EVS-25
Shenzhen, China, Nov. 5-9, 2010

Technology Evolution in Formula Electric and Hybrid Italy

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Abstract

Formula Electric and Hybrid Italy is an annual international competition among student teams of University and Technical Institutes students, exhibiting and demonstrating vehicles developed by themselves, incorporating innovative technological concepts and solutions for Battery electric, Hybrid and Fuel cell vehicles.
The aims are:
The competitive events offer an overview of the advanced technology and trends in the field of electrically propelled road vehicles.
From the beginning in 2005 the technology achievements in the field of battery, hybrid and fuel cell vehicles have been progressively enriched and contributed to introduce new concepts, solution validation, for hint to industrial development and market indication.
The results, achieved with the contribution of student teams of various European, American and Asian Countries, concern innovations and validation in the field of:

- Hybrid propulsion technology, including "plug-in" operation
- Electric power train, including multiple motors drive and new regenerative braking concept
- Application and management of advanced storage systems, Lithium Batteries and Supercapacitors
- Fuel cell vehicle operation.

The operation in team by students on engineering projects, oriented to competition, is a stimulating factor to the innovation and an important element for their technical and cultural formation, in view of their future integration in the industrial world. *EVS25 Copyright*

Keywords— "Electric vehicle","Hybrid vehicle","Technology demonstration","Student competitions"

1. The Technology Demonstration

1.1 Scope and objective of Formula EHI

A considerable contribution for the achievement of new technology solutions and for the validation of innovative system concepts for electrically propelled vehicles is given by the research and development actions performed by Universities and Technical Institutions, acting on the guidelines and support of Industries and Research Institutions.

A concrete example of these actions are the competitive demonstration events of vehicles and projects developed by students, working in team, from the design to the operational tests.

Formula Electric and Hybrid Italy is an annual international competition among student teams of Universities and Technical Institutes, presenting and demonstrating vehicle prototypes incorporating innovative technological concepts and solutions of hybrid, battery electric and fuel cell power train.

The aims are: to stimulate students interest to initiatives and research activities in the field of energy saving, energy effective and environmentally friendly mobility systems, to propose a complement for the technical formation of students and young engineers with practical construction of electric prototypes, to contribute for the assessment of the state of the art and future trends of the technology, to promote possible transfer of technical solutions to the Industry, to establish a platform for exchanging experience and cooperation between Universities and Technical Institutes and, finally, to increase the culture of electrically propelled vehicles, preparing their market acceptance.

Formula EHI was initiated by ATA, the Italian Technical Association of Automobile, in year 2005, wit the denomination of Formula TECH.

From 2005 it took place in different circuits In Italy. A set

of Rules was established, also in coordination with other international competition and the participating teams have been progressively increased.

1.2 The structure of the competition

Three Classes of research exhibits are demonstrated in the events:

- Class 1: sport prototype cars, with formula style
- body, with Electric or Hybrid propulsion systems
- Class 2: vehicles without structural constraints, including two or three wheelers, with electric or hybrid or fuel cell systems
- Class 3: vehicle concepts, components and projects, addressing new technology ideas and considered as bases for future developments.

The competition is deployed in Static Presentation and Dynamic Events.

The evaluation of the outcomes is operated by a jury of experts and the scoring is performed on the basis of merits according to the following criteria:

- Operational performance
- Energy and environmental effectiveness
- Innovation level
- Industrial and marketing aspects

Formula EHI 2009 took place in Roma, at the Center ENEA "Casaccia" and registered the participation of 14 Teams out of 7 international Countries [1]:

- Formula Hybrid Team, from ETH Zurich, with a plug-in hybrid car (Class 1)
- Squadra Corse, from Politecnico di Torino, with a plug-in hybrid car (Class 1)
- Drexel Formula Hybrid, from Drexel University, U.S.A. with a hybrid car with supercapacitor
- TUFHT, from Thapar University, India, with a plug-in car (Class 1)
- ENEA Urbe,from Roma La Sapienza – Roma TRE, with a battery electric vehicle (Class 2)
- CroLITH, form Linkoeping University, Sweden, with a battery electric scooter (Class 2)
- TrecoLITH, from Linkoeping University, Sweden, with a battery electric threewheeler (Class 2)
- PicoFarad Racing Team, from Politecnico di Torino, with an electric vehicle (Class 2)
- H2politO, from Politecnico di Torino, with a low motion resistance fuel cell vehicle (Class 2)
- HyTeam, from Università di Pisa, with a project on advanced fuel cell system (Class 3)
- Hyke, from Università di Padova, with a prototype of electrically assisted fuel cell bicycle (Class 3)
- SYNECTRIC, from Erasmus College Brussels & Vrije Universiteit Brussel; with a project on hybrid car (Class 3)
- PED TEAM, from Roma TRE, with a wheel chair integrating motors in wheel electronically controlled (Class 3)
- ENEA Ginko, from Roma La Sapienza, with a concept car integrating an advanced electric power train (Class 3)

1.3 Innovative technology results

The prototypes and the projects, which have been presented and demonstrated, have offered a wide range of innovative solutions for systems integrated in various types of vehicles and structures, which are here summarized:

1.3.1 Hybrid propulsion systems

Two vehicles externally chargeable (plug-in), with parallel system architecture, and different management concept have been demonstrated:

- Prototype of Squadra Corse of Politecnico di Torino, with manually shifted gear and clutch power transmission (see scheme in Figure 1 and the car in Figure 2)

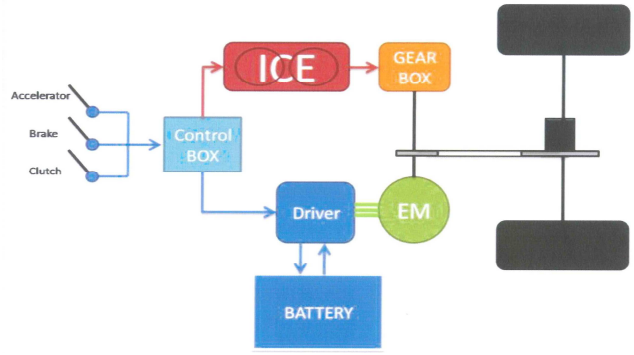


Figure 1: scheme of parallel hybrid architecture with gear box control and clutch

Figure 2: Squadra Corse car during the competition

- Plug-in parallel hybrid by ETH Zurich Team, with speed/power control operated by means of the electric traction motor and clutch (see scheme in Figure 3 and car in Figure 4)

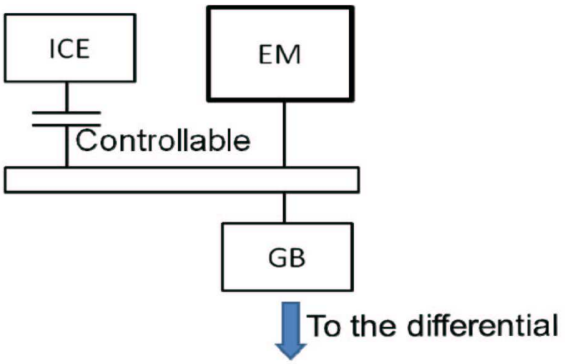


Figure 3: Scheme of parallel hybrid power train controlled by electric motor and clutch

Figure 4: ETH Zurich car on the competition track

Both cars have demonstrated very good operational performance and have been classified at the first and the second place in Class 1.
Two main differences characterize the systems:

- The power/speed control

In the firs case it is performed by variable ratio mechanical gearbox and clutch, operated by the driver. In the second case it is performed through the only control of electric traction motor and clutch. In this case the electric drive covers the function of variable speed transmission and is automatically actuated by the electronic control. The electric drive is based on a permanent magnet brushless motor with an efficiency of over 96% for full load and speed from 2000 and 11000 rpm [1].
The choice of the system design concept involves trade-off between weight/cost of the power train and the overall vehicle energy efficiency, taking also into consideration the ergonomic aspect of driving.

