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LAYMAN'S REPORT



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Executive summary

The RE-USE project, co-funded by the EU LIFE+ programme was launched in February 2013 by Alstom Transport S.A. (France), Azienda Trasporti Milanesi Spa(Italy) Alstom Belgium Transport S.A. (Belgium), Alstom Ferroviaria SpA (Italy). The overall objectives of this project were:

- to demonstrate under commercial services conditions the efficiency of the Hesop 1500V technology to efficiently recover braking energy and reduce energy consumption by at least 15%;
- to disseminate the project results effectively for a wide spread of the technology, and to adapt regulations to the new technologies;
- to reduce project environmental footprint as low as possible, notably by following Ecodesign rules.

After having performed preliminary studies allowing validating the project objectives, the partners have started the development and the production of the Hesop 1500V prototypes. The prototypes have been validated after intensive type tests up to 12MW.

In order to measure the environmental impact of the prototypes a full LCA has been performed too.

Then the prototypes have been shipped to Milan and implemented at the Rogoredo Substation (Metro Line 3). After successful commissioning and night test sessions, a trial phase under commercial service conditions has been performed from October 2017 to July 2018. During this phase, energy savings thanks to the Hesop prototype has been continuously monitored. After 10 months of testing the actual energy savings achieved reached 22% of the energy consumed, so far beyond the initial objectives.

The prototypes will continue to run until end of 2018 before being dismantled.

Based on these highly promising results, Alstom will obviously continue to promote the Hesop technology to railway operators.

The first chapter of this report presents the environmental challenges tackled by the RE-USE project, as well as its main objectives and the description of the project partners. The second chapter summarizes the project results and achievements. The final chapter is dedicated to the environmental benefits of the project and the next steps.





1. Introduction

Environmental challenges tackled by the project

In the transport sector, rail transport is the more environmental friendly. However, improvements are still possible to further reduce its environmental impact and fulfil the European environmental policy.

The principal objectives of the railway policy in Europe by the year 2020 are numerous:

- For rail to achieve a 10% market share of passenger traffic in the EU with no detrimental environmental impact. (Based on Eurostat/UIC Statistics);
- A threefold increase in productivity (UIC Strategy);
- Elimination of avoidable fatal accidents within proposed interoperable European railway system;
- A 50% gain in energy efficiency over vehicle or product life cycles;
- A 50% reduction in the generation of pollutants over the life cycle of rail industry products and services;
- An increase in network capacity to accommodate the traffic projections given above.

Moreover, the European rail sector strongly supports the opinion issued by the European Parliament on 6 July 2010 to decarbonize transport through all available means - including the internalization of the external costs for all modes of transport, and the doubling of rail passenger transport by 2020.

Since a long time, braking energy recovery has proved to be one of the most promising way to increase energy efficiency of urban rail systems and reduce its CO2 emissions. Nowadays, modern traction units are fitted as a standard with regenerative dynamic braking. Therefore, when a train is braking, part of the recovered energy is re-used by another accelerating train. The part of braking energy that is not re-used by other trains is dissipated in resistors.



The net braking power depends on the network and its characteristics: consumption per kilometer, headways (in minutes) and distance between stops. Based on figures from several dense networks, the braking energy represents about 42% of the train energy consumption but between 40 to 60% is recovered. Due to their operating characteristics (short distance between stations, high speed and acceleration and deceleration), a metro and suburban network has a big net braking power and as only a fraction is being recovered, they have a high potential in terms of CO2 reduction if the "burnt" part of the braking energy is recovered.







Jointly with ATM, Alstom decided to demonstrate the reduction of environmental impact of the rail public transport with its advanced reversible power substation, Hesop.

The RE-USE project: Objectives and expected results

The RE-USE project aimed to demonstrate and validate the environmental benefits of an innovative technology, called Hesop, in terms of energy efficiency and reduction of CO2 emissions.

Thanks to this innovative technology, the part of the braking energy usually burnt in resistors is not wasted but sent back into the electricity network or re-used through the passenger station equipment (escalators, lighting and ventilation) resulting in a drastic reduction of CO2 emissions. In the RE-USE project, the validation and quantification of the reduction of the Hesop's environmental impact has been performed through a "full-scale" demonstration on a Milan metro line 3 during commercial operations.

