# AP-7
# Pump Station Controllers

## Introduction

The following application note discusses the use of the SR and APB family of micro PLC's for use as pump station controllers. The example will illustrate use in pump down applications such as waste water treatment plants although the same techniques may be used to implement pump up solutions.

In pump down applications the primary function is to ensure that holding tanks are emptied. The inflow of material (waste water) is typically not directly controlled. The pump station controller will measure the level of the liquid in the tank and attempt to keep the tank empty, or below a specified level.

Pump Station Controllers typically will control 2 pumps, one referred to as the 'lead' pump and the second referred to as the 'lag' pump. The use of 2 pumps ensure that there is a backup if one of the pumps fail and if the inflow rate exceeds the capacity of one pump a second pump may be activated. It is typical to provide an option to alternate the use of the pumps to even the wear on the two units.

There are a variety of ways to monitor the tank level. In most applications low cost float switches may be used although only discrete levels are actually detected. More sophisticated control may be implemented using continuous level monitoring using pressure, ultrasonics or other analog signal measurements. The use of analog signals allows system control to be adjusted based on operating conditions or power cost/time of day considerations.

In addition to controlling the pump activity a typical pump station controller will monitor the health of the pumps. Submersible pumps provide an analog signal that will indicate if water has leaked by the internal pump seal (Seal Monitor). Pumps will also offer an 'over temperature' contact that could indicate bearing problems, dry operation or other failures.

To ensure that the pump has been activated a contact from the external motor starter auxiliary contact is monitored. In advanced application the pump power draw (amps) can be monitored to provide an early indication of pending failures.

Finally, some form of operator over-ride is typically necessary for testing and to handle extreme situations.

## Two Pump Controller

The APB-22MRDL provides 14 inputs and 8 outputs and will be used to implement a 2 pump controller that uses float switches to sense the discrete levels within the holding tank. To ensure that standard pump controller features have been addressed the DWYER INSTRUMENTS FPC-1200 model has been used as a model.

Four float switches will be used to sense EMPTY, LOW, MEDIUM and HIGH levels. The EMPTY input indicates that the tank is empty and no pumping is required. The LOW input indicates that liquid is present and pumping is required. The MEDIUM input indicates that the current pumping rate is not sufficient and the second (lag) pump must be activated. The HIGH level input indicates an error condition and pending overflow.

Each pump will use 3 inputs. A normally open PUMPONx input will be closed by the starter auxiliary contact to indicate that the pump is running. An analog input SEALOKx from the pump seal monitor will be used to detect if the resistance

drops below 50k ohms indicating a seal failure. A normally open dry contact TEMPOKx from the pump temperature sensor will be closed to indicate that the pump temperature is okay.

Four operator control inputs will be used. Two inputs, MANUAL/AUTO and PUMPSELECT, will be used to select the lead/lag operation as shown below. An ALARMTEST input will be open to test the Alarm signals. The HORNMUTE input disables the HORN output.

| MANUAL /AUTO | PUMP SELECT | Operating Mode |
|---|---|---|
| OFF | OFF | Disabled – no automatic operations. |
| OFF | ON | Automatic operation and automatic switching between Pump1 and Pump2 as lead pump. |
| ON | OFF | Automatic operation. Pump1 is lead pump |
| ON | ON | Automatic operation. Pump2 is lead pump |

| Input | Function |
|---|---|
| I00 | EMPTY |
| I01 | LOW |
| I02 | MEDIUM |
| IO3 | HIGH |
| IO4 | PUMPON1 |
| IO5 | SEALOK1 ( > 50 kohm) |
| IO6 | TEMPOK1 |
| IO7 | PUMPON2 |
| IO8 | SEALOK2 (> 50 kohm) |
| IO9 | TEMPOK2 |
| IO10 | MANUAL/AUTO |
| IO11 | PUMP SELECT |
| IO12 | TESTALARM |
| IO13 | HORNMUTE |

Each pump requires 2 outputs. A PUMPRUNx signal provides SPST contact that is closed to activate the pump. A PUMPFAILx output will open if the pump temperature PUMPTEMPx opens, the PUMPSEALx input resistance to ground is < 50k ohms or if the Fail To Start condition (see below) occurs. Note that the 'model' only offers a single 'Seal' fail output that is activated if either seal fails.

