PROGRAMMABLE LOGIC CONTROLLERS IN OILFIELD PRODUCTION OPERATIONS

RICHARD A. KOWALSKI
ARCO OIL AND GAS COMPANY

ABSTRACT

In recent years programmable logic controllers (PLCs) have evolved to such a point that it is often technologically desirable and more economical to apply them preferentially over hard wired relays in the small control systems typically found in oil field production facilities. This paper will provide a short history of PLC development, describe the features and capabilities of PLC's, examine possible applications for small PLC's in oil field production operations, and illustrate several applications.

THE HISTORICAL BACKGROUND OF PROGRAMMABLE LOGIC CONTROLLERS

The revolution in the control industry caused by programmable logic controllers began when the Hydramatic Division of General Motors Corporation specified the design criteria for the first PLC in 1968. These criteria called for a solid state, microprocessor based control system which would provide greater flexibility for control function changes than the hard wired relay controlled systems used to date. Up to that time, the assembly lines at General Motors plants were controlled by hard wired relay control systems, and the annual model changes required either completely new control systems, or extensive, time consuming modifications to the existing relay control systems. Both methods required an unacceptable amount of production line downtime. In addition to the flexibility and reusability of the PLC control system, GM specifications called for relatively easy programming language such that the programming changes and system maintenance could be performed by the production engineers and/or technicians rather than the computer or system programmers.

The original programmable logic controllers were nothing more than relays, and timer replacers. Ladder logic diagramming evolved as the control system program development language, and Boolean algebra functions were used to input the program to the device's microprocessor.

As the microprocessor and computer technologies advanced, the power of PLCs also increased. Initially arithmetic functions were added, providing the PLCs with the ability to operate processes based on numerical input data. Later, software and hardware enhancements improved the capabilities of PLCs to a point that in many applications they rivaled those of process control computers. Some of those capabilities are listed as follows:

- Larger memory capacities (128K user memory and larger)
- Input/Output (I/O) capabilities upwards of 8000 points
- Remote I/O system
- Self-diagnosis of the processor and I/O system
- PID loop control algorithms
- Analog I/O capability
- Enhanced operator interface
- Machine to machine and external communications

Multi-axis position control for machines
Advanced programming languages in addition to ladder diagramming
Floating point math capabilities

Today's programmable logic controllers come in hundreds of different models, styles, and designs. According to trade magazines, Control Engineering and ICS as of March, 1987 there were 65 manufacturers of PLCs. This is 4 more than in January, 1986 and 16 more than in January, 1985. Most major manufacturers provide large family of PLC products from very small models, 32 or less I/O to extremely large, top of the line units exceeding 8000 I/O. The families of products are usually vertically integrated and use the same programming language and communication protocols; however, these features must be verified with the vendor prior to selection of their equipment for applications, since some manufacturers do not provide these commonalities.

SMALL PROGRAMMABLE LOGIC CONTROLLERS

As the acceptance of programmable logic controllers grew in the control industries, the major manufacturers competed to make their models the largest, fastest, and full of exotic features. Only several years ago, some manufacturers have discovered the market for the very small PLCs to replace very few relays and/or timers. In general all of the major manufacturers have now released miniature PLC models with less than 32 I/O and IK memory capacity, with single unit construction. Some of these units can be upgraded to 64 or 128 I/O by adding fixed I/O. The memory configurations vary from manufacturer to manufacturer; however, almost all offer battery backed up CMOS RAM or EPROM. The memory capacity of these devices is usually less than 1000 words, and the programming is accomplished with an external programmer which plugs into the unit. The programming languages also vary; however, it usually is based on some form of ladder or Boolean algebra programming.

The I/O structure is generally fixed on small PLCs due to single unit design. Various voltage inputs and outputs are available but a mixture of different voltage inputs or outputs in the same unit is usually difficult to accomplish due to lack of modular design. Usually LED indicators are provided on the unit for all inputs and outputs as well as status LEDs for power, CPU, and/or battery condition.

The miniature PLCs in general do not provide mathematical functions or analog I/O capabilities; however, they are ideal devices for replacing relays, timers and counters in very small control systems. The prices for these units can start as low as $250 when purchased in quantities.

If the control system dictates the necessity for use of mathematical functions and/or analog inputs or outputs, there are several manufacturers offering small PLCs that can fulfill these demands. These units are of modular construction i.e., one can purchase only the I/O units necessary for the control system. The I/O cards come in a great variety of operating voltage ranges, analog (4-20MA, 1-5V) or thermocouple input capability, high speed counter capability, and 4-20MA analog output capability. Other I/O cards are being developed as the demand dictates. Some units offer remote I/O structure. The memory of these units can usually be expanded to over 4000 words, and the construction is similar in variety to those of the mini-PLC models. Basic arithmetic functions are provided, thus enabling the PLC to operate on the input data from the processes and perform other mathematical operations. Some of these PLCs can also handle external communication interfaces, thus enabling the operator to access the process parameters from a remote location. Units in this category can be purchased for as little as $1,000 depending on system configuration.

