CONTROLS AND INTERLOCKS FOR THE NEW ELETTRA SUPER CONDUCTING WIGGLER

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Abstract

During the last two years, triggered by the construction of the XRD2 beamline, and to comply with the topup operations, a complete refurbishment of the Elettra Super Conducting Wiggler (SCW) has been carried out. Alongside with the mechanical, cryogenic and electrical components, also the electronics, the control and interlock systems have been upgraded. The MVME5110 PowerPC single board computer, which is a standard in the Elettra control system, has been adopted, as well as RS232 communication modules, analog to digital converters and digital I/O lines. To cope with the high output power of the SCW, up to 18 KW, the interlock system, protecting both the wiggler and the beamline frontend, has been completely redesigned. The control system software has been rewritten from scratch using the TANGO software framework. The complete system has been tested during the second half of 2014 and is now fully operational.

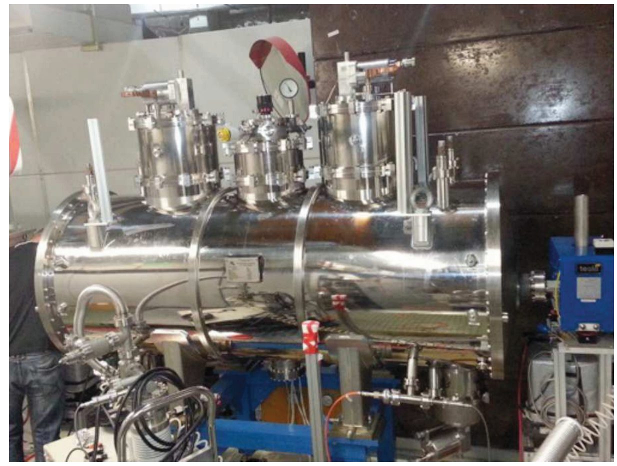

Figure 1: The refurbished super conducting wiggler installed in the Elettra storage ring.

INTRODUCTION

A 3.5 T superconducting wiggler, designed and built by the Budker Institute of Nuclear Physics (BINP), has been installed in the Elettra storage ring as a photon source for the X-ray diffraction beamline XRD2 in 2002 [1,2]. Due to the lack of funding for the beamline construction, the SCW didn't came in operation in the subsequent years. Then, in 2011, a collaboration agreement between the Indian government and Elettra Sincrotrone Trieste provided the funds required for the beamline construction and the SCW refurbishment. During 2012 and the first months of 2013, at the BINP laboratory in Novosibirsk, the SCW has been provided with a new cryostat aimed at decreasing the helium consumption and increasing the reliability. Then, in July 2013, after successful site acceptance tests, the SCW has been installed in the Elettra storage ring [3]. A picture of the installed wiggler is shown in Fig. 1.

Simplifying, the main components of the SCW are the chassis, the cryostat, the liner and the superconducting coils; the principle of operation of the SCW consists in keeping the cryostat temperature near to the 4.5 K, using liquid helium, and feeding the superconducting coils with the appropriate currents in order to reach the desired magnetic field.

ELECTRONICS

The original Danfysik MPS883 power supplies, powering the central and the side superconducting coils, after being revised have been kept in operation, as well as the four existing Leybold Coolpack 6000 compressors, provided with new Coolpower cooling heads. A new junction box, shown in Fig. 2, has been designed by BINP to replace both the old cabled box and the VME-based signal conditioning and acquisition board. The new junction box, based on an Atmel ATmega128 microprocessor, acquires the signals coming from the temperature and pressure sensors installed into the cryostat and implements the quench interlock logics. If a quench occurs the junction box turns off the power supplies that feed the superconducting coils driving their external interlock input. A RS232 serial line is available for remote control and supervision.

Figure 2: The new Junction Box.

Ion pumps, powered by the DUAL high voltage power supplies manufactured by Varian, are also installed to provide the requested vacuum levels. A pirani vacuum gauge allows to monitor the pressure in the vessel insulation, whilst some penning gauges are used in the front-end vacuum chamber; they are all powered with two TPG300 power supplies.

CONTROLS

In conjunction with the refurbishment of the cryostat the SCW control system has also been updated. The legacy control system, based on a VME crate and a Motorola 68K microprocessor single board computer running VxWorks, provided by BINP as a turnkey system, has been dismantled. Also, the ELTEC BAB40 single board computer, run-

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ning Microware OS-9, which acted as gateway to the legacy RPC based control system has been removed.

Hardware

A new dedicated front-end computer, based on the Artesyn MVME5110 VME single board computer, which is a standard for the Elettra control system, has been installed in a VME64x crate. A number of RS232 serial lines are requested to interface the two Danfysik MPS883 power supplies, the four compressors, the junction box and the vacuum power supplies. Two TIP866 industry pack mezzanine cards, each providing 8 RS232 serial lines, are installed on a TVME220 VME carrier board. An in-house developed signal conditioning board, compliant to the VME64x rear I/O board specification, provides the opto-insulation on the serial lines. To acquire some additional analog signals, such as the current monitor of the MPS883, a TIP501 ADC industry pack mezzanine card is used. Also, a new peripheral of the machine interlock system has been installed to interface signals mandatory for the machine protection.