Three outputs are used to drive alarm signals. The HIGHALARM output will be ON if the HIGH float detector is open. The ALARMFLASH will toggle at a 1 second rate if the HIGHALARM output is active. The HORN output will be active if the HIGHALARM output is active.

| Output | Function |
|---|---|
| Q00 | PUMPRUN1 – closed to activate pump1 |
| Q01 | PUMPOK1 – closed if no problems |
| Q02 | PUMPRUN2 – closed to activate pump1 |
| Q03 | PUMPOK2 – closed if no problems |
| Q04 | HIGHALARM – close if HIGH active |
| Q05 | HORN – close if HIGH active |
| Q06 | ALARMFLASH – 1 cyc/sec HIGHALARM |
| Q07 | ATTENTION – open if any pump fails |

The ATTENTION output, not found in the 'model' will be active if any motor fault is active or the HIGHALARM is active. This signal may be tied to a facility wide fault monitoring system or used to simply activate a signal lamp to indicate that some aspect of the controller requires servicing.

Operation

The controller will monitor the 4 level switches. If the level drops below the EMPTY sensor (sensor goes open) all pumps are turned off.

In normal operation, with an empty tank (EMPTY input off) waste water will flow into the tank. When the level activates the EMPTY switch no action is taken. When the liquid activates the LOW switch the 'lead' pump will be turned on. If this pump is sufficient to cause the level to drop below the EMPTY level the pump will be turned off.

If the flow rate is such that the level continues to rise even with the 'lead' pump active it will cause the MEDIUM level switch to be activated which will cause the 'lag' pump to turn on. Both pumps will remain on until the level drops below the EMPTY level.

If both pumps are insufficient to handle the flow the liquid will rise and activate the HIGH level which will cause the alarms to be activated.

To manage the energy consumption and to minimize pumps from tripping on due to marginal conditions there is a time lag of 8 seconds between the first and second pump being activated. Similarly, when being turned off the lag pump (second pump activated) will continue to operate for 4 seconds after the lead pump has been turned off.

Pump Lead/Lag position

As discussed above, two inputs are provided to allow the operator to select which pump is to operate as the lead pump. In most situations the lead pump will be sufficient to pump down the liquid below the EMPTY level and the lag pump will never be activated. To allow both pumps to experience equal wear the pumps are alternated. The first time a pump is required pump1 will act as the lead pump. The next time a pump is required pump2 will act as the lead pump.

If a pump indicates a SEALOK failure it will automatically be demoted to act as the 'lag' pump. If the TEMPOK contact is open the pump will be eliminated as both the lead or lag pump until the error clears.

Pump Failures

A pump can enter a 'marginal/failure' condition due to three reasons, any of which will cause corresponding PUMPOK output to open:

- Seal Leak Failure
- Over Temperature
- Fail to Start

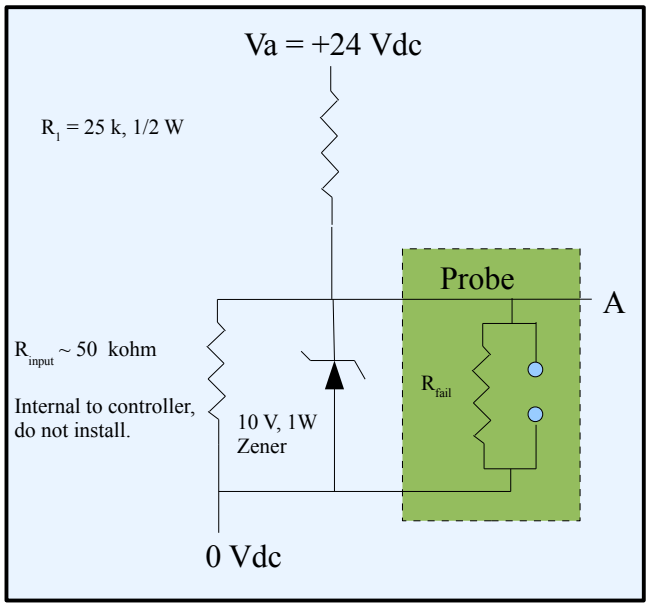
If the resistance to ground of the pump seal input drops below 50k ohms it indicates that water has leaked past the internal seals of the pump. This is not immediately catastrophic. The pump will be removed from the 'lead' position option (in automatic mode) but will still operate in the lag position.

