LIMERICK BWR TURBINE CONTROL AND PROTECTION SYSTEM UPGRADE SUCCESS

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Abstract

Westinghouse and Exelon have successfully implemented a digital electro-hydraulic control (DEHC) at Limerick BWR Unit 1 Station to perform the turbine control, protection and reactor pressure functions. The DEHC replaces analog controls and addressed system performance, obsolescence and reliability. This was a first-of-a-kind application for control and protection of the main turbine and BWR pressure control for the distributed control system utilized. The demolition of analog equipment, main control room and front standard modifications, and acceptance testing were completed on schedule during the normal 2014 outage. Key aspects of the project that facilitated this success will be discussed and presented.

Introduction

Limerick Generating Station is a nuclear power plant located in southeastern Pennsylvania, about 20 miles northwest of Philadelphia in Montgomery County. The station consists of two BWR/4 units. Unit 1 and Unit 2 began commercial operation on February 1, 1986, and January 8, 1990, respectively, utilizing the General Electric (GE) Mark I analog electro-hydraulic control (EHC) system, with mechanical overspeed trip devices and an electrical backup overspeed trip system. Each BWR unit had been uprated to a reactor thermal power of 3515 MWth, with a rated electrical power output of 1245 MWe. The original high-pressure (HP) turbine and three low-pressure (LP) turbines had been replaced with Siemens turbines during the 1998-1999 time period, but had been operating with the original analog EHC system. The steam flow to the turbines are controlled by four main stop valves, four control valves, and six combined intercept valves. The turbine steam flow bypass system capacity is approximately 24.3 percent of rated turbine flow, and consists of 9 bypass valves arranged in a steam chest.

1.1 Limerick Boiling Water Reactor and Turbine Electro-Hydraulic Control System

Limerick Generating Station is a nuclear power plant located in southeastern Pennsylvania, about 20 miles northwest of Philadelphia in Montgomery County. The station consists of two BWR units. Unit 1 and Unit 2 began commercial operation on February 1, 1986, and January 8, 1990, respectively, utilizing the General Electric (GE) Mark I analog electro-hydraulic control (EHC) system, with mechanical overspeed trip devices and an electrical backup overspeed trip system. Each BWR unit had been uprated to a reactor thermal power of 3515 MWt, with a rated electrical power output of 1245 MWe. The original high-pressure (HP) turbine and three low-pressure (LP) turbines had been replaced with Siemens turbines during the 1998-1999 time period, but had been operating with the original analog EHC system. The steam flow to the turbines are controlled by four main stop valves, four control valves, and six combined intercept valves. The turbine steam flow bypass system capacity is approximately 24.3 percent of rated turbine flow, and consists of 9 bypass valves arranged in a steam chest.

1.2 Digital Upgrades of Turbine Electro-Hydraulic Control Systems in BWRs

To address the issues of analog control system obsolescence, reliability, maintainability, and monitor ability, turbine suppliers and third parties started to upgrade power plant turbine control systems in the late 1990s, using various digital platforms. Both triple redundant modular (TMR) and duplex architectures have been applied to a number of pressurized water reactors (PWRs) (Reference 1), while the TMR platform had been utilized in BWRs (Reference 2). Typically, the turbine original equipment manufacturers performed the digital system upgrades, but in recent years, third parties have the necessary expertise to compete and have successfully implemented EHC upgrades (References 1 and 2).

1.3 Digital Upgrade of Turbine Electro-Hydraulic Control System at Limerick BWR

The Exelon/Westinghouse team successfully executed the digital turbine control system upgrade at Limerick Unit 1. Key aspects of the project that facilitated this success are discussed including the project planning, project management/risks, software and hardware development, testing program, simulator, and installation and commissioning. Cyber security provision in the DCS is not discussed in this paper.

2. SYSTEM REQUIREMENTS AND MODIFICATION SCOPE

Prior to the EHC upgrade at Limerick, Exelon had performed upgrades at three other nuclear sites in the Exelon fleet (Dresden, LaSalle, and Quad Cities). For these sites, the EHC upgrade work scope included TMR electronics along with the installation of a redundant front standard manifold and the installation of a significant amount of redundant field devices (pressure switches, position indicators, level transmitters, etc.) all with the purpose of eliminating single-point vulnerabilities (SPVs). These upgrades were completed in late 2008.

