Intelligent distributed systems

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Outline

1. SCADA
   - Bird's eye view
   - SCADA Components
   - Acquisition, Processing, Control and Failures
   - Evaluate SCADA
   - The Four SCADA Levels
2. SCADA, DCS and PLCs
   - SCADA vs DCS
   - SCADA and PLC
3. Take home message

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SCADA

One primary application at a higher level than the fieldbus level is the *Supervisory Control And Data Acquisition* (SCADA) systems.
The networked SCADA systems often provide a supervisory-level factory-wide solution for *coordination of machine and process diagnostics*, along with other factory floor and operations information.

SCADA

History

SCADA has been around as long as there have been control systems.

The first SCADA systems utilised data acquisition by means of *panels of meters*, *lights* and *strip chart recorders*.

Supervisory control was exercised by the operator *manually operating various control knobs*.

These devices were and still are used to do supervisory control and data acquisition on *plants, factories and power generating facilities*.

SCADA

SCADA in a nutshell

SCADA = *Supervisory Control And Data Acquisition*

- *Supervisory* feature available to operators, engineers, etc.;
- *Control* which can be monitoring, telemetry and remote or local;
- *Data Acquisition*, that is access and acquire information or data from the equipment, both digital and analog, and sends it to different sites through telemetry.

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SCADA

How it works?

SCADA is *not* a specific technology, but a *type of application*. In a very wide sense:

Definition

Any application that gets data about a system in order to control that system is a SCADA application.

SCADA

Components

A SCADA application has two elements:

- The *process/system/machinery* to monitor and control, e.g., a power plant, a water system, a network, a system of traffic lights, etc.;
- A *network of intelligent devices* that interfaces with the first system through *sensors* and *actuators*.

The network *is* the SCADA system since it gives the ability to measure and control specific elements of the considered plant.
A SCADA system can use several different kinds of technologies and protocols.

SCADA

Simplest SCADA system

Figure: Simplest SCADA system: warning/alarm light.

SCADA

Fields of application

SCADA is used to manage *any kind of equipment*.
Typically, SCADA systems are used to *automate complex industrial processes where human control is impractical*.
For example, systems where there are more control factors, and more fast-moving control factors, than human beings can comfortably manage.

SCADA

Electric power generation, transmission and distribution

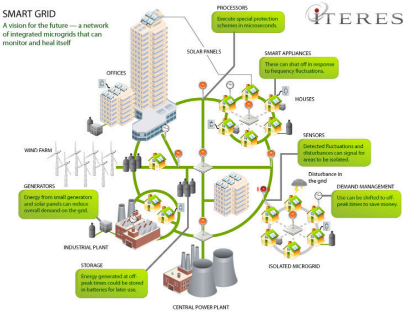

Figure: Power grid.

Electric utilities use SCADA systems to detect current flow and line voltage, to monitor the operation of circuit breakers, and to take sections of the power grid online or offline.

SCADA

Electric power generation, transmission and distribution

Figure: Example of a SCADA system in ABB with water pressure control, Sesto San Giovanni, Milano, Italy.

SCADA system produced by ABB for energy optimisation of water supply in smart buildings.

SCADA

Electric power generation, transmission and distribution

Figure: Example of a Smart Grid SCADA system in ABB, Sesto San Giovanni, Milano, Italy.

Control room produced by ABB for Smart Grid SCADA systems.

SCADA

Water and sewage

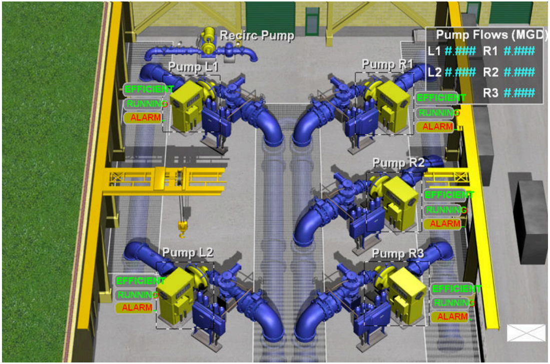

Figure: Water distribution monitor.

