The compact controller

PP D104: A low-end extension to the AC 800PEC Control Platform

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We are surrounded by electronic devices of all types and descriptions, and expect these to perform autonomously and correctly. In power electronics, the demands on such devices are especially tough. The time domain, which must be handled, ranges from nanoseconds for the triggering and monitoring of the individual switching actions to seconds for long-term operational transients. Designing a single, slim and efficient controller to handle all this is no easy task.

ABB's AC 800PEC controller was designed specifically with such applications in mind. The model can flexibly be adapted to handle different time domains and code can efficiently be created from Matlab/Simulink™ models.

The processing unit inside the early AC 800PEC controllers was the PP D103. However, specifically targeting smaller systems where both space and costs are critical, ABB has produced a new controller based on the PP D104 processor – an ultra-compact device taking up less space than a credit card.

Converters

In 2002, ABB introduced its high-end control platform, AC 800PEC, to target the important field of high-performance control.

The market required a combination of several features:
- High processing power
- Short cycle-time (<100 µs)
- Fast time-to-market for applications
- Suitable for small series
- Industrial grade hardware
- High integration of devices

Principle of AC 800PEC

The AC 800PEC is a powerful control platform. On the hardware side, it combines the floating-point computing performance of the CPU with the high-speed flexibility of an FPGA.[1)] On the software side, it combines the system design capabilities of ABB's Control[IT] with the application control and simulation capabilities of MATLAB/Simulink™ (from The Mathworks®).[2)]

From a user's perspective, the system is separated into three levels, representing different tasks in the development life-cycle of a product:

System engineering (Level 1)

ABB's Control[IT] is based on the IEC61131-3 programming language and uses ABB's Control Builder as programming tool. This is the level on which system engineers implement functions not demanding real-time performance but needing to remain flexible during the lifecycle of the product/system. Another important attribute of this level is the integration of the AC 800PEC controllers in ABB's 800xA system. AC 800PEC controllers are integrated by means of "800 Connect," which provides native access of 800xA nodes to the application entities within the AC 800PEC controller.

Product development (Level 2)

Fast closed-loop control applications are programmed using MATLAB/Simulink. C code is then generated from this using MATLAB/Simulink's Real-Time Workshop. This is compiled to an executable code using a C-Compiler and then downloaded to the controller device where the control application will start immediately after the controller is started-up. If the control application is part of a large control system requiring the presence of a Control[IT] IEC61131-3 application, engineering will supervise the execution of the fast control application.

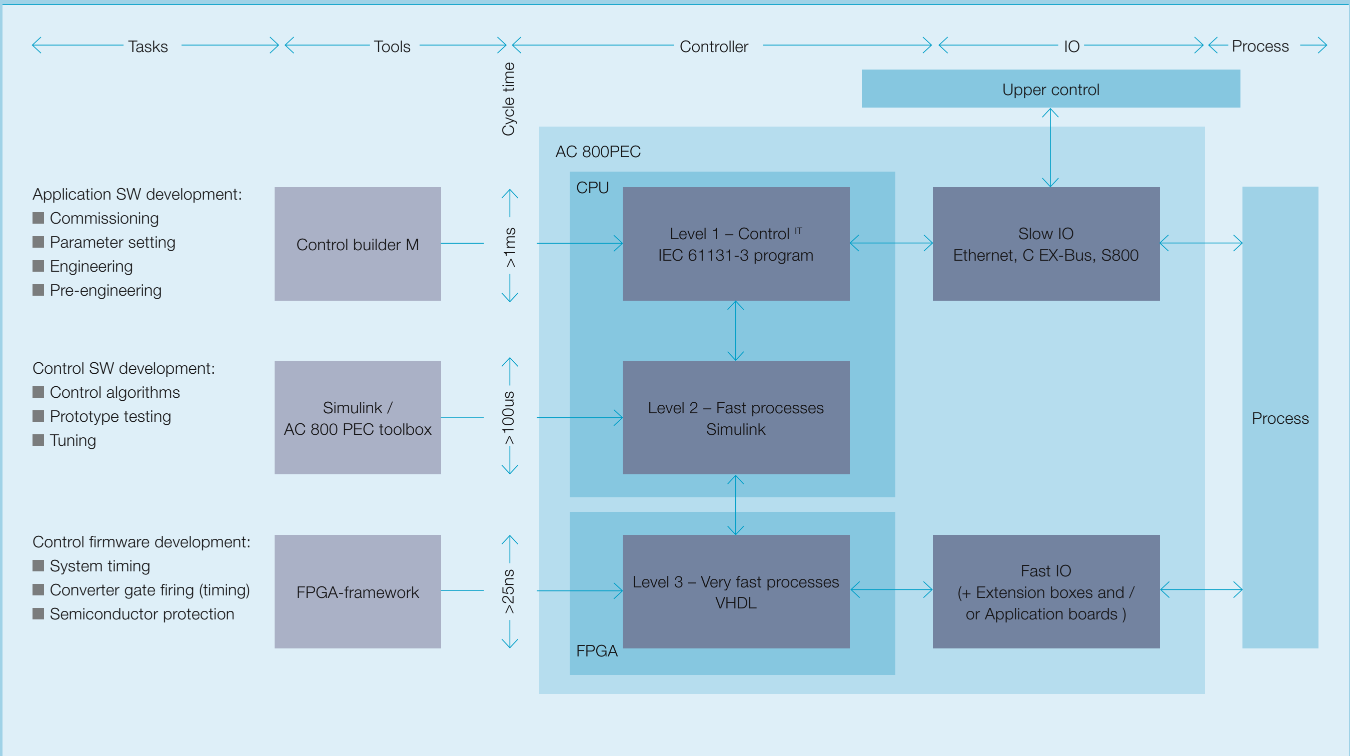
Typically, control developers will implement the control, the protection, the state machine and other algorithms on this product level. An important aspect to note is that this fast closed-loop control application runs in parallel with an 1131 application (from Level 1). Control engineers and system engineers can exchange signals in either direction via an efficient software interface. This interface is realized using a standard Control[IT] Protocol handler.

