CHAPTER 2

Literature Review

This chapter presents an evaluation of the energy market including the characteristics of regulators in many parts of the world such as the Council of European Energy Regulators (CEER), the Federal Energy Regulatory Commission (FERC) of the United State and the Australian Energy Regulator (AER), and also defines the oddities and weaknesses that come from their regulation. Then this chapter gives an evaluation of the energy regulation in Thailand by also comparing the oddities and weaknesses of the Thai energy regulators. As a result, it shows the reasons why energy regulation became necessary for Thailand. The other part of this chapter presents the characteristics of the energy market by analyzing and comparing the characteristics of the energy market both in Thailand and in other countries. Then it presents the type of market competition in Thailand and also presents the change in the market framework when there is an Energy Regulator, and the problems that occur in energy market.

By adding the regulatory feature in the electricity system industry (ESI), the decision-making seems to be an increasingly important factor that affects many participants. Consequently, this chapter presents the relationship of decisions by evaluating the decision-making processes of general business and then focuses especially on the electricity industry. Moreover, the analysis on decision-making frameworks of energy regulators compared with the regulators in other countries is also shown in this chapter. Besides a presentation of the important role of decision-making in the electricity system industry

2.1 Characteristics of the Energy Market

2.1.1 Definition of Economics

The market is an old invention, which can be found in every organization. It can be defined as any place where buyers and sellers meet to see if deals can be made. Therefore, we firstly need to understand the definition of the word “Economics” in general terms before understanding the power system economics. Economics is considered to have two main participants, buyers and sellers, who have an interest in the price of products sold in the market, and the accepted number of products the buyer can get from the market (Pallapa Ruangrong, 2008). When looking on the buyer or consumer side, it seems that buyers make their decision to buy greater quantities of products if the price of that product is lower than their expectation.

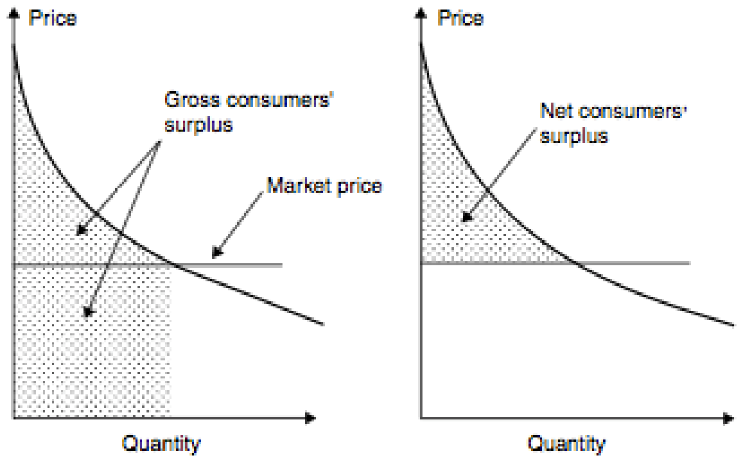

Figure 2.1 Gross Consumer Surplus and Net Consumer Surplus in Economic Market

This picture presents the demand of consumers, which increases until the price is marginal (market price), where sellers and buyers commit to trade their product or service at the committed price.

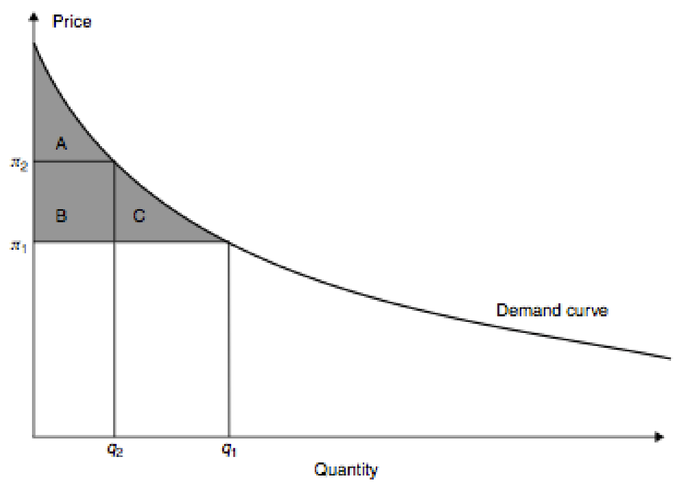

Figure 2.2 Elastic of Demand in Economic Market

It shows the elasticity of demand where the price of products will decrease along with greater quantities of the product that the end user intends to buy.

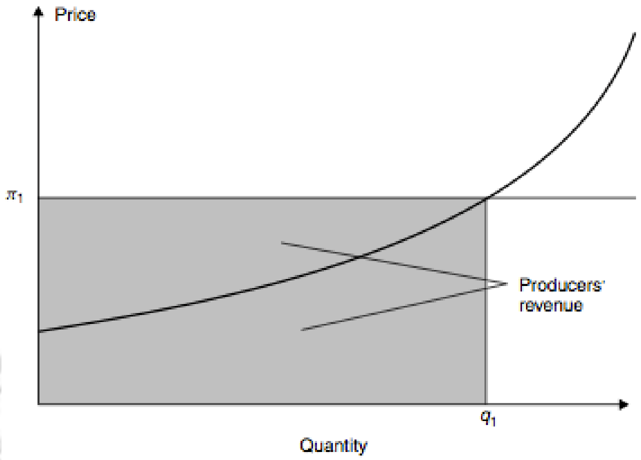

Figure 2.3 Producer Revenue and Profit on Economic Market

Figure 2.3 present and the revenue and the producer profit, or net surplus. It means that the profit for the producer can come from producing more products at the cheapest cost per product.

