PLC Programming Issues

Herb Strong

Pam Gurd

December 4, 2001

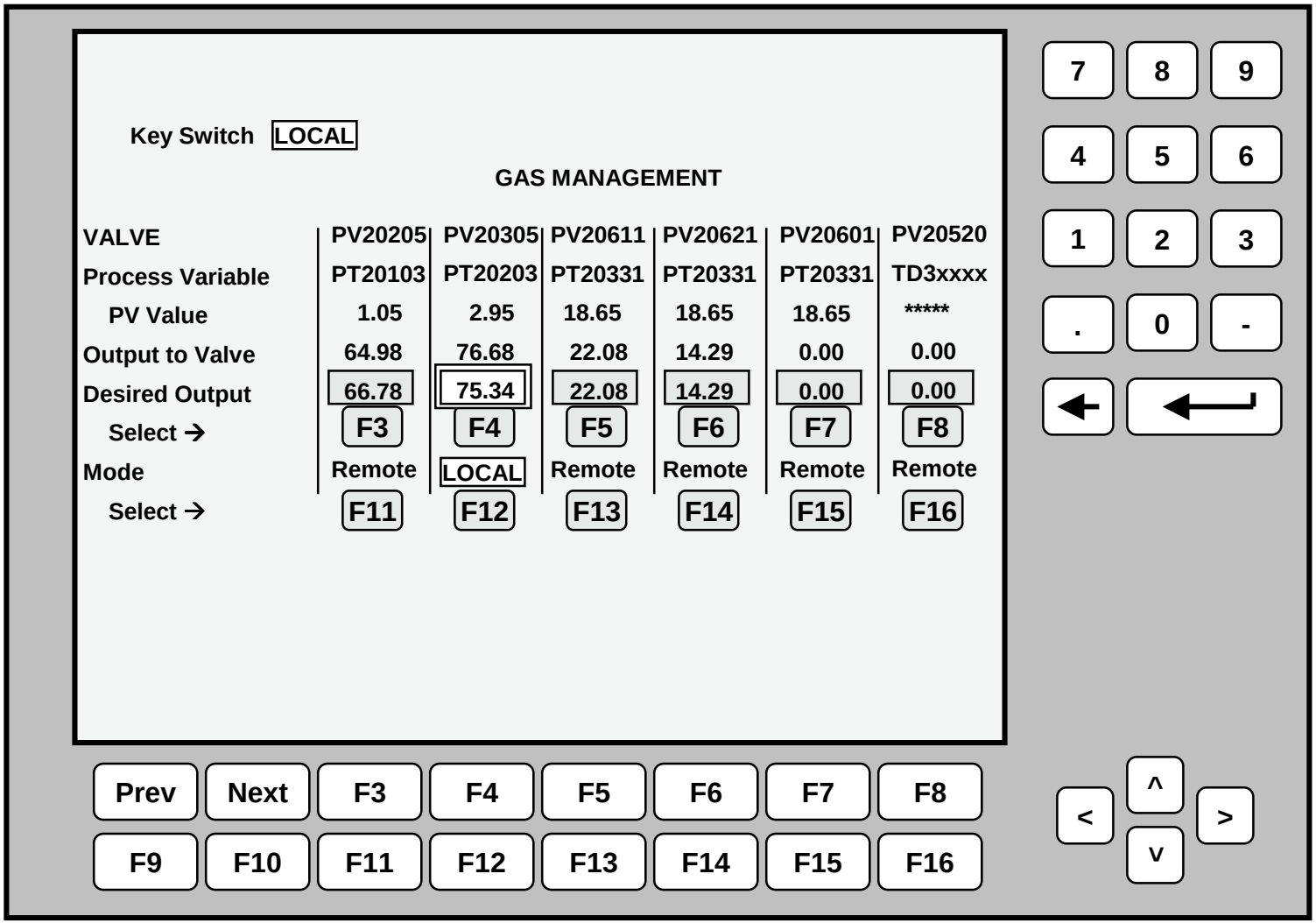
Why Use PLCs with EPICS

- PLCs can perform low level interlocks and logic needed to protect equipment
- If the IOC communicating with the PLC is offline for some reason (software update, reboot, etc.) the PLC may still allow the process to remain in operation.
- Inexpensive local operator interface available for PLCs
- Long term hardware and software support provided by vendors
  - » Can still purchase new modules for 15 year old PLCs