State and municipal water utilities use SCADA to monitor and regulate water flow, reservoir levels, pipe pressure and other factors.

SCADA

Buildings, facilities and environments

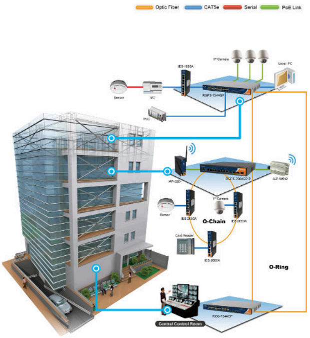

Figure: Building monitor.

Facility managers use SCADA to control HVAC, refrigeration units, lighting and entry systems.

SCADA

Manufacturing

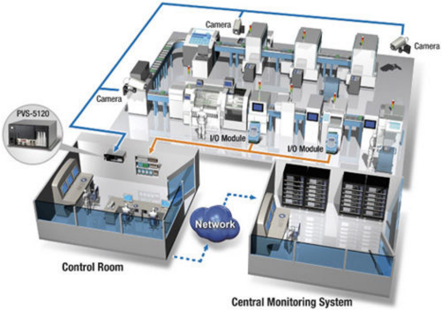

Figure: Manufacturing system.

SCADA systems manage parts inventories for just-in-time manufacturing, regulate industrial automation and robots, and monitor process and quality control.

SCADA

Mass transit

Figure: Mass transit SCADA system.

Transit authorities use SCADA to regulate electricity to subways, trams and trolley buses; to automate traffic signals for rail systems; to track and locate trains and buses; and to control railroad crossing gates.

SCADA

Traffic signals

Figure: Traffic lights monitoring and control.

SCADA regulates traffic lights, controls traffic flow and detects out-of-order signals.

SCADA

Summary of applications

The potential applications for SCADA systems are almost unlimited: SCADA is used in nearly every industry and public infrastructure project, i.e., *anywhere automation increases efficiency*.

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SCADA Components

SCADA encompasses the transfer of data between:

- A number of remote sites (*Remote Terminal Units* or RTUs), connected through *data multiplexing* (MUX);
- A *central host computer*;
- The *operator terminals*.

Basically, the MUXs serve to *route data* to and from a (relatively high) number of RTUs on a local network.
Very *few physical links* on a Wide Area Network (WAN) backbone are instead used to pass data back to the central host computer.

SCADA Components

Example

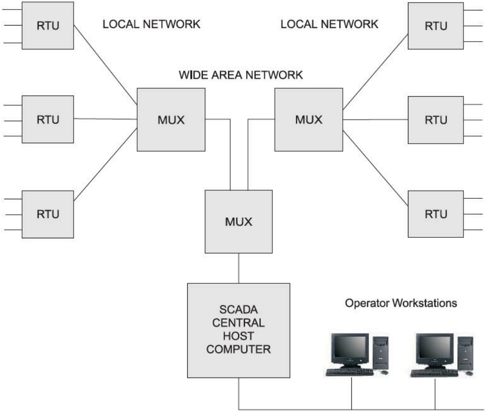


Figure: SCADA system with *data multiplexing* (MUXs) between the central host and the RTUs.

SCADA Components

The various elements

SCADA systems consist of:

- One or more *field data interface devices*, usually called *Remote Stations*, *Remote Terminal Units* (RTUs), or *Programmable Logic Controllers* (PLCs), which interface to *field sensing devices* and *local control* switch-boxes and valve actuators.
- A *communication system* used to transfer data between field data interface devices and control units and the computers in the SCADA central host. The system can be radio, telephone, cable, satellite, and so on, or any combination of these.

