MICRO-CONTROLLED VACUUM SYSTEMS AT NAC

P.J. Celliers and E.J.S. Franklin

National Accelerator Centre, P.O. Box 72, FAURE, 7131 Republic of South Africa

ABSTRACT

The vacuum systems for both the 'beam swinger' and the newly-installed spectrometer at NAC are controlled by an OS/2-based 386 micro-computer (PC). The operating system's multitasking environment allows both vacuum control programs to run simultaneously and its graphical capabilities provide an intuitive and easy-to-use interface for the operator. Graphical layouts of the systems, showing pump and valve states and beamline pressures, are displayed on the colour monitor, while a pointing device enables an operator to communicate with the system directly on the monitor. A local-area network allows control of the systems from any node on the network. A description of the hardware and software of the two vacuum systems is presented here.

1. INTRODUCTION

The new system for vacuum control is the third-generation of such systems being used at NAC. The first was an electronic system with a mimic panel to display the state of the system and press buttons to operate pumps and valves. The interlocking was done electrically. The second[1-3] is a microprocessor controlled system with a station-dependent mimic panel, a specialized keyboard and an alpha-numerical display for communications. The third generation has the following features:

(a) dynamic display of the layout and state of the system,
(b) simplified operator control via a mouse,
(c) software access for later enhancements in the layout or control of the system,
(d) standardization in hardware and communication, and
(e) multitasking.

A layout of the beamlines and cyclotron facility at NAC is depicted in reference 4. The systems under discussion are on the right of the figure.

2. CONTROL

The control for the new system uses a 386 micro-computer, a cardcage with the SABUS interface back-plane to hold all the necessary modules, a mouse and a VGA colour monitor (see Fig. 1). The layout of the vacuum system(s) is displayed on the monitor. The pressures measured by all the gauges and the states of the various pumps and valves are displayed in various colours at the appropiate positions on the screen. Green symbolizes a "closed" or "off" state and red an "open" or "on" state. Black symbolizes a valve state which is neither "open" nor "closed". It is therefore very easy for the operator to establish the state of the vacuum system.

The computer communicates with the hardware by means of two differential drivers, one in the computer and the other in the SABUS crate. This crate holds the four 32-bit relay output modules, the four 80-bit opto-isolator input modules and the 32-channel analogue (ADC) input module. Each relay output module consists of 2.5 V reed relays which latch 220 V relays thus enabling the system to switch pumps on/off or to close/open valves. An electronic watchdog has been installed on each module which will cause the relays to unlatch if they are not addressed within 22 s. The 24 V opto-isolator modules are responsible for reading the limit-switches on the pumps and valves. The 2.5V ADC input module reads the analogue signals for the gauges and translates them to pressure readings.

Each element (bit) on the modules can be addressed by means of the port addresses on the motherboard, the addresses of the modules and addresses within the modules. Correct wiring of these modules ensures that each vacuum element can thus be addressed. All these modules were designed and manufactured at the NAC.

The computer communicates with the operator by means of messages on the screen. Changes in vacuum system state are represented by colour changes of the pump and valve symbols and a display of the pressure at the corresponding positions. Under OS/2 Presentation Manager a 'window' for each symbolic pump, valve and meter is generated on the screen. Any change in the vacuum state is reflected by writing to the respective window using its software window 'handle'.

The operator communicates with the system by means of the mouse which is easy and intuitive to use. To change the state of a pump or valve the mouse cursor is moved to the desired window (pump or valve) and the left mouse button is depressed. This causes a request flag to be set. A white dot or square on the relevant window indicates that a request was made. If the

