Control Engineering of Controlled Power Supply for Transient Condition Experiment

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1. Introduction

The Optimized Supercritical Cycle Operation (OSCO) apparatus is being designing at the Seoul National University (SNU). Its main goal is to obtain experimental data of the supercritical carbon dioxide cycle power conversion system in transient states. To make the transient condition, OSCO adopts a controlled dc power supply for its heaters which can generate various transient power patterns to represent the transient phenomena of heat exchangers or heat sources.

A simulator of transient dc power supply for nuclear applications was proposed in [1]. This power supply was designed to represent a typical nonlinear decay heat of fission reaction by adopting a simple proportional controller. Because the actual system is not linear, this type controller still generates a significant error. To the nonlinearity system, a nonlinear controller can be adopted [2]. But the controller design will be more complicated. In this paper, a concept to control the load power is proposed. The concept adopts a load power model to estimate the actual power of the load (heater). Thus by relying only on one actual variable value information, the controller can estimate other variables and resistance of heater.

2. Systems Design

The power supply is designed to supply a controlled power to a set of heaters that represents as heat source.

2.1 Existing Apparatus

Originally, OSCO is an extended version of the existing Pressure Applied CO_2 Operation (PACO). PACO aim s to obtain a collection of thermophysical characteristics of SCO_2 by using a vertical small circular tube to guide the upward flow. The scheme of PACO test section is shown in Fig. 1. Six heater rods are used to control the heat flux on the test section.

2.2 Controlled Rectifier

A thyristor three-phase full wave rectifier is used to control the power of the heater as shown in Fig. 2. The heater average voltage is given by [4]

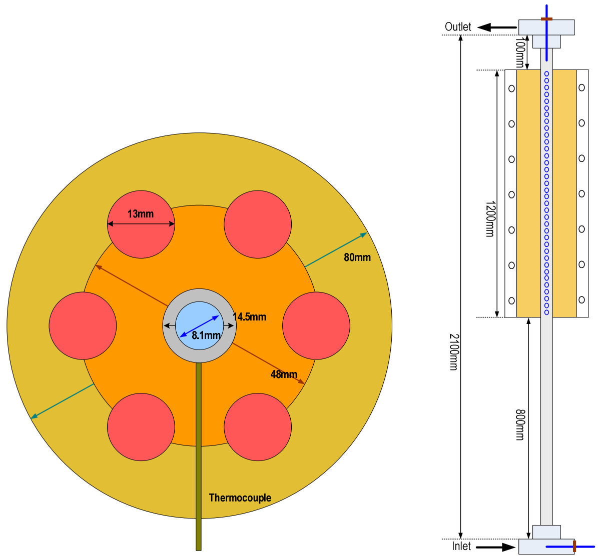


Fig. 1. PACO test section [1].

$$V_{H-avg} = \frac{3\sqrt{2}V_{l-l}}{\pi} \approx 1.35 V_{l-l} \cos\alpha \quad (1)$$

where α is firing angle of the rectifier

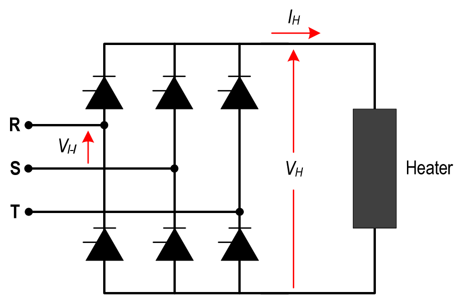


Fig. 2. Three-phase full wave rectifier.

2.2 Control System

The simplest method to control the heater power is by adopting a current controller to control heater current. But heaters have a variance on their resistance in a range of working temperature. Moreover, the relationship of current and heater power itself is not linear. To overcome these problems, by applying a superposition law, a heater power estimator is used. The block diagram of power estimator is depicted in Fig. 3.

R_H^* and P_H^* represent estimated heater resistance and actual heater power, respectively.

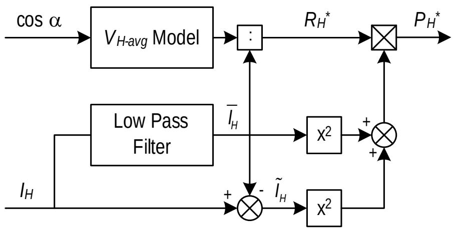
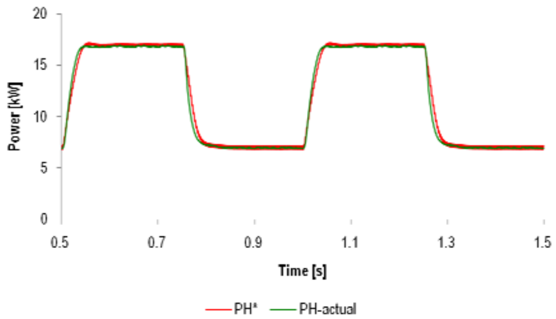


Fig. 3. Heater power estimator.

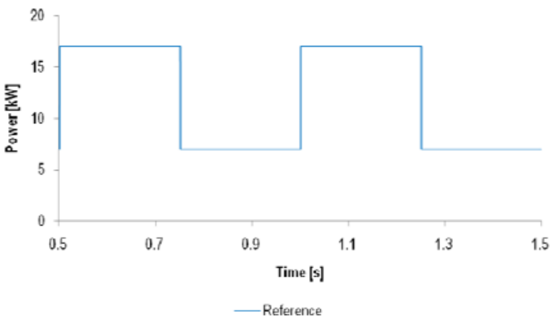
3. Simulation Results

A 10 ohm heater that supplied by a three-phase full wave rectifier is simulated by standard power simulator software. For this simulation, it is assumed that only actual current of heater is available and the rectifier is on continuous conduction mode. To represent a transient condition, a step power pattern is used as reference. The minimum and maximum values of reference are 7kW and 17kW, respectively.

Fig. 4(a) and (b) show the estimated and actual power values and the reference, respectively. The heater power estimator model can estimate the actual power well as depicted in Fig. 4(b). Moreover, in steady state, the estimated resistance of heater is 10.1 ohm. This value is close to the actual value (10 ohm).



(a) Estimated power and actual power



(b) Reference power

Fig. 4. Simulation results.

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