Original Article: Investigating the Performance of DCS Wide Control Systems

Shahram Mohammadi*

Department of Computer Engineering, Mahalat Branch, Islamic Azad University, Mahalat, Iran

Use yor device to scan and read the article online

Citation S. Mohammadi*, **Investigating the Performance of DCS Wide Control Systems.** *J. Eng. Ind. Res.* **2023**, 4 (1):44-60.

https://doi.org/10.48309/jeires.2023.1.5

Article info:
Received: 2023-04-02
Accepted: 2023-06-22
ID: JEIRES-2306-1081
Checked for Plagiarism: Yes
Editor who Approved Publication: Majed Amini

Keywords:
Distributed Control System; Network; Computer; Central Control Room; Industrial Monitoring.

ABSTRACT

The implementation of control operations for factory processes required control panels. As a result, it required much labor and did not provide a precise result. The next step in development was to transfer all factory measurements to a central permanent industrial monitoring and control room that would act as the hub of all local panels and reduce the need for manpower; however, this did not seem very convenient because virtually every control loop has its own control management hardware. With the evolution of graphic displays and electrical processors, digital controllers were placed on an array of input and output racks. This concept gave rise to the development of a distributed control system (DCS). Over the years, the term DCS has changed from distributed control to decentralized control systems. Distributed Control System is one of the smartest systems used in factories and control centers. Each system component has its own function, such as the data management and access section, processing management, and graphic display and data collection unit. The communication between each element in the factory is done through a distributed computer, which is also called a control network. The main component of the factory is the distributed control system, which is used to make automatic decisions according to the real-time update of product information throughout the factory.

Introduction

PROCONTROL P system manufactured by ABB is one of the wide control systems used to control power plants. In this system, by using the memory in the microprocessor, it has been tried to use software instead of hardware as much as possible [1-3]. Also, a bass system has been used instead of using the usual wiring method. The bus contains all the signals and complete information of the system. This system is designed in such a way that it performs all the process control tasks and its display. These duties include:

- ✓ Transformations of signals.
- ✓ Data transfer.
- ✓ Supervision.
- ✓ Digital control.
- ✓ Analog control.
- ✓ Protection
- ✓ Process management.

***Corresponding Author: Shahram Mohammadi,** (mohamadi.sh1986@gmail.com)

- ✓ Operation and maintenance of the process [4].

PROCONTROL P has a communication highway that establishes the transfer of information with these devices and control components. Serial and continuous information transmission for system control is done through a communication highway. This highway often has a two-channel structure due to redundancy. The stations are connected to the communication highway [5]. These stations are used for converting signals and digital and analog control. Operator control and process monitoring can be done through the communication device with the POS operator. Pos uses color images to display the process and a keyboard or mouse to receive the message [6]. Utilizing the CDS fault-finding system, in addition to the automatic fault-finding of the system and equipment, the ability to view and access all system information has been provided [7]. A standard connection allows the connection between Pro control P and the computer or other control systems. Pro control P also controls and protects critical and sensitive parts such as turbine control and protection or steam boiler protection. Combining unique and decentralized systems and components creates comprehensive and complete processing groups hierarchically at different control system levels [8]. An electronic module controls one or more interdependent actuators, which is done at the actuator control level. At the drive control balloon level, several drive control modules related to one part of the process are guided and coordinated using one module at the group control level. In advanced automatic control systems, the entire system is controlled by a single control unit. Due to its decentralized structure and reliability, the POS system can meet all the needs to access the system. The management level manages and supervises several different units to carry out particular operations [9].

Different accessible or support needs and requirements for power plant systems are:

- ✓ Quick access to systems that have a direct impact on production.
- ✓ Medium access to parts where a short-term problem or error does not affect production.
- ✓ Access to parts that have little impact on production (Figure 1).

Access needs in each of the above cases are met by a suitable design with the creation of a support system [10].

Fault finding system

Pro control P control system automatically shows system problems. Converters, gauges, transmission system modules, and controllers are thoroughly investigated and controlled. All modules have self-diagnosis capability. Fault-finding equipment is entirely independent of operational equipment. In addition to being visible on different modules, the warning signs are also displayed with details in the control room. The automatic function of fault diagnosis for control equipment will include quick fault finding, reduced repair time, and, as a result, increased reliability.

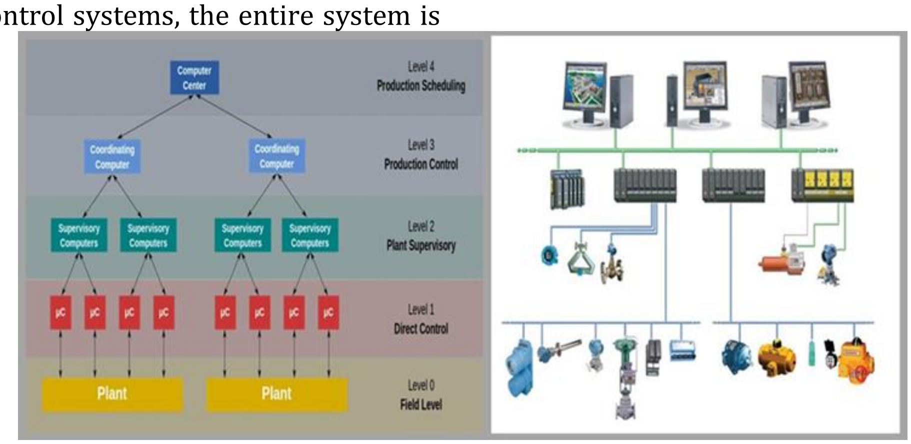

Figure 1: Different accessible or support needs and requirements for power plant systems.

