USING DISTRIBUTED INTELLIGENCE TO CONTROL THE VACUUM SYSTEM OF A VERY LARGE ACCELERATOR

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ABSTRACT

The control system for the LEP machine is based on the concept of distributed intelligence. Hence the controls for the Vacuum System have to follow the same approach. There are a number of benefits available from having distributed computing power, among them the possibility of having powerful control devices made available to the vacuum operators on the site where they work, rather than in a central control room.

The paper outlines the advantages of having so called intelligent equipment controllers for every item installed, which makes it possible to control them via a local area network, using standardised messages. This local area network, though completely transparent to the main control system, allows complete independence at the level of a vacuum sector when the general control system is not available.

This contribution also describes in some details the light pen driven mobile consoles which were used during the commissioning of the LEP Vacuum System, providing the operators with a global overview of the equipment they had to control from anywhere in the LEP tunnel.

INTRODUCTION

The LEP Vacuum System extends over 27 kilometres and is divided into 130 sectors. One sector can be as long as 474 metres. Pumping and measuring equipment is distributed over the length of one sector during commissioning, whereas the ion pump power supplies, the gauge power supplies and the sector valve controllers are located in underground service areas at the bottom of each access pit, which can be as far as 1700 metres from the actual sector. Both for financial reasons and also because of the risk of damaging components by the synchrotron radiation which is produced when LEP is running, the initial pumping and bakeout is made using mobile equipment, which is moved from one sector to another [1].

The spread of the equipment over such long distances means that traditional local controls (e.g. front panel knobs) are not suitable for LEP. The vacuum operator must be given tools to operate all vacuum equipment, no matter where it physically resides nor if it is permanent or mobile, from any convenient place: from the LEP ring tunnel during commissioning, from the underground service area for routine maintenance and from the control room during normal operation [2,3].

These constraints led us to design every power supply or controller as so called intelligent equipment, incorporating a microprocessor. In this way, the equipment can be connected trough a local area network to generalised control panels, which are made out of a 7 inch screen for data display and a light pen for data input. These control panels, which will be called light pen consoles thereafter, can be connected anywhere and at any time to the local area network. The local microprocessor also does some local supervision and prepares the data to be returned on the local area network.

As the vacuum system is divided into sectors, we decided to build the vacuum controls in layers, with the lowest layer controlling one vacuum sector. Indeed, all of the commissioning work can be done at this level. Above this first layer, the sectors are grouped into octants and finally into a whole machine. The latter two steps are taken care of by the main control system of LEP.

REQUIREMENTS FOR THE VACUUM CONTROLS

The vacuum controls have to satisfy the following requirements:

- Allow commissioning and supervision of a complete vacuum sector, even if the main control system is not available (not yet ready during construction or down for maintenance).

- Allow supervision from everywhere in a standard way, in order to minimize the number of vacuum operators.

- Provide the vacuum operator with a user-friendly interface. In particular, take into account that vacuum operators have little or no skill in computer science.

EQUIPMENT INVENTORY

1) Permanent equipment

In each sector, permanent equipment typically consist of two to seventeen ion pump power supplies, one Pirani gauge controller, one sector valve controller, one light pen console and one interface to the main control system of LEP. Additionally there may be one multi-head ion gauge controller, one NEG pump thyristor controller or several sublimation pump controllers in special sectors. All these items are grouped in the underground service areas (US).

2) Mobile equipment

The mobile equipment consists of up to six mobile pumping stations (which include Pirani and Penning gauges and controllers), up to six high temperature water heaters for the bakeout, up to six thyristor controllers for the activation of the NEG pump and up to six ion gauge power supplies to monitor the vacuum at the end of the bakeout. In addition, each mobile pumping station includes a light pen console.

The following table summarizes the equipment required for one vacuum sector (with the exception of the sublimation pumps which can not be remotely controlled yet):

Equipment	US	Tunnel	
Ion pump supplies	2-17		
Ion pumps		5-36	permanent
Pirani gauge controllers	1	2-6	mobile
Pirani gauges		1 2-6	permanent, mobile
Penning gauge controllers		2-6	mobile
Penning gauges		2-6	mobile
Pumping groups		2-6	mobile
Ion gauge controllers	0-1	2-6	mobile
Ion gauges		1-18	permanent
Gas Analysers	0-2	1-3	mobile
Thyristors for NEG pumps	0-1	3-6	mobile
Bakeout heaters		2-6	mobile
Sector valve controller	1		
Sector valve		1	permanent
Light pen console	1	6	mobile
Interface to LEP controls	1		

PARTICULARITIES

Aside from the very large size of the LEP machine, which led us to find original solutions in order to minimize the cabling costs [2], and the decision to install a private local area network at the sector level, the following points are worth mentioning:

1) Mobile equipment

The extensive use of mobile equipment anywhere around the LEP machine poses the problem of identifying it and keeping track of it. To solve this problem, each light pen console is able to find out which addresses are used and what type of equipment is available by scanning all possible addresses on the local area network. Hence the console builds up a dynamic table of all the equipment, permanent or mobile, which belongs to the vacuum sector it is looking at.

