This project has received funding from the European Union's Seventh Programme for research, technological development and demonstration under grant agreement No 314125

Public Summary of

D4.7 DESIGN OF AUXILIARIES CONTROLLING ALGORITHMS

What is MERLIN?

MERLIN is a collaborative project funded under the European Commission's 7th Framework Programme on Research and Development. MERLIN started on 1st October 2012 and will last 36 months.

MERLIN's main aim and purpose is to investigate and demonstrate the viability of an integrated management system to achieve a more sustainable and optimised energy usage in European electric mainline railway systems.

What are the issues at stake?

Energy management is a key issue for railway systems and this situation will continue to be prominent for the foreseeable future. Multiple operational scenarios add complexity to the development of suitable and appropriate energy management solutions. Moreover, existing assessment tools lack an integrated approach, and tend to omit the variation in emission levels, energy usage and associated costs resulting from differing traffic peaks.

Given that the railway system is a complex and interconnected system, a single supplier, operator or infrastructure manager (as large as they may be) cannot tackle the energy management issue for the entire network alone. Hence, only through a collaborative approach such as **MERLIN** can effective solutions for this issue be developed. Appropriately, the **MERLIN** consortium brings together the key rail stakeholders from across Europe.

What are MERLIN's main achievements?

- Proposals for technical recommendations (UIC/UNIFE TecRec) on Specification and verification of energy and power consumptions of railwaysystemsand on Energy and power related information protocols at operational level;
- Future business models & recommendations (smart energy management, cost saving);
- Optimised solutions for current and future business models;
- Reference architecture and interfaces related to a strategic support tool and operational energy management tool which supports real time suggestions to network actors.

Public summary:

WARNING*: This document is a synthesis of a confidential document. Access to the full content of the deliverable is restricted to the members of the MERLIN consortium and to the European Commission's services.*

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Introduction

In recent years, some models have been developed to estimate energy consumption of train operation and tests were also conducted on real railway links and electric trains.
For the purpose efficiency on board is important to take into account the contribution not only of the traction system (electronic converter that feeds the traction motors, and other power components), but also that of the auxiliary loads.
Models to estimate the train energy consumption require detailed train running states outputted from train performance simulator or speed profile generator, including train speed, running time, corresponding traction effort and braking force.
Generally some models estimate the voltage and current with reference to the train speed, and then compute electric power, others estimate electric power through train speed, corresponding traction effort and energy efficiency curve.
In this document the study to define models obtaining an energy efficiency by the on-board auxiliary services an evaluation of the power for the different categories of service and a description of some technological solutions widely implemented in modern electrified transit systems has been developed.

Auxiliary Loads Manager (ALM)

The main parts of the system involved as producers and managers of the data of interest are:

Central Control Unit (CCU);

Traction Control Unit (TCU);

Auxiliaries Control Unit (ACU);

All these subsystems which are part of TCMS can support the DOEM to optimize the energy absorption. The system is based on algorithms implemented in the distributed logic of the vehicle, the historical data related to the energy consumption, the current position of the vehicle, the load and on the time-table. An heavy weight in the energy absorbed on-board is also represented from the driving style of the driver: in this case the system can suggest to the driver the optimal speed profile for the train and a better management of the auxiliaries loads.

In the process are involved the following subsystems:

- the subsystem integrated on the vehicle;
- the subsystem of ground to support in automatic the service of one or more trains.

In particular the **on-board system** must input the following data:

- on-board subsystems information regarding consumptions, energy dissipation and efficiency;
- information for the geo-referencing and the running data;
- indications from ground (speed limitations, time-table variations, route exchange, indications to save energy)

From the analysis of these data it is possible to manage the traction and the auxiliary subsystems in order to optimize energy.
In the Figure 1 a REM diagram is represented.

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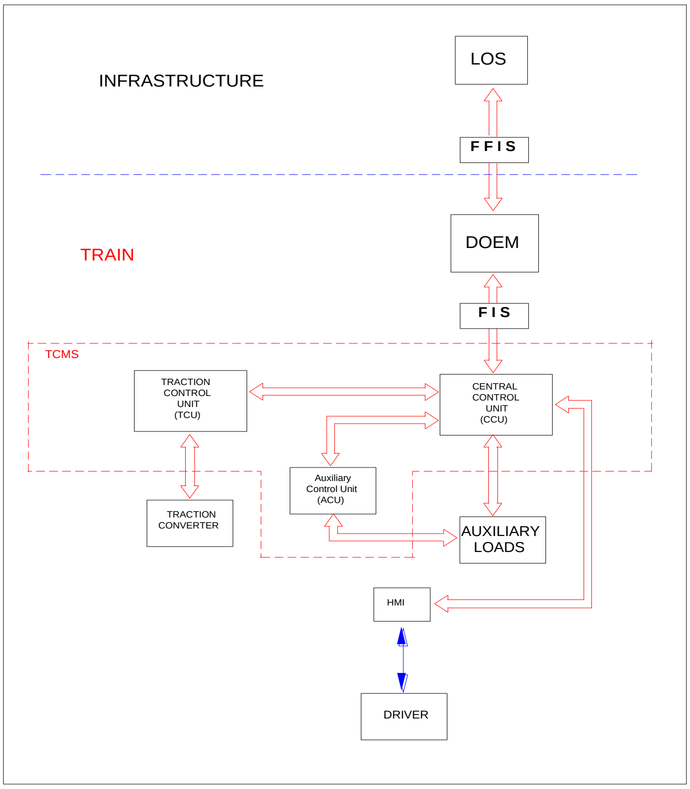

