CHAPTER 3

OVERVIEW OF THE DCS PROJECT

3. Overview of the DCS Project

In this chapter I have firstly discussed the meaning of the distributed control system or DCS. Then I have discussed the general processes of the DCS project execution in the company ABC. They are as following.

3.1 The Meaning of the Distributed Control System

There are several meanings of the term 'distributed control'. Dobrowolski (1981) has listed 29 definitions of the distributed control and all of them are valid. Therefore to understand the picture of the distributed control system clearly, some background of the instrumentation such as analog and digital, industrial process control and the evolution of instrumentation are necessary. The details of them are discussed as following.

3.1.1 Analog and Digital Instrumentation

Analog signal is a signal which is measured from a process variable measuring devices such as transmitters or sensors. The signal represents the quantity of the process variable (e.g. flow rate, tank's level, and pressure).

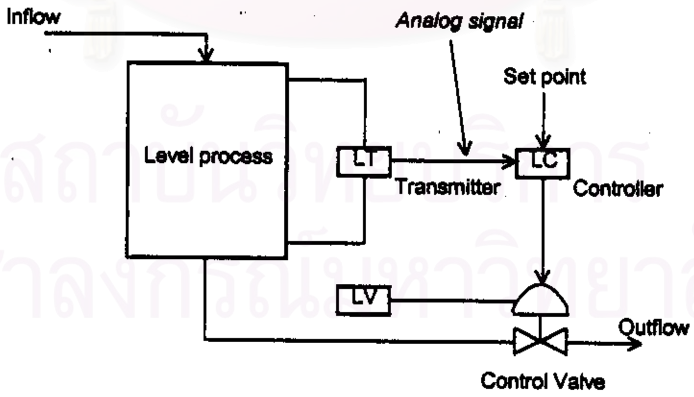


Figure 3.1 Analog instrumentation – Feedback Control Loop
Adapted from Understanding Distributed Process Control by Moore and Herb (1987: 9).

For example, the level of the tank in the figure 3.1 above is measured with a strain gage and a millivoltage is developed proportional to the value of the tank's level. The millivoltage is the *analog* of the level. If the level in the tank changes, the millivoltage changes in exact proportion. This signal (millivoltage) is amplified and converted into a variable compatible with the operating range of the controller. The converted signal is also the *analog* of the level and might be either volts or psi. The low end and high end of the level range become 1 volt (or 3 psi) and 5 volts (or 15 psi) respectively.

The digital (or discrete) signal is expressed either on or off. It can be in all or nothing values. An electric light switch on the following figure is an example of a digital device. When the switch is turned on, the relay coil is energised. As a result, the relay contact (CR-1-1) is closed and the light is active.

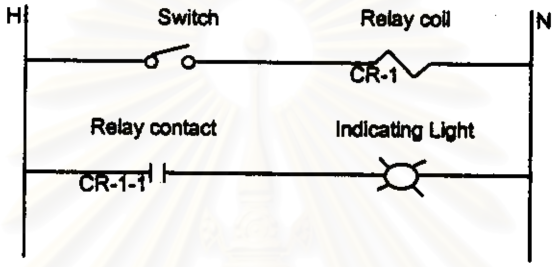


Figure 3.2 Digital Instrumentation – On-Off Control
Adapted from Understanding Distributed Process Control by Moore and Herb (1987: 9).

3.1.2 The Industrial Process Control

The industrial process control is the control of variables that are analogs of the process conditions representing correct or desired conditions for best operation (Moore and Herb, 1987: 7). In other words, the process control is to control variables (e.g. tank's level or flow rate) to the desired conditions in order to produce the best results, even if there are environmental changes or disturbances.

The process in the discussion is an operation involving the transfer of material or energy in the manufacture of industrial products. The examples of process include chemicals, steel, primary metals, environmental processes, and power (Moore and Herb, 1987: 7). The model of a process can be simply illustrated as below.

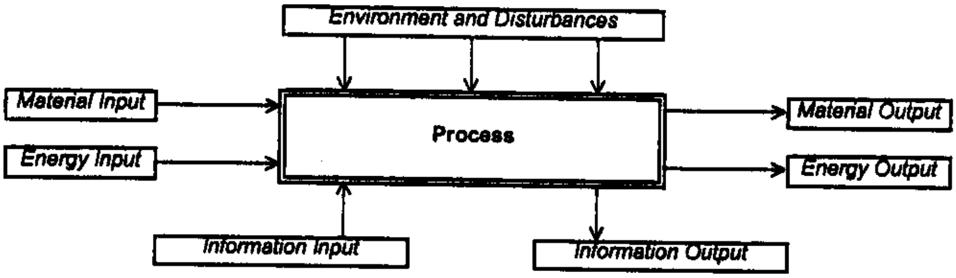


Figure 3.3 The Process Model

Adapted from µXL Fundamental Course: DCS by Vira (1995: 1-2).