The same approach is also used in the gateway which is used as the interface to the main control system of LEP. This allows us to run identical software in each sectors.

2) Protection of the NEG pump

The operating pressure of the NEG pump during its activation is too high to keep the ion pumps or ion gauges on, but too low to have a safe interlock level from the Pirani gauge. The solution is to use residual gas analysers locked onto peak 40 (Argon) as an interlock against large leaks, taking advantage of the fact that Argon is not pumped by the NEG to increase detection sensitivity.

3) Absence of classical control panels

As it was clear very early in the project that all the equipment would have to be remotely controlled, very few systems were equiped with manual control panels. Therefore, the man/machine interface provided on the light pen consoles had to be user-friendly enough to be easily used by vacuum technicians who have little or no skill in computer science.

COMMUNICATION BETWEEN EQUIPMENT

In order to transmit the information between the various pieces of equipment, a message protocol has been proposed by the LEP controls group [4]. The main features of this protocol are the following:

- The destination of the message is part of the message itself. Different type of equipment are grouped into families and each individual piece of equipment is a member of a family. The concatenation of family and member uniquely identifies any piece of equipment throughout the LEP control system.
- Each message conveys an action. Parameters can also be added in a so called user area.
- The format of the data exchanged between equipment can also be defined in the message, although at present we only use ASCII representation.

A typical message, which would start up an ion pump power supply looks as the following:

VRPA_101623,HV_RS,0_0!START

All the messages for the control of vacuum equipment have been defined in the LEP database. A single message decoder is used in every type of equipment, which is fully data driven. A suite of programs, running on the LEP database VAX, produce the data tables for the decoder, which will personalize each type of equipment [5].

KEEPING TRACK OF MOBILE EQUIPMENT

A fully dynamic approach has been chosen to keep track of the mobile equipment.

Each equipment controller or power supply can usually control several members of several families. For instance, an ion pump power supply and up to 8 pumps are controlled by a single microprocessor. A dummy family, called IDENT, is included in every equipment controller. This family has a single member, the same for every equipment controller, and the family can accept two actions which allow to return the families and members accessible trough this equipment controller.

The light pen console (or the interface to the main control system of LEP) periodically scans the addresses on the local area network and issues the identification messages. It then keeps a table of the used addresses and of the equipment accessible at each address. This table can later be used by the application programs to address the equipment.

SOFTWARE FOR THE LIGHT PEN CONSOLE

The software for the light pen console has been written in a very modular way. With the exception of small part of assembler code, it is completely written in PASCAL.

At start up, the program scans the complete program memory area to find out which modules are implemented. In a second step, the program checks that the address it was allocated via a front panel thumbwheel switch is free and if so, sets up a menu page which lists all available functions on the screen. These menus are organised around the equipment which can be controlled (e.g: one menu item for the ion pumps, another one for the sector valve, etc...).

After the operator has chosen one menu item by pointing on it with the light pen, the program scans the range of network addresses allocated to the desired vacuum equipment in order to identify the equipment which is available. It then draws a global control screen, which shows for example all pumps in one sector. Global on and off functions or global settings of a reference value can be performed via this first control screen.

From most of the global control screens, the operator can get more detailled information about an item by pointing on the data displayed for it. These more detailled screens are mainly used to display individual item names and read or set individual calibration factors.

EXPERIENCE

The number of available menus on the light pen console have been progressively increased to cover all the required functionality and their performance has been improved using feedback from the operators. At present time there exists seven main menus, allowing to control ion pumps, mobile pumping stations, thyristor units for NEG pumps, super-heated water units, ion gauges and sector valves.

The reliability of the various components has proved to be adequate. The most frequent problems occur when the various components are first connected to the network and are mainly due to cabling faults. The stability of the software still has to be improved for some items. The experience gained so far will guide this improvement work.

A negative aspect of the distributed intelligence and the use of a local area network is the difficulty in diagnosing faults. Many problems seem to show up as a network or a software fault, but are most frequently due to a mismatch in line impedance adaptation (e.g. a missing terminator resistor). A serious effort has to be put in proper diagnostic and fault finding equipment.

On the positive side, using distributed intelligence allowed us to implement distributed controls in order to cope with the very large size of LEP. During the last few months of installation and commissioning, all operations could be successfully conducted from the tunnel by a team of 2 people per vacuum sector. Operation from the control room, and in particular the writting of the application programs, is considerably easier when the equipment is able to recognize its name and to return already pre-treated data. Dynamic address recognition makes adding or removing equipment straightforward and allows us to control the mobile equipment.

REFERENCES

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