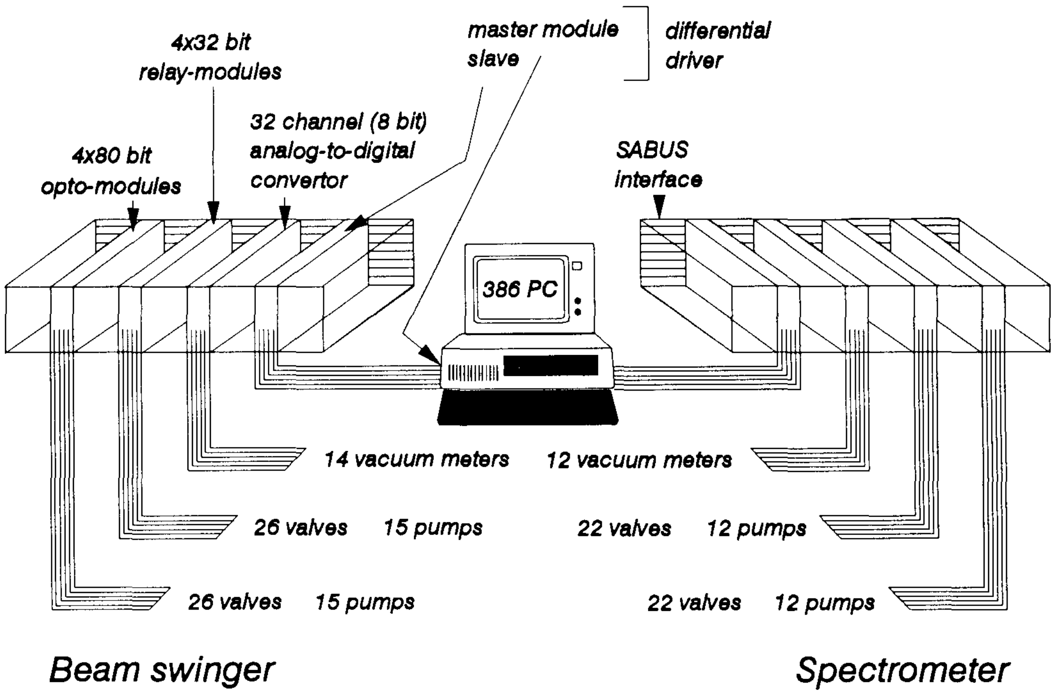

Fig. 1. A scematic view of the instrumental node for the two vacuum systems.

interlocking conditions are met the state is changed. The right button is used to switch off any pump or close a valve immediately without considering the interlocking conditions or to reset the request before it was executed.

The system is fully automatic by utilizing five OS/2 threads in the program. They continiously monitor the pressure and limit switches, control the screen display and the relays, and handle all network communication.

In addition to the monitoring, the following active procedures are also initiated as a result of a change of the state of the system:

- Valves will close on any unacceptable rise in pressure. Because the request flag remains set the valve will open if the pressure decreases sufficiently again.
- Valves are also protected from the particle beams. If a beam is passing through a beamline and the valves are closed for any reason, signals sent to the cyclotron interlocking system will result in stopping the beam on Faraday cups.
- Turbopumps will be switched off if signals indicating malfunctions are received. If a turbopump fails to start, the fore-pump will be switched off in 20s.

3. MULTITASKING

The computer is supported by the OS/2 operating system with Presentation Manager as the graphical user interface. The programs are written in the C language. The multitasking environment allows more than one complete vacuum control system to run concurrently on one machine. Multiple windows and icons provide for a convenient display. One or both vacuum systems can be displayed on the screen in separate windows. The one that is displayed is graphically active and is identified by its title bar located on the top of the window. Messages can be sent or received from this window. To select

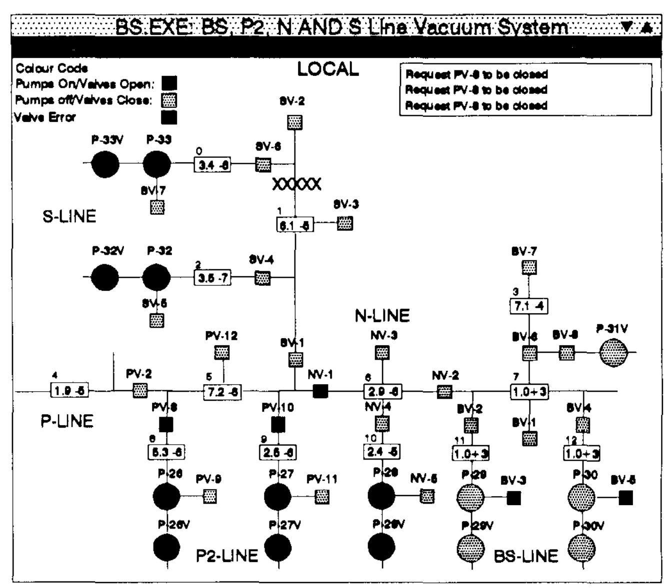

Fig. 2. A screen copy of the colour monitor video display of the 'beam swinger' vacuum system.

another window to become active, the operator must shrink the active window by pointing the mouse to the 'minimize' box at the top hand right corner of the present window and press the mouse button. Next, the mouse cursor is pointed to the icon which represents the program to be viewed and whose name is displayed at its bottom and the button is pressed to maximize the icon.