The principle steps of the process control are to gather information (e.g. process variables), to make computations and decisions, and to take action. In the process control, there are four major variables. These include

SV: Set point Variable (Reference Variable)
MV: Manipulated Variable
PV: Process Variable (Controlled Variable)
DV: Deviation Variable (DV = PV – SV)

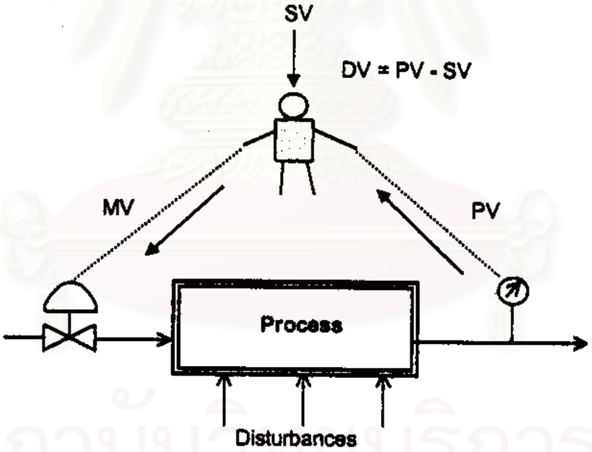


Figure 3.4 Fundamental Scheme of Process Control

Adapted from µXL Fundamental Course: DCS by Vira (1995: 1-4).

From the figure above, the operator sees the process variable (PV) and compares it to his desired set point (SV). Then he increases or decreases the valve through the manipulated variable (MV) in order to decrease the difference between PV and SV (called deviation variable or DV).

The method to directly control processes is roughly divided into two categories: the loop control (including both feedback control and feedforward control) and sequence control. The definition of each control is shown below (Vira, 1995: 1-5).

- Feedback Control: Control which acts to correct the process variable (e.g. temperature in a tank) to agree with the target value (set point) by comparing both.
- Feedforward Control: Control which takes a corrective action by measuring the disturbance (e.g. ambient temperature) and directly driving the valve before it affects the process.
- Sequence Control: Control which successively advances each control step in accordance with a predetermined sequence.

3.1.3 The Evolution of Instrumentation

3.1.3.1 Traditional Process Control

Instrumentation is about the measurement and control. In the past, the measurement and control for any products were done by eye, by feel, and by instinct. Later people noticed that the conditions that produced 'just right' products did not produce the same results everyday. This was because there was no any measuring instruments to measure the process variables and control them to produce the best results.

When the Industrial Revolution came into existence and people used machines to produce products, a new criterion for measurement came to be important because people considered not only the product's quality but also the way to manufacture products with consistency. For example, a bottle manufacturer had to be assured that his products had the same size and wall thickness from one batch to the next, as well as having a composition that made them free from cracks (Moore and Herb, 1987: 10).

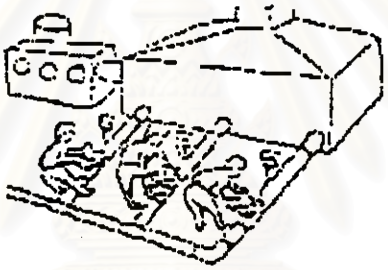
Due to the needs to manufacture quality products with consistency, many indicating instruments were produced. For example mercury-in-glass thermometers, manometers, and bourdon tube pressure gages were produced to measure heating conditions, vessel pressures, and flow rates respectively. These were useful for operators because they could read these instruments and adjust hand valves, levers, or dampers to change process conditions in order to produce good results or products. Note that the operators and indicating instruments during this period were distributed *all over the working area*. The adjustments to the process conditions were based on the basis of the measurements they observed.

It was not easy for operators to manually control the process with the indicating instruments located all over the plant. This was because operators could not see the overall picture of the process at the same time before making a decision to adjust instruments. Therefore it became obvious that there were advantages to having a number of instruments in one place, particularly those related to one process. As a result, a *panel* was used to provide a surface on which the indicating instruments or indicators could be mounted. Operators were able to observe the process conditions at some distances from the process area.

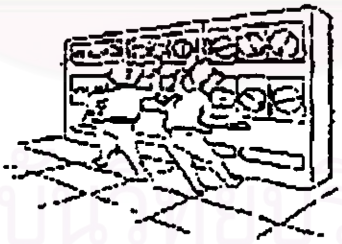
Next, the recorders were invented. The recorders were used to record the history of operating conditions during previous operating periods. This was very useful for both the management and the operators to determine and study the past process control in order to improve their process even better. The recorder can be the form of round chart (single pen devices, recording one process variable) or strip chart (multipoint).

There was also an invention of an analog controller. An analog controller was used to calculate the deviation of the process variable from set point and send a signal to move a valve or other devices in such a way that the process variable moved closer to the set point. Both recorders and controllers were also mounted on the instrument panel. Panels were popularly used in the process plants during this period. A panel may consist of recorders, controllers, indicators, lights and switches, and pneumatic control equipment.

(a) Period of 1930~ (Mechanical instruments and local operations)



(b) Period of 1940~ (Large Pneumatic instruments and signal transmission)



(c) Period of 1950~ (Small Pneumatic instruments)

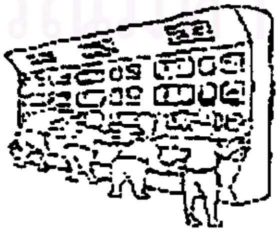


Figure 3.5 Process Control during the Early Period

3.1.3.2 Technological Advances

There were dramatically changes once again during World War II. Three principle areas of change are as follow (Moore and Herb, 1987: 12).

