

Development of Electric and Range-Extended Electric Vehicles Through Collaboration Partnerships

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Jochem Wolschendorf, Kevin Rzemien and David J. Gian
FEV Inc.

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ABSTRACT

In the last few years, almost every automotive OEM has announced the development of some sort of electric vehicles. Many of those have already been shown to the public, either as concept vehicles, or as pre-production demonstration vehicles. In order to support the development of this technology, FEV has, over the last 18 months, developed more than 20 different electric, or range-extended electric vehicles. All those vehicles are driving successfully on the road today, either as demonstration or fleet vehicles. The development of those vehicles was only possible through partnerships, and very close cooperation with key suppliers. In contrast to conventional powertrain technology, key components (e.g. battery, traction motor, electric HVAC, inverters) are not yet off-the-shelf technology and need further development and adaptation to the new vehicle concepts. Therefore, the integration of all partners has proven to be key to the rapid development of electric and hybrid vehicle technology.

An overview of some of the vehicles which have been developed at FEV is provided. In most cases, those key partners were already involved in the early concept definition phase. They were continuously involved as the projects evolved, in some cases even co-located into the FEV project center, to ensure best possible communication and resolution of issues.

INTRODUCTION

The electrification of the vehicle drivetrain is rapidly moving forward. Supported - and in some cases triggered - by government incentives, every vehicle manufacturer around the globe has started to develop hybrid and electric vehicles. However, despite all the publicity associated with electric

vehicles, all forecasts show only a relatively small market penetration within the next decade. By 2015, the market share for electric vehicles - even with very optimistic views - will most likely be not larger than 1%. By 2020, this share could climb to 3%.

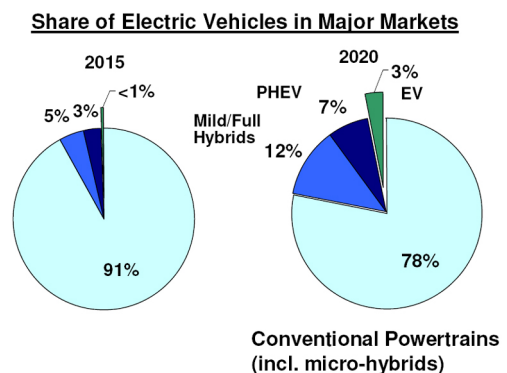


Figure 1. Forecast of Share of Electric Vehicles in Major Markets

Nevertheless, despite the relatively small short- and medium term market opportunities, significant development effort is presently spent on this technology.

TECHNOLOGY

In general, the electrification of the powertrain is increasing rapidly. The introduction of micro, mild, and full hybrid vehicle - with or without plug-in capabilities -, plus the development of full electric vehicles makes it increasingly difficult for the consumer to understand the terminology “hybrid”, and to differentiate between the various technologies. For the purposes of this paper, we are focusing

only on electric vehicles, and range-extended electric vehicles (ReEV).

Whether it is an electric vehicle, or a range-extended electric vehicle, in either case the vehicle is propelled only by an electric motor. The additional combustion engine in the case of the range-extended electric vehicle is only used to generator electric energy via an attached generator (“series hybrid”). This arrangement is different to the conventional drivetrain installation, which has a direct mechanical connection between the combustion engine and the wheels (“parallel hybrid”). Therefore, with the conventional drivetrain, the operating condition of the engine is determined by the road load demand of the vehicle. In contrast, the engine operating condition of a series hybrid can be flexibly chosen, as the engine only drives the generator. Depending on the selected operating strategy, this electric energy is either used for recharging the battery, or is used to directly provide power to the electric traction motor (see Figure 2).

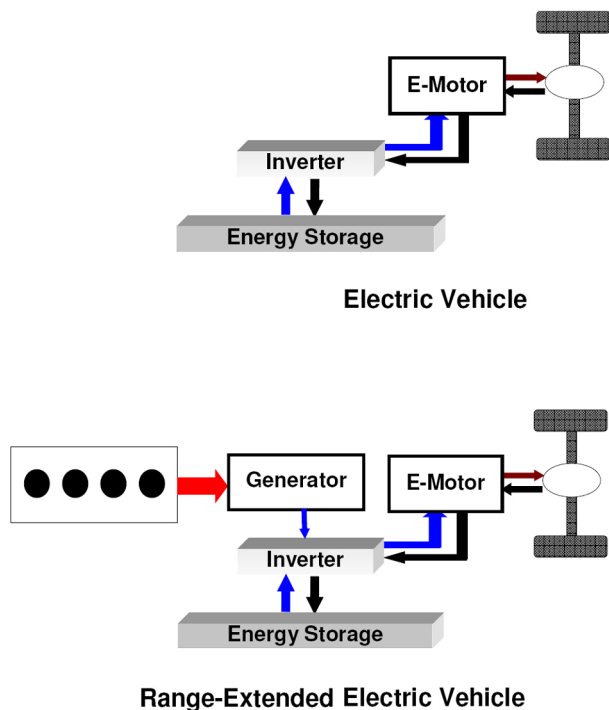


Figure 2. Schematic Layout of Electric and Range-Extended Electric Vehicles

VEHICLE EXAMPLES

Over the last 18 months, FEV has developed more than 20 electric vehicles and range-extended electric vehicles for various customers and applications. All of those vehicles are driving today successfully on the road, either as demonstration or fleet vehicles. Examples of those vehicles are the following pictures.

During the SAE World Congress 2009, the Hummer H3 Range-Extended Electric Vehicle (Figure 3) was shown for the first time. The vehicle was developed in cooperation with Raser Technologies, Inc. It features a 41 kWh Electrovara battery, distributed into 3 modules. Vehicle testing results revealed a more than 40 miles all-electric range for this vehicle. If the down-sized combustion engine is used as a range-extender, the total range is extended to ~300 miles.

- Electric Vehicle with 200 kW motor
- 41 kWh Li-Ion battery
- All-Electric Range ~ 40 miles
- With 100 kW Range-Extender: total range of ~300 miles



Figure 3. Hummer H3 Range-Extended Electric Vehicle

The other end of the spectrum in respect to vehicle size is the Fiat 500 city car (Figure 4), which was also developed as a range-extended electric vehicle. The vehicle features a 12 kWh battery, and gives the vehicle a 60 miles all-electric range. Due to the packaging restrictions of this very small car, the integration of the range-extender module created particular challenges. In addition, experience has shown that the NVH characteristics of the range-extender module is one of the most critical aspects of a ReEV. Therefore, it was decided to use a small 20 kW rotary Wankel engine as a range-extender engine. As this engine is only driving a directly attached generator, the corresponding flexibility allowed the installation under the rear seat (Figure 5).

- Electric Vehicle with 75 kW motor
- 12kWh Li-Ion battery
- All-Electric Range ~ 60 miles
- With 20 kW Range-Extender: total range of ~200 miles



Figure 4. Fiat 500 Range-Extended Electric Vehicle