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ESRF RAMPING INJECTOR POWER SUPPLIES CONTROLLED BY TANGO

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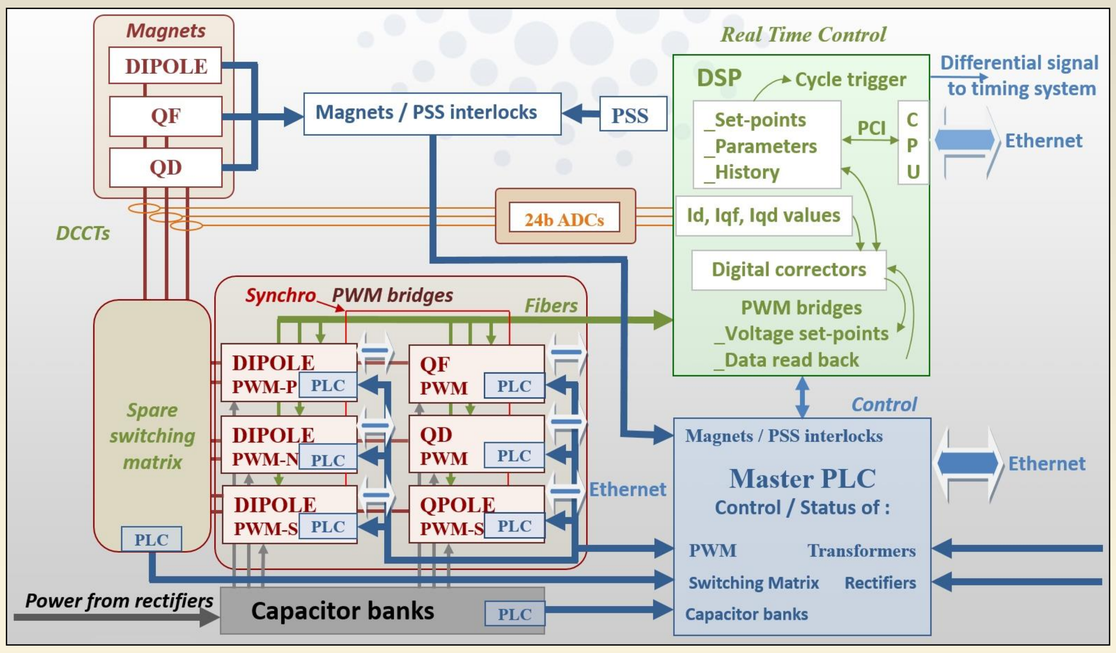
A new design of ESRF booster power supply system has been developed and installed. A multiple power supplies control through network including real time control is now operational at ESRF. It manages 4 power supplies to generate 3 waveforms defined with 3x1600 values in a set point file. The power supplies states are managed by PLCs. The ramping waveforms are managed by a real time program running on a FPGA board. A high level control on top of them is assumed by a TANGO[1] multiple classes system.
This poster presents how these three levels of controls are interlinked and shows the results achieved.

Originally, a 10 Hertz resonating circuit was supplying the current in the three main ESRF booster magnets chains. Although this equipment ran more than 25 years without major trouble, there are in the circuits huge specific transformers for which the time to repair is of one month and, furthermore, some components of the power circuits are now discontinued. Decision was made that this whole equipment was to be replaced by a new one, based on ramping of the current. The new functionality brought to the current behavior is the possibility to correct any point in the slope (6400 Hz / 156.25 µs). This allows the stabilization of the tunes during the ramping to improve the efficiency of the electron beam cleaning in the booster [2].

- The 15 PLCs (power supplies, switching matrix,…) are controlled by a TANGO device server through TCP/Modbus sub devices.
- The FPGA board is controlled by another TANGO device through a library developed at ESRF. It manages 58 attributes to be able to adjust loop parameters, start/stop ramping, measures, status,… It is able to load the waveform file in FPGA memory as set point. During the ramping phase, it get a set of 23x1600 measures and status from the FPGA at 4Hz and save these information in a file to be analyzed later by a dedicated application.
- A TANGO device is able to generate the waveform file using MATLAB library.

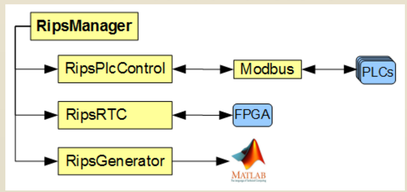
Layout

The 4 PWM bridges units are connected to the FPGA board dedicated to the real-time control by means of optic fibres driven by Rocket IOS with a serial data communication rate of 1.25Gbps.
The PLCs control the states of the different units and report to a master PLC itself controlled by a remote Tango application.



TANGO Control Servers

Main control functions

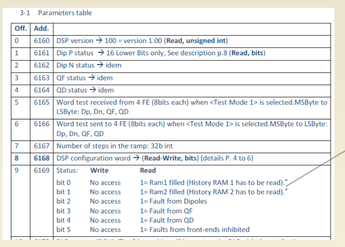


Control summary

For the full project:
- 8 TANGO servers
- 19 TANGO classes
- 56 TANGO devices

And it manages more than 450 attributes.

