1. PUBLISHABLE SUMMARY

List of Beneficiaries

Beneficiary Number	Beneficiary name	Beneficiary short name	Country
1 (Coordinator)	Centro de Estudios e Investigaciones Técnicas	CEIT	Spain
2	YORK EMC SERVICES (2007) LIMITED	Y-EMC	UK
3	IDIADA AUTOMOTIVE TECHNOLOGY SA	IDIADA	Spain
4	TEKNOLOGIAN TUTKIMUSKESKUS VTT	VTT	Finland
5	Politecnico di Milano	POLIMI	Italy
6	MIRA LTD	MIRA	UK
7	JEMA ENERGY SA	JEMA	Spain

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Summary description of project objectives

Nowadays, road transport relies almost exclusively on fossil fuels. In fact, road transport is responsible for one-fifth of the EU's total emissions of carbon dioxide, and these emissions have increased by 26% since 1990. Thus, to achieve the 2020 target of reducing energy consumption and CO2 emissions, Fully Electric Vehicles (FEVs) need to reach a significant market share. Progress towards mass production of FEVs presents vehicle manufacturers with new challenges due to the relative immaturity of the new technologies that are involved. The most notable of these is the electric powertrain, comprising the electric traction machine and its associated power electronics.

One of the main objectives of the HEMIS project is therefore to design an in-vehicle Prognostic Health Monitoring System (PHMS) for the powertrain in order to enhance the safety and maintainability of FEVs. This system will be able to analyze the failsafe state of the powertrain by monitoring selected physical characteristics. It will also estimate its remaining useful life (RUL), and which component will fail first, thus enabling a predictive maintenance policy.

The HEMIS project has a second main objective. The electromagnetic fields emitted by the electric powertrain and their possible effects on the human body, as well as any interference with other systems on the vehicle, will be analyzed. It will then be assessed whether these fields, which may differ from those in a conventional car, could exceed current standards. In that case, HEMIS project proposes to recommend adaptations to the automotive standards so that the electromagnetic field is always below acceptable limits.

The main objectives of the HEMIS project are divided into the sub-objectives specified below:

O.1 Define a generic architecture for the FEV and undertake hazard and RAMS (Reliability, Availability, Maintainability and Safety) analysis.

O.2 Improve the knowledge of failure mechanisms, identifying the most critical ones, and asses which physical magnitudes are the best to monitor the powertrain failsafe state considering the reliability, accuracy, cost and feasibility of integration into FEVs.

O.3 Integrate hybrid information into prognostic algorithms to estimate a RUL value.

O.4 Design, develop and test a prognostic health monitoring system for the powertrain of electric vehicles (PHMS).

O.5 Identify possible limitations of current legislative requirements regarding electromagnetic fields (EMF) from FEVs and propose Electromagnetic Compatibility (EMC) testing methods to standards bodies.

O.6 Study the relationship between low frequency emissions and the current density induced in the occupants in order to propose reference levels for in-vehicle human exposure to EMF.

Work performed and main results achieved

The HEMIS project is broken down into eight work packages (WPs) that will lead to the completion of the ultimate goals of the project. All the tasks for the period from 1st June 2012 to 31st May 2013, described in Annex I (Description of Work) have been completed as planned. The following activities for WP1, WP2, WP3, WP4, WP5 and WP8 were performed during this period:

WP1: Coordination and management

This work package deals with all the management aspects of the project and the monitoring of the progress towards the ultimate objectives, identifying shortcomings and recommending remedial action when necessary. All the deliverables and milestones for the period from 1st June 2012 to 31st May 2013 described in Annex I have been achieved.

WP2: PHA and RAMS apportionment of the FEV

This work package is devoted to the definition of the architecture of a generic full electric vehicle. This allows undertaking the RAMS analysis of the vehicle and the RAMS apportionment, which in turn define the requirements of the powertrain and the HEMIS PHMS. The following objectives have been achieved:

- A generic architecture for FEVs, representing the common features of electric vehicles has been defined. The architecture is focused on the electrical powertrain and takes account of vehicles that may purely battery powered or equipped with range extenders. Results have been compiled in the deliverable D2.1.
- The main hazards of the FEV for the driver and passengers have been identified, including hazards related to EMC issues within the vehicle. Every hazard has been classified using the ISO 26262 risk criteria. Results have been compiled in the deliverable D2.1.
- The RAMS analysis of the FEV which consists of a Fault Tree Analysis (FTA) and a Failure Mode, Effect and Criticality Analysis (FMECA) have been carried out concluding hazard mitigation techniques. Results are gathered in the deliverable D2.1.
- A representative mission profile has been identified, representing average physical and operational characteristics of the vehicle networks. Results have been compiled in the deliverable D2.1.
- The expression of the core hazard limit has been defined as a function of the functional elements reliability (the failure rate), and the characteristic of the monitoring system.

Additionally, test cases of the monitoring system have been defined following the requirements of the ISO 26262. Results have been compiled in the deliverable D2.2.

