Chapter 4

Analysis of DCIS Configuration of the Case Study

4.1 Introduction

This chapter has an intention to show the critical discussion on the problem area of the DCIS configuration of the case study, which will be based on the reliability and availability aspects. In order to make a smooth presentation in this chapter, the necessary technical information of the DCIS controller of the case study will be presented, then follow with the major problem of the DCIS configuration design. The critical discussion will pay attention to the partitioning of the DCIS controller. By using the reliability modeling for system prediction, the good fit configuration for the DCIS controller in the area of partitioning problem will be considered and presented.

4.2 The DCIS to be implemented to Krabi Project

Krabi thermal power plant project is the new power plant project of EGAT as it was explained in Chapter 3. The DCIS, which was proposed by contractor to use in this project, is K. K is the current model for power plant process control of K manufacturer. The necessary technical information of K model, which is important to the critical discussion in this chapter, is attached in the appendix of this thesis paper.

4.2.1 Technical Information of K Model

There is a lot of document that concerns about the technical details of K series. In this chapter, there are only necessary technical details, which need for the critical evaluation especially on the reliability and availability aspects of K DCIS controller. Figure 4.1 on the next page shows a typical configuration of K series from K manufacturer.

DCIS Configuration for Krabi Thermal Power Plant, UNIT

Main Control Room

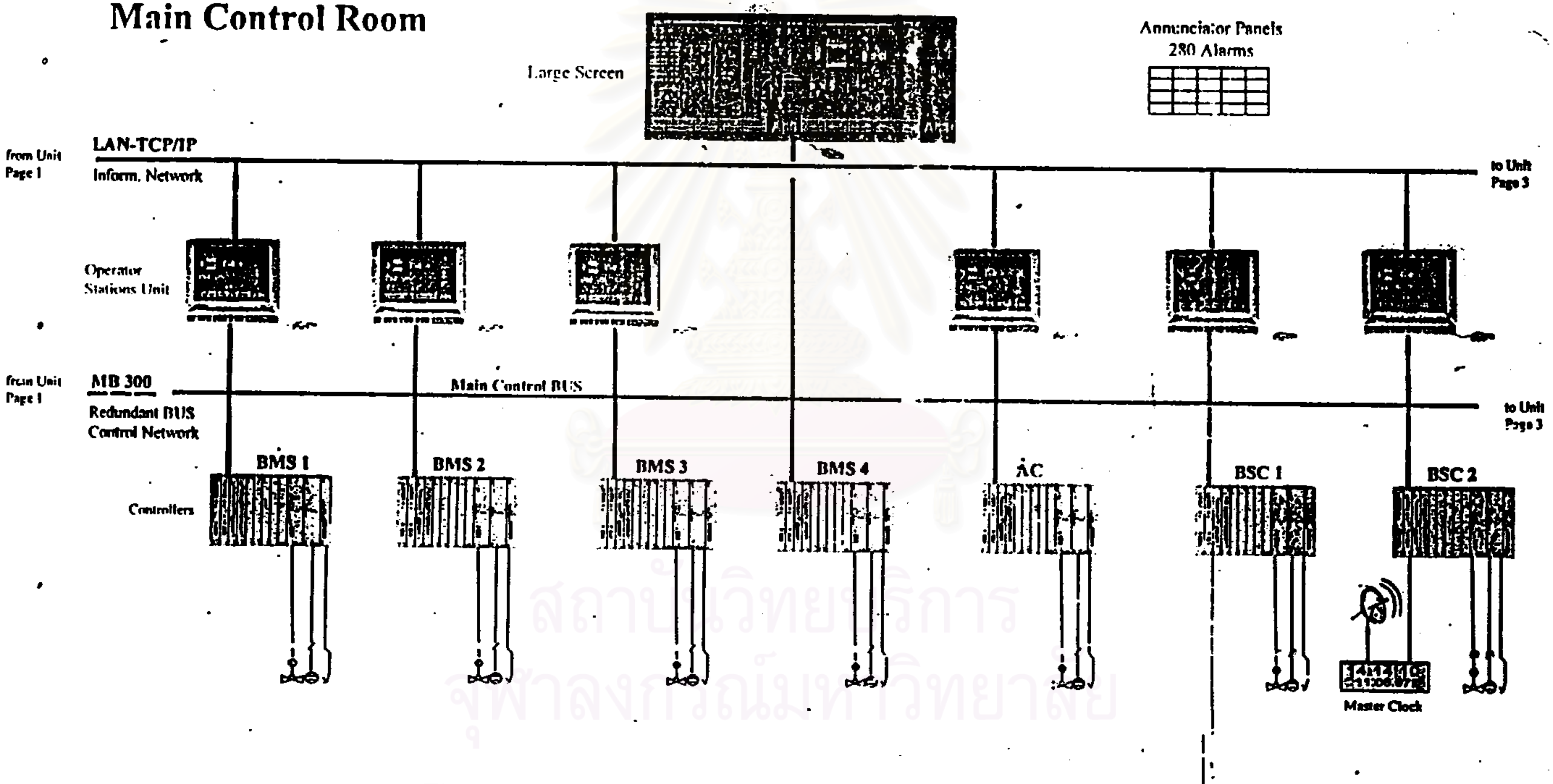

Figure 4.1 A typical configuration of K series from K manufacturer

Figure 4.1 shows DCIS typical configuration of K series. There are four major parts, which show in this figure. The four major parts are human machine interface, communication, controller and field input/output device. This research study looks over especially to the controller part where the problem occurs during the engineering phase of the case study. The necessary technical information for the critical evaluation on the reliability and availability aspects of the controller part, are the value of Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR) of the DCIS controller and its peripheral devices of K series.

4.2.2 MTBF and MTTR of DCIS Controller and Its Peripheral Devices of K series

From the technical information of the K, the MTBF and MTTR of the DCIS controller and its peripheral devices are as follow:

Description	MTBF(Year)	MTTR(Minute)
1. Processor Module	772	30
2. Power Supply Module	50	30
3. Communication Module	320	30
4. Digital Input / Output Module	39	30
5. Analog Input / Output Module	39	30

Table 4.1 The MTBF and MTTR of DCIS controller and its peripheral devices of K series. (Source from technical data sheet of K series which was filled in the technical data sheet for Krabi thermal power plant project by K company, see in Appendix.)

Before further discuss on the critical evaluation of the DCIS controller configuration, the reliability of an individual DCIS controller will be explained and calculated. It's much clearer to explain about the reliability of the DCIS controller. Firstly, by using the fault tree analysis, the considered area that has a failure impact to the reliability of each individual DCIS controller, will be discussed.

Then the critical analysis of the reliability of DCIS controller of K series will be analyzed by using the reliability modeling for system prediction. Hence, the reliability for each individual DCIS controller can be calculated by using the MTBF and MTTR of DCIS controller and its peripheral devices of K series. The furthermore details of calculation are in the following paragraph.

4.3 Fault Tree Analysis of Individual DCIS Controller

By using the fault tree analysis, the cause of the individual DCIS controller failure can be identified as shows in figure 4.2.

