Hardware-in-the-Loop-Testing of Control Units for Dynamic, High-Precision Electric Drives

03/02/2015

Authors: Andreas Himmler

Publication MEA 2015 More Electric Aircraft

OAI: oai:www.see.asso.fr:10638:20100

DOI:

- Document accessible sous conditions - vous devez vous connecter ou vous enregistrer pour accéder à ou acquérir ce document.
- Accès libre pour les ayants-droit

Abstract

Collection

Hardware-in-the-Loop-Testing of Control Units for Dynamic, High-Precision Electric Drives

Authors
La SEE (Société de l'Electricité, de l'Electronique et des Technologies de l'Information et de la Communication – Association reconnue d’utilité publique, régie par la loi du 1er juillet 1901) met à la disposition des adhérents et des abonnés à ses publications, un ensemble de documents numériques accessibles à partir de son portail des publications. Ces documents incluent notamment les articles des revues REE, 3 EI et e-STA disponibles sous forme numérique ainsi que des publications additionnelles regroupées dans l’espace eREE. Les présentes conditions précisent les conditions de diffusion et d’utilisation de ces documents et des informations qu’ils contiennent. L’accès à ces documents, qu’il se fasse de façon gratuite ou dans le cadre d’abonnements ou d’achats faits à titre onéreux, implique l’acceptation sans restriction de ces dispositions.

Droits de propriété et de diffusion des contenus télé chargés sur le portail des publications

Les contenus rendus accessibles sur le portail des publications sont, en règle générale, protégés par le droit d’auteur. En tant que producteur, et le cas échéant d’auteur, des informations rassemblées dans les contenus accessibles par ce portail, SEE se réserve l’exclusivité des droits de copie et de diffusion de tout ou partie de ces contenus.

Les contenus sont rendus accessibles à titre individuel, pour les besoins de la personne en détenant des droits d’accès en cours de validité. Aussi, la modification, la reproduction et/ou la diffusion via Internet ou le Web, intranet, extranet ou toute autre forme numérique ou imprimée, de tout ou partie des contenus téléchargés sont interdites. Une tolérance est consentie quant à la reproduction d’extraits limités de ces contenus, dans le cadre de travaux ou d’activités auxquels ils sont utiles, à la condition que l’origine de ces reproductions partielles soit mentionnée de façon lisible et sans ambigüité. Figurent en particulier : la REE (ou toute autre revue accessible sur le portail) en tant que la source, la référence de la publication et le nom de l’auteur (s’il figure dans la revue).

Ces dispositions s’appliquent également aux figures, illustrations, logos ou images.

Publication externe des contenus du portail des publications

Tout extrait des contenus du portail destiné à être utilisé dans des publicités, des communiqués de
presse ou du matériel de promotion nécessite un accord préalable écrit de la SEE. Une version préliminaire du document proposé contenant ces extraits doit accompagner chacune de ces demandes. SEE se réserve le droit de refuser un tel usage externe pour quelque raison que ce soit.

Responsabilités

La SEE apporte tout le soin possible à la préparation des informations délivrées dans les contenus produits. Cependant elle ne peut être tenue pour responsable d'aucune perte ou frais qui pourrait résulter d'imprécisions, d'inexactitudes, d'erreurs ou de possibles omissions portant sur des informations publiées, ni des résultats obtenus par l'utilisation et la pratique des informations délivrées.

Utilisation des informations recueillies lors du téléchargement de contenu

Le portail des publications est susceptible d'utiliser des « cookies » afin notamment de permettre l’utilisation de paniers d’achat et de personnaliser les parcours sur le site. SEE se réserve la possibilité d’utiliser les informations recueillies lors des téléchargements pour ses besoins internes et notamment pour l’amélioration de ses services, sans qu’elles puissent être cédées à des partenaires commerciaux. Conformément à la loi "informatique et libertés" du 6 janvier 1978, chaque utilisateur du portail dispose d’un droit d’accès et de rectification aux informations qui le concernent. Pour exercer ce droit, les utilisateurs doivent s’adresser à SEE – 17 rue de l’amiral Hamelin – 75783 Paris Cedex 16, par simple lettre ou en utilisant le formulaire de contact disponible sur son site.