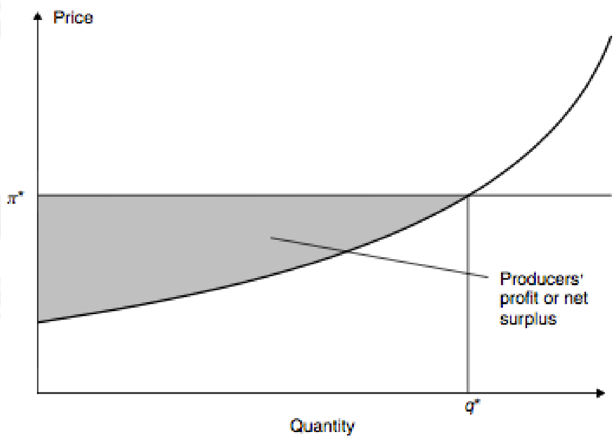

Figure 2.4 Producer Profit or Net Surplus on Economic Market

Figure 2.4 show the profit area that supplier can gain from the product. In this area demand can adjust the price of each product until the price has meet the break-even point, so electricity industry can control the generation and service cost to make the profit to their industry.

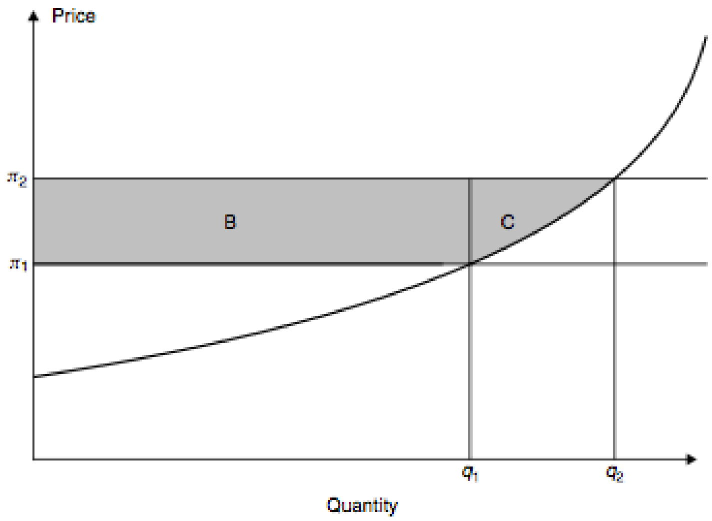

Figure 2.5 Separate Between Revenue and Profit on Economic Market

Figure 2.5 show the gap between revenue and profit in order to adjust the price for make their profit. As a result, economics in general terms is considered to be the balancing of demand and supply in the market. This is called “Market equilibrium”, which is shown in figure 2.6

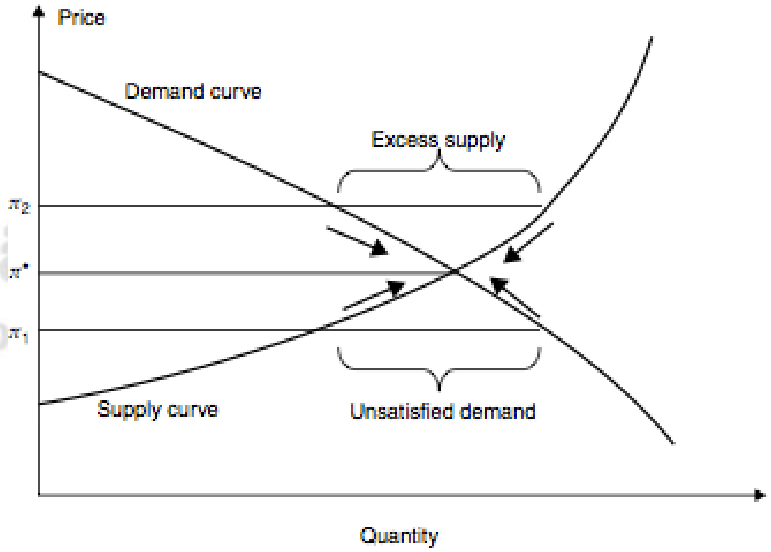

Figure 2.6 Characteristic Balance Supply and Demand in Economic Market

2.1.2 Defining Power System Economics

When concentrating on the electricity market, it can be shown that this market is more complex than markets for other products. The primary difference between the electricity energy market and other markets is that the time to transfer the electricity, on the physical system, is much faster than any other market. For power systems, the supply and demand, or generation and load, must be *balanced* on a second-by-second basis. If the system is imbalanced, it may lead to major problems such as system breakdown and cause the country to be without electricity for many hours as the complex process to restore the power system may take more than 24 hours Therefore, balance of supply and demand for the electricity energy market must be maintained through a mechanism that does not rely on the market to select and dispatch resources. The second difference of power system economics is that the energy produced by one generator cannot be served directly to specific consumers. The power produced by all generators will be pooled on its way to the load resulting in valuable economies of scale that lead Stof to claim that “the maximum generation capacity must be commensurate with the maximum aggregated demand rather than with the sum of the maximum individual demands” (Lol lei lai, 2001).

The final difference is that demand on power system economics cannot predict daily and weekly cyclical variations, so the electrical energy must be produced at the same time as it is consumed. Therefore, it can be argued that power system economics has many different aspects from other business, but the core concept of economics is still the same with the concept of the general theme of balancing the demand of the consumer and supply of the producer. Stof defined the meaning of power system economics in his book, **Power System Economics**, as the way to produce electricity at optimal cost, and deliver that electricity directly to the customer who most needs it (Šljivac Damir, 2009).