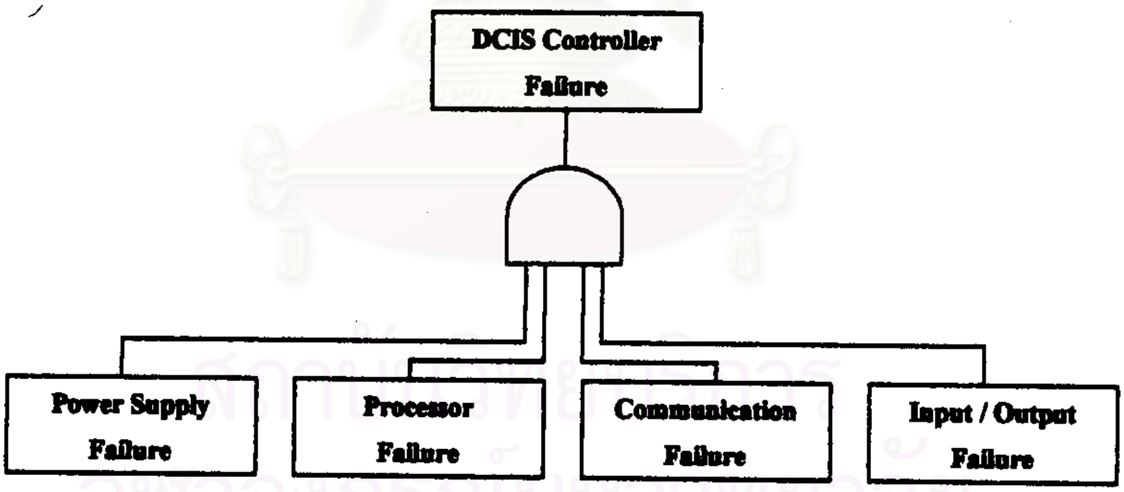

Figure 4.2 Fault Tree Diagram which shows the cause of DCIS Controller Failure

From figure 4.2, it shows the fault tree diagram of the DCIS controller failure. The information which is used to identify the failure causes of the DCIS controller, come from the basic structure of the DCIS. In Chapter 2, the necessary parts of the DCIS which is needed to perform each individual DCIS controller has been explained. This fault tree is a graphical picture, which can explain an overview picture of the cause of failure for each individual DCIS controller.

4.4 Reliability Modeling for System Prediction of Each Individual DCIS Controller

From the reliability modeling for system prediction method which was explained in Chapter 2 and the result from fault tree analysis, the reliability block diagram of DCIS controller of K series which will be used for Krabi thermal power plant project, can be performed as follow:

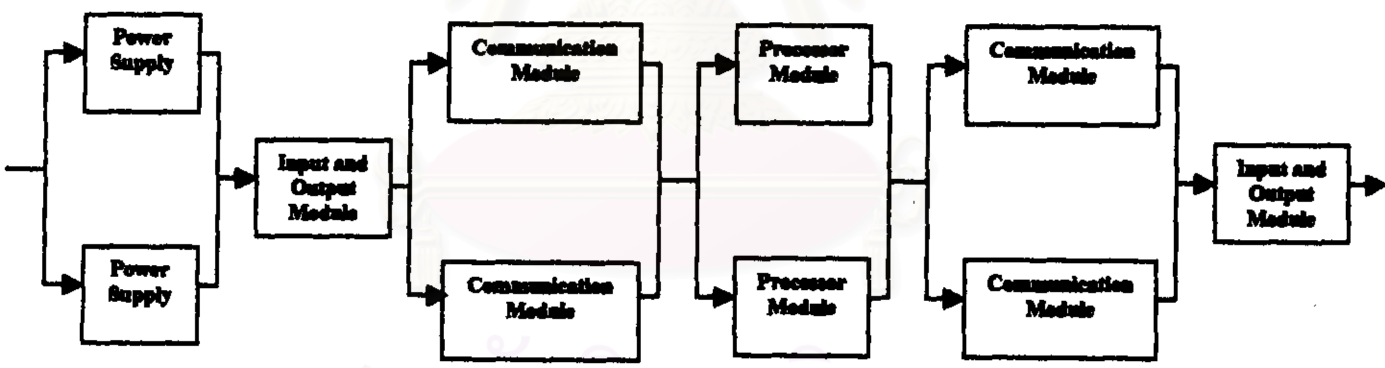

Figure 4.3 A Reliability block diagram of each individual process station of K.

In figure 4.3, it is the reliability block diagram of DCIS controller of K series for each individual process station. The individual process station consists of power supply, input-output, communication and processor module. The wording process station is a technical term, which is used to define each individual DCIS controller and its peripheral devices in the technical document of K series. The power supplies, communication and processor modules are the areas that use the redundancy concept to increase the system reliability of each individual process station.

In order to simplify the way to calculate the system reliability of the individual DCIS controller, the reliability block diagram will be eliminated the communication module and input and output module by assume that it's the same devices. Therefore the simple structure of the reliability block diagram of K DCIS controller and its peripheral devices will be changed to the structure which shows in figure 4.4 as follow.

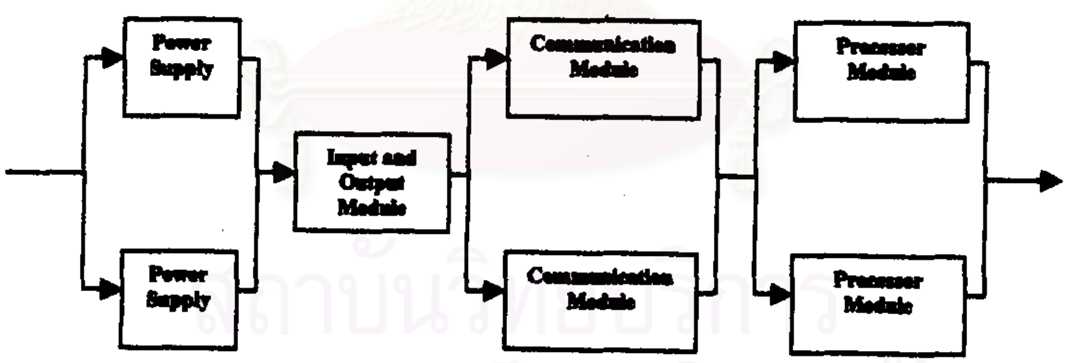

Figure 4.4 A simplify reliability block diagram of the individual DCIS controller.

From table 4.1, it is the information of Mean Time Between Failure (MTBF) and Mean Time To Repair (MTTR) of the DCIS controller and its peripheral devices of K series. These values will be used to calculate the system reliability of the individual process station of the DCIS controller of K series. The reliability block diagram, which will be used for the system reliability calculation is the block diagram in figure 4.4. In figure 4.4, it presents the equivalent equipment to the reliability block in figure 4.3 but the way to calculate by using the block diagram in figure 4.4 is much simpler. From figure 4.4, the system reliability of each individual process station can be calculated as follow:

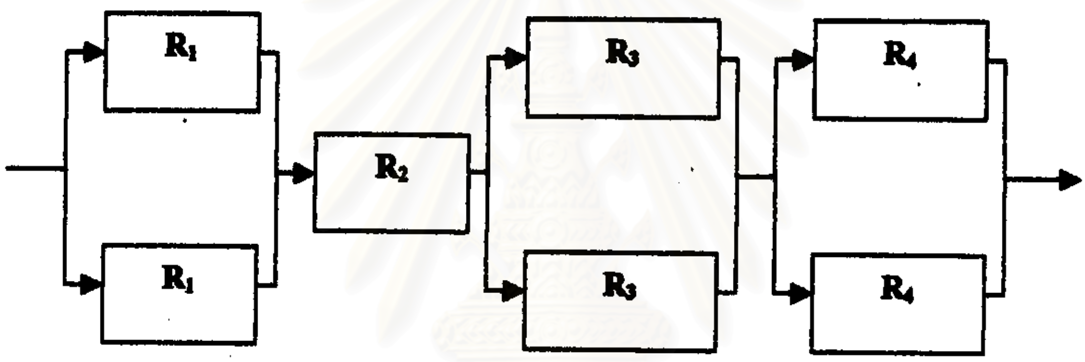

Figure 4.5 The reliability block diagram from figure 4.4 which presents the reliability in each block area.

$$R_{sys} = [1-(1-R_1)^2] * R_2 * [1-(1-R_3)^2] * [1-(1-R_4)^2] \quad (4.1)$$

Where:

R_{sys} = system reliability of each individual process station of K series

R_1 = reliability of power supply

R_2 = reliability of input / output module

R_3 = reliability of communication module

R_4 = reliability of processor module

More formally, reliability relates to its dependability or " the probability that the system will perform satisfactorily for at least a given period of time when used under stated conditions ". Hence, the relation between **reliability** and **MTBF** over a period of time t, which was explained in Chapter 2, Reliability is $\mathbf{R = e^{-t/MTBF}}$

$$\mathbf{R = e^{-t/MTBF}} \tag{4.2}$$

Where: **t = mission (or operational) time**

MTBF = Mean Time Between Failure

The mission time is selected to be either the equipment lifetime (15 to 20 years or more) or the time between scheduled equipment outages (generally once a year or once every two years). The value chosen depends on the purpose of the analysis. For this study, we will use once a year period because normal power plant shutdown period, which has been done the maintenance activities by EGAT's maintenance staff, is once a year.

