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INTEGRATION OF EXISTING DISSIMILAR POWER SUPPLY CONTROLS INTO A STANDARDIZED EQUIPMENT-ORIENTATED CONTROL SYSTEM

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Summary

Having analysed the existing equipment and the needs of the control rooms staff as well as of the various maintenance teams, a conceptual framework was conceived and the necessary interface hardware specified to integrate about 1200 rather different existing magnet power supplies controls into the new PS computer control system. To facilitate communication, a common precise terminology was developed. The concept aims achieved are: i) full transparency for the accelerator operation staff who will only see the global commands and the corresponding status information irrespective of the type of equipment controlled; ii) more detailed controls and appropriate malfunction indications for the power supply specialists; iii) standardization of the new interface as against dozens of different interfaces in use now for manual or various computer controls. The standard interface fits both future equipment and, with slight additions, a large fraction of the existing equipment. Other elements taken into account for the interface optimization are the efforts required for software production and hardware maintenance.

Introduction

There are about 1200 magnet power supplies in the CERN Proton Synchrotron complex (CPS) including the Linac, the PS Booster (PSB), the Proton Synchrotron (PS), the Antiproton Accumulator (AA) and the primary beam lines of the experimental areas.

Some of these power supplies have been in operation for up to 20 years; most of them are presently controlled from the Main Control Room (MCR) via a computer-assisted system[1]. The power supplies are of a large variety, either industrial products or custom designs; data are transmitted to the computer either via the in-house developed data transmission systems STAR[2] or DTS[3] or via standard industrially-produced CAMAC.

For historical reasons, sub-system-orientated implementations developed throughout the CPS complex, which finally led to even more inhomogeneous layouts requiring considerable maintenance effort.

The controls of the numerous power supply systems were reconsidered and assessed in the framework of the new computer system[4]; this in view of i) providing a homogeneous control scheme, ii) coping with MCR requirements, iii) satisfying the needs of the maintenance and exploitation staff. We also took into account the plan to transfer rather large slices of the complex at a time from the old to the new system with a minimum interruption of accelerator operation, as well as minimum effort and extra cost during the changeover period.

Requirements and constraints

Standardization

Standardization of the power supply control was adopted to ease MCR operation, to minimize production of software, and to facilitate the maintenance of the interface. To elaborate a standardization in detail, numerous discussions between many specialists were required. For this, an accurately defined terminology was elaborated; for instance two fundamental power supply states were defined: the DOWN state, and the UP state which consists of the OFF, STAND-BY, ON and FAULT operational states (see Fig. 1). This standardized terminology has eased collaboration between the many people concerned and who were not necessarily interested in standardization. Standardization will eventually be achieved by means of both the hardware and the software interfaces; it will be the result of a joint effort of the operations staff, the power supply specialists, and the controls team.

Experience and needs of the PS operation staff

For the past twenty years the PS operation staff have been operating the CPS complex from the MCR. There are two basic types of operation: i) normal "proton factory" operation, for which beams with predefined qualities have to be supplied to the users on a pulse-to-pulse basis with high availability and good reproducibility; ii) operation for machine experiments or developments carried out mostly by machine experimenters and often calling for extra control or easy control access to equipment subassemblies. With the new computer system, all procedures from the MCR will be standardized. Equipment reliability and fast fault-finding procedures will help to keep the down-time of the machine as low as possible.

Global commands

The control of power supplies from the MCR will be performed on coherent sets of variables[5] corresponding to a subsystem of an accelerator (e.g. PS fast ejection) or beam transfer lines rather than on individual control variables. Three global commands are specified: i) SET-UP, which will activate the power supply set concerned into a normal running state for either proton factory or experimental run operation; ii) PAUSE, which will suspend, usually for a short period of time, the normal operation of the power supply set concerned, which will however remain ready to execute any subsequent SET-UP command within a machine cycle; iii) FULL STOP, which will totally deactivate the relevant elements of the subset concerned and then cancel the operation for a non-defined period of time; a subsequent SET-UP command will require a transitory period proper to the power supply set concerned (e.g. warning-up time of vacuum tubes). Any power supply, irrespective of its design, must be able to execute (or simulate) the three above commands.