(1) Changes in Design Techniques

The control system in the industrial control was to obtain a final result that reduced to zero the *difference* between 'what was' and 'what was desired'. The tank's level control in the figure 3.1 is an example. If the tank's level is desired to have a level of 20% (set point) from the existing level of 70% (process variable), the *difference* is 50%. The controller, after receiving the process variable (tank's level) and comparing to the set point, calculates the output signal and sends the signal to open the control valve. Therefore the water flows out of the tank and the tank's level decreases. When the tank's level decreases to the level of 20%, the controller sends the signal to close the valve because the difference between the set point (20%) and the process variable (20%) is now zero.

During the world war, there was a military requirement to move large masses (radar scanning frames and gun mounts) rapidly and with accurate positioning. Technology based on *frequency response* was developed. Since the concept of moving and controlling the large masses to the right place in the armed forces' activities was similar to control's concept in the industrial process explained above. The industrial process industry has adopted the *frequency response theory* to the applications of process control. The results were new design strategies and new instruments for measuring and control were developed.

(2) Changes in Signal Transmission

During the war, the hydraulic and electrical transmission were increasingly used to move the heavy military devices quickly and accurately. Servomotors were used to position the remotely located operating parts of a large aircraft from the cockpit. Servo valves and servo amplifiers were also commonly used. Electrical transmission was used to bring large amounts of information instantaneously to the pilot of an airplane.

The technologies used in the military area were adapted to the industrial process area. The electrical and electronic transmission of process variable measurements and regulating command signals were developed.

(3) Changes in Expertise

During the war, many young men were trained to service electrical and electronic circuitry that were the heart of radar and of the flight control equipment. When the electronic instrumentation began to appear in the process plants, there were people with the required skills already developed for servicing it. These people become instrument technicians and operators.

These changes in design techniques, signal transmission, and expertise took place in the 1950's and early 1960's. The transistors, operational amplifiers, and printed circuit cards were also developed during this period. As a result, the instrument used in the plant became smaller, the distances for transmission of signals became greater, and the panels became fuller (Moore and Herb, 1987: 14).

3.1.3.3 Control Using Digital Devices

The next step of the instrumentation's evolution was to use digital computers for control. As process engineers came to realise that computers could be programmed to do the control calculations and computations. The computer could also develop signals to regulating devices that could be used to maintain process control. Computers were used in three ways.

(1) Data Acquisition and Record Keeping

The process variables were sent to the computer system and printed to the printer for record keeping purpose.

(2) Supervisory Control

In the past, operators saw the process variables and made a decision whether to increase or decrease the set point of the related controller in order to get the desired results. In 1960, there was an introduction of the Supervisory control system. The Supervisory control system helped operators perform this function by calculating the optimum process conditions. The results of the calculation of the computer system were the desired set points. Signals were sent from a digital computer to analog controllers to change set points to the values computed by the computer.

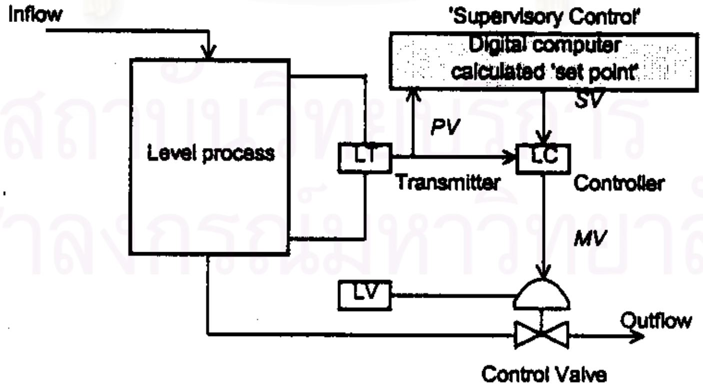


Figure 3.6 Supervisory Control or Set Point Control

(3) Direct Digital Control

The Direct digital control or DDC was firstly introduced in 1965. The DDC was similar to the supervisory control but in this case the signals calculated and generated by the computer were *directly* sent to the final control device and the controller function was supplied as part of the computer programming. Note that this control system was centralised where the *single* digital computer was used to control many loops. The problems related to the use of DDC were the system's reliability. If there was a failure of the computer system, the plant operation that was controlled by the Direct digital control had to shutdown. Therefore the needs to having spare parts of the CPU and other computer parts were necessary but it was quite difficult because of the expensive price of the computer at that time.

