23

Instrumentation, control and monitoring system

David Bloxom and Mark Wilf*

23.1 Introduction

Process control and monitoring in commercial RO desalination systems utilizes almost exclusively computer based Supervisory Control and Data Acquisition (SCADA) system. The SCADA configuration includes a central computer providing video display, data storage and reports. The SCADA is connected through communications network with a distributed network of process monitoring and controlling microprocessors–programmable logic controllers (PLC's). As shown on the schematic diagram of a control system of RO plant in Fig. 23.1, the master PLC, database server and plant operators monitoring stations are located in the control room. The local controllers are distributed at locations adjacent to the equipment being controlled. Each local controller can include a full PLC or just be a remote Input/Output (I/O) rack with power supply and input-output adaptors, enclosures for instrumentation and sensors input. If the rack includes a PLC Processor it can operate independently from the Master PLC in the control room in the event of a Master PLC or communications system failure. The local PLC or Remote I/O uses a communication module for data transmission to and from the master PLC located in the control room.

*Vice President, Tetar tech Inc., 18311 Bothell Everett Highway, Suite 260, Bothell, WA 98012
e-mail: david.bloxom@tetratech.com

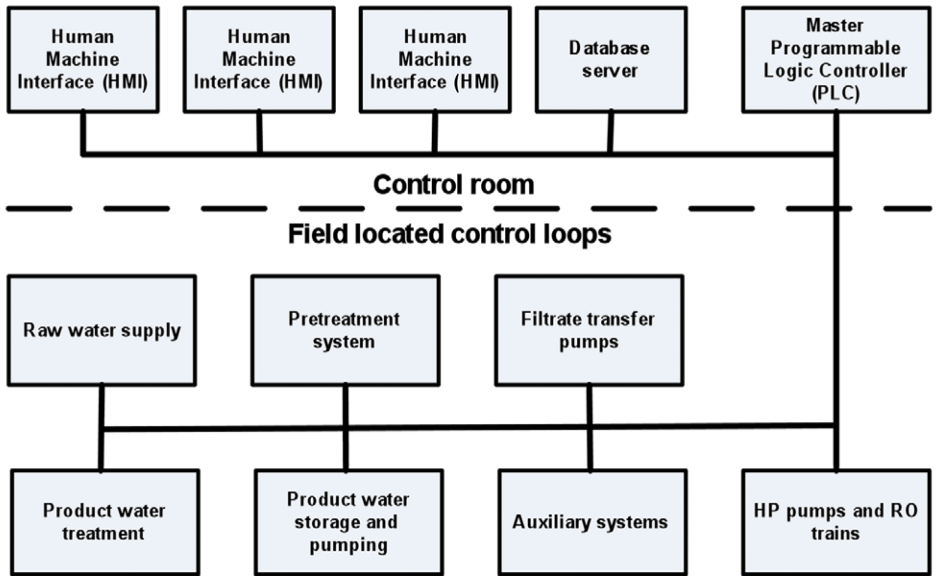

FIG. 23.1 Schematic configuration of a control system.

The Master PLC evaluates process parameters of designated system unit and control its operation within the determined limits. Local PLC's communicate with the central control unit usually through fiber optic cables that provide connection free of electric noises. In some cases of remote systems, a wireless communication between control system components is practiced (1).

Please note that the term PLC is being used as it is the most common microprocessor based system currently being utilized. A Distributed Control System (DCS) which is more common in industrial process control applications can be utilized in lieu of a PLC based system.

Process control is achieved through evaluating the output signal from sensors installed in the plant, and controlling operation of pumps and valves.

Operation of the control system is supported by Uninterruptable Power Supplies (UPS), that provide sufficient energy (capacity and time duration) to maintain control system operational during the gap period between the time of failure of the main energy supply and the time that the emergency power generator is operational.

The control equipment should be configured and programmed to return automatically to accurate measurements immediately upon restoration of power after a power failure or when transferred to emergency power supply.

The components should be of heavy duty type, designed for continuous operation in environment of a water treatment plant. Sensor, transmitters and control devices field mounted should be protected from exposure to extreme temperatures and weather conditions.

The control system should have sufficient redundancy to enable maintaining process control capability also in case of partial failure of the control equipment. Transfer of process control to backup equipment is done automatically based on self diagnostic capability of the control equipment.

Majority of currently applied control systems provide the following functionality:

1. Protecting system from operating at conditions that may result in equipment damage.

   For example: Equipment operation is started in predetermined sequence. Pumps are protected from operation at inadequate suction pressure, at extreme pH or temperature feed water is diverted to drain etc.

2. Maintaining equipment operation within the design process limits.

   For example: Operation is controlled to maintain design limits of feed temperature, pressure, flow etc.

3. Activating a design sequence duration of operation of selected equipment

   For example: During startup and shutdowns valves and pumps are being activated and maintained in operation for a period required to fill system with feed water or to replace high salinity concentrate.

4. Allowing controlled intervention of operators in system operation.

   For example: Plant operators are allowed to change setting of operating parameters or activate/deactivate operation of equipment according to predetermined authorization.

5. Maintaining production of the design quantity and quality of product water.

   For example: Feed pressure is adjusted to produce design output capacity. Permeate is diverted to drain if design quality is not met. Dosing pumps are controlled to maintain designed pH and hardness of the product water.

