A PLC APPLICATION FOR LARGE MOTOR MONITORING

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Abstract

Programmable Logic Controllers (PLC's) offer unprecedented capabilities for the acquisition and display of information to operators concerning the status of large motors in an industrial plant. Operator effectiveness in gathering and assessing information through the use of such displays, especially in critical operating situations, can be increased substantially. This paper describes the application of a PLC for gathering data from solid state motor protective devices and displaying that information in a control room some distance away. The PLC logic programming and BASIC programming required to accomplish the display of information are described. Programming tools and techniques to aid the engineer in implementing such a system are discussed.

Background

The #3 Combination Unit of the Conoco Ponca City Refinery consisted of three process units at the beginning of 1987. In that year, two more process units were added with no increase in the operating personnel. All five units are controlled from a central control room in the area. One of these five units is the #2 Reformer. This unit has a 2000 HP electric motor driven compressor. The motor starter for this machine is located in a switchgear building approximately 300 feet from the central control room. The starter is provided with a solid state programmable motor protector (PMP).

Due to the present economics of the Petroleum industry, it is sometimes necessary to operate our large motors beyond normal design limits. Many large motor manufacturers use a standard rotor and frame for a series of horsepower ranges and at times the motors are in the upper end of the range. In the case of the Reformer motor, however, the motor had considerably more horsepower capability than the nameplate indicated. Although the Reformer motor is rated at only 2000 HP, it has operated at horsepowers as high as 2500. This is possible using the PMP which has current as well as RTD inputs. The PMP allows the motor current to be above normal rated current as long as the termperatures inside the motor remain at acceptable levels. This has allowed a longer run time between Reformer regenerations than would otherwise have been possible.

To closely monitor the status of the motor, the operators would go to the the substation to read and record the critical motor parameters, such as currents, voltages, and temperatures which are displayed on the face of the PMP. Under some circumstances such checking could be done once per shift. However, when the motor was running close to its thermal limits, it required more frequent checking. Such frequent monitoring of the motor status would be more difficult if the operators had the added responsibility of operating two more units than they had in the past.

Another time consuming item for the operators concerned the annunciator located in the substation. The annunciator was used for alarming abnormal conditions at the substation such as breaker trips, hydrocarbons in the substation, transformer malfunctions, and loss of substation pressurization. At times, the door would be left ajar at the substation, resulting in a loss of pressurization alarm. The operators in the control room had only a common trouble alarm from the

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substation displayed on the panel in the control room. To determine the actual cause of the alarm, they would go to the substation to check the annunciator located there. With the increased operator work load, this became unacceptable.

Project Goals

A project was initiated to provide improved monitoring capabilities of the 2000 HP Reformer compressor motor from the control room to reduce the work load of the operators. This involved presenting critical motor information in a readily usable format for the operators to increase their effectiveness in controlling their processes.

Another goal was to minimize the trips to the substation caused by nuisance alarms. Alarms occuring in the substation were to be displayed at the control panel in the control room to better enable the operators to take appropriate action immediately. However, there was a constraint on this task in that the already congested control panels had insufficient room to add many more annunciator points.

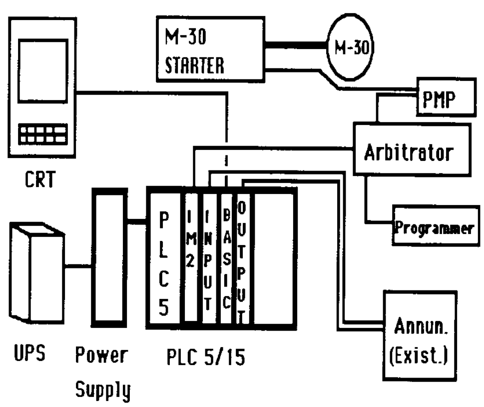

Figure 1

Hardware

The block diagram shown in Figure 1 represents the hardware system chosen to implement the above goals. A Programmable Logic Controller (PLC) system was the method chosen. The PMP manufacturer makes a card that fits in the rack of several of their PLC processor racks which would accept motor parameter information from the PMP.

A Cathode Ray Tube (CRT) screen provided the motor information display as well as the annunciation of alarms from the substation without taking up much space.

It also provided ease of expansion for future additions. In fact the expansion capabilities of a CRT display are practically inexhaustible. Many pages of information can be provided to the operator and selected through the use of function keys on the face of the display. The real limitation of such a system is the speed of response necessary to provide acceptably fast access to a particular screen and control by the operator. The CRT screen provides a large amount of control and data display in a very small area.

A monochrome CRT display screen was specified in order to keep costs as low as possible. In retrospect, the use of color for displaying information is extremely valuable, and we would recommend using color on such future applications. Attention can be drawn to items through the use of appropriate colors and the display is much easier to read and understand.

A sealed membrane keyboard on the face of the CRT provided the user interface. Touch screens are not suitable for our environment and a computer keyboard is confusing to operators. The sealed keyboard with a limited number of keys serves the application's purposes nicely.