Structure characteristics of the investigated systems

The technical criteria considered in the structure of the investigated systems are as follows:

- ✓ The ability to test the system in the start-up stages and during work, the existence of test points from hardware and software aspects.
- ✓ Ease of diagnosing and correcting defects in the system.
- ✓ Ease of using the system and quick training.
- ✓ High availability coefficient of the system structure.
- ✓ High-reliability coefficient of the system.
- ✓ Allocating points for the mentioned criteria.

In the following, all the mentioned criteria are examined and compared, and the relative importance of the criteria in the evaluation is summarized in the table below. The percentage of points obtained for each company will be as follows:

Table 1: The percentage of points obtained for each company

characteristic	CCR Factures	UCB Facture	Data tron sintle fea	Other system	Compa feat	Struct feat	Special feat	Total
Evaluation percentage	20	20	15	20	10	10	5	100 %

It should be mentioned that tables have been prepared for each characteristic in the above table, the results of which are transferred to the above table. For example, the characteristic of UCB, which determines 20% of the total score, is divided into more detailed characteristics, and a percentage of 20% of UCB is obtained from the total points obtained.

Summarizing the reviewed systems from a technical point of view

Table 2 demonstrates the score and rank of the examined systems.

Table 2: Summarizing the reviewed systems from a technical point of view

Privilege system	system
78.6	Pro control P (ABB)
69.5	TELEPERM ME (Siemens)
63.5	INFI 90 (Bailey)

Advantages of ABB

- ✓ A long history of participation in power plants and DCS systems.
- ✓ Having ISO 9000 series quality detail standards.
- ✓ Providing a suitable educational system.
- ✓ Providing acceptable documents for review.
- ✓ Having valid industrial standards.

Extended Control Systems (DCS)

The different layers in the hierarchical structure are:

- ✓ All direct connections with the process are on the level, and if there is more than one level, they are indicated by I.B. and I.A..
- ✓ Supervisor control is generally located at layer 2.
- ✓ Control of the range or coordination within the range is called the third level.
- ✓ Information planning and management are at the fourth level. Usually, this level

has two 4A parts that cover the connection with the plant.

Primary computer control systems

Before the introduction of computers to industrial control, control was done by a large number of analog control loops, pneumatically or electronically. In the early 1960s, computers were used in a supervisor structure that changed the list of working points of the control loops, but analog loops did the lower layer control. This method has the following disadvantages:

- ✓ Since the design process for these units was done after the purchase and order, implementing and implementing such systems took a long time.
- ✓ Since all the signals must be collected in one center and the necessary control signals applied from there, there were noise and disturbance problems in information transmission.
- ✓ Since all the functions and the controller are located in one place, the whole system will fail if the computer breaks down. To solve these problems, it is usually used with another computer as a backup, which increases the system's price.

Extensive control

Around 1970, due to two reasons, there was a change in the affairs of control and the elimination of the deficiencies of centralized control. One is that microprocessors were produced cheaply due to the development of integrated circuits, and there was much progress in communication technology. In addition, Honeywell company used a decentralized structure for computer control. The idea of this issue was that the different control boxes were distributed entirely on the process level, using their internal microprocessors to control several control loops. These independent units are connected to the central operator through a transmission line. This collection, which was produced under the name TDS2000 by Honeywell company, solved the problem of the unreliability of previous systems in two ways.

- ❖ Each control unit was responsible for several rings.
- ❖ The creation of support for these units was done more simply and at a lower price.

The real potential of the computer in the control of the systems was created only when the information processing and display facilities for the supervisor and the coordination action for the different parts of the system were created. Regarding control theory, the supervision and coordination of control systems are done with the theories of large-scale and multi-variable systems. A DCS is based on a wide computer network, a set of a separate graphic structures, each part of which has independent computing equipment with input and output facilities and the ability to connect through digital communication lines. Although each of these building systems has unique and specialized aspects, the structure of most of these systems can be described in the context of a general system. The devices in this structure are divided into three groups:

- ✓ Those directly related to the process are to be controlled or monitored.
- ✓ Those that have high-level computing functions and intermediary functions between man and machine.
- ✓ Those that form communication devices between other components, a brief definition of each of these devices is given below.

1- Local control unit (ICU): the smallest hardware in the system that can perform closed-loop control.

2- Low-Level Intermediary or Human (LLHI): A device that allows the precision instrument operator or engineer to directly exchange with the ICU. LLHI can also directly mediate the process and system. The hardware dependent on the operator at this level is called the intermediary of the lower levels of the operator. The hardware related to the precision instrument engineer is called the middle level of engineering.

3- Data input and output unit (PI/OU): It is a device that is related to the process. This unit does not have a control function just because it acquires or outputs data.

4- High-Level Intermediary or Human (MLHI): A set of hardware whose function is similar to LLHI, but with enhanced capabilities and more assistance for the HIHI user, it connects to other devices only through standard communication devices. The hardware related to the operator and engineer of the precision instrument is respectively called the high-level operator and high-level engineer of precision tools.

5- High-level computing device (HLCD): a set of hardware based on a microprocessor that performs the management functions of the production unit, which was traditionally performed by a computer. HLCD connects with other devices only through common communication devices.

6- Intermediate device or computer (CID): a set of hardware that allows an external public computer to connect with other devices in a wide system using common communication devices.

7- Shared communication devices: one or more communication hardware and software levels that allow data sharing between all devices in the wide system. Shared communication devices do not include dedicated communication channels between specific devices and lower hardware elements within the device.

