THE UPGRADE PROGRAMME FOR THE ESRF ACCELERATOR CONTROL SYSTEM

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Abstract

To reach the goals specified in the ESRF Upgrade Programme [1], for the new experiments to be built, the storage ring needs to be modified. The optics must be changed to allow up to seven meter long straight sections and canted undulator set-ups. Better beam stabilization and feedback systems are necessary for the nano-focus experiments planned. Also we are undergoing a renovation and modernization phase to increase the lifetime of the accelerator and its control system.

This paper resumes the major upgrade projects, such as the new beam position monitoring (BPM) system, the fast orbit feedback, the ultra-small vertical emittance and their implications on the control system. Ongoing modernization projects such as the solid state radio frequency amplifier or the high-order mode (HOM) damped cavities are described. Software upgrades of several sub-systems e.g. vacuum and insertion devices, which are planned either for this year or for the long shutdown period, beginning of 2012, are covered as well. The final goal is to move to a Tango [2] only control system.

THE ESRF UPGRADE PROGRAMME

In 2008, the Council of the ESRF launched the ESRF Upgrade Programme 2009-2018, an ambitious ten-year project. Funding for a first phase of the Upgrade (from 2009 to 2015) has been secured to deliver:

- Eight new beamlines, mainly with nano-focus, with capabilities unique in the world
- Refurbishment of many existing beamlines to maintain them at world-class level
- Continued world leadership for X-ray beam availability, stability and brilliance
- Major new developments in synchrotron radiation instrumentation

Producing nano-sized beams needs long beamlines, which at the ESRF will reach 120 metres. An extension of the experimental hall will be built to house the new beamlines.

Nano-focusing also requires a high reliability, stability and brilliance of the x-ray source. To reach the goals of the update program, the x-ray source also needs to be modified.

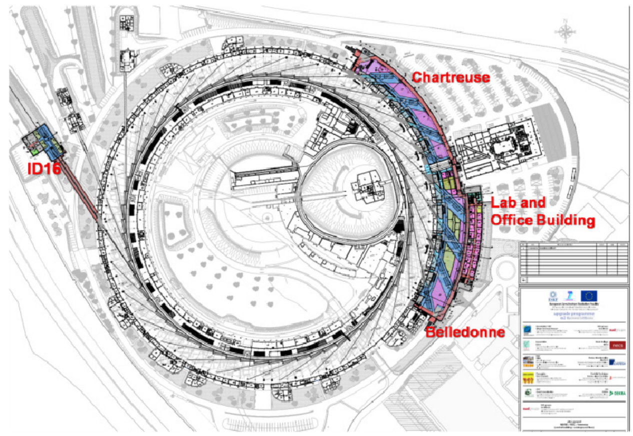


Figure 1: Experimental Hall Extension.

X-RAY SOURCE IMPROVEMENTS

Several improvements are already in preparation since 2009 in the framework of the ESRF Upgrade Programme.

BPMs and Fast Orbit Feedback

The old beam position monitoring system was already replaced at the end of 2009 with 224 Libera [3] measurement systems. With these high precision e-beam position measurements, the exchange of all 96 steerer power supplies and the installation of a fast, redundant communication network, we are now able to prepare a new fast orbit feedback system with a correction rate of 10 kHz. The result should be a better correction of e-beam movements.

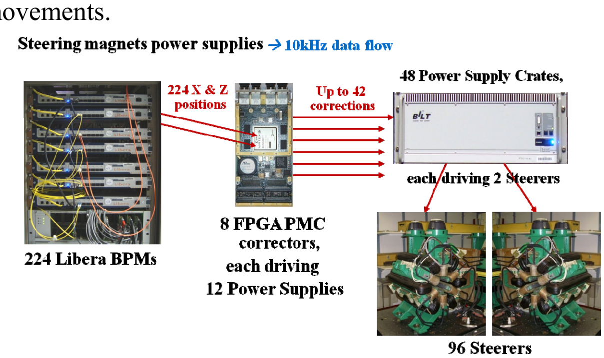


Figure 2: Fast Orbit Feedback System.

The feedback system is actually under test and should be operational at the end of 2011. The challenge for the control system was the progressive exchange of the steerer power supplies, during several months, without perturbing the operation.

Ultra-Small Vertical Emittance

A new algorithm for coupling correction was developed and implemented for the storage ring. Using this, together with the high precision Libera beam position monitors a vertical emittance of $\varepsilon_z = 4.4 \pm 0.7$ pm could be reached.

