A modular approach for accelerator controls components deployment for high power pulsed systems

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SY Accelerator Systems

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Introduction

Lately, significant advancements have been achieved in the refinement and enhancement of kicker control systems, driven by a growing emphasis on modularity of its associated hardware components. Industrial distributed PLC systems combined with a generic finite state machine approach involves the careful management of kicker thyratrons, management inclusive of their respective heater controllers and heater power supplies. These PLC library components ensures also the efficient management of capacitor bank switches, a key element in the majority of kicker systems within Accelerator and Beam Transfer (ABT) kicker systems facility. Typically, these systems incorporate an initial energy storage element, such as a capacitor bank, to effectively store energy from the Direct Current Power Supply (DCPS) and subsequently deliver by resonant charging to a Pulse Forming Network (PFN), a task typically overseen by the Capacitor Charger and Protection Unit (CDPU). Upon successful validation of these initial stages the DCPS can be activated, enabling the rapid charging of the capacitor bank.

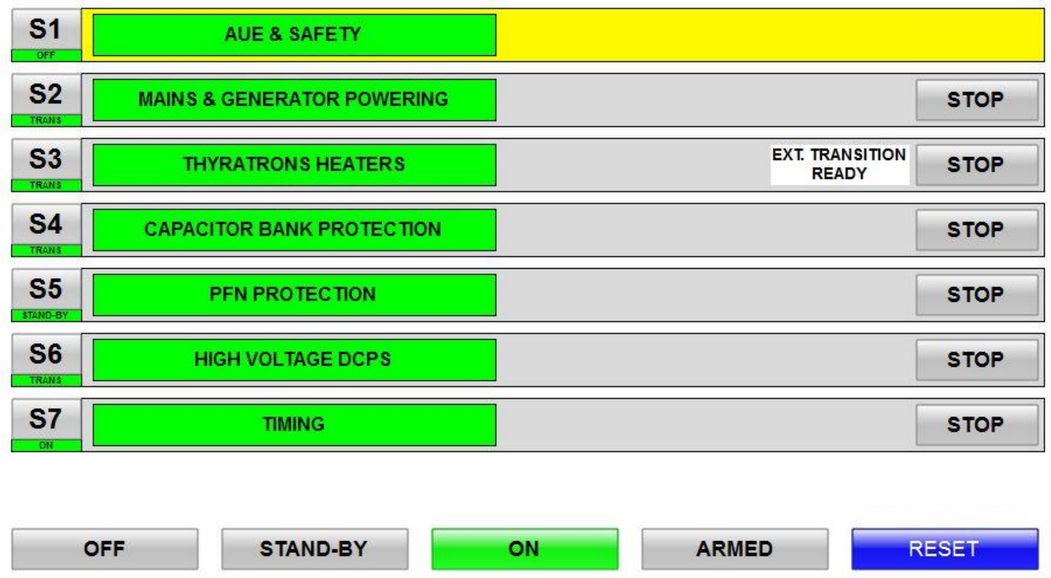

Fig.1 - Typical finite state machine view for supervisory control of kicker systems

The ultimate functionality of the entire state machine hinges on the precise timing system, critical for coordinating the delivery of pulses to the magnet.

Thyratron Heater Power Supplies

The 19” rack mounted heater power supplies manufactured by CE+T provide a remotely adjustable AC output voltage to the kicker thyratron tubes to modify both the temperature/pressure in the reservoir and heating of the cathode gate element (increasing or reducing the length and speed of the discharge pulse). Their output range covers the entire requirements of old and new thyratrons (variable between 130 – 250VAC), and the power supply modules are redundant.

Fig.2 – Thyratron Heater Power Supplies

Capacitor Charger and Protection Unit

The Capacitor Charger and Protection Unit (CDPU) incorporates an electrical resistive discharge mechanism, an identifiable manual grounding, real-time safety indicators and a VAT making a significant improvement in capacitor discharge systems here at CERN within the PSB and PS kicker systems, being modular they can be fitted to several different type of systems.

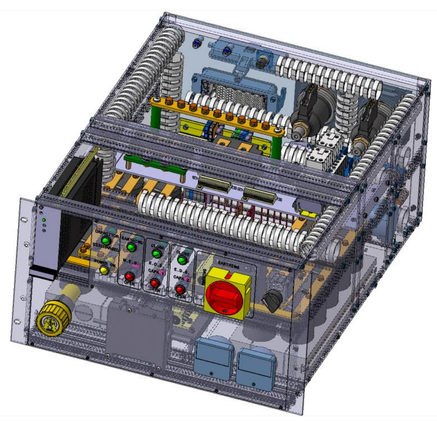

Fig.3 - Capacitor Charger and Protection Unit

Fast Interlock Detection System

At CERN fast pulsed kicker magnet systems necessitate precise control and monitoring of high-voltage and high-current pulse generators. The utilization of fast high-voltage switches, such as thyratrons, GTOs, and IGBTs are essential for managing the rapid energy discharge process. The hardware architecture of FIDS (Fast Interlock Detection System) is designed with specific functionalities in mind. An AMD Zynq-7000 SoC has been selected to implement these functions. The Field Programmable Gate Array (FPGA) within the SoC handles the rapid detection and interlocking logic, while the ARM processors provide flexibility for integration within CERN's Front-End Software Architecture (FESA) framework.