RIPS PWM control device



3-1 Parameters table

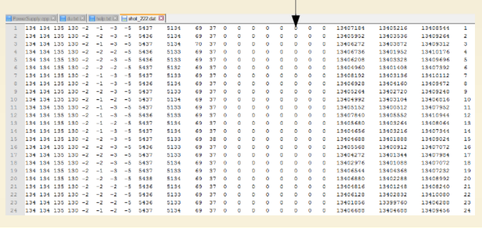
Off.	Add.		
0	6160	DSP version → 100 = version 1.00 **(Read, unsigned int)**	
1	6161	Dip P status → 16 Lower Bits only, See description p.8 **(Read, bits)**	
2	6162	Dip N status → idem	
3	6163	QF status → idem	
4	6164	QD status → idem	
5	6165	Word test received from 4 FE (8bits each) when <Test Mode 1> is selected.MSByte to LSByte: Dp, Dn, QF, QD	
6	6166	Word test sent to 4 FE (8bits each) when <Test Mode 1> is selected.MSByte to LSByte: Dp, Dn, QF, QD	
7	6167	Number of steps in the ramp: 32b int	
8	6168	DSP configuration word → **(Read-Write, bits)** (details P. 4 to 6)	
9	6169	Status: **Write** / **Read**	
		bit 0 No access / 1= Ram1 filled (History RAM 1 has to be read).*	
		bit 1 No access / 1= Ram2 filled (History RAM 2 has to be read).*	
		bit 2 No access / 1= Fault from Dipoles	
		bit 3 No access / 1= Fault from QF	
		bit 4 No access / 1= Fault from QD	
		bit 5 No access / 1= Faults from front-ends inhibited	

2- PCIe History → from DSP to PCIe: 2 memories with the capability of 16kWords of 64bits each. 7 x 16b int data x 4 power supply x 2048 packed into 14336 words of 64 bits:

2-1 File format of the history, ramp of "N" steps:

	2nd 32b word	1st 32b word	
	64bits		
	QF Status	QD Status	Dip_P Status	Dip_N Status	
	QF V_out	QD V_out	Dip_P V_out	Dip_N V_out	Record pulse 1
	QF V_in	QD V_in	Dip_P V_in	Dip_N V_in	
	QF D.Cycle	QD D.Cycle	Dip_P D.Cycle	Dip_N D.Cycle	
	QF Saturation	QD Saturation	Dip_P Saturation	Dip_N Saturation	
	QF I_out_H	QF I_out_L	Dip I_out_H	Dip I_out_L	
	32 bits Index 1		QD I_out_H	QD I_out_L	
	QF Status	QD Status	Dip_P Status	Dip_N Status	Record pulse 2 etc…
	QF V_out	QD V_out	Dip_P V_out	Dip_N V_out	
	QF V_in	QD V_in	Dip_P V_in	Dip_N V_in	
	QF D.Cycle	QD D.Cycle	Dip_P D.Cycle	Dip_N D.Cycle	
	QF Saturation	QD Saturation	Dip_P Saturation	Dip_N Saturation	
	QF I_out_H	QF I_out_L	Dip I_out_H	Dip I_out_L	
	32 bits Index N		QD I_out_H	QD I_out_L	Record pulse N

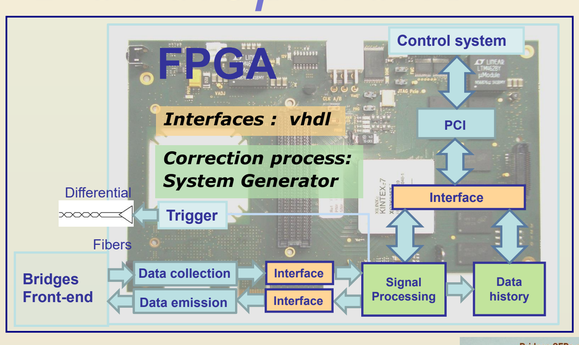
When a RAM is full, the DSP fills the other one, while TANGO device read values and generates 1 file/shot containing
- 14 integers (32 bits)
- 1600 rows
- the shot time stamp.

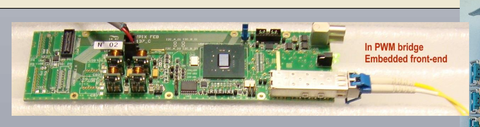


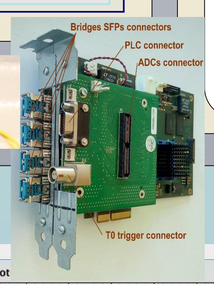
All pieces of equipment are equipped with a dedicated PLC connected to a server through Ethernet. These PLCs are controlling the states of the different units and reporting to a master PLC itself controlled by a remote Tango application. All commands and safety aspects are managed by the master PLC while the history of events goes directly from each PLC to the Tango server.

