Hybrid electric vehicle (HEV) production is projected to reach upwards of two million vehicles worldwide in the next few years. In the U.S., HEVs may account for 5-10 percent of total vehicle sales by 2015. HEVs are not only seen as a key means to achieve higher fuel economy, but also to reduce our dependence on fossil fuels as well as to reduce carbon emissions. However, in order to achieve these goals, HEVs have to rely on complex electronic controls. In this article, we highlight some of the issues faced by U.S. OEMs during the development of electronic controls and also make recommendations that can help in solving some of those issues.

Typical HEV controls development process

The challenge of building an efficient, economical and attractive HEV is daunting. That explains why OEMs that normally compete with each other are now working together to develop hybrid powertrains. The key factor in the rapid market success of HEVs is that OEMs were able to add this new technology to existing powertrain products without major redesign or tear up. HEV development, however, depends on the level of hybridization (i.e., micro, mild, or full hybrid) and the type of configuration (i.e., series, parallel, or split).

The development process typically starts from a concept (level, configuration) that is then simulated using tools (e.g., PSAT, Simulink® models, GT-DRIVE, DYNA4 from TESIS, etc.) specifically designed for HEV development. During this step the HEV components, including the IC engine, are sized and the layout of the transmission planetary gears is determined, while key parameters like driving performance, fuel economy, and emissions are optimized. This process also delivers important data about the battery charging and discharging cycles, brake energy regeneration, and transmission gear changes, which is useful in the initial development of control systems for the HEV subsystems. Simultaneously, OEMs select the ECU architecture for the HEV. In some cases, existing ECUs have to be updated in order to accomplish additional HEV-related tasks, while in other cases a new ECU may be needed to properly control the entire system. A typical HEV ECU architecture is shown in Figure 1.

In most cases, HEV controls development is synchronized with existing gasoline/diesel ECU development. The engine control module (ECM) for HEV applications consists of approximately 80 percent base ECM code and 20 percent hybrid-related code (e.g., to handle features like start/stop, regenerative braking, power modeling, etc.). The additional hybrid features are mostly hand-coded by a dedicated group of HEV-knowledgable software engineers. Similarly, most of the software development for the hybrid control unit (HCU), and the battery and motor control units (BCU, MCU) in the first generation of hybrid vehicles has been done manually. This was necessary because of immense time pressure on those programs, and made possible because of availability of resources and prototype vehicles to quickly test and validate the concepts. Therefore, most OEMs did not follow the standard V-cycle for ECU development for the first generation of HEVs. Model-based development was not fully leveraged, rapid controls prototyping techniques were not used as much and Hardware-in-the-Loop validation was used sparsely.

Issues faced by HEV controls developers

Since the V-cycle was bypassed for HEV software development, this left engineers with a lot of “clean-up” tasks. As an example, HEV engineers took ownership of the ECM code and modified it themselves, bypassing the central software development process and creating variants of ECM code that were outside the mainstream. As HEV development moves into the mainstream powertrain development process at most OEMs, these ECM variants need to be integrated back into the standard process. This requires converting the manually-coded HEV strategies to graphical models so that automatic code generation techniques may be used and models may be reused for future programs. Moreover, HEVs can then also benefit from future advancements in gasoline/diesel technology.

Some of the other issues faced by HEV engineers arise from the complexity of the HEV system architecture – with several ECUs added for controlling the electric motors, battery, and generator/inverter. Testing each ECU in its real-world environment and testing the interaction of ECUs over the CAN network is itself a challenge. In addition, HEV development is distributed over several groups – each with their own expertise, toolssets, and processes.

Recommendations

Several ETAS tools can help ease the transition from the first generation of HEVs to the next. See Figure 2 for a process layout with ETAS tools.

INTERCIO offers a powerful solution of desktop co-simulation between different modeling environments – e.g., Simulink®, AMESim, GT-POWER, CarSim, etc. It also provides a way to easily validate the functionality of manually developed C-code against that of automatically generated code from RTW-eCoder, AScET from ETAS, or third-party code generators. Finally, with our partner product INCODIO, HEV developers can bring their existing C-code into desktop and rapid prototyping environments. INTERCIO, therefore, offers a very flexible environment to accomplish a variety of Model-in-the-Loop (MIL), Software-in-the-Loop (SIL), and prototyping tasks. It is of tremendous advantage when moving towards integrating HEV-specific code into the standard development process.

The XETK ECU interface offers a unique way to instrument a cluster of ECUs and connect them to a PC over an Ethernet network. This is ideal for HEV applications and reduces the instrumentation hardware costs significantly. The XETK interface may be used for calibration and rapid controls prototyping purposes, and is designed for data capture rates typically needed in HEV development.

The ESP10 prototyping hardware can be used for in-vehicle development of advanced HEV strategies via the INTERCIO environment using the bypass methodology.
The high computational power of the ES910, combined with the variety of ECU interfaces (ETK, CAN, FlexRay) and protocols (e.g., XCP-on-CAN) supported a flexible platform for HEV development. Customers can execute HEV strategies developed in Simulink® directly on the ES910, while communicating with the ECM or TCM via ETK or CAN.

The INCA measurement and calibration software allows not only the in-vehicle calibration of ECU software via the ETK or CAN interfaces, but also the desktop calibration of ECU strategies integrated with plant models using INTECRIO. Using INCA, HEV developers can seamlessly develop and calibrate new strategies on the PC, on the ES910 rapid prototyping hardware, and then on the ECU.

The seamless ETAS tool chain makes the transition to the next generation of HEV development straightforward. Worldwide ETAS support and engineering services make integration of the tools into customer processes even easier.

ETAS and TESIS DYNAware Sign Cooperation Agreement

For quite some time, ETAS GmbH and TESIS DYNAware GmbH (Munich) have provided dedicated hardware and software for the development of electronic control units (ECUs). Both companies have recently entered into a partnership agreement, with the express purpose of close cooperation in the development of products and services in the areas of Hardware-in-the-Loop (HiL) simulation, real-time simulation models, and function development (MiL/SiL). The declared objective is to vigorously promote the continual product refinement of attendant solutions in close coordination with corporate customers over the long term.

TESIS DYNAware provides real-time simulation software for engine and vehicle dynamics (enDYNA, veDYNA, Realtime BrakeHydraulics, and DYNAanimation). This comprehensive simulation framework for virtual test drives in the lab covers all phases of ECU and component development. In addition, TESIS DYNAware provides consulting and support services to determine solutions for sophisticated simulation tasks.

Both parties to the agreement are convinced that the newly forged partnership translates into a significant added value to customers on both sides. As global players on world markets, both ETAS and TESIS DYNAware continue to consolidate and expand their respective worldwide market shares. Dr. Cornelius Chucholowski, CEO of TESIS DYNAware, perceives the partnership as a natural response to the demands of everyday practice: “Our customers are looking for applications both flexible and reliable, not only with regard to simulation software but also in the context of the smoothest possible interaction with the hardware involved. And precisely in this area our partnership provides exactly what is needed.”