After completion of the first three sites and before work began on Limerick, the Exelon project team was challenged to review the project requirements and reduce the project cost by a third. It was quickly identified that the only way to achieve this level of cost reduction would be to reduce the installation work scope. In the vast majority of cases the cost of designing, testing, and installing equipment far exceeded the cost of the equipment itself. This cost-reduction challenge also presented a significant risk to the goal of maximizing reliability and eliminating SPVs.

To achieve the desired cost reduction while maintaining maximum reliability, the original project work scope was reviewed and the work scope was broken down into areas such as electronics, front standard components, and field devices. The performance of the Exelon EHC systems was compared against industry data (References 3 and 4) and an estimated cost of lost power was assigned to each work scope area. In general, it was found that the electronics and front standard components were responsible for most EHC system-related events. Failures in the system electronics accounted for approximately 60% of the lost power generation due to EHC system failures. The front standard components (trip solenoids, mechanical linkage, and overspeed protection) accounted for an additional 20-25 percent and the remaining field devices accounted for the rest. Since the front standard is a common location for multiple components, the cost to address these vulnerabilities was determined to be much lower than the field components that are scattered around the turbine.

Based on this analysis, the decision was made to limit the project work scope to the system electronics (circuit cards, power supplies, relays, etc.) and front standard components. This decision allowed known SPVs to remain in the field due to the high cost of addressing them and relatively low frequency of event occurrence.

2.1 Modification Scope

The GE Mark I analog EHC system was replaced with a digital control system during the spring 2014 outage. The DCS platform utilized is a duplex control architecture used in modern control applications in power plants worldwide, but this was the first application for control, protection, and monitoring of the main turbine and pressure control system in a DEHC system for a BWR. The DEHC system resolves obsolescence issues and reduces the number of SPVs.

The modification replaced the EHC equipment within the existing panels and installed a server panel (infrastructure panel) in the Auxiliary Equipment Room (AER), added two remote input/output (RIO) panels for front standard trip functions located on elevation 239', replaced the MCR turbine control operator interface with a 22-inch human-machine interface (HMI) monitor, and replaced the vertical valve test panel with a 27-inch HMI monitor.

Modification of the turbine front standard included removal of the permanent magnet generator (PMG) and mechanical overspeed trip devices, and replacement of the trip devices with two redundant testable dump manifolds (TDMs) for tripping of the turbine. Existing field devices such as servo valves, linear variable differential transformers (LVDTs), analog transmitters, and discrete inputs/outputs (I/Os) were not modified.

3. PROJECT PLANNING AND MANGEMENT OF RISKS

For the project to be successful, it was essential to have effective project management and control using accepted project management principles. The project management was complex because one integrated project manager needed to be responsible for many phases of the project, including design, installation design, and installation site services. To start, a detailed project plan was created and adhered to by the project team. The resource plan included selecting a mix of experienced resources for lead roles and less experienced resources for supporting roles. An open and cooperative relationship between all parties was established early in the project. From the project kickoff meeting forward, team meetings involved key leads from each phase of project design and implementation and included sub-suppliers and end users. The installation lead and plant operators were involved in early design meetings to ensure familiarity with the project and understanding the decision process that lead to the design. The team had a common goal - Project Success - and held each other accountable. Weekly schedule and action item meetings were conducted to measure progress and communicate team decisions or identify project risk. A series of design reviews were planned and implemented for each phase of the project. The team design reviews were effective and produced high-quality end results. As the project team identified risks, proactive plans and contingent plans were scheduled and implemented to mitigate the risk.

Lessons learned meetings were periodically conducted to track and review lessons learned from the following sources:

- Industry
- Limerick past projects
- Project /walkdown lessons learned
- Westinghouse iKnow lessons learned
- Westinghouse past and ongoing turbine control projects

To mitigate the risk of a digital upgrade to a nuclear power plant, the project team reviewed and applied appropriate lessons learned from past digital upgrades (References 5, 6, 7 and 8). The lessons learned in References 7 and 8 were directly applicable to the Limerick DEHC and were incorporated during the design phase.

