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.

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.

Regulation/Control boards

The RegFGC3 platform provides three different regulation options. In addition to the FGC3, the regulation can be performed by the VS RegulationDSP or SIRAMATRIX. The DSP Regulation Board is based on the TMS320C32 DSP and is used for high-precision PWM control. The SIRAMATRIX is an FPGA-based regulation board developed for fast Pulse-Converter control. The State Control board is a generic board which is used to control the converter state machine and timing.

Interlock boards

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.

Measurement boards

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

Powering

The VS PSU is the control board of the converter power module delivering all the regulated power 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 in 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
- VS State Control
- VS Analogue Interlock
- VS Digital Interlock
- VS Beam Interlock

Specific boards
- VS Analog measurement
- VS Analog Firing
- VS Drive

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 FG3 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 32 four-level 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.

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 Transformer (CT) and Direct Current Transmitters (DOCT) are used to measure the currents. The UV board interfaces the DOCT 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.

Conclusions

The authors of this paper are grateful to the MPC section at CERN (Medium Power Converters) in charge of the design, installation and commissioning of Thyristor power converters (https://sezione-mpc.web.cern.ch/).

Acknowledgment

One of the most challenging objectives 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.