UFTR Digital Control System Upgrade for Education/Training of Engineers and Operators

FINAL REPORT November 2014

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Executive Summary

As nuclear power plants age, analog safety instrumentation obsolesces and becomes difficult to maintain. Adoption of advanced digital instrumentation and control (I&C) technologies in the nuclear sector has significantly lagged that of other industries. Utilities have been slow to implement these systems due to regulatory licensing uncertainty and a lack of internal expertise with new systems. As the previous generation of the nuclear workforce retires, the pool of available expertise in analog technology declines. The experience at Japan's Fukushima Power Station shows the need to continually modernize and augment reactor safety and operational systems.

In Operation since 1959, the UFTR has undertaken an ambitious project to renovate replace all aspects of the facility, with a center point on upgrade of the 50-year old analog I&C systems with new, modern digital systems. Once modified, the facility will provide training and education for the future workforce as well as a demonstration platform in the area of advanced digital I&C for nuclear reactors. This effort ushers in a new focus on advanced digital I&C research, development, and testing, and greatly augments the existing Nuclear Engineering Program at UF. Further, the UFTR facility will offer training courses for other educational institutions in the state, such as Florida International University and Indian River State College, who provide the majority of nuclear technician education in Florida, as well as training for personnel from nuclear utilities and government agencies, including the Nuclear Regulatory Commission.

The refurbishment project was launched based on the conversion of the reactor core from high-enriched uranium to low enriched fuel as part of a nationwide effort after 9/11. As part of this program, many major upgrades have been completed over the FESC project period, including an NNSA-funded security system ($460k), a renovated HVAC system ($250k), a new stack exhaust monitor and high plume exhaust system funded by DOE ($212k), and a new nuclear instrumentation system ($300k). FESC funding has been leveraged to augment these efforts, including the design of a new control blade drive systems for the UFTR and purchase of field instrumentation sensors to integrate with the new control design.

The completion of the full digital control system portion of the upgrade has been adversely affected by two external factors. First, the UFTR had established a contract with Siemens Energy for the design and manufacture of the control system interface which has been dissolved. A business restructuring driven by Siemens Global resulted in the disbanding of the Siemens Energy Nuclear I&C division responsible for this project. After this, the UFTR decided to pursue another vendor partner for this system. Secondly, the Nuclear Regulatory Commission has de-prioritized licensing actions for existing research reactors resulting in multi-year delays in the approval of upgrades. Congress has declared the shortage of medical isotopes a national security concern. Several new nuclear reactor-based medical isotope production projects have begun and are in the process of submitting licenses to the Nuclear Regulatory Commission, which has prioritized these projects over licensing of existing research reactors.

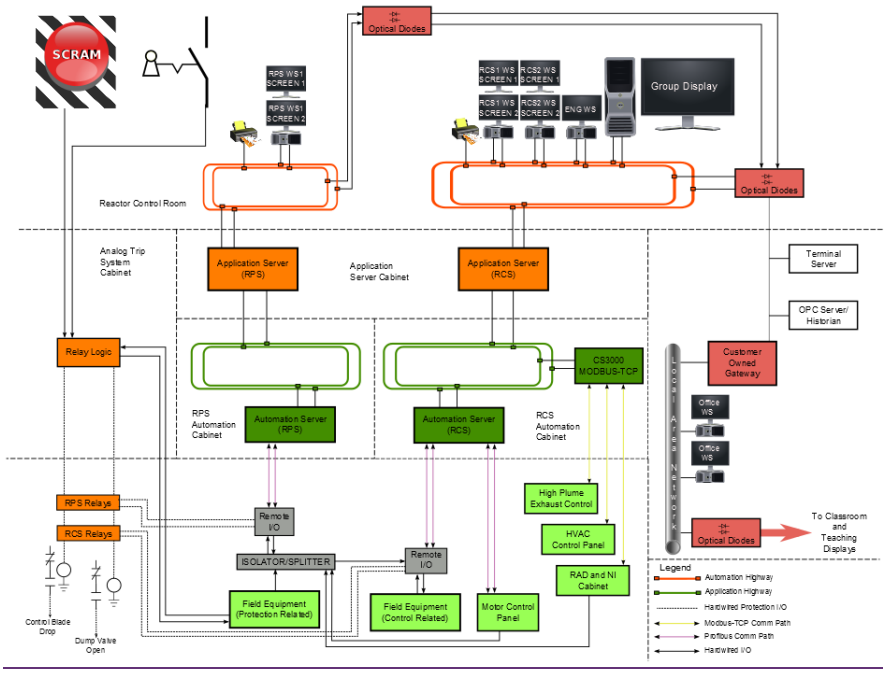
Despite these adverse project impacts, the UFTR will restart operations at the end of 2014, with most upgrades fully implemented. The digital control interface design is complete and manufacturing and install are on hold pending both identification of a new manufacturing partner and regulatory approval. FESC funding has been instrumental in maintaining progress of refurbishment and ensuring the success of existing efforts despite these adverse impacts.