The above equation came from $\mathbf{R = e^{-\lambda t}}$ where λ is a failure rate [2]. The failure rate equals to 1/MTBF [2]. This reliability equation is used to calculate the reliability when the failure rate is constant. From the bathtub-shaped failure rate curve shown in figure 2.4 of Chapter 2 consists of three separate phases: the "infant-mortality" or " burn-in" phase (initial high but falling failure rate λ), the useful-life phase (stress-related failures, constant flat failure rate λ), and the wear-out phase(end of life, increasing failure rate λ)[12]. The MTBF figure applies to the flat part of the bathtub-curve, where failure rate is constant and reliability (probability of no failure) is approximated by an exponential curve [12].

The other important character which should be clarified before further more discussion is the failure characteristic. The failure characteristic of the electronic equipment has two major failures, which are complete failure and malfunction failure. In this thesis research, only the complete failure will be considered. Hence, the result of the reliability in each block area of the reliability block diagram in figure 4.5 will be calculated and shown in table 4.2 as follow:

Item	MTBF(year)	T (year)	Reliability
R_1	50	1	0.980198673
R_2	39	1	0.974684913
R_3	320	1	0.996879877
R_4	772	1	0.998705501

Table 4.2 The reliability of each component of an individual process station

From the reliability of each component of an individual process station in table 4.2, the system reliability prediction for the whole individual process station can be calculated from the equation $\mathbf{R_{sys} = (1-[1-R_1]^2) * R_2 * (1-[1-R_3]^2) * (1-[1-R_4]^2)}$ which is explained in the previous paragraph. Hence the system reliability of an individual process station of **K** series is:

$$R_{sys} = (1-[1-R_1]^2) * R_2 * (1-[1-R_3]^2) * (1-[1-R_4]^2) \quad (4.3)$$

$$R_{sys} = (1-[1-(0.980198673)]^2)*(0.974684913)*(1-[1-(0.996879877)]^2) *(1-[1-(0.998705501)]^2) \quad (4.4)$$

Hence, $R_{sys} = 0.974291628$

We can calculate the system reliability of K series for each individual process station and the result is $R_{sys} = 0.974291628$. For furthermore study, I would like to do the calculation of other configuration of each individual process station in order to use it for the comparison discussion between each different configuration in the next paragraph. The other configuration of each individual process station is shown in figure 4.6, 4.7and 4.8.

In figure 4.6, it is the simplest configuration, which has no redundancy in any part of the individual process station. In figure 4.7, it is the same configuration which shows in figure 4.6 but it has a different point in the processor area that redundancy will be used in this configuration in order to increase the system reliability of the whole process station.

In figure 4.8, it is the same configuration, which shows in figure 4.4, but it has a different point in the processor area that triple redundancy will be used in this configuration in order to increase the system reliability of the whole process station. For the system reliability of each configuration, it can be calculated as in the following paragraph.

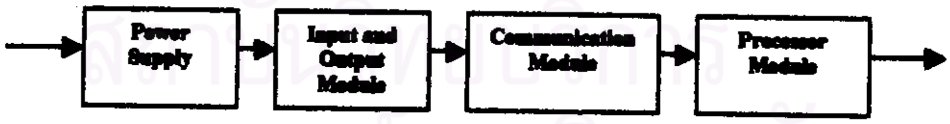

Figure 4.6 Reliability block diagram of a simplify success diagram (No redundancy)

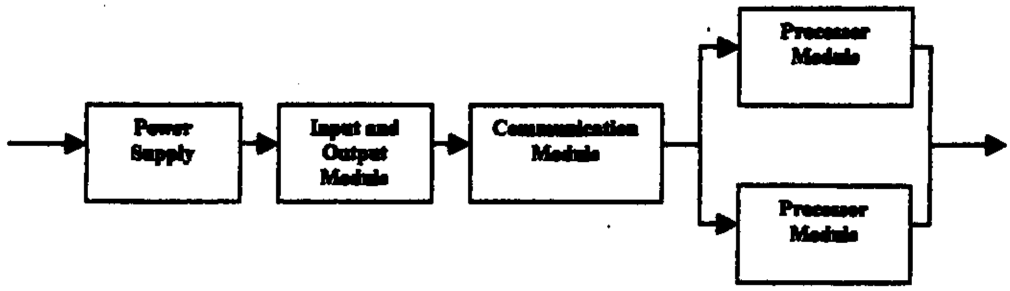

Figure 4.7 Reliability block diagram for the individual process station where redundancy has been used only for the processor module.

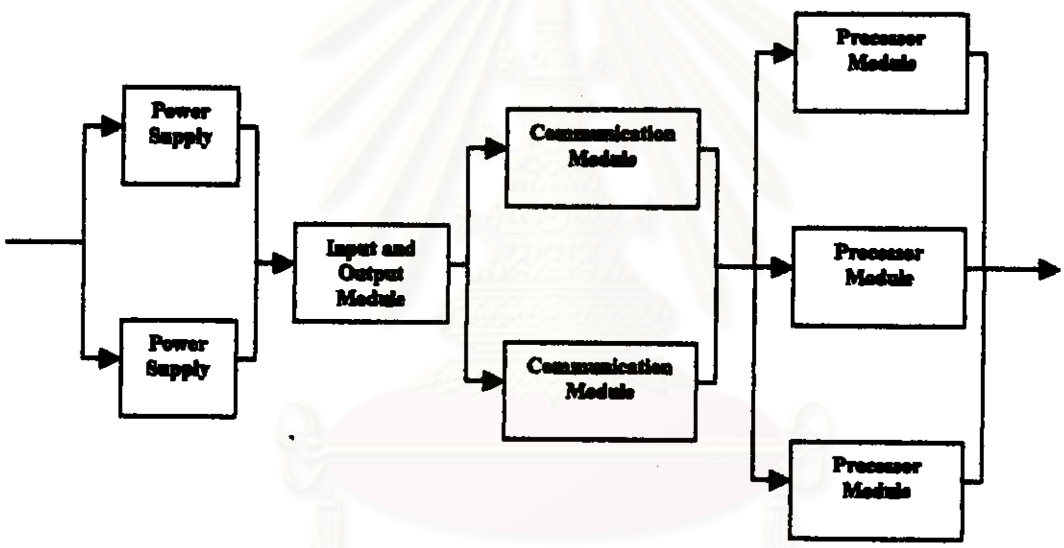

Figure 4.8 Reliability block diagram for individual process station where redundancy has been used for power supply, communication module and triple redundancy has used for processor module.

