APPLICATION OF SOFTWARE AND HARDWARE COMPONENTS OF CAN-TECHNOLOGY FOR ACCELERATOR CONTROL

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CAN-technology was developed for embedded hard real time automotive applications. CAN-bus together with high-level application protocols is used now to control large experimental installations and particle accelerators. CAN-technology includes fieldbus, universal and specialized controllers, sensors and actuators. Software components of CAN-technology consist of high level application protocols, programs for testing, monitoring and configuring of CAN-nodes as well as the components which bind CAN-components with SCADA systems and ensure control through the WEB-browsers. CAN-technology is used in INP to control accelerators, for beam diagnostic and, in cooperation with the RRC Kurchatov Institute, in automation of the large neutrino detector Borexino. CAN-bus adapters for PC have been constructed. Such software components as drivers for PC adapters, the bus emulator and protocol analyzers have been developed under Linux. Original specialized high level protocols have been developed for closed specialized systems. Source codes have been developed and verified for compatibility with international standards such as DeviceNet and CANopen for use in the systems that are supposed to be extended with commercially available software and hardware components. Long-term positive experience of CAN-technology usage allows us to recommend this technology for accelerator control especially if industrial style and compatibility is desired.

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1. CAN-BUS AS A FIELDBUS FOR ACCELERATOR CONTROL

CAN-bus is a real-time fieldbus originally developed by BOSCH for automotive applications. It is widely used for industrial automation, as embedded network in industry, in railway coaches and locomotives, in building automation and security systems as well as for data acquisition and control in big installations for nuclear physics. It was approved by CERN as one of the perspective fieldbus for present and future projects [1].

We consider CAN-bus as a framework technology which consists of the following components:

- feildbus specification CAN 2.0B [2];
- standardised high level protocols CANopen [3] and DeviceNet [4] for “open” applications;
- non-standard high level protocols for proprietary applications;
- set of CAN-bus hardware interfaces for computers;
- set of intelligent distributed and/or embedded controllers with CAN-bus;
- software which consists of the CAN-bus drivers, CAN-bus hardware abstraction interface (CHAI) with standardised API and application software tools for monitoring and tuning of CAN-bus.

CAN-bus interfaces for X86-compatible computers with ISA-8/16 interfaces [5] (including microPC and PC104), PCI, USB have been designed. The following stand alone and embedded CAN-controllers are supported by software: Philips SJA1000, Infinion C16x, Fujitsu MB90F54x, Texas Instrument TMS320C2x. CHAI is implemented as under the Linux as under the different versions of the MS Windows.

The following decisions have been used for the describing systems: diskless PC running under Linux with real-time extension RTLinux [5,6]; stand-alone intelligent controllers [7]; CAN-bus technology [8].

2. CONTROL SYSTEM FOR COMPACT ELECTRON LINAC

A control system (CS) has been developed for a small industrial CW linac with the following parameters [9]:

- output beam energy 1.2 MeV;
- maximum beam current 50 mA;
- maximum beam power 60 kW;
- length 1.3 m;
- gun/ klystron high voltage 15 kV;
- plug power consumption ~150 kW;
- electric efficiency ~40%.

The accelerator and CS fit the requirements imposed by installations for industrial applications.

The CS (Fig.1) [10] consisted of two levels – non-real-time top level and front-end level with fast real-time algorithms. CAN-bus is used to control embedded intelligent controllers which support functions of real-time digital feedback control and data acquisition [7].

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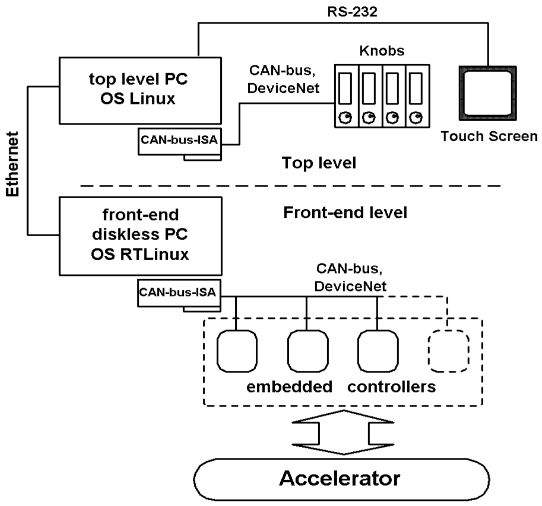

Fig.1. Layout of the control system

3. BEAM DIAGNOSTIC SYSTEM FOR RACETRACK MICROTRON

Very compact pulse 70 MeV racetrack microtron (RTM) is under operation now since 2001 year [11]:

- injection energy 50 keV;
- energy gain/orbit 5 MeV;
- output beam energy 10-70 MeV;
- number of orbits 14;
- output beam current at 70 MeV 40 mA;
- pulse length ~6-10 μs;
- pulse repetition rate 150 Hz;
- dimensions 2.2x1.8x0.9 m;
- weight 3200 kg.

To measure amplitudes of the beam current in each orbit a multi-channel distributed data acquisition beam diagnostic system is used. Beam current monitor (BCM) is a passive wide-band current transformer with sensitivity up to 4,9 V/A and double-ended 50 Ohm-coupled output. The diagnostic system provides data necessary for control algorithms and human-machine interface (HMI) of control system of the RTM [12].

CS has a traditional three level architecture. Front-end level consists of diskless PC with data acquisition boards. Middle level consists of diskless PC running under Linux together with real-time extension of the Linux - RTLinux. Linux is used to implement static and soft real-time algorithms whereas RTLinux is used to run hard real-time algorithms. HMI and the data bases are implemented in the third level. The beam diagnostic system looks from the top level of CS like one more dedicated acquisition subsystem.

