CHAPTER 2
THEORETICAL CONCEPTS

In this chapter, the theoretical concepts related to the substation design will be discussed such as the Quality, Quality Assurance, Quality Costs, ISO 9000, FMEA and Electrical Substation Concept.

2.1 Quality

We should understand the meaning of "Quality" which has many meanings by various writers before. Here is the definitive meanings of the word "Quality" :

- Fitness for purpose or use. **(Juran)**
- Conformance to requirements. **(Crosby)**
- The total composite product and service characteristics of marketing, engineering, manufacture and maintenance through which the product and service in use will meet the expectation by the customer. **(Feigenbaum)**
- The totality of features and characteristics of a product or service that bear upon its ability to satisfy stated or implied needs. **(ISO 8402)**

2.2 Quality Assurance Concept

The background to quality assurance is the customer-supplier relationship. The ultimate purpose of any quality system is to ensure complete satisfaction by the customer with the goods or services provided by the supplier. Thus, the customer-supplier relationship is an active rather than a passive one. The first step in this relationship is to determine the customer. Depending on the nature of the product or service, either the customer will, or should, provide a full specification of requirement, or the supplier, by market research and feedback from the market-place, will produce services or goods to a presumed customer requirement. Any quality system must, therefore, involve the customer, either directly or indirectly. Although this customer-supplier relationship may be regarded, at least partly, as external to the supplier's activities, the same philosophy applies internally within a supplier's workplace at each stage of the operation. The

customer becomes the user or consumer of the next stage in the operational process and so a quality system applies through the whole complex of activities within any organization.

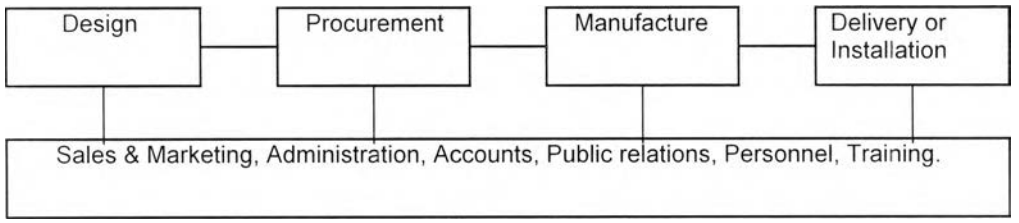

Figure 2.1 Internal customer-supplier relationship

2.3 Quality Costs

Quality costs in plants and companies are accounted so as to include two principal areas : the costs of control and the costs of failure of control (Figure 2.2)

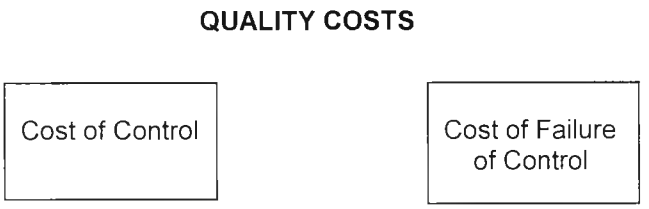

Figure 2.2 Areas of quality costs

The principle quality-cost areas are broken down as in Figure 2.3 . The costs of control are measured in two segments : Prevention costs keep defects and non-conformities from occurring and include the quality expenditures to keep unsatisfactory products from coming about in the first place. Included here are such cost areas as quality engineering and employee quality training. Appraisal costs include the costs for maintaining company quality levels

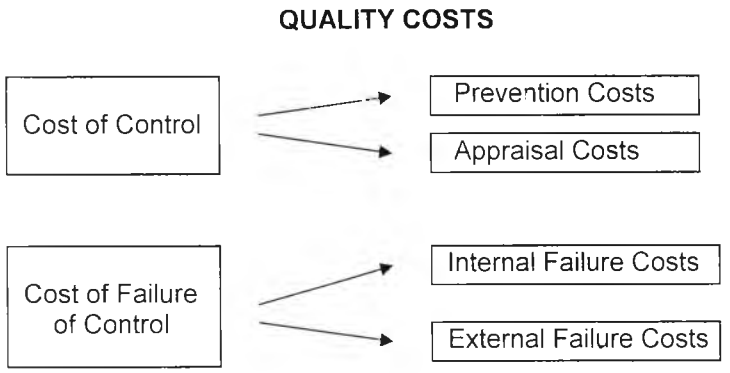

Figure 2.3 Break down of quality costs

by means of formal evaluations of product quality. This includes such cost areas as inspection, test, outdise endorsements, quality audits, and similar expenses.

