# Examples of Applications of Industrial Control Systems (PLCs) for Vacuum Equipment

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**Abstract**

This paper describes some developments in the domain of vacuum controls, using industrial control systems (Programmable Logic Controllers or PLCs). After showing the different advantages of the PLC for vacuum applications, when compared with a specific solution, we mention the main points that led us to make this choice.

Then, we describe some realisations (pumping groups and test benches for vacuum chambers) using a PLC and the related fieldbuses to interconnect these controllers to the upper layer of the control system. Finally, we sketch out one of the possible solutions to control some vacuum equipment of the future LHC machine.

## 1 Introduction

In recent years, PLCs have been more and more used in the control systems of accelerators and physics experiments. This situation is the consequence, on one hand, to their intrinsic qualities and, on the other hand, of the current trend to integrate industrial equipment instead of 'home-made' developments and to go toward global industrial control solutions [1]. For these various reasons, and after a complete study of the different possible solutions, we have decided to use PLCs for two applications in the vacuum field: the control of vacuum pumping groups and the control of a set of two test benches for the vacuum chambers.

## 2 Using PLCs for vacuum applications

The vacuum system of accelerators and physics experiments require the control of a large number of equipment (valves, gauges, pumps, etc.) coming from different manufacturers (e.g. more than 1800 vacuum devices in the LEP, more than 800 in the PS Complex [2]). To control this equipment we use devices supplied by the vacuum manufacturers or specific controllers developed at CERN and assembled in industry (e.g. G64 chassis for the control of valves, pump power supplies, etc.).

In both cases we are faced with the same drawbacks and the same constraints:

- specific controller for one family or one type of equipment,
- incompatibility between manufacturers,
- large number of different controllers to maintain,
- no fieldbus interface or only a serial interface (RS232) with specific protocol,
- difficulties to implement hardware or software modifications after initial installation.

The PLC solution avoids most of these problems and shows the following main advantages:

- robustness (massive use in industry),
- easy to use (powerful developing tools),
- easy hardware modifications (modularity),
- reduced number of spare parts,
- reduced maintenance,
- connectivity to at least one fieldbus,
- MMI programmes available,
- long lifetime and long-term support from the manufacturer.

This solution has therefore been adopted for the control of the two applications describes below.

## 3 Examples of applications

### *3.1 Vacuum pumping groups*

Vacuum pumping groups are used in large numbers in accelerators for the pumping of the beam pipe, down to a pressure of some $10^{-9}$ mbar.

A typical pumping group is composed of a mechanical roughing pump, a turbomolecular pump with its own speed controller and 4 or 5 valves (for isolation, venting, leak detection, ...). In addition other auxiliary devices, like pressure gauges or switches, heating element and cooling system may be found (fig.1).

The controller must manage all these devices to satisfy the different operational modes required by the vacuum technician. The pumping group is usually used in a stand-alone mode, via a local control panel, but it also can be remotely controlled when connected to a fieldbus.

Until now our choice was to buy a complete pumping group on the market with its own control system or to buy all the components separately from different vacuum manufacturers, integrate them , and develop a specific controller. This practice has lead to the situation where we find ourselves with tens of different pumping groups (with nearly the same functionality) with as many different types of controllers!

The need for new pumping groups provided the opportunity to use the PLC solution to develop a 'universal' controller for all pumping groups whatever their origin or their configuration.

#### *3.1.1 PLC selection*

The main criteria of selection are:

- Technical: CPU power, input/output modules, fieldbus connectivity, limited size (installation inside a 3U Europa chassis), adequate development tools.
- Others: quality/price ratio, European origin, technical support from the manufacturer and inside CERN, etc.

