78BF2E
La Salud Izquierda	701D58	701D58
La Salud Derecha	901671	6A1671
La Salud Derecha	961F76	961F4E
La Salud Derecha	9C144A	5E207A

**Opciones de cálculo de potencias**

Calcular Potencia Regenerativa  
 Suavizar velocidad 30 s.

Iteraciones máximas: 5  
 Tiempo máximo: 250 ms  
 Ajuste del error: 1.000 %  
 Veloz  Intermedio  Óptimo (Lento)

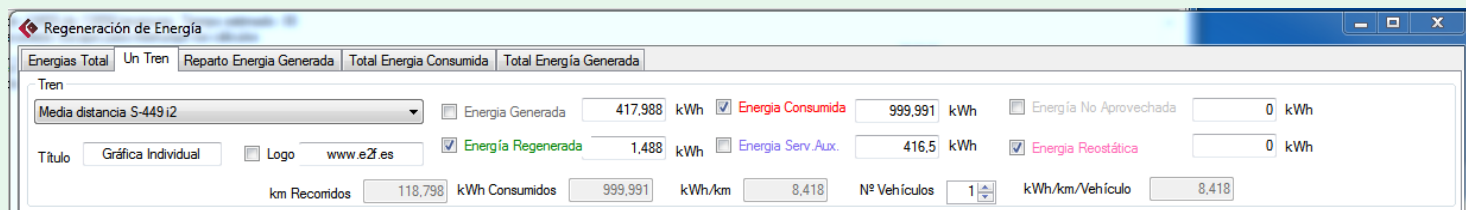
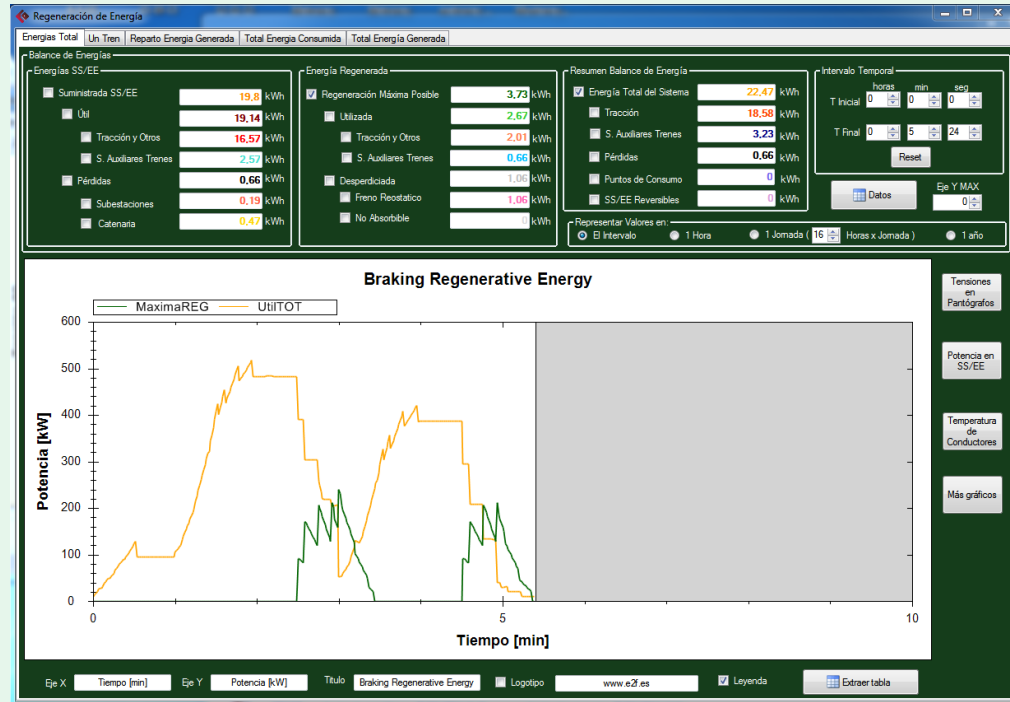
Potencias/Intensidades eficaces  
 Ventana de tiempo: 900 s.  
 00:15:00  
 Valores eficaces  
 Valores instantáneos  
 Cálculos previos a la ventana

Potencias y pérdidas SS/EE  
 T. Inicial: 0 Seg. T. Final: 0 Seg.  
 Intervalo: 1 Hora  
 Energía SS/EE: kWh  
 Pérdidas SS/EE: kWh