To do so, the RE-USE project was relying on the 3 following main objectives:

1. The first objective was to further reduce the environmental impact (CO2 operating footprint) of the rail sector, especially Public Transport in Urban areas.

The project has quantified the gain of energy and CO2 reduction allowed by the Hesop advanced reversible substation for a 1500VDC railway network based on the full regeneration of the train braking energy.





The RE-USE project aimed at demonstrating at a real pilot scale level that the proposed innovative technology could help the transport sector reducing its energy consumption and CO2 emissions. At first, quantitative targets have been set at 15% at the ATM substation where the Hesop technology was about to be implemented.

2. The second objective targeted the dissemination of the results for a wide spread of the technology.

One of the objectives of the RE-USE Project, through a precise quantification of the reduction of the environmental impact of rail transport, was to demonstrate that urban guided systems equipped with advanced reversible power substation, allowing the feeding into the Grid of the part of the brake energy of metro trains usually burnt in resistors, could be applied universally to all DC railway systems.

3. The last objective was to keep the project environmental footprint as low as possible.

The Hesop technology follows the ECO design rules set by ALSTOM and is in line with solutions promoting sustainable development within the railway sector.

The design and manufacturing of Hesop had a minimum impact on the environment, as the industrial process integrated all aspects from eco-design, recycling, use of chemicals and end-of-life. The solution's design respects environmental criteria and sustainable development that must be met to certify to the Environmental ISO 14021/14025 label.





Project partners

ALSTOM Transport SA

Saint-Ouen (FR)

Coordinating Beneficiary

ALSTOM Belgium Transport SA

Charleroi (BE)

Associated Beneficiary





ALSTOM Ferroviaria SpA

Milano (IT)

Associated Beneficiary

Azienda Trasporti Milanesi SpA

Milano (IT)

Associated Beneficiary



Beneficiary	Main Expertise	Main Roles
Alstom Transport S.A (Coordinator) (FR)	Railways systems and more precisely in power supply substation	 Project Coordinator Participation in each major phase of the project from the initial power simulations of the HESOP technology on the Milan metro line 3 until site monitoring of the prototype Dissemination activities
Alstom Ferroviaria S.p.A. (IT)	Systems for the command and control of train movements	 Support of Alstom FR in its activities and relation with ATM Purchasing of power equipments for interfacing prototype with existing substation Responsible for the on-site installation of the prototype Supervision of the prototype testing on-site Dissemination activities
Azienda Trasporti Milanesi S.p.A. (IT)	Railway operator	 Give availability of its infrastructure for installation of the prototype inside the existing substation Supervision of the site installation Participation to site testing Dissemination activities
Alstom Transport Belgium (BE)	Converter development and prototype testing	 Design and development of the converter Assembling of the prototype Testing of the prototype





2. Background on Hesop technology

What is Hesop?

Hesop is an advanced reversible substation with a single converter both rectifier & inverter. This technology, suitable for trams, metro and suburban railways has two main advantages:

- Capturing over 99% of the recoverable energy in braking mode;
- > Providing dynamic voltage regulation to optimize power use in traction mode.



This technology also leads to numerous environmental benefits:

- Less energy consumed and reduced CO2 emissions;
- Less heat dissipation in tunnel;
- Better in-tunnel air quality.

What is the Hesop architecture?

The Hesop substation includes the following equipment:

- 1 traction transformer to adapt the incoming voltage,
- 1 AC filter to smooth the harmonics and control the power factor,
- 1 converter including an IGBT controlled rectifier / inverter bridge,
- ➤ 1 DC inductor.







3. Main project achievements

First, preliminary studies have been performed with the objectives of:

• Simulating the metro line to define a baseline and estimate the potential achievable savings;



 Defining the requirements of the Hesop 1500V reversible substation in terms of functionality, operation ability, environmental and standardization constraints, manufacturing and factory validation;

During this phase, Eco-design rules have been studied and all components (see below) are compliant with the current hazardous substances regulations.







