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HyHEELS

Hybrid High Energy Electrical Storage

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

PRIORITIES 6.1.4.2.2/4.1.1

Sustainable Energy Systems/Sustainable Surface Transport

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Revision and history chart

Version	Date	Reason
0.1	21.11.2008	Initial template & structure by IMC
1.0	02.06.2009	Compiling of partner inputs.

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Executive publishable summary

The overall goal of HyHEELS was to provide an UltraCap energy storage system for the use in hybrid- and fuel cell vehicles, which satisfies all properties necessary to make an integrative component. Therefore, the development work comprised the optimisation of the electric properties of the basic cap, its combination into scalable modules with integrated power balancing within the modules, power prediction and the communication interface with the drivetrain.

The work programme consist of two technical work packages 1000 and 2000 for the development of the UltraCap modules and the UltraCap controller, and a work package 3000 concentrating on simulation & modelling as well as on testing & evaluation of the developed hardware.

After the kick-off meeting several workpackage meetings take place to achieve a fine tuning of the project.

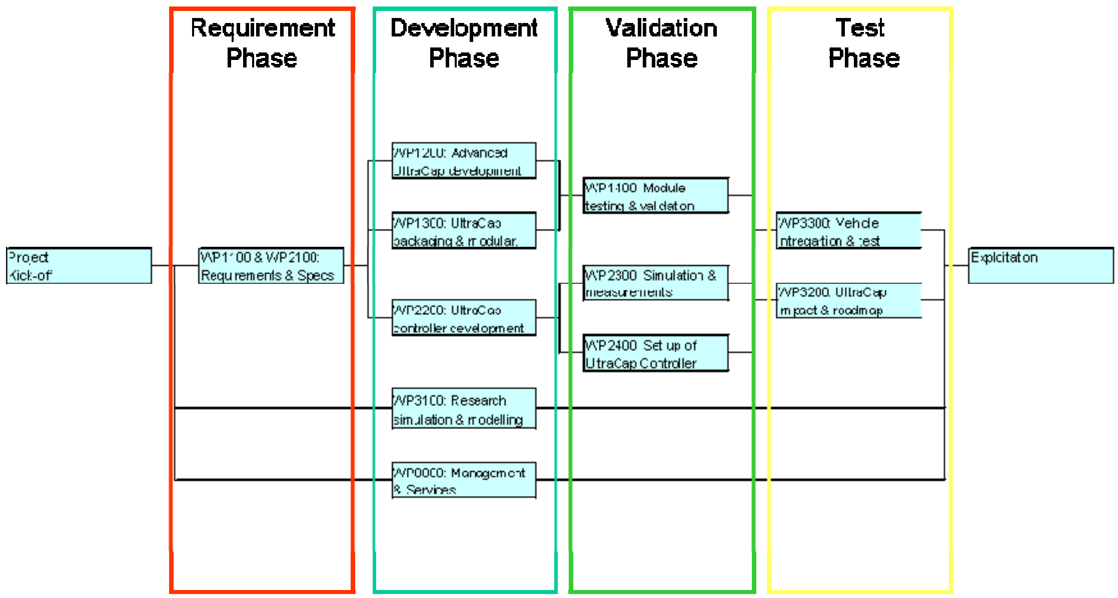

Figure 1: Project phases of HyHEELs.

The requirement phase of the UltraCap module specification as well as of the UltraCap Controller specification was finished in the first project year. Further activities were conducted in the development phase, which were part of WP 1200 and 1300 as well as WP 2200 and WP 3100 within the second project year. These activities covered the cell and the module development of the capacitors, the set up of the UltraCap controller prototype which will include cell balancing and voltage measurement and consideration regarding to design simulations of the power train. Furthermore the evaluation of modules based on traditional UltraCaps was conducted and simulations of the power losses of the UltraCap controller were performed and measurements were done.

As one partner left the consortium the tasks of this partner were shifted to internal partners of the consortium.

All partners proceed with their activities. However these discussions and additional deliveries results in a delay of the project as several activities could not started at time.

The actual project duration was prolonged until end of the year 2008. The final, total project period was 38 months.

Results of WP1000

Within the HyHEELS project a newly cell/stack technology was developed and a new module was designed. The stack is made of one positive cell and one negative. On one side the positive electrode is connected to the lid and the other side to the bottom can. The 2 bottom can thickness, once laser welded together, have the same thickness as the lid. A plated connection is laser welded between the 2 cells to give a very low resistive connection for voltage measurement. A thermal shrink tube insulates the stack.

Figure 2: A completed stack with two aluminum connectors (+) and (-), shrink sleeve.