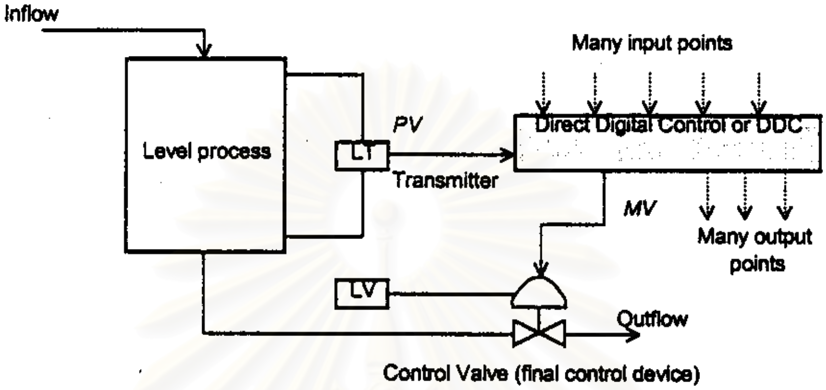


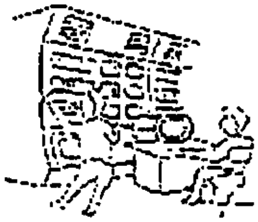
Figure 3.7 Direct Digital Control (Centralised Control and Centralised Monitoring)

However the computer control was not successful. There were two reasons. One was that the computers were expensive, both the cost of hardware and software. The hardware's size was big and very expensive. In addition to the software part, the programmer had to write the software in such a way that the computer could perform the function of the controller and this was not an easy task. Programming had to be done to scan variables, to store the information and to update it, and to move the information into various registers in a precise way that allowed all the necessary operations to be done in a proper sequence. The cost of the software development was, therefore, expensive (Moore and Herb, 1987: 15).

The second reason was that the computer was not completely reliable. If the computer failed, the entire plant that the computer serviced had to be shutdown. Therefore people did not rely on the computer and were reluctant to risk their production capability on the operation of a computer.

Until the 1970's, there was a development of the LSI (large-scale integrated circuits). The size of electronic components became smaller where many circuit devices can be combined on a small silicon chip. Prices decreased and the reliability increased. Microcomputer, CMOS chips, and advances in communication technology have dramatically changed the structure of instrumentation and control. The *distributed control* was introduced during this period.

(a) Period of 1960~ (Small electronic instruments and digital computer control)



(b) Period of 1970~ (Distributed Control System and CRT operation)

Figure 3.8 Process Control during the 1960's to 1970's Period

From the evolution of the process control described above, the control is developed from the manual control to the distributed control system. The process control's development relative to each decade during 1930 to 1990 can be simply shown on the following figure.

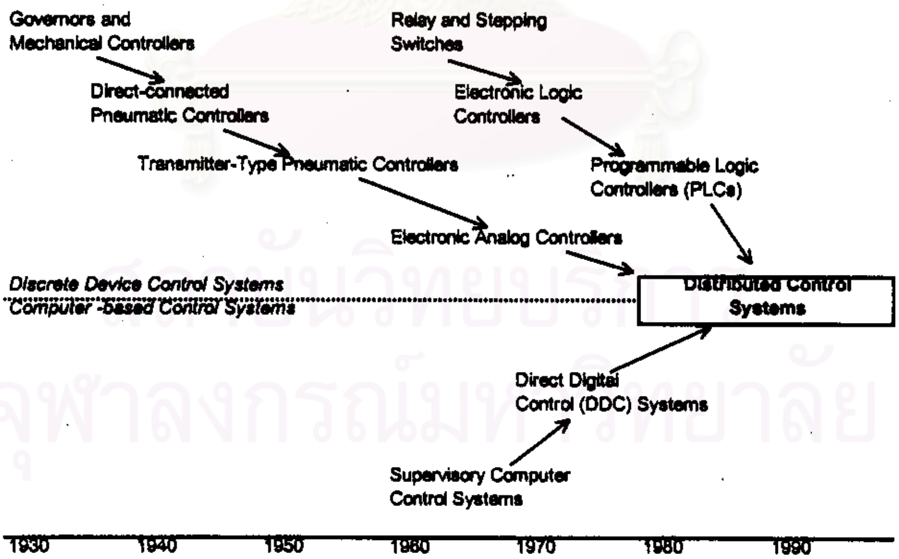


Figure 3.9 The Development to the Distributed Control Systems

Adapted from μXL Fundamental Course: DCS by Vira (1995: 1-11).

3.1.4 Distributed Control System (DCS)

Due to the development of the LSI explained above, the instrument companies began to release distributed control equipment. The equipment was manufactured using the microprocessor-based technology. These microprocessor-based measuring and controlling devices can be located all through the processing areas. Meanwhile, the operators can sit in a central location and manipulate all of the control loops in all of the areas. They rely on communication with the remote areas over a 'data highway' made of a single coaxial cable (a twisted pair of wires) or a fiberglass conductor of light. The interfacing device between operators and the control areas is a CRT (cathode ray tube) and keyboard. With this new control concept, the *capacity for control is distributed* about the plant, while the *operating function is centralised* at one point. This new control form is called *'distributed control'* (Moore and Herb, 1987: 20).

In order to see the picture of the DCS better, the figure below illustrates the DCS concept clearly.