The output signal of BCM is measured by a stand-alone intelligent controller [13]. The digitising process is synchronised by a dedicated pulse generated by the general synchronisation system of the RTM. CAN-bus is used to connect controllers with the diskless x86-compatible host computer running under Linux (Fig.2). BOOTP protocol is used to download the operating system to the host. It is equipped with CAN-bus adapter.

The pulsed nature of the data allows transfer of the data in time gaps between two following beam pulses.

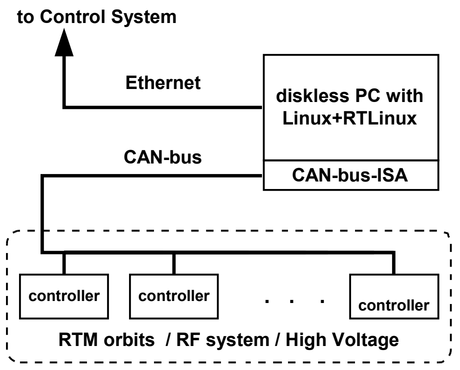

Fig.2. Structure of the beam diagnostic system

Application software of the system was developed in ANSI C and consists of the low level software of the slave controller running on the DSP and the high level software of master. The dedicated high level CANdiag protocol is used [12].

Software for slave part of the CANdiag protocol was completely created, tested and debugged under Linux in emulation mode. Software of the master consists of a loadable module for RTLinux 3.0 and application software running under Linux on the same host computer.

4. LINEAR COUNTERS FOR BOREXINO

Borexino is a real-time device for low energy neutrino spectroscopy which is under completion of construction in the underground laboratories at Grand Sasso, Italy (LNGS). The experiment's goal is the direct measurement of the flux of ^{7}Be solar neutrinos of all flavours via neutrino-electron scattering in an ultra-pure liquid scintillator [14]. Borexino detector has fiducial volume of about 300 m^3, filled with a liquid scintillator, which is viewed by more than 2400 photomultipliers. The phenomenon of a one-photoelectric pulse in the photomultiplier (PMT) lies in the fundamentals of event registration techniques used in Borexino. Only coincidence of many such pulses from different PMTs during short period allows the conclusion about the presence of a substantial physical event in the detector volume to be made. But the essential property of PMT is to produce sporadic pulses; each one taken separately is almost indistinguishable from the one bearing the information on physical event. These spurious pulses, being mainly a result of photocathode thermoemission, followed by departure of electrons with the subsequent amplification, are called photocathode dark noise. Other sources of dark noise are radioactive decay in the glass bulb of PMTs, cosmic rays, auto emission under electrical field supplement etc. Therefore a problem of the dark noise PMT inspection is of special importance. The dark noise should be registered separately for each data channel during all the experiment. For this purpose the system of dark noise monitoring has been designed in addition to the main events registration system. Monitoring of dark noise means continuous analysis of a pulse rate generated by every single PMT or group of several PMTs. The large volume of the arriving information defines the requirements for the performance of the real-time system, its stability and usability. The architecture of the system is a set of multi-channel counters which are connected via CAN-bus. DeviceNet compatible high level protocol over CAN-bus is used in the system. The system of a dark noise monitoring has the following parameters:

- measured values - frequency of dark noise pulses;
- number of acquisition channels - 256;
- frequency range - 10 Hz - 1 MHz;
- period of frequency averaging - 1 s.

The system consists of up to 16 independent modules with 16 independent counter channels each. The actual value of dark noise for each counter channel and results of the analysis are available in a real-time through the Web.

5. CONCLUSIONS

Positive experience of the application allows one to consider the components of CAN-bus technology as a framework useful for development of distributed real-time control systems as for accelerators as for big experimental installations.

Wide accessibility of the knowledge, standards and specifications, hardware and software decisions [15] allow to construct complete control system on the base of CAN-bus technology quickly and successfully. Due to the standardisation of the CAN all the efforts in the field of software and hardware design have a high level of a reusability if one follows standards during a design.

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ПРИМЕНЕНИЕ ПРОГРАММНЫХ И АППАРАТНЫХ КОМПОНЕНТ CAN ТЕХНОЛОГИИ ДЛЯ УПРАВЛЕНИЯ УСКОРИТЕЛЯМИ

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CAN технология была разработана для применения в качестве встроенной сети жесткого реального времени для автоэлектроники. В НИИЯФ МГУ технология CAN применяется для контроля и управления ускорителями, диагностики пучка и, совместно с РНЦ Курчатовский Институт, для автоматизации большого нейтринного детектора Borexino. Многолетний позитивный опыт работы с CAN и эксплуатация систем управления с CAN позволяют рекомендовать эту технологию для построения систем управления ускорителями.

ЗАСТОСУВАННЯ ПРОГРАМНИХ І АПАРАТНИХ КОМПОНЕНТІВ CAN ТЕХНОЛОГІЇ ДЛЯ КЕРУВАННЯ ПРИСКОРЮВАЧАМИ

А. Чепурнов, Ф. Недеогло, А. Етенко, А. Шабельників

CAN технологія була розроблена для застосування як убудовану мережу жорсткого реального часу для автоелектроніки. У НІДЯФ МГУ технологія CAN застосовується для контролю і керування прискорювачами, діагностики пучка і, разом із РНЦ Курчатовський Інститут, для автоматизації великого нейтринного детектора Borexino. Багаторічний позитивний досвід роботи з CAN і експлуатація систем керування з CAN дозволяє рекомендувати цю технологію для побудови систем керування прискорювачами.