Software

All the control software has been moved to the TANGO Controls framework [4]. More in detail, one TANGO device server for each family of devices to be interfaced has been developed:

- Danfysik MPS883 power supplies;
- Leybold Coolpack 6000 compressors powering cryocooler models 4.2 GM and 10 MD;
- junction box.

The TANGO device servers for the DUAL and TPG300 high voltage power supplies of the FERMI vacuum subsystem have been reused.

In charge of the overall SCW supervision, one more TANGO device server, that interacts with the junction box device server and the power supply device servers, has been developed. Dedicated additional threads are in charge of:

- ramp the magnetic field;
- monitor the junction box status and:
  - ramp the SCW magnetic field to zero in case of helium level warning or temperature warning;
  - stop any magnetic field ramp whenever a quench, or other alarm, are detected;
- monitor the power supplies and compute the actual magnetic field from the currents; this thread is also in charge of pushing the reading events to the clients.

In order to follow a precise trajectory, a look-up table is used to compute the power supplies currents corresponding to the requested magnetic field, using linear interpolation. The look-up table also specifies the speed of the current ramps, in A/s, for a number of predefined magnetic field ranges: different intensities require different speeds. The power supply currents versus the magnetic field are plotted in Fig. 3.

Moreover, even when ramping up or down the field different speeds have to be used. The thread driving the ramps also checks that the actual magnetic field value moves along the predefined trajectory; if the tolerance is exceeded the current ramps are stopped and a new one started to move to an allowed value on the calibrated trajectory, following the shortest path.

The status of the MPS883 power supplies is also monitored and, should a fault occurr, the magnetic field ramp

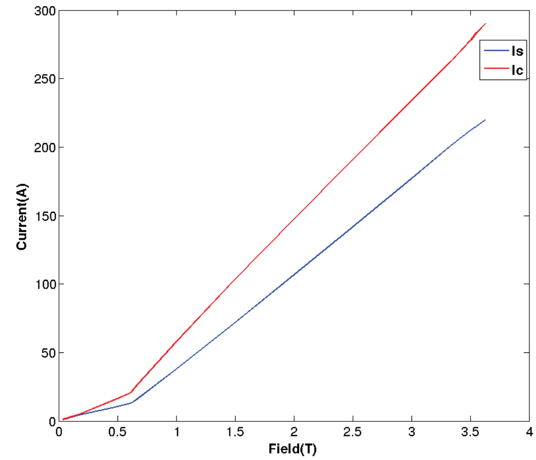

Figure 3: Side coil [blue] and central coil [red] power supplies currents versus magnetic field.

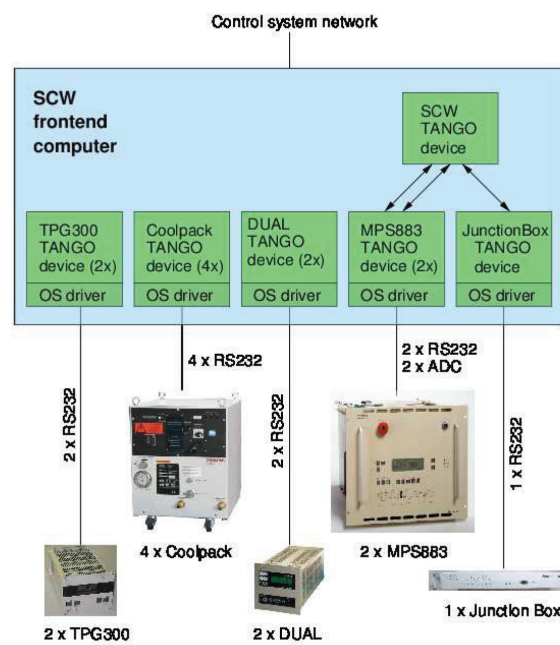

Figure 4: TANGO device servers layout on SCW front-end computer.

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stopped. The structure of the control software deployed on the SCW front-end computer is shown in Fig. 4.

All the relevant parameters of the SCW are continuously monitored and stored into the historical database of the accelerator, using the HDB++ archiving system, on both variation and periodic basis. A large number of values are stored during the magnetic field ramps, in fact at each setting of the power supplies currents; when the wiggler is not ramping just a few values are stored on a periodic basis.

Graphical User Interface

A graphical user interface, to be used by the control room operators and the insertion devices specialists, has been developed with Qtango and the Qt graphics library. All the parameters and the readings, such as temperatures, power supplies status and currents, helium level, junction box and compressors status and, last but not least, wiggler magnetic field are shown over a synoptic image of the SCW. In addition the pressure levels and the temperatures of the front-end are also displayed. Moreover, the operator can input the desired magnetic field value and start the ramp. A screenshot of the current SCW GUI is shown in Fig. 5.

