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Technological aspects of an electrical vehicle powertrain

Karsten Müller[1], Wolfgang Reimann, Ian King
[1] *Karsten Müller (corresponding author) IAV GmbH, Rockwellstraße 16, 38518 Gifhorn, Germany,*
karsten.mueller@iav.de
wolfgang.reimann@iav.de
ian-david.king@iav.de

Abstract

There are a lot of new ideas, new components, and new technologies, which are first introduced into electrical vehicle. Therefore the long-term experiences with these items are still limited. Working more than 15 years in the field of hybrid and electrical cars the authors would like to show, which technological aspects has to be observed in the development and integration of an electrical vehicle powertrain. Beginning from the requirements to the components themselves via the integration of the components into an existing vehicle to the requirements to the verification and validation of the components and the whole vehicle the most important issues are discussed.

Keywords: EV vehicles, HV batteries, powertrain integration

1 Introduction of IAV

Employing over 3.500 staff across the globe, IAV is one of the leading providers of engineering services to the automotive industry. Our core competencies include powertrain, electronics and vehicle development. As a result, we can provide our clients with production-ready solutions for the entire vehicle on a one-stop shop basis. IAV engages in its own primary research, performs its own advanced development activities and works on an interdisciplinary basis. Our clients include all major automobile manufacturers and component suppliers.

As a recognized development partner to the automotive industry, we work hand in hand with our clients in providing solutions for the powertrain of tomorrow that go far beyond conventional concepts or the common approaches in control engineering. IAV consistently applies fully integrated, start-to-finish development processes and tools from the concept formulation stage, in the project management stage and right through to the production-ready solution.

2 Long-term experiences in HEV, PHEV and EV vehicle development

IAV has been developing various Electrical Drive Systems since as far back as 1993 with the presentation of the City STROMer, our first attempt at a full hybrid vehicle based on a series Golf III. Further milestones in our development history were:

- In 1998, in a JV co-funded by Saxony's Ministry of Economics, IAV developed the UNI 1 utilising a single shaft, parallel Hybrid.

- In 1999 we supported the delivery of the Lupo 3L vehicle to the market utilising an electric motor pared to a small SI engine to achieve an average fuel consumption of 3L/100km.
- In 2001, IAV presented VW's Chairman, Dr. Ferdinand Piëch, with a new concept vehicle capable of 1L/100km. The concept never reached production at the time but series development has been recently re-activated.

Being a Creative Solutions company, IAV currently supports various series and concept development projects in the field of HEV, PHEV and EV worldwide.

3 Motivation of an electrical powertrain

There are various reasons pushing the development of "Alternative Drive Systems" including governmental and environmental regulations regarding the amount of emissions produced and the preservation of precious natural resources. These factors have been apparent for a number of years and engineers have been striving to find viable solutions suitable for consumers. The most popular and series-ready of these ideas has been Hybrid technologies. The most famous and successful has been the Toyota Prius introduced to the market in 1997 utilising a FULL HYBRID SYSTEM. In the years after the launch of the Prius more and more companies have introduced various HYBRID SOLUTIONS and even more are planned.

As pressure on our resources increases so does the pressure on the market to change its current philosophy and endeavour to increase the reliance on Electrical Drive Systems.

4 Technological requirements

What does it mean to make an Electrical vehicle? Do we just buy an electric motor from the market, bolt it on to the wheels, connect a battery and press the go button? Unfortunately not. There are three aspects to take into account:

1. The components themselves
   - Energy storage – battery or other electricity storage device
   - Energy Transfer system – transferring power in both directions between the storage device and the motor
   - E-Motor – possible to provide drive (or Torque) and generate electricity
   - Power Transmission – a method to deliver the torque to the vehicle in a useable and controlled manner.
2. Integrating these components into a passenger vehicle and meeting the various passenger and pedestrian safety requirements or governmental requirements
3. Validating these components to ensure the durability and safety once in a vehicle as well as the interaction with the systems currently used in passenger vehicles today.

5 Requirements of the components

There are some overall requirements for all components used in a passenger vehicle, i.e.:

- High efficiency in the working area
- Optimised size and weight/power ratio
- Robust and durable in vehicle usages
- Package for available room
- Electrical and functional safety
- Low cost

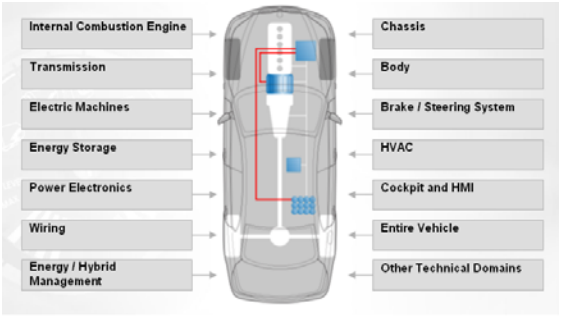
Additionally there are further component specific requirements for the special application of the components by installing them into a passenger car, i.e.:

