Chapter 1

BASICS OF SUPERVISORY CONTROL & DATA ACQUISITION (SCADA)

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1. Introduction

Supervisory Control and Data Acquisition (SCADA) is a modern technology for control of industrial processes. In order to understand the concept of SCADA and its need, let us consider three different scenarios of industrial process control:

Scenario-1: The given industrial process is small and simple involving just a few variables which need to be controlled independently of each other. In this case, ***"direct control"*** of each variable can simply be carried out. In case a digital controller is employed, the control would be called as ***"direct digital control".***

Scenario-2: The given industrial process is large and complex from control viewpoint but not spread over a large area. It contains a number of controlled variables, which are distributed all over the process. In this case, the controllers have to be also distributed all over the process with each controller located as close to the variable controlled by it as feasible, and their operation needs to be coordinated from a single point, called as ***"control room"***. This type of industrial process control is called as ***"distributed control"*** and the control system as ***"distributed control system"*** or ***"DCS"***. This control technique works satisfactorily if only a limited intervention in the control is needed from outside, that is from the control room.

Scenario-3: The given industrial process which is spread over a large area, though it needs simple distributed controllers, but the controllers require frequent or regular intervention from the control room. In this scenario, a third type of control strategy, called as ***"supervisory control"***, would be the best solution. In this control strategy, controllers are distributed all over the process as in the case of distributed control, but the whole of the distributed process (along with these controllers) is supervised from a central location/ facility. The controllers used in this case are generally simpler than those used in the distributed control. An essential requirement of the supervisory control to be effective is that feedback data be acquired from all the variables and objects distributed throughout controlled process that have a bearing on its overall operation and control, and made available at the control room. The complete control technique is therefore known as ***"supervisory control and data acquisition"*** or ***"SCADA"***, and the control system is called as ***"SCADA system"***.

2. Definition and Purpose of SCADA

Having explained the concept above, we can define SCADA in simple terms as under:

"Supervisory control and data acquisition, or SCADA, is the control technique that enables the operator of a controlled industrial process or plant to obtain data from the process/plant and to send necessary control instructions to it."

We can enumerate the dual purpose of SCADA as below:

(i) To extend the ability of the operator of a controlled industrial process or plant to see what is happening in the process/plant.

(ii) To extend the operator's ability to make appropriate changes in the controlled process/ plant.

3. Types of Industrial Processes and their Control

3.1 Classification of Industrial Processes

From the control view-point, the industrial processes can be divided into three categories as under:

(i) Production processes, which include processes of producing/ manufacturing goods, power generation, refining, fabrication, etc.

(ii) Infrastructure processes, often referred to as ***public utilities***, or just as ***utilities***, electrical power transmission, power distribution, water treatment and distribution, sewage treatment and disposal, oil and gas pipelines and distribution, wind power farms, public telecommunication system, civil defence system, rail transport, road transport, and so on.

(iii) Facility processes, that take place in large buildings, airports, railway stations, ships etc and include heating, ventilation and air-conditioning (HVAC), energy consumption, etc.

3.2 Control of Industrial Processes

Production processes have hitherto used either direct control or distributed control depending on the size of the process and dispersion of the controlled variables in the plant, the latter one being the choice for large and distributed processes. There is a growing tendency now to prefer SCADA to distributed control wherever data acquisition and transmission to the control room improves the effectiveness of control.

Infrastructure and facility processes are generally spread over large areas and their control requirements are usually simple, but the controls mostly need frequent or regular intervention of the operator. Therefore, SCADA turns out to be the best control technique for these types of industrial processes, and more so for the infrastructure processes which are often spread over a state or a nation, and sometimes interconnect two or more nations.

3.3 SCADA Suitability

The foregoing discussion suggests that the SCADA technology is best suited to the industrial processes:

(a) that are spread over large areas,

(b) that are relatively simple to control and monitor, and

(c) that require frequent, regular or immediate intervention of the operator.

3.4 SCADA versus DCS

Since SCADA system and distributed control system (DCS), both, are suitable for the control of large distributed industrial processes, a comparison between the two would be in order. The table below compares them in respect of the three important features, viz., direction of data transmission, type of control and extent of intervention by the operator.

Feature	**DCS**	**SCADA**
1. Direction of data transmission between the control room and the controlled process	One way transmission (from control room to the controlled process)	Two way transmission
2. Type of control	Full or elaborate control	Limited or simple control
3. Extent of intervention by operator	Limited intervention	Regular intervention

4. Variables and Objects in Controlled Plant

From the view-point of data acquisition and supervisory control, the following two types of variables and two types of objects in the controlled plant need to be considered:

(a) Controlled Variables

The physical variables of the process, which are under control, are provided with automatic (or feedback or closed-loop) controllers placed as close to the respective variable as practically feasible to ensure high reliability, speed and accuracy. The actual values of these variables, called as ***analog values***, are acquired using appropriate ***analog sensors***, signal conditioning units/ circuits and a microprocessor, and sent to the control room. Further, the ***set-point*** of the ***automatic controller***, which is the desired value of the variable at a given time, is adjusted as and when required by sending suitable ***control instructions*** to the controller from the control room. The automatic controller makes correction in the controlled variable to bring it to the set-point value by applying appropriate ***control signal*** to a ***linear actuator***. This is illustrated in the upper half of figure1. Examples of the controlled variables are temperature, pressure, flow, level, power, frequency, and so on.