A dedicated application GUI displays the status of all equipment components on a synoptic and allows to set parameters, send commands, load and generate waveforms and execute diagnostics on the full system. A tab pane allows to show the loaded waveform. 16 curves (currents, voltages, duty cycles, …) of 1600 points can be analyzed for each 4Hz shot.

Development







FPGA module

Commercial card in a PCI.
Communication From ESRF Digital Electronics Group [3].
- Communication node and signal processor, the FPGA embeds the signal processing
→ *Real time inside the FPGA*
all tasks completed in a few µs
- Diagnostics or transfer of parameters through the PCI interface
→ *Not real time*

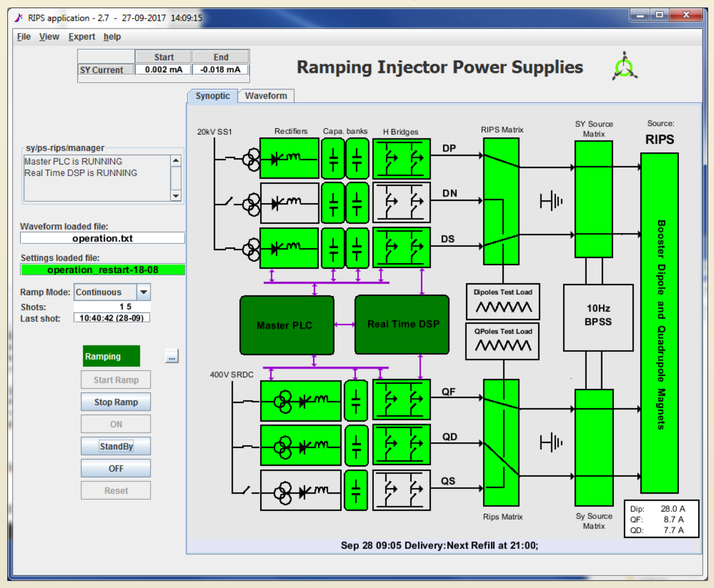
TANGO GUI

Parameters to generate a new waveform file using Matlab is based on tune variation (Qx/D)

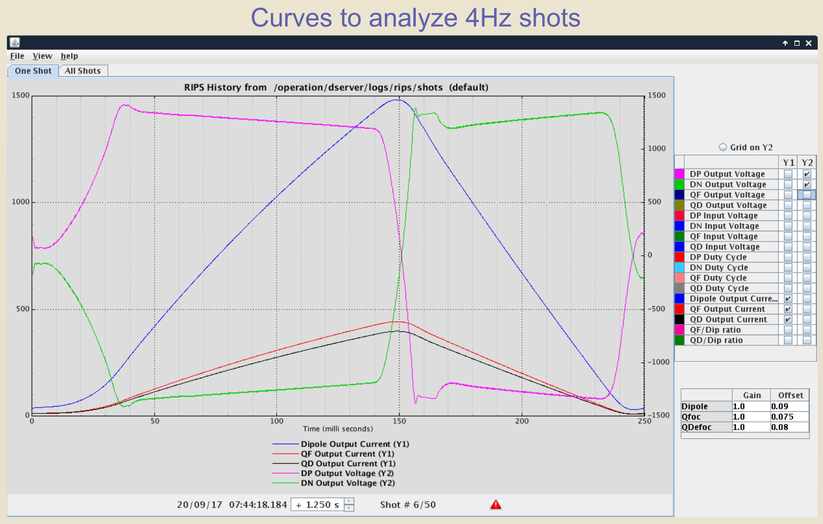
	Time (m…	ΔQx	ΔQy
Point 1	0.5	0.0	0.0
Point 2	1.0	0.0	0.0
Point 3	3.25	0.0	0.0
Point 4	7.75	0.0	0.0
Point 5	10.0	0.0	0.0
Point 6	13.125	0.0	0.0
Point 7	14.6875	0.0	0.0
Point 8	17.0	0.0	0.0

	Time (ms)
Phase QF	0.0
Phase QD	0.0

GUI main panel with synoptic



Curves to analyze 4Hz shots



	Gain	Offset
Dipole	1.0	0.09
Qfoc	1.0	0.075
QDefoc	1.0	0.08

Many parameters:
- states
- Temperatures
- shot number
- FPGA loop
- waveform file
- ....

are stored in TANGO HDB++ using TANGO events.

Tests result

The current flowing in the magnets is raised following a specific shape which gives the best voltage shape. Indeed this latter must never hang with the maximum available at the bridges inputs.
The red and black curves correspond to the result of the ratio between quadrupoles currents and the dipole one.
The deviation must stay within 10^{-3} .

References

[1] http://www.tango-controls.org/
[2] E. Plouviez, L. Farvacque, J.M. Koch, T. Perron, B. Roche, K. Scheidt, R. Versteegen, S. White , "Cleaning of parasitic bunches for time structured filling of the ESRF storage ring during top up operation", TUPIK041 in Proceedings of IPAC2017, Copenhagen, Denmark.
[3] https://www.xilinx.com
http://wikiserv.esrf.fr/del/images/6/6b/Seb.pdf]

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