**PROJECT**

**ILHYPOS**

**Ionic Liquid-based Hybrid Power Supercapacitors**

**Funding:** European (6th RTD Framework Programme)  
**Duration:** Dec 2005 - May 2009  
**Status:** Complete with results  
**Total project cost:** €2,866,168  
**EU contribution:** €1,643,184

**Call for proposal:** FP6-2004-HYDROGEN-1  
**CORDIS RCN:** 78773

**Background & policy context:**

The demand for clean energy is rapidly expanding worldwide and one of the most promising solutions is non-polluting energy production by fuel cells. Supercapacitors (SCs), due to their capability to deliver high specific power in a few seconds, are considered as electrical energy storage devices for smoothing the short-time power burst required in transport and stationary applications of fuel cells.

Commercial SCs are double-layer carbon SCs (DLCS) which make use of electrolyte solutions consisting of a salt dissolved in an organic solvent, which permits relatively high operating voltages (around 2.5 V). The main drawback with these SCs is that the organic solvents do not often fulfil the requirements of environmental compatibility and safety for vapour generation, flammability and explosions. This is the case for DLCSs with acetonitrile-based electrolytes, which are the most common high-voltage DLCSs on the market.

The high vapour pressure of these electrolytes requires a careful and expensive thermal control. Temperatures above 40° C, normal in fuel cell vehicles and CHP (combined heat and power) systems, may cause the degradation of present SCs in terms of performance and safety. The volatility of organic solvents increases sharply with temperature, making SCs potentially unsafe beyond 50-60° C and, generally, non-environmentally friendly with the presence of polluting chemicals.

The hybrid SCs to be developed in the project ILHYPOS are based on the use of ionic liquids as electrolytes and on a novel hybrid configuration using electronic conducting polymers (ECPs) as positive electrodes. Ionic liquids are excellent ionic conductors, virtually non-volatile and thermally stable up to 300° C, with a high working voltage (in excess of 5 V). These properties make ionic liquids excellent candidates as electrolytes in SCs with improved performances: specific energy and power of about 15 Wh/kg and 7 kW/kg can be reached.

**Objectives:**

The ILHYPOS project aimed at developing green, safe, and high specific energy and power hybrid SuperCapacitors (SC) for application as peak power smoothing device in Polymer Electrolyte Membrane (PEM) fuel cell-powered electric vehicles and, as an additional second option, in delocalised small energy production plants based on PEM fuel cells.

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The scientific objectives were:

1. Synthesis and characterisation of an ionic liquid (or a mixture of ionic liquids) having improved properties (overall ionic conductivity, electrochemical, chemical and thermal stabilities) at low temperatures (down to -20° C), while maintaining its superior performance at 60° C and above with respect to present ionic liquids;
2. Synthesis of Electronically Conducting Polymers (ECPs) optimised for the use as positive electrode
in ionic liquid-based SCs by electrochemical techniques;
3. Identification of high surface area carbons (e.g. activated and aerogel carbons) optimised for the use as negative electrode in ionic liquid-based SCs;
4. Investigations of the electrochemical performance of current collectors in ionic liquids based SCs.

Surface treatments would be developed onto the Al current collectors used in these hybrid SCs to decrease the series resistance of the cells.

**Methodology:**

The project was organised in four phases.

During phase 1 (Electrode and electrolyte materials R&D), academic and basic research organisations' work was concentrated on the optimisation of the electrode and electrolyte materials in order to significantly improve the overall technical performances of each single component with the respect to present state of the art.

With phase 2 (Development and production (D&P) of SC materials), the focus was on the scale up processes for optimising the materials production.

In phase 3 (Application requirements and full-scale prototype production), an application specific study was performed by two end users in collaboration with a research organisation as hybrid vehicle configuration investigator, and, based on these studies, hybrid SC components were designed and assembled in the final prototypes.

In phase 4 (Application testing), testing procedures were developed and used to experimentally verify the performance of the prototype with the respect to the project targets.

