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DESIGN AND STATUS OF THE MICROTCA.4 BASED LLRF SYSTEM FOR TARLA

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Abstract

The Turkish Accelerator and Radiation Laboratory in Ankara (TARLA) is constructing a 40 MeV Free Electron Laser with continuous wave (CW) RF operation. In order to control and monitor the four superconducting (SC) TESLA type cavities as well as the two normal conducting (NC) buncher cavities, a MicroTCA.4 based LLRF system is foreseen. This highly modular system is further used to control the mechanical tuning of the SC cavities by control of piezo actuators and mechanical motor tuners. This paper focuses on giving brief overview on hardware and software components of LLRF control of TARLA, as well as updates on the ongoing integration tests at DESY.

FACILITY INFORMATION

TARLA facility - located in Ankara – will be the first particle accelerator of Turkey with the Free Electron Laser (FEL) of 3–250 µm. Other usages will be the Bremsstrahlung radiation and the fixed target experiments. The Technology Lab of DESY is responsible for delivering a turn-key system for Low Level Radio Frequency (LLRF) control to TARLA. There are six cavities that need to be controlled by LLRF system. Four of these cavities are TESLA type 1.3 GHz superconducting whereas others are normal conducting buncher cavities operating with 1.3 GHz and 260 MHz respectively. The RF operation will be continuous wave (CW) with the expected total beam energy of 40MeV. Main machine parameters are on Table 1.

Apart from the hardware delivery and the commissioning of the complete system, DESY is also cooperating with TARLA to train personnel in order to make sure that know-how is transferred.

Main design of the accelerator is quite similar to the ELBE in HZDR-Dresden / Germany where difference is that TARLA uses piezos on SC cavities. Since ELBE is also in the process of switching their control system to MicroTCA.4 standard, parallel development is ongoing [1]. The main construction on TARLA facility has been finished and accelerator modules have been delivered.

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Table 1: Machine and Beam Parameters

Parameter	Unit	Base Value	Upgraded Value
Beam Energy	MeV	0 - 40	0 - 40
Max. Bunch Charge	pC	77	115
Max. Average Beam Current	mA	1	1.5
Horizantal Emittance	mm mrad	<15	<15
Vertical Emittance	mm mrad	<12	<12
Longitudinal Emittance	keV ps	<85	<85
Bunch Length	ps	0.4 – 6	0.3 - 6
Bunch Repetition	MHz	13	0.001 – 52
Macro Pulse Duration	µs	10 – CW	10 – CW
Macro Pulse Repetition	Hz	1 – CW	1 - CW

LLRF DESIGN

Overview

The overall LLRF system consists of 6 RF station controls and the corresponding mechanical tuner control components. In additional to RF and mechanical tuning of the cavities, additional drift compensation modules (DCM) will be installed to compensate the slow drifts on RF signal paths caused by humidity and temperature. The RF amplification after the LLRF system is realized by Solid State Power Amplifiers (SSPA). As for the control system environment, EPICS will be used on the LLRF system.

Using the MicroTCA.4 technology standard, each cavity is controlled by one Advanced Mezzanine Card (AMC) and Rear Transition Module (RTM) pair. The AMC with a FPGA, contains the control loop and PCIe component while the RTM has mostly the analog part of the signal path. Each AMC + RTM pair is connected to a CPU-AMC card to transfer data over the MicroTCA backplane using PCIe bus [2].

The synchronization of all LLRF controls is realized by applying the same main clock and reference signals generated by a Master Oscillator (MO).

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Mechanical tuning of the cavities is done via stepper motors. Moreover, SC cavities are also equipped with piezos which will be controlled by PZT4 RTM.

All the LLRF components and their spare parts will be housed in one single rack, shown in Figure 2. with inter rack cabling and custom top patch panel for connecting RF signals, motor cabling, IT connections etc. Furthermore this rack also houses the master oscillator which allows for an optimal connection of the LLRF system to the master clock.

Crate Layout

Foreseen crate occupation can be seen on Figure 1. Apart from crate management board (MCH) and power supply, main crate components are listed below. The further information on listed hardware can be found in [3].

- CPU-AMC: from Concurrent Technologies, Runs on Ubuntu 16.04 LTS contains all servers for operation
- DAMC-SIS8300L2: Digitizer board from Struck (10 Channel 125 MS/s 16 bit)
- DAMC-x2Timer: Main timing board used to synchronize LLRF system
- DRTM-DWC8VM1: Down conversion from 1.3 GHz to 54 MHz intermediate frequency.
- DRTM-DS8VM1: Direct sampling board used for 260 MHz buncher cavity
- FMC25-AMC: FMC Carrier Board having MD22 Motor control card
- PZT4-RTM: Piezo Control RTM

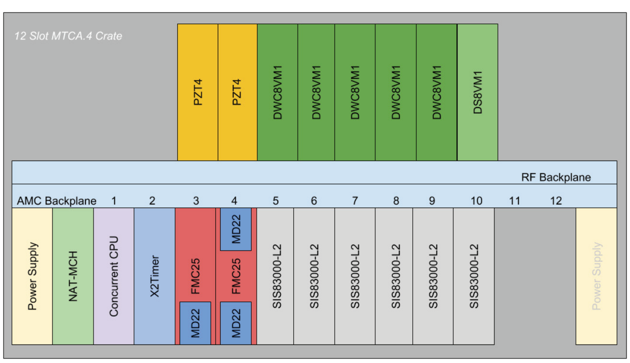

Figure 1: TARLA Main Crate Occupation

Current Schedule and Rack Layout

All the hardware components will be delivered to DESY site for initial tests. After the system integration one rack containing all the hardware with the cabling will be shipped to TARLA around Q2 of 2019. Currently complete system integration is taking place at DESY. This includes hardware tests of the individual components, firmware design for the LLRF controls, server deployment etc.

