PLC's and SCADA - A Water Industry Experience

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These authors have collective experience of design and implementation of PLC's and SCADA systems on Water and Wastewater applications totalling over 50 years

Abbreviations Used

DCS	Distributed Control System
EC	European Community
ICA	Instrumentation, Control & Automation
I/O	Inputs and Outputs
LCD	Liquid Crystal Display
NWW	North West Water
PC	Personal Computer
PLC	Programmable Logic Controller
RTS	Regional Telemetry Scheme
SCADA	Supervisory Control and Data Acquisition

Summary

This paper reviews the experiences of Bechtel Water Technology (formerly NWW Engineering), in the application of Programmable Logic Controllers to projects which were designed and constructed on behalf of a major water & wastewater utility, NWW Ltd.

The paper outlines how experience of industrial disputes followed by the introduction of EC Drinking Water Directives during the 1980's generated a requirement to build a substantial number of unmanned automated plants. This resulted in a substantial increase in the number and sophistication of process control solutions produced.

It outlines the challenges encountered during the life cycle of these sophisticated solutions and continues by considering how, in addition to the control requirements other factors such as the investment regime, operational constraints, and manpower skill levels influence the design of PLC control systems and led to different solutions being proposed for the Water and Wastewater treatment plants.

It identifies how by the use of dynamic modelling techniques the company has been able to focus the application of advanced technology only to the areas where it is specifically needed, thus allowing simpler control systems to be provided for the bulk of its treatment processes.

The paper reviews the adoption of PLC systems with SCADA interfaces, in preference to DCS packages.

Standardisation on a single supplier for PLC systems is identified as an opportunity to reduce project costs by allowing the generation of standard control systems architectures and the production of standard portable software.

Introduction and Historical Overview

In the late 70's the water industry's experience of labour disputes gave added momentum to extend plant automation as widely as possible thus reducing dependence on the plant operator. Design briefs issued to engineers included the phrases "the plant shall be capable of fully automatic unattended operation 24 hours/day 7 days a week, 365 days a year." Fortunately this coincided with the birth of the mass production PLC as we know it today.

Further stimulus was applied by the introduction of the EC Drinking Water Directives and the advent of a Regional Telemetry Scheme both of which encouraged a proliferation of some ambitious automation tasks. The requirements of the former led to the need to develop a remote monitoring telemetry infrastructure. To achieve this outstations were installed at hundreds of sites which were previously attended or served by automatic dial-out devices, also provision was made for some 20 additional Master Stations at strategic locations throughout the region, and establishment of three Area Control Centres for monitoring alarms out of normal working hours. There was a need to provide considerable new instrumentation to detect abnormal operation on the plants themselves. The rapid installation of the instrumentation and communications systems highlighted a skills vacuum of the in-house resources which were required to support and maintain these systems.

Towards the end of the 80's a comprehensive fast-track construction programme was undertaken to improve facilities for Potable Water treatment enabling compliance with EC directives and many new "green field" Water Treatment Plants were constructed. These plants again required maximum automation and minimal operator attendance. This imposed demanding levels of instrumentation, some included inlet flow control algorithms linked to abstraction licences, automatic coagulant dosing control systems derived from multi-variable analytical instruments and triple validation of critical chemical dosing control systems to meet operations concerns over prosecutions and adverse publicity surrounding pollution incidents. This rapid growth highlighted several areas for concern :-

- Elaborate but untested designs of PLC networks and SCADA systems evolved to meet these operational needs.
- Overloaded SCADA systems.
- Differences in design philosophies.
- Maintenance difficulties through the amount of instrumentation installed.
- The resources employed for system maintenance did not possess the relevant software engineering skills to maintain PLC's, SCADA and Regional Telemetry.
- Insufficient time or design resources to rationalise equipment suppliers.

In 1989 privatisation of the water industry took place. Since then, a change in outlook has caused the re-appraisal of the business case for such extensive de-manning which had driven production of ICA solutions edging towards not only state of the art hardware and software but in some cases "Art for art's sake".

Water compared with Wastewater

In comparing Water treatment applications of PLC's with those of Wastewater treatment we will consider the following areas:

Capital Investment, layout, operational considerations, manpower skill levels, control requirements and environment.

Capital Investment

In NWW only modest construction work had taken place for approximately 10 years on Water Treatment, but by the latter half of the 1980's a large scale investment programme commenced to meet the EC Drinking Water Directive. NWW has constructed and substantially refurbished some 23 water treatment plants, many of these comprising three stages of treatment, during a 5 year programme.

Investment on Wastewater was constant and progressive and many of the process control functions were well understood. The operating environment, the treatment processes and the levels of maintenance on these two different types of plant need careful consideration.

