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DESIGN SUPPORTING SYSTEM FOR ELECTRICAL SWITCHBOARD MANUFACTURER

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for the Degree of Master of Engineering Program in Engineering Management

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การวิจัยนี้มีวัตถุประสงค์เพื่อการสร้างระบบสนับสนุนการออกแบบในตู้ควบคุมระบบไฟฟ้า โดยที่การวิจัยได้อาศัยหลักการใช้วงจรการพัฒนาระบบ (System Development Life Cycle) และ ระบบจัดการฐานข้อมูล (Database Management System) ซึ่งกระบวนการในการทำการวิจัยนั้นได้ทำให้ก่อเกิดระบบฐานข้อมูลและระบบการเชื่อมต่อระหว่างฐานข้อมูลกับผู้ออกแบบตู้ควบคุมระบบไฟฟ้า ซึ่งรวมถึงโปรแกรมประยุกต์เพื่อวิเคราะห์ต้นทุนของตู้ควบคุมระบบไฟฟ้า

ซึ่งผลลัพธ์ที่ออกมานั้น ทำให้ทางผู้เขียนค้นพบถึงการลดระยะเวลาในการออกแบบพร้อมทั้งทำให้เกิดการประโยชน์สูงสุดทางด้านต้นทุนของผลิตภัณฑ์ซึ่งจะก่อเกิดประโยชน์อย่างมากต่อผู้ใช้งานเนื่องจากการออกแบบตู้ควบคุมระบบไฟฟ้าที่คุ้มค่าทางด้านต้นทุนราคาและเวลา

นอกจากนี้การวิจัยได้เกิดขึ้นโดยยึดหลักการพัฒนาระบบกับการจัดการระบบฐานข้อมูลซึ่งก่อให้เกิดระบบที่มีประสิทธิภาพและประสิทธิผลสูงสุดสำหรับองค์กรที่เป็นตัวอย่างการวิจัย

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CHANAPATT PATTARAMAETAKUL: DESIGN SUPPORTING SYSTEM FOR ELECTRICAL SWITCHBOARD MANUFACTURER. THESIS PRINCIPAL ADVISOR: ASSOC. PROFESSOR JEERAPAT NGAOPRASETWONG, 109 pp.

This research study aims to build the design support system for electrical switchboard manufacturer by implementing the database approach. The database approach is conducted in a number of steps in order to conform the system development life cycle (SDLC) and database management system (DBMS). This approach is used for constructing the database application together with the interface program design to achieve the optimum switchboard design system.

Moreover, by developing such approach together with the implementation of database and its interface application tool, the reliable design system is therefore constructed to reduce the lead time and enhance design optimization that can yield in cost reduction for the design.

The study is conducted to follow the guideline of system development life cycle in combination with the database management system in order to create the effective system that will be future used for the designated company.

The Regional Centre for Manufacturing Systems
Field of Study : Engineering Management
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CHAPTER I

INTRODUCTION TO DESIGN SUPPORTING SYSTEM FOR ELECTRICAL SWITCHBOARD MANUFACTURER

1.1 Introduction

In today business especially in the electrical panel manufacturing industry, engineering and costing systems have played an important role since they primarily assist organization to operate effectively with the strategic goal contribution to the firm; any organizations operating at the lower cost with the desired quality are deemed as the profitable organizations.

As design process is crucial in such type of product, the product design has to be conformed to given engineering specifications with the consistent and accurate engineering perspective. Therefore, well-established database system shall be thoroughly considered significantly.

Plus, a nature of the electrical control panel has shown that the product is usually categorized as a tailor-made product, which is varied from one job to another. To determine the cost of this kind of product, it is found necessity to implement the job costing system where the product is managed by job.

Furthermore, it is very important to understand a role of the job costing system, where it is suitable for the product as one states that this job order costing system is widely used and mostly applied to the individual unit. This emphasizes the conclusion that the job costing system is certainly suitable for the electrical control panel. On the designing part, the consistent system with data should be the key issue, since this issue can definitely yields the reliable operation.

This proposal has given the insight of the interest in the design support system according to the industry selected, electrical switchboard manufacturer. The database support system for designing purpose and the few parts of costing aspect can be observed.

1.2 Company Background

PMK Industry, our interested company, is the leading local manufacturer in electrical controlling panels which has been acquired a number of international standards such as ISO 9001, IEC (International Electro Commission) and TIS (Thai Industrial Standard). These standards have marked the significance of the company that can compete with the international competitors.

Having been in its own market for more than 25 years, PMK product is pervasively accepted by its customers in both domestic and international markets. Its product range covers from the low-voltage to medium-voltage panels.

With its corporate strategy, it states that to be a leader in its market by fulfilling the timely needs of customers together with the good welfare of all employees by creating good working environment. Regarding to the operation strategy by [1], the corporate strategy can be subset with the divisional strategy, whereas the divisional strategy can result in the marketing, design/engineering, manufacturing, and financial strategy, respectively. Having been emphasised on the design strategy, PMK Industry's design department has shown the strong contribution to the corporate strategy by defining itself for providing the good quality designs in a time manner in accordance with the engineering specification and acceptable cost.

As earlier mentioned, the major product of PMK Industry is the electrical control panels, which is categorized as the engineering product. Moreover, the product has to be customized regarding to the requirements of electrical designers. This definitely means that the product is only made to order, which leads to the complication in every process starting with the design and cost estimation through the quality control. To gain deeper understand about electrical control panel, the product description can be explored subsequently.

1.3 Product Description

Electrical control panel is an engineering product that requires some technical and expertise to manufacture. Plus, the labour intensive manufacturing process increases the level of difficulty to the product.

The components of the product mainly include steel, copper, and other electrical equipment.

- Steel Enclosure

  This is the steel made with the purpose of covering the electrical conductive parts. Also, it is the area that protects users from touching the electrical part.

- Copper Bar

  The bar is used as a conductor in the panel. It comes with various sizes depending on the ampere rating required.

- Metering Unit

  The unit is designed with the metering unit for displaying any necessary electrical parameters such as current, voltage, and power.

- Functional Unit

  Mostly, the panel includes the electrical circuit breaker for interrupting the system in case of fault incurred.

Figure 1A Steel Enclosure

Figure 1B Functional Unit (Circuit Breaker)

1.4 Manufacturing Process

The manufacturing process starts from the steel work and will finish at quality controller, which can be succinctly described as follows.

- Steel Work

  The electro-galvanized steel is used in order to maximize the performance of the enclosure since electro-galvanized steel is stated to be rust proof material. The operation starts from the CNC machine to punch the hole into the desired form and shape; in the meantime, the aluminium-zinc frame is bolted to form the entire frame of the enclosure. Recall from the punched steel, the finished parts will be conveyed to our painting line whereas an epoxy powder coating is applied.

- Assembly Work

  The ready-to-assembly material from the paint line will be bolted and drilled to the frame. Afterwards, the associated equipment are installed and wired along with the copper bar installation. At this level of process, the semi-automated tools are used.

- Quality Control

  This process is performed according to the finished and wired products. The routine test and other additional required tests are usually done by the qualified inspectors. The main inspection includes two areas: physical (mechanical) and electrical inspections. Any defections or fault operation must be solved at this stage before proceeding to the latter department, logistic department.

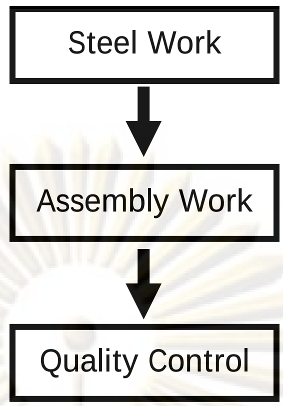


Figure 1C Manufacturing Process

1.5 Designing Process

Prior to manufacturing process, it is the designing and cost estimation process in order to generate bill of quantity for the procurement process to place the raw material order. As previously explained, it can get very convoluted to design the product and appraise the cost. Therefore, this paragraph succinctly explains this process concisely for the readers to understand. Firstly, the process operators will collect any associated details such as electrical single line diagram. Below figure shows the example of the electrical single line diagram.

In addition to the single line diagram, there can be other several documents required in order to meet the customer needs and conform to specifications. There can be a pile of specifications, vendor list, and other associated comments. The designers must observe carefully to determine any special criteria that must be identified.

Overall, the designers are ones whom analyzed all collected data and translate to his/her own understanding under the common and company engineering practices for designing the electrical control panel before passing on estimation department for performing costing activity.

Illustrated by the following diagram, there are a number of designing factors in the electrical switchboard design. Looking in the diagram, it composes of customer needs, IT tools and system, database system, engineering know-how, cost compliance (if applicable), and other relevant details (e.g. single line diagram and specification).

1.6 Statement of Problem

The electrical control panel designing process can be a hectic job especially for a newcomer staff due to its complexities and experiences required. This can lead to the inconsistent, inaccurate, and time consuming task for every beginner. Such scenario is a case for PMK Industry as new hired employees are recruited every year for meeting the growth of the business; although, some IT tools and techniques like spreadsheets are adopted in designing process, it seems insufficient since these difficulties still occurs frequently.

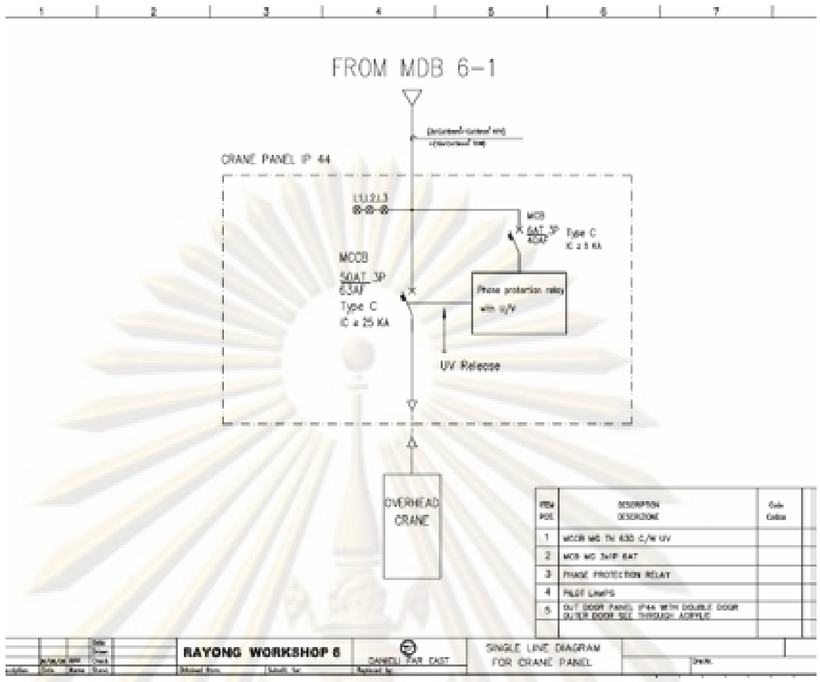


Figure 1D Example of Single Line Diagram

As a result, it has led to emotional factor concerned such as the low satisfaction rate from employees and clients. Plus, the long time consumption gives the loss of order in some cases. This shows such unprofitable performance for the designers. After thoroughly investigated the causes of this, it is believed that the design system is not well-planned; the IT tools and systems are used inefficiently, additionally.

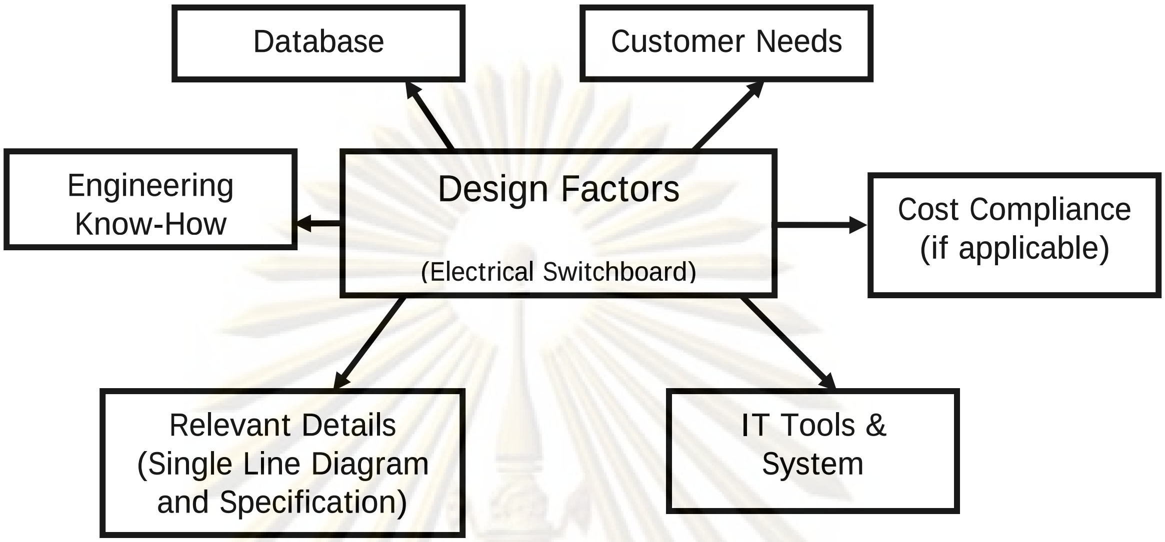


Figure 1E Design Factors for Switchboard

As a result, it has led to emotional factor concerned such as the low Having been suggested by the owner of the firm, Mr. Wirat Pattaramaetakul, the design supporting system must be investigated and newly planned and thus implemented in order to ameliorate these difficulties.

To sum up, there are some major areas that are the problems regarding to the design system which are:

- Long Time Consumption
- Human Error
- Human Dissatisfaction

1.7 Objective

To effectively generate the design supporting system for the electrical control panels.

1.8 Scope of the research

The research study mainly focus on the designing process in electrical control panels. Highly placing an emphasis on the design process, the design supporting system must be thoroughly explored and later planned or adapted for ameliorate existing difficulties.

1.9 Methodology

In order to achieve our expected outcomes, it is necessary to establish the below methodology.

1. Thoroughly identify the causes of the problems according to the designing process and system.
2. Study the existing design process and system.
3. Study the relevant database system in the electrical switchboard or other similar business.
4. Plan the design supporting system in the electrical switchboard.
5. Create the guidelines for a design operator to follow.
6. Measure the results in terms of qualitative and quantitative aspects.

1.10 Expected Results

1. The design supporting system in electrical switchboard is generated.
2. The database system planning is given.
3. Lower time consumption in designing process after the system is implemented.
4. The corporate strategic goal is partly fulfilled by improve job satisfaction in designing employees.

5. The accuracy and consistent work in designing electrical control panel is given; human error reduction is shown.

1.11 Overview of the Research

The overview of the research study on design support system can be given to highlight the overall detail for preliminary understanding of this dissertation.

- Chapter 1

  The overview of introduction for switchboard design is outlined with the brief detail in switchboard components. This can provide the readers with the clear understanding in basic information of the switchboard combing with the methodology conducted.

- Chapter 2

  This chapter focuses on the literature review, where the technical terms are appeared for the electrical engineering field. Overall switchboard design and equipments are explained in this chapter. Apart from the technical knowledge described, the detail on database management is explored thoroughly in the theoretical aspect.

- Chapter 3

  The cost structure of every manufacturing industry is apparently expressed, yet the primarily address is on the cost structure of the switchboard manufacturer that can be fallen into three basic categories: direct materials, direct labours and overhead.

- Chapter 4

  The system development life cycle is pointed out deeply in this chapter together with the database management system. These two basic principles are applied to switchboard industry and later are the main idea for this dissertation to follow.

- Chapter 5

  System analysis is the later phase after planning stage is the process to scrutinize the overall system. The analysis starts from the existing system analysis to the prospect system analysis. This chapter uses a technique tool called Fishbone diagram in order to analyze the existing system, which leads to the development of system analysis for the newly planned system to diminish all possible errors.

- Chapter 6

  A system design is the prime element for this research study where the dissertation will point out the design of the system in to three basic categories: conceptual, logical and physical. To achieve the objective of this dissertation, the logical and physical designs are only emphasized. In addition to both specific designs, the application program design is planned at this chapter for reader acknowledgement of the understanding of the application program in interface.

- Chapter 7

  The system verification is given at this chapter to provide the level of verification and validation of the results obtained from the newly planned system compared to the previously designed system.

- Chapter 8

  The conclusion is given for the benefits mostly combined with the future work that shall be performed in extent of this dissertation. The benefits are largely emphasized in this chapter to assure the readers with the verification of this system.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction to Switchboard Design

PMK has an experience in switchboard design and manufacturing over 25 years; thus, it is undoubtedly seen as one of the most experienced switchboard manufacturers in Thailand. Furthermore, PMK has a number of professional experts in this field combining with the technical support from the reliable strategic partner as ABB. This has led PMK to be one engineering-based firm in Thailand that has served all sectors.

This chapter will explore the depth detail of the switchboard features, components and rough design methodology; since by understanding this information, it helps the readers to gain the understanding of the overall concept of the switchboard and to be able to determine the factors in helping designing time, cost, and error.

2.2 The Switchboard Components

Electrical switchboard is the term for interpreting the electrical equipment for conveying electricity from one source to others as suggested by [2]. The electrical switchboard is aimed for the protection of electricity shock to human by the mean to use of electrical protection switches such as fuses and circuit breakers, respectively.

Switchboard consists of three major elements: conductivity part, functionality part, and enclosure part. Each part performs different functions, which will be later described. Furthermore, an individual part includes different equipment used in assembly.

Figure 2A General Switchboard

The conductivity part is the component in the switchboard performing the function of carrying the current, which is considered as a crucial function in the switchboard. Inevitably, such component has to possess one main characteristic: the conductivity property. This property can be seen in a number of materials; yet, the widely used material is copper (Cu). The copper is certainly not the best material in electrical conductivity; however, by comparing the cost issue with the conductivity property leads to the undeniable matter in using copper for switchboard work [2].

The functionality element performs mainly as switching task in order to turn on/off the path for preventing the flow of the current in the system. The practical example of functionality components can be the circuit breaker and fuse as shown below.

The enclosure part is the element to protect the overall components of the switchboard elements altogether. It is mainly manufactured of the steel.

Generally, the specification of steel defines the thickness of 1.6 mm. to 2.0 mm. to be used in the switchboard.

There are a number of steel types used in electrical switchboard. The manufacturers usually used the electro galvanized steel instead of other types due to its durability, cleanliness, and colour adhesiveness.

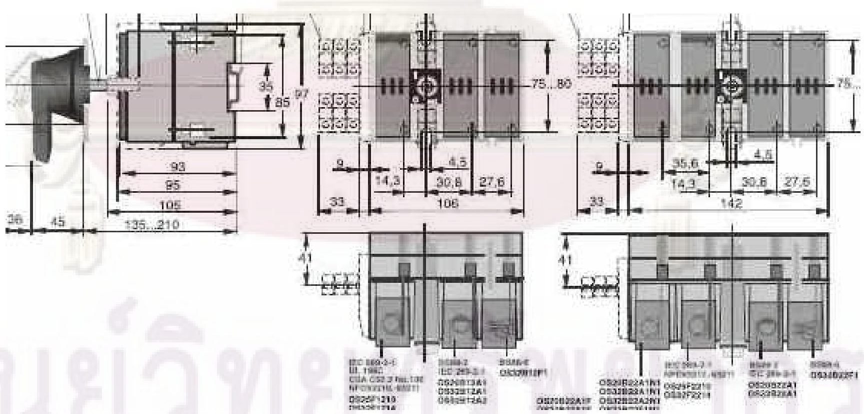


Figure 2B Circuit Breaker and Fuse

- Conductivity Part

  [3] shows that the conductivity part in switchboard is made of copper. The copper is defined to be the most suitable material in terms of cost and conductivity. It is mostly used material in electrical wires and cables. Copper configuration in the switchboard can be done in differently according to International Electrical Commission (IEC) standard. However, the guideline is only given, the calculation can be performed with ease from the formula and the summary of the current rating is listed.

