CONTROL AND ACQUISITION SOFTWARE COMPLEX FOR TBTS EXPERIMENTS

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Abstract

The Two-beam Test-stand (TBTS) is a test area in the CLIC Test Facility (CTF3) to demonstrate the high power RF extraction and acceleration at a high accelerating gradient, which are feasibility issues for the Compact Linear Collider (CLIC) project. In order to achieve an efficient data collection, an acquisition and logging software system was developed. All year round these systems store the main parameters such as beam position, beam current, vacuum level, pulse length etc. For predefined events they also gather and store all information about the last several pulses and the machine status. A GUI interface allows from anywhere to plot many logged characteristics at a maximum of 10 minutes delay, to go though all events and to extract any logged data. A control interface configures actions and long-term control procedures for conditioning accelerating structures. The flexible configuration of the logging, the acquisition and the control systems are integrated into the same GUI. After two years operation the critical components have shown highly fault-tolerant. Logging data are used for physic researches.

INTRODUCTION

CTF3 is a test facility which addresses the feasibility demonstration of the Compact Linear Collider (CLIC) [1,2]. The CLIC machine will produce electron-positron collisions at the nominal center of mass energy of 3 TeV at a luminosity of $2\times10^{34}\,cm^{-2}\,s^{-1}$ with a two-beam acceleration scheme. This scheme is studied in the Two-beam Test-stand (TBTS), which is a part of CTF3. An electron beam (the drive beam) of 12 GHz is generated from a 1.5 GHz electron beam in a Delay Loop and Combiner Ring and then sent to the TBTS. The drive beam of an intensity of up to 32 Amps passes through a Power Extraction Structure (PETS). The extracted 12 GHz RF power from the drive beam is used to accelerate the second, low-intensity, beam (the probe beam). In the TBTS set-up the CLIC feasibility, stability and protection issues are studied, such as the beam changes during the deceleration, the RF extraction properties by the PETS, the high-gradient acceleration, as well as the Two-beam scheme performance and the fault-tolerance [3].

A control and acquisition high-level software complex was developed in order to assist all TBTS experiments, measurements and control routines. From the user point of view, the acquisition and logging parts of the system must be extremely reliable and robust; and it must work round-the-clock. The software system is flexible and adaptive to failures of hardware or software components involved in the TBTS set-up. Another issue is that the development of the software continues during several years such that it follows the requirements of R&D experiments and the hardware installation; and it remains light in support and compatible. The automatic control part contains a material protection mechanism and an accelerating structure processing.

FRAMEWORK

The TBTS software design approach is based on a model-driven architecture. The software developing process contains two distinct periods of time. During the first and initial period the developer followed the waterfall model approach. Specifications for different software aspects were completed iteratively during an extended period of time. That is why the first four stages of the software development consecutively alternated: requirements analysis → software design → integration → testing → requirements analysis → and so on. During this period the full range testing is very time consuming and some aspects remain unknown. Hence the testing, the validation and the performance estimations were made for some aspects of typical situations. The model merging is one of the most difficult processes during this phase. In order to simplify this problem, a core model was designed, which covers the static part of the set-up and it remains independent of the software and hardware realisations. The core software model was developed based on the instrumentation, controllers and machine time triggers layouts and general specifications. The acquisition model defines the generalized device interfaces for different data access interfaces and different types of equipments. The control model depends on only the core model and the acquisition model. At the end of the first period most of this was defined and realized in the server part of the software. The remaining part is gradually put in operation during the second period taking into account the importance of the blocks. So the second period of the development relies on the feed-back from results, goals and tasks of experiments and set-up changes. During this period the development becomes lighter and faster, the development tends to be agile.

ACQUISITION

The acquisition part of the software complex is to obtain all necessary information about the CTF3 machine status and the experiment. CTF3 can run in several modes for the TBTS beam lines:

- only the drive beam is on;
- only the probe beam is on; synchronizly;
- probe and drive beams are on, but not synchronized;
- probe and drive beams are on and synchronized.

Moreover all measurement equipments are located on different front-end crates in the network, and measurements are updated non-simultaneously. Thus in all running modes the acquired data must be synchronized in a way to get the beam, RF and other measurements resolved for each pulse in both beam lines. If the read-out of some of equipments fails, the missing information is treated as a special case.

Machine status

In CTF3 there are several parameters which relevant to TBTS beam properties. The status of the electron gun and the pulse length define the initial beam. Meanwhile the recombined beam pulse can be cut by a tail clipper, which is installed after the extraction from the Combiner Ring. The CTF3 safety interlock system protects the equipment and the personal from harm. Any TBTS control activity is stopped on the activation of one of interlocks; and it resumes when the system is okay. All these parameters are synchronized with a CTF3 acquisition trigger and they are synchronously acquired by the TBTS software.

At present the distribution in the waveguide system of the extracted RF from the PETS is controlled by RF actuators: two RF attenuators and one RF phase shifter that can be remotely changed. The actual position of stepping motors is read using a spring return. The read-out and the control of RF actuators are also synchronized with CTF3 triggers.

RF Simulation

Most of the time the TBTS set-up is running in the RF recirculation mode: a part of the extracted RF feeds back the PETS with a certain phase shift and the other part of RF goes to the accelerating structure [4]. Taking into account the status of RF actuators, the RF propagation in the RF waveguide system is simulated based on the drive beam intensity for every pulse. The simulation is compared to the RF power measured by directional couplers, which are installed in 5 different places. This allows detecting anomalies of the RF transportation and recirculation every pulse. In case of a normal pulse the comparison between the simulation and the measurement gives the beam quality: the bunch form factor and the beam phase along the pulse.

