TIME TRAVEL MADE POSSIBLE AT FERMI BY THE TIME-MACHINE APPLICATION

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Abstract

The TANGO archiving system HDB++ continuously stores data over time into the historical database. The new time-machine application, a specialization of the extensively used save/restore framework, allows bringing back sets of control system variables to their values at a precise date and time in the past. Given the desired time stamp t0 and a set of TANGO attributes, the values recorded at the most recent date and time preceding or equalling t0 are fetched from the historical database. The user can examine the list of variables with their values before performing a full or partial restoration of the set. The time-machine seamlessly integrates with the well known save/restore application, sharing many of its characteristics and functionalities, such as the matrix-based subset selection, the live difference view and the simple and effective user interface.

TERMINOLOGY

Context

The context is a set of TANGO attributes gathered together under a name; the context structure is exactly the same as the one beneath the classical save/restore database.

Snapshot

The snapshot is always associated to a specific context and stores the values of the attributes at the very moment the snapshot itself was taken. The relation between a context and the snapshot is represented by the context ID and a snapshot has a unique snapshot ID. Each context can have multiple snapshots taken at different instants, while each snapshot is linked to a unique context. Of course, there is no constraint in the definition of the contexts: distinct ones can have one or more attributes in common.

WORKING PRINCIPLE

The classic save/restore [1] control room application was designed to save a snapshot of a set of TANGO attributes on a database at a given point in time. The snapshots can be later revised and restored on the field. Only previously saved sets of values, identified by an ID, a comment, the date and time the snapshot was taken, can be put back on the equipments. The time machine takes a different approach. Relying on an event-based TANGO historical database archiver, named HDB++ [2], it is able to restore a set of attributes to their values at any date and time in the past. The HDB++ constantly saves TANGO attributes into the database according to a given threshold. Taking advantage of the event-based archiver and the specific extraction library, it is always possible to retrieve the value of a quantity at an arbitrary point in the past. Historical database snapshots can thus be created on the fly at a given date and time.

THE HISTORICAL DATABASE LIBRARY

The HdbExtractor++ framework allows fetching data from a historical database in a simple object oriented fashion. The library currently supports the HDB (the original version of the TANGO archiver) and HDB++ MySql database schemas. Scalar and vector data can be fetched from the database, given a start and stop date and time. A separate module provides a Qt interface to the extraction library and also a dedicated GUI, aimed at displaying scalar and vector data over time. Extraction in the Qt module operates in a separate thread. Vectors are displayed over time by a surface plot, based on the MathGL framework. Errors are notified by NULL values. They typically reflect a read error from the device at the moment of the save process. If the data of a given source is not recorded in a given period, it is possible to fetch values older than the start date. Moreover, data sets pertaining to different curves can be aligned in time, so that a point on the curve is associated to each time stamp in the x axis. Even if the HdbExtractor++ library is tailored to deal with TANGO data (as far as data type, write mode property and data format are concerned), it is not dependent from TANGO specific types and libraries. The Qt module is multi threaded and can be easily integrated in graphical user interfaces [1].

THE GRAPHICAL USER INTERFACE

The Time-Machine graphical user interface is written in Qt and is made up of two sections: the classical save/restore and the new time machine mode. When the application is launched, the classical save/restore mode is selected by default (see Fig. 1). A radio button allows to switch to the time machine view (see Fig. 2). The design of the user interface unifies the approach to the selection of the contexts and the restore process in both modalities. The top left view is a list of the available contexts. Note that the save/restore contexts and time machine ones are defined in distinct databases, so in principle they don't overlap. The right view displays the TANGO attribute names and properties. The information is updated with the read and write values of each quantity as soon as a