  160A, 250A, 400A, 630A, 800A, 1250A, 1600A, 2500A, 3200A, 4000A, 5000A, 6300A

Figure 2C Frame of Enclosure

Also, the major cost composition in the switchboard is copper. The recent trend of copper price from the London Metal Exchange (LME) market is increasing because of many factors such as the increasing demand in

China consumption of copper, the oil price increase, depreciation of US dollar currency, and the fund investment trend in commodity.

- Functionality part

  The functionality part allows the flow of current and the protection of the electricity users. The protection operated by the functional part mainly is the over current protection and current short circuit protection.

  The over current protection primarily works on the basis of limitation of current which can be calculated from the basic formula of:-

$$I = \frac{S}{\sqrt{3}V_{LL}} \quad \text{Unit in Ampere}$$

  After acquiring the current limitation value; we have to use the 20% factor in multiplying to such value for selecting the current in circuit breaker used. Generally, the current limitation is ranged from 6 amperes up to 5000 amperes as can be seen in any commercial circuit breaker catalogues [3].

  Besides the current limitation value, the current interrupting capacity is another consideration in designing the electrical switchboard. The calculation can be roughly determined from the transformer capacity for the main distribution board. Mostly, the value used for current interrupting capacity is in kA-value unit.

  The voltage value is another factor in selecting the circuit breaker for using in switchboard. There are two major voltage-values adopted: one is the rated service voltage (Ue) and another is the rated insulation voltage (Ui). Both values in Thailand electricity system are normally 690 volts and 1000 volts for Ue and Ui, respectively.

- Enclosure Part

  This certain element is used in order to enclose all the conductivity and functionality components. The enclosure part is usually manufactured of the steel, which can be in any types of steel material. Yet, the most commonly used is the electrogalvanized steel- the steel is treated with the galvanizing process by chemicals for cleaning up the dust and oil.

Standard size of electrogalvanized steel is 2mm.-thickness in floor standing type. PMK also adopt this standard in the steel used.

2.3 Switchboard Designing Process

The switchboard design process in PMK is mainly divided into three main steps: receiving specification and electrical single line diagram from the customer, electrical switchboard design analysis by the costing engineering department, designing the switchboard by the existing database and engineering knowledge available. The summary of the switchboard designing process can be depicted as following:

- Receiving the specification and electrical diagram

  The sale personnel of PMK will receive the specification and electrical single line diagram as shown in figure2E. These specification and electrical diagram are designed by the authorized electrical engineer. After obtaining these documents, PMK engineering personnel who estimate and design switchboard will make a contact to the customers for further queries on these designs and specifications together with the confirmation of complete schedule.

- Electrical switchboard analysis

  The analysis must be conducted thoroughly by the estimate engineers in order to understand the given document for designing switchboard. The analysis start from the electrical system designed together with the information printed. Plus, investigate any error in the design where occurred. The analysis of such design and relevant document must be based on the following criteria:

Voltage system

Each territory requires different system of voltage system; presently, Thailand requires 380/220 V for designing switchboard.

Conductor standard

Conductor standard is varied for each standard. Either DIN (German standard) or IEC (International standard) is commonly adopted in the practical design of switchboard.

Short circuit value

This value is usually determined by the electrical designer which is usually specified in the electrical diagram.

Completing this analysis, the following step of designing switchboard

will be further performed. More importantly, PMK associated staffs are possessed with the expertise of these design and associated knowledge for these analysis and design together with the design manual from electrical text references.

- Designing switchboard

In this stage, PMK utilizes the expertise and past experiences together with the accumulated electrical switchboard knowledge in designing of the switchboard.

This stage is how PMK using the expertise and past experiences together with the accumulated electrical switchboard knowledge in designing the switchboard. The switchboard design in Thailand generally follows the international electro commission (IEC) standard. This standard is pervasively accepted all around the world.

The designing of the switchboard is performed practically by the experience accumulated, which follows the electrical engineering practice. The designing process actually starts with the step of the sizing of functionality part in order to get the rough size of the panel.

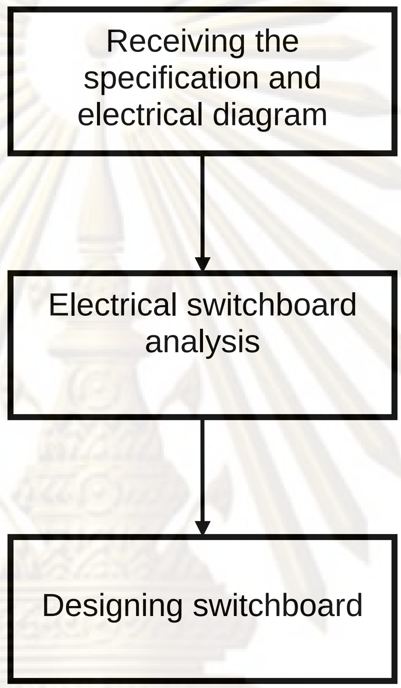


Figure 2D Designing Process Diagram

The later stage is to matching the sizing of conductivity to the functional part, which actually stated in the single line drawing. Yet, the conductivity part as conductor bar is commonly calculated by the formula. Generally, the table of the conductor size from general calculation can be illustrated below.

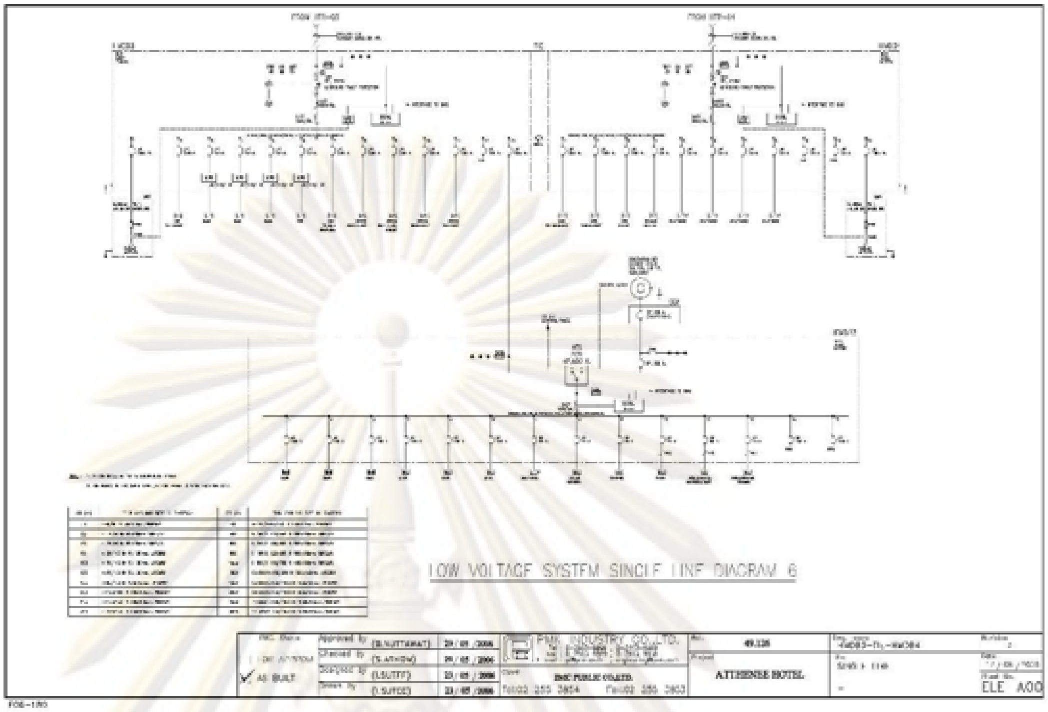


Figure 2E Electrical Single Line Diagram.

After finishing these two simple steps, the last part is the quality controlling part of the functionality part. This step is done by comparing partly from the previous design or partly from the designing provided by the clients.

Upon the completion of these stages, the switchboard design can be produced in the drawing. Moreover, the bill of material describes the part must be given according to this drawing. This allows the cost of the panel designed to be calculated.

Continuous current-crrying capacity of copper conductors (DIN 43 671)

Copper conductors of rectangular cross-section. Ambien temperature 40°C Conductor temperature 85°C

Continuous current in A (Bare)					Continuous current in A (Painted)				
Size	No. of conductors bare ratting				Size	No. of conductors painted ratting			
mm.	1	2	3	4	mm.	1	2	3	4
12 x 3	121	212	277		12 x 3	138	237	298	-
19 x 3	175	297	308		19 x 3	203	335	389	-
26 x 3	228	376	453	-	26 x 3	255	429	477	-
45 x 3	382	584	654	-	45 x 3	432	676	686	-
12 x 5	163	311	418		12 x 5	185	346	472	
12 x 10	266	526	737		12 x 10	300	587	822	
20 x 5	246	447	617	-	20 x 5	285	501	651	-
20 x 10	382	737	1,056	-	20 x 10	444	826	1,180	-
25 x 5	290	524	711		25 x 5	343	590	750	-
25 x 10	448	845	1,194		25 x 10	525	952	1,340	
30 x 5	339	601	801	-	30 x 5	409	679	844	-
30 x 10	612	946	1,323	-	30 x 10	604	1,073	1,493	-
40 x 5	451	747	974		40 x 5	512	851	1,019	
40 x 10	639	1,153	1,582	2,038	40 x 10	700	1,314	1,788	2,306
50 x 5	621	989	1,126	1,718	50 x 5	622	1,079	1,169	1,707
50 x 10	762	1,360	1,824	2,324	50 x 10	912	1,538	2,074	2,537
60 x 5	615	1,028	1,287	1,978	60 x 5	738	1,189	1,350	2,068
60 x 10	684	1,608	2,058	2,502	60 x 10	1,056	1,792	2,333	2,941
80 x 5	791	1,206	1,564	2,401	80 x 5	957	1,502	1,636	2,530
80 x 10	1,004	1,880	2,494	3,084	80 x 10	1,341	2,154	2,884	3,513
100 x 5	905	1,540	1,833	2,852	100 x 5	1,102	1,792	1,922	2,950
100 x 10	1,332	2,217	2,014	3,558	100 x 10	1,516	2,540	3,326	4,250
120 x 10	1,566	2,567	3,343	4,023	120 x 10	1,805	2,932	3,617	4,660
130 x 10	1,664	2,722	3,556	4,258	130 x 10	2,020	3,125	4,064	4,857
140 x 10	1,772	2,858	3,767	4,489	140 x 10	2,152	3,316	4,308	5,174
150 x 10	1,879	3,049	3,976	4,718	150 x 10	2,203	3,506	4,561	5,306
160 x 10	1,966	3,209	4,184	4,943	160 x 10	2,414	3,692	4,791	5,650
170 x 10	2,091	3,372	4,393	5,177	170 x 10	2,545	3,881	5,033	5,914
180 x 10	2,196	3,533	4,602	5,399	180 x 10	2,679	4,070	5,272	6,177
190 x 10	2,301	3,694	4,809	5,623	190 x 10	2,810	4,257	5,511	6,434
200 x 10	2,405	3,853	5,016	5,846	200 x 10	2,941	4,443	5,748	6,690

These calculation is computerized to compiled witch *DIN 43 671* by PMK INDUSTRY CO., LTD.

Figure 2F Conductor Bar Table

The PMK procedure in designing switchboard is thus pursuing the above steps; however, following the engineering practice, PMK has yielded a lot of data to be place in database such as the list of functionality part (circuit breaker).

Nonetheless, PMK has the existing database, the process still take some times since the design has to be done by experienced personnel and the data existed cannot be properly used because the data cannot immediately generate the compact design. The staff still has to do hand calculation. This results in time consuming together with the human error especially in newly recruited employees.

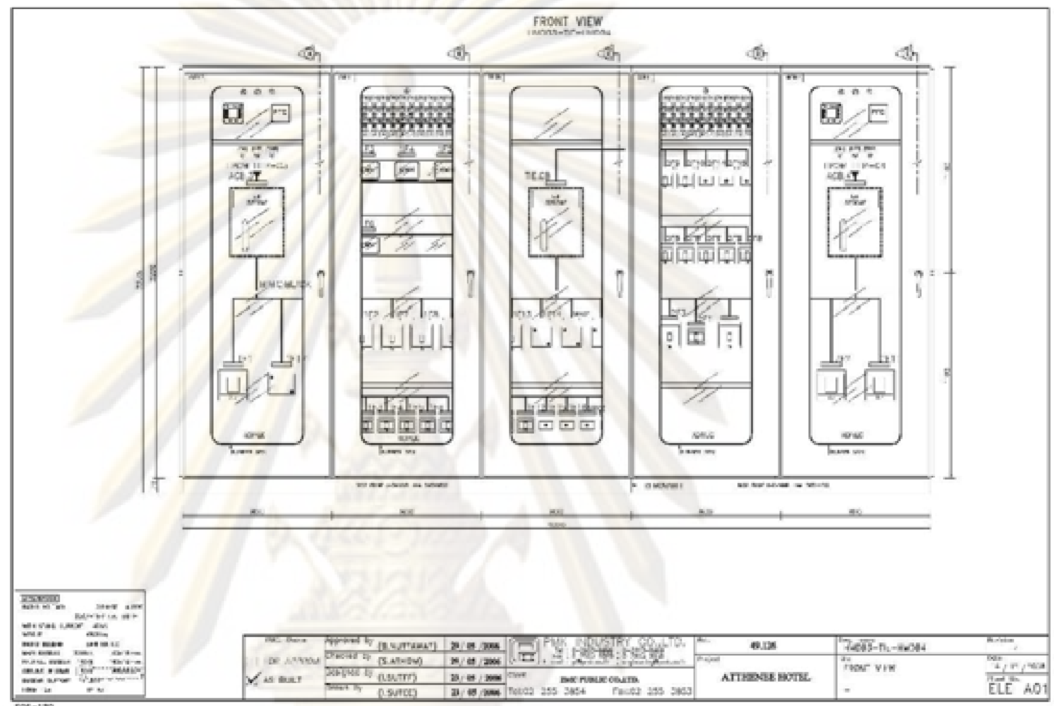


Figure 2G Switchboard Design

The PMK process must be further explored and improved in order to increase the efficiency and reduce the time consumption for ameliorating the satisfaction for both customers and internal staff itself.

2.4 Introduction to Database System

Database is deemed as an important component in every organization. It has been said that the company with the superior database can certainly maximize its profitability. The strong database management can also provide the competitive advantage toward the firm such as in The Amazon.Com, who boasts for the strength for the best database management in the core competency [4]. Additionally, the proper database system management must come from the carefully planned database system by systematically organizing the available data in the system along with the optimization in time management for executing the data.

In previous decades, the database is designed by rough tools such as the block diagrams together with the common specification form; whereas presently, the database has been evolved into the design methods and models that can be performed in parallel with the database system technology [5].

The database system is the storage of data organized systematically. To manage the database system, the term database management system is therefore defined, which will be later described in the content.

2.5 Benefits of Database Management System

Database offers a number of benefits, and applying such benefits to switchboard supporting systems, it can ultimately yield profitability to the firm. Moreover, designers who rarely rely on the design methodology are often found the failure of the development of information systems in the organization [5] [6].

[5] outlines some benefits for database management system: minimal data redundancy, consistency of data, integration of data, data sharing, enforcement of standards, ease of application development, uniform security, privacy and integrity controls, data accessibility and responsiveness, data

independence, and reduced program maintenance. Each benefit can be following described.

- Minimal Data Redundancy

  As the data have been collected, the redundancy in using the data can occur. The well structure of data into one integrated file can ameliorate the excessive data gathering. Thus, the adoption of database can reduce the redundancy of information.

- Consistency of Data

  Due to the redundancy is minimized, the consistency of the data thus definitely improved.

- Integration of Data

  As the data are organized in logically structured pattern, this definitely eases the users in the organization for filtering, utilizing, and further amending the data if necessary.

- Share of Data

  The data must be shared and used concurrently by authorized personnel in the firm for the purpose of data optimization; yet, the restriction of the data might be enforced in order to prevent certain users to access to confidential information.

- Uniform Security, Privacy, and Integrity Controls

  Since the data is collected and organized in one primary domain, the authority then can easily control the access to optimizing the security and privacy of the data. The pitfall can also be observed if the proper protection is not placed.

- Data Accessibility and Responsiveness

The data in the DBMS can be easily manageable in the access of the data path, which certainly give the faster response to the user in searching the data and utilizing it.

- Data Independence

  In the database approach, the data is separate from the programme application, which benefits the users in modification of the data that will not affect the programme application unlike other approaches.

- Reduced Programme Maintenance

  By independently separating data from the programme application, this gives the true benefit in the renewal and modification of time consumption and environment adaptation occurred to data and programme.

2.6 Cost Occurrence to Database Management

Although there are a lot of advantages mentioned, there is indeed cost exposed to the firms by adopting the database management. [6] has suggested the subsequent cost factor in implementing the database management.

- New, Specialized Personnel

  Whilst the database system needs to be integrated in a desired manner under the well structured design, it is necessary to have a specialized personnel to look after the whole system. For example, the programme administrator is set to control and manage the system successfully.

- Explicit Back Up

  Though the database management system has been successfully established, it is still very crucial for the company to have the back up since no database system is completely perfect and does not contain any errors. The back up can be formed in the similar pattern to the existing database.

- Interference with shared data

  The data in the system can be interfered because two or more users can access the date simultaneously; the data can also be altered by others without informing others additionally. This can lead to the data misinterpretation and abuse. The solution can be conceptualized in the way of transparency of the data access.

- Organizational Conflict

  As information in the system have to be shared, the responsibility with the consensus of the data owners must be accepted and used wisely in order to maintain the rightfulness in the organization. Also, the commitment in data development must also be performed for the ultimate goal of the overall organization.

2.7 Database in Organization

[7] claims that the database system in the organization can be classified into three main components: transaction processing, management information, and decision support systems, respectively. Each system performs the function differently.

- Transactional Processing System (TPS)

  The routine tasks can be performed by this system with aiming to accuracy, the rapid of the work and ease in use.

  The data access at this processing system can be mainly operated by the clerical persons.

- Management Information System (MIS)

The level of system is usually done by the management level, which can be from the head of the department in order to support the planning and control of the process in the firm. This system is presumably simplified to ameliorate the planning and control.

- Decision Support System

  Typically, the decision support system is used in the upper management level as the major decision often made at this level.

Having been elaborated on switchboard design and manufacturing, the research study explores on the database aspect. The aspect on costing is described in the next chapter by specifying on the switchboard.

CHAPTER III

COST STRUCTURE FOR SWITCHBOARD

3.1 Introduction

In manufacturing any electrical switchboard, it is similar to other manufacturing industry. Thus, the typical cost structure for manufacturing goods can be adopted. To be mentioned, the cost can be classified from its characteristics; for example, to make decision, to allocate the object costing, and to predict cost behaviour [8]. To apply to the switchboard manufacturing industry, it leads to the usage of manufacturing costs allocated in direct materials, direct labour and manufacturing overhead.

3.2 Switchboard Cost Structure

The manufacturing costing concept can be employed to our production process. The manufacturing costs comprise direct material, direct labour, and the last costing category of manufacturing overhead. [8] states that these three broad categories of costs can generate the term of conversion cost from direct labours combining with the manufacturing overheads, which comes from the experiencing of cost converting the direct material into finished product. In the production of switchboard, the conversion cost can be the production employees together with other necessary overhead like manufacturing machines.

3.2.1 Direct materials

The direct materials are defined to be any necessary materials that yield the finished goods. For the switchboard production, the direct materials are steels, electrical bars, circuit breakers, and metering equipment.