The two vacuum systems mentioned above are the beam swinger and associated beam lines and the spectrometer beamline[4]. The computer layouts for the two vacuum systems are shown in Fig. 2 and 3.

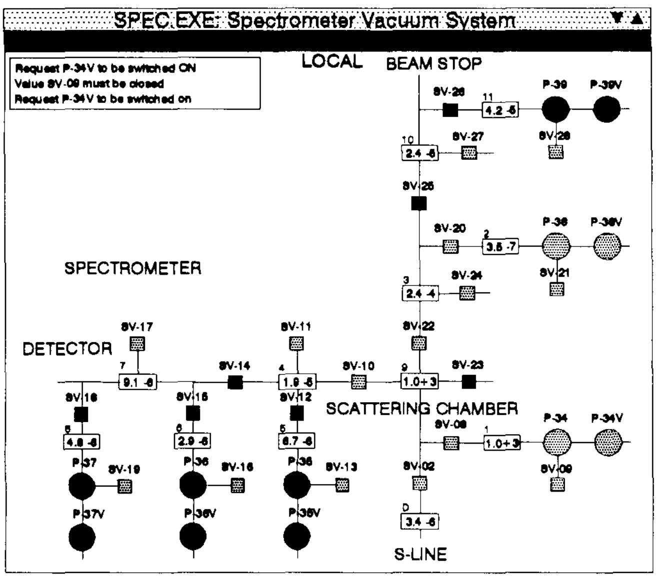

Fig. 3. A copy of the colour monitor video display of the spectrometer vacuum system.

4. LOCAL AREA NETWORK

The network consists of a thick Ethernet baseband cable connected to the nodes via transceivers and cluster boxes where the nodes are closely spaced. The local computer with its hardware (known as the instrumentation node), the console computer and any other nodes are connected to these multiport transceivers by means of the Ethernet communication interface as shown in Fig. 4. By means of the interface, data is sent to or received from the network. Data packages are sent at a rate of 10 Mbits/s and consist of data, the destination and source address.

The local node controls the vacuum systems which are in turn being controlled by one or more console nodes. Each instrumentation node has a memory-resident table which is a dynamic database of all the actual values of vacuum system parameters at that local station. Any change in the state of the vacuum system is written to the local table and is transmitted to all the nodes on the network. The table in the local node can

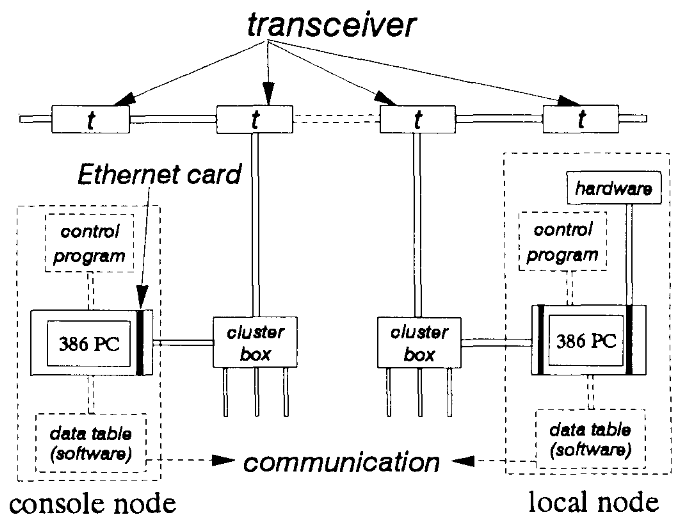

Fig. 4. A schematic representation of the Ethernet network.

also receive commands from the console nodes via the network, update the variables and then controls the instrumentation accordingly.