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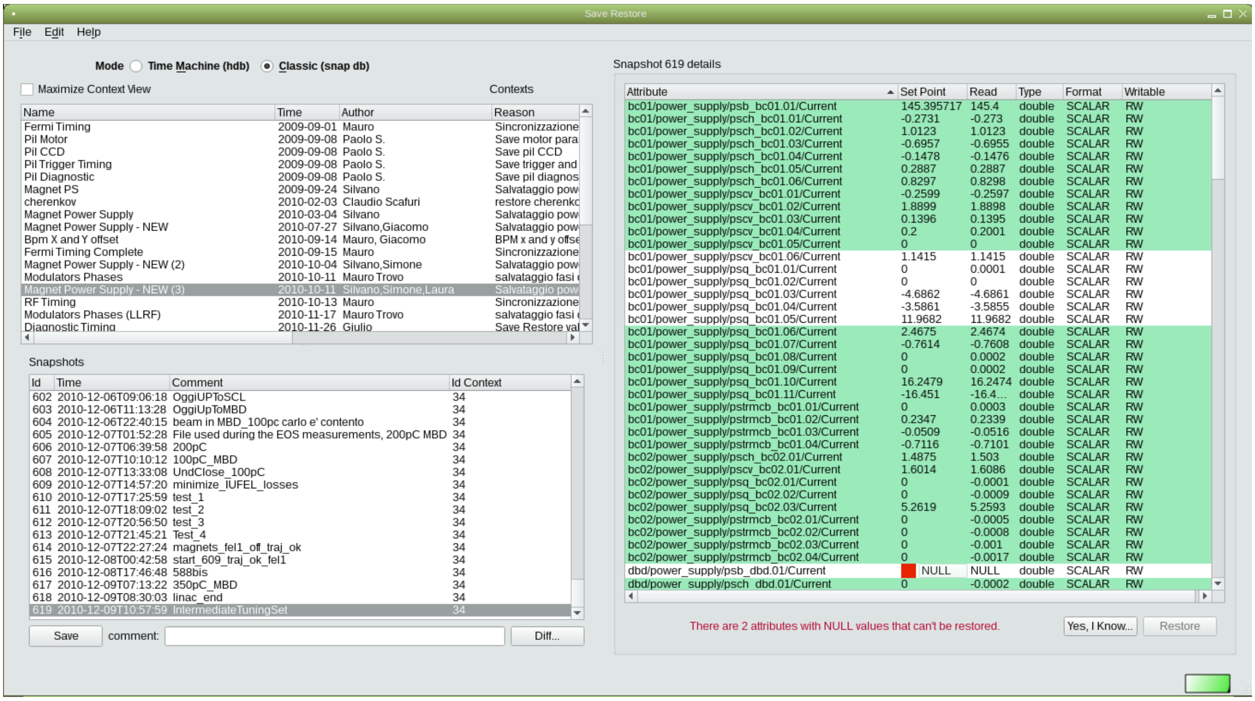
snapshot is selected or historical data is fetched from the database, according to the active modality. NULL values are highlighted by a red square in the set point column. In order to restore a set of attributes, you must select them



Mode ○ Time Machine (hdb) ● Classic (snap db)

☐ Maximize Context View

Contexts

Name	Time	Author	Reason
Fermi Timing	2009-09-01	Mauro	Sincronizzazione
Pil Motor	2009-09-08	Paolo S.	Save motor para
Pil CCD	2009-09-08	Paolo S.	Save pil CCD
Pil Trigger Timing	2009-09-08	Paolo S.	Save trigger and
Pil Diagnostic	2009-09-08	Paolo S.	Save pil diagnos
Magnet PS	2009-09-24	Silvano	Salvataggio pow
cherenkov	2010-02-03	Claudio Scafuri	restore cherenkc
Magnet Power Supply	2010-03-04	Silvano	Salvataggio pow
Magnet Power Supply - NEW	2010-07-27	Silvano,Giacomo	Salvataggio pow
Bpm X and Y offset	2010-09-14	Mauro, Giacomo	BPM x and y offse
Fermi Timing Complete	2010-09-15	Mauro	Sincronizzazione
Magnet Power Supply - NEW (2)	2010-10-04	Silvano,Simone	Salvataggio pow
Modulators Phases	2010-10-11	Mauro Trovo	salvataggio fasi (
Magnet Power Supply - NEW (3)	2010-10-11	Silvano,Simone,Laura	Salvataggio pow
RF Timing	2010-10-13	Mauro	Sincronizzazione
Modulators Phases (LLRF)	2010-11-17	Mauro Trovo	salvataggio fasi (
Diagnostic Timing	2010-11-26	Giulio	Save Restore val

