Accepted Manuscript

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PII: S1738-5733(17)30252-8

DOI: 10.1016/j.net.2017.09.006

Reference: NET 439

To appear in: *Nuclear Engineering and Technology*

Received Date: 4 May 2017

Revised Date: 5 September 2017

Accepted Date: 8 September 2017

Please cite this article as: S. Yu, J. Lee, B. Park, I. Cho, H. Lee, Design Considerations for Teleoperation Systems Operating in Gas-Tight Argon Cells, *Nuclear Engineering and Technology* (2017), doi: 10.1016/j.net.2017.09.006.

Design Considerations for Teleoperation Systems Operating in Gas-Tight Argon Cells

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Abstract

In the nuclear industry, mechanical engineers spend a significant portion of their time designing equipment such as manipulators, bogies, mechanical grippers, and so on. Some customized designs can be considered standard mechanical equipment in this area, although it is not unusual to find that an existing design cannot simply be copied from one project to another. Varied performance requirements can dictate that redesign, often quite extensive redesign, is required. However, if something similar has been done before, engineers could use that as a starting point for the new project. In this regard, this study presents several guidelines inspired by previous design knowledge for similar development cases. Moreover, this study presents more detailed suggestions such as design guidelines for an argon-based hot cell atmosphere and design experience for a large-scale practical hot cell facility. Design considerations and case studies dealt with in this study are dedicated to teleoperation manipulators applied at a large-scale argon cell facility, PRIDE, at the Korea Atomic Energy Research Institute (KAERI). In particular, as case studies to support recommendations, a fabricated telemanipulator system for PRIDE is introduced and several kinds of experimental results associated with it are presented.

Keywords: Hot cell facility, Teleoperation system, Telemanipulator, Design requirement

1. Introduction

Remote handling manipulators are widely applied to operate and manage the equipment installed in a hot-cell facility. This kind of manipulator is generally composed of a master system and a slave system, which have the same structure in order to simplify mechanical structure while achieving operability by the user. Until now, many kinds of remote manipulators related to remote handling tasks in a cell have been developed, and teleoperation systems using manipulators are known as a reliable technology for reducing user radiation exposure (Rennich and Burgess 2006; Pittman et al. 1999). In particular, this technology is accepted not only as a solution in the nuclear industry for completing tasks such as dismantling outworn equipment and managing nuclear reactor cores, but also for extreme cases (Lee 2009). This study deals with several issues regarding design guidelines for telemanipulator systems and the practical telemanipulation tasks presented with them. In particular, the remote handling performance of the considered teleoperation system, known as a bridge-transported dual-arm servo manipulator (BDSM), installed at the developed pyroprocess integrated inactive demonstration (PRIDE) facility (Fig. 1), is evaluated under a maintenance task. The BDSM is designed to cover a large area while minimizing unreachable areas, and this system can be operated with a master-slave manipulator (MSM) for the various cooperative tasks in the PRIDE cell (Lee et al. 2012). This study is organized as follows. First, basic information and specifications of the target facility are presented. Second, several guidelines for selecting telemanipulators are suggested for the facility that is under consideration based on the mechanical and electrical aspects of the mechatronic system in an argon atmosphere. Third, several case studies for the suggested approaches are presented with a practical system consisting of a telemanipulator and its auxiliary devices, and finally, this study concludes by discussing the suggested guidelines.

2. Target Facility

In this section, a similar, well-known fuel conditioning facility (FCF) is introduced for comparison. All handling and process equipment at the FCF at the Idaho National Laboratory (INL) is operated and maintained using remote control technologies such as master-slave manipulators (MSMs), electro-mechanical manipulators (EMMs), and overhead cranes. In-cell equipment or components fit within a transfer envelope of 70 in diameter × 94 in height (178 cm × 239 cm). Weights