PROGRAMMABLE CONTROLLER COMMUNICATIONS TO REMOTE I/O

An Alternative to Communications Conductors in Submarine Cable?

William J. Bender
Control Engineering Specialist
Florida Area

Square D Company
Tampa, Florida

Before talking about communications in Programmable Controllers it is important to understand what a Programmable Controller is, why, and where they are used. Programmable Controllers, PC's for short, in their simplest form are relay replacers. These relays are the electro-mechanical relays used in not only bridge control, but almost any other type of control. Besides relay replacers, PC's can do tasks such as timing, counting, and sequencing with little difficulty.

Programmable Controllers are computers that are designed to receive real world inputs from 5v to 240v ac or dc and energize outputs or loads in the same ranges. They are designed to operate in 60 degree C temperatures, up to 95% non-condensing humidity, and extreme electrical noise such as motors starting and stopping. They are programmed in relay logic very similiar to the way a relay panel is wired. These characteristics make the PC easy to adapt to any application and acceptable to most maintenance staffs.

The following block diagram will aid us in understanding the basic parts of a PC:

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INPUT                                                                OUTPUT
DEVICES                     PROCESSOR (CPU)                          DEVICES
            __________        __________________        __________
  _1_   1          1     1                  1     1          1    _
--o o--1 INPUT     1     1  USER PROGRAM    1     1 OUTPUT   1--(_)---
        1          1--->1        &          1--->1           1
--o o--1 MODULES   1     1      LOGIC       1     1 MODULES  1---/\/--
   \    1          1     1                  1     1          1
   ^    1__________1     1__________________1     1__________1
             1                  1                      1
             1__________________1______________________1
                                1
                          ______1______
                          1           1
                          1   POWER   1
                          1   SUPPLY  1
                          1___________1
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The left section is the input section. PC's must receive signals from various input devices to allow the PC to know what is going on in the real world. These inputs may be push buttons similiar to the ones used to activate the bridge oncoming and offgoing gates and the traffic signals. They could be limit switches to indicate bridge or gate position, or they could be photo cells to indicate people or automobile presence on the bridge in critical positions.

The center section is the logic section. This is where the Central Processing Unit, called CPU, is located. The CPU receives the inputs, and based on the program, makes a logical decision. The program is very similiar to a relay wiring diagram and is stored in the CPU's solid state memory which has up to a one year battery backup in case of a power failure. The battery backup is located in the power supply that supplies power to the processor and the logic functions of other modules. The CPU sends the decision to the output section for action.

The section on the right is the output section. Its job is to take the CPU's decision and transform it into real world signals. The output section would send electrical signals to devices such as the motor starters that control the motors on the bridge leafs and gates. They would send signals to the relays that control traffic signals and horns.

The place the communications come in is transmitting the CPU's decisions to the Input and Output (I/O) sections. These communications take place over a wide variety of distances (up to three miles) and environments. These distances and environments are important in the decision as to the type of communications to be used. The majority of the installations utilize a shielded, two twisted pair of 20 to 24 gauge communications cable. This cable can also be a fiber optics cable that is more suitable for adverse environments. The small communications cable can replace many large control cables that otherwise would be run extremely long distances. This is probably the greatest area for savings in most Programmable Controller installations, both in cost of cable and time for installation.

Typical control circuits used in bridge operations are the traffic signals, the audible alarm bells and horns, and much interlocking used to verify bridge and gate positions. Each bridge leaf and traffic gate may have 4 to 6 limit switches mounted in various locations. Several locations also have pedestrian gates also requiring interlocks. These signals on the far side now utilize up to 40 control conductors in a typical submarine cable. Wiring these limit switches and interlocks to a remote I/O rack for "transmission" back to the Programmable Controller through a single communications cable could eliminate these 40 control conductors. If "bulk" power could be sent through the submarine cable and then distributed on the far side to relays or contactors, actual control of gates or even bridges could be accomplished by the remote I/O, thus decreasing the number of power conductors required.

Since the shielded two twisted pair communications cable is most common, we will cover this method first. This system utilizes two serial I/O interface modules, one at the CPU location called a "local interface" (LI), and one at the remote I/O rack called a "remote interface" (RI). The CPU rack would be located in the Bridge Tender's Control Room on the near side; the remote I/O racks would be located both on the near side and the far side, closer to the actual loads it controls.

The local/remote I/O interface system is a high speed serial, multi-channel, multi-drop system. The LI receives instruction from the CPU. The LI then serializes this information and transmits it to the appropriate RI. An LI module does this over either of its two independent communication channels. Each channel operates full duplex at a rate of 31.25K baud. The RI interprets this data, verifies and acknowledges it and then acts accordingly. The information being exchanged is stored in an image table located in each LI and RI.

The continuous exchange of information between the LI and RI image tables is independent of the CPU scan. Transmitted information includes ON/OFF commands for I/O as well as storage register information and housekeeping functions (i.e., loss of communications, error control,and freeze or reset of I/O).

The RI module stores control register information. This information defines the action to be taken in the event of a fault at any location. It can allow the operational drops to keep running or to shutdown. The shutdown state of the outputs will then be either a reset (OFF) or freeze (last state) condition.