These direct materials are purchased either in kilogram unit for steel and copper bar or by quantity for other electrical equipment such as circuit breakers and metering equipment.

The underlying reasons for purchasing some products such as copper bar and steel in kilogram are because today's market environment adopts this principle as it is related to the world commodity market price and also this price unit is pervasively used in Thai market.

In switchboard manufacturer's perspective, every copper bar size will be converted from square meter into kilogram. Similarly, the steel price is projected from the commodity market, such that the price used in calculation for switchboard will be converted to kilogram.

Circuit breakers and electrical measuring instruments like ammeters, voltmeters and other controlling meters are measured based on the unit as they are traceable by pieces. These prices for all units are very standardized.

3.2.2 Direct Labours

As indicated, the direct labours are the labours that can be traced easily to any single element of products [8]. Interchangeably, it is often referred to the touch labour, which implies the touch of labour to the finished goods. Essentially, the direct labours for manufacturing the switchboard are often seen as the steel workmen, electricians, painters, and service engineers. This level of workmanships in the production lines can be observed during the process of producing the switchboards. So, in switchboard manufacturing process, they will be classified as the direct labours. The unit used for calculating the cost for the direct labour is in man-day unit.

3.2.3 Manufacturing Overhead

Apart from the direct materials and labours, other cost categories will be fallen under this cost classification. This type of cost includes indirect materials and labours, maintenance and repairs of manufacturing equipment, heat and light bills, and other facilities costs [8] [9]. Therefore, it is rather difficult to sort this cost type. In switchboard manufacturing design process, PMK has adopted the percentage of summation from direct materials and labours, which is applicable in all cases. Plus, this approximation has led to many advantages:

- The time reduction

  As the manufacturing overhead can be very tiny and insignificant; thus, it will not be necessary to break down this cost immediately under the design process.
- Validity proven by manufacturing and accounting departments

  Proving to be validated by both departments that is directly associated with the switchboard designing system can certify the applicable cost estimation and design. Specifically, this kind of cost estimation can benefit extremely especially for the future forecast that needs to be given to the government revenue office.

PMK has implemented this cost estimation in its costing sheet for a number of years and it is validated, this ultimately ascertains the success of cost estimation in designing switchboard.

3.3 PMK Cost Structure in Switchboard Design System

The switchboard design system consists of the above costing structure. These three categories are applied to two costing designing sheets, which are illustrated in the following figures.

The first designing and costing sheet in figure 3A primarily comprises of the overall three bases of cost categories. Yet, main equipment such as circuit breakers and instruments will be inputted in excel database as shown in the figure 3B.

These two costing and design sheets are the current version of the designing system in PMK switchboard designing system, which mostly designed manually.

Eventually this version of design system takes amount of time and experiences of design engineers to perform such work. Therefore, the newer designing system should be executed and explored in order to diminish such problems.

Cost Calculation Sheet								
PMK INDUSTRY CO., LTD.								Switchboard
Calculated By :-	0	Review :-	0	By :-	0		Date :-	00/00/2551
Project Name :-	0		Customer :-		0			
Switchboard Name :-							Page No.:-	1 of 1

ITEM	DESCRIPTION						COST	
A	Cubicle [/] Galvanized Sheet	[ ] Normal Steel Sheet						
	A.1 Cubicle approx. Size :-			(HxWxD)		Channel		
	A.2 Partition (- 1,000 Baht / Partition)						-	-
	A.3 Labour Charge(+ Man-Day - Baht)						+	-
					Total Item A			-
B	Copper Busbar, Support, Insulator and Accessories							
	Ambient Temperature	Busbar Rating :- [ ] Painted [ ] Bare [ ] 1,000 A/inch2						
	[ ] 35 C [ ] 40 C	Electrical interlocking for			Set.			-
				Cost :-		Baht/kg/M.	Kg / M	
	B.1 CU MAIN	A. Size :		mm.		M.		-
	CU N	A. Size :		mm.		M.		-
	CU G	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	CU	A. Size :		mm.		M.		-
	B.2 Busbar Support type PI-101s,125s			EA Cost :-		Baht / Ea		-
	Busbar Support type PI-270s			EA Cost :-		Baht / Ea		-
	Insulator type PI-76			EA Cost :-		Baht / Ea		-
	Insulator type PI-51			EA Cost :-		Baht / Ea		-
	Insulator type PI-35			EA Cost :-		Baht / Ea		-
	B.3 Power Cable type THW / Sq.mm			M. Cost :-		Baht / M.		-
	Cable Lug for Cable			Pcs. Cost :-		Baht / Ea		-
	Power Cable type THW / Sq.mm			M. Cost :-		Baht / M.		-
	Cable Lug for Cable			Pcs. Cost :-		Baht / Ea		-
	Power Cable type THW / Sq.mm			M. Cost :-		Baht / M.		-
	Cable Lug for Cable			Pcs. Cost :-		Baht / Ea		-
	Control Cable type VSF/ Sq.mm			M. Cost :-		Baht / M.		-
	B.4 Accessories.					Chamber.		-
	B.5 Labour Charge.			Man : Day		Baht		-
					Total Item B			-
					Total Item A+B			-
					Engineering Charge and O/H 3%		-	-
					Transportation			
					Total Cost			-

Figure 3A Current Costing Sheet for Switchboard No. 1

PROJECT : Mock-Up Project

Q.PI 000-1/2551

Item	Description	Type	Brand	Q'ty.	Unit Price	COST		
						Discount	Price Each	Total Cost
A6	EACMCC-P1-02							
1	MCCB 3P 11-16AT/160AF 16KA 415V R16	T1B160	ABB	1	3,000.00	50+10+10%	1,215.00	1,215.00
	- Rotary Handle (RHE) For Tmax T1-T3	T1-T3	ABB	1	2,300.00	50+10+10%	931.50	931.50
2	DOL STARTER 1.1KW / 1.5 HP C/W	-	ABB	1	1,470.00	50+10%	661.50	661.50
	1- MAIN CONTACTOR	A9-30-10						
	1- OVER LOAD	TA25DU 3.1						
3	Auxiliary Contact Block 1NO	CA5-10	ABB	1	165.00	50+10%	74.25	74.25
4	Control Fuse with fuse base rail mounting	E931-32	ABB	4	-	-	65.00	260.00
5	Pilot lamp LED 230 V AC.	CL-523	ABB	8	170.00	50%	85.00	680.00
6	Push button spring return	CP1-10	ABB	2	160.00	50%	80.00	160.00
7	Selector switch 2 position (L / R) ,Size 48x48 mm.	CA10 A220 THB	Blue line	1	1,020.00	45+10+10+10%	408.97	408.97
8	Control Relay 4NO/NC coil 220 V AC.	RU4S-NF	IDEC	5	236.00	50+2%	115.64	578.20
	- Socket 14 Pins for RU4	SY4S-05DF	IDEC	5	178.00	50+2%	87.22	436.10
9	Cubicle Steel thickness 1.6 mm Wall Mounted Indoor Type	-	PI		-	-	-	-
	- Approx Size : xx mm. (hxwxd) c/w							
	- Wire & Accessories.							
	TOTAL A6							5,405.52

Figure 3B Current Costing Sheet for Switchboard No.2

3.4 Proposed Version of Newly Designed System (Preliminary)

It is cumbersome in designing each switchboard, the newly proposed solution must be able to automatically generate the above designing sheet promptly with the less amount of time consumed.

The new design system must be user friendly as the new design engineers take little time to study on the system in order to design the switchboard.

In addition to all these features, the newly design system will include the randomly generated various designs according to the same requirement for the optimization design purpose.

CHAPATER IV

SYSTEM DEVELOPMENT AND DATABASE MANAGEMENT SYSTEM FOR SWITCHBOARD

4.1 Introduction

In development the system, the understanding of the principle is necessary in order to acquire the knowledge of the system operation. Under the study of our switchboard design support system, it is better to know this principle of such development. The concept of system development life cycle will be apparently used together with the management of the system by introduction to the database system in this chapter to gain the deeper knowledge in managing the switchboard design system.

4.2 System Development Life Cycle (SDLC)

As introduced in a number of textbooks, generally there are two approaches as elaborated in [10]:- the system development life cycle (SDLC) and non traditional methods. Having been executed over decades, SDLC can be assured the beneficial edge for any system development.

The system development life cycle is the model for people to use in development of any system. Thus, it can be found suitable in applying this fundamental to the supporting system for the switchboard manufacturer.

Typically, the SDLC is performed in sequence as implied in other name of waterfall model development as stated in [10]. The following figure briefly depicts this waterfall model.

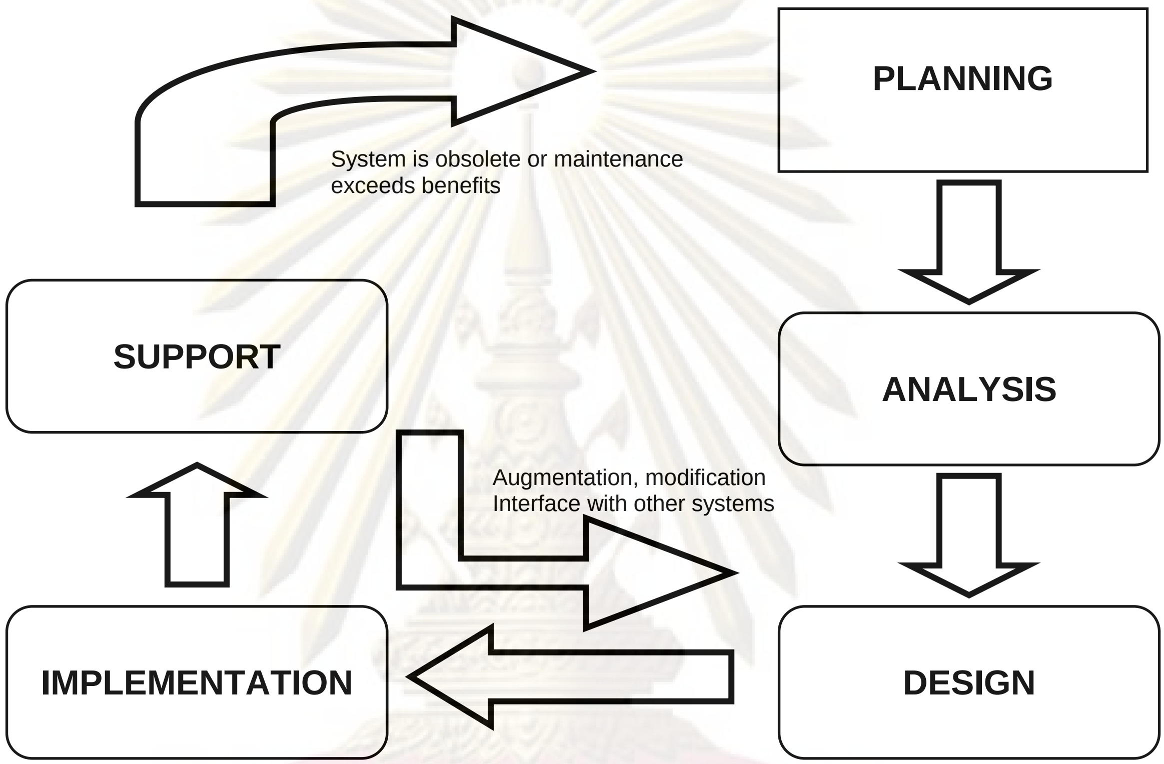


Figure 4A The System Development Cycle (SDLC) [Adapted from [10]]

The system development cycle is divided into 4 major phases: planning, analysis, design, implementation and support respectively. The step names are simply directly interpreted.

- Planning is how the users plan the system of how it will be used.

  Planning is the procedure where the users organized the system that will be implemented.

- Analysis is to determine the system in various aspects. [11] has summarized these aspects into the following points: investigation, technical, economic, operational studies, and requirement definition.
- Following the previous steps, the acquirement of comprehensive list of the requirement will generate the design of the system to explain the description of the components and how they work, construct and testing.
- Implementation takes place after the design has been accomplished. As a result, there is an execution of the program by users. To convert from the preceding or existing system into new system can be done in several ways, yet, the most widely used one must be the pilot project that can reduce the errors and inaccuracies of the system.
- The final phase is the support where the IT support staff usually performs this role with two main tasks in user help and maintenance functions.

As succinctly explained on the SDLC method, it will later be carried out throughout this research. Simultaneously, the database management system, thus, should be explored by the readers to obtain some overview of the process of database in combination with the operation of its database system; since in designing switchboard, the database is an important element in this supporting system.

4.3 Database Management System

Recalling from literature review, database management can be performed in the systematic form to benefit organizations to operate effectively and efficiently. Most of the database functions are conducted to support the major functions along the company value chain. Nevertheless, the system can be conducted to be a main task in the value chain to optimize the profit as well [12].

4.3.1 Introduction to Database Management System

The database management system (DBMS) can be clarified in a number of meanings. To be easily perceived, [13] has briefly explained the DBMS to be a software system for defining, creating and maintaining the database by the users with the provision of controlled accessed made by the users.

In executing the database management system, it has provided a number of advantages such as the control of data redundancy, the consistency of data, data sharing, and productivity increasing; these primary benefits are definitely applied to switchboard designing system.

4.3.1.1 Database Management System Components

The components of the database management system are similar to other systems, which consist of hardware, software, data, procedure and people [13].

- Hardware: this element is certainly crucial for users to operate as it is the interface device for the operators to work on. It can be either single notebook to the large main frame in case of the large data storage.
- Software: the software components mainly include the non-procedural language such as SQL or any application program such as C for manipulating the overall system.

- Data: the most crucial part of the system can be stored in the schema, which is the structure of the database that contains the tables and attributes.
- Procedures: the components that guideline users of the operation. It is mostly generated in documents. It can starts from the log-on process to the modification of any necessary data in the database.
- People: it can be the data administrators; IT related staff, or the system users. They are all relevant to the system management. This people factor seems to be the one of the most difficult factors as it is the most problematic part amongst all elements.

4.3.2 Database Management System for Switchboard Design

Adopting the principle of the database, the relationships of the entities are linked by non-procedural manipulating language SQL and the application software written by C#.NET called Estimate Calculation Program developed by the researcher.

Prior to further developing the system in the Switchboard Design, the above principle in planning process is under the necessary consideration.

4.3.2.1 Database Planning for Switchboard Design

According to [13], database planning is the activities that permit the process of database application to be identified as effectively and efficiently as possible. The common relationship diagram can be done accordingly in order to complete the switchboard design process.

By thoroughly considering a number of relationship from entity-relationship model (E-R model) from [5], it can be pictorially illustrated the relation of entity by the subsequent symbols.

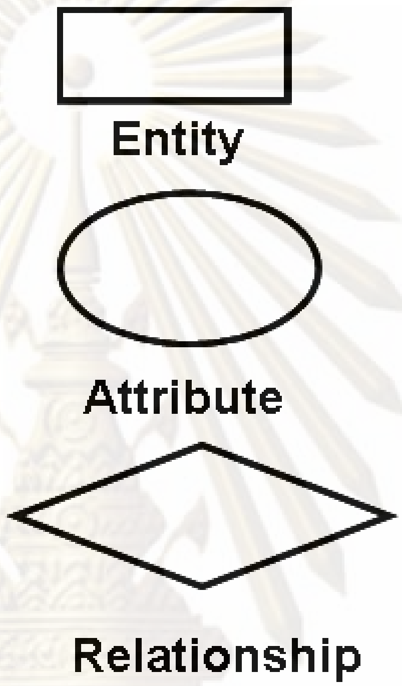


Figure 4B Typical Symbols for E-R [13]

Applying the E-R model for the corporate data model, the switchboard design system can be built based on the corporate data model; yet, only design engineers are identified as the design functional area of switchboard.

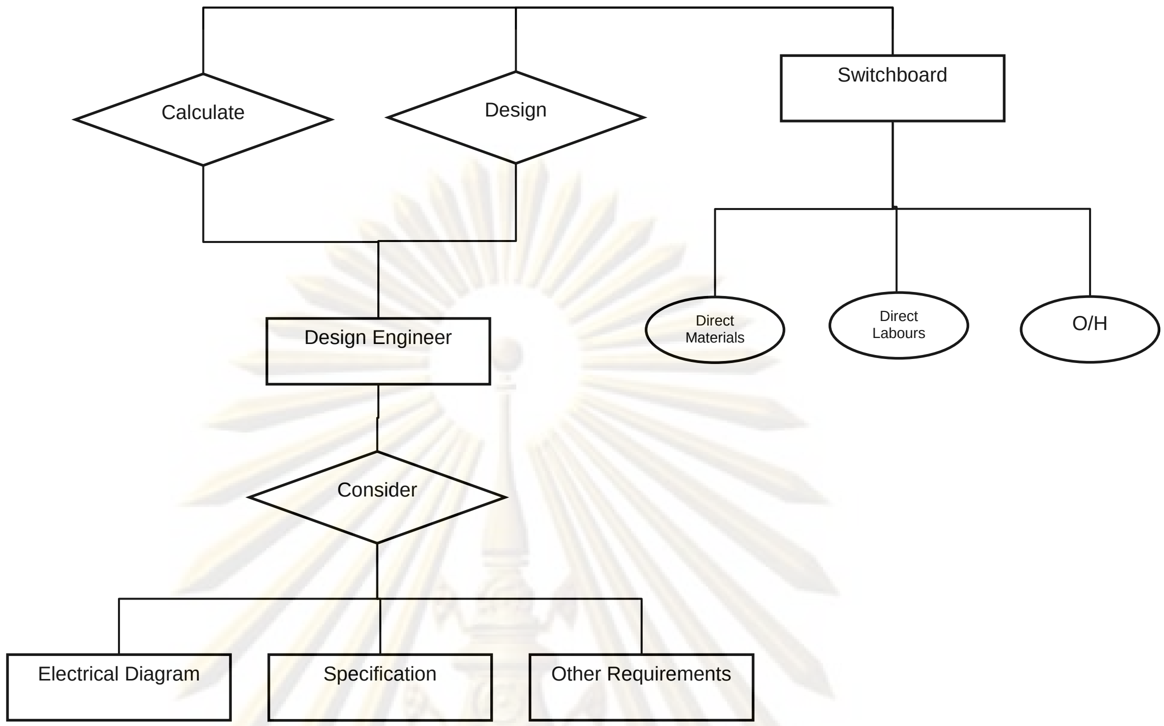


Figure 4C The Switchboard Design Planning System E-R

The above entity relationship diagram has illustrated the planning system in supporting the switchboard design process. However, the attributes of switchboard mentioned is the financial factor, whilst in the latter chapter, the attributes specified will be focused on the equipment factor such as copper, circuit breakers, steels and so on.

Consequently, the planning diagram is guiding the database system for switchboard support process. The next chapter will explore on the analysis of the design system used in designing switchboard. The current system and proposed design systems are investigated simultaneously for the readers.

CHAPTER V

SYSTEM ANALYSIS

5.1 Introduction

The analysis of the database management system is exploited in order to ensure the correctness and reliability of the system that the firm will create. This chapter will elaborate on the existing system analysis together with the newly designed system analysis. Regarding to [13], the system analysis is used to determine and explore the system elements in combining with its pros and cons of such designed system. Therefore, to fulfil such definition, the use of analysis tool can be found in the subsequent section.

5.2 Current System Analysis for PMK Switchboard Design Support System

The current system employed in PMK is the basic adoption on the spreadsheet program in collaboration with the engineering expertise. In brief, the existing system in designing switchboard is mostly done manually, only the equipment data are stored in the excel program.

This process involved the analysing and designing of the switchboard to result in the bill of material summary has been used for a number of years. However, there is some dissatisfaction amongst all involved parties by using this method for generating such bill of material and the switchboard design because of the time consumption. The analysis of such current design process can be summarized by the cause and effect (fishbone) diagram in the following chart.