Two procedures to preserve the small vertical emittance during beam delivery were successfully tested: stable ε_z = 6-7 pm for a 7/8 +1 filling mode and 10 pm for a uniform filling.

During the last winter shutdown, 32 new skew quadrupole magnets have been installed on the storage ring to correct the coupling induced by insertion device movements. The goal is an ultra small vertical emittance of ε_z = 2 pm. The first already carried out tests are promising, and the new fast orbit feedback system will help this goal to be reached.

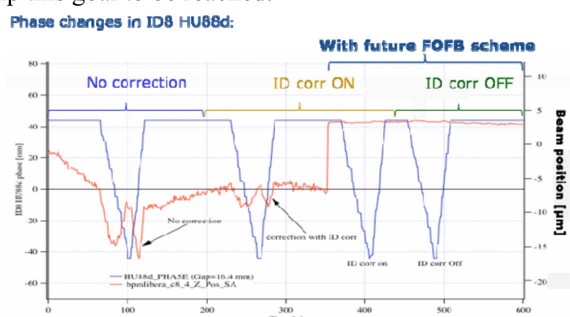


Figure 3: Correction of ID beam perturbation.

6m Straight Sections

The lattice of the ESRF storage ring was designed with 32 long straight sections of alternating high and low horizontal beta values. This currently provides 5 m of available space for insertion devices. The ESRF Upgrade Programme proposes to increase the length of selected insertion device straight sections from 5 to 6 or even 7 meters. This will provide a higher level of brilliance and increased insertion device flexibility. For example, longer insertion devices for a single beamline, sharing of the straight sections between two experimental stations using the canted undulator approach, reshuffling the RF cavities layout and freeing straight section space for new beamlines are possible uses of the increased straight section length.

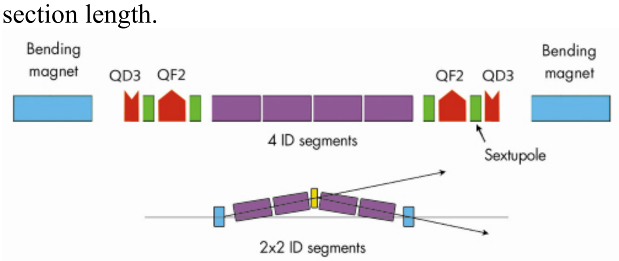


Figure 4: Uses of long straight sections.

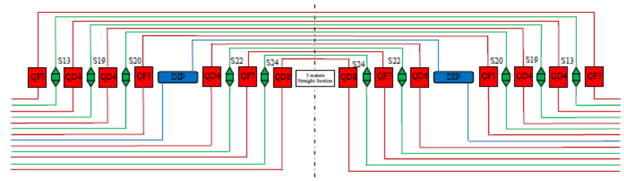


Figure 5: Initial, family-wise, power supply steering.

To allow such long straight sections, a lot of power supplies need to be changed from a family-wise control to individual control. The beam steering algorithmns had to be revised.

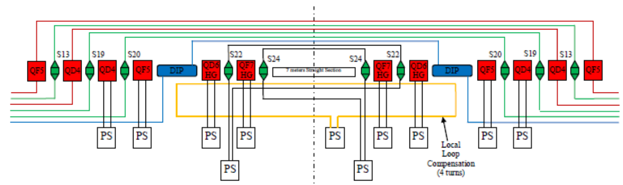


Figure 6: Power supply control for a 7m straight section.

High Power Solid State Radio Frequency Amplifiers and HOM Damped Cavities

The sub-system with the highest failure rate on the ESRF storage ring during the last years was the radio frequency system. To increase the long term reliability, two projects are in progress in the frame work of the Update Programme.

The replacement of the klystron based radio frequency transmitters with solid state radio frequency amplifiers and the development of new HOM-damped accelerating cavities.

Solid state amplifiers consume less power, have a high redundancy and need much less tuning effort compared to a klystron.

The first amplifier tower has been tested at the ESRF. Delivery and installation of the first full transmitter is planned for the end of 2011.

A careful software design is important, because the control system needs to combine the new and the old radio frequency controls in a coherent way.

Figure 7: Solid state RF amplifier at Soleil.

High order mode tuning of the accelerating cavities, especially at higher e-beam currents, is complicated to achieve. To overcome the limitation, a new design of a HOM-damped cavity [4] was made. The prototypes have been delivered to the ESRF and are currently under test.