The costs of the failure of control, which are caused by materials and products that do not meet quality requirements, are also measured in two segments: internal failure costs, which include the costs of unsatisfactory quality within the company, such as scrap, spoilage, and reworked material, and external failure costs, which include the costs of unsatisfactory quality outside the company, such as product-performance failures and customer complaints.

Because operating quality costs include key costs associated with quality, it is important to be aware that they embrace the other relevant quality characteristics. Operating quality costs thus relate to the total-customer-oriented aspects of quality.

Definitions of Operating Quality-Cost Items

1. Cost of prevention

a. Quality planning

Quality planning represents costs associated with the time that all personnel whether in the quality function or in other functions-spend planning the ongoing details of the quality system and translating product-design and customer quality requirements into specific manufacturing controls on quality of materials, processes, and products through formal methods, procedures, and instructions. It also represents costs associated with the time spent doing other quality-planning work, such as reliability studies, preproduction quality analysis, and writing instructions or operating procedures for test, inspection, and process control.

b. Process control

process control represents costs associated with the time that all personnel spend studying and analyzing manufacturing processes for the purposes of establishing a means of control and improving existing process capability, and providing technical support to shop personnel for the purposes of effectively applying or implementing quality plans and initiating and maintaining control over manufacturing operating processes.

c. Design and development of quality information equipment

Design and development of quality information equipment represent costs associated with the time that personnel spend designing and developing product and process quality measurement, data, control, and related equipment and devices. This item does not include the cost of equipment or depreciation.

d. Quality training and work force development

Quality training represents the cost of developing and operating formal quality training programs throughout the company operations, designed to train personnel in the understanding and use of programs an techniques for the control of quality, reliability, and safety. It does not include training costs of instructing operators to achieve normal quantity proficiency.

e. Product design verification

Product design verification represents the cost of evaluating pre-production product for the purpose of verifying the quality, reliability, and safety aspects of the design.

f. Systems development and management

Systems development and management represent the cost of overall quality systems engineering and management and support for quality-systems development.

g. Other prevention costs

Other prevention costs represent administrative cost involving quality and reliability organizational costs not otherwise accounted for, such as managerial and clerical salaries and travel expenses.

2. Cost of appraisal

a. Test and inspection of purchased materials

Test and inspection of purchased materials represent the costs associated with the time that inspection and testing personnel spend evaluating the quality of purchased materials and any applicable costs of supervisory and clerical personnel. Also, this may include the cost of inspectors traveling to vendors' plants to evaluate purchased materials.

b. Laboratory-acceptance testing

Laboratory-acceptance testing represents the cost of all tests provided by a laboratory or testing unit to evaluate the quality of purchased materials.

c. Laboratory or other measurement services

Laboratory or other measurement services represent the cost of laboratory measurement services, instrument calibration and repair, and process monitoring.

d. Inspection

Inspection represents the costs associated with the time that inspection personnel spend evaluating the quality of the product in the plant and applicable costs of supervisory and clerical personnel. It does not include the cost of inspection of purchased materials included in 2a, inspection equipment , utilities , tools, or materials.

e. Testing

Testing represents the costs associated with the time that testing personnel spend evaluating the technical performance of the product in the plant and applicable costs of supervisory and clerical personnel. It does not include the cost of testing purchased materials included in 2a, test equipment, utilities, tools, or materials.

f. Checking labor

Checking labor represents the costs associated with the time that operators spend checking quality of own work as required by the quality plan, checking product or process for quality conformance at planned points in manufacturing, sorting lots which are rejected for not meeting quality requirements, and other in-process evaluations of product quality.

g. Setup for test or inspection

Setup for test or inspection represents the costs associated with the time that personnel spend setting up product and associated equipment to permit functional testing.

h. Test and inspection equipment and material and minor quality equipment

Test and inspection material represents the cost of power for testing major apparatus, such as stream or oil, and materials and supplies consumed in destructive tests, such as life test or tear-down inspections. Minor quality equipment includes costs of non-capitalized quality information equipment.

i. Quality audits

Quality audits represent the costs associated with the time that personnel spend performing audits.

j. Outside endorsements

Outside endorsement represent external laboratory fees, insurance inspection costs, and so on.

k. Maintenance and calibration of quality information test and inspection equipment

Maintenance and calibration of test and inspection equipment represent the costs

associated with the time spent by maintenance personnel calibrating and maintaining quality information test and inspection equipment.

l. Product-engineering review and shipping release

Product-engineering review and shipping release represent the costs associated with the time of product engineers who review test and inspection data prior to release of the product for shipment.

m. Field testing

Field testing represents the costs incurred by the department while field test in the product at customer's site prior to final release. These costs might include traveling costs and living expenses.

