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APPLICATION OF OBJECT-BASED INDUSTRIAL CONTROLS FOR CRYOGENICS

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The first application of the CERN Unified Industrial Control system (UNICOS) has been developed for the 1.8 K refrigerator at point 1.8 in mid-2001. This paper presents the engineering methods used for application development, in order to reach the objectives of maintainability and reusability, in the context of a development done by an external consortium of engineering firms. It will also review the lessons learned during this first development and the improvements planned for the next applications.

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Abstract

The first application of the CERN Unified Industrial Control system (UNICOS) has been developed for the 1.8 K refrigerator at point 1.8 in mid-2001. This paper presents the engineering methods used for application development, in order to reach the objectives of maintainability and reusability, in the context of a development done by an external consortium of engineering firms. It will also review the lessons learned during this first development and the improvements planned for the next applications.

1 BACKGROUND

Cryogenics will be extensively used in LHC, both in the accelerator and in the detectors. In order to rationalize the control effort a common project has been launched in 1999. This project called UNICOS for UNified Industrial Control System, has to provide an homogeneous control system for the cryoplants supplying liquid helium to the LHC accelerator, the cryogenic equipment in the machine tunnel, and the ATLAS & CMS cryogenic systems.

During the past years controls & cryogenics groups have developed an expertise in the control of cryogenic and other systems for LEP, LEP2, LHC String test and other R&D facilities. A synthesis of the different approaches has been made and led to the elaboration of a technical design both for hardware and software.

The hardware architecture is based on a three-layer model using distributed I/O connected to PLC via field-networks, PLC to hold the process control software and a SCADA System as operator interface.

The software design is an evolution of the "object oriented" philosophy used with former control system [1,2]. In this approach each process component (I/O channel, actuator, set of sensors and actuators constituting a process entity) is modelled in an object. This object integrates the process behaviour and the Human Machine Interface (HMI) .

2 UNICOS OBJECT MODEL

2.1 HMI & PLC repartition

In the UNICOS concept the object is split in two parts (fig. 1):

- The process behaviour, programmed in the PLC.
- The HMI functionality programmed in the SCADA

The HMI part includes the interaction with the operator by mean of widgets and dedicated panels called faceplates; these graphical elements inform the operator on the object status, and allow him to send orders.

The PLC part contains the process behaviour of the object. The programmer can parameterise this process behaviour. The object is linked to the plant through the I/O board that may be linked to the PLC via either a fieldbus or the backplane

Both parts are connected together thanks to the communication middleware.

2.2 Object Integration

An object receives :

- Requests from the operator via the SCADA part of the Object, these requests are transmitted to the PLC by the Manual Requests through the middleware (fig. 1).
- Configuration parameters (HMI or PLC) set during the programming phase and accessible for modification by a program specialist (fig. 1).
- Information from the process (process inputs), consisting of analogue or binary values from sensors and statuses of other objects (fig. 2)
- Order from the control logic programmed into an object of a higher hierarchical level via the Auto Requests (fig. 2),

According to its internal states (driven by the PLC/driven by the Operator, interlocked or not, started or stopped etc.) the PLC Object logic processes the inputs & requests and emits orders either to the process outputs or to other objects,(fig. 2). The PLC object logic publishes the status of the object to inform the operator or any other objects to trigger coherent action in the control logic.

2.3 Main object types or classes

Three main types of objects are defined in the UNICOS architecture

- Input-Output objects: These objects provide the interface to the plant. They link the devices and actuators to the control system. Some basic treatments may be embedded in this object class. Input/Output (I/O) channels shall be accessed through such objects exclusively.
- Field objects: These objects are the images of the hardware elements such as valves, heaters, motors, and other devices. For each type of Field object an Object standard logic is defined. This logic integrates specific functions (alarm generation, ramping, interlocking).