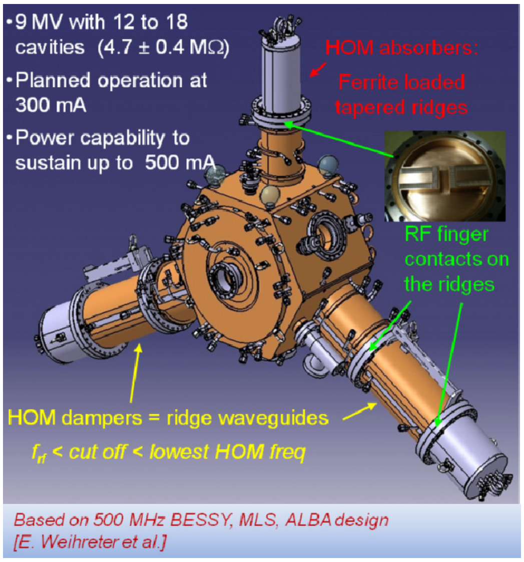


Figure 8: HOM-damped cavity design.

CONTROL SYSTEM UPGRADE

The first goal for the control system is the smooth integration of all X-ray source improvements without losing the reliability achieved over the last years.

In addition, specific long term goals have been defined for the control system.

Move to a Tango-only Control System

The ESRF accelerator complex is controlled with a mix of our legacy control system Taco, developed in the 1990's and our new Tango control system. Tango is a collaborative development which offers much more features, development and survey tools. For several years already we have been working on the replacement of Taco by Tango.

The Upgrade Programme and the long shutdown period from the end of 2011 until May 2012 offer a good opportunity to progress on the goal to replace Taco completely by Tango. The software redesign of several sub-systems is in progress to be ready for a long testing period. The exchange of the vacuum control software will be finished, by the end of 2011 and the new software for frontend and insertion device control is progressing.

A software redesign means a complete review of all features from the hardware interface to the graphical user interface.

In 2010 we still had 45% Taco devices. In 2012 we would like to have less than 25%.

Increase the Reliability

Several measures have been taken to increase the reliability of the control system.

A survey of all control computers was set up with NAGIOS [5] so that any CPU, memory or disk problem, for example, can be detected automatically.

The usage of the Tango administration system allows an immediate overview of all device servers running on control system hosts. With the new failure statistics, we can even identify infrequently occurring software crashes and schedule the necessary action.

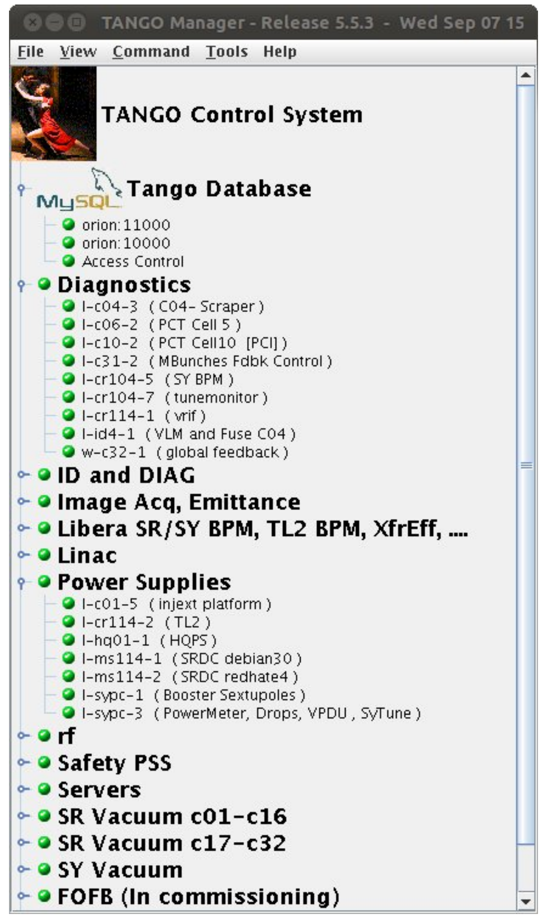
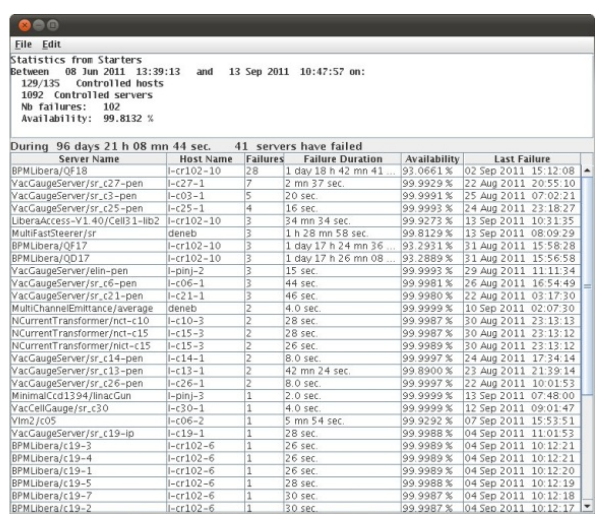


Figure 9: Tango administration GUI.