The console node has the same programs as the instrumentation node, namely the vacuum control program and the console table program for the database. The console table is updated via the network when changes in the hardware are written to the local table and then transmitted to the console nodes. The latter then displays the updated vacuum system parameters on the colour monitor by writing the latest pressure and displaying the correct state of the pumps or valves. The table program can also display the actual and reference values of all the parameters in the database in a page format.

We are now running two independent vacuum systems on the local computer. In addition there is a console node situated in the control room from which both vacuum systems can be controlled. Control of the system from any other node has also been demonstrated. A detailed description of the NAC distributed control system, which includes the vacuum control, is given in the present proceedings[5].

5. INTERLOCKING

The interlocking function is only accessed when a request has come from an operator or if a system parameter such as the pressure or a limit-switch position, has changed. The interlocking conditions are specified for pumps and for valves. The pumps have separate conditions for fore-pumps and for high-vacuum pumps. The conditions for the valves are classified according to whether they are isolation valves (between beam lines), ventilation valves, or valves connecting pumps to beam lines.

The interlocking principle is as follows. Each parameter is identified by its state, its requested state and the number of requests. In the case of valves an additional value, the differential pressure across the valve, is set. To operate a pump or valve, all these various values (software flags) for the affected valve(s), pump(s) and pressure difference(s) are grouped together in a byte. If this value corresponds to a pre-calculated value then a pre-defined action is taken and messages are written to the display window.

The maximum pressure difference (MPD) allowed across the valves mentioned above, is set to change according to the geometrical average pressure difference across the valve. This is to ensure that the MPD will always have a realistic value. The relation is given by

$$\mathrm{MPD} = \frac{100 \times \sqrt{(P_1 \times P_2)}}{\sqrt{(1 + P_1 \times P_2)}} \text{ mbar.}$$

P_1 and P_2 are the pressures on each side of the valves. For high pressures (1000 mbar) the maximum difference is high (100 mbar) and for low pressure (1×10^{-6} mbar) the maximum difference is low (100×10^{-6} mbar).

These interlocking conditions were tested in the laboratory on an electric system of switches, LEDs and potential dividers before the program was installed on the various computers.

6. METERS

The software is designed to accomodate two sets of meters. One set has two voltage signal outputs and therefore two ADC channels are used, one for each of the Pirani and Penning gauge signals. Two tables of 128 values each are also necessary for converting the voltage signals to pressure in mbar.

The other set, which was built at NAC, supplies only one output signal and the relation for converting the signal to pressure is very simple. If the voltage is given by a 3-digit, 2 decimal figure, which we can write as A.BC volts, then the pressure is given by $\mathrm{B.C} \times 10^{-(A-9)}$ mbar.

The pressure is only recorded if the output voltage of the gauges change with 2/128 V. The accuracy of measuring the pressure is 1/128.

7. TROUBLE SHOOTING

The majority of problems are caused by valves which close unexpectedly. This is mainly due to faulty gauges or meters. On rare occasions some of the output relays malfunction, inhibiting pump or valve operations. A chart is available to locate the faulty relays very easily.

8. CONCLUSION

After two years of experience with the beamswinger system and a few months with the spectrometer system for it is evident that the performance is very good. The new NAC vacuum-meters also behave very well. Similar vacuum control systems will be installed in future systems for the second injector (SPC2) and associated beamlines[4].

9. ACKNOWLEDGEMENTS

The authors wish to thank Mr Hanekom for his assistance in preparing the computer-processed diagrams in this paper.

10. REFERENCES

1) Visser, K. and Mostert, H., "Vacuum control systems at the NAC cyclotrons," in **Proceedings of the 11th Int. Conf. on Cyclotrons and their Applications** (Ionics Publishing, Tokyo, Japan, 1986) pp 426-427.

2) NAC Annual Report 1984, NAC/AR/84-01, pp. 81.

3) NAC Annual Report 1985 NAC/AR/85-01, pp. 91.

4) Botha, A.H. *et al.*, "Commissioning of the NAC Separated-Sector Cyclotron", in **Proceedings of the 11th Int. Conf on Cyclotrons and their Application** (Ionics Publishing, Tokyo, Japan, 1986) pp 9-16.

5) Weehuizen, H.F. *et al.*, "The new distributed control system of NAC", (these proceedings).