The two categories of PLC systems described above, both small and relatively inexpensive, lend themselves to the applications in the oil and gas production facilities since requirements for I/O and programming memory in the control systems are usually not very large.

POSSIBLE APPLICATIONS

The majority of control systems encountered in the oil and gas production facilities are relatively small (except for gas processing plant) and do not require a great deal of control sophistication. However, in many cases PLCs can replace the hard wired relays, timers, and counters found in those applications to provide greater control flexibility and data acquisition when these systems require changes and/or expansion.

Several PLC applications are listed below, but the list is by no means complete. Only the imagination of the control system designers or operations personnel can make this list more representative of total possibilities. Here are some possible control system applications to consider:

Water Injection/disposal System Control
Tank Level Control
LACT Unit Control
Injection Well Control
Producing Gas Well Control
Well Pump-off Control
Hydraulic Pumping Unit Control
Compressor Station Control
Well Testing Skid Control
Lease Data Acquisition
Chemical Treatment Control

APPLICATION EXAMPLES

LACT UNIT CONTROL SYSTEM - At ARCO's Oil and Gas Company Central District, a standardized control system has been developed for the control and sequencing of the Lease Automatic Custody Transfer Units. The requirements for the external sensing and control devices as well as the control panel have been specified, and control software has been developed and fully documented. The control system is based on General Electric Company's SERIES ONE JUNIOR programmable controller. This device's basic unit is constructed with 15 inputs and 9 outputs for a total of 24 I/O points. (I/O points can be added to this device; however, they are not used in this control system.) The standardized wiring schematic is shown in Figure 1. The unit's program can be entered manually via a portable programmer or by audio tape playback of a previously saved program.

There are approximately 15 units in operation equipped with this control system. As the control systems of the existing units are in need of refurbishing, they are replaced with the PLC based systems. In addition new LACT units are purchased to our control specifications.

The standardized control system greatly reduces the need for keeping up with various vendors documentation, wiring diagrams, and their updates. It saves manpower in the control system development and greatly reduces manpower required in troubleshooting of the units. In addition the system components are interchangeable and the need for spare parts is reduced since only standard specified components are used. This is an excellent illustration where a miniature PLC with a fixed number of I/O could be used, and no manipulation of numerical data is necessary.

WATER INJECTION CONTROL SYSTEM - IATAN EAST HOWARD LEASE

A control system was custom designed for water injection control on ARCO Oil and Gas Company's Iatan East Howard Lease. The system controls all of the necessary shutdown any sequencing functions of three 150HP triplex pumps and five control valves. It also maintains proper liquid levels in the produced and fresh water tanks and annunciates shutdown conditions to the lease operator

Figure 2 illustrates the water system interconnections. The main objective of this control system is to provide constant rate injection while disposing of all produced water. Produced water production is very erratic. Tank levels are sensed with low range pressure transmitters. The signals from the transmitters are fed to current relays and digital displays indicating tank liquid levels. The current relays provide digital inputs to a General Electric Company's Series One Programmable Logic Controller. The logic software in the PLC controls the necessary valves such that the produced water tank stays pumped down by varying the number of pumps pumping the produced water. Each of the pumps is protected against low suction pressure, low and high discharge pressure, and excessive vibration. The pump motors are protected against excessive number of starts during a given time period, and the overall electrical system is protected against single phasing.

Even though a system has been custom designed for an operation there are ways to reduce development manhours if careful attention is paid in the initial design. If the I/O structure is properly assigned for example: inputs for each pump are on different modules but in the same order (see Figure 3), then the logic software may be developed in modular form. Once shutdown logic is developed for one pump it could be used for the other two pumps by just changing the I/O reference numbers. The same philosophy could be used in assignment of internal relay functions, timing/counting functions, etc. If properly developed, these logic software modules may be used on different control systems employing similar type of equipment. The effort of modular program development may not be the most convenient for all logic software, but with careful planning it will reduce significantly the system development time required.

The programmable logic controller based control system documentation can be designed such that a great deal of standardization is used. The standardized forms can be developed for documentation of I/O assignments, I/O wiring, etc. These forms if carefully designed will reduce system development time requirements on subsequent control system applications. Some PLC manufacturers as well as other third party vendors offer personal computer software packages for control system development and documentation, thus attempting to further reduce manpower requirements for PLC based control systems development.