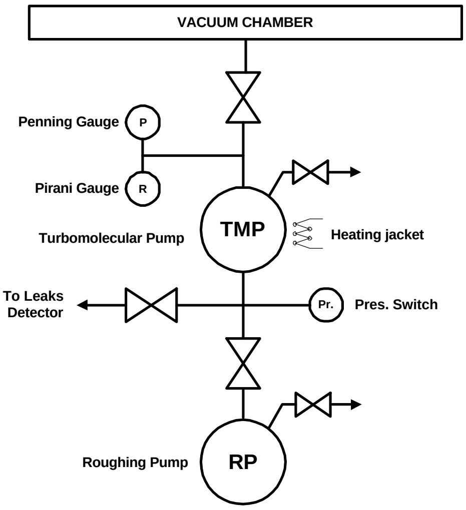


**Fig. 1 - Pumping Group**

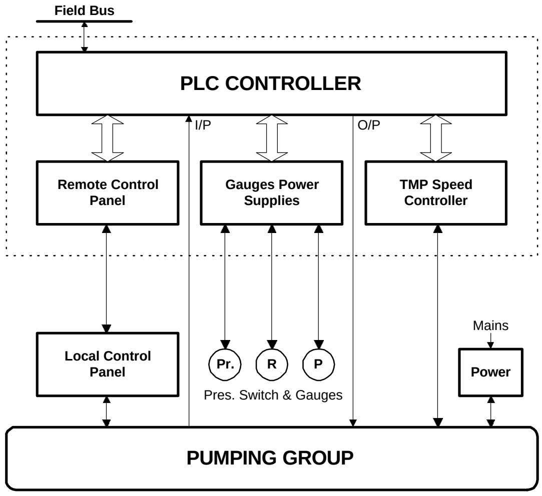


**Fig. 2 - Pumping Group Controller**

The PLC selected for this application belongs to the Simatic© S7/300 family of Siemens. We use the following modules: one power supply PS307, one CPU313, one 32 input and one 16 output digital modules. A pre-prototype had been realised before with the previous Simatic© family S5-95U [3].

*3.1.2 System description*

The PLC is installed inside one half of a 3U Europa chassis. The remaining half is reserved for the speed controller of the turbomolecular pump. There is a control panel on the front used for 'remote' operation, as the pumping group can be located at a distance of up to 300m from its controller. There is a 'local' control panel and a mains distribution box near the group itself (fig.2).

The input module of the PLC is connected to the signals coming from the various components (pumps, valves, etc.), from the control panels and from the gauges.

The output module is connected to the different actuators (valves, power breakers, etc.).

*3.1.3 Operating modes*

A pumping group is an ideal application to use a PLC. The main phases of operation are the following:

- starting sequence,
- pumping at nominal or reduced speed,
- leak detection,
- stopping sequence.

All these operating modes can be clearly defined with sequential logic. There is one programming bloc dedicated for each component of the group (object). The program is stored on an EEPROM card which is very easy to change to match the program to the type of group or to its configuration.

*3.1.4 Dual-controller*

For smaller pumping groups we have integrated 2 speed controllers for turbomolecular pumps inside the same 3U Europa chassis. With the addition of 2 extra input/output modules and of a second control panel we can control, with the same PLC, two pumping groups in an totally independent way.

*3.2 Test benches for vacuum chambers*

The second application is the rejuvenation of two test benches for the vacuum chambers.

The following tests are executed:

- leak detection before and after bakeout,
- measure of the degassing rates,
- measure of the limit pressures,
- residual gas analysis.

The two test benches are identical. They are equipped with a 6m long measurement chamber connected on one side to four pumping groups and on the other side to the devices to test (DUT) via six isolation valves.

The measurement chamber is equipped with 3 gauges, a gas analyser and a ion-pump. On every output we find also a gauge an a ion-pump (fig.3).

The rejuvenation consists of replacing the oldest equipment (pumping groups, gauges, etc.) and, in a second step, to install a supervision system for the remote control of the test benches.

*3.2.1 Description*

For the new pumping groups we have used the dual-controller describe in 3.1.4 . For the supervision of the test benches we have chosen the following solution (fig.4). We use as main controller a Siemens PLC type S7/400 for reasons of compatibility. It is connected to the pumping group controllers via the MPI© fieldbus.