(b) Uncontrolled Variables

Certain physical variables are not controllable but do affect the working of the controlled process. Obviously, the ***analog values*** of such variables have to be only acquired and sent to the control room. There are no controllers for these variables, and hence ***no set-points*** are to be communicated from the control room. This is illustrated in the lower half of figure 1. Examples of the uncontrolled variables are ambient temperature and humidity inside a manufacturing plant, water level in the dam of a hydro-power plant, etc.

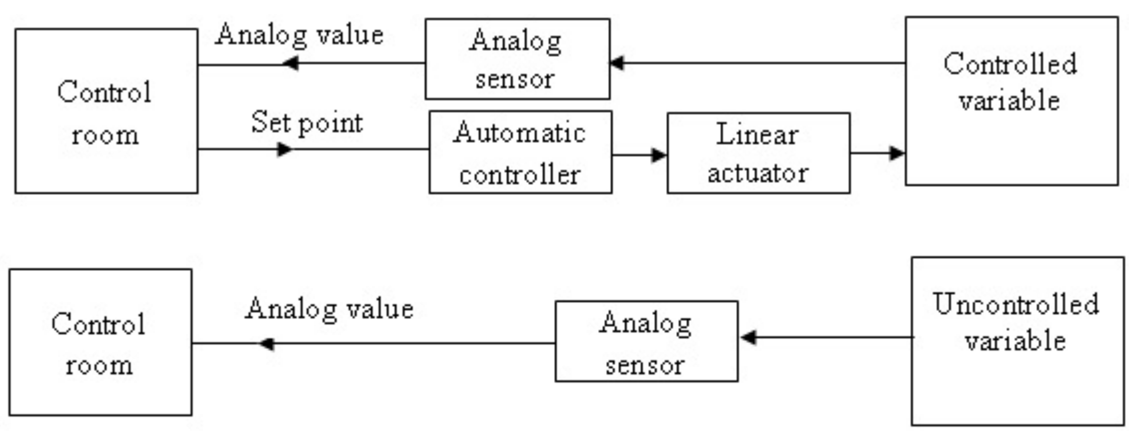

Figure 1: Data and supervisory control requirements for the two types of variables

(c) Remotely Controlled Objects

There are several objects, like circuit breakers, large motors and pumps, gates of a dam, etc., in the controlled process/ plant, which have multiple discrete states that need to be controlled remotely from the control room. The actual ***status*** (like 'on' or 'off' state, 'clockwise' or 'anticlockwise' rotation, 'normal' or 'faulty' condition) of these objects is acquired using appropriate ***status sensors*** and a microprocessor, and sent to the control room. Acquisition of ***status information*** consists in finding the discrete state each object is actually in. The state of these remote objects is changed as and when required by sending ***discrete control commands*** to their ***discrete actuators*** from the control room. These requirements are illustrated in the upper half of figure 2.