4. SYSTEM DESIGN, TESTING AND COMMISSIONING

For EHC system upgrades at operating plants, reliability and economics are important considerations. SPVs in the digital system must be eliminated as much as possible, and performance must be better than, or at least equal to, the postulated failure modes analyzed in a plant's Final Safety Analysis Report (FSAR). Extensive verification and validation (V&V) activities must be performed in the design and testing phases. Operating procedure development and initial operator training should be performed as part of the V&V activities. Labor-intensive activities, such as installation of new power or signal cables, must be minimized. Modification of the existing system and installation of new equipment must be completed within the plant outage schedule. Thus, activities that can be completed with the plant online should be maximized.

The essential activities for DEHC system design, factory testing, installation, system modification testing, simulator upgrade, and commissioning of the system are discussed in this section.

4.1 Dynamic Modeling of a BWR

To mitigate the risk of implementing first-of-a-kind DEHC system using the Westinghouse DCS platform in a BWR application, extensive testing of the hardware and software was planned. In a BWR, pressure control is performed by modulation of the turbine control valves and bypass valves. The Limerick BWRs used throttle pressure as feedback signals to the pressure regulators. A dynamic model of the BWR was necessary to demonstrate and test turbine/pressure control system stability, to develop operator displays, and for software and factory acceptance tests. One primary objective of the dynamic model was to be able to integrate the control system software and operator displays and controls in order to run simulations in real time on a portable computer. The BWR transient analysis code BISON was chosen for developing a simplified model for these purposes. The BISON code was approved by the Nuclear Regulatory Commission for transient analyses, and has been used for core reload analyses and FSAR transient analyses (Reference 9). It has been further validated using plant startup test data from an advanced BWR (Reference 10).

Using BISON, a simplified model was derived using MATLAB system identification techniques. Transfer functions, with the appropriate constants, were derived for the reactor reactivity and power processes, reactor vessel, and main steam lines. A dynamic phenomenon in the BWR called the steam line pressure resonance existed, where the fundamental resonance frequency was a function of the main steam length from the reactor vessel nozzle to the main turbine stop valves area. Thus, it was important for the simplified model to be able to model the fundamental resonance frequency for the purpose of examining the effectiveness of the dynamic compensators used in the pressure control system.

4.2 Software, HMI, and Dynamic Model Integration

Dynamic models for the HP turbine, moisture separators, LP turbines, generator, and steam admission valves were integrated with these transfer functions. The operator interface displays and control functions were integrated with these models, to simulate system performance in a laptop computer, and for development and testing of the control system software. Important pressure control functions such as the pressure regulator lead/lag, and steam line resonance compensators (SLRCs), were individually tested and their dynamic response compared to their theoretical response. The pressure control system performance and the integrated BWR dynamic model was subsequently validated using plant startup test data from Limerick steady-state and transient performance tests. The software running in this development system eventually became implemented and operated in the actual system control equipment. Changes were implemented and tested in this development system prior to implementation.

4.3 DEHC System Design and Architecture

The DEHC system replaced the existing analog controls for the turbine and eliminated the hard control and indication interfaces on the main control board. The DEHC system utilizes a DCS platform that provides the infrastructure to add and incorporate other plant control functions in the future. The DCS equipment is summarized below:

- One set of redundant controllers for turbine control and pressure control functions
- One set of redundant controllers for turbine protection
- Controller/I/O backfit plates into existing cabinets
- Two RIO cabinets (one for turbine protection and one for turbine/pressure control
- One combined engineering/database/developer tools/ historian workstation
- Two MCR operator workstations
- One datalink server
- Two network servers
- One antivirus workstation
- Two Fast Ethernet root switches supporting up to three fan outs
- Two IP Ethernet switches
- One color laser printer

The DCS utilizes duplex control architecture, with decoupled redundant I/Os between the controllers and I/O modules for critical control functions. From a functional reliability perspective, it has been argued that the duplex architecture is as good as, or better than, a TMR architecture (Reference 11).

