ROV Control System Upgrade

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***Abstract*— Remora III, a 6,000-meter rated Remotely Operated Vehicle (ROV) designed, built, and operated by Phoenix International Holdings, Inc. (Phoenix), has performed extremely well during its 16 years of service as a search and recovery vehicle. While several mechanical upgrades have been made to the vehicle during this period, the desire to increase Remora's service capability and operational availability necessitated an upgrade to its control system. Programmable Logic Controller (PLC) technology was selected to serve this purpose due to its many advantages including proven reliability, world-wide availability, future expansion of capabilities by simply adding modules, and easy to program interfaces. Phoenix's previous experience in implementing PLCs for ROV control systems includes work completed on the U.S. Navy's Deep Drone ROV upgrade and the design/build of the U.S. Navy's new Hydros ROV.**

Keywords—Programmable Logic Controller, PLC, Remora III, ROV Control System Upgrade, Phoenix International Holdings, Inc.

I. INTRODUCTION

Phoenix's Remora III (Fig. 1) was purpose built in 1999 as a deep water search and recovery ROV. Remora III has performed numerous operations including expeditions to the Titanic in 2004 and 2010, the recovery of Air France Flight 447 flight data and cockpit voice recorders, and the recovery of a private plane off the coast of Jamaica in 3,000 meters of sea water earlier this year. Since Remora's inception, few changes have been made to its control system, which has limited any changes to its existing performance capabilities. In addition, the onboard computer is a PC-104 stack consisting of several input/output (I/O) boards that have been discontinued. When the decision was made to replace Remora's control system, several factors were taken into consideration. The new control system had to be reliable, built from components that were Commercial-off-the-shelf items, and easily programmed so that it could quickly integrate new apparatus into the vehicle. With all these considerations in mind, the decision was made to use Programmable Logic Controller technology.

Fig. 1. Remora III Remotely Operated Vehicle being recovered after an operation.

II. BACKGROUND

Programmable Logic Controllers (PLC) are industrial computers designed for repeatable tasks in harsh environments. Modules can be added to a PLC stack to provide increased capability and the software can be quickly modified to adapt to new operational requirements. PLCs are widely used in factories, production plants, and water treatment facilities for their reliability, longevity, and easy-to-program interfaces.

PLCs have been performing automation tasks since the 1960s. They were first designed to replace systems with hundreds of relays and miles of wire in automobile factories. The driving force behind the invention of PLCs was the need to have a device that would decrease downtime and expense when redesigning a production line for a new product.[1]

The use of PLCs in factories and elsewhere has created a global demand for these devices. As a result, PLCs are now available worldwide. For Phoenix and Remora III, this level of availability means having world-wide access to PLC replacement parts should they be needed. Unlike computers where rapid obsolescence is a normal state, the PLC market is more stable. PLC modules are produced for several years before they are retired from production so even after they are discontinued, used modules can still be obtained. In short, the

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high degree of availability of PLCs is critical to supporting the worldwide response capability of Phoenix's Remora III.

III. Programmable Logic Controller

Phoenix selected Allen-Bradley CompactLogix PLCs to support our Remora III control system upgrade. Allen-Bradley was selected because of the support offered by the manufacturer as well as the support of our vendor Rexel Automation. This PLC consists of a processor and I/O modules. The vehicle I/O is connected using an Ethernet module. All communication between the topside PLC, vehicle PLC, and GUI computer is on Category 5 cable over Ethernet/IP. The Ethernet signal is transferred between topside and the vehicle through multiplexers which are connected using a fiber optic cable in the umbilical (Fig. 2). Over the last decade, the speed and processing power has increased to where it can handle auto functions without straining the PLC. Entire I/O scans are completed in less than 5ms. Ethernet allows topside and vehicle communication in real time.

The PLCs are attached to top hat EN 50022 DIN rails in a one-atmosphere pressure housing within the topside control console. This attachment method allows for easy modification when expanding the PLC stack (Fig. 3). Each module locks into its neighboring module through a single sliding tab. They also feature wiring blocks (Fig. 4) that make replacement quick, simple, and easy.