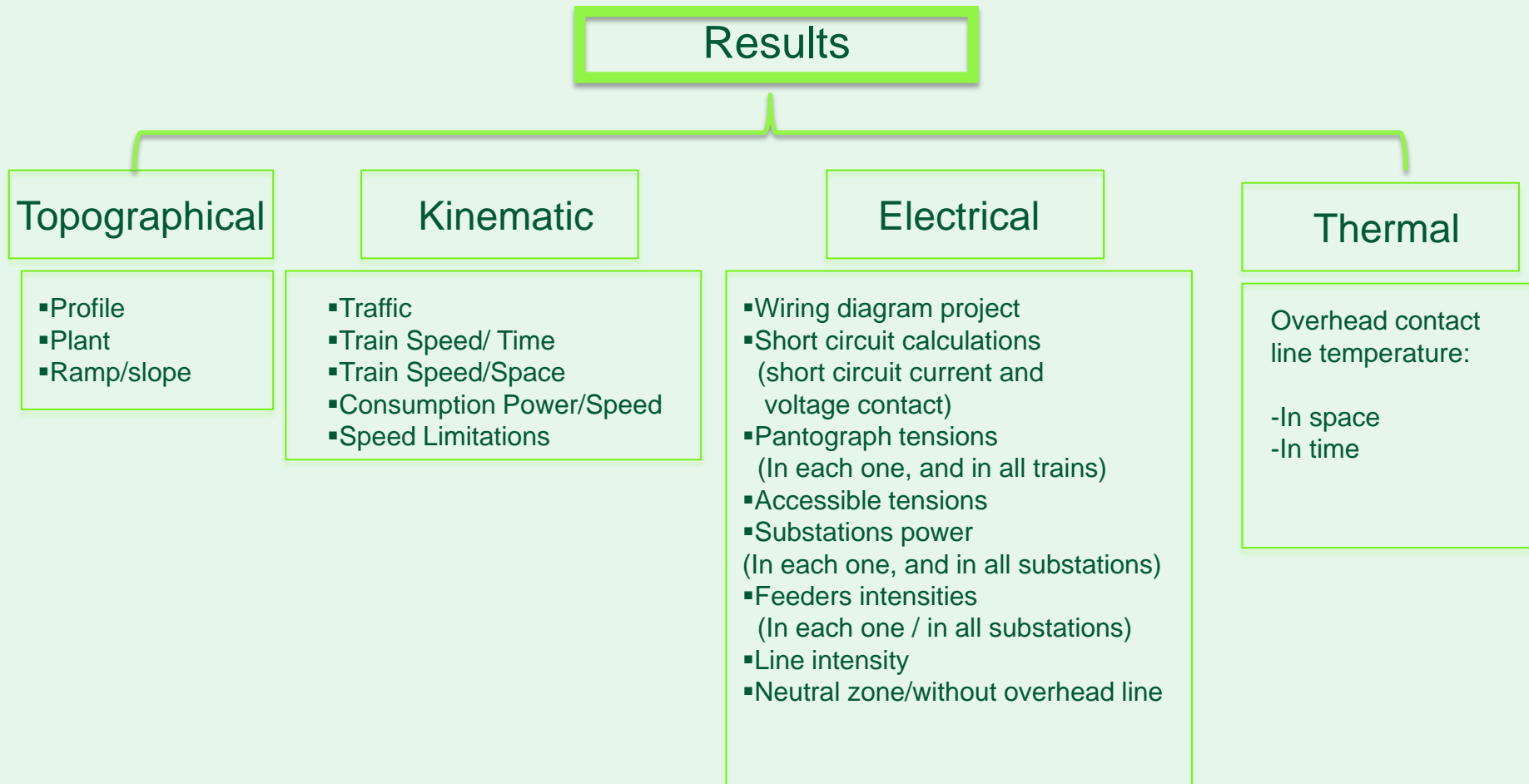
**Opciones de gráfica**

Reiniciar Colores  
 Mostrar suma de las potencias  
 Valores absolutos (módulo) para los feeders  
 Limitar valores en:  
 Subestaciones: 5000 KW  
 Feeders: 1000 A  
 Título: A15  
 Color del fondo  
 Tamaño de las fuentes: 8  
 Legenda  Logotipo  Título  
 Texto logotipo: www.e2f.es  
 Eje X: Tiempo en m Eje Y: Potencia (kW)  
 Intensidad (A)

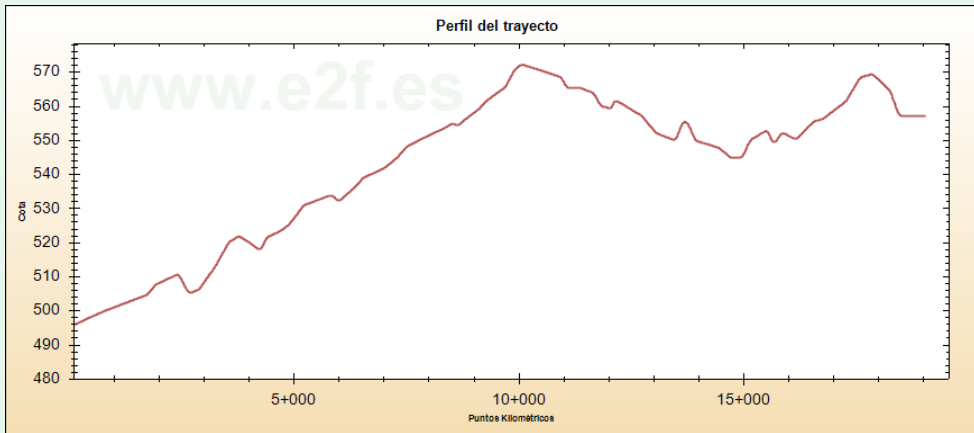
# Energy balance from facilities. With/without regeneration