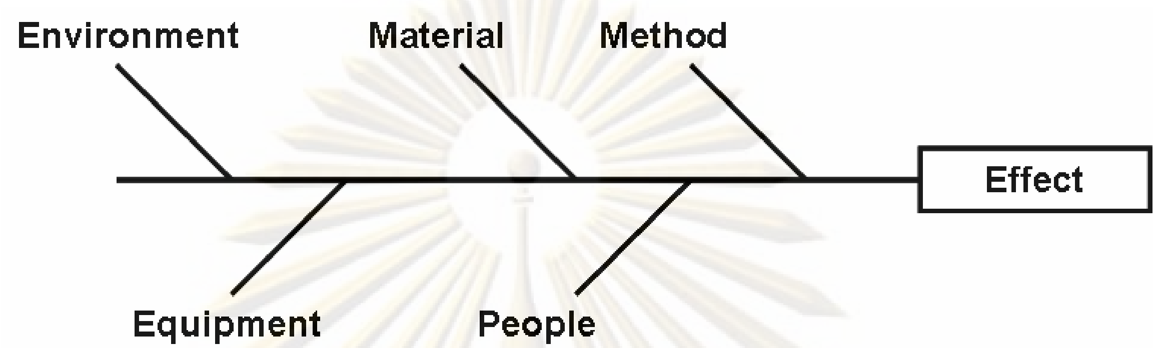


Figure 5A Cause and Effect Diagram by Ishikawa

Mr. Ishikawa (the inventor of fishbone diagram) invented this diagram in order to analyse the quality management problem in the manufacturing process [12]. Presently, it is executed in various applications that have to be analyzed for the findings of causes to the problem. This diagram comprises the factors influencing the quality yielded in the process.

There are six major factors described by Ishikawa affecting the quality in any manufacturing process; this case the diagram is adapted to the designing process of the switchboard nonetheless. Plus, this diagram can be exploited for the identification of cause and effect of the design process.

1. Machine

   Machine can be interpreted in the tool usage in the process for example the drilling machine for the wooden chair manufacturing process. Yet, the machines for switchboard process are computer and calculator for example.

2. Method (process)

   Method or process in any manufacturing process can be the production method in making one wooden chair such as the drilling and cutting process. The process is the cause of any dissatisfactions occurred which has to be explored in particularly the switchboard design. This significant can be how the existing process slowing the time or making any error in the resulted design.

3. Material

   Low quality Material in the manufacturing of any product definitely leads to the poor quality of product such as the poor quality of wood can provide the deprived quality of the chair as a result. For adapting to the switchboard process, the material can be insignificant in considering the quality problem of the design outcome.

4. Measurement

   The measurement is how to detect the ongoing process and outcome whether the process meets the requirement level of the operator. This factor for switchboard design can be measured in term of accuracy of the quantity design.

5. Man

   The cause of the problem can come from the man or operator. In all manufacturing process, human error is considered to be the significant cause that can produce the error in any manufacturing process. For an example of the switchboard design of PMK, the expertise and experience of the design engineer can generate the effect of the problem found such as the newly recruited design engineer certainly takes longer time consumption in designing the switchboard.

6. Mother Nature (Environment)

The Mother Nature is the factor that cannot actually be controlled by any involved personnel. Since this factor is uncontrollable, general manufacturing process has to be under careful attention of necessary parties to prevent the effect from this factor. In the case of switchboard design, Mother Nature is not profoundly important because the design process is taken place in close condition of the office.

Apart from analysing the designing support process by the fishbone diagram, the in-depth interview method conducted with the design engineer managers can be viewed accordingly in numbers for the causes of delaying the design support process.

1. The electrical diagram is unclear.
2. No electrical specification is provided.
3. Waiting for technical and price from the suppliers.
4. Inexperienced staff.
5. Other incoming designs requested are interfered.
6. Whilst performing the design, customers terminate the design request.
7. During on-queue design process, there is other emerging design requisition interruption.
8. Inappropriate working ambience such as hot condition.
9. Too many numbers of proposals are requested.
10. Different designs for each panel leads to difficulty in design.

To sum up, the cause and effect diagram for PMK support system in designing switchboard is in figure 5B.

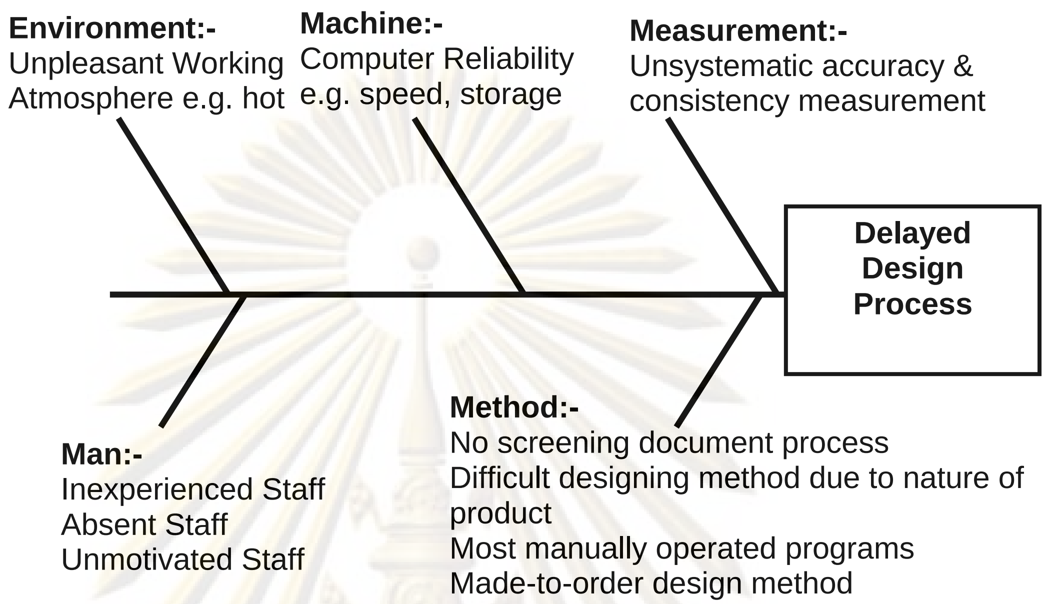


Figure 5B Cause and Effect for Switchboard Design Process

Focusing on the causes found in this fishbone diagram, it is inevitably seen that the method and man can be the major roots of the cause, which can be changed and ameliorated by the system and data reorganization. As stated above, the complication method in designing the switchboard in combination with the difficult nature in designing switchboard are the prime causes for the time consumption of designing process.

Apart from the method, other factors can influence the undesired time consumption of designing process; however, other causes of such above effect can be undoubtedly manipulated by human as opposed to method factor that can be done by system and data rearrangement. Thus, this method cause will be under interest throughout the remaining of the report.

As current methodology takes considerable time in designing switchboard, these difficulty barriers must be diminished and eventually eliminated for the faster process in preliminary design.

From all these difficulties found, the new system has to be developed to mitigate the troubles found in the design support process.

5.3 Future System Analysis for PMK Switchboard Design Support System

Prior to examine the proposed design support system, the system definition shall be given as it will inform the scope of the work conducted in the database area for PMK supporting design system.

5.3.1 System Definition for PMK Design Support System

The scope of the design support system for PMK will be the design of the switchboard with the generated documents of material used for the electrical diagram and requirements. Further, the cost for the design is also given. Referring to this definition, the two primary programs will be designed and employed: the database program and application program, where the later application program is for the interface between the design engineers and database.

5.3.2 Requirements Collection for Switchboard Design System

In order to obtain the requirements, the interview techniques have been performed to all of the design engineers. The conclusion from PMK staff for switchboard design system is summarized as followed.

- The user-friendly function is a mandatory.
- Automatic operation shall be set.
- The program must include all detail in switchboard design.
- The simplified design must be generated for the data input done by the designer.
- Time concern is the primary consideration.
- All relevant documents must be created from such program set.

By acquiring this information from the interview, the analysis of prospect design support system is therefore explored.

5.3.3 Prospect System Analysis for Switchboard Design

There are five areas of analysis for the design support system in switchboard, which is adapted from [10]. There are investigation, technical feasibility study, economic feasibility study, operational feasibility study, operational feasibility study, and requirements definitions. All aspects of analysis are given.

- Investigation

  As earlier explored, the design support system for PMK switchboard design covers the area of the design process, which is considered difficult in designing as the intricate nature of the switchboard product design.

  The support system will answer the opportunity in time mitigation for designing the switchboard, which contributes to the increase level in customer and employee satisfactions together with the reduction in error of design and cost miscalculation.

- Technical Feasibility Study

  The viable programs are available in the market for this design system. The implementation of SQL in database part and C# for application program part are the possible solution.

- Economic Feasibility Study

  The economic part is not in the focus under research interest. At large, the resource is currently available at PMK, and overall benefits outweigh the overall cost incurred.

- Operational Feasibility Study

  Certainly, the system employed will be appropriate for the intended users, which indicates the possibility in operation of the system.

- Requirements Definitions

  As mentioned previously, the features must include the program in building up the design lists for switchboard design, which can be performed automatically. Plus, the application program is used to interface the database to the design engineer, which adopts the concept of drag and drop.

In conclusion, the analysis of the support system has been given. The subsequent chapter will investigate on the design of the overall support system. The design of the support system consists of the section of the database system and application program, which will be focused in the next chapter of the research.

5.4 Design Criteria

In designing the switchboard, the design engineer has a number of criteria to strictly follow because electrical engineering knowledge and practices is the point that cannot be compromised as they are determined for safety concern. The mandatory standard for the switchboard manufacturer must follow is the IEC standard. This standard is obtained from the testing performed at the accepted laboratory such as ASTA in Italy.

5.4.1 Reasons for Setting Design Criteria

In conforming to IEC standard for designing the switchboard, there are several reasons to establish the standard and design criteria in order for all designers to follow. These setting criteria certainly lead to benefits for the clients as well.

- Correct design standard

  To comply to IEC standard as PMK achieved from abroad, it is necessary for designers to design the switchboard in compliance with this standard to ensure to correct of the design.
- Adjustment of client requirements

  Most of the time, customers always concern on price factor- the cheapest solution. Nonetheless, the adjustment of requirement must be done as PMK always produces the standard set to IEC compliance. This leads to the solution of cost optimization to IEC standard, nor the client standard.
- Cost Optimization

  As previously stated, the cheapest cost solution for the customer with the lack of standard cannot be occurred in PMK design criteria. Therefore, the cost optimization with the PMK standard establishment is the only offering made by PMK designers.

- Reliable Standard Assurance

  The design criteria also benefit the customer in standard setting with the affirmation in IEC correct standard.

- Designer Reminding Factor

  The design criteria will lead to the switchboard designer to strictly follow the IEC standard, which is well accepted around the world. Plus, this reminder will teach the designers how to design properly and correctly.

5.4.2 Designing Model Analysis

This model is built to ensure all designers have taken the rules of IEC standard seriously. There are three elements in the initial step: electrical single line, specification and customer requirement, which will be later screened by PMK staff with IEC compliance standard criteria. This further leads to the switchboard design with the conclusion of customer proposal.

Having been focused on PMK standard, it follows the IEC compliance. There are a number of criteria which has to be followed in order to be placed in the design system in the further phase.

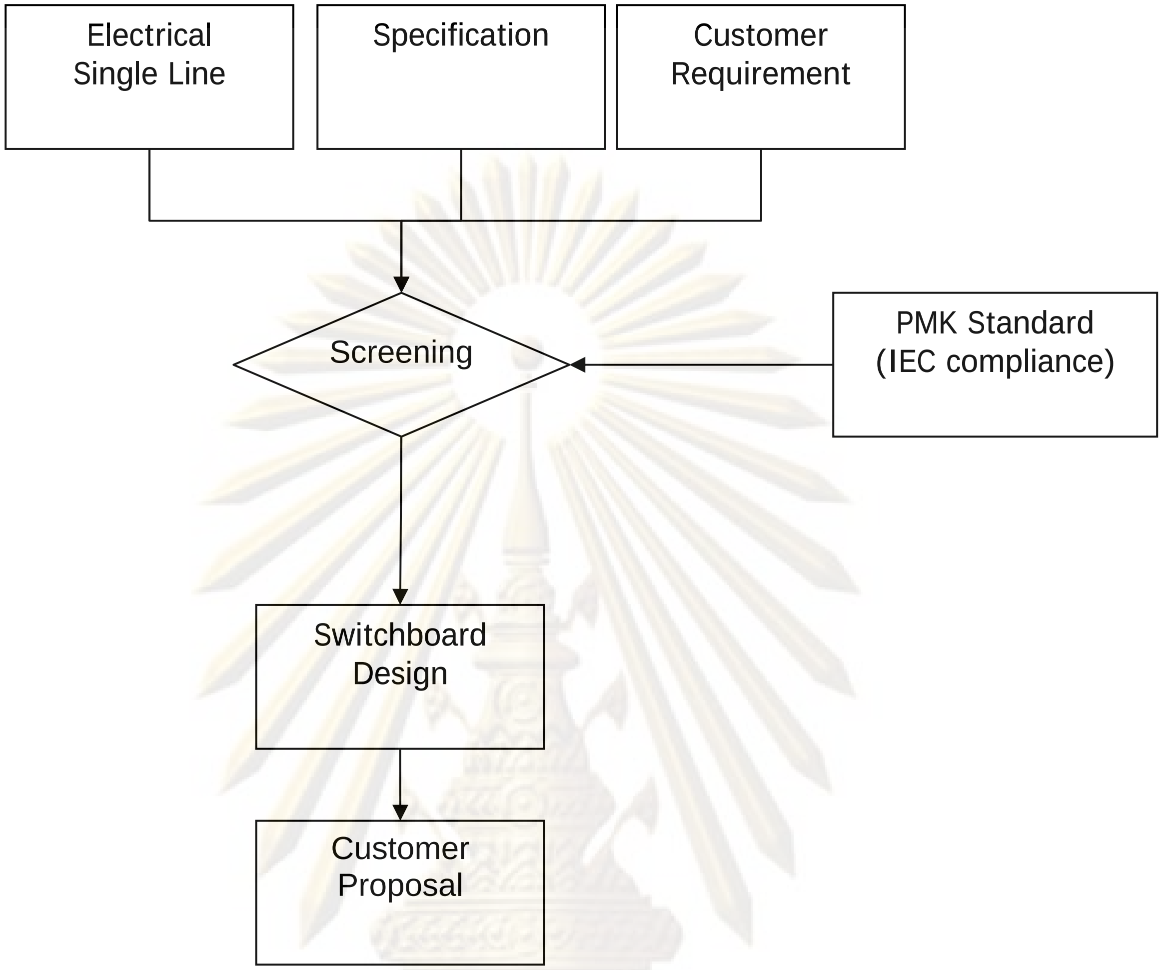


Figure 5C Design Process Model

5.4.3 Design Criteria Establishment

The completion of the standard has led the company to design the switchboard conforming to such standard. The following information will be the technical guidelines and models for designing the switchboard, which will be conducted prior to the implementation of the switchboard design program.

By strictly following the IEC standard, the cost optimization can be generally obtained by considering a number of factors as follows:-

- Current Rating with unit in amperes
- Voltage System with unit in volts

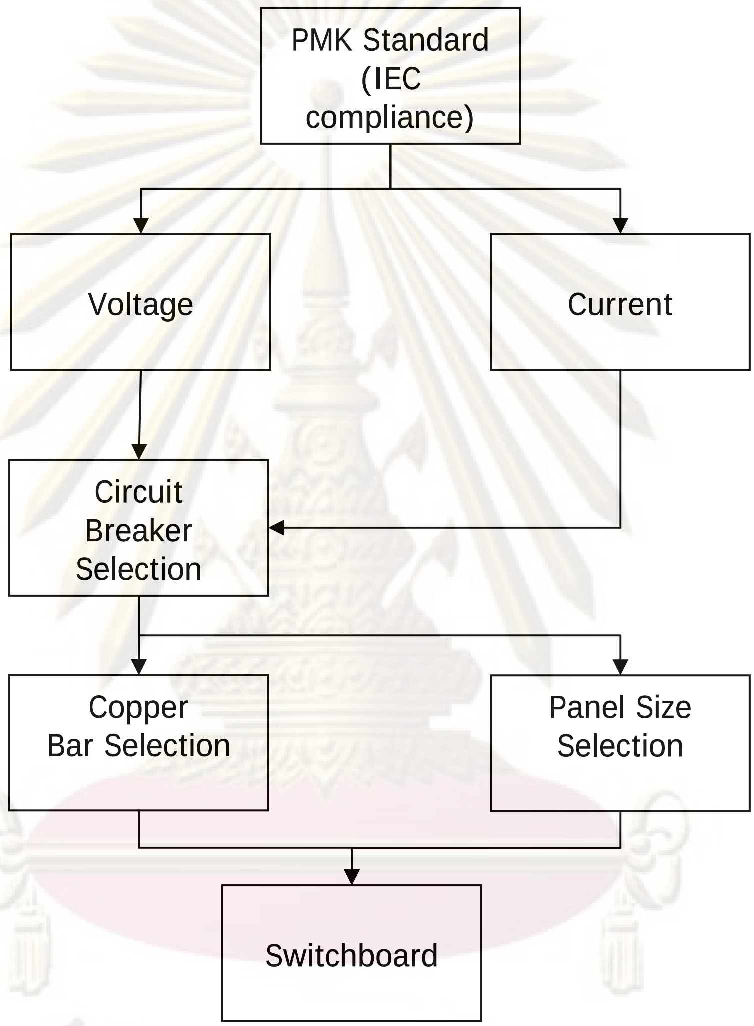


Figure 5D Design Criteria Model

By contemplating these two factors, it can generate the model of the used of copper bar and panel size, which implies the use of steel for each panel.

Recalled from chapter 2, the relationship model explained will contain several equations. Initially the current rating of the panel starts from the calculation of this equation [2].

$$I = \frac{S}{\sqrt{3}V_{LL}}$$

I stands for the current that will be united ampere.

S stands for the complex power that can be described in VA, however, this value is actually found in the transformer capacity.

V_{LL} stands for line voltage that can be described in the unit of volt. In Bangkok and suburb area under the MEA (Metropolitan Electricity Authority) utilizes the 380 volts

Mostly, the safety factor ranged from 10% to 20% is added up to current value to ensure the tolerance level [3].

Precisely, the value of current rating can be generated by this equation. Afterwards, it is the selection of circuit breaker current, which must be more than this calculated current rating.

The current ratings of circuit breakers are selected according to market availability. The range is 160, 250, 400, 630, 800, 1250, 1600, 2500, 3200, 4000, and 5000 amperes.

This circuit breaker selection will lead to the manipulation of copper bar selection with the following size.

All conductor bars are derived from the formula according to [3] the equation is shown as follow.

$$j = \delta \times E$$

The j stands for current density with the unit of ampere per unit area.

The δ is used for the conductivity factor, which can be provided in the table [3].

E stands for electric field in Volts

By simplifying this equation, the table of the following current rating can be given in order to reduce the time consuming in calculation of the conductor bar size in matching with the current. This equation is pervasively calculated to acquire the data on the cross sectional area of the copper bar. There will be use in the equation towards the current.

This above equation generates the conductor bar table for using in connection with the circuit breaker. This bar size can be derived and summarized into this following figure 5E [2].

The size of copper bar is selected to determine the panel size in conjunction with the breaker size.

5.4.4 Selection for Panel Size

The panel size is selected accordingly from above criteria; the primary factor for selecting the panel size is circuit breaker size. The example of selecting the panel can be illustrated.

Regarding to [2], the panel size can be chosen based on the circuit breaker size. The above figure is wisely illustrated the clearance space for panel on both side of circuit breaker. To optimize the design, the clearance must be kept at half of circuit breaker width. For instance, if the circuit breaker is 400-mm width, the clearance must be kept 200 mm. for both side of the panel for optimization in designing the panel.