**Parent Programmes:**

FP6-SUSTDEV-3 - Global Change and Ecosystems

**Institute type:** Public institution

**Institute name:** European Commission

**Funding type:** Public (EU)

**Lead Organisation:**

**Ente Per Le Nuove Tecnologie, L'energia E L'ambiente**

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2358 ROMA
Italy

**Organisation Website:**
http://www.enea.it

**EU Contribution:** €0

**Partner Organisations:**

**Micro-Vett Spa**

**Address:**
Via Gambellara
40026 Imola
Italy

**Organisation Website:**
http://www.micro-vett.it

**EU Contribution:** €0

**Université Paul Sabatier**

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Key Results:

In 3.5 years of the project, the activities were, in-line with the planning, mainly devoted to the research and development of key materials for the preparation of SCs, together with the scale-up process analysis for the realisation of SC components and the study of the application technical requirements. Finally, cell prototypes were produced and tested according to three different designs confirming most of the project targets, with significant new inputs from novel asymmetric configuration and wound stack technology for cell assembly.

Investigation and development of electrode materials and their compatibility with ionic liquid electrolyte were carried out. Furthermore, experimental activities were performed for scaling up ECP production, as well as for selecting separators and optimising current collectors.

In parallel to optimised electrode materials investigation, new ionic liquids (and mixtures) were synthesised using simple processes (one is an original aqueous route, developed by ENEA), fully characterised and then prepared in suitable quantities at laboratory scale (many batches up to 30 g each) for verifying the compatibility (electrochemical stability up to 5 V) and performance characteristics of electrodes materials with these new compounds. After selection and characterisations at ENEA, scale up processes were studied and optimised at Evonik up to the production of ionic liquids for sample productions.

The ILHYPOS project addressed key applications for SCs, both in conjunction with PEM fuel cells (FCs):
- the use in hybrid electric vehicles (HEVs) with or without batteries; and
- the stationary application in UPS, which was selected during the project, as more commercially interesting with respect to the initial CHP systems.

For both applications, a preliminary analysis, supported by experimental data and simulations, was carried out to identify the technical requirements and the potential advantages achievable with the introduction of SCs. In order to establish the guidelines for the ILHYPOS SCs, the research team investigated:
- SCs sizing both for HEV and FC-UPS;
- the application of SC for HEV - and FC-UPS;
- the modelling and simulation of energy storage systems for HEV and FC-UPS.

Three generations of prototype cells were finally assembled and tested according to a defined test procedure:

1. Symmetric carbon / carbon cells with ionic liquid-based electrolyte, mainly aimed to

Technical Implications

The project has significantly advanced the knowledge and performances of novel materials (such as ionic liquids and electronic conducting polymers) and cell design (hybrid and asymmetric supercapacitors) with dedicated pilot production processes.

Project contribution to Carbon reduction

Commercially available SuperCapacitors based on organic electrolytes suffer of limitations associated with the operating temperature. Temperatures above 40°C, frequently encountered within fuel cell powered vehicles and stationary (CHP=Combined Heat and Power or other possible usage, such as UPS) systems, may cause the degradation of the commercial supercapacitors in terms of performance and safety. The volatility of organic solvents such as acetonitrile increases sharply with temperature making the devices containing them unsafe at 50-60°C. Moreover, ILHYPOS SuperCapacitors relieves from more polluting chemicals largely used in present SC (organic electrolytes substituted by 'green' ionic liquids).

Policy implications

The project had mainly scientific and technological challenges but the potential political and social impacts are related to the introduction of a new green technology in a novel industrial sector with significant benefits to the society for the introduction of clean technologies.

Documents:
- Publishable Final Activity Report (Final report)
STRIA Roadmaps:
Transport electrification, Vehicle design and manufacturing, Low-emission alternative energy for transport

Transport mode: Road transport

Transport sectors: Passenger transport, Freight transport

Transport policies: Decarbonisation, Societal/Economic issues

Geo-spatial type: Other