CHAPTER 50

SCADA SYSTEMS IN WASTEWATER TREATMENT

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50.0 INTRODUCTION:

This chapter is intended to serve as a guide for those interested in applying a Supervisory Control And Data Acquisition, (SCADA) system to their wastewater treatment processes. Condensing the subject of SCADA applications down to a single chapter is limiting, but I have attempted to provide brief but useful descriptions of the economic drivers supporting the installation of SCADA systems, the functions that SCADA systems perform, the components that make up SCADA systems, the elements of design that should be considered when specifying or selecting a system, and what lies ahead for SCADA systems in the not-to-distant future.

50.1 INVESTMENTS IN PROCESS CONTROL

Since the advent of reliable, low-cost microprocessors, tremendous growth has occurred in the use of computers and computer technology for monitoring and controlling industrial manufacturing processes. To a lesser degree, this trend may also be seen in applying these same technologies to industrial and municipal water and wastewater treatment systems. The rate of spending has been slower and the number of dollars has been less for utility and waste treatment process controls mostly because the rates of return on capital projects in these segments are often thought to be negative or at least much lower than for the profit-making manufacturing processes. Nonetheless, most if not all of the same benefits that support the justification for manufacturing process control and SCADA systems is equally valid for the utility and waste treatment processes. Specific benefits include reductions in energy costs through more efficient usage and shifting of loads to off-peak hours, reductions in maintenance costs, and increases in effective capacity through optimization of processes. These factors result in significant reductions in net operating costs, and therefore are capable of yielding net positive returns on investments in process control technology.

In one sense, the slower pace of investment in process control for water and wastewater applications actually works to an advantage: to be positioned just slightly behind the “bleeding edge” of a technology is often the best place to be if funding is tight and risk-tolerance for the project is low. In the case of process control technology, the pace of development of new technologies is so rapid that simply remaining fiscally conservative allows the more aggressive, risk-tolerant manufacturing community to bear the costs and risks of proving out the newer, more expensive technologies. Those with less lavish budgets are able to pick and choose their investments from technologies that are mature, robust, and have already demonstrated their track record for improving operations.

50.2 SCADA SYSTEM SIZE AND FUNCTIONALITY:

To the uninitiated, SCADA may seem like just another chunk of consonants and vowels floating around in the alphabet soup of today’s culture. But a SCADA system is, in reality, an extremely important application of computer technology that has created huge gains in productivity and efficiency in the processing industries. A SCADA system is an assemblage of computer and communications equipment designed to work together for the purpose of controlling a commercial process. SCADA is usually implemented on manufacturing processes, (chemical and pharmaceutical processing, food processing, and discrete manufacturing), treatment processes, (wastewater treatment, municipal water treatment systems), and distribution systems, (gas, oil and water pipelines). Besides control, SCADA systems also perform monitoring, data logging, alarming and diagnostic functions so that large, complicated process systems can be operated in a safe manner and maintained by a relatively small staff.

50.2.1 SYSTEM SIZE

SCADA Systems can have a considerable range in terms of size and scope:
At the lowest end, a SCADA system could be nothing more than a single personal computer coupled to a small laboratory or manufacturing process through some on-board I/O cards. Typical costs for a system such as this could be under $10,000 and much of the configuration could be done by in-house staff.
At the intermediate level, one or more PLC's (programmable logic controllers) could be networked together with distributed I/O, (Input/Output) subsystems and multiple operator interfaces. Costs for a system of this size and scope would typically range between $10,000 and $100,000. Again, some part of the

configuration can be handled by in-house staff, but at this level it can become quite a burden on resources   At the largest end of the spectrum can be found networks of far-removed RTU's (Remote Terminal Units) spanning entire plant complexes or pipeline distribution systems, utilizing data concentrators and I/O subsystems that communicate over a variety of media including traditional electric cables, fiber optic media, or radio-wave wireless media. Costs for systems like this could easily extend up into the hundreds of thousands of dollars. For cases like these, it is almost always best to hire in a SCADA system provider to focus exclusively on the tasks and challenges of getting the SCADA system designed, installed and operating.

5.2.2 SYSTEM FUNCTIONALITY

SCADA is a somewhat loosely defined term that can result in some differences in capabilities between vendors. Below are listed some of the more "plain vanilla" functions that should serve as bare minimum capabilities. Keep in mind that some offerings are "closed" or proprietary systems that require that the provider do all the programming and configuration work. Others are more open and with a little training, in-house staff or your average local system integrator can do the configuration, programming and maintenance of the system.

Control Functions – SCADA systems are capable of running standard control algorithms like P, PI, and PID regulatory control algorithms for maintaining specific levels in tanks, maintaining prescribed flow rates, and maintaining processes at specific temperatures and pressures. They also can also execute some form of boolean logic for automating the starting and stopping of pumps, opening and closing of valves, and other discrete functions. SCADA systems also generally provide some sort of command set or scripting language to serve as a programming tool to allow for the need to sequence or stage these functions.