Bar Size (mm.)	Weight (kg./m.)	Conducting Current Rate at ambient temperature 35°c and conducting temperature 65°c		
		Bar Amount per Phase		
		Bare Rate		
		I	II	III
12 X 3	0.352	135	238	310
12 X 5	0.558	177	312	398
12 X 10	1.116	285	553	811
15 X 10	1.339	347	667	921
20 X 5	0.893	274	500	690
20 X 10	1.785	427	825	1180
25 X 5	1.116	327	580	787
25 X 10	2.232	501	896	1187
30 X 5	1.339	379	672	896
30 X 10	2.678	573	1060	1480
40 X 5	1.785	482	836	1090
40 X 10	3.571	715	1290	1770
50 X 5	3.214	583	994	1240
50 X 10	4.464	852	1510	2040
60 X 5	2.678	688	1150	1440
60 X 10	5.356	985	1720	2300
70 X 10	6.249	1116	1748	2104
75 X 10	6.696	1178	1832	2193
80 X 5	3.571	885	1450	1750
80 X 10	7.142	1240	2110	2790
90 X 10	8.035	1366	2297	3028
100 X 5	4.464	1080	1730	2050
100 X 10	8.928	1490	2480	3260
120 X 10	10.71	1740	2860	3740
140 X 10	12.449	1982	3229	4214
150 X 10	13.329	2102	3410	4448
160 X 10	14.28	2220	3590	4680
200 X 10	17.84	2690	4310	5610

Figure 5E Conducting Bar Size in Correlation with the Current Rating

- Statement of Problem

  During designing process, either design engineers or customers may request for unnecessarily larger panel size above the standard of IEC complied standard.

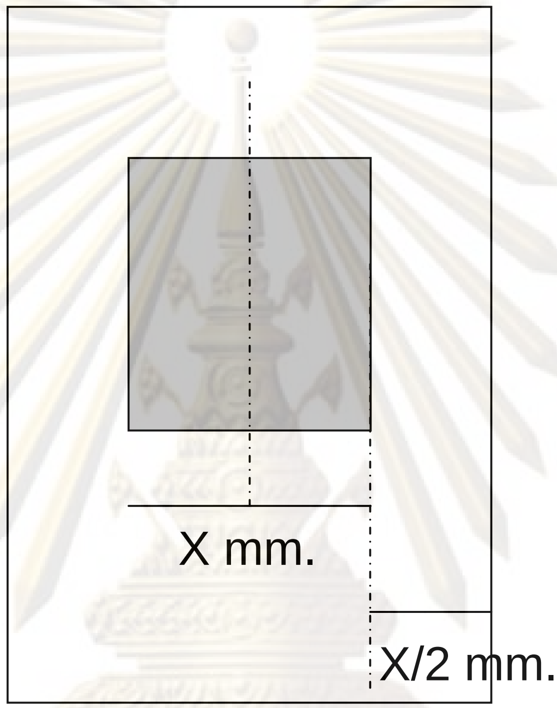


Figure 5F Panel Size Clearance Illustration

The underlying requests come from the inadequate knowledge in switchboard design or the larger size of panel may imply the better switchboard. This seems incorrect because the larger size does not mean the better quality. Also, this leads to the cost additional factor and unnecessary material required, which may result in the less opportunity in competitive marketplace.

- Design Optimization

  After investigation of all relevant detail of the switchboard, the design optimization must be exploited thoroughly. Thus, the author has added the optimization feature in the application program by alerting message box of non optimization found

- Alternative Solution

  After the redundancy appeared in the program, the designers have two solution provided to the clients.

  Firstly, the designer will inform the clients for the non optimization found and ask him/her to change the design. If the clients still insist in the design, the designer therefore proposes this design with price and material for the clients.

  Secondly, the designers alter the design for the optimization purpose and propose this solution to the client later, but the remark will be notified in the proposal.

  Nonetheless, the optimization design is always proposed to the client for the purpose of cost benefit.

- Proposed Solution

  The design optimization can be generated in application combining with the design and material list.

5.5 Summary

Following the step of designing the panel, the designer can rely on the correct data and optimum design obtained. The last step of criteria selection is the panel size. Whilst designers complete the determination of the panel size, the designers afterwards will go through the database program that is used with the application program for choosing the panel size and determine all the necessary bars used.

CHAPTER VI

SYSTEM DESIGN

6.1 Introduction

After understanding the analysis of the future system implementation, it is the next role of system design that this chapter will explore. The support system is designing switchboard mainly consists of two elements: database design and application design. The database design addressed on how system operates based on the data storage, whilst the application design emphasizes on the program function to interface between database system and design engineer.

For database system design, three primary components are referred: conceptual, logical and physical design. To be concise, this research study will show the support system design in single unit of the design. Also, the application design for interface with the design engineers. However, the program code for both database and application design will not be strongly focused under the research.

6.2 Database Design

As previously mentioned, there are three database designing points. However, only the overall database design is focused with the findings of database design that can be fit to the PMK switchboard support system.

In conclusion, the following table describes the brief view of database design.

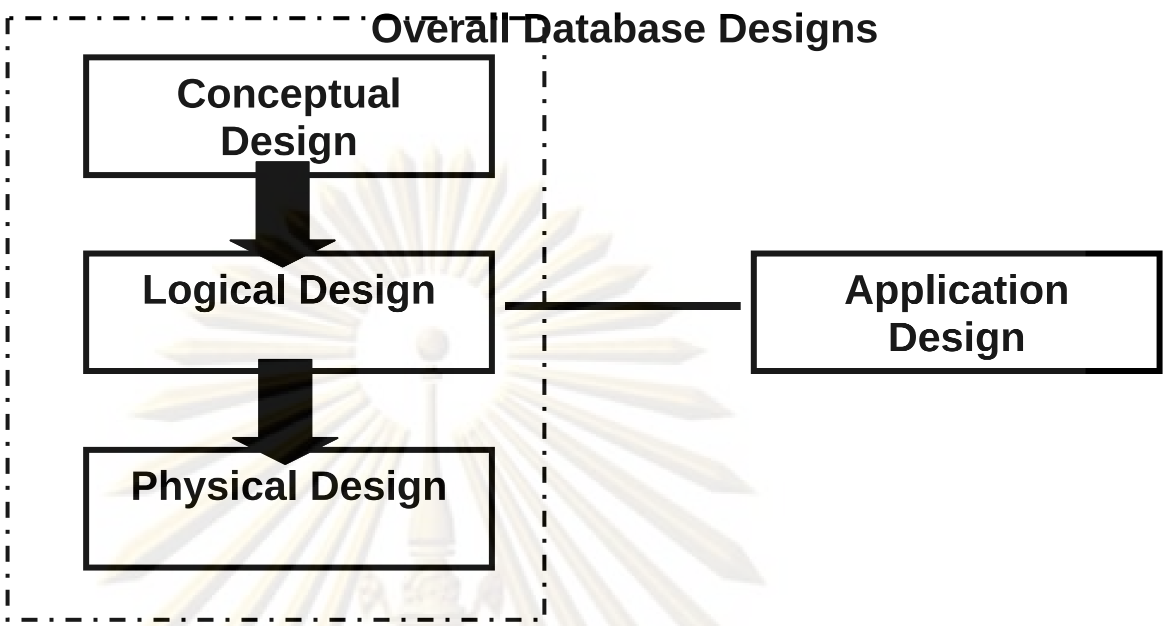


Figure 6A The Overall Database Design Diagram

6.2.1 Conceptual Design

[10] has claimed that the conceptual design is the model used in the design at the initial stage for understanding the overview and relationship of the database and relationship. Therefore, in switchboard design support system, the concept of the database design is provided as in planning stage together with the program implementation for the database program called SQL. Further, the use of C# programming is for the application design. Similar to logical design, the conceptual design is not strongly mentioned in this chapter.

6.2.2 Logical Design

Follow the conceptual design, the utilization of ER relationship that has been previously mentioned is once addressed. Plus, the logical design is the process of constructing the model that relates all information in the database before starting the physical design [10].

Referring in the planning process of the database design, the methodology is the additional discussion carried out in this chapter.

This is practical approach that used in the PMK switchboard design system.

There are a numbers of components to be designed in switchboard design; only three major equipments in design are addressed along with the relationship of associated man cost.

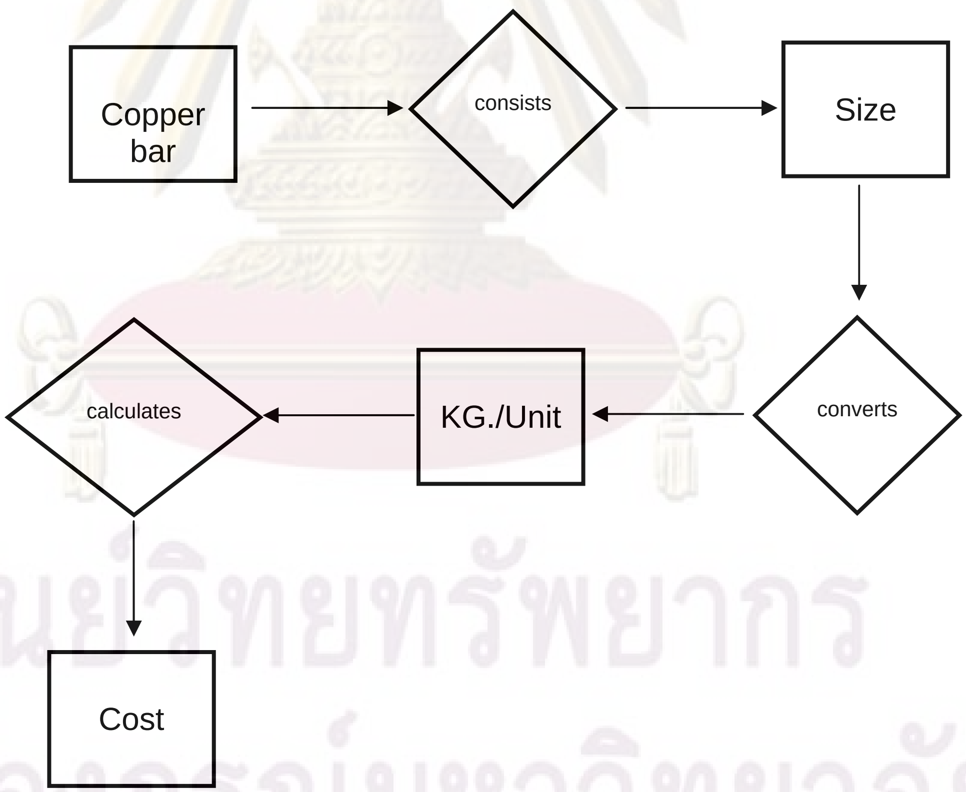


Figure 6B Logical Diagram for Copper Bar

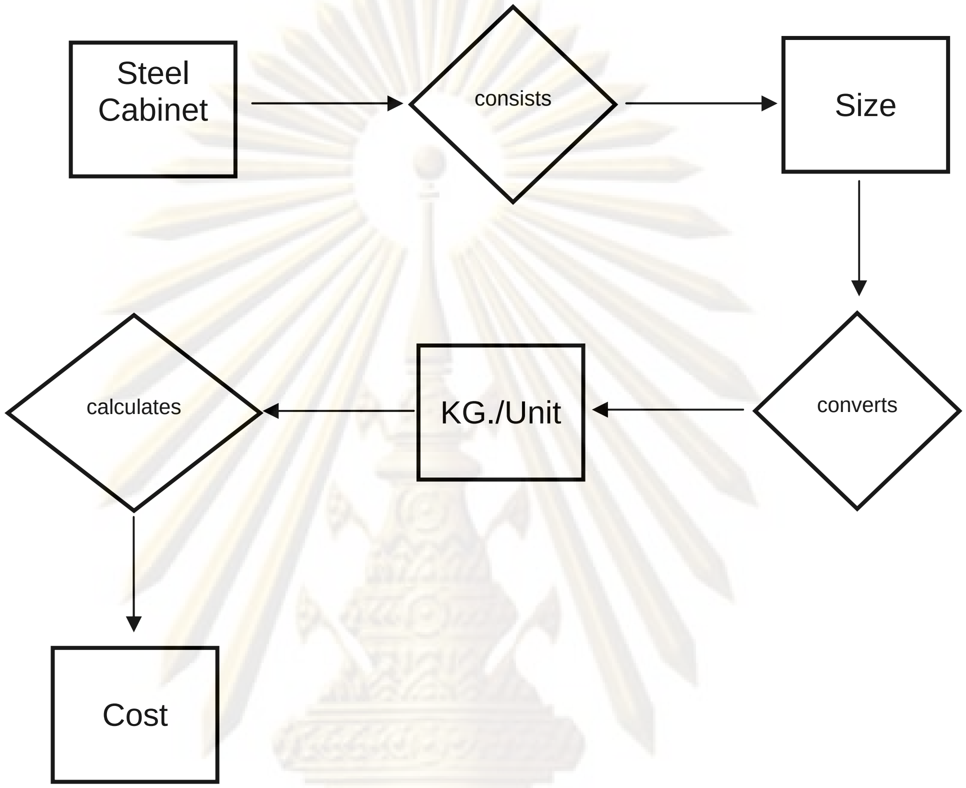


Figure 6C Logical Diagram for Steel Cabinet

Figure 6B and 6C show the relationship of the main components in manufacturing switchboard. As both diagram are steel and copper, thus, they will convert into the weighted per unit for the calculation of the cost as can be referred to the costing sheets as referred to the figure 3A.

Apart from these two primary elements, the costing structure from figure 3A comprises labour cost and engineering overhead. The engineering overhead is certainly the predetermined rate of 3%, which has been used for many years and certified by PMK accountant department. The structure of the overall labour costs is illustrated.

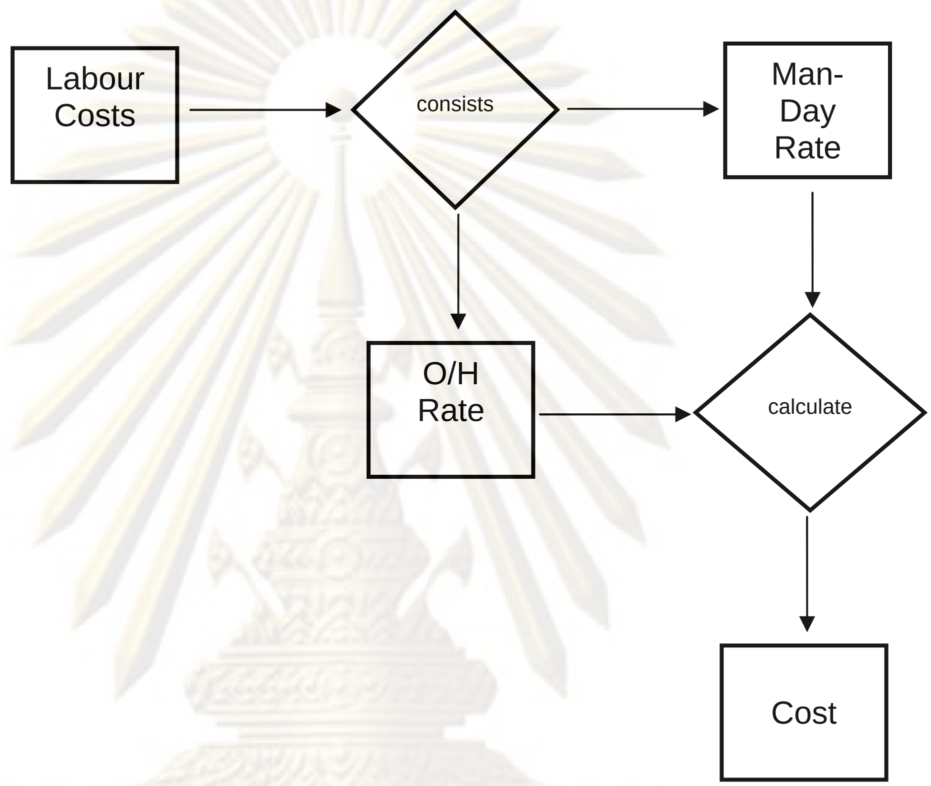


Figure 6D Logical Diagram for Man Cost

As earlier explained, the man cost for manufacturing switchboard are divided into two classification:- the direct labour cost and other overhead cost. The direct labour cost will be counted from the relationship of cabinet size related to man-day rate; on the contrary, the overhead rate is calculated based on constant rate.

These three mentioned diagrams from 6C exhibit to 6E exhibit will contribute to the costing sheet in figure 3A. However, to complete the overall costing sheet in figure 3B, the main equipment must be added with the logical structure as in figure 3E.

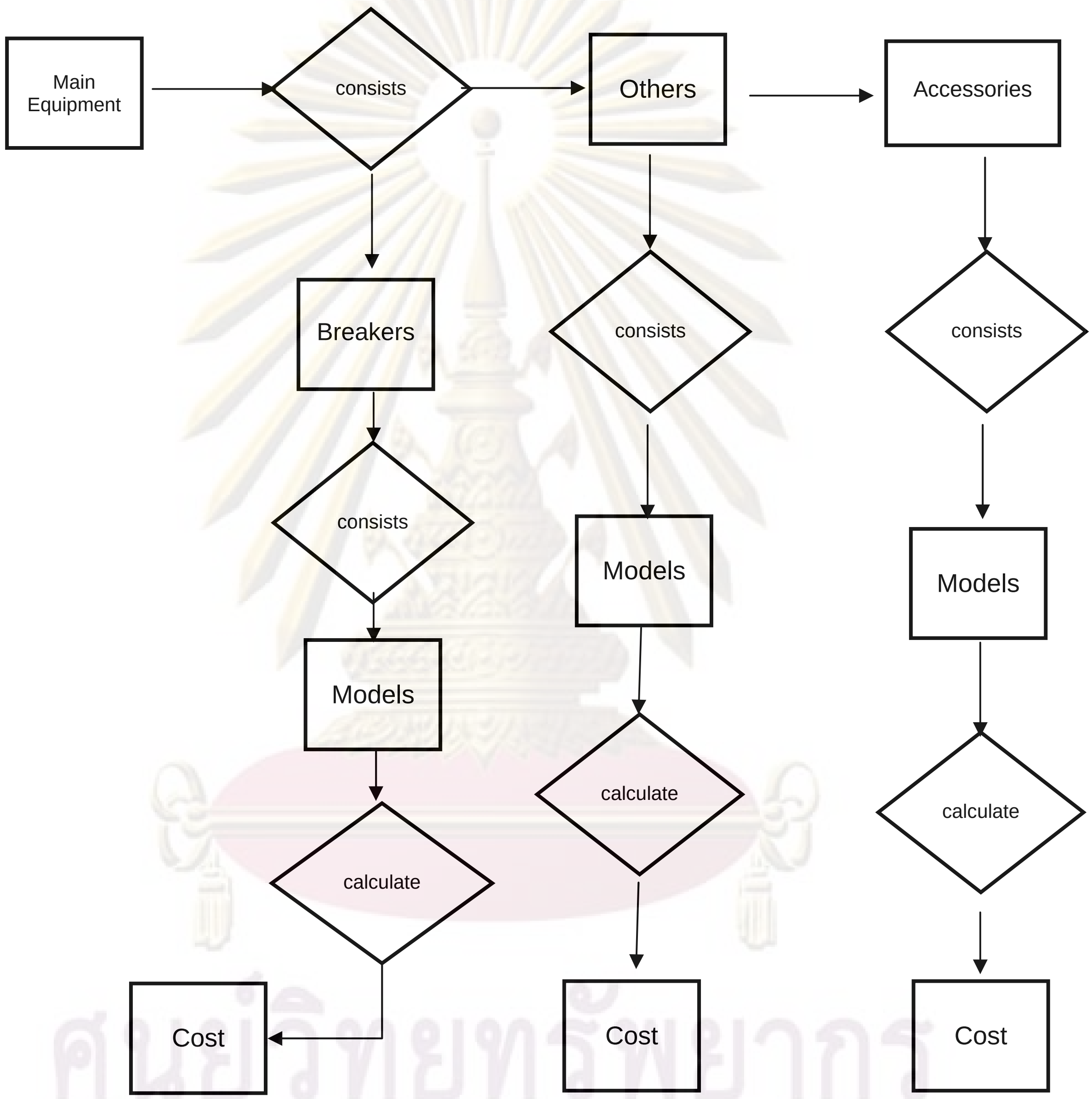


Figure 6E Logical Diagram for Other Main Equipment

Afterwards, the costs in each category will be added to obtain the overall cost of the design together with the overall design of that switchboard including size and each component detail such as model used.