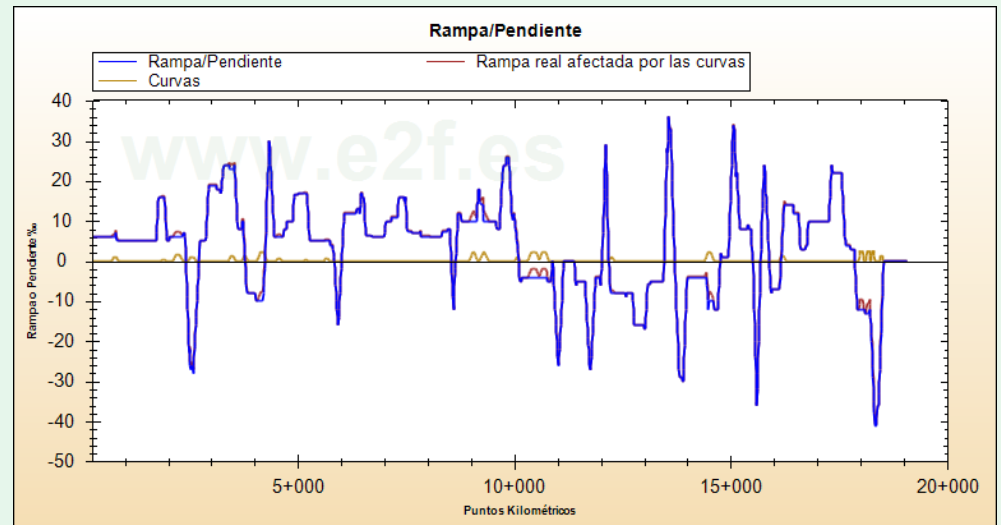
## Obtained results by CECAT®



# Topographic results

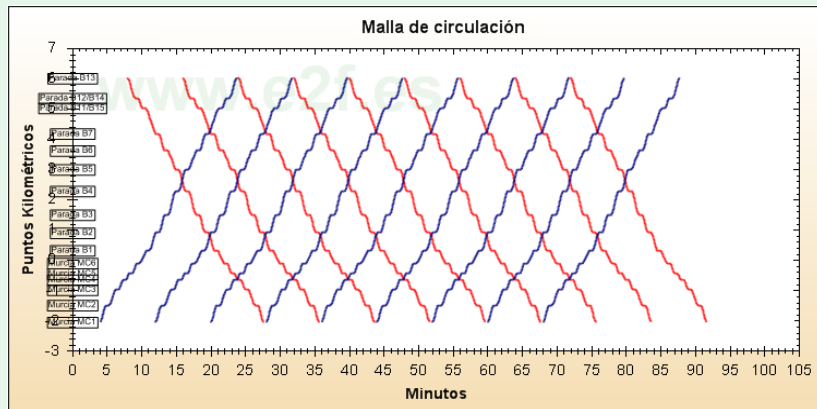


Path profile

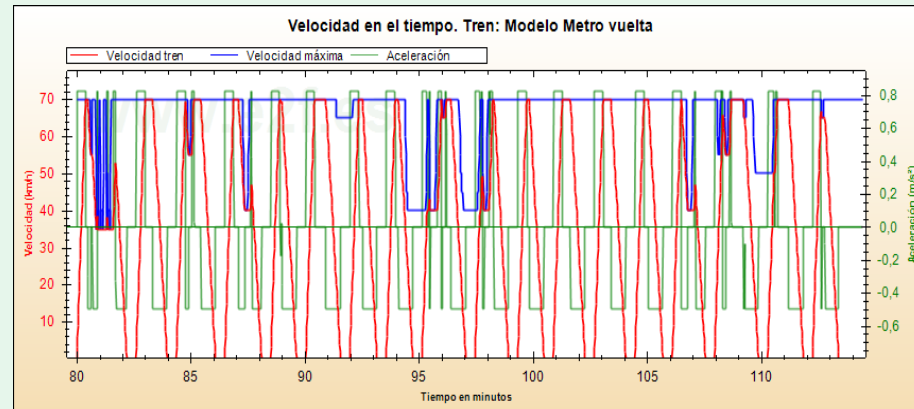


Slope/ curves

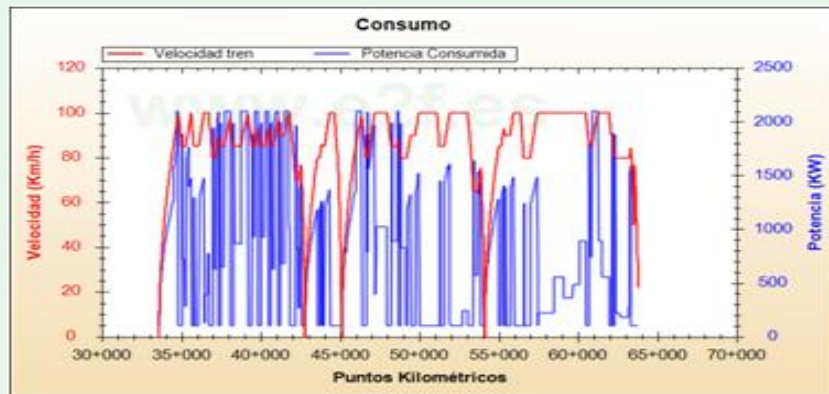
# Kinematic results



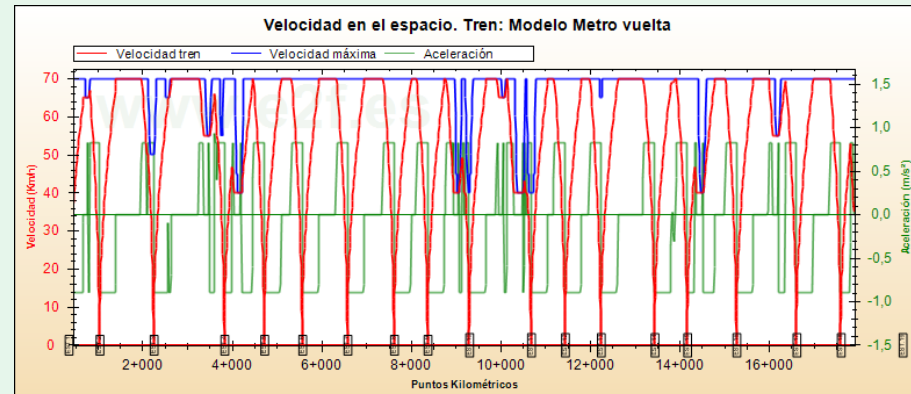