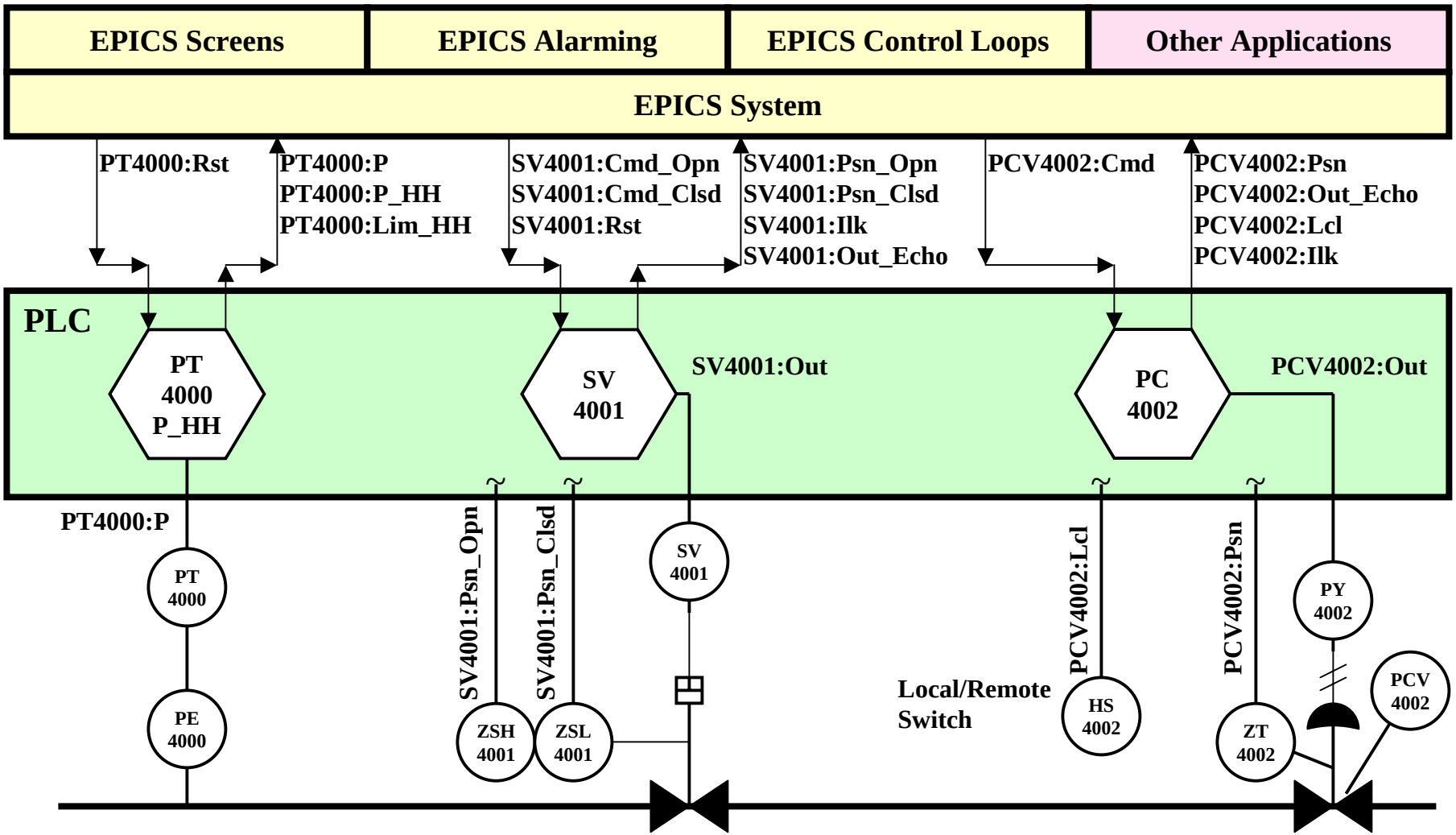
Why Use PLCs with EPICS

- PLC operation is stable.
  - » Once the PLC operation is verified, updates are very infrequent.
- Changes can be made on-line with no reboot.
  - » Process can remain running while changes implemented.
  - » Easy to roll back to previous version if unexpected results.
- PLCs may be used where high-speed (millisecond and faster) data acquisition and control is not required
  - » Fast enough for utility type systems; HVAC, vacuum, cooling tower water, Cryogenic, etc.
- EPICS drivers are available for several PLCs