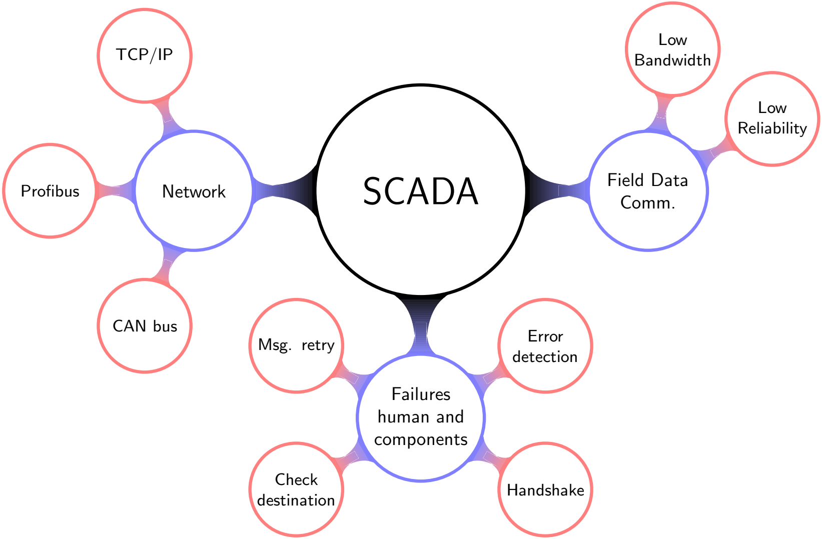
SCADA Components

The various elements

- A *central host computer server* or servers (sometimes called a *SCADA Center*, master station, *Master Terminal Unit* or MTU).
- Another *communication system* to support the use of operator workstations that may be geographically remote from the central host computer.
- A collection of *standard and/or custom software*, usually called *Human Machine Interface* (HMI) software or *Man Machine Interface* (MMI) software, which are used to provide applications and support at the operator terminal.

SCADA Components

Communications



SCADA Components

Field Data Communications System

The following communications media are common:

- Licensed radio links (UHF and VHF);
- Unlicensed “spread spectrum” radio links;
- Public switched telephone networks;
- Mobile telephony;
- Microwave;
- Cable TV networks;
- Dedicated satellite links;
- Dedicated cable, including fiber optics (for very short distance communication);
- Corporate WAN computer communications systems.

SCADA Components

Field Data Communications System

Selection of the preferred communication media depends on several important factors:

- The remoteness of the field equipment site;
- The required reliability of the communications media (primarily determined by the perceived operational importance of the remote site);
- Availability of communications options;
- Cost of each option for the particular application;
- Availability of power (power company, battery, solar, or other).

SCADA Components

Field Data Communications System: Example

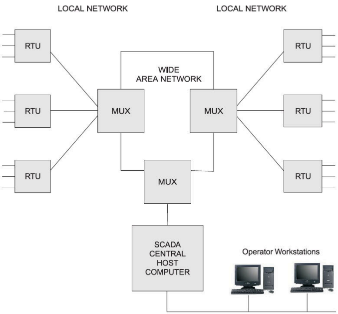


Figure: SCADA system with WAN and LAN (courtesy of Bentley Systems Inc. 2004). The WAN links are generally *full duplex* and may be configured in a *star or loop topology*. The LAN usually adopts *half duplex or simplex* communication over *bus* and *Time Division Multiplexing* (TDM).

SCADA Components

The Central Host Computer

The Central Host computer

SCADA Components

The Central Host Computer

The *central host computer*, or *master station*, is most often a single computer or a network of computer servers that provide a *man-machine operator interface* to the SCADA system.

The computers process the information received from and sent to the RTU sites and present it to human operators in *a form that the operators can work with*.

Operator terminals are connected to the central host computer by a *computer network* so that the viewing screens and associated data can be displayed for the operators.

The central host computer acts as a *server* for the SCADA application and the operator terminals are *clients*.

