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THE NEW MODULAR CONTROL SYSTEM FOR POWER CONVERTERS AT CERN

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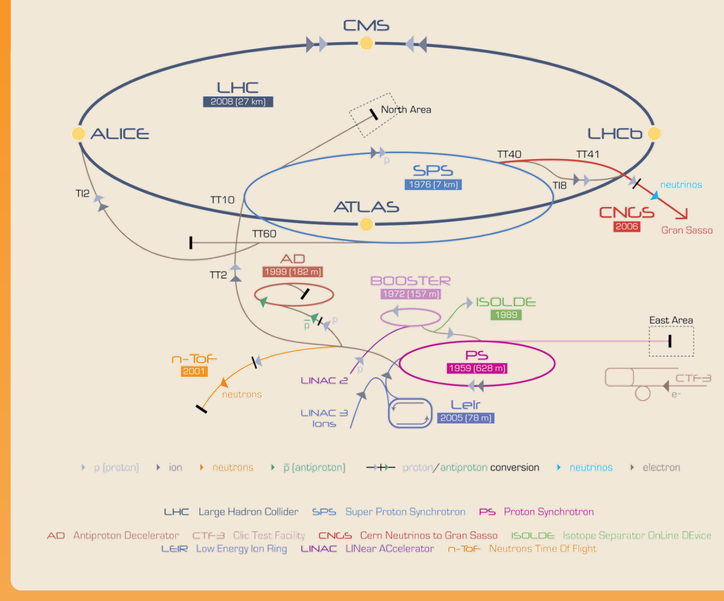
Introduction

The CERN accelerator complex consists of diverse generations of particle accelerators, with around 5000 power converters supplying regulated current and voltage to normal and superconducting magnet circuits. Today several generations of converter control platforms can be found in the accelerator complex, ranging in age and technology. The diversity of these platforms has a significant impact on operability, maintenance and support of power converters. Over the past few years a new generation of modular controls called *RegFGC3* has been developed by CERN's power conversion group, with a goal to provide a standardised and cost effective control platform, supporting the largest number of converter topologies.

Control system	Area	# of converters
MIL1553	PS	1218
PLC	SPS,AD,LIER	510
RS422	PS	366
Junction Crate	North Area	322
MUGEF	SPS, TTs	652
FGC2	LHC	1782
RegFGC3	Various	497



The RegFGC3 Control system

The RegFGC3 is a modular converter control platform developed at CERN with the main goal of providing a standardised solution and satisfying as many requirements as possible for power converter controls, whilst using the minimum diversity of boards as possible. The platform is based on the third generation of a Function Generator Controller (FGC3). The RegFGC3 platform extends the FGC3 capabilities by providing interface modules in order to control power elements of the converter. The RegFGC3 board portfolio consists of several FPGA-based generic modules that can be used for numerous applications.

FGC3

The FGC3 is an embedded computer developed by the Electrical Power Converter group. It consists of a mainboard, an Ethernet-based communication board and an acquisition card providing four high precision ADCs (ADS1274) and two 16-bits DAC (MAX5541). The mainboard includes an RX610 microcontroller, a TMS320C6727 DSP and a Xilinx Spartan3 FPGA used for low level peripheral handling.

Interlock boards

VS Analog Interlock **VS Digital Interlock** **VS Beam Interlock**

The Analog and Digital interlock boards provide power converter and load protection against dangerous signal levels. The Beam Interlock is the interface with the Beam Interlock System, which prevents from any accidental release of beam energy.

Regulation/Control boards

VS RegulationDSP **Siramatrix** **VS State Control**

The RegFGC3 platform provides three different regulation options. In addition to the FGC3, the regulation can be performed by the VS RegulationDSP or Siramatrix board. The DSP Regulation Board is based on the TMS320C2834x DSP and it is used for high-precision PWM control. The SIRAMATRIX is an FPGA-based regulation board developed for Fast Pulse Converters control.
The State Control board is a generic board which is used to control the converter state machine and timing.

Measurement boards

The VS I2V and VS V2V are boards used to interface the Direct Current Current Transformer (DCCT) and deliver adapted voltage levels to the rest of the control system. The VS Measurement board is a generic ADC-based acquisition board providing up to 11 analogue measurements. The board digitises and dispatches the data to the regulation system.

VS Measurement **VS V2V** **VS I2V**

Powering

VS PSU

The VS PSU is the control system power module delivering all the required voltage levels to the control electronics.