The overall structures are described and thus the creation of the structure plan will result in the SQL programming in the session of physical design of database system.

6.2.3 Physical Design

The physical design is the part of programming of database in switchboard design support system. The SQL has been executed for such physical design to be used.

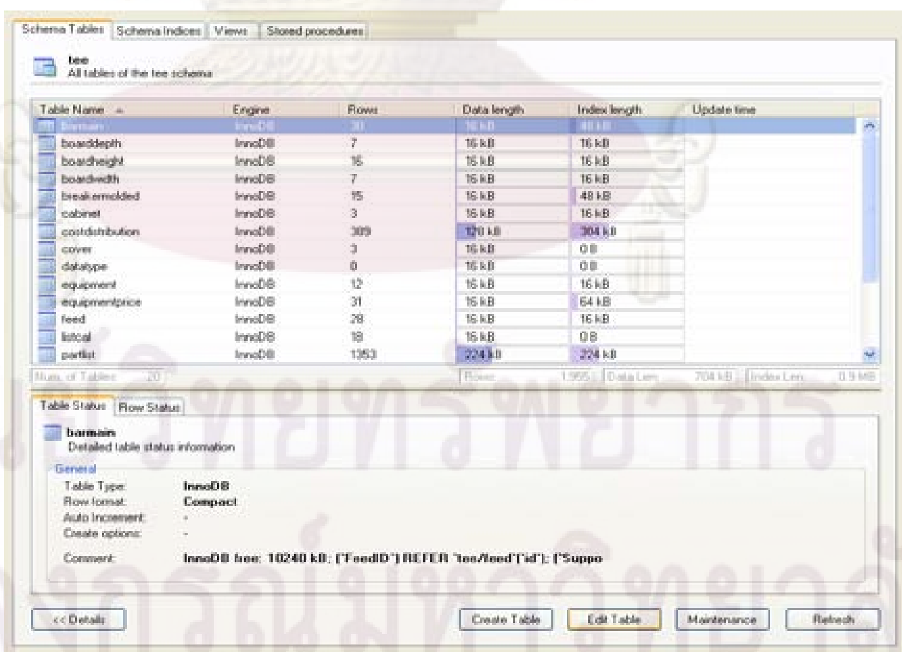


Figure 6F Example of Physical Design in Creating the Schema of Table

The above illustration shows the schema created in the physical design of the PMK switchboard components. The database created in the schema is stored in the database unit and manipulated by SQL, the data manipulation language. As all data have to be treated confidential on behalf of PMK; therefore, the physical design cannot be all exhibited. yet, the overview use of database can be explained.

project
projectcubicle
- cabinet
- breakermodel
- breakerpic
- barmain
- boardheight
- boardwidth
- boarddepth
- costdistribution
- cover
- equipment
- equipmentprice
- feed
- partlist
- typelocation
- supporttype

projectlist
update projectcubicle,project

Figure 6G Example of Data Retrieval in the Database for PMK Switchboard Design

The overview use of database is started from the cabinet type selection, and then the breaker models are selected and retrieved the data. Afterwards, the exploration of copper bar will be retrieved which will lead the overall panel size.

The summary of information will retrieve the cost of information retrieval in all equipment, steel and copper bar.

The last phase of SQL will be the summary of overall design of the switchboard. Nevertheless, the SQL in retrieval of database cannot be solely used. The application program from C# programming has to be executed simultaneously.

6.3 Application Design

The overall of application design will be executed for interfacing between the design engineer and the database system in program SQL. For easily explained of the application program design, the logical design of such program will be shown below.

The program initially starts with the format selection by having to choose the data in database and the quotation design process. As the database has been proceeding described, the design process will be further investigated as it is the component of application design.

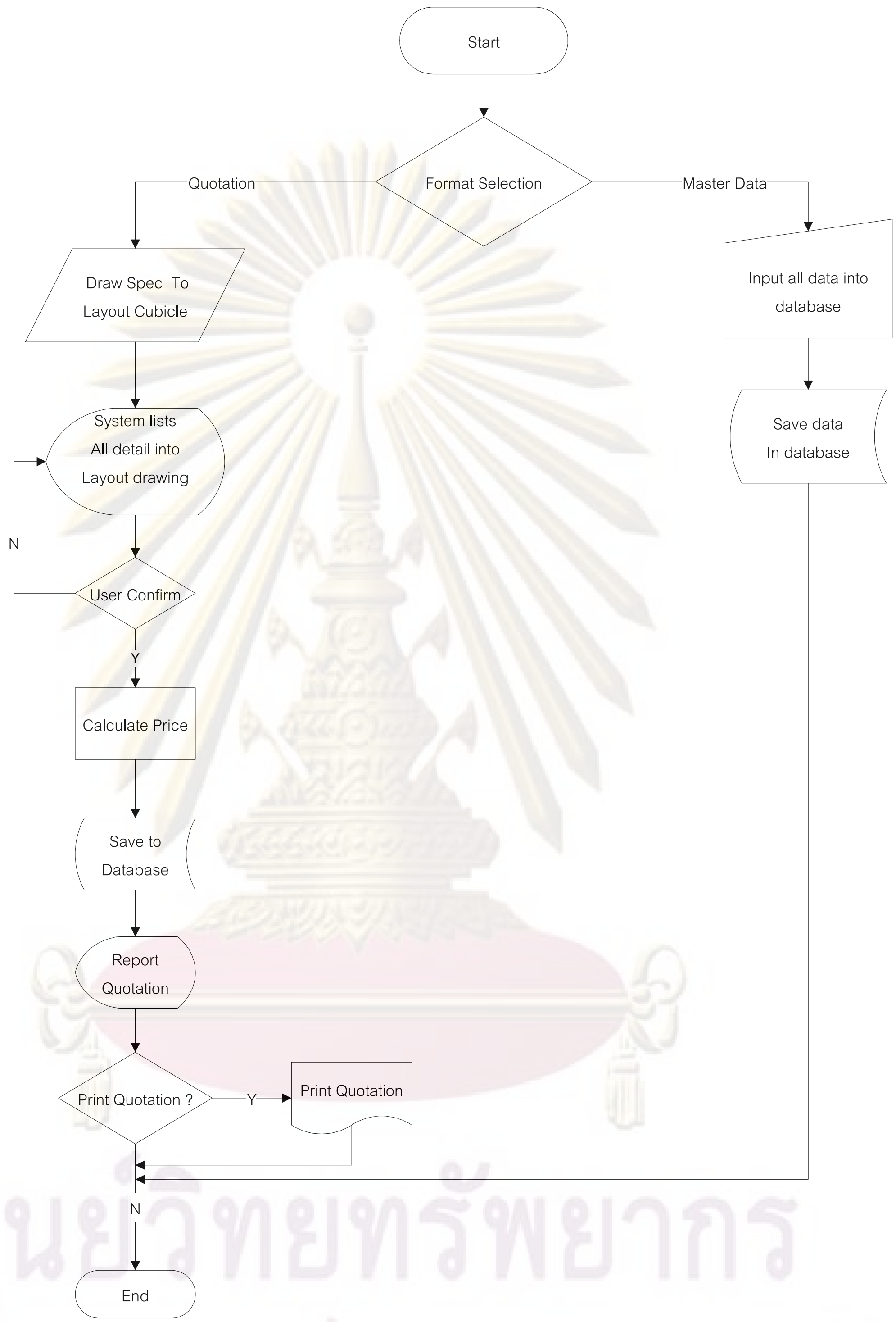


Figure 6H Program Operation in the Logical Diagram for Switchboard Design

Steps of application design supporting system:-

- The specification and electrical diagram draw out will be conducted to ensure the correct of data.
- Then the system enlists all relevant details of the drawing out to ensure the users the exact drawing.
- After the confirmation by the designer, the price will be combined and calculated for the overall cost.
- The overall detail for design and cost of the switchboard will be stored back into the database.
- The quotation and design report will be either printed or not depending on the requirement of designer.
- The final stage will show all of the result in price and component details.

The overall of application design will be executed for interfacing between the design engineer and the database system in program SQL. For easier explained of the application program design, the logical design of such program will be shown below.

The example of the design application system is shown. There is the summary of items used in the panel, which are listed below of the program screen. This application program for switchboard design is called Estimation Calculation.

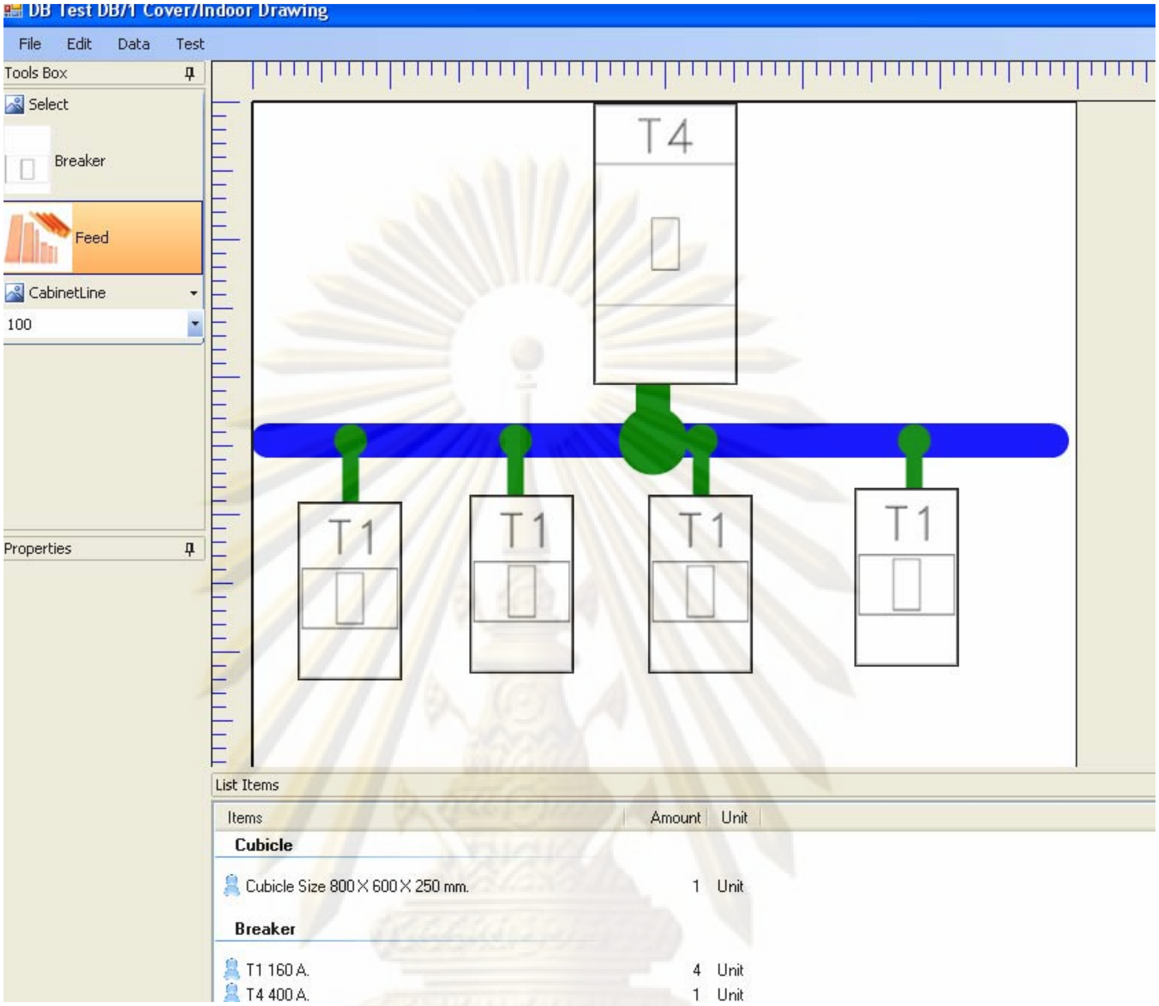


Figure 6I Example of Designing Support Program in Switchboard Design

By generating the program result, the details are listed in the design together with the costing summary for each panel design. The following chapter will verify the data obtained from the program in comparison with the previous data summary that has been done.

By performing this comparison, the actual cost from the production department will also be compared in order to yield the data verification that produced by the program.

6.4 Essential Principle in Application Program

This paragraph content explore further in detail of the fundamental of application program set to optimize our design which the cost priority is the design principal issue.

Therefore, it is deemed for programming to generate the combination of the panels under defined constraints and variables.

Moreover, the characteristics of application program can be elaborate in the following detail.

- Random generation combination of the variable, which are configurations of circuit breakers and possible set of panel sizes.
- In generating the combination of panel, the feeder circuit breaker models are the considered factor; the amounts of circuit breaker feeders are not considering factor in combination.
- Optimization rank is done based on the cost factor, this means the lowest cost get the first rank, whilst the highest cost are ranked in the last order.
- As there can be a vast number of combinations appeared, only first 5 most optimized designs in cost are listed for the designers to select for the design information.

Prior to discover the 5 most optimization switchboard design, a number of criteria must be mentioned regarding to the design rules and constraints from the IEC standard [2].

1. The main circuit breaker can only be placed in vertical due to the panel specification in the factor of engineering operation criteria.
2. Feeder circuit breakers can be configured in both vertical and horizontal positions.
3. There must not be the mixture between horizontal and vertical configurations of feeder circuit breakers in the same panel because of electrical design standard in the current flow compliance [2].

6.5 Switchboard Combination Generation

Adoption of combination principle, the simplification of this concept can generate the set of combination for the panel selection.

The following diagram best demonstrates the combination of any panel combinations.

H stands for horizontal configuration of circuit breaker, whilst V stands for vertical configuration of circuit breaker. The last column of the diagram is the panel size, where there are 5 sizes for general selection of the panel under the optimization.

For instance, main circuit breaker of 400 A, feeder circuit breaker 0f 250 A x 1 unit, and feeder circuit breaker of 160 A x 2 units with the 5 panel sizes. Thus, there are 2 models of circuit breakers; the total combination of this scenario will be 2 of feeder circuit breakers x 2 of circuit breaker configuration x 5 of panel sizes=20 combinations.

The panel combination employs this principle in generating the combination; the program will work randomly according to this model.

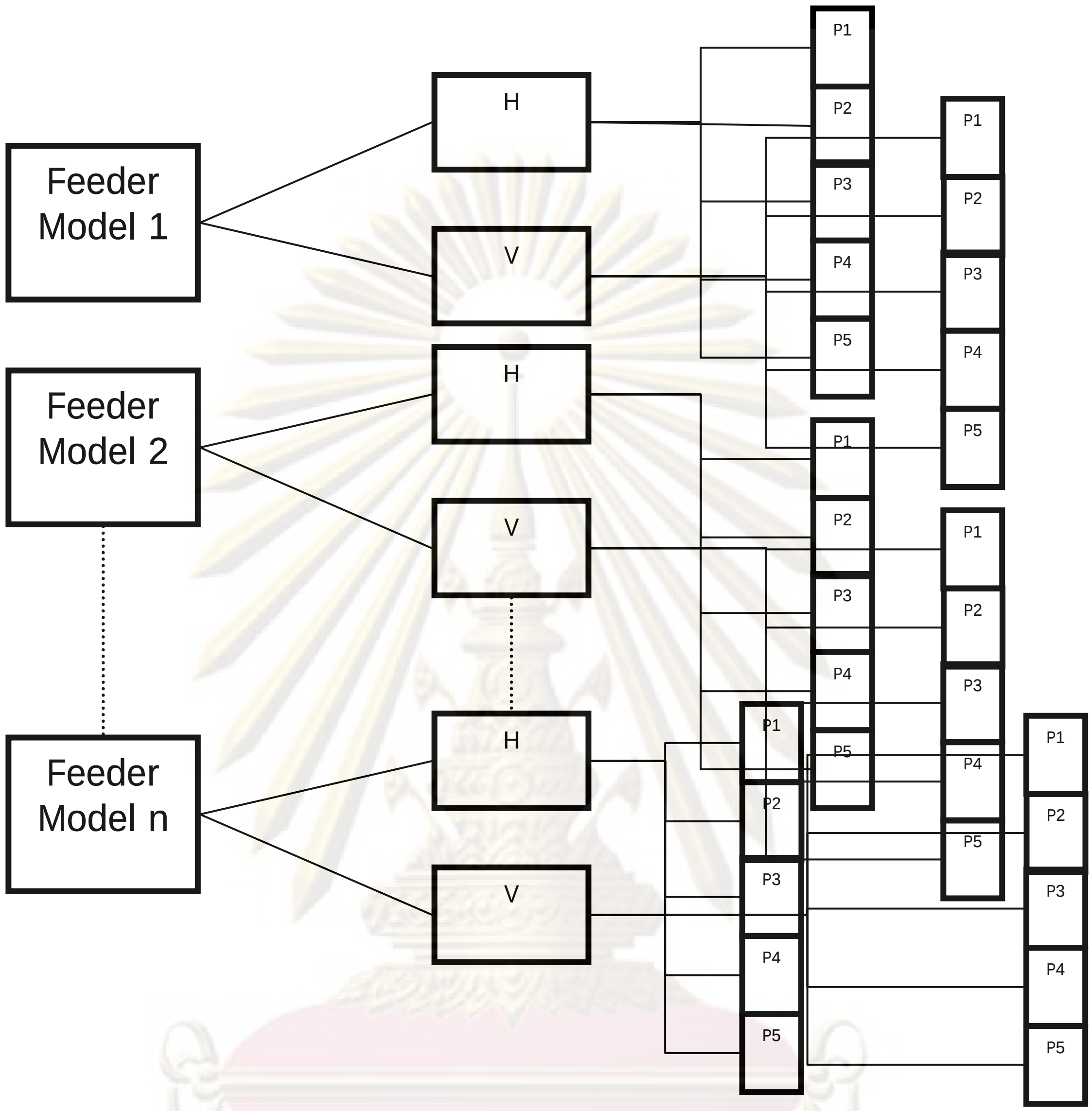


Figure 6J The Panel Combination Generation Diagram

6.6 The Application Program Implementation Concept and Outcomes (Optimization Approach)

The concept of implementation can be investigated by stages as followings.

1. The input variables must be entered into the system for generating the combination of results; there are two major components to be typed in.
   - The main circuit breaker with the current rating
   - The feeder circuit breakers with the current rating and unit used in the panel.

   It can be remarked that there must be only one main circuit breaker, yet there can be more than one feeder circuit breakers with various current ratings.

2. Afterwards, the combination of panel will be randomly created and generated for the optimization summary table with the concluded description of below features.
   - The total number of panel combinations
   - The optimization rank from 1 through 5
   - The panel dimension
   - The circuit breaker placement (either horizontal or vertical position)
   - The total cost of each combination

To better understanding the combination generation of the application program, the program illustration will be further shown in chapter 7 for verification part.

