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SUNDAE1: A LIQUID HELIUM VERTICAL TEST-STAND FOR 2m LONG SUPERCONDUCTING UNDULATOR COILS

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Abstract

Superconducting Undulators (SCUs) can produce higher photon flux and cover a wider photon energy range compared to permanent magnet undulators (PMUs) with the same vacuum gap and period length. To build the know-how to implement superconducting undulators for future upgrades of the European XFEL facility, two magnetic measurement test-stands named SUNDAE 1 and 2 (Superconducting UNDulAtor Experiment) are being developed. SUNDAE1 will facilitate research and development on magnet design thanks to the possibility of training new SCU coils and characterizing their magnetic field. The experimental setup will allow the characterization of superconducting coils up to 2m in length. These magnets will be immersed in a Helium bath at 2K or 4K temperature. In this article, we describe the experimental setup and highlight its expected performances.

INTRODUCTION

The advancement of SCU technology has a strategic importance for the future development of the European XFEL facility. In the recent years, SCUs have been succesfully employed in synchrotron radiation sources [1, 2]. In a similar way of what happened with their application to synchrotrons, SCUs can potentially improve the performance and flexibility of advanced Free Electron Lasers (FELs). In particular by working at short undulator periods, superconducting magnet technology would allow reaching higher photon energies while keeping a wide range of tunability of the setpoint.

The extension of the energy range of the radiation towards higher values at European XFEL would fully exploit the high electron energy beam capability of the accelerator [3]. Moreover, this development can be considered complementary to the study on the upgrade of the XFEL linac for continuous wave (CW) operation [4]. CW operation at European XFEL is considered possible only with reduced electron beam energy. Specifically the electron beam energy will be limited to about 7 GeV, while the present maximum value is 17.5 GeV. The replacement of the existing PMUs beamline with SCUs having shorter undulator periods would enable the 7 GeV linac to cover the same photon energy range as the present accelerator.

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For all those reasons, a project for the realization of a SCU afterburner for the SASE2 line is being set-up. The main parameters and specifications for a pre-series prototype module (S-PRESSO) of such afterburner have been presented in [5].

The availability of equipment for the characterization of the magnetic coils of the undulator is a critical point to monitor the performances of the undulators that have been produced prior to the installation. For this reason two test-stands, SUNDAE1 and SUNDAE2 (Superconducting UNDulAtor Experiment 1 and 2) for the diagnostics of the novel SCUs are under realization in the DESY campus.

The test-stand SUNDAE1 will be dedicated to the training, tuning and characterization of new SCU coils by means of magnetic field measurements [6]. The cryostat of SUNDAE1 will have a vertical configuration and will be constituted by a liquid Helium bath in which the coils are immersed. SUNDAE2 will be used for the characterization of the final afterburner cryomodules [7]. This cryostat will have an horizontal configuration and the coils will be tested in their final cryostat. In this second test-stand the characterization of the module using the pulse-wire technique will also be foreseen [8, 9].

OVERVIEW OF SUNDAE1

Figure 1 shows the schematic drawing of SUNDAE1. The coils of the SCUs will be immersed in a liquid or superfluid Helium bath, at 4K or 2K respectively. Two Hall probes will be installed on a sledge driven by a Linear Motion System (LMS). The sledge will be able to move between the two coils constituting a SCU. The system will be able to characterize coils having a magnetic gap down to 5 mm. The coils are supported by a structure anchored on a plate of the lid. Several thermal shields guarantee a low heat load from the surroundings to the cryogenic vessel. The magnet is connected to the power supply outside the cryostat through current leads. Several feedthroughs at the lid allow the connection of diagnostics sensors (temperature sensors, voltage taps, Hall probes etc.) to the outside of the cryostat.

As illustrated in Fig. 1, the orientation of the Hall-probes allows the characterization of the y-component of the magnetic field of the coils, B_y. The resolution of the measure-

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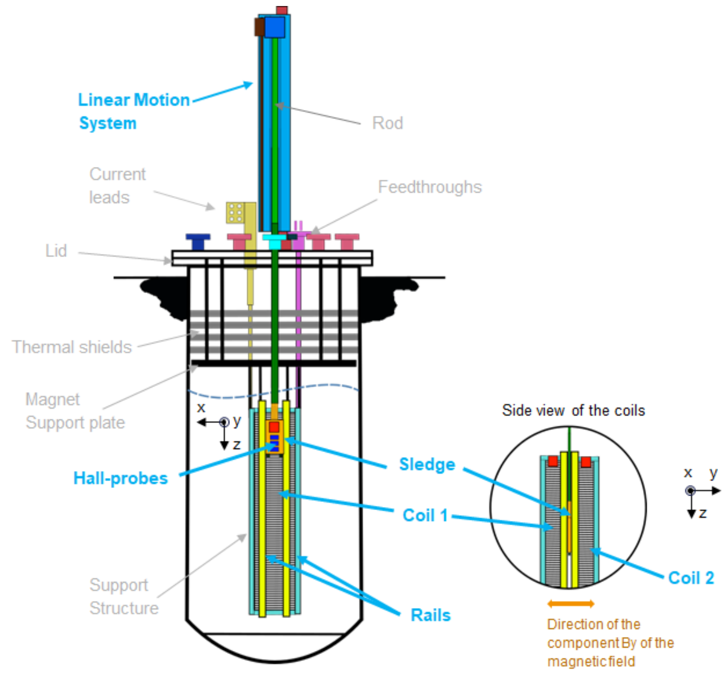

