SCADA: Supervisory Control and Data Acquisition
4th Edition

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Unit 10:
Operator Interface
Unit 10

Operator Interface

We have learned that of all the applications that the MTU performs, 99% or more happen independently of the operator. Most automatically generated applications, such as scanning and communications checks, are vital, but not process-related applications. They are activities like polling the RTUs in a scheduled scan, checking for communication errors, and the like.

Most of the control applications that SCADA implements are not initiated by the SCADA system, but rather are under the direct control of the human operator. Recall how the pipeline leak detection system in the last unit advised the operator that there was a potential leak in the pipeline, but left it to the human operator to make the final decision to shut in the pipeline.

SCADA is a hands-on operating tool with some automatic capabilities.

The very concept of a hands-on tool implies a requirement for fast, meaningful feedback from the process to the operator, and effective control input methods to the process. This unit will consider the operator interface, also called the human-machine interface (HMI) or the input/output (I/O). The operator interface is the junction from which information travels from the SCADA system to the operator and from the operator to the SCADA system.

The SCADA system should allow for monitoring of the status of equipment like valves and motors. It should receive input from process equipment when out-of-limits conditions exist, and tell the operator that there is an alarm condition. It should be able to present analog values, representing such things as level in tanks, electric current in conductors, speed of compressors, or percentage composition from chromatographs. Totalized values of flow, kilowatt hours, or process cycles should be viewable by the operator. Finally, some mechanism should be provided to receive instructions from the operator to switch certain equipment on and off and to adjust other equipment by incremental amounts.

Learning Objectives—When you have completed this unit you should:

A. Know the various media that are available to convey information from the SCADA system to the operator.
B. Understand the various ways in which information is presented by the system to the operator.

C. Understand how the SCADA system can be developed to make the presentation of information to the operator most effective.

D. Appreciate how operator instructions to the SCADA system can best be organized.

10-1. Operator Interface on Very Small Systems

Many SCADA systems are installed to operate as little as one pump. The status, alarms, and controls for such a system can be adequately interfaced by a couple of panel lights and a switch. One light will tell the operator if the pump is running or not, a second light will tell if there is a power failure at the site, perhaps a third will tell if the pump station pressure is too high or too low, and the switch will let the operator turn the pump on and off. If the system grows much beyond one or two pumps, hardware operator interfaces are not the best way to go; thus, it will probably make more sense to have a computer screen dedicated to each of the stations and to build software copies of each station’s panel lights and switches. With multiple stations, computer screens with graphic representations of the site equipment can provide more flexibility, lower maintenance costs, and lower capital cost than a hardware interface.

Even if the interface is hardwired lights and switches, the master terminal unit will still be a computer. Those changes in status or alarm that the MTU recognizes may be archived, with time and date stamps, for future reference if the design team believes that there would be a benefit to doing so. At least one hardcopy report of process changes, printed at a regular time (usually first thing in the morning), is usually available. A list of time-stamped alarms is also printed on a scheduled basis. These report types can also be printed on demand.

10-2. Operator Interface on Mid-sized Systems

Once the process complexity grows beyond six or eight status and alarm points and three or four controls, it becomes more effective to have information presented to the operator as symbols on a graphic that resembles a process flow drawing. When the design team is designing these graphic interfaces, or “screens,” they should resist the urge to make them complex just because they can. The goal should be to have the graphical representation of the process be as simple as possible while still presenting all the information needed to operate the process.
Figure 10-1 shows an operator interface screen showing the status of three inlet valves (lower left side). It also shows that pop-up controls for each of the controllable valves sit hidden until required and that pop-up controls for the compressors and pumps are available. The valve controls use a mouse to locate the cursor over one of the two choices, “open” or “closed,” with a click to select. The compressor and pump speed are controlled by using the mouse to drag the speed set-point indicator to a lower or higher location on the speed indicator. The density and pressure of each of the gas/liquid blends are available, and flow rates (in metric tonnes/day) for three of the fluid streams appear at the upper right. This screen does not directly show alarm conditions, but if the process conditions are out of limits and there is an alarm, the density numbers, pressure numbers, and/or flow rate numbers could be made to blink. Most graphic screens developed today use colors extensively; perhaps too extensively.

