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THE NEW CONTROL SYSTEM OF THE SPS INJECTION KICKER

A. Antoine, E. Carlier, A. Marchand, H. Verhagen

Abstract

The SPS accelerator will be used as injector for the LHC and has to be adapted to the LHC requirements. The tight specification on beam blow-up and bunch spacing in the SPS has required an upgrade program of the SPS injection kicker in order to obtain a reduction of the magnetic field ripple to less than ± 0.5 % and of the magnet current rise time to less than 145 ns. In this context, the slow control part has been entirely rebuilt on the basis of off-the-shelf industrial components. A hierarchical architecture based on a SIEMENS S7-400 master programmable logic controller interconnected through PROFIBUS-DP to S7-300 deported and decentralised I/Os has been implemented. Integration of in-house specific G-64 hardware systems inside this industrial environment has been done through a PROFIBUS-DP to G-64 intelligent interface based on an OEM fieldbus mezzanine board on one side and an FPGA implementing the required functionality on the other. Simultaneously, the fast timing system has been completely reshuffled in order to provide the required SPS multi-cycling functionality and a synchronisation of the 16 magnets to 5 ns. This modular architecture has been successfully integrated inside the new SPS accelerator control infrastructure and will be duplicated in the future for the control of the different SPS extraction channels.

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The SPS accelerator will be used as injector for the LHC and has to be adapted to the LHC requirements. The tight specification on beam blow-up and bunch spacing in the SPS has required an upgrade program of the SPS injection kicker in order to obtain a reduction of the magnetic field ripple to less than ± 0.5 % and of the magnet current rise time to less than 145 ns. In this context, the slow control part has been entirely rebuilt on the basis of off-the-shelf industrial components. A hierarchical architecture based on a SIEMENS S7-400 master programmable logic controller interconnected through PROFIBUS-DP to S7-300 deported and decentralised I/Os has been implemented. Integration of in-house specific G-64 hardware systems inside this industrial environment has been done through a PROFIBUS-DP to G-64 intelligent interface based on an OEM fieldbus mezzanine board on one side and an FPGA implementing the required functionality on the other. Simultaneously, the fast timing system has been completely reshuffled in order to provide the required SPS multi-cycling functionality and a synchronisation of the 16 magnets to 5 ns. This modular architecture has been successfully integrated inside the new SPS accelerator control infrastructure and will be duplicated in the future for the control of the different SPS extraction channels.

1 INTRODUCTION

The future role of the SPS as injector for the LHC has required an important upgrade of the SPS injection kicker system designed more than 20 years ago for the needs of a fixed target accelerator. The main new requirements are a reduction of the kick rise time by 25% and a decrease of at least 50% of the ripple on the flat top of the magnetic field pulse, which was about ±1%.

The SPS injection kicker magnet system (MKP) is composed of 16 travelling wave magnets with a total length of more than 16 m. The magnets are of the delay line type. They are connected in pairs via a 190 m long transmission line to eight pulse generators. The pulse generators are lumped element Pulse Forming Networks (PFNs) with a maximum operation voltage of 60 kV and a maximum continuously adjustable pulse duration of 12 μs.

During the long 2000/2001 SPS shutdown, the new layout of the high voltage circuit, based on four independent generators, was implemented [1]. Each generator includes one resonant charging power supply, two PFNs, six thyratron switches, four magnets and 6 terminating resistors. At the same time, the MKP control system was upgraded in order to replace the 20 year old electronics, to fulfil the SPS multi-cycling requirements and to integrate the new system in the SPS2001 software control framework.

2 CONTROLS ARCHITECTURE

The MKP controls architecture consists of two independent entities: one for the control of the equipment state (ON, OFF, STANDBY) and one for the control of the equipment operational settings (kick strength, kick delay, kick length).

Typically, the equipment state control requires a response time in the order of 25 ms and is independent of the machine running cycle. For these reasons, industrial components like programmable logic controllers (PLC) have been selected to implement this functionality.

On the contrary, the control of MKP operational settings is tightly linked with the machine running cycle. It requires a software response time better than 1 ms and timing delays with a resolution of 5 ns. For these reasons, a real-time operating system and dedicated hardware electronics modules have been used.

