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PROGRESS OF MicroTCA.4 BASED LLRF SYSTEM OF 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 RF field inside four superconducting (SC) 9-cell 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 also used in resonance control of the cavities via piezo actuators and mechanical motor tuners. This paper gives brief overview on hardware and software components of LLRF control of TARLA, as well as updates of the ongoing integration tests at DESY.

PROJECT OVERVIEW

TARLA facility, located in Ankara, will be the first particle accelerator of Turkey with the Free Electron Laser (FEL) of operating at 3–250 μm wavelength. Other usages will be the Bremsstrahlung radiation and the fixed target experiments [1]. The MicroTCA Technology Lab (A Helmholtz Innovation 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 maximum total beam energy of 40 MeV. Main parameters of the accelerator are shown in Table 1.

Main design of the accelerator is quite similar to Electron linac for beams with high brilliance and low emittance (ELBE) in HZDR-Dresden / Germany where difference is that TARLA uses additional piezos for resonance control. Since ELBE is also in the process of switching their control system to MicroTCA.4 standard, parallel development is ongoing [2]. The main construction on TARLA facility has been finished and accelerator modules have been delivered.

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.

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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

MicroTCA.4 Standard Overview

Using the MicroTCA.4 technology standard, each cavity's RF regulation is controlled by a pair of Advanced Mezzanine Card (AMC) in which FPGA holds the controller and digital signal processing and Rear Transition Module (RTM) card which has the analog RF circuitry to provide the down converted cavity signals over the Z3 connection. On the same crate CPU-AMC board communicates with digitizer AMCs with PCIe lanes using the backplane. Remote access is established through Ethernet via MicroTCA Carrier Hub where crate management takes place [3].

LLRF System Architecture

The LLRF system for TARLA consists of 6 RF station controls and the corresponding resonance control components. In additional to RF and mechanical tuning of the cavities, additional drift compensation modules (DCM) will be installed to the rack in order to compensate the slow drifts on RF signal paths caused by humidity and temperature.

The RF amplification of the drive signal on LLRF system is realized by Solid State Power Amplifiers (SSPA). As for the control system environment, EPICS will be used on the LLRF system.

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Master Oscillator (MO) provides the 1.3GHz and 260 MHz reference to MTCA crate where Local Oscillator Generation Module (LOGM) then produces the LO signal at 1354 MHz and distributes it to the downconverting RTMs.

Mechanical tuning of the cavities is done via stepper motors attached the the cavities. These motors will be controled via FMC carrier AMC (DFMC-FMC25) where MD22 FMC card will drive the motors. In order to compensate microphonic effects on super conducting cavities, piezos will be driven by PZT4 RTM. [4]

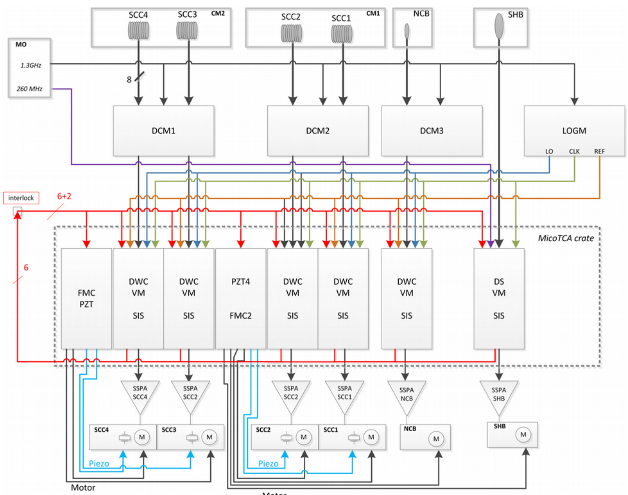

Figure 1: Overview on TARLA LLRF system.

Figure 1 shows the block diagram for complete LLRF system for TARLA. All the LLRF components and their spare parts will be housed in one single rack with inter rack cabling and custom top patch panel for connecting RF signals, motor cabling, interlock connections etc.

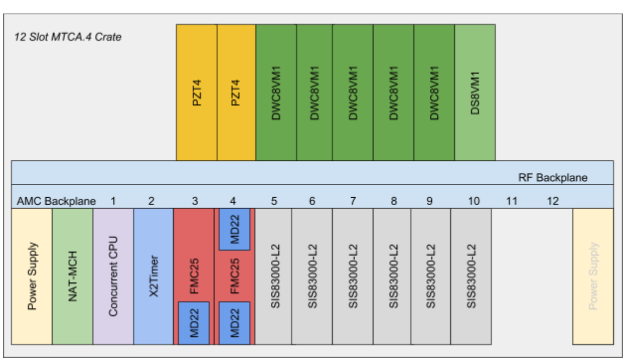

Figure 2: Main MTCA crate layout.

