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## **RECOMMENDATIONS FOR THE USE OF** **PROGRAMMABLE LOGIC CONTROLLERS (PLCs) AT CERN**

### **The Working Group on Programmable Logic Controllers**

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### **ABSTRACT**

Programmable Logic Controllers (PLCs) have been increasingly used at CERN for several years. In future control solutions, PLCs will initially be considered for the rejuvenation of old and obsolete systems, and then for the control of new equipment to be installed in technical services, accelerators and experiments. Many industrial systems will be installed for the control of equipment during the next 5 to 10 years, particularly for the construction of the LHC project. In order to increase efficiency, to reduce the initial investment and to minimise the long term maintenance costs in terms of money and human resources the Working Group recommends that all CERN equipment control projects, based on PLCs, select or specify PLCs from the product lines of the recommended PLC manufacturers.

## **1 OBJECTIVE**

Programmable Logic Controllers (PLCs) will be used extensively to upgrade old and obsolete systems, to control and monitor new equipment for technical services, accelerators, experiments and to construct the LHC machine. A single manufacturer's line of PLC products may not satisfy all the needs of the various users, however, CERN cannot support the large diversity of PLCs proposed by industry. In order to reduce design time, installation cost and later maintenance effort, the number of PLC families of products used for integration of equipment at CERN must be reduced to a minimum.

For this purpose the CERN Controls Board<sup>1</sup>, at its meeting of March 27, 1997, created the Working Group on the usage of PLCs in controls at CERN. The objective of this PLC-WG is to define a policy, valid for the next 5 to 10 years, for CERN and for the Institutes collaborating to the LHC project.

## **2 INVESTIGATION PROCEDURE**

### **2-1 General Approach**

The first task of the PLC-WG members has been to clarify the definition of the technical terms used in the PLC world, with the aim of improving our common technical understanding. In order to make its recommendation the next tasks of the PLC-WG were to make a detailed inventory of the existing PLC applications at CERN, to define the technical and commercial selection criteria and to initiate a market survey of the main PLC manufacturers. The technical selection criteria take into account CERN's existing "Recommendation on the Usage of Fieldbuses<sup>2</sup>".

### **2-2 PLC Definition**

A PLC is a component used for industrial controls. The structure of a PLC is that of a computer; it consists of a Central Processing Unit (CPU), a memory, input/output modules and an internal bus. The peripherals and the programming are conceived to be adapted to industrial process control. The functions implemented by a PLC are written in the form of programs stored in memory. A PLC receives input signals from process equipment to be controlled (switches, sensors), processes them according to a precise model defined by programs and provides output signals to the process equipment such as relays, motor starters, etc... The PLC is usually programmed with languages conforming to IEC-1131 standard and is conceived to work in an industrial environment. Unless a system reconfiguration is required, the functions executed by a PLC is fixed, the programs do not change and therefore they may be stored in Programmable Read Only Memory (PROM).

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<sup>1</sup> CERN Controls Board Members: G. Baribaud IT, P. Ciriani ST, B. Frammery PS, R. Lauckner SL, H. Burckhart ATLAS, F. Perriollat CMS, D. Swoboda ALICE, Chairman: M. Rabany LHC.

<sup>2</sup> "Recommendation on the Usage of Fieldbuses at CERN", Memorandum from H. Wenninger to Division Leaders, DG/DI/HW/sm (96-197), dated 30<sup>th</sup> August 1996.

PLCs can be divided into at least three categories:

- full-size, for top level applications requiring fast program execution with very short instruction cycle times. They are capable of supporting several CPUs for multiprocessing to provide more processing power. They offer the TCP/IP communication capability over general purpose networks to the supervisory workstations, and support fieldbus data transmission with equipment controllers.

- middle-size, intended for industrial automated systems of medium power. They offer a large choice of analog and digital input/output modules. They are usually connected to a fieldbus on one side and to the equipment on the other side; their speed is not an important parameter, the amount of data transferred is small and the average price per function is low.

- small or micro-size, for direct interface with sensors and actuators. They are very simple electrically and mechanically and are sometimes integrated with the intelligent sensor itself, they are characterised by short reaction times and they transfer a small amount of data.