Monitoring Functions – Providing an effective visual interface between the process and an operator is often the main function of the system. Most SCADA systems usually have a sophisticated set of tools for displaying individual process values and incorporating them into animated graphic depictions of the process. They also provide the means of taking real time data and showing it as a trend so that subtle process changes may be observed.

Data Logging Functions – Once data has been brought into the system, the SCADA system will archive selected data into electronic records that may be recalled and reviewed at a later time. In many cases, this historical data may be exported from the SCADA system as a Comma Separated Variable or .CSV file, which can then be drawn into a different application like MS-Word or MS-Excel for further analysis or formatting into reports. Many SCADA users choose to print out status and alarm data in hard copy at a dedicated printer. The dates and times of these events are recorded at the time of printing so they serve as a chronological record of changes that occurred within the system, i.e., what alarms occurred, what setpoint changes were made, and what equipment was started or stopped.

Alarming Functions – Integrated into the data and graphical displays are alarm functions that can raise and display alarms as they occur. On some systems they can be tied into Auto-Paging and Auto-Phone-dialing features that will automatically notify operating personnel of a problem.

Diagnostic Functions – Some SCADA systems have incorporated statistical packages that can be used for online analysis of process data to detect “when something has changed for no reason”. Such changes can often be tied to drifts in calibration of instruments and/or imminent failures of control components.

50.3 THE ANATOMY OF A SCADA SYSTEM:

A SCADA System’s components are comprised of one or more CPU’s (Central Processing Units), RTU’s (Radio Telemetry or Remote Terminal Units), I/O Subsystems, Video monitors, Field Sensors, Control Devices and lots of software that drives the I/O, runs the control algorithms, generates control outputs, displays graphics and monitored values, senses alarm statuses, and stores the monitored points in a series of data files that can be archived and recalled at a later time for analysis or process verification.

