University of Western Ontario – Jin Jiang IRC

NSERC/UNENE Senior Industry Research Chair in Control, Instrumentation and Electrical Systems

The Control, Instrumentation & Electrical System (CIES) Laboratory at The University of Western Ontario was established in 2003 with the support of UNENE. CIES covers a wide array of research topics related to instrumentation, control, and electric systems in nuclear power plants. Current research encompass six major subjects including modeling, simulation, advanced control, safety systems, performance monitoring and diagnostics, networks and devices. Each of these subjects is addressed with respect to the short, medium and long term requirements of nuclear power industries.

Research Program

Reactor Modeling, Control and Diagnosis

Pressurized Heavy Water Reactor (PHWR) modeling focuses on the development of MATLAB/Simulink based models to facilitate the analysis and design of the control systems within CANada Deuterium Uranium (CANDU) reactors. The flux control loop model is developed and can be extended to encompass larger subsystems and other type of reactors.

Dynamic modeling of CANDU reactor using Modal Synthesis method, compared with Coarse Mesh Nodal method, is performed. This method will be integrated into the existing MATLAB/Simulink platform of CANDU reactor. This enhanced model will be used to investigate multivariable feedback control for reactor power regulating systems.

Super Critical Water Reactor (SCWR) is one of the six types of Gen IV reactors. The dynamic characteristics of a nuclear SCWR are quite different from other existing reactors. Therefore, it is important to develop adequate models for SCWR to facilitate design, analysis and controls.

A fault detection and isolation strategy for fixed In-Core Flux Detectors (ICFD) in CANDU reactors is proposed and validated, where the correlations between proximate ICFDs are utilized. Advanced performance monitoring and diagnostic techniques are being developed for safe operations of existing and future nuclear power plants.

Advanced Process Control, Fieldbus, and Communications

Evaluation of Distributed Control Systems (DCS), fieldbus technologies, and advanced control algorithms for potential applications in nuclear power plants are carried out. These evaluations are performed on a test-bench composed of relevant commercial products, physical mock-ups, and an OPG desktop training simulator. Further the development of smart sensors with advanced diagnostic capabilities is investigated.

Smart sensor development involves the implementation of sensors which are able to communicate through fieldbus protocols such as Profibus and Foundation Fieldbus and are also capable of performing additional functions on top of basis control tasks. These algorithms can include diagnostic schemes and also cryptographic algorithms for security purposes. The suitability and performance of these algorithms are evaluated, and prototypes are constructed.

Research on wireless communications and computer networks in nuclear power plant environment involves the design and implementation of wireless systems that conform to the electromagnetic compatibility (EMC) conditions and regulations in nuclear power plants. Using wireless technologies can bring many potential benefits, for example, reduced cabling, lowered installation and maintenance cost, and fast commissioning and upgrading.

Design, Evaluation, and Innovative Safety Systems

Application of Field Programmable Gate Array (FPGA) technology to Shutdown System One (SDS1) involves converting SDS1 trip logics to digital system logics, and then implementing them into an FPGA device. FPGA technology provides a more reliable platform and faster execution rate of control logic and can potentially increase the safety

margin of a plant. To validate and qualify FPGA implementation, simulation and safety analysis are being performed.

Similar to FPGA implementation, Programmable Logic Controller (PLC) implementation of SDS1 logic is performed. SDS1 logic is translated to function block diagrams and is implemented on a Tricon v9 triple redundant PLC. The performance of the system is evaluated against expected response from the nuclear power plant simulator. Simulation capabilities are established through incorporation of the advanced digital controller hardware (FPGA or PLC) into a hardware-in-the-loop (HIL) simulation environment. Through HIL simulation, new technologies can be qualified, verified and validated for specific applications.

Advanced shutdown systems can be achieved by implementing the concept of analytic redundancy. Based on mathematical models of the dynamic systems within a NPP, the next evolution of shutdown parameters will be calculated, supplied to the shutdown system logic, and compared with the trip set-points. This research aims to develop advanced shutdown systems which can reduce common cause failures, decrease the mean failure down time, avoid complex channel separation and increase the pressure boundary integrity.

