1. INTRODUCTION:

The need to find different ways of teaching technique in control education for different specialty of control system maintenance and operation technician. The variety of skills that technical students should master is also increasing. This paper describes pedagogical methods that have been adopted as a response to these needs and to the desires of both students, trainers and lecturers to achieve better learning and training results.[1]

And in particular, due to the increasing demands on having skilled trained kwaiti technicians with knowledge of Distributed Control Systems to join both of governmental and industrial sectors, mainly in instrumentation maintenance and industrial process control fields, the lecturer in the institute of "Higher Institute of Energy" motivated to find an experimental methods to follow the technological aspects and to fulfill Institute Vision.

The field of process control comprises a wide set of functions through all levels of the automation system pyramid. To give students a glance of the complexity of process control it is important to provide the possibility to try as much functionality as possible at own hand. That is why the practice on industrial relevant hardware- and software should be an important part of control education. Beside theoretical basics given in lectures, study trips to industrial plants and deepening loop-control-laboratories a laboratory along the levels of the automation pyramid, a plant give the students the big picture of process automation.[2]

This paper presents the challenges of design new automated process control experiment using DCS Trainer by applying sequential control method joining multi processes to get the desired output response. The control system is integrated with DCS process management package called Delta-V and process training Rigs. Where the Industrial control systems comprise Rig's for Temperature, Pressure and Level processes. The paper concentrate of how to create a basic close loop control system is integrated with DCS process management package, Delta-V, with a selection of proprietary process training rigs that offer a range of target processes: 1. Level and Flow; 2. Temperature; 3. Pressure. The rigs may be operated in combination to produce a multi-process, multi-loop system.[3]

1.1 Brief information about the DCS system hardware

The Feedback Distributed Control System trainer, 38-009, is a complete DCS training solution Fig.(2). It integrates a commercial DCS process management package, Delta V, with a selection of proprietary process training rigs that offer a range of target processes: 1. Level and Flow; 2. Temperature; 3. Pressure.

The experimental approach was taken under consideration to verify the varieties of Control technique in industrial control field using DCS technology. Coupling the software and hardware to create a useful control system experiment that can give a strong effect in training process. Understanding and Programming the DCS was the challenge to run the industrial plant processes available in the Trainer DCS System. The sequential control method was implemented the experiment. Besides creating different control scenarios for controlling the processes.

Moreover this paper, we will explain how we can utilize the DCS controller in training and control education programs of the Industrial Control Systems for real-time control systems and design the training programs to meet the goals of professional training.
1.2.3 Tips on DeltaV software used in DCS

Equipment Hierarchy

DeltaV supports a logical hierarchy which includes the following:

1. Area – logical division of a process control system. Areas typically represent plant locations or main processing functions.
2. Process Cell – may be class-based (available to Batch Executive) or non-class based. The process cell can be used to organize units and modules.
3. Unit Module – allows you to take advantage of advanced alarming techniques. Units are also key to a Batch Hierarchy.
4. Equipment Module – a grouping of equipment that performs a minor task like a totalizer or header. Allows you take advantage of advanced alarming techniques.
5. Control Module – links I/O, algorithms, conditions displays and other parameters to the equipment. Modules typically control a single entity like a motor or flow loop.

A typical hierarchical structure is shown in Fig.(4). A DeltaV system may use any, but not necessarily all, of these levels. For example, the DCS trainer uses only Area and Control Module levels.[3]

2. METHODS:

The method used to create an automatic control system divided into five stages.

1. Understanding the DCS hardware and software needed in this application
2. Proposal of control loops conditions need to be applied by using DCS
3. Creating the scenario of operation.
4. Programming stage by apply the expressions in the command boxes of Delta-V software
5. Running the process and monitor the results by DCS output Display

2.1 Stage 1: Understanding the DCS hardware and software needed in this application

DCS produce outgoing signals in the range 4–20 mA and used to control the process. Typically, direct current (dc) pulses were used to drive electromechanical counters, and 24 V dc.