Figure 1: REM block diagram

Energy Model and Control Algorithm for Auxiliary Loads

The operation of the various loads is not continuative in the time but occurs at intervals. The cooling system of the traction converter is generally in operation during the whole phase of traction/coasting/braking. Its operation is interrupted when the train stops at the station (compatibly with the temperature values recorded on the high-voltage components).
The air conditioning system for the driving cab and passengers compartment is regulated primarily by the external and internal temperature. There will be a first time interval in which the system will work at full power to reach the set temperature limit, then the system will turn off turn on again working to intervals of time at reduced power to maintain that temperature.
A similar approach holds for the compressor. This will work at intervals to ensure the set pressure values. Against pneumatic braking, opening doors, and suspension adjustment operations and pantograph turn up will be spending a certain amount of air that will have to be replenished.
Even the battery charger will have a certain cycle of charge that depend on the current drawn by the low voltage circuits.
An algorithm of calculation for the energy must take into account several parameters:

- Mission;
- Train set;
- Environmental conditions;
- N° of passengers carried;
- State of pressure in the pneumatic system

For the purpose of a simulation for the calculation of energy (which can be considered ideal) absorbed by the auxiliary loads of a train can be considered the following algorithm:

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$$E_{ideal\ train}(t_i) = E_{cool}(t_i) + E_{motor\ fans}(t_i) + E_{batt}(t_i) + E_{air}(t_i) + E_{HVAC}(t_i) + E_{static\ conv}(t_i)$$

where: E*cool* is the total energy absorbed by the fans and pumps of the cooling system of the traction converter; E motor fans is the energy absorbed by the motor fans of the single motor car; E batt is the energy absorbed by battery chargers; E air is the energy for the air compressor; E HVAC is the energy absorbed by HVAC; E static conv is the energy absorbed by static converters.

The energy optimization can be actuated starting from the simulation of the Energy *"ideal"* as calculated by the previous algorithm and comparing this with the energy measured E *"measured"*.
E *ideal* can be calculated on the train by a board with microprocessor integrated in the CCU dedicated for the energy simulation.
The HMI receive the signal from the board and is able to get past the ideal graph of the energy compared with the graph of the energy measured by transducers of the auxiliary converters.
The CCU calculates the E ideal and compares it with the E measured. From the comparison it evaluate the Energy that can be saved. If it is negligible will not be taken any corrective action, if it is relevant input is sent to DOEM on the train. DOEM communicate to CCU the actions to try to reduce the energy consumption by some loads (eg. HVAC, cooling system or air compressor).
The process to optimize the energy can be schematized as in Fig.2. LOS establishes the power/energy restriction (MAO Limitations) from the infrastructure according to Minute Ahead Optimization (MAO) strategies: every MAO slot has a configurable time, and it sends the information to the train if a power/energy restriction occurs. In particular this restriction is communicated to DOEM and VEM. Internally VEM makes an assessment of power / energy consumption for auxiliary loads of the train which outcome is named as P/E Limit.
The energy monitoring period is configurable. ALM will compare the E_{meas} with the energy profile calculated by itself (E_{ALM}) which is uploaded once each minute.
Every minute ALM verifies the condition $E_{meas} > E_{ALM}$ and if it is valid (in particular when a deviation greater than x% ([1]) occurs, for example 5%) the system in a first time carries out an evaluation of auxiliary loads conditions and then starts with the implementation of the optimization actions.
If the above condition is not verified the system proceed with a new calculation of the energy values.

[1] This value is configurable inside the ALM module.

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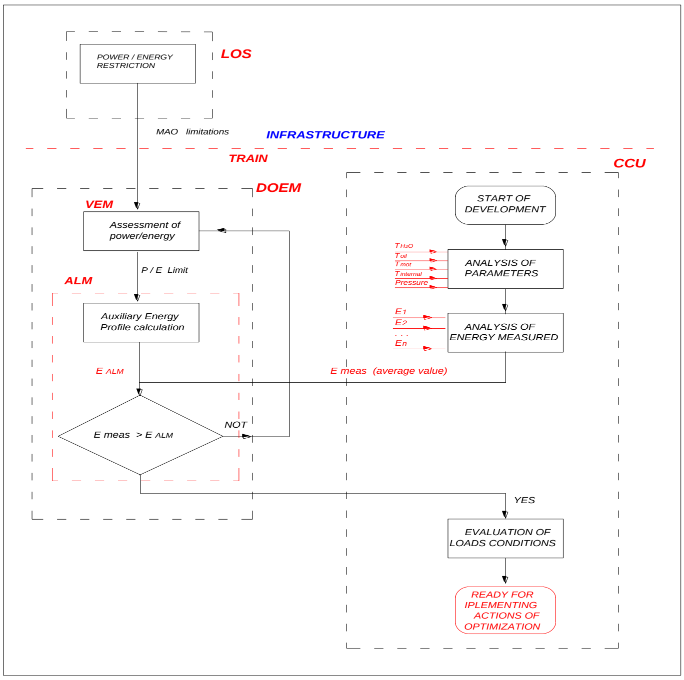

Figure 2: Representation of a serial development for energy saving

More information

To know more on the MERLIN project, please visit http://www.merlin-rail.eu.