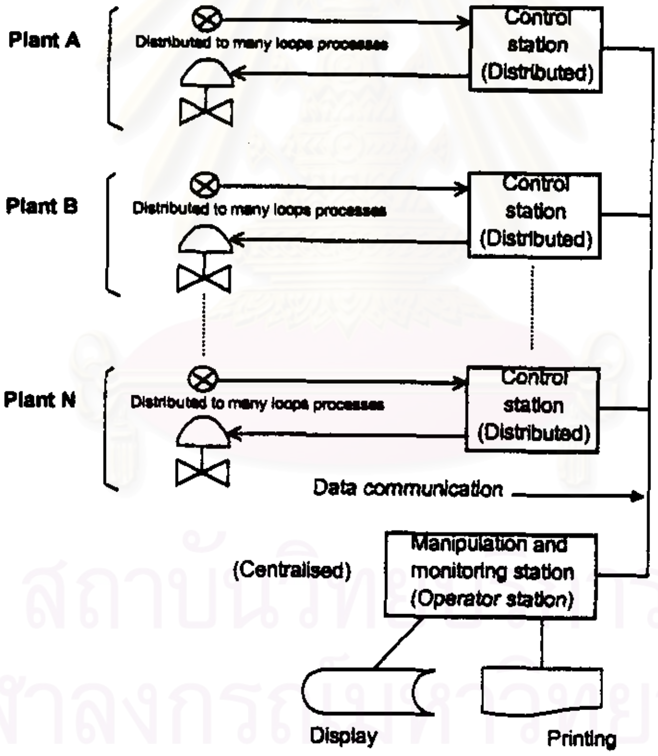


Figure 3.10 Distributed Control System (Distributed Control, Centralised Monitoring) Adapted from µXL Fundamental Course: DCS by Vira (1995: 1-14).

The DCS have many chip microprocessors which are distributed to each control station. Note that the control station divided depends on each process plant or process method. Each microprocessor is used to monitor and control each loop in the plant. Therefore the control function is distributed and each controller is independent from others. Operators can monitor or control loops in the plant using the operator stations and the setting data (if any) were sent to the related control station via the bus communication.

3.1.4.1 Definition of the Distributed Control System (DCS)

Moore and Herb (1987: 55) has defined the DCS as following: "Distributed control is a form of instrumentation that locates the controlling portion of the control system in the processing area. The DCS measures process variable values (and discrete inputs) and produces output signals to position actuators as a function of deviation from set point. While, by means of electrical transmission, process information is communicated to a central location where the operator can sit and manipulate all the loops of control in the system. The interface of the operator with the process will be a CRT and a keyboard. The capacity for control is distributed about the plant, while the supervisory function is centralised at one point".

3.1.4.2 DCS Architecture

The architecture of the distributed control system is shown on the following figure.

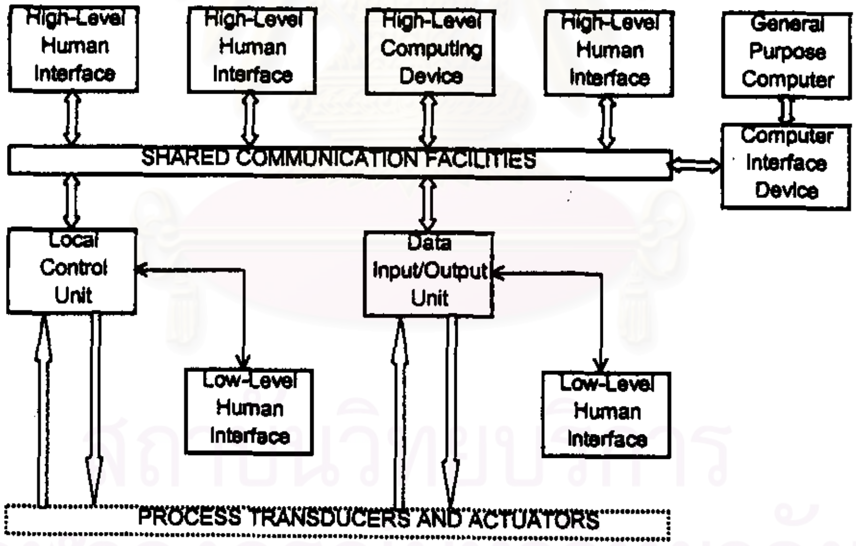


Figure 3.11 Generalised Distributed Control System Architecture

Adapted from Distributed Control Systems by Lukas (1986: 10).

From the DCS architecture in the figure above, the definition of each device is explained as following (Lukas, 1986: 10).

1. *Local control unit (LCU)*: The smallest collection of hardware in the system that can do closed-loop control. The LCU interfaces directly to the process.
2. *Low-level human interface (LLHI)*: A device that allows the operator or instrument engineer to interact with the local control unit (e.g. to change set points, control

modes, control configurations, or tuning parameters) using a direct connection. LLHIs can also interface directly to the process.

3. *Data input/output unit (DI/OU)*: A device that interfaces to the process solely for the purpose of acquiring or outputting data. It performs no control functions.
4. *High-level human interface (HLHI)*: A collection of hardware that performs functions similar to the LLHI but with increased capability and user friendliness. It interfaces to other devices only over the shared communication facilities.
5. *High-level computing device (HLCD)*: A collection of microprocessor-based hardware that performs plant management functions traditionally performed by a plant computer. It interfaces to other devices only over the shared communication facilities.
6. *Computer interface device (CID)*: A collection of hardware that allows an external general-purpose computer to interact with other devices in the distributed control system using the shared communication facilities.
7. *Shared communication facilities*: One or more levels of communication hardware and associated software that allow the sharing of data among all devices in the distributed system. Shared communication facilities do not include dedicated communication channels between specific devices or between hardware elements within a device.