Snapshots

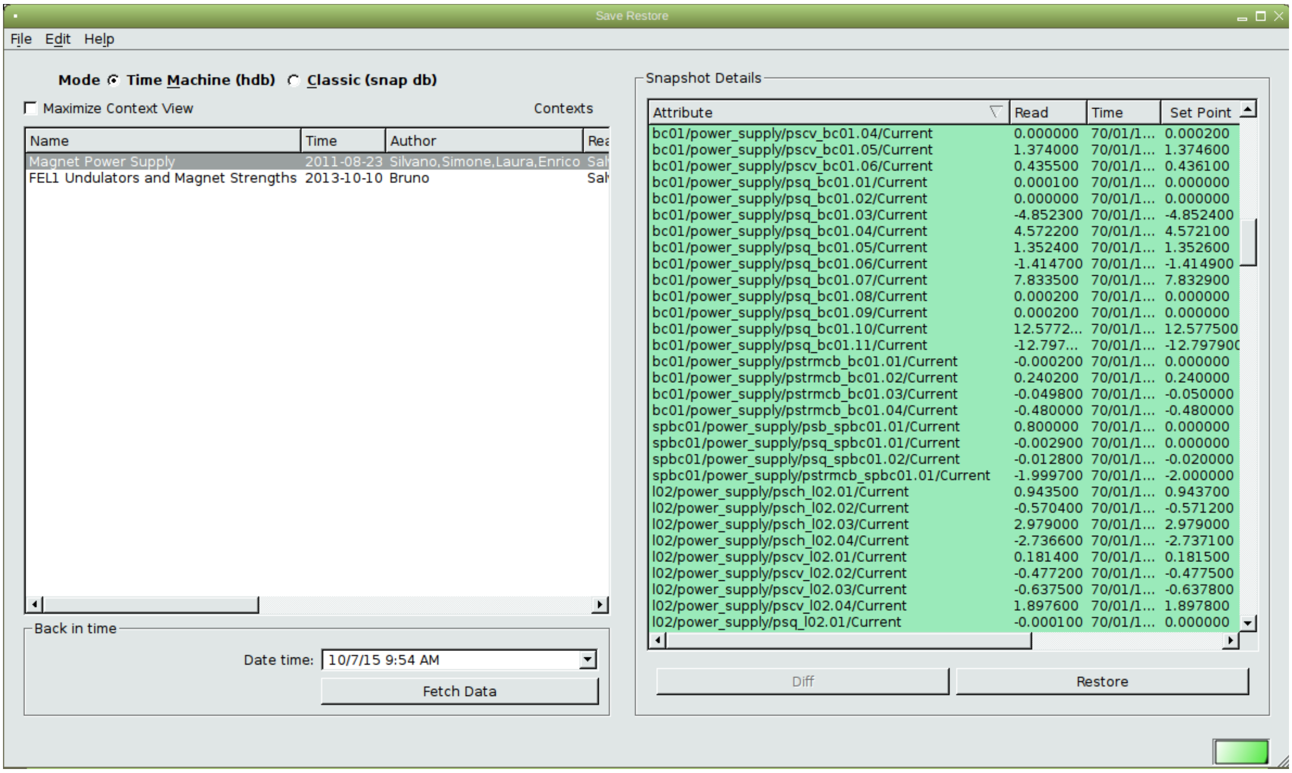
Id	Time	Comment	Id Context
602	2010-12-06T09:06:18	OggiUPToSCL	34
603	2010-12-06T11:13:28	OggiUpToMBD	34
604	2010-12-06T22:40:15	beam in MBD_100pc carlo e' contento	34
605	2010-12-07T01:52:28	File used during the EOS measurements, 200pC MBD	34
606	2010-12-07T06:39:58	200pC	34
607	2010-12-07T10:10:12	100pC_MBD	34
608	2010-12-07T13:33:08	UndClose_100pC	34
609	2010-12-07T14:57:20	minimize_IUFEL_losses	34
610	2010-12-07T17:25:59	test_1	34
611	2010-12-07T18:09:02	test_2	34
612	2010-12-07T20:56:50	test_3	34
613	2010-12-07T21:45:21	Test_4	34
614	2010-12-07T22:27:24	magnets_fel1_off_traj_ok	34
615	2010-12-08T00:42:58	start_609_traj_ok_fel1	34
616	2010-12-08T17:46:48	588bis	34
617	2010-12-09T07:13:22	350pC_MBD	34
618	2010-12-09T08:30:03	linac_end	34
619	2010-12-09T10:57:59	IntermediateTuningSet	34

