THE LEP-RF SYSTEM - GLOBAL CONTROL FACILITIES AND APPLICATION SOFTWARE

E. Ciapala, P. Collier and S. Hansen
CERN, Geneva, Switzerland

Summary

The eight RF units currently installed in LEP are operated from the control room via the general control system. Communication between control room and equipment is by the use of a remote procedure call. This is used by a library of routines which are the basis for remote equipment access commands and the applications programs required to operate the RF system. A man-machine interface to the RF system has been written based on a commercial interactive graphics package. This provides facilities for both the LEP operators and the RF equipment specialists based on a series of synoptic views. The structure of the programs is described, together with the methods used to dynamicise the views. In the Prévessin Control Room (PCR) a fixed screen has been provided to display unit and overall status information. The software used to collect and allow selective display of this information is described. Work has already started on the upgrade of LEP to higher energies with the provision of superconducting RF cavities. The present control system is being extended to incorporate the new RF units.

Introduction

The the RF system for LEP Phase 1 is made up of eight accelerating units grouped in pairs around interaction points 2 and 6. A common frequency source and fibre optic distribution together with the LEP General Machine Timing (GMT) ensure synchronous operation of the units. The units are otherwise autonomous and can be operated independently, either remotely or locally. General control of the RF system is possible from the PCR via the control system network. Equipment for frequency distribution and synchronization is situated in the PCR and in surface buildings. The equipment is distributed over large distances. Direct access to over 20,000 individual states, settings and parameters, all of which have some bearing on the operational state of the RF system, must be made available to a remote operator or equipment specialist. Access to these is provided by sets of simple commands, sent over the control system network, which invoke the corresponding read or set functions at the equipment level. Applications programs, which carry out more complex actions involving sequences of such accesses, make use of libraries of equipment function definitions. These functions form the relevant commands and convert equipment replies to the required data type. This approach is used for both application programs at the level of the RF units and in the PCR. Additional PCR level commands and functions exist which call applications programs resident in the RF units.

Controls Configuration

Each RF unit contains its own local control system [1]. It is based on a set of G64 based Equipment Controllers (ECs) connected via IEEE488 buses. A VME based Data Manager (DM) coordinates overall control of the unit.

The four DMs at each point are connected to a Process Control Assembly (PCA) in the surface building via a MIL-1553B multidrop. Surface building equipment equipment is attached to the same multidrop. Another DM coordinates RF equipment in the PCR with connection to a PCA. The PCAs provide the connection to the LEP machine token ring nework. Operation consoles (two permanently dedicated for RF) are attached to a small PCR token ring network which is linked to the machine token ring.

Communications

A primary requirement is simple direct access to all equipment states, settings, values and readings. This permits any type of diagnostics or control action to be carried out remotely. The commands are directed to the ECs which carry out the required actions. Direct individual equipment access is however not the most efficient method for normal PCR operation. As far as possible PCR aplications programs make maximum use of the DM's ability to execute application programs for control of the unit. At the level of the RF unit communication between DM and ECs is based on simple command response in ASCII format. This is extended to communications at higher levels. Both direct equipment access and the invoking of DM control procedures are handled by the same means, a string command is passed from the calling console to the appropriate DM and a reply is returned. This is handled by a Remote Procedure Call (RPC) system. It links the process on the console to the PCA to allow transmission of the command string. This is retransmitted by the PCA to the DM