CONCLUSIONS

The programmable logic controllers provide an economic control system alternative when considering hard wired relay control system. The standardization of control system development and documentation is possible for reduction of development and training time.

With properly trained maintenance personnel troubleshooting is simplified and spare parts requirement is reduced due to standardization of the PLC based control systems.

REFERENCES:

1. Jones, C. T., Bryan, L. A.: PROGRAMMABLE CONTROLLERS CONCEPTS AND APPLICATIONS, International Programmable Controls, Inc., Atlanta, GA 1983

2. Flynn, W. R.: "1987 PROGRAMMABLE CONTROLLER UPDATE", CONTROL ENGINEERING, January 1987

3. Cleaveland, Peter: "Annual Programmable Controller Technology Update", I&CS, March 1987

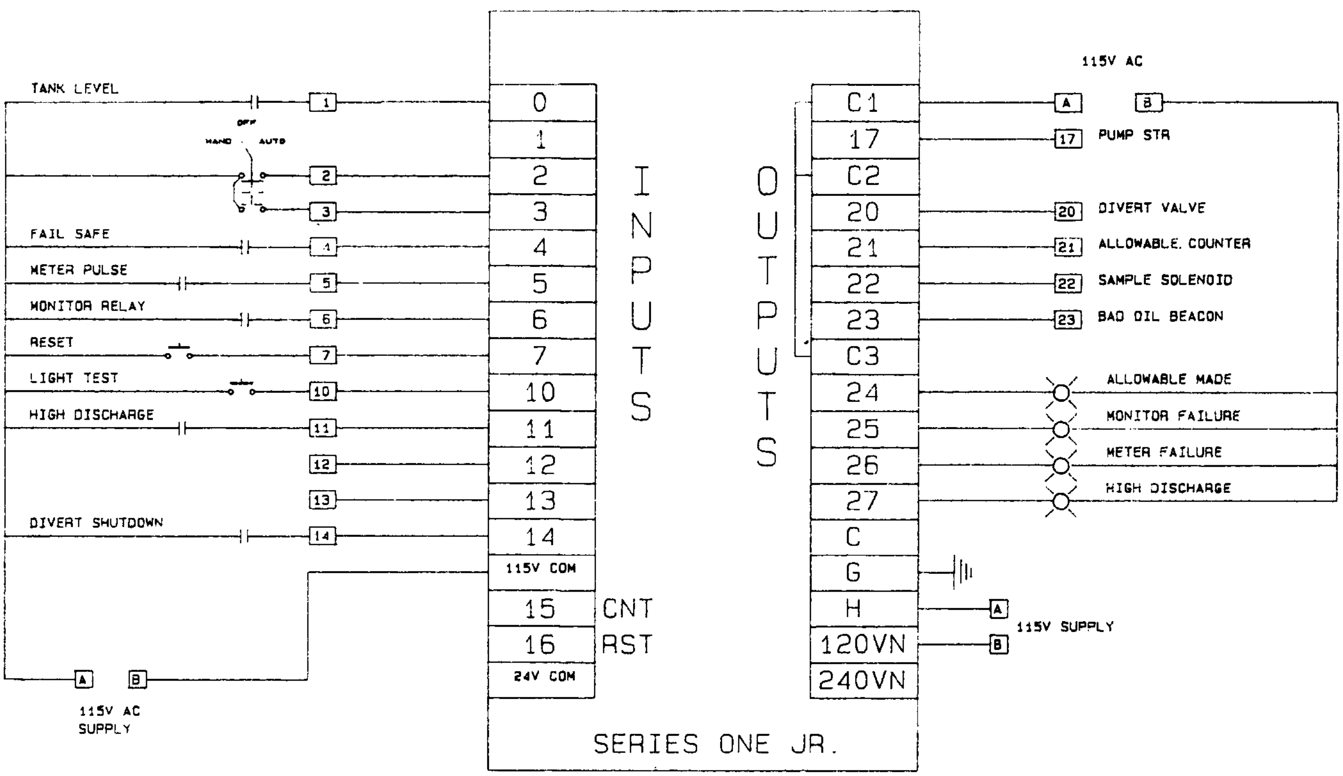

Figure 1 - Typical LACT unit wiring diagram

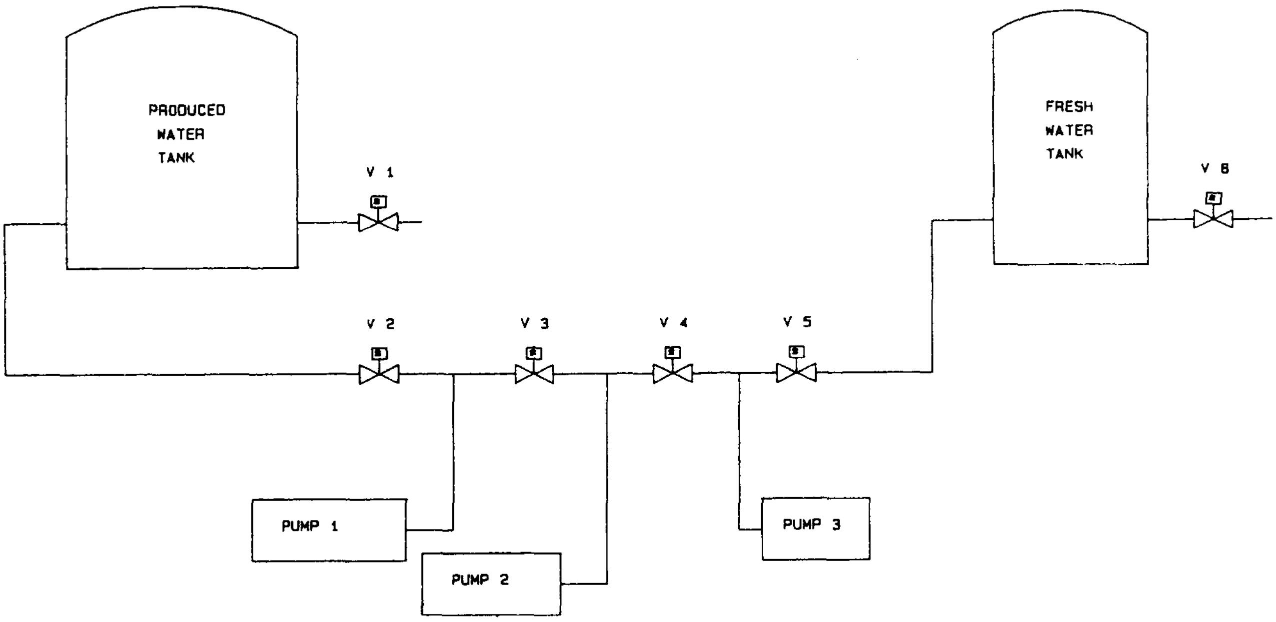

Figure 2 - Water injection system schematic

MODULE NUMBER	I / O REFERENCE	I / O	DEVICE NAME / FUNCTION LOCATION			WIRE NUMBERS	
02	020	I	PUMP J1 LOW OIL PRESS.	MURPHY SWITCH	FIELD WIRING	+020	-020