File Edit
Statistics from Starters
Between 08 Jun 2011 13:39:13 and 13 Sep 2011 10:47:57 on:
129/135 Controlled hosts
1092 Controlled servers
Nb failures: 102
Availability: 99.8132 %

During 96 days 21 h 08 mn 44 sec. 41 servers have failed

Server Name	Host Name	Failures	Failure Duration	Availability	Last Failure
BPMLibera/QF18	l-cr102-10	28	1 day 18 h 42 mn 41 ...	93.0661 %	02 Sep 2011 15:12:08
VacGaugeServer/sr_c27-pen	l-c27-1	7	2 mn 37 sec.	99.9929 %	22 Aug 2011 20:55:10
VacGaugeServer/sr_c3-pen	l-c03-1	5	20 sec.	99.9991 %	25 Aug 2011 07:02:21
VacGaugeServer/sr_c25-pen	l-c25-1	4	16 sec.	99.9993 %	24 Aug 2011 23:18:27
LiberaAccess-V1.40/Cell31-lib2	l-cr102-10	3	34 mn 34 sec.	99.9273 %	13 Sep 2011 10:31:35
MultiFastSteerer/sr	deneb	3	1 h 28 mn 58 sec.	99.8129 %	13 Sep 2011 08:09:29
BPMLibera/QF17	l-cr102-10	3	1 day 17 h 24 mn 36 ...	93.2931 %	31 Aug 2011 15:58:28
BPMLibera/QD17	l-cr102-10	3	1 day 17 h 26 mn 08 ...	93.2889 %	31 Aug 2011 15:56:58
VacGaugeServer/elin-pen	l-pinj-2	3	15 sec.	99.9993 %	29 Aug 2011 11:11:34
VacGaugeServer/sr_c6-pen	l-c06-1	3	44 sec.	99.9981 %	26 Aug 2011 16:54:49
VacGaugeServer/sr_c21-pen	l-c21-1	3	46 sec.	99.9980 %	22 Aug 2011 03:17:30
MultiChannelEmittance/average	deneb	2	4.0 sec.	99.9999 %	10 Sep 2011 02:07:30
NCurrentTransformer/nct-c10	l-c10-3	2	28 sec.	99.9987 %	30 Aug 2011 23:13:13
NCurrentTransformer/nct-c15	l-c15-3	2	28 sec.	99.9987 %	30 Aug 2011 23:13:12
NCurrentTransformer/nict-c15	l-c15-3	2	26 sec.	99.9989 %	30 Aug 2011 23:13:12
VacGaugeServer/sr_c14-pen	l-c14-1	2	8.0 sec.	99.9997 %	24 Aug 2011 17:34:14
VacGaugeServer/sr_c13-pen	l-c13-1	2	42 mn 24 sec.	99.8900 %	23 Aug 2011 21:39:14
VacGaugeServer/sr_c26-pen	l-c26-1	2	8.0 sec.	99.9997 %	22 Aug 2011 10:01:53
MinimalCcd1394/linacGun	l-pinj-3	1	2.0 sec.	99.9999 %	13 Sep 2011 07:48:00
VacCellGauge/sr_c30	l-c30-1	1	4.0 sec.	99.9999 %	12 Sep 2011 09:01:47
Vlm2/c05	l-c06-2	1	5 mn 54 sec.	99.9292 %	07 Sep 2011 15:53:51
VacGaugeServer/sr_c19-ip	l-c19-1	1	28 sec.	99.9988 %	04 Sep 2011 11:01:53
BPMLibera/c19-3	l-cr102-6	1	26 sec.	99.9989 %	04 Sep 2011 10:12:21
BPMLibera/c19-4	l-cr102-6	1	26 sec.	99.9989 %	04 Sep 2011 10:12:21
BPMLibera/c19-1	l-cr102-6	1	26 sec.	99.9989 %	04 Sep 2011 10:12:20
BPMLibera/c19-5	l-cr102-6	1	28 sec.	99.9988 %	04 Sep 2011 10:12:19
BPMLibera/c19-7	l-cr102-6	1	30 sec.	99.9987 %	04 Sep 2011 10:12:18
BPMLibera/c19-2	l-cr102-6	1	30 sec.	99.9987 %	04 Sep 2011 10:12:17

Figure 10: Failure statistics.

