AP-9
Run Time Verification

Introduction

The following application note discusses the use of the APB family of micro PLC's in machine *run time verification* applications. The example will illustrate monitoring and controlling pumps as used in a waste water treatment facilities although the same techniques may be used in a wide variety of systems.

In many industrial systems, critical sub-systems require specific monitoring to ensure that the intended operation is being performed. In the case of waste water treatment plants a failure of the pump system will result in extremely expensive and potentially life threatening overflow conditions.

In addition to protecting against a catastrophic failure, monitoring of pump performance may lead to improved performance, better scheduling and usage of repair/maintenance resources and reduced energy costs. When taken as a whole, these secondary advantages often will provide a very short return on investment.

For the purposes of this application note the pump and the associated controls will be viewed as a subsystem. The pump subsystem will accept a single 'input' indicating that the pump should be activated and will generate 3 outputs, indicating whether the request can be accepted and the current operating condition of the subsystem.

Measurable parameters may be separated into two broad classifications: those that are present prior to activating the pump (status Parameters) and those that are measured while the pump is operating (Running Parameters). A sub classification is those parameters that prevent the pump from operating and those that indicate that the pump is operating at less than optimal performance.

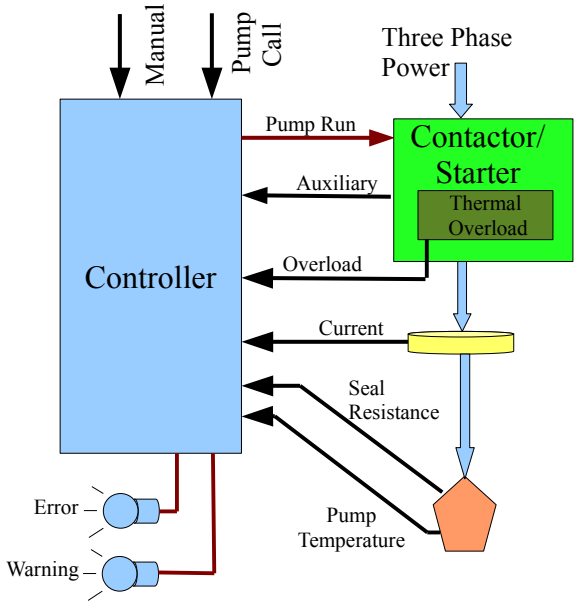
Pump Status Parameters

Parameter	Level	Description
Seal Resistance	1 or 2	Indicates if water has leaked past the motor seals. Indicates that the pump will fail.
Motor Temperature Contact	2	Indicates pump motor is over temperature and inhibits starting of the pump.

Pump Running Parameters

Parameter	Level	Description
Motor Temperature Contact	2	Indicates pump motor is over temperature and forces pump to immediately shut down.
Starter Auxiliary Contact	2	Indicates that motor starter has been activated.
Starter Thermal Contact	2	Indicates excessive current draw by pump has tripped the motor thermal overload relay.
Pump Current draw	1 or 2	Instantaneous current draw of the pump. If out of range indicates clogging, loss of prime, jamming or pump bearing/impeller wear.

Level 1 – (Warning) indicates performance/long term problem
Level 2 – (Error) indicates pump is not/should not operate



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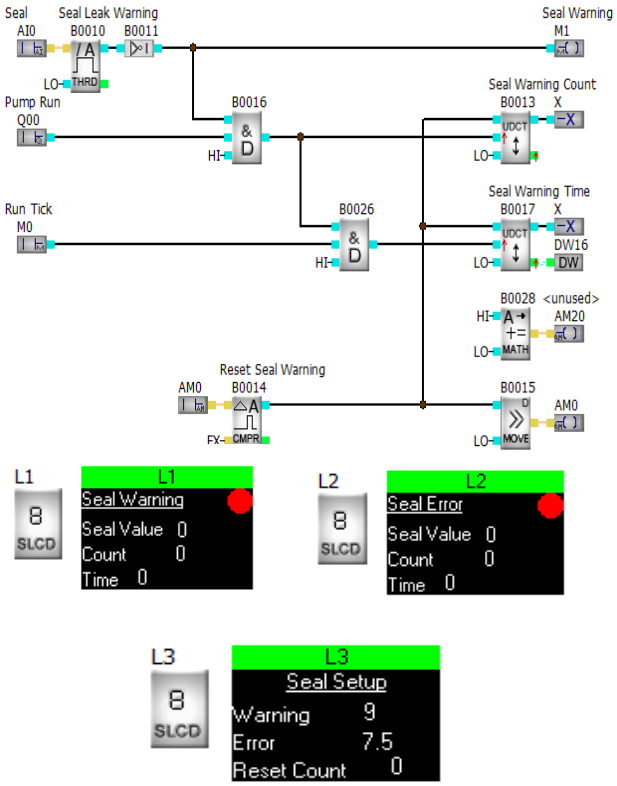
The Run Time Verification will activate an Error and/or Warning light if the controller detects any errors within the pump system. In addition, run time statistics will be collected including the number of errors/warnings of each type and the running time under either warning or error conditions.

