Chapter 5

Development of DCIS Configuration Design Criteria

5.1 Introduction

From the discussion of the case study in Chapter 4 and the basic principles in Chapter2 and 3, the DCIS configuration design criteria will be performed in this chapter. Before the development of the design criteria for the DCIS configuration will be explained, it's better to remind that only the case of Krabi oil-fired power plant will be considered and the research will be confined to the partitioning of DCIS's controllers within the configuration design.

From the analysis of the case study in Chapter 4, the design criteria for the DCIS configuration can be created to meet the requirements that fit for the reliability aspect, availability aspect, current technology capability and the need of design engineer. The explanation in this chapter will show the creation of the design criteria for the DCIS configuration. Firstly, the major impacts to the design criteria of DCIS configuration will be explained. Secondly, the design criteria will be created from the result of the analysis in Chapter 4 in addition with the major impacts of the DCIS configuration design. Finally, the limitation of the using of the design criteria will be explained.

Power plant process control is so complex and hard to understand for people who never have any background experiences. In this Chapter, it's only a small area of the DCIS for the power plant control system. Hence, the design criteria for the DCIS configuration in this chapter will be considered only in the study area, which is the DCIS controller and only the reliability aspects will be treated to perform the design criteria.

5.2 The Major Impacts to the Design of the DCIS Configuration

From the results of the analysis in Chapter 4, the major impacts to the design of the DCIS configuration, which specify to the controller area, can be listed as follow:

- The capability of the DCIS controller.
- The concept of the partitioning of the DCIS controller.
- The concept of the control system hierarchy.
- The concept of the plant protection system.
- The concept of dual design for main equipment.
- The concept of standby equipment
- The interfacing to other system.
- The safety factor which is used to limit the usage of DCIS controller capability.
- The response time of control software which is implemented into the individual controller of the DCIS.

5.2.1 The Capability of the DCIS Controller

The capability of the DCIS controller is one major impact to the DCIS configuration design. In the current market of the DCIS, it has so many vendors of DCIS such as ABB, Elsag-Bailey, Westinghouse, Foxboro, Honeywell, and Yokogawa, etc. These vendors are the front line of the automation business for the power plant control system. The capability of the DCIS controller can be discussed in many areas. Anyway, in this thesis research only the interesting area will be presented which is the input/output handling capability of each individual controller.

By using the current information of the available DCIS vendors for power plant control system in the electricity generation industrial market, the capability of the DCIS controller from these vendors have been compared as shown in table 5.1. From table 5.1, it shows the capability of the DCIS controller from the front line vendors in the current market. This information indicates that each DCIS controller has a different capability.

DCIS vendors	Controller Capacity/ Controller
K	≈ 5,700 Input / Output
A	≈ 1,500 Input / Output
B	≈ 3,000 Input / Output
C	≈ 1,750 Input / Output
D	≈ 1,250 Input / Output
E	≈ 1,280 Input / Output

Table 5.1 The DCIS capability from the front line DCIS vendors in the current Market. (Source from the DCIS manufacturer catalogs)

The information in table 5.1 is only an approximate number of input / output handling capability that the processor of the DCIS controller has a capability to handle. In the real case, there are so many type of input / output modules of the DCIS. These different types of the input/output module of the DCIS controller have a different handling capability. Hence, the information in table 5.1 is only an approximate capability and gives a roughly initiate idea about the handling capability of the DCIS controller.

Even the same software application of the power plant process control is implemented; the DCIS configuration still has a different figure because of the different capability of the DCIS controller. Hence, if the design engineer do the design of DCIS configuration, this information has a direct impact to the number of the DCIS controller. Design engineer must consider to the information of the capability of DCIS controller during their design process and treat this information together with the other impacts as in the following paragraph to perform the entire DCIS configuration.

5.2.2 The Concept of the Partitioning of the DCIS Controller

The concept of the partitioning of DCIS controller is applied to use in the design of the DCIS configuration to meet the control philosophy of EGAT which are maximum security for personnel & equipment, safe, reliable, efficient operation under all operation conditions and high availability of the plant operation. In the real case, the technical staffs of the DCIS vendors are the people who do the software implementation of the DCIS according to the requirements of their customer, which is EGAT. They can do the software implementation for DCIS in many ways according the design concept of EGAT, which can be achieved the same result of the control philosophy.

Hence, it is not so easy to specify the exactly way to do the DCIS configuration implementation. Moreover, the technology of the automation control for power plant has a rapid change with the product life cycle not more than 4 years period. Therefore, the specific outline of the DCIS implementation today may be an old fashion for tomorrow.

