CERN SL 93 49 BT-A

Fermilab Library
0 1160 0035121 7

# The Control System for the LEP Beam Dump

E. Carlier, A. Aimar, J. L. Bretin, A. Marchand, V. Mertens, and H. Verhagen.
European Organization for Nuclear Research (CERN) - SL Division,
CH - 1211 Geneva 23, Switzerland

C93/10/18

3

*Abstract*

A beam abort system has been developed and installed in LEP to allow the proper and controlled disposal of the stored beam energy. In view of the importance of the system for the protection of the experiments and the machine, and the technical problems in a pulsed high-power environment, special care has been taken to arrive at a clean functional separation between the different elements of the control electronics, using also optical transmission of information. All interlocks have been implemented in hardware. The slow controls part of the control and the monitoring tasks have been realized in the framework of a modular and parametrizable software tool kit.

## I. INTRODUCTION

LEP is the largest particle accelerator ever built, with a circumference of 26.6 km. 2 x 8 counter-rotating positron and electron bunches of less than 2 cm length collide in 4 interaction points, where huge multi-purpose detectors are installed.

In view of the increase in LEP beam intensity resulting from a higher current per bunch, the doubling of the number of bunches in the framework of a Pretzel scheme [1] and the future increase in beam energy within the LEP200 programme, it has become necessary to dispose of the 2 counter-rotating beams in a fast and safe way at the end of a physics run by means of a beam dumping system. This system will also be used in emergency situations like excessive beam loss in the detectors.

The main components of the beam dumping system are a fast kicker magnet [2] and 2 absorber blocks located on either side of the kicker at a distance of about 45 m. The kicker deflects the beams vertically downwards onto the absorbers. During dumping, the deflection angle decreases so that the bunches are swept over 20 mm on the absorber front faces.

In the following, an overview of the general layout of the kicker electronics is given followed by a description of the main building blocks and their functionality. Finally, the layout of the control software and the advantages of the modular layout are discussed.

## II. GENERAL LAYOUT

Since fast pulsed magnet systems such as beam dumps generate very high electrical noise levels, a careful design of their electronics is necessary. The electronic components can be divided into two groups: the power electronics which are nearest and physically connected to the pulse generator (thyratron heater, thyratron power trigger, thyratron grid polarization, high voltage power supply, ...) and the control electronics which perform data acquisition and remote equipment control (timing, slow and fast interlocks, emergency interlocks, tracking, ...).

To prevent noise propagation between the different parts of the electronics and to gain flexibility, a modular design is used and a physical separation imposed between control and power electronics. The two parts are electrically isolated from one another with two different ground planes and are linked together with plastic fiber optics.

The remote control of all the electronics is performed with an industrial 486 type PC controlling different busses: a MIL1553 field bus for the control of the equipment and for the data logging, and a GPIB bus for instrumentation control and signal diagnostics.

## III. HARDWARE LAYOUT

To achieve minimum noise propagation, the control electronics is composed of modular blocks called controllers, with distinct logic control functions. Each block consists of a number of specific G64 hardware cards. For safety and speed reasons, all time critical actions are performed directly at the hardware level, so that little or no local intelligence is needed at the controller level.

In the following the different major components will be presented:

Optical interface (OI): Fiber optics cables are insulators, so they can be used to send signals between devices with separate grounds and, unlike ordinary cables, they do not act as antenna for impulse noise. A set of modules was developed to interface pulse, analogue and digital signals or relay contacts [3] with fiber optics between power and control electronics.

Pulse Generator Controller (PGC): The basic function of the PGC is to continuously acquire 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. For safety reasons the acquisition of the actual state and the resulting actions are made in a hardware interlock system.

Timing Controller (KTC): The beam dump generator can be triggered in two different ways: by a standard or repetitive dump trigger generated upon reception of a LEP

timing event (slow trigger) or by an emergency dump trigger upon reception of an emergency dump request (fast trigger). The KTC synchronizes these trigger pulses with the LEP revolution frequency by means of the 'Beam Synchronous Timing' clock [4], then it delays the trigger pulse in such a way that the magnetic field increases between the passage of 2 bunches through the kicker magnet.

Power Supply Controller (PSC): The PSC interfaces an industrial DC power converter to the control system. It controls the remote setting and acquisition of the kicker high voltage with a 4 MHz voltage-to-frequency mechanism. Some typical interlocks, acting on faults related to short circuits or wrongly connected high voltage cables, are also included in the PSC.

Tracking Controller (TIC): A direct current-current transformer pick-up was installed on the bus bar of the main dipoles to measure, in real time and with a high accuracy, the LEP energy. The resulting signal is used as reference for the tracking system. The beam dump kick strength is linked to the LEP energy within 1% precision to keep the deflection angle constant during all different machine modes (i.e. filling, ramping, and colliding).

Emergency Controller (EMC): To protect LEP experiments from severe damage that could be caused by uncontrolled beam losses, a fast emergency trigger system was added to the kicker electronics. The emergency actions can be triggered via hardwired channels from the experiments and the main control room connected to fault detectors [5]. All channels are equipped with enable/disable switches in order to allow their insertion into, or disconnection from, the emergency trigger system. The control of the position of these switches can either be local or remote.