3. Cost of internal failure

a. Scrap

For the purpose of obtaining operating quality costs, scrap represents the losses incurred in the course of obtaining the required level of level of quality. It should not include materials scrapped for other reasons, such as obsolescence, overruns, and product-design changes resulting from further evaluation of customer needs, Scrap might be further subdivided, e.g., between fault of own manufacture and fault of vendor.

b. Rework

For the purpose of obtaining operation quality costs, rework represents the extra payments made to operators in the course of obtaining the required level of quality . It should not include extra payments to operators for any other reasons, such as rework caused by product-design changes resulting from further evaluation of customer needs. Rework might be further subdivided, e.g., between fault of manufacture and fault of vendor.

c. Material-procurement costs

Material-procurement costs represent those additional costs incurred by the material-procurement personnel in handling both rejects and complaints on purchased materials. Such costs may include getting disposition from vendors for rejected materials, making certain that vendors understand quality requirements for either rejects or complaints, and so on.

d. Factory contact engineering

Factory contact engineering represents the costs associated with the time spent by product or production engineers who are engaged in production problems involving quality; e.g., if

a product component or material does not conform to quality specifications, a product or production engineer may be requested to review the feasibility of product-specification changers. It does not include engineering development work which may be performed on the factory floor.

4. Cost of external failure

a. Complaints in warranty

Complaints in warranty represent all costs of specific field complaints within warranty for investigation, repair, or replacement.

b. Complaints out of warranty

Complaints out of warranty represent all accepted costs for the adjustment of specific field complaints after expiration of the warranty.

c. Product service

Product service represents all accepted product service costs directly attributable to correcting imperfections or special testing, or correction of defects not the result of field complaints. It does not include installation service or maintenance contracts.

d. Product liability

Product liability represents quality-related costs incurred as a result of liability judgments related to quality failures.

e. Product recall

Product recall represents quality-related costs incurred as a result of the recall of products or components of products.

2.4 International Standard ISO 9000

ISO 9000 is an international standard for quality assurance, recognized throughout the world. Nearly all countries also have their own national equivalent to the international standard and in the case of the UK this is not only equivalent but identical in content. Since mid-1994, this British Standard has been designated as BS EN ISO 9000 but before then it was BS 5750 and it is still better known as this. BS 5750 was also the equivalent of and identical in content to ISO 9000. In fact ISO 9000 was developed from BS 5750.

ISO 9000 is set out in published form in a series of publications as indicated in Table 2.1. These publications fall into two groups: three models. indicated in Table 2.1 in bold typeface, and other guidance document. The models define the Standard and anyone seeking registration to ISO 9000 must design a quality system to meet one of these three models. The other documents provide guidance which may be found more or less useful in practical application.

Table 2.1 The ISO 9000 series of standard

ISO reference	Subject
9000-1	Guidelines for selection and use of ISO 9000.
9000-2	Guidelines for application of ISO 9000.
9000-3	Guidelines for application of ISO 9001 to the development, supply and maintenance of software.
9000-4	Dependability management.
9001	**Model for quality assurance in design, development, production, installation and servicing.**
9002	**Model for quality assurance in production, installation and servicing.**
9003	**Model for quality assurance in final inspection and testing.**
9004-1	Guidelines for quality system elements.
9004-2	Guidelines for services.
9004-3	Processed materials.
9004-4	Quality improvements.
9004-5	Quality plans.
9004-6	Project management.
9004-7	Configuration management.

The Requirements of ISO 9000 and Selection of a Model

The requirements of the ISO 9000 models are set out under a number of headings and these are listed in Table 2.2. In the case of ISO 9001 the requirements fall under twenty major headings and for ISO 9002 nineteen- the difference between ISO 9001 and 9002 is just the inclusion or exclusion of design activity. ISO 9003 includes only twelve of the requirements and is largely concerned with the inspection and testing approach to quality management rather than full

quality assurance. Implementation of ISO 9003 rather than 9001 or 9002 is not common and will be ignored from here on.