Pulse Summary

Every pulse, the full set of data is summarized into a set of scalar values. The summarized data is used later in the control part of the software. For the user it is a possibility to monitor the evolution and the processing of the system. The main waveform measurements are summarized into the data set by the type of measurement:

- forward power – the peak power, the total power over the pulse duration, and the total period, when the power exceeds 50%, 75% and 90% of the peak power;
- reflected power - the peak power and the total power over the pulse duration;
- BPM – the mean current, vertical and horizontal positions at the flat top of the intensity waveform;
- Faraday cup – the peak signal.

Based on the predefined conditions the acquisition system determines anomalies during the high-field travelling in three sections of the TBTS: in the RF recirculation loop, in the RF waveguides towards the probe beam and in the accelerating structure. The typical indications are a high relative reflection, a missing energy, a high ion emission and a significant difference between the measured and the simulated RF.

Event

In order to minimise the amount of logged data and to provide a “one row data access”, the event system was implemented. For predefined conditions, such as breakdowns, interlocks and errors, the event system gathers all data together about the last and several preceding pulses and the machine status. In particular data from about 50 additional signals predefined by the user and two MTV cameras are acquired and saved, which are analysed off-line. The user can also raise an event by an external trigger from the GUI panel or he can activate the periodical event trigger.

CONTROL

The software system controls relevant TBTS actuators: the gun mode, the gun interlock, the gun pulse length, the tail clipper, the RF attenuators and the RF phase shifter. The user can control actuators in physical units. Control subsystems were implemented that atomise the control routine. The most important controllers are the interlock and the accelerating structure conditioning systems.

Interlocks

The interlock control subsystem is needed to protect the experiment hardware and to provide the purity of the experiment. There are two typical actions on an interlock: to cease the drive beam and to reduce the power production. These actions avoid problems with high vacuum, beam losses, klystron instabilities, PETS and accelerating structure breakdowns. The main indications for an interlock are a high reflection, a high vacuum level, beam losses, a missing energy and a breakdown. After vacuum level sparks the system waits until the vacuum level is below the normal level. Similarly, the system waits a predefined time to calm down the experiment set-up after a breakdown. The operation is automatically resumed only when all detected problems are solved.

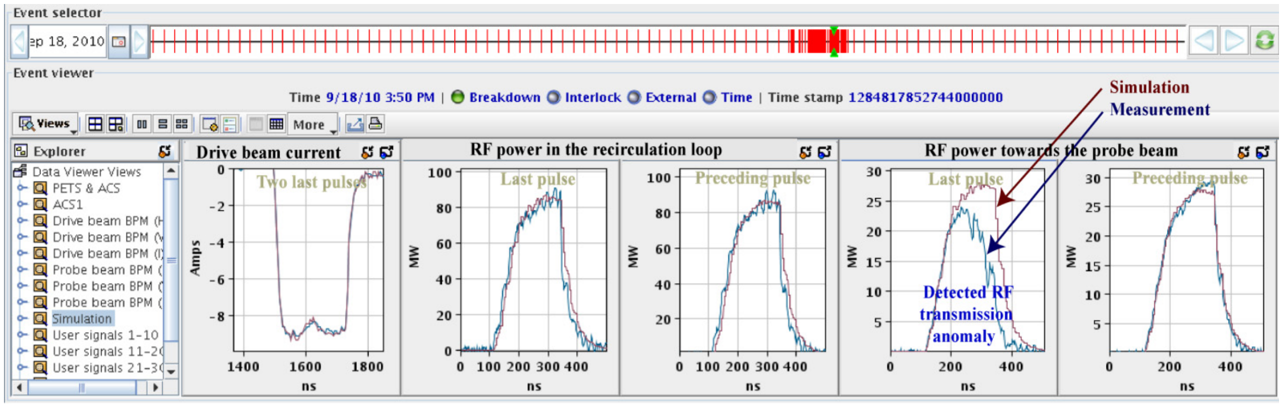

Figure 1: Illustration of the event chronograph, where a detected RF transmission anomaly in the waveguide is shown.

Conditioning controls

The conditioning strategy is an automatization of the conditioning, preparation and the long-term measurement processes. The control software must initialise the machine with an initial attenuator position and the pulse length and verify that all interlocks are deactivated. Then the programme ramps up the pulse length to a target pulse length by a pulse length step and a delay between changes. After that it changes the attenuator stepping motor position towards the target attenuation by steps and delays. If a breakdown occurs during that procedure, the control system must follow the interlock specification. If the number of breakdowns exceeds a threshold over a period, the programme should increase the target attenuation by a specified increment. If the procedure reaches the target positions and it stays for more than a predefined time, the programme reduces the target attenuation by a certain decrement. All parameters of the conditioning strategy are defined by the user.

LOGGING & GUI

The logging system permanently stores most of the acquisition data and many other parameters, in total several thousand parameters. All data are available after a several seconds for CERN internal users and after less than 10 minutes for external users.

The GUI part is composed of different display instruments. Quick access panels are an actuator control panel, an experiment description, the last pulse summary and the logging status. Remote configurations are an accelerating structure processing setup, interlock configurations, connections and signal treating configurations, RF simulation settings and others. The logging tools are a logging data plotting and the data extraction into MAT-format files. Acquisition visualizations are a last pulse waveform display and an event chronograph display. An example of the event chronograph display is shown in Fig.1, where a RF transmission anomaly was automatically detected.

CONCLUSIONS

An approach to develop dedicated software for the TBTS research was worked out. It allowed to create a model based system with rich functionality and flexibility, which meets the physics requirements. It is light in support during the operation. The complex of developed systems has been used in CTF3 for two years. The software has shown highly fault-tolerant and it is an efficient instrument within the scope of Two-Beam studies.

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