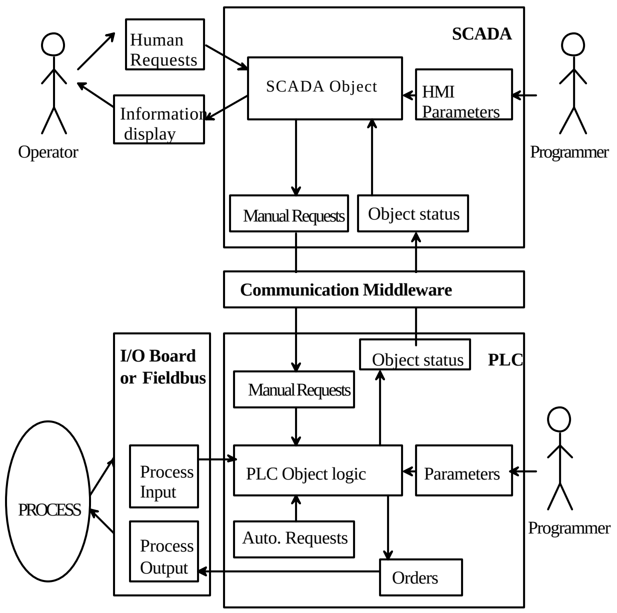

Figure 1 : PLC/SCADA Object interface

- Process Control objects PCO: These objects control equipment units grouping several Field objects and/or other process control objects. The PCO object logic is split between a standard part insuring an homogeneous interface to the environment, and a specific part to cope with the process to control.

3 IMPLEMENTATION

From the above design the implementation of the control system requested :

- The supply of the control hardware
- The development of PLC and SCADA components for each type of object
- A communication middleware between PLC and SCADA
- A SCADA framework to offer an homogeneous User interface
- The realisation of Control

4.1 Contract Award

The contract which, includes the delivery of the above items was awarded to a European consortium (GTD SA Spain, CEGELEC France & Belgium).

4.2 Hardware architecture

This implemented architecture is a classical three layers control architecture (fig. 3):

- The Supervision Layer: The HMI is located in this layer. The chosen implementation relies on Operator Workstation (OWS) as human interface and client of a redundant data server holding the real time database, the chosen SCADA software is PCVue32® from ARC Informatique.

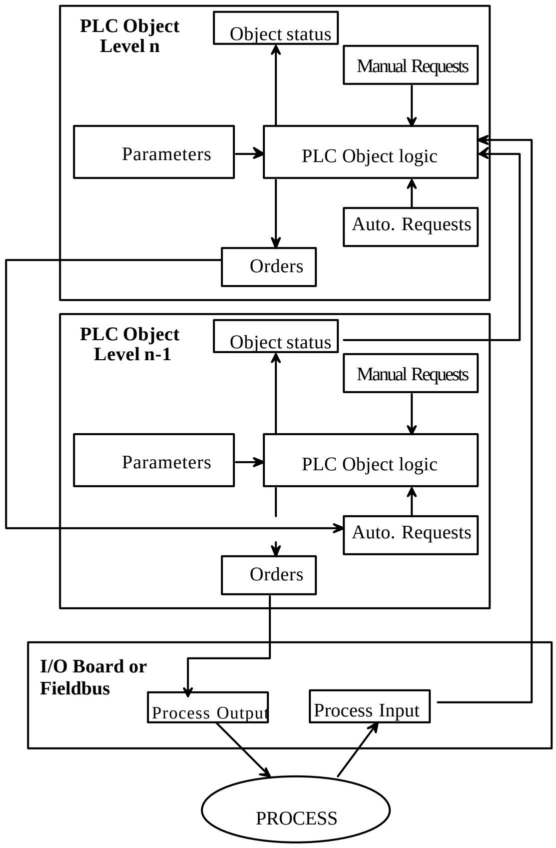

Figure 2 : PLC object/PLC object hierarchy

- Control Layer: All process control duties are performed in this layer in Schneider Quantum PLC; the programming is done via an Engineering Workstation (EWS)
- Field Layer: Schneider Premium PLC are used to connect the process channels to the control system. An alternative solution using a proprietary Schneider bus technology and Quantum remote I/O can also be used.
- Communication: Based on the Ethernet TCP-IP CERN infrastructure this network must be highly reliable as control loops are closed trough it.