Layout

Modern water treatment plants tend to be built in a single large structure or a series of several closely coupled buildings whereas wastewater treatment plants are outdoors, the process requirements dictating a larger site area although new process techniques such as Deep Shaft are reducing the footprint.

Wastewater Treatment plants are more likely to have their PLC and SCADA systems extended during the normal working life of such hardware, since these plant are more prone to successive upgrading of treatment facilities and refurbishment of existing process equipment. There are several instances of one site where 3 concurrent contracts on that site require to be served by a common SCADA system whose hardware is to be provided by only one of the contractors. This situation cannot be avoided where future extensions of a works will necessitate further growth of the PLC network.

Operational Considerations

Potable water treatment plants must produce water within specified quality limits. Should any aspect of the process or its control fail, (this being detected by water quality instrumentation at key points between treatment stages and prior to entering the distribution system), the plants are arranged to shut down in a controlled manner, thus avoiding an incident. During these shutdown periods, supplies can generally be maintained by utilising water stored in treated water service reservoirs located within the distribution system whilst repairs are undertaken.

In contrast on Wastewater treatment plants, the design normally requires incoming effluent to be pumped under all conditions to prevent flooding in the associated catchment area. Additionally the very large volumes of effluent which reach wastewater treatment plants make the provision of on any significant capacity for on site storage virtually impossible. Consequently any effluent reaching a wastewater treatment plant must be treated regardless of incoming quality to prevent both flooding and contamination of the receiving watercourse.

These fundamental differences in operational requirement and consequential differing failsafe strategies influence the design and architecture of any PLC system.

The requirement for a SCADA system on many sites was being driven by the need to reduce operating costs and de-man sites, although this trend is now being reversed using multi-skilled operators with specific training in first line maintenance.

The electrical environment on water treatment plants is normally more "communication friendly" as fewer large drives are used in the treatment process, in contrast to that of wastewater where modern design and associated control modelling, usually result in large variable speed pumping station at the works inlet or at coastal locations to pump the outflow dependant on the tidal conditions. Recent developments in fibre optic communications have provided immunity from this noise for communication systems, these techniques being utilised on plant currently under construction.

Manpower Skill Levels

There are historical differences in the skill levels between operations at water and waste water treatment plants. For Water Treatment Plants, operators were traditionally skilled and were required to react quickly to changing raw water conditions. They have to respond to any failures in chemical dosing equipment in order to prevent contamination of drinking water supplies to customers. Accordingly they require information systems which give comprehensive status and alarm information about the plant. Typical Water Treatment plant operators have a good understanding of operating laboratory equipment, including PC's and are be immune to "keyboard fright". They are generally computer literate and may run applications other than the licensed SCADA software on the same PC. This involves downloading archived data files into other spreadsheet or database programmes for the production of statistical performance reports. The majority of Water Treatment plants which have had a major refurbishment or extension since the 1980's been equipped with a SCADA system in a purpose-built control room.

For Wastewater the operator skill level was in great contrast to this. The operators favour simplicity with very obvious methods of control and minimal use of PLC's. As there is no buffering capacity within the process, their immediate priorities are the avoidance of pollution and flooding. Great emphasis is placed on reliable systems, adequately backed up and of rugged construction to withstand a harsh environment and suited to the manual worker as operator. The process environment is not conducive to delicate equipment such as printers and keyboards and reliability of the control equipment under arduous operational circumstances is paramount. The introduction of SCADA systems by design engineers needed sensitive handling and training to avoid frightening operators who previously used warning lamps, edgewise indicators and chart recorders, and who had occasional fixed mimic panels depicting the process flow diagram along with critical flows and some levels.

Control Requirements

Unlike other process industries the water treatment industry has no control over its raw influent material. Water companies are legally required to meet consents on the quality of treated water fed into the distribution system and wastewater returned to watercourses. This would be an arduous task for any process industry even when the incoming materials came from a QA approved suppliers, but in the water industry the influents are a chemical and biological cocktail, sometimes comprising illegal trade discharges.

This variable influent, which must be accurately monitored, controlled and treated if pollution incidents are to be avoided, places considerable demands on the monitoring and control systems provided.

For water treatment plant start-up and shutdown complex algorithms are sometimes required. This may require slow starts for rapid gravity filters, failsafe shutdown valves downstream to prevent the filters from dry-bedding, complex algorithms are used in the control of chemical dosing pumps, automatic changeover to standby drives and the triple validation of instrument outputs controlling the final and interstage water quality.

Depending on the amount of treated water storage at the site, unavailability of the automatic control system may become a problem and therefore hot-standby PLC's and/or dual communications are employed on certain sites. The PLC's are arranged such that a duty/standby pair, where considered necessary, controlled a discreet process area such as Dissolved Flotation, First stage filters etc. This necessitated reliable data communication between process area PLC's for common information such as flow and level signals to be available at several locations together with a requirement to pass information to a Supervisory Control and Data Acquisition system.