### **2-3 Inventory of Present Usage of PLCs**

A detailed inventory of all existing PLCs installed since 1984 allowed us to identify the number of PLC suppliers, the diversity of models, the type of connection and the variety of communication protocols in use. The PLC-WG has quantified the average number of new PLC installations made each year. The survey included all types of PLCs, general purpose PLCs, system specialised PLCs (electricity, ventilation, buildings) and PLCs provided with Distributed Control Systems (DCSs). A DCS is defined here as a complete industrial turn-key control system delivered to CERN, with all the components from the I/O modules up to the supervisor including the process computers, the communication network and the supervisory workstations with all the system specific software (as for cryogenics or electricity for example). On average, some 80 to 100 PLCs per year, of various types and provided by 16 different manufacturers, have been installed at CERN, over the past 10 years, (see table in the Appendix).

### **2-4 Scope of Application**

At CERN PLCs are finding their application in accelerators, technical services, experiments and in the laboratory for equipment test-beds. The technical requirements of the accelerators, the technical services and the experiments are mostly the same. Thus, a range of PLC products is needed for general purpose applications in a large diversity of fields such as electricity, water, gas, cryogenics, cooling, ventilation, process control, magnet control, machinery, personnel access and safety systems. It is planned to use PLCs for accelerator specific systems like: interlocks for main magnet power supplies, beam targets, dumps, stoppers, collimators, aperture limiters and beam extraction electronics. In addition, over the past 25 years, a large volume of control equipment has been based on the MPX System, developed at CERN, on the CAMAC, G64 and VME standards and on special solutions. Most of this will be replaced with PLC products in coming years.

### **3 PLC MARKET SURVEY**

PLCs are offered by a large number of manufacturers with a vast variety of models; most of them are for general purpose applications and some are designed for specific control domains. At CERN we are looking for products that fit our particular needs, that are commercially available from manufacturers playing a leading role in the fast evolution of PLC technology and having a fair chance of still being on the market in a few years time to continue the support of their products.

CERN contracts are placed in the member states following CERN's official purchasing rules. The selected tenderers must supply equipment originating from the members states.

To gain knowledge of the industrial offer in the field of PLCs, a Market Survey exercise has been undertaken. For this Market Survey<sup>3</sup> we have specified our technical requirements, listed our commercial and technical qualification criteria and prepared a detailed questionnaire to help in the discussion with manufacturers.

#### **3-1 Commercial Qualification Criteria**

##### **Perenniality**

As particle accelerators have a life-time of 20 to 30 years it is highly desirable that the products which have been selected for their construction will still be available for purchase, repair and replacement by equivalent units during such a period, or at least, until new uses are required from the equipment.

##### **Turnover**

CERN is looking for large manufacturers of PLCs having an annual turnover of at least 50 MCHF in the field of PLCs. The turnover figure gives a measure of the manufacturer's capacity to innovate, to do research, to create, to develop, to implement standards and to support its products over several years in many countries. CERN's needs for PLCs are small compared to those in industry and consequently CERN wants to follow the main stream of industry.

##### **Experience**

The manufacturers must have at least ten years of experience in the design and production of PLCs. Ten years is approximately the life-time of a PLC product line. Over this time one can observe the evolution of the product to match the changes of the environment, the increase in performance and the emergence of new product lines. Ten years experience demonstrates, with good probability, the PLC manufacturer's ability to provide long term support.

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<sup>3</sup> CERN Market Survey MS-2547/SL, Supply of Programmable Logic Controllers (PLCs), December 1997.

## **European Origin and Availability**

As CERN contracts are placed in Member States following its official purchasing rules, the manufacturers must supply PLC products originating in the Member States. The manufacturers must offer commercial and technical support in most of CERN's Member States. As contracts are placed in all Member States a tenderer who needs information on PLCs or who has a particular problem to solve is in a better situation if he can rely on local support to obtain technical training, expertise, help and advice from the PLC manufacturer.

### **3-2 Technical Qualification Criteria**

#### **General Purpose PLCs**

The manufacturer must have a proven experience, or demonstrate that his PLCs are used in a large variety of fields such as electricity, water, gas, cryogenics, cooling, ventilation, process control, machinery and safety systems.