2.1.3 Type of Market Competition in General

Since people first created a place used to trade their goods and to find the things that they needed, the market has become an important factor in every business. However, business can be categorized under many characteristics, not only the monopolistic but also oligopolistic and the perfect market (Timothy J. Brennan, 2002). The characteristics of these markets are as follows:

Table 2.1 Type of Market Competition

Market Structure	No. of buyer	No. of Seller	Buyer entry barriers	Seller entry barrier	Size of the firm	Product differentiation	Market share	competition
Perfect Competition	Many	Many	No	No	Relatively Small	No Homogeneous product	Small	Fierce
Monopolistic competition	Many	Many	No	No	Relatively Small	Basically substitutes, but not alike as branding is different	Small	Fierce
Oligopoly	Many	Few	No	Yes	Avg.	Homogeneous/differentiated	Avg.	High
Oligopsony	Few	Many	Yes	No	Relatively Small	Homogeneous	Avg.	Imperfect competition
Monopoly	Many	One	No	Yes	Relatively Large	No substitute good/service	Highest	No competition
Monopsony	One	Many	Yes	No	Relatively Small	substitute good/service	Avg.	Imperfect competition

2.1.3.1 Monopoly and Monopsony Competition

The competition in the market starts from a single thinker (Innovator) who presents a new product to the market, and subsequently the demand from buyers increases. With only one supplier in the market, this is called a *monopoly* market because it has only one supplier with many buyers, and has no substitutes for the product so the supplier is free to set up the product cost as high as it desires without adverse effects, and maintains the quantity of products to serve the demand of buyers. On the other hand, a monopsony is present when the market has many suppliers while there is only one buyer. This type of market competition mostly happens with substitute goods and service products (Ben W.F. Depoorter, 1999; Frank A. Wolak, 2009).

2.1.3.2 Oligopoly and Oligopoly Competition

Oligopoly competition occurs when there are many buyers with only a few suppliers in the market. So the competition in this market may use market strategies to gain the market share. The strategies such as price competition, product function competition or design competition become important. There is no market barrier for the new comer. An oligopoly is different because there are few buyers but many sellers, so this type of market competition will happen when the product is homogeneous and buyers can easily find substitute products. In this competition sellers also need to use strategies as they operate within an oligopoly market competition.

2.1.3.3 Monopolistic Competition

The monopolistic market exists for the group of buyers and sellers, where buyers have an opportunity to buy the product from the sellers that offer the suitable price. However, the product in this market is still difficult to replace with other products, so the barrier of this market happens when the current sellers in that market try to drop their price as low as possible.

2.1.3.4 Perfect Competition

The perfect competition is the market in which sellers and buyers have the freedom to trade their products in the market, so the market controller needs to control the seller’s price to avoid an unnecessary dropping of the price so as to prevent new comers into the market.

2.1.4 Competition in Electricity Supply.

In the year 1996, Hunt and Shuttle worth described the characteristic of the electricity supply industry by separating it into four models from monopoly to full competition (INTERNATIONAL ENERGY AGENCY, 2001; Anton Eberhard, 2002). These four models can be described as follows:

- Model 1: Monopoly

This model will happen when one company has control over all process of the product which can be showed in the figure below:

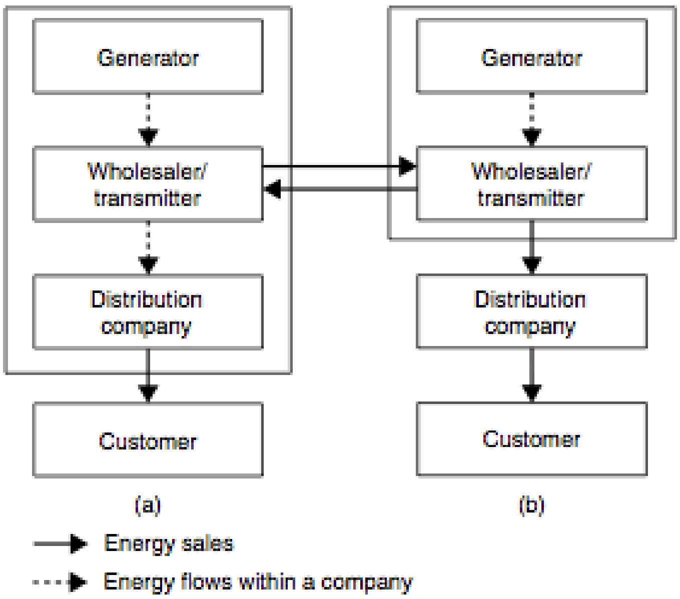

Figure 2.7 Electricity Industry Structure on Monopoly Market

Figure 2.7 show the structure when one company control over the process of generation, transmission and distribution of electricity, or just only control over the generation and transmission and the sale of their energy to the local monopoly distribution company.

- Model 2: Purchasing agency

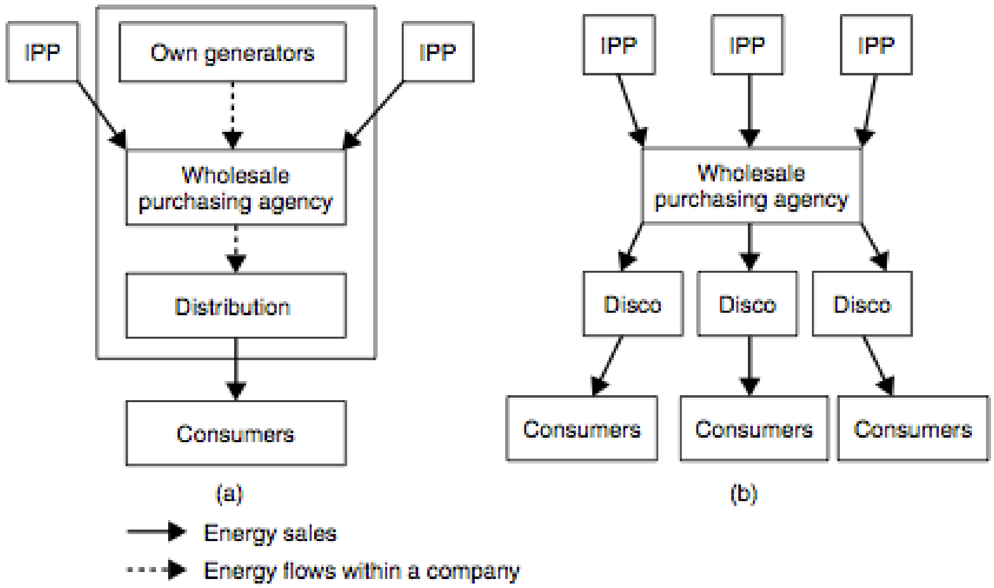

Figure 2.8 Electricity Industry structure on many purchase agents

This model represents limited competition in the electricity supply industry where one company no longer owns all the generation capacity as it is shared by another company called an "Independent Power Producer" or "IPP", which is connected to the network and sells its output to the distributor. However, the price of electricity is still under-controlled by the wholesale purchase agency because IPPs need to transmit their electricity on the agency's transmission network before distributing it to the consumer.