The inputs of DC Powered APB controllers may act as digital or analog inputs. The input impedance is a

nominal 50 kohms. The following circuit may be used to connect to the seal leak sensor of the pump and the Table shows expected input voltages.

If an external Pump Seal relay is used it may be connected as a normally open (close if fail) contact between the SEALOK input and ground.




| Condition | $R_{fail}$ | Voltage (A) |
|---|---|---|
| Oil only | > 1 mohm | 10 Vdc |
| Slight leak | 100 kohm | 7.5 Vdc |
| Fault leak | 50 kohm | 5.0 Vdc |
| Short | 0 ohm | 0 volts |

If the Over Temperature contact opens it indicates that the operating temperature has been exceeded. The pump will be removed from service and will not operate until it has been cooled. A timer is activated when a TEMPOK input indicates an over temperature and will open the PUMPOK output and the ATTENTION if the temperature is not corrected within 20 minutes, a feature not found in the 'model'.

A Fail To Start error is indicated if the PUMPON signal from the starter axillary contacts fails to become active within 4 seconds after the PUMPRUN signal becomes active. A Fail To Start error will cause the ALARM output to become active, another feature not found in the model.

Each pump has a dedicated output (PUMPOK) that will become open if any pump failure occurs. Only the Fail to Start error will cause the ALARM output to become active.

Manual Operation

If the MANUAL/AUTO and the PUMPSELECT inputs are both inactive no automatic pump operation will be performed. External switches in parallel to the controller output relays may be installed to allow manual operation.

If the MANUAL/AUTO input is inactive and the PUMPSELECT switch input is active the controller will automatically switch the lead pump between Pump1 and Pump2.

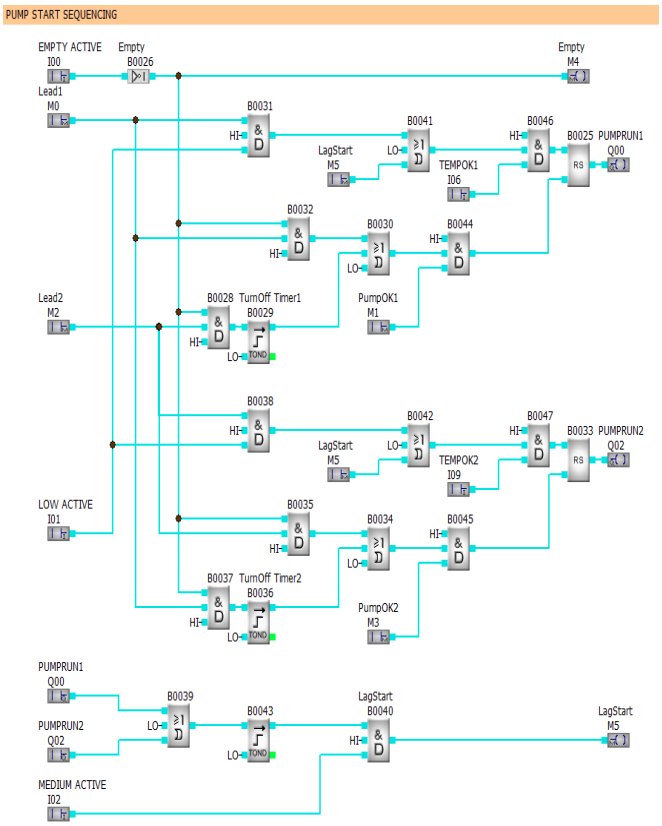
If the MANUAL/AUTO input is active the PUMPSELECT switch selects which pump will act as the lead pump.