Comparison with previous structures

As we mentioned, one of the most critical goals in developing extensive control systems is to preserve the best aspects of the system, the central computer and the dual system. The most crucial issue is that the new systems have such a structure that integrates the power and flexibility of digital control with the consumer's familiarity with traditional analog and sequential control systems (Figure 2).

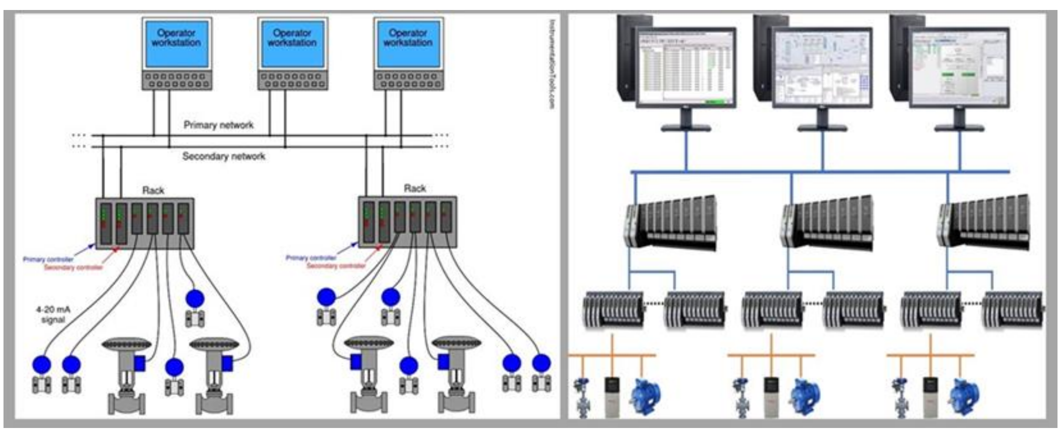

Figure 2: Comparison with previous structures.

Dual central computer systems

The structure of the extensive control system has many advantages over the other two systems, but the comparison should not be one-sided. Like any new action, moving from a traditional analog control system to an extensive type requires the user to solve several potential problems and variables in operation. One of the most noticeable changes is that the microprocessor control system offers a new technology that the people of the production unit must learn, and a certain amount of retraining of people, whether operators, precision tool managers, or maintenance managers, must be done in order to achieve the success of the first widespread control system installation. To be guaranteed in that production unit. Also, operational procedures will change. Operators should remove process monitors in the control room, and instead of viewing the system through panels, they now have DVUs and other digital facilities at their disposal. The new extension system gives great flexibility to the consumer to choose the control algorithms and the location of the equipment in a production unit. While this is an advantage in many ways, it also requires the user to provide a suitable plan for the installation, such that the control system is distributed correctly, as well as the appropriate location and necessary protection in remote locations. Remote control hardware is available. When deploying a control system, the user must be aware of the consequences of the various delays in processing and communication that are inherently present in the extended control system. Although the rapid advances in digital system hardware make these delays negligible in many cases, the consumer must know the specific application needs. If the control system is geographically distributed in addition to the distribution of functions, the user must be sure that the hardware installed in remote locations can survive in the environment and that the spare hardware is suitable for replacement in case of an error in the supplied equipment. The above comparison and design considerations are only a beginning to include the necessary issues in evaluating and designing extensive control systems. In the next part, discussions related to the components of the extensive system and specific technical issues will be discussed [11].

Basic requirements in the extended control system

1- Establishing communication or process: Input and output, mediating analog I/O to read input, converting analog to digital and vice versa, linearizing, converting to engineering units, working on bits and Boolean operators and access to I/O devices using labels instead of hardware addresses.

2- Coping with the issue of real-time: According to the hardware used, there must be the necessary coordination with the industrial system:

- ✓ Microprocessor speed.
- ✓ Hardware in LCU.
- ✓ Also, the following points should be observed in the soft construction to have actual working conditions:
- ✓ Ability to accept interruptions to react to external events.
- ✓ The ability to schedule programs and execute tasks simultaneously and share data.
- ✓ The ability to manage shared memory resources and peripherals.
- ✓ A software timer and a real-time pulse.

3- Communicating with other elements in a wide control system: It should be possible to communicate with LUC. For example, they may use each other's information, and it is also possible to connect sensors and CRT peripherals., with the LCU.

4- Provision of protection: Some of the necessary protection issues are as follows:

- ✓ Protection during registration or compilation in case of errors, giving a clear message.
- ✓ Perform the appropriate procedure when an error occurs and at runtime.
- ✓ Using an additional processor in a way that the software can recognize.
- ✓ Have memory to keep the parameters during power failure.
- ✓ If you have shared memory for two or more LCUs, access to the memory must be carefully controlled by the software.

5- Auxiliary software requirements: The issues that are needed when writing the program, correcting, and registering it on the LCU are:

- ✓ Text corrector.
- ✓ Error fixer.
- ✓ File manager.

6- The standard of high-level languages: This is because the software written for a microprocessor can be used for other processors in a wide control system or whether everything should be started from scratch [12].

Input/output design

1- Input/output requirements: These include the following specifications and fields:

- ✓ The general and normal state of the voltage transition level.
- ✓ Isolating the voltage of the system's input and output terminals and electronic devices.
- ✓ Input impedance.
- ✓ The ability to start the output load and these specifications differ in different industries.

2- Input/output methods: There are two modes:

- ✓ Using multiple I/O selection modes.
- ✓ Production of additional DI/OU products such as Multiplexer, an intermediary unit of the data consumption process. In this method, an LCU whose software is designed exclusively for I/O is usually used. The use of IO/OU has the problem that the cost of maintenance and spare parts and the hardware complexity of the system increases.