CHAPTER VII

SYSTEM VERIFICATION

7.1 Introduction

This chapter investigates the correctness and accuracy of the outcomes from the newly automated program in comparison with the manual method and the actual production cost. Two main features of programming system are generated: the manual design and automatically optimum design. Yet firstly, the five pilot projects are verified under normal design to compare the results with the current system use in the company for equipment list, cost, and time consumption; however, the names of the projects are unidentified due to the confidentiality of the company sake.

7.2 Pilot Project Verification

Five pilot projects are detailed in this chapter to ensure the reliability of the system compared to the actual cost in production and manually switchboard design operation.

To be concise, the explanation will be done by mock-up names for the projects.

- Project A

  The 1600-ampere panel for main circuit breakers, the design components are all the same amongst three-side lists. The price for each unit is different as tabulated.

Table 7A Result Comparison for Project A

Project A	Actual Cost	Manually Design	System Design
Item Lists	Same	Same	Same
Cost in THB	234,054.75	278,900.00	255,697.25
Time Usage	n/a	1 hr	25 minutes
% Diff to Actual Cost	n/a	19.16%	9.24%

- Project B

The 1250-ampere panel for main circuit breakers, the equipments are all the same, yet the price come out differently.

Table 7B Result Comparison for Project B

Project B	Actual Cost	Manually Design	System Design
Item Lists	Same	Same	Same
Cost in THB	198,524.00	233,000.00	225,455.50
Time Usage	n/a	45 minutes	18 minutes
% Diff to Actual Cost	n/a	17.37%	13.57%

- Project C

The 2500-ampere panel for main circuit breakers, the equipments are all the same, yet the price come out differently.

Table 7C Result Comparison for Project C

Project C	Actual Cost	Manually Design	System Design
Item Lists	Same	Same	Same
Cost in THB	467,734.28	525,675.50	499,875.00
Time Usage	n/a	1.25 hrs	32 minutes
% Diff to Actual Cost	n/a	12.38%	6.87%

- Project D

The 3200-ampere panel for main circuit breakers, similar to other projects, the items are the same.

Table 7D Result Comparison for Project D

Project D	Actual Cost	Manually Design	System Design
Item Lists	Same	Same	Same
Cost in THB	687,824.50	785,900.00	715,987.25
Time Usage	n/a	1.35 hrs	40 minutes
% Diff to Actual Cost	n/a	14.26%	4.09%

- Project E

  The 4000-ampere panel for main circuit breakers; yet, the error in item list for manually design is found as some equipment are missed out in during the design. However, the system design generates the same equipment list as production process.

Table 7E Result Comparison for Project E

Project E	Actual Cost	Manually Design	System Design
Item Lists	Same	Missing 1 item	Same
Cost in THB	929,855.35	1,021,288.50	988,325.45
Time Usage	n/a	1.43 hrs	48 minutes
% Diff to Actual Cost	n/a	9.83%	6.29%

7.3 Verification by Design Scenario and its Constraints

To verify the best alternative in design, the number of viable designs must be generated. However, before the design is generated, the constraints must be identified.

- The Constraints of Switchboard Design

  Size of Circuit Breaker

  In the design of switchboard, the constraints of the design will be on the size of circuit breaker, which is set with the current rating. Therefore, it is not possible to change the size of current rating of the circuit breaker.

  Size of Copper Bar

The size of the copper bar cannot also be altered as it will be fixed with the circuit breaker current breaker.

- Possible Variable Factors in Design

  As two above factors cannot be changed, thus, the last factor in the switchboard primary cost will be on the panel size and circuit breaker configuration

  Panel Size

  The panel size can be altered according to the user requirement, but cannot be less than the tolerance level mentioned in chapter 5 due to its engineering design. However, the larger of the panel size can lead to the increase in cost and material used.

  Configuration of Circuit Breaker

  The circuit breaker generally can be configured into two ways:- the vertical and horizontal models. The vertical model is the placement of circuit breaker in the upright position, whilst the horizontal model is placed vice versa.

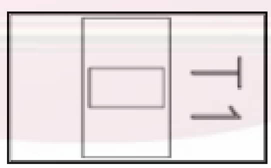


Figure 7A Horizontal Position

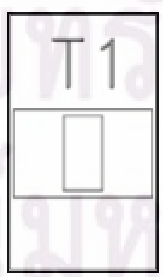


Figure 7B Vertical Position

7.4 Design Scenario for Optimum Design

The design scenarios above thus can be arranged into four major design arrangements which can be conducted by each scenario with the statement of its criteria and difficulties in designing each one.

The following scenario is performed under the same condition of one main circuit breaker of 250A and three circuit breakers of 160A.

Input: Main Circuit Breaker 250 A x 1 unit

Feeder Circuit Breakers 160 A x 3 units

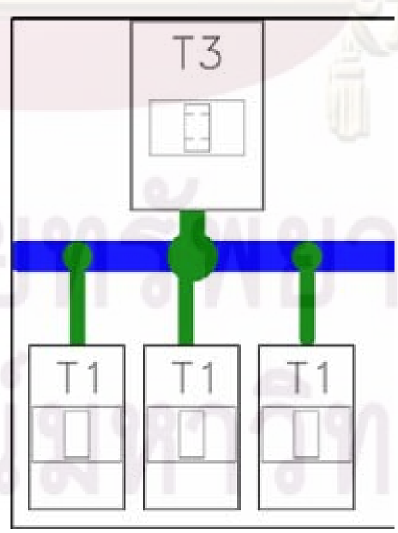
- Scenario 1 (Normal Design)

  Vertical Configuration of Circuit Breakers and Normal Size of Panel

  This scenario is conducted on the basic of the standard panel size generated by Estimate Calculator.

  The panel size is 400x300x200 with the copper bar as described below.

  Yet, the total cost from this scenario is 12,853.98 THB. This includes the 400A bar of 885 mm, 250A bar of 120 mm, 160A bar of 510 mm.



Calculation Wizard

Items	Amo...	Unit	Total Cost
Cubicle			
DB Cubicle Size 400 X 300 X 200 mm.	1.00	Unit	1,490.00
Breaker			
MCCB 3P 10AT/160AF 10KA 415V	3.00	Unit	6,000.00
MCCB 3P 175-250AT/250AF 36KA 415...	1.00	Unit	4,500.00
Copper Busbar			
Main Bare 400 A.	885.00	mm.	720.99
Feed Bare 250 A.	120.00	mm.	39.11
Feed Bare 160 A.	510.00	mm.	103.88

Figure 7C Scenario 1

- Scenario 2 (Horizontal Configuration of Circuit Breaker)

  Horizontal Configuration of Circuit Breakers and Normal Size of Panel

  This scenario is conducted on the basic of the standard panel size generated by Estimate Calculator.

  The panel size is 400x300x200 with the copper bar as described below. Yet, the total cost from this scenario is 13,056.82 THB. This includes the 400A bar of 975 mm, 250A bar of 105 mm, 160A bar of 1170 mm.

Calculation Wizard

Items	Amo...	Unit	Total Cost
Cubicle			
DB Cubicle Size 400 X 300 X 200 mm.	1.00	Unit	1,490.00
Breaker			
MCCB 3P 10AT/160AF 10KA 415V	3.00	Unit	6,000.00
MCCB 3P 175-250AT/250AF 50KA 415...	1.00	Unit	4,500.00
Copper Busbar			
Main Bare 400 A.	975.00	mm.	794.31
Feed Bare 250 A.	105.00	mm.	34.22
Feed Bare 160 A.	1,170...	mm.	238.29

Figure 7D Scenario 2

- Scenario 3 (Change in Panel Size Factor)

  Vertical Configuration of Circuit Breakers and Larger Size of Panel

  The panel size is 700x500x200 with the copper bar as described below. Yet, the total cost from this scenario is 14,045.43 THB. This includes the 400A bar of 1,515 mm, 250A bar of 285 mm, 160A bar of 1,305 mm.

  As the panel layout will be exactly the same as figure 7C, only the size of panel alters; therefore, the layout will not be shown underneath.

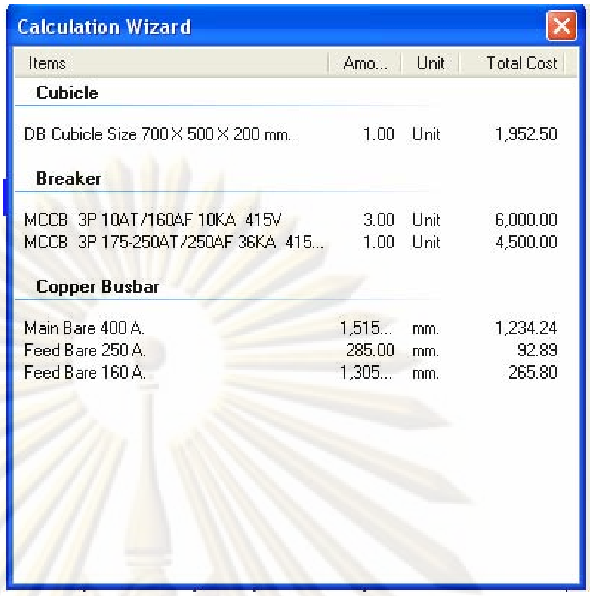


Figure7E Scenario 3

- Scenario 4 (Change in Panel Size Factor)

  Horizontal Configuration of Circuit Breakers and Larger Size of Panel

  The panel size is 700x500x200 with the copper bar as described below. Yet, the total cost from this scenario is 14,292.25THB. This includes the 400A bar of 1,650 mm, 250A bar of 105 mm, 160A bar of 2,265 mm.

  As the panel layout will be exactly the same as figure 7D, only the size of panel alters; therefore, the layout will not be placed underneath.

Figure7F Scenario 4

7.5 Design Scenario Verification

After simulating these possible 4 scenarios, these scenarios can be summarized accordingly. (H: height, W: width, D: depth)

Table 7F Result Verification of 4 Scenarios

Scenario	1	2	3	4
Panel Size	H400xW300xD200	H400xW300xD200	H700xW500xD200	H700xW500xD200
Main Bar Size 400A	885mm.	975mm.	1,515mm.	1,650mm.
Feed Bar Size 250A	120mm.	105mm.	285mm.	105mm.
Feed Bar Size 160A	510mm.	1,170mm.	1,305mm.	2,265mm.

Configuration	Vertical	Horizontal	Vertical	Horizontal
Cost	12,853.98	13,056.82	14,045.43	14,292.25
%Difference from lowest cost	n/a	1.5%	9.27%	11.18%

The panels are varied according to the variables that can be changed. Here, there are two variables changed in circuit breaker configuration and panel size in case of customer request.

The normal configuration together with the use of program generation in panel size leads to the most optimization cost. The vertical configuration with the program selected panel size generates the second best cost, whilst the horizontal configuration and larger size of panel and the vertical configuration and larger size of panel yield the third and fourth best costs, respectively. However, the difference between circuit breaker configurations can only slightly vary the cost as in case of scenario 1 and 2. Similarly, the scenario 3 and 4 are acting the same way.

This can draw the conclusion of cost optimization design to be normal size selection of panel together with the vertical circuit breaker configurations.

7.6 Verification of Application Program for Panel Combination Generation for Optimization (Automatic)

To better understanding the combination generation of the application program, the following program illustration is set.

Step 1 Input all variables:-

Type in main circuit breaker model and feeder circuit model with the amount. (Input: Main Circuit Breaker 400x1Unit, Feeder Circuit Breaker 160Ax2Units, 250Ax1Unit)

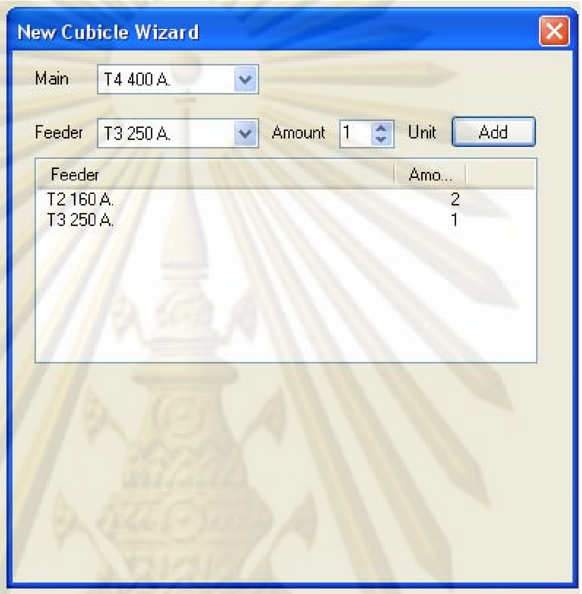


Figure 7G Panel Combination Generation Program 1

Step 2 Combination ranking:-

The combination of panel is generated with the most cost optimization is ranked no. 1 and followed by the remaining 4 orders with the 20 total combinations of design.

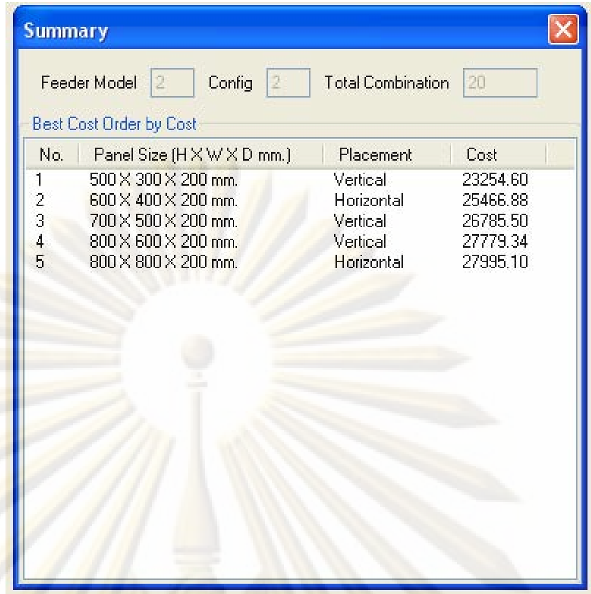


Figure 7H Panel Combination Generation Program 2

Step 3 Design generation:-

The design generation of the panel is lastly generated to show the panel layout for the optimization design.

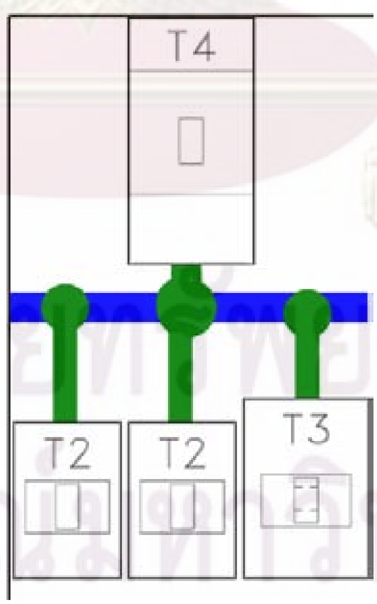


Figure 7I Panel Combination Generation Program 3

Step 4 Design summary:-

The design summary is therefore illustrated to show all the equipment used in the panel with the list of equipment and its quantity.

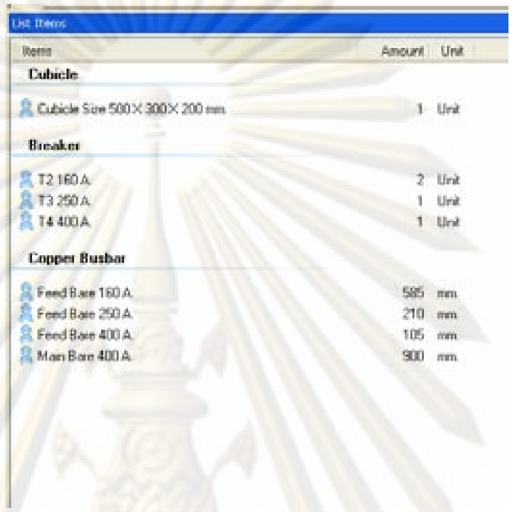


Figure 7J Panel Combination Generation Program 4

7.7 The Qualitative Approach in System Verification

The approach for qualitative perspective has been conducted primarily in the in-depth interview technique for all participants, where the readers can find the interviewing topic in the appendix. The results summary shows moderately satisfaction by eight personnel and completely satisfied by seven personnel with this program in terms of user-friendly, timely focus, and sufficient information generation. The topics investigated during the interview are on the following topics.

- User-Friendly Aspect
- Time Consumption
- Training Need for Using the Program

- Future Adaptation of the Program
- Overall Satisfaction of the Program and System

7.8 System Guidelines

Prior the completion of the system, the system guideline is provided in order fulfil the requirement of the dissertation. The guideline will be pointed out in the following bullets.

- Major Characteristics of the System

  The system is operated on two major programming which is the database program of SQL and application program of C#. The application program is the user interface program for the user to retrieve the data from the database system by SQL.
- Program Use

  The use of the program can be found in the appendix. The use of the program has fulfilled the requirement of the user-friendly function by the system program design of drag and drop technique with the implementation of the illustrated pictures.
- Error and Maintenance

  Any error found while using the program can be directly addressed to the programme and system responsible party, which is assigned for the company to maintain and repair the system to ensure the system reliability.
- Optimization Approach

The system and program are designed based on the optimization approach in design. Any redundant design found will be addressed in the program for the designers to be immediately informed.

- Data Update

  Data update can be done frequently by informing the responsible party. The information updated can be model of equipment change, price, and relevant detail in design.

- Training

  The routine training must be conducted for understanding of the designers. The new designers recruited must be on-the-job training together with the routine training for using the system and program.

7.9 Summary of Verification

Thus, the program and system can be verified into three main areas:

1. The comparison of system and programming compared with the manual method in various aspects such as equipment list, price and time consumption. It shows the significant result of time improvement and quantity accuracy.
2. The predefined scenario of designing the panel, this leads the result of cost optimization of vertical configuration of circuit breakers and programmed size of panel.
3. The most crucial of the system is the combination function where the generation of the panel combination is created with the most cost optimization is set in first rank.

At last, performing the verification, the relevant drawing and summary of panel design are generated for the designers and users.

CHAPTER VIII

CONCLUSION

8.1 Introduction

Lastly, the research study of design supporting system for electrical switchboard manufacturer comes to conclusion. The chapter will explain the benefits of the design supporting system that has been created plus the future work that can be carried out for the contribution of the company.

8.2 Benefits of the System

There are three areas of benefits that will be explored throughout this chapter, which are time benefit, cost benefit, and human benefit.

- Time Benefit

  An extremely important aspect of the entire benefit criteria is in the time area as the less time consumption in design can lead to a number of advantages such as the satisfaction increase for the customers. Also, design engineers have more time in spending on other useful activities such as developing new product features. Time cannot exactly be converted into cost, yet, it is estimated for PMK design system can yield at least a sumptuous amount of money.

- Cost Benefit

  The optimization design can lead to optimization in cost area that is deemed as a crucial part in design. This also contributes to the major advantage to sales department in bidding the work, which the closer cost to the actual cost in manufacturing can lead to the better judgement in conclusion of price bidding.

In addition to design optimization, the over specification of design will not be the problematic issue as the more accurate design is adopted.

- Human Benefit

  Human error is certainly mitigated as the automatic system can support the design engineer very well, though, the inexperienced skills of engineer is an issue.

  Also, the error decrease can result in the satisfaction of all stakeholders. By rough interview with the staff in every associated department, they claimed that they are more satisfied with this new system adoption.

8.3 Awareness for the Support System

The system awareness must be undertaken by careful precautions since the system is found new for the organization. The training for design users must be carried out. Moreover, in the first phase the error identification from program is not found, yet the research study indicates that there must be some errors [5]. So, there must be the design checker to check for the correctness of design in combined with the further suggestions on the system.

The change in the designing structure and department can be the primary point as each designer may not be familiarized with the system. Therefore, the change management must be performed in the way of frequent training.