6. Storing operating data and generating reports in form of visual display and hard copy.

   For example: Historical results and performance trends reports are generated. Membrane performance results are normalized. Operating cost data are calculated. Operating data are organized to demonstrate regulatory compliance with required product water quality. Records of operating parameters are maintained to satisfy conditions of major equipment warranty terms.

The control system is usually divided in to functional sections (control loops) according to logic of plant operation functions, performed by individual sections of the plant.

The functional control loops may include:

- Feed water supply control loop
- Pretreatment control loop
- Main membrane system control loop
- Membrane trains control loops
- Motor control center loop
- Electrical circuits and VFD loop
- Permeate post treatment, storage and pumping control loop
- Residuals management system control loop

Usually each functional section of the plant is controlled by a separate PLC that communicates with the master PLC using a dedicated communication network (distributed control configuration).

Current programmable controllers are increasingly more powerful and are capable to handle large number of input and output signals, perform extensive calculation and control functions. It is possible to have a single programmable controller to control the complete desalination process, even of a large plant (centralized control configuration).

Decision between distributed or centralized system control configurations depends on the preferences of the system designer or the end user.

The detailed design of system configuration, selection of components and operating software of the control system is developed by process control professionals. However, the design is based on the configuration of wastewater reclamation system, operational logic and range of operational parameters specified by the process engineer that supervises project execution

The advanced wastewater reclamation system is relatively complex as it is composed of two autonomous membrane processing systems: feed water membrane filtration system, treating feed water to the RO membrane units, and RO desalination system operating for reduction of concentration of dissolved constituents in the final product.

Out of two membrane units, operating in series, the configuration and operation of membrane filtration pretreatment unit is more complex than configuration and operation of the RO unit treating filtration effluent.

Operation of membrane filtration unit is composed of series of relatively short and frequent sequences of operational steps:

- Direct (dead end) filtration
- Backwash step applying reverse flow of filtrate
- Air scouring sequence
- Chemical enhanced backwash (CEB)
- Chemical cleaning in place (CIP)
- Integrity test

The first, direct filtration step, is the only process step which results in filtrate production. The filtrate production step usually lasts between 20–60 min. A constant flow of filtrate is maintained by adjusting feed water pressure (or vacuum on the filtrate side of the membrane) and/or by adjusting throttling of the filtrate flow. The objective of the subsequent process steps is to restore water permeability of the membrane that rapidly declines during direct filtration step. In addition, the integrity test is conducted periodically to verifying integrity of the membrane barrier.

Maintaining constant level of filtrate output and proper sequence and duration of the above operation steps requires precise control of opening/close position of large number of valves and adjustment of operation of numerous pump drivers.

Practically in all cases, the membrane filtration system is composed of number of membrane trains that undergo different operational steps in an overlapping sequence. The sequence among different trains has to be designed to maintain constant level of filtrate production from the pretreatment system, delivered as a feed to the RO unit. The operational sequence of each membrane unit has to account also for the need for sufficient availability of filtrate flow rate for the backwash and scheduled availability of common auxiliary equipment, such as air compressors, backwash pumps and chemical dosing pumps. Time required for proper positioning of numerous valves has to be built in to the overall system control program scheduling equipment operation.

Compared to the membrane filtration system, the operation of RO unit consists of very long periods of operation, during which the constant product water flow is maintained through gradual adjustment of feed water pressure. Feed pressure fluctuates mainly to compensate for changes of feed water temperature or slow increased membrane resistance to water permeability due to fouling of membrane surface.

Control of maintaining design operating conditions of RO membrane train is accomplished by two control loops as shown in the Fig. 23.2. Permeate flow rate from the membrane unit is measured by a flow sensor installed on the permeate line. Te signal from the flow sensor is transmitted to a control unit that controls the driver of the high pressure feed pump. The permeate flow rate is adjusted by changing feed pressure to the RO membrane unit.

The second control loop controls flow rate of the concentrate by adjusting close/open position of the concentrate valve. The signals of permeate and concentrate flow rates are compared in the process control unit to maintain the design flow ratio (recovery rate) and product flow.

Similarly to the membrane filtration system, the RO section of the wastewater reclamation plant usually also consists of multiple membrane units, mainly to provide flexibility of adjustment of plant output capacity. Control of operation of individual membrane units (RO trains) is different then it is practiced in the case of multiple membrane filtration units. Due to long periods of

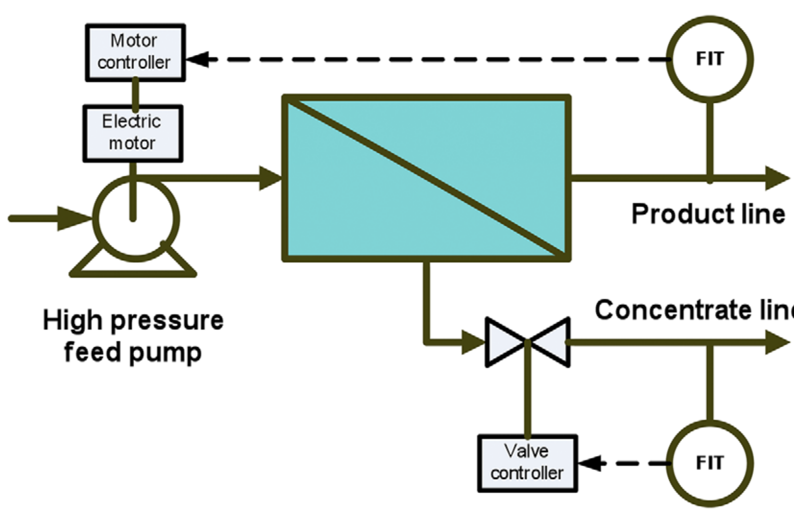

FIG. 23.2 Configuration of control loops for RO membrane unit.

operation of membrane unit in water production step, as compared to frequency and duration of maintenance steps, automatic scheduling of operation steps of different membrane units is not required. However, it is sometimes practiced to set up priority of startup and shut down of various RO trains, according to units performance, to improve economics of plant operation.

