Global Voltage Control for the LEP RF System

E. Ciapala, A. Butterworth and E. Peschardt
CERN, 1211 Geneva 23, Switzerland

Abstract

The LEP RF system is installed as independent 16 cavity units. In addition to the eight copper cavity units originally installed 12 units with super-conducting cavities are being added for the LEP200 energy upgrade. The total RF voltage determines the synchrotron tune (Q_S) and must be controlled precisely during energy ramping. Local function generators in each of the RF units are pre-loaded such that when triggered simultaneously by ramp timing events transmitted over the general timing system the total voltage varies to give the Q_S function required. A disadvantage is that loss of RF in a unit at any time after the loading process cannot be corrected. As the number of RF units increases automatic control of the total RF voltage and its distribution around LEP becomes desirable. A global voltage control system, based on a central VME controller, has recently been installed. It has direct and rapid access to the RF units over the LEP time division multiplexing system. Initial tests on operation and performance at fixed energy and during energy ramping are described, as well as the implementation of a Q_S loop in which Q_S can be set directly using on-line synchrotron frequency measurements.

I. INTRODUCTION

The RF system of LEP is made up of individual RF units. For the first phase of LEP and operation up to 50 GeV 128 room temperature coupled cavity assemblies have been installed in the form of eight individual RF units. Each unit consists of 16 cavities and two 1 MW klystron power sources, high voltage power supply, low level and digital controls. For the LEP200 upgrade to energies approaching 90 GeV a further 192 super-conducting (SC) cavities will be installed. These will be arranged as an additional 12 RF units using as far as possible the same type of infra-structure, but with one klystron per unit, making a total of 20 RF units. Furthermore for high beam intensities the SC cavity units may be equipped with two klystrons per unit, each driving a group of eight cavities, each group thereby operating independently.

The method originally envisaged for control of the total RF voltage was based simply on the individual control of the voltage of each unit [1]. For energy ramping the total RF voltage must increase according to a pre-determined function such that the synchrotron tune Q_S is maintained throughout the ramp. To achieve this each RF unit was equipped with its own RF voltage function generator. These are pre-loaded with calculated values prior to the ramp and triggered simultaneously by ramp events transmitted over the LEP general machine timing (GMT) system. This system works satisfactorily provided that all units continue to contribute the expected voltages during the ramp. It cannot cope with unexpected changes in the state of individual RF units due to interlock trips. Some form of overall and automatic control of RF voltage is clearly desirable and becomes increasingly important with the large number of RF units for LEP200.

A software global voltage control system running on a central workstation was implemented last year. This was used successfully to maintain fixed voltage (at injection or at top energy) but could not be made fast enough for ramping. The limitation was due to the time required to get commands and status information to and from the equipment inside the RF units. Access from PCR to the main 'Data Manager' (DM) which controls the RF unit over the Ethernet connection used for remote control takes around 50 ms. Access from the DM to the 'Equipment Controller' (EC) [2] which interfaces the equipment of the low level RF of the unit (one of 23 such ECs) over IEEE bus takes a further 50 ms. These times can not be predicted exactly and can be considerably increased depending on network activity and on IEEE bus activity inside the RF unit.

Ideally the performance of the overall system should be limited only by the response of the RF voltage control loop inside the RF unit. This loop has been designed such that the RF voltage can be ramped at a rate of 5% of maximum per second, this being at least an order of magnitude greater than that required during energy ramping. If the RF voltage is to be maintained to a precision of 0.1 % then the system must be capable of acting on each unit at least every 20 ms. Guaranteed access times can be obtained only by dedicated connections. In LEP the most economical way of implementing these is over the time domain multiplexing (TDM) system. It connects all the interaction points (IPs) of LEP and the control room via fibre optic links and is the backbone for the Ethernet and Token Ring networks and timing systems. Commercial equipment exists to multiplex various types of analogue and digital signals over TDM systems. The transmission and reception of analogue signals directly to a hardware based central controller would provide fast overall response but would lack flexibility. The use of a computer based central controller and the transfer of data over the TDM to the RF units can provide more than adequate speed for this and also the possibility of directly transferring additional low level RF system information useful for global voltage control, such as loop states and RF phase settings.

A global RF voltage control system making use of the TDM system in this way has recently been installed. The system hardware and software is described and the results of an initial test made at the end of 1992 presented.

