Power Monitoring for Transient Supercritical Power Conversion System Experiment

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1. Introduction

The Optimized Supercritical Cycle Operation (OSCO) apparatus is being designed at Seoul National University (SNU) to simulate the power conversion system by adopting supercritical carbon dioxide (S-CO_2) as working fluid. The main goal is to obtain experimental data of the S-CO_2 cycle power conversion system, particularly in transient states. OSCO adopts a controlled power supply for its heaters which can generate various transient power patterns to represent the transient heat exchangers or heat sources.

In the previous studies, a computational analysis of a programmable power source simulator for nuclear applications transient experiment was described [1, 2]. This paper focuses on the power monitoring system of OSCO to deal with various transient condition of supercritical power conversion system.

2. System Description

2.1 OSCO Power Conversion System

OSCO is an upgraded system of the previous Pressure Applied CO_2 Operation (PACO). PACO aims to measure the heat transfer characteristic of the CO2 near the critical point using a vertical small circular tube to guide the upward flow as depicted in Fig. 1 [3]. The PACO apparatus was equipped with a variable AC power source to deal steady state condition experiment. OSCO is equipped with a programmable alternating current (AC) power supply to simulate various transient states. The test section of OSCO has six heater rods for controlling the heat flux on the test section. To measure the fluid temperature along the test section, 39 type-K thermocouples are installed at the outer wall of the pressure tube.

2.2 Power Monitoring System

The main purpose of OSCO power monitoring is to measure the actual power delivered to the test section heaters and generate a power reference for a three-phase silicon-controlled rectifier (SCR) converter. The actual power is measured by using a Yokogawa WT130 power digital meter. The power digital meter is set to measure voltage, current, power of all phases. All of these data are sent to a dedicated PC via RS232 cable communication and a Labview module as the main control program. By processing actual power and power reference, the control program will generate a reference signal to a current generation DAQ module for generating a reference current (4-20 mA) as a firing signal of SCR converter. By controlling the firing signal, the actual power can be controlled as well, as illustrated in Fig. 2.

The OSCO power monitoring system is utilized not only to monitor the power delivery to the heaters. But it is also developed to monitor temperature along the test section as shown in Fig. 2. The temperature is sensed by using K-type thermocouples. All of thermocouples are connected to NI TC-2095 and SCXI 1000 modules. A standard USB cable connection is adopted to handle the dedicated PC and these modules communication. The data communication is managed by the same Labview module as the power control one. The display of OSCO power monitoring system is illustrated in Fig. 3.

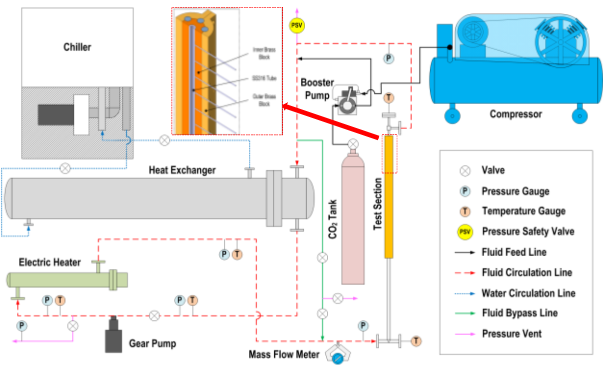


Fig. 1. OSCO power conversion system [3].

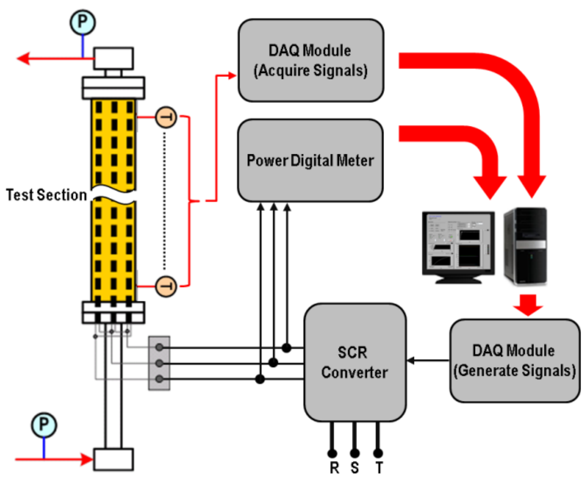


Fig. 2. Power control and data communication scheme.