Moreover, a full LCA of Hesop has been performed studying not only the production but also the distribution channel (i.e. shipment of materials to Charleroi and shipment of the prototype to the demo site Milan, the use of the prototypes during its whole lifetime (35 years) and its end-of life).

As highlighted in the figure below, the main environmental impact for 10 out of 11 indicators is generated by the use phase due to the energy consumption of the traction substation. Secondly, the manufacturing phase (all the materials of the substation) is the second contributor for raw material depletion as well as the hazardous waste production.



During the next phase of the project converter and transformer prototypes have been developed as well as all required auxiliary equipment. Prior implementing the prototypes as foreseen at Rogoredo Substation of the Milan Metro line 3, Factory Acceptance Tests (FAT) have been performed for both prototypes (see below HESOP converter):

- At Alstom Charleroi site for testing up to 6 MW;
- At GE Belfort site for testing up to 12 MW.







Once the validation testing achieved, the prototypes have been shipped to Milan to implement them in the substation. After several successful night tests sessions of the prototypes, a trial phase under commercial service of the prototype has been launched in October 2017 up to July 2018.

During the trial phase of the project, the energy recovered or "saved" thanks to the Hesop technology has been thoroughly monitored on the Milan metro line 3. The results have been very positive: more than 479 MWh of energy have been saved during the recorded period – i.e. up to 22,15% of the traction energy consumed at the ATM's substation.

Each day, Hesop 1500V allowed to recover more than 2MWh at the ATM's substation.

With an average electricity carbon intensity of 358 gCO2eq/kWh in Italy, the Hesop trial has led to a reduction of 171 tons of CO2 emissions over the trial period.

MONTH	ENERGY CONSUMPTION (kWh)	ENERGY RECOVERY (kWh)	RATE (%)	CO2 EMISSION REDUCTION (t)
October 17	372,274	69733	18,73%	25
November 17	292,224	60642	20,75%	22
December 17	161,418	45057	27,91%	16
January 18	88,912	31176	35,06%	11
February 18	416,899	71451	17,14%	26
March 18	323,406	74013	22,89%	26
April 18	140,393	53862	38,37%	19
May 18	83,826	17039	20,33%	6
June 18	86,201	12183	14,13%	4
July 18	196,273	43703	22,27%	16
TOTAL	2161826	478859	22,15%	171

The trial results have exceeded the project objectives of 15% energy savings and CO2 emissions reduction set at the start of the project. This is very encouraging as it demonstrates the benefits of the Hesop technology for improving energy efficiency of the rail DC networks and reducing CO2 emissions.





4. Project long term benefits and next steps

Environmental Benefits

The environmental benefits obtained during the trial phase of the project are highlighted in the chart below and have well exceeded the original objectives set-up in the project, with more than 22% of energy savings at the Rogoredo Substation and more than 2MWh of daily recovery.



On top of the environmental benefits above mentioned, it is worth noting that the technical advantages of HESOP technology will also allow reducing the number of substation to be implemented for a railway system, making the technology fully viable from an economic point of view.

Next steps

The Hesop advanced reversible substation is now available for DC traction networks from 600V to 1500V and from 900kW to 4MW (urban and suburban).

Prior to the Hesop 1500V trial on the Milan metro line 3, the Hesop technology has been implemented on the Victoria Line of the London Underground. This Hesop 600V 1MW entered into service in March 2015 and is operating as an inverter. This unit allows to recover more than 800kWh per day, which is the equivalent amount of energy to power 2 medium-sized passenger stations.

Since the start of the project, Hesop has been implemented by other transport networks worldwide – for both metro and tramway systems:

- In Australia where 13 Hesop (9 Hesop 750V 1.2MW and 4 Hesop 750V 2MW) are being tested on Sydney Light Rail;
- In Panama where 8 Hesop 1500V 4MW are being implemented on Panama City metro line 2;
- In Saudi Arabia where 70 Hesop 750V 1.2MW are being installed on Riyadh metro lines 4, 5 and 6;
- In Dubai where 15 Hesop 750V 2MW are being implemented for the enhancement and extension of the existing metro lines.