(Internal Proposal of Student Project)

Project Title: Decoupling and Disturbance Rejection Control for Target Circulation Loop

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Two Year (Jan 1, 2006 - Dec. 31, 2007)

1 Background Introduction

The pilot target circuit (TC-1) of the 1 MW power accelerator-driven system (ADS) was designed and developed by Institute of Physics and Power Engineering (IPPE) and Experimental and Development Organization (EDO) "Gidropress" under the International Science and Technology Center (ISTC) project #559 in 1998. Liquid lead-bismuth eutectic (LBE) is employed as spallation target in TC-1. The TC-1 is requested by Los Alamos National Laboratory (LANL) for LANSCE proton accelerator infrastructure (proton energy ~800 MeV, current ~1.25 mA).

In 2000, the tasks of design, fabrication and demonstration tests were accomplished in IPPE without beam. The initial objective of irradiating TC-1 at LANL is cancelled, because of the unavailability of the irradiation facility. In June 2002, TC-1 was delivered to University of Nevada, Las Vegas (UNLV) for basic research as a LBE loop. In 2003, Russian scientists visited UNLV to begin the hood up of the TC-1 lead bismuth target. In September 2005, the ISTC project, with partners of IPPC, LANL, and UNLV, has successfully complete a very important technical milestone of starting TC-1 and completing a set of thermal and engineering tests.

However, the current **M**onitoring and **C**ontrolling and **S**cram **P**rotection **S**ystem (MCSPS) for TC-1 heater controlling, as well as pump controlling would be improved to satisfy the requirement for optimization, safety, and easy-handling purpose for future research on UNLV campus.

One **M**onitoring and **C**ontrolling and **S**cram **P**rotection **S**ystem (MCSPS) was developed in LANL. This MCSPS is used for data acquisition and process controlling, besides, the protection process in case of overheat or operation error.

During the thermal and engineering testing in September 2005, the improvement of controlling algorithm was proposed to satisfy the requirement for UNLV research objectives.

First, the heater controlling would be improved to reach the setting point simultaneously and efficiently. Due to the compacted arrangement of all hydraulic components and heaters, the influence between each heating zone is very significant. In addition, the electro-magnetic (EM) pump is another heater due to its low efficiency when EM pump is running. These influences were not taken into consideration in the current version of MCSPS. As a result, it was found that heating the TC-1 loop to its target temperature takes approximate one day, which is not acceptable for UNLV research objectives. In addition, in order to keep all the required target parts at the same temperature level during heating, the current control approaches are not suitable due to the following reasons:

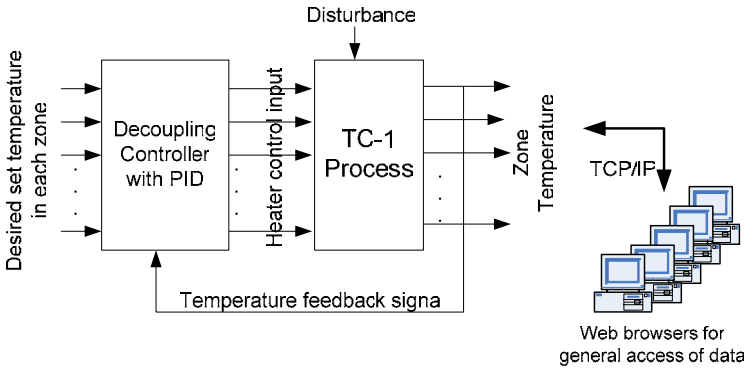
1. The TC-1 system is a coupled MIMO (Multiple Input and Multiple Output) dynamic system and the existing version of the MCSPS does not consider these coupling terms between inputs and outputs.
2. The current version of the MCSPS does not consider the various disturbances existing in the control loop, such as the influence of the EM pump on temperature distribution in the loop.

Therefore, more advanced control scheme is needed to solve the above problems. In addition, the Monitoring and controlling and scram protection system (MCSPS) does not have the emergency alerting sub-system. Considering that 24-hour-a-day monitoring by students is not practical in UNLV, the internet based remote monitoring and control system is necessary for automatic alarming and data retrieval from any authorized networked PCs.

2 General Approaches and its Deficiencies

As described previously, the TC-1 system has more than a single input and a single output and it exhibits the property of interaction between the heater inputs and temperature outputs in the target parts. For the effective control of the temperature in multiple locations of the TC-1 system, these interaction terms must be eliminated in the control loop. Eliminating the interaction terms requires the identification process of these interacting or coupling terms. After the successful elimination of the coupling terms, we can design the closed loop control algorithm that can achieve the precise tracking of the temperature on multiple locations of the TC-1 under external disturbance. One example of such algorithms can be a PID (Proportional-Integral-Derivative) control law that can be easily implemented for the existing LabVIEW codes of the MCSPS. The following describes the brief overview of the proposed research task:

1. Identify the interacting terms between heater inputs and target temperature outputs in each zone experimentally. These identified terms will be expressed in discrete transfer function matrix.
2. Design of noninteracting or decoupling control algorithm based on the model identified in the step 1.
3. Assuming that all coupled terms are eliminated in the previous steps, the suitable temperature control algorithm will be formulated for each zone based on
    a. Desired temperature response time based on the constraint of heating/cooling ramping rate
    b. Allowable tolerance of controlled temperature
    c. Level of disturbance in the control loop
4. Internet based remote monitoring and control system for automatic alarming and data retrieval from any authorized networked PCs.



Overall Control Block Diagram of TC-1 System

3 Research Objectives and Goals:

The decoupling and active disturbance rejection controls are the effective control scheme in this special multivariable control process to TC-1 loop.

The research objectives are:

- To identify the interacting terms between heater inputs and target temperature outputs in each zone experimentally,
- To design of decoupling and active disturbance rejection control (ADRC),
- To monitor system through internet based remote monitoring, automatic alarming and data retrieval from any authorized networked PCs,
- To automatic 24-hour safety and emergency monitor system.

The goals are:

- To understand the interaction between heater inputs and target temperature outputs, as well as the influence of EM pump,
- To employ the decoupling and active disturbance rejection control algorithm in the complex target circulation loop,
- To accomplish the automatic safety alarm and monitoring system.

4 Capabilities at the University:

UNLV has significant expertise in controlling and liquid metal circulation loop. In addition, the hardware used for controlling system is in good condition.

5 Project milestone and deliverables:

Year one:

- Collaboration with Russian scientists: J
    - June 2006, Russian scientists will visit UNLV,
- Initial experiments for control parameters,
- Progress quarterly report:
    - brief reports indicating progress will be provided every quarter,
- Annual report:
    - written reports detailing experiments performed, data collected and results to date. Control process simulation results,
- One conference presentation.

Year two:

- Control process simulation
- Real control of TC-1 loop with improved control algorithm,
- Quarterly report and annual report,
- One conference presentation,
- One journal paper,
- One Master Degree thesis.

6 Reference:

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