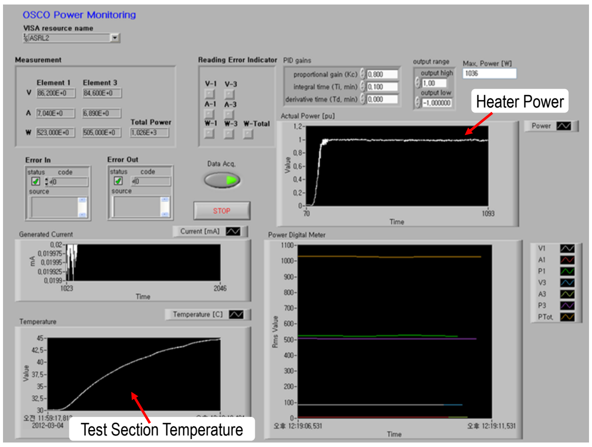


Fig. 3. OSCO power monitoring system.

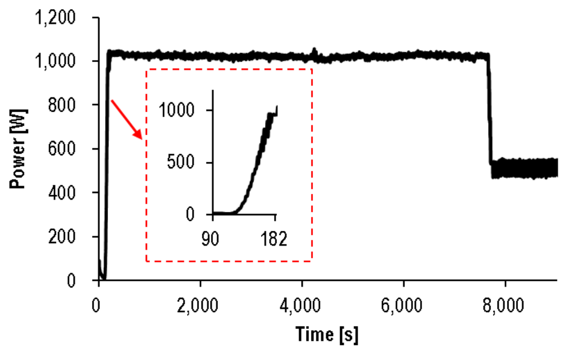
3. Experimental Results

The OSCO test section is equipped with three-phase delta connection 21 ohms heaters which are supplied by a three-phase programmable SCR converter. The SCR converter is supplied by standard 380 V_{pp} 60 Hz AC power source. As reference, ITER operation scenario is adopted in this experiment [4]. To simulate a power increase condition, the power reference is set to zero and a maximum value from t = 0 s to t = 115 s and from t = 174 s to t = 7644 s, respectively, as shown in Fig. 4. The maximum generated power is 1,056 W. As illustrated in Fig. 4, the temperature response is much slower to reach steady state condition than the power one. This phenomenon indicates that a long operation of experiment is required to simulate the transient condition. From t = 0 s to t = 115 s the minimum fluid temperatures at T-01, T-16, T-32 are indicated as 30.0 ^{o}C, 30.1 ^{o}C, 30.3 ^{o}C, respectively. During the maximum power operation, the maximum fluid temperatures at the same thermocouple positions are 45.8 ^{o}C, 47.9 ^{o}C, 52.6 ^{o}C, repectively.

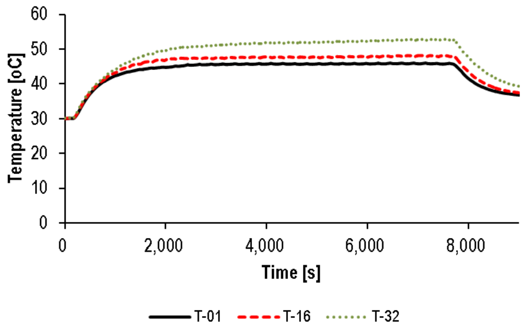
To investigate another power transient phenomenon, a power down scenario is also simulated. In this scenario, the power is downed by 50% from the original setting. The power down scenario is set the power to 518 W in average from t = 7702 s. As in the power increase scenario, the temperature response is also much slower than the power response as depicted in Fig. 4.

4. Conclusions

A power monitoring system of Optimized Supercritical Cycle Operation (OSCO) apparatus was presented in this paper. This system has been developed to monitor a transient supercritical power conversion system experiment.



(a) Heater power



(b) Test section temperatures

Fig. 4. Experimental result.

Acknowledgments

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