Paris, le 28 avril 2013

Sponsors

Organizers

Sponsors
Hardware-in-the-Loop-Testing of Control Units for Dynamic, High-Precision Electric Drives

Dr. Andreas Himmler
dSPACE GmbH, Rathenaustraße 26, 33102 Paderborn, Germany, ahimmler@dspace.de

Abstract

The More Electrical Aircraft (MEA) means the replacement of traditional hydraulic fluids and compressed air to drive non-propulsive aircraft systems. Electrical systems are often favourable due to a significant reduction in weight and therefore fuel consumption. They also often bring benefits with regard to performance, integration and maintenance. However, the MEA is a challenge to the design, development and testing of the electric actuator technology. Two fundamental components in this are the electric motor and associated electronic controllers. Especially the development of controllers for dynamic, high-precision control units is challenging for HIL simulation of electric. This paper focusses on an advanced hardware-in-the-loop (HIL) technology that requires the signals to be calculated and output much more frequently than once per PWM cycle. Besides the technical challenges user friendliness of tools and the efficiency of workflows need to be taken into account. Introduction Over the last few years, electrical drives have become more widespread, not only in vehicles but also in the fields of drive and automation technology. In the future, electric drives will be increasingly used in aircraft. The term 'more electrical aircraft' (MEA) has been coined to describe this trend toward replacing pneumatics and hydraulics for an aircraft's secondary power needs with power from electric generators. The objective is to produce more eco-friendly and economical aircraft. In automotive applications, electric drives are already being integrated into fundamental, complex and safety-related vehicle functions. Some well-known examples are hybrid or purely electric vehicle drives; others are electric steering systems, electric brake systems, and auxiliary aggregates (oil pumps, water pumps, etc.) This paper describes today's state-of-the-art technology for developing and testing electric drives. Further the challenges that electric drives pose for hardware-in-the-loop (HIL) tests of electric drive Electronic Control Units (ECUs) will be described. These challenges are similar across the spectrum of applications and industries. This paper also describes the tools required to test electric actuators with sophisticated real-time simulations: HIL hardware (incl. FPGA I/O boards) and software, fast electronic loads that can act as both current sources and current sinks, and real-time simulation models for FPGAs and standard processors. Examples of applications are also discussed. HARDWARE-IN-THE-LOOP-SIMULATION OF ELECTRIC DRIVES A general challenge for the HIL testing of electric drive ECUs arises from two fundamental system properties: The ECU has to control the drive power directly and that the system dynamics are very fast. This is unlike ECUs for other types of actuators that regulate the thermodynamic or hydraulic power. Fig. 1: Hardware-in-the-loop simulation The HIL testing of electric drive ECUs is particularly challenging if the controller signal level (see the Fig. 2) interface is not accessible to stimulate controller inputs for testing purposes because then the entire real electric power transients and dynamics have to be included in the tests. These real power dynamics can be included if the real actuator's electrical and mechanical components are part of the test setup with capability to control its loading effects or if a dynamic electric loading capability is available. In many cases, these are the only ways to test a production ECU with its real interfaces as the controller part and power electronics drive electronics are part of a single, integrated unit. Using mechanical components in a test setup has inherent limitations on ability to perform failure and error testing, and such test setups are difficult to handle, expensive, and inflexible. On the other hand, comprehensive tests are feasible if the fast electronic loads that represent the load behaviour of the electric drive are included in the test setup. In performing system software testing at signal or power level, electric motor simulation is a necessary component of the test setup. The fast dynamics of electrical system characteristics require very fast computation of simulation model in order for the ECU and test system to operate meaningfully in a closed-loop manner. The model computation has to be synchronous to the control signal (PWM) operating at very high speeds ranging from 10-20 kHz commanded by the