Table 2.2 Requirements of ISO 9000 models

		Model		
Reference	**Requirement**	**9001**	**9002**	**9003**
4.1	Management responsibility	•	•	•
4.2	Quality system	•	•	•
4.3	Contract review	•	•	
4.4	Design control	•		
4.5	Document and data control	•	•	•
4.6	Purchasing	•	•	
4.7	Control of customer supplied product	•	•	
4.8	Product identification and traceability	•	•	•
4.9	Process control	•	•	
4.10	Inspection and testing	•	•	•
4.11	Control of inspection, measuring and test equipment	•	•	•
4.12	Inspection and test status	•	•	•
4.13	Control of nonconforming product	•	•	•
4.14	Corrective and preventive action	•	•	
4.15	Handling, storage, packaging, preservation and delivery	•	•	•
4.16	Control of quality audits	•	•	•
4.17	Internal quality audits	•	•	
4.18	Training	•	•	•
4.19	Servicing	•	•	
4.20	Statistical techniques	•	•	•

2.5 Failure Mode and Effect Analysis (FMEA)

2.5.1 The Meaning of FMEA

A failure mode and effect analysis (FMEA) is an engineering technique used to define, identify, and eliminate known and/or potential failures, problems, errors, and so on from the system, design, process, and/or service before they reach the customer (Omdahl 1988; ASQC 1983).

The analysis of the evaluation may take two courses of action. First, using historical data, there may be analysis of similar data for similar products and/or services, warranty data, customer complaints, and any other appropriate information available, to define failures. Second, inferential statistics, mathematical modeling, simulations, concurrent engineering, and reliability engineering may be used to identify and define the failures (Stamatis 1989, 1997a, 1992).

Any FMEA conducted properly and appropriately will provide the practitioner with useful information that can reduce the risk (work) load in the system, design, process, and service. This is because it is a logical and progressive potential failure analysis method that allows the task to be performed more effectively. FMEA is one of the most important early preventive actions in system, design, process, or service which will prevent failures and errors from occurring and reaching the customer (Kececioglu 1991).

2.5.2 Types of FMEA

Generally, there are four types of FMEA which are shown in figure 2.4. The four types of FMEA are

1. **System FMEA** – Used to analyze systems and subsystems in the early concept and design stage. A system FMEA focuses on potential failure modes between the functions of the system caused by system deficiencies
2. **Design FMEA** – Used to analyze products before they are released to manufacturing. A design FMEA focuses on failure modes caused by design deficiencies.
3. **Process FMEA** – Used to analyze manufacturing and assembly processes. A process FMEA focuses on failure modes caused by process or assembly deficiencies.
4. **Service FMEA** – Used to analyze services before they reach the customer. A service FMEA focuses on failure modes (tasks, errors, mistakes) caused by system or process deficiencies.