SCADA Components

Software Systems

The most obvious *software component* is the operator interface or *MMI/HMI package* through a *graphical user interface* (GUI).
Data from the field are processed to detect alarm conditions, and if an alarm is present, it will be displayed on dedicated *alarm lists* on the application software running on the central host computer.
In case of an alarm, operators can then *investigate* the cause of the alarm by using the SCADA system.
Where variables in the field have been changing over time, the SCADA system usually offers a *trending system* whereby the behaviour of a particular variable can be plotted on a graphical user interface screen.

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SCADA Operations

Data acquisition mechanisms

Data acquisition within SCADA systems is accomplished by letting the RTUs scanning the field data interface devices connected to them.

The time to perform this task is called the *scanning interval*.

The central host computer scans the RTUs to access the data in a process referred to as *polling the RTUs*.

Some systems allow also the RTU to transmit field values and alarms to the central host *without being polled* by the central host, *unsolicited messaging*.

Unsolicited messages are usually only transmitted when the field data has deviated by a pre-specified percentage, so as to minimize the use of the communications channels, or when a suitably urgent alarm indicating some site abnormality exists, i.e., *event-based*.

SCADA Operations

Supervisory control mechanisms

Control actions that are performed by using the central host are generally treated as data that are sent to the RTU.
As such, any control actions by an operator logged into the central host will initiate a communication link with the RTU to allow the control command to be sent to the field data interface device under control.
Remark: SCADA systems usually employ *several layers of checking mechanisms* to ensure that the transmitted command is received by the intended target.

SCADA Operations

Levels of control

In contrast with DCS, SCADA systems generally cover large geographic areas and rely on a *variety of communication systems* that are normally less reliable than a LAN associated with a DCS.

Loop control based in the central host computer is therefore *less desirable*.

Instead, the controller application, that can be *adjusted* by the central host, is housed in the RTU.

If communication to the remote site is lost, it is desirable that the *local automatic control system continue to operate*; therefore, the RTU is an autonomous unit which could control the valve without constant direction from the central host computer.

SCADA Operations

Handling of data during scada failures

Different SCADA systems cope differently with a *failure event*:

- *Storage of data in the RTUs*: Some SCADA systems rely on the capacity of the RTU to store data collected from the field under normal operation and then periodically transmit that data as an unsolicited message or when polled by the central host. In times of SCADA system failure, the capacity of the RTU is used to archive information until a backup central host is brought online or the original system has recovered;

SCADA Operations

Handling of data during scada failures

- *System redundancy*: Most SCADA systems incorporate some form of redundancy in their design, such as dual communications channels, dual RTUs, or dual central host computers. Such systems may be designed for such redundant equipment to be online (*hot standby*) to ensure a seamless transfer upon SCADA system failure, or offline (*cold standby*) where the backup mechanism must be manually brought online to operational capacity.

Most SCADA systems employ a *combination* of the preceding mechanisms.

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SCADA Evaluation

Evaluating complex systems as a SCADA can be very tricky.
However, there are some guidelines to what look for in a SCADA system.

SCADA Evaluation

RTU

SCADA RTUs need to communicate with all the on-site equipment and survive under the *harsh conditions* of an industrial environment.
Hence, the RTU should offer:

- *Sufficient capacity* to support the necessary equipment, but not more capacity than can actually be used.
- *Rugged construction* and ability to withstand extremes of temperature and humidity, since the SCADA system needs to be the *most reliable* element in your facility.
- *Secure, redundant power supply*: The RTU should support battery power and, ideally, two power inputs, since it has to work 24/7.
- *Real-time clock* for accurate date/time stamping of reports.
- *Watchdog timer* to ensure that the RTU restarts after a power failure.

SCADA Evaluation

RTU

- *Redundant communication ports*: Network connectivity is as important to SCADA operations as a power supply. A secondary serial port or internal modem can keep the RTU online even if the LAN fails. Plus, RTUs with multiple communication ports easily support a *LAN migration strategy*.
- *Nonvolatile memory (NVRAM)* for storing software and/or firmware. NVRAM retains data even when power is lost. New firmware can be easily downloaded to NVRAM storage, often via LAN.
- *Intelligent control*: Sophisticated SCADA remotes can control local systems by themselves according to programmed responses to sensor inputs. This is not necessary for every application.