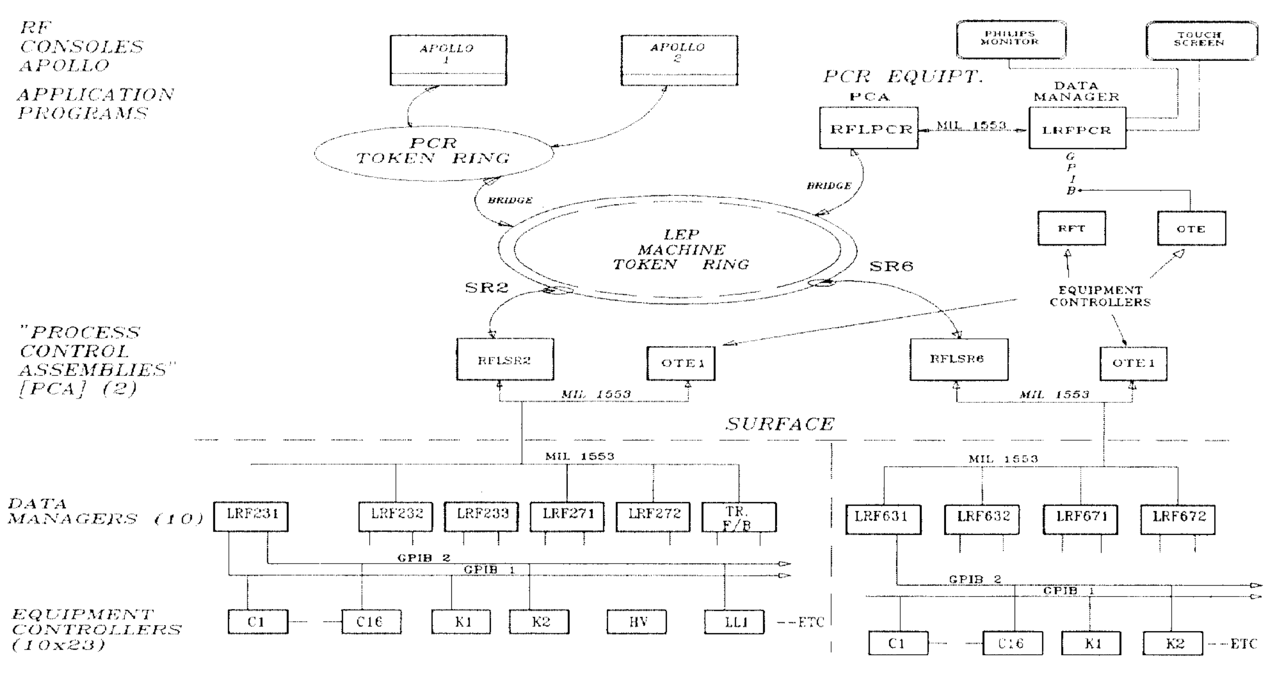

Fig. 1: Overall Control Layout

Two MMI programs exist. One is designed for the LEP operators and contains only those facilities needed for day to day running of the RF system. The second is a much bigger program, designed for RF experts and allows access to all aspects of the equipment. Both are based on the commercial package DVdraw/DVtools. The method used to dynamicise the views is based around the ability in DVdraw to name objects. The group of objects forming a view are drawn using the graphics editor DVdraw. The program itself interacts with this view via the library routines provided by DVtools. When the mouse is clicked on an object in the view a string name for this object can be recovered. In general this name indicates the operation required, which may include moving to a new view or reading/setting a parameter in an RF unit. The name string contains an identifier to indicate the type of operation to perform, followed by a series of arguments.

For example the object name "v:unit_interlocks.v" would result in the program drawing a new view, called unit_interlocks and dynamicising it. For equipment access the name strings are often more complex. To read the forward cavity power in cavity 12 of unit LRF_231, the name string would be:

"eqflo:LRF_231:LRF_C12:cap(FOR):cav_pow_value:"

where cav_pow_value is the name of the variable to fill with the result. This value would be attached to another object displaying the result.The parameters forming the name are broken down by the program to from the input values for the lrf_eq_float() routine shown above. For setting objects to values input objects must also be provided, to allow the operator to select the new value. For example the name

"eqsetint:LRF_PCR:LRF_RFT1:s_phase(ELECTRON,:0:360:slider: current_e_phase:"

would result in a slider being drawn to get a value between 0 and 360 degrees from the operator. Once received a command would be sent to the RF PCR equipment and the RF electron injection phase set to this value. An automatic update of the value 'current_e_phase' would be made by reading back the set value.

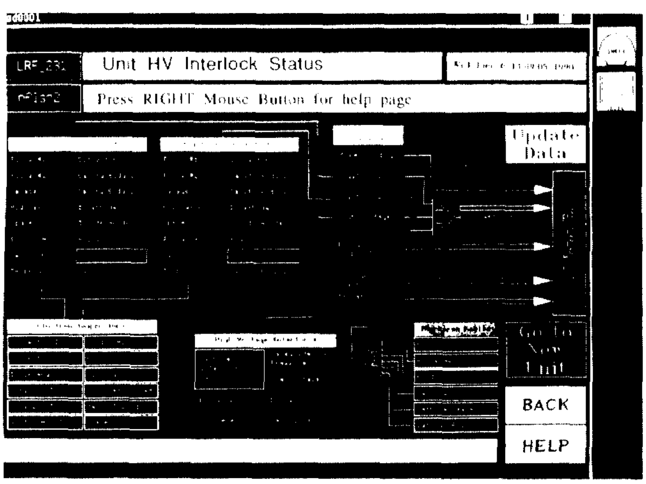

Fig. 3: Synoptic Display of an RF Unit's High Voltage Interlock Chain.