However from the analysis of the case study in Chapter 4, the concept of the controller partitioning also has a direct impact to the DCIS configuration design. The analysis from the previous chapter has shown that some of the reliability requirements of EGAT in the controller partitioning may cause the decreasing of the system reliability of the concerned process station.

Hence, design engineer must consider that what is the satisfied choice for them between system reliability and the consequence of failure in the power plant process control. The flow chart in figure 5.1 on the next page is the roughly idea of the comparison between both needs.

In the figure 5.1, there are some phases which is needed to clarify such as the consequence of failure. The consequence of failure is the affect of the DCIS controller failure to the power plant process control after the controller has failed its operation. The interesting point of the consequence of failure is the time to recover the power plant process control after the failure of the DCIS controller occurs.

From figure 5.1, it is an evaluation flow chart of the DCIS configuration design, which based on reliability of the DCIS controller and the consequence of failure. The first block is the process system design. The process system design is the entire power plant process, which will be implemented into the distributed DCIS controller. The second block is the identified block. The identification block is the way to do the DCIS controller allocation according to the power plant process control. The familiar name of the DCIS controller allocation in this thesis research is the partitioning of the DCIS controller.

The next two blocks in the flow chart are probability of failure and determine consequence of failure. The probability of failure is the reliability, which is calculated according to the considered DCIS controller configuration, which is designed by the design engineer. By using the reliability modeling for system prediction, the reliability of each DCIS configuration figure can be calculated. The result of the reliability calculation is the numerical result as shown in the critical analyzes in Chapter 4.