- E-Motor: Low moment of inertia, overload resistant
- Power electronics: High max. temperature, overload resistant
- Battery: Light weight, package flexibility, large storage capacity, quick charging time, cycle resistant, resistance to high working temperatures, cooling management, puncture resistance, non-flammable, non-corrosive…

It is easy to see that the requirements to the batteries are very high. Therefore the price for that component currently determines the speed of propagation of full Electrical powertrains. The industrialisation of LiIon-Batteries in conjunction with new technological or business models of vehicle usage by the customer (i.e. vehicle to grid integration, battery or car leasing, vehicle distribution models etc.) are essential to lower the barriers allowing full electrical powertrains to enter the markets at entrance level prices.

6 Requirements of the integration

The difficulties of developing a hybrid or an electric vehicle don't just stop with the selection or design of the various components. A number of other, mainly existing, systems are also reliant on the engine. This picture shows the effects of the hybridisation of an existing car:



In principle all of the mentioned systems (except the internal combustion engine and possibly the transmission) must be adapted for a whole electric vehicle, too. So it needs a system approach and an interdisciplinary cooperation of body & white designers, crash, chassis (due to the high load) and electric and electronic experts to find practical solutions for the overall system changes. Some of these approaches, successfully used in several projects, are:

Internal Combustion Engine

- Engineering of the Base Engine and all Accessory Systems
- DMU, Design, Prototyping, Testing and Calibration
- Engine Controls (HW, SW, Strategy)

Hybrid Transmission

- AT, AMT, DCT, e-CVT, etc.
- Design, Calculation and Prototyping
- Transmission Controls (HW, SW, Strategy)

Electric Machines

- Concept, Design and Prototyping
- Package and Cooling
- Controls (HW, SW, Strategy)

Power Electronics

- Inverter
- DC/DC Converter
- Cooling
- Controls (HW, SW, Strategy)

Entire Vehicle

- Body in white
- Component package
- Crash / Safety
- Suspension

HVAC

- Heating System
- Ventilation, Cooling, Air Ducting
- Air Conditioning System
- Alternative HVAC Systems and Coolants

Energy Storage

- NiMh, Li-Ion, Ultra-Caps
- Battery Control
- Cooling / Conditioning
- Mounting and Assembly Strategy, Simulation, Design, Testing

Break System / Recuperation

- Performance and Strength
- Powertrain Interface, Drag Control
- ‚Active' Brake Pedal / Booster, Force Feedback

Energy and Hybrid Powertrain Management

- Complete System Architecture
- Simulation
- Hardware, Algorithms and Software
- Calibration and Testing

Wiring

- High Voltage Harness
- Low Voltage and Signal Harnesses
- Connectors, Relay and Fuse Boxes
- EMC and Safety

Cockpit and HMI

- Indicators, Gauges and Switches
- Infotainment System
- Pedals, Gear Lever and Actuators

Steering System

- EPS / EHPS
- System Integration inc. Stop/Start Sensor
- Testing and HIL

7 Requirements of the validation

Another very important point for the market penetration of electric vehicles is the legal release process. A special consideration must be made to the safety and robustness requirements. Therefore the components must be tested and validated to ensure the durability and safety as well as the functionality.

In order to test these new types of components, new test equipment must be developed.

The motor for example, has high torque and high rotation speeds. Current engine dynos cannot safely and accurately assess the E-Motors and therefore IAV has had to develop specific test benches and test equipment to carry out the validation. Not only are the speeds and power requirements important but the high voltages provided by the E-Motors must also be validated and that calls for specific equipment to accurately measure the characteristics of these machines.

Even more efforts must be made for testing the battery systems. Monitoring of the energy flow (charge and discharge) must be performed to ascertain which battery cells meet the defined requirements. IAV has created such a bench that can measure the performance of individual cells or complete battery packs. All major types (Lead, NiMh, LiIon) batteries can be tested with the similar apparatus. The requirements for the buildings where the test benches are installed are enormous.

The test benches are not just used to ascertain which batteries best suit the customer requirements but also to determine the full characteristics of various available batteries and to build up a catalogue of data. Important characteristics such as charging quality after x-number of cycles is also collected ensuring that not just the customer requirements are met but also how the system will work over its' life time.

Other tests required for passenger vehicles are also carried out in these laboratories. The "Nail Test" is carried out, where a nail is inserted into the battery pack to see what happens when the pack is punctured. Due to the chemical properties of the cells is it important to know if the packs will combust, leak poisonous gasses or leak corrosive liquids. Another test is the "Pressure Test" where the pack is put under extreme pressure (as would happen in a crash) to see the effects. Again, these tests cannot be carried out in a standard workshop, a controlled and safe environment must be created to ensure that the tests are repeatable, accurate, comparable and most of all, safe for the workers.