8.4 Future Work for the Support Design System

The future work must be employed as there must be some development and update for the overall system. Plus, many have stated that there must be some pitfalls unexplored.

The future work can be carried out to find the better way for the system in combining with the additional feature in the application program system. Furthermore, the linkage to the autocad file is the next phase that will under the research interest in the near future.

- The DSS (Decision Support System) Construction

  As the database and application programs are fully exploited, the decision support system can be the latter stage for the company to be explored on since many projects designed in the company can be an auctioned project. The DSS system can be produced for the sales manager to decide whether there are any factors concerned before making decision on putting any auction.

  On the production front, the production manager can plan his production faster and decide whether when and how to purchase each item of material in order to reduce the inventory.

- The CRM (Customer Relationship Management) Program Implementation

  On the of the customer side, the next phase for this implementation can be related to customer views. The marketing department can further exploit this system to customer relationship program where the marketers and sales representatives can well observe the preference of the switchboard design for each customer.

8.5 Conclusion

This overall study is on the design support system for switchboard manufacturer with the case example for PMK Industry, the leading manufacturer for switchboard panel. It has contributed the overall advantages in many areas to the firm and expected to be improved as in the system development cycle, which shows that the improvement and reiteration of the system must be conducted for the better and more reliable system.

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APPENDICES

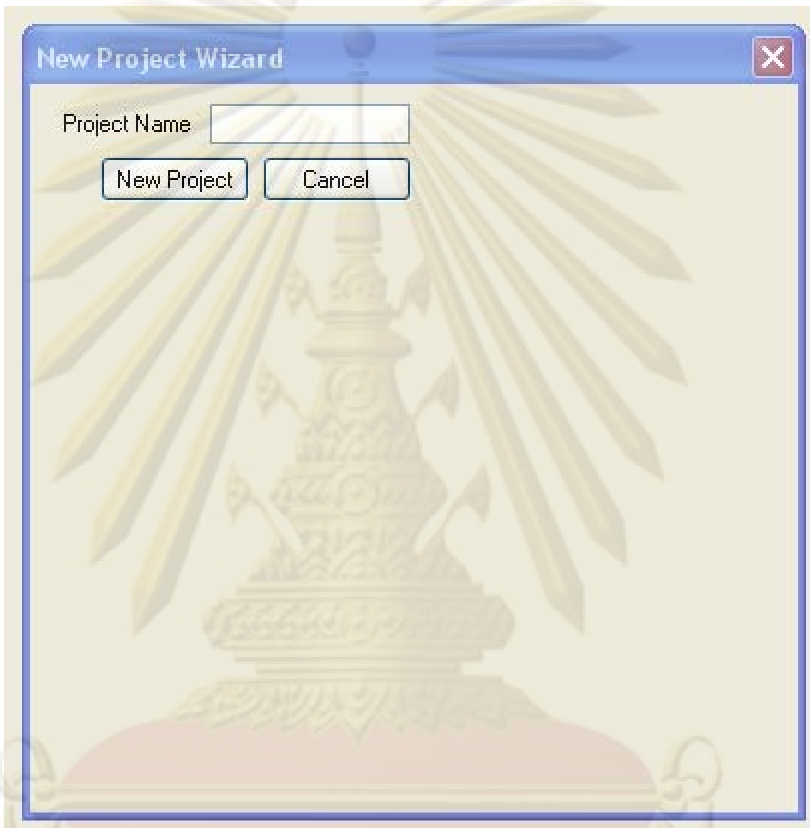
APPENDIX A

OPERATION MANUAL

ESTIMATE CALCULATOR

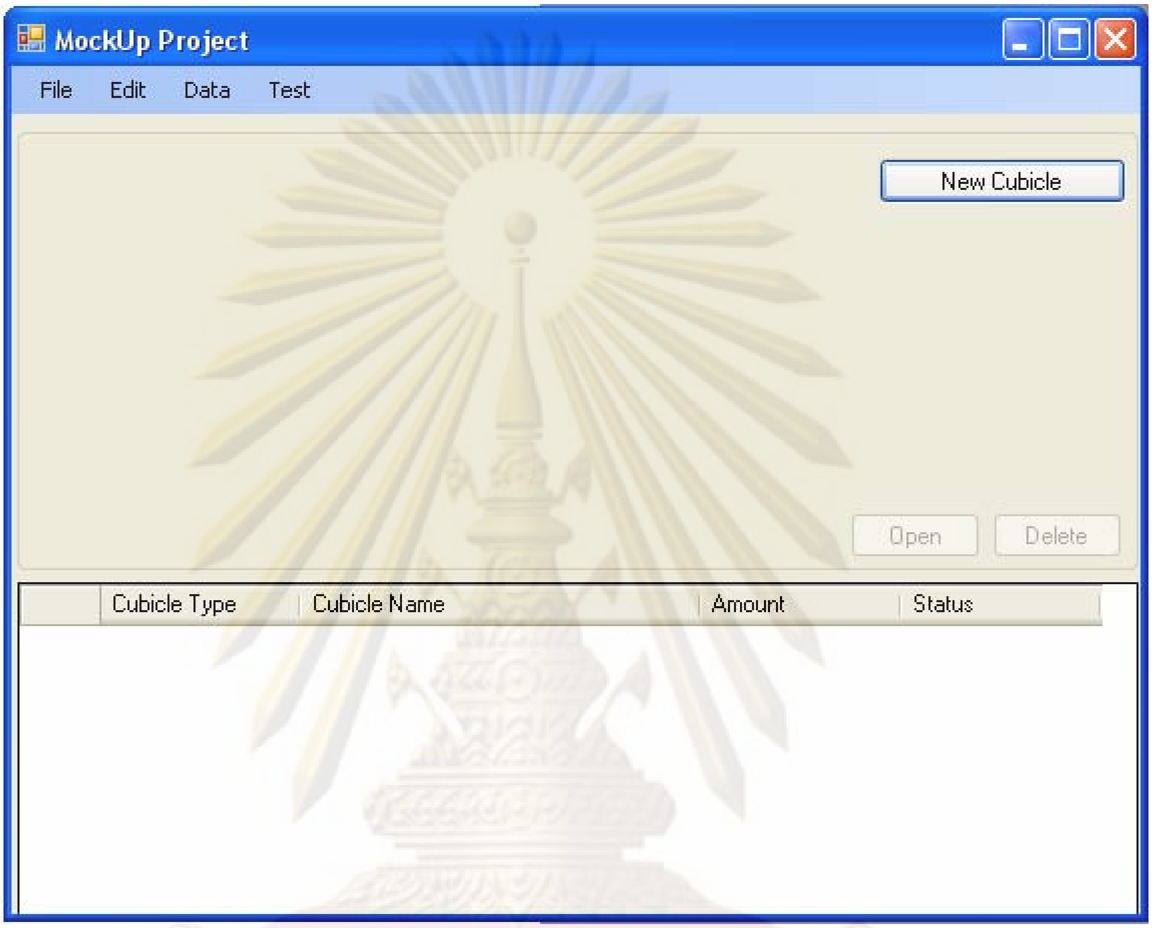
This operational manual is designed to be used with switchboard design program called "Estimate Calculator" This manual will guide the users through the program.

Step 1: Turn on Estimate Calculator Program



Type in the project name and press the new project, then the name of the project is defined.

Step 2: This window appears and click on the new cubicle



Step 3: This New Cubicle Wizard will appears and then type in the Cubicle Name.

Select the cubicle type between MDB or DB.

Select the cover amount between 1 or 2.

Select the type of cubicle between indoor or outdoor.

Then click Next.

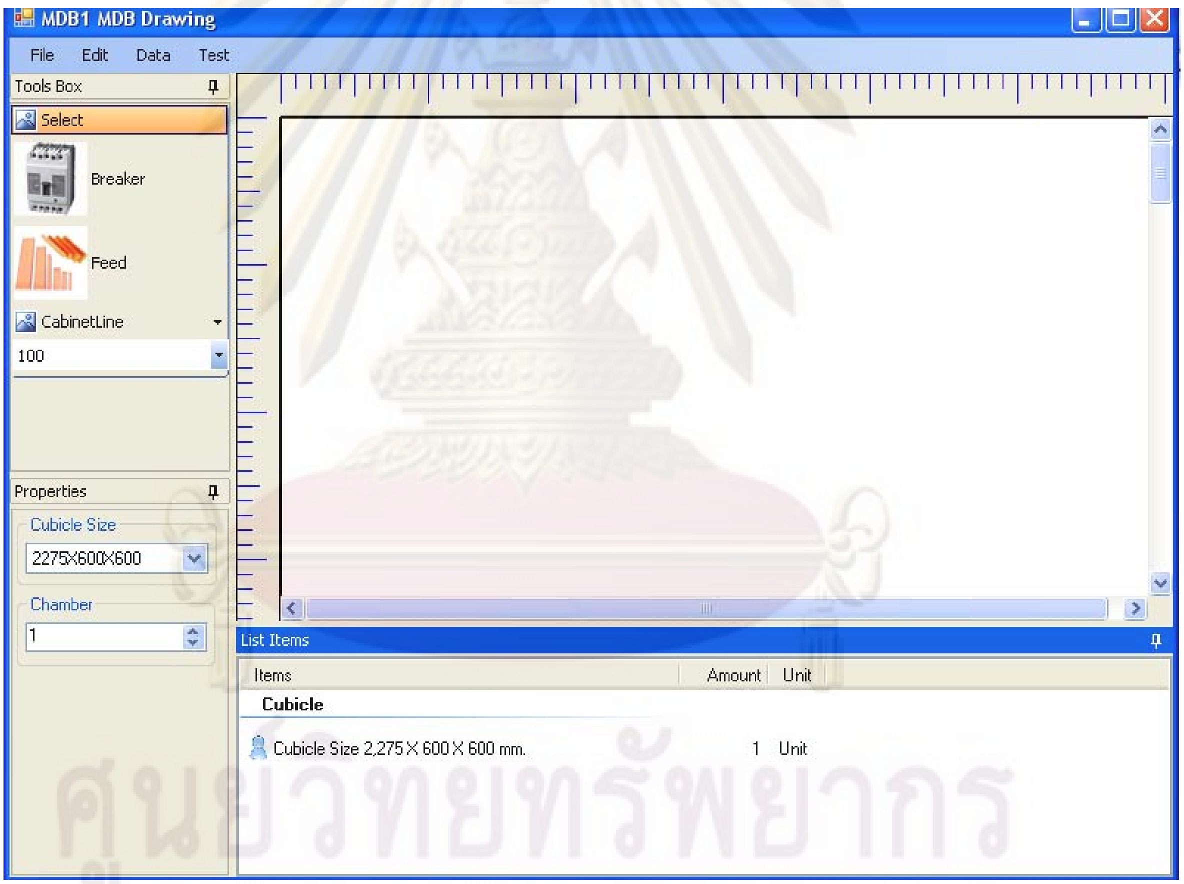
Step 4: Up until this point, the drawing screen will pop up.

Choose the cubicle size from the drop-down box.

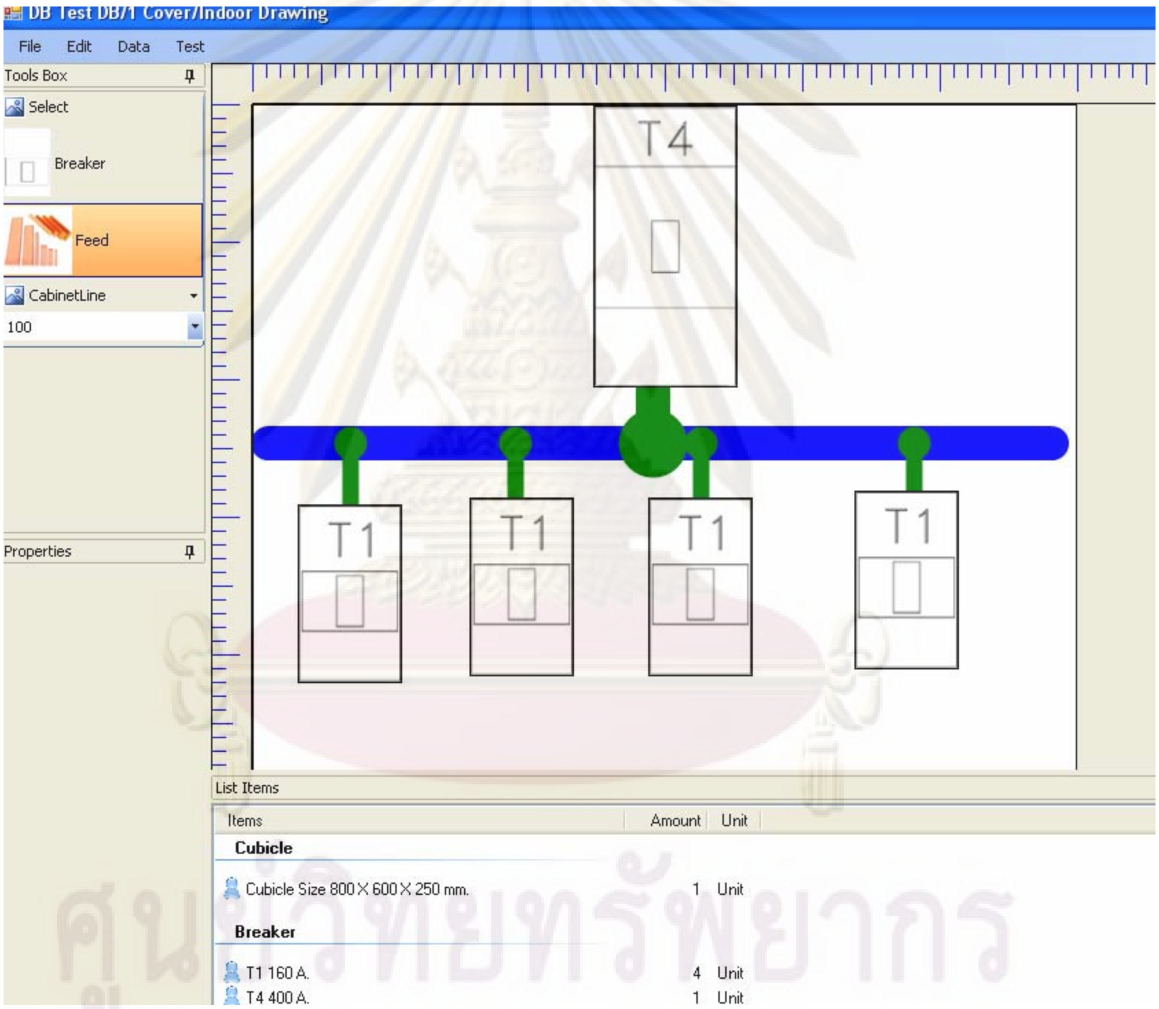
Then amount of chamber and follow by selecting the picture of circuit breaker with the model that is specified by current rating.

Select the feed button for the bar size part.

Then use the drag and drop function to draw the layout of the panel.

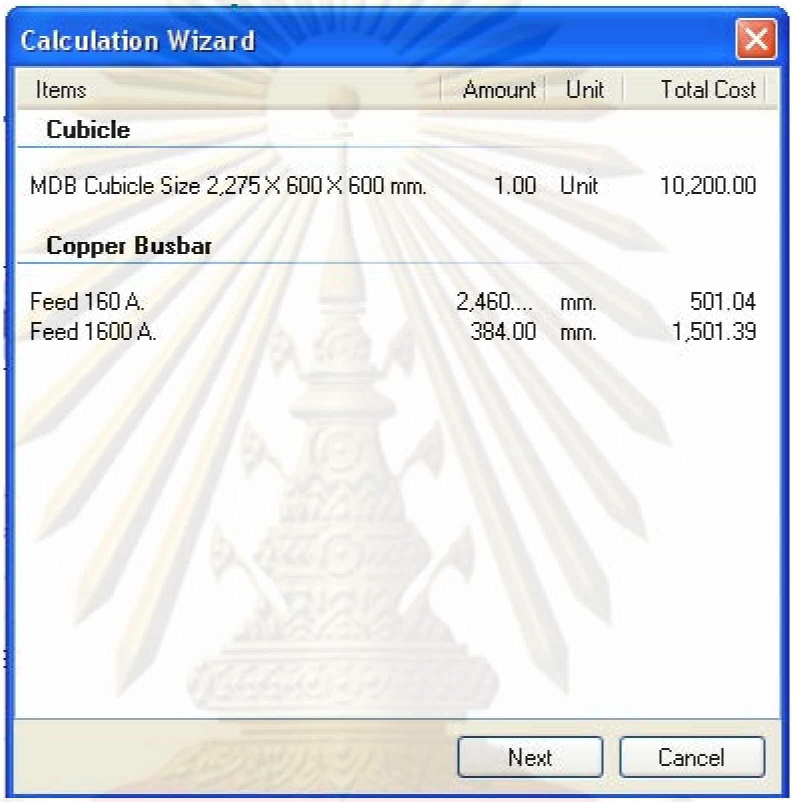


Step 5: After drawing the lay out of the panel, the summary of detail will be displayed at the bottom of the screen for the users to confirm the detail of drawing including the panel size in cubicle area, the circuit breaker model with current rating together with the copper bar model and its length.



Step 6: Then click Calculate at File menu to simulate all the data.

The total cost summary together with all detail will pop-up for the users to see the summary.



These are the brief operating guide for the users to look as a guideline, for further information; please contact the author of this thesis.

APPENDIX B

INTERVIEW GUIDELINE

The interview guideline is used for the interviewer to conduct the interview for all relevant parties that are involved with the design system. The satisfaction levels are divided into three scales of unsatisfied, moderately satisfied, and completely satisfied.

- User friendly aspect

  Elaborate the program and provide trial for designers. The aspect of key and symbols in the system program are addressed.
- The time consumption

  The time usage is pointed out for each user in implementing the system under the same criteria of design.
- The training

  The training guidelines are told together with the use of program manual is provided to all interviewees.
- Future adaptation

  The future adaptation and features addition are pointed out to all users for further recommendation.
- Overall satisfaction

  Overall satisfaction is asked to ranked the level of satisfaction towards the system and program.
- The Recommendation

  The recommendation is asked from all interviewees to point out for further improvement of the system.

APPENDIX C

THE INTERVIEWEE NAME LIST

The name lists of interviewees are provided.

1.	Mr. Prateep Pigulthong	Sales Manager
2.	Mr. Tanawat Kaokaew	Senior Sales Representative
3.	Mr. Matee Kuptanon	Sales Representative
4.	Mr. Rattana Kruekunpetch	Sales Representative
5.	Mr. Sanchai Assawaolarn	Sales Representative
6.	Mr. Nattawat Boonmee	Design Head
7.	Mr. Anuphan Chaiwattanatorn	Design Head
8.	Mr. Akom Somsakul	Design Engineer
9.	Mr. Attaporn Chubarnyen	Design Engineer
10.	Mr. Metee Adomsuk	Design Engineer
11.	Mr. Charnchai Wachirabul	Design Engineer
12.	Mr. Nuttawut Niamtakian	Design Engineer
13.	Mr. Klar Kerdkaew	Design Engineer
14.	Mr. Sorachat Plangsorn	Design Engineer
15.	Mr. Kitsada Suwannasri	Design Engineer

BIOGRAPHY

Chanapatt Pattaramaetakul was born on 20 June 1982 in Bangkok, Thailand and graduated his bachelor in Electrical and Electronic Engineering from University of Nottingham, UK. He later has pursued his career path as solution engineer and marketing executive for PMK Industry Corporation Limited in the electrical switchboard manufacturer.

After graduating from Chulalongkorn University in Master of Engineering in Engineering Management and Master of Science in Engineering Business Management at The Regional Centre for Manufacturing Systems Engineering, he will pursue his passion in running his business at PMK Industry Corporation Limited.