23.2 Designing instrumentation and control system

The specifications of instrumentation and control system (I&CS) are included in the request for proposal (RFP) or scope book of the system.

The specification are in form of descriptive narrative of the system and process. The description includes tables with specifications of operating parameters and specifications of equipment and instrumentation components. All the instruments and equipment components are included in the process and instrumentation diagram (P&ID). An example of a P&ID showing instrumentation, alarms and controls is provided in Fig. 23.3.

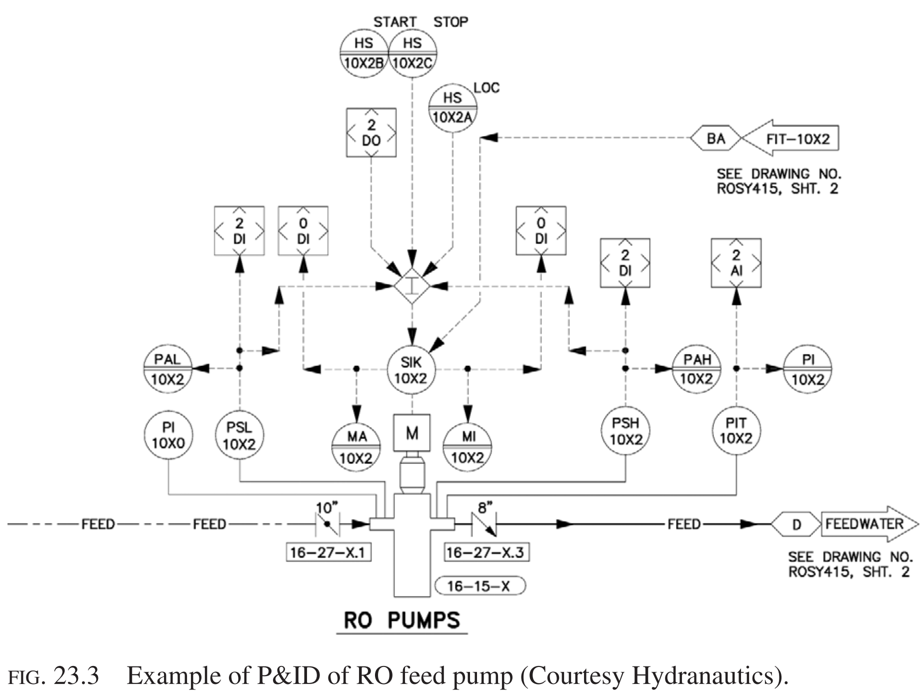

FIG. 23.3 Example of P&ID of RO feed pump (Courtesy Hydranautics).

23.2.1 Control system specifications

The membrane filtration systems are usually supplied by the manufactures of the membrane filtration modules or limited number of system integrators, designated by the membrane modules manufacturer. Operating parameters of the membrane filtration process are specific for the membrane module type and in some cases are part of proprietary information covered by patents. Therefore, in most of the instances, the supplier of the filtration unit provides also the control system as a part of the overall scope of supply.

The parameters of the RO process are uniform for different membrane types and are well known. Therefore, development and supply of a control system for the RO unit could be subcontracted to a third party, specialized in this type of work.

Control system specification usually starts with the overview of control system architecture, communication approach and strategy of controlling operation of the membrane system.

The specification then usually follows with general information of control system configuration, approach strategy and equipment type of major components.

Next the instrumentation equipment requirements are defined in the form of data sheets of individual components that includes parameters measured, range of measurements, type of instrument, material of construction and approved manufacturers.

Designing of control system requires detailed description of membrane system configuration and operation conditions.

Usually it will include:

- Plant configuration
- Startup and shut down sequence
- Conditions during normal operation including range of operating parameters for major equipment
- Conditions for emergency shut down
- Procedure of plant operation recovery from shut down due to equipment failure or due to operation outside the design range of operating parameters

The detailed description of control system is included in a dedicated section of system specifications. It will include:

- Control system narrative description

- Architecture of the control system
- Description and specifications of hardware
- Description and specifications of software
- Description and specifications of data storage, display and reporting
- Specification of plant equipment and process parameters that will be controlled
- Approach for operator intervention in process control

23.2.2 Monitoring of system performance

All or some of the following process parameters are being monitored in RO plants:

- Raw water conductivity
- Raw water temperature
- Raw water flow
- Raw water pump suction and discharged pressure
- Raw water turbidity
- Dosing rates of pretreatment chemicals
- Raw water free (combined) chlorine
- Media filters head loss
- Filter effluent turbidity
- Filter effluent particle count
- Filter effluent SDI (MFI)
- Cartridge filters pressure drop
- High pressure pump suction and discharged pressure
- Feed water pressure
- Feed water pH
- Feed water free (combined) chlorine
- RO permeate flow
- RO permeate pressure

- RO permeate conductivity
- RO permeate temperature
- RO permeate pH
- RO concentrate flow
- RO concentrate pressure
- Dosing rate of post-treatment chemicals
- Product water turbidity
- Product water free (combined) chlorine
- RO permeate storage tank level

The above information is measured and transmitted to PLC as 4–20 mA signal. According to control process algorithm, the information is utilized to display and calculate performance parameters, adjust system operating conditions or alarm operators about equipment malfunctioning.