Research Facilities

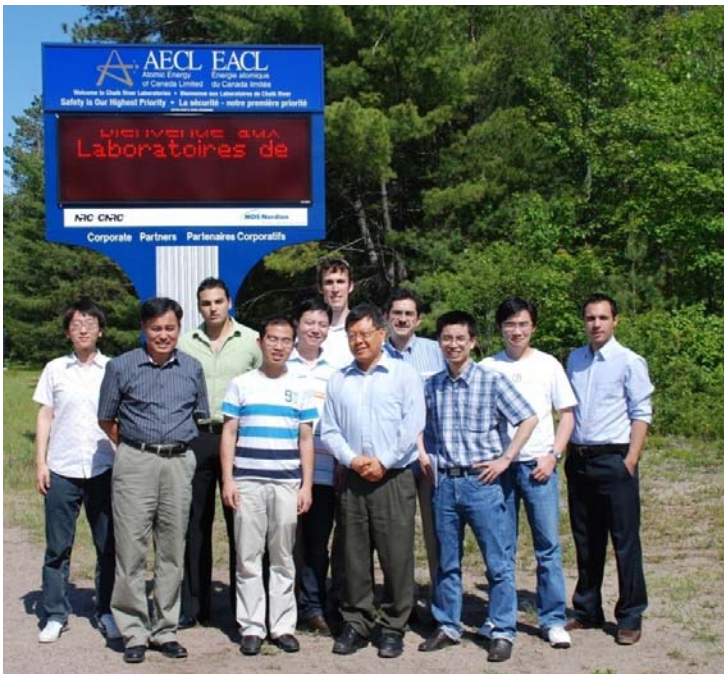
Over the last seven yours, we have developed some state-of-the-art research facilities to support the above research activities and training programs for highly qualified personnel. In 2009, we have moved into a new lab in green building. We have also acquired with six large projection displays and an operator console to mimic a full digital human machine interface station. This facility has full connectivity to existing I&C systems, which includes:

- Tricon v9 system
- HFC 6000
- HFC non-safety DCS
- FPGA development system
- Siemens PCS 7 redundant control system
- Honeywell C-300 DCS
- Emerson DeltaV DCS with full fieldbus connectivity
- RTDS real-time grid simulator
- Hardware experimental test bench
- Wireless monitoring nodes, and
- Smart sensor development systems.

Current Research Team

- Prof. Jin Jiang (IRC Chair)
- Dr. Xinhong Huang (Research Engineer)
- Dr. Qingfeng Li (Research Engineer)

- Mr. Mahmood Akkawi (MESc Candidate)
- Mr. Sungwhan Cho (PhD Candidate)
- Mr. Hash Hashemian (PhD Candidate)
- Mr. Jianping Ma (PhD Candidate)
- Mr. Drew Rankin (PhD Candidate)
- Mr. Jingke She (PhD Candidate)
- Mr. Peiwei Sun (PhD Candidate)
- Mr. Ahmad Osgouee (PhD Candidate)
- Mr. Lingzhi Xia (PhD Candidate)
- Mr. Quan Wang (PhD Candidate)



Publications (Selected)

Book

1. J. M. Zhang and J. Jiang, *Control of Nuclear Reactors*, Atomic Energy Press, 2009 (in Chinese)

Journal Papers

1. H. M. Hashemian, and J. Jiang, “A Practical Review of Methods for Measuring the Dynamic Characteristics of Industrial Pressure Transmitters,” ISA Transactions, 49(1): pp. 2-9, Jan. 2010.
2. H. M. Hashemian, and J. Jiang, “Pressure Transmitter Accuracy,” ISA Transactions, 48(4): pp. 383-388, Oct. 2009.
3. A.Kadri, R. Rao, and J. Jiang, “Low-power chirp spread spectrum signals for wireless communication within nuclear power plants,” American Nuclear Society Nuclear Technology, Vol. 166, pp. 156-169, 2009.
4. Q. Li, D. Rankin, and J. Jiang, “Evaluations of foundation fieldbus H1 network-induced delays,” IEEE Transactions on Instrumentations and Measurement, Vol. 58, No. 10, pp. 3684-3695, 2009.
5. H. Javidnia, and J. Jiang, “Modelling and simulation of a CANDU reactor for control system design and analysis,” American Nuclear Society Nuclear Technology, Vol. 165, pp. 174-189, 2009.
6. S. Cho and J. Jiang, “Analysis of surveillance test interval by Markov process for SDS1 in CANDU nuclear power plants,” Reliability Engineering and System Safety, Vol. 93, pp. 1-13, January 2008.
7. S. Cho and J. Jiang, “Effect of the surveillance test frequency of SDS1 on the core damage probability, ANS Journal of Nuclear Technology, 2007.
8. L. Lu and J. Jiang, Joint failure importance for noncoherent fault trees, IEEE Trans. on Reliability, Vol. 57, No. 3, pp. 435-443, Sept. 2007.
9. L. Lu and J. Jiang, Analysis of on-line maintenance strategies for k-out-of-n standby safety systems, Reliability Engineering and System Safety, Vol. 92, No. 2, pp. 144-155, Feb. 2007.