If this graphic screen represented most or all of the process, monochrome would be sufficient. If there were three or four times as much process equipment being monitored and controlled by the SCADA system, you would use multiple pages, with an intuitive way to move from one page to any other. If the process were very complex, you could consider several video screens. One or two pieces of video display hardware with graphic screens laid out like this one would be sufficient for a SCADA system of nearly any large size. In addition, another piece of hardware that is
dedicated to alarm indications and is equipped with a fast way to change the Status/Control Screen for each process section to one that may have an alarm should be provided for a SCADA system of any size. Much of the technology for a SCADA operator interface is shared with a distributed control system (DCS) operator interface.

10-3. **Operator Interface on Large Systems**

Most large systems could be controlled by an operator interface similar to the one just described for medium-sized systems. One video screen dedicated to alarms and one or two video screens for control/status and totalizer amounts (or some corresponding value in an electrical distribution system) are normally sufficient. Remember that the SCADA system is normally an operationally simple one that will usually be operated by one person, and that safety-related functions will be handled by local-loop, hardwired controllers. This means that fast operator response to upsets is not as important in Supervisory Control as it may be in Direct Process Control.

10-4. **Local Security Considerations**

When you consider that with a few keystrokes on a standard keyboard or a few mouse clicks on a screen it is possible to shut in an entire oil field, electrical power system, or pipeline, it will be apparent that some security measures should be in place to control who makes those keystrokes or clicks. We will deal, in some detail, with security considerations in Unit 12. For now, you should be aware that keeping unauthorized people away from the controls of the facility is important. Physical security and passwords are the first layers of protection to consider.

10-5. **Monitor Status Points**

Since SCADA is put into place to extend the operator’s view and the operator’s control of the process, let us first look at presenting process equipment status to the operator. Very early systems used a narrative list of equipment status that was updated and printed at regular intervals, perhaps every hour. This method did not provide any intuitive aid for the operator. Human beings think in terms of pictures and using a graphic screen similar to Figure 10-2 will help the operator remember how the field device that he or she is checking fits into the overall process.

When there are multiple devices that have similar effects on different process streams, they should be arranged in a similar way. Notice that the six pairs of valves on the left in Figure 10-2 allow produced fluid from each of six wells to be transferred to the Test Separator if the upper valve of the pair is open and the lower valve is closed. If the valve positions are
reversed, the fluid will bypass the separator and go to the pipeline. Borrowing a convention from driving, “Green for Go and Red for Stop,” is often used for color-coding open/closed valves. If the valve is open, its symbol on the graphic should be green. If the valve is closed, its symbol should be red. This can be taken one step further, have the valve appear orange on the graphic while it is transitioning from open to closed.

In the lower right of the figure, two air compressors are shown. The color codes used for electrical equipment are not consistent. Some companies use, “Green for Go and Red for Stop,” others opt for an electrical standard that is based on “Red for Run and Green for Safe(ly off).” Whichever convention you decide to use, be consistent throughout the company.

10-6. Monitoring Alarms

Two of the economic justifications for installing SCADA are keeping the operation running and restoring it to operation quickly when it does shut down. In Unit 11 we will discuss safety instrumented systems, which act to shut down (or otherwise make safe) a process so as to prevent injury to staff or the public, damage to the process, or negative environmental impact. In Unit 11 we shall make a very strong argument for having these safety systems local. Except for pipeline shutdown due to leaks, safety
shutdown logic, which does not depend on the SCADA system, should be hard wired at the remote location to ensure that communication failures do not result in failure to shut down when an unsafe process condition requires shutdown.

When the safety systems do operate and shut down the process, the operator should be advised quickly so the upset condition can be rectified and downtime can be minimized. To this end, the MTU treats alarms in a special way. At the field site and in the RTU, they are treated the same as a status point. They exist as voltage levels on the output of a physical or electronic switch and influence the setting of a register position. Once they arrive at the MTU, they are treated differently. The condition of each point that has been identified as an alarm point is compared to its condition on the previous scan. The upper left portion of Figure 10-3 shows a simple eight-bit register in the MTU that holds the previous condition of eight alarm points. All alarm conditions are off except the ones stored in bits 3 and 4. The lower part of the figure is the register into which the last scan information has been entered. The MTU now does a bit-by-bit comparison to check for differences. When it checks bit 1 and finds that it is the same, it does nothing and moves to the next bit. When it checks bit 2 and finds that a new alarm has been generated, it goes into alarm mode. (More on that later.) When the MTU checks bit 3, it sees no change. Notice that there is an alarm here, but because it is not a change, it is ignored. When the MTU checks bit 4, it sees that the alarm that had been on is now off, and it passes this information on for additional processing. When it checks bits 5 to 8, it sees no change.

