A system test platform for the CERN power converter control electronics

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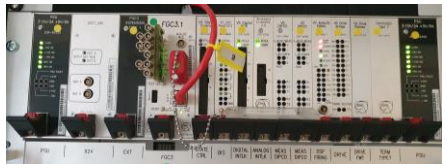
Introduction

Synchrotron particle accelerators at CERN use RF cavities and magnets to accelerate, bend and focus the beam. The Electrical Power Converter group is responsible for delivering more than 5000 power systems ranging from 1W to 10MW to fulfil the wide range of requirements of these applications. To handle this complexity, the power converter controls must be remotely programmable electronics. However, such flexibility in the control devices is vulnerable to regression and requires extensive testing before deployment. As such, a new test platform has been designed allowing to validate regularly and before the final deployment the high-level functionalities of the electronic controls.

Test platform requirements

Devices under test



The power converter controls are characterised by modularity allowing them to adapt to the variety of power systems complexities. These systems are based mainly on microprocessors, DSPs and FPGAs to achieve their functions. However, as each power converter has its own requirements, the number of combinations of versions and configurations is one of the big challenges for this tester platform. For the controller electronics, there are:

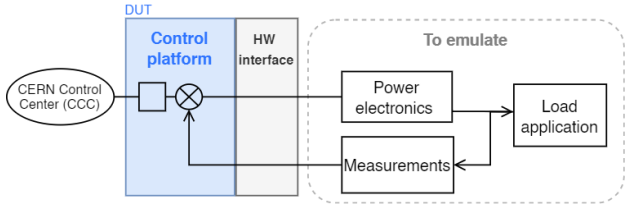
- **>130** hardware designs
- **>100** programmable logic designs
- A software build approx. each week to be tested in the lab

Although these codes are checked with unit tests, it is necessary to validate the entire system to avoid versions incompatibilities.

Power converter emulator

For the power converter side, smaller power systems can be deployed in a lab environment for testing the controls. However, there are others that due to their size (e.g., up to 30m³) must be emulated in a deterministic way. The test platform has to be able to deal with real and emulated power converters.

Interface connections



CERNs power converters have two broad types of interface to the controller:

- **Fast signals** that control the converter; the gate firing lines, the current and voltage feedback. These signals allow the controller to close the loop around the load application.
- **Slow signals** relating to the status of the converter; fault signals for over temperature, error in the cooling system or large ground currents.

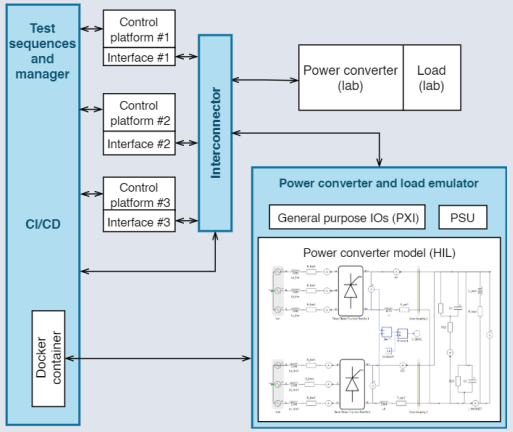
42	Fast digital
30	Fast analog
123	Slow digital
23	Slow analog

The tester platform has to access them for the tests. One challenge is to deal with analog and digital signals with many different electrical standards.

Test flexibility

The permutations of converter, SW and FW builds and HW which are required to be tested, present a complex problem for developing an architecture to manage this. The complexity of this problem is increased by the need to allow different teams to initiate the tests and by the fact that some tests share hardware resources. To ensure ongoing confidence, the tests should be run repeatedly on a weekly cycle but should also be run when a new build of software is available. As a result of this, the scheduling of testing using the test platform is a complex topic in itself.

Test platform design



Example of control platform #3 and test devices (corresponding to the diagram above).

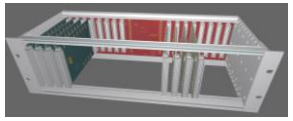
Hardware solutions

The interface connection requirement has been solved by designing a chassis with digital and analog boards. It allows the connection between the DUTs (Controls + HW interface) and the instrumentation that make up the test platform.

For the slow signals, a 18-slot NI PXI has been selected. It allows the connection of several PXI boards depending on the I/O necessities and offers timing and synchronization functions.

To simulate the power electronics in real time and handle the fast signals a Typhoon HIL (hardware in the loop) is used. It allows the modelling of the different power converters using the installed libraries and the interaction with the simulated system.

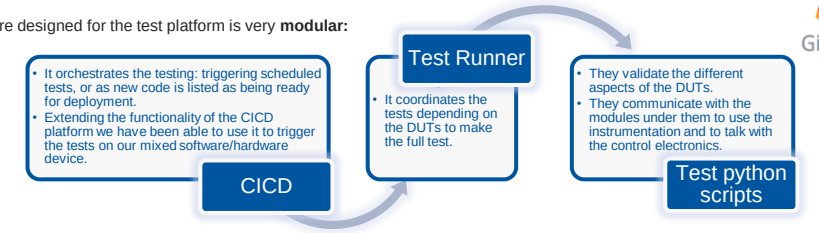
Interconnector



It is a multiplexer chassis prepared to test diverse DUTs (with different types of HW interfaces) using the same instrumentation's resources.

Software solutions

The structure designed for the test platform is very **modular:**



To achieve the greatest flexibility, the test is completed inside a lightweight system, a docker container. This ensures that a new and consistent environment is used for every test minimising the risk of the environment being contaminated as it would be if it were to be run on a local computer. Additionally, this separation ensures that all users use the system in the same manner which aids the control and scheduling of the testing.

Future challenges

With the aim of having a more robust and flexible test platform, it has to evolve at the same time that the DUTs are improved or new power systems are integrated in the accelerator complex. Related to this, one of the future challenges is to have as many emulated models in the HIL as power converters are deployed. It is also necessary to prove the scalability of the tester handling more devices and to ensure that the system is capable of coordinating these resources between different users. Among the next steps is the possibility of including in this CICD platform the unit tests developed and used by the software and firmware teams. Having a unique tester could simplify the validation of new versions.

Conclusions

This new system platform gives the capability of validating code for regression whenever a new code compilation is made, or before the deployment. It helps to avoid that a change in the hardware, software or firmware harms the whole control system or the power converter, at the same time that it detects incompatibilities between versions. To achieve this, a wide range of challenges has been faced, from the amount of analog and digital connections up to the use of continuous integration and continuous delivery techniques to test electronics. The development of this test platform continues to include more flexibility for the system to be able to simulate more types of power converter.

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