Local control unit

Local control units are parts of the wide system in which the output function of the process is performed. Some primary controls, usually independent of LCUs, are performed in this unit. If the control of that part of the system using the data of other LCUs is not numerous, the central processor monitors the control operations.

A) The main parameters of a local controller: In designing or specifying a local controller, some of the most critical parameters that must be specified are as follows:

- ✓ The maximum number of loops to be closed.
- ✓ Type and level of input/output signals.
- ✓ The required degree of local independence.
- ✓ Methods considered for local user interference.
- ✓ Degree of self-diagnosis, redundancy with self-repair capacity.
- ✓ The degree of intelligence for an unintelligent user that the degree of intelligence of the system probably allows the user to modify and develop his system.
- ✓ The degree of construction and standardization of hardware and software in a controller, as well as hardware and software between controllers.

B) Conditions for increasing capabilities: the average failure time of a microcomputer-based local controller is less than 8 years. Reliability is one of the important and sometimes determining issues in using such systems. Some of the methods of increasing reliability will be mentioned below.

B1) redundancy in a local controller: In this structure, two controllers work side by side. One is in charge of control, and the other is on standby. Switching between two controls occurs when the fault detection unit detects that the control unit is not functioning properly. This structure can be seen, and perhaps one of its most critical essential parts is the error detection section, which must have high reliability.

B2) A spare local control unit to replace several working local controllers: in this case (n+1), controllers are meant to do the work. This method requires less hardware than the previous method, but due to the complexity, the reliability decreases. Meanwhile, the replacement controller should be more significant than a normal controller.

C) Dynamic redundancy: All plant signals are available to local controllers through a data link. A coordination controller performs the act of assigning tasks to these controllers. If a failure occurs, the assignment of tasks is performed again. It is clear that regardless of the complexity, the reliability of this method is very high. In addition, in this method, it is assumed that the data link has high reliability.

D) Increasing reliability: for this purpose, it is necessary to place an alternative communication line that, after detecting an error in the primary data link, exchange information through the new link and the intermediate circuit of the standby controllers.

Control programming languages

In the last few decades, hardware prices have decreased daily, and software prices have increased. This article is calculated based on the price of software and hardware in a project, which may reach 88% of the entire project. This has caused industrial control companies to produce software in different forms.

Among the most critical main languages designed for industrial control today are the following:

- ✓ Block and pre-programmed functions whose parameters and modes cannot be changed, and the user connects these blocks to reach the desired structure.
- ✓ There are two types of pol. One is filling in the form, and the other is Batch programming. In the first type, the user selects the type of control he wants and then fills out the forms prepared by the seller. This information is entered into the computer by an operator. As it is clear, this type of language has many limitations, including limitations in the structure of the controller and its parameters. The second type of Pol language is called batch language, which is used in controls with the same name.
- ✓ High-level languages give the user more flexibility in designing the controller. At the same time, it maintains its compatibility with the last two types, which give commands for operations such as opening a valve, and reaching another temperature by filling a tank. Although they are called Pol languages, such as AUTORAN, PEARL, ATLAS, and PROSPRO, they are high-level languages that we will explain.

Until the beginning of 1980, high-level languages such as PASCAL, FCRTRAN, and BASIC were used in minicomputers as digital control languages of computer systems and supervisor control. With the progress of microcomputers, LCUs became more powerful, and the need for high-level languages was created in these units. It should be noted that general-purpose languages such as BASIK and FORTRAN cannot be used in real-time processes and are suitable for batch processes. In real-time processes, several tasks must be performed simultaneously. In addition, a quick and appropriate response should be given to various events. Some of the mentioned languages have removed these defects with proper development, but recently languages such as PEAEL, MODULA, and ADA have been specially designed for industrial control. These languages should be able to serve as interrupts to respond to external events. In addition, the ability to schedule several tasks and programs simultaneously is one of the features of these languages. Having an accurate real-time clock for use in various application programs and high reliability are other characteristics of these languages.

All control and communication functions are summarized as follows:

- ✓ Information acquisition and signal limiting functions include input scanning, filtering, linearization, and conversion of engineering units.
- ✓ Range sensing functions and alarms.
- ✓ Modulation control functions, including PID control with all its changes.
- ✓ Hierarchical control functions for implementing Boolean logic such as: AND, OR. Not.
- ✓ Arithmetic, addition, subtraction, multiplication and division, trigonometric (sin, cos), and dynamic signal processing functions such as integral, derivative, and filter.

- ✓ The functions of the output signals for the drive of various drives and indicators.
- ✓ Communication functions to establish communication between different ICUs in a DCS.
- ✓ Communication functions for proper communication of different cables with lCU.

In the old DCS model, many of these functions were performed in powerful central computers, and only some operations were performed in lCU, but as these systems become more advanced, many of these functions are performed in lCU.

One of the good features of a programming language is its portability, which is considered an advantage for two reasons:

1- The user may use the same software for another system.

2- If the seller wants to develop a control system with more powerful processors, the software can also be developed and used.

Intermediary or operator requirements

The operator interface of an extensive control system should allow the operator to perform tasks in the field of the following usual responsibilities:

A) Monitoring the process.

B) Process control.

C) Recognizing the signs of problems in the system.

D) process data storage.

A) process monitoring:

1- The current values of all process variables should be available. These variables include continuous variables and process logical variables. Quick access to each variable and its exact value, updated values, and invalidity of information for any reason should be visible to the operator.

