Front-end Computing in the LEP2 RF System

L. Arnaudon, A. Butterworth, E. Ciapala
CERN, CH-1211 Geneva, Switzerland

Abstract

Since 1996 the Large Electron Positron Collider (LEP), has been running at beam energies above the W^{+-} production threshold, following the LEP2 energy upgrade which involved the installation of a large superconducting (SC) RF system. Much of the intelligence required to run this RF system resides in the front-end machines of the RF control system, and many enhancements have been made to meet the increasingly complex requirements of the new SC cavity equipment. A large number of G64-based crates containing the equipment interfaces are connected to a layer of VME machines which are in turn connected to the accelerator control system via the LEP machine Ethernet. New hardware and software has been installed in the VME systems to monitor rapidly-changing parameters such as oscillations in cavity fields and vacuum outbursts in the cavities' main power couplers. A closed loop system has been implemented for automatic RF conditioning of cavities and couplers. The VME/G64 communications interface has been upgraded, leading to improved reliability. A new touch-screen operator interface has been implemented using the MGR window manager.

1 Introduction

The LEP2 superconducting cavity RF system [1] consists presently of 240 accelerating cavities powered by 32 klystrons, each capable of delivering 1.3 megawatts at a frequency of 352 MHz. Power is supplied to these klystrons by 16 high voltage power converters.

Each klystron drives up to 8 cavities, mounted in cryostat modules each of which contains 4 cavities. An assembly of 2 klystrons and their cavities, a high voltage power converter and all the associated high and low power electronics is termed an "RF unit". There are 18 such SC cavity units (including 4 "half-units" which share 2 power converters) in addition to the 6 remaining room-tempera-ture copper cavity units of the LEP1 RF system [2].

2 Controls structure

2.1 Interfacing to equipment

The fact that each type of RF equipment is replicated many times imposes a similar layout for the control system (Fig. 1). Each equipment (cavity, cryomodule, klystron, etc.) has an associated "Equipment Controller" (EC) chassis which contains the interface electronics connected to the equipment. Each EC is a G64 system whose function is limited to reading and setting values and surveillance of its associated equipment. The crate controller is either a Z80 MPU with no operating system, running a single interruptible task, or a 68030 single board computer (SBC) running OS-9. Both types of EC are ROM-based.

2.2 Front-end machines

Each SC RF unit has up to 27 ECs, depending on its exact configuration. These ECs are linked via a General Purpose Instrumentation Bus (GPIB) to the "Data Manager"(DM), a VME chassis with a 68040 SBC running disk-based OS-9. The DM performs message passing between the ECs and the UNIX application software running on workstations in the control room. It also hosts numerous local applications, such as the unit switch-on procedure, which are usually launched via remote procedure calls (RPCs) from the control room software.

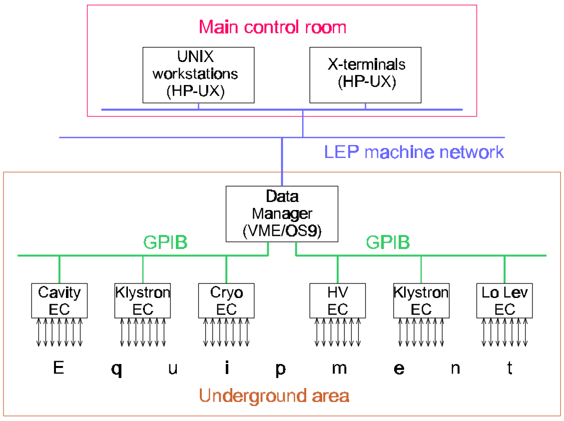

Fig. 1 Structure of the RF control system

3 Data manager hardware

The DM is a VME chassis with an Eltec E17 single board computer connected to the LEP machine network via its on-board Ethernet interface. Two Greenspring IP-488 GPIB interfaces provide communications with the Equipment Controllers. A battery-backed SRAM board gives non-volatile storage for certain configuration parameters. Two ADC boards provide 64 differential analogue inputs for fast acquisition (1 ms sample rate) of certain signals. A local hard disk is used for booting and for storage of program binaries and data.

4 Operating system and network

The DM uses the OS-9/68000 operating system from Microware. All program source code is resident on a UNIX fileserver and accessed via the Network File System (NFS). File access between DM local disks is facilitated by using the OS9-NET system.