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II. The Global Voltage Control System

A. System configuration

A block diagram is shown in Figure 1. The central controller is situated in the Prevessin control room (PCR). TDM channels at 2 MBit/s have been allocated for each of the points of LEP where RF is already installed (IPs 2 and 6) or will be installed (IPs 4 and 8). Serial line multiplexers at the end of each TDM link provide individual connection between the central controller and the RF units at each point. In the PCR connection is by sets of RS232 lines, one for each unit. In the underground klystron gallery where the distances are up to 500 metres the connection to the remote RF units is by RS485 differential transmission.

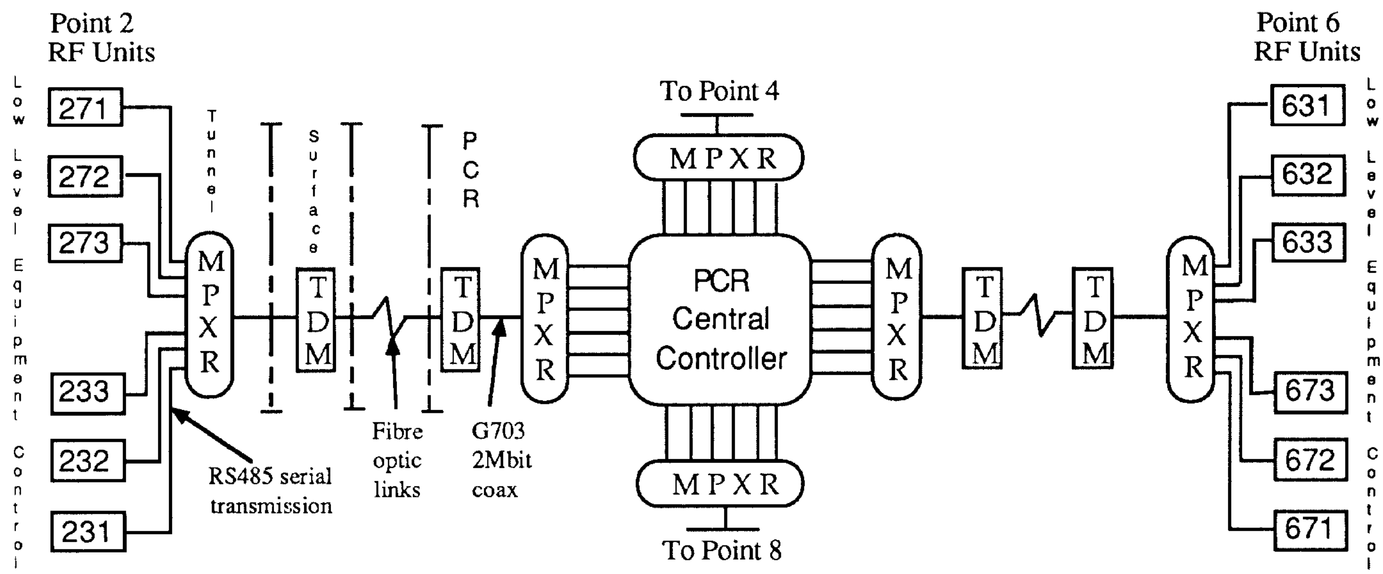

Figure 1. RF Global voltage control system - overall layout.

B. Central controller

The central controller is a VME crate containing a 68030 based CPU module. An intelligent IO module carries the multiple serial IO controllers for communication with the RF units. The OS/9 operating system is used and the global voltage control is implemented as a 'C' language program which continuously monitors all the RF units and sets RF voltages depending on equipment states and the desired modes of operation.

C. Multiplexing equipment

The CCITT G703 standard is used for the TDM equipment of LEP. Multiplexing equipment in the form of crates allowing a range of up to 16 interfaces of different types, each using 32 kBit of the 2 Mbit per channel, was obtained from industry. The global voltage system uses serial interfaces of RS232 and RS485 types but other interfaces allowing the transmission of analogue signals are used on spare channels, for example the analogue signal representing the synchrotron motion of the beam from tunnel equipment to the PCR.

D. RF unit interface

The serial RS485 line is connected to the low level EC of the RF unit. This EC contains the interfaces which allow the setting of RF voltage and phase, the reading of the detector sum of all cavity voltages and the state of the voltage control loop. The global voltage control system can set values and read information in the same way as the DM over the GPIB but this must be independent of all other processes and with higher priority. The RF voltage is set to the value required by a linear software ramp at a pre-determined rate. The existing EC software is however based on single task operation with a single interrupt level and the condition of absolute priority was difficult to implement. For this as well as other reasons the Low Level equipment controller has been fitted with a 68000 type processor module and VME to G64 converter such that interrupt driven multi-tasking software can be used. This was not completed in time for the initial test described later but will be installed for the final operational system this year.