Overall status display and Logging

An acquisition/logging system has been implemented for the RF system with a fixed display in the PCR. This has proved very useful for both equipment specialists and the LEP operators. The acquisition program for this system runs on a PCR console and the data is updated every 30 seconds. Once acquired the data is stored in a file which can be accessed by any other user. One user is the PCR DM, which reads the file over the network and displays several pages of information on a colour screen. Page selection is by a neighbouring colour touch screen. Thus an operator can see at a glance the overall state of the RF system or, for example, look at data such as the RF power or vacuum in all 128 cavities in histogram form..A second 'user' is a logging program which checks the status of each RF unit and logs any undesired changes of state in another file. This can be read by the equipment specialists to help diagnose and keep track of faults in the RF system.

Upgrade for LEP 200

For the upgrade of LEP to higher energies the number of RF units will increase from 8 to 20. The new units will use superconducting cavities. The first of these extra units is partially operational, with 4 of the 16 cavities installed and working. The new units will be based on the same control system as those currently in use, with extensions for the cryogenics system. At the level of applications software relatively few changes will be needed, but many new acquisition and diagnostic programs will be required.

Conclusions

All the harwdare and software for essential applications and diagnostics was ready for LEP startup July 89. Since then some extensions and additions have been made with operational experience and to include the first of the superconducting RF units which was installed at the beginning of 1990. The use of local intelligence within the RF units simplifies applications software in the control room. This together with a simple approach to communications, consistent at all levels, has given the flexibility to easily add new functions and new equipment with relatively minor changes. The communications path for central acquisition is too complex and the present performance of the logging/display system is not completely satisfactory. A major improvement will be to provide a direct network link between the DMs and the token ring network via a local Ethernet and an Ethernet/Token Ring bridge. This will allow the PCR DM to collect RF system data in a more direct and reliable manner.

Acknowledgements

We would like to acknowledge the assistance of R. Keyser (SL-ACC) and A. Artero for their work on providing the RPC call used for the RF communications and P. Anderssen for information on the LEP consoles.

References

[1] E. Ciapala, P. Collier, M. Disdier and S. Hansen, "The Distributed Local Control System for an RF Unit", paper presented at this conference.

over the MIL-1553B. The DM interprets the command and carries out the action itself (DM function) or retransmits it to specified ECs. When the action is completed or replies have been received from the ECs a reply is sent back over the MIL-1553B and the RPC to the calling process. The message format contains information on the destination of the command, the command itself and any parameters required. The use of ASCII strings for the equipment replies results in the need for only one RPC for the whole of the RF system and avoids problems with data type format. Library routines provided for the calling process perform any conversions required.

Software Library for Equipment Access

Applications software at the level of the DM and in the PCR is written in 'C', as are all the libraries for equipment access. There is a direct correspondance between equipment function calls and their resulting commands. The communications command format chosen is such that the command and its paramaters are made to resemble as far as possible the actual 'C' language functions which produce them. This is the case both at the level of the PCR and at the level of the DM.

At the level of the DM a library of routines have been written to provide an interface for applications programs. The equipment access function calls used in 'C' language applications are actually macros which expand to send a command string over the IEEE488 buses then call one of a small number of routines to convert the reply to the appropriate type. e.g. string, state or numerical value. Arrays of these are returned for accesses to several pieces of equipment (multiple accesses). The same approach is used for the PCR equipment functions definitions. All DM equipment access functions have an equivalent in the PCR. The definitions have similar form, the same command strings are specified, but the functions for sending the commands and converting the replies are different. A single RPC control routine performs all network communication tasks. This routine also contains facilities for retry and error recovery in the case of communication problems. Once the reply has been received from the RPC the string reply is passed back to the conversion routine which performs the necessary data conversion. The function then returns this value to the calling program, together with a communication status value and, where necessary, an error message. To illustrate this the 'C' equipment access function to read the forward cavity power in cavity 12 of unit 1 of LEP sector 23 is:

```
status = LrfCavPow(LRF_231,LRF_C12,FOR,&power_reading)
```

