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A PLC TEST BENCH AT ESS

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Abstract

The European Spallation Source (ESS) is an accelerator-driven neutron spallation source. The Integrated Controls Systems (ICS) is responsible for providing control and monitoring for all parts of the machine (accelerator, target, neutron scattering systems and conventional facilities) [1]. A large number of applications have been identified across all parts of the facility where PLCs will be used: cryogenics, vacuum, water-cooling, power systems, safety and protection systems. The Controls Division at ESS is deploying a PLC Test Bench. The motivation is to evaluate different technologies, to test PLCs and their integration into EPICS, to prototype control systems and use the test bench as PLC software development platform. This report defines the architecture of this infrastructure. The first stage to procure a first set of hardware and to perform initial tests has already been finished, consisting of a comparison between the performance of the *s7plc* EPICS driver and the Modbus EPICS driver. The results of these tests are discussed and future plans for this infrastructure are presented.

INTRODUCTION

The use of PLCs in accelerators has been increasing and increasing during the last years. They have multiples advantages related to their cost, scalability of the PLC based control systems, reliability, and an relatively easy-to-find man power as it is also extensively used in the industry [2]. On top of that, there are a big range of applications in accelerators where the PLC perfectly match the controls requirements: cryogenics systems, vacuum systems, safety and protection systems, etc. In the last years PLCs are also expanding their functionality and capabilities by incorporating new technologies, such as FPGA. Because of this ICS has proposed a test bench to serve various purposes: to be a platform where to test different PLC technologies, to prototype PLC based controls and also to develop PLC code. The Test Bench and its current and future activities are described in this paper.

THE ARCHITECTURE OF THE PLC TEST BENCH

The PLC Test Bench is not only meant for testing different PLC technologies but also to provide an standard platform for PLC code development for the ICS and all its stakeholders. Therefore, on top of containing PLC CPUs and IO, they will be integrated into an EPICS IOC (see Figure 1). One of the computers of the PLC Testbench will be in charge of providing the development environment for generating code for the PLC. The other will contain the EPICS IOC. Each of these computer will have its own console. The IOC console contains CSS BOY based HMIs (Human Machine Interface) for the different applications prototyped. To keep track and maintain the code generated in this infrastructure as developing platform, it will be connected to the ESS Development Environment. This infrastructure provides a code repository, which permits versioning and the sharing of the code with all the ICS software developers. Another activity that will be described in detail later is the connection to the ESS Timing Infrastructure. All the PLCs installed will be connected to an NTP server. This server will have as time provider the ESS Timing System. In this way, all the process variables generated in the PLC could be correlated to other events in other areas of the control system. The connection with some critical services of the control system was also considered necessary. Two of them were chosen as the most important ones: cable database and naming server. Taking into account that the test bench will be used to prototype systems for the ESS facility it will be necessary to request cabling for those systems and name signal. Therefore, the development PLC will have available a connection to those services. Finally, another important component for prototyping systems is some simulation infrastructure. Some applications (like cryogenics or vacuum) may need to be simulated in order to debug the PLC based control system. A computer containing Simulink package for the simulation of complex process is planned. The possibility of adding some hardware-in-the-loop was also planned.

S7PLC VS. *MODBUS TCP*

One of the first activities in the PLC Test Bench was the comparative analysis of the transference of data between a PLC (Siemens S7-400) and an EPICS IOC using Modbus/TCP and the s7plc driver. The performance of both solutions was measured. Modbus was originally a serial communication protocol created by MODICON, today Schneider Electric, in 1979 with the goal of communicating PLCs. Some versions of the protocol have been created since then. One of them is Modbus/TCP (analysed here), which is basically a Modbus communication encapsulated in an Ethernet TCP/IP wrapper.

In this test the performance of the Modbus TCP/IP EPICS driver. The goal was to measure the capability of exchanging data regarding the exchange rate and the number of channels (connections) used. The default EPICS program uses a waveform record to send data to the PLC and a waveform record to read data back from the PLC. Also a record is used that changes the value of the output record at a defined rate and some records to detect when data is read back from PLC.