- The sharing strategy between fuel and electricity

The plug-in concept offers the opportunity to establish the appropriate sharing between the use of the two energy vectors through the appropriate management control.
The energy use sharing involves, at the level of system design, the trade-off related to the energy sizing of the battery and relevant weight, tied to mission requirement, the cost of the fuel and the electricity at the utilisation level and also the consideration of the impact on the use of the primary energies and on the environment.

These two cases of hybrid systems are examples of the various approaches that can be considered in the design of the architecture and of the utilisation strategy.
Summarising, the trade-off to be considered are:

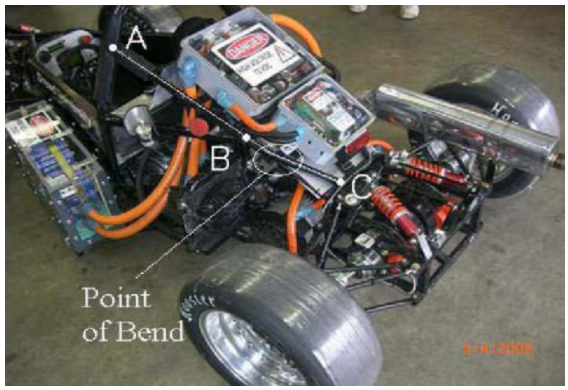
- Weight/Efficiency/Cost of the power train and storage system
- Performance/control ergonomic
- Balance between energy vectors use

The following constraints are meanwhile to be considered:

- The utilisation conditions with respect to the environment area of operation
- The mission profile
- The availability of infrastructure for energy supply
- The priority given to the best utilisation of the primary energy sources

Two hybrid vehicles with series architecture have been presented and demonstrated.

- Prototype by Drexel University, in Class 1 (Figure below)



- Prototype by University of Roma La Sapienza – Roma TRE – ENEA, in Class 2 (Figure 6)

Figure 6: Series hybrid prototype, with supercapacitors, by Roma La Sapienza – Roma TRE – ENEA

Both systems, with series architecture, are making use of supercapacitors as energy storage system.
Also in accordance with the vehicle presentation, the following consideration can be made:

The choice of a supercapacitor bank in a hybrid system, as an alternative to a battery, to be used as a buffer to smooth the power dynamic supplied by the Internal Combustion Engine and to recover the braking energy, involves a trade-off analysis among the parameters characterising the performance and the use feature of the energy storage and the mission and road profile:

- Efficiency of the energy storage over the working duty cycle
- Weight/Volume/Cost
- Cell balancing system
- The continuous use of the generating unit with ICE, including the necessity of start charging the supercapacitors.

1.3.2 Power train

The participating vehicles integrated different types of electric drive and power train.
The electric drive are based on synchronous motors:

- Permanent magnet brushless (ETH Zurich, Squadra Corse Politecnico di Torino)
- DC brushed (Drexel)
- Syncronous reluctance (PicoFarad)

The following vehicles integrate double motors, individually driven by electronic control:

- Series hybrid of Drexel University
- Electric car PicoFarad of Politecnico di Torino (presented as concept in Class 3)
- E - Snack threewheeler of University of Padova (presented in previous editions of EHI) [2].

The system design approach with two electric motors offers the opportunity of releasing the structure from the mechanical transmission constraints and also of contributing to the vehicle handling, through the appropriate coordinated management of the two drives.

1.3.3 Vehicle structure

Formula EHI opens the way to innovations in various technology fields, including the vehicle structure itself.
Class 1 vehicles, which are more oriented to high performance and handling, with constraints related to body structure and dimensions, can offer the opportunity of particular studies on suspensions and lightweight chassis design.
Class 2 vehicles, which are free from body constraints, can stimulate the initiative for studies on structure and body configuration.

Examples in this field are given by the three wheelers, which were presented and demonstrated in the edition EHI 2010 and in previous editions.