This expands to the conversion library routine call:

```
status =
lrf_eq_float(LRF_231,LRF_C12,"cap(FOR)",&power_reading);
```

the conversion routine passes all these parameters to the RPC handling routine which performs the call by routing the message to the relevant PCA and DM. At the level of the MIL-1553B the message is re-arranged into a standard format:

```
LRF_231:C12_RS:0000_0000:cap(FOR)
```

The DM intercepts this message and will re-route the message "cap(FOR)" to the cavity 12 EC. The response, in ASCII string format, will be of the form "R!112.23". This is passed back up the MIL-1553B and RPC to the conversion routine. Here an ASCII to floating point conversion routine is called and the parameter 'power_reading' is set to the result. If no errors occured the return value 'status' is set to zero, otherwise it is set to the error number which occured and an appropriate error message is returned in a globally defined string. Similar calls can be made to return multiple results from the unit.

Applications Software

Application programs can be called up as UNIX command line programs. The lowest level program 'lrf_cmd_rsp' simply directs an input command to the selected equipment and prints the reply. Whilst this allows direct access to all equipment data and allows any action to be performed it is inconvenient for the reading of any more than a few values. Many applications programs are needed to obtain blocks of data for display purposes and to provide fault diagnostics for the equipment specialist. The program 'lrf_interlocks', for example, gets the status of all the interlocks in specified RF unit allowing diagnosis of a switch on problem. Acquisition of forward and reflected powers on all cavities and all tuner positions for a given unit is allowed by the program 'lrf_cavpowers'. Program 'lrf_setpoints' allows an equipment specialist to check the current values of the cavity tuning reference setpoints. Altogether there are around 30 such application programs.

Simplification of the overall operation of the RF system is achieved by having a relatively small number of high level operation application programs. These perform tasks such as globally switching the RF units on or off, and setting up the RF for voltage ramping. They contain long sequences of actions and make maximum use of local intelligence at lower levels. As far as possible these applications programs are data driven and minimum operator intervention is required. They make use of machine optics data, i.e. parameters and resulting machine settings and the LEP Run Table (LRT) which contains operator requirements for the run. Specific RF system data is in the form of a table known as the RF Current Data Set (CDS). This contains information on the operational status of each of the RF units, klystron power converter setting, the RF injection level and the maximum RF voltage.

For example the operations program 'lrf_switch_on' first looks at the CDS to find which units are to be switched on, gets the current state of the units concerned from the DMs then carries out the required stages of the switch on in all units in parallel starting with those in the lowest state. Status is checked after each stage and the process continues untill all units are in the requested state or a non-resolvable problem occurs. The program 'lrf_constqs' takes the value of Qs (synchrotron tune) specified in the command line, calculates the voltage function required to maintain this constant value throughout the ramp using optics data and downloads corresponding ramp function values to the DMs in the units to be ramped, as specified in the CDS. Data is read back for checking before the DM downloads the array to the function generator.

MMI and Interactive Graphics

A 'Man Machine Interface' (MMI) considerably simplifies equipment access, data acquisition and diagnostics as well as the overall operation of the RF system. All of the facilities provided by the above acquisition and diagnostic programs can be selected by the mouse from synoptic menus and the resulting data presented graphically in an easy to read form, with important information highlighted. Access to practically all critical equipment data has been provided. High level application programs can also be called from the menu system. An overview of the whole procedure of RF system operation is displayed to the operator and the options presented. This is shown in Fig. 2.

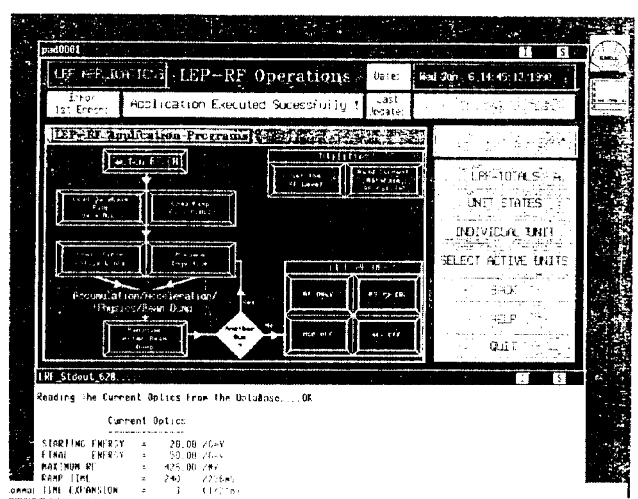

Fig. 2: Synoptic Menu for RF System Operation