The topside PLC stack contains the processor and I/O modules for the consoles. Unlike Remora's old control system, the topside processor controls the entire control system and is independent of a computer. The vehicle I/O is connected to the topside PLC stack via fiber optic cable using an Ethernet communication module. An Ethernet expansion module is located in the vehicle's main bottle. This Ethernet module extends the capability of the PLC network by allowing the connection of input and output modules in the vehicle side without the need of additional computing power. Analog and digital input and output modules, as well as relay modules are used to pass information to and from all the vehicle's sensors. The PLC can also control serial communications such as RS-232 and RS-485 protocols between computers or sensors such the compass, depth sensor, and the navigation computer.

The new PLC-based control system enables ROV pilots to use rotary encoders in place of potentiometers to change vehicle system control functions. Unlike potentiometers that have a defined and limited range, rotary encoders allow a vehicle control function to be controlled from multiple locations. Each rotary encoder is configurable with a minimum value, maximum value, and step size. The step size controls how much to increase or decrease the vehicle control function with each step. The rotary encoders on the new Remora III consoles have 16 steps per turn. Remora III also uses rotary encoders to control the light outputs, as well as the auto depth and auto altitude functions.

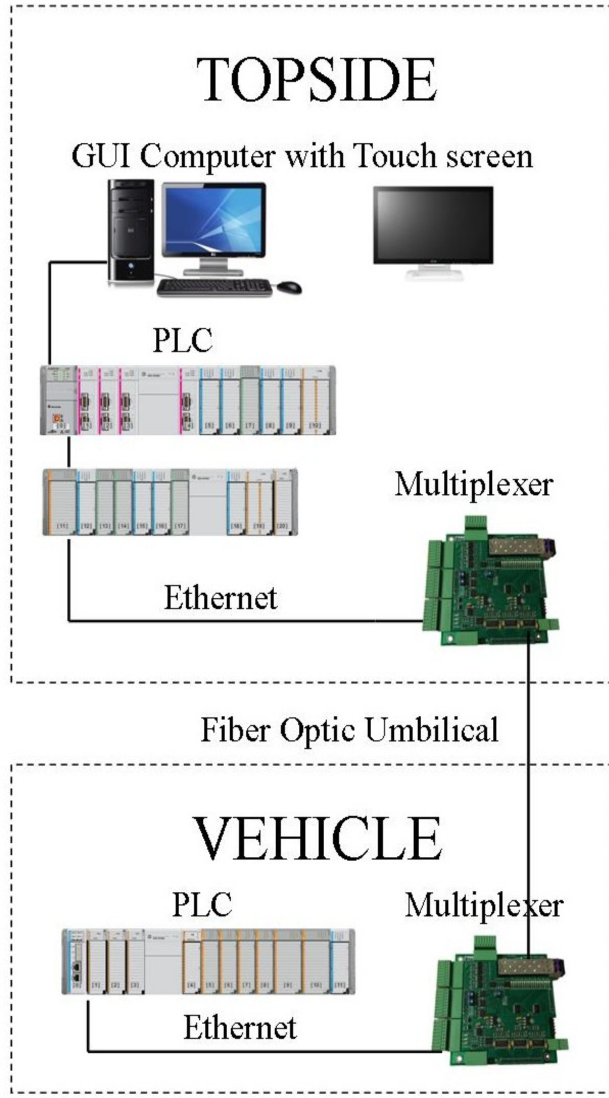

Fig. 2. Remora III's new control system layout. The PLCs use Ethernet/IP to communicate. A multiplexer on each end is used to extend the Ethernet over the 6000 meters of umbilical.

Fig. 3. An Allen-Bradley CompatcLogix PLC with 3 I/O cards. From left to right; a L36-ERM processor; 1769-IF16V 16 analog input module; 1769-PA4 4-amp power supply; 1769-IG16 16 input TTL module; 1769-OV16 16 output 24V DC sinking module.