Trains traffic network



Train speed vs time

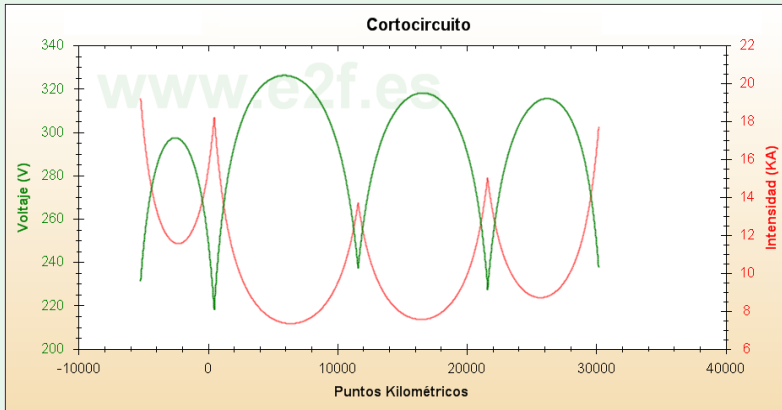


Train consumption

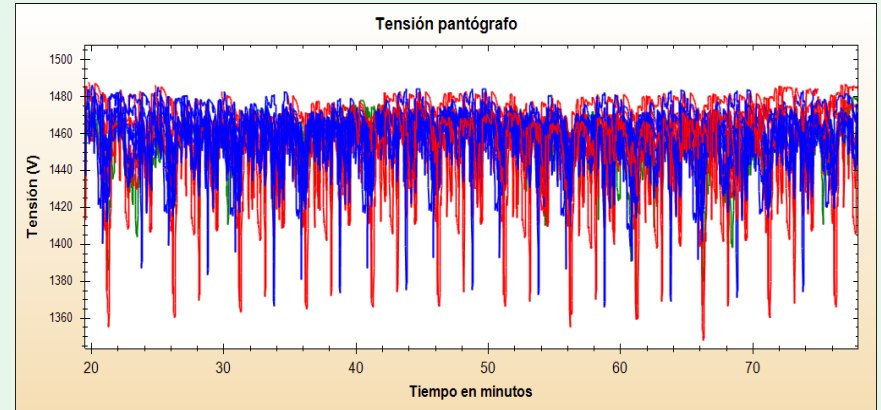


Train speed vs space

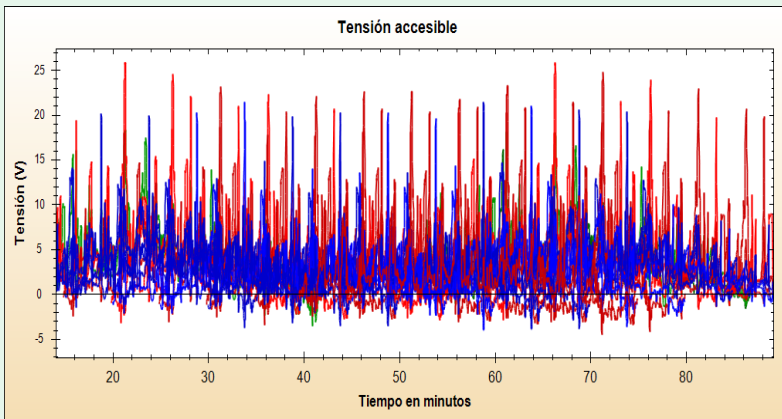
# Electrical results



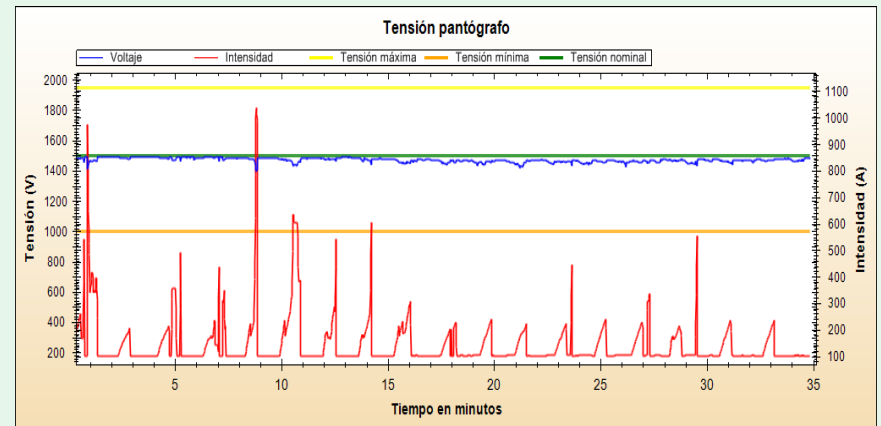
Short circuit



All trains pantograph voltage

