UKAEA-CCFE-CP(20)70

Guy Burroughes

Control System Frameworks for Long-lived Remote Handling Plants

Control System Frameworks for Long-lived Remote Handling Plants

Guy Burroughes

This paper has been submitted to
UK-RAS Network Conference on Robotics and Autonomous Systems: robots working for and among us,
Bristol, UK, 12 December 2018

Control System Frameworks for Long-lived Remote Handling Plants

Introduction

The European Spallation Source (ESS) is a multi-disciplinary research facility which will be the world's most powerful pulsed neutron source. A critical component of ESS will be a facility for handling radioactive waste and preparing it for safe disposal; this facility must operate for at least 40 years. Safe disposal of ESS waste requires the dexterous tele-manipulation of large, highly activated payloads in a shielded chamber: a hot cell.

Traditionally hot cells are built with lead glass windows to allow direct observation by operators. However, as the complexity and scale of required handling operations increases, the restrictions imposed by such windows become problematic, motivating the development of hot cells without any windows. RACE is building on its experience operating the Joint European Torus (JET) remote handling system to develop a windowless hot cell for the ESS Active Cells Facility (ACF), featuring a fully integrated remote handling system and a state-of-the-art synthetic viewing system.

The ESS ACF will contain equipment for dividing large activated components and storing them in shielded containers. Due to the high levels of radiation being emitted by the components, it is not safe for a human to do this from within the cell. It is therefore necessary to remotely handle the components and operate size reduction equipment, requiring robotic manipulators to be operated by humans in a control room outside the cell.

Commented [KR1]: some repetition of concepts, can be trimmed

Following a brief background into the current state-of-the-art in control systems for robotic remote handling, this paper will present the proposed design of the ESS ACF control system.

Background

JET has been remotely maintained since the mid 1990's, accumulating a legacy of over 35,000 person-hours of operations time. Routine remote maintenance work is undertaken by a dexterous, force-reflecting master-slave servo-manipulator called MASCOT. The MASCOT slave unit is transported on the end of a 12-metre-long articulated robot: a Boom. Meanwhile the MASCOT master station is driven by a team of experienced operators situated in the Remote Handling Control Room. A second articulated Boom works in parallel with the first to transfer components and tools between storage facilities outside the torus and the workplace within the torus.

Commitment to a man-in-the-loop philosophy has allowed the JET Remote Handling capability to increase stepwise with the number of applications. This philosophy has resulted in a flexible remote handling system where the expensive and long lead-time elements such as the Articulated Boom and MASCOT are not required to change with the application. However due to decades of contract extensions and short-term engineering adaptations, the plant has become highly coupled and suffers from low cohesion, meaning that small engineering changes in one area can have drastic effects on the rest of the system. One example of such a situation is the case whereby the control cubicle for camera units was adapted to also control the remote welding rig, simply because there was spare capacity. This in turn meant that the camera system could no longer be safely accessed during welding operations, delaying necessary upgrades. Clearly adaptations of this kind are harmful to the maintainability of a long-lived plant, and hence a key focus for the ESS ACF control system design for is maximising Reliability, Availability and Maintainability (RAM).

ACF Control System

The overarching requirement for the ESS ACF Control System is to bind together a kaleidoscope of devices into a single coherent system, allowing control of all aspects of the facility from a single control room. This integration of dozens of third-party functional units must be implemented at varying levels, ranging from closed-loop control of individual motor drives or command-and-response style PLC control up to high-level inverse kinematics solving and logical interlocks.

The long lifespan and complexity of the facility precludes a monolithic architecture like that of the JET remote handling system. Aside from the obvious maintainability issues it would cause, the constrained size of the control room would not allow dedicated Human-Machine Interface (HMI) stations for each piece of controlled equipment. Instead, a distributed design providing flexible software-based HMIs has been chosen.

The ESS ACF will require advanced control systems that will need to be maintainable and upgradable for decades, whilst also meeting stringent safety and functional requirements. For this purpose, it has been determined that the RACE's CorteX control systems framework will be used. CorteX is a robust decentralised systems-of-systems framework, which enables pieces of complex equipment to communicate. The framework utilises extensive layers of abstraction combined with standardised self-describing communications to make the ESS ACF control system maintainable, upgradable, and avoid needless vendor lock-in.

The ESS ACF control system will be comprised of reusable modules that can be proven and verified. The system will implement logical interlocks between devices to maximise equipment lifespan, but will not provide Functional or Radiological safety. This design decision has been made to limit undue burden on the control system and allow for more conventional and proven safety solutions to exist in parallel, allowing rapid development and integration with third party systems.

The unusually extensive level of control systems integration will optimise Human-Machine interactions, as a single unified HMI for controlling all aspects of the plant will be presented to users. This will help reduce training costs and the number of incidents caused by human error. The data-driven Graphical User Interface will allow rapid reconfiguration as operational needs evolve over the lifespan of the facility.

Finally, the deep level of integration allows all sensor data to be accessible from a single unified data structure. The primary advantage of this in the short-term is the provision of condition monitoring analysis, which allows anomalies in hardware to be identified and quickly corrected as part of an ongoing preventative maintenance scheme. More importantly, it lays the foundations for autonomous control strategies to be developed, by providing a single interface for monitoring and controlling the facility.

Conclusion

The ESS ACF will use a state-of-the-art distributed control system, built using the CorteX framework. This system will provide a single interface between human operators and robotic equipment, optimising process workflows with a focus on long-term reliability, availability and maintainability. Flexibility for future upgrades such as autonomy is built into the system architecture, allowing the system to be used for the projected 40-year lifespan of the European Spallation Source and beyond.