The *s7plc* driver is intended to connect Siemens PLCs via TCP/IP protocol to an EPICS IOC, using the so called

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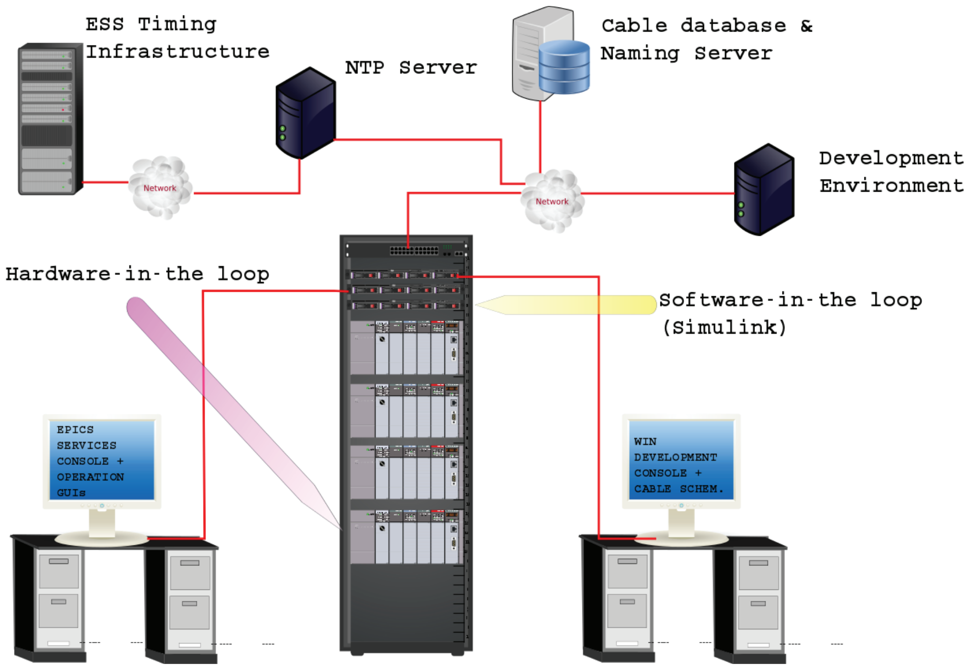

Figure 1: PLC Testbench Architecture.

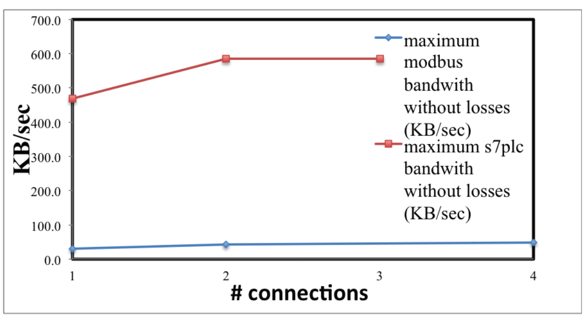

Figure 2: Maximum bandwith without losses depending on the number of socket connections setup in the IOC .

"send/receive" protocol. The driver was originally developed by Swiss Light Source in 2000. The driver and the PLC periodically exchange data (process variables) over the network. The performance of the *s7plc* driver was also benchmarked. As before, the goal is to measure the exchanged data regarding the exchange rate and the number of channels (connections) used. The EPICS program uses a long out record to send a data to the PLC and longin record to read data back from the PLC. For each amount of data transferred the same number of records is used as in Modbus/TCP tests.

For all the tests, input records were monitored and stored to text files. Basic operations of EPICS and PLC programs of the testt is:

- aSub record is used as a counter and writes new values to an output table.
- Output records send new values to the output table.
- Output table sends values to the PLC at a predefined rate.
- PLC sends values to the EPICS input table at a predefined rate in the PLC program.
- Input records read new values as they get it from the input table.
- If the new value of the counter is not read back with the input record, it means that it was lost in the loopback test. At the end of the test, the values of the input records are reviewed. The number of not detected counter changes measures the amount of data lost.
- A data exchange is successful if counter changes to new value, the value is sent to the PLC and read back with the input record.

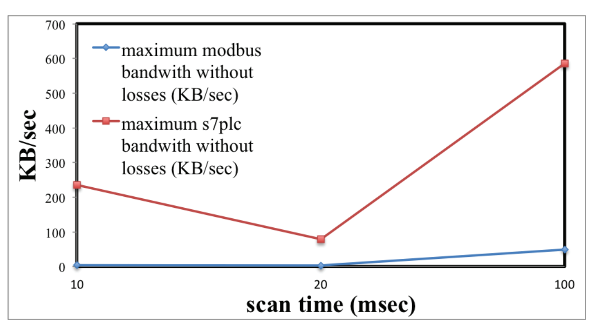

Figure 3: Maximum Bandwith without losses for different scan times.

The basic procedure for the text was:

- An EPICS test program was created with some large data-blokcs.
- Run the EPICS IOC

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- Different change rates were chosen.
- Exchange of data between PLC and EPICS.
- Monitor input records and store results to text files
- Repeat of the test for all data sizes and exchange rates
- Repeat the test using more communication channels
- Repeat the test for PLC chicly time 10 msec. and 20 msec.