Processes in wastewater tend to be simple logical control of drives or a series of drives with associated levels etc in process vessels and structures. More complex control algorithms are being introduced particularly in the control of the inlet pumping especially where underground storage in interceptor sewers is being utilised or priority pumping is afforded to sewerage systems with little or no storage in conjunction with underground storage. The current developments at Southport which form part of NWW's Sea Change programme utilises PLC control of such sewers.

On Wastewater treatment plants there is little need for data transfer between process areas, in some cases, for reliability, these signals are hardwired in addition to PLC communication. A recent wastewater treatment project required only 24 signals between process areas for operation of the works. Data communication is provided to support the SCADA and for off-site telemetry and to enable alarms to be accessed at various plant locations, the latter being necessary as the manning levels are low (typically 1-2 persons for operation of a major installation) hence considerable time is spent on the plant and away from any control room.

In designing control systems for water and wastewater treatment plants, consideration must be given to future expansion which may be required and to the evolutionary process changes which may occur during the lifetime of the control system as a result of external factors or legislation.

For example North West Water is currently undertaking a programme to substantially modify the control strategies on a large number of its water treatment plants with rapid gravity filters in order that they may comply with recommendations of the Badenoch report to prevent cryptosporidium oocysts entering potable water systems.

Similarly the introduction of new treatment technologies on existing sites, such as the deep shaft treatment process at Southport Wastewater Treatment Plant, require that the systems be open and flexible enough to allow future expansion without having to re-engage the services of the original equipment supplier.

Value for Money

There is now considerable emphasis in the water industry to reduce the cost of the capital programme. This in turn has resulted in Electrical Engineers examining software engineering costs and ease of programming/configuration. PLC and SCADA systems which facilitate system builder familiarity and hence competitive pricing has led a trend towards "Small is Beautiful".

Operators encouraged the plant electrical/ICA designer to incorporate as much functionality as possible into the displays of the SCADA. It would not be unusual for an operator to ask for:

- Annual flow control algorithms
- Provision of detailed live mimic diagrams allowing remote operation of all major valves
- Daily reports of flow, power and chemical usage
- Interrogation of off-site facilities directly connected hydraulically to the works
- Maintenance and plant usage reports
- Automated re-ordering of chemicals
- Access to weather statistic
- Simulated replay of plant operation in elapsed time to view conditions leading up to a failure

In practice the cost and practicality of commissioning such systems would be highly prohibitive. Previously the planner and the operator were the joint clients of the design engineers . The operator was not responsible for the cost but needed to be satisfied at the design and handover stages. A tendency arose to require every possible technical refinement irrespective of cost. Recent re-structuring of NWW has given rise to the concept of the asset Manager who pays the capital and running costs for a plant for which he determines the overall specification and level of automation.

Standardisation

Here challenge for the electrical design engineer is how to permit future expansion without leaving himself exposed to the potential obsolescence of his chosen hardware. He must also ensure the successful interfacing of PLC systems onto a common communications network. Until truly open systems and protocols are widely offered by the majority of equipment suppliers there is no easy answer to this problem.

PLC SYSTEMS

The NWW procurement policy for Programmable Logic Controllers evolved in the early 1980's. Prior to 1991 NWW comprised three autonomous engineering divisions which each had its own preferred supplier of PLC systems with a large installed base in each division. The introduction of the NWW Regional Telemetry Scheme at this time gave the opportunity to formalise the procurement strategy and the three divisional PLC preferences became the preferred suppliers of PLC systems to the company. At the same time, this allowed communication protocols to be developed oocyst the newly emerging regional telemetry master stations which allowed the three preferred suppliers PLC to act as private wire outstations to the master stations. The evolution of this procurement strategy ensured a certain level of consistency of hardware design to take place but only limited software standardisation. Recent external changes in the PLC manufacturing market affecting the three preferred suppliers have produced a situation whereby standardisation has become increasingly difficult, particularly for software. Recognising the benefits that could be achieved by standardisation, especially software, NWW Engineering have initiated a review of the procurement strategy with the objective of reducing the number of hardware suppliers, preferably to one, and selecting product ranges which would allow the generation of standard portable software for NWW applications.

A working group was formed to review the PLC system requirements of the company, comprising staff from both the Engineering and Operations divisions. The working group identified a comprehensive set of requirements that PLC systems should meet, covering hardware, software, communications and support. These requirements have been translated into a commercial tender in accordance with EC procurement directives for utilities which require all procurement by NWW to be advertised in the European Journal, and an audit trail be kept of the resulting assessment of responders. It is NWW's intention to enter a Framework Agreement for the supply of PLC's in the near future.

SCADA SYSTEMS

The NWW strategy for plant monitoring has been to keep the monitoring functions completely separate from the control function with each running on its own dedicated hardware.