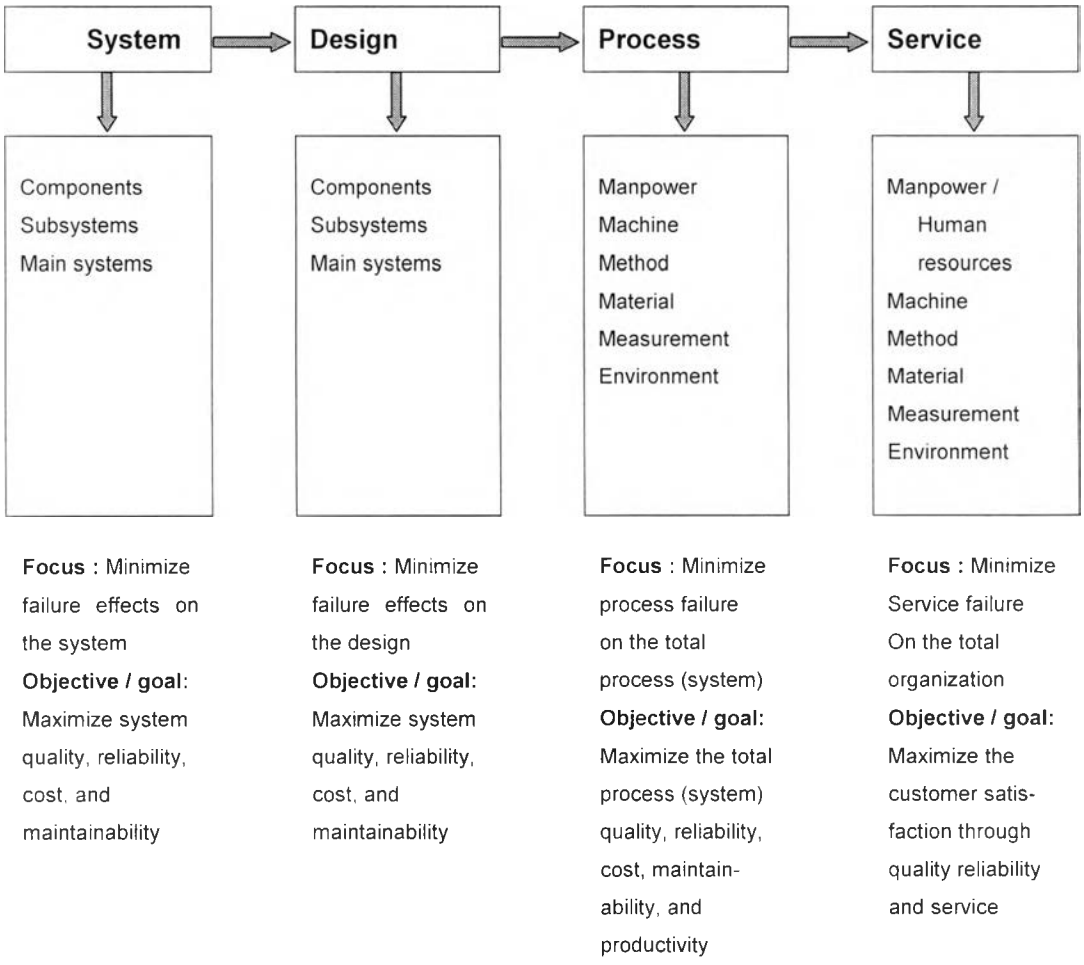

Figure 2.4 : Types of FMEA (Stamatis, 1995: 47)

2.5.3 When to Start FMEA

The FMEA program should be started as follows;

- When new systems, designs, products, processes, or services are designed
- When existing systems, designs, products, processes, or services are about to change regardless of reason
- When new applications are found for the existing conditions of the systems, designs, products, processes, or service
- When improvements are considered for the existing systems, designs, products, processes, or services

After the FMEA begins, it becomes a living document and is never really complete.

2.5.4 Persons to Conduct the FMEA

The FMEA is a team function and cannot be done on an individual basis. The team must be defined as appropriate for a specific project and cannot serve as the company FMEA team. The knowledge that is required for the specific problem is unique to that problem. Therefore, the makeup of the team must be cross-functional and multidisciplined for each FMEA (Stamatis 1991b).

2.5.5 Interpretation of the FMEA

The essence of the FMEA is to identify and prevent known and potential problems from reaching the customer. Thus, finding the priority is important and the thrust of the methodology.

There are three components that help define the priority of failures

- Occurrence (O)
- Severity (S)
- Detection (D)

Occurrence is the frequency of the failure. Severity is the seriousness (effects) of the failure. Detection is the ability to detect the failure before it reaches the customer.

There are many ways to define the value of these components. The usual way is to use numerical scales. These guidelines can be qualitative and/or quantitative.

If the guideline is qualitative, it must follow theoretical (expected) behavior of the component. The expected behavior of occurrence, severity and detection are normality, lognormal and a discrete distribution respectively. (Stamatis, 1995:34-35)

If the guideline is quantitative, it must be specific. It must follow actual data, statistical process control data, historical data, and/or similar or surrogate data for the evaluation. Table 2.3 are shown the selection guideline.

If	Then use	Select
The design is similar to others or historical data exist	Statistical data from either historical or surrogate systems: Reliability data, actual distribution, mathematical modeling, simulation	Actual data and/or CpK
Failure history is available with the design itself or similar, or surrogate parts	Historical data based on reliability, system, actual, distributions, mathematical modeling, simulation, cumulative data, and/or fraction defectives.	Actual data and/or cumulative number of failures.
The design is new and/or no quantification for any data is available	Team judgment	Subjective criteria. Use team consensus and be conservative.
The process is under statistical process control (SPC)	Statistical data; reliability data, process Capability, actual distribution, mathematical Modeling, simulation.	Actual data and/or CpK
The process is similar to others or historical data exist	Statistical data from either historical or surrogate systems: Reliability data actual distribution, mathematical modeling, simulation	Actual data and/or CpK
Failure history is available with the process itself or similar, or surrogate parts	Historical data based on reliability, system, actual. distributions, mathematical modeling, simulation, cumulative data, and/or fraction defectives.	Actual data and/or cumulative number of failures.
The process is new and/or no quantification for any data is available	Team judgment	Subjective criteria. Use team consensus and be conservative.