			HyHEELS Cell		
	Unit	**Initial**	**Current**	**Improved**	**Target**
Nominal cell voltage Un	**V**	**2.5**	**2.7**	**2.7**	**2.7**
Maximum cell voltage Umax	**V**	**2.7**	**2.85**	**2.85**	**2.85**
Gravimetric energy density at Umax	**Wh/kg**	**3.7**	**6.6**	**7.5**	**7.5**
Volumetric energy density at Umax	**Wh/l**	**5.0**	**9.0**	**9.0**	**9.5**
Gravimetric power density at Umax	**kW/kg**	**3.5**	**10.3**	**15.6**	**15.0**
Volumetric power density at Umax	**kW/l**	**4.7**	**14.0**	**18.8**	**19.3**

Table 1: HyHEELS cell current data, improved versus initial and target.

The Table 1 shows the very good positioning of the HyHEELS cell according today's standard product. The energy density, one of the major HyHEELS projects' technical targets, is already as good as a future cell with 2,85V nominal voltage.

If the tests will qualify the cell for this 2,85V voltage, the results would be even better. And the building of a 3000F cell would also increase the power and energy densities, as the increasing weight and volume is proportionally lower!

The HyHEELS final module version is presented in Figure 3.

Figure 3: HyHEELS module 54V 100F in final version, including the controller

The ESR used for the maximum power corresponds to the value measured at 1kHz. This value is about 66% of the DC ESR, which correspond to 8.35mOhms.

The possible mass of the module, using lighter plastic bases, has been evaluated to 8370g.

Using these evaluations, the calculated results are given on the line "HyHEELS possible", depending on the 2 assumptions above. (red numbers in the table)

			HyHEELS Module		
	Unit	Initial	Current	Improved	Target
Nominal cell voltage Un	V		54	54	54
Maximum cell voltage Umax	V		57	57	57
Gravimetric energy density at Umax	Wh/kg		4.9	5.4	5.0
Volumetric energy density at Umax	Wh/l		4.9	4.9	6.3
Gravimetric power density at Umax	kW/kg		7.8	11.6	10.0
Volumetric power density at Umax	kW/l		7.9	10.6	12.9

Figure 4: HyHEELS final module: measured vs targeted values

Results of the Controller development WP2000

UltraCaps are available on the market. However, there are restrictions with regard to automotive applications when looking on max. voltage and max. working temperature and packaging requirements. As the max. voltage of a single capacitor is only 2.5 V, several capacitors have to be connected in serial to a module if higher supplying voltages are required. This makes it necessary to develop an advanced UltraCap module packaging with optimised thermal behaviour, weight and cost. Furthermore, caused by different self-discharge of the single capacitors, the individual voltages of the module will drifting away. Finally, the capacitor module will be mismatched in voltage. Battery systems will be usually overcharged to keep it balanced in charge and voltage. However, capacitors could not be overcharged. Therefore, special charge balancing systems were developed in the past. These charge-balancing systems exchange the energy between the single capacitors in such a manner, that all capacitors achieve equal voltages. However, additional information about the UltraCap module and functions are necessary for a secure operation under automotive conditions.

Within WP2000 all requirements of an UltraCap controller were compiled. The prepared document "Controller requirements" was the basis for the development of the UltraCap Controller.

According to the requirements only a recharging balancing concept from an external source was possible. Therefore the following concept was chosen for the UltraCap Controller realization.

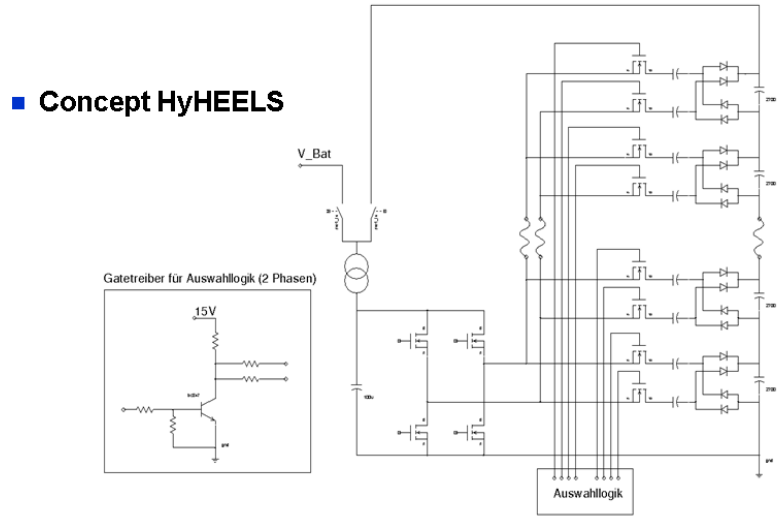

Figure 5: Selected concept for the UltraCap Controller.

This concept provides the cell voltage measurement and the recharging of weak cells with up to 1 A. Of cause additional functions were necessary for the controller. Finally the following architecture was developed to realize all requirements.