	021	I	PUMP J1 HIGH VIBRATION	MURPHY SWITCH	FIELD WIRING	+021	-021
	022	I	PUMP J1 HIGH DISCH. PRESS.	MURPHY SWITCH	FIELD WIRING	+022	-022
	023	I	PUMP J1 LOW DISCH. PRESS.	MURPHY SWITCH	FIELD WIRING	+023	-023
	024	I	PUMP J2 LOW OIL PRESS.	MURPHY SWITCH	FIELD WIRING	+024	-024
	025	I	PUMP J2 HIGH VIBRATION	MURPHY SWITCH	FIELD WIRING	+025	-025
	026	I	PUMP J2 HIGH DISCH. PRESS.	MURPHY SWITCH	FIELD WIRING	+026	-026
	027	I	PUMP J2 LOW DISCH. PRESS.	MURPHY SWITCH	FIELD WIRING	+027	-027
03	030	I	PUMP J3 LOW OIL PRESS.	MURPHY SWITCH	FIELD WIRING	+030	-030
	031	I	PUMP J3 HIGH VIBRATION	MURPHY SWITCH	FIELD WIRING	+031	-031
	032	I	PUMP J3 HIGH DISCH. PRESS.	MURPHY SWITCH	FIELD WIRING	+032	-032
	033	I	PUMP J3 LOW DISCH PRESS.	MURPHY SWITCH	FIELD WIRING	+033	-033
	034	I	PUMP J1 RUNNING	J1 STARTER AUX. CONTACT	FIELD WIRING	+034	-034
	035	I	PUMP J2 RUNNING	J2 STARTER AUX. CONTACT	FIELD WIRING	+035	-035
	036	I	PUMP J3 RUNNING	J3 STARTER AUX. CONTACT	FIELD WIRING	+036	-036
	037	I		(SPARE)			

Figure 3 - Series One I/0 Reference Summary -
water injection plant control