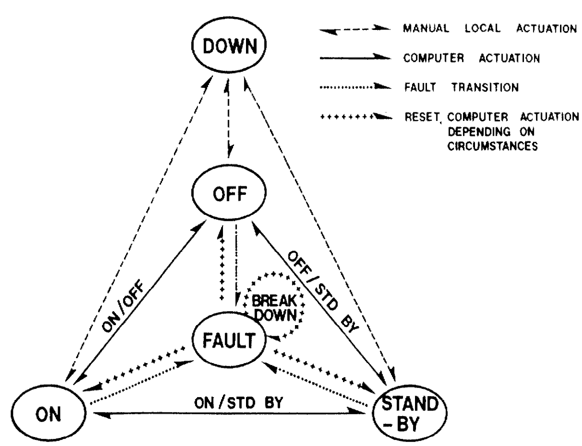

Fig. 1 - Power supply states and transitions

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Experience and needs of the hardware specialists

As the multiple tasks of the CPS complex continue to require extending the performance of existing equipment and building of new, standardization and rationalization were also adopted throughout the CPS complex, at an appropriate level of subassemblies. Despite an unfavourable starting point, standardization of the control interface has the following aims: i) to have a unique control scheme (or protocol) with fully defined operational states and a common terminology to facilitate interchangeability of interface equipment and technical communication between specialists from various machines; ii) to separate the control and acquisition channels of the power supplies up to the digital data transmission system for ease of running-in tests and/or repairs; iii) to concentrate the specialists' design effort on the power supplies themselves as distinct from the interface; iv) to have a common approach towards equipment diagnosis for all people concerned; v) to provide efficient computer-assisted local diagnosis facilities to the hardware specialists. Last but not least, galvanic isolation must be provided for large blocks of power supplies. The design of the specific part of the power supply interface to match the standard interface is carried out by the hardware specialist concerned.

Desiderata of software specialists

The software load related to the controls of the power supplies is drastically reduced, since a standardization scheme is incorporated at an appropriate level in the hardware interface. Computer memory requirement and execution time will be minimized by the use of a common control pattern.

Elaboration of control procedures

The control algorithms

The standardization implies that 1200 power supplies be treated through the same algorithms and have a similar control layout. The power supply algorithms are subdivided into the two basic functions: i) the control algorithm dealing with the setting of the operational states known as actuations and the setting of the amplitude of the current; ii) the monitoring algorithm dealing with the surveillance of a set of status bits generated within the power supply system (including sometimes the load).

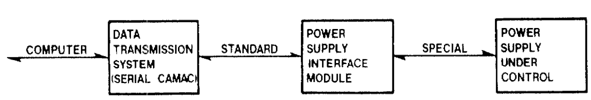

Fig. 2 - Control layout of a single power supply

The over-all control layout of a single power supply (see Fig. 2) shows that the interface module must translate the standardized signals at the data transmission system port into sets of specialized commands and acquisitions to match the actual power supply characteristics. However sophisticated the interface module design may be, the standardized control algorithms (control and acquisition) must be matched to the capability and the required operation of the power supply[6]. The meanings and the electrical definitions of all standardized signals between the data transmission system and the interface module take also into account requirements such as personnel and equipment safety as well as problems related to disconnected cables and power network failure and so on.

Control scheme for the magnet current

The power supplies can be classified in three classes: i) the classical dc power supplies (mostly used in beam transport lines); although of the dc type, the output current of these power supplies may be pulse-to-pulse modulated (PPM); ii) the pulsed power supplies (e.g. condenser discharge type) which require at least a trigger pulse to generate an output current of fixed shape (mostly used in beam transport lines or in injection or ejection systems); the peak current value is usually the power supply main output parameter; iii) the power supplies programmed by an analog fonction which can be either unipolar or bipolar and considered as large current amplifiers (exclusively powered during the acceleration process). In the three cases, the control of the output current is carried out through a single digital multiplying factor applied either to a fixed analog reference (for the dc and pulsed power supply units) or to the output of an analog function generator. A common control scheme for the magnet output current can then be elaborated for all the three classes of power supplies.

Acquisition of output current

As the power supplies are controlled through a single digital multiplying factor, the acquisition of the resulting output current is also limited to a single value in most cases. The analog to digital conversion process required for the computer acquisition is performed once per machine cycle at a specific time. The dc power supplies and the relevant value of the pulsed power supplies are measured at a time related to the beam, while programmed power supplies are measured during the acceleration process at a time controllable by the user from the MCR. In some cases, extra acquisitions will be required for further monitoring of the current shape of particular power supplies (e.g. slow injection kickers of the PSB, pole face winding currents of the PS main magnet) or for hardware specialists' needs. These acquisitions will be made separately and considered as non standard. In conclusion, any power supply output current is known, in general terms, to the MCR operation staff as a single command and a single acquisition parameter.

Power supply operational states

Combining the requirements of the operation staff and of the hardware specialists, a complete description of operational states was elaborated. The terminology and the meaning of all states was accurately defined[7]. Two fundamental states (Fig. 1) were defined: i) the UP state, if in that state, the power supply is ready to execute any MCR request unless it is definitively in the FAULT state (see below); ii) the DOWN state, which is defined as the complement of the UP state. In this state the power supply is no longer under computer control. The transition between the two states will be made locally and manually under the power supply specialists' responsivility. The power supply must be put in the DOWN state for all local interventions to make sure that any spurious computer command is inhibited (personnel and equipment safety).