From figure 4.6 the system reliability of the reliability block diagram of this configuration is $\mathbf{R}_{sys} = \mathbf{R_1{*}R_2{*}R_3{*}R_4}$. Hence, the system reliability of an individual process station of K series according to the reliability block diagram in figure 4.6, can be calculated as follow:

$$R_{sys} = R_1 * R_2 * R_3 * R_4 \quad (4.5)$$

$$R_{sys} = (0.980198673)*(0.974684913)*(0.996879877)*(0.998705501) \quad (4.6)$$

Hence, R_{sys} = 0.951171054 (According to reliability block diagram in figure 4.6)

From figure 4.7 the system reliability of the reliability block diagram of this configuration is $R_{sys} = R_1*R_2*R_3*(1-[1-R_4]^2)$. Hence, the system reliability of an individual process station of K series according to the reliability block diagram in figure 4.7, can be calculated as follow:

$$R_{sys} = R_1*R_2*R_3*(1-[1-R_4]^2) \quad (4.7)$$

$$R_{sys} = (0.980198673)*(0.974684913)*(0.996879877)*(1-[1-(0.998705501)]^2) \quad (4.8)$$

Hence, R_{sys} = 0.952402344 (According to reliability block diagram in figure 4.7)

From figure 4.8 the system reliability of the reliability block diagram of this configuration is $R_{sys} = (1-[1-R_1]^2)*R_2*(1-[1-R_3]^2)*(1-[1-R_4]^3)$. Hence, the system reliability of an individual process station of K series according to the reliability block diagram in figure 4.8, can be calculated as follow:

$$R_{sys} = (1-[1-R_1]^2)*R_2*(1-[1-R_3]^2)*(1-[1-R_4]^3) \quad (4.9)$$

$$R_{sys} = (1-[1-(0.980198673)]^2)*(0.974684913)*$$
$$(1-[1-(0.996879877)]^2)*(1-[1-(0.998705501)]^3) \quad (4.10)$$

Hence, R_{sys} = 0.974293259 (According to reliability block diagram in figure 4.8)

In table 4.3 on the next page, it shows the reliability, which is the result of each case from the calculation in the previous paragraph. It shows a trend of reliability from no redundancy at all level of equipment, which is increasing to the triple redundancy case. The graphical picture in figure 4.9 is much clearer to show the increasing trend of reliability because of the redundancy implementation.

Different Configuration in each process station	No Redundancy at all level of equipment	Double Redundancy Only in controller area	Double Redundancy for the case study	Triple Redundancy in additional from the case
Reliability	**0.951171054**	**0.952402344**	**0.974291268**	**0.974293259**

Table 4.3 The reliability of each case of the different configuration in the individual process station of K series

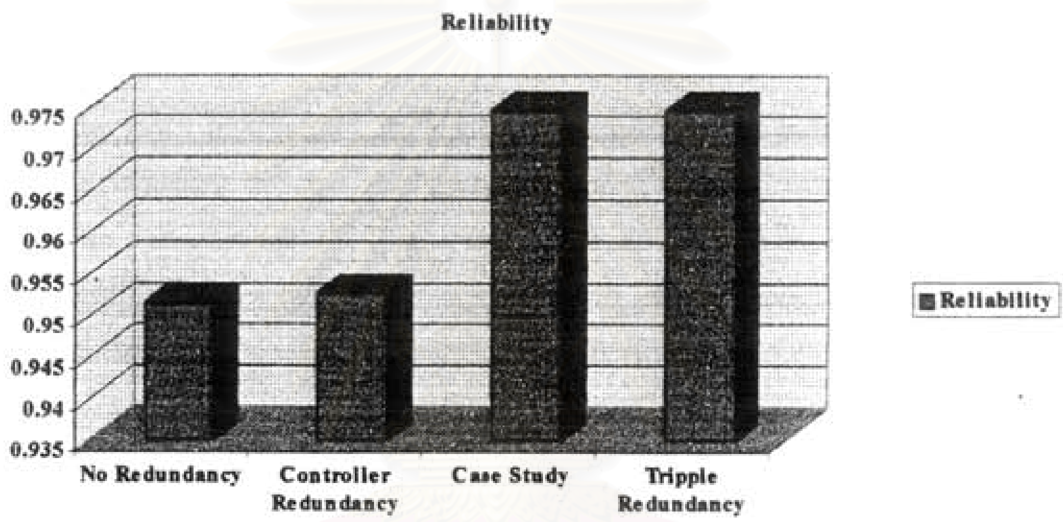

Figure 4.9 The graphical picture of the reliability of each case which is calculated in the previous paragraph.

From figure 4.9, the trend of the reliability in each configuration of the process station of **K** series is increasing according to the implementation of the hardware redundancy. Anyway, when we look over the reliability of the case study compare with the reliability of triple redundancy in the controller area, the reliability from both cases has a small different. Hence, the reliability of the implementation of the redundancy in the controller area by using the triple redundancy indicates that it does not so much effect to the increasing of the system reliability of the whole process station. If the designed engineer need to increase the system reliability of the individual process station by using the triple redundancy, he must ask himself that how much reliability that he can accept against the increasing cost of additional hardware.

The system reliability of each individual process station is blocked by the short MTBF of the input & output module which has the MTBF = 39 years. So, if we need to increase the system reliability of the whole individual process station, it's much better to implement the redundancy to the input & output module instead of the using of triple redundancy in the controller area. Anyway the MTBF of the input & output module in the case study, has confirmed from the DCIS vendor that it is the worst case data. From the past experience, the input & output module area have never been used any redundancy implementation to increase the system reliability.

The result of reliability for system prediction in each case of the previous paragraph indicates that the implementation of the redundancy equipment can improve the system reliability. Hence, in the area, which is an important part of the DCIS controller, the redundancy can be used to improve the system reliability. However, the MTBF of the component, which is used to perform each individual process station of DCIS, is also important to result the of the system reliability prediction.

4.5 The Problems of DCIS Configuration Design

EGAT always has a problem of DCIS configuration design in all new power plant projects. The problem of DCIS configuration design, which is always discussed and it is always a serious problem for EGAT's C&I engineer, is the partitioning of the DCIS controller. What is the partitioning of the DCIS controller? It will be explained in the following paragraph.

4.5.1 Partitioning of the DCIS Controller

As it was explained in Chapter 2 that **DCIS** is the abbreviation of Distributed Control and Information System. Some abbreviation of the same thing as DCIS is DCS. It's also written in many textbooks. So if anyone see the word DCIS and DCS, it refers to the same thing. The general configuration of DCIS is shown in figure 4.10. DCIS composes of four major parts, which are human machine interface, communication, controller and field input/output device. The controller is one of the most important parts of the DCIS.

The principle of the DCIS is to distribute the entire tasks of a plant control system into hardware part of microprocessors base device, which was named the DCIS controller. The partitioning of DCIS controller is the distribution criteria to specify power plant process control software into the hardware, which will be implemented the process control tasks to perform the entire DCIS.

The outcome of the DCIS partitioning is the amount of the DCIS controller and its specific process control tasks, which will be implemented. The benefits of DCIS partitioning are to minimize the affect of controller failure to the power plant process control when the controller failure occurs and to increase the power plant operation availability. If some controllers fail its operation, the impact of the controller failure will affect only a small portion of the total plant control system. Furthermore, if we do well on the partitioning of DCIS controller, the power plant operation will be take smaller time to recover the affect of failure during down time period of the power plant operation.

4.5.2 Problem, which always occurs during DCIS configuration design

The problem, which always occurs during the DCIS configuration design, is the partitioning of the DCIS controller. EGAT needs the contractor who does the implementation of the DCIS for power plant control system to distributed the power plant process control tasks into some amount of the DCIS controllers which EGAT think that it fits for the reliability and plant availability.