Seal Resistance

The Seal Resistance measures the presence of water that has leaked past the seals within the pump. This indicates that maintenance is required but does not generally not take the pump out of service unless an extreme leak has been detected.

The circuit shown below, based on similar circuits discussed in AP-7 Pump Station Controller, provides two threshold detectors that monitor the resistance of the pump seal contacts. One threshold is set to detect when minor leakage is present which is treated as a Warning level. The second threshold detects when severe leakage is present and is treated as an Error level. A counter is provided to track the number of times the pump is started when the seal has leakage.

Two HMI screens are provided. The first shows the status of the Error and Warning indicators, the current seal leak reading and the number of times the pump has been started with the seal signal out of specification. The second HMI screen, protected with a password, allows setting the two thresholds and resetting the counter.



Pump Temperature

The Pump Temperature sensor is typically a normally closed contact that will open when the pump temperature exceeds the manufacturer rating. If the pump temperature is too high the pump will be disabled (prior to running) and will be shut down (if running).

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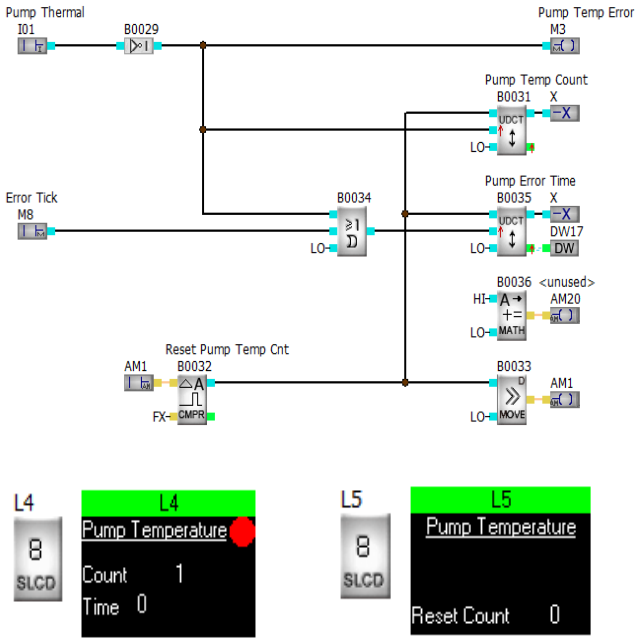
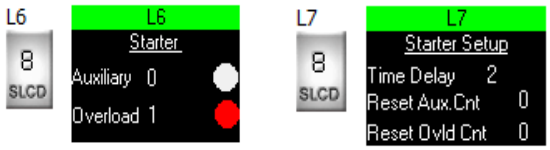




The circuit shown uses a time-on-delay triggered by the Pump Run signal going active. If the Contactor, such as a CHINT NC1 auxiliary contact closes within the programmed time the Contactor Error is held off. A counter is used to track the number of errors.

The HMI allows displaying the state of the Contactor Error signal and the number of times the error has occurred. A second HMI screen allows setting the delay time and resetting the count under password control.

When the pump is initially started there is a high in-rush current. Once the pump has reached it's operating speed this should settle to the running current.

The CHINT NR2 Thermal Overload Relay connects to the CHINT NC1 contactor to monitor the pump currents and will trip if the running current exceeds a preset level. In addition to mechanically opening the contactor auxiliary contacts (N/O and N/C) are available to indicate that the device has tripped.