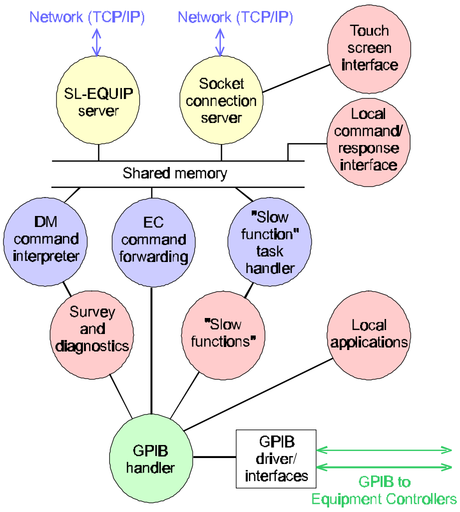

Fig. 2 Data Manager software layout

5 Communications and command execution

5.1 GPIB

The DM GPIB interface has recently been completely revised and now uses Greenspring IP-488 IndustryPack boards, with the IBF file manager software from Ark Systems, instead of the slave processors originally used in the LEP1 DMs [3]. GPIB requests from all processes are queued before being passed to a GPIB handler process which performs the command-response transaction, detec-ting and clearing error conditions and ultimately rebooting ECs if necessary. These modifications have led to a consi-derable improvement in overall reliability.

5.2 Access from LEP operations software

The primary entry point for communications between the UNIX control room software and the DM is a server using the CERN SL-EQUIP package [4]. A server is also provided for older applications using direct TCP/IP socket connections. Three command interpreter processes handle different types of command-response transactions:

- Equipment accesses: the message is passed directly to one or more ECs. This interpreter also executes some more complicated equipment access procedures which must, however, execute quickly enough to return within the time allowed for a single command-response transaction.
- Data manager commands: the command is processed in the DM itself without accessing any EC.
- Task handler commands: commands to start, stop or query the status of local tasks ("slow functions").

5.3 "Slow functions"

The "slow functions" are command procedures which take more time than is acceptable for a single command-response cycle, and so are implemented as background processes run under control of a task handler. These include tasks for switching various parts of the unit on and off, which may take many seconds or minutes, and tasks for changing the settings of high voltage and accelerating field. There are also slow functions to start and stop RF conditioning of the unit and to adjust the cavity tuning to counteract ponderomotive oscillations in the cavities [5].

6 Surveillance

Two background processes survey continuously the status of the RF unit: a local survey task and a fault diagnostic task.

6.1 Local survey

The local survey process loops continuously, retrieving survey data from the ECs, storing it locally in shared memory in the DM and sending it via RPC to a data server resident on a UNIX workstation in the control room, from where it is made available to logging and fixed display applications.

6.2 Fault diagnostics

A background process acquires readings of the cavity fields via an ADC card in the DM chassis. The fault diagnostic task monitors continuously these fields, along with the data collected by the local survey task. Any abnormal status or drop in cavity field triggers a diagnostic procedure which sends an alarm to the CERN central alarm system [6] and optionally launches a task handler comm-and to restart the unit. The field readings are taken at a sampling rate of 1kHz, allowing any ponderomotive field oscillations (which in the LEP2 cavities have a frequency of around 100Hz) to be monitored and an alarm generated if excessive oscillations are observed.

7 RF conditioning of cavities and power couplers

Before being put installed in LEP, and at the start of each year's running period, the cavities and other high power RF components must undergo RF conditioning to elimina-te any contamination present in the cavities which would lead to bad vacuum and the risk of dangerous electrical discharges. The conditioning procedure consists of slowly increasing the RF power while ensuring that the vacuum in the cavities does not deteriorate beyond a certain threshold. The procedure used is shown in Fig. 3.

RF conditioning is characterised by rapid vacuum outbursts caused by the onset of resonant electron emiss-ion known as "multipacting". In conjunction with the fast cryopumping action of the large cold surfaces inside the cavities, this leads to short vacuum "spikes" with a growth time of the order of a few milliseconds. In order to catch these transients, the vacuum signals are sampled at a rate of 1kHz by the same background acquisition process

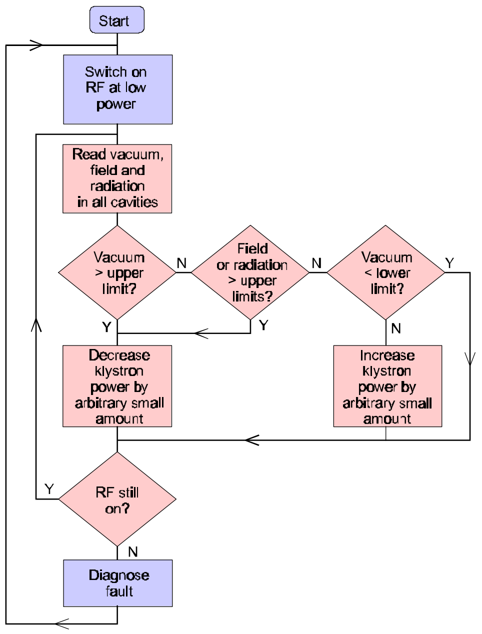

Fig. 3 Procedure for conditioning of RF modules

which is used for the cavity fields (Fig. 4). Since the conditioning program loops much more slowly than this, a "peak hold" is performed inside the acquisition task.