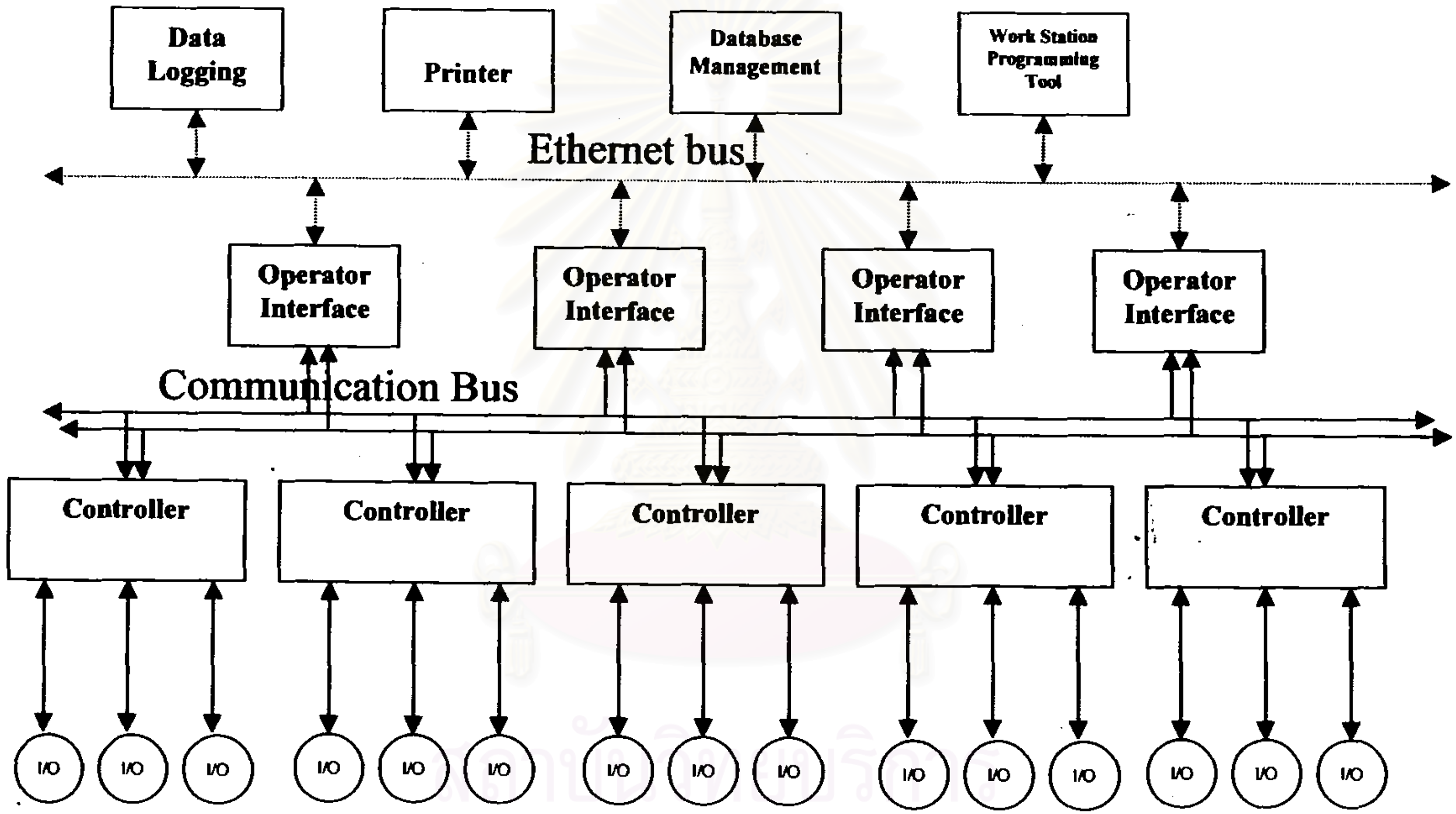

Figure 4.10 The picture which shows the four major parts of the DCIS configuration

But the contractor looks from their site to minimize the initial cost of controller implementation. They try to negotiate at the beginning of the kick-off meeting during the engineering phase of the power plant project to reduce the amount of the DCIS controller as many as possible.

The opinion of EGAT engineer needs the contractor to partial the power plant process control tasks into the distributed controllers base on the safe operation of power plant process control, maximize the reliability & availability of the power plant process operation and DCIS system. The way that the contractor needs to do is to group all power plant processes, which they think that it can be grouped together into the same controller and omit to talk about the reliability & availability of power plant process operation. By this way, they can minimize the amount of the DCIS controller by omit to do the necessary function, which EGAT requires in the Technical Specification of the power plant project.

If the contractor follows the requirements of EGAT, they have to spend much more initial costs on the additional number of the DCIS controller. Hence, the conflict between these two parties about this topic always occurs at the beginning of the kick-off meeting during the engineering phase in every new power plant project. This problem never has any clear support reasons which base on the reliability & availability aspects to achieve the highest reliability and availability of the DCIS and power plant operation.

The concept of the partitioning of DCIS controller is always discussed during the negotiation period of the engineering meeting. The major topic of the discussion is the reliability and availability of the DCIS controller, major mechanical and electrical equipment (such as Boiler Feed Pump, Main Transformer, Incoming Feeder of the electrical system and plant protection system), which is needed for the safety operation of the power plant process control.

From EGAT point of view, the mechanical equipment, which is designed as standby or redundant equipment, has a higher capital cost more than ten times when we compare to the unit price of the DCIS controller. Hence, it has a question among the engineering staff of EGAT that if we specify to use any standby mechanical or electrical equipment to increase the availability of the power plant operation, why this standby concept is blocked by the limitation of the small amount of the DCIS controllers? Moreover, the affect of this limitation could be a bottleneck inside DCIS system.

If the implementation of the power plant processes into the DCIS controller does not have any considerations about the reliability and availability of the power plant process operation, it may causes a wide failure area in the power plant process when any DCIS controllers fail its operation. Hence, when we need to discuss about the topic of reliability and availability of the DCIS configuration, we have to concentrate to the reliability and availability of the DCIS controller in parallel with the power plant processes operation.

From the previous paragraph we can conclude the problems of DCIS configuration design, which concentrate to the partitioning of the DCIS controller as follow:

- No clear design criteria to do the partitioning of DCIS controllers, which fit for power plant availability and maximize the reliability of DCIS controllers and other main equipment in power plant process.

Hence, the target of this thesis research is to develop the criteria for the DCIS configuration design that fit for power plant availability and maximize the reliability of DCIS controllers and other main equipment in power plant process.

4.6 The DCIS Configuration Design Process

In order to do better understanding that how DCIS configuration design can be performed, the typical way to do the DCIS configuration design process which concentrate to the partitioning of DCIS controller can be explained step by step as follow:

4.6.1 To Determine the input / output of the power plant process from **Piping & Instrumentation (P&I) Diagram** by separation into its process area.

4.6.2 Identify the power plant process. Normally, the power plant generation process can be identified to four major processes which are steam generation process, turbine generation process, burner management process, and balance of plant. Hence, we can estimate the initial number of DCIS controller by using these major processes of power plant as a guideline, then distribute the power plant processes, which are identified into the roughly estimated number of the DCIS controllers.

Moreover, the DCIS of the power plant must consists of the controllers which use to interface to any autonomous or standalone control system, the controllers which are used for 2 out of 3 plant protection concept and off line controller.

Note 4.1: Off line controller is the DCIS controller, which normally doesn't use for any operation activity. It uses for the modification or maintenance work purposes. Maintenance engineers can do any modified logic implementation into this off line system during the plant operation, until they believe that their modification work does the properly operation function. Then they will down load the modification software into the active controller of the DCIS pass through the DCIS communication network.

4.6.3 Critical evaluation the capability of the DCIS controller to find the roughly number of the DCIS controllers which are fit for the maximum reliability of DCIS configuration and optimize the maximum plant operation availability.

4.6.4 By using the technical information of the DCIS manufacturer who provides the hardware and software tool to implement the entire DCIS in addition with the result from item 4.6.1 to 4.6.3, the DCIS configuration, which is the preliminary hardware design, will be performed. Finally, with the need on hardware and software for human machine interface and data logging from the technical requirement of the DCIS manufacturer, it will be integrated to perform the entire DCIS configuration. Anyway, the human machine interface and data logging part are not in the scope of this thesis research.

Note 4.2: This typical way to do the DCIS configuration design process comes from the past experience of doing the DCIS configuration design in the Power Plant Control System Engineering Department of the Electrical and Control System Engineering Division which is under the Engineering Business Unit of EGAT. This typical way is performed by take into a consideration of C&I engineer who has a past experience in the Power Plant Control System Engineering Department.

4.7 The Reliability Requirements

For the reliability requirements of the DCIS configuration design, it is an important guideline to specify the boundary of the DCIS configuration design, which base on the reliability and availability aspects. Normally, EGAT never use the clear reliability requirements to do the DCIS configuration design. Hence, a creation of the reliability requirements of the DCIS configuration design, which specify to the partitioning of DCIS controller, will be very useful to do the criteria of the DCIS configuration design for power plant.