ECU. Fig. 2: Interfaces for HIL tests of electrical drives ADVANCED HIL SIMULATION OF ELECTRIC MOTORS The development of controllers for dynamic, high-precision electric vehicle ECUs is sometimes beyond the scope of conventional HIL simulation of electric drives. An advanced real-time simulation requires the signals to be calculated and output much more frequently than once per PWM cycle. This can be achieved by running not only the I/O model on the FPGA but also the entire plant model, since FPGAs achieve very high sampling rates. Low harmonics can be ignored with this approach, even without synchronization. In comparison to processor-based models, the measurable latency between the hardware input and hardware output is typically reduced from 25 to 30 µs to about 1 µs. The simulated current values are output every 100 ns. Together, all of these factors lead to a significantly more precise and more stable simulation. Such a high-resolution simulation makes it possible to simulate the PWM-induced current ripple in inductances, improve the precision of the simulation of high frequencies, and represent the closed control loops with a simulator exactly and stably. In addition, using FPGAs also simplifies the real-time representation of the nonlinear effects of power electronic components. Fig. 3: Different sampling strategies: synchronous sampling vs. oversampling Fig. 4: Simulation of the current ripple of a permanently excited synchronous ELECTRONIC LOAD MODULES The HIL emulation of electrical machines, such as motors or generators, requires electronic load
modules. They need to work as both a current sink and a current source to provide bidirectional current flow, i.e., generating or consuming real current on ECU motor outputs. In addition, they need to be optimized for high-speed operation. The concept of an electronic load emulator can be used for simulating all types of motors. The physical properties of each motor, such as motor inductivity, torque generation and power consumption, are represented very realistically. For variable inductivities (such as in an interior permanent magnet (IPM) motor, or with saturation effects), mean values have to be used in the load emulator due to the constant substitute inductivities. Nevertheless, correct representation of the torque and the power is possible. EXAMPLE: HIL SETUP FOR FPGA BASED SIMULATION ON SIGNAL LEVEL Figure 4 shows the block diagram for FPGA based HIL simulation for electric drives. The real-time model of the electric motor and the inverter are running in an FPGA, as well as the I/O models. In this setup, the real-time processor usually runs those parts (i.e. simulating the mechanics of an electric drive) of the real-time plant model, that are less demanding concerning turn-around times and latencies. Fig. 5: Block diagram of FPGA based HIL simulation of electric motors Figure 5 shows the hardware and software for the setup shown in Figure 4. The HIL technology needs to fulfill technical requirements, like an I/O network ensuring short latencies between the real-time processor and the FPGA-based I/O board. In addition, the technology also needs to support tools and workflows for model-based development and eases the use of FPGA-based models within the Matlab/Simulink workflow. Fig. 5: Hardware and software for FPGA based simulation of electric motors CONCLUSION This paper describes requirements and solutions to test electric actuators with sophisticated real-time simulations: HIL hardware (incl. FPGA I/O boards) and software, fast electronic loads that can act as both current sources and current sinks, and real-time simulation models for FPGAs and standard processors. Examples showing state-of-the-art applications of electric drives are also discussed. References 1 Himmler, A., “Hardware-in-the-Loop Technology Enabling Flexible Testing Processes”, 51st AIAA Aerospace Sciences Meeting including the New Horizons Forum and Aerospace Exposition, Grapevine (Dallas/Ft. Worth Region), Texas, 2013, doi:10.2514/6.2013-816. 2 Himmler, A., Allen, J., and Moudgal, V., "Flexible Avionics Testing - From Virtual ECU Testing to HIL Testing", SAE 2013 AeroTech Congress & Exhibition, Montreal, 2013, SAE Technical Paper 2013-01-2242, 2013, doi:10.4271/2013-01-2242. 3 Himmler, A. “Openness Requirements for Next Generation Hardware-in-the-Loop Testing Systems”, AIAA Modeling and Simulation Technologies Conference, National Harbor, Maryland, 2014, doi:10.2514/6.2014-0636. 4 Schütte, H., Wälttermann, P., “Hardware-in-the-Loop Testing of Vehicle Dynamics Controllers – A Technical Survey, SAE Technical Paper [online database], Paper 2005-01-1660.

https://www.see.asso.fr/en/node/20100/landing