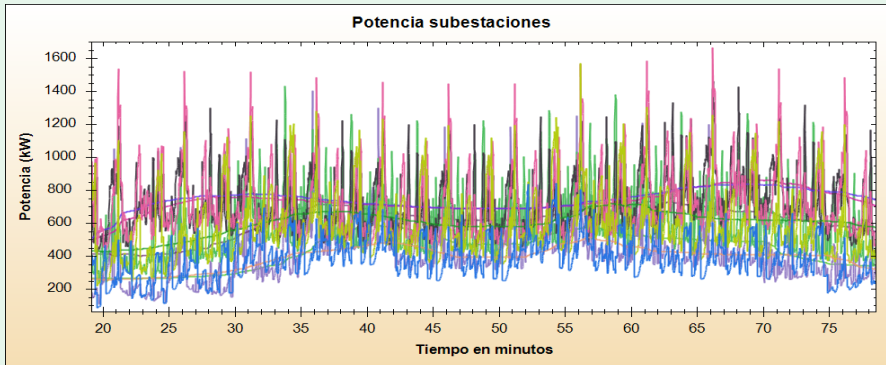


Rail voltage with respect to ground

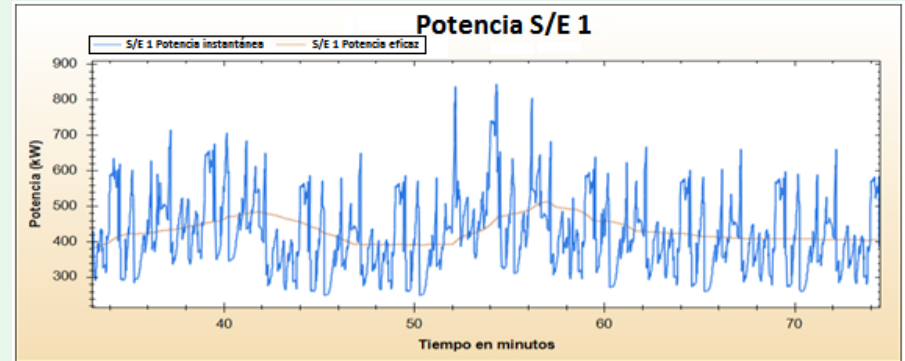


One train pantograph voltage

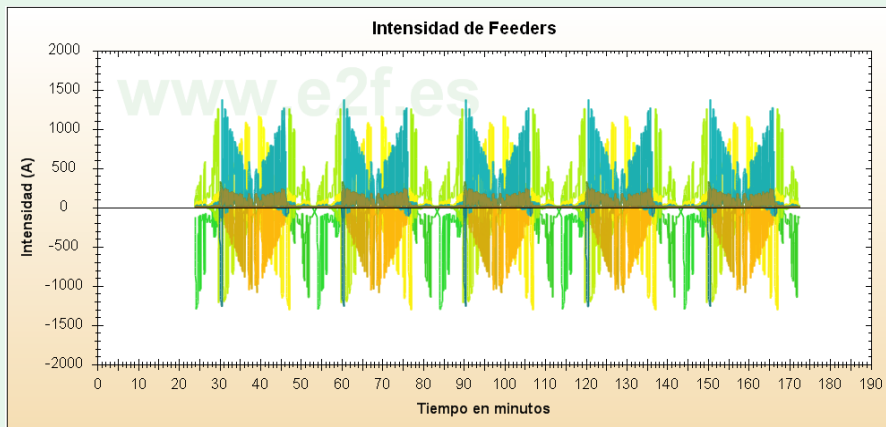
# Electrical results



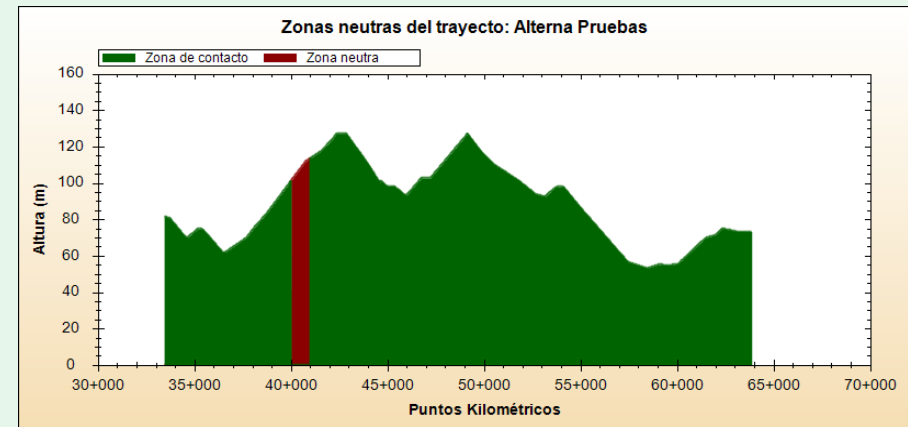
All rectifier stations power



One rectifier stations power