In addition to the DCS equipment, an uninterruptible power supply (UPS) was provided to replace the PMG, and a maintenance and test system (M&TS) was provided for maintenance training and testing of system equipment. The purpose of the M&TS is to serve as a platform for software development, software debugging, hardware maintenance and testing, and engineers' training and testing. It is an off-line system not connected to the plant network or I/Os. It has same number of controllers and I/O modules with the same I/O layout as in the plant design, but has only one server performing the functions of the domain controller, historian, operator workstation, and engineer workstation. Simulation controllers have the ability to run the simplified BWR dynamic model, enabling simulation of non-existent I/O interfaces via software and over the network. For I/Os that require very fast simulation (faster than 100ms), the simulation code resides in that particular controller. None of the real I/Os are hardwired to any external simulation devices. Using equipment identical to the plant, the M&TS provides closed loop I/O simulation, which allows the end user to test and validate software and hardware modifications off-line, generate maintenance procedures, and validate maintenance activities to verify their outcomes prior to attempting them on the plant.

4.3.1 Turbine and Pressure Control

When upgrading an analog EHC system to a digital system, the normal turbine control and pressure control functions were incorporated into one set of redundant controllers. In addition to the standard function of a typical turbine control system for power plants, the pressure in a BWR is controlled by pressure regulators that modulate the turbine control valves and turbine bypass valves. In normal operation, the turbine bypass valves are closed, with the turbine operating in the turbine-follow-reactor mode. The pressure regulator function opens the bypass valves whenever the turbine cannot accept the generated steam flow from the reactor, such as during plant startup, shutdown, turbine trip, and load rejection.

The DEHC installed at Limerick contained the necessary algorithms as the analog EHC for pressure control, such as the lead/lag network and two SLRCs that were second-order notch filters. The first SLRC was designed to attenuate the fundamental pressure resonance frequency in the main steam lines, while the second SLRC was intended to attenuate the third and higher harmonic frequencies. The DEHC pressure control functions and the turbine control functions acted in conjunction with each other during turbine startup, load changes, shutdown, valve tests, overspeed tests, and testing of trip devices.

DEHC incorporated two functions not typically included in an analog EHC: (1) Compensation for control valve test, and (2) Automatic reactor cooldown control during a plant shutdown. During a control valve test, the compensation scheme opened the other control valves to an appropriate position in conjunction with the valve test closure. This minimized the pressure changes in the reactor during the valve test. The automatic cooldown function controlled the bypass valves, based upon the operator selection of a cooldown rate and a pressure target from the HMI. This automatic function relieved the operator from the tedious task of having to manually command opening of the bypass valves and trying to achieve the desired cooldown rate during a plant shutdown.

4.3.2 Turbine Protection

The turbine protection features were incorporated into a separate set of redundant controllers. As part of the EHC upgrade, the turbine front standard was modified. The new front standard equipment was designed to fit into existing equipment space constraints for ease of installation. The turbine mechanical trip devices were removed, and this trip function was replaced with a diverse turbine overspeed protection system (DTOPS). DTOPS uses three passive speed sensors that are diverse from those used for normal speed control, and three separate electrical trip modules. Each speed sensor signal inputs into a separate trip module to compare to the overspeed trip setpoint. When speed exceeds the trip setpoint, the module trip output causes de-energization of the normally energized trip solenoid in the TDM. The turbine is tripped if any two of the TDM trip solenoids are de-energized, depressurizing the emergency trip system oil resulting in rapid closure of the steam admission valves.

DEHC utilizes two redundant TDM for turbine protection. One TDM is dedicated to DTOPS, and another TDM is used for turbine trips and backup overspeed trips. The hydraulic arrangement of the TDMs is such that tripping of either TDM will trip the turbine. The backup overspeed trip uses three active speed sensors, each inputting into a speed detector module (SDM). The SDM is diverse and independent of the control software, and its trip output results in de-energization of a trip solenoid in its associated TDM. De-energization of any two of the three TDM trip solenoids results in a turbine trip. In addition, tripping of either TDM results in a cross trip to the other TDM.

4.4 Operator Reviews of HMI Design

A set of proposed HMI displays was developed for the DEHC, based upon extensive Westinghouse experience in digital upgrades of turbine control systems. In addition to the displays for turbine control, displays for the BWR pressure control functions were necessary. Prior to formal testing of the system software, Exelon's operating personnel performed reviews of the displays by simulating the various modes of plant operation, and made recommendations for improvement. This activity was made possible using the simplified BWR model integrated with the DEHC logics, displays, alarms, and control functions. The display improvements and enhanced functionality were incorporated prior to the performance of the formal software tests. The main operator interface panel utilized on the project which depeicts the turbine layout and interfaces is provided in Figure 2.

