COMMISIONING OF THE MODULATOR TEST FACILITY AT DESY

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Abstract

The European XFEL, an X-ray free electron laser, is planned as an European project with a strong connection to the DESY research center in Hamburg. Construction started in summer 2007 and commissioning will begin at the end of 2013. The LINAC of the XFEL incorporates 27 RF stations, which supply the RF power required by the superconducting cavities. In order to generate the RF pulses (1.3GHz, 10MW) HV pulse modulators are required to operate the klystrons. Each modulator has to supply 12kV pulses at 1.8kA for 1.7ms pulse duration. A 1:12 pulse transformer converts these pulses to 120kV at 140A required at the cathode of the klystrons. Although extensive experience exists from the test facilities FLASH (DESY, Hamburg site) and PITZ (DESY, Zeuthen site) a dedicated modulator test stand has been setup to test and investigate new modulator prototypes developed by different companies. The test stand setup is similar to the setup of the future XFEL RF-stations.

INTRODUCTION

The XFEL project [1] will benefit from the experience and the knowledge of more than 10 years of research in the field of superconducting accelerator technology at DESY. In the linac of the XFEL electrons get accelerated by superconducting cavities. The RF-power required by these cavities is generated at 27 RF-stations. An important part of a RF-station is the HV-pulse modulator, which has to supply 12kV pulses at up to 1.8kA for max. 1.7ms pulse duration and up to 30Hz pulse repetition rate. This pulse is conducted by means of a 1,7km long special HV pulse cable to a pulse transformer, which converts it to typical 120kV/140A. This pulse drives a klystron which feeds 32 cavities with RF-power.

Although experience exists from the test facilities FLASH (DESY, Hamburg site) and PITZ (DESY, Zeuthen site) a dedicated modulator test facility has been constructed for testing and investigating the modulator prototypes in a real setup similar to that of the future RF-station at XFEL. The result of these tests will influence the final design of the XFEL modulators and the process of modulator procurement for XFEL.

THE XFEL MODULATOR PROTOTYPE

In 2005 first discussions have been started concerning to build or test facility at DESY, Zeuthen site. The technical specification [2] for the future XFEL modulator was completed in February 2006 and an invitation to tender has been send out to five companies (Europe and USA) in May 2006. Finally two companies have been selected and contracted in January 2007.

Table 1: XFEL Modulator Specifications

HV pulse Repetition Rate	1 - 30Hz
HV pulse duration	max. 1,7 ms
Output Voltage.	2 - 12kV
Output Current:	up to 2kA
Average Power	< 380 kW
HV pulse rise/fall time	< 70 µs
Pulse flatness variation	< +/-0.3%
Energy deposit in klystron in case of gun spark	< 20J

One of the prototypes will be a bouncer type modulator, which is well known from the operation of FLASH and PITZ.

The other modulator is of different layout: a so-called pulse step modulator, which uses several switching modules in series to generate the full output voltage.

THE MODULATOR TEST FACILITY

The existing klystron hall for PITZ at DESY, Zeuthen site, has been extended to accommodate the Modulator Test Facility (MTF). The construction was finished in July 2006. Since then, all the necessary components like pulse transformers, klystrons, low level RF, pulse cables, water cooling system, main power transformer, the control and interlock hard- and software have been installed.

Figure 1: The new Modulator Test Hall.

The new MTF hall provides the possibility to install and to run two complete RF-systems in parallel.

Why a Special Test Facility is Needed?

The XFEL modulator is a complex system. Testing such a device in a complete RF-system setup is desirable but not possible at the manufacturers site. To perform precision measurements special test equipment is needed. Furthermore, sophisticated tests have to be done to investigate open technical details (pulse cable, cable compensation network optimization, EMI and others). Long term testing is another important issue. Also, it is necessary to integrate the modulator control into the existing slow control environment (DOOCS). Finally, the results of the test phase will improve (optimize) the specification for the final design of the XFEL modulators.

Since the test hall was designed to be capable of testing two modulators in parallel the test facility incorporates two complete RF stations. But due to the amount of space required to install the pulse cable only one system is equipped with a long pulse cable.

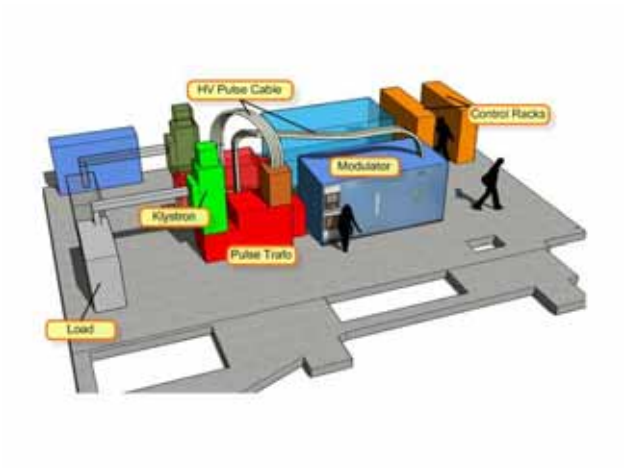

Figure 2: Layout of the MTF Hall.

During the testing process it has to be verified if the modulator prototypes comply with the specification. This covers the specification parameters itself but also inspections of the amplitude/phase stability of the RF-power, drift of the parameters, pulse to pulse variation, pulse transmission over the pulse cable and optimization of the cable compensation network. Furthermore meantime to failure and meantime to repair have to be verified. Also, investigations are planned concerning the energy efficiency and the EMI characteristics.

The first prototype was designed and manufactured by Thomson Multimedia, Switzerland [3]. It is a pulse step modulator. In July 2008 the factory acceptance test has been completed successfully at the manufacturers site and then the device was shipped to DESY, Zeuthen site.

After a short commissioning period long term testing started in October 2008 first with a 5 MW klystron.

Figure 3: The Thomson modulator in the MTF hall.

Actually these tests have been finished and the system is rebuilt to incorporate a 10 MW klystron.

The results of testing the modulator with a 5 MW klystron are:

- The Thomson Modulator fulfills the specification at 5 MW klystron output power and up to 10 Hz pulse repetition rate
- The modulator works fine with the HV pulse cable
- the flatness of the voltage and current pulses, measured at the cathode of the klystron, is well within the specification

Figure 4: Klystron current.

The next test activities will be:

- Repeat all the tests with the 10 MW klystron
- Test the modulator at 30 Hz repetition rate. To perform this test a new cable compensation network is needed
- Design and build a facility to simulate a klystron arc to verify the energy deposition in such a case

SUMMARY

At DESY, Zeuthen site, a Modulator Test Facility has been setup for intensive testing of XFEL modulator prototypes within a complete XFEL-like RF environment.

As a result of an international bidding process, two companies have been offered contracts to develop and to build a XFEL modulator prototype

The first prototype was delivered to DESY in summer last year, systematic testing started in October 2008 after a short commissioning phase. The delivery of the second prototype is actually delayed.

At this time the test setup is in a reconstruction phase to install a 10 MW klystron. During the next month systematic testing will be continued at 10 MW but also with a pulse repetition rate up to 30 Hz.

REFERENCES

[1] M. Altarelli et al., “XFEL, The European X-Ray Free Electron Laser, Technical Design Report”, DESY 2006-097, July 2007.

[2] “The HV Modulator for the XFEL RF Station. Requirements and Specifications“, Revision 2006-05-12, DESY 2006 (DESY internal document)

[3] J. Alex et al, “A new Prototype Modulator for the European XFEL Project in Pulse Step Modulator Technology“, TU5PFP101, PAC’09, Vancouver, May 2009