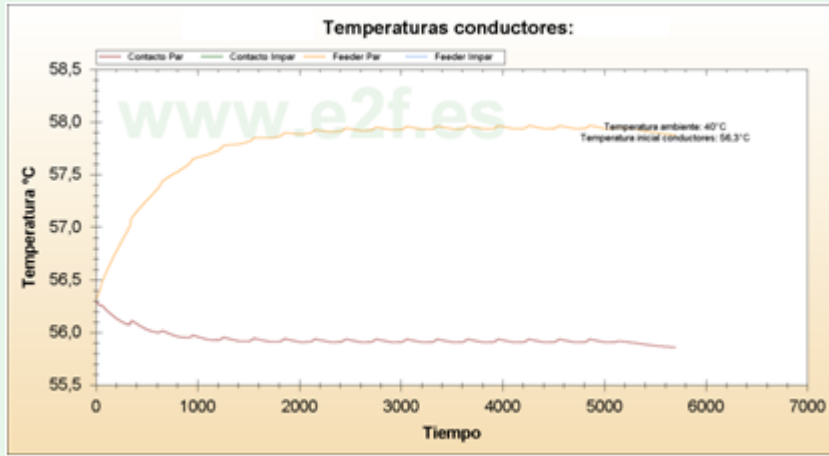
Lead feeders current



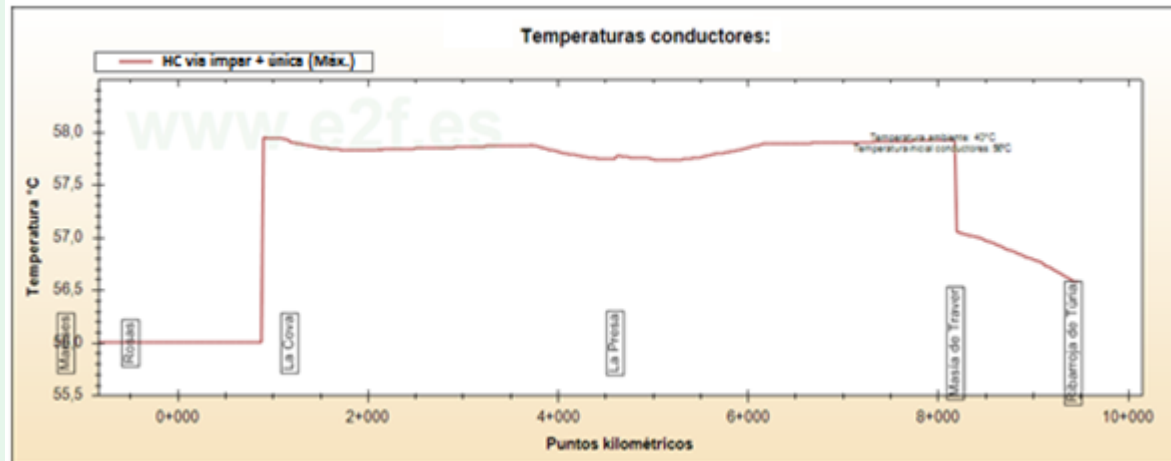
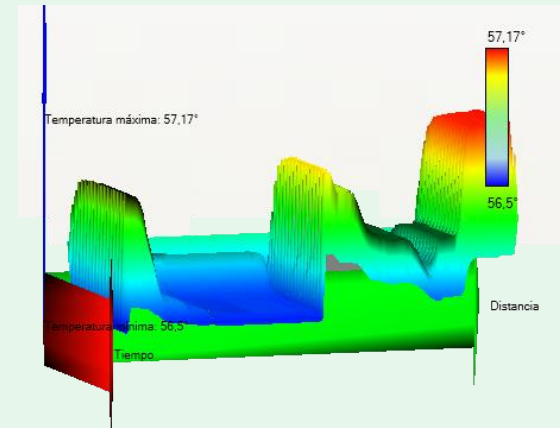
Neutral sections



# Thermal results



OHC temperature vs time



OHC temperature vs space

## Regenerative Breaking results

### Results

Rectifier stations power  