WP3: Identification of the causes of degradation of the motor and the control, and their consequences

This work package is responsible for defining the causes of degradation of the motor and the control, as well as the analysis of the effects and criticality of the different failure modes of these subsystems. A review of the available literature on the reliability of the electrical machine and its associated control was carried out in order to identify the nature, causes and prevalence of likely failure modes.

Deliverable D3.1 summarizes the failure modes of the powertrain and the analysis on their effect and criticality. In addition, their contribution to the hazards indentified in WP2 is represented by means of Ishikawa diagrams. Possible methods for monitoring the health of the electrical machine and the control are also noted, as an input to WP4. The powertrain architecture is documented in deliverable D3.2.

WP4: Monitoring of the physical characteristics of the motor and control and prediction of their RUL

The aims of this work package are to identify which physical characteristics are most appropriate to monitor the performance of the powertrain and to define prognostic algorithms able to deal with the associated hybrid data in order to estimate the powertrain's remaining useful life. The objectives for the first period have been achieved:

- The failure modes of the powertrain defined in WP3 have been assessed in order to identify the most relevant ones considering their effect and frequency.
- Some physical characteristics have been preselected to monitor the heath of the powertrain. They will be assessed considering the accuracy and reliability of their measurement, as well as the cost of the sensors and the feasibility of their integration in a commercial powertrain.
- A literature study of the empirical and physical models of motor bearing degradation and electrolytic capacitors degradation has been performed. As a result of the investigation, it has been proposed to model the capacitor degradation process by using: i) the Arrhenius Law for the representation of the effect of the temperature on the capacitor lifetime, II) exponential laws for the representation of the effects of the capacitor degradation on the ESR and capacity measurements and iii) exponential laws for modelling the effect of the temperature on the ESR and capacity measurements on a new capacitor. Finally, a preliminary model for the prediction of the capacitor remaining useful life has been developed.

WP5: Analysis and measurement of EMC characteristics and health impact of EMF

This work package is devoted to identifying possible limitations of current legislative requirements regarding EMF from electric powertrains and proposing EMC testing methods. It is also devoted to study the impact of low frequency emissions on the occupants in order to propose reference levels for in-vehicle human exposure to EMF.

Along the first period, a detailed review of existing and planned automotive standards has been carried out. It was concluded that further development of standards is required in order to fully reflect the features of electrical powertrain. The deliverable D5.1 details the issues with the current automotive EMC standards and tests when they are applied to FEVs. A measurement plan for the use of obtaining measurements from a suitable powertrain has been written and will be applied during the second period.

Additionally, an approach for modelling the impact of low frequency magnetic field exposure (due to traction currents, for example) on the human body, in terms of induced currents and in-body electric fields, has been proposed. The objective of this is to investigate the validity of existing field reference levels, which have been developed for a standing human under uniform

field exposure, for the in-vehicle environment where the occupant is seated and exposed to non-uniform field distributions.

WP6: Identification of hazard limits and design and implementation of on-board monitoring systems

In this work package, which will start in August 2013, monitoring systems for the analysed subsystems will be designed, developed and tested.

WP7: Verification of the on-board monitoring systems for the fail safe transition

This work package will start in February 2014. Its aim is to integrate the prototype of the on-board monitoring system. Latter, it will be verified by means of a test setup.

WP8: Dissemination and exploitation

This work package focuses on the dissemination of the R&D results of the project. The dissemination was implemented through the following activities: media, web page, conferences and workshops with the industrial advisory panel.

Expected final results

The **first outcome** of the project is a prototype of an in-vehicle prognostic health monitoring system for the powertrain, comprising the electric traction machine and its associated power electronics. This system will provide information on the failsafe state of the electric powertrain and will enable to apply a condition based maintenance policy on its subsystems.

The **second outcome** of the project will be the proposal of design guidelines with mitigation techniques regarding electromagnetic compatibility and the impact of electromagnetic fields on human health; as well as low frequency emissions testing methods. This information will be handled to standardization bodies and manufacturers of FEVs.

Potential impact and use

HEMIS will contribute to increase the reliability of FEVs by analysing the failure modes of new building blocks, such as traction electrical motors and the associated power electronics. Moreover, the safety of FEVs will be significantly improved by means of the PHMS, able to detect the failsafe state of the FEV's electric powertrain. This could be used both to trigger safety automatic actions and/or to warn the driver about the failsafe state of the vehicle.

Besides, the RAMS analysis developed in HEMIS will improve the FEV design. In this sense, FEVs' manufacturers will .be provided with information about the major contributors to the degradation of the powertrain, as well as with design guidelines on EMC issues. This way, HEMIS will strengthen Europe's position in existing markets, such as automotive industry, on-board monitoring systems and predictive maintenance.

Moreover, the PHMS will predict the remaining useful life of the subsystems analysed, thus aiding to the decision on when maintenance actions should be performed. Hence, maintenance costs will be reduced, while additional services are provided to FEV users.

Project logo and website

http://www.hemis-eu.org/