Energy Efficient Vehicles for Road Transport

Road transport alone contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2), the main greenhouse gas[1]. With this in mind the Energy Efficient VEhicles for Road Transport (EE-VERT) project is working towards a 10-12% reduction in fuel consumption and CO_2 generation for conventional vehicles by only implementing minimal changes to existing vehicle platforms. Hybrid Electric Vehicles (HEVs) and Full Electric Vehicles (EVs) currently offer good CO_2 savings, however their market penetration is slow, meaning conventional vehicles are likely to play a significant role for the foreseeable future. Despite improvements in modern conventional vehicles, a considerable amount of energy is wasted due to the lack of an overall on-board energy management strategy. In order to alleviate this; electrifying auxiliary systems and operating them only when needed will generate energy and efficiency gains, however there is an additional need for a coordinated approach towards the generation, distribution and use of the energy. By bridging the gap in the market between current conventional vehicles and HEVs/EVs, EE-VERT offers an innovative solution to this problem. (Figure 1).

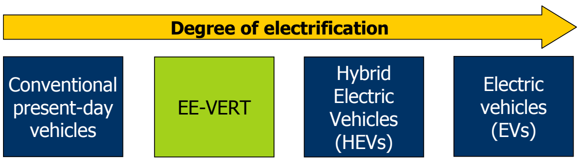

Figure 1 Market gap between present conventional vehicles and HEVs/EVs

Central to the EE-VERT concept is the electrification of auxiliary systems and the supply of their energy (from energy sources such as recuperated braking energy, waste heat recovery or solar cells), forming an overall energy management strategy. With a conventional car using a 14V network, the EE-VERT concept is able to retain the majority of this energy in order to minimise additional costs, furthermore improved efficiency and power is achieved by the generator operating at 40V.

To enable the the elements to the standard electrical system to be connected a new architecture has been devised that works with 40V and 14V levels (Figure 2).

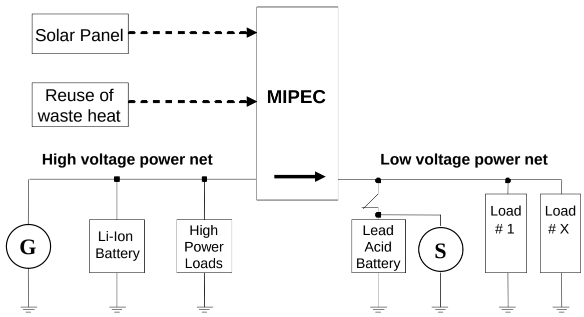

Figure 2 The EE-VERT power net architecture

[1] http://ec.europa.eu/clima/policies/transport/index_en.htm

The main components of the 40V network consist of a new generator based upon claw pole technology with integrated permanent magnets, a Li-Ion battery system and a DC/DC converter with multiple inputs (MIPEC) for interfacing between two separate voltage levels and additional energy sources such as a solar panel. Running the generator at 40V enables up to 10kW of electical power to be recuperated during braking. This energy is stored in the Li ion battery and then used to run the electrified auxiliaries such as the fuel and vacuum pumps.

By selecting Li-Ion battery, MIRA was able to satisfy the key requirements of accepting a 10 second, 10kW charge pulse during recuperation. The main characteristics of this type of battery are shown in Table 1.

Cell capacity and chemistry	8Ah, $LiFePO_4$
Configuration	12 series and 8 parallel
Battery capacity	64Ah
Nominal voltage	40V
Maximum charging voltage	44V
Maximum charging current	250A

Table 1 Characteristics of the Battery

The battery, generator, MIPEC and control unit were integrated into a system test bench by Lear with communications conforming to the automotive standard CAN message-based protocol. After successful tests the main components were transferred to CRF for fitting into the demonstrator car.

Figure 3 illustrates the components that are currently being fitted to the demonstrator car.