Project Activities, Results and Accomplishments

Digital Controls System

University of Florida Training Reactor has completed the detailed design work for the digital controls system and produced a final Functional Requirements Specification document from which a system can be built. The UFTR will commission operations at the end of 2014. After manufacture, the digital system will be integrated into operations for an extensive testing and monitoring phase designed to satisfy requirements of the Nuclear Regulatory Commission.

The final system concept design, showing the system breakdown into a separate shutdown and control sections is shown below:



Expenditure of FESC Funds

FESC funds were spent in as follows:

- $35,000 to Siemens for digital control hardware
- $3,921 to contractors for the UFTR high plume exhaust control system
- $1,441 for electronics for the temperature monitoring system.
- $4,600 for control system components

The high plume exhaust system was funded by a Department of Energy grant in 2012. FESC funds were used for hardware and contracting work to integrate the exhaust system with the digital control system. Funds for the temperature monitoring system was used similarly.

Nuclear Instrumentation: The new nuclear instrumentation is the link between the operating reactor and the new digital control system. Several of the functions of the old control system will be moved into the NI system, including calculation of reactor power and period. The equipment was delivered at the end of 2012, and installation will occur throughout 2013 and 2014, concurrent with the control system. This was funded by from a mix of sources, including a Department of Energy Grant ($118,000), a contribution from Progress Energy ($125,000), and UFTR funds ($60,000).

Body scanner: Canberra donated a Gem 5 whole-body radiation monitor. This device is for exit monitoring of personnel leaving the reactor cell. Measurement ensures that workers are not contaminated by radioactive material. This unit replaces the existing obsolete exit monitor.

Wallplate networking upgrade: The digital control systems communicate using networking protocols. $22,000 was spent upgrading the UFTR building infrastructure to the wall plate networking system.

Waste disposal: The UFTR had accumulated more than six cubic meters of radioactive waste material. We contracted with a transport and disposal firm to send the waste for disposal in Tennessee. This improved facility safety and cleared out sections of the reactor cell that were previously blocked off.

HVAC: Control equipment and instrumentation have strict humidity and temperature requirements, and the existing air handling unit is unable to continue meeting those requirements. A new air handler, filter unit, and ductwork has been installed to replace the existing unit.

Physical Infrastructure Upgrades: There are ongoing efforts with procuring field equipment and interface equipment in support of the Digital Control Project, along with modifications to both control rooms. Machine shop cleanup and abatement of lead and cadmium contamination has been completed.

Security: The National Nuclear Security Administration (NNSA) has provided the UFTR with $462,000 to add new security features and completely renovate its existing security systems. This work has been completed during the project period.

New Partnerships Developed

Three new partnerships have been formed in this reporting period: an industrial training partnership, an in-state medical physics effort, and an international research collaboration on reactor safety.

UFTR – IRSN – FPL Workforce Development Partnership

A new partnership has been formed for nuclear training with FIU and IRSN as primary educational partners. The UFTR has linked up with the $3M-funded Regional Center for Nuclear Education and Training hosted at IRSN and Florida Power and Light / NextEra to develop an enhanced program for training of non-nuclear engineers in the nuclear industry.

To ensure growth and sustainability of Florida's nuclear energy industry, there is a need to enhance Florida's nuclear careers. Training next generation nuclear workforce will provide the skillset needed to expand industry in the state of Florida, engagement at all levels of education (including the graduation of new engineers, technicians and outreach to K-12). Collaboration of Florida academic institutions and industrial partners is paramount to success. Both organizations have appointed representatives to the UFTR advisory board and committed funds for acquiring a nuclear plant simulator, should federal funding also become available.

UFTR – UF Health Cancer Center

The UFTR has participated as a partner with the UF Health Cancer Center for several large center grant proposals on the intersection between nuclear engineering and radiation oncology, including proposals to NASA and NIH. The partnership core leverages four facilities for animal and human irradiation as described in Facilities and Resources: NSRL (heavy ions), UFPTI (protons), UF NGF (neutrons), and UF Shands Cancer Center (gamma-rays for reference irradiations). This core further provides both computational modeling to support both the design of proton and neutron animal irradiations, and anatomic models for organ dosimetry.

UFTR – EPFL Research Reactor Safety Collaboration

Finally, the UFTR is partnering with the Swiss Federal Institute of Technology, Lausanne (EPFL) and the CROCUS reactor to develop new methods for characterizing safety performance of research reactors. This collaboration has a financial commitment of $300k from EPFL to acquire new graduate students and postdoctoral scientists to work with UF in this area.

The principal aim of the project is, in collaboration with the University of Florida and the University of Florida Training Reactor (UFTR) facility, to develop and validate a detailed coupled multiphysics models of the zero-power CROCUS reactor at EPFL and the UFTR, for the comprehensive analysis of the reactor behavior under transient (neutronic or thermal-hydraulic induced) conditions.

