HYPERION NET – A DISTRIBUTED MEASUREMENT SYSTEM FOR MONITORING BACKGROUND IONIZING RADIATION

by

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Received on June 28, 2003; accepted in revised form on September 8, 2003

The distributed measurement system – HYPERION NET, based on the concept of FieldBus technology, has been developed, implemented, and tested as a pilot project, the first WEB enabled on-line networked ionizing radiation monitoring and measurement system. The Net has layered the structure, tree topology, and is based on the Internet infrastructure and TCP/IP communication protocol. The Net's core element is an intelligent GM transmitter, based on GM tube, used for measuring the absorbed dose in air, in the range of 0.087 to 720 μGy/h. The transmitter makes use of an advanced count rate measurement algorithm capable of suppressing the statistical fluctuations of the measured quantity, which significantly improves its measurement performance making it suitable for environmental radiation measurements.

Key words: radiation monitoring, distributed measurement system, nuclear instrumentation

INTRODUCTION

The modern information technology approach to the measurement of physical quantities, control of technological processes, environmental/object monitoring aimed at protection of humans and environment requires the execution of multiple measurements at many remote sites. A measuring system organized in this way is called a distributed measuring system.

So far, a number of stand-alone (wall-mounted, benchtop, portable, *etc.*) nuclear measuring instruments have been developed and produced in large series in the Electronics Department of the VINČA Institute of Nuclear Sciences. The first PC based radiation monitoring system having network connectivity was developed in 2000 [1], but it had some restrictions as pilot project: concept "Client-Server" was implemented in the way contrary to the usual implementation, the supporting software required installation at each PC user, the probes were intended for indoor use only, *etc.* The emerging trend of networking and WEB enabling of instrumentation has given rise to the development of HYPERION NET. The implementation and functional testing of the pilot project was carried out in 2003. HYPERION NET represents a versatile system primarily meant for environmental monitoring and human protection in the vicinity of nuclear machines, technological processes using radioactive materials, and areas with high risks of radiation pollution. It is a rugged and robust ionizing radiation monitoring system, used for in-building, near-building, and field measurements operating under exceptional working conditions. In order to meet its purposes, the HYPERION NET had to obey specific international standards and regulations [2-5].

THE ARCHITECTURE AND ORGANIZATION

The distributed measurement system HYPERION consists of three hierarchical layers. Each individual layer performs its task in the process of measurement, acquisition, and processing of the measured data.

The lowest layer of the system is the net of transmitters (intelligent sensors), in the FieldBus terminology denoted as "Device Network" [6, 7].

Technical paper
UDC: 621.3.08:539.1.074.2:539.166
BIBLID: 1451-3994, *18* (2003), 1, pp. 42–46

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A constituent part of the device net is an intelligent GM transmitter (IGMT); it measures the layer of ionizing radiation, performs local processing of the measured data, and, on request, and forwards the data to the local node C_1 using standard digital communication interface. Within the device net the master-slave relation is clearly defined in that the local node C_1 is a master and all IGMT in the net are slaves.

The data collected by the local node are processed and stored in the local database, they are available on a PC display to the operator, and, in the form of packages, they are exchanged with the higher hierarchical layer – the central node C. The hierarchical layer higher to the Device Network is called Field Network. It consists of local control nodes C_1 to C_m and the central control node C. The exchange of data between any local node C_i $(i = 1, m)$ and the central node C is carried out by using standard digital TCP/IP protocol via Ethernet or Internet.

The data collected from local nodes C_1, C_2, ..., C_m are processed by the central node C, stored in the central database of the HYPERION net, displayed to the operator in the central node, and organized in a WEB site, in HTML document format, for the purpose of further vertical connection to the higher hierarchical layer (Management Network) or public information services.

DESCRIPTION OF THE INTELLIGENT GM TRANSMITTER

The basic measuring element in the distributed measuring system HYPERION is an IGMT. It performs the following tasks: measurement of the levels of ionizing radiation, processing of the measured data, self-testing for the purpose of identifying the state of the transmitter, and communication to the higher hierarchical layer, local node C_1. Block diagram of the IGMT is shown in fig. 1.

The IGMT is based on two SI-8B GM tubes supplied by a 400 V d. c. power supply [8]. The selected GM tube has sensitivity of 114 imp/s at 10 μGy/s for ^{60}Co, which was sufficient for this type of measurement. The pulses from the two detectors are collected and processed by the microcontroller subsystem. The speed and accuracy of the applied preset count measurement method have been improved by implementation of a new algorithm for suppressing statistical fluctuations of measured data [9]. The new implemented algorithm significantly improves measurement performance of an IGMT, makes it suitable for environmental radiation measurements. The microcontroller subsystem [10] also performs the autotest of the IGMT functions, *e. g.* control of the high voltage supply, operating temperature of the transmitter, *etc*. This subsystem prepares the processed measurement data and through the communication subsystem forwards them to the local node C_1.

