**Introduction**

The CERN's converter control libraries are a collection of libraries written in C, available under the GNU Lesser General Public License from https://github.com/cclibs.

CCLIBS currently includes four libraries and two more will be added in 2016. Together they provide a rich set of features for the regulation of power converters in accelerators:

- **libreg**: Current, field, and voltage regulation
- **libref**: Reference manager
- **libsig**: Function generation
- **liblog**: Analog and digital signal logging (planned for 2016)

The function generation and regulation libraries, libref and libreg, were already presented in a paper and poster at ICALEPCS 2011 (WP05/ND05).

Both libreg and liblog have been significantly improved in CCLIBS v2.

**CCLIBS v1 at ICALPCS'11**

This poster focuses on the reference manager library, libref, which is new in CCLIBS v2.

- A function can be armed in the IDLE state, resulting in the state changing to ARMED.
- The new function must start from the initial reference.
- The armed function is started with a time event and the state changes to RUNNING.
- The function is disarmed automatically on completion, and the state machine returns to IDLE.
- The function can be aborted before the end by returning to the IDLE state.

**Polarity Switch Manager**

Libref allows a low-cost unipolar converter to be used with a polarity switch to drive a bipolar circuit. The polarity can be set manually, or can be controlled automatically when in the DIRECT or CYCLING states, based on the polarity of the reference function.

**Reference Manager State Machine**

Example of the CERN-designed 700A 1-channel self-protecting polarity switch.

**Cycling Reference Functions**

The CYCLING state is used for fast cycling accelerators. Reference functions are armed in advance. The real-time selection of functions is made by the timing system.

- The function can be suspended and resumed with timing events. It will wait in the PAUSED state.
- The CYCLING state can automatically perform a magnetic pre-cycle to improve magnetic reproducibility between cycles.
- An "economy" cycle with reduced RMS run if no beam is injected, without affecting the next cycle magnetically.
- If a polarity switch is in use, it can switch automatically as required.

**DIRECT Reference**

A reference function is needed that can:

- Ramp smoothly from one reference value to another
- Work even if the voltage reference is being clipped
- Provide the RAMP function in libreg. It is a special parabolic + parabolic function, which can accumulate a time offset if the reference is being limited.

**Polycycle**

The RAMP function

If the reference from the previous iteration was clipped, the time offset is adjusted so that the clipped reference would have been generated.

**Smooth start/stop of 2-Q converter using RAMP and open-loop reference**

- Error in load model: 30%
- Open-loop reference
- Closed-loop threshold
- Closed-loop reference
- Open-loop to closed-loop

**Road map for CCLIBS**

- CCLIBS v1 at ICALPCS'11
- CCLIBS v2
- CCLIBS is built on 15 years of experience with controlling power converters

**Single-use Reference Functions**

The IDLE, ARMED and Running states are used by the CERN LHC converter controllers to run functions synchronously on demand.

- A function can be armed in the IDLE state, resulting in the state changing to ARMED.
- The new function must start from the initial reference.
- The armed function is started with a time event and the state changes to RUNNING.
- The function is disarmed automatically on completion and the state machine returns to IDLE.
- The function can be aborted before the end by returning to IDLE state.

**Libreg implements an internally stable closed-loop RST regulator, which connects the three regulation variables:**

- Voltage
- Current
- Field

**The RST realizes a (pseudo) dead-beat control and allows up to 2.4 period of delay. Libreg also implements an open-loop model for an inductive load, which connects the open-loop reference with the actuation:**

- Open-loop reference
- Closed-loop reference
- Open-loop to closed-loop

Both open-loop and closed-loop algorithms work in either direction, or when running in open-loop, the closed-loop reference is being calculated, and vice versa. When combined with the RAMP function, this allows smooth transitions from open-loop to closed-loop when starting and stopping.