By using the past experience, opinion of control & instrumentation engineer of EGAT and the way to create the reliability requirements from the reliability and maintainability module of the Regional Centre for Manufacturing Systems Engineering, the reliability requirements for the DCIS configuration design can be created as in the following paragraph.

4.7.1 Reliability Requirements for the Case Study

The reliability and maintainability requirements are defined by the utilities at the beginning of the acquisition process during the conceptual design phase [3]. In Figure 4.11, Armand A. Lakner and Ronald T. Anderson show the system life cycle in the Reliability Engineering for Nuclear and Other High Technology Systems, a Practical Guide [3]. From this system life cycle, it indicates that a good design process which base on the reliability and availability aspects need a good plan, guide, assess and control along the system life cycle. Reliability must be treated as a fundamental performance parameter beginning with the design and specification phases of the system development and continuing into and during the useful operating of the system [3].

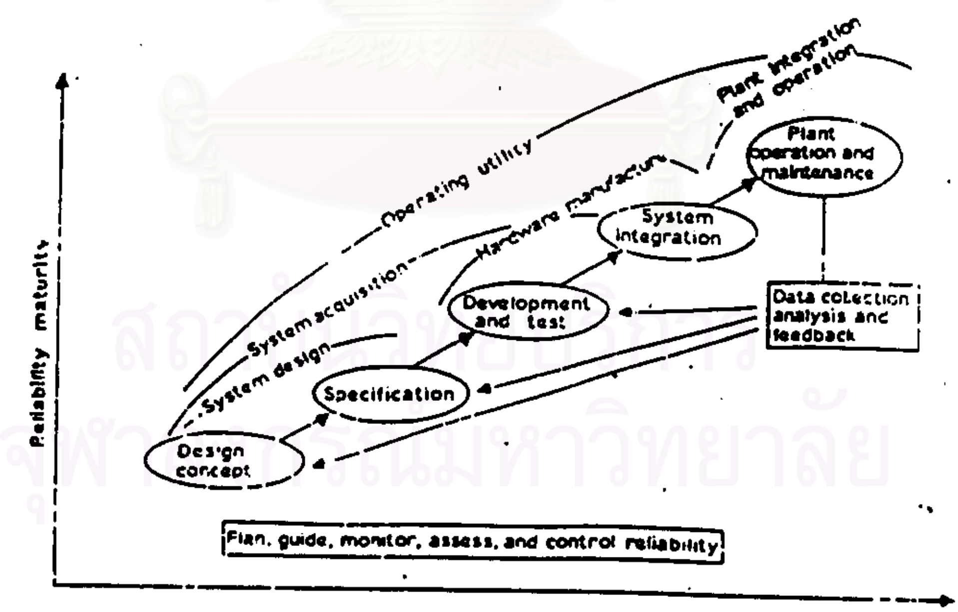

Figure 4.11 The system life cycle (Source from Armand A. Lakner and Ronald T. Anderson, Reliability Engineering for Nuclear and Other High Technology Systems, a Practical Guide) [3].

The system life cycle of power plant also has the same details as the system life cycle, which shows in figure 4.11. It composes of feasibility study, design concept, specification, detail design, development and test, system integration and plant operation & maintenance. So that the creation of the reliability requirements have to consider for the whole life cycle to increase the reliability, availability and maintainability of the system.

The study of this thesis research plays important role to the initial state of the product life cycle, which is design concepts and specification. This period is so important to the design, which base on the reliability and availability aspects. If we can do well on the initial state of the life cycle, the design will meet the minimum requirements at the lowest cost for the whole life cycle.

4.7.2 List of the Reliability Requirements

The list of the reliability requirements, which is presented in this thesis paper, is the specific requirements only for the creation of the criteria of the DCIS controller configuration design. Therefore, almost details of the reliability requirements are about the operation of DCIS controller and its peripheral devices. The creation of this list has been used the past experience of the control & instrumentation engineers of the power plant control system engineering department and the current technical requirements of the DCIS in the Technical Specification of Krabi thermal power plant project. Hence, the reliability requirements can be created as follow:

- DCIS Controller Redundancy
- DCIS Communication Redundancy
- Power Supply Redundancy
- Process Allocation of DCIS controller
- Minimize the failure area because of the controller failure
- Minimize the MTTR in order to increase the system availability
- Maximum security for personnel and equipment
- High availability of the plant operation

- Hierarchical structure of the control systems
- Support dual design concept for the equipment in power plant process control
- Support standby concept for the equipment in power plant process control
- 2 out of 3 Plant Protection concept for the power plant

4.8 The Partitioning of the DCIS Controllers for the Case Study

The partitioning of the DCIS controllers for the case study in this item has an intention to show the way to do the partitioning of the DCIS controller for the case study. The amount of the DCIS controllers from this partitioning procedure is only the preliminary number of the DCIS controller. There are some more impacts and external factors, which effect to this amount of the DCIS controller. Hence, the partitioning of the DCIS controllers for Krabi thermal power plant project can comply with the previous steps in item 4.6 as follow:

4.8.1 From the P&I diagram of Krabi thermal power plant, which is attached in the appendix, the estimated input/output signals from this typical P&I Diagram, is around 20,000 signals. This number is only an estimation. During the detail design of the DCIS configuration, which is the next step of the engineering work, there are some more factors which will effect to this amount of the input/output signal.

Hence this roughly number of input/output signals will give an overview picture of the whole signals of the entire DCIS system for Krabi thermal power plant. This roughly number will be used to perform the entire Krabi thermal power plant control system. The input/output signals information will be used to evaluate together with the capability of the DCIS controller according to the handling capability of its input/output signals, in order to find a good fit DCIS configuration.

Note 4.3: The P&I Diagram that is attached in the appendix of this thesis paper, is only some small part. This P&I Diagram are only an example for the reader to give an idea about the diagram. The whole P&I Diagram compose more hundred of paper. So it is impossible to attach all in the appendix.

4.8.2 From Chapter 3, it is a design concept of Krabi thermal power plant project. From this design concept, it explains about Krabi thermal power plant process. If anyone who never have any background experiences about the power plant processes, it is so complicate to understand in the details. Anyway, we can simplify and categorize the whole power plant processes into some major areas as follow:

- Turbine Generation Process
- Steam Generation Process
- Burner Management Process
- Balance of Plant Process
- Plant Protection System
- Interface to Other Autonomous and Standalone Control Systems

Note 4.4: Another autonomous or standalone control system is the system, which is not done its control system by the DCIS. It has a standalone control system or control system package integrates into its operation system. The examples of another autonomous or standalone control system in power plant process control are the autonomous or standalone control system for turbine control, conveyor system, water treatment system, ball mill system, de-watering system, air compressor system, etc.

4.8.3 From the technical information of K series, which was attached in this thesis paper, the capability of K series DCIS controller can handle the approximate 5,000 input / output field signals.

4.8.4 From item 4.8.1 to 4.8.3, we can use this information to perform the initial number of the DCIS controller. Hence the initial number of the DCIS controllers which is a roughly number to perform the entire DCIS system for Krabi Thermal Power Plant are as follow:

- One Controller for Turbine Generation System
- One Controller for Steam Generation System
- One Controller for Burner Management System
- Two Controller for Balance of Plant System
- Three Controller for Plant Protection System
- One Controller for Interface to the Other Autonomous System

From the result of item 4.8.4, we can see that the number of the DCIS controller should be 9 controllers. But in the real case, EGAT considers about the reliability aspects of the DCIS configuration in parallel with the availability of the power plant process operation, so the number of DCIS controller must be increasing to serve the reliability requirements.

From the reliability requirements, which can be listed in item 4.7.2, EGAT need to use the redundancy concept to increase the reliability of the DCIS by doing the redundancy only to the important areas of the DCIS system, which are processor, communication and power supply area. From the technical information of the DCIS vendors in the current market, almost DCIS vendors can provide the redundancy for processor, communication and power supply parts. Some DCIS vendors provide the redundancy for these parts as their standard equipment.