Each entity is composed of a set of modular blocks called controllers that fulfill distinct and independent logic control functions. The controllers consist of a number of specific sets of input and output channels associated with their related software implementing the required operational functionalities.

For safety reasons, all time critical actions, like personal protection, are still performed directly at the hardware level with software only being involved for status acquisition.

3 HARDWARE CONTROLLER

3.1 Pulse Generator Controller (PGC)

The basic functions of the PGC is to continuously acquire, either through a hardware or software connection, the actual state of all the generator’s vital components, to perform pre-programmed actions upon detection of a faulty component and to memorize these events.

3.2 Power Supply Controller (PSC)

The PSC interfaces an industrial DC power converter (2 kV/15 A) to the control system. Some typical hardware interlocks, acting on faults related to short circuits, wrongly connected high voltage cables or surveillance of capacitor charging characteristics are included in the PSC and interfaced to the PLC master through a PROFIBUS-DP to G-64 intelligent interface [2].

3.3 Thyratron Heater Controller (THC)

Twenty thyratrons equipped with double cathode and reservoir heaters are used in the SPS injection kicker system. High stability 1 kVA industrial AC/AC converters are used in order to guarantee and maintain constant thyratron switching characteristics. The THC interfaces these converters to the MKP controls system. It controls the reservoir heater level, monitors the stability of the cathode and reservoir heater voltages and currents, and interlocks the converters in case of failure in the cooling circuit.

3.4 Terminating Resistor Controller (TRC)

PFNs, transmission lines and magnets are adapted on both sides by high power terminating resistors which have to accept for every injection a 1 kJ pulse within 12 µs. The cooling system of the resistor is based on a forced silicon oil circulation combined with a water-cooling system for heat extraction. The TRC surveys the different resistor oil levels and controls the oil and water flows.

3.5 Fast Signal Controller (FSC)

Thyratron switches are equipped with a current pick-up connected to the hardware fast interlock system. The FSC supervises the coincidence between the thyratron trigger pulse and current pick-up signals. If a fault condition is detected (erratic or missing thyratron pulse), the fault is recorded and the appropriate action is initiated. In addition, the FSC surveys also the transmission lines and the magnet delay lines. Any spark in this part of the high voltage circuit is detected, recorded and appropriate actions are triggered.

3.6 Kicker Timing Controller (KTC)

Upon reception of slow and fast timing events, the KTCs generate and distribute the different trigger pulses required to activate the resonant charging power supplies and to trigger the thyratron switches in phase with injected and circulating beam. In addition, individual fine timing delay modules are used in order to compensate the cable lengths and the thyratron turn-on delays.

3.7 Kicker Setting Controller (KSC)

The basic functions of the KSC controller are to generate the reference voltage for the high voltage power supply and to fan out and acquire pulsed high voltage signals.

4 EQUIPMENT STATE CONTROL

The MKP state control entity (Fig. 1) is based on a SIEMENS S7-400 master PLC interfacing, through 4 identical PROFIBUS-DP segments, the different controllers connected either as deported I/Os or as decentralized I/Os when low-level intelligence is required. A fifth PROFIBUS-DP segment is implemented to interface the resources common to the four generators as the FSC or the magnet temperatures and vacuum monitoring system. The PLC master is connected to the Ethernet TCP/IP network for communication to the application layer.

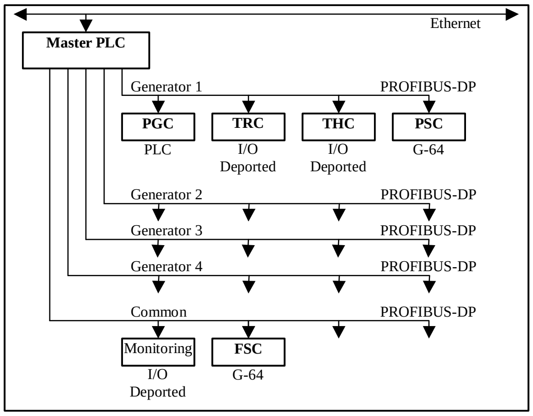

Figure 1: State control architecture

Modelling of the different controller functionalities (PGC, PSC, TRC & THC) at the master level is performed through dedicated software functional blocks (FB). Each FB is parameterised dynamically with its operational data located in data blocks (DB) attached individually to each controller. At runtime, the FBs are sequentially invoked and supplied with the declared instance DBs.