23.2.3 Alarms

The monitoring activity conducted to protect plant equipment includes monitoring operating parameters of major equipment. This activity includes setting alarms and shut off switches to indicate off limits conditions.

The alarms are grouped in several classes of events:

- Equipment failure to execute completely designated task(s). This type of incomplete operation is usually experienced with motor operated equipment: valves and pumps.
- Process parameters outside high or low limits. The parameters of concern includes all measured water quality parameters (temperature, pH, concentrations, flows, pressures and levels in clear wells and storage tanks.
- Conditions endangering equipment integrity. These could include signals from the sensors indicating presence of constituents in feed water that could be harmful to the membranes (oil, oxidants, etc..), excessive vibration of pump bearings, insufficient flow of cooling water, etc..
- Operator generated general alarms.
- Levels in water storage tanks
- Levels in chemical storage tanks

- Flow of treatment chemicals
- Water temperature
- Water pH
- Water turbidity
- Free (combined) chlorine concentration
- Pressure drop in cartridge filters
- Pumps suction pressure
- Pumps discharged pressure
- Feed pressure
- Permeate pH
- Permeate conductivity
- Permeate temperature
- Permeate pressure
- Concentrate flow
- Concentrate pressure
- Pressure drop in RO system
- Temperature of electric motors

Both alarms and shut-down procedure will start after some delay time, length of which will be defined during the detail design process.

Some of the alarms will be designed to clear when conditions changes, others may required acknowledgement of operator or plant supervisor

23.3 Access level

The important issue in a control systems is security and access level. An example of functional access levels structure is provided below:

Level 1—Anyone Authorized to have minimal access. View any display screen except for set point values.

Level 2—Operator level. View any display screen, except for set point values. Ability to stop any equipment. Ability to print reports and enter data.

Level 3—Plant engineer level. Access to all functions of the operator and ability to modify set points and all process parameters.

Level 4—Plant supervisor level. Access to all functions of the plant engineer and ability to add/delete users, change access level and change password.

Level 5—PLC program developer. Unrestricted access and modification authority,

23.4 Specification of scope of work

The scope of work includes specification of scope of supply provided by contractor of the control system.

In most cases, the scope of supply will include:

- Primary sensors, transmitters, filled instruments and associated mounting hardware.
- The programmable controller system including communication modules, modules and racks for input/output signals
- Local control panes and enclosures
- Communication gears

Specifications defines what is the source of reference information that should be used by contractor for design of control system, procurement of components and development of process control software.

Usually, the contractor is also responsible for submitting technical information on the control system supplied and performing the following work:

- Functional description of the control system
- Technical documentation of the control system
- Factory testing of the control system and components
- Field testing and commissioning of the control system
- Providing engineering support (specified in number of days of field presence) during commissioning and acceptance test of the membrane system
- Training of plant personnel in operation of the control system

23.5 Performance optimization through process automation

Presently, application of process automation in RO treatment plants provides limited ability for direct optimization of system performance that would result in achieving optimum product quality or minimum water cost. The limitations of process optimization are related to complexity of commercial membrane systems and difficulty to develop algorithms of process optimization. Any optimization approach has to consider, ion addition to relations of operating parameters, changes of membrane performances due to membrane fouling and compaction, which are difficult to predict and model.

One of limited direct cost reduction measures related to process automation, which is applied currently in RO systems, is sequencing operation of desalting units according to predetermined cost parameters. For example, system production capacity is utilized according to variable energy cost or priority of units operations is based on prior determined operating cost of individual units (unit required highest operating pressure will be activated last).

Operating cost component that has potential for optimization through continuous on line adjustments is dosing rate of chemicals. In wastewater RO unit, the chemicals used are acid (in majority of cases sulfuric acid is being used) and scale inhibitor.

The above cost reduction measures are applied based on evaluation, conducted off line, of the prevailing economic conditions. Optimization of RO unit (or plant performance) so far has been conducted mainly through manual adjustment of operating parameters in response to change of selective process conditions.

For example, with increase of feed salinity the recovery rate is reduced. This is to prevent an increase of feed pressure and energy consumption. Recovery rate could be also reduced or feed pressure increased if lower permeate salinity is required.

Dosing rate of acid and/or scale inhibitor could be adjusted accordingly to concentration of scale forming constituents. However, except for pH, continuous measurement of relevant species: bicarbonate, calcium and phosphate is difficult to conduct on line with sufficient accuracy.

Algorithms for RO system optimization are seldom available in any standard form. It can be expected that with increasing number of large desalination plants an economic incentive for process optimization will increase and therefore more efforts will be directed towards operation optimization and process algorithms development.