4.5 System Verification and Factory Testing

The major turbine control functions of the DEHC system are turbine shell and chest warming, turbine startup and synchronization, load control after synchronization, pressure control, valve surveillance tests, testing of trip and overspeed trip devices, turbine trips and overspeed protection, full-load rejection control, and pressure/cooldown rate control during a plant shutdown. All pertinent functional requirements were captured in a requirements traceability matrix (RTM).

The actual system equipment was staged in the factory for formal tests. Test procedures were developed for dynamic system performance tests, software and logic functional tests, and factory acceptance tests. These tests were performed using the simplified BWR dynamic model running in real time, and witnessed by Exelon personnel consisting of project management, design, instrumentation and control (I&C), maintenance, and plant operations. Test reports were reviewed and approved, and issues resolved prior to equipment shipment to the site. Appropriate requirements in the RTM for these tests are considered complete upon satisfactory performance. Certain RTM requirements were verified after further testing during site acceptance testing, modification acceptance testing, and power ascension testing

4.6 Plant Operating Procedure Development

Due to new HMI displays and controls for the DEHC, plant operating procedures needed to be modified to reflect their use. Approximately 95 plant procedures were modified, which included normal, abnormal, surveillance test, alarm response, and emergency operating procedures. One benefit of modifying these procedures using the integrated model and HMI was the ability to verify the proper operation of the system in various modes of operation, including plant startup, turbine roll up and synchronization, power ascension, valve surveillance testing, trip devices testing, overspeed trip testing, and plant shutdown. After the procedures were modified, they were validated in the full-scope plant simulator by licensed operators, and any needed changes were made to the procedures prior to their formal use in the MCR.