The valves, transducers and transmitters associated with the training equipment are standard industrial components that operate using either 4–20 mA current loop control or 24 V dc control. [1]

2.1.1.2 Process Rigs Part:

Temperature and Level rigs - Input/Output Devices:

- 1. Manual valves (MV1, MV2, MV3, MV4)
- 2. Reservoir
- 3. Process Tank
- 4. Water pump. Digital output (0, 1)
- 5. Solenoid valves (SV1, SV2, and SV3). Digital Output
- 6. Servo Valve. Analogue Output
- 7. Float Level. Analogue input
- 8. Flow sensor. Analogue input

Remarks: Digital output (0, 1) which represent (0V, 24V), Digital input (0, 1) represents (4mA, 20mA), Analogue input (0% to 100%) represent (4mA to 20mA) and Analogue Output (0% to 100%) represent (4mA to 20mA)

Figure no. (5) show us how Temperature process Rig monitored from HMI Display

2.1.1.2 Software

Brief information about DeltaV software used in DCS- Equipment Hierarchy.

2.1.2 Temperature process Rig monitored from HMI Display

The following Fig. (6) show us how Temperature process Rig monitored from HMI Display

Fig.(5): Temperature process Rig monitored from HMI Display

38-600-Temperature process Rig compromise of:

- 1. Manual valves (MV1, MV2)
- 2. Reservoir (Boiler)
- 3. Heat Exchanger
- 5. Water pump. Digital output (0, 1)
- 6. Fan. Digital Output
- 7. Servo Valve. Analogue Output
- 8. Flow sensor. Analogue input
- 9. Temperature sensors. (T1, T2, T3, T4, T5) Analogue input

Remarks: Digital output (0, 1) which represent (0V, 24V), Digital input (0, 1) represents (4mA, 20mA), Analogue input (0% to 100%) represent (4mA to 20mA) and Analogue Output (0% to 100%) represent (4mA to 20mA)

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Fig.(6): Temperature process Rig monitored from HMI Display
DeltaV supports a logical hierarchy which includes the following:

1. Area – logical division of a process control system. Areas typically represent plant locations or main processing functions.
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5. Control Module – links I/O, algorithms, conditions displays and other parameters to the equipment. Modules typically control a single entity like a motor or flow loop.

A typical hierarchical structure is shown in Fig. (7). A DeltaV system may use any, but not necessarily all, of these levels. For example, the DCS trainer uses only Area and Control Module levels. [3]

2.2 Stage 2: Proposal of control loops conditions need to be applied by using DCS

The idea was to create an automatic control system by using DCS system to maintain the level and temperature at certain pre-defined values with certain conditions.

The following conditions were proposed for system operation which was applied in Temperature and Level Processes rigs:-

1- Create close loop control system using sequential control
2- Maintain the water level in the process tank within the range (60% and 80%)
3- If water level reach close to 100% then the float switch will send a signal to trip the pump (switch off) automatically
4- Heating up the water till 35 degree centigrade
5- Switch off the heater element if temperature reach 60 degree
6- Maintain the protection of pumps during circulating of the water (Servo and solenoid valves in open position)

2.3 Stage 3: Creating the scenario of operation.

Describing the scenario of the process operation after running the system, which can be summarized by the following statements:

2.3.1 LEVEL PROCESS PART

1- In the beginning we have to open both Servo valves manually to 100% which is not included in this automatic control scheme
2- The control system will start running directly after switching on the heater element from mimic board (display) consequently the two pumps in both Temperature and Level process rigs will start running automatically.
3- The solenoid valve No.1 will be opened simultaneously after the pump running, which mean that has a direct relation to the pump condition.
4- The Solenoid valve 2 will be opened when the water level in the process tank reach 70% or above, to start drain the water to reservoir.
5- The Solenoid valve 3 will operated with inverse relation to the pump state. Therefor SV3 will be opened when the pump OFF at a level 80% and keep opening till the pump switched ON again at a level of 60%.
6- There was protection from water flood by Float switch which send command to switch OFF the pump at a level of 90% or above.
7- Once the water level reach below 60% the process will be repeated again several times.

See Mapping of input output devices for processes control programming in appendix Table no. (1)

2.3.2 Heating process Part

1- Once the Heater Element is set to ON position (equal to 1) and start heating the primary water in the reservoir (boiler) the pump will be switched On automatically and the water start to flow in the pipes through the Heat Exchanger
2- The Temperature sensors measuring the process temperature from both Primary side and secondary side, and the heater and pumps will be switched off automatically if Temperate T5 =35°C.