23.6 Control system redundancy

Process designers always design redundancy in pumps, equipment trains, etc. but redundancy in the electrical and control systems often gets lost in the design.

During the design of facilities, the level of redundancy of all components of the treatment processes should be closely considered. There is a balance between budget and reliability that is always in a delicate balance because increased redundancy—which leads to increased reliability—costs more money. External influences such as regulatory agencies will also affect the level of redundancy that will be required in a project.

During the initial phases of the project, there needs to be close communication with the Client and design team to determine the level of redundancy that is to be developed by the RO manufacturer as well as the entire plant control system. The design that should be considered would utilize redundant Power supplies (Utility & generator), segregated power distribution systems, and Motor Control Centers.

Redundancy of the control system is provided through configuration that includes Programmable Logic Controller (PLC) processors located in separate control panels that communicate to and Input/output (I/O) system that are also located in separate control panels that are powered by separate power panels and each have separate Uninterruptible Power Supply (UPS) Systems.

Redundancy will reduce the potential of inadequate treatment as the result of a control system failure since the redundancy will keep ½ to the entire RO equipment system operating during a PLC failure.

Redundancy will also save operator time because manual intervention will not be required to operate the RO process in the event of a control system failure.

Figs. 23.4–23.6 show 3 simple examples of control system configurations that address redundancy.

Fig. 23.4 shows control system configuration that has no redundancy. The failure of any single component–processor, communications media, I/O base has the potential of completely shutting down a plant until repairs are made. While this is the leas costly to install and implement (program and start-up), if the plant is a facility that has significant impact on down stream facilities, this would not be the configuration that would be recommended.

The second example (Fig. 23.5) shows redundant PLC processors, with an "off the shelf" hot back-up controller. Each process area has separate I/O racks, each controlling 1/2 of the process systems (i.e., train 1 and 2 on one rack and 3

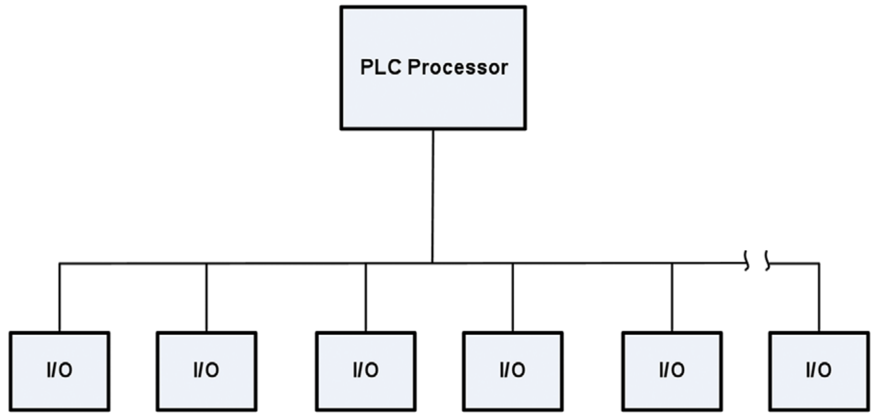

FIG. 23.4 Configuration of non-redundant control system.

and 4 on another). This configuration allows the processes to operate from the commands of one PLC processor. In the even of a fault of that processor, the Hot Back-Up controller automatically switched control to the other PLC processor.

The communications media to each of the independent I/O racks can be redundant (recommended) or not. The failure of a single component (with the exception of the hot-back-up controller) would not affect much of the production.

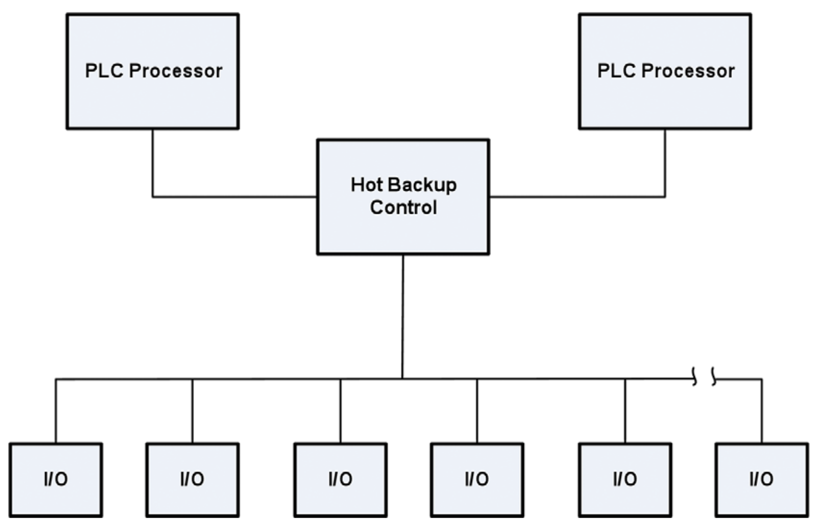

FIG. 23.5 Configuration of partially redundant control system with "hot backup" PLC processor.

