The IP-Meter, Design Concept and Example Implementation of an Internet Enabled Power Line Quality Meter

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Abstract— **An Internet Protocol enabled meter, IP-meter, has been designed. As an example of the IP-meter a power line quality meter fully accessible over the Internet has been implemented. The meter is capable of measuring line frequency harmonics with spectral information, transients, line voltage RMS with sags and swells analysis. The Internet access for this application is made over a thin Ethernet medium.**

The Internet connection is made with a three part design concept: sensor part, microprocessor part and communication part. Served by the built in webserver the meter is fully accessible via a standard internet browser. Meter setup, data display etc. are made using html pages and Java applets.

I. Introduction

Today's sensors and actuators used in the process industry communicate with control systems via current loops, RS-232, Fieldbus etc. In many cases the communication is one-way. The Fieldbus did introduce a two way communication scheme. Due to the extraordinary development speed found in the internet business we anticipate that sensors and actuators for the industry will benefit from this. Thus we have developed a meter concept where the meter has a direct connection to the Internet, the Internet Protocol enabled meter, the IP-meter.

Currently several bus systems have been or are being developed by different organizations. Examples are the GP-IP bus [1], the Fieldbus [2], ASI [3] and the CAN bus [4] just to mention a few.

To exemplify the approach, an implementation of a power line quality meter was chosen. Here a number of internationally agreed standards like EN61000 [5] give the scope of measurement variables of interest. A more detailed specification of the power line quality meter can be found in [6].

This paper presents a general approach to internet enabled sensors and measurement devices.

II. General design considerations

The Internet-Protocol meter concept has the following general functionalities:

- sensor/actuator functionality
- data extraction and processing
- data and security management
- two way data communication over any communication line connected to the Internet using TCP/IP.

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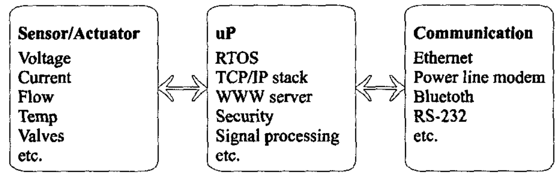

Fig. 1. General three part design concept used in the IP-meter.

The IP-meter is implemented with a design concept shown in figure 1.

The data communication protocol is a standard TCP/IP implementation from Internich. Thus we can make use of standard features as www, FTP, e-mail, etc. found on the Internet. The meter is given its own IP-number and other necessary assignments for a proper internet connection. The sensor/actuator part can contain any technique that is suitable for the application. The uP part is a 16 or 32 bit micro controller with appropriate memory and I/O hardware. On the uP a real time operating system (RTOS) is running. This enables a good control of timed events both on the sensor/actuator side and on the communication side. The IP-meter user interface is based on web server technology thus enabling the use of standard browsers for the following tasks:

- IP-meter configuration
- data display
- up- and download of data
- download of IP-meter software updates.

III. Implementation

A. Hardware

A first implementation of this concept is made for a power line analyzer i.e. the IP-power line analyzer. The design conforms to the concept above. The basic functions and the associated architecture are outlined in figure 2.

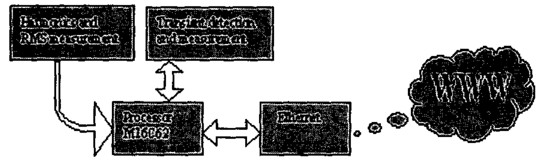

Fig. 2. IP-Power line analyzer implementation.

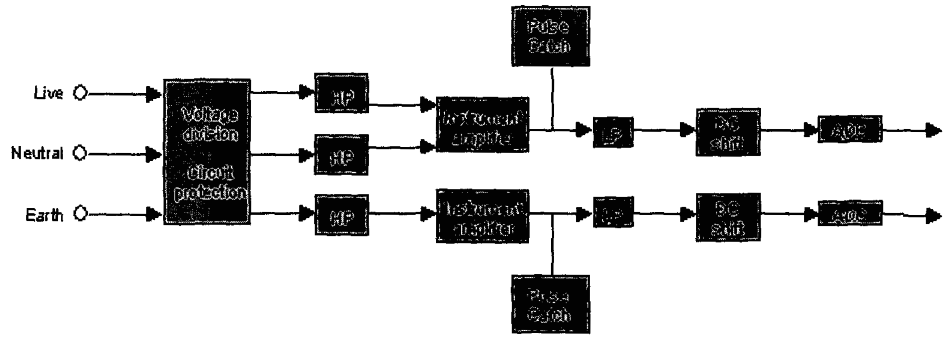

Fig. 3. Block diagram of the transient measurement circuitry.

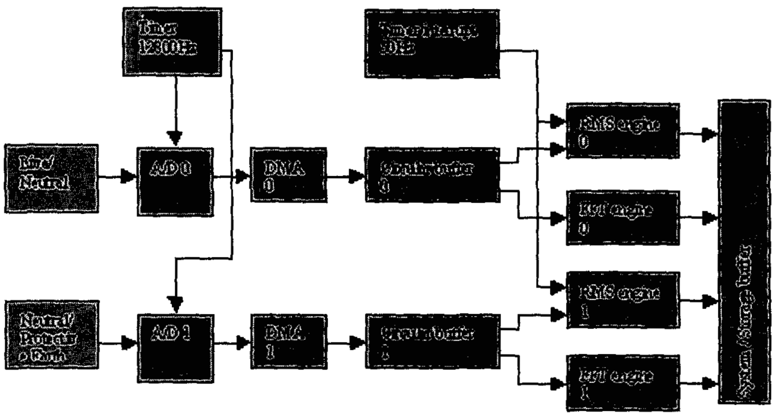

Fig. 4. Block diagram of the LF measurements circuit, including the measurement of harmonics, sags, swells and RMS voltage.

The measurement part of the design has two major function blocks: the transient and the low frequency blocks. A block diagram of the transient and pulse catch circuitry is shown in figure 3. For the transient measurement a 4 Ms/s A/D converter external to the microprocessor was used together with a 4 Mbyte memory buffer. To ensure a continuous measurement of transients a special circuit using a dual memory bank was used to ensure measurement functionality when transient data are moved from the transient buffer. To catch transients of very short duration a pulse catch circuit was implemented.

To ensure synchronization between the processor, the transient memory and the LAN a special circuit was implemented using an FPGA.

In figure 4, a block diagram of the low frequency measurement circuitry is given. Here RMS voltage, sags, swells and harmonics are measured. For these low frequency measurements the internal A/D converter in the microprocessor is used. Standard FFT signal processing is used to determine harmonics.

The microprocessor design is straightforward. The connection to the communication part is outlined in figure 5.

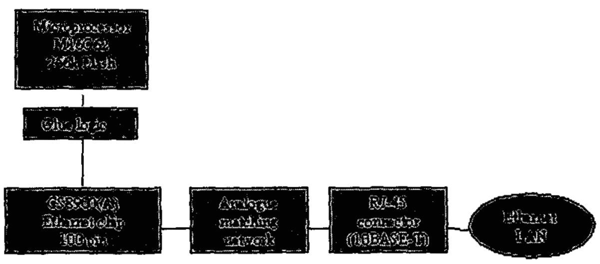

Fig. 5. Block diagram of the interface to an Ethernet LAN.

B. Software

In the software implementation the general requirement was a simple access using an ordinary web browser. The specified functions to be handled from a web page were:

- index over menus
- instrument status
- communication settings
- measurement settings
- harmonics measurement with spectrum display

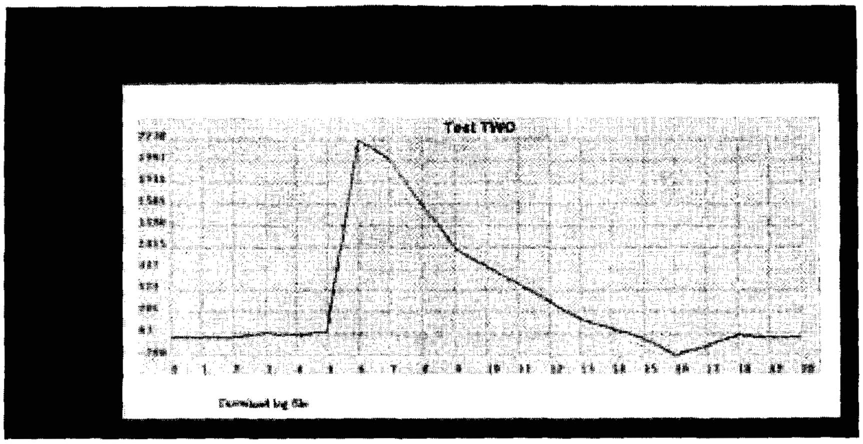

Fig. 6. Example web page from the power line quality meter, showing transient data.

- transients measurements with transient wave form display and data download
- line voltage RMS measurements with sags and swells analysis
- HELP.

In this application it is highly desirable that the software is maintainable over the Internet. This calls for the use of Java or Java applets for as many operations as possible. In our case Java applets were chosen since the used RTOS (RTXC) does not support Java, furthermore Java applets require much less memory.

For devices connected to the Internet a serious question is security. To handle this a three level log in procedure was introduced. No hacker tests of the web server has been made.

In figure 6 an illustration of the transient measurement web page is given. The data presented in the web pages, using a Java applet, are obtained from the measurements taken by the two major measurement blocks. Since most of the measurements are made concurrently and with high rate a careful real time systemization and associated software design were made.

IV. Performance and design issues

Our work indicates that the following memory resources are needed to give a fairly simple instrument like this an internet connection:

- RTOS memory — 40 kbyte
- communication sw including TCP/IP stack and web server — 100 kbyte
- application code — 40 kbyte.

Thus a fully functional internet appliance can easily be built with less than 200 kbyte program memory. This enables small 16 bit processors and potentially even 8 bit processors to host internet appliances. This implementation was made with the 16 bit M16C/62 processor from Mitsubishi, featuring 256 kbyte flash memory and 20 kbyte RAM running at 16 MHz. This processor allowed a data throughput of at least 100 kbyte/s of measurement data over the Internet. Since much smaller implementations than the one used do exist (8 kbyte is known to us) and because the size of the RTOS can be optimized more we foresee that a fully functional system can be built with a memory demand of clearly less than 50 kbyte, leaving at least 14 kbyte for code and data in a small 16 bit address environment. This shows that it is possible to build a fully internet enabled device using small 8 bit processors. Thus further cutting the cost for internet connections of small devices like simple sensors for temperature, pressure, level etc.

V. Conclusion

The implementation has shown the feasibility of putting a meter on the Internet. It further shows that even comparatively low cost sensors and actuators already today can be equipped with internet access. To reach mass markets it is clear that a few issues have to be addressed. The most critical one is security and its low cost implementation. These problems are currently addressed in two projects at Luleå University of Technology.

This work shows that "small" products built around 8 bit processors are possible. In the future we can expect internet enabled meters to work in clusters giving them capabilities to react on Java code or applets sent between sensors and actuators, potentially forming "intelligent" systems without the use of any central or master computer running the complete system. Thus a part of Mark Wisers ubiquitous computing vision becomes a reality within the process control community. An obvious extension to the presented IP-meter design concept is the addition of Jini, thus making mobility and more reliable networking operation of sensors and actuators become true.

The use of Internet, Java and Jini [7] calls for standardized communication languages for instruments, sensors and actuators. Currently such standards are available from various sources like Fieldbus Foundation [2], IEEE 488.2 [1], etc.

VI. Acknowledgment

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