According to item 4.6.2 in the detail of process allocation, EGAT need to distribute the implementation of the software for power plant process control into an individual controller as many as possible. The major power plant processes are already listed in item 4.8.2. Hence, by using the power plant processes as a guideline, the initial number of the DCIS controllers has been performed in item 4.8.4.

The other interesting area is an implementation of opened-loop and closed-loop control into the DCIS controller. Power plant processes are composed of too many process controls. Some processes are composed of both opened-loop control and closed-loop control, some are composed of only opened-loop or closed-loop control. However, the power plant process control can succeed its operation, it must comply even opened-loop or closed-loop control in any power plant processes.

It does mean that if one process control which composes of both opened-loop and closed-loop control, both must be integrated into the same DCIS controller. If the same process is divided into the separated controller for opened-loop control and closed-loop control, the failure of the process will occur when one controller has failed.

The advantages of the implementation of the opened-loop and closed-loop control into the same DCIS controller are reducing the complexity of the cabling system from the field device into the DCIS. Furthermore, it will not affect to other power plant process control if the failure of the controller occur, easy for maintenance and easy for software modification work. Anyway, the partitioning of the DCIS controller on this interested area also has to consider the availability of the power plant operation.

Hence, the control software of the same process should be implemented into the same DCIS controller to minimize the failure chance of the power plant process, when the failure of the DCIS controller occurs during the operation period. Furthermore, we must consider to the process allocation into each individual DCIS controller because we can minimize the MTTR of the DCIS system when the failure of DCIS controller occurs. By this way, the availability of the power plant process control will be increased.

In the design concepts of Krabi thermal power plant, the dual design concept is applied to use with the main equipment or system, which is so important to the power plant process control in order to increase the power plant reliability and maintainability. Moreover, the standby concept is also applied to use in this project because of the same reason. So in item 4.7.2, the reliability requirements are listed about the support of both dual design concept and standby concept for the main equipment or system of power plant process.

The examples of main equipment in power plant process are Boiler Feed Pump, Induced Draft Fan, Forced Draft Fan, Electrical Incoming Feeder, Electrical Bus Feeder, Station Service Transformer, etc. For the major mechanical equipment that is Boiler Feed Pump, it is the major mechanical equipment which is in the steam turbine generation process. From the P& I diagram of Krabi thermal power plant, this project has three Boiler Feed Pumps. Its capacity is 2*50% capacity and one pump for standby. The Boiler Feed Pump is the equipment that uses the standby concept to increase the steam turbine generation process reliability and availability.

The other important area, which is needed to distribute the process control software into the different individual controller because of dual design concept, is the electrical service system, which is in the Balance of Plant process. Even power plant is a plant that generate the electricity, it also need the reliable electricity source to supply for in house-plant operation.

Normally, the electricity service system is designed at least two power source in all level of the electrical system such as high voltage incoming feeder, power transformer, low voltage incoming and outgoing feeder to supply in the power plant. Hence, in order to serve this dual design, at least two DCIS controller for balance of plant process shall be provide to support this dual design concept according to the list of the reliability requirements in item 4.7.2.

For the other major mechanical equipment, which is Steam Turbine, Boiler or Booster Fan, these are too expensive to do the standby equipment. Hence, EGAT do other thing to increase the reliability and availability of this equipment such as the implementation of the conditioned monitoring system to do the predictive maintenance. The purpose is to predict any failures, which will be occurring during the operation period, so we can maintain the operation of this equipment at the highest performance and efficiency along its operation period and minimize the down time period in order to increase the plant availability. Anyway, it doesn't in the scope of this thesis research.

The DCIS partitioning problem which always discusses for the distribution of the control software, is the implementation of the Boiler Feed Pump control software into each individual controller. The contractor need to minimize the number of the controller by asking EGAT to combine all control software for boiler feed pump into the same DCIS controller. By this way, they don't need to provide more hardware of DCIS controller according to the reliability and availability requirements. When EGAT discusses this item together with the contractor about the configuration of DCIS controller in the reliability and availability aspects, it always has no clear answers, which base on the reliability and availability basis.

4.9 The application of the reliability modeling for system prediction to the problem area according to the reliability requirements of the case study

From the way to calculate the system reliability of each individual process station for the case study and the reliability requirements in item 4.7, which are repeated again as in the following lists, the problems of the DCIS configuration design will be analyzed.

- DCIS Controller Redundancy
- DCIS Communication Redundancy
- Power Supply Redundancy
- Process Allocation of DCIS controller
- Minimize the failure area because of the controller failure
- Minimize the **MTTR** in order to increase the system availability
- Maximum security for personal and equipment
- High availability of the plant
- Hierarchical structure of the control systems
- Support dual design concept for the equipment in power plant process control
- Support standby concept for the equipment in power plant process control
- 2 out of 3 plant protection concept

From these requirements, the **K** series DCIS, which will be implemented to use for Krabi thermal power plant project, has been used the redundancy in the area of power supply, controller and communication module. Hence, for the requirement of redundancy, normally it has no problem during the engineering meeting between EGAT and the Contractor as it was explained about the problem area at the early of this chapter.

The maximum security for the plant personal does not in the scope of the study. It is in the area of function requirement of the control software of the DCIS. The hierarchical structure of the control system, the support dual design concept for the equipment in power plant process control, the support standby concept for the equipment in power plant process control and 2 out of 3 plant protection concept are impacts which has an effect to the amount of the DCIS controller. These impacts concern to the reliability for the other equipment operation in power plant process control. For furthermore detail of these impacts, it will be discussed in the next Chapter which is the development of DCIS configuration design criteria.

The problems ,which always occur, are in the area of process allocation of DCIS controller, minimize the failure area because of the controller failure, high availability of the plant operation. These problem areas will be analyzed and find the good fit of DCIS configuration by using the reliability modeling for system prediction and the result of the system reliability of the individual process station of K series, which is calculated in item 4.4.

4.9.1 Process Allocation of DCIS Controller, Minimize Failure Area and High Availability of the Plant Operation

The way to do the process allocation into each individual process station have to consider two factors which are the reliability of the concerned DCIS process station and the consequence of failure in power plant process which does occur because of controller failure. The highest reliability will be calculated for the DCIS configuration, which all of the control software is implemented in as fewer numbers of DCIS controller modules as possible.

On the other hand of this approach is that when a failure does occur, a very large part of the plant is affected. Hence, the minimizing the probability of a failure has maximized the consequences of the failure. By using the system reliability of the individual process station and the reliability modeling for system prediction, we can see the reliability for the case of process allocation as follow:

- **The same process area should be implemented into the same controller**

From the system reliability of the individual process station for the case study which is calculated in item 4.4,the system reliability is $\mathbf{R_{sys} = 0.974291268}$.

When we have consider one process of power plant process control. If we implement the control software for the power plant process into the same DCIS controller the result of system reliability will equal to the system reliability of the individual process station, which is $\mathbf{R_{sys} = 0.974291268}$

But if we separate the implementation of the same control software for the same power plant process into the two different individual controllers, the result of system reliability will equal to **{(R_{sys})* (R_{sys})} = 0.949243474 where R_{sys} = 0.974291268**. Hence, if you compare the reliability of both cases you will found that the reliability of the way to implement control software of the same power plant process into the two different individual controllers will be less than the reliability of the implementation of the software into the same controller. The graphical picture of both cases can be shown on figure 4.12 on the next page.

The implementation of the control software of the boiler feed pump, should be implemented into the same controller or separate into each individual controller.

It was explained in Chapter 3 that there are three Boiler Feed Pumps for Krabi thermal power plant project. The intention of the C&I engineer of EGAT need to implement the control software of each boiler feed pump into the different individual DCIS controller. These three boiler feed pumps are needed for the operation of the steam turbine generation process. Two of these pumps must be in operation and one is in standby mode.

