

SCADA: Decoding the Acronym

Supervisory Control and Data Acquisition Systems Play a Vital Role in Our Water Infrastructure

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SCADA – Supervisory Control and Data Acquisition – it is something that everyone in the water sector deals with at one level, but what are these systems and how do they work? To many, SCADA is just the computer terminals that they sit at every day, which display process screens that represent what is going on in the real world just beyond the control room. To others, it is a necessary part of any design or construction contract, which is tricky to implement and always seems to require a group of specialized ‘computer nerds’ to get it up and running. Still for others, they know SCADA is there but what it does and how it works remains a mystery. The common thread is that whenever SCADA stops working, it becomes immediately noticeable. Without SCADA systems, it would not be possible for us to run our plants and facilities as smoothly and efficiently as we do today.

This issue of *INFLUENTS* is all about automation, so it is only appropriate to start off with the big question of process automation: ‘What really is a SCADA system?’ To answer this, let’s start with the wording of the question itself, specifically the word ‘system.’ In any installation, the SCADA system is comprised of a number of discrete parts that all have to work together to make a complete system. Put another way, the SCADA system is not one particular piece of software or equipment; rather it is many separate sub-systems that are tied together. It’s the reason why those who work on SCADA are often referred to as ‘system integrators.’ It is their job to look after putting together and configuring the components that make up a modern SCADA system, and ensuring that they all work together to provide a fully integrated and smoothly operating system.

Another way to look at SCADA systems is to think of them as a jigsaw

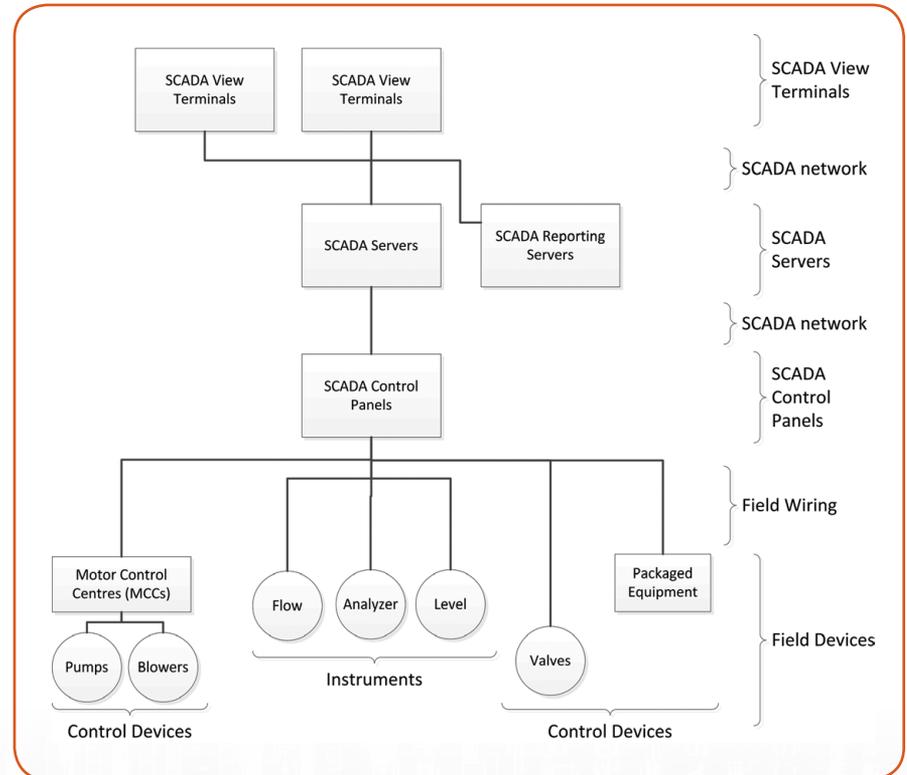


Figure 1 – Block Diagram of a SCADA System

puzzle. While individual pieces may be odd looking and hard to fit together, once they are assembled they form a complete picture. It is a puzzle of numerous parts working in harmony to accomplish what its acronym describes: Supervisory Control and Data Acquisition. The SCADA system allows for the seamless automatic control and monitoring of plant equipment while acquiring data to be presented to a supervisory agent (e.g., an operator).

Structure of SCADA Systems

SCADA systems can be thought of as a hierarchy of equipment, wiring, panels, and computers. A schematic diagram can be found in Figure 1. At the bottom are the field devices, which consist of instruments (sensors, transmitters and

analyzers) and output devices (pumps, valves, blowers). The next layer is the field wiring that connects the field devices to the SCADA control panels, which exist in the layer above. The SCADA control panels include the SCADA system controllers (e.g., programmable logic controllers (PLCs), remote terminal units (RTUs), and programmable automation controllers (PACs) as well as the input/output (I/O) terminals that the field wiring connects to.

For some field devices, particularly control devices, an intermediate layer may exist between the field devices and the SCADA control panels. This is the case for motors (pumps, blowers, fans) which typically may use motor starter panels or motor control centers (MCCs). For these types of equipment,

the SCADA control panels will monitor and control the equipment via these intermediate panels.

Above the SCADA control panels is the SCADA network. This is the network that ties all the SCADA higher-level equipment together including: SCADA control panels, SCADA servers, Operator View Terminals, and network connections to other systems. The SCADA network itself is usually segmented, or divided into zones, so that different parts of the network are dedicated to separate tasks. In many networks SCADA control panels (and the controllers they contain) are on a separate network segment than SCADA reporting systems.

Running on top of the network are SCADA servers and View terminals. The SCADA servers provide the centralized monitoring of the SCADA system, as well as looking after tasks such as recording historical process data, routing alarm notifications, and generating reports. The View terminals are the computers that provide the view screens that users of the SCADA system typically use on a daily basis to view the status of the plant.

An Example – Using SCADA to Monitor a Flow Meter

In order to better understand how this is accomplished, let's follow the path of a single field device, a flow meter, right from the source up through all of the sub-systems until it reaches the end user. As shown in **Figure 2**, the flow meter on the right does the measuring of the flow in a pipe. The electronics in the flow meter convert the flow measurement to a 4-20 mA current signal that is sent to a SCADA control panel via field wiring. The programmable logic controller (PLC) in the SCADA control panel reads in the current signal and interprets it for the SCADA system. The SCADA server then reads the status of the measurement from the PLC using the SCADA network. In turn, the operator uses a SCADA view terminal to read the measurement value from the SCADA server, which is running the SCADA application software. It is the SCADA view terminal that presents the human machine interface (HMI) to the operator.

Now that we have an overview of the SCADA system in mind, we can

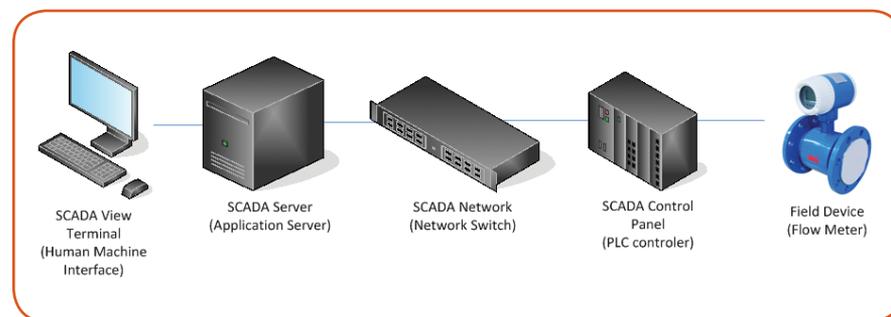


Figure 2 – Path of a Flow Meter Signal to an Operator

go over some more details about how the various sub-systems of the SCADA system function.

Field Devices

Field devices are anything that physically interacts with the process and are typically divided into two categories: instruments and control devices.

Field instruments typically consist of a transducer (otherwise known as a sensor or sensing element) and a transmitter. The sensor converts physical characteristics (pressure, temperature, flow) into an electrical

signal. This is accomplished in a variety of different ways, depending on what is being measured. For example to measure pressure, a piezoelectric crystal can be used to generate a tiny electrical current in proportion to the amount of pressure applied to it. As another example, the sensor element in magnetic flow meters create a tiny electrical current proportional to flow.

The tiny current from sensors must, however, be converted into something more meaningful, and this is where the transmitter part of field instruments comes into play. The job of the

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transmitter is to amplify and convert this raw electrical signal into the signal type that controllers in a SCADA control panel can use. Common types of output signals from transmitters are 4-20 mA current loops, pulse outputs, and digital communications busses. These days most transmitters are electronic and can also implement signal processing such as offsets, damping, error correction, and basic calculations. Many transmitters also have local measurement readouts on them as well.

The 4-20 mA current loop is a commonly used output signal from transmitters so it is worth explaining why this signal type is used. The mA in this case refers to milli-amperes, a measure of current. In a current loop, the current signal is proportional to the value being transmitted. Thus if a flow meter is set up to measure 0-500 L/s, and it is transmitting a 250 L/s signal, the output signal would be 50% of the 4-20 mA, which is 12 mA. Likewise for a 0 L/s reading in the example, the output would be 4 mA; and for a reading of 125 L/s, the reading would be 8mA. Notice how the current loop is set up as 4-20 mA, not 0-16 mA, so it uses a 'live zero' signal of 4mA for a zero reading. Thus, if the signal ever drops down to 0 mA, it is immediately apparent that there is a broken wire.

Field Wiring

In addition to the 4-20 mA current loop, there are a variety of other types of signals that are used between field devices and SCADA control panels. These include hardwired on/off signals, pulse signals, and a variety of field-busses. Traditional signals types, such as the on-off signals or current loops, typically allow one type of information to be transmitted per pair of wires. Field-level networks, which run protocols such as MODBUS, HART, or Profibus, allow controllers to talk directly to devices or instruments; this allows a single pair of wires to be used to transmit multiple pieces of data in both directions, just like between two computers on a network.

The 'field wiring' is the actual wiring that conveys the signals from field devices to the SCADA control panels. Field wiring can take many forms, but it is usually run in conduit, as armored cables, or in cable trays. For on/off signals, a combination of 120-volt and 24-volt signals is typically used. The 120-volt control wiring is more often seen in motor control circuits, whereas 24-volt wires commonly used for field devices such as pressure switches. For analog signals, it is best to use shielded cables which have the inner wires twisted to minimize electromagnetic interference. Special care also needs to be taken to ensure

field wiring for SCADA systems is kept separated from power wiring, especially high voltage cables, to reduce the chance of interference.

SCADA Control Panels and Controllers

The next set of components after the field wiring is the SCADA control panels. In SCADA control panels, the field wiring is terminated into terminal blocks, which in turn are then wired to the I/O terminals on the SCADA system's controllers. You may have heard any number of acronyms to describe the typical controller; PLC, RTU, PAC or perhaps you have a distributed control system (DCS) as opposed to a traditional SCADA system. You can get lost in a sea of acronyms trying to understand the difference between controller types but for our purposes they are all just flavours of the same thing: a specialized computer that is used to read-in, interpret, process, and output electrical signals to/from the field.

If we use our flow meter example, the reading of the flow meter is read into the controller via the field wiring and converted into a value (e.g., 50 L/s) that is stored in a 'memory register' within the controller. This register is essentially an address, like a house's address within a neighborhood. It allows the controller to find a piece of information whenever it is requested.

There are now numerous things that can be done with a stored number in a controller. If we use our flow meter example, the flow reading can be used in the controller's automatic control logic to ramp up the speed of a variable frequency drive (VFD) if the flow is too low, or cause another process to stop if the flow exceeds a preset value. This is where the second part of SCADA controllers comes into play. In addition to the controller hardware, SCADA controllers also need to each have a custom logic program that has to be written for each application. This is called the control code, or in the case of a PLC, the 'PLC program.'

This type of control code is written by a systems integrator based on a process engineer's description of how the process should run (referred to as the Process Control Narrative) and is what allows the process to operate



Figure 3 – Photo of SCADA Control Panels in a Motor Control Centre



Figure 4 – Interior of a typical SCADA control panel. Note the two SCADA controllers located at the top of the panel backplane

in the absence of any operator intervention. The flow signal could stop here and the controller could manage the entire process on its own, but then we'd be missing the 'Supervisory' aspect of SCADA, and so the signal must be sent on to the next part of the system.

The SCADA Network

The network is the courier of the SCADA realm, shuttling information between devices at lightning speed. A single SCADA system for a water treatment utility can contain dozens or even hundreds of devices that need to be able to share their information with one another. In order to do that, the devices have to have a number of things in common:

- They have a means to communicate – they are connected to one another through some physical link, known as a 'medium.' These include things like copper cables, fibre optic strands or even, in the case of wireless, electromagnetic radiation.
- They speak the same language – in computer terminology, this is called a communication 'protocol.'
- They have a way of finding each other – these are the 'network addresses' and each device will have a unique address in order to differentiate it from every other device
- They each need to have their memory registers laid out in a carefully planned and standardized manner – this is so custom control code on one controller can be written to fetch data from another controller in a systematic and predictable way.

Up until recently, SCADA networks tended to be proprietary in nature and very slow. However, starting about 10 years ago, most SCADA networks are now based on Ethernet. Ethernet is the network the Internet runs on; however, in the case of SCADA networks there are a number of differences. The first is that the type of security used is much higher, the second is that SCADA networks are closed networks which are not connected to the open Internet, and the third is that the type of devices used on them are specially designed for SCADA applications. Also, the types of network switches, routers and

firewalls are specially designed to be used in a SCADA environment.

Due to the spread-out nature of SCADA networks, often covering up to 100km from one end of a water district to another, a variety of forms of Ethernet network can be used. This can include copper wiring, fibre optic networks, radios, microwave links, and a variety of commercial networks including DSL, cable or leased lines. In some networks telephone lines are still used, though these are gradually being replaced with fibre optic connections.

SCADA Servers

At the heart of every SCADA system is the application software that brings the virtual world back to reality for the end user. SCADA servers provide the vital function of being the hub of all information pertinent to the operator, which they do by maintaining a database of all the most current statuses and values both from the User side (the HMI) and from the process side (the controllers).

The software, and the corresponding process status databases, can exist on a single computer, or be located on multiple computers, depending on the size and configuration of the SCADA system. Even the way that servers are physically deployed can vary considerably. The physical boxes are not the important part, but rather it is

the software that runs on these machines that is most crucial.

Most SCADA software packages consist of a bundle of several programs that run concurrently in order to provide both the 'Supervisory' and 'Data Acquisition' parts of a typical SCADA installation. One program polls both the controllers and the HMI for their most recent data and stores it in a database. Another program acts as a translator between the controllers and the database, to ensure that all the data from the controllers are put into a format that the SCADA software can use. This is especially important if more than one type of controller is being used in the SCADA system. Another program then takes periodic snapshots of the current data in the SCADA database, tacks a timestamp on each value and then records them into a time-series database for use in historical trends and reports (i.e., a historian program). The SCADA software also has screen development tools to allow system integrators to draw and configure the screens that populate the final piece of the puzzle, called the HMI.

The Human-Machine Interface

The Human Machine Interface, more commonly known as the HMI, is the part of SCADA that most of us are familiar with. The HMI provides the computer screens that we see when we look at a SCADA View Terminal. It is



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“At the heart of any SCADA system lays the application software that brings the virtual world back to reality for the end user.”

the visualization of the process in real time, provided by screens, that shows device statuses, process values, alarms and trends. It is also where the user can adjust process control setpoints and modify the operation of equipment in the real world from the comfort and safety of the control room.

In a nutshell, the HMI consists of a series of screens and scripts that are programmed by a Systems Integrator to animate icons or show alarms based on the values present in the SCADA database. Each of these screens must be carefully designed so that there is enough information available to allow a user to easily discern the current status of the process, but not be so detailed that the user is overwhelmed by information overload.

For example, if a pump is shown as ‘running’ on an HMI screen that means a ‘running’ status signal has been sent from the pump controller, via the field wiring, to a SCADA controller which conveyed that signal via the SCADA network to a SCADA server. On the SCADA server, the memory register from the controller is being read into a live tag database, which in turn is read by the software module that shows the running status on the HMI screen. This status can then be conveyed by a combination of colours (say red running, green for stopped), animations and/or text status indicators on the screen.

The other major task that the HMI undertakes is to generate SCADA alarms. In the SCADA system, alarms are configured to notify the operator if part

of the process is operating abnormally and requires an operator response. An example, would be a high level in the wet well at a wastewater lift station. In this case, the SCADA system would generate an alarm that would notify an operator that corrective action is required.

The HMI software is part of the overall SCADA software package and runs on a computer terminal, often referred to as a ‘client.’ These clients are served information by the SCADA Servers and take process setpoints from the User via the HMI to send down to the controllers. The system as a whole operates continuously by passing information through its various layers to provide the operator with a real-time representation of what is happening in the plant, along with looking after all of the automatic control details in the background.

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The Missing Letters in SCADA

All of this has been a very condensed account of what a basic SCADA system is, but today’s SCADA systems can be so much more than simple monitoring, process control and alarming. Essential functions like reporting can also be tied into SCADA. For example, historical data collected by the Historian server and other ‘big data’ sources can be used to calculate, compare and analyze the numbers to provide insight to both operations and management not just ‘what is happening right now’ but also ‘what *has* happened and how can we make it better.’

Due to the availability of more advanced SCADA software packages, more and more functionality is becoming available that can be used by system integrators to provide utilities with more insight into their process systems. SCADA systems can now be used to make Standard Operating Procedures and Operations & Maintenance Manuals readily available along with process information. Automated workflow support is now available, and can be triggered by



SCADA alarms or events to alert crews how to respond to a certain problem or to initiate work orders. SCADA systems can also now be tied into Asset Management programs to help utility managers better plan ahead for upgrades and capital works projects.

Leveraging SCADA Technology

SCADA systems play a vital role in the smooth and efficient operation of both water treatment plants and other water related facilities. As a key component of water infrastructure, SCADA systems ensure that plant staff have ready access to up-to-date and accurate process information, that operators are notified when process adjustments are required, and that key process data is recorded in a consistent manner. Looking to the future, as technology continues to evolve, SCADA systems are increasingly offering additional functionality that can be used by the personnel who look after our water treatment infrastructure.

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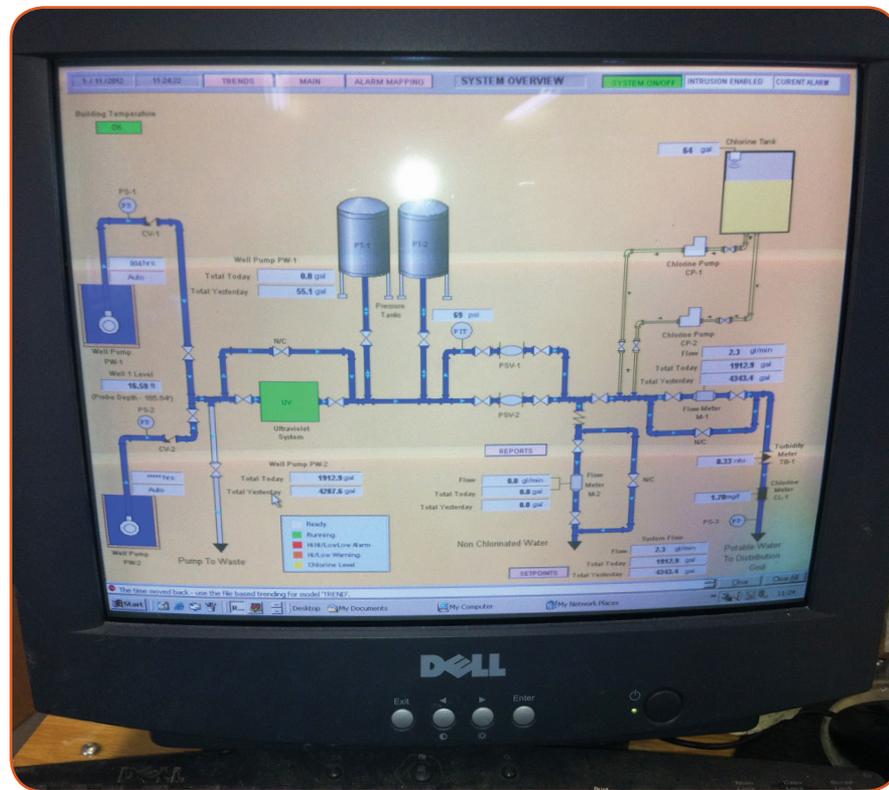


Figure 5 – Example of an HMI Screen on an SCADA view terminal



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