Complete LLRF system also has spare MTCA Crate with bare minimum components to run the each of 6 cavities. This option will be also used as research and development crate where new features can be tested before it gets deployed to the main crate.

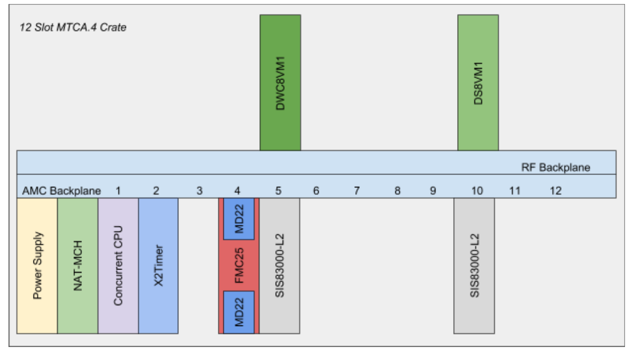

Figure 3: Spare MTCA crate layout.

Current Schedule

All the hardware components of LLRF system delivered to DESY site for tests. After the system integration, one rack containing all the hardware with the cabling will be shipped to TARLA around Q3 of 2019. In order to commission the cavities and first tests, spare crate and LOGM module have been shipped to TARLA site. Currently, system integration for hardware firmware and software is being finalized. After this step, inner rack cabling will begin to take place.

During the system integration, additional proof of concept setups are constructed at Cryo Module TestBench (CMTB) facility at DESY in order to test the hardware, firmware and servers. These setups are mostly for LLRF field regulation stability using setup similar to European XFEL and single cavity regulation like TARLA [5].

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 are foreseen.

USER INTERFACE IMPROVEMENTS

TARLA is using EPICS Control System for their major subsystems. This requires that all the servers that are running on the MTCA crate must be interfaced to EPICS in order 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 [6].

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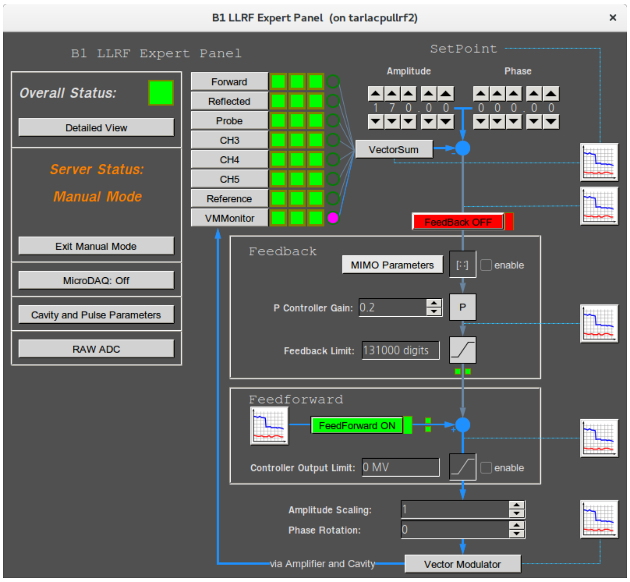

Figure 4: LLRF Expert panels on CSS.

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 (LLRF server, timing server, watchdog server piezo server and motor server), 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 are developed using Control System Studio (CSS). Figure 3. shows the latest LLRF expert panels designed with CSS. These panels went through a significant improvement regarding usability and performance. Remote access to Process Variables (PVs) have been tested along with the logging functionality of the Input Output Controllers (IOCs) output.

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. Resonance control for the 6 cavities will be also a part of the LLRF system which will be achieved via stepper motors and piezos on the cavities.

Currently, complete system integration is taking place at DESY site. This includes hardware test, software and firmware design and complete system integration. Spare crate which is foreseen for research and development has been already shipped to TARLA. This crate will be used for first RF operation on normal conducting cavities. The LLRF expert panels which was designed using CSS is improved and successfully interfaced to LLRF servers. All electronics housed in a single rack, will be shipped to TARLA around Q3 of 2019.

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