This performance test was designed to compare the operation of botch drivers. Results obtained show the behaviour of the loopback communication. Figure 2 show some results of the test. It contains tha maximum bandwidth achieved without losses depending on the number of socket connections setup in the IOC. The throughput of the s7plc is significantly bigger than the Modbus/TCP. The maximum bandwidth possible without losses stabilises when the number of connections grows. Figure 3 shows the dependency of the maximum bandwidth without losses with the scan time of the PLC. The maximum bandwidth from all the different test with different numbers of connections was chosen for each scan time. In general, the bandwidth is better with bigger scanning times in the PLC CPU, despite some irregularities in the behaviour of the s7plc. As a general rule the s7plc seems a better solution in terms of bandwidth with respect to Modbus/TCP. On top of that, s7plc has inherent solutions for very important aspects as timestamping.

FUTURE WORK

Different activities for testing different hardware and creating prototypes are planned for the near future. For example, a whole range of activities for testing the EPICS integration of vacuum devices is expected in the following months. Also some prototypes for the Machine Protection System. One of the main activities currently going on is the creation of a prototype for the time correlation of data acquired from PLCs. The Integrated Control System will archive data from very different sources. A big part of the data will be acquired through the acquisition of different controllers, which can be directly synchronised through the ICS Timing System. However, ICS is planning to use a significant number of PLCs for different use cases (cryogenics controls, vacuum, Conventional Facilities Integration, etc.). Typically, PLCs synchronisation needs to done connecting the PLC CPU to a NTP Server. So, they cannot be connected directly to the Timing System in a straightforward way. The simplest possibility to provide an overall synchronisation for the PLCs is to configure the Timing System as the time provider for an NTP server. This NTP will provide overall synchronisation to all PLCs. To perform this activity, the following prototype in Figure 4 is proposed.

The prototype will consist of two IOCs. One of them (IOC Timing) will host the ICS standard timing infrastructure and the NTP server. In this IOC the ICS Timing System will be set as the time provider for the NTP server. The second

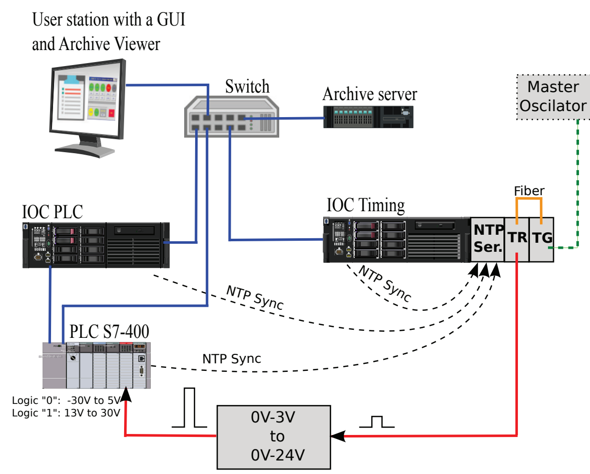

Figure 4: PLC Time Correlation Prototype.

IOC will acquire data from a PLC. An Archiving Server will collect all the relevant information to be analysed. The timing receiver will generate an event, whose signal will be acquired by the PLC (a voltage conversion is required for the signal coming out of the timing system in order to be acquired by the PLC). This event will be acquired as an EPICS Record in both IOCs and both values will be archived later on. The goal of the activity is to measure the timestamp different between the same event but recorded by the two different IOCs. The aim is to show that this model does not provide unacceptable event time differences between the two sources and that event coming from PLCs can be correlated to data coming from other controllers in the machine.

CONCLUSION

This work presents the PLC Test Bench at ESS. An infrastructure has been built in order to fulfil various objectives. The PLC Test Bench is aimed to be a platform where to test different PLC technologies, to prototype PLC based controls and also to develop PLC code. The architecture of the system has been described. On top of the PLCs and the development environment, EPICS integration has been provided. Also this infrastructure is connected to different control services and functionalities, like archiving, development environment, timing system, etc. The first of the parts of this PLC test stand have been already procured. Also the first results are presented. The first significant task was the comparative analysis between the Modbus/TCP EPICS driver and the *s7plc* EPICS driver for Siemens PLCs. The results show a better performance for the second candidate.

REFERENCES

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[2] Workshop on PLC Based Interlock Systems for Accelerators and Other Large Research Installations `http://eval.esss.lu.se/DocDB/0003/000311/001/PLC-Based-Interlock-Systems.pdf`