- The university of Linkoeping presented a battery electric threeewheeler characterised by a tilting body (Figure 7), with an electric motor driving the rear wheel and the two front wheels connected to hydraulic motors, for recovering the braking energy into an hydraulic accumulator.
- The University of Padova demonstrated in previous EHI editions the E – Snack, a threewheeler with tilting body, with two electric motors directly integrated in the rear wheels [2].

Figure 8: The threewheeler TrecoLITH by Linkoeping University

1.3.4 Studies on low motion resistance

The emphasis given in the competition evaluation to performance and energy efficiency stimulate the teams to give high priority in the design criteria of their prototypes every possible factor to reduce the motion resistance.
A special test is provided in the evaluation to measure the rolling resistance of the vehicles, by making use of a dynamometer and the results are taken into account in the evaluation frame of the Engineering Design.

The aerodynamic resistance is in particular considered in by special structure vehicles demonstrated in the Formula EHI 2010 and inprevious events [3].
The team H2politO demonstrated the IDRA 08, propelled by fuel cell system, supplied with compressed hydrogen, with light weight chassis and low aerodynamic drag body (Figure 9)
Consistently with the new body shape, the steering system and the control command have been studied to match the constraint of the body shape and the light weight with the requirement of safety and ergonomic aspect.

Figure 9: IDRA 08 on the competition track

Various hints and technical solutions can be drawn from the consideration of the vehicle design, which can be taken

as basis for possible development follow up.

1.4 Technology validation

The demonstration given by the competing vehicles offered a validation regarding functional behaviour and reliability of various elements of the electric vehicle technology and regarding the electric and hybrid vehicles operation; in particular:

- Lithium – Ion storage batteries

Lithium – Ion batteries with different types were use in the majority of vehicles, either battery electric or hybrid., showing good level of reliability and management response.

- Plug-in system practice

The externally chargeable hybrid vehicles demonstrated the viability of the plug-in operation procedure and the consequent flexibility of energy management with sharing between electricity and fuel utilisation.

- Electric motors

Design application examples of different types of synchronous motors, with single or double motor solutions, including direct integration of the motor in wheel.

- Supercapacitors

Design solutions and operation for hybrid systems with only supercapacitors as buffer energy storage ere successfully demonstrated.

- Fuel cell systems

Vehicle operation with fuel cell supplied by compressed hydrogen were demonstrated, as a confimation also of previous demonstrations, showing the functional and energy potential of Hydrogen supplied systems.

2. Conclusion

Formula Electric and hybrid Italy, which is yearly organised by ATA since 2005, has been progressively enriched by significant technology results as innovative solutions and validations, demonstrated in vehicles developed by Universities and Technical Institutes student teams.

Formula EHI scope is basically addressing the formation of students and young engineers, in the field of the technology for the sustainable mobility, as a completion of the education in technical and economical disciplines, which are dealt out in the academic courses.
On the other hand, the demonstration of the research efforts and results produced by the Academic World, in coordination with the Industry is a way to increase the sensitiveness and the interest for the ecological vehicles in preparation of their future diffusion.

The challenging targets of the competition constitute important stimulus for the innovation to be pursued in the design and realisation of the prototypes.
Working in team is an effective and productive way for a fertilisation of initiative and the confrontation context of the competition is a hint to further progress in the research.

The various editions of Formula EHI offer an overview on the technology status and on the evolution trends in the area of electrically propelled vehicles.
The technology solutions which are proposed and demonstrated can produce follow-up for industrial application and give indication for future developments.

References

[1] Brusaglino Giampiero, *Advanced Power train Concepts demonstrated in Formula Electric and Hybrid Italy 2009*, IAMF, Geneva, March 2010.
[2] G. Brusaglino, A. Doria, P. Guglielmi, L. Martellucci, M. Razzetti, *Innovation for Ecological Sustainable Mobility in Formula Electric & Hybrid Italy 2007,* EET-2008 / IAMF, Geneva, March 2008.
[3] G. Brusaglino, G. Buja, M. Carello, A.P. Carlucci, C.H. Onder, M. Mazzetti, *New technologies demonstrated at Formula Electric and Hybrid Italy 2008,* EVS 24, Stavanger, May 2009

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