2- Each variable must be identified by a tag, not by a hardware address, and a descriptor system that reads and describes tagged variables must be included with the tag.

3- The value of the variables should be shown in engineering units; the units should also be shown along with the variable.

4- In many cases, the desired variables are measured by a multi-variable function. These variables are shown like standard variables and must include the tag unit.

Detection of unusual cases

1- The control and computing hardware in the extended system should recognize the warning states of specific variables in the process and show them clearly to the operator. There are warnings for each variable, such as upper limit, lower limit, and deviation from toxic value.

2- The operator interface should also report a warning for the calculated variables.

3- The intermediary of the operator shows the dangerous limits of the variables along with the process variables or makes it possible for the operator to access it easily.

4- If a part of the system detects alarm conditions, the intermediary must inform the operator of these conditions and demand a response from the operator.

5- If the system receives several warnings in a short time, the intermediary must announce all of them to the operator.

6- In some processes, abnormal working conditions cannot be identified according to the values of several variables, and they should provide a suitable mechanism to make it possible to consider this multi-variable warning and change it appropriately. Sometimes, in addition to multi-variable values, process monitoring pays attention to their changes in a consecutive period and the trend of these values in the future. In this sense, is the poison that the process is moving towards, along with the problem or not? The operator interface should provide quick access to the recent history of values, not necessarily all values.

Some effects related to tendency variables

1- The grouping of trend variables should be possible in the time scale of interest. For example, grouping all temperatures related to a particular part of the process.

2- The trend curve should be clearly defined with engineering units.

3- The operator should be able to read both the exact current value and the past value of variables and trends regarding engineering units.

4- If possible, the same curve that shows the trend should also show auxiliary information to help the operator evaluate the trend variables (Figure 3).

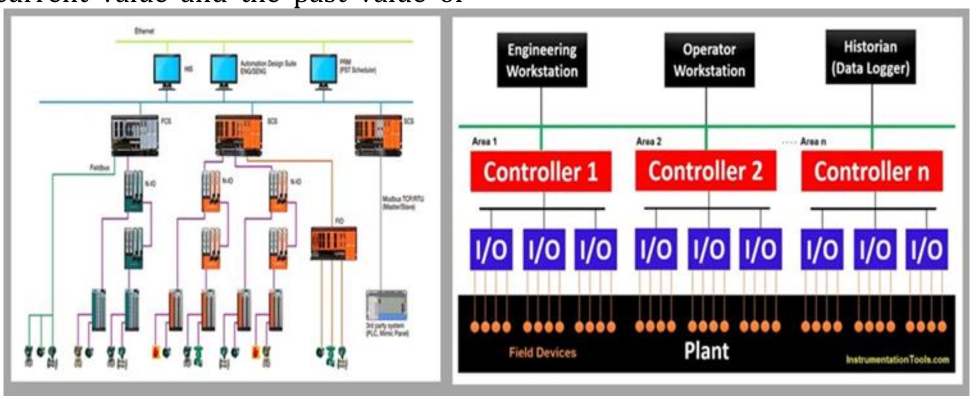

Figure 3: Some effects related to tendency variables.

B) Process control: issues that should be considered in the software used in the DCS system for process control:

1- Quick access to all control loops in the process control system.

2- The intermediary must allow the operator to perform all normal control functions for each continuous control loop.

3- The intermediary must give the operator the possibility of logical control operations such as starting and stopping pumps or opening and closing valves.

4- In the case of Bath production control, the operator's intermediary must allow the operator to see the current level of the sequence and start or stop a new stage with the possibility of intervention.

5- In both continuous and sequential control modes, the intermediate system should give the operator access to the control outputs and possible manipulation.

C) Diagnosing process problems:

Monitoring and control in normal conditions is relatively simple. However, the intermediary system of the operator must first provide enough information during these normal conditions so that the operator can identify the damaged device and take measures to correct it, and the process returns to normal.

There are ways to achieve this goal:

1-Continuous tests and checking the logicalness of the output of sensors and process analyses are measured.

2-Continuous self-testing of the components and components inside the extensive control system.

Morphological functions

In extensive control systems with several variables, the probability of problems occurring in each system's variables is very high. Different methods are used to investigate these problems and solve them:

1- The initial diagnosis of the alarm that informs the operator which alarm occurred earlier.

2- priority warning detection categorizes the current warnings according to their importance and temporarily leaves less dangerous warnings aside.

3- More advanced functions combining data and warning information in process variables to diagnose the problem.

Record process results

It should be possible to record the process results and the variables' values in the control system. The available methods for recording the results are as follows:

1- Registering information related to the trend in a short time.

2- Manual entry of process data; the operator must be able to enter the collected information manually in order to save it.

3- Recording warnings on the printer, a data storage device, or both.

4- Recording a period of process variable information on the printer or storage or both on the source every few minutes or hours or storing the average value over time instead of the instantaneous value.

5- Long-term storage of votes and data recovery, which information should be able to be stored for a long time. Also, it can be restored quickly and instantly.

In the past, the design of the operator's device was mostly done according to the interest of the seller, but today it has been concluded that a small investment in the proper design of the intermediary equipment has interesting benefits:

- ✓ Fewer operator errors.
- ✓ More efficient use of transporters and less fatigue of operators.

Some guidelines in the design of operator relationship systems for industrial control include the following.

1- Consideration of all possible operators.

2- System design for operators and not for computer programmers or engineers.

3- allowing quick access to all necessary controls and displays.

4- The equipment of the indicators should be divided in terms of operations or functional operations.

5- The colors, signs, names, and places should be used to minimize the possibility of the operator's mistake.

