THE ESRF TEMPERATURE MONITORING SYSTEM FROM AN OPERATIONAL POINT OF VIEW

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Abstract

The ESRF is in operation since many years and we are not only faced to an aging vacuum system but also to continuous developments aiming for higher machine performances. Temperature monitoring became an important diagnostic tool to anticipate failures and safely commission theses upgrades.

Our initial measurement system faced various operational problems and obsolescence.

We have been reviewing our philosophy of temperature acquisition and monitoring, while using new technologies and taking into account our gained operational experience. We have installed shielded “intelligent” devices inside the SR tunnel while taking benefit of the available distributed low level intelligence.

This paper outlines our work based on Programmable Logical Controller (PLC) and their integration towards a dynamic remote control system.

INTRODUCTION

Initially no electronic board has been installed in the Storage Ring (SR) tunnel, due to its hazardous environment. Our sensors where connected via long cables and numerous electrical connections to their controllers. This architecture turned out to be a bad choice.

The thermocouples have been connected to Cu extension cables and therefore required not only a local thermal compensation but induced an important number of electrical inter-connections (eight / thermocouples) between the sensor tip and its measuring unit.

The initial system was simultaneously dedicated for bake-out and vacuum chamber monitoring with a total of about 2000 thermocouples connected to the acquisition system. The risk of mismatches and faulty connections was extremely high. Furthermore, any changes in the in-situ configuration implied the update of software resources and the restart of server/client programs at different control levels. It was then extremely tricky to keep track of all the successive changes and, by consequence, the guaranty a reliable system.

EVOLUTION OF THE ACTUAL SYSTEM

It became clear to distinguish the requirements needed during SR operation and shutdown periods.

The temperature monitoring during bake-out is realized by mobile PLC units which regulate and monitor the complete heating cycle. These data are stored on a local PC which monitors various bake-out parameters.

Temperature monitoring of SR vacuum chamber parts during machine operation requires a high flexibility in terms of numbers of channels, their naming and geographical localisation as well as their attributed alarm levels and interlocks. In order to follow-up these requirements a number of hardware and software modifications have been undertaken and are still ongoing.

HARDWARE UPGRADE

Thermocouples

The originally chosen thermocouples where too fragile and due to radiation and high temperature bake out their external liner (fibreglass material) became extremely brittle. The length of the cables and the multiple electrical connections appeared to be the source of frequent faulty temperature readings leading to doubted interpretations of their meaning.

The new sensors are twisted wires with a Polyimide isolation layer directly connected to the PLC temperature inputs. Each SR cell has been divided into 2 or 3 sub-parts to keep the cable as short as possible (see fig. 1).

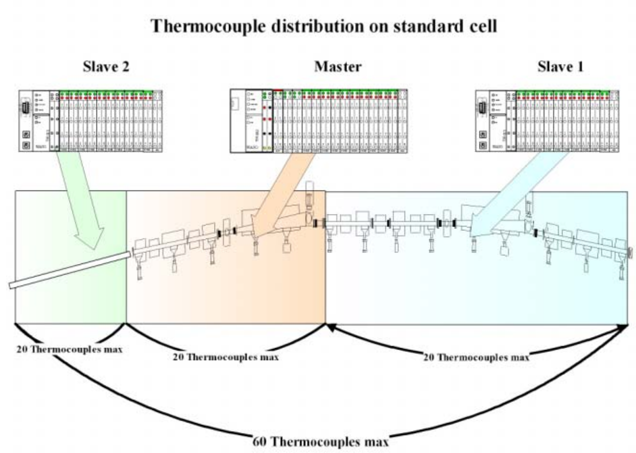

Figure 1: PLC set-up of a SR cell.

This dramatically reduced the number of electrical connections, eases their installation and removed the requirement of local temperature compensation.

Actually about 900 thermocouples are connected to 32 PLC units all around the SR tunnel.

Temperature Acquisition System

This PLC system can be characterised as extremely modular, small and very easy to handle. Each SR section has been equipped in a master – slave configuration with its functionality of temperature processing, alarm and interlock handling and most important the identification of each thermocouple by its name and geographical coordinates (see fig.2).

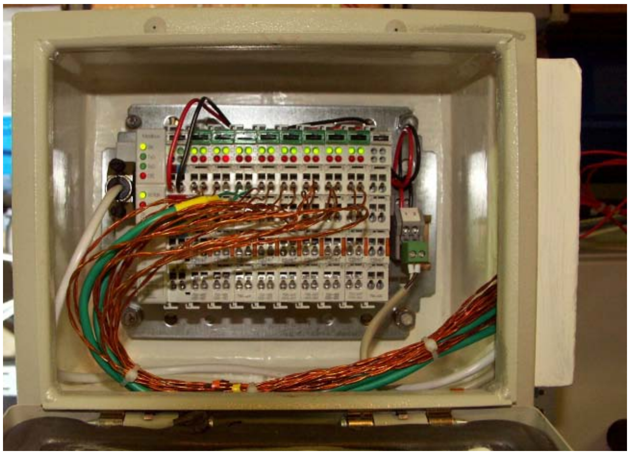

Figure 2: shielded modular PLC slave.

In order to appreciate the necessary shielding, we performed some preliminary tests.

We based our experiments on the fact that the neutron radiation dose rates where low, like the losses due to Bremsstrahlung which where less than 1% for most sections of the SR. Therefore the main amount of radiation is due to scattered synchrotron radiation with important variations in its spatial distribution [1].

We installed one of these PLC's in the accelerator tunnel without shielding, to check its radiation resistance at the chosen location. Measurements showed a total dose of 3.78Gy before its failure. Comparative temperature measurements with our standard measurement system indicate a slow degradation of the actual measurement signal but no erroneous measurements or other problems related to communication or failures (see fig. 3).