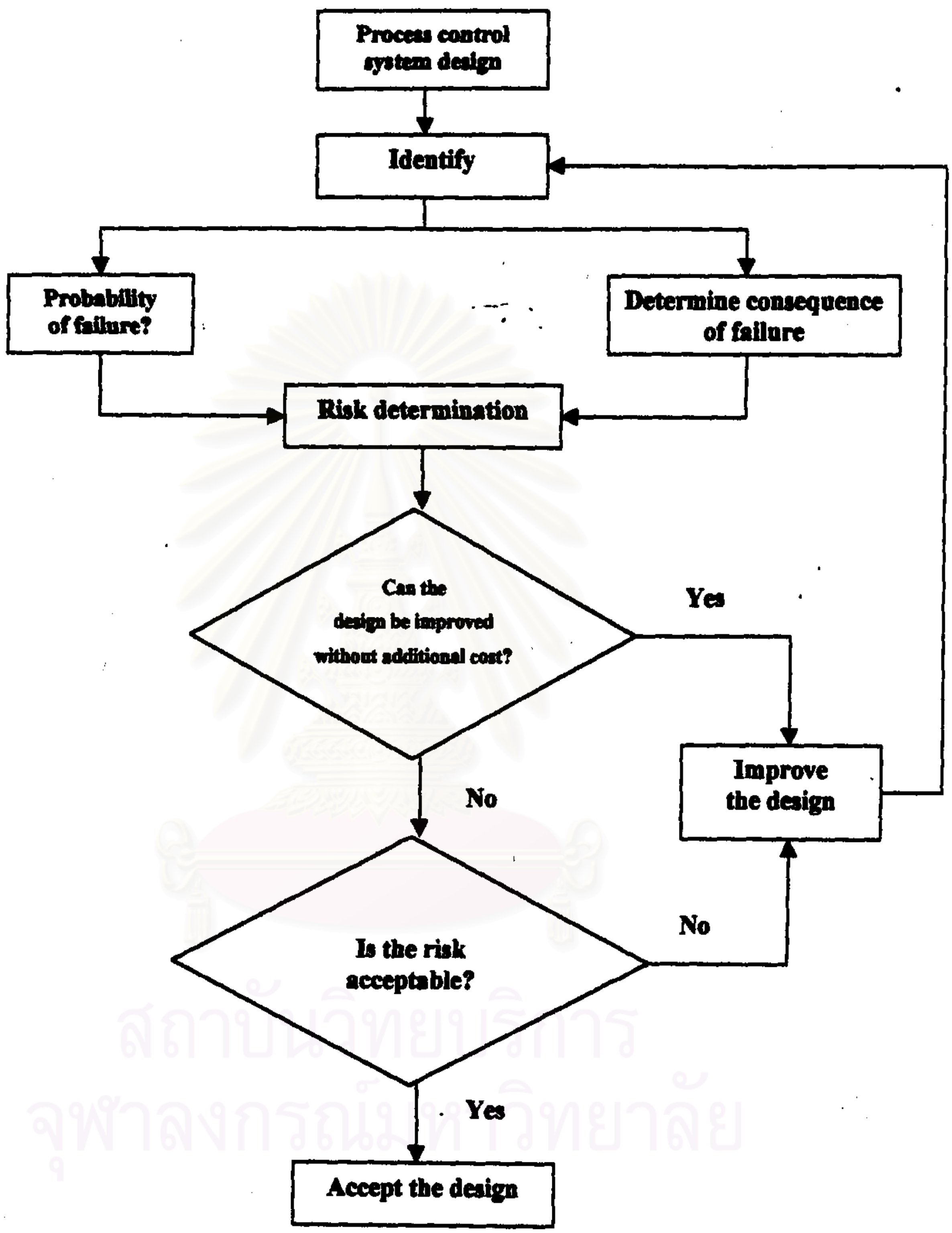

Figure 5.1 Flow chart shows the roughly evaluation idea to do the DCIS configuration design by comparing between probability of failure and consequence of failure.

The consequence of failure is the consequence of the power plant process control failure because of controller failure. Design engineer must consider to the consequence of failure which the DCIS controller according to the configuration of their design has failed. As it was explained in the previous paragraph that the consequence of failure is the affect of the DCIS controller failure to the power plant process control after the controller has failed its operation. The result of the consequence of failure consideration can be the cost of failure or the recovery time of the power plant process control after the power plant process control failed its operation because of the controller failure.

The design engineer must compare and evaluate these two factors that what is an appropriate choice for the power plant process control by using the risk determination block diagram which show in the flow chart of figure 5.1. How risk can be define? It depends upon the design engineer that how much risk that can accept among the availability of the power plant operation, the loss if the DCIS controller failures occur and the acceptable reliability of their DCIS configuration design.

After the compare and evaluation process between the probability of failure and the consequence of failure, if the design of the DCIS can be improved without any additional costs, we do the improvement and reconsider again for the comparison and evaluation process. If it has an additional cost for any changes of their design, the design engineer will consider that does their design without the improvement can acceptable? If it can not acceptable, it does mean that we have to pay additional cost to improve our design to meet the minimum requirement. Finally, the design of the DCIS configuration would be accepted.

5.2.3 The concept of the control system hierarchy

The control hierarchy is the steps of operation of the power plant process control. Figure 5.2 shows the example of the control system hierarchy of the coal-fired power plant of EGAT. In figure 5.2, it's very useful concept for the design engineer to do the process allocation by using the information of the control system hierarchy. Normally the control system hierarchy is composed of start up sequence, shutdown sequence, master key operation level, function group level, function sub-group level, function drive-group level and drive level.

Because of the control system hierarchy concept, the DCIS configuration needs an individual controller to do function of control system hierarchy. The DCIS controller that is implemented to do the function of control system hierarchy, can be claimed that it's a management controller for the power plant process control. Normally, the concept of control system hierarchy is applied to use with discrete control. Another name of the discrete control is opened-loop control, which is more familiar to the reader for this thesis research.

Although, the impact of the concept of control system hierarchy does not concern about the system reliability of the DCIS controller, which is a topic for this thesis research but the impact of this concept effect to the number of the DCIS controller. If the size of the DCIS controller is big enough, the concept of control system hierarchy can be implemented including into the same controller which is implemented other power plant process control.

However, the best location of the DCIS controller, which is used to implement this concept, must be considered by the design engineer to avoid any single failure that may cause plant trip. Moreover, it should be follow the control philosophy and operational concepts those are maximum security for personal & equipment, safe-reliable-efficient operation under all operational conditions and high availability of the plant operation.

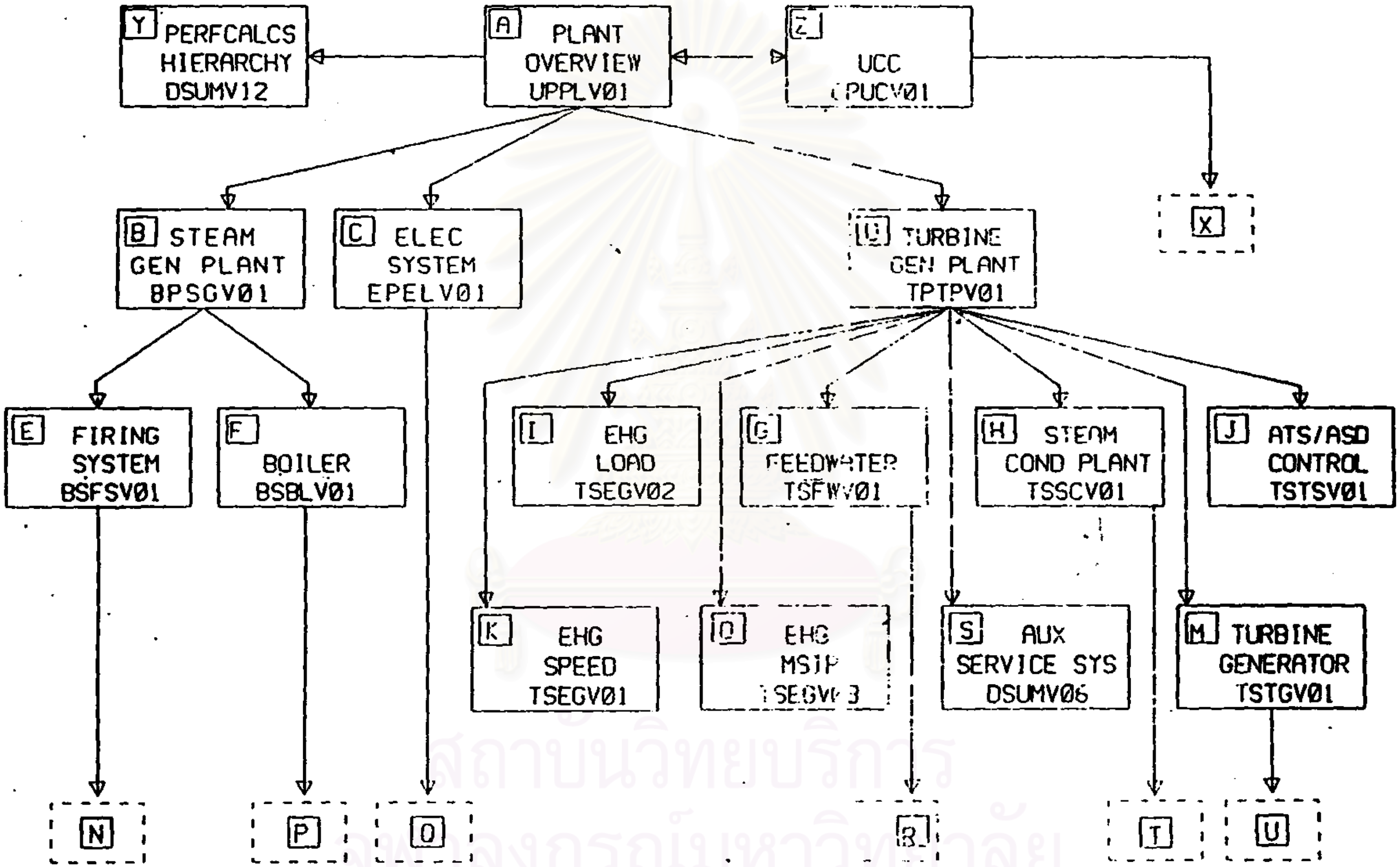

Figure 5.2 The example of the control system hierarchy of the coal-fired power plant

5.2.4 The concept of the plant protection system

In power plant process control, the application of 2 out of 3 plant protection system has been used to ensure the safety of the power plant operation. The principle of 2 out of 3 plant protection system come from the redundancy K out of N which has been explained in Chapter 2 of this thesis research. Because of the redundancy of the protection signal, the plant protection system needs three sets of hardware in every level of power plant operation. The DCIS controller is one part, which is used to perform the function of the plant protection system. Hence, at least 3 DCIS controllers with redundancy must be used to perform the plant protection system.

Figure 5.3 shows the roughly idea of plant protection system which is a current application that use in EGAT power plant for several years. The concept of the plant protection system is very important to the power plant operation. We can not omit to do this philosophy when we do the DCIS configuration design. If one power plant trip because of any malfunction of the power plant process control, it may be affect in a wide area. Anyway, if we do well on the plant protection system concept, we can limit the consequence of failure into the smallest area. Moreover some fetal failure of the power plant operation may cause the electricity loss in the wide areas of the whole country. Although, the scope of the study does not concern about this topic, this concept is way to ensure the power plant process operation at the highest reliability and availability. Hence, EGAT force to use three sets of hardware and software component in all levels for the plant protection system of every power plant project of EGAT.

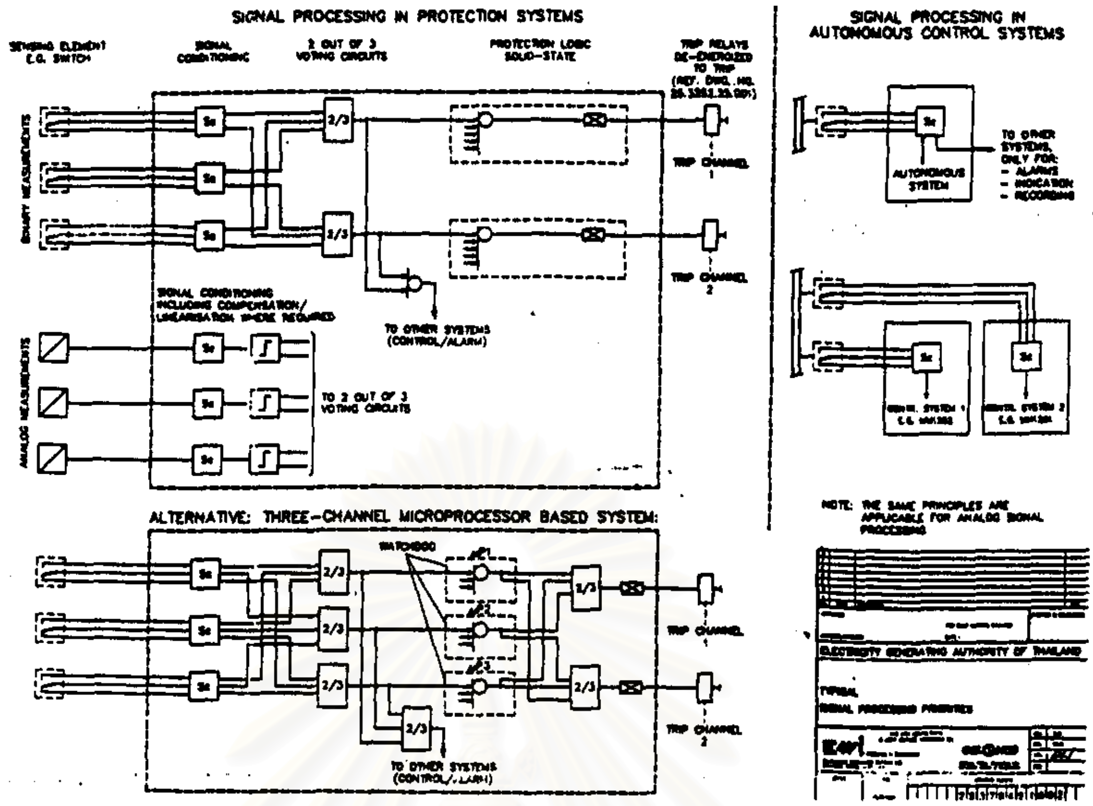

Figure 5.3 The concept of plant protection system which is a current usage in Krabi thermal power plant project [17].

5.2.5 The Concept of Dual Design for the Main Equipment

It was explained in Chapter4 about the concept of dual design for the main equipment. In order to increase the availability of the power plant operation, the main equipment of the power plant process (such as Boiler Feed Pump, Main Transformer, Main service feeder, Induced Draft Fan, Force Draft Fan, etc.) always design on the dual design concept. Hence, the DCIS controller also, must be designed base on this concept. The design engineer must consider to the implementation of the control software that it should support the dual design concept for the main equipment. This concept is an impact to the DCIS configuration design. At least two DCIS controller should be provided to support this concept in every power plant process control.

5.2.6 The Concept of Standby Equipment

It also was explained about the concept of the standby equipment in Chapter 4. The concept of standby equipment is an impact to the design of the DCIS configuration. Design engineer must consider to the implementation of the control software into the DCIS controller according to this standby equipment concept. According to the reliability requirement in Chapter 4, the design of the DCIS controller must be considered to the impact of standby equipment concept. The distribute of the control software which will be distributed into the DCIS control, must be considered to avoid any single failure to trip the power plant operation for example in the case of Boiler Feed Pump in Chapter 4.

Hence the design engineer must consider about the impact of the standby equipment concept during their DCIS configuration design process. This concept is an impact to the number of the DCIS controller. The main reason, which should be used to consider during the designing process, is to avoid any fetal single failure and increasing the power plant operation availability.

5.2.7 The interfacing to other system

The power plant control system is not composed of only the DCIS system. The power plant control system composes of so many control system of other auxiliary plants and system such as water treatment plant, flue gas de-sulphurization plant, fuel oil tank farm, the existing power plant, air compressor system, soot blower system, turbine control, etc. The control system of these processes is not performed by the DCIS, but it has own standalone control system.

Hence, the interfacing to other system is an impact to the DCIS configuration design. The DCIS must be used the individual controller to do the interfacing between DCIS and the other aliens control system. The design engineer must consider the number of this individual controller, which will be used to do the interfacing purpose during the designing process.

It does not have any limitation that how many controllers, which should fit for the interfacing to other aliens control system. It depends on the decision of the design engineer that between the capacity of the DCIS controller and the number of the interfacing signal, what is the good fit for the DCIS configuration. Moreover, the need for easy maintenance also should be considered in parallel with the other impact factors.

5.2.8 The safety factor which is used to limit the usage of DCIS controller capability

Because of the maintenance and modification purposes, the usage of the DCIS controller has a limited boundary. The DCIS controller is an area that the control software will be implemented to perform the power plant process control. Because of the maintenance and modification purposes, the programming area of the DCIS controller is limited not exceeding than 60 % of its capacity. The rest area of the DCIS controller must be kept for the future modification work of the software application for power plant process control. For the limitation not exceeding than 60% of its capacity comes from the past experience of the implementation of the DCIS for the power plant process control system of the leading engineering firms such as Electro-Watt Engineering Company (Switzerland), Colenco Company (Switzerland), or Black & Veatch International Inc (U.S.A).

As it was explained in Chapter 2 about the principle of the DCIS, almost of the programming languages of the DCIS in the current market use function block language to do the software implementation. Function block language is a software tool, which is used to implement the control software into the DCIS controller. The benefits of the using of the function block language are to eliminate the complexity of the programming language, easy to understand for the user and error free. The modern DCIS in the current market has a feature to check the usage of the function block language compare to the capacity of the memory inside its controller. Hence, the user will know the situation of the controller that how much free space is available and they will keep the usage of the DCIS controller not exceeding than 60% of its capacity.

This limitation is a direct impact to the number of the DCIS controller. If the DCIS that has a large capacity in the controller area, it can be implemented the software application more than the DCIS controller that has a smaller capacity. Anyway, the other factor, which has an affect to the software implementation into DCIS controller, is the response time of the software application in the DCIS controller. If we implement too much control software into the same DCIS controller, it may cause a slow response time.

5.2.9 The response time of control software which is implemented into the individual DCIS controller

Because the microprocessor of the DCIS controller is a multi-tasking, if we implement too much control software into the same DCIS controller until nearly reach its limitation capacity, the response time of the process controls in the DCIS controller may not meet the technical requirement. Hence, the design engineer must consider to this problem during the designing process. If the response time of the process control can not meet the technical requirement, we must reduce the amount of the software control by adding more DCIS controller.

It has so many factors, which concern to the response time of the DCIS controller. Anyway, it is not in the scope of this thesis research. Even the response time can be checked and estimated during the programming period, the ways to ensure the response time of the process control of the DCIS controller still shall be tested during the commissioning period of the DCIS. Hence, the other benefit that we get from the safety factor, which is used to limit the usage of DCIS controller capability, is that it can keep the response time of the process control of the DCIS controller to meet the technical requirement. Therefore, it is an impact to the number of the DCIS controller, which will be used to perform the entire DCIS configuration.

5.3 Criteria for Configuration Design of a DCIS System

This thesis research has an intention to create the design criteria of the DCIS configuration in the term of reliability. The scope of the study is only the case of Krabi oil-fired power plant will be considered and the research will be confined to the partitioning of the DCIS controllers within the configuration design. Hence, the design criteria of the DCIS configuration will be shown only in the consideration area. From the explanation in the past item, we can conclude criteria for configuration design of a DCIS system in terms of reliability as follow:

Criteria for Configuration Design of a DCIS System in Terms of Reliability

- **The reliability of the individual DCIS controller**
- **The redundancy of the power supply module**
- **The redundancy of the network communication module**
- **The redundancy of the Processor module**
- **The partitioning of DCIS controller for the power plant process controller**
- **The MTTR of the DCIS**
- **The safety factor of the software implementation into the DCIS controller**
- **The DCIS controller for the interfacing signal**
- **The DCIS controller for the plant protection concept**
- **The DCIS controller for off-line modification work**

From the list of the design criteria, it is lists of the necessary design criteria for the DCIS configuration in the scope of the study are within the reliability aspect. For furthermore details, it will be shown as in the following item.

5.3.1 The Reliability of the Individual DCIS Controller

In Chapter 4, the reliability modeling for system prediction has been used to do the calculation of the system reliability of the individual DCIS controller. The result of the calculation can tell design engineer about the system reliability of the DCIS configuration, which he designs. Hence, if we can specify the minimum requirement of the system reliability of the individual DCIS controller, the DCIS configuration can be designed at the acceptable point in the term of reliability.

From the statistical method, if we use 95 % confidential significant, the system reliability shall be at least not less than 0.95. Hence by using the reliability modeling for system prediction to calculate the system reliability of the individual DCIS controller, the design engineer can check the system reliability of their DCIS configuration design that it can meets the minimum requirement or not. In the current market of the DCIS for power plant control system, almost vendors claim that their product has the system reliability more than 0.95. Therefore, the minimum system reliability at 0.95 is an acceptable point to justify that the system reliability of the DCIS, which will be used, can be accepted or not.

5.3.2 The Redundancy of Power Supply Module

As it was explained in Chapter 4 that the power supply module is an important area that is important to the operation of the DCIS controller. In order to increase the system reliability of the DCIS controller, the power supply module must be used the redundancy technique to ensure the operation of the DCIS controller that it can do properly control function along the operation period of the power plant process control.

5.3.3 The Redundancy of Network Communication Module

As it was explained in Chapter 4 that the network communication module is an important area that is important to the operation of the DCIS controller. In order to increase the system reliability of the DCIS controller, the network communication module must be used the redundancy technique to ensure the operation of the DCIS controller that it can do properly control function along the operation period of the power plant process control.

5.3.4 The Redundancy of the Processor Module

As it was explained in Chapter 4 that the processor module is the most important area that is important to the operation of the DCIS controller. It can be claim that it's the heart of the DCIS system. In order to increase the system reliability of the DCIS controller, the processor module must be used the redundancy technique to ensure the operation of the DCIS controller that it can do properly control function along the operation period of the power plant process control.

5.3.5 The partitioning of the DCIS controller for power plant process control

In Chapter 4 the partitioning of the DCIS controller for power plant process control has been discussed in terms of reliability. By using the result from the analysis in Chapter 4, the design criteria can be created. Firstly, control software of main equipment must be implemented into the different DCIS controller. The main equipment is the equipment that the failure of its operation may cause the fatal failure of the power plant operation.

Secondly, the control software of the same power plant process shall be grouped into the same DCIS controller as much as possible. However, the designed engineer must consider to the consequence of the failure if the controller fail its operation in order to avoid the affect single failure, which can cause plant trip.

Finally, the opened-loop control and closed-loop control of the same power plant process must be implemented into the same DCIS controller. It's not necessary to separate the controller for the opened-loop control and closed-loop control of the same power plant process from each other.

The other concept, which shall be used to consider during the DCIS configuration design, is the concepts of dual design for the main equipment and standby equipment. The criteria must be specified that the DCIS configuration must be design to support the concept of dual design for the main equipment and standby equipment. The DCIS configuration must be performed to support these concepts and at least 2 DCIS controllers shall be provided for each major power plant processes.

5.3.6 The MTTR of the DCIS

The MTTR of the DCIS, which was explained in Chapter 2, is the Mean Time To Repair. In order to keep the highest availability of the DCIS controller, the MTTR should be kept as less as possible. From Chapter 2, the availability equals MTBF divide by (MTBF+MTTR). Hence, if we can specify the smaller number of the MTTR, the availability can be increasing. Anyway, the way to specify the MTTR needs the real information from the vendors of the DCIS, which provide for the power plant process control.

MTTR is **the average frequency of (preventive or corrective) maintenance actions upon the item, whether or not the maintenance actions impose or are in response to an outage** [3]. It is the average time taken up by maintenance activities, whether or not the item is inoperable during the maintenance activities. It composed of a logistics delay time and administrative downtime in addition to maintenance downtime. From the past experience, almost DCIS can provide the MTTR at an approximate 30 Minutes. Hence, the design criteria in the item of the MTTR of the DCIS controller should be specified at not more than 30 Minutes.

5.3.7 The safety factor of the software implementation into the DCIS controller

From the past experience of EGAT in power plant process control and the past experience of the leader of Engineering Firms from U.S.A. and European Country, the safety factor of the software implementation into the DCIS controller shall be limited not more than 60% of the controller capacity.

This limitation should be specified as the design criteria of the DCIS configuration because of the maintenance purpose as it was explained in the previous paragraph.

5.3.8 The DCIS controller for the interfacing signal

In item 5.2.5, the DCIS controller for the interfacing signal has been explained. The concept of the DCIS controller for the interfacing signal can improve the maintainability of the DCIS system. Hence, the design criteria should be specified that the DCIS configuration shall be provided the DCIS controller especially for the interfacing to other aliens control system. If we specify this concept into the design criteria of the DCIS configuration design, we can reduce the erection schedule, the wasting time during the maintenance activities, and keep low maintenance cost.

5.3.9 The DCIS controller for the plant protection concept

In Chapter 5.2.4, the DCIS controller for the plant protection concept has been explained. This concept is very important to the power plant operation. It is a concept to ensure trip signals, which are so important to the power plant operation. From the past experience of EGAT and the past experience of the leader of Engineering Firms from U.S.A. and European Country, the plant protection concept is used three-separation hardware equipment in all level of the plant protection hardware. Hence in the design criteria of the DCIS configuration, the DCIS controller shall be specified three sets of DCIS controller with redundancy application.

Figure 5.3 is the approval plant protection concept, which is used to perform the DCIS configuration. EGAT has used this plant protection concept for more 30 years with no doubt about its operation. It is an important technique, which is needed to attach into the design criteria of the DCIS configuration.

5.3.10 The DCIS controller for off-line modification work

The off-line DCIS controller has a purpose to do the modification work of the control software of the DCIS system while the system still running. This concept has used to increase the system reliability. By using the off-line DCIS controller, it is no need to shutdown the DCIS controller in order to do any modification or maintenance activities on the control software of the DCIS. Every modification work and maintenance activities can do hot line during the DCIS system is running. This is an important impact to the DCIS configuration. Hence, the design criteria should be specified the implementation of the off-line controller of the DCIS system.

From the item 5.3.1 to 5.3.10, the design criteria of the DCIS configuration for the power plant in terms of reliability can be listed as follow:

Criteria for configuration design of a DCIS system for power plant in terms of reliability

1. **The reliability of the individual DCIS controller shall be not less than 0.95.**
2. **The redundancy of the power supply module shall be provided.**
3. **The redundancy of the network communication module shall be provided.**
4. **The redundancy of the Processor module shall be provided.**
5. **The partitioning of DCIS controller for the power plant process controller shall be done as follow:**

Criteria for configuration design of a DCIS system for power plant in terms of reliability (continue)

5.1 The control software of main equipment that may cause a single failure trip to the power plant operation must be implemented into the different DCIS controller.

5.2 The control software of the same power plant process shall be grouped into the same DCIS controller as much as possible.

5.3 The opened-loop control and closed-loop control of the same power plant process must be implemented into the same DCIS controller.

5.4 In the case of power plant process control that may be used only 1 DCIS controller is enough, at least 2 DCIS controllers shall be provided for each major power process control in order to support the dual design and standby concepts for the main equipment.

6. The MTTR of the DCIS Controller and its peripheral devices shall be not more than 30 minutes
7. The safety factor of the software implementation into the each individual DCIS controller shall be not exceeding 60% of its capacity.
8. The DCIS controller for the interfacing signal shall be provided at least one set of the DCIS controller and its peripheral devices with the redundancy application.
9. The DCIS controller for the plant protection concept shall be provided three sets of the DCIS controller and its peripheral devices with the redundancy application.
10. The DCIS controller for off-line modification work and maintenance purposes shall be provided at least one set with redundancy application.

5.4 The limitation of the design criteria of the DCIS configuration

There are several limitations of the using of the design criteria of the DCIS configuration. From the DCIS configuration design criteria in item 5.3, EGAT has a limitation to do the DCIS configuration because of the reasons as in the following list.

- EGAT can not specified the exact DCIS vendors in the bidding document. Hence, it's impossible to do the exact number of the DCIS controller. However, the design criteria of the DCIS configuration in item 5.3 can help the design engineer of EGAT to do the DCIS configuration for power plant in terms of reliability.

- Power plant process control is so complex. EGAT doesn't own any power plant process technology. It depends on the technology of the contractor who provides each power plant process to EGAT. Hence, the deviation of the power plant process control from the specific requirements in the bidding document of EGAT has an affect to the process allocation into the DCIS controller. EGAT can not do the exact power plant process control because of the lack of technology capability. So the process allocation into the specific DCIS controller is impossible to do. However, the idea from this research study may help the design engineer of EGAT to do the reliability evaluation through their design.