- Model 3: Wholesale competition

For wholesale competition, this model presents a situation where any one company does not control the transmission network.

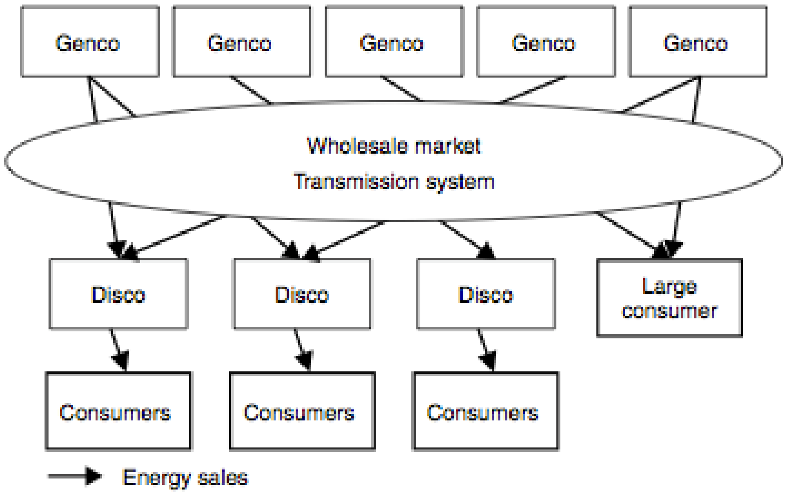

Figure 2.9 Electricity industry structure on fully market competition on wholesale

The electricity distributor can purchase the electrical energy directly from generating companies. In this model, it seems that the main centralized functions are the operation of a spot market and the operation of the transmission network (William W. Hogan, 1993). Therefore, this model creates competition for generating companies because the electricity price has been determined by the interplay of supply and demand.

- Model 4: Retail competition

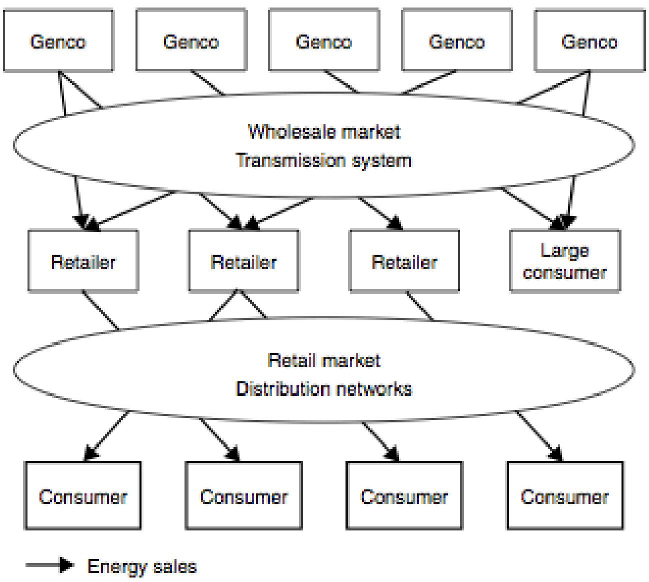

Figure 2.10 Electricity industry structure on fully market competition on retail

This model presents full competition on the electricity market where all consumers can choose to purchase energy directly from their selected supplier or retailer, and the only monopoly functions of this model are the transmission and distribution network. In this model the electricity price is no longer regulated because some consumers can change their retailer when they are offered a better price (Larry Holloway, 2004).

2.2 Revolution of Energy Regulatory

2.2.1 Energy regulatory in world wide

When looking at energy regulation around the world, we can see that many countries present the regulator in business as an important factor in order to help make business fairer.

2.2.1.1 Australian Energy Regulator (AER)

The AER was established under the Trade Practices Act 1974 as a part of the Australian Competition and Consumer Commission (ACCC). They regulate and make decisions for the wholesale electricity market and also regulate both electricity and gas transmission and distribution networks except in Western Australia and the Northern Territory (Geoff Swier, 2006). Their responsibility for regulating the oil and gas market can be shown as follows:

Table 2.2 Compare responsibility between regulate electricity and gas

Electricity	Gas
• making electricity transmission and distribution regulatory decisions • developing and publishing service standards to be applied to electricity transmission and distribution networks	• approval of certain access arrangements required to be submitted by service providers under the National Gas Law and National Gas Rules • review of annual reference tariff variations in accordance with relevant access arrangements

Table 2.2 Compare responsibility between regulate electricity and gas (Continued)

Electricity	Gas
• making and amending guidelines for the ring-fencing of operations and information flows between activities, or within a business, of a regulated entity • promulgating the regulatory test referred to in the National Electricity Rules (the Rules) • enforcing the National Electricity Law (the Law) and the Rules made under that Law and investigating and bringing proceedings in connection with any breaches.	• annual monitoring of compliance of service providers' obligations under the National Gas Law and National Gas Rules • undertaking enforcement functions as required in relation to breaches of the National Gas Law, National Gas Rules and Regulations • hearing disputes in relation to the terms and conditions of access for relevant pipelines • approval of competitive tendering processes and and terms and conditions of access for competitive tender pipelines as required under the National Gas Law and National Gas Rules • other functions and powers required to be undertaken under the National Gas Law and National Gas Rules including those associated with the Gas Market Bulletin Board

Table above show that AER has difference rule in order to regulate between electricity and gas, and they present the power to guide the stakeholder in industry for balance their industry demand and supply. However, AER also has some limitation which can showed in table balow:

Table 2.3 Responsibility limitation of regulator

Responsibility	Not Cover
□ Regulates the transmission and wholesale sales of electricity in interstate commerce; □ Reviews certain mergers and acquisitions and corporate transactions by electricity companies; □ Regulates the transmission and sale of natural gas for resale in interstate commerce; □ Regulates the transportation of oil by pipeline in interstate commerce; □ Approves the siting and abandonment of interstate natural gas pipelines and storage facilities; □ Reviews the sitting application for electric transmission projects under limited circumstances; □ Ensures the safe operation and reliability of proposed and operating LNG terminals; □ Licenses and inspects private, municipal, and state hydroelectric projects; □ Protects the reliability of the high voltage interstate transmission system through mandatory reliability standards; □ Monitors and investigates energy markets; □Enforces FERC regulatory requirements through imposition of civil penalties and other means;	□ Regulation of retail electricity and natural gas sales to consumers; □ Approval for the physical construction of electric generation facilities; □ Regulation of activities of the municipal power systems, federal power marketing agencies like the Tennessee Valley Authority, and most rural electric cooperatives; □ Regulation of nuclear power plants by the Nuclear Regulatory Commission; □ Issuance of State Water Quality Certificates; □ Oversight for the construction of oil pipelines; □ Abandonment of service as related to oil facilities; □ Mergers and acquisitions as related to natural gas and oil companies; □ Responsibility for pipeline safety or for pipeline transportation on or across the Outer Continental Shelf; □ Regulation of local distribution pipelines of natural gas; □ Development and operation of natural gas vehicles; □ Reliability problems related to failures of local distribution facilities; and □Tree trimmings near local distribution power lines in residential neighborhoods.

Regarding the decision-making process of the AER, they make decisions in accordance with the National Electricity Law and National Electricity Rules.

2.2.1.2 Federal Energy Regulatory Commission (FERC)

The Federal Energy Regulatory Commission in the United States is an independent organization that comprises 6 Commissioners who are nominated by the United States' President and the Senate (Sophie Meritet, 2002). The committee serves at least a 5-year term and has responsibility for regulating and making decisions for the transmission of electricity, gas, oil and the wholesale and services under Parts II and III of the Federal Power Act. It also has the responsibility of making decisions for generating the licenses and safety agreements for hydroelectric dams and oil pipeline transportation. In addition it has a responsibility to create and update the energy strategy plan under the authorization of the Energy Policy Act 2005 of the United States.

2.2.1.3 Council of European Energy Regulators (CEER)

The CEER was established in March 2000 following the signing of the "*Memorandum of Understanding for the establishment of the Council of European Energy Regulators*" by ten European energy regulatory authorities for the cooperation of the independent energy regulators in Europe. They have an objective to facilitate the creation of a single, competitive, efficient and sustainable system for gas and electricity in Europe (Robert *Schuman*, 2009).

2.2.2 History of Thailand's Electricity Reforms

Over several years, electricity reform was the main discussion topic of Thai researchers because the government policy on the electricity industry changed rapidly from limited participation private entrepreneurs to a fully competitive market. An evaluation of electricity market in Thailand can be described as follows:

2.2.2.1 The State Era (1950 – 1980)

Thailand's electricity supply was generated from US-Led investment in the year 1950 according to the advice of the world bank in line with cold war geopolitics because at that time the Unite State government needed to create motivation for many countries in the South East Asia to go against communist doctrine, which disseminated from Russia to China and North Korea. During the initial period, electricity was used in limited areas like in the royal palace to prove that electricity was important and could create benefits for the country's development. In the year 1960, Field Marshall Sarit Thanarat announced the first five years countrywide economic plan for the years 1961-1965 that included the country's strategic plan for many sectors, and had electricity economics as an important part of this plan (Jean-Jacques Laffont and J. Tirole, 1991). The first economic plan focused on setting the electricity standard structure such as a transmission network on roads, reservoirs and canals while the large power generation stations, being the first water powered form of electricity generation, Bhumipol hydroelectric dam, and thermal (lignite coal) power plant, were supported by the World Bank. With the support of the World Bank, the Thai government established a state-owned electricity company in 1958 called the Metropolitan Electricity Authority (MEA). Its responsibility was to distribute the electricity into the Bangkok Metropolitan area and their metamorphic aureole. The Provincial Electricity Authority (PEA) was established in 1960 to distribute electricity to the rest of the provinces around the country. The Electricity Generating Authority of Thailand (EGAT) was established in 1968 under the Office of the Prime Minister to generate electricity and transmit it to the MEA and PEA.

2.2.2.2 Setting the foundation of privatization (1980 -1990)

In early 1981, the Thai government estimated that fifty percent of the Thai population could access electricity for use in public infrastructure, the industry sector and in their homes. This situation sent the message to the Government that the electricity sector had become an important service for Thai citizens. The rising demand interrupted the cooperation between the three state-owned electricity companies; EGAT, MEA and PEA, needed in order to provide more power generation. However, to set up one power generator required a high investment cost, so the World Bank offered financial loans with low interest rates provided by bilateral lenders from Canada, Germany, Japan and the Middle East. Therefore, the Thai government claimed a long repayment period between twenty to forty years under the guarantee to repay these loans, and also asked for the additional funds from public investors. In order to repay the loans in time, the Thai government made their profit from the benefit of state-owned industry by setting the “cost plus” formula including the rate of return (ROR), which meant that more utilities costs spent equaled to more profits that could be earned. Therefore, the Thai government could expand the electricity system during the rapid economic growth period between the 1980s to the early 1990s. In the years 1980 – 1988 the GDP, a key performance indicator of the Thai economy, lead to rapid growth in demand for electricity and required substantially more fuel to be imported, thus increasing the government’s investment in the electricity sector. The benefits of this situation were that it made the Thai government not only invest in new power plants by constructing more hydroelectric dams but also to invest in the safety of old power plants that could have an effect on the environment of the surrounding area.