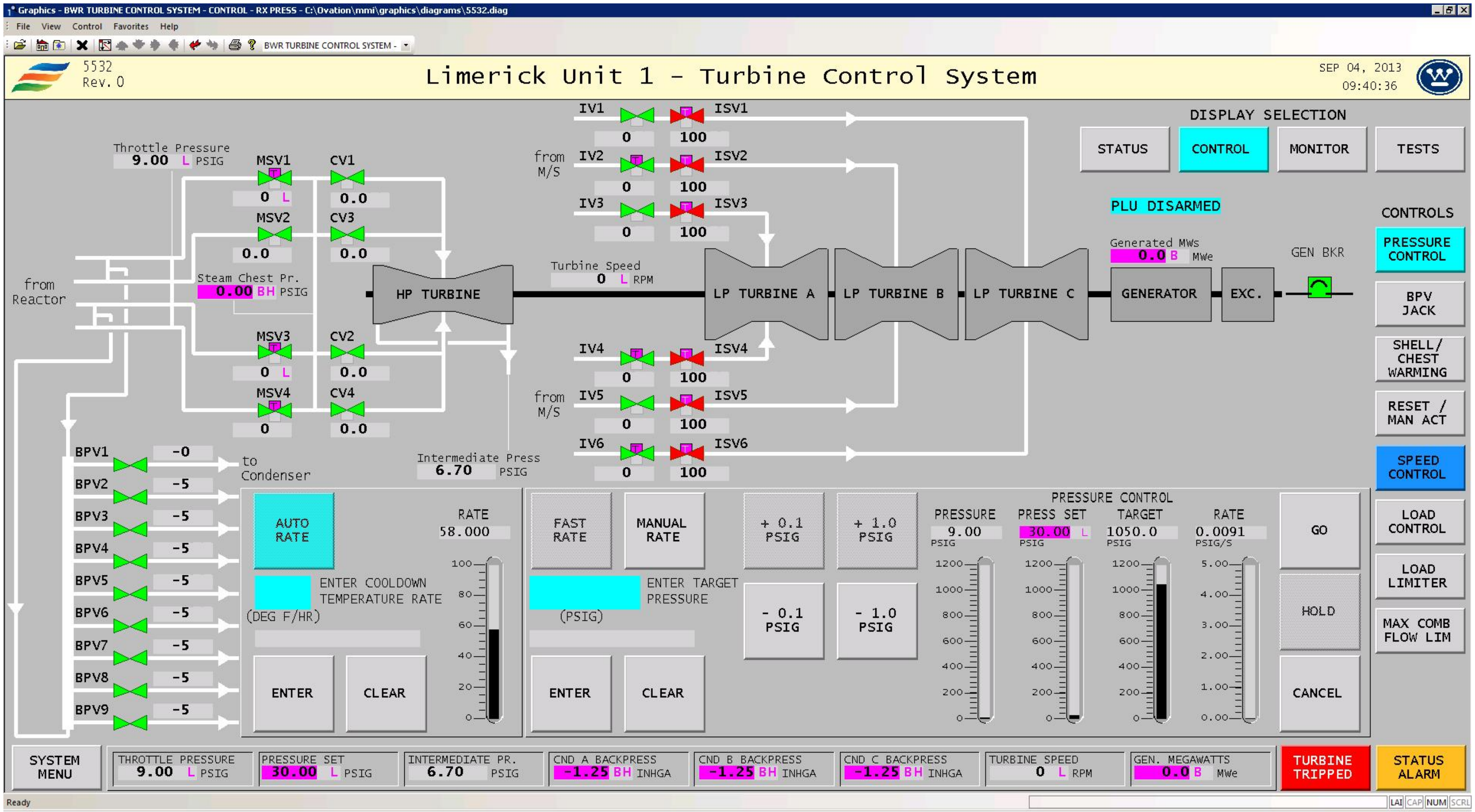

Figure 1. Main Turbine Interface Control Panel Display illustrating turbine layout and pressure control interfaces.

4.7 Site Acceptance Testing

After completion of the factory acceptance testing activities, the equipment was shipped to the site. Site receipt inspection and the following activities were performed:

- Panel wiring verification
- Equipment labeling
- TDM solenoid valve actuation
- Application of power to equipment
- Verification of network configuration
- Analog input checks and calibration of signal and display
- Analog output checks for correct display
- Calibration of input signals to the power-load unbalance (PLU) function
- Function testing of the PLU
- Discrete I/O testing
- TDM and turbine trip testing
- UPS power supply testing
- Verification of alarm relay response
- Loss of HMI/communication testing.

Some of these tests overlapped those that were performed at the factory acceptance test, but they provided confidence that the equipment will perform as expected after installation.

4.8 Installation

Modification of the existing system and installation of new equipment must be completed within the plant's aggressive outage schedule. The equipment install window was contractually limited to 10 days. Equipment, cable trays, conduit, and most of the new cables were installed while the plant was online, which included the infrastructure cabinet in the AER, the RIO cabinets in the Lube Oil Room, UPS, and related cables.

During the outage, the equipment in the front standard was modified, and the analog equipment in six bays of the EHC cabinets was removed and DEHC equipment was installed. Cable terminations were made to existing terminations for input signals and output signals. The front standard modification included the removal of the mechanical trip devices and the PMG, installation of two TDMs, installation of turbine trip pushbuttons, and installation of speed sensors on an existing speed bracket. An additional speed bracket was installed with new passive speed sensors for inputs to DTOPS. In the MCR, the manual turbine trip capability was retained, but the EHC control and monitor devices were removed and a 22-inch HMI monitor and keyboard for control and monitoring was installed. The valve test panel was removed and replaced with a 27-inch HMI monitor mounted at the same location. Wiring terminations were verified by the installation team, and independently checked by an engineering team. A hydraulic flush was performed after installation of the TDMs as part of the preparations for modification acceptance testing.

4.9 Modification Acceptance Testing

The purpose of the modification acceptance test (MAT) is to test specific functions of DEHC to demonstrate acceptable performance of the equipment installed to replace the Mark I analog turbine control and protection system. The MAT included the following tests performed after equipment installation:

- Resistance and ground checks
- Energization sequence
- DCS system testing
- DCS network administration, maintenance, and work station operation rights
- Electro-hydraulic oil system flush
- TDM orifice test
- Annunciator tests
- Instrument loop calibration
- Main turbine trips
- Valve loop calibration and LVDT/servo valve
- Turbine overspeed trip verification.

Because these tests were performed with the plant off-line, sensor inputs (such as speed and throttle pressure) were simulated using a pressure source and function generators, respectively. Discrete inputs were simulated by forcing logic states using an HMI test feature. In conjunction with the successful performance of software test, factory acceptance test, and site acceptance test, successful performance of these tests formed the basis for declaring DEHC ready for plant startup.