This serial bus (RS485) is integrated in every CPU module and can be used with a maximum length of 50m at 187.5 kbit/s. It is very cost effective for small applications because we do not need additional communication module. The 20 analogue inputs from the gauges are connected to three 8-input modules with a resolution of 13 bits . For the control of the 12 separation valves we used two distributed

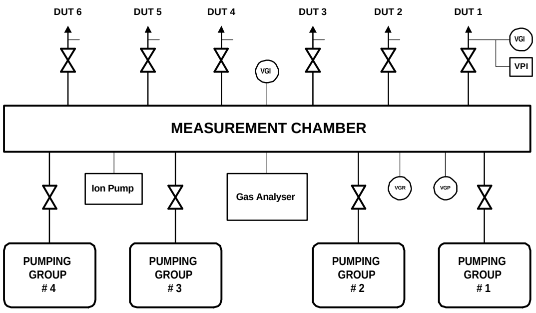


**Fig. 3 - Test Bench for Vacuum Chambers**

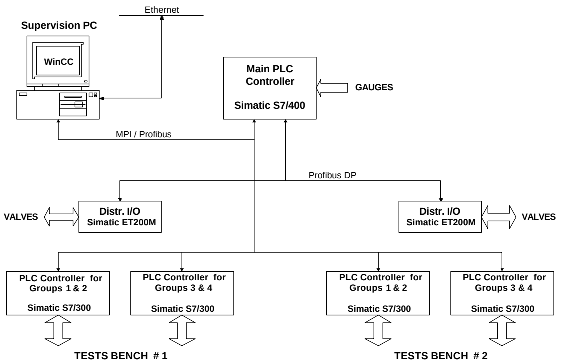


**Fig.4 - Test Benches Control Layout**

32-input and 16-output modules connected via Profibus, using the DP protocol.

*3.2.2 Operation*

The main PLC is used as master and works in polling mode. The data transmission with the pumping group controllers is made periodically by exchange of data blocks between master and slave PLCs. The remote control of the valve signals is seen as 'normal' input/output, after the initial configuration of the Profibus DP protocol. Finally, all the data of each test bench are stored to be accessed by the supervision system.

*3.2.3 Supervision*

The selected MMI program is WinnCC© (Version 3.1) from Siemens. It runs on a PC under Windows 95© or Windows NT©. The PC is connected to the main PLC either via the MPI or the Profibus fieldbus, according to the selected interface. The representation of the system is made using hierarchical view derived from photographs of the test bench down to the detailed synoptics of the equipment. The program also provides function modules for graphic display, messages and archives.

## 4 Control of vacuum equipment for the LHC

Considering the good results obtained with these two applications, the use of PLCs and distributed I/O connected via a fieldbus such as Profibus, could be an interesting solution for the control of the numerous vacuum devices that will be installed in the future LHC accelerator. One way to do it would be to install, for every LHC octant, a main PLC connected, via a Profibus line to either, other PLCs acting as local controllers or, directly to distributed inputs/outputs interfaces. All the 8 main PLCs could be connected to a local supervision system and also to the upper layer of the general control system.

## 5 Conclusion

We have seen with these two applications that the slow control systems used in the domain of vacuum for accelerators and physics experiments can use and integrate PLCs instead of specific or 'home-made' controllers, with all the benefit of industrial equipment. It is a first step to a global approach of a complete industrial solution to our requirements.

## References


[1] M. Rabany, Industrial Control Solutions in Research Laboratories, ICALEPCS’95 Chicago.

[2] R. Gavaggio, P. Strubin, The New Vacuum Control System of the CERN PS Complex, ICALEPCS’95 Chicago.

[3] R. Gavaggio, Utilisation d'un API pour le Controle d'un Groupe de Pompage, CERN Note technique LHC-VAC NT96-07.