3.1.4.3 Major Devices of the Distributed Control System (DCS)

The devices in the DCS architecture above can be grouped into two major categories as following.

(1) *Controllers (or Control stations)*: those that interface directly to the process to be controlled or monitored.

The controllers are electronic assemblies that are capable of making decisions on the basis of measurements and generating signals that are sent to actuators. The controllers can be located remotely from the central control room, near the process area. A single remote unit (a controller) may receive information as many as several hundred analog process variables and as many as several hundred digital inputs. The controller may send analog actuating signals to as many as sixteen analog actuators and as many as several hundred digital outputs (Moore and Herb, 1987: 48).

(2) *Operator Stations*: those that perform high-level human interfacing and computing functions.

The operator station displays information collected from all the local areas (controllers). The operator station is located in a central area or control room from which the operator can manipulate the process through the local controllers. The central area or control room allows operators to sit, watch the displays (CRT), and address the process from the keyboard.

The operator stations are connected to the local areas (controllers) by cabling that permits the transmission of information. Note that the DCS is much more tolerant of failure than is the case with the traditional computer (large, single mainframe central computer) because the failure of one local station will not interfere with the operation of other local stations (controllers). In the event that the central station (operator station) should fail, the local stations can continue to operate without it. This is the basis for the claim that the DCS have greater reliability than the traditional computers can offer (Moore and Herb, 1987: 50).

The operator stations provide the operators with the following displays.

(1) *Information displays*: Overview display, group display, and detail display.

(2) *Trend displays*: Real-time trend and historical trend.

(3) *Graphic displays*: A combination of lines, shapes, alphanumeric characters to draw a picture of a portion of the process. Note that the portions of the display can be made to change shape or colour as discrete events take place in the process.

(4) *Tabular displays*: Display tag name, show the current value, show the range of the variable, and show 'high/low limits' for process variable values (it is used to initiate alarms).

(5) *Alarm displays*: Generate the audible annunciation to attract the operators' attention and color's changes on the graphic displays.

The major benefit of using the CRT for displays is that the information that operators need is compressed into an area that the eye can scan without a head movement. Therefore operators can respond to changes in the process faster than the traditional process control. In addition these displays can also provide the operators what is going on or going wrong in the plant.

3.2 The General Processes of the DCS Project Execution

In order to set up the distributed control system (DCS) to a factory, we have to consider both DCS hardware and software. The hardware include the control stations and the operator stations. The numbers of control stations used are related to the size and capacity of the plant whereas the numbers of operator stations are related to the number of operators in the plant and the control concept used.

For software side, we have to consider the types used to control the process in the plant. These include feedback control, feedforward control or sequence control. The application software, which suites only to the plant, is then built according to the specified control concept. Note that the application software for one factory is not similar to that of another factory. When the software was made, it cannot be used with another factory because of the differences in size, capacity, and control concept between the plants.

Before the distributed control system will be installed in a plant completely, it requires a lot of works to be done and it is called 'DCS project'. For this thesis, I have observed the general processes of the DCS project execution in the company ABC. The overview of the current DCS project executing processes in the company ABC can be simply illustrated as shown on the figure 3.12. From the figure 3.12, there are fourteen steps to complete the DCS project. These steps include,

1. The internal kick off meeting (Internal KOM) process
2. The customer kick off meeting (Customer KOM) process
3. DCS hardware specification design and approval process
4. DCS software specification design and approval process
5. DCS software design process
6. DCS software generation process
7. DCS software debugging process
8. Factory acceptance test (FAT) process
9. Recovery work process
10. Delivery the DCS process
11. Final document preparation process
12. Installation, startup and commissioning process
13. Project review process
14. As built document preparation process

As shown on the figure below, the table consists of four columns. The first column is the step number of the DCS project execution. These numbers can be used further in the next chapter when we discussed the project execution in more detail. The second column is the input, such as the related document of a process, into the process. The third column is the overview of the project's workflow, which generates the output, shown on the fourth column.