The End of process

2.3.3 Brief Description on the process loops and devices used in each loop in the combination of both Rigs see Fig. (9).

We have two loops of water flow related to heater exchanger:

1- Primary Loop of Heat Exchanger (hot water from boiler)
2- Secondary Loop of Heat Exchanger (process water Level)

PRIMARY LOOP Input /Output devices (Temperature Rigs) consist of:

1- Manual valves (Mv1)
2- Reservoir (Boiler)
3- Heat Exchanger
4- Heating Element. Digital Output
5- Water pump. Digital output (0,1)
6- Servo Valve. Analogue Output
7- Float Level Analogue input
8- Temperature sensors. (T1,T2)Analogue input

SECONDARY LOOP Input /Output devices (Level & Temperature Rigs) consist of:

1- Manual valves (MV1,MV2,MV3,MV4)
2- Reservoir
3- Process Tank
4- Waterpump. Digital output (0,1)
5- Solenoid valves (SV1, SV2, and SV3). Digital Output
6- Servo Valve. Analogue Output
7- Heat Exchanger
8- Float Level. Analogue input
9- Flow sensor. Analogue input
10- Float switch. Digital input
11- Fan. Digital Output
12- Temperature sensors, (T3,T4,T5) Analogue input

2.4 Stage 4: Programming stage by apply the expressions in the command boxes of Delta-V software Programming the control strategies by writing the proper Expressions in CND to Devices Control Studio in the Control Module:

RIG38-600 TEMPERATURE RIG
1- [RIG38-600/38-600-HEATER]-Control Studio Heater Element
   AND 1
   CND1 Expression: '/38-600-TEMPSEND/AI1/OUT.CV<35;
   CND2 Expression: '/38-600-CV/AO1/OUT.CV>60;
   CND3 Expression: '/38-600-TEMPSEND/AI1/OUT.CV<50;
   DO1: IO_OUT=DCS_CONTOLLER/DI/CO7/CH07/OUT_D
   Heater Element

2-[RIG38-600/38-600-PUMP]-Control Studio PUMP
   CND1 Expression: '/38-600-HEATER/DO1/OUT_D.CV=true;
   DO1: IO_OUT=DCS_CONTOLLER/DI/CO7/CH06/OUT_D
   PUMP

RIG38-100 LEVEL PROCESS RIG
1- [RIG38-100/38-100-PUMP]-Control Studio PUMP
   AND 1
   CND1 Expression: '/38-100-LEVELSEND/AI1/PV.CV>80;
   CND2 Expression: '/38-100-LEVELSEND/AI1/PV.CV<60;
   CND 3 Expression: '/38-100-FLOATSW/DI1/PV_D.CV=false;
   CND4 Expression: '/38-600-HEATER/D01/OUT_D.CV=true;
   CND 5 Expression: '/38-600-CV/AO1/OUT.CV>80;
   DO1: IO_OUT=DCS_CONTOLLER/DI/CO7/CH01/OUT_D
   PUMP
2- [RIG38-100/38-100-SV1]-Control Studio Solenoid Valve 1
   CND1 Expression: '/38-100-PUMP/DO1/OUT_D.CV=true;
   DO1: IO_OUT=DCS_CONTOLLER/IO1/CO7/CH02/OUT_D

3- [RIG38-100/38-100-SV2]-Control Studio Solenoid Valve 2
   CND1 Expression: '/38-100-LEVELSEND/AI1/PV.CV>70;
   DO1: IO_OUT=DCS_CONTOLLER/IO1/CO7/CH03/OUT_D

An example of the navigation between widows in DELTA V to program the control studio commands of SV3 and SV1 were explained in appendix Figures no (1,2,3,4,5,6).

2.5 Stage 5: Running the process and monitor the results by DCS output Display.

Before running the control system the analogue and digital input devices were calibrated for accurate process control. In the meanwhile the level output response of the system was adjusted by manual valves (open and close) to meet the system constraints see appendix figure (1).

The sequential process control system was tested, in the meantime an automatic control system was verified to maintain a closed loop control according to the proposed scenario. The big challenge in this research was how to put your hands on the system to run a close loop system and view the desired results. It took several working hours to be acquainted with DCS system including implementing your proposed control scenario by joining the software and hardware parts of the DCS system.