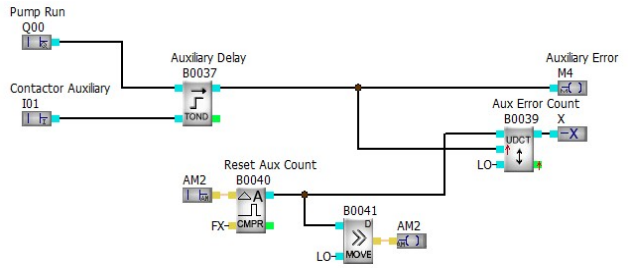
The circuit shown accepts a N/C input and if it opens it indicates that the Thermal Overload Relay has tripped which is treated as an Error condition.

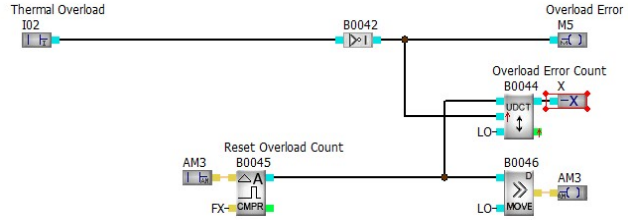
A counter will track the number of errors, available on the HMI and the setup HMI screen allows resetting the error count and time delay under

Starter Auxiliary Contact

The CHINT NC1 general purpose contactor provides 3 phase control for 9-100 Amp. The unit is available with an 'auxiliary' contact closure that indicates that the contactor has been activated.

Because there is a mechanical time delay between the activation signal to the starter and the starter physically closing the signal is typically sampled a set time period after the signal has been issued to start the pump.





password protection.

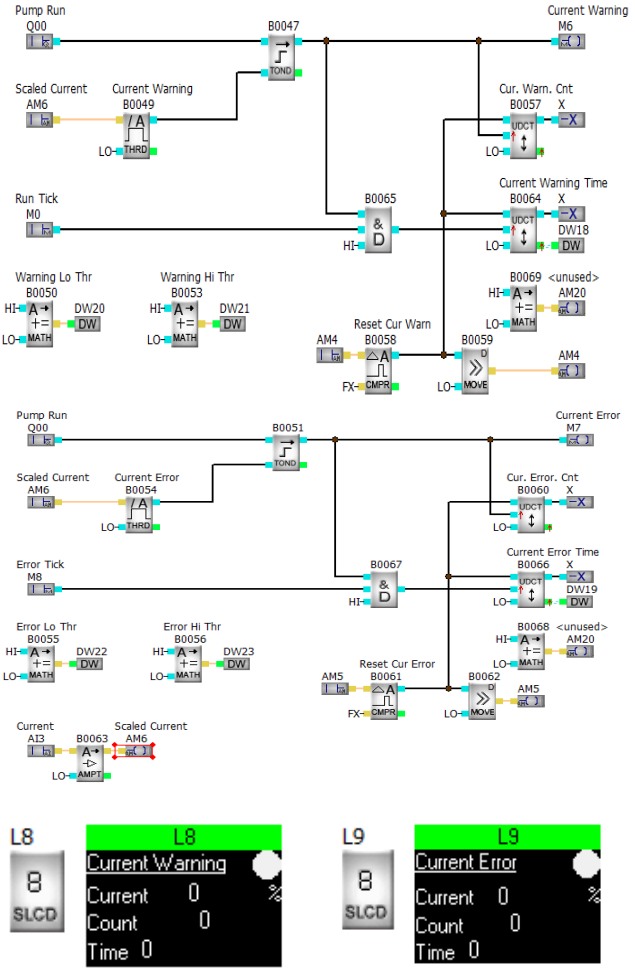
Pump Current

The addition of an analog current sensor to the pump system will provide valuable information for both short term operation and long term maintenance.

In normal operation the pump would be expected to draw a fairly constant current. If the inlet becomes clogged or if the pump loses its prime the load on the pump is reduced and the current will typically drop. Conversely, if the pump impellers become clogged or damaged or as the pump bearings wear the current will typically increase, although not enough to trip the Thermal overload relay.