MKP state transition management and state acquisition have been implemented into a finite state machine running at the PLC master level.

Figure 2: Electronics racks of one high voltage generator showing thyratron heater power supplies, thyratron heater and terminating resistor controllers.

5 EQUIPMENT SETTINGS CONTROL

The MKP settings control entity consists of 13 G-64 crates connected trough a MIL1553 field bus to a LynxOS VME PowerPC front-end synchronized with the machine timing events through a TG8 VME module (Fig. 2).

Each G-64 crate is composed of a set of either programmable modules (DAC’s 12 bit, ADC’s 12 bit, coarse timing delay units with a resolution of 1 ms and fine timing delay units with a resolution of 5 ns) or passive signal conditioning modules (pulse fan out units, pulse mixing units, pulse local delays units or interlock units).

In order to reduce the number of modules, the same set of modules is used for each injection attached to a different running cycle. The operational functionality of the complete system is obtained through individual settings linked with each injection.

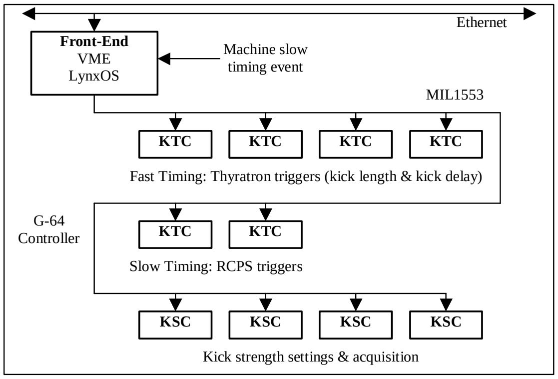

Figure 3: Setting control architecture

The management of the different operational settings is based on a real time task implemented at the front-end level. Upon reception of an injection warning timing event, the TG8 module detects and decodes the event and interrupts a server thread that is in a blocking read state. Recognized interrupts make the thread reload the G-64 modules with voltage and timing parameters fetched from a preloaded local table. This table is structured in terms of SPS cycle types and injection numbers and their associated voltage and timing parameters.

Figure 4: Electronics racks of the timing system

6 REMOTE CONTROL

Remote control of both entities is realized through independent SPS2001 compliant device servers [3] running in a LynxOS front-end for settings control or in a dedicated HP-UX workstation for the state control. In the new scheme, the server processes are aware of the actual elementary SPS running cycle and client programs can automatically be informed of data changes in servers through a data publish/subscribe mechanism. State management, setting and measurement contracts have been implemented through callback routines at the server level. Expert actions have as well been implemented in order to obtain in depth analysis of the complete system.

Additionally, local facilities for control and monitoring of the complete installation are provided within a “Supervisory Control And Data Acquisition” (SCADA) system. The hardware consists of a SIEMENS RI45 PIII PC, communicating with the master PLC via Ethernet. The software is based on SIEMENS “WinCC Control Center V5.0”, plus the add-on “PM-OPEN EXPORT” for exporting data archives and “WebNavigator” for remote visualization through the World-Wide-Web (WWW). At this level, a structured architecture based on a set of view and navigation menu permits to visualize and control the data attached to each controller either at a global or at an individual level. Logging, trending and alarm management are used to get all the facilities to perform correct diagnostic of the installation’s operational behaviour.

7 CONCLUSIONS

Throughout the 2001 SPS run, the SPS proton inflector MKP was controlled through the described device servers and a general purpose application program called “Device Explorer”.

Despite this major modification, both in hardware and software, SPS operation did not suffer any lack of functionality in the control of the voltage and timing parameters and the global state of its inflector.

The use of industrial components, whenever possible, permitted to reduce the development time and the overall project cost. It has resulted in an open and modular control system. The same architecture has meanwhile been re-used successfully for the consolidation of the SPS extraction channel electronics.

8 ACKNOWLEDGMENTS

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