Current account

How Modbus enables a new current measurement system

PAWEŁ LUDOWSKI, HARM DEROO, FILIPPO APUZZO, ROLAND PRÜGEL – Commercial and industrial enterprises are very dependent on the reliable operation of their electrical systems. Furthermore, there is a clear trend across the board toward more efficient use of energy – a trend driven by both environmental and financial considerations. While top-level energy or current usage is a quantity relatively easily monitored, transparency closer to the devices is more difficult to achieve and commercially available systems that target this fail to meet ABB requirements in several areas. What is needed is a completely new approach to monitoring current close to the load. This new approach is called the ABB Current Measurement System and its Modbus-based communication protocol is a core element of its functionality.

1 A sample electrical installation monitored by CMS

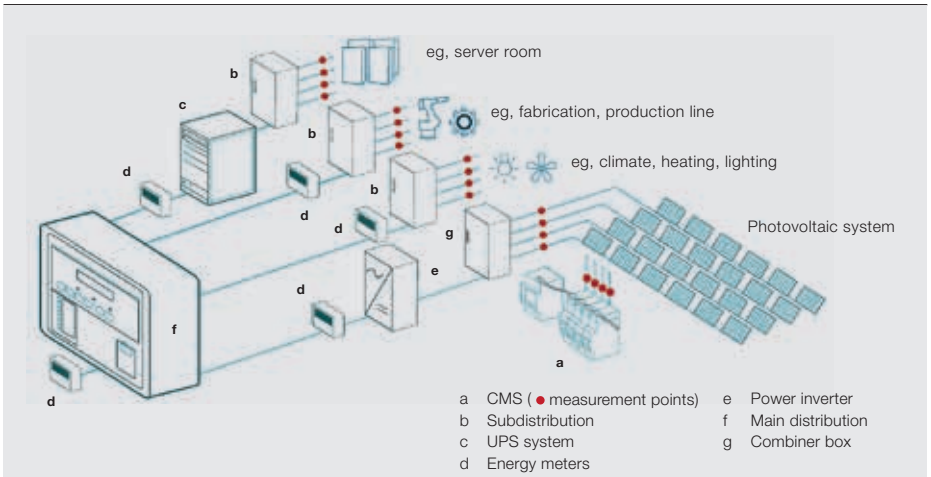

ABB began development of the Current Measurement System (CMS) in 2009. The CMS consists of several current sensors connected by a serial bus to a control unit. The control unit and the current measurement modules were developed in close cooperation with external partners. The communication protocol, which is an important part of the functionality of the CMS, is based on a protocol developed by ABB in a previous project.

The CMS opens up completely new possibilities for monitoring the status of power distribution units (PDUs) and their single branches ➔1. The CMS makes it possible not only to detect potential failures but also to predict overloads and the subsequent risk of tripping circuit breakers.

Communication protocol

As stated above, an important part of the CMS functionality is the communication protocol, which defines the user communication, address assignment and sensor management. This protocol regiments communication between the control unit and external devices, as well as the internal communication between the control unit and the sensors, and is based on a well-known Modbus serial line protocol. Experience garnered during a previous project helped ABB and its external partners prepare a detailed protocol specification (hardware interface, data format and so on).

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A four-wire flat cable connects the control unit to the sensors. Two of the wires supply power to the sensors and the other two are used for data transmission. The physical interface RS-485 was selected for external device connection ➔ 2.

Modbus uses a master-slave protocol. In this, only one master will be connected to the serial bus, but up to 247 slaves can be connected. In the case of the CMS, the control unit is the master device and current sensors are slave devices.

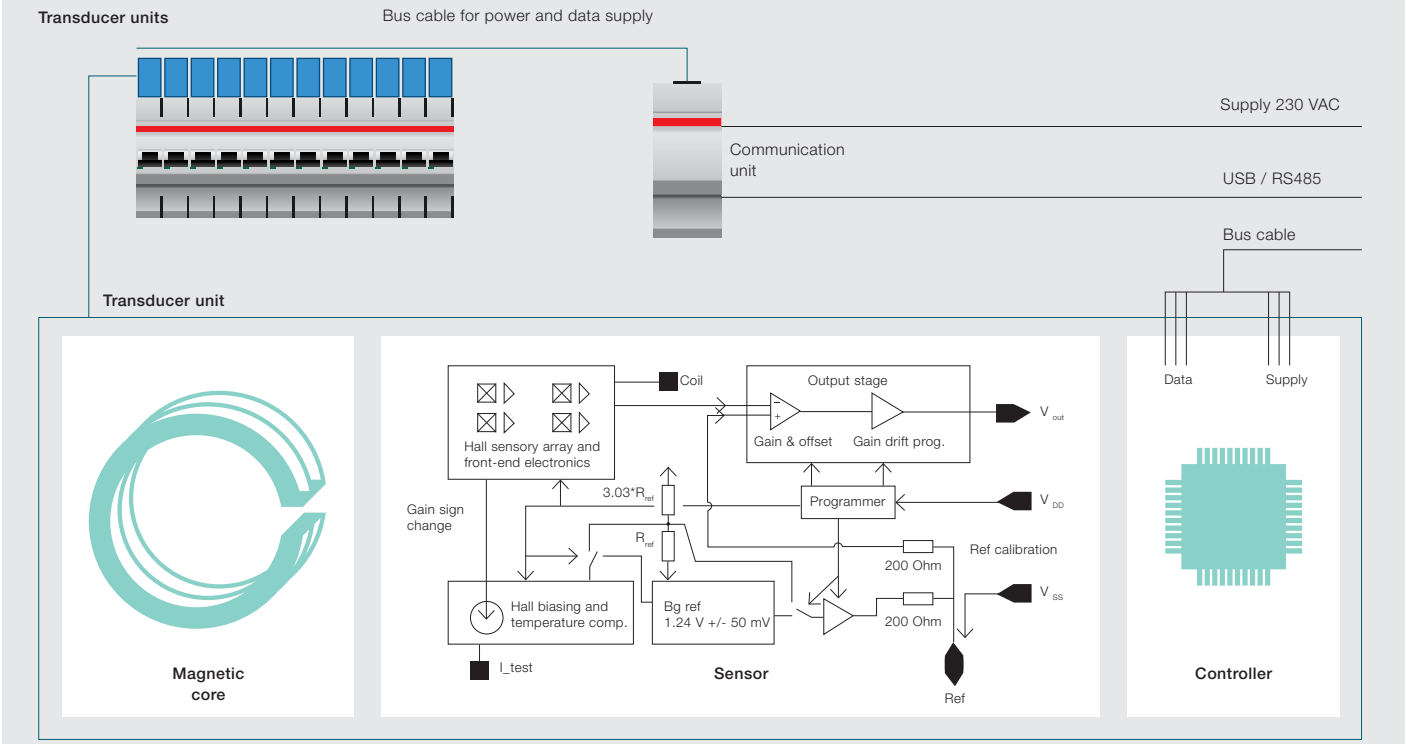
Modbus communication is always initiated by the master and only one transaction at a time is possible. Modbus has two request modes: unicast and broadcast. In the unicast mode the master device addresses an individual slave device, which returns a response message after processing the request. In the broadcast mode the master sends a request to all slaves and no response is returned by them.

The maximum size of a Modbus/RTU (remote terminal unit) frame is 256 bytes and it must be transmitted as a continuous stream of characters. If a silent interval of more than 1.5 character periods occurs between two characters then the message frame is declared incomplete and is discarded by the receiver. Messages have to be separated by a silent interval of at least 3.5 character periods.

Modbus uses a “big-endian” representation for addresses and data items. That means when a numerical quantity larger than a single byte is transmitted, the most significant byte is sent first. For example, the 16-bit (ie, two-byte) hex value 1A3B is sent as two 8-bit (ie, one-byte) hex values 1A then 3B.

The data model in Modbus is based on a series of tables, where the four primary tables are: read-only discrete input, read-write coils, read-only input registers and read-write holding registers. A coil is a boolean (bit) variable and a register is an integer (word) variable. There are also three categories of Modbus function codes: public function codes (validated by the MODBUS-IDA.org community),

Title picture
How does ABB’s Modbus-based communication protocol in the CMS enable visibility of current consumption in industrial devices?



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user-defined function codes and reserved function codes. Registers in the CMS are always two-byte (16-bit). While the Modbus application protocol defines memory area for read-only registers (input registers) and read-write registers (holding registers), the CMS current sensor module supports only holding registers.

In the CMS, the Modbus protocol has been extended by a few additional features. These initialize the network by assigning Modbus ID addresses to sensors and linking them to appropriate registers in the control unit. By default, all sensors have the same address (247), so it is necessary to assign a new individual ID address to each sensor during the installation phase. Because a CMS sensor does not have a hardware switch to set the ID it was necessary to develop a software ID assignment procedure. This procedure is based on Modbus custom functions for broadcast addressing. Depending on installation requirements, several configuration procedures are available: In the most general form, the master module broadcasts a message with a custom code containing a unique sensor serial ID (SID) and new Modbus ID. When this frame is broadcast, all devices on the bus are informed about the ID assigned to any other device. To prevent conflicts, every device that received a broadcast ID assignment frame has to compare its own SID with the SID of the destination sensor in the broadcast frame and, if they agree, it changes its ID to the ID in the assignment message. Otherwise, the request is ignored.

An important part of the CMS functionality is the communication protocol, which defines the user communication, address assignment and sensor management.

This protocol fulfills a global standard, which allows the CMS to be used in a wide spectrum of customer applications.

3 The CMS is compact and easy to install.

4 Typical applications

Data center
Data centers consume significant amounts of energy, so there exists the potential for large cost savings if energy consumption can be reduced, even by a small percentage.

The power consumption in a data center is known at a high level, but is tricky to ascertain at the device level – and it is at this level that energy-efficiency measures can be very effectively implemented.

This is where the CMS comes in. In combination with an AC500 PLC (programmable logic controller) and an energy meter, the CMS can provide energy usage transparency. Several such CMS projects are underway and there is growing interest from the market.

Hospital
Life-support systems in hospitals are, literally, vital. These systems must work without any interruption.

The CMS is being used in combination with SMISSLINE TP to ensure this by offering electrical current monitoring in each branch of the power system and giving operators the chance to detect abnormal system parameters before they evolve into problems.

ABB has helped many hospitals increase the reliability of their equipment in this way.

The system is very flexible and can be customized and extended with new devices regardless of manufacturer.

The communication protocol was fully documented by 2010. In 2011, the CMS was transferred into the product development phase and at the end of that year the first prototypes of the control unit and sensors were available, at which point intensive work on the device firmware started.

Tests and production

Special test software was written in the Perl programming language for the CMS. A new Perl module was created to support the Modbus/RTU protocol that had been extended by the Modbus custom functions specially for the CMS. Included in this module is a set of functions that can be used for quick and easy creation of any test scenario for both the control unit and the current sensors. These functions allow testing of all device registers and operation of the Modbus custom functions.

A set of configuration functions was also written that allows the CMS to be easily set up and prepared for testing. A log file records information about all operations performed by the software as well as Modbus frames that were sent to and from the CMS. To facilitate software setup, system configuration data is stored in XML format.

CMS advantages

The first production version of the CMS was released in mid-2012. The product launch took place at the “Light + Building” fair in Frankfurt in July 2012, where the compact size, technology, measurement results, user-friendliness and flexibility of the CMS was exhibited.

The CMS opens up a multitude of monitoring possibilities in many industrial applications ➔ 3–4. However, the capabilities of the system need not be confined to current measurement alone and further innovative applications are already being investigated.

Communication is based on a well-known Modbus serial line protocol.

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