Optimal Energy Management and Recovery for FEV

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***Abstract*—This paper briefly describes the latest achievements of a new functional vehicle system to overcome the range anxiety problem of Fully Electric Vehicles (FEV). This is primarily achieved by integrated control and operation strategies to optimize the driving range. The main focus of these control strategies is cooperated electric drivetrain and regenerative braking system. The diverse source of information with on-board and off-board sensors, including navigation system, satellite information, car-to-car, car-to-infrastructure communication and radar and camera systems are primarily utilized to maximize the energy efficiency and correspondingly the range of the FEV.**

Keywords- Energy manager, FEV range anxiety, all electric range, network architecture, control, operation strategies, vehicle simulation, regenerative vacuum free braking, environmental sensors, radar, video, satellite navigation, safety, GPS, car-to-car, car-to-infrastructure, Hybrid Electric Vehicles (HEV).

I. Introduction

Today's Fully Electric Vehicles (FEV) have quite limited driving ranges. To maximize FEV range, and limit range anxiety, considerable efforts are being made e.g. higher capacity batteries and powertrain efficiencies. However, new control, operation, and driving strategies are needed to significantly increase the efficiency, driving range, and safety of electric vehicles. This is to be achieved by the development of an intelligent energy management and recovery system, integrating existing subsystems with on-board and off-board sensors. A particular focus will lie on an optimal cooperation between the electric drivetrain and the regenerative braking system, supported by data from radar, video, satellite navigation, car-to-infrastructure and car-to-car. This will consequently reduce the "range anxiety" that drivers of FEV experience, through the realization of a longer, more consistent, predictable and clearly displayed remaining electric driving range, with the use of highly innovative controller software algorithms.

II. Objectives

The objective of the paper is to show solutions how to achieve maximum energy efficiency and minimize energy losses under all dynamically varying road traffic boundary conditions. Therefore, a new energy manager is needed coordinating the required control and driving strategies. The system provides advanced driver support based on a networked architecture comprising battery management, e-machine, vacuum free regenerative braking, satellite navigation, dashboard displays, whilst integration of the vehicle stability controller and environmental sensing care also for safety issues.

We show a new functional vehicle topology with integrated control and operation strategies to optimize the driving range. This includes the definition of all subsystems to be used by the central energy manager, the E/E architecture and the interfaces for communication and cooperation between the subsystems. Furthermore, advanced human machine interaction solutions are integrated to keep the driver in the loop and to encourage energy efficient usage patterns (see Fig.1).

In order to define a base calibration and adaptation of all subcomponents as well as to setup the coordination and cooperation between the recuperation system, the drivetrain and the regenerative braking system and the vehicle stability controller a cross-domain simulation approach has to be used. Co-simulation of highly diverse subsystems and components will support the simulation on vehicle level including the underlying E/E architecture. The specification of vehicle and powertrain simulation tool chain environment is primarily defined to have confident and functional simulation tools, including co-simulation ability. This environment enables to develop vehicle and system simulation models that allow FEV modeling for intelligent recovery. Then the simulation tools can be used for subsequent up scaling of test results with further simulation.

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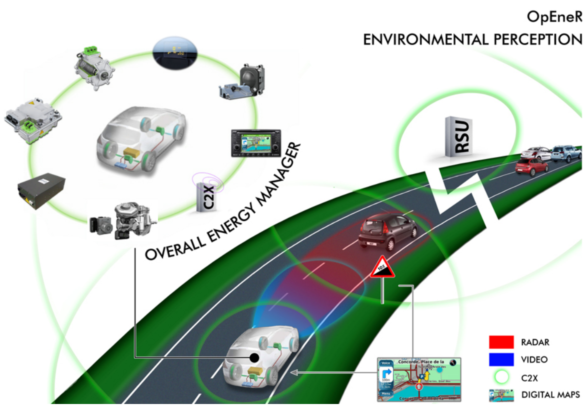

Figure 1. Environmental perception and overall energy manager

III. CHALLENGES

A. Development of a new concept for FEV and the integration of ADAS functionalities

Developed technology aims to unlock the FEV market by increasing the driving range, not by enhancing battery technologies, but by the development of an intelligent energy management and recovery system, integrating existing subsystems with on-board and off-board sensors. The objective is a new energy manager coordinating control strategies to maximize real world energy saving. The system provides advanced driver support based on a networked architecture comprising battery management, e-machine, regenerative braking, satellite navigation, dashboard displays, whilst integration of the vehicle stability controller and environmental sensing care (radar & image processing) also for safety issues.