The communications between the LI and RI is achieved via a dual shielded twisted pair cable. It is usually recommended that the shielded communications cable be routed away from any power conductors. This physical seperation is to avoid any EMI or RFI interference. It is believed a shielded cable routed through the submarine cable could provide satisfactory communications but no known field testing has been done. The EMI/RFI noise level would also depend on the number and size of motors located on the far side and the type drives controlling them. An alternate pair of two conductor twin-ax cables normally used for longer distances could be utilized to provide an extra measure of shielding.

In environments where lightning is prevalent, signal line protection is recommended to prevent hardware failure.. Even though transient protection is designed into most communication circuits, additional specialized protection devices are suggested in areas where there is a high probability of secondary lightning strikes occurring. The specific environments which are of greatest concern are where communication cable runs are in the outside environment such as a bridge application.

The second option of communications cable is that of Fiber Optics. The viability of an optical fiber as a data transmission medium has been questioned for quite some time and has been limited in its use until just recently. Since copper cable has a high degree of reliability, there has been a great reluctance to try other types of untested medium. The outstanding features of fiber optic cable have just begun to be noticed now that cable costs have come down, connector standards have been set up, and link costs are less. Several attractive features are noise immunity, & high speed data transmission.

The primary advantage of fiber optics is its supurb dielectric characteristic. Environments with high lightning susceptability or other EMI/RFI interference are ideal for fiber optics. Another advantage of non-conductivity is the cost savings due the lack of line or lightning protection devices. Even with expensive protection systems no conventional system is 100% safe from lightning damage.

Square D's Fiber Optic Interface is a differential-to-fiber optic converter with a repeater. The Fiber Optic Interface receives a differential electrical signal (electrons) from the terminal block, converts it to an optical signal (photons), and sends it out through the TRANSMIT Channel. An optical signal received from the RECEIVE Channel is converted to an electrical signal and transmitted out the terminal block. The Fiber Optic Interface Modules are utilized with the LI/RI Modules as discussed earlier except the two twisted pair of communications cable is kept to a length of only inches and contained within the control cabinet.

The Fiber Optic Interface transmits light with a center wavelength of 820 nm, which is in the infrared region of the electromagnetic spectrum. Pure infrared light is invisible to the human eye. The LED emitters which transmit this infrared light also transmit small levels of "border" frequencies of light producing a small amount of visible red light.

Fiber optic cables have a distance limitation of 3,280 feet without repeaters and 10 miles utilizing up to the maximum of 7 repeaters. Since the signals are transmitted light in the optical cable, it is very important to allow for gradual bends in the cable. A sharp bend could drastically cut down the light able to be transmitted through the bend. Fiber optic cables should not be used where large amounts of movement are necessary.

Fiber optic connectors must be properly polished to correct finished ferrule length as excessive length may damage optical communication channels. The cable ends, transmitters, and receivers must be kept clean. Any debris buildup will cause attenuation of the optical signal. Channels of the interface not used should have protective covers to prevent any debris buildup. Cable and connectors should be cleaned with isopropyl alcohol and a small cotton swab to prevent film buildup.

Since fiber optic cable is not susceptable to EMI or RFI noise or lightning it offers definite advantages in bridge applications. The fiber optic cable could be routed through the same submarine cable as the power conductors with no possible noise interference. Care in routing the fiber optic cables must be taken to prevent physical damage after it leaves the submarine casing and to prevent sharp bends in the cables. With these two limitations the fiber optic cable would offer superior communications capability and reliability in a bridge controller.

After much investigation of both bridge construction and Programmable Controller applications and results, I believe that Programmable Controllers have many advantages to offer in the area of bridge control. They will provide a lower cost system than relay logic, can reduce the size and cost of the submarine cable, and offer more flexability and error checking than is obtainable from relays. They have the capability of providing an easy to use operator interface that could greatly automate bridge operation and maintenance. The automation could watch motor amperage, bridge position for more accurate speed control, double check gate positions, and leave the operator free to provide visual safety checks of automobile, marine, and pedestrian traffic.

By utilizing Programmable Controllers as an alternative to relay logic, not only a significant cost savings can be realized, but a higher degree of reliability and a decreased downtime will also result. Should ont of the interlocks or limit switches fail, a message could be displayed to the operator giving the location of the interlock not verified. At the operators discression, and using visual checks he could override the interlock to allow completion of the bridge operation. This would give maintenance crews time to repair the problem on a non-emergency status. Diagnostics of the system can be programmed to annunciate preselected abnormal conditions allowing the operator to know about failures even before they are called upon to perform their various functions. Redundancy for the CPU and I/O can be utilized to provide 100 % uptime through a backup path.

As Programmable Controller technology advances, they will be able to provide more and more functions that must now be done manually with susceptability to operator error or omission. Already, Square D's SY/MAX Programmable Controller can provide data-logging and report generation in a compact, inexpensive module as well as networking many Programmable Controllers on a cable, by radio, by telephone wires, by micro-wave, or even by satellite to provide supervisory control of many systems from one location. As these type features become standard every day systems, the choice of Programmable Controller brand becomes more significant to enable the user to take advantage of a single manufacturer's proprietary system features.