All trains/ each train

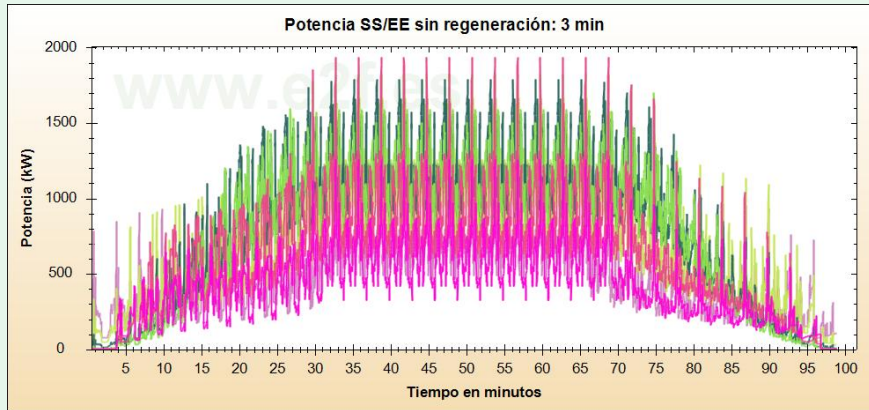
Pantograph voltage  
All trains/ each train  
(time and space)

Energy values

Analyze the waste  
energy to use it in  
other devices or for  
trains traction.

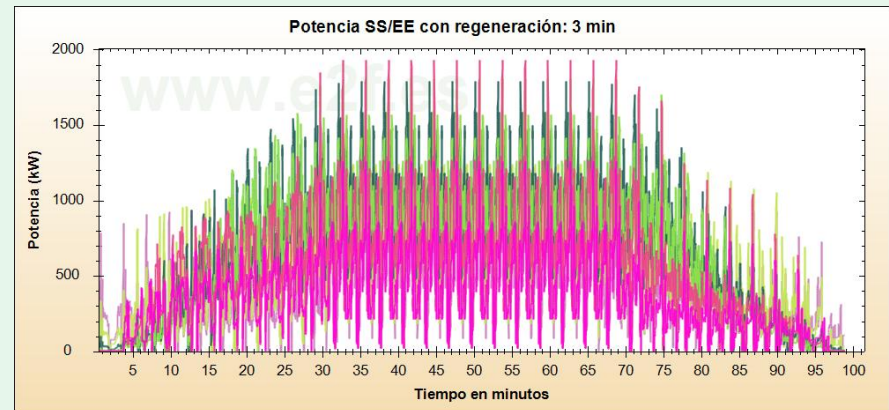
- Energy balance in substations
- Energy balance in the system