GENERALIZED SCADA SYSTEM ARCHITECTURE

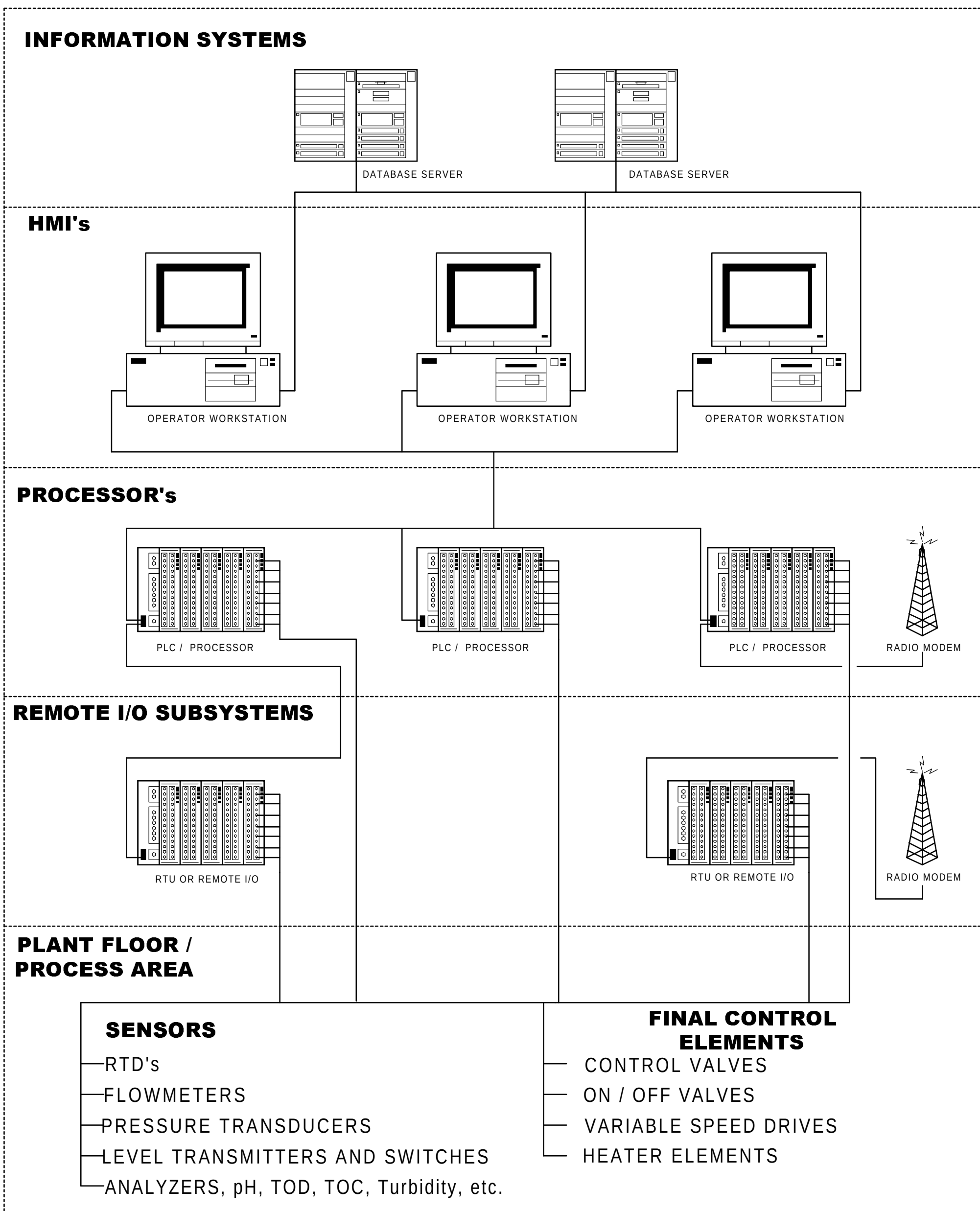

FIGURE 1

50.3.1 PROCESSORS, CONTROLLERS and RTU's

The heart of any SCADA system is the central processing unit or units, (CPU's). This single feature provides the largest basis for comparison between systems. I have compiled a list of the types of CPU's you may come across if you were to canvass the SCADA offerings available today:

PC based systems – These systems utilize one or more Personal Computers to provide the graphical displays as well as the necessary computational and networking horsepower. Being PC's, they run on Intel or AMD chips. The SCADA software is usually some type of Commercial Off-the-Shelf software like Wonderware, RSView, Intellution, Citect, or Iconics. These packages still must operate within the bounds of the PC operating system software, namely Windows, so care must be taken to run a form of Windows that is stable and robust. In the early years some of these SCADA software manufacturers offered products that were configured with DOS-based programs then loaded up their own real-time operating kernel for runtime. They worked pretty well with only the occasional computer freeze-up. When Windows 3.x came along it was a very trying time because users wanted the versatility of being able to switch back and forth between windows applications, but their real time operating kernels would not permit this. PC-based systems really received a black eye because of Window's propensity for shutting down with General Fault Protection errors giving rise to the phrase "Blue Screen of Death". For years, it was strictly taboo to consider running any type of critical manufacturing system on a PC-based SCADA system but this is now changing. Microsoft to it's credit, responded to the instability situation by releasing Windows NT. There are still issues around the use of PCs for control such as whether they can deliver "hard-real-time" multi-tasking, but more and more applications have been showing up in factories and treatment systems on NT machines. Now, Microsoft is releasing Windows 2000, which is supposed to be an improved version of NT for industrial applications. Long story short, before applying a PC based system, be sure to consider what the consequences will be if the PC dies in the middle of a run. Also be sure that if you do install a PC based application, make sure it is running NT or 2000, not Windows 95 or 98!

VME-bus systems – VME-Bus hardware is a rack mounted system that allows different processor boards, communications boards, and I/O boards to be loaded into a commonly powered backplane and programmed in a highly configurable and flexible fashion. These systems have, in the past, usually been powered by Motorola 68000 series microprocessor chips, but now there are versions available using Intel and AMD PC-type chips as well. As is usually the case, increased flexibility generally leads to increased complexity, in this case choosing the correct board combinations from the many types available is a somewhat daunting task best left to the experts. Many SCADA system providers have climbed this learning curve and build very dependable turn-key systems from rack-mounted VME-bus components. The SCADA provider will provide a complete solution that includes component selection, configuration, programming, and even the commissioning of the system.

Controllers – PLCs or Programmable Logic Controllers are control devices that originally gained popularity as economical replacements for the hardwired relay panels that were prevalent in early years of process automation. Then, because of their flexibility and ease of programming, they became popular for control of discrete manufacturing and motion control applications. In recent years, the programming languages and environments have become much more sophisticated. A programming standard (IEC 1131-3) has been established to provide some commonality in the programming tools. At the same time, processing power, networking capabilities and program memory storage capabilities have all increased greatly. As a result, these controllers are evolving into very capable and cost effective process controllers and are rapidly becoming very popular for nearly all process control applications including serving as RTU's for SCADA systems.

RTU's - In some applications it is required that monitoring devices be located far out in the field at isolated equipment sites, at pump stations, wells, or along a distant stretch of pipeline. In these applications, these units communicate back to a host computer using Radio waves and are hence called Radio Telemetry

Units. These units typically require FCC licensing because they operate in the range of commercial radio frequencies. In other instances, the same concept of a remote monitoring device exists but it uses traditional electrical cabling to convey the data signals to the Host. In these cases the units are considered Remote Terminal Units. In either case, the units serve the purpose of handling Inputs, generating Control Outputs, and concentrating data for transmission back to the host system.

50.3.2 OPERATOR INTERFACES

If the CPU is the heart of the SCADA system, the operator interface would have to be considered the eyes and ears. It is through the Operator Interface that humans interact with the process being controlled. Operator Interfaces are alternately known as OI's, MMI's (Man-Machine Interface), HMI's (the more politically correct Human Machine Interface), VDU's (Video Display Units), VDT's (Video Display Terminals), and probably many, many more contributions to the alphabet soup. There is a spectrum of operator interfaces ranging from small, simple monochrome terminals that provide modest capability to display process variables and text messages, all the way up to 23" and larger full-color displays with animated graphics and touch-screen capabilities. The small displays are typically used as local interfaces mounted out at the process equipment so that the operator can make allowed process changes from that location. The large displays are typically located in a central control room that is staffed by personnel responsible for overseeing the entire operation and keeping everything running smoothly. All the display types share the same mission though, which is to convey the status of the process being monitored to a human operator, to alert him or her to the existence of any problems in the system, and to give that operator the means with which to effect changes to the process.

50.3.3 I/O SUBSYSTEMS

Any type of SCADA system, be it laboratory-sized, plant-sized or a county-wide distributed system, is going to consist of measurement points or variables that need to be monitored. The measurements will be made using electronic sensors and instrumentation, (pressure, temperature, flow, position, etc) and will be brought into the SCADA system through the Input/Output, (I/O), Subsystem. The Input side is comprised of Analog Inputs, (AIs), which accept a continuous input of an analog signal, (usually 4 to 20 mA, 0 to 5 VDC, or 0 to 10 VDC) from a transmitter, and, Discrete Inputs, (DIs), which typically accept an on or off signal from switch or contact closure. There are quite a few permutations of these basic types allowing for differences in voltage level, (TTL,12VDC, 24VDC, 48VDC, 120VAC); electrical isolation or grounding, (single-ended inputs versus dual-ended inputs); and source of the electrical power, (sourcing versus sinking inputs and internally versus externally powered loops or outputs). There are also quite a few types of specialized inputs including High Frequency Pulse Counter Inputs, which accept very fast pulses from certain types of flowmeters and rotary encoders, and direct RTD and Thermocouple input cards, which accept the special resistance and millivolt electrical signals from these temperature measuring devices. On the Output side there are Analog Output modules, (AO), which send a continuous signal to modulating control elements like control valves and motor speed controllers, and, Discrete Outputs, (DO), which send signals to start and stop motors and open and close block valves. The I/O modules may be "local" or close-coupled to the CPU, (in the same rack or cabinet), for a small system, or, the I/O may be "remote", i.e., distributed out in the field through the use of electrical cabling. In some cases radio modems are used to connect the I/O to the CPU wirelessly.

50.3.4 CONNECTING IT ALL TOGETHER

The components previously mentioned all need to be connected together and function as one system for the application to be successful. Depending on the size and scope of the system, this can be somewhat challenging. In some cases there will more than one CPU, so some form of peer to peer communications network will have to be installed to facilitate this. A network for I/O communications may be required if remote I/O or RTU's are used. The method of interconnection of these devices is dictated by the capabilities of the hardware itself. Serial communications have, until recently, been the normal method, either through some proprietary communications protocol, or, through the use of an open standard protocol like Modbus. Serial communications can be complicated, owing to the existence of different transmission standards, (RS-232, RS-422, RS-485), and variations on the implementation of these standards. RS-232 handles point-to-point communications over distances of ~50 feet, RS-422 extends the practical distance to ~1.2 kilometers, and RS-485 allows for daisy-chaining multiple devices together. More recently, the use of ethernet connections between processors and I/O modules has become popular because of it's simplicity, economical implementation, and ability to easily interconnect many different types of devices.

50.4 ELEMENTS OF DESIGN OF A SCADA SYSTEM:

SCADA systems can be acquired in one of three ways. The first way is for a SCADA System manufacturer to be hired to design, build, install, program, and commission a system built from their own components. This is the typical path followed for first time installations of SCADA. It typically affords the lowest risk and associated costs to the customer because the SCADA manufacturer assumes complete and sole responsibility for the success of the system. There are fewer unknowns in this undertaking; the SCADA provider is working with components that he is completely familiar with. The only task he has to deal with is to learn the intricacies of the customer's process.

The second way that a SCADA system can be acquired is to hire a Systems Integration firm to create a system from components that the customer already owns or prefers to be used. This option is often pursued for follow-up projects when the customer already has an installed base of some brand of control hardware, perhaps some existing PLCs from vendor control packages, or perhaps a small existing SCADA system that he wants upgraded, extended, or linked in to the new system. The customer wishes to minimize the amount of spare parts he has to carry or minimize the training costs necessary to teach his personnel how to operate and maintain the system. This method can sometimes involve a bit more risk and cost, because now, besides having to learn the customer's process, the integrator must also learn about the system or hardware components already in place, and he has to figure out how to make it all work together. The integrator may be forced to work with hardware and software that he is not totally familiar with. The good news is that most integrators can quickly adapt and apply the knowledge they have acquired from previous projects. As long as proper care is taken to define the roles and responsibilities of the integrator, provide sufficient technical information regarding the existing hardware, a good systems integrator can climb the learning curve quickly.

The third way to acquire a SCADA system is for the customer to put the system together himself. The customer has the absolute best understanding of the process being outfitted, but probably the least level of understanding of the workings of a SCADA system. Moreover, most companies I am familiar with are running quite lean these days with regards to internal resources that could be dedicated to the task of designing a SCADA system. For this reason I feel that this the least desirable method for installing a system. What method is best? My vote goes to either of the first two options, providing that a strong engineering representative from the customer's organization be assigned to work closely with the SCADA manufacturer or Systems Integrator to provide essential details. If the customer has absolutely no installed base of control equipment, then they will probably have their best, lowest cost experience with a system acquired from a single-source SCADA manufacturer. Regardless of the method of acquiring a SCADA system, one fact remains unequivocal: the success of the project in terms of cost, scope and functionality is always determined by two factors:

1) How well-defined are the roles and responsibilities of the parties involved, and,

2) How clearly understood are the system requirements.

It is a shared responsibility between the customer or owner of the completed system, and the system provider, to ensure that these factors are addressed.

50.4.1 DOCUMENTING THE SYSTEM REQUIREMENTS – CREATING A FUNCTIONAL SPECIFICATION:

This undertaking is probably the single most significant contributor to the success of a SCADA project. It may seem obvious but I'll say it anyway: writing the Functional Specification must occur BEFORE design work on a SCADA system begins. The biggest cost and schedule killer on a project is having to rework part or all of a design. This is because every phase of a project is built on the foundation of data and work performed in a preceding phase. If some equipment function or I/O point or signal format is missed or omitted, the work of adding or correcting it later in the project can have a seriously negative impact. Another reason underscoring the importance of a functional spec is that through the design and implementation phase of a project, many decisions and compromises are made to keep the project within budget and on schedule. Only by having a firm grasp on the system functional requirements can decisions about what to cut from the project be made objectively. The best known medium for building an understanding of the system requirements comes in the form of a Functional Specification. The document carefully lays out, in a structured fashion, how the process operates and how the SCADA system will interact with that process.

To my knowledge there is no established standard for a Functional Spec. My belief is that any definition of the functionality of a system should be done with a "top-down" approach, i.e., work on the over-arching functions, tasks and communications first and then work down to more specific tasks and functions. Regardless of the format, the functional spec should contain the following elements:

Describe the process: - include material inputs, outputs, processing steps, cycle times, periods of operation, a complete detailing of normal operating conditions as well as any abnormal conditions that could exist during routine operations. Include in this section what control strategies and algorithms must be in place for the various pieces of equipment. If closed loop control is planned for any levels, temperatures, pressures, or flows it should be stated explicitly. The need for more sophisticated control loops like cascade or feed-forward or the need to interface to variable frequency drives should be identified up front. Special needs for placing these loops into or out of automatic or manual control should also be documented.

Describe the physical layout of the process: include any documentation, drawings, sketches, etc, that provides a feel for where the processes and related equipment are located relative to each other and to the intended Operator Monitoring/Control Stations.

Include any known or suspected restrictive conditions that may exist within the parameters of the project. Shortage of adequate electrical power, or extreme heat or humidity conditions, or the involvement of classified hazardous areas should all be brought up at the beginning of the project rather than sometime after things have gotten underway.

Assess the SCADA system's "mission criticality": what might be the consequences if a failure in the SCADA system results in the process going out of control? Minor inconvenience or out-and-out catastrophe? What if data or communications are lost? Is it simply an operational or procedural nuisance or will public safety be compromised? Some form of structured failure analysis, such as FMEA, (Failure Mode Effects Analysis), is beneficial at this point. This technique addresses the likelihood of failures occurring, the likelihood of detecting these failures, and the level of severity of the consequences of the failure. It results in a ranking of the different failures that can occur. This type of assessment will drive decisions regarding the hardware platform that will be selected and the need for redundancy in processors, networks, and data storage devices. Extremely critical processes, ones that, if not operating correctly, can cause injury or significant damage to equipment or property should be identified as such as this will drive decisions in selecting hardware that can make a real difference in cost. Providing redundancy in CPUs or I/O or comm links can all be accomplished but at a considerable cost.

Describe how information will flow through the system: - Begin at the beginning with Operator Inputs and Record-Keeping, records that operators currently keep on paper forms that they create or are supplied with, entries made in log books, etc.; Information that is available through existing process instrumentation, circular or strip chart recordings that are made; Information that will be available through linkages with other information systems, databases, existing SCADA systems, etc.; information that will flow into the system through the SCADA I/O, temperatures, pressures, flows, etc.; and finish up with what the destination of the SCADA information is intended to be. Simply displayed on local operator workstations? Distributed to remote locations over a county-wide area network? Pushed up to a database on an administrative mainframe?

Formatted into active server pages to be accessed over an intranet or internet? Included in this section should be a listing of the I/O points that will be configured in the system, the range of engineering units for these points, a desired frequency of update for each point.

Define a Security Strategy: - Typically, at least 2 user levels are implemented in a SCADA system. The first level is for average users and generally permits access to all operational screens and permits modification of process setpoints as necessary for smooth operation of the plant. The second level is usually given a higher level of access, access to configuration screens and permission to modify alarm points and data collection frequencies.

Document an Alarm Strategy: First, define the points in the system that will need to be alarmed. Next, determine if you wish to have different levels of severity for the different alarms that will exist in the system. Sustained deviations between a setpoint and a process variable for a non-critical process parameter will generally result in a simple deviation alarm and simple operator notification is the appropriate response. The same type of deviation on a more critical process value might coupled with process interlocks or operator corrective action guidelines therefore this level of alarming should be treated differently within the system. Alarms that will be coupled to emergency shutdowns of process equipment should receive yet a higher priority within the system. Also have a strategy in mind for how alarms will be logged, acknowledged and cleared out of the system. This will probably be different for the different types of alarms. It is commonplace for a log file to be built, (and perhaps printed out in hard copy), that documents every action and event that occurs within the SCADA system including alarms. Alarms that are operator notifications can often be self-clearing, i.e. when the deviation goes away, so does the alarm. Higher priority alarms ought to be latched in so that an operator acknowledgement will quiet the klaxon but as long as the alarm condition exists, the alarm cannot be fully cleared. Be sure that the final list of alarms and the alarming strategy is reviewed and approved by the process engineers in charge of the process, and the operations people who are responsible for keeping the process in control, and the maintenance people that will have to respond to the alarm conditions. The motives and goals of these different groups are quite different, so there will be much negotiation before the final list and strategy is approved. Process engineers generally want more alarming than is practical resulting in the occurrence of many nuisance alarms. These are bothersome to the operators and quite often are jumpered out or overridden shortly after they are implemented. It is far better to install a reduced set of alarms that are meaningful and useful to the operators. Maintenance people generally prefer alarms that can act as predictors of equipment malfunction rather than process deviations so they will have some alarms in mind that might be overlooked by the first two groups.

Define System Testing and Acceptance Criteria: - The final thing that should be said about functional specifications is to mention their role in the testing and validation of a SCADA system after commissioning. It is essential to keep the notion of testing in mind at the time that the functional specs are generated. For every function that is described in the spec, a test or verification method should at least be conceived and documented. This document will come in handy later on when it becomes the basis for your System Acceptance Testing Plan. If you can't conceive of a test or verification step for the function you are describing, then perhaps you really do not need that function or you don't understand it well enough to describe completely.

50.4.2 HARDWARE SPECIFICATIONS:

Hardware specifications provide an opportunity to dictate specific requirements that have to be complied with in the execution of the project. National and local electrical codes must naturally be adhered to, but there are also a number of standards organizations like the ISA, (Instrument Society of America), UL, (Underwriter's Laboratory), and FM, (Factory Mutual) that have standards in place for designing instrument installations, panel layout and fabrication, and the use of certain types of equipment in hazardous areas. There may also be plant standards on the NEMA ratings of enclosures, wire colors of conductors, and preferred materials and manufacturers to be used. All this information should be gathered up into a hardware specification that will tell the SCADA provider or installers which choices to make. The more details that are provided, the more accurately costs can be estimated for the total project. Some items that should be included:

Hardware materials of construction – specify if any exotic metals or engineering plastics will be required for wetted parts in a particularly corrosive or aggressive process. Specify if panels are to be painted steel, stainless steel, or fiberglass. Stipulate what the painted finish should be for painted panels.

Number of spare I/O, or spare terminal strips to be included in panels - Invariably there are some points that are overlooked in the initial I/O list, or there may be some future expansion planned in a certain area of the plant. The spec should indicate how many spares are to be included at each marshalling point.

Documentation requirements – The customer may desire that the SCADA system be documented in a certain format, or, certain specific elements must be included, like spare parts listings, bound copies of instrument specs, print-outs of the software code, or flow diagrams of the software logic. Drawing packages will most certainly be generated during the project detailing the Electrical and Instrumentation installation. How many copies are to be provided? Does the customer want the electronic CAD files? Does the customer want a specific CAD package used like AutoCAD or Microstation?

Interfacing with existing equipment – In some cases, it may be that the customer has an installed base of control equipment that he does not wish to deviate from. He may wish to specify down to the PLC level or even to the sensor level. Additionally, it should be indicated when special equipment will have to be connected to or interfaced with. Some pieces of existing equipment, (centrifuges, pump controls, or dosing systems), may already have an on-board PLC that must be tied in to the new system.

Specification Formats – One common format for issuing specifications is the CSI specification, (available from the Construction Specifications Institute), which provides a framework for project specifications. Most contractors are very familiar with this format, but it is quite dense and doesn't make for easy reading, (or writing for that matter). It can or should be supplemented with less structured text describing in plain English what the customer wants, needs or expects.

50.4.5 EFFECTIVE OPERATOR INTERFACES:

I categorize this subject as "visual ergonomics". The challenge is to convey information to the operators in the most understandable way possible. It is very easy to simply pack a display chock-full of data points and complicated graphic displays, but this can hamper the ability of an operator to recognize and react to potential problems. With a little forethought, the operator interface can be an intuitive, easy to navigate tool that can enhance operator's understanding of the process and speed their response to problems. This topic becomes more relevant when the processes being monitored involve a lot of unit operations or have a large number of data points being monitored.

SCREEN NAVIGATION – This pertains to the way an operator would switch from one screen to another. Typical methods used involve the placement of screen icons or buttons that have the name of the screen that will be brought up written right on it. Quite often a function key, (F1 through F12), is defined to create a keyboard shortcut to the screens. Another way that is a little more sophisticated is to define "hot" areas or screen targets on the display that run a script when clicked on with a pointing device like a mouse, to bring up a new screen that contains more detailed information relevant to that zone. Even more sophisticated is to have a pop-up menu appear when a screen target is selected. This menu can have different screen change options appear such as the ability to choose whether the operator wished to view a trend of the variables relevant to that process region, or a maintenance display that shows machine status variables, or a simply a detailed graphic with process variables

SCREEN HIERARCHIES – Defining a screen hierarchy is analogous to looking at a patch of ground from an airplane then zooming in to inspect specific areas when desired. Typically an overview screen is displayed on bootup that shows a plan view of different areas of the plant. The operator then selects areas of the plant that he/she is interested in. The screen hierarchy should be laid out in a way that matches the layout of the process.

ANIMATED GRAPHICS – One of the best features of SCADA system operator displays is the opportunity they provide for having the display graphics change color or position in response to changes in the process variables they are displaying or tied to in the database. Rotating equipment can actually be shown to rotate, levels in tanks can actually change, and the active or passive states of equipment can be easily displayed.

COLOR STANDARDS - When using color graphics, it is EXTREMELY important to adhere to a standard for the usage of certain colors. If a valve appears in green on a display does that mean it is open or closed? If a motor is shown in red does that mean it is stopped or running? Once the standard is agreed upon, it must be complied with entirely or you are setting your operators up for confusion and failure.

SYMBOLIC REPRESENTATIONS - It is a very good idea to have the process graphics resemble, at least in outline and relative size, the size and shape of the real process equipment being displayed. This allows the operators to form intuitive associations with the process displays because they can more easily equate the process displays with the concepts they have of the process in their heads. They become familiarized with the process displays much more quickly.

DENSITY OF SCREEN INFORMATION

There is data to suggest that the more densely packed a display screen is, the longer it will take for an observer to find a specific piece of information or to recognize that a specific piece of data is moving out of a normal range and into a problem range. Guidelines exist for the informational density of a screen and the amount of data should be between 30% and 50%. If the density is higher than 50%, an operator's ability to process specific information is significantly impaired.

TEXT DISPLAYS – Of all the types of data that can be represented on a screen, text messages of more than just a word or two contain the most densely-packed informational content and therefore they are the most difficult information for the brain to process. Text messages should therefore be used sparingly and no more than one or two messages should be displayed at one time. The ideal use of text messages is for relating specific alarm conditions. These messages should appear at the bottom of the display and should flash at a frequency of 2 to 3 times per second to grab the operator's eye.

NUMERICAL DATA – Numerical data is very easily interpreted and understood, providing that the data appears in a context and order that matches the interpreter's understanding of what the context and order should be. In other words, the numbers that indicate what the temperature of a process stream is should not be displayed in a screen location where it might be construed as a flow or pressure reading. Having the engineering units displayed next to the value helps this situation but it also contributes to the overall density of the display. The most important information should be kept in the central part of the screen.

DIGITAL versus ANALOG REPRESENTATIONS – One of the problems encountered with numeric display of information is that, while it is more precise, it loses a considerable amount of comparative information regarding relative changes that are occurring. Good old fashioned dial indicators and bar displays are still great for showing relative changes of a variable. These displays also make it easier for the human eye to "visually average" a variable that may be fluctuating. As such, there is still a place for analog displays even in today's digital world. Modern HMI software has full capabilities for accepting a digital value and displaying it an analog format. One note, however, if you are planning on using a grouping of analog displays, the most effective layout for these faceplates is one that would have all the analog indicators pointing in the same direction under normal conditions. In that way, when one or even several of the pointers are indicating non-standard conditions, those indicators will be skewed from the normal indicators and readily visible.

TRENDING - Trending, when done correctly, is probably the most descriptive interface available for understanding the behavior of a process variable. Listed below are some of the things that are often done incorrectly:

1) Having too many variables trended on the same chart - Try to use no more than 2 or 3 pen traces on a trend screen, clearly labeled and distinguished by different colors. Use multiple charts if you have a lot of points you want trended. Always try to group the points that you are showing on a trend chart so that they have some meaning to each other. For example, a controller's Setpoint, Measured Process Variable, and Output should all be shown on the same trend chart so that the performance of the controller can be assessed by looking at the one chart. Assign colors in a consistent fashion so that there is similarity from chart to chart for the same type of variable, i.e., if dark blue is selected as the color for a controller output on one trend display, then the dark blue color should also be used for other controller outputs shown on other trend displays.

2) Configuring variables on the same trend chart that have widely dissimilar ranges – Information on a trend chart may often be derived from the fluctuations or inflections seen on the chart. If trend points with dissimilar ranges are used, it may result in one or more of the trends being compressed into a fraction of the available chart space, making the reading of useful information difficult at best.
3) Using incorrect value or time scaling – Incorrect value scaling will result in the same problem as was described in #2. Another problem arises when using incorrect time scaling for the display. Determining the rate of change of a variable is one of the very useful attributes of a trend chart. If the time increment over which the variable is displayed is too long or too short it is entirely possible to obscure this type of information.

50.5 TECHNICAL FRONTIERS:

I said at the beginning of this chapter that SCADA systems for wastewater treatment benefit by remaining behind the technology development curve, but let's face it: there is a little bit of techno-junkie in all of us. So below I have listed some of the fast-moving fronts occurring with SCADA systems in manufacturing applications. So if you can hold off for just a little while, some of these technologies may very well cross over from being good-but-expensive ideas to mainstream, competitively priced applications. (Of course by then there will be a whole new slate of good-but-expensive ideas!)

50.5.1 WEB ENABLED APPLICATIONS:

Internet technologies are rapidly finding their way into process control applications. One of the hottest developing technologies for SCADA systems right now is the ability to post live data onto an internal corporate intra-net through the use of a common web-browser. This requires that the SCADA system contain it's own web server and also that it be connected into the intranet. Few, if any, users seem anxious right now to go the next step and actually post their data on the Internet, mostly for security reasons. Security issues are being addressed, so before long it will be commonplace for an engineer or supervisor to be able to log onto the world wide web and view the current state of their plant's operation. The driver for this developing technology is the desire to put information at the fingertips of the people who must make informed decisions swiftly.

50.5.2 WINDOWS CE and HAND-HELD TERMINALS, WIRELESS TECHNOLOGIES

Another rapidly moving front in manufacturing SCADA systems is the development of small, distributed devices capable of running data acquisition and display applications similar to the PC. These units fall into a category known as "information appliances". The current state of the technology is the existence of Windows CE Terminals. Windows CE is a scaled-down version of Microsoft's

Windows operating system that can run on smaller “boxes”, but still retain good display and graphics capabilities as well as extensive communications interconnectivity. It is only a matter of time until this technology couples with the tremendous advances in cellular wireless communications and results in Personal Digital Assistants, (PDA’s) like 3COM’s Palm Pilot VII or some of the new Internet Ready Cellular Phones that will be serving up process data to their owners. The immediate benefits of this technology are extreme portability and being able to access current information regardless of an individual’s location.

50.5.3 INTEGRATION WITH OTHER INFORMATION TECHNOLOGIES: GIS and CAFM

Geographic Information Systems, (GIS), and Computer Aided Facilities Management, (CAFM) are applications that provide a graphical user interface into a database of information for a geographic region or manufacturing facility. The interface is a series of maps or plan views of the region or facility. The user may select a section of the map or floor plan on which to “zoom in”. Underlying data relevant to that selected area is then accessed from the database and displayed. Currently, these tools are used to display relatively fixed or static information such as the depth of the water table at a specific point, or the age of the well at that site, or the concentration of a marker chemical at that site. In the case of CAFM systems, the information in the database might pertain to the brand and part # of a piece of equipment at the zoom-in point, or the last date that repairs were done, etc. Work is underway to integrate these databases with real time process control systems so that in addition to the static support data, access will be available to realtime process data that would be useful for gauging the operational status and process conditions at the monitored points. This feature will afford a comprehensive view of an entire enterprise, and provide the ability to perform diagnostics and troubleshooting with all of the relevant data at hand.