PanelView Local Control Screen



General Signals, PID loop closed in IOC

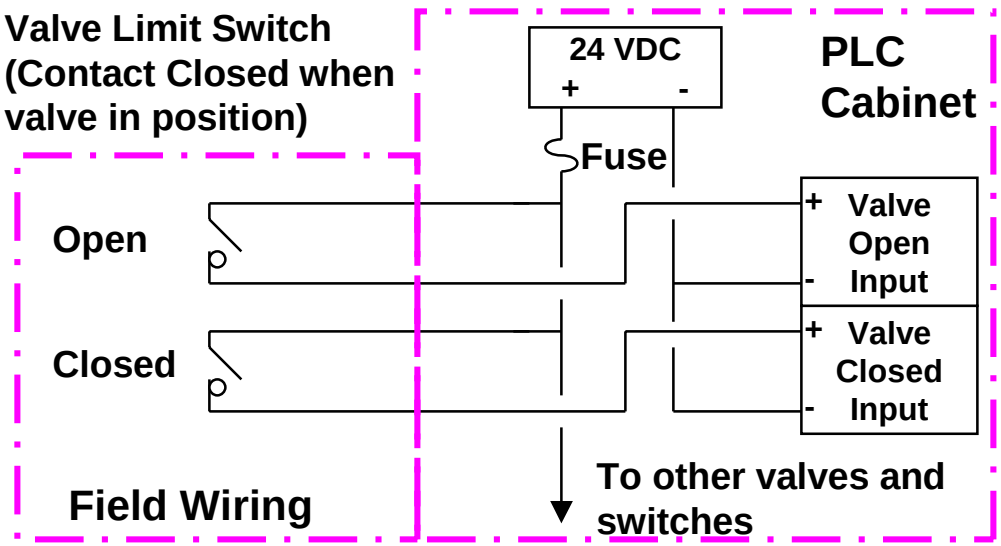


Contacts, Normally Open or Closed

- All switches and contacts will be wired in a fail safe manner such that
  - A closed contact indicates a "good", "normal", or "known" condition
  - An open contact indicates an "alarm", "off normal", or "unknown" condition
- Position switches on solenoid valves
  - Positive indication of the valve position at each end of travel

Valve position switch wiring (1/2)

Normally Open Limit Switch

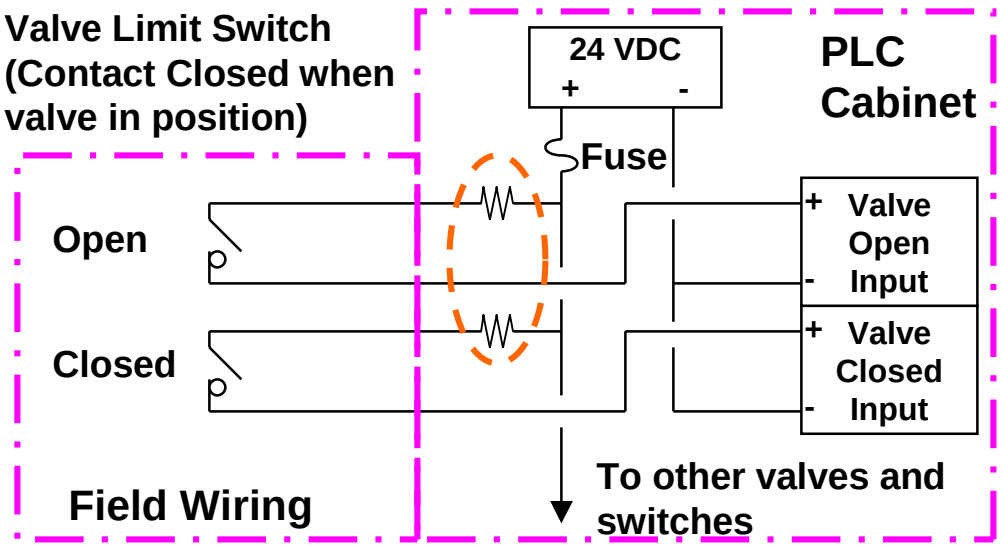


PLC Input Bit		Meaning
Open	Closed	
0	0	Transition, fail if too long
0	1	Valve Closed
1	0	Valve Open
1	1	Fault

- Advantage: If a wire breaks, indication of that position is lost. If a valve in the beam path is open and the open wire breaks, the PLC will indicate that the valve is not open. The beam would be turned off. Fail Safe
- Disadvantage: If work is being performed on the valve and the +24 vdc is shorted to ground, indication of all other inputs powered by the same fuse will be lost.

Valve position switch wiring (2/2)

Normally Open Limit Switch



PLC Input Bit		Meaning
Open	Closed	
0	0	Transition, fail if too long
0	1	Valve Closed
1	0	Valve Open
1	1	Fault

- Advantage: If a wire breaks, indication of that position is lost. If a valve in the beam path is open and the open wire breaks, the PLC will indicate that the valve is not open. The beam would be turned off. Fail Safe
- Advantage: If work is being performed on the valve and the +24 vdc is shorted to ground, indication for only that valve is affected.
- Disadvantage: Extra components to install and check. Added costs for installation

PLC General Operation

- Some PLCs asynchronously read the inputs while processing interlock logic.
  - » An input might change state part of the way through the program logic scan.
- All PLC inputs should be scanned into input buffer arrays, analog and discrete, at the beginning of the each program scan so that any sequence dependent logic will operate on a time consistent set of inputs.
- Output modules should be configured to set the output to a known fail safe state in the event:
  - » Communication to the PLC processor fails
  - » The PLC is not in the "Run" Mode
  - » The output module fails