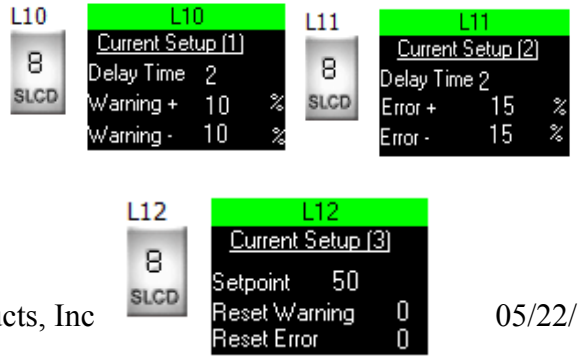
The Furison FCS521-SP-10V AC current sensor provides a 0-10 volt signal proportional to the AC current and supports a variety of ranges from 10 Amp full scale to 50 Amp full scale. The FCS2151-SP-10V extends this to 100 Amp – 200 Amp.

Two identical circuits are used, one to provide a warning signal and the second to provide an error signal. The HMI screen shows the unscaled current being drawn (0.0 – 10.0), the warning status and the number of times the warning state has occurred.



The Current Error circuit is identical but uses a separate set of High/Low threshold values.

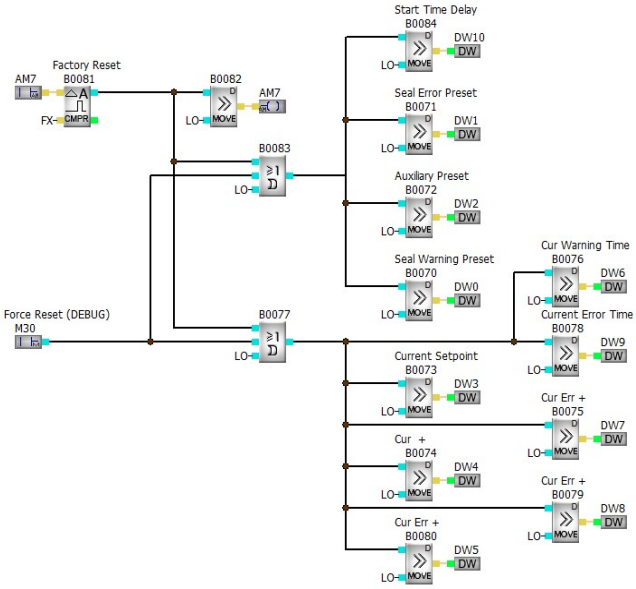
The warning signal is triggered if the current falls out of the specified range for a time greater than the 'warning' time. If the fault clears before the 'error' time is reached the circuit will reset and remove the warning condition. If the current draw stays out of the specified range until the error time is reached the error condition will occur, shutting down the pump.



Two password protected HMI screens allow setting the delay time and the +/- tolerance (percentage) for the Warning and Error level sensing. The third screen sets the 'normal' operating current set-point and allows resetting the Warning and Error counts.

Factory Reset Option

Due to the number of parameters that may be set a 'factory reset' option has been provided. The reset values are all defined in the 'MOVE' blocks.



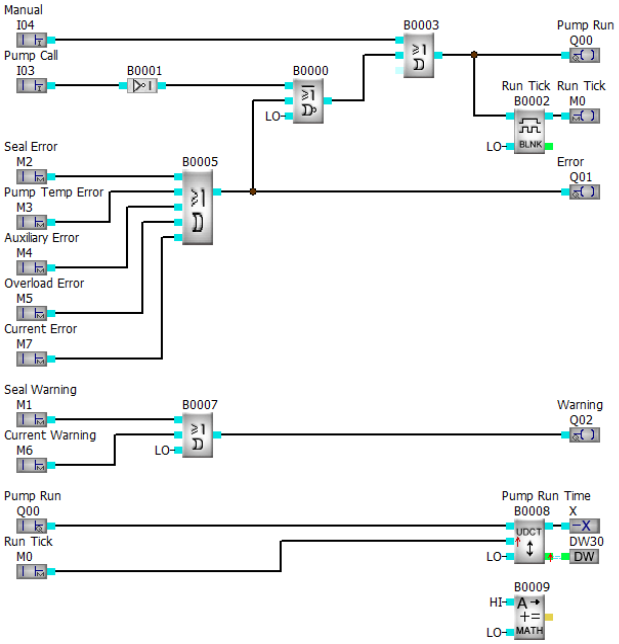
Control Function

The control function accepts a 'Pump Call' contact closure that will activate the pump provided no error conditions are present.