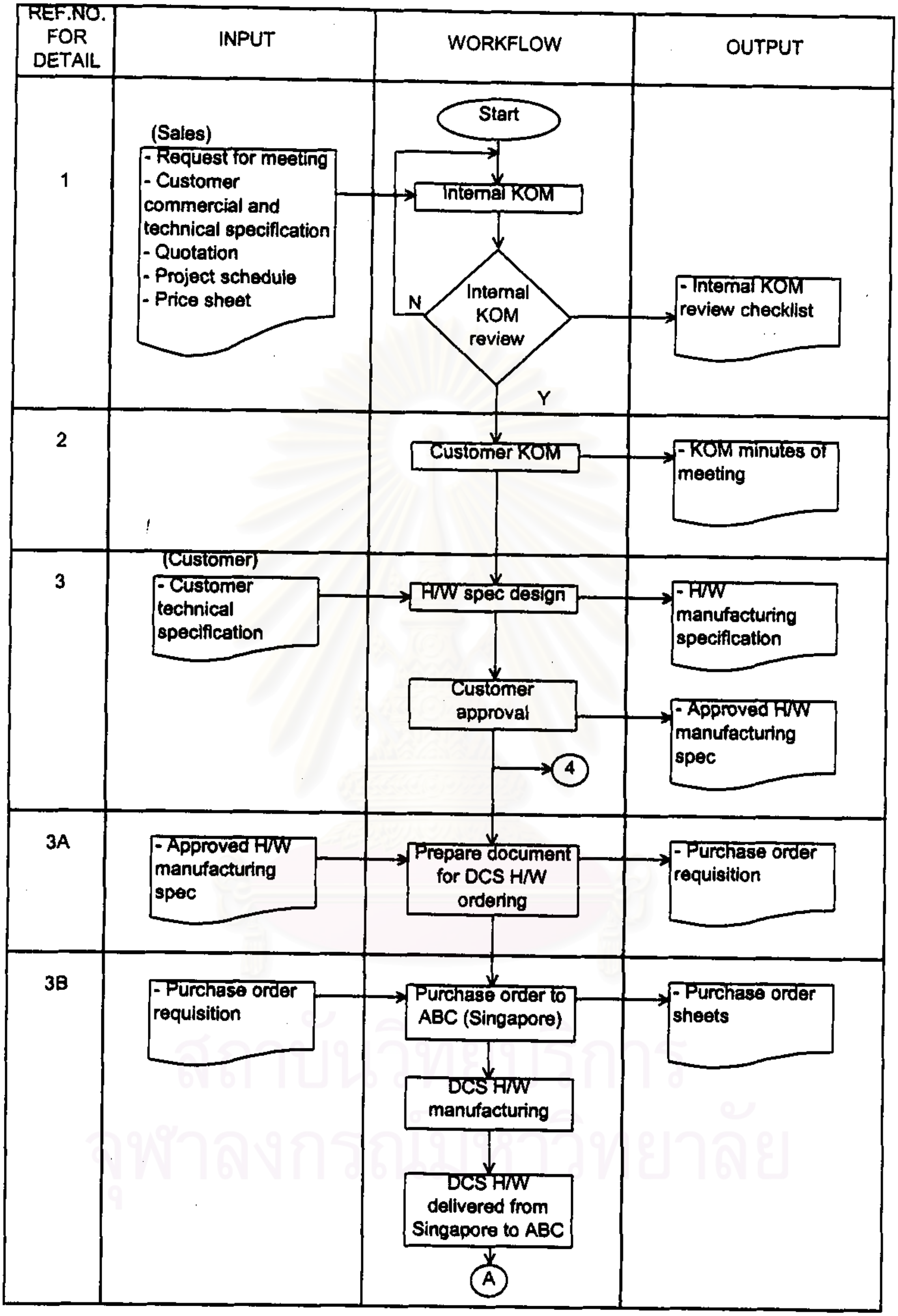


Figure 3.12 Overview of the DCS Project Execution

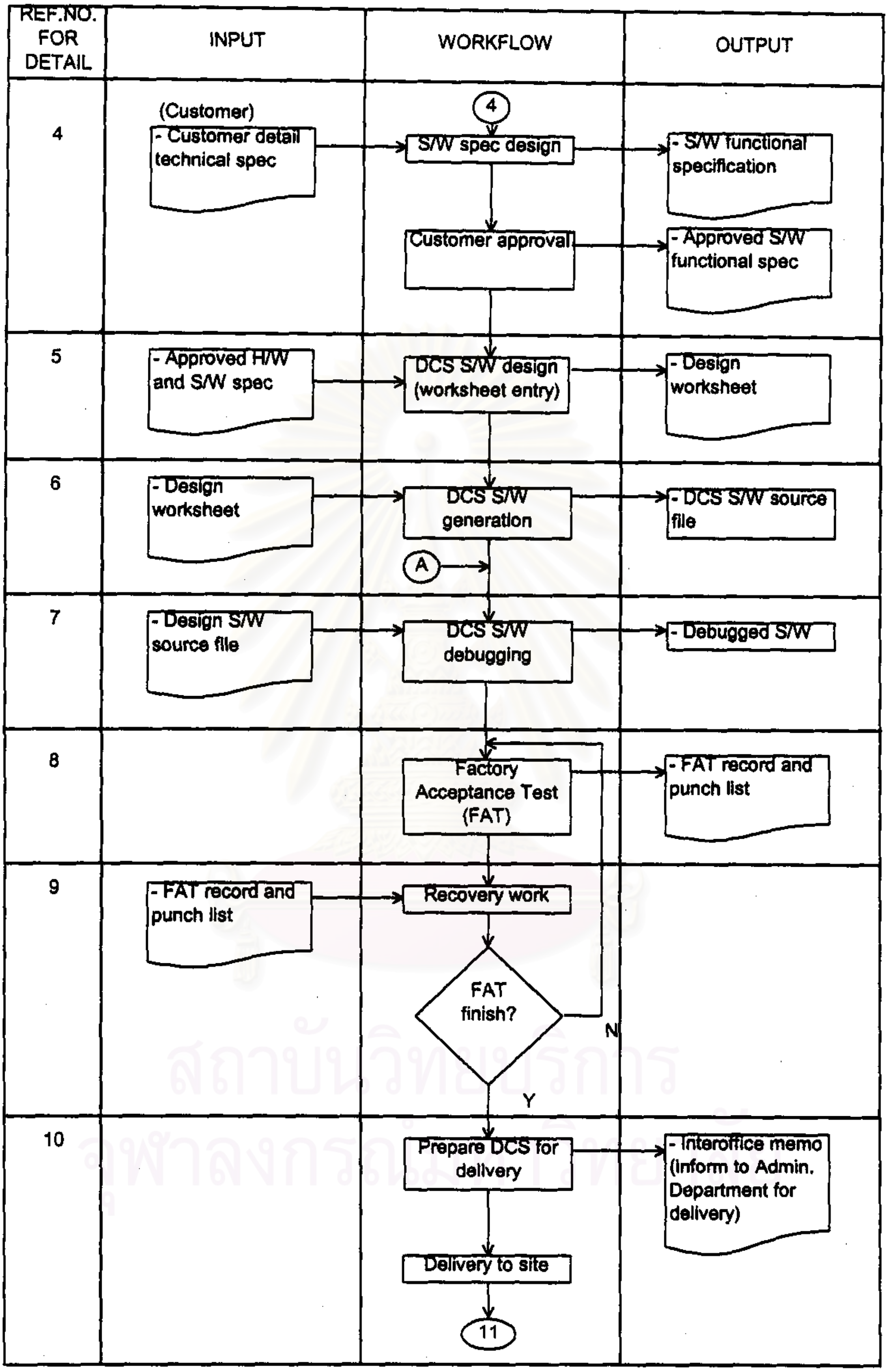


Figure 3.12 Overview of the DCS Project Execution (Cont.)

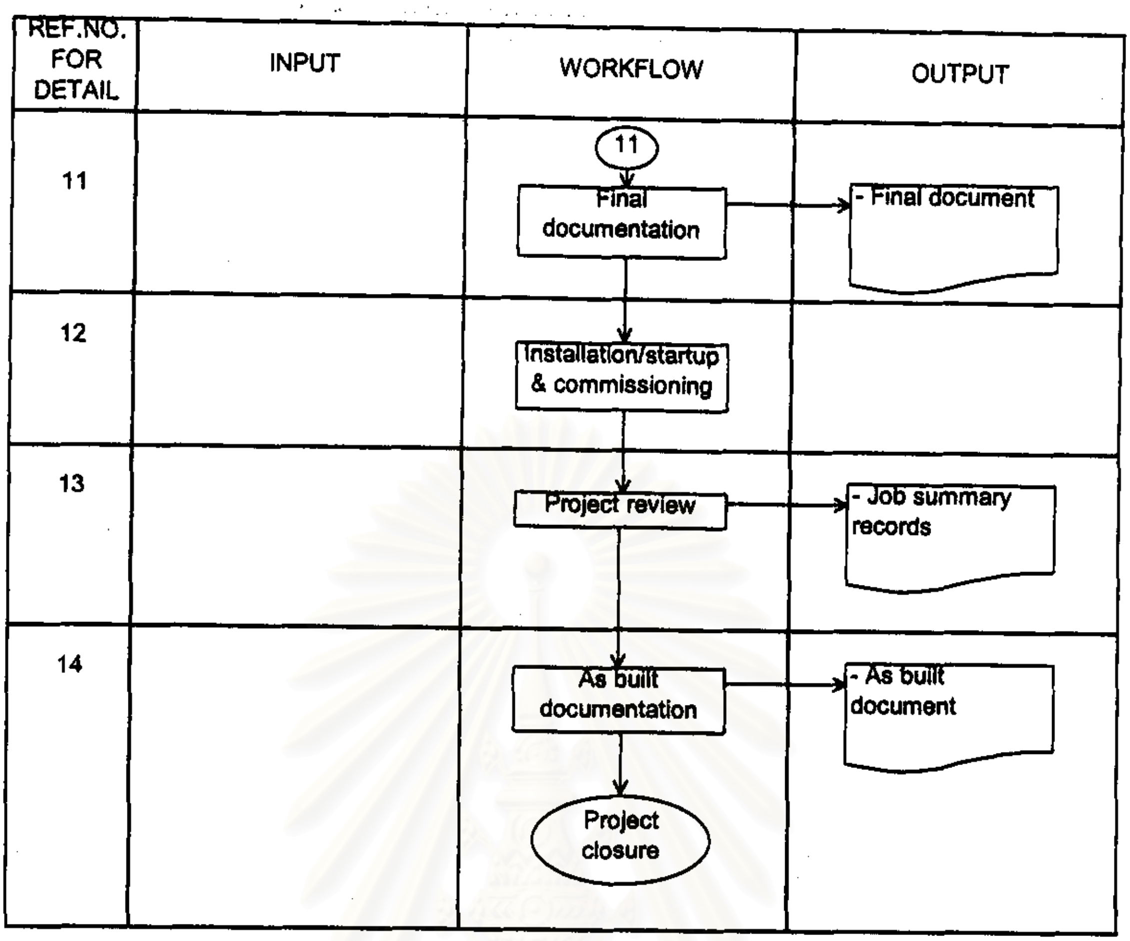


Figure 3.12 Overview of the DCS Project Execution (Cont.)

Note that the reference no. 11 to 14 in the workflow above is not a part of this thesis. It appears as a part of workflow till project closure.