These two reactors differ significantly in the core design and thermal power output, but share unique heat transfer and flow characteristics (single-phase laminar flow in complex geometries with the possibility of mechanically entrained air bubbles). Validation experiments will be design to expand the validation domain of these existing models and computational codes and techniques. In this process, emphasis will be put to validate the coupled models developed and get confidence in their applicability for safety analysis.

EPFL will be principally responsible for the design and implementation of transient experiments to generate a database of reactor parameters, i.e. flow distribution, power profile and power evolution to be used to validate against code predictions. UF will focus on the generation of the coupled neutron kinetics and thermal-hydraulic models, including implementation of a TRACE/PARCS reactor simulator model, a PARET model, and development of full-field computational fluid dynamics models (using OpenFOAM) for refined thermalhydraulics physics treatments. In this subtask of the project, the aim is to verify by means of CFD the validity of TRACE predictions for atmospheric pressure water flow.

The work in this project serves as a basis to develop two Ph.D.s, one at each University. The scientific understanding of these multiphysics domains will be expanded and the validation base of commonly-used calculation methods will be expanded to cover a new range of research reactor types. From a practical perspective, CROCUS and the UFTR will have fully validated reactor dynamic and transient models for accident analysis. With these validated models, both facilities will have improved capabilities and flexibility for extended operations. CROCUS and the UFTR will be able to make future reactor modifications with reduced regulatory resistance. A feasibility analysis of future power uprates at these facilities will also result.

Patents
None

Publications

1. K.A. Jordan, D. Springfels, D. Schubring, ``Modern Design and Safety Analysis of the University of Florida Training Reactor" Nuclear Engineering and Design *Submitted*.
2. C.R. Hughes, O. Pelaez, D. Schubring, and K.A. Jordan ``One-row Scwr Design Analysis Using Coupled RP/TH Analysis" Nuclear Technology *Submitted*.
3. J.M. Lewis, R.P. Kelley, D. Murer, and K.A. Jordan ``Fission Signal Detection using Helium-4 Gas Fast Neutron Scintillation Detectors" Applied Physics Letters. 105 (1), 014102.
4. J.M. Lewis, D. Raetz, D. Murer, and K.A. Jordan, ``In-situ Fission Rate Measurements using Helium-4 Scintillation Detectors" IEEE Transactions on Nuclear Science. 64.4, (2014) 2217-2221.
5. C.R. Hughes, O. Pelaez, D. Schubring, and K.A. Jordan ``One-Row SCWR Design Analysis using Coupled RP/TH Analysis" TH'14 International Embedded Topical Meeting on Advances in Thermal Hydraulics 2014, June 15-19, 2014, Reno, NV.
6. K.A. Jordan, K. Goluoglu, B. Shea ``Status of the Major Refurbishment and Digital Conversion of the University of Florida Training Reactor" Trans. American Nuclear Society Winter Meeting, Nov 2013 *Invited*.
7. K.A. Jordan, D. Schubring, G. Girardin, A. Pautz ``Validation of Reactor Physics-Thermalhydraulics Coupled Calculations in Water-Cooled Research Reactors with Laminar Flow Regimes" Joint IGORR (International Group on Research Reactors)/IAEA 2013 Conference, Oct. 13-18, 2013 Daejeon, Korea.
8. K.A. Jordan, D. Seifman, S. Kowalczyk, D. Cronin ``A Fully-reconstituted Safety Basis at the University of Florida Training Reactor" Joint IGORR (International Group on Research Reactors)/IAEA 2013 Conference, Oct. 13-18, 2013 Daejeon, Korea.
9. K.A. Jordan, B. Shea, M. Berglund ``Preparing a Research Reactor for the next 50 years: The UFTR Facility Renovation" Joint IGORR (International Group on Research Reactors)/IAEA 2013 Conference, Oct. 13-18, 2013 Daejeon, Korea.
10. C. Hughes, D. Schubring, K.A. Jordan , D. Raetz, ``Coupled Computational Heat Transfer and Reactor Physics for SCWR" Proc. 2013 ASME Summer Heat Transfer Conference, Minneapolis, MN, July 14-19 2013
11. J. Lewis, G. Bickford, and K. A. Jordan ``Licensing Aspects of the Digital Upgrades to the UFTR Protection and Control Systems" Proc. 8th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies (NPIC&HMIT 2012), San Diego, CA, July 22-26, 2012.
12. G. Bickford, J. Lewis, and K. A. Jordan ``Implementation of Digital Upgrades to the UFTR Protection and Control Systems " Proc. 8th International Topical Meeting on Nuclear Plant Instrumentation, Control and Human Machine Interface Technologies (NPIC&HMIT 2012), San Diego, CA, July 22-26, 2012.