Snapshot 619 details

Attribute	Set Point	Read	Type	Format	Writable
bc01/power_supply/psb_bc01.01/Current	145.395717	145.4	double	SCALAR	RW
bc01/power_supply/psch_bc01.01/Current	-0.2731	-0.273	double	SCALAR	RW
bc01/power_supply/psch_bc01.02/Current	1.0123	1.0123	double	SCALAR	RW
bc01/power_supply/psch_bc01.03/Current	-0.6957	-0.6955	double	SCALAR	RW
bc01/power_supply/psch_bc01.04/Current	-0.1478	-0.1476	double	SCALAR	RW
bc01/power_supply/psch_bc01.05/Current	0.2887	0.2887	double	SCALAR	RW
bc01/power_supply/psch_bc01.06/Current	0.8297	0.8298	double	SCALAR	RW
bc01/power_supply/pscv_bc01.01/Current	-0.2599	-0.2597	double	SCALAR	RW
bc01/power_supply/pscv_bc01.02/Current	1.8899	1.8898	double	SCALAR	RW
bc01/power_supply/pscv_bc01.03/Current	0.1396	0.1395	double	SCALAR	RW
bc01/power_supply/pscv_bc01.04/Current	0.2	0.2001	double	SCALAR	RW
bc01/power_supply/pscv_bc01.05/Current	0	0	double	SCALAR	RW
bc01/power_supply/pscv_bc01.06/Current	1.1415	1.1415	double	SCALAR	RW
bc01/power_supply/psq_bc01.01/Current	0	0.0001	double	SCALAR	RW
bc01/power_supply/psq_bc01.02/Current	0	0	double	SCALAR	RW
bc01/power_supply/psq_bc01.03/Current	-4.6862	-4.6861	double	SCALAR	RW
bc01/power_supply/psq_bc01.04/Current	-3.5861	-3.5855	double	SCALAR	RW
bc01/power_supply/psq_bc01.05/Current	11.9682	11.9682	double	SCALAR	RW
bc01/power_supply/psq_bc01.06/Current	2.4675	2.4674	double	SCALAR	RW
bc01/power_supply/psq_bc01.07/Current	-0.7614	-0.7608	double	SCALAR	RW
bc01/power_supply/psq_bc01.08/Current	0	0.0002	double	SCALAR	RW
bc01/power_supply/psq_bc01.09/Current	0	0.0002	double	SCALAR	RW
bc01/power_supply/psq_bc01.10/Current	16.2479	16.2474	double	SCALAR	RW
bc01/power_supply/psq_bc01.11/Current	-16.451	-16.4...	double	SCALAR	RW
bc01/power_supply/pstrmcb_bc01.01/Current	0	0.0003	double	SCALAR	RW
bc01/power_supply/pstrmcb_bc01.02/Current	0.2347	0.2339	double	SCALAR	RW
bc01/power_supply/pstrmcb_bc01.03/Current	-0.0509	-0.0516	double	SCALAR	RW
bc01/power_supply/pstrmcb_bc01.04/Current	-0.7116	-0.7101	double	SCALAR	RW
bc02/power_supply/psch_bc02.01/Current	1.4875	1.503	double	SCALAR	RW
bc02/power_supply/pscv_bc02.01/Current	1.6014	1.6086	double	SCALAR	RW
bc02/power_supply/psq_bc02.01/Current	0	-0.0001	double	SCALAR	RW
bc02/power_supply/psq_bc02.02/Current	0	-0.0009	double	SCALAR	RW
bc02/power_supply/psq_bc02.03/Current	5.2619	5.2593	double	SCALAR	RW
bc02/power_supply/pstrmcb_bc02.01/Current	0	-0.0005	double	SCALAR	RW
bc02/power_supply/pstrmcb_bc02.02/Current	0	-0.0008	double	SCALAR	RW
bc02/power_supply/pstrmcb_bc02.03/Current	0	-0.001	double	SCALAR	RW
bc02/power_supply/pstrmcb_bc02.04/Current	0	-0.0017	double	SCALAR	RW
dbd/power_supply/psb_dbd.01/Current	🟥 NULL	NULL	double	SCALAR	RW
dbd/power_supply/psch_dbd.01/Current	0	-0.0002	double	SCALAR	RW

There are 2 attributes with NULL values that can't be restored.

Figure 1: The save/restore classic view.



Mode ● Time Machine (hdb) ○ Classic (snap db)

☐ Maximize Context View

Contexts

Name	Time	Author	Rea
Magnet Power Supply	2011-08-23	Silvano,Simone,Laura,Enrico	Sal
FEL1 Undulators and Magnet Strengths	2013-10-10	Bruno	Sal

Back in time

Date time: 10/7/15 9:54 AM

Snapshot Details

Attribute	Read	Time	Set Point
bc01/power_supply/pscv_bc01.04/Current	0.000000	70/01/1...	0.000200
bc01/power_supply/pscv_bc01.05/Current	1.374000	70/01/1...	1.374600
bc01/power_supply/pscv_bc01.06/Current	0.435500	70/01/1...	0.436100
bc01/power_supply/psq_bc01.01/Current	0.000100	70/01/1...	0.000000
bc01/power_supply/psq_bc01.02/Current	0.000000	70/01/1...	0.000000
bc01/power_supply/psq_bc01.03/Current	-4.852300	70/01/1...	-4.852400
bc01/power_supply/psq_bc01.04/Current	4.572200	70/01/1...	4.572100
bc01/power_supply/psq_bc01.05/Current	1.352400	70/01/1...	1.352600
bc01/power_supply/psq_bc01.06/Current	-1.414700	70/01/1...	-1.414900
bc01/power_supply/psq_bc01.07/Current	7.833500	70/01/1...	7.832900
bc01/power_supply/psq_bc01.08/Current	0.000200	70/01/1...	0.000000
bc01/power_supply/psq_bc01.09/Current	0.000200	70/01/1...	0.000000
bc01/power_supply/psq_bc01.10/Current	12.5772...	70/01/1...	12.577500
bc01/power_supply/psq_bc01.11/Current	-12.797...	70/01/1...	-12.797900
bc01/power_supply/pstrmcb_bc01.01/Current	-0.000200	70/01/1...	0.000000
bc01/power_supply/pstrmcb_bc01.02/Current	0.240200	70/01/1...	0.240000
bc01/power_supply/pstrmcb_bc01.03/Current	-0.049800	70/01/1...	-0.050000
bc01/power_supply/pstrmcb_bc01.04/Current	-0.480000	70/01/1...	-0.480000
spbc01/power_supply/psb_spbc01.01/Current	0.800000	70/01/1...	0.000000
spbc01/power_supply/psq_spbc01.01/Current	-0.002900	70/01/1...	0.000000
spbc01/power_supply/psq_spbc01.02/Current	-0.012800	70/01/1...	-0.020000
spbc01/power_supply/pstrmcb_spbc01.01/Current	-1.999700	70/01/1...	-2.000000
l02/power_supply/psch_l02.01/Current	0.943500	70/01/1...	0.943700
l02/power_supply/psch_l02.02/Current	-0.570400	70/01/1...	-0.571200
l02/power_supply/psch_l02.03/Current	2.979000	70/01/1...	2.979000
l02/power_supply/psch_l02.04/Current	-2.736600	70/01/1...	-2.737100
l02/power_supply/pscv_l02.01/Current	0.181400	70/01/1...	0.181500
l02/power_supply/pscv_l02.02/Current	-0.477200	70/01/1...	-0.477500
l02/power_supply/pscv_l02.03/Current	-0.637500	70/01/1...	-0.637800
l02/power_supply/pscv_l02.04/Current	1.897600	70/01/1...	1.897800
l02/power_supply/psq_l02.01/Current	-0.000100	70/01/1...	0.000000

Figure 2: The save/restore application in time machine modality. Note that all the attributes have been selected for restoring and the presence of the *back in time* box.

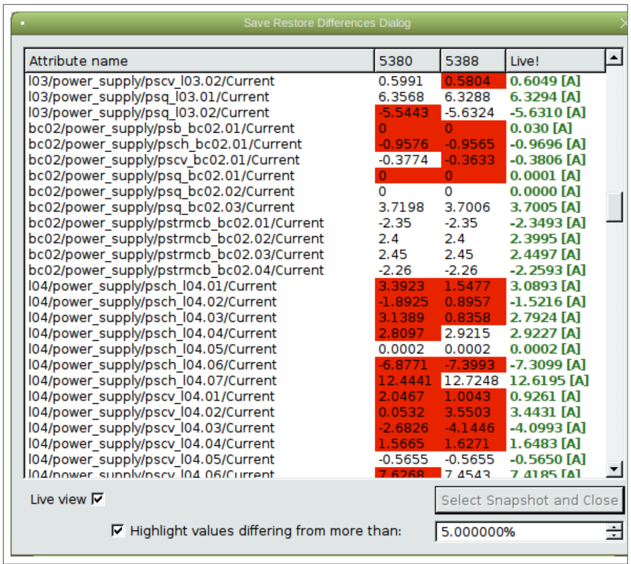
with the mouse. All items can be selected at once by right clicking on the view and activating the corresponding option from the menu. If NULL values are present, it is compulsory to click on the "*Yes I know*" push button before restoring (see Fig. 1). In time machine mode (see Fig. 2), the restore process requires the following steps:

- selection of the desired context;
- fetch data from the historical database, specifying a date and time in the past (see Fig. 2, bottom left box) and clicking on the "*Fetch Data*" button;
- select the attributes to restore and restore them.

The save (in the save/restore mode) and the restore processes are run on a separate thread so that the graphical interface remains responsive. A progress bar appears at the bottom of the panel to indicate the advancement of the process. For further information about the classic save/restore application, please refer to [1].

The "diff" View

When save/restore mode is enabled, selecting two or more snapshots of the same context makes it possible to view the differences between the snapshots and the current values read from the field (see Fig. 3).



Attribute name	5380	5388	Live!
l03/power_supply/pscv_l03.02/Current	0.5991	0.5804	0.6049 [A]
l03/power_supply/psq_l03.01/Current	6.3568	6.3288	6.3294 [A]
l03/power_supply/psq_l03.02/Current	-5.5443	-5.6324	-5.6310 [A]
bc02/power_supply/psb_bc02.01/Current	0	0	0.030 [A]
bc02/power_supply/psch_bc02.01/Current	-0.9576	-0.9565	-0.9696 [A]
bc02/power_supply/pscv_bc02.01/Current	-0.3774	-0.3633	-0.3806 [A]
bc02/power_supply/psq_bc02.01/Current	0	0	0.0001 [A]
bc02/power_supply/psq_bc02.02/Current	0	0	0.0000 [A]
bc02/power_supply/psq_bc02.03/Current	3.7198	3.7006	3.7005 [A]
bc02/power_supply/pstrmcb_bc02.01/Current	-2.35	-2.35	-2.3493 [A]
bc02/power_supply/pstrmcb_bc02.02/Current	2.4	2.4	2.3995 [A]
bc02/power_supply/pstrmcb_bc02.03/Current	2.45	2.45	2.4497 [A]
bc02/power_supply/pstrmcb_bc02.04/Current	-2.26	-2.26	-2.2593 [A]
l04/power_supply/psch_l04.01/Current	3.3923	1.5477	3.0893 [A]
l04/power_supply/psch_l04.02/Current	-1.8925	0.8957	-1.5216 [A]
l04/power_supply/psch_l04.03/Current	3.1389	0.8358	2.7924 [A]
l04/power_supply/psch_l04.04/Current	2.8097	2.9215	2.9227 [A]
l04/power_supply/psch_l04.05/Current	0.0002	0.0002	0.0002 [A]
l04/power_supply/psch_l04.06/Current	-6.8771	-7.3993	-7.3099 [A]
l04/power_supply/psch_l04.07/Current	12.4441	12.7248	12.6195 [A]
l04/power_supply/pscv_l04.01/Current	2.0467	1.0043	0.9261 [A]
l04/power_supply/pscv_l04.02/Current	0.0532	3.5503	3.4431 [A]
l04/power_supply/pscv_l04.03/Current	-2.6826	-4.1446	-4.0993 [A]
l04/power_supply/pscv_l04.04/Current	1.5665	1.6271	1.6483 [A]
l04/power_supply/pscv_l04.05/Current	-0.5655	-0.5655	-0.5650 [A]
l04/power_supply/pscv_l04.06/Current	7.6268	7.4543	7.4185 [A]

Live view ☑

☑ Highlight values differing from more than: 5.000000%

Figure 3: The *diff* view

The Matrix Selection

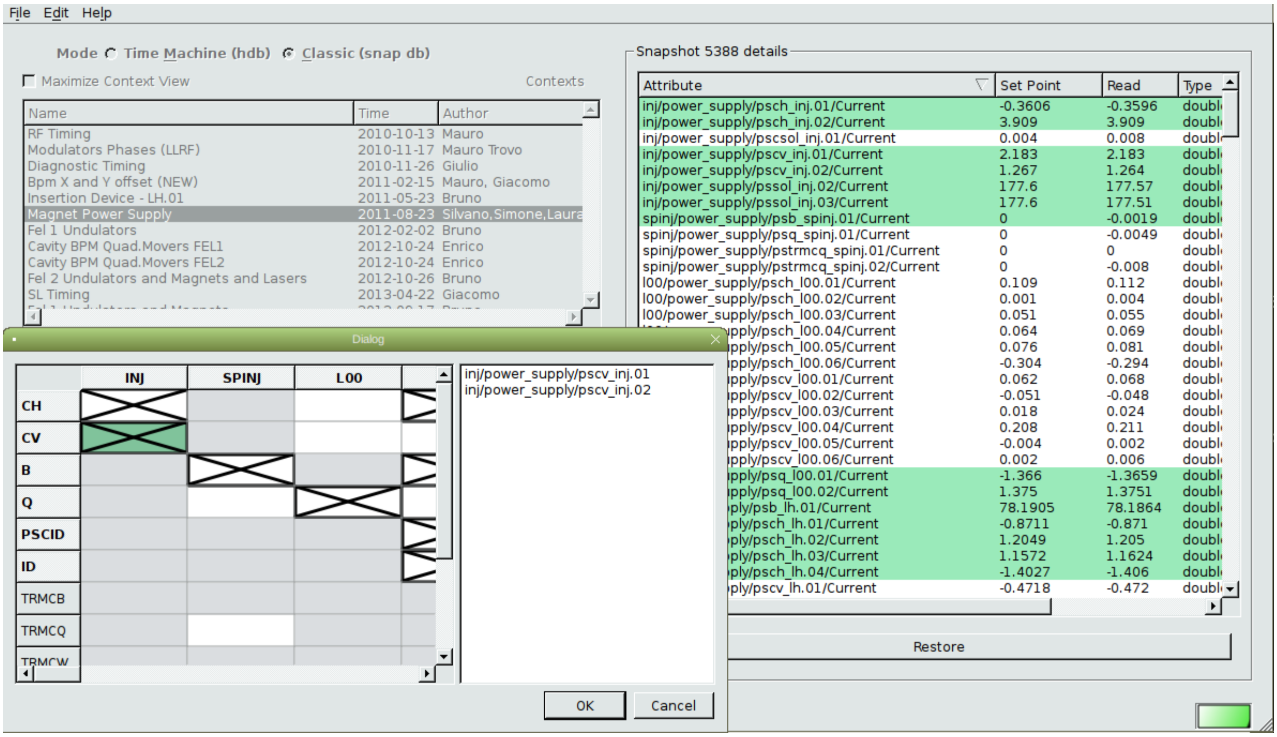
Alongside the classic item selection mode in the attribute selection list, a matrix selection is available. The selection groups and the different kinds of devices are defined into the database itself and reflect the sections in which the machine is organized. The actual matrix structure is based on the plant structure and the operational needs of FERMI. As shown in Fig.4, toggling an element of the matrix allows the selection (de-selection) of the items of the same type belonging to the corresponding section of the machine.

Helper Application

Right clicking on an item of the attribute list view gives the user the opportunity to launch a linked helper application. Helper applications are defined into the TANGO database and are fully equivalent to helper applications used by the QTango framework [3].

CONCLUSION

The combination of the classical snapshot-based save/restore procedure with the new historical database extraction opens new possibilities to restore the state of a complex machine, bringing it back to a previous condition. In particular, the time machine has been introduced in the FERMI control room to repair a situation after an accident or an unforeseen occurrence, such as a device failure, a thunderstorm and so forth, bringing back the system to a known healthy working state at a given time in the past.



Mode ○ Time Machine (hdb) ● Classic (snap db)

□ Maximize Context View

Contexts

Name	Time	Author
RF Timing	2010-10-13	Mauro
Modulators Phases (LLRF)	2010-11-17	Mauro Trovo
Diagnostic Timing	2010-11-26	Giulio
Bpm X and Y offset (NEW)	2011-02-15	Mauro, Giacomo
Insertion Device - LH.01	2011-05-23	Bruno
Magnet Power Supply	2011-08-23	Silvano,Simone,Laura
Fel 1 Undulators	2012-02-02	Bruno
Cavity BPM Quad.Movers FEL1	2012-10-24	Enrico
Cavity BPM Quad.Movers FEL2	2012-10-24	Enrico
Fel 2 Undulators and Magnets and Lasers	2012-10-26	Bruno
SL Timing	2013-04-22	Giacomo

	INJ	SPINJ	L00	
CH	☒			☒
CV	☒			
B		☒		☒
Q			☒	
PSCID				☒
ID				☒
TRMCB				
TRMCQ				
TRMCW				

inj/power_supply/pscv_inj.01
inj/power_supply/pscv_inj.02

Snapshot 5388 details

Attribute	Set Point	Read	Type
inj/power_supply/psch_inj.01/Current	-0.3606	-0.3596	doubl
inj/power_supply/psch_inj.02/Current	3.909	3.909	doubl
inj/power_supply/pscsol_inj.01/Current	0.004	0.008	doubl
inj/power_supply/pscv_inj.01/Current	2.183	2.183	doubl
inj/power_supply/pscv_inj.02/Current	1.267	1.264	doubl
inj/power_supply/pssol_inj.02/Current	177.6	177.57	doubl
inj/power_supply/pssol_inj.03/Current	177.6	177.51	doubl
spinj/power_supply/psb_spinj.01/Current	0	-0.0019	doubl
spinj/power_supply/psq_spinj.01/Current	0	-0.0049	doubl
spinj/power_supply/pstrmcq_spinj.01/Current	0	0	doubl
spinj/power_supply/pstrmcq_spinj.02/Current	0	-0.008	doubl
l00/power_supply/psch_l00.01/Current	0.109	0.112	doubl
l00/power_supply/psch_l00.02/Current	0.001	0.004	doubl
l00/power_supply/psch_l00.03/Current	0.051	0.055	doubl
upply/psch_l00.04/Current	0.064	0.069	doubl
upply/psch_l00.05/Current	0.076	0.081	doubl
upply/psch_l00.06/Current	-0.304	-0.294	doubl
upply/pscv_l00.01/Current	0.062	0.068	doubl
upply/pscv_l00.02/Current	-0.051	-0.048	doubl
upply/pscv_l00.03/Current	0.018	0.024	doubl
upply/pscv_l00.04/Current	0.208	0.211	doubl
upply/pscv_l00.05/Current	-0.004	0.002	doubl
upply/pscv_l00.06/Current	0.002	0.006	doubl
upply/psq_l00.01/Current	-1.366	-1.3659	doubl
upply/psq_l00.02/Current	1.375	1.3751	doubl
ply/psb_lh.01/Current	78.1905	78.1864	doubl
ply/psch_lh.01/Current	-0.8711	-0.871	doubl
ply/psch_lh.02/Current	1.2049	1.205	doubl
ply/psch_lh.03/Current	1.1572	1.1624	doubl
ply/psch_lh.04/Current	-1.4027	-1.406	doubl
ply/pscv_lh.01/Current	-0.4718	-0.472	doubl

Figure 4: Selection matrix. Toggling an element of the table selects or deselects items on the attribute list.

REFERENCES

[1] G. Strangolino et al., “Control room graphical applications for the ELETTRA new injector”, WEP015, PCaPAC08, Ljubljana, Slovenia, (2008)

[2] L. Pivetta et al., “HDB++: a new archiving system for TANGO”, ICALEPCS’15, Melbourne, Australia, (2015)

[3] G. Strangolino et al., “QTango: a library for easy TANGO based GUIs development”, THP096, ICALEPCS'09, Kobe, Japan, (2009)