ATTENTION Output

The ATTENTION Output will become open if any condition is detected that indicates servicing is required, such as Pump Seal leaks, Over Temperature for greater than 20 minutes or HIGHALARM conditions.

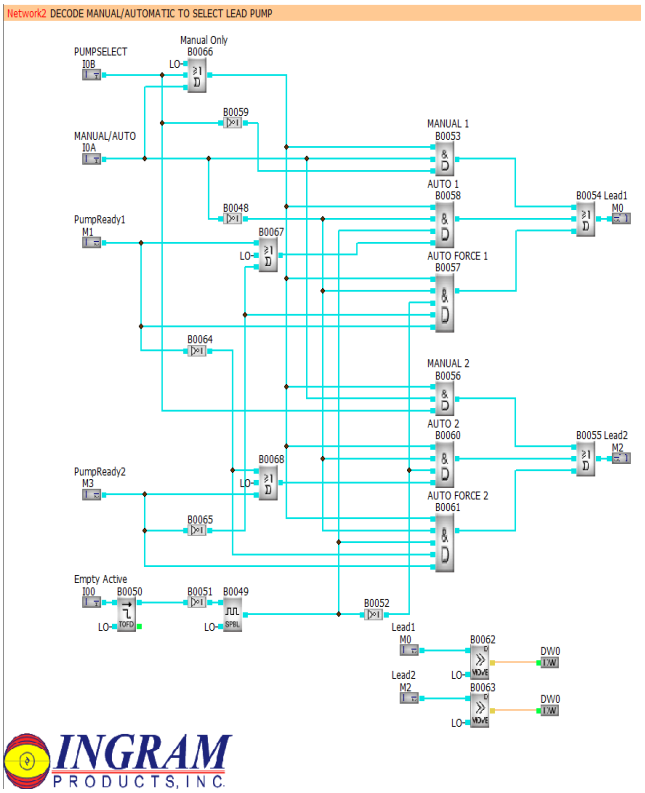
Solution

The following diagrams show the entire program, broken into 3 'networks'. Networks allow the grouping of similar sections of the program in logical 'sections'. In most cases, the code required for pump1 mirrors the code required for pump2.




The pump start sequencer detects when the LOW signal is activated and will latch ON the current lead pump. If the MEDIUM input is activated the lag pump will latch on provided 8 seconds have elapsed from the lead pump turn on.

When the LOW signal goes inactive the lead pump will immediately shut off and 4 seconds later the lag pump will shut off.