6- Prioritized information should be reported correctly when a significant change occurs.

7- Enter a complex sequence of pressure operations into the operator's short-term memory. In these cases, aids such as the operator's guide, menu, and interaction with the device are of particular importance.

8- In the event of an error, the type of internal error and the method to deal with it should be stated.

9- The operator's work environment must be designed appropriately [13].

Usual operations in the LCU unit in new stations

The following operations are generally available on the LCU continuous control unit:

- ✓ Replacement of manual, automatic remote control.
- ✓ Changing the setting point, replacing the output, and also its unit.
- ✓ Manual load station.
- ✓ Indicating station.
- ✓ logical station

Also, the main control unit should include all control loops, such as standard PID, cascade, and ratio/bias change unit.

Smart annunciators

In new devices, microprocessor-based annunciators with the following functions are used:

1- warning priority.

2- Selection of receiving and announcing modes Some signals indicate receiving, and some indicate warnings, such as a beep, flashing buzzer, or voice message.

3- Announcing the first warning.

4- Stop the warning after the operator answers.

Chart recorders

Pie chart recorders or memory tapes are often used to record process variables in extensive control systems, but digital recorders that use microprocessors are gradually becoming more affordable and common.

Selection of station components

The type of display and components selected for the station differ from the devices used in home systems. Therefore, the following points are of particular importance:

1- Indicators should be protected against atmospheric effects to avoid contamination.

2- The displays must have high environmental visibility with the expected light.

3- When any button is released, it should return to its original position so as not to cause potential errors.

4- The type of display is also different. In the usual systems, LED is used a lot, but according to technological progress, it is possible to use discharge lamps and plasma gas to prepare bar graphs with high-resolution or liquid crystal displays (LCD), which are very flexible.

Introducing the DCS emulator software

This program is written in MATLAB language, and its purpose is to simulate a comprehensive control system (DCS). This software package runs in the Windows environment. Its writing and execution method is predominantly object-oriented and event-driven in execution. Therefore, here we provide brief explanations about object-oriented programming to gain more familiarity with the internal structure of the software. Of course, it is clear that this review is only a simple introduction and does not include many of the main and essential aspects of the object-oriented method.

A) Description of the software: This software consists of approximately m50 files and over several thousand program lines in MATLAB language (version 4.2c). Since it is impossible to explain all the details of the written program here, we try to explain the general outlines of the program and its essential points. In the continuation of the discussion, we will explain the topics of the program and its capabilities, as well as some internal points of the program.

B) How to use the program: When we are in the MATLAB environment under Windows and called workspace, it is enough to type the program's name, i.e., Dcs so that the software starts working. The selection of options can be done everywhere in the program using Windows capabilities and can be seen in different parts of the program in the form of a menu, static text, pop-up menu, Poush-huttoncditabletext, each of which will be explained in the relevant part. It seems to mention that the reason for using the Windows working environment, like other Windows applications (upLications), is that this program is also run event-driven, and there is a more flexible speed for the application. That option can be activated on the main page of this program, called form, or by pressing the computer mouse once on any of the push buttons. To close the page and exit the program, you can click on the signs and the top of the page and select the close option.

C) The main form of the program: the options that can be seen in this software include DATA HIWAY, START, and OPERATOR options. Now we will explain each of the mentioned options. The START button is actually for starting the system and starting numerical calculations. By pressing this button, a dialogue window with the name "File Get" will appear, and by using it, you can find and display any file from the desired path. It should be noted that only files with m extension can be evaluated in this window. The rest of the files are not visible at all. Also, if you give the wrong address, make a wrong choice, or press the cancel button, the following message will appear in the workspace.

The file does not exist, or the path is wrong

Press any key to return to the main figure; we return to the main form by pressing any key. Therefore, it is enough. The user writes the plant equations in an m file and enters its name in this section so that the program executes it to that file. Here, as mentioned, an Oil/Gas production unit has been simulated by MATLAB, whose outputs are placed in a file named plant.m. So, by selecting plant.m, the software runs it, and the calculation part becomes numerical. Therefore, here it is necessary to explain how to perform numerical calculations and their storage.

Calculations and process control system

The program is placed in a loop in the numerical calculations section, and the calculations are performed periodically. At the same time, a time clock is created by using the ICH software interrupt. This clock has the feature that if the numerical display is stopped for any reason, the clock will continue to work, and by reactivating the numerical and graphic display part, it is possible to command the execution of a series of operations once every second for the period when the calculations were stopped. A further explanation is that an ICH interruption is in the operating system. Regardless of the type of device, this break is automatically leased every 55 milliseconds and is removed without any particular work. If this interruption is executed 18 times, the time will last approximately equal to one second, which can be used as the system's internal clock, and calculations can be scheduled accordingly. After every second, a complete series of operations is executed. In this operation, the outputs of different units, the parameters of the control system, and other values required by the program are calculated and sent to the output.

It should be noted that the execution of any computing operations takes between 50 and 200 milliseconds, depending on the type of computer and the speed of the information displayed. An important point here is receiving error messages in the same system operation and the time of occurrence of each one immediately. This software is designed in such a way that if problems occur in the operation of the system, it will simultaneously inform the operator of the problems in the system by writing a message based on the location of the problems and the time of receiving the alarm, as well as sounding a warning horn. Therefore, in short, the task of the Start button is to start the system's computing operations, generate the required outputs and send them to the program and a part of the memory. It is worth mentioning that the operation of this section can be assigned to an intermediate board connected to the computer from the outside, and the real information from the process output is sent to the software, and the program behaves with these values similar to the calculation outputs. It analyzes them, calculates the necessary signals for control, and sends them to the actual process. In this case, the operator can see all statistical results and alarms; in this way, the software can replace a part of the real control system. Another option located in the program's main form is the DH button.