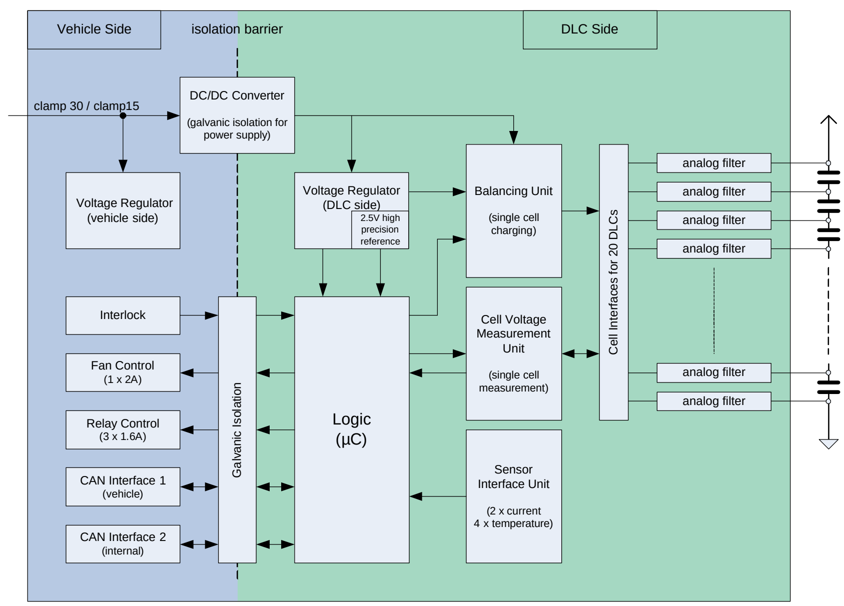

Figure 6: Architecture of the UltraCap Controller.

The UltraCap Controller has a sampling rate of 10 ms for 20 cells (voltage channels). The average failure in the voltage measurement was in the relevant voltage area better than 10 mV. Furthermore the Controller is able to calculate the ESR and the capacitance of the capacitor and therefore also provides the usable and restorable energy.

The final design of the controller is shown in the following figure.

Figure 7: Picture of fully assembled UltraCap controller

The performance as well as the mechanical design of the controller ensure the reliable operation of the module and satisfy the future requirements of all automotive applications in this area.

Results of WP3000

New simulation models were developed to design and configure the Ultracap modules for different vehicles. The simulations were validated by experimental results. The modular ultracap packs were virtual designed and recommendations for these configurations as well as for the power management strategies were provided to the OEM's of WP1000.

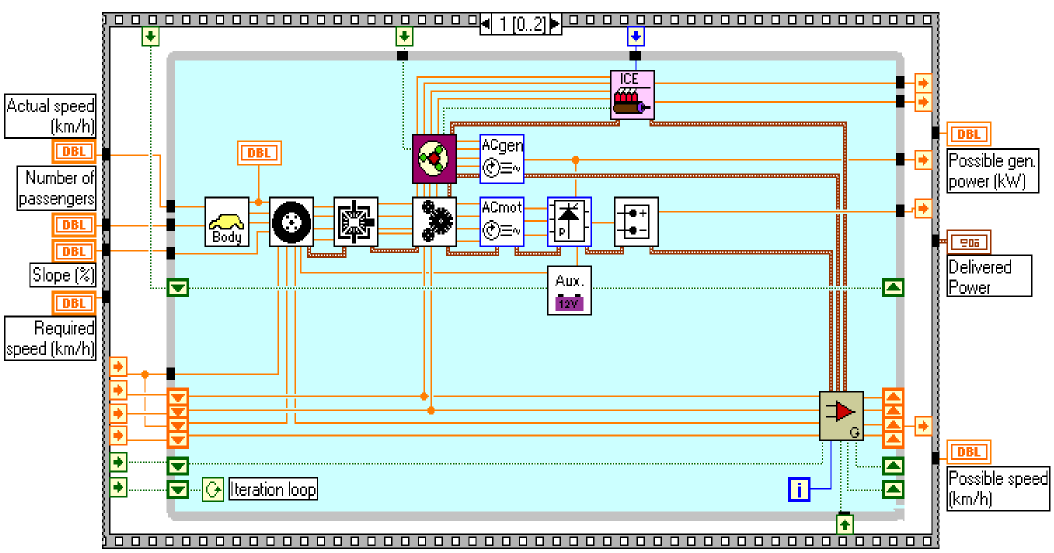

Figure 8: Representation of system modelling.

The test platform at Vrije Universiteit Brussel was applied to verify the configuration the super capacitor based energy storages for passenger cars and heavy duty vehicles, with respect to the voltage variation, maximum charging/discharging current, power losses in speed cycles (e.g. NEDC, FTP and so on).

After 55000 km equivalent driving distance on the experimental test rig, there were no over temperature, mechanical deviation or significant change in the self discharging observed.

The driving cycle tests have confirmed very good electrical stability even in the pre-series UltraCap modules. As a result, the super capacitor modules developed in the HyHEELs project are suitable for the automotive applications.

A Life Cycle Assessment was done to compare the environmental impact of ultracaps with batteries. The uncertainty analysis was performed through a Monte Carlo analysis. The ultracapacitor scored better than all the assessed battery technologies. The relatively low weight of the super capacitor and the high recyclability rate of its main material (aluminium) are the most important reasons for this. Recommendations were formulated to further improve the environmental performance of ultracapacitors.