4.10 Plant Simulator Update, Testing, and Training

Concurrent with other system upgrade activities, the Limerick plant simulator was updated with the DEHC HMI interfaces and control logics. As part of the simulator testing activities after the update, transient response results from the simulator for specific events were verified to provide similar results as those from simulator response for the analog EHC system. This provided confidence that the turbine/pressure control functions were performing as expected.

After the plant simulator was updated, it was then used for further testing by the simulator personnel, and for operating procedure validation activities. As previously discussed, the simplified BWR dynamic model was used to test functions of the DEHC system from plant startup to power operation. On the other hand, the plant full-scope simulator has far more capabilities to simulate off-normal and abnormal conditions and events. Thus, it was considered prudent to use the full-scope plant simulator to further test the DEHC HMI and logics under these conditions. In addition, operator training began shortly after DEHC implementation in the simulator. As a result of these tests and operator training, several minor changes were made to the HMI due to operator preferences, and one minor logic error was found and corrected. Operating procedures that were changed due to DEHC were validated and refined using the plant simulator prior to their use in the MCR. Use of the plant full-scope simulator for testing modifications was an important part of the overall project success.

4.11 Power Ascension Testing

The final tests for the DEHC were the performance tests performed in actual plant operation. These tests included control stability tests performed during reactor heatup and pressurization with the bypass valves controlling pressure, bypass valve pressure control at approximately 15 percent power, turbine roll up, overspeed trip tests, generator synchronization and loading, and power ascension to various power plateaus. Steam valve surveillance tests were performed at the maximum power level previously established. These valve tests included stroke tests of the main stop valves, control valves, combined intercept valves, and the turbine bypass valves. Data for these tests were captured by the DCS data capture and trending tool, as well as by the plant process computer data acquisition system. System performance was evaluated for each test against specified acceptance criteria. Successful tests validated that the system performed as expected, and enabled continued plant operation with confidence. The automatic reactor cooldown function had been partially tested during plant heatup; however, the full cooldown process will need to be tested during the next plant shutdown for refueling.

5. LESSONS LEARNED

A lessons learned meeting was conducted two weeks after the outage that included the all-inclusive design team and key installation craft. Both positive and negative lessons learned were recorded. Lessons learned have been incorporated into the design, installation design, and work orders. The most significant lessons learned were:

1. Interface between MAT and station procedures needs improvement. Need to consider all plant modes and initial conditions (main generator breaker position, condenser vacuum, reactor water level, etc.) when performing each testing section for interface between MAT and station procedure interfaces and provide precautions/limitations.
   Resolution: Review all operations and I&C procedures for interface of testing for plant conditions. Perform a trial run of procedures and testing on the M&TS and/or simulator, with scenarios for potential schedule changes. Include prerequisites, cautions or limitations, as appropriate in applicable sections (MAT and station procedures) alerting personnel of interface issues and restrictions.

2. Tuning of valve responses took longer than anticipated, delaying startup.
   Resolution: Prepare a detailed tuning document, with pre-written/ pre-scripted steps with established criteria for each power level. Practice tuning scenarios based on Unit 1 conditions and experience. Include site operation and management in the practice scenarios so that tuning evolutions are understood and communicated to all stakeholders.

6. CONCLUSIONS

The Limerick BWR turbine control and protection digital upgrade was successful and achieved the project and utility requirements. This project demonstrated that I&C digital upgrades can be successfully implemented when the following attributes are incorporated into the process:

- Adequate planning
- Well-staffed organization, including utility and vendor representatives
- Committed utility management sponsorship
- Adequate communication protocols
- Discipline to hold scope that will fit into outage window and avoiding scope creep
- Completed design
- Use of Mock up cabinets to reduce installation risk
- Adequate testing, both pre- and post-modification
- Risk identification and mitigation measures
- All team members are accountable to project commitments and schedule

Tremendous financial and operational paybacks are achieved by applying proven applications and the right technologies, and incorporating lessons learned from past I&C upgrade projects. When the strategies outlined in this paper are employed and the team approach between utility and vendor is utilized, great innovation and rewarding success is achieved in upgrading I&C systems in our nuclear plants.

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