THERMAL ANALYSIS OF A SUPERCONDUCTING UNDULATOR CRYOSTAT FOR THE APS UPGRADE

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ABSTRACT

The Advanced Photon Source (APS) contains four 4.15 T superconducting undulator (SCU) cryostats, each containing two up to 175 m long undulator (und) magnets. Each SCU cryostat is cooled with LHe and consists of three parallel scallop-shaped cryostat stages. The superconducting magnets are cryogenically cooled and are located in the second stage of each cryostat. The first stage, which is cryo-cooled by a single cryocooler, is used to cool the warm end of the undulators. The third stage contains LHe tank and the liquid can be drained through cold lines. The second stage, cooled by the three cryocoolers to 4.2 K, cools the beam chamber and is located at the bottom center. It connects to a copper circulating LHe lines in the channel of the cryostat. When the SCU is in operation a trim heater is energized to regulate the beam chamber at the temperature of 4.2 K.

The thermal model predicts an excess cooling power of 4.8 mW. The reaction probe in ANSYS automatically calculates the additional heat to keep LHe at 4.2 K which corresponds to the excess cooling power.

1. INTRODUCTION

Currently two parallel superconducting undulators (SCUs) are two undulator (und) cryostats at the Advanced Photon Source (APS) storage ring. In three stages, the magnets are cryogenically cooled with three parallel cryocoolers in the first stage. The SCU system is designed to operate two undulators in tandem using a regulating trim heater which maintains the operational heat load to the involved cooling power. The temperatures of the first stage load are maintained at 70 K. The stages are connected using cold lines which provide an excess cooling power for various operational modes of the superconducting undulator.

2. COOLING SCHEMATICS

The APSU-SCU cryostat is a one shield cryostat (similar to the 2nd generation cryostat) but with three thermal circuits. The 1st stage load map is calculated using ANSYS. The cryocoolers are connected using cold lines. The SCU cryostats are cooled by three cryocoolers to 4.2 K.

3. M ETHOD TO CALCULATE EXCESS COOLING POWER

When the SCU is in operation a trim heater is energized to regulate the LHe reservoir at 760 Torr, maintaining saturated conditions at 4.2 K. The SCU tank pressure will equilibrate below 760 Torr without this power since the cooling power at 4.2 K exceeds the system heat load. This additional trim heat represents the excess cooling power. In our ANSYS numerical simulation, this excess is calculated by constraining the temperature at the LHe tank inner surface to a value of 4.2 K. A reaction probe in ANSYS automatically calculates the additional heat to keep LHe at 4.2 K which corresponds to the excess cooling power. The validity of this method has been confirmed with thermal models of existing Undulator planar that have been benchmarked against actual performance (1). Our measured load lines of 415D 3rd stage (1.5 W cryocooler) and 418D 2nd stage (2 W cryocooler) are compared and used as an input model.

4. 1ST GENERATION SCU CRYOSTAT

The thermal isolation between the beam chamber and the magnets is achieved using low thermal conductivity Teflon stands.

5. SUMMARY

The original design with 41SD has excess cooling power of 1.8 W. Using 2 W cryocooler increases the excess cooling power as much as 4.8 W. The high cooling capacity of the entire system suggests the feasibility of conduction-cooled system in the near future. The thermal conductance temperatures in the system, total 4 K heat loads and an excess cooling power for various operational modes of the superconducting undulator.