Refereed Conference Papers

1. J. Ma, and J. Jiang, “Applications of Fault Diagnosis in Nuclear Power Plants: An Introductory Survey,” Proceedings of the 7th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes (SAFEPROCESS 2009), pp. 1150-1161, Barcelona, Spain, June 30 – July 3, 2009.
2. J. Ma, and J. Jiang, “A Fault Detection and Isolation Technique for In-Core Flux Detectors,” Proceedings of the Sixth American Nuclear Society International Topical Meeting on Nuclear Plant Instrumentation, Control, and Human-Machine Interface Technologies (NPIC & HMIT 2009), Knoxville, Tennessee, April 5-9, 2009.
3. S. W. Cho, and J. Jiang, “Drift Detection of Sensors in the PHT System of CANDU-6 Plants using Analytic Redundancy,” NPIC & HMIT 2009, Knoxville, Tennessee, April 5-9, 2009.
4. J. K. She, and J. Jiang, “Application of FPGA to Shutdown System No. 1 in CANDU,” NPIC & HMIT 2009, Knoxville, Tennessee, April 5-9, 2009.

5. A. Kadri, J. Jiang, and R. K. Rao, “Wireless Sensor Networks and their Potential Applications in Nuclear Power Plants,” NPIC & HMIT 2009, Knoxville, Tennessee, April 5-9, 2009.
6. M. Bahramali, J. Jiang, and A. Reyhani-Masoleh, “Security Issues in Industrial Network Control Systems: A Survey,” NPIC & HMIT 2009, Knoxville, Tennessee, April 5-9, 2009.
7. Q. Li, and J. Jiang, “Hardware-In-The-Loop Performance Evaluation of Network-based Steam Generator Level Control,” NPIC & HMIT 2009, Knoxville, Tennessee, April 5-9, 2009.
8. D. J. Rankin, J. K. She, and J. Jiang, "Evaluation of Safety PLCs and FPGAs for Shutdown Systems in CANDU Nuclear Power Plants," 3rd International Symposium on Future I&C for Nuclear Power Plants (ISOFIC2008), Paper ID: 148, Harbin, Heihongjiang, China, 2008.
9. Abdullah Kadri, and J. Jiang, "Experimental Evaluation of Wireless Sensor Networks for Potential Applications in Nuclear Power Plants," 3rd International Symposium on Future I&C for Nuclear Power Plants (ISOFIC2008), Harbin, Heihongjiang, China, 2008.
10. D. J. Rankin, and J. Jiang, "Hardware-in-the-loop Simulation using Tricon v9 Safety PLC," Proc. of the 16th International Conference on Nuclear Engineering (ICONE), Orlando, Florida, May 11-15, 2008.
11. Q. F. Li, D. J. Rankin, and J. Jiang, "Evaluation of Distributed Control Systems and Network-based Control for Nuclear Power Plants," International Atomic Energy Agency (IAEA)Technical Meeting on Instrumentation and Control Systems, Toronto, Ontario, Oct. 28 - Nov. 3, 2007.

Other Activities

Dr. Jiang has maintained close ties with industry partners in AECL, OPG, and Bruce Power. He also actively participated activities in IEC standard committee on I&C systems important to safety. He has contributed to IAEA in developing technical guides for I&C systems and serve as technical expert on I&C system review missions in Korea.

In the last five years, Dr. Jiang organized UNENE Annual I&C Workshops every year at partners’ facilities to report to the research activities in details and to interact with industrial partners.

He also served on the program committees for several key conferences in nuclear I&C area, such as ANS Topical Meeting on Nuclear Instrumentation, Control and Human Machine Interface Technology.

Dr. Jiang also collaborated with partners in Xi'an Jiaotong University, China, which results in a publication of a book on "Control of Nuclear Reactors".