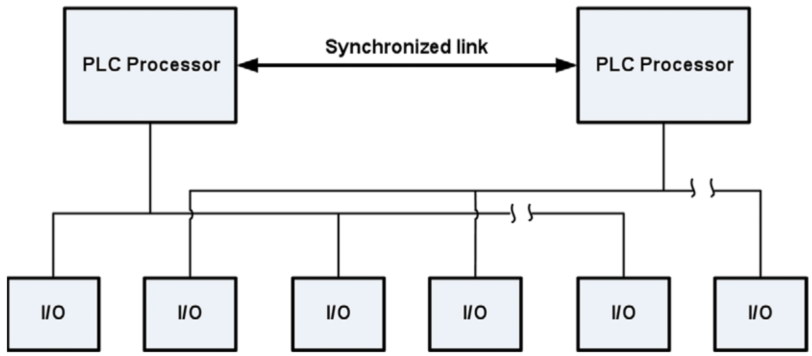

FIG. 25.6 Configuration of fully redundant control system.

Worst case scenario would be a 50% reduction in the facility to operate in automatic. This option is more costly than the first but still has very simple programming and is still very simple to start-up and troubleshoots. This option would come at approximately a 25% premium over the first.

The last example (Figure 23. 6) would be for all systems to have totally independent PLC systems, each controlling 1/2 of the process systems (same as example 2). This would be the most reliable to ensure at least 50% of the facility would always be able to operate in automatic. This is the most costly of the 3 options (about a 50% premium over option 1 and 25% over option 2. This type of configuration is also has the most complicated PLC logic to keep the 2 PLCs synchronized and also would be the hardest to troubleshoot.

A final consideration is redundant sensing devices (i.e., pressure transmitters, flow transmitters, temperature transmitters, etc.). If the facility is so critical that no down time is acceptable, either for economic reasons or public health and safety, each process variable that is critical for automatic operation should have a redundant/back-up transmitter. This would, for the most part, double the cost of the control system. However there can be justifications if economics or public safety dictates the expense

23.7 Implementation of control system

Process control functions are implemented by various control devices, such as process switches, instrumentation, automatic valves, Programmable Logic

Controllers (PLCs), the facility SCADA system, vendor-supplied packaged control systems, and the process control Ethernet Local Area Network (LAN). Those control devices are used to execute the operating sequences and modes of the electrical, mechanical, and process equipment at the facility.

The information system functions are implemented by PLCs, the facility process control Ethernet LAN, the facility SCADA system (including historical data logging and analytical reporting utilities), and by a Client administrative and management system, typically called an "enterprise" or "business" system, located at the facility connected to the Client's Wide Area Network (WAN).

23.7.1 Implementation options

Various options are available pertaining to the level of technology, complexity, functionality, and cost of the control and information systems specified for the facility. Operator preference, facility staffing, cost, current technologies and industry standards, and interoperability with emerging enterprise systems (such as Maintenance Information Systems) should be considered in selection of the preferred options. The options can be broken down into the categories listed below.

1. *Process Control PLCs:* It is believed that smaller distributed process control PLCs provide better, more flexible, more fault-tolerant, higher-functionality service than a single centralized master PLC. The hardware cost for multiple smaller PLCs is marginally higher, but offers a considerable reduction in conduit and wiring installation and maintenance costs.

2. *Instruments and Process Switches:* Traditional analog output process instruments and contact closure process switches could be employed at the facility. Alternatively, intelligent, programmable process instruments and bussed protocol-driven switches and interface devices could be employed to reduce installation costs and provide higher levels of functionality. Device Net and Foundation Fieldbus are examples of standard facility device and instrument protocols.

3. *Redundancy and Fault Tolerance:* Some or all equipment can be installed in redundant, non-redundant, or partially redundant reconfigurations. Critical items such as facility SCADA system components, process control PLCs, and facility process control Ethernet LAN

cabling are key areas wherein redundancy and fault tolerance should be considered. Input from the Client is needed on this subject to determine their level of tolerance for working the system during a control system failure. The lower the tolerance for manual control and/or system down time increases the level of redundancy that should be considered.

4. *Facility Automation:* Interfaces and controls should be provided for all facility processes and equipment to allow full manual operation of all functions. Some or all processes and equipment may operate automatically without supervision. More highly automated processes will require a smaller staff of operators but a larger and more qualified maintenance staff. As with Redundancy and Fault Tolerance discussed above, Client input is required to determine the desired degree of automatic and unattended operating capabilities. Automation level primarily affects PLC and SCADA programming complexity, and therefore, cost. Membrane systems are always designed to operate in automatic unattended mode. The control system should provide the ability for unattended, automatic, sequenced restart.

5. *Human Machine Interface (HMI):* The SCADA system should provide a comprehensive HMI for all facility processes. Stand-alone touchscreen operator interface terminals (OIT) can also be provided at each process control PLC for local HMI capabilities. Providing the local OIT's would increase hardware and programming costs but provide greater functionality and possibly reduced operating cost.

6. *Level of Integration and Remote Access:* Facility process control computing and information systems may connect to other business information systems and network resources, or can be isolated from off-site systems for security reasons. Security and vulnerability issues should be identified and addressed by a facility Vulnerability Assessment. Client input on the level of connectivity allowed between facility systems and off-site functions and services should be determined. These issues will impact remote access and alarm annunciation configuration and capabilities.

7. *Local Controls:* All equipment manual controls are typically located at Motor Control Centers (MCCs). Local control stations can also be provided for equipment operating in the field and out of sight of con-

trollers. The number and configuration of local control stations should be coordinated with the Client.