The Market Survey aims at identifying families of general purpose PLCs applying equally well to all the above systems. It does not address the supply of complete Distributed Control Systems (DCS), spanning from the sensor level up to the human-machine-interface, including the networks and the supervisory control software. The manufacturer's PLC product line should cover all the categories, ranging from the full-size units down to the small size units and very simple I/O modules. The PLCs should have a modular structure suitable for plugging into crates or fixing on standard rails.

#### **TCP/IP Communication**

In order to connect single or clusters of PLCs to the CERN controls network it is essential that the manufacturer offers an Ethernet interface unit with the standard TCP/IP suite of communication protocols. Proprietary networks and protocols are not acceptable to CERN. To make sure that the PLC communication offered is really compliant with the standard, CERN will test and validate them on the controls network.

#### **Standard Fieldbuses**

As the CERN Directorate has endorsed the Fieldbus Working Group's Recommendation on the usage of only three fieldbuses, it is mandatory that the PLC manufacturers offer interfaces to at least one of them: CAN, Profibus or WorldFIP. If the manufacturers offer either Profibus or WorldFIP it would be an asset to offer also a CAN interface. CAN, is limited in its transmission distance but is suitable for use in experiments and inside buildings while Profibus and WorldFIP, which can transmit over longer distances, provide solutions for inter-building communication links and large accelerators. WorldFIP offers, in addition, hard real time features for time critical applications. It is required that manufacturers implement their fieldbus hardware and software in conformance with the related Standard Specification Documents. Conformance certification of PLC communication interfaces by official fieldbus test centres is clearly an asset.

For the CAN fieldbus, CAN controllers should be available, either from the selected PLC manufacturers or from second source suppliers certified by the PLC manufacturers. The Standard CANopen Communication Protocol must be implemented.

### **Safety and Security**

Some CERN systems, controlled by PLCs have to work safely in noisy and sometimes explosive environments. Thus, the PLC manufacturers should have in their catalogue a line of products conforming to the French, Swiss or European safety and security standards.

### **Standard software**

In order that CERN can limit its investment in software for industrial systems the PLC programming has to be done according to the IEC 1131-3 standard languages and the development software should be available for Windows 95/NT. CERN intends to negotiate, with the selected PLC manufacturers, site licences for the development environment, for the target environment and for software maintenance.

## **4 THE RECOMMENDATIONS**

The purpose of the PLC market survey was to get a complete and up-to-date information on hardware and software available in industry and to evaluate what are the current technological trends. The PLC-WG's objective is to recommend European manufacturers capable of providing a full range of PLCs for general purpose usage, which respect standard network interfaces, communication protocols along with the software environment for development and target applications. This recommendation for PLCs is tightly coupled to the existing 'Recommendation on the usage of standard fieldbuses at CERN'.

With the help of the CERN Management and Finance Division Office contracts will be negotiated and signed with these selected PLC manufacturers. These contracts will give CERN's project engineers access to all the hardware and software from the respective product catalogues, make available the support offered by the manufacturers, and this without having to justify the choice of the PLC manufacturer. The engineer will be free to choose the PLC products best suited for his/her project. In writing his Technical Specification a project leader will consequently be justified to ask the tenderers to base their offer, as far as technically sound, on the recommended PLC manufacturers only and on the three recommended fieldbuses.

### **4-1 Administrative and Commercial Support**

In order to support the usage of the recommended PLCs (and fieldbuses) as widely as possible, commercial and administrative support will have to be set up at CERN. This support should be limited to the PLC products from the recommended manufacturers. Given the large amount of PLC equipment to be purchased by CERN, either directly by CERN personnel or via CERN industrial contracts, centralised negotiation and purchasing procedures should be set up. For the development and

target software CERN site licences should be negotiated with the selected PLC manufacturers.

#### **4-2 Expertise and Technical Support**

In order to create the necessary incentive to use the recommended PLCs and fieldbuses, as widely as possible, technical support and training will have to be made available.

Advice and expertise, on the products from the recommended PLC manufacturers, will be available from different groups of existing CERN users. Support for each family of products should be provided in a decentralised manner by experts who have current practical experience with a particular PLC line of products. These experts should be from groups involved in controls projects. A specialised central service of experts, not directly involved in controls projects, is not recommended. Experts can be consulted for advice but they will not provide any operational support to the users nor take up the responsibility to maintain industrial systems. Experts will advise users on the capabilities and limitations of PLCs and fieldbuses, they will help the users in the selection of hardware and software components, on the selection of development tools, explain the software tools and communication protocols. Experts will also ensure a technical liaison with industry and with the recommended manufacturers.