4.2 Framework deployment

The framework has been deployed Using ESA PSS-05 methodology. The first phase for the consortium was to reformulate the framework requirement exposed in the call for tender. Then Based on this analysis an Unified Modelling Language (UML) study of the object behaviour has been produced from which the PLC objects were developed in IEC 61131-3 language. In parallel to the PLC object all SCADA modules have been developed using ActiveX and proprietary SCADA script.

Finally a prototype integrating all layers and the communication middleware has been delivered and validated

4.3 Communications

In order to optimise the communication bandwidth an event-driven protocol based on MODBUS on TCP-IP has been developed by the consortium between the PLC and the SCADA.

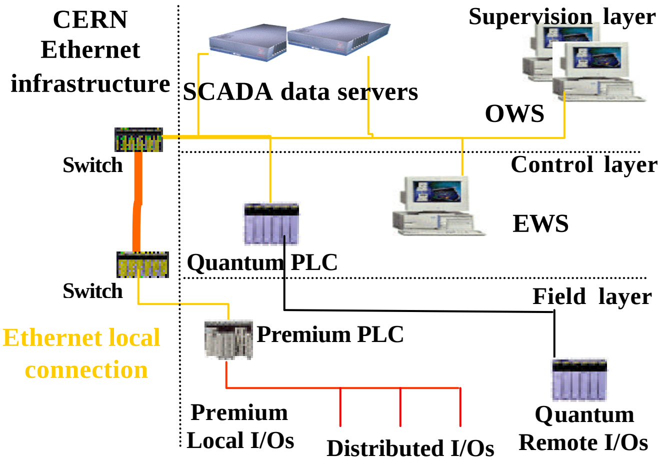

Figure 3 Hardware Implementation.

4.3 User application developments.

Phase 1 : Specification

- Object list: from the process specifications one has to establish a complete list of the I/O and field object. We have provided spreadsheet templates to capture all relevant information.
- Object hierarchy: the process engineer analyses his system and proposes a hierarchical organization down to the field objects
- Control logic: for each PCO specific logical modules have to be developed, these modules contain typically the interlocks and the logic used to control dependant objects. A specification template has been elaborated with guidelines.

Phase 2: Software development.

- Database generation: From the object list spreadsheet an automated tool generates all variables together with their memory assignment into the PLC and the SCADA
- PLC Object instantiation: The same tool generates the code instantiating all object in the PLC. Then 100% of the premium code is automatically generated, and a large part of the Quantum
- Control logic: The programmer has to fill the program sections following the programming guidelines .

Phase 3: Acceptation and Maintenance

- Acceptance tests to check the conformity to specification. Then the commissioning of the cryogenic system can be made; this includes a large amount of the process logic modification
- Maintenance, follow up during the lifetime of the application of all medication using a case tool

5 LESSONS DRAWN FROM APPLICATIONS

From the first application commissioning since July 2001, several pros and con can be noted

5.1 Pros

- Easiness of modification during commissioning due to the readability, the modularity and reusability of the code.
- Once mastered, the specification template are easy to use by the programmer and few errors are generated allowing a good quality of the produced control software
- Excellent stability of the PLC.
- Easy and efficient creation and modification of Process display
- The operator can interact with any objects through a standardized interface. This possibility allows troubleshooting flexibility during tests, or in case of equipment failure.

5.2Cons

- This model needs an appropriate training to be understood and deployed. Mainly for the process engineer.
- Programming templates have to be established in order to optimize the object interactions.
- The use of objects implies extra memory usage and additional CPU load. Hence this method is not suitable for time critical control (<10ms).
- Necessity of an automated tool to generate the database in PLC and SCADA.
- Stability problem in the present version of the SCADA implementation but work undergoes with good preliminary results

5.3 Conclusions

The present UNICOS system provides the expected results. The teething problem will be soon solved and the mass production of the user application software will follow.However, in order to face CERN recommendation we have to migrate to another SCADA and a technological evolution in the PLC implies a framework upgrade. These evolutions are in agreement with the project schedule and will not compromise any dead lines. Moreover, these evolutions and other developments (UNICOS for Siemens PLC, Premium PCO & Field objects) will open the possibility to use UNICOS out of the cryogenic systems.

7 REFERENCES

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