8. *Alarms:* Specific equipment and process data points in the facility should be configured as alarms in the SCADA, data logging, and autodialer functions. Alarm lists, severities, and annunciation requirements should be coordinated with the Client.

9. *Historical Data Logging:* Specific equipment and process data points in the facility should be configured to log to a historical database. The point list and logging procedure should be coordinated with the Client.

10. *Analytical Reporting:* Reporting can be accomplished manually or via preconfigured report formats operating on data logged in the historical database. Reports operating out of the historical database can be configured with varying levels of automation. The level of automation primarily affects report configuration complexity, software requirements, and therefore, front-end cost. The benefits of report automation are reduced operating costs. The type, requirements, and level of report automation should be coordinated with the Client.

23.7.2 Recommended implementation approach

Process Controllers:

1. Each major subprocess or process area can include a local PLC control panel to control the process or processes in the area. Processes should be able to start and operate autonomously from their local PLC without SCADA communications; however, SCADA communications may be required for sequenced automatic facility restart.

2. Distribution of process control PLCs to process locations eliminates the need for a master PLC and reduces the amount of conduit, wire, and associated maintenance and troubleshooting required to connect I/O points.

3. Vendor-supplied control panels should provide packaged control of specified subsystems. Vendor control panels can be specified to interface with local area process control PLCs and the facility SCADA system.

4. The SCADA system should provide overall facility supervisory control and monitoring.

Process switches and instruments:

1. MCCs, stand-alone motor controllers, electrical equipment, machine monitoring systems, process switches, etc. can connect to local process control PLCs via Device Net to the maximum extent practical.
2. Interlocks critical to safety or the protection of life or required to prevent catastrophic failures, spills, etc. should be hard-wired to equipment controls.
3. Temperature, vibration, and speed feedback sensors for motors over 200 hp should be hard-wired to motor controllers.
4. Field instruments and automatic valves can be provided with Foundation Fieldbus communications capabilities to the maximum extent practical.
5. Interfacing instruments to local area PLCs via Device Net or Foundation Field Bus reduces field conduit wiring and associated maintenance and troubleshooting. Foundation Field Bus also provides remote diagnostic and configuration utilities, which can further reduce maintenance and operation costs.

Facility and process automation:

1. Facility subprocesses should be automated as specified in written control strategies developed during the design. These control strategies, when used in conjunction with Process and Instrumentation Diagrams (P&IDs) are the communications tool that the deisgnteam uses to develop the design and communicate how the facility will operate to the Client.
2. Each subprocess, as well as the entire facility, should be capable of fully automatic, unattended start-up and operation unless directed by the process engineer of Client..
3. Processes should start and operate autonomously from their local PLC without SCADA communications; however, SCADA communications may be required for sequenced automatic facility restart. Subprocess automatic restart modes should be programmed for both SCADA off-line and SCADA on-line operating conditions.

4. The facility SCADA system should provide overall supervisory control and automatic sequenced restart of the facility following power failures or unattended operation for specified durations.
5. Vendor-supplied control panels should interface with local area PLC process control panels, and should provide interfaces and functionality as required to follow the automatic facility restart sequence as directed by the facility SCADA system.
6. The SCADA HMI and local process area operator interface terminals should be programmed to facilitate easy input of parameters, recipes, data tables, set points, thresholds, timing sequences, etc. as required for automatic operation modes.

Backup systems, redundancy, and fault tolerance:

1. The level of fault tolerance will be as specified based on discussion between the deisgn team and the Client.
2. Hard-wired redundancy will be used as dictated for life safety specifically noted.
3. Electronic control components, such as local area process control PLCs, should be installed in fault-tolerant and redundant configurations as determined. Multiple PLCs may be installed in processes involving many pieces of equipment to meet fault tolerance requirements. If absolute single point fault tolerance is required, all facility PLCs should be installed in fully redundant configurations.
4. SCADA system computer hardware and software should be provided in a fault-tolerant, hot-backup redundant configuration.
5. Intra-facility process data communication media and channels should be provided in redundant configurations.
6. Process control PLC I/O points w should ill be segmented and distributed across process control PLC I/O modules such that the failure of an individual module reduces process capacity by no more than 50 percent.
7. The facility SCADA system, process control PLCs, and vendor-supplied systems should be capable of automatic sequenced restart following power failure.

Vendor-supplied packaged control systems:

1. Vendor-supplied control panels should interface with local area process control PLCs and the facility SCADA through the process control LAN. Interfacing should be via specified hard-wired points or preconfigured process data communication registers in the vendor PLC. Vendor-supplied PLCs and communications capabilities should be consistent with facility standards for ease of integration and maintenance.

2. The vendor-supplied control panels should provide interfaces and functionality as required to follow the automatic facility restart sequence as directed by the facility SCADA system.

3. Remote monitoring and maintenance service capabilities may be provided for vendor-supplied control systems. The connection of these capabilities to communication channels should be dependent on Client security solutions, and should be at the discretion of the Client.

Process data communications:

1. Intra-facility process data communications should occur over redundant fiber optic cable Ethernet. This LAN should provide connectivity between the facility SCADA system, process control PLCs, Foundation Fieldbus instruments, and vendor-supplied PLCs.

2. Inter-facility communications between the facility and the Client WAN should be dependent on a Client-supplied security solution at the Client's discretion.

