EQUIPMENT AND MACHINE PROTECTION SYSTEMS FOR THE FERMI@Elettra FEL FACILITY WEPMU025

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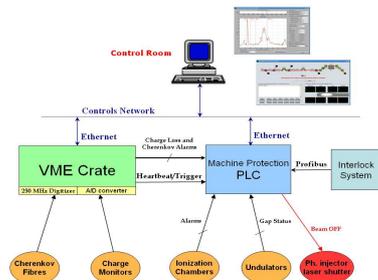
FERMI@Elettra is a Free Electron Laser (FEL) based on a 1.5 GeV linac presently under commissioning in Trieste, Italy. Three PLC-based systems communicating to each other assure the protection of machine devices and equipment. The first is the interlock system for the linac RF plants; the second is dedicated to the protection of vacuum devices and magnets; the third is in charge of protecting various machine components from radiation damage. They all make use of a distributed architecture based on fieldbus technology and communicate with the control system via Ethernet interfaces and dedicated Tango device servers. A complete set of tools including graphical panels, logging and archiving systems are used to monitor the systems from the control room.

Introduction: The protection systems are based on Siemens S7 PLCs with an extensive use of Profibus to connect several distributed I/O peripherals and LCD operator panels. The communication between systems is realized either by means of Profibus or digital I/O signals, while Ethernet-TCP/IP is employed to interface to the FERMI@Elettra control system using the Send/Receive protocol and dedicated Tango servers. In all, the protection systems make use of five 315-2DP and 16 IM151 CPUs, 30 operator panels and 31 Profibus nodes. The systems manage in total about 1900 digital inputs, 500 digital outputs and 250 analog inputs.
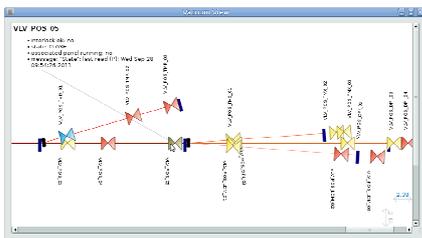
The machine protections system

The Machine Protection System (MPS) protects the FEL undulators from the deposition of excessive radiation doses caused, for example, by bad alignment of the electron beam. Several diagnostics are used to detect radiation, including ionization chambers, charge loss monitors and Cherenkov fibres. In order to guarantee the required reaction time a specific PLC has been dedicated to the MPS.
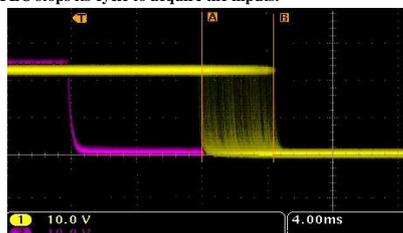

The supervision system

Supervision applications run in the FERMI@Elettra control systems and are developed using the Tango framework. The PLC systems communicate with the control system through Ethernet links and dedicated Tango servers, which acquire alarms and send commands. A Tango Device Server for each PLC is in charge of receiving the DBs and saving them into a MySQL database. A number of graphical interfaces have been developed using Matlab and QTango, a C/C++ graphical library for the Tango control system. They display the status of the systems and warn operators of interlock alarms.

Synoptic panel of the vacuum interlock system
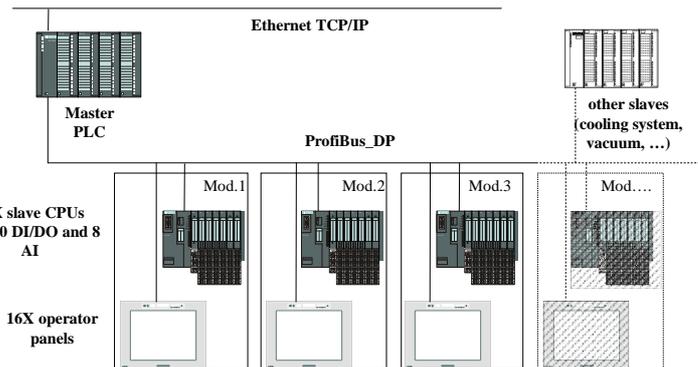
Measuring the PLC reaction time

This snapshot was taken during the first tests to measure the reaction time of the PLC. The same signal, provided by a pulse generator, has been used both as a trigger of an oscilloscope and as an input to the PLC (simulating an alarm); this signal was completely asynchronous to the PLC cycle. Thus we have got a family of curves with a fixed base of about 8 ms which depends on the PLC program, plus a variable time from 0 to about 4 ms, which depends on the time-difference between trigger and the moment when the PLC stops its cycle to acquire the inputs.

The RF plants interlock system

As shown in the figure each RF modulator is equipped with one PLC (CPU_MU), which guarantees performance in terms of reaction time. The goal is to allow no more than one linac shot after an interlock alarm is detected; given that the linac maximum repetition frequency is 50Hz, the protection action must be accomplished in less than 20 ms. This has also been achieved with an accurate design of the software architecture and a thorough programming. It has been necessary, for example, to avoid pre-compiled functions in favour of very primitive home-made functions and, whenever possible, to make extensive use of "jump" instructions. With a Siemens IM151 CPU controlling about 18 digital I/Os and eight analog inputs, the maximum reaction time is 12 ms.

Each RF plant has one touch-screen operator panel manufactured by UNIoP. A number of synoptic panels display the modulator interlock states and the analog input values, such as temperatures and klystron focalization currents, and allow the operator to set the corresponding interlock values.

The block diagram of the linac RF plants interlock system.

The vacuum interlock system

The purpose of the vacuum interlock is to avoid the propagation of possible leaks along the vacuum chamber. In the accelerator the PLC receives vacuum alarms from ion pump and vacuum gauge controllers by means of voltage free contacts; the alarm thresholds (set points) are set on the controllers. In the machine front end, instead, also analogic signals are acquired from temperature sensors, turbo-ionic pumps and vacuum gauges.

According to the coded protection logics, the PLC closes at least two valves in order to isolate the segment of vacuum chamber where an anomalous pressure increase has been detected; at the same time the PLC disables the electron beam to avoid damages of the valves. The vacuum valves can be remotely controlled (status reading and open/close command) either by using the local operator panels or via the Ethernet TCP/IP interface.

The figure 1 shows a page of one of the four operator panel display dedicated to the front-end vacuum interlock system; these are cheap 5,6" black and white touch panels, each panel is programmed with about 90 pages.

By touching each symbol it is possible to enter in the page dedicated to the selected device, for ex. by touching the valve symbol the associated page appears (figure 2).
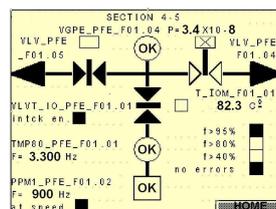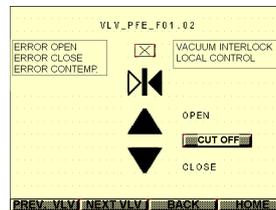

Fig.1: A section of the front –end vacuum chamber

Fig.2: The vacuum valve control page

Meaning of the symbols (basic)

 = go to previous page (or next with reverse arrow)

 = valve open with open command enable

 = valve closed with open command not enable and key to force the closed position inserted

 = turbo molecular pump running at 3300 Hz , Speed > 95% of max; no errors

 = open cmd (or close with inverse arrow)

 = possible error messages (one of the three)

 = valve state; now is : vacuum interlock and both switches pressed (it means error of contemporaneity)

 = cut off push button

 = cut off activated (the valve is blocked close)