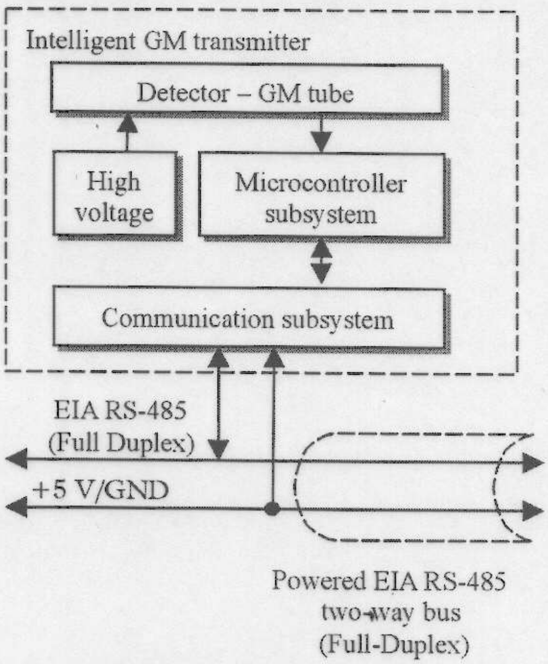

Figure 1. Block diagram of the IGMT

THE INTERCONNECTION OF IGMT AND LOCAL NODE C_1 AND THE DEVICE NET

The IGMTs are connected to the local node C_1 by a common bus and constitute a segment of the device net clustered around the local node C_1. The communication between IGMT and C_1 is realized as a standard two-way digital EIA RS-485 interface with additional lines required for the IGMTs power supply [11, 12].

Figure 2 shows the block diagram of the interconnection between the local node C_1 and n IGMTs forming its Device Network. In the case where a larger number of IGMTs is required ($n > 32$) or meeting the requirements has to be on the maximum EIA RS-485 segment length, the repeaters are needed. The repeaters link the Device Net segments implementing only the physical layer of the OSI 7 layer communication protocol by using the repeaters the maximum covered distance is extended to about 10 km and up to 255 IGMTs can be interconnected. The configuration and parametrization of an IGMT is carried out using point-to-point communication mode implementing the well established concept of FDT Technology [13].

The communication protocol for the C_1 – IGMT system is defined as follows:

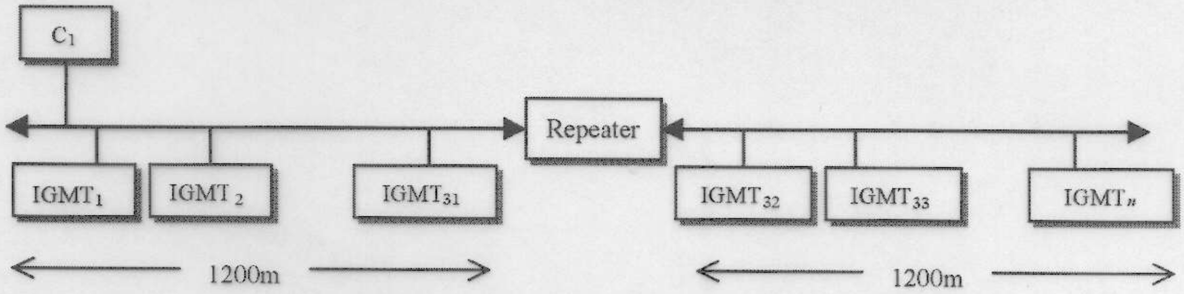

Figure 2. Block diagram of the device net and interconnection of a local node C_1 to a large number od IGMTs

(1) *The process of reading measured data from IGMT*

• The protocol is cyclic, *i.e.* the local node polls IGMTs in the device net, point-to-multipoint.

• The communication is initiated by the master, the local node C_1, which sends two bytes formatted SYNC + ADR (SYNC = 7Eh, ADR – IGMT address) to identify the IGMT requested to send its measured data.

• The identified IGMT returns measured data to the master, the local node C_1, seven bytes formatted ALARM + DATA + CHECK_SUM (ALARM – autotest status, one byte, DATA – mean time between successive pulses, four bytes, CHECK_SUM – general parity check).

(2) *The process of parametrization of IGMT table*

• The protocol implies point-to-point communication of the configuring PC and IGMT.

• The communication is initiated by the master, the configuring PC, which sends one byte CALW (CALW = 2Ah).