The UP state consists of a set of four operational states: i) the OFF operational state; the input power is interrupted at an appropriate level, but the power supply is available for further MCR request without any local intervention; it is ready to execute a computer command in a non-defined period of time; ii) the STAND BY operational state in which the power supply does not feed any current to its load but is ready to do so in a very short period of time (a few milliseconds), iii) the ON operational state in which the power supply feeds the requested current to its load; iv) the FAULT state, which indicates that the power supply is no longer able to be in the requested operational state. The transition between states are also illustrated in Fig. 1; they can be either manual or computer control commands (actuations) or uncontrollable fault transitions (leading to the FAULT state).

Definition of interface system

Equipment orientated interface

The input and output parameter of a CPS power supply can be summarized as follows: i) the amplitude and the sign of the output current controlled by means of a single input - single output parameter for all types as far as the MCR operation is concerned; ii) the actuations and the resulting status bit pattern, standardized independently of the type of power supply; iii) time-related events triggered by internal standard timing pulses generated by computer-controlled preset counters. In conclusion, all the elementary functions required to control remotely a power supply can be grouped in a unique set of standard functions, which together permit the elaboration of a standard control protocol and then a standard interface.

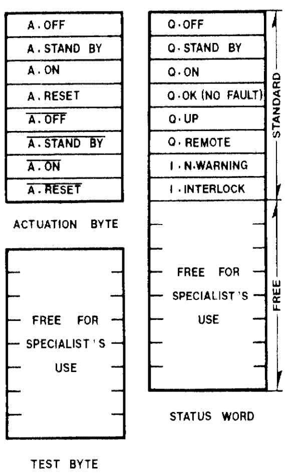

Fig. 3 BIT format for digital control of power supplies

Input and output power supply control parameters

The magnet current will be controlled at the standard interface level in either of the following form; i) from an analogue voltage for power supplies requiring a 12 binary bit resolution or less and a sign bit to control a current inverter (if the power supply needs one); the voltage range will be ±10 V and it may be dc or driven by an analog function generator; ii) from a 16 bit word for 13 to 16 binary bit resolutions, the Digital to Analog Convertor (DAC) is then incorporated in the power supply system. The acquisition philosophy follows a similar process whereby the Analog to Digital Converter (ADC) is also housed in the power supply system for resolution higher than 12 binary bits.

The actuations have been standardized to four bits (see Fig. 3) namely: A.OFF, A.STAND-BY, A.ON, which drive the power supply, respectively, in the OFF, STAND-BY or ON operational state and A.RESET which resets fault detectors to get out of the FAULT state (see Fig. 1). A standardized control byte includes the 4 actuation bits together with their logical complements. A standardized 8 bit byte is used in conjunction with the actuations; each bit corresponds to a fully defined internal state of the power supply. These bits are called "quittance" (receipt bits); they are generated within the power supply or its specific interface, they will be used as input for a standard surveillance and alarm procedure to inform the MCR staff.

As the hardware specialists' needs cannot be fully standardized, since they may differ widely, an extra control test byte and an extra acquisition indicator byte are also provided for further hardware diagnosis by computer (see Fig. 3). The meaning of these bytes will be defined by the hardware specialist concerned.

Overall features of the proposed standard interface

The proposed standard interface is available in two versions. Both versions are built as a plug-in module five units high and 3 units wide and are directly powered from the 220 V ac mains. The hybrid version consists of a 12 binary bit multiplying DAC and a 13 binary bit ADC for the analog part, a two-byte output register (test and actuation) and a 16 bit input register (quittance and indicator). The digital version does not use any analog part; instead a 16 bit output register (current control value) and a 16 bit input register (measurement of shunt current) are provided; the actuation, test, quittance and indicator registers are the same as those of the hybrid version. The hybrid version has a built-in circuitry for direct analog observation of the shunt current in the MCR through the standard signal observation system.

They are housed in a CERN Instrumentation Module (CIM) crate; the data are available on a 86 pin connector. The single transceivers are connected to the CAMAC via a serial communication link and a special one-unit wide CAMAC module, called quad-transceiver which can control up to four independent power supplies.

Conclusions

After an analysis of the requirements both of the operation staff and of the power supply specialists, standard control functions for power supplies could be defined independendly of the particular type of power supply. The fundamental functions required for building up a control procedure are grouped in a unique set of elementary functions leading to the concept of a standard equipment-orientated hardware module for all power supplies. The detailed implementation was optimized so as to require a minimum of changes of the existing power supplies.

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