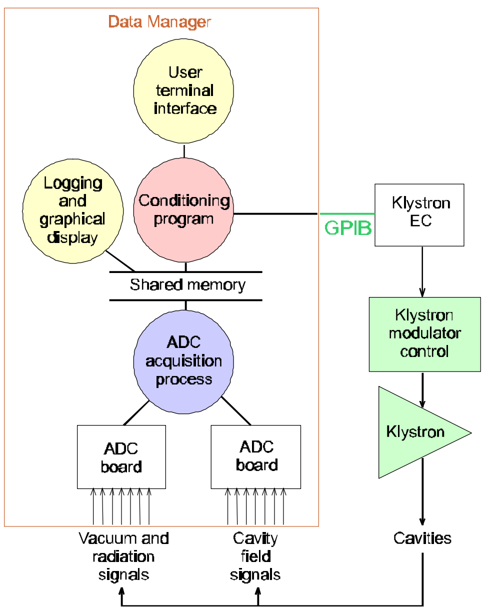

Fig. 4 RF conditioning software

The conditioning program must also take into account many other parameters, such as field and power limits, and radiation measurements from ionisation chambers attached to the cavity modules to monitor dark currents in the cavities, and must handle any fault condition which occurs due to interlocks on the vacuum or cryogenic system.

8 Touch screen interface

A new touch screen interface for local operator control has been implemented using the MGR window manager [7]. MGR is a client/server system which enables the construction of simple graphical user interfaces with a look and feel similar to that of X/Motif. The touch screen interface can also be run on a remote OS-9 station since all its equipment accesses pass via the socket command-response server. MGR also has the facility to display on a remote X-terminal. A sample screen is shown in Fig. 5.

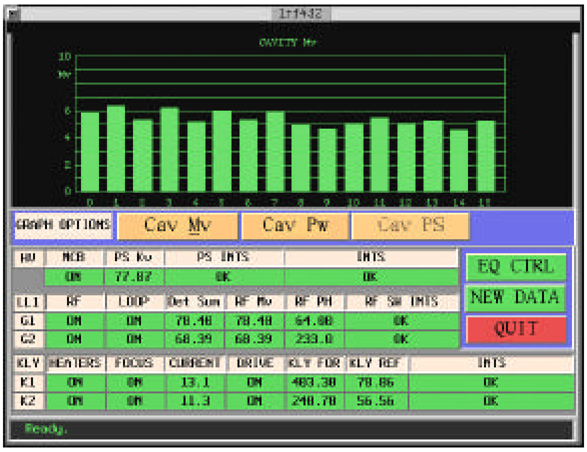

Fig. 5 Example panel from touch screen interface

References

[1] C. Wyss (ed.), LEP Design Report, Vol. III: LEP 2, CERN-AC/96-01 (LEP2) (1996) p. 61.

[2] The LEP RF Group (eds. G. Geschonke, S. Hansen), Status and performance of the LEP RF system, Proc. XIV Internat. Conf. On High Energy Accelerators, Tsukuba, Japan, 1989 (Gordon and Breach, New York, 1990), p. 779 and CERN-LEP-RF/89-53.

[3] E. Ciapala and P. Collier, A Dedicated Multi-Process Controller for a LEP RF Unit, Proc. 1989 Particle Accelerator Conf., Chicago (1987) pp. 1583-1585.

[4] P.Charrue, Accessing equipment in the SPS-LEP controls infrastructure, SL/Note 93-86 (CO), (CERN, 1993).

[5] D. Boussard, P. Brown, J. Tückmantel, Electroacoustic instabilities in the LEP2 superconducting cavities, CERN-SL/95-81 (RF) (1995).

[6] C. A. Cameron, User Interaction with the CERN Alarm System, SL/Note 93-48 (CO), (CERN, 1993).

[7] W. Ocker, "SYSTEM-PAK I/MGR", Reccoware Systems, Rapperzell (1995).