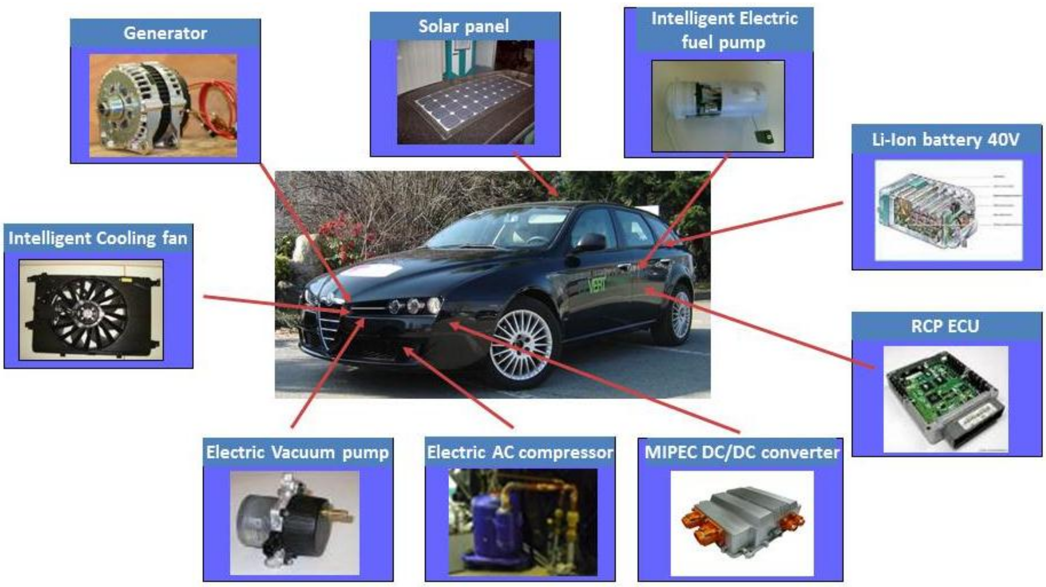

Figure 3 EE-VERT components for the demonstrator vehicle

Although the potential savings for the components are shown in Table 2, the actual savings experienced will be dependent upon the driving conditions, the energy management strategy applied and the behaviour of the driver.

Initial tests with the demonstrator car confirmed savings of 7.5% on NEDC. Simulation predicts savings up to 19%, with more electrified components on real life mission cycles with a high urban content. Table 3 shows the potential fuel savings that could be achieved when all of the auxiliaries are included in the EE-VERT car. EE-VERT closes the gap between conventional vehicles and HEVs at a low incremental cost

EE-VERT Measures	**Comments**	**Benefit range on NEDC**		**Benefit range on mission profile**	
Power Generation		Pessimistic	Optimistic	Pessimistic	Optimistic
Energy recuperation during braking(generator, Li-ion battery, DC/DC)	Recovered energy can supply the basic powernet load of 350W	4.2%	4.2%	4.2%	4.2%
Use of solar energy (Solar panel)	An average power of 100W can be supplied on a sunny day.	0.0%	0.0%	1.2%	1.2%
Electrified Auxiliaries					
Electric engine oil pump	Operation on demand possible. Engine pre-lubrication for start-stop to reduce drag starting ICE.	1.0%	2.0%	0.5%	1.0%
Electric water pump	Optimised thermal management of engine can improve engine efficiency by up to 2%.	0.5%	1.0%	0.5%	1.0%
Engine cooling fan		0.0%	0.0%	1.0%	2.0%
Electric fuel pump	Operation matched to specific demand rather than maximum.	1.0%	2.0%	1.0%	2.0%
Electric power steering	Operation on demand. No hydraulic fluid.	2.0%	4.0%	1.0%	2.0%
Electric vacuum pump	Only operates when required.	1.0%	2.0%	1.0%	2.0%
Electrical actuator for the Variable Geometry Turbocharger	An enabler for vehicles without a vacuum system.	-	-	-	-
Lights (LED)	LED lights have a longer life than conventional lamps.	0.0%	0.0%	0.0%	0.5%
AC compressor, electrically actuated	Operation possible during stop phase.	0.0%	0.0%	2.0%	4.0%
EE-VERT Concept		9.7%	15.2%	12.4%	19.9%

Table 2 Initial assessment of fuel consumption savings

Fuel Consumption (l/100km)	**NEDC**	**Home 2 work**	**Work 2 home**	**Freetime**	**Saturday**	**Sunday**
Reference car	6.82	5.89	5.62	7.78	7.32	5.68
Full EE-VERT Car*	5.51	5.27	5.02	6.32	6.1	5.05
Li-ion battery change in SOC	-6%	-16%	-15%	2%	4%	-1%
Fuel saving	19%	11%	11%	19%	17%	11%

*Full EE-VERT car fitted with electrified Fuel, Vacuum, Water, Oil and Power steering pumps, and an optimized Engine Fan. Operated using only the recovered braking energy to charge the Li ion battery.

Table 3 Fuel savings predicted by the simulation software for the Reference and the full EE-VERT Cars

EE-VERT is a collaborative project: with MIRA taking the role of project coordinator. Split into work packages, each section has a team a leader. The members of the consortium, with their principal roles, are shown in Table 4.

Organisation	**Principal Roles**
MIRA Limited (UK)	Coordinator, Li ion battery, AC compressor testing, Driver behaviour, Impact on safety systems.
Volvo Technology AB (Sweden)	System work package leader, Quality plan, Impact on commercial vehicles, Life Cycle analysis
Centro Ricerche Fiat (Italy)	Requirements, Demonstrator car
Robert Bosch GmbH (Germany)	Components leader, Generator, Vacuum pump
LEAR Corporation (Spain)	Multi-input DC/DC convertor, System test bench
Engineering Center Steyr (Austria)	Novel actuator for VTG turbocharger
FH-Joanneum (Austria)	Simulation software, Solar panels
Universitatea Politehnica din Timisoara and SC Beespeed Automatizari, (Both Romania)	New generator and actuator technologies

Table 4 The EE-VERT Consortium

The EE-VERT project is supported by the European Commission's Seventh Framework programme, grant reference SCS7-GA-2008-218598.
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