The technology concepts are currently implemented in two fully operational electric vehicles, which will be tested under real world conditions. The baseline for the new FEVs is a Peugeot 3008 Hybrid, which will be equipped with two e-motors integrated at the front and the rear axle. The system will provide advanced and fully integrated driver support, based on a networked architecture comprising for example, vehicle, battery, e-machine, regenerative braking, adaptive cruise control, and 3D satellite navigation route data, as well as car-to-infrastructure and car-to-car communication and enhanced dashboard and head-up display technologies.

B. Simulation Environment Development for the Optimized Energy Management for FEV

An appropriate and standardized prototype simulation tool chain, introducing all necessary vehicle system information interfaces and the preliminary strategy assessment metrics is needed to develop a well-suited vehicle topology with optimized energy management and the integrated control, operation and driving strategies. The simulation environment prototype is based on powertrain modeling and the modeling of the vehicle, chassis, suspension, wheel, tire, road surface, 3D route and human driver as well as maneuver-based test cases, primary controller and energy management models and is able to co-simulate all aspects together with the underlying E/E architecture in order to include related communication and computation latencies.

The tool chain and the models for simulation of energy efficient driving strategies in relevant driving maneuvers on a vehicle level are defined, set-up, calibrated, tested and utilized. Co-simulation of highly diverse subsystems and components support the simulation on vehicle level. The vehicle and powertrain simulation tool chain is primarily defined to have confident and functional simulation tools, including co-simulation ability. This environment enables to develop vehicle and system simulation models that allow FEV modeling for intelligent recovery including the incorporation of different operation modes of the subsystems to optimize the total energy consumption. The achieved results of the developed simulation environment will be presented during the special session to show the effectiveness of the simulation tools, how certain traffic scenarios are visualized in the simulation environment. Furthermore, first results will be shown regarding the energy manager system integrated to developed simulation environment using restricted sensor infrastructure.

C. Subsystem assessment, System Integration and test methodology

Subsystem assessment is one of the major parts of the development of a FEV. All subsystems to be used by the energy manager within the FEV are defined and specified. Simulation models of subsystem supports to define a base calibration, E/E-architecture as well as the communication bus system. Requirements engineering is widely used for the specification and adaption of subsystems. For the definition and the development of the HMI concept, the most promising state-of-the-art technologies are considered, such as haptic elements, displays (including head-up display), etc.

Interfaces for communication and cooperation between all subsystems are implemented and integrated into the reference vehicle. Coordination and cooperation between the recuperation, drivetrain and regenerative braking system as well as the vehicle stability controller is assured. Based on this, the recuperation strategy depending on the two-motor concept and the provided recuperation efficiency can be optimized.

For the verification and validation of the targeted objectives, driving tests on vehicle level will be carried out, including pilot testing and final testing. For its usage an existing proving ground (including test tracks and intelligent corridor consisting on available enhanced digital maps and car-to-car and car-to-infrastructure communication network) is adapted. A dedicated test methodology is applied to quantify the effectiveness of the implemented system.

IV. CONCLUSION

This paper summarizes ongoing activities to develop new technologies to increase the energy efficiency of a FEV using diverse source of on-board and off-board information to assure the best compromise between efficiency and safety. Consequently, the range anxiety problem of FEV is attenuated through the realization of a longer, more consistent, predictable and clearly displayed remaining electric driving range, with the use of highly innovative controller software algorithms. Furthermore, it will be shown that the developed technologies can be adapted to HEVs and conventional vehicles.