As explained in the third chapter, the data highway is the information artery of a wide control system and has a fundamental and essential role in the structure of such systems. What makes a wide control system different from a series of separate controllers, each controlling part of the process is a data highway and communication network between different elements of the wide system, especially between different controllers.This quality has been fully considered in the program, and DH DH in the program is a channel between all the objects and different classes. That is, each unit can exchange information with other units through DH Here, for a better view of how the program works and how the information rotates, you can enter the information on the highway and view it at any time using the DH DH button. The main form is cleared by pressing this button, and the complete list of information in DH is displayed in the workspace. This information is columnar and page by page, and you can move to the next page by pressing any key on each page. After showing the last page, by pressing any button, the program will return to the original form and be ready to accept orders again.

Operator display screens

The third option in the main form of the program is the OPERATOR option. The main form is closed by clicking the mouse on this push button, and another form named OPERATOR SCREEN is opened. In fact, from now on, the computer screen will be a monitor for the system operator, and he will see all kinds of information and graphs on the screen. In this section, we have tried to make the display pages and other information as similar as possible to the Operating displays in the TDS 2000 system from Honeywell. Here we briefly explain these display pages.

A) Program display pages: The display pages in the software follow a hierarchical structure. This is the same structure that Honeywell company proposed in the mid-70s for monitoring industrial processes. It has been accepted almost as a standard by all the companies producing such systems, and little changes are noticeable.

B) Plant level: level displays provide information about the entire plant, which can be divided into several areas in case of a large volume.

C) Area level: Displays of this category provide information related to a part of the equipment in the plant and are usually specified according to the geographical location or the function of the part. In the target plant, which is an ail gas plate form, there are two areas: the drilling area and the oil production area, where the production area is the target of the project simulation.

D) Unit level: This section contains information that belongs to a special work unit. Generally, column charts show values and curves in this section. These graphs are suitable in the sense that process operators are generally more familiar with these graphs, and due to the similarity with the display or analog, four central units have been simulated in this software, which are:

- ✓ Oil extraction unit.
- ✓ Distillery tower unit.
- ✓ Heating unit or furnace.
- ✓ Storage tank unit.

E) Group level: the views of this level deal with control loops and information related to a separate process unit, and usually up to 8 control loops from each unit are classified into a group level so that this information should be closely related to each other and the operator would like to see them all together.

F) Alarms: This screen is a substitute for traditional alarms. Due to the importance of alarm notification, an operator station is usually assigned to view the summary of alarms. This display can include important critical information characteristics for the points in alarm mode. Also, in this way, alarms can be accepted. The time of the entry of the point into the alarm state and the time of receiving the alarm message is specified, and if several points are in the alarm state simultaneously, they will be located in chronological order. Here, it should be noted that Alarm reports are also available on every level, like normal display pages. For example, in the software, the forms Unit alarms, Area alarms, and plant alarms can be accessed, each showing the alarms related to their level.

Statistical trends (Treds)

The history of information for one or more variables can be reviewed on the display pages. It is also possible to view several variables together on one page for comparison. At this stage, there are trending trends at different levels, including group, unit, and area trends, which together provide statistical trends related to their levels. The above show structure has several advantages.

1- It includes all the information about the operator's interest in a control system.

2- It allows the grouping of information in a way consistent with the structure of the process itself.

3- It provides a mechanism that allows the operator to create a personal model of dependencies between different parts of information in the plant.

Description of some details

After familiarizing yourself with how the software works and its screens, in this section, we will take a closer look at the text of the written program and examine some details. First, we state the salient points about executable files:

- ✓ The characteristic equations of A must be written under the ing system and the whole Plantplant, each producing an output vector of m at the moment t(x). This vector shows the closed loop subsystem outputs; the LCU.m file also considers the effect of local controllers.
- ✓ For each local controller in the LCU.m file, in addition to the control algorithm, we need at least three memory vectors.
- ✓ The input vector from plupt.m is the output vector produced by the controller and the vector that conveys the necessary information to the local controller through the Data Highway and can include information from other units or operator commands or commands from the HLCD unit.
- ✓ Please note that in the LCU.m file, both the plant.m and HlCD.m files must be executed recursively.
- ✓ To define each high-level controller, necessary inputs are received from DH.
- ✓ HLHI is the section to which all DH information is transferred, and this information can be seen graphically and numerically in private sections. Meanwhile, here is the part where the operator enters the requested information, changes the previous values, or writes an algorithm for the controllers. Also, errors, alarms, and related messages can be seen in this section through the monitor [14].

The history module is a part that contains all or part of DH information to be visited and analyzed if necessary. This part is similar to a data structure, and information is stored in it in specific ways so that it can be accessed more quickly and easily; these methods are called information storage strategies.