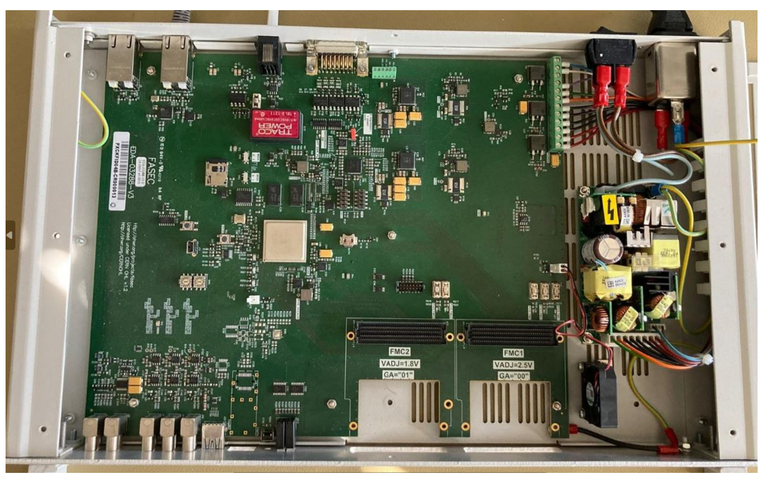

Fig.4 – FIDS system deployed at the PS Booster injection chain.

Kicker Timing System

The Kicker Timing System (KiTS) software is the ABT standard software used for the control of the main kicker operational parameters: delay, length and strength. It is a generic software, capable of adaptation to different kicker system configurations, with various number of RCPS, Pulse Forming Network (PFN) and presence of main, dump and clipper HV switches. It is responsible for the generation of the triggers for the CDPU and is based on CERN timing events, as well as the MS, DS and CS triggers synchronised with Beam based on RF pre-pulses, and it provides the voltage reference for the DCPS. It performs the acquisition of voltages and timing event timestamps to allow for diagnosis. For large systems equipped with more than one kicker magnet and associated HV generator, it provides load balancing functionalities to share the total kick strength requested by operation between available generators, and so allows for increased availability in case of generators transitioning into an erroneous condition thus increasing strength on the other available kickers to guarantee a constant total kick strength. It is a software developed using the Front-End Software Architecture (FESA) framework available at CERN, to provide interfaces to CERN controls middleware (CMW) for operation.

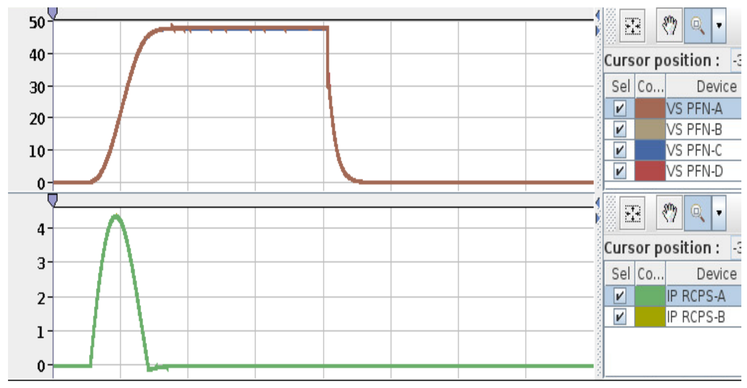

Fig.5 – RCPS current and PFN voltage captured by IPOC

Internal Post Operation Check

The acquisition of signal waveforms such as kicker magnet current, terminating resistor voltages, HV switches currents, power trigger currents, RCPS current and voltage reveals to be extremely useful to diagnose problems, and follow-up equipment performance stability. A software framework, called Internal Post Operation Check (IPOC), was developed to acquire and analyse waveforms. Initially developed for the surveillance of LHC Beam Dumping System (LBDS) extraction and dilution kicker current waveforms, it is planned to be deployed over all kicker system at CERN. It was implemented using the FESA framework, and make use of many CERN control services, like NXCALS logging system to save waveforms and analysis results. It is connected to the state control PLC systems for interlock in case a abnormal waveform is detected outside nominal values.