2.2.2.3 IPPs, SPPs and the rise of the Power Pool (1990 – 2001)

Based on rise steeply economics and the energy growth rate in Thailand, the Thai government was able to repay the loans to the World Bank in time. By doing so, foreign investors gained confidence and invested more in every business sector, with sums as high as US$80 billion in 1995. In the 1990s, the Thai government established an independent power production programme and a power pool plan model, called the National Energy Policy Office (NEPO), to serve as secretariat to the National Energy Policy Council (NEPC), which acted and reported directly to the Prime Minister’s office on energy matters in line with policy. The NEPO spent the early years setting up the policy of restructuring the oil sector and presenting the oil fund. Their responsibility was to manage fuel to serve the demand for electrical energy produced by EGAT. They started the first stage by introducing the Independent Power Producers (IPPs) to open more comprehensive competition in the power generation market. IPPs were defined as the private power producers seeking to gain long-term supply concessions to help EGAT to produce electricity, and produced electricity according to long-term power purchase agreements (PPAs). However, they used a “take-or-pay” policy to guarantee profit and maintain a low risk for private investors. Meanwhile, the Thai government also launched Small Power Producers (SPPs) that used clean energy, such as natural fuel, wind or solar power, or used domestic renewable energy sources with a limited plant size for producing power of not more than 90 MW. However, many companies complained about the unfairness of generation licenses under EGAT and the PEA because they granted the licenses for only large industrial power customers while some potential power producers; hospitals, shopping malls, universities, etc., were rejected.

In early 1996, the economic crisis affected the economy of many countries around the world including Thailand. By increasing the Thai currency from 25 to 54 Baht per US$, the Thai government showed that Thailand still needed electricity capacity and needed more investment from foreign investors to serve the demand of the Thai population. However, under this situation of a dropping in demand for electricity together with the extreme devaluation of the Thai baht, the Government needed to save EGAT's finances by reviewing the existing PPAs to reduce the number of producers, and took steps to sign the new PPAs, which committed consumers to 25 years of additional take-or-pay contracts with guarantees of a risk-free of 19 the present IRR on equity. In order to do this, the Thai government made the privatization programme the biggest success, proved by the fact that the number of PPAs that decided to sign continued to climb in spite of the weak baht and high oil and gas prices. Therefore, in October 2000 the Thai government started up stage two of a plan for fully restructuring the electricity supply industry by following the same track as the UK power pool model of unbundling the generation, transmission and distribution of electricity in order to create full competition in the power sector by the year 2003. Following this plan, the Government tried to split EGAT, MEA and PEA into private companies and sell their assets to private investors, and also suggested having their own private generators (GENCOs) that made bids within the wholesale power pool. This model included an Independent System Operator (ISO) who would be responsible for controlling power plants on the basis of generation prices. However, the plan was interrupted by the Thailand's political problems because the policy was changed due to the change of the government. Thus the plans to split Thai electricity utilities into many companies and to bring the market to be a fully perfect market were opposed by Thai politics.

2.2.2.4 The Downfall of the Power Pool and the Rise of the "National Champion" (2001 – 2008)

The big change for electricity in Thailand began in early 2001 starting with the change of the Thai government. There was very high consumer dissatisfaction with electricity rates at that time. With the new government, many power plant projects were created under the direction of Thaksin Shinnawat, the Prime Minister of Thailand who adopted a CEO style to make quick decisions, to take risks and to break down barriers posed by existing laws, without public participation. With his style, Thailand could complete repayments to the IMF's fund and could stimulate foreign investors to invest in many parts of Thailand's business sectors. Besides the power pool model, the important topic discussed was that EGAT should propose a third party company to manage and choose suppliers while EGAT retain the monopoly on both power generation and transmission. Another reason was that EGAT needed to reconcile their risk from procuring the energy resources price to a third party. EGAT also introduced the "Ft" to manage the price risk by including the cost of new capacity, take-or-pay gas contracts, revenue shortfalls (due to inaccurate demand forecasting), and foreign exchange risks. Even though the CEO style strategy of Prime Minister Thaksin was contradictory with the beliefs and norms of Thai people, he tried to reform the electricity business and make it a private company by taking EGAT into the stock market. This strategy was opposed by a large group of Thai people who did not want to let foreign investor's takeover this main important sector in Thailand. As a result, EGAT set up a regulator body under its own control to cooperate with third parties in order to make decisions for energy resource selection and electricity price adjustment.

2.2.2.5 Enhance Single Buyer (ESB) structure model and Energy regulation in Thailand (2008 – Present)

Before the establishment of an energy regulator in Thailand, the Thai energy market was controlled by the three main sectors, not only the electricity generators who generate, transmit, and control most parts of the electricity sector but also the distributors like the MEA and PEA who distribute electricity to their areas of responsibility. The first sector called upon EGAT to have responsibility for many parts of the energy market. The most important part was electricity generation where EGAT made 50 % of electricity generated in Thailand. The electricity operators could be separated into four types. The first was EGAT who was the owner of all power plants above 100 MW or power plants that used oil, gas or water to produce the electricity. The power plants under control by EGAT could be separated into 3 styles. These were power plants that operated 24 hours with low investment cost, the power plants that operated on fixed operation schedules with high investment cost, and the power plants that operated for only 2-3 hours a day during a high demand period. The other 50% of electricity operators gave the opportunity for independent organizations to take a chance to bid at auction in a competitive market. The independent organizations composed individual power plants (IPPs) that had the owners of power plants above 100 MW but controlled by private organizations. Another two generator types were called small power plants (SPPs) and very small power plants that had the owner of a power plant, which generated electricity from 1MW to 99 MW and used the energy like renewable, solar and wind to produce the electricity.

As there was a main controller of the electricity generators, it meant that they also had responsibility to procure the energy such as oil, gas and coal. Due to the crisis in the price of oil and gas in the year 2008, the price of oil and gas were increased rapidly from \$50 up to more than \$100 per barrel, which effected electricity cost, so EGAT changed their strategy to support smaller producers like SPP and VSPP to producing their electricity from clean energy like renewable, solar and wind to keep costs down. The other sector, which EGAT had a monopoly over, was transmission lines, which sent electricity from electricity generators to distributors within the whole of Thailand. The next sector was the MEA and PEA who had responsibility to distribute electricity to end-users like personal, industry and government. The last important sector was system operators (SOs) who were controlled by EGAT and had the responsibility of making decisions for controlling the investment cost and maintaining balance between the energy supply and demand for energy of their users. SOs also had the responsibility to set up the electricity strategic plan, not only the long-term plan like the Power Development Plan (PDP) but also for the middle and short-term plans which were Power Purchase Agreements (PPAs) and Operation Reports. The PDP showed predictions for the use of fuel for the next 15 years and described the change in ratio of energy types to be used for producing the electricity and could suggest the way of using energy in the near future. Moreover, the PDP also gave the plan for creating the new power plants and maintaining the old power plants, which it showed in a year-by-year schedule.