If a Warning condition is present the Warning Light will be on and the pump will still operate. The timer associated with the warning condition will track the hours of operation with the condition present.

If an Error condition is present the pump will not operate and if operating the error condition will shut the pump off and activate the Error Light.

A manual override input has been provided that will force the pump on even if an error condition (pump temperature, seal error, current error) does exist. If the error condition has been indicated by the starter auxiliary contact, the starter overload relay the manual input will have no affect.



The following tables provide the I/O interface information as well as the assignments of counter/timer blocks and the DW registers. If a Modbus interface is developed accessing these parameter fields would allow remote control and monitoring of the Run Verification controller.

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Counter	Function
B0013	Seal Warning Count
B0017	Seal Warning Time
B0031	Pump Temperature Count
B0035	Pump Temperature Time
B0039	Aux. Contact Count
B0044	Overload Count
B0057	Current Warning Count
B0064	Current Warning Time
B0060	Current Error Count
B0066	Current Error Time

The implementation includes counters that track each time a warning or error condition occurs and counters used to track time (number of seconds) that the pump operates with either the warning or error condition present.

All variables that affect thresholds or time delays are maintained in non-volatile DW registers, allowing a 'user friendly' HMI interface for setting and displaying these parameters.

In a final implementation many of the DW based parameters could use the internal presets of the function block. Although the HMI can still be used to tune these parameters the interface is done at the block level and would require a more detailed operating manual.

DW Registers	Usage
DW0	Seal Warning Level (0-10 Vdc)
DW1	Seal Error Level (0-10 Vdc)
DW2	Auxiliary Contact Time Delay (x.xx seconds)
DW3	Current Set-point (Percent)
DW4	Current Warning + tolerance (percent)
DW5	Current Warning - tolerance (percent)
DW6	Current WarningTime Delay (x.xx seconds)
DW7	Current Error + tolerance (percent)
DW8	Current Warning + tolerance (percent)
DW9	Current Error Time Delay (x.xx seconds)
DW10	Starter Contact Time Delay (x.xx seconds)
DW non-retained	
DW15	Seal Warning Run Time (seconds)
DW16	Seal Error Run Time (seconds)
DW17	Temperature Error Run Time (seconds)
DW18	Current Warning Run Time (seconds)
DW19	Current Error Run Time (seconds)
DW20	Current Warning intermediate
DW21	Current Warning intermediate
DW22	Current Error intermediate
DW23	Current Error intermediate
DW24	Pump Run Time (seconds)
Internal Relay	
M0	Run Tick – .1 pulse/sec if running
M1	Seal Warning (active HI)
M2	Seal Error (active HI)
M3	Pump Temp Error (active HI)
M4	Contactor Auxiliary Error (active HI)
M5	Overload Relay Error (active HI)
M6	Current Warning (active HI)
M7	Current Error (Active HI)
M8	

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Summary

A generic pump Run Time Verification system has been developed that monitors and verifies:

- Seal Leak resistance
- Pump Temperature
- Starter (Contactor) close verification
- Starter Thermal Overload
- Motor Current draw

The controller will provide a Warning and/or Error indication if the monitored parameters are out of a user defined range. For statistical tracking, the controller counts the number of times (and the operating times) if the pump is operated under each of the warning or error conditions.

The implementation required 86 Function Blocks (25%) of the APB-12MRDL controllers' capacity. Additional functions, such using an ultrasonic absolute level measurement or flow rate monitoring on the pump could be added to further enhance the system.

A Modbus interface could be added to allow data collection of the overall health of the pump.

References

AP-1 Liquid Level Monitoring
AP-3 APB Process Timing
AP-7 Pump Controller
AP-8 Run Time Control

NC1 General Purpose Contactor
NR2 Thermal Overload Relay

FCS521 Current Sensor

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