III. Operation

The system can be considered to have different modes of operation depending on the reference used for the total voltage. In addition the distribution of voltage on the various units is determined by requirements of RF symmetry around the machine.

A. Modes of operation

- Fixed RF voltage - The reference is a value fixed by software. This mode is applicable to injection and coast.

• RF voltage ramp - For energy ramping the RF voltages corresponding to each of the individual energy ramp vectors are loaded into a table in the central controller. The reference voltage during the ramp is derived from the table using a vector interval counter triggered by the events of the GMT.

• Q_S loop - Readings of synchrotron frequency (f_S) can be derived from acquisition and processing of the synchrotron frequency spectrum from a phase detector which compares RF and bunch signals. If Q_S is specified as reference, either fixed or varying according to the ramp, the loop can adjust RF voltages to maintain the required value. This requires rapid, accurate and reliable measurements of f_S.

B. RF voltage distribution

The voltages which can be provided by the various units are not identical. The SC units produce more voltage than the copper cavity units, for the SC units the voltages may not all be the same and during operation certain units may be down or unable to provide their nominal voltage. The distribution of the RF voltages making up the total has to be arranged according to the voltages available and to the degree of symmetry required. The RF 'current data set,' (CDS) a table containing information on RF unit states and voltage limits, is kept up to date during operation. When this is changed the updated table is sent to the central controller. Symmetry conditions can be specified by the operator and the system will maintain these as long as the available voltage at each point or individual unit permits. The following conditions are allowed for :

• Asymmetrical - All units maintained at the same fraction of their individual maximum voltage. This allows ramping to maximum voltage with all units reaching maximum at the same time, without symmetry considerations

• IP symmetry - Equal voltages from RF on either side of the IP, all units at each side having the same fraction of their maximum.

• Symmetrical - Equal voltages at opposite interaction points, This can be with or without IP symmetry.

Since the symmetry conditions are stored in array form any possible configuration can be used.

IV Initial Test with Beam

A first test with beam was carried out on the RF global voltage control system just before the start of the LEP annual shutdown in November 1992. Switching the system on with seven RF units running brought the voltage to the set fixed voltage reference of 50 MV. Switching on of another RF unit was correctly compensated by the system. This is shown in Figure 2. A relatively slow rate of RF ramp was set in the low level equipment.

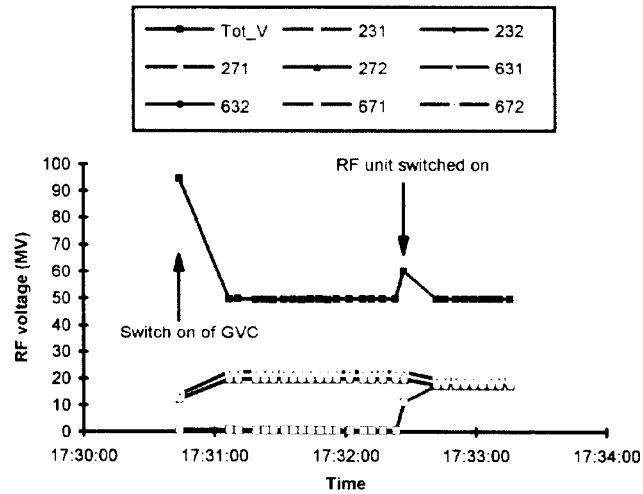

Figure 2. Switch on of system with seven RF units followed by switch on of new RF unit

Over long term operation, however, and during ramping, occasional delays in communication over the serial channels hampered operation. This was caused by interference with other activities at the level of the low level ECs. This should be resolved by the improvements previously described. The tests showed the feasibility of the Q_S loop. Response was slow, however, due to the time taken to make accurate measurements with the spectum analyzer. A more rapid synchrotron frequency detector using FFT methods is in preparation.

V Conclusions

A global RF voltage system capable of meeting the requirements of LEP operation has been installed and initial tests carried out. Some modifications to resolve problems discovered during these tests are being carried out and further tests will be done soon with the aim of having the system fully operational during 1993.

VI Acknowledgements

The provision of the TDM channels by the SL-CO group and the assistance of specialists in the group is gratefully acknowledged.

References

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