More High-level Analysis Tools

To allow better diagnostics or prediction of problems on the accelerator complex, a lot of effort goes into high-level data analysis tools. These analysis features can be implemented in the different device server layers, but must be regrouped into specific graphical user interfaces (GUI).

One example of such a high-level data analysis tool is the vacuum leak detection system, based on the residual gas analysers (RGA) [6], installed on the storage ring. The goal is to detect air leaks, water leaks and any abnormal out-gazing.

For example, the relative partial pressure survey is a 3-dimensional representation of selected partial pressures. Each relative pressure corresponds to a pressure change against its own reference. There is one reference pressure for each mass for every residual gas analyser and for every storage ring filling mode. This is particularly useful for a first and quick analysis of vacuum events. Figure 11 shows a typical partial pressure change signature in the case of an air leak event. Air leaks are clearly linked to strong relative changes of partial pressures corresponding mainly to masses 14, 28 and 40 (N, N2, and Ar).

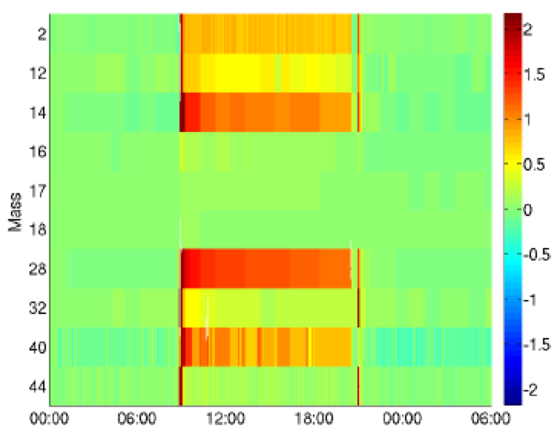


Figure 11: Real-time relative partial pressure survey.

The specific graphical user interface enables the handling of all RGAs around the storage ring and provides a complex alarm configuration as well as online and post-mortem data analysis.

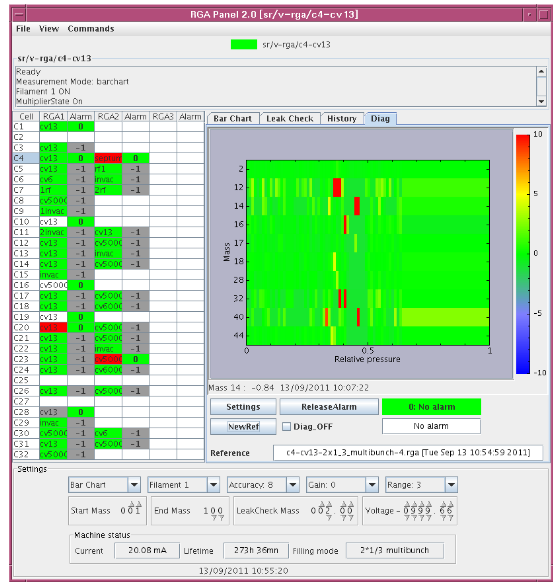


Figure 12: RGA monitoring GUI.

CONCLUSION

Conducting the upgrade in parallel to full user operation and maintaining the high stability and reliability of the X-ray source is very demanding.

As a consequence of the construction work of the experimental hall extension, a long shutdown period of 5 months is scheduled, at the beginning of 2012. During this period a lot of modifications of hardware and software will be prepared and installed. The challenge is to restart the accelerator complex with the same reliability in May 2012 to continue user operation.

We hope that all the different modifications and improvements on the X-ray source as well as on the control system will lead to a successful implementation of the new nano-focus beamlines.

REFERENCES

[1] http://www.esrf.fr/AboutUs/Upgrade
[2] http://www.tango-controls.org/
[3] http://www.i-tech.si/accelerators-instrumentation/libera-brilliance
[4] V. Serrière, J. Jacob, B.Ogier, D.Boilot, “252.2 MHZ HOM Damped Normal Conducting ESRF Cavity: Design and Fabrication”, IPAC'11, San Sebastian, Spain, 2011, http://www.JACoW.org
[5] http://www.nagios.org/
[6] A. Meunier, I. Parat, J.-L. Pons and M. Hahn, “Upgrade of the ESRF RGA System”, IPAC'11, San Sebastian, Spain, 2011, http://www.JACoW.org