Table 2.3 : Criteria for selecting ratings. (Stamatis, 1995: 37-38)

The ranking for the criteria can have any value. There is no standard for such value; however, The ranking of 1 to 10 is used widely and highly recommended because it provides ease of interpretation, accuracy, and precision in the quantification of the ranking.

The product of the 'occurrence', 'severity', and 'detection' is call RPN (risk priority number). The purpose of this number is used for the ranking order of the identified failure nodes. It is important to understand that not all the failure modes are solved. It depends on the 'threshold of examining the failures'. We have to check how critical of the system, design, product, process,

and/or service is and set the percent of the statistical confidence level. The critical one may require that 99 percent of all failures must be addressed whereas the non-critical one may require 90 percent.

The occurring risks should be classified by the team before starting the evaluation process. They can be defined as minor, moderate, high, and critical risks. The level of actions taken is also different based on different risks. The example of action taken is shown below (Stamatis, 1995: 39).

- Under minor risk: no action is taken.
- Under moderate risk: some action may take place.
- Under high risk, definite action will take place. (selective validation and evaluation may be required).
- Under critical risk, definite actions will take place and extensive changes are required in the system, design, product, process, and/or service.

2.5.6 The Process of Conducting an FMEA

To conduct an FMEA effectively one must follow a systematic approach. The recommended approach is an eight-step method that facilitates the system, design, product, process, and service FMEA.

1.Select the team and brainstorm – Make sure the appropriate individuals are going to participate. The team must be cross functional and multidisciplined and the team members must be willing to contribute (Stamatis 1991b).

2.Functional block diagram and/or process flowchart – For system and design FMEAs the functional block diagram is applicable. For the process and service FMEAs the process flowchart is applicable.

3.Prioritize – After the team understands the problem, the actual analysis begins in order to know where the team should begin and what part is important.

4.Data collection – To collect the data of the failures and categorizes them appropriately.

5.Analysis – Utilize data for a resolution. The analysis, may be qualitative or quantitative. The method may be brainstorming, cause-and-effect analysis, mathematical modeling and anything else which is suitable.

6.Results – Use the information to quantify the severity, occurrence, detection, and RPN

7.Confirm/evaluate/measure – To confirm, evaluate, and measure the success or failure. The information from this step will be used to recommend actions and to see the results of actions.

8.Do it all over again – To improve all over again which is continual improvement.

2.5.7 The Process after completion of the FMEA

Generally there are seven steps that the team must follow (Stamatis 1993)

1.Review the FMEA – Make sure that the function, purpose, and objective have been met.

2.Highlight the high-risk areas – A visual inspection of the critical column, the severity column, and the RPN column generally will identify the high-risk areas.

3.Identify the critical, significant, and major characteristics – Upon completion of the FMEA, a visual check of the RPN and critical columns should identify the critical, significant, and major characteristic.

4.Ensure that a control plan exists and is being followed – Make sure that all critical, significant, and major characteristics have a documented plan for controlling, improving, and/or handling changes.

5.Conduct capability studies – After the control plan is in place and statistical control has been established, a potential capability or a long capability must be performed.

6.Work on processes which have a CpK less than or equal to 1.33 – The point is to continually improve the process by eliminating variation, Produce everything around the target.

7.Work on processes which have CpK greater than or equal to 1.33 – All standards are minimum performance. Consequently, continual improvement dictates that one should, at all times, try to exceed all standards, including all CpK targets.

2.6 Electrical Substation Concept

An electrical substation is an assembly of electrical equipment such as busbars, switchgear, power transformers, auxiliaries, etc. The various substations located in generating stations, transmission and distribution system. Normally, an electrical substation consists of a number of incoming circuits and outgoing circuits connected to common busbar systems. Busbars are conducting bars to which a number of incoming or outgoing circuits are connected. Each circuit has certain electrical equipment such as circuit breakers, isolators, earthing switches, current transformers, voltage transformers, etc. These equipment are connected in a definite

sequence such that a circuit can be switched off during normal operation by manual command and also automatically during abnormal conditions such as short-circuits.