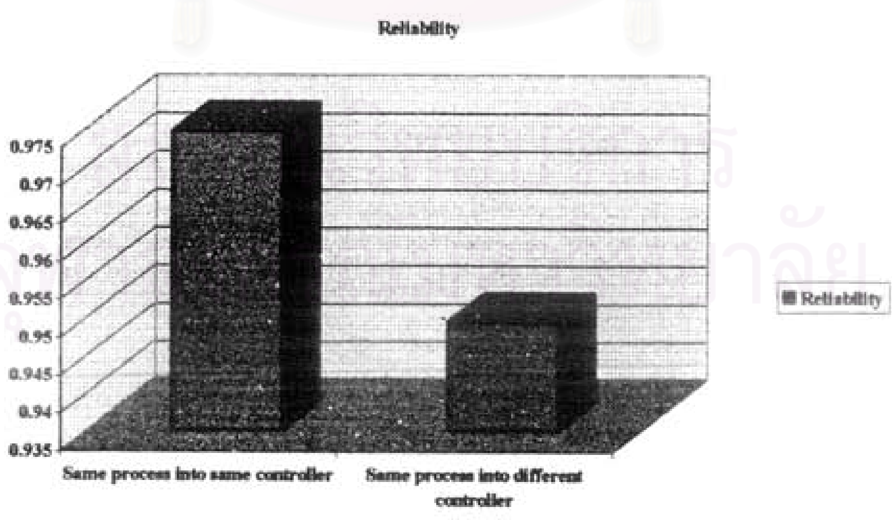

Figure 4.12 The comparison of the reliability between the implementation of the control software of the same process into the same controller and the different controllers.

Hence, if we implemented the control software of these pumps into three different individual controllers, these three different controllers must be available during the plant operation. The relation of the system reliability of this group of controllers is a series modeling. Therefore, the calculation of the system reliability for this case will be calculated as follow:

In the case of the control software for the whole group of boiler feed pumps is implemented into the same DCIS controller, the result of system reliability will equal to the system reliability of the individual process station, which is $\mathbf{R_{sys}}$ = **0.974291268**.

In the case of the control software for each boiler feed pump, is implemented into three different DCIS controllers, the result of system reliability will equal the three series modeling of the system reliability of the individual process station. Hence, the calculation will be equal to $\{(\mathbf{R_{sys}})^* (\mathbf{R_{sys}})^*(\mathbf{R_{sys}})\}$ = **0.924839628 where $\mathbf{R_{sys}}$ = 0.974291268**. In figure 4.13, it shows a graphical picture of the comparison for both cases of control software implementation of the boiler feed pump.

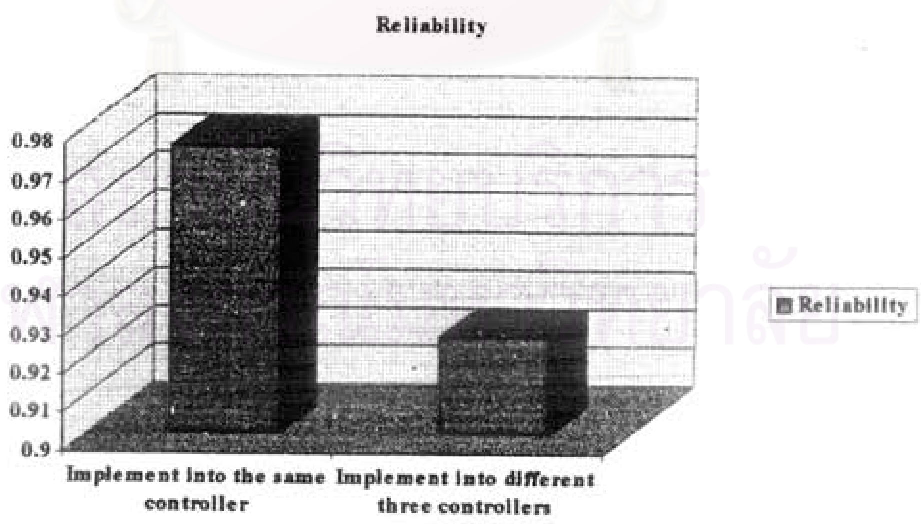

Figure 4.13 The comparison of the reliability between the implementation of the control software into the same controller and the different three controllers for the case of boiler feed pumps.

In figure 4.13, it shows that the implementation of the control software of the boiler feed pump into the same DCIS controller has higher reliability rather than the implementation of the control software into three different DCIS controller. However, even the implementation into the same controller has higher reliability rather than different three controllers, it may cause a wide failure area of the power plant process control. Because the boiler feed pump is the important mechanical equipment which may cause a plant trip if we loose the control of two boiler feed pumps at the same time.

Hence, the way to implement the control software of the major mechanical equipment which may cause a plant trip into the different DCIS controller, still believe among the C&I engineer of EGAT that it has a better reliable configuration rather than the implementation the control software into one controller. However, the support reason must be changed from the reliability aspects to the minimized failure area and consequence of failure in power plant process and we can operate the rest boiler feed pump even one redundancy DCIS controller for the boiler feed pump has failed.

- **The opened-loop control and closed-loop control of the same process should be implemented into the same controller or separate to different controller.**

For the implementation of the opened-loop control and closed-loop control of the same power plant process into the same controller, the result of system reliability of this case will equal to the system reliability of the individual process station, which is $\mathbf{R_{sys} = 0.974291268}$.

If the implementation of the opened-loop control and closed-loop control of the same power plant process into the different DCIS controllers, the system reliability will depend on the amount of the controller that the control software of opened-loop and closed-loop will be implemented. If two separated DCIS controllers are used to implement the opened-loop and closed-loop control, the system reliability will equal to $\{(R_{sys})^* (R_{sys})\}$ = **0.949243474 where R_{sys} = 0.974291268.**

If the implementation of the control software of the opened-loop and closed-loop control of the same power plant process are implemented into more than two DCIS controllers, the calculation is follow the series modeling and the result of the system reliability will be decreasing as shows in figure 4.14.

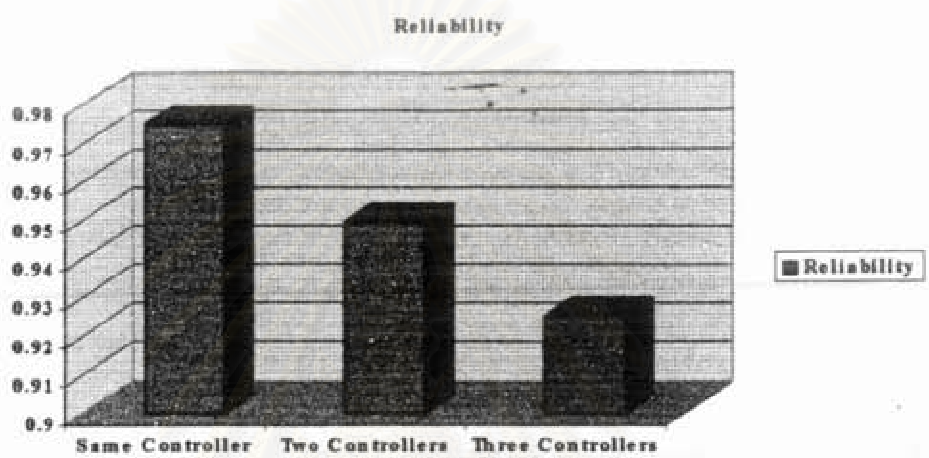

Figure 4.14 The comparison of the system reliability of the using only one DCIS controller and more controllers to implement the opened-loop and closed-loop control of the same power plant process.

The graphical picture of the reliability of each case in figure 4.14 indicates that if the number of the DCIS controller, which is used to implement the software control of the same process is higher, the system reliability of the considered DCIS controller is decreasing. Therefore, the control software of the opened-loop and closed-loop control of the same power plant process should be implemented into the same DCIS controller as many as possible.