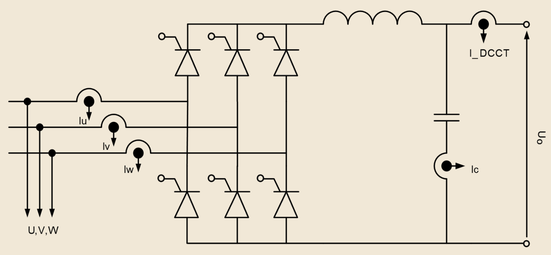
RegFGC3 for Thyristor converters control

Three-phase Thyristor-based power converters are a specific family of converters widely used at CERN especially in the injectors and experimental areas. The RegFGC3 has been chosen as the candidate for the upcoming upgrade of the Thyristor converter control. The control system consists of a set of generic modules and some specific cards for the generation of the firing pulses.

List of boards

Generic boards
VS PSU
FGC3
VS State Control
VS Analogue Interlock
VS Digital Interlock
VS Beam Interlock

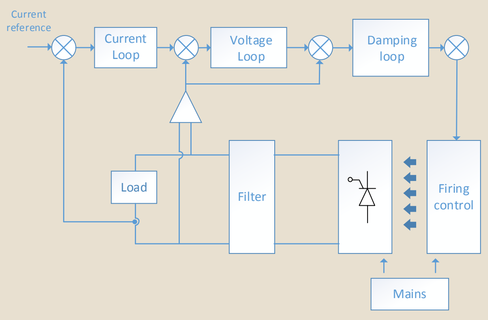
Specific boards
VS Analog measurement
VS Analog Firing
VS Drive



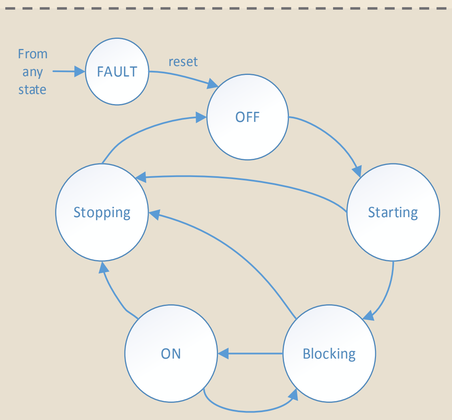
6 Pulses Thyristor converter.

Machine	Number of converters	Period
SPS + TTs	218	2016-2020
AD	6	2016-2020
ISOLDE	14	2016-2020
nToF	6	2016-2020
F61	59	2016-2020
LEIR	23	2016-2020
LINAC3	4	2016-2020

Estimated number of converters to upgrade.



Regulation and Thyristor firing
The core component of the regulation for Thyristor converters is the VS Analog Firing board which is based on an evolution of the Cassel/Van der Meer principle used at CERN since the SPS era. The FGC3 implements the current and voltage loop receiving the user external reference through the network and a series of analogue signals required for the regulation. The VS Analog Firing board generates up to 24 low power firing pulses allowing the control of a two-bridge converter. Finally the firing pulses are adapted to high-power Thyristor-gate pulses by the VS Drive board.



Thyristor power converter state machine

Power converter State Machine control
The power converter operation can be represented by a state machine which defines the different actuations and statuses the converter handles during operation. The state machine is implemented in the VS State Control board.

Measurements
The control of a Thyristor converter requires several analogue signals to be monitored for the regulation as well as for protection purposes. High-voltage measurements are performed using high-voltage dividers while Current Transformers (CT) and Direct Current Current Transformers (DCCT) are used to measure the currents. The I2V board interfaces the DCCT delivering a voltage proportional to the current being measured. The VS Analog Measurement board is a Thyristor converter specific module which receives the voltage measurements from the voltage dividers and makes them available to the rest of the control system.

Interlocks
The RegFGC3 control system implements a protection mechanism based on safety daisy chains shared by all the boards through the backplane. The VS Analogue and VS Digital interlock boards provide a local protection mechanism for the converter and the load. The BIS board is the interface with the Beam Interlock System, an important component in the accelerator complex which prevents from any accidental release of beam energy.

Conclusions

One of the most challengings objective for the Electronic Power Converter group at CERN is to reduce the number of converter control systems by using adaptable and scalable modular electronics. The RegFGC3 platform offers a standard solution that can be adapted to many different user requirements using a large set of generic boards. Development time and costs are decreased by taking advantage of a common platform.

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