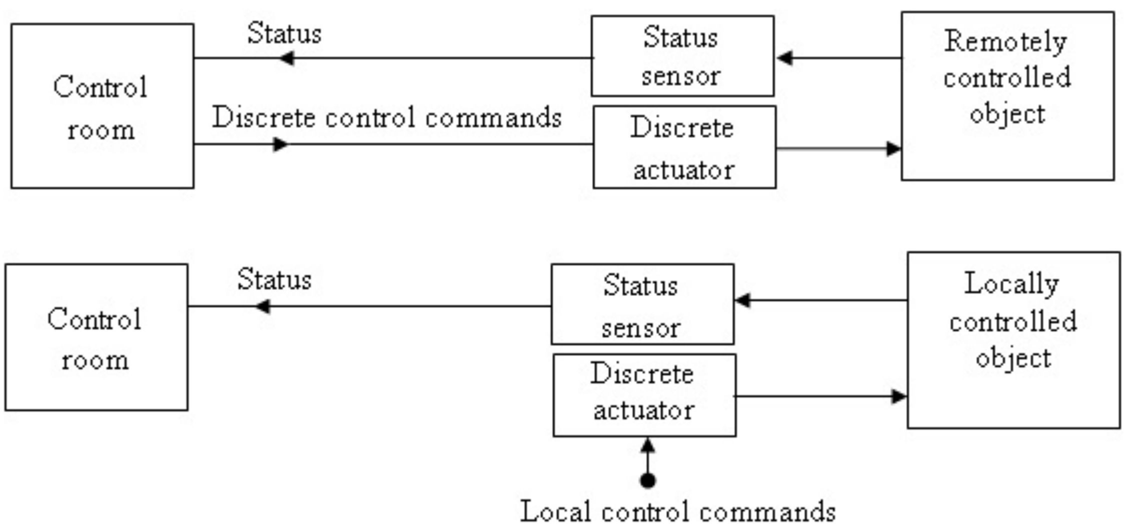

Figure 2: Data and supervisory control requirements for the two types of objects

(d) Locally Controlled Objects

In addition to the objects to be remotely controlled from the control room, described above at (c), there are generally several more objects in the process/ plant that are controlled locally. Obviously, ***no control commands*** are to be sent to such objects from the control room. Only the ***status information*** has to be acquired from these objects using appropriate status sensors and a microprocessor, and sent to the control room. This is illustrated in the lower half of figure 2. Examples of the locally controlled objects are oil pumping unit (OPU), small motors and pumps, braking unit, power back-up unit, etc.

A summary of the data acquisition and control requirements for the above mentioned four types of items is presented in Table 1.

Table 1: Data and control requirements of various items of the controlled process

Item	Data to be acquired and sent to control room (D)	Control instruction to be sent from control room (C)
(a) Controlled Variables	Analog values from analog sensors	Set point to automatic controllers
(b) Uncontrolled Variables	Analog values from analog sensors	Nil
(c) Remotely Controlled Objects	Status information from status sensors	Discrete control commands to actuators
(d) Locally Controlled Objects	Status information from status sensors	Nil

5. Layout and Components of SCADA System

Let us consider an industrial process which is spread over a large area, has simple control requirements and needs regular and frequent intervention of the operator sitting the control room. In other words, the process/ plant is a fit case for supervisory control. Let the plant be partitioned for the purpose into five sections, as illustrated in figure 3.

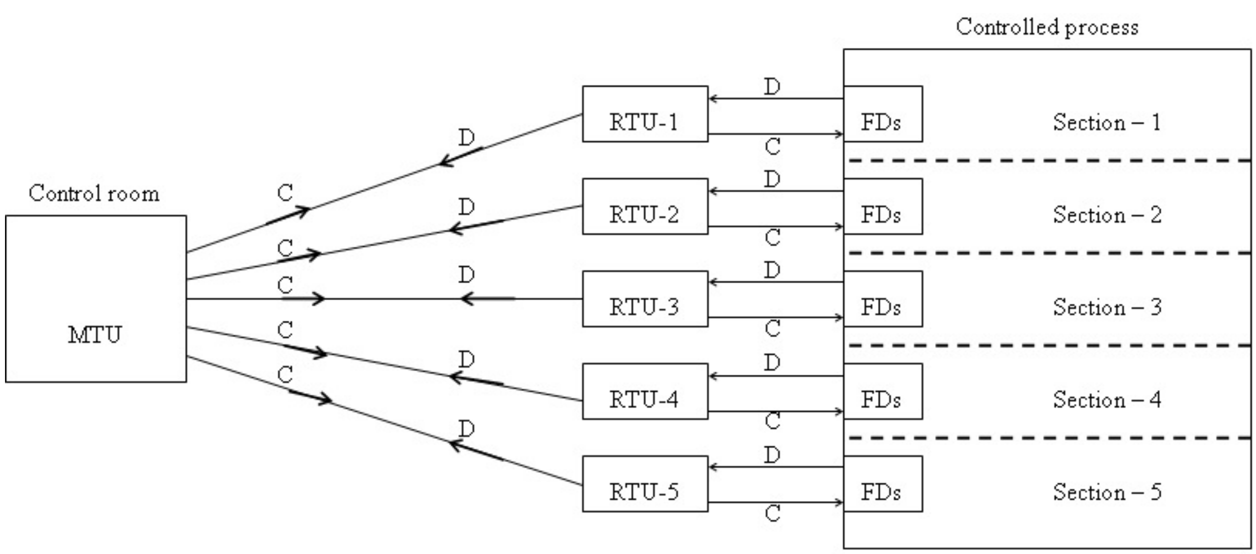

Fig. 3: Basic Layout / Architecture of SCADA system
(D: Data, C: Control instruction/signal)

A small microprocessor based unit, called ***remote terminal unit or RTU***, is placed in and interfaced to each section of the plant. Thus there are five RTUs in the example in hand, and they constitute the first component of our SCADA system. Then there is a large computer based central supervisory unit, or the control and monitoring unit, called ***master terminal unit or MTU***. Some people refer to it as ***master station or MS***. It is located in a central or strategic place, called control room. In large public utilities, this place is often referred to as the control centre. MTU is the second component of our SCADA system. Depending on the process being controlled and the overall objective of the control, the MTU takes different names. For example, in the load dispatch system of a power system the MTU is known as ***load dispatch centre***, in centralized traffic control (or management) system it is often called as ***traffic control room***, in oil field operation (or management) system it is referred to as ***supervisory station***, in train dispatch and control system the MTU is given a name like ***train dispatch office***, and so on.