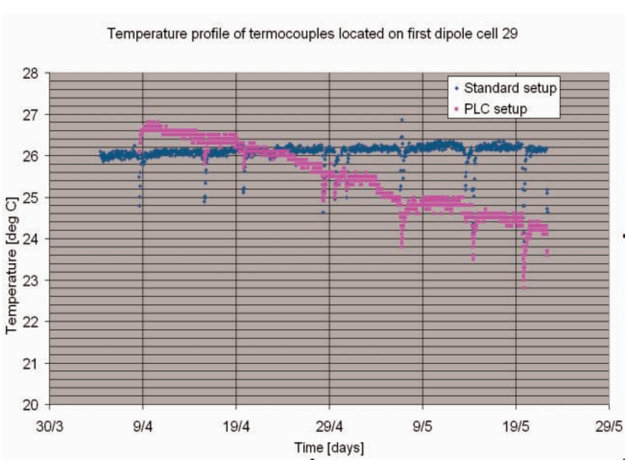

Figure 3: Temperature profile of an unshielded PLC.

With 3 mm of Pb-shielding, the dose rate could be reduced to 20mGy/month without any degradation of the measurement signals or other suspicious behaviour (see fig. 4).

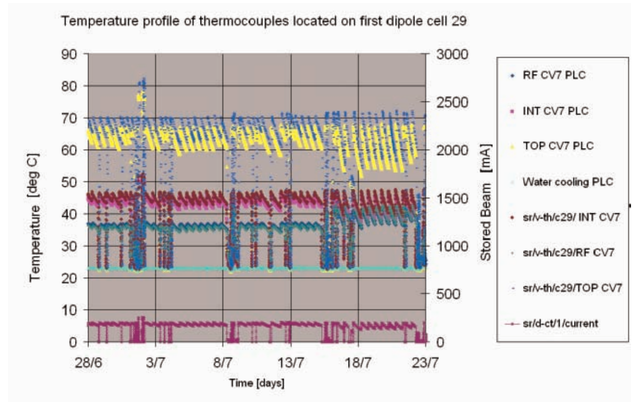

Figure 4: Temperature profile of a shielded PLC.

This PLC has been working for more than 5 years without any remarkable degradation.

SOFTWARE UPGRADE

Device Server

A Tango [3] device server program of our general control system accessing the PLC via a Modbus TCP/IP protocol does the data acquisition.

The PLC has two operation modes. In maintenance mode the device server stops its data polling and enables the modification of the actual system such as to add, remove or change names or location of thermocouples without any support from the computing services. Once these modifications have been completed, the PLC is set back into operation mode. This triggers the Tango device server to start with its data polling while dynamically updating any changes compared to its initial configuration. The restarts of the user application programs are necessary to upload the latest modifications. This significantly improved the reliability of our temperature measurements, which was spoiled due to a complicated set-up of hardware and software which always involved different persons to perform any simple modification.

We introduced a round-robin buffer at the device server level, keeping all measurement data of the SR thermocouples stored for at least three hours. The device server itself triggers the archiving of temperatures in our historical data base, as soon as a significant data change is detected in this round-robin buffer.

Vacuum Graphical User Interfaces (GUI)

The SR temperature survey GUI represents each sensor in a bar chart with its actual and maximal readout by different colours since its last manual reset. This provides a global survey of the "hot spots" during a certain period of time.

The re-grouping of thermocouples by families allows in one glance the identification of unusual heat loads, cooling problems or misalignments referring to a specific accelerator part.

We can easily correlate temperature increases with other equivalent accelerator parts data thanks to the precise time stamping of these temperature maxima.

The 3-dimensional survey indicates unusual temperature changes during machine operation such as during injections or gap changes. The SR temperatures are normalized with their family average temperatures and divided by this normalized temperature readout 60 seconds earlier.

The identification and geographical localisation of a thermocouple showing a suspicious behaviour or triggering a temperature alarm is done with the help of a graphical application program. This application uses the stored PLC thermocouple coordinates referring to its actual position in the SR cell and places them on an up-to-date cell layout from our drawing office.

All these user applications are dynamically uploaded in case of any changes in the thermocouple set-up as their numbers, location naming or alarm level [2].

CONCLUSIONS

The designed temperature acquisition system based on shielded PLC units located inside the SR tunnel fulfilled our requirements of reliability and flexibility.

Our actual temperature monitoring system is daily used to identify unusual heat loads. Problems with the cooling circuits of the crotch absorbers as well as “missing” air-cooled ceramic chambers have been identified in time and ahead of any machine interlock. Wrong alignments of crotch absorbers which induced a heat load of up to 200deg C on a badly cooled vacuum chamber has been immediately identified during the accelerator restart. Faulty RF-liners could be identified or confirmed. Thermocouples placed on our cryo-invacuum undulator, strip line kickers or other ceramic chambers help to monitor the safe operation of these equipments.

In many cases major problems could be anticipated and fixed during machine dedicated times.

We wish to develop a wireless, mobile PLC unit which can be used for temporary temperature measurements and other signal acquisition. This will allow an even faster installation and doesn’t spoil our global survey and historical data base with very specific problems or experiments. An embedded WEB server program should display and identify the connected thermocouples or signals. In our historical data base we would reserve a certain amount of signals which are identified by their numbering rather than their names to allow retrieving these measurements.

ACKNOWLEDGMENT

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[2] D. Schmied, E. Burtin, JM. Chaize, R. Kersevan, P.Verdier, “The ESRF Temperature Monitoring system from an operational point of view”, EPAC, June 2008, Genova.

[3] http://www.tango-control.org (tango control system).