What has just been described is a “report-by-exception” mode. A SCADA system might monitor three thousand alarm points. If one hundred of them were in alarm (not an unusual situation) and the operator was advised of every scan, information overload would bring the system (and maybe the operator) to its knees. Report-by-exception alarming tells the operator about alarms only when their status has changed.

In large systems, even that amount of information may be too much. “Alarm storms” can occur inundating the operator with such a large series of report-by-exception alarm indications that he or she is overwhelmed and doesn’t know how to respond. Consider the alarm regime of an unmanned oil production platform. Figure 10-4 lists four possible alarm conditions. If the generator has failed, the electrically-driven pumps will not operate, so it is not necessary to advise the operator about each one that has stopped running. The MTU can be programmed to inhibit the “Transfer Pump P-101 Stopped” alarm whenever the “Generator Failed” alarm is on. This is called alarm override mode. It can reduce the decision load during process upsets when the operator is busiest. The other two
alarms in Figure 10-4 would not be overridden because they would be expected to operate even during a power failure.

Some alarm conditions are more important than others. Some cause no reaction except a comment in the next routine maintenance report. But in most SCADA systems, all changes in alarm status are logged and time and date stamped into an archive. This data is important enough that, often, a copy is made of it at the end of each day and the copy is stored off-site. Note that the time stamp is generated by the MTU based on when the

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**Figure 10-3. Checking for New Alarms**

![Diagram of alarm checking logic](image)
change in alarm status was received by the MTU. For systems with long scan intervals, this time may be as much as one-half hour after the event actually happened.

If the alarm is not being overridden, it will be checked by the system for priority. When the system is being configured, each alarm point is assigned a priority. There may be between one and five levels of priority. Figure 10-5 shows that the lowest priority (in this case a priority 3) would result in the alarm being displayed on the dedicated “alarm screen.” The second-lowest priority would cause the alerting of the operator, perhaps by a flashing symbol on the screen to refer to the alarm screen for further information. The highest priority would also result in the alarm being displayed on the dedicated alarm screen, but would sound an audible alarm as well, calling the operator to the operator interface station from wherever he or she was in the facility.

<table>
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| 1.             | Print on “Alarm Screen”  
|                | Print on “Alarm Log”    
|                | Flash “Alarm” on any active screen  
|                | Sound audible alarm     |
| 2.             | Print on “Alarm Screen”  
|                | Print on “Alarm Log”    
|                | Flash “Alarm” on any active screen |
| 3.             | Print on “Alarm Screen”  
|                | Print on “Alarm Log”    |

Figure 10-5. Effects of Various Priority Alarms

Alarms must be acknowledged by the operator. When they are acknowledged, the special features (flashing and sirens) go away. Generally, a return to normal on a later scan will not cancel the features
unless the operator has acknowledged the alarm. Time-stamping the operator acknowledgement into the alarm log is normally done by the MTU. Time-stamping the “Return to Normal” event is also done by the MTU.

An operator interface method that is becoming common is designed to reach operators that are not located at the site of the MTU. For those alarms that are prioritized at or above a selected level, the MTU can initiate a phone call to a telephone list of operators, dialing each name on the list until it is successful in reaching one. The MTU will then play a pre-recorded message that is tied to the type of alarm that has occurred. The operator can communicate with the MTU by using the telephone keypad numbers to indicate that he/she has received the message and acknowledges it. In some cases, the operator may also have limited control functionality using his or her keypad. Security may be a problem, and passwords will be required to assure the MTU that the operator is in fact the person answering the phone. This technique is becoming much more popular with cell phones and laptop computers that are wirelessly connected to the Internet.

10-7. Totalized Values and Trending

Most of the totalized data gathered is presented to the operator on graphic screens in order to contextualize it. Refer to Figure 10-2. The totalized flows of water, oil, gas, and emulsion are presented on the test separator graphic symbol to help the operator recognize that they refer to the present test. Below the separator, the current production rates of the six wells are presented, in tabular form, on the graphic of the production facility through which they produce. Any large SCADA system, whether for oil and gas production, electric transmission or distribution, irrigation, or water and sewer, will have totalized data points widely scattered. Presenting the data tied to their location will be more effective than presenting them as a large table or list.

Trending aids the operator by providing a graphic depiction of progress. By plotting recent history as well as the current reading, the operator can see at a glance if the situation is stable or is getting better or worse. He or she can also see when volumes or levels started to move away from optimal, and knowing this can aid in troubleshooting (see Figure 10-6). You can tell when the trouble began on this process just by glancing at the trend. You can tell how bad the trouble is and you can extrapolate to learn how much time you have to fix it.