## Rectifier stations power results

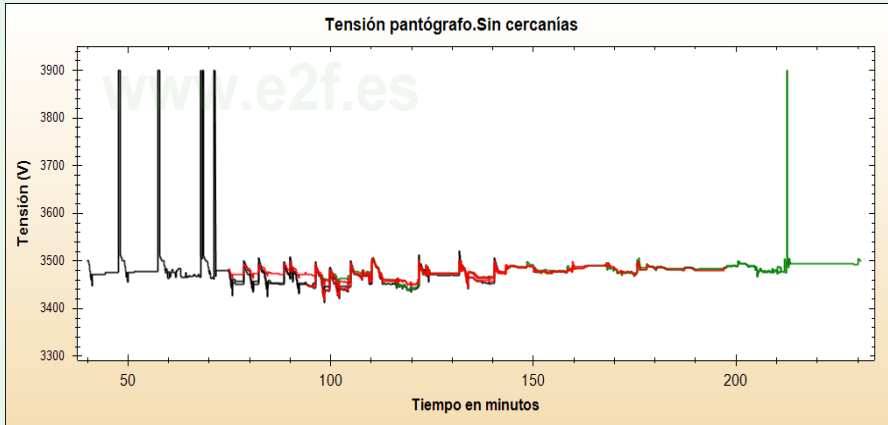


Power of all rectifier stations

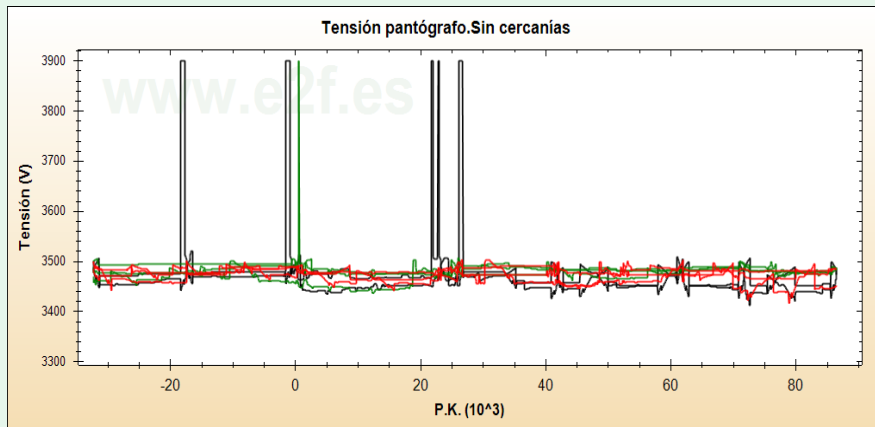
Power of all rectifier stations  
Simulation using regenerative  
braking process



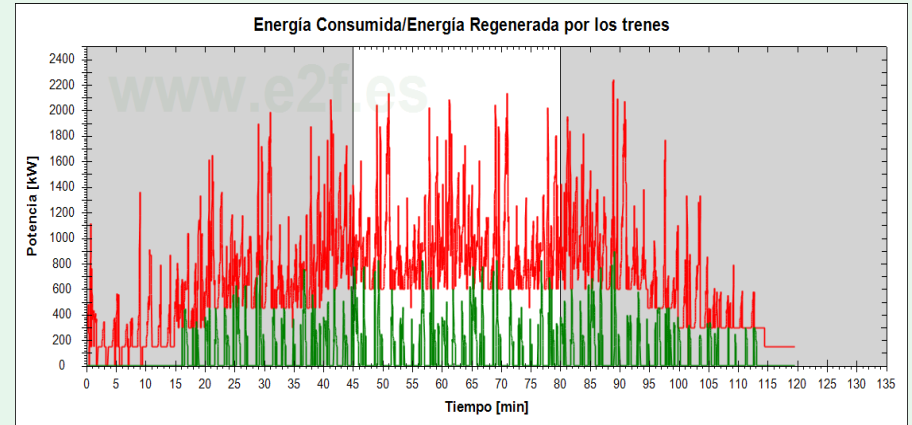
# Pantograph voltages and energy results



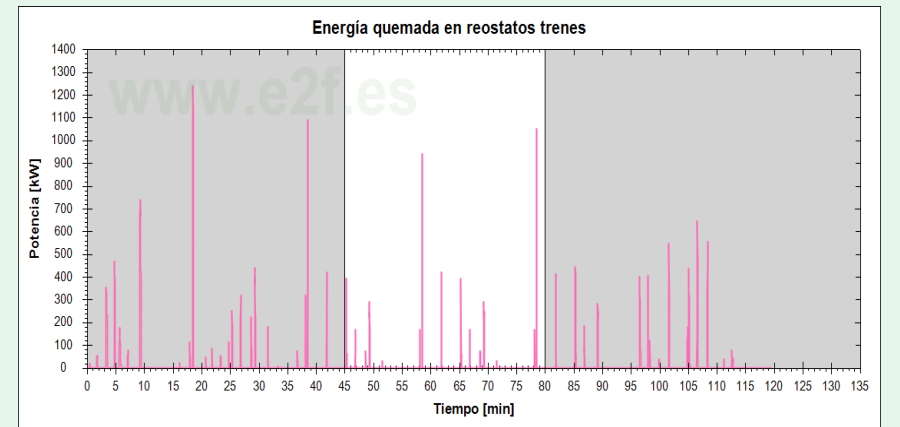
All trains pantograph voltage vs time. Simulation using regenerative braking process



All trains pantograph voltage vs space. Simulation using regenerative braking process



■ Energy consumed by trains  
■ Energy regenerated for traction uses



■ Rheostats burned energy