Summary

Introduction

Road transport is the second largest producer of greenhouse gases within the European Union. The EC has set targets for the average CO_2 emissions of new vehicles to be 120 g/km by 2012, with further reductions needed to achieve a 40% reduction in CO_2 from light passenger vehicles by 2020. 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. By bridging the gap in the market between current conventional vehicles and HEVs/EVs, EE-VERT offers an innovative solution to this problem. The EE-VERT project has demonstrated an approach that can play a key part in achieving CO_2 reduction goals through a 10-20% reduction in fuel consumption and CO_2 generation for conventional vehicles at an attractive cost-benefit ratio.

Concept

The EE-VERT project has taken a conventional ICE vehicle and with minimum changes produced a prototype “more electric” road vehicle where the vehicle’s electrical energy and efficient management of the energy generation and distribution within the vehicle are the key to achieving the societal improvements expected of road transport, in particular in reducing the carbon footprint of road transport and in permitting the deployment of advanced “eSafety” applications with a guaranteed level of service. In this “more electric” road vehicle, many of the systems such as climate control and steering are powered using electrical energy rather than by the traditional auxiliary mechanical drives from the engine. Even those services that have been electrically-powered for many years will make use of advanced electrical machines to improve the efficiency of energy conversion by the consumers. Furthermore, the generation of electrical energy from the traditional alternator is supplemented by energy recovery from other sources. By combining a network of smart generation and smart actuators, along with an overall energy management strategy, the EE-VERT project has shown that a significant reduction in CO_2 generation by road transport is possible while at the same time paving the way for greater deployment of advanced electronic control systems.

Electrical power in a modern passenger car is generated with little knowledge of the actual loads. Some auxiliary systems (both electrical and mechanical) consume power continually regardless of demand. As more and more electric and electronic equipment is integrated in modern road vehicles to deliver a high grade of functionality, such as driver assistance systems, safety or entertainment systems, this leads to a steadily increasing total energy demand. However, a considerable quantity of energy is wasted due to unused or inefficiently used energy within the vehicle.

The users of passenger cars, who pay several thousand euros or more for a car, expect from their vehicles a high level of functionality but also a high level of safety and dependability. The key requirements for the modern road vehicle are now high functionality, high safety, high reliability, efficient and sustainable use of fuel, and environmental protection. The noticeable climate change effects and the high level of fuel prices along with instability in fuel supplies have led to a heightened awareness of the importance of these requirements. Furthermore with the state-of-the-art solutions, it is often not possible to find resolutions between conflicts in these requirements. For example, guaranteeing the energy supply to safety-related systems traditionally means generating additional power that is wasted for the majority of the operational time of the vehicle. The introduction of systems such as intelligent alternators are first steps towards optimising energy use but they operate in isolation. EE-VERT is developing strategies for overall energy management to reduce fuel consumption and CO_2 emissions, and will tap into new sources such as recuperation of braking energy and solar cells.

The user of a passenger car with EE-VERT technology will find these requirements fulfilled. They will also find some important additional advantages compared to current road vehicles. EE-VERT has developed approaches in conventional vehicles to overall energy management strategies in order to reduce the fuel consumption and therefore the CO_2 emissions. This will not only help to protect the environment but also decreases the fuel costs associated with vehicle use. In addition high dependability in the energy supply will give the possibility to introduce new vehicle systems with even more functionality. X-by-wire systems such as brake-by-wire and steer-by-wire for example are strongly dependent on a highly reliable energy supply. But they also offer new possibilities for advanced and interconnected vehicle safety systems. For all these advantages the energy supply system is the enabling technology, driven and realised by EE-VERT.

The key EE-VERT concept is the electrification of auxiliary systems, operating them demand oriented and supplying their energy by CO_2-neutral energy from energy sources such as extended recuperation of braking energy, waste heat recovery or solar cells, using an overall energy management strategy. To achieve improved efficiency and power, and maximise energy recuperation during braking the generator operates at 40V. To connect the high voltage elements and the lower voltage energy harvesting units to the standard electrical system a new architecture has been devised that works with 40V and 14V levels.

The main components of the 40V network are a new generator based on the claw pole technology with integrated permanent magnets, a Li-ion battery system and a DC/DC converter with multiple inputs (MIPEC) for interfacing between the two voltage levels. The generator power available during recuperation is up to 11kW. This power pulse must be captured by the Li-ion battery. The efficiency of the new generator is above 80% in the low range of speed while in the high range of speed the efficiency is still above 70%. The MIPEC efficiency is around 94%.

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 network in order to minimise additional costs, furthermore improved efficiency and power is achieved by the generator operating at 40V.

Approach

The generator, Li-ion battery and MIPEC were integrated into the high voltage network, firstly on a test bench and later in the demonstrator vehicle. Optimised and electrified actuators including a fuel pump and a vacuum pump together with a commercial electrical AC compressor and a solar panel were also fitted to the demonstrator vehicle. In addition an electric actuator for the VTG turbocharger was developed and successfully tested on an engine and new electric actuator designs suitable for .an AC compressor were evaluated on the test bench.

The safety implications of introducing a dual-voltage architecture were also investigated at length. This work established a systematic process for analysing safety goals in order to derive functional safety requirements. These functional safety requirements are to be applied to both electrical loads within the vehicle and to the underlying electrical architecture and power generation system. Together this partnership forms a ‘safety contract’ to ensure that safety goals (at the vehicle level) are met. Generally, the process used fits within ISO 26262 *“Road Vehicles – Functional Safety”*, as a framework, although this has been expanded somewhat to accommodate new concepts such as the two levels of Functional Safety Requirements and the *safety contract*. These expansions allow the standard to be applied to more distributed systems and systems (such as EE-VERT) which provide a service rather than a vehicle level function.

Results

A simulation software "platform" was developed, using Matlab/Simulink, which models the project reference car, an Alfa Romeo 159. This simulation model is based on specifically developed models for each of the new components mentioned and realistic models for the other elements in the vehicle. The simulation work indicates that average fuel savings of 10% for real life driving cycles and up to 20% when the start and stop functionality is applied to real life urban cycles are possible and that real life urban driving cycles benefit the most from the EE-VERT concept. Fuel consumption results for the demonstrator car validated the simulation work, confirming that the EE-VERT concept can lead to fuel savings of 10-20% depending on the mission cycle for a modest increase in costs.

Partners: MIRA Ltd, Volvo Technology Corporation, Centro Richerche Fiat, Robert Bosch GmbH, Lear Corporation, Engineering Center Steyr, FH Joanneum, Universitatea Politehnica din Timisoara, Beespeed Automatizari

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