Considering the close relationship between PLCs and fieldbuses we recommend that these two domains be combined in a single entity. A single and common User's Group will exchange information between people having activities linked to PLCs and fieldbuses. This User's Group could be an emanation of an existing body with enlarged scope and should also monitor the evolution of the PLC market.

To help user's to learn and start-up with PLC's and fieldbuses it would be advisable to have available for them on loan a few complete demonstration assemblies, including the necessary software development tools.

#### **4-3 Training**

The technical staff involved in controls projects should be knowledgeable in PLCs and fieldbuses in order to make the best use of them. According to the needs, the "User's Group" will organise practical training courses given by experts of the selected manufacturers and also in the context of the Training Programme of CERN's Education Services; for standard IEC-1131 programming, as an example.

### **5 CONCLUSION**

The Working Group on PLCs recommends limiting the choice of PLCs which should be used at CERN during the next five to ten years. Two PLC manufacturers satisfying the required commercial and technical qualification criteria should be chosen according to the official CERN procedure.

This recommendation has an economic grounding. It aims at keeping development, maintenance, installation effort and cost to a minimum. It pays tribute to CERN's attempts to reduce manpower. The PLC-WG invites the Controls Board to support its recommendation and to present it to the CERN management for its endorsement.

The trend towards industrial controls will undoubtedly be of great benefit to CERN at a time when human resources become scarce and will enable industry to make a larger contribution to the LHC Project.

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## PLC INSTALLATIONS at CERN

<u>MANUFACTURERS</u>	<u>TYPE of PLC</u>	<u>NUMBER of PLCs</u>	<u>TOTAL</u>
<b>SIEMENS</b> (1984-97)	S5 S7(New Model)	336 29	365
<b>SCHNEIDER</b> (1984-97)	EPS SEPAM	23 130	
- TELEMECANIQUE	TSX APRIL	6 9	
- MERLIN-GERIN	PB400	8	
- CEGELEC	C370	1	
<b>ELTEK</b> (1993)	SMNSP	40	40
<b>HAZEMEYER</b> (1992)	CIT	31	31
<b>SACE</b> (1992)	MEGAMAX	25	25
<b>SAINCO</b> (1992)	EMS	17	17
<b>TEXAS</b> (1987-88)	520	16	16
<b>TRANE</b> (1987)	M-S	16	16
<b>MR</b> (1992)	TCS	6	6
<b>MANNESMAN</b> (1996)	HNC	1	1
<b>SILICON</b> (1996)	SILICON	1	1
<b>PLCs used Individually</b>			<b>GRAND TOTAL = 695</b>

<b>ABB</b> (1987-97)	AC MP	8 43	51
<b>LANDIS</b> (1986-97)	various	205	205
<b>PLCs Integrated into DCSs</b>			<b>GRAND TOTAL = 256</b>

# **Mandate for the PLC Working Group**

**To recommend solutions for PLCs to be used for controlling equipment during the next 5-10 years.**

Solutions should:

- cover accelerator, experiment, services, test equipment and laboratory equipment.
- apply to all equipment supplied to CERN.
- aim to minimise long term maintenance costs both in terms of money and human resources.  
(LHC construction and exploitation 20 years)
- take into account the recommendation on fieldbuses.
- list the different selection criteria and discuss their importance.
- discuss advantages and disadvantages of diversity.
- consider programming environment (languages, ...)
- consider communication and integration.
- give recommendations for the selection of PLCs either isolated or embedded in DCSs.
- evaluate purchasing volumes.
- consider guidelines for purchasing (procedure, contract, pricing).
- consider support.

## **Schedule**

- Interim report: end of September 1997
- Final report: end of November 1997

## **Members**

- D. Blanc/ST
- W. Heinze/PS
- O. V.D. Vossen/SL
- R. Rausch/SL (Chairman)
- D. Brahy/LHC
- J.M. Maugain/EP
- S. Waeffler/EP