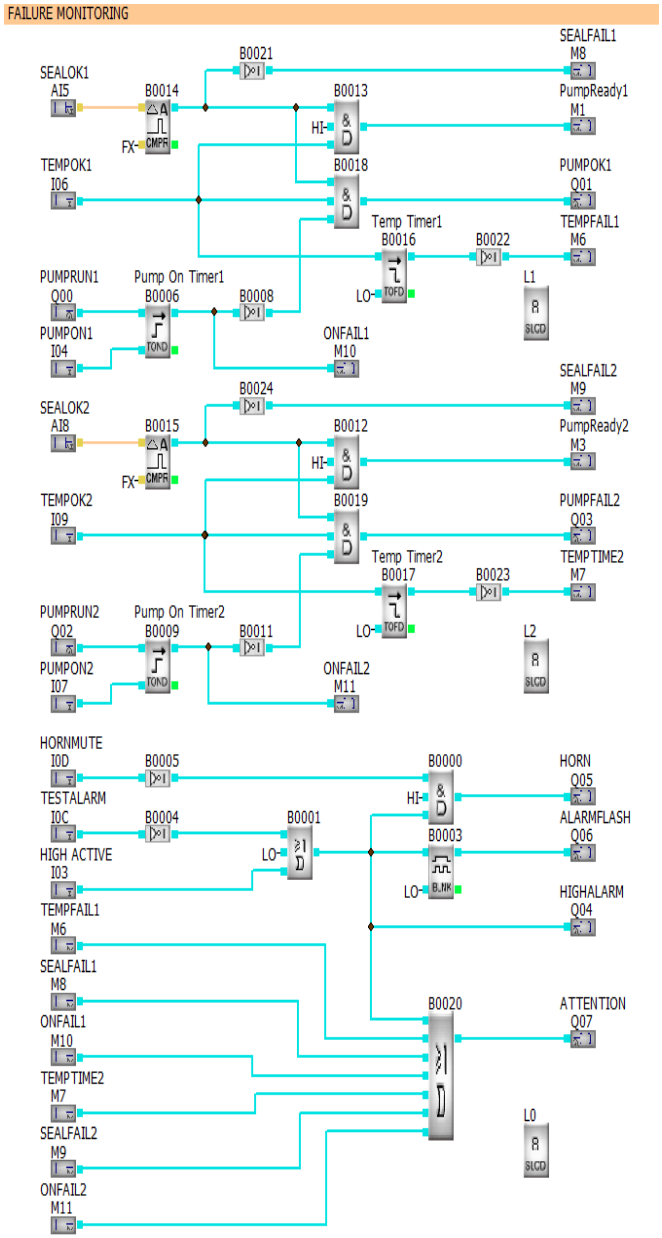





The Lead/Lag pump determination is made in network 2. If the MANUAL/AUTO switch is ON the PUMPSELECT switch will activate either Lead1 or Lead2 which is provided to the Pump Start Sequencing network.

If the MANUAL/AUTO and PUMPSELECT switches are both off neither Lead1 or Lead2 will be active and the start sequencing network will not start either switch. The system is entirely manual.

If the MANUAL/AUTO switch is off and the PUMPSELECT switch is ON the network uses the EMPTY switch going from the ON to OFF state to start a 5 second timer. After the time elapses a toggle is switched. The remainder of the circuit uses the pump status information to determine if the pump may be used as the lead pump.




The Failure Monitor network monitors the Seal input, temperature and pumpON inputs. If the Seal input is <5.0 volts or the PUMPTEMP input is inactive the pump status is disabled so that it will not take the lead position.

The PUMPONx signals are applied to a timer. If the pump has been activated a timer is started and if the PUMPONx signal is not applied within 4 seconds an error condition is reported.

The HIGH and TESTALARM inputs are used to activate the ALARM output. A BLNK function block provides a 1 second ALARMFLASH output when activated. The ATTENTION output will be activated if any out of the ordinary conditions exist.

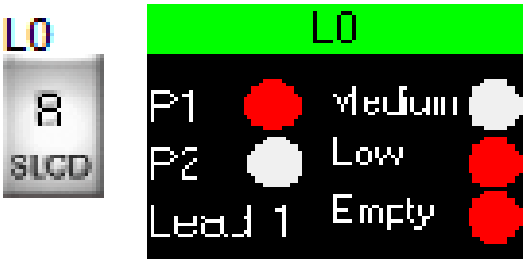
Three HMI screens are provided (shown below) that provide the overall running status and the status of each of the pumps.