It is also intended to ship the spare crate before hand around Q3 of 2018 to pre-test the system on site in order to identify challenges before main rack is shipped. This spare crate will be used to commission the NC buncher cavities.

During the system integration, additional proof of concept setups is being constructed at Cryo Module Test-Bench (CMTB) facility at DESY. These setups are mostly for testing the piezo operation using PZT4 and CW-RF operation tests with 1.3 GHz TESLA type cavities [4].

Once the hardware is shipped next stage will be functionality and performance demonstration on site. Acceptance is done for a set of default machine operation parameters. Finally, several upgrades to the system like beam position monitors, beam based feedbacks is planned.

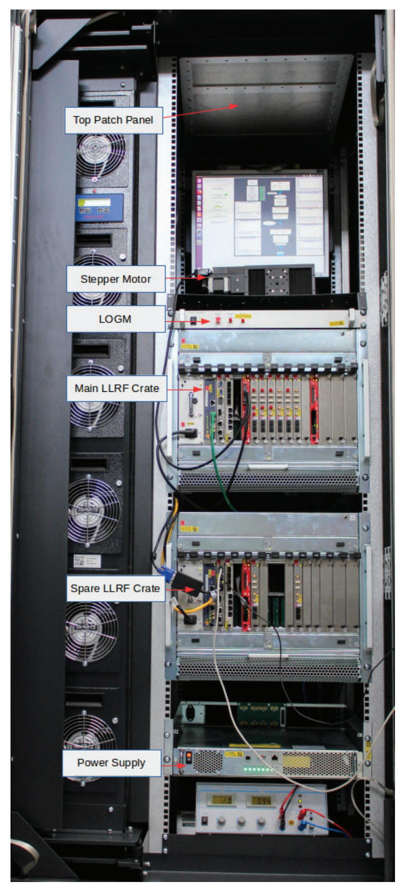

Figure 2: TARLA Rack (Front View)

Figure 2 shows the TARLA Rack with most of the hardware installed. Main components are two crates with one being the main and other as spare. Local Oscillator

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Generation Module (LOGM) is responsible from distributing the 1354 MHz LO, to DWC8VM1 RTM boards for down conversion to 54 MHz. There will be a custom patch panel for routing the RF, interlock and IT signals at the top of the rack.

EPICS INTEGRATION

TARLA is using EPICS Control System on site. This requires that all the servers that are running on the crate must be interfaced to EPICS to have common ground. This interfacing is possible with the ChimeraTK framework.

ChimeraTK Framework

In order to access the data from the MicroTCA.4 crate bidirectionally over PCIe bus, the ChimeraTK framework was developed in DESY. The scope of this framework focuses on abstracting specifics of underlying system as well as giving user the ability to create portable user applications across different control system choices [5].

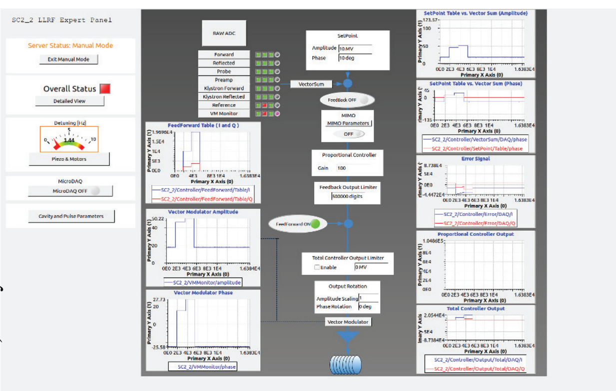

Figure 3: LLRF Expert Panels on CSS

The ChimeraTK toolkit comes with Control System Adapter which makes application to be interfaced to different control systems such as EPICS, DOOCS, OPC-UA etc. This gives ability to re-use the LLRF server written for one facility at another facility with completely different control system. Same LLRF server written for TARLA is currently used in ELBE.

All the LLRF servers as well as watchdog running running on MicroTCA.4 system, are developed using ChimeraTK framework. Currently these servers are being tested at the DESY site. First successful close loop LLRF operation on dummy load using the MicroTCA.4 crate with the LLRF server written on ChimeraTK framework has been demonstrated.

The graphical user interface for control panels developed using Control System Studio (CSS). Figure 3. shows the first LLRF expert panels designed with CSS. Features such as logbook entry, history of PVs, user login will be added to the interface.

CONCLUSION

The Technology Lab of DESY will be delivering a turn -key LLRF system to TARLA to monitor and control 4 SC cavities and 2 NC buncher cavities. Additional control for the mechanical tuning of the cavities will also be part of the system. The LLRF control electronics is based on the MicroTCA.4 technology standard where each cavity controlled with one AMC + RTM pair.

Currently, the system integration is taking place at DESY site. This includes hardware test, software and firmware design and complete system integration. Since TARLA is using EPICS as the control system, server integration using ChimeraTK framework is currently ongoing. The LLRF expert panels have been designed and successfully interfaced to LLRF servers. All electronics housed in a single rack, will be shipped to TARLA around Q2 of 2019.

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