The easiest way to drive such a display is from the serial port of a computer. Several PLC manufacturers have BASIC modules which fit in the slot of a PLC rack. These modules provide simple ways to drive displays, do complex calculations, accept operator input, etc. The module chosen for this application was provided with a BASIC interpreter and 12 kBytes of random access memory on a single board. The BASIC language provided on such a module is somewhat limited. There are, however, ways of working around such limitations [1], and small programs, such as this project required, are not at all difficult to accomplish in such an environment. The module comes with two RS-232 serial communications ports, one of which was used for driving the CRT display.

The block diagram in Figure 1 indicates that the RS-232 connection went directly from the BASIC module to the CRT, and so it did, even though they were approximately 300 feet apart. The RS-232 standard specifies, and most serial communications manuals state, that the maximum allowable distance for this type communication is 50 feet. Because of this, we initially thought that we would have to provide some additional hardware to span this distance. Several solutions are possible in such a situation. RS-422, modems at each end of the line with phone lines between, or line drivers would each provide a suitable method for transmitting the data from the substation to the control room. However, such solutions would add cost and complexity to the project.

Some references in the literature led us to believe that direct transmission of the data was possible using RS-232 for 300 feet[2]. This course was selected with the above alternatives as fall back positions should the attempt to use RS-232 for such a great distance fail. Another option was to try dropping the speed of communication to as low as 300 bits per second if that would help. Low capacitance cable, at 12 pF per foot, installed in a rigid galvanized steel conduit from the substaion to the control room was used to minimize noise effects from adjacent power lines, lightning, etc. This data link has worked without difficulty at 1200 bits per second, and there are indications that both the distance and the speed of transmission could be increased without difficulty.[2]

An Automatic Arbitrator unit mounts in the motor starter enclosure and attaches to both the PMP and the manual programming unit which was previously attached to the PMP. The Arbitrator provides a data path to and from the PMP. An interface card in the PLC receives information concerning motor status from the PMP and sends commands to the PMP from the PLC. The interface module is provided with LEDs on its face for communications status indication.

Whereas before, the field annunciator contacts fed directly to the annunciator, they were reconnected directly to the PLC to provide it the information needed for alarms. The PLC then provided contact closures to the annunciator for local indication of alarms at the substation. The PLC was then able to pass the alarm information on to the BASIC module for subsequent display on the CRT in the control room.

Software

A flowchart provides a useful tool for planning and documenting the software, though the programs are written in two different languages. The software which we provided for this project consists of ladder logic programming for the PLC and BASIC programming for the BASIC module. Flowcharts help the programmer to think through the logic of a program and uncover options, potential problem areas, lapses in thinking and logic, and interfaces between the system components during the design stage. Later, after the project is completed, flowcharts help to document the programs and enable programmers and users to remember what the program was supposed to be doing. These charts are especially useful for documenting ladder logic programming. Ladder logic can be difficult for even its author to decipher a year or two after it is written. A flowchart is of immense aid in such work.

Other PLC documentation includes I/O charts, internal I/O tables, and register use tables. Such charts provide necessary information to ease the process of future changes and trouble shooting of the system. These documents are kept by the electrician responsible for the process area. Copies are kept by the plant Electrical Engineer.

Ladder logic programming in the PLC handles data transfer from the PMP to the PLC. Block transfer statements are used to pass information from the arbitrator to registers in the PLC. The following ladder logic rungs are used in the PLC to transfer data from and commands to the Arbitrator. Such block transfer commands make the programming of the PLC quite easy. (See Figures 2 and 3)

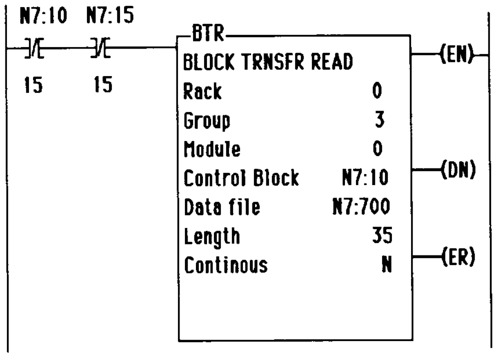

Figure 2

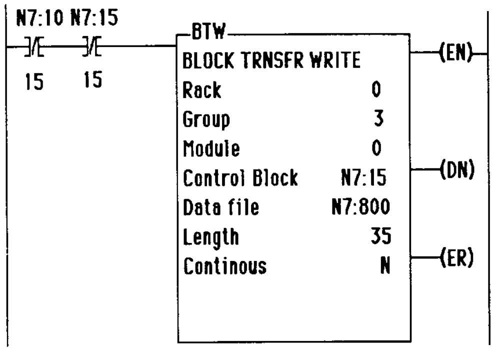

Figure 3

Communication between the PLC and the BASIC module is handled by setting up block transfers in the PLC ladder logic and by calling machine language routines in the BASIC program. The ladder logic for block transfers is much the same as the transfer of information from the Arbitrator. The PLC writes to the BASIC module. (See Figure 4)