Each RTU is expected to acquire data (analog values of controlled and uncontrolled variables and status information of remote and locally controlled objects) from the plant section assigned to this particular RTU and to ***transmit data*** to the MTU after necessary processing of the acquired data. Likewise, each RTU expects to ***receive control instructions*** (relevant to the plant section assigned to it) from the MTU and deliver them to the plant. This two-way digital communication between RTUs and MTU is carried out on the so-called ***MTU-RTU communication sub-system***, which constitutes the third component of our SCADA system.

As explained in the last section, the RTU acquires analog values and status information through analog and status sensors, respectively. Similarly, it delivers the set points and discrete control commands to automatic controllers and actuators, respectively. These devices thus act as the interface between the RTU and the controlled plant. Being located in the field (within the plant), these devices are known as ***field devices (FDs)*** and constitute the fourth component of our SCADA system. The communication (signals) linking the field devices to RTU may be analog (in old systems) or digital (in modern systems). The ***RTU-FD communication sub-system*** constitutes the fifth component of the SCADA system.

Thus a SCADA system is broadly comprised of the following ***five components***:

(i) Remote terminal units (RTUs)

(ii) Master terminal unit (MTU)

(iii) MTU-RTU communication subsystem

(iv) Field devices (FDs)

(v) RTU-FD communication subsystem.

The MTU-RTU communication subsystem shown in figure 3 comprises individual point-to-point communication links between each RTU and the MTU. Such an arrangement would require the MTU to have one transceiver (transmitter + receiver) per RTU and the total length of communication cables would also be very large. This would make the cost of MTU-RTU communication subsystem very high and its performance and reliability very poor. The communication arrangement can be immensely improved by replacing all the point-to-point communication links with a single data network linking all the RTUs with the MTU, as shown in figure 4. However, depending on the geographic size of the controlled process and dispersion of its facilities, the data network may be a LAN (local area network), MAN (metropolitan area network) or WAN (wide area network). For the supervision/ control of a public utility spread over a nation or beyond, even the Internet may be used for data communication between the MTU and the RTUs, subject to data security considerations.

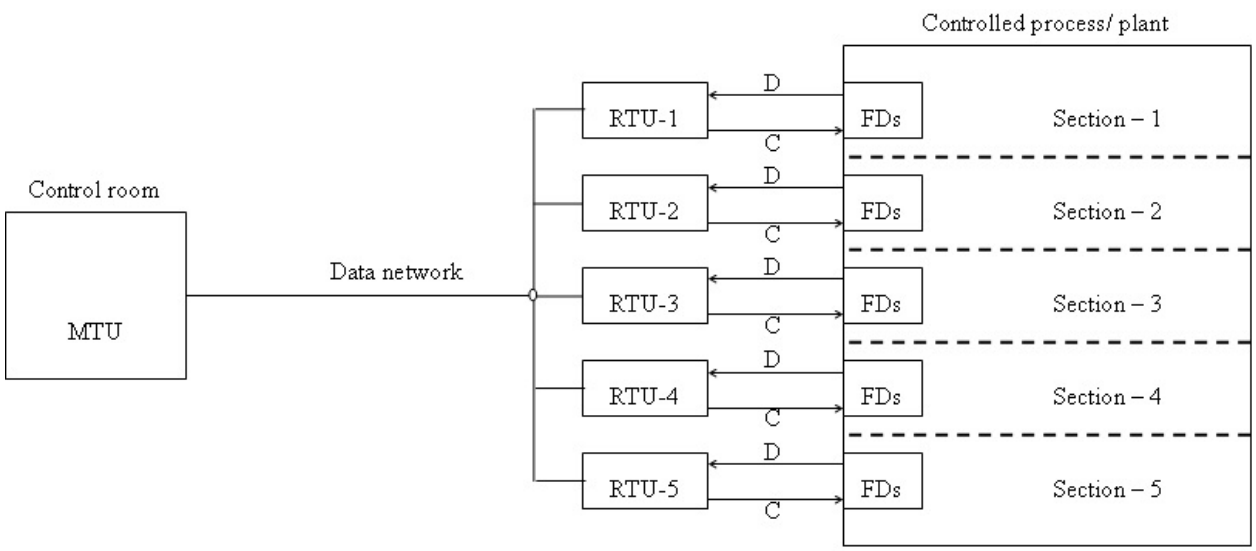

Figure 4: Modified layout of SCADA system
(D: Data, C: Control instruction/signal)