The devices of the AC 800PEC platform can be integrated into an 800xA system, thus allowing plant-wide data exchange and control.

Technology development (Level 3)

Very fast processes are programmed in VHDL.[3)] Protocols and some control logic requiring very short cycle times are implemented on Level 3. In many cases, suitable code already exists that can be combined according to the customer's need.

1 Structure of AC 800PEC control platform and solutions implemented using its technology



2 Typical PP D104 based controller box with integrated I/O

Levels 1 and 2 can access the signals (realized as a dual port memory) and specific blocks. In Control IT, the so called "FPGA Protocol handler" was developed to allow intermediate access to the fast signals of the I/Os. This feature is intended primarily for very fast peer-to-peer communication of AC 800PEC controllers (in the range of a one to few milliseconds).

In addition, the devices of the AC 800PEC platform can be integrated into an 800xA system, thus allowing plant-wide data exchange and control. It is important to note that the two controller modules described below use a common software architecture, thus allowing exchange of control code and system engineering data 1.

High-end controller

The first devices to be used in applications were PP D113 controllers. These are based on the PP D103 processor unit and form the high-end solution in which controllers and fast-I/O are separate devices. The CPU is a PowerPC 750FX with a clock speed of up to 600 MHz.

These devices currently form the controller backbone of the power electronics business.

Low-end controller

This article is primarily concerned with solutions based on the PP D104 processor board, in which controller and fast-I/O are integrated into a single device. This solution is targeted at small systems, in which limited space and controller cost are critical to the success of the end-product 2.

> The design of the PP D104 is trimmed for the sharing of the duties within a control system.

The PP D104 processor board contains a microcontroller MPC5200 (Freescale, Power PC core 603) with a clock speed of 396 MHz, a 10/100 Mbps Ethernet MAC, two CAN controllers, 3 serial interfaces (UART) and a large programmable logic device (FPGA) – all on an area less than the size of a credit card.

In contrast to the high-performance controller, the design of the PP D104 is consequently trimmed for the sharing of the duties within a control system. A small, but powerful controller unit forms the brain of the control system. It is optimized for performance per space and supported by application specific communication and application boards or a combination of both – depending on the application's needs. All of these sub devices constitute the controller package, and are optimized for the application's specific purpose.

It has been shown in the past that this design is a door opener for a number of applications that were not previously thinkable due to cost and performance restrictions. The following two application discussions outline the opportunities that PP D104 has created.

Footnotes

1) An FPGA (field-programmable gate array), is a hardware component with a programmable logic.

2) See also "Design patterns" in *ABB Review* 2/2006 on pages 62–65.

3) VHDL: very high speed integrated circuit hardware description language

Application in auxiliary traction converters

Electrical converters on-board trains can be separated into two groups: Main converters as drives for the electrical (traction) motors and auxiliary converters for other electrical needs on-board the train, such as heating, cooling and lighting.