A substation receives electrical power from generating station via incoming transmission line and delivers electrical power via the outgoing transmission lines. Substations are integral parts of a power system and form important links between the generating stations, transmission systems, distribution systems and the load points.

The functions of substation in the transmission and distribution systems include the following :

- Protection of transmission system.
- Controlling the exchange of energy.
- Ensuring steady state and transient stability.
- Load shedding and prevention of loss of synchronism by maintaining the system frequency within targeted limited.
- Voltage control by reducing the reactive power flow.
- Securing the supply by providing adequate line capacity and facility for changing the transmission paths.
- Data transmission via power line carrier or optic fiber for the purpose of network monitoring; control and protection.
- Determining the energy transfer through transmission lines
- Establishing economic load distribution and several associated functions.

2.7 Literature Review

Wisit Sasiparimanond, 1995

This research study quality management system which relevant to quality standard ISO 9001. The projection of study will be defined in specific case study factory and will carry out on all topic of quality system according to the existing quality standard ISO 9002.

Jakrapong Karnjanasomwong, 1995

This research study and develop the appropriate process quality assurance for the model factory and also find the way to reduce defective products which have been generated during manufacturing process. Model factory is the recording magnetic head assembly factory.

Somsak A.Kongkiat, 1995

This research study the main problems of the implementation of quality assurance system in the Grease Manufacturing plant and making improvement of quality assurance system only in the part of Inspection. Testing, and Testing Equipment.

Sawat Sukaachin, 1993

This research study about quality and factors affecting the quality of product. In this study was used fishing net factory in a case study to develop quality assurance system that is appropriate for the model factory.

Sayom Surijamongkol, 1999

This research study the application software development of the distributed control system (DCS) in a manufacturing company named ABC (unreal name). This research focuses only at the software development from the process of gathering the customer requirements to the software inspection test and product delivery.

Paisit Tangkitsiri, 1998

This research study about supplier quality improvement which is a key part of continuous improvement plans to achieve customer satisfaction. It is important to understand and exceed the requirements and expectations of all customer as well.

Weerawat Svastdi-xuto, 1996

This research study about the development of the quality management system for large-scale computer center. The quality management system focuses on the processes of report production, which its defects are about 9 percent of total defects. This research also defines the essential inspection in the process, develop the operating manuals for report production.

Thavachchai Lovichit, 1996

This research is to design the quality management system and propose an appropriate quality system in documentary forms for the manufacturing process of metal casting and lathing. The result of the study by statistical techniques proposed in the quality system revealed that the percentage of the finished products, which did not pass the hydrostatic pressure test, decreased from 19% to 6.5% by improving the lathing method.

Suwit Boonchoejarud, 1996

This research study about the problems occurring after the implementation of the quality assurance of the Grease manufacturing plant. It suggests the improvements at the part of inspection, testing, and testing equipment of the quality assurance system.

Somnuk Liabma, 1997

This research is to establish the quality assurance of the supplied parts for hard-disk drive manufacturing. The author has applied the use of statistical process control and Gage P&R study to control and review supplier process variation, identified the potential product related process failure modes by using the process FMEA (failure mode and effect analysis). After implementation, about 85% of all machines meet with Cpk of 1.33 in June 1996 and increase to 100% in July. The corrective actions, taken on the major defect, can improve the quality more than 50%.

Thana Boonprasit, 1994

This research is to improve the quality inspection system of in-coming parts and production processes using a refrigerator factory as a case study. The author has proposed to designing and improving the document system used in the quality inspection task, setting the training courses for staffs and inspectors, and developing the performance indication and corrective action system. After implementation, the rejection of in-coming parts was reduced by 22% and the quantity of the defective product using the sampling inspection was reduced by 41%.

Tawichart Dechwitayaporn, 1997

This research is to develop a quality assurance system for brake drum manufacturing process. The quality assurance system used in the brake drum manufacturing process includes quality planning, quality control, quality audit, and preventive procedures. The author also established the quality tools for the quality assurance system such as the check sheets, statistical method, and control chart. The established system can be a guideline for quality assurance system in the same area of manufacturing.