Regarding the PPA, it showed the plan for purchasing electricity from SPP and VSPP to power systems over the next 5 years. Finally were Operation Reports, which were generated every month by EGAT by comparing the real operations for adjusting the operations of the next month. This report showed the energy usage of every power plant under the control of EGAT and the IPP. It was used for tracking and predicting the investment cost, which could affect the electricity costs of the end-users. According to the change in the Government's 5 years strategic plan, the energy market needed to change from government control to generate more cooperation between government organizations and private organizations, which would affect the country's energy standard plan. Moreover the development of energy standards was not only designed by governments but also needed to gain acceptance from society. Due to the strategy change, the factors that EGAT used in their decision was changed from only analyzing economics at break-even point and area optimization to include the effect on the environment around the power plants and the acceptance of society.

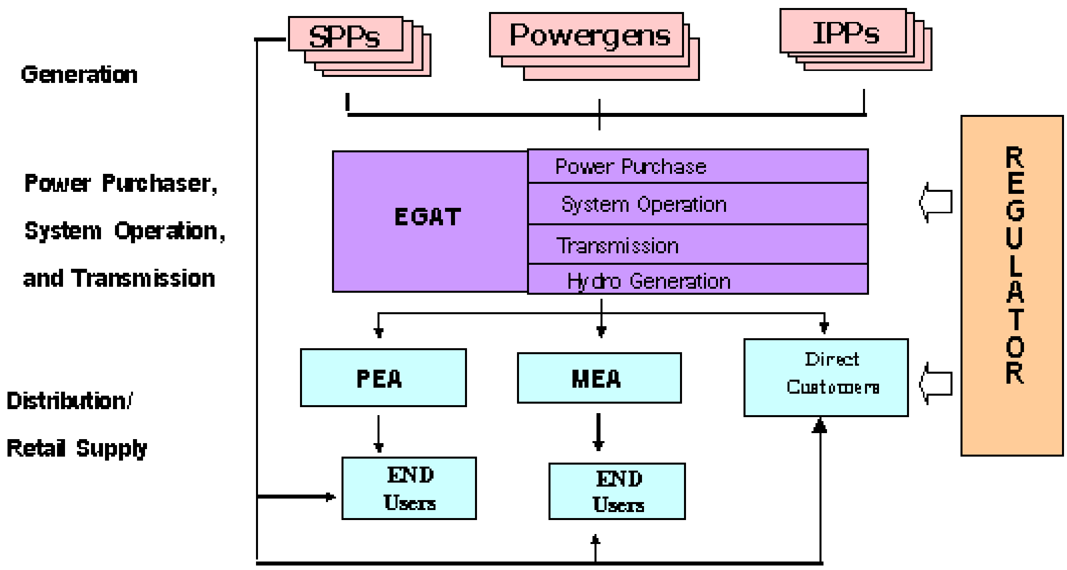

Figure 2.11 Thailand electricity market structure

According to this change, the Government announced the standard called the *Enhanced Single Buyer Model* under the Thailand Energy Act 2008 by adding private organizations that were composed of 6 regulator committees to regulate for fairness in electricity generation, and included auctions in order to create new power plants for EGAT and the independent organizations (Rudi Hakvoort, 2011). By doing this, it could now make electricity operation more stable, reliable and also maintain the level of investment costs and ensure a high quality of service with fairness for the end-users. However, private research suggests that the operation ratio of EGAT is too high and it will lead to many problems.

2.3 Decision-making and Problem Solving

In the general sphere of the business sector worldwide, decision-making is an important process that controls the development of every business because it is related to solving problems, which need to be quickly identified and resolved. Along with the different levels of the decision making process, the decision may have more complex functions and need more information (Janos Fulop, 2003). An example would be a board member making decisions at the policy level while upper management implement the policies and the middle managers make decisions at the procedural level. This demonstrates that decisions are important factors within a company.

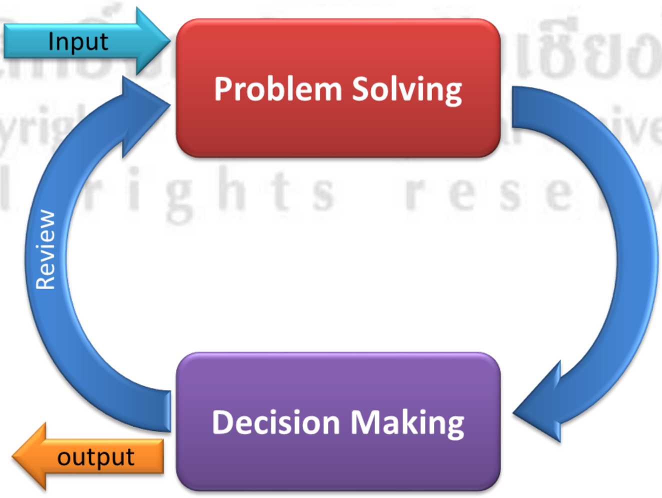

Figure 2.12 Relationship between problem solving and decision-making

A **decision** can be made both formally and informally. The *formal decision* can be defined as relatively complex, non-routine decision-making where the decision may not always exist for the problem faced, while *informal decisions* are more repetitive and routine in nature. **Decision-making** can be defined as the process of identifying and selecting from a range of possible solutions for a problem, according to the demands of the situation, while **problem solving** can be defined as a continuous, conscious process, which seeks to reduce or correct the difference between the reality and desired conditions Romero (Pedro Linares and Carlos Romero, 2006). Therefore it seems that decision-making is only one step in the process of problem solving. The general processes of problem solving presented are as follows:

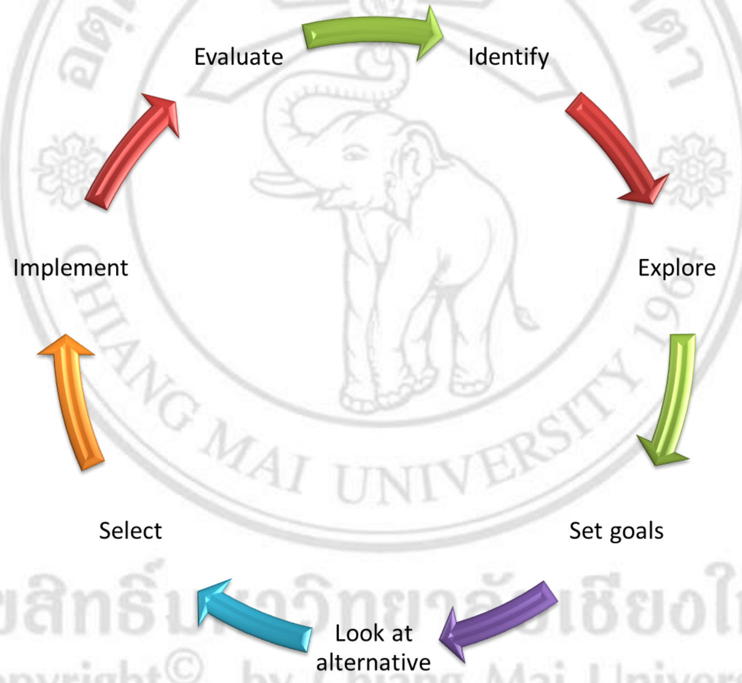

Figure 2.13 Problem solving process

Figure 2.13 shows the cycle of problem solving by start from identify the problem of each question and explore it to the small issue. Then they set the goal that they think it can solve the issue, and look of each alternative to complete their goal. After that they selected on of alternative which accept to use for solve the problem, then they implement and evaluate that alternative to see that it can solve the problem or not

(Texas State Auditor's Office, 2004; Murthy B.V., Lake S.P. and Fisher A.C., 2008). Consequently, each problem can describe are as follow:

- Recognize the problem and state it clearly.

  In this stage the decision maker needs to identify the problem according to the gap between their planned objective and their current situation, which shows what should happen in the future and what the actual condition is forecast to be. In this step, the control report might be the tools used by a manager to monitor this problem. The useful methods that people use to define the problem are; listing (blast/refined), brainstorming, brain writing, forced relationship, free association, idea checklist, interview, observation, survey, etc.

- Determine the significance of the problem

  In this stage, the problem solver should focus their attention on significant problems, which have many factors. The problem solver should not only consider the control the group have over the problem and its solution, the importance showing the seriousness or urgency of the problem and the difficulty in finding the solution to solve the problem, but they should also focus on the time used to solve the problem, the payoff, showing the expected return from solving the problem, and the resources required to solve the problem.

- Gather data and information relevant to the conditions associated with the problem. Identify possible causes of the problem.

  In this stage, the decision maker should gather data and information from the primary research in the first step. The information in this step may have different sources and different formats, so the decision maker needs to arrange the information into the same format for easier comparison.

- Decision-making

  "Decision making is the study of identifying and choosing alternatives based on the values and preferences of the decision maker. Making a decision implies that there are alternative choices to be considered, and in such a case we want not only to identify as many of these alternatives as possible but to choose the one that best fits with our goals, objectives, desires, values, and so on.” (Chris Harris, 1980)

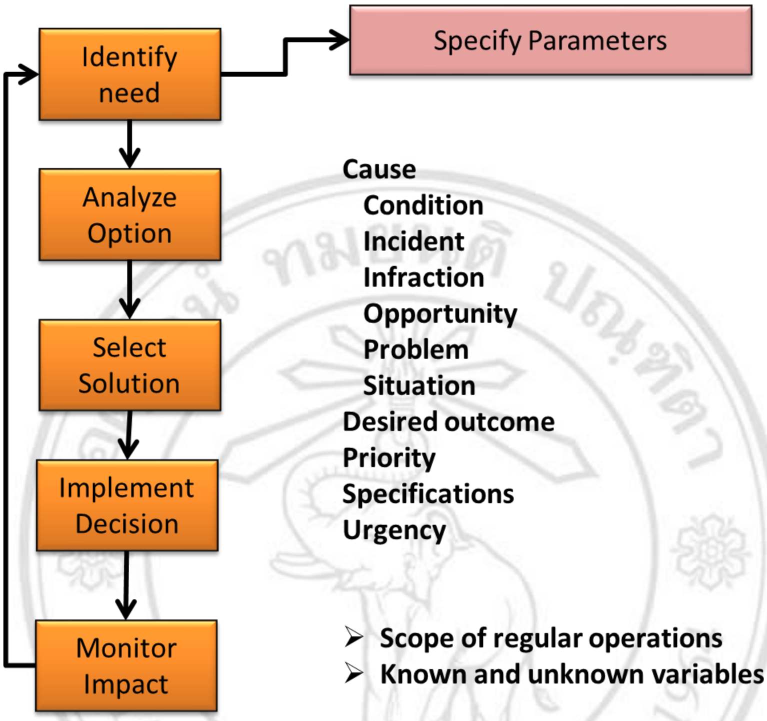

Figure 2.14 Decision-making process

Figure 2.14 show the characteristic of decisions can be separated into many steps, not only the first stage call *identification of the problem*, where people show the "need" to get something, but also the steps by which people find, compare and select the information to support their decision. In the first stage, the decision starts from the need to do or act on something by people and identify root causes, limiting assumptions while setting the system and organizational boundaries and interfaces. Once the decision maker can identify the problem, they will try to *determine requirements* to show the conditions any acceptable solