REVOLUTION IN MOTION CONTROL AT SOLEIL: HOW TO BALANCE PERFORMANCE AND COST

D. Corruble*, Y-M. Abiven, F. Ben Zekri, P. Betinelli-Deck, M. Cerato. C. Engblom, R. Millet,
Synchrotron SOLEIL, Paris, France

Abstract

SOLEIL is a third generation Synchrotron radiation source located near Paris, France. REVOLUTION (REconsider Various contrOLlers for yoUr moTION) is the motion controller upgrade project at SOLEIL. It was initiated by the first "Motion control in radiation facilities" workshop, held in May 2011, that resulted in the development of an international community for motion control in large research facilities. The next meeting will take place during a pre-ICALEPS workshop: Motion Control Applications in Large Facilities **.

As motion control is an essential key element in assuring optimal results, while a competitive price is also important, the REVOLUTION team selected alternatives by following a theoretical and practical methodology: advanced market analysis, tests, measurements and impact evaluation. Products from two major motion control manufacturers are on the short list. They must provide the best performance for a small selection of demanding applications, and the lowest global cost to maintain operational conditions for the majority of applications at SOLEIL. The search for the best technical, economical and organizational compromise to face our challenges is detailed in this paper.

CONTEXT OF REVOLUTION AT SOLEIL

Hardware Architecture

The standardized hardware architecture of the motion control system is designed to be modular and flexible. The first principle is the separation of control unit and power units, and then the use of standard signal between units. Motion units are packaged in a 19" rack that integrates industrial products. These racks (known as Boxes) specified by SOLEIL have the objectives of being easy to use, easy to maintain and cost-effective.

The first rack is the CONTROLBOX which integrates the GALIL [1] DMC-2182 8-axis industrial motion controller and provides easy to use connectors.

Three power units are standardized and used according to applications and motor technology. DRIVERBOX and VACUUMBOX integrate driver boards for four-phase stepper motors in air or in vacuum respectively. SERVOBOX contains power boards developed by SOLEIL, dedicated to brushless and DC motors.

Furthermore the flexible architecture can be connected to other driver technologies in order to control three or five-phase stepper motors and ceramic actuators.

While keeping CONTROLBOX as the only controller, and therefore keeping the same software, the range of motor technology supported can easily be extended by using dedicated external power units which meet SOLEIL specifications (industrial signals, connectors and pinouts, etc.). See Figure 1.

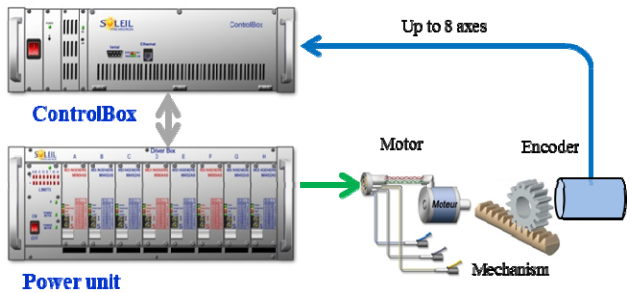

Figure 1: Standardized hardware architecture.

Software Architecture

Motion control features are shared between embedded software in motion controllers (called microcode) and TANGO [2] software devices distributed on many servers. SOLEIL has developed applications embedded in the GALIL [1] controller. They provide generic services and in some case specific functionalities to some particular applications, especially to ensure the safety of equipment. See Figure 2.

A set of motion control Tango device servers dedicated to our motion controllers has been developed in C++ by SOLEIL's software control and data acquisition group. Binaries can run on Windows or Linux servers.

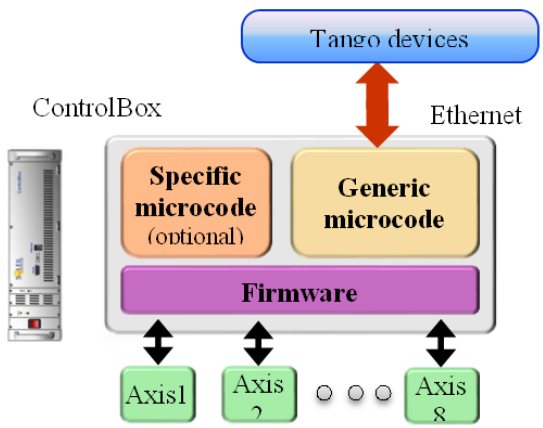

Figure 2: Microcode and Tango devices.

Installed Base Of Motion Controllers

Today this base is wide and quite homogenous. In August 2013, 320 operational CONTROLBOX control

* dominique.corruble@synchrotron-soleil.fr

** MOCRAF workshop: http://www.synchrotron-soleil.fr/Workshops/2013/motioncontrol

ISBN 978-3-95450-139-7

2000 axes by using or not standardized single-axis power boards, out of a total of over 2300 axes. However some specific applications, such as magnetic insertion devices, complex diffractometers, nanopositioning and hexapods, used non-standard controllers. Approximately 85% of axes controlled by a CONTROLBOX are standardized.

Motivations for Upgrading

Firstly, GALIL [1] released a new generation of motion controller (Accelera products) in 2009, so our standard controller belongs to the previous generation. It will one day be discontinued. This is not expected to occur in the next few years, but nevertheless the risk of obsolescence increases with time. Secondly, new motion control applications become more complex and demand more performance and more advanced functionalities. Examples include Hexapods, Nanopositioning, Multiaxis synchronization and nonlinear trajectories.

Successful completion of these challenges is essential to maintain SOLEIL in its position as a leading synchrotron.

CHANGING STRATEGY

REVOLUTION, the motion controller upgrade project, has three goals which are more or less compatible with each other.

- Significantly increase performance (firmware and user embedded software execution time) and advanced functionalities (continuous closed loop on stepper motor, multi-axis nonlinear trajectories and synchronization, kinematic equations, virtual axes and so on)
- Ensure the operational continuity of the installed base, and provide the best support and maintenance.
- Keep overall costs under control (hardware products and human resources)

To reconcile and to achieve these goals, we must change our motion control strategy and adjust solutions to different cases.

Segmentation of Motion Control Applications

The first change is that until now the motion control strategy was based on the principle of a single universal controller for all applications (except very specific cases). This strategy is suitable for a very small team which has to implement many applications with limited complexity.

The analysis of the distribution of the number of motion control applications according to the level of performance or functionalities showed that this is an example of the Pareto principle (also known as the 80-20 rule). Most applications require relatively low performance and few advanced functionalities, conversely a small number of applications require high performance and many advanced functionalities. Moreover the proportion of high-performance applications tends to rise proportionally faster than the average. See Figure 3.

Therefore SOLEIL chose to use two standardized motion controllers.

- The first one is the CLASSIC motion controller, used in most cases, suitable for applications requiring a limited level of performance or advanced functionalities. This controller is fully compatible with the current hardware and software motion control architecture.
- The second one is the HIGH PERFORMANCE controller, used in few cases, suitable for applications requiring a high level of performance or advanced functionalities. The compatibility with the current hardware and software motion control architecture could be limited.

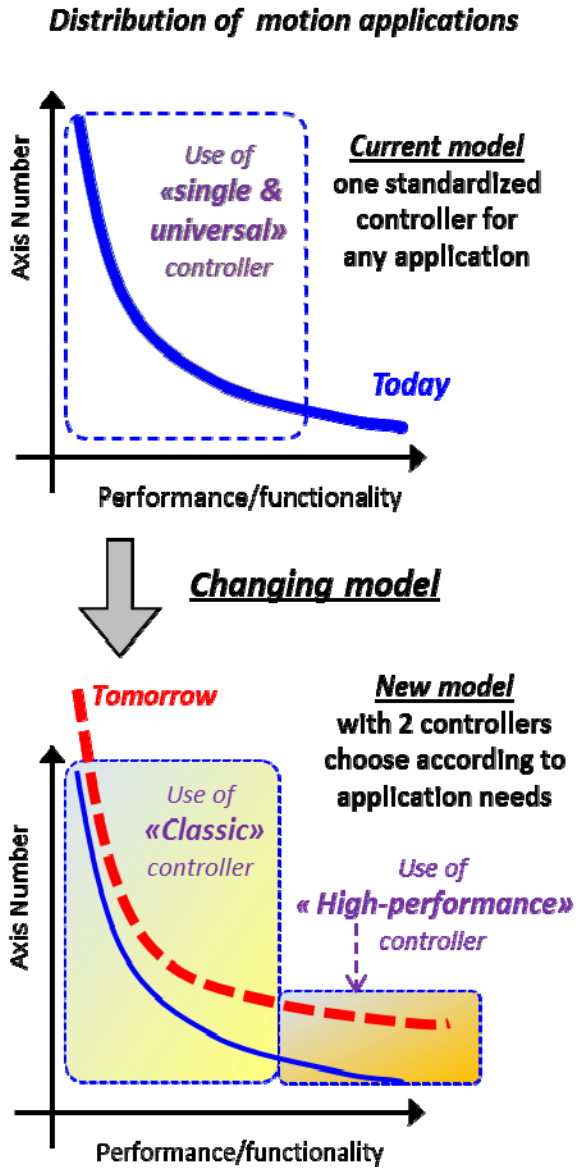

Figure 3: Change of strategy and model.

Changing Hardware Architecture

The second change is that products from two major manufacturers are on the short list of the selection process for the high-performance controller (see 'High performance controller' section). These high-end products

ISBN 978-3-95450-139-7

are expensive. To achieve the goal of keeping the overall cost per axis under control, SOLEIL chose to integrate the motion controller and the power units in the same rack, while keeping standard signals available to drive an external power unit

CLASSIC CONTROLLER UPGRADE

The goal of the motion controller upgrade for 'classic' applications is firstly to ensure operational continuity. That means full compatibility with the current hardware and software motion control architecture.

On the software side, since the current embedded software is written in a language proprietary to GALIL [1], the choice of new motion controller was obvious. The current DMC-2182 will be replaced by DMC-4183, its backward-compatible natural successor. SOLEIL tested its compatibility and improved its embedded software to implement some new features.

The main benefits of DMC-4183 compared to DMC-2182 are long-term continuity of a last generation product, a stronger TCP-IP stack, a faster user application execution time (divided by 2), a USB port, and more.

On the hardware side, full compatibility requires the current CONTROLBOX rack to be used to integrate the new board. Some minor changes (power supply socket, position of mounting holes, USB socket) are necessary to integrate the new board in the CONTROLBOX. The biggest change is to add an interface electronic board, called MIG-4121, which adapts DMC-4183 connectors to the DMC-2182 pinout. The MIG-4121 prototype is currently being specified. See Figure 4.

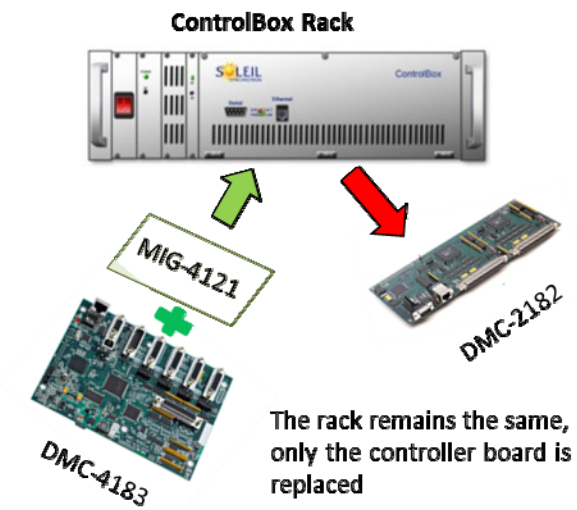

Figure 4: Replacement of controller into CONTROLBOX.

With no strong short-term constraints, the CONTROLBOX upgrade will be gradual and technically transparent for users. On the one hand, forthcoming CONTROLBOX procurements will include the new controller. On the other hand, progressive maintenance will, when necessary, replace the old controller board by the new one while keeping the rack.

HIGH PERFORMANCE CONTROLLER

The REVOLUTION project, which primarily involves the selection of a new motion controller at SOLEIL, started in 2011. The first step of this selection process was to collect user needs. Thus technical requirements could be defined, in particular advanced functionalities not implemented with our current system, such as continuous closed loop for stepper motor, kinematic equations, virtual axes, multi-axis and nonlinear trajectories.

Running time to execute calculation is one of technical criterion. While the selection criteria are mainly TECHNICAL, they also include:

- TRADING (provider as an industrial manufacturer known in scientific facilities, price, support and maintenance, etc.)
- TIME (availability of ready-to-use system)
- ORGANIZATION (necessary skills and resources)

Once criteria were defined, the methodology was structured in four steps, eliminating candidates at each successive step. See Figure 5.

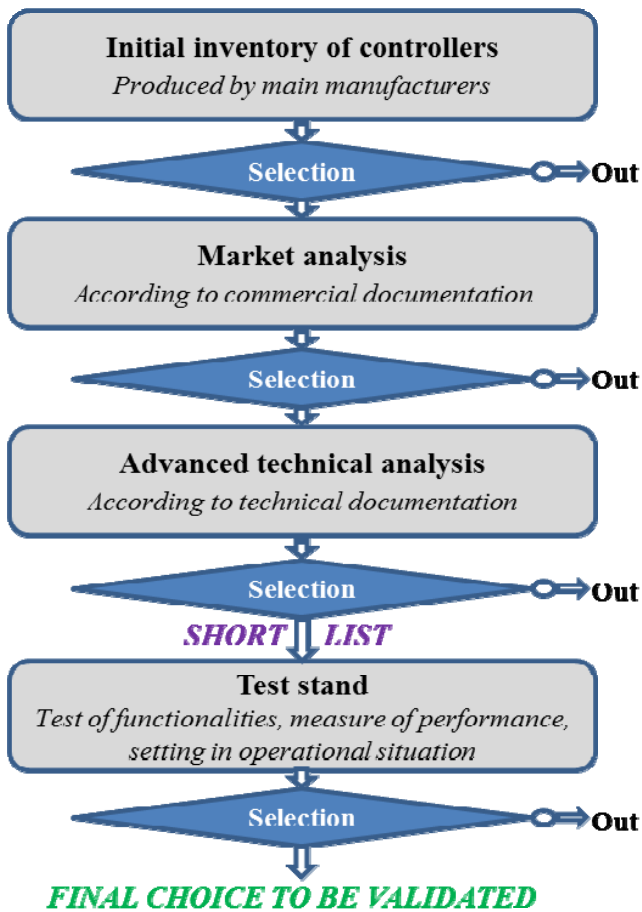

Figure 5: High performance controller selection steps.

Two products from two major manufacturers made it through to our final shortlist:

- GALIL DMC-4080
- DELTA TAU [3] Power PMAC.

ISBN 978-3-95450-139-7

Performance measurements and availability of advanced functionalities are in favour of the Power PMAC. This technical advantage was confirmed by two tests made in an operational situation. The closed loop for stepper motors and the implementation of kinematic equations on DELTA TAU [3] controller allows a better static and dynamic control for a monochromator and also a faster positioning time for a hexapod.

From SOLEIL's perspective each controller has its advantages and disadvantages, summarized in the following table:

	SOLEIL's comparison	
	DELTA TAU Power PMAC	GALIL DMC4080
Plus	Highest performance More advanced functionalities available Full versatility Hardware rack with amplifiers available	Embedded and Tango software available and tested Skills and expertise present at SOLEIL Continuity of current system, no risk Easy to use
Less	More complex to use Skills and expertise to be developed Embedded software to be developed Tango software to be tested	No continuous closed loop for stepper motor available Limited versatility No direct access to user compiled code Need to develop a dedicated rack

There was no perfect solution, but a choice had to be made. SOLEIL chose to evaluate Power PMAC in Power Brick LV format (a single rack with controller and drivers), in spite of the change of technological direction (language, parameters, tools, etc.) with the current system. This decision was initially justified by certain technical benefits of Power PMAC, and comforted by the ability to control the impacts of the partial use of this controller at SOLEIL. SOLEIL studied the organization of the motion team at the Diamond Light Source [4] control group, which is in charge of DELTA TAU [3] products (Turbo PMAC controller in UMAC and Geo Brick LV format). The results of this study are:

- Reorganize the electronics control team and find sufficient additional resources to handle the workload
- Hold training sessions to enhance global skills for all team members and ensure that some become experts
- Create a generic process in order to standardize deployment, configuration and software development methods
- Develop and gradually deploy motion applications from the simplest to the most complex

SOLEIL took an inventory of motion applications which could benefit from Power Brick functionalities, such as continuous closed loop for stepper motor, kinematic equations and virtual axes. The first applications to be implemented with DELTA TAU [3] are currently being selected.

Achieving the first real operational applications will confirm SOLEIL's ability to manage the impacts of this evolution and its decision to widely use a leading-edge controller.

CONCLUSION

Reconciling the three objectives (performance, operational continuity and cost control) of the motion controller update required a change of strategy, moving from a model with a single universal motion controller to a model with two specialized controllers that divide applications according to a border that should progressively be clearly defined.

Cost control has changed the hardware architecture by removing the principle of separation of units for high-performance controller parts and thus by integrating the controller and power boards into a single rack.

The choice of a change of technological direction involves a significant increase to the workload of electronic control team. This had to be managed by a new organization and additional human resources. A workload rise is generally inevitable if you increasingly have to handle new complex and/or high performance applications. It is hastened by the management of the technical transition.

These structural and organizational changes were not initially planned in a project that seemed to be very technical. REVOLUTION is a technical project, but its impacts go beyond a purely technical scope.

REVOLUTION is well under way, but it might bring new surprises.

REFERENCES

[1] GALIL company http://www.galilmc.com/
[2] TANGO framework http://www.tango-controls.org/
[3] DELTA TAU company http://www.deltatau.com/
[4] DIAMOND facility http://www.diamond.ac.uk/

ISBN 978-3-95450-139-7