Control has always been carried out within the PLC system, with the monitoring system operating purely as Data Acquisition System with the added ability to alter setpoints for control algorithms residing within the PLC systems.

This has proved to be the most cost effective solution for the majority of NWW plant which typically have low I/O counts, allowing the monitoring system to be sensibly sized for the application requirements. It also provides an open system therefore ensuring that for future expansion or refurbishment NWW are not tied to the original single supplier.

This strategy also has the advantage that the monitoring system is able to notify the plant operator of a failure within the control system, allowing the user to examine events immediately prior to control system failure also allowing the control system to continue to operate on default or last known values in the event of a monitoring system failure.

Current trends in System Design

System Modelling

As the processes within Water Industry continue to develop in complexity and the required performance specifications become more onerous the techniques employed to control the process have become more complex. It is now essential for design engineers to have an understanding of the dynamic behaviour of the processes, and of the methods available for analysing and improving dynamic performance.

Traditionally, process alternatives or control options for treatment plants have been assessed by building pilot streams at the treatment plants. Whilst this approach undoubtedly has its merits, it is expensive and can cause disruption to the process. Additionally the time delays and costs associated with obtaining analyses and exploring different options are prohibitive. Within NWW Engineering dynamic real-time mathematical models of the process plant and equipment are produced which allow various structured design and process control options to be considered. The fundamental understanding of a plant obtained using the plant models enables systems and strategies to be designed which operate the plant much closer to its fundamental constraints whilst still maintaining plant integrity and security for minimal investments. This technology allows prediction of plant performance to be made in advance of construction, furthermore it is possible to design the process components to achieve a required performance, and to optimise the control strategies. In addition by using the model to test these strategies before implementation, safety can be substantially improved and on site commissioning time greatly reduced, with the consequent reduction in implementation costs.

The next phase of NWW's strategy is to use the real-time models of the plants to test the control system implementation on the target hardware before leaving the factory enabling NWW Engineering to prove the control system design is optimised and fully functional before going on site.

Fieldbus

Moves towards an establishing a true international fieldbus standard have been painfully slow, and over the last five years numerous companies have claimed to NWW that they are in a position to offer the company the "industry standard fieldbus". Whilst these numerous manufacturer specific fieldbus systems exist at the present time none of the benefits of inter-operability have been shown to exist to the end user. Against this background NWW has not seen any significant advantage in moving to fieldbus based systems. It should be noted that it is the opinion of NWW that it is difficult to justify fieldbus on the relatively small benefits that can be achieved due to savings in the cost of wiring alone.

Currently NWW can see limited advantage in moving to fieldbus based systems until the major benefits, of inter-operability are realised and more significantly the benefit of being able to transfer the intelligence, which is now becoming resident in the sensor, into the control and monitoring system. It is considered unlikely that this technology will be in widespread use within the company until at least 1997.

PLC versus DCS

The historical tendency for PLC's to be used within the Water Industry evolved due to the dominance of logic and sequential tasks as opposed to regulatory control and to the lower initial cost of purchase for PLC systems in comparison to DCS systems. However as the technological processes within the Water Industry continue to increase in complexity, and the cost of DCS systems continues to fall at the same time as the capabilities of PLC systems continue to expand. The selection of the appropriate device is becoming more difficult for the designer.

The strategy in use at the current time within NWW is based on networked PLC's each controlling discrete areas of process automation. Each process area PLC is provided with a directly connected local operator interface which replaces the traditional front of panel indicators, switches and alarm annunciators that would have been provided on ICA panels. Where a site is also provided with a proprietary SCADA system, this is only configured to provide primarily a monitoring function, thus in the event of SCADA system failure the plant can be safely operated from the distributed PLC operator interfaces.

A considerable number of the key selling points of DCS systems are associated with vertical integration, whereby all the plant control and management information systems are combined in the same hardware platform.

Finally the DCS has the disadvantage of tying the user to one manufacturer throughout a site.

Hot Standby PLC's

Hot standby PLC's have not delivered the increased security of service perceived by their adoption. This view is supported by the PLC manufacturers who state that in some cases the PLC system availability is lower with hot standby than without. To achieve the desired reliability, hot standby installations must be supported by a rigorous maintenance regime to ensure the duty machine is immediately repaired should the changeover to the standby occur after a fault.

To overcome this problem we have recently adopted the concept of a "Warm Standby" PLC as mains borne disturbances have been responsible for damage to both PLC's in Hot standby configurations. A second PLC is provided mounted within the control panel steelwork, loaded with the programme and connected to the mains supply although isolated. No connections are made to the I/O or communication systems. On failure of the main PLC an alarm is raised and the standby PLC is powered up manually after connection to the I/O and communication network. Current set points may then be entered manually or downloaded from the SCADA. This significantly reduces the complexity and results in significant cost saving.

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