Conclusion

In today's world, automation covers various fields. Ease of work, performing complex operations, flexibility, safety, saving energy, preserving the environment, and comfort are among the valuable achievements of automation. In the last decade, the growth of electronic equipment technology has made postal equipment manufacturers present their products more smartly so that they can provide the proper facilities and platform for creating an information system and decision-making in the post office. With the emergence of the intelligent generation of substation control and protection equipment, the regional power companies who are regular customers of these equipment's and who spend enormous costs annually to develop transmission networks to purchase these equipment's, faced various issues. Pioneering companies in the field of manufacturing these equipment's, on the one hand, along with the growth of technology, some of their old generation products are out of the production cycle; regional power companies are often faced with a list of equipment's that is out of the list of production or support services every year. And on the other hand, with their fast approach, the companies above began to produce new equipment with entirely different capabilities from the old generation. This way, regional power companies willingly or unwillingly accept the new substation technology. The distributed control system (DCS) includes a set of IEDs that are connected using microprocessors and telecommunication ports. IEDs can exchange data and basic control commands, including monitoring, control and automation, data storage and analysis, and send to their upstream equipment. One of the significant differences between DCS substations and conventional substations at the voltage levels of 400 and 230 kV is that the control and protection boards are centralized outside, and the boards related to each bay are in the rooms known as Bay Control Room (BCR). are distributed a large number of sub-distribution substations, the high importance of the economic factor, the smaller dimensions of these substations, which make the operator superior to all external equipment, the small number of cables and the shortness of the cable routing routes, have made the substation operational and economical. The above-distributed ones do not have BCR. DCS substation control system generally has four control levels or layers. The first layer is related to the performance level (Process Level). The set of high-pressure equipment located in the switchgear forms the control surface of the operation. This control operation is performed by intelligent processor units or IEDs. It is necessary to explain that currently, at this level, IED equipment is not used on high-voltage equipment such as breakers, disconnects, current transformers, voltage transformers, and power transformers, and it is still used conventionally. The second control level is Bay Level. At this level, a Bay Control Unit (BCU) is considered for each feeder or several feeders. BCUs are located in BCRs and are responsible for receiving, processing, and sending B information. Also, recording the events and incidents of receiving, calculating, and sending electrical parameters, providing the possibility of controlling the feeder equipment from the BCR of synchronizing operations, receiving the synchronization pulse, acting as an intelligent intermediary between the performance level and the station level (Station Level) and communicating with the nearby BCUs. It is also done at the control level. The station level is the third control level. This control level takes place in the central control room of the station. The core of the automation software is located at this level. The main task of this level is to communicate with the operator of the upstream center, receive and distribute synchronization signals, manage the control network, control the load, store information, and process the general information related to Bs. Central control equipment, including PRINTER, FRONT END, STARCOVPLER, ROUTER & MODEM, GATEWAY and PROTOCOL CONVERTER, GPS, LAN, HUB, HMI, SERVER are placed at this level. The arrangement of control equipment at the station level may be linear, star, or ring topology, and this is one of the different factors of the substation DCS system. The fourth control level is related to the network level (NETWORK LEVEL). This level is related to the connection of the post with nearby posts, upstream, and dispatching centers. The requirement to establish this communication is to be able to send or receive information thoroughly and logically according to the variety of communication protocols and different arrangements of the DCS system.

Reference

[1]. M.R. Garey, D.S. Johnson, Computers and intractability: a guide to the theory of NP-completeness, Freeman, San Francisco, CA, **1979**. [Google Scholar], [Publisher]

[2]. M.S. Rahman, M. Kaykobad, On Hamiltonian cycles and Hamiltonian paths, *Information Processing Letters*, **2005**, *94*, 37-41. [Crossref], [Google Scholar], [Publisher]

[3]. C. Umans, W. Lenhart, Hamiltonian cycles in solid grid graphs, in *Proceedings 38th Annual Symposium on Foundations of Computer Science*, IEEE, **1997**, 496-505. [Crossref], [Google Scholar], [Publisher]

[4]. F. Luccio, C. Mugnia, Hamiltonian paths on a rectangular chessboard, In *Proceedings of the 16th Annual Allerton Conference*, **1978**, 161-173. [Google Scholar]

[5]. A. Itai, C.H. Papadimitriou, J.L. Szwarcfiter, *SIAM Journal on Computing*, **1982**, *11*, 676-686. [Crossref], [Google Scholar], [Publisher]

[6]. D. Chen, H. Shen, R. Topor, An efficient algorithm for constructing Hamiltonian paths in meshes, *Parallel Computing*, **2002**, *28*, 1293-1305. [Crossref], [Google Scholar], [Publisher]

[7]. A.N.M. Salman, H. Broersma, E.T. Baskoro, *Journal of Automata, Languages and Combinatorics*, **2003**, *8*, 675-681. [Google Scholar], [Publisher]

[8]. F. Keshavarz-Kohjerdi, A. Bagheri, *Journal of Applied Mathematics*, **2012**, *2012*, 475087. [Crossref], [Google Scholar], [Publisher]

[9]. T.W. Chang, O. Navrátil, S.L. Peng, *Frontiers in Artificial Intelligence and Applications*, **2015**, 59-66. [Google Scholar], [Publisher]

[10]. F. Keshavarz-Kohjerdi, A. Bagheri, *Theoretical Computer Science*, **2016**, *621*, 37-56. [Crossref], [Google Scholar], [Publisher]

[11]. F. Keshavarz-Kohjerdi, A. Bagheri, *Theoretical Computer Science*, **2017**, *690*, 26-58, [Crossref], [Google Scholar], [Publisher]

[12]. F. Keshavarz-Kohjerdi, A. Bagheri, *The Journal of Supercomputing*, **2017**, *73*, 3821-3860. [Crossref], [Google Scholar], [Publisher]

[13]. F. Keshavarz-Kohjerdi, A. Bagheri, *Discrete Optimization*, **2020**, *35*, 100554. [Crossref], [Google Scholar], [Publisher]

[14]. Hydara, S. Gannes, N. Traore, W.E. Kevin Yanogo, A study of end-to-end Longest Path Problem with two missing vertices, National Dong Hwa University CSIE Department, **2017**. [Google Scholar], [Publisher]