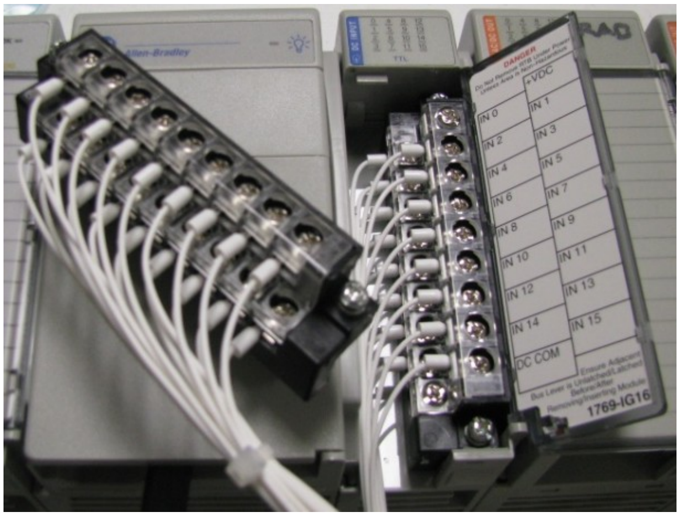

Fig. 4. Wiring blocks for the 1769 series PLC modules. No wires have to be disconnected to swap a module.

IV. Programming

PLC programming is accomplished utilizing the ladder logic in Rockwell Automation's Studio 5000 Logix Designer software which is based on relay logic (Fig. 5). The ladder logic consists of drag-and-drop blocks to write the code rather than traditional scripts, thus making it easier to troubleshoot the code. It also makes programming easier and avoids having only a single programmer understanding the system. Additionally, the ladder logic structure is easily understood and facilitates the training of engineers and technicians.

While the building blocks of ladder logic are quite simple, they can be used to create advanced features. For example, Phoenix has implemented auto functions, depth and compass histories, and a simulation environment. The depth and compass history features provide the ROV pilot with excellent spatial awareness of where the vehicle is and where it has been. Through the simulation environment, new ROV pilots can become easily and quickly accustomed to the ROV controls before operating the vehicle at sea. The simulation environment feature also proved valuable for testing the vehicle's auto functions. Scans of the logic are performed in less than 5ms producing accurate real time data processing.

These advanced PLC capabilities are made possible by the development of add-on instructions within the programming software. These add-on instructions were created by Phoenix to enable the use of modular code blocks. These code blocks control everything from push buttons to encoders to input calibration and scaling. These add-on instructions allow repeatability of complex tasks and simplify the programming process. Future programming becomes a process of simply cutting and pasting these add-on instructions - thus significantly reducing the complexity and time consuming nature typically associated with traditional programming.

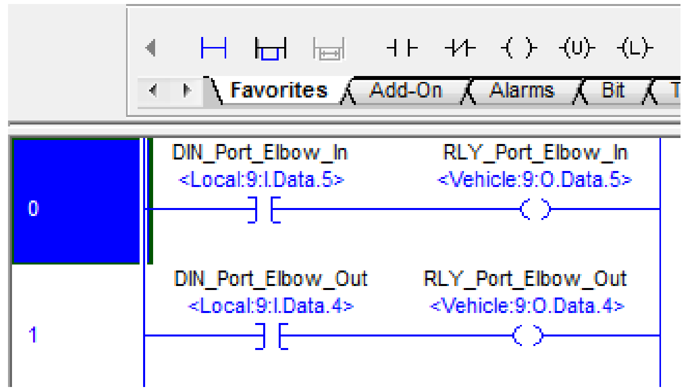

Fig. 5. Sample ladder logic in Rockwell Automation's Studio 5000 software.