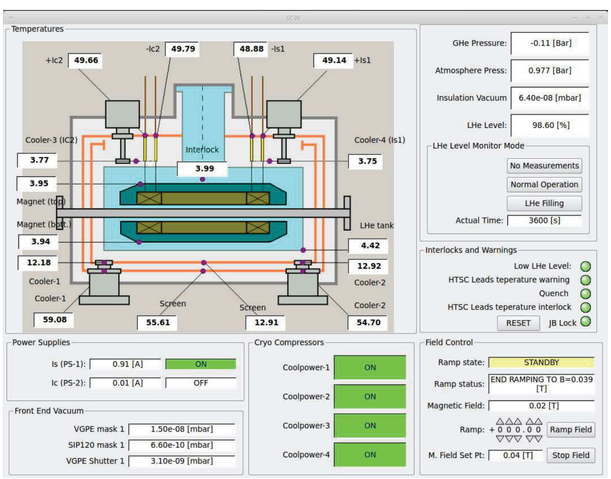

Figure 5: The SCW graphical user interface.

INTERLOCKS

The high output power of the 3.5 T superconducting wiggler introduced a novel issue on the accelerator light exit as well as the beamline front-end.

The machine protection interlock system of the Elettra storage ring is based on Siemens S7 programmable logic controllers (PLC). The interlock PLC, though operating independently, is connected to the control system via Ethernet and a dedicated TANGO device server provides all the process variables to the supervisory system, which is also based on TANGO.

A vacuum valve, protected by a beam shutter, usually separates the Elettra storage ring vacuum chamber from the beamline front-end vacuum. In case of increasing pressure on the beamline, the interlock PLC, in protection of the storage ring vacuum, closes the valve and, to protect the valve from the beam, the corresponding shutter. However, the standard beam shutter used at Elettra can not cope with the full SCW power. On the other hand, a 18 KW capable shutter is large and expensive, and an additional one is required for the beamline photon shutter. Therefore, the decision has been taken to install a new photon shutter, capable of holding 18 KW photon beam power and to implement a mechanism to protect the existing exit valve/shutter. Consequently, the storage ring interlock system for the XRD2 beamline has been completely redesigned to include the vacuum, the valve/shutter and the front-end protection. A new peripheral of the interlock system, connected via PROFIBUS to the nearest S7 CPU, acquires the SCW power supply currents by means of two dedicated DCCT converters, as well as a number of thermocouples, flowmeters and vacuum gauges, installed on the front-end. To define the operating status of the wiggler two thresholds have been introduced:

- beam shutter protection threshold;
- fast orbit interlock threshold.

The first one, usually set at 1.0 T, enables the interlock protection of the beam shutter/vacuum valve: if the valve is closed, hence the shutter, and the SCW magnetic field is higher than the threshold the electron beam is dumped. The second, usually set at 0.42 T, tells the fast orbit interlock system that the SCW is operating and the tolerance on permissible orbit distortion has to be lowered.

A large displacement of the superconducting coils power supplies currents from the reference trajectory values, possibly due to control software or hardware failure, can lead to heavy orbit distortion and, considered the big output power, to the damage of the vacuum chamber. The PLC monitors the actual power supply currents by means of two DCCTs; the values are compared to the theoretic values, computed from the current magnetic field by a reverse calculation, and, if the tolerance is exceeded, the electron beam is dumped.

The status of all the interlocks related to the SCW operation is summarized on a dedicated GUI, shown in Fig. 6.

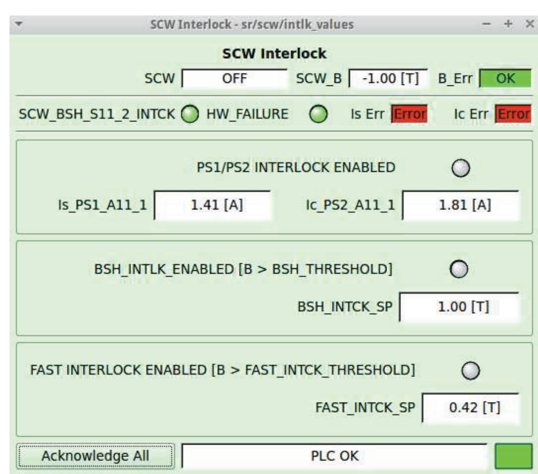

Figure 6: The SCW interlock GUI.

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Thermocouples, flow meters and vacuum gauges installed on the front-end are also monitored and the appropriate interlock logics implemented. Currently, in case of low flow the electron beam is immediately dumped. Conversely, a two step mechanism is in place for the front-end temperatures and pressures. First, some alarms have been set up in the TANGO alarm system to alert the operator of possible problems with the temperatures or the vacuum. In case of increasing front-end temperatures, for instance, the operator can ramp down the SCW magnetic field decreasing the output power. Should the operator miss the action, the second step belongs to the interlock PLC that dumps the electron beam.

CONCLUSION

The control system for the new SCW is in operation since autumn 2014. Also the interlock system, updated in two steps, is now fully operational. A number of alarms are already in place to help the machine operator to supervise and operate the SCW at the best condition and, because of the need of electron beam dump in plight, to prevent possible issues.

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