3. Remote access to the facility SCADA system and process control PLCs may be provided pending a Client security solution. The remote access could be provided via the Client WAN or by other direct access means, and should be at the discretion of the Client.

4. Alarm annunciation should be performed locally in the facility and remotely via autodialer. Alarm management and telephony software, such as WIN911 or its equal, should be installed on the facility SCADA system. Software utilities and functions can include alarm management and voice, pager, or e-mail annunciation, and remote dial in acknowledgement. The connection of software-based autodialer capabilities to communications media is dependent on a Client security solution and should be solely at the discretion of the Client.

5. A hardware/hard-wired autodialer system can be provided in the event the Client does not allow connection of software autodialer equipment to communications media. Critical alarm points should be hard-wired to the autodialer.

Process equipment interface:

1. Discrete indicators, switches, pilot lights, etc. should be provided at MCCs and stand-alone motor controllers for indication and control.
2. Local control stations, such as Lock Out Stop stations, should be provided for equipment operating in the field away from associated motor control equipment.
3. Touch-screen operator interfaces should be at provided at local process control PLCs to monitor process parameters and update set points, thresholds, timing sequences, ramp-soak profiles, etc., as required to modify automatic operation characteristics.
4. Vendor-supplied packaged control panels should provide touch-screen operator interfaces, consistent with facility standards and discrete indication and control devices as specified.
5. The facility SCADA system can host HMI Client applications running on computers at the locations throughout the plant; HMI Clients can run on desktop or laptop computers, which can be connected to the process control LAN at any part of the facility. The SCADA HMI should be programmed for easy review and modification of all parameters and sequences required for automatic operation modes.
6. Remote access to the facility SCADA system, process control PLCs, and smart instruments should be provided pending. Remote access can be provided via the Client WAN or other direct access means, and should be at the discretion of the Client.
7. Hardware- or software-based autodialers discussed above can provide automatic alarm dial-out annunciation to on-call maintenance and operations staff. Software-based autodialer applications can also provide alarm management and remote dial-in acknowledgement functions.
8. All process and equipment data in the facility can be made available to alarm management and annunciation functions. Alarm lists and annunciation requirements should be coordinated with the Client.

9. All process and equipment data in the facility can be made available to historical data logging and analytical reporting functions. The point list and logging and reporting requirements should be coordinated with the Client.

Interface to other facility systems:

1. Many jurisdictions require that a fire alarm system be installed in water treatment plants. This requirement is typically due to the storage of oxidizers such as chlorine and other chemicals typical to water treatment facilities. These systems are typically tied directly to an off site licensed alarm monitoring company. It is also typical for these systems to be tied to the facility SCADA system. This interfaces can allow for alarm horn and light initiation, interfacing to certain systems that should be shut down in the event of a fire, and for call out of plant personnel through the autodialer.
2. Security systems use many types of intrusion detection devices such as motion detectors, door switches, and video based (camera) motion detecting. These systems are commonly tied to the SCADA system in a manner that allows for Security System video signals to alert plant staff and allow them to access to security camera views in all parts of the plant form any SCADA computer.

Business information systems interface:

1. The Client Maintenance Information System can be available on the Client WAN but may not be available to the facility process control and SCADA LAN. A manual transfer of process data to the Client WAN may be required.
2. Lab and SCADA PCs and laptops can connect to the facility process control LAN to run PLC programming software, SCADA configuration, Client and server software, smart instrument configuration and diagnostic software, operator interface configuration software, historical data logs, etc. Manual disconnection from the process control LAN and connection to the Client WAN may be required to obtain Client IS resources or to transfer facility process data to the Client WAN.
3. Connection of the facility process control and SCADA LAN to the Client WAN to achieve full enterprise integration should be dependent on a Client security solution to limit exposure to computing system threats.

4. The process data historian, historical database, and trending and reporting functions should be installed on computers connected to the facility process control LAN. Manual transfer of historical data to the Client WAN may be required for access by WAN users.

5. Communications between the facility and the Client WAN can occur over an existing T1 phone line. Facility business system computers can connect to the Client WAN. Connection of the facility SCADA and process control systems LAN to the Client WAN should depend on a Client security solution and should be solely at the Client's discretion.

References

1. S.A. Avlonitis, M. Pappas, K. Moutesidis, M. Pavlou, P. Tsarouhas, V.N. Vlachakis, Water resources management by a flexible wireless broadband network, Desalination, 206 (2007) 286–294
2. P. Glueckstern, M. Wilf, J. Etgar and J. Ricklis, " Use of Micro-processors for Control, Data Acquisition and on Line Performance Evaluation in a Reverse Osmosis Plant." Proceedings of the Second World Congress on Desalination and Water Reuse. Bermuda (Nov. 1985).
3. N. Lior, A. El-Nashar, C. Sommariva, M. Wilf, "Automation and operation optimization to reduce water cost" Middle East Research Desalination Center, Report of contract # 97-AS-002 (2006)
4. N. Lior, A. El-Nashar, C. Summariava and M. Wilf, An update on the state of information, measurement, control and automation in water desalination, Proceedings of IDA Water Desalination Conference, Singapore (2005)
5. S. A. Avlonitis , Operational water cost and productivity improvements for small-size RO desalination plants, Desalination, 142 (2002) 295–304