The topic of this section is the latter, auxiliary converters. These auxiliary converters are produced according to the needs and demands of the end-customers as customized products in batch-sizes that can be as low as only a few pieces. Therefore, the most important requirement on the control platform is:

Easy adaptation and rapid deployment
This requirement is met by the automatic code-generation feature for fast real-time applications using MATLAB/Simulink: With a few changes in the graphical user-interface of Simulink, the software can be adapted to incorporate customer-specific wishes. Whereas in a normal control system in such a situation, changes would have to be implemented in the code and system tests made to guarantee the proper functioning; in the AC 800PEC platform the code is automatically generated from the graphical user-interface.

Another demand stems from the fact that such auxiliary converters are typically located on the roof or below the carriage. This placement within the train imposes some additional requirements on the control system: The hardware must be industrial grade and must be contained within limited space.

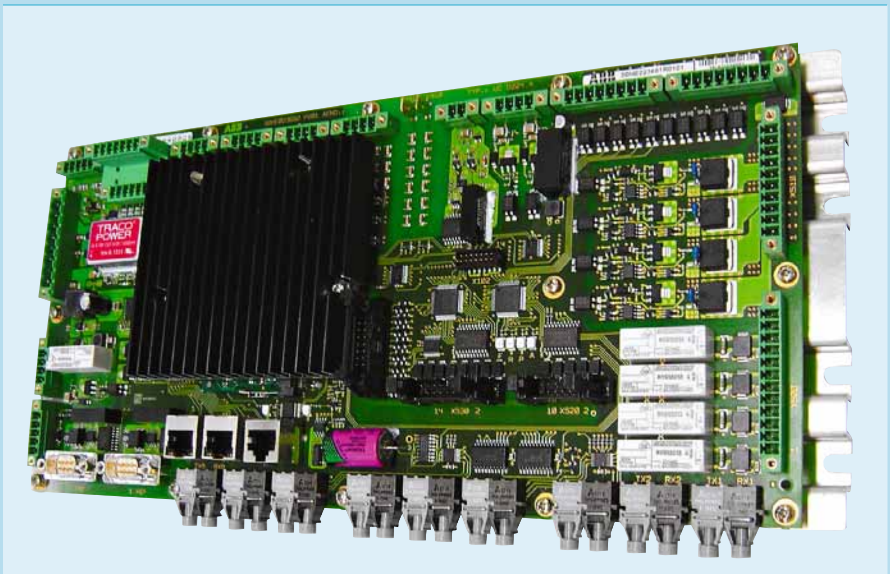
Traction is the most important application of AC 800PEC, and since traction has particularly harsh environmental conditions, the requirement for industrial grade hardware is met by all devices belonging to the AC 800PEC platform. Besides conformal coating, which is typically used in areas where clean air cannot be guaranteed, the devices have an extended temperature range of – 40 to + 75 °C, and must be resilient to vibration according to the traction standard IEC 61373 (Railway applications – Rolling stock equipment – Shock and vibration tests).

The traction environment presents particularly harsh environmental conditions.

The need to be accommodated in restricted available space is ideally matched by the PP D104 based solutions, which allow the integration of the processing unit with all its I/Os in the same compact hardware device 3.

The compact PP D104 not only provides general control of the product, but also drives all the PEBB's (power electronic building blocks) used to generate the AC and DC currents via power-link signals.

3 PP D104 based processor board for traction applications



Application in excitation systems

Excitation systems are typically used in power-plants for generator control. This is an application in which reliability is the most important requirement. As opposed to the previous example, these systems can be very large and incorporate several subsystems.

In this case, the introduction of the PP D104 permitted the division of the entire system into several independent sub-systems, each dedicated to a particular subset of tasks, and with each subsystem being controlled by a separate controller. The total system is then controlled and coordinated by a powerful main controller based on the PP D103 processor module.

This modularization not only greatly reduced the complexity of the overall system, but presents two further main advantages: scalability and reliability.

Traditionally, systems that are scalable over a very broad range of sizes come at the cost of a complex architecture and hence impose difficulties for the engineering staff. The modularization made possible by the low-end extension of AC 800PEC allows the implementation of a very natural scalability over a broad range. Each sub-system can be instantiated several times without further complicating the software in the main controller.

As already mentioned, reliability of the system is a key issue in power-generation, and often full redundancy is required. Whereas in slower systems, the controllers themselves can be realized as redundant devices, the cycle-times found in and required by power electronic systems make traditional redundancy concepts for controllers unworkable.

Here, the solution of choice to achieve redundancy is no longer on a device level, but on a system level. For the redundancy concept implemented in ABB's UNITROL® excitation systems, each subsystem is available n-times. In case of a problem in one subsystem, the main controller switches over to the remaining subsystems, which are scaled in such a way that the overall task can still be fulfilled 4.

Should the main controller fail, there is always a second controller available in hot-standby.

4 UNITROL 6000 excitation system with converters using PP D104-based controller boxes

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