EPICS to Allen-Bradley PLC Interface

- The EPICS driver for communicating to ControlLogix PLCs over Ethernet will be used to transfer data between the PLCs and EPICS
- The most efficient method for data transfer is to use arrays in the PLC
  - The transfer of one byte of data takes nearly as long as 512 bytes of data.
  - Real or Integer (Int or DInt) arrays for analog I/O and control commands
  - Boolean or Integer arrays for discrete I/O and control commands

ControlNet Communication

- Used to send and receive information from the concentrator PLC to remote PLCs
- Each node must have an unique address 1 to 99
- Data should be combined into arrays or user defined data types to minimize connections
  - » Use one user defined type tag for data from the remote PLC (producer) to the concentrator PLC (consumer)
  - » A second user defined type tag for data to the remote PLC (consumer) from the concentrator PLC (producer)

EPICS and PLC watchdog signals

- A heart beat signal should be sent from the IOC to the PLC
- If the IOC heart beat signal stops
  - The PLC will continue to process all interlocks
  - The PLC will freeze the EPICS commands to all control devices
  - The EPICS commands will remain frozen until the IOC heart beat is updated for at least 2 seconds
- The PLC will provide status information to the IOC
  - PLC processor status
    - Mode: run, program, etc.
    - Major and minor fault data
    - Scan times
  - I/O module status

Discrete Status Signals to/from EPICS

- For each type device, a group of bits should be reserved in the PLC array for transfer of process information to EPICS
- A standard format (bit order) should be developed for each type of device
- All EPICS command signals should be momentary
- Input, interlock, and status variables should be copied into the buffer array read by EPICS
- The elements in the EPICS buffer array should not be used in the PLC interlock logic since the elements could potentially be modified by EPICS

Analog Input Signals

- The ControlLogix analog I/O modules have the capability to convert signals to engineering units
- Thermocouple and RTD signals should be converted to engineering units by the T/C and RTD I/O modules.
  - The converted values will be monitored by EPICS
- Linear analog input signals should be converted to engineering units by the analog input module. Example:
  - A pressure transmitter with a 4 – 20 ma output that is calibrated such that 0 PSIG = 4 ma and 30 PSIG = 20 ma.
- Non-linear analog input signals should be converted to engineering units by the IOC

Analog Output Signals

- **Use real values, not integer, for all analog signals**
- **Analog input and output module scaling**
  - **Configure the current modules to scale the 4 to 20 ma signals so that 0.0 ma = –25.0% and 20.0 ma = 100.0 %. This allows the EPICS to send a slightly negative value if there is some drift in the operation of the control device.**
  - **Configure the voltage modules to scale the 0 to 10 vdc signal to 0.0 to 100.0 %.**
- **This should make the EPICS scaling easier since all analog signal raw values will be a percent of full scale.**

Alarms

- All alarm generation should be done in EPICS
  - Alarm processor works well
  - Limits readily available to the operator
  - Limits are included with several record types
  - Easy to add new alarms
- Some PLC modules have the ability to check alarm limits and generate alarm status bits
  - Maintenance of limits is difficult
  - Alarm limit data may be hidden from operator
  - Additional PLC and EPICS work required to allow operator modification of limits
  - Additional EPICS work required to handle the status bits
  - Hard to add new alarms, reconfigure module
  - Not recommended

Interlock Signals

- These are signals like high pressure alarm, low temperature alarm, etc. that are used to indicate alarm conditions and/or to initiate an action performed by the PLC logic
- Alarm action limits and alarm status bits should be monitored by EPICS
- When an interlock input signal (analog or discrete) indicates an alarm condition, a bit in the PLC should be latched to indicate the alarm status
- EPICS will provide a reset command to reset the latched PLC bit
  - » If the alarm condition no longer exists, the PLC alarm latch bit will be reset
  - » If the alarm condition still exists, the EPICS reset command will have no affect on the PLC alarm latch bit

Control Algorithms

- PLCs include instructions for performing many control equations including standard PID instructions.
- In general, it is better to implement PID loops in EPICS
  - Input and output signals may come from different IOCs
  - Easy to substitute an alternate process variable if the primary process variable sensor fails
  - Tuning coefficients more readily available to operator
  - Update time adjustable by operator
- PIDs may be implemented in the PLC
  - If communication delays between the IOC and PLC are too great for proper loop operation
  - If all input and output signals needed for a PID loop are connected to a PLC
  - If IOC reboot cannot be tolerated in the control loop

Recommendations

- **Use PLCs where**
  - **High availability of interlock control is required**
  - **Maintenance of control capability is required even during IOC reboot**
  - **High speed data acquisition and control is not needed**
  - **Complex control algorithms are not required**
  - **Remote I/O is needed**
- **Do not use PLCs**
  - **For I/O modules, VME is probably less expensive**
  - **For alarm generation**
  - **For high level sequences**