Fast Signal Controller (FSC): The thyratron switch is equipped with a current pick-up connected to the hardware fast interlock system. The fast interlock system surveys the coincidence between the trigger pulse and the thyratron pick-up signal. If a fault condition is detected (erratic or missing thyratron pulse), the fault is recorded and the appropriate action is initiated.

Absorber Blocks Controller: The temperature and the warming-up of both absorber blocks is continously measured with an industrial datalogger. PT100 type resistors are located at different depths and locations inside the blocks in order to survey the temperature gradient and the block cooling system whenever a beam dump occurs.

## IV. SOFTWARE LAYOUT

The software layout is divided into a hardware dependent equipment level and a hardware independent control level.

The equipment level consists of a small server built under the standard SPS/LEP equipment access facility [6]. Each hardware block is identified by a unique logical name address and the hardware specificity is encoded inside the equipment server. The main services furnished for each block are the possibility to read all the data in a compressed mode in one call and to execute individual low level commands.

The control level is built in the framework of a data-driven generic software tool kit [7,8]. The application specific behavior is given through data files. No C above the tool kit itself was written for this application. States transition and command sequences were designed following the GRAFCET logic [9] and Petry network diagrams, and integrated inside the tool kit.

The main advantage of this configuration is that the hardware blocks and their corresponding equipment software code can easily be reassembled in case of future modification of the equipment.

## V. COMMISSIONING

The complete kicker system was installed in LEP during the 1993 shutdown and commissioned with 2 x 4 and 2 x 8 bunches at an energy of 20 and 45 GeV.

The timing was fine tuned to achieve a synchronization between the trigger pulses and the circulating beam to within 50 [ns]. The tracking system was controlled at 20 and 45 GeV and the deflections measured were very close to the values predicted by the calculations.

The temperature distribution after a 45 GeV dump with more than 2.5 mA beam current was measured and found to be safely within the calculated limits.

The different trigger sources were successfully tested and the emergency trigger channels for the experiments and the main control room were enabled and connected to the kicker. An emergency inhibit of the injection kickers was added in order to prevent beam injection when one of the emergency input channels is in a faulty state.

## VI. CONCLUSION

The control for the LEP beam dump has been the first system in which the tool kit presented in [7,8] was successfully implemented. The control and diagnostic facilities provided by the tool kit were useful during the commissioning of hardware and software.

The hardware modularity and the configurable software used for the LEP beam dump reduced considerably the time needed for the development of the control system and will facilitate any future extensions or modifications.

The control system has now been in operation for 4 months and works very well.

The same hardware and software scheme, without any further developments, is currently being used for the refurbishment of the control of the fast resonant extraction kicker for the SPS neutrino line.

## VII. ACKNOWLEDGEMENTS

Thanks go to G. Schröder and his team for the design of the kicker generator and magnet. S. Peraire and his team built the two absorber blocks. J. Bonthond designed the power electronics and helped to solve many grounding problems. The authors would also like to thank G. Bertrand, V. Garlenc, J.P. Pianfetti, and J. Ternullo for their help during the preparation and installation of the control system.

## VIII. REFERENCES

[1] W. Kalbreier et al., The Pretzel Separation Scheme in LEP, Proc. XVth Int. Conf. on High Energy Accelerators, July 20 - 24, 1992, Hamburg, Germany, Int. J. Mod. Phys. A (Proc. Suppl.) 2A(1993) Vol. I, pp. 401-404, and CERN SL/92-33 (DI).

[2] E. Carlier et al., A High Power Pulse Generator for the Beam Dumping Kicker System of CERN's Large Electron Positron Collider LEP, 9th IEEE International Pulse Power Conference, Albuquerque, USA, June 21 - 23, 1993, and CERN SL/93-33 (BT).

[3] J. Bonthond and E. Carlier, Transmission of Information Concerning 16 Status Contacts over a Single Line, CERN SL/92-14 (BT).

[4] G. Baribaud, et al., The Beam Synchronous Timing System for the LEP Instrumentation, Proc. Int. Conf. on Accelerator and Large Experimental Physics Control Systems, Vancouver, Canada, October 30 - November 3, 1989, and CERN LEP-BI/89-66.

[5] G. Baribaud, Operational Requirements for the LEP Beam Dumping Trigger, CERN SL/92-46 (BI).

[6] P. Charrue, Accessing Equipment in the SPS-LEP Controls Infrastructure: The "SL-Equip Package", CERN SL/93-86 (CO).

[7] V. Mertens, A. Aimar and E. Carlier, A Simple Generic Software Tool Kit for Distributed Controls Applications, this conference.

[8] A. Aimar, E. Carlier, and V. Mertens, An User-Friendly Approach to Process Control Software in the Framework of a Generic Tool Kit for Distributed Applications, to be presented at the Workshop on Workstations and Software Tools for Automatic Control, Prague, Czech Republic, October 26 - 27, 1993.

[9] Agence National pour le Développement de la Production Automatisée - ADEPA, "Le GRAFCET", Diagramme Fonctionnel des Automatismes Séquentiels, 13 - 17 , rue Périer, 92120 Montrouge, France.