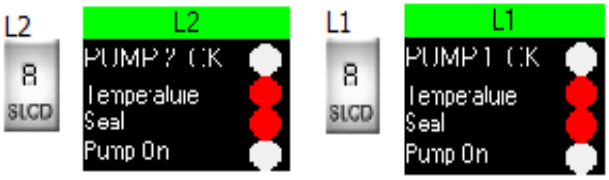
Debugging

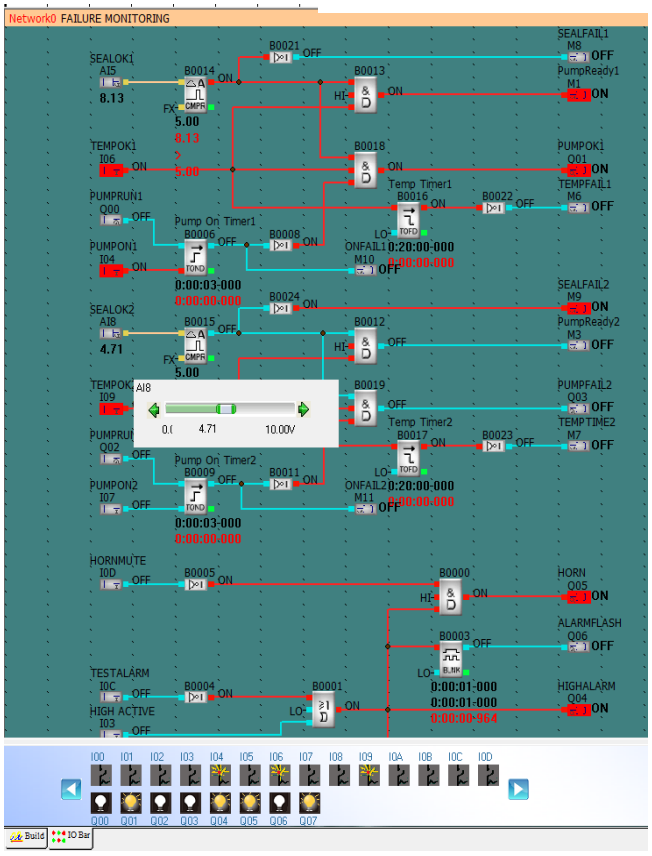
One of the power features of the APB and SR software development packages is the ability to write and test the firmware without connecting any hardware.

In the circuit shown below the screen shows the program executing in the 'simulate' mode. Each of the analog points may be set to a specific value and the digital points may be toggled ON/OFF using the IO Bar at the bottom of the screen or by double clicking the input symbol within the function block program. Times and counters show the preset and current values.

By double clicking a SCLD (HMI) function block during simulation the corresponding screen is shown.




Enhancements

The intent of the solution was to model as closely as possible the FPC-1200 commercial unit. With the power and flexibility of the APB controller numerous enhancements could be offered.

The monitoring of the pump starter auxiliary contact to ensure that the pump is operating could be replaced with monitoring the actual pump current, providing a early warning of possible pump failures if excessive current is drawn.

The commercial unit used float switches that are 'closed' when the water reaches a predefined level. Since wires tend to break more often then short, and since a broken connection would result in a missed signal these could be made selectable through the HMI interface as 'active high' or 'active low'.

Alternatively, the 4 level contacts could be replaced with a single hydrostatic or ultra-sonic sensor that measured the actual level of the water. Again, the HMI could be used to allow various set-points to be used and in advanced systems the 'time of day' information available on the APB could be used to better manage pump and energy uses by having dynamic levels. The HMI can be used to display the actual level.

The commercial unit provided fixed times of 8 seconds for pump turn on sequencing and 4 seconds for pump turn off sequencing. These times, as well as the pump on failure detection time, could be adjustable using the HMI interface.

System maintenance can be improved by anticipating failures. The seal contact information could be displayed on the HMI (actual measured voltage) to

provide an indication of a pending seal failure. By replacing the on/off motor feedback with the actual pump current draw bearing wear can be anticipated. The number of times a pump goes into a over-temperature failure could be tracked and made available on the HMI.

In larger facilities it is often desirable to collect information from all the controllers. A Modbus interface is available for the APB to allow networking multiple controllers, providing the option to collect and time-stamp controller events.
If networking is available, centralized control of each controller is possible, with set-points (time delays, level trip points etc.) to be broadcast from the central controller to each station.

Summary

Lead/Lag pump controllers may be easily created using the APB microPLC. A regular commercial unit was used as a model to implement a dual pump 'pump down' model with automatic switching between lead and lag pumps and the ability to monitor pump temperature, seal leaks and motor on feedback. The solution required < 25% of the APB capacity (69 out of 320 available blocks).

The APB microPLC has provided a very low cost alternative for implementing a standard Duplex Pump controller. A wide range of enhancements could be easily introduced that would provide greater energy management, better preventative maintenance and the opportunity of centralized control and data logging.

References

AP-1 Liquid Level Control

AP-3 APB Process Timing

Mercoid FPC-1200 Duplex Pump Controller Bulletin L-22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