The PLC programming software runs on Microsoft Windows and is continuously updated and supported by the PLC manufacturer. Due to the large worldwide installation base of the Windows operating system and their past history of supporting new versions of Windows, it is expected that PLC manufacturers will support and continue working with future versions of the operating system. As a result, upgrades to the PLC or the operating system can be done without the fear of compatibility issues.

V. Graphical User Interface

The Graphical User Interface (GUI) feature that supports the Remora III control system upgrade is programmed in Rockwell Automation's FactoryTalk View software. This software allows a user to easily create and modify a custom user interface. The GUI can be displayed on a conventional computer or on an industrial-grade touch-screen panel. This software can be used to quickly add buttons or indicators on the GUI as needed, even in the midst of an at sea operation. There are also a variety of more complex indicators that can be added to increase the pilot's control system capabilities. Some of these include a compass rose with history and relative ship's position, attitude indicator, turns counter, and depth and altitude indicators with history. These indicators are completely customizable and can be tailored to meet the needs of the vehicle and still resemble the previous control system's GUI screen functional display. By configuring the new GUI to resemble Remora's previous control system's screen, Remora ROV pilots have immediate familiarity with the new control system capabilities. This configuration results in a significantly reduced learning curve, since critical information and data appear in the same screen location where it was previously located.

For Remora III's new control system GUI, a total of eleven displays, including six new displays were created to reflect the added functionality of the PLC while maintaining the look and feel of the old GUI screen. The pilot screen's display shows only the information critical to flying the ROV while the other ten serve as configuration and feedback displays. These new displays included a slider and joystick calibration page, a GUI configuration display, an I/O data display, a simulation display, and two serial port configuration displays. These additional displays are in addition to the existing primary flight and thruster configuration displays. The control system monitors 27 modules; each one with up to 16 inputs or outputs. Up to

200 parameters can be continuously logged and viewed in Excel. These parameters can also be selected for monitoring with visual or audible alarms or warnings.

Remora's new GUI includes a dual-monitor high-resolution display. One monitor is dedicated to pilot information and a second touch screen is placed between the pilot and copilot for vehicle diagnostics and configuration (Fig. 6). These displays replace the single low-resolution monitor of the old GUI system and provide the pilot and copilot with a quick and responsive interface with the PLC.

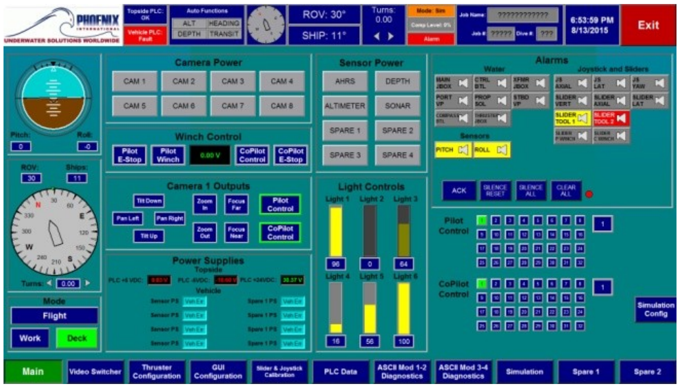

Fig. 6. The new main touch screen GUI display.

CONCLUSION

The new PLC control system has significantly enhanced the capabilities and readiness of Phoenix's Remora III ROV to meet the needs of a larger and more diverse customer base. Remora III clients have included the U.S. Navy, oil and gas companies, and scientific organizations. Each client has a unique set of mission requirements which often drive the development of new vehicle configurations and capabilities. With Remora's advanced PLC-based control system, mission-specific reconfigurations can be performed quickly and with less cost to the customer. Custom payloads can also be easily added to the vehicle with additional PLC modules and integrated seamlessly into the vehicle via a single Ethernet connection. The reliability, supportability, and configurability of PLCs will serve to maintain the operational readiness and worldwide availability of Phoenix ROVs.

REFERENCES

[1] PLC History: The concise PLC History (2007). Retrieved August 12, 2015, from http://www.machine-information-systems.com/PLC_History.html