Figure 1: Scheme of SUNDAE1.

ment of the magnetic field is of the order of a few T but its accuracy is limited by the error on the calibration of the Hall probe, which is of the order of 0.1 mT.

The LMS will be equipped with a single axis vertical translator with 2400 mm of travel-range.

Besides its application for the final magnetic characterization of the SCUs, SUNDAE1 will also be used for the training of coils. Quench events happening when the coil is initially brought into operation have to be managed in a safe way. In order not to damage the superconducting coil, the power supply of the coil has to be switched off immediately after the detection of a quench event. For this reason, the power supply is connected to a quench detection system.

For the detection of the quench event, the three voltage taps marked with crosses in Fig. 2 are used. The voltage difference between points 1 and 2 (ΔV_{12}) and the one between points 2 and 3 (ΔV_{23}) are monitored and the reference value $\Delta V_{ref} = \Delta V_{12} - \Delta V_{23}$ is calculated. A quench event is detected if the signal ΔV_{ref} exceeds e.g. 100 mV within 10 ms [10, 11].

When a quench-event occurs, the power-supply of the undulator is switched off and the fraction of stored magnetic energy, that has not yet been dissipated in the cryostat, is sent to a dump resistor.

At SUNDAE1, the maximum allowed voltage of the power supply during the discharge is 1 kV. Three different dump resistors having resistance 2.5 Ω, 1.25 Ω and 0.66 Ω will be available in order to minimize the decay time for different nominal current and inductance values of the coils.

During the magnet training procedure, the input current of the coil is increased slowly and quench events due to imperfections of the physical setup are triggered. In absence

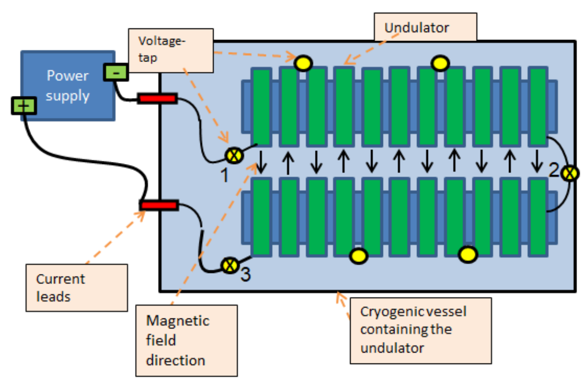

Figure 2: Simplified scheme of the distribution of the voltage taps. The voltage taps marked with crosses are used by the quench detection system, the other ones are used to identify the “hot-regions”.

of errors in the design of the magnet and in the experimental setup for the test, after a quench event the system ends up in a more stable state, thus allowing to increase further the input current. At the end of the training procedure, the magnet has reached its nominal current value [10].

During the training process, it is useful to dispose of diagnostics able to detect the hot-regions in the coil. The ”hot-regions” are the regions of the magnet where the quench event has originated and, therefore, the temperature has reached higher values.

Hot-regions can be detected by monitoring voltage signals along the coil. For this reason, voltage taps are distributed along the SCU coil and the voltage difference between different portions of the magnet during a quench

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is monitored [11]. Spikes in the voltage readout identify the hot-regions. At SUNDAE1, 40 voltage taps will be available for hot-region diagnostics (see Fig. 2). For a 2m-long magnet with 18 mm period length, this roughly corresponds to one voltage tap every six periods. The voltage taps will be connected to IMC CRONOSflex units with 40 simultaneously readable channels and a sampling rate per channel of roughly 50 kS/s.

CONCLUSION AND OUTLOOK

The advancement of SCU technology has a strategic importance for the future development of the European XFEL facility. In particular, the realization of an afterburner for the SASE2 line of the facility has been foreseen. The characterization of the magnetic field of the novel SCUs is a key step to understand and evaluate the technology prior to the installation in the beamline. The test-stand SUNDAE1 will allow the training and characterization of one stand alone coil in a liquid or superfluid Helium bath. In this contribution, we have presented an overview of the test-stand. The setup is presently undergoing its procurement phase, while the commissioning of the cryogenics and diagnostics is foreseen to start next year. For the commissioning of the test-stand the characterization of coils produced within the SCU research and development program is foreseen.

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