The designing and the application stages of a control scenario were compared step by step and the combination of temperature and Level process was tested to have a stable control system.

1.1. RESULTS: The experimental results of close loop system was implemented to control both water temperature and level in the same steps designed for. Where in the beginning the Heater was switched on to start the sequential operation to get started, pumps started to run and solenoid valve SV1was opened automatically to let water flow in the pipe lines to fill the process tank to a level of 80%. see Fig(10)

Fig.(10): SV1 opened & pump (ON)

While water level increasing and reach 70% the SV3 opened see fig. (11).

Fig.(11): SV3 opened at level>70%

When the level reach 80% the system switched off the pump and closed SV1 and SV3 opened with SV2 to drain the water to the reservoir see fig. (12). When the level reached 70% or less SV3 closed and the same control loop will be repeated again to maintain the level between 60% and 80%.

Fig.(12): SV3 and SV2 opened at level = 80%

Fig.(13): SV3 closed SV2 opened at level < 70%

See appendix Fig. (1): Time response for the level process stages

Once the Heater Element switched ON and start heating the water in the reservoir (boiler) used for primary loop of Heat Exchanger, the two pumps switched ON automatically and the water start to flow in the pipes through the Heat Exchanger in Primary and Secondary loops.

The Temperature sensors measuring the process temperature from both Primary side and secondary side, and the heater and pumps will be switched off automatically if Temperate T5=35°C.

The End of process

4-DISCUSSION:
The practice on industrial relevant hard- and software should be an
important part of control education. Beside theoretical basics given in lectures, study trips to industrial plants and deepening loop-control-laboratories a laboratory along the levels of the automation pyramid as well as along the life-cycle of a plant give the students the big picture of process automation.[2]

This research concentrated on a practical experimental approach that enrich the educational means of training toward the industrial plants. And a combination of multi processes in one control systems to produce a useful products is part of educational goals. The table (1) in the appendix showed how to design your control system by mapping input /output devices together in the software side to get an Automatic Control System. The knowledge gained from the execution procedure of this practical experiment is helpful to give the new trainees with a practical and theoretical methods through programming and controlling techniques.

The major consideration in industrial processes control are summarized in:

1- Sequential control of output devices actuators to maintain the desired output response.
2- Calibration of input sensors
3- Calibration of output devices
4- Minimize the errors by using different techniques.
5- Safety operation of process in case of malfunction appear.
6- Alarm need to be provided for warning hazards
7- Data logger for tracing the history of problems in small and large scale systems.
8- Maintain the automation control with system stability.

Different experimental strategies are examined to capture all economical, operational and environmental aspects of the problem. [4] The results of this experiment can be easily explained from the figure (1) in appendix. The time response curve of the level process showed that sequential control of the valves and pump create automated close control system. And if we concentrate more deeply on the slope of each part of the curve with respect to time we realize that:

1- The time needed to fill tank till 70% was depended on flow rate of water in the pipes which depended on pump rate and opening% of servo valve
2- The level from 70% 80% the filling was slow compare the previous case due to SV3 was opened.
3- While from 80% to 70% the draining rate was depend on may three devices SV2 mSV3 and manual valve opening percentage

By execution of this practical control system the technical trainees will have the access to DCS world and programming and gain more self-confidence in modifying and control of processes scheme.

5. CONCLUSION:
By using one of the advanced Distribution Control System (DCS) in training process, we enrich the Maintenance of Measuring and Control Equipment training program with the advanced technology and great knowledge of how to operate and maintain the control systems using different types of processes and controller devices.

In the DCS system, we can tailor different training courses under the control programs such as operation of control systems (monitoring and control), maintenance of DCS equipment and Process devices and how to trace/repair faults and finally how to create control strategy, program the control system criteria and modify the software program.

The table in appendix can be used as a template to create new scenario of operation for the process adding different types of control technique such as PID control.

<table>
<thead>
<tr>
<th>Table no. (1): Mapping of input output devices for processes control programming purposes</th>
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Fig. (1): Time response curve for the level process

App. Fig. (2): Exploring DeltaV and module unit 38-100-SV!

App. Fig. (3): right click on SV1 icon to open Control studio

App. Fig. (4): adding the CND module to the control studio of Sv3

App. Fig. (5): right click on CND1 to open Expression
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