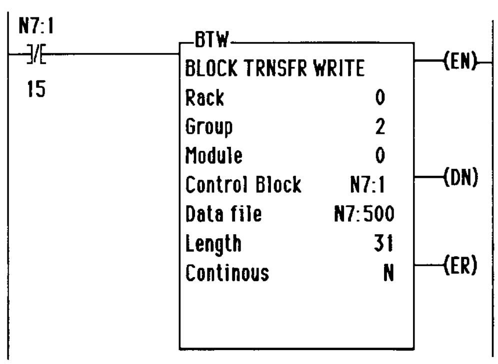

Figure 4

The BASIC program transfers information from the PLC to the BASIC input buffer. The main program in the BASIC module consists primarily of subroutine calls. An example is listed below.

```
100 REM MAIN PROGRAM
105 STRING 1301,25  : REM STRING SPACE
106 REM SET UP COMM
107 PUSH 7,2,1,1,0: CALL 30:
108 PRINT #USING(######.)
109 REM SET UP INITIAL VALUES
110 GOSUB 4000
115 REM SET UP DISPLAY ON CRT
120 GOSUB 3000
130 GOSUB 2000: REM SET UP BLK READ
142 GOSUB 10000:REM DELAY
145 CALL 3:POP X
146 IF X<>0 PRINT "NO TRANSFER"
147 REM ANNUNCIATOR DISPLAY ON CRT
150 GOSUB 5000
160 GOSUB 6000: REM MOTOR CURRENTS
170 GOSUB 7000: REM GET VOLTAGES
180 GOSUB 8000: REM GET # STARTS
190 GOSUB 9000: REM CHECK PMP STATUS
195 REM GET MAX STATOR TEMPERATURE
200 GOSUB 12000
210 GOTO 142: REM LOOP FOREVER
220 END: REM END OF THE MAIN PROGRAM
```

The data transfer from the PLC is set up by a machine language call to the BASIC ROM (Read Only Memory):

```
2000 REM SET UP BLOCK TRANSFER READ
2010 PUSH 31 : REM THE # REGS TO READ
2015 REM ROM CALL TO READ DATA
2020 CALL 4
2030 RETURN
```

Then the BASIC module uses simple PRINT statements to access the peripheral serial port and send information to the CRT. The following excerpt from the program is inside a loop which prints all three currents:

```
6065 REM PRINT CURRENTS TO THE CRT
6066 REM POSITION THE CURSOR
6070 GOSUB 1100
6080 PRINT #C(I)
```

This illustrates an appealing feature that seems to be common to all BASIC language implementations. BASIC makes it very simple to use peripheral devices, especially the serial ports. This feature is important for any language to be used for industrial control and data acquisition. BASIC provides a friendly environment for accomplishing such work quickly and easily. BASIC has the added advantage of being interpreted, thus making debugging much easier than with a compiler. The speed of execution of BASIC, however, leaves something to be desired. Perhaps the answer to increased speed is faster hardware. Newer 80x86 and 680x0 processors possess speed sufficient to make interpreted BASIC acceptably fast.

In discussing languages, let us note some aspects of the two languages used on this project, ladder programming and BASIC programming. Engineers find BASIC easy to use, perhaps due its similarity to FORTRAN. Little training, other than self teaching, is necessary for an engineer to pick up almost any dialect of BASIC and begin programming. Electricians, however, seem uncomfortable using BASIC and working with the aspects of this project which use BASIC. Electricians are accustomed to working with ladder logic, and they readily adapt to the use of such programming whether it is in a relay box or a PLC. Though some training of electricians has been done in the application of BASIC to data acquisition tasks, work with BASIC programs is normally done by the Electrical Engineer, while ladder logic program modifications are easily handled by the electricians. More thought is required in this area to establish training for electricians to enable them to pick up the maintenance on the system as a whole.

Future Directions

Two more motor monitors will be added to the system in 1988 for monitoring a new 4000 HP two speed motor. The CRT system is certainly flexible enough to provide display of as much information as desired by creating pages of information for each motor as well as an overview page.

It is possible to add any measurable quantity of interest to our display with a suitable measuring device and connection at the PLC which has the capability of interfacing with 4-20 mA, voltage, discrete inputs and outputs, thermocouples, RTDs, etc.

A modem can be added to the second serial port on the BASIC module to enable the system to accept incoming phone calls and transfer information concerning the motor to supervisors at remote locations.

Results and Conclusions

A low cost PLC system has provided accurate, timely information to the unit operators. By having the information concerning motor status displayed in the control room, the operators have been able to operate the motor closer to its limits and thereby get more yield from our Reformer unit before having to regenerate the catalyst.

The system is expandable, so that other motors can be added for display of their critical operating parameters with a small additional capital expenditure.

Operators can check alarms from the substation and evaluate the need for response without having to go immediately to the substation building. Though we had been concerned about screen update times using serial communications and the BASIC communications program, we find in practice that the speed of communications is fine for this application.

References

1. Priba, Paul, "The Application of a BASIC Preprocessor for Programming PLC User Interfaces", Advances in Instrumentation, Volume 42, Part 2, 1987, pp. 875-882.

2. Campbell, Joe, The RS-232 Solution, Sybex, 1984.