Color adds another dimension that improves the “at a glance” ability of operators. Adding a limited number of colors draws the attention of the operator to the things that he or she must concentrate on.
10-8. Control Interfacing

Because the available control functions are rather limited, the operator interface screens that allow these changes do not have to be complex. Figure 10-1 shows a simple screen that includes the control functions for an injection compressor and pumping station. Notice that for this application, and, in fact for most control and monitoring screens, all of the points refer to equipment at one location. In this example, most of the control functions can be effected by moving the screen cursor to a spot next to the control function and pressing the ENTER button. In the case of adjustments to the speed, the selected speed could be typed in after the cursor has been moved to near the speed select area, or the speed control could be selected by the mouse and dragged to the preferred speed.

Some control screens include an additional column to advise the operator of the present status of each control function. If this is done, some provision must be made to alert the operator that an order has been given and the system is waiting for the next scan to confirm that the order was implemented. Starting a compressor may require a dozen or more individual actions, each one of which must be accomplished in a definite sequence and only after various conditions have been confirmed. The logic for this detailed control is located at or near the equipment, often in the RTU. It is neither necessary nor advisable to locate it at the MTU. The SCADA operator is interested only in getting the compressor to start.
After it is ordered to start, the operator wants to know if it did. If it fails to start, a message should come back telling of the failure. The operator can then send out a maintenance crew to repair the compressor or its control system.

10-9. Reports

Two of the vast number of reports that may be required from a SCADA system are alarm logs and communication reports. These reports may be grouped in several ways. It is common to pre-format the reports rather than have them printed in an ad-hoc form, and to have them grouped by function. Another grouping is those that print automatically at a fixed time and those that print only when asked for, or on demand.

Most companies operating SCADA still require that one dedicated printer be allocated to alarms. This is becoming less of a rule since the reliability of MTU computers and, particularly, their disc memories are much better than before. Alarm data is now archived in a historian, and that historian will probably be stored off-site as will the printed version. Although many days' worth of alarms may never be looked at, they are available if needed and don't take up much storage space. Since the alarm log printer records each alarm, as well as the time of its acknowledgement and return to normal, it is usually busy and noisy. Dedicated alarm log printers are often relegated to closets or other sound-proof rooms near the control room.

There may be need for routinely printed reports that the SCADA operator does not normally see. Daily communication reports, accounting-related information, and reports detailing the need for process maintenance are examples. These reports should also be printed away from the control room.

The final group of reports consists of those that the operator uses to run the facility. Examples include a special alarm report to help analyze a problem or a run report that enables each field operator to carry a hard copy detailing the recent operation of the part of the process that is his or her responsibility. The printer that produces these reports should be in the control room.

As SCADA systems are becoming integrated electronically with the rest of the corporation by local area networks, many of these reports are generated by other computers that are owned by other corporate departments. These reports use data gathered by the SCADA system, but their presentation method will be customized by the end user.

Portable computers, carried by maintenance workers, can be set up to gather and present information needed by the maintenance worker in his or her rounds. If these rounds take the worker into potentially combustible
areas, the portable computer should be rated for the atmosphere to which it will be exposed.

10-10. Parallel Operator Interface

In its upward spiral, computer technology has now made it possible for multiple screen/keyboard stations to be connected to one computer workstation. Translated into SCADA language, this means that more than one interface can be driven by one MTU.

It is seldom a problem to have more than one operator running a SCADA system. If the load exceeds the ability of one operator, the system can be split into two or three completely separate sub-operations within the SCADA system. Operations that are growing or that are being updated can benefit from having the system engineer or technologist connected to the MTU. But when this is done, each operation uses a separate interface and is enabled by a password or the appropriate authority to avoid interfacing with the action of the operator.

This parallel operation requires that great attention be paid to enabling the various people who can access the MTU to communicate with each other. It also increases the importance of security for the system because now the system interface equipment has several physical locations.

Unit 10 Exercises:

10-1. MTUs can present information to operators in two forms. What are they?

10-2. Why is trending, the graphic representation of a series of data points, so effective?

10-3. What is the advantage of clustering pieces of similar data together for presentation to the operator?

10-4. In what way does the MTU treat an alarm point differently than it treats a status point?

10-5. What is the purpose of an alarm log?

10-6. What is meant by “reporting by exception”?

10-7. What technological tools are making the printing of maintenance reports unnecessary?

10-8. The purpose of SCADA is to extend the view and the reach of the operator. How is success in this purpose going to be economically justified?