SCADA Evaluation

Central host

For the central host:

- *Flexible, programmable response to sensor inputs*: The system has to provide easy tools for programming *soft alarms* (reports of complex events that track combinations of sensor inputs and date/time statements) and *soft controls* (programmed control responses to sensor inputs).
- *24/7, automatic pager and email notification*: If equipment needs human attention, the SCADA master can automatically page or email directly to repair technicians.
- *Detailed information display*: The system should display reports in natural language, with a complete description of what activity is happening and how you can manage it.

SCADA Evaluation

Central host

- *Nuisance alarm filtering*: Nuisance alarms reduces the sensibility to alarm reports, hence the SCADA master should include tools to filter out nuisance alarms.
- *Expansion capability*: A SCADA system is a longterm investment that will last for as long as 10 to 15 years, so it has to adapt to new necessity and requests.
- *Redundant, geodiverse backup*: The best SCADA systems support multiple backup masters, in separate locations.
- *Support for multiple protocols and equipment types*: Support for multiple *open* protocols safeguards the SCADA system against unplanned obsolescence.

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SCADA Levels

Level IV - Enterprise

The Level IV - *Enterprise* comprises:

- Corporate WAN/LAN.
- World Wide Web.
- Virtual Private Network.
- Firewalls for external users.

SCADA Levels

Level III - SCADA/MTU

The Level III - *SCADA - Central host* comprises:

- Operator workstations.
- Control.
- Engineering workstations.
- Servers and data logging systems.

SCADA Levels

Level II - Telecommunication

The Level II - *Telecommunication* comprises:

- Communication media.
- Communication protocols.

SCADA Levels

Level I - Field

The Level I - *Field* comprises:

- Field devices.
- RTUs and PLCs.
- Sensors.

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SCADA vs DCS

There is a considerable confusion nowadays about the difference between a SCADA system and a *Distributed Control System* (DCS).
As by the name, the DCS is focused on *control* issues, while a SCADA system comprises the *data acquisition* part and the *supervisory* control.
The difference between the *supervisory control* and the *control* is that the first one is executed sporadicly and comprises high level behaviours of the control law, while the second is more close to the classic low-level dynamic control of machineries.

SCADA vs DCS

- DCS is *process oriented*, while SCADA is *data acquisition* oriented.
- DCS is *process state* driven, while SCADA is *event driven*.
- DCS is usually used to handle *local production processes*, while SCADA is more related to *large geographic areas*.
- DCS operator stations are always connected to *field devices I/O*, while SCADA is expected to *operate despite failure or field communications*.

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PLC

The *Programmable Logic Controller* (PLC) is still one of the most widely used control systems in industry. As needs grew, the PLCs were *distributed* and the systems became more intelligent and smaller in size.
Hence, what are the differences between the RTUs and the PLCs?
PLCs have their origins in the *automation industry* and therefore are often used in manufacturing and process plant applications, *without communication capabilities*.
The RTUs, instead, were adopted for remote telemetry, hence no *control programming* was needed.

SCADA

PLC vs RTU

Today, PLC and RTU manufacturers *compete for the same market*.
Therefore, the line between PLCs and RTUs has *blurred* and the terminology is virtually interchangeable.
In general, the term RTU can be used to refer to a *remote field data interface device*.
If such a device could include *automation programming* that traditionally would have been classified as a PLC.

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SCADA

SCADA systems are used for *geographically distributed* systems.

The main purpose is to *collect data*, *extract meaningful and statistical data*, use a *GUI* for the operator, generate *supervisory control* actions to manage the system.

The field devices are called *Remote Telemetry Units*, which are nowadays similar to the PLCs.

There is no need for *determinism* in communication, rather it is important the *reliability*.

A SCADA system is parametrised into four *different levels*.