• Upon receipt of the CALW byte, IGMT is ready to receive the configuring data. The data contain the identification, measurement, and calibration parameters.

(3) *The process of reading the identification, measurement, and calibration parameters from IGMT table*

• The protocol is not cyclic, *i. e.* the local node reads the table of parameters of the IGMT in the device net upon request by the operator, the configuration is point-to-multipoint.

• The communication is initiated by the master, the local node C_1, which sends two bytes formatted CALR + ADR (CALR = 2Dh, ADR – IGMT address) for identification of the IGMT requested to send its parameter table.

• The identified IGMT returns 28 bytes from its EEPROM table and, for the purpose of ensuring the synchronization master-slave, upon receipt of each byte the local node C_1 returns one ACK byte for confirmation (ACK = 2Eh).

DESCRIPTION OF THE LOCAL NODE AND THE CONCEPT OF VIRTUAL MEASURING POINT

The local node, as the central point of the lowest hierarchical layer of the distributed HYPERION system, *i.e.* of the Device Network, is designed on the basis of the concept of virtual measuring multi-probe instrument [14]. The functions of the local node are: acquisition of data from IGMTs, processing of these data, storing the processed data in a local database, displaying locally the measured data, generation of reports on the measurements carried out by the portion of the device net it controls, and forwarding the acquired data to the higher hierarchical layer, the central node C.

A general purpose PC can be used as the local node C_1. The necessary adjustment required for connecting the PC to the device net is the use of the adapter EIA RS-232 to EIA RS-485 full duplex with a +5 V supply for the bus. The adapter allows two-way communication with the device net at the speed of 9600 baud at distances up to 1200 m without repeaters. The local node is equipped with an autonomous power supply (UPS).

The data acquired by the device net are forwarded to the higher hierarchical layer, central node C, by the standard digital protocol TCP/IP [15].

INTERCONNECTION OF THE LOCAL NODES WITH THE CENTRAL NODE AND THE CONTROLLER NET

The local nodes, C_i (i = 1, 2,..., m), are connected to the central node C, by using net topologies of Ethernet (LAN or MAN) or by Internet, and constitute a net of controllers. The communication between a local node C_i and the central node C is realized by using the standard digital protocol TCP/IP. Figure 3 shows a block diagram of the interconnections of local nodes C_i with the central node C.

The use of the standard digital protocol TCP/IP ensures the integrity of data sent from local

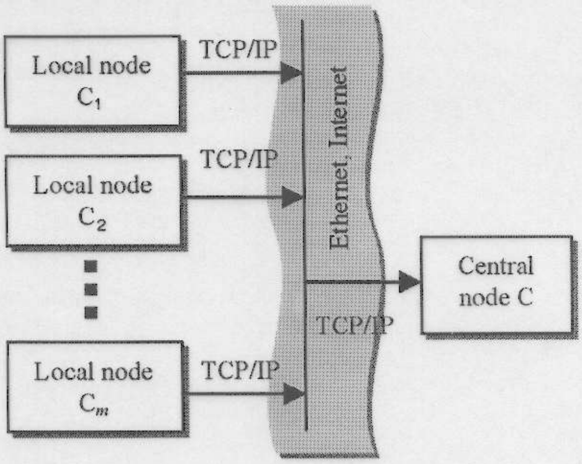

Figure 3. The interconnections of local nodes C_i with central node C

nodes C_i to the central node C. The distributed measuring system HYPERION allows the possibility that the local nodes could be statically or dynamically IP addressed, whereas the central node C must have a fixed IP address.

DESCRIPTION OF THE CENTRAL NODE C AND THE ORGANIZATION OF SOFTWARE

The central node C is the central point of the Field Network of the HYPERION system *i. e.* the net of controllers. The functions of the central node are: collection of the measured data from the local nodes, processing and storing the processed data in the central database, displaying of the status of the measuring system and displaying of the measured data to the operator, generation of reports on the measurements carried out by the complete HYPERION Network, presentation of the collected data by WEB technology using HTML data format [16] in the manner that they are accessible to the higher hierarchical layers (Management Networks or public information services) using standard WEB browsers.

A general purpose PC can be used for the realization of the central node C of the minimum configuration of HYPERION measurement system. If needed, the performance and reliability of the system could be increased by using two separate servers for the database application (database server) and a WEB access application (WEB server). The central node is equipped with UPS in order to ensure the autonomy of the power supply.

The software of the central node comprises: the application for acquisition of data from the local nodes based on TCP/IP, the application database, and the application WEB server. The Apache server is used as the WEB server application. Configuring the Apache sever is carried out locally by the operator of the central node.

CONCLUDING REMARKS

The distributed measurement system HYPERION NET follows the modern concept of Field-Bus technology. The system has been developed, implemented and tested as a pilot project. It represents the first WEB enabled on-line networked ionizing radiation monitoring and measurement system realized in the Electronics Department of the VINČA Institute. The Net has a three-layer structure, tree topology, and is based on the Ethernet or Internet infrastructure. For increased data integrity and reliability, it uses the TCP/IP communication protocol. For measurement of the absorbed dose in air in the range of 0.087 to 720 μGy/h an intelligent GM transmitter is used. The transmitter makes use of an advanced count rate measurement algorithm capable of suppressing the statistical fluctuations of the measured quantity which significantly improves its measurement performance making it suitable for environmental radiation measurements.

The developed, implemented and tested, distributed, Internet-based, monitoring measurement system is shown to represent a suitable low-cost solution for Government institutions, interested scientific community and the public in order to be on-line and accurately informed on the level of background ionizing radiation.

REFERENCES

[1] Popović, A., Drndarević, V., A Distributed Measurement System Based on Client-Server Architecture, *Proceedings*, X Telecommunications Forum, Belgrade, 2002, pp. 400-403

[2] ***, IEC 61559-1 Radiation in Nuclear Facilities – Centralized Systems for Countinuous Monitoring of Radiation and/or Levels of Radioactivity, Part 1, International Standard, 1st edition, June 2002

[3] ***, IEC 61559-2 Radiation in Nuclear Facilities – Centralized Systems for Countinuous Monitoring of Radiation and/or Levels of Radioactivity, Part 2 – Requirements for Discharge, Environmental, Accident, or Post-accident Monitoring Functions, International Standard, 1st edition, June 2002

[4] ***, Draft IEC 61585/PWI: Guide for Specifying Basic Environmental Conditions and Test Requirements for Nuclear Instrumentations, IEC, October 1998

[5] ***, Committee Draft 45A/352/CD: Nuclear Power Plants – Instrumentation and Control – Framework for Developing Standards on Com-

puter Based Systems and Software Aspects, IEC, December 1998
[6] ***, Profibus – Technical Description, Process Field Bus Foundation, September 1999
[7] ***, HART – Field Communication Protocol, Application Guide, HART Communication Foundation, 1999
[8] ***, SI-8B GM Counter, Data Sheet, Techsnabexport, June 1989
[9] Arandjelović, V., Koturović, A., Vukanović, R., A Software Method for Suppressing Statistical Fluctuations in Preset Count Digital-Rate Meter Algorithms, *IEEE Trans. on Nucl. Sci., 49* (2002), 5, pp. 2561-2566
[10] ***, AT89S8252 – 8 Bit Microcontroller with 8K Bytes Flash – Data Sheet, Atmel, 1997
[11] ***, ADM485 – +5 V Low Power EIA RS-485 Transciever, Analog Devices, Rev., 0, 2001
[12] Haseloff, E., Beckemeyer, H., Zipperer, J., Data Transmission Design Seminar, Reference Manual, Texas Instruments, 1998
[13] Hadlich, T., Szczepanski, T., FDT – The New Concept for FieldBus Communication, Control Engineering Europe, September 2002, pp. 33-37
[14] ***, LabWindows/CVI – User Manual, National Instruments, 1998
[15] Murhammer, M. W., Atakan, O., Bretz, S., Pugh, L. R., Suzuki, K., Wood, D. H., TCP/IP Tutorial and Technical Overview, IBM Internation Technical Support Organization, 6th edition, October 1998
[16] Mullen, R., HTML 4 Programmer's Reference, 2nd edition, The Coriolis Group, 1997

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HYPERION NET – ДИСТРИБУИРАНИ МЕРНИ СИСТЕМ ЗА МОНИТОРИНГ НИВОА ПОЗАДИНСКОГ ЈОНИЗУЈУЋЕГ ЗРАЧЕЊА

Развијен је примењен и тестиран дистрибуирани мерни систем – HYPERION мрежа заснован на FieldBus технологији као први WEB умрежени интерактивни мерни систем за праћење радиоактивног зрачења. Мрежа има хијерархијску структуру, топологију дрвета и заснована је на Интернет инфаструктури и TCP/IP комуникационом протоколу. Основни елеменат мреже је интелигентни Гајгер-Милеров трансмитер, заснован на Гајгер-Милеровом бројачу, који мери апсорбовану дозу у ваздуху у опсегу од 0.087 до 720 μGy/h. У трансмитеру је примењен усавршени алгоритам за мерење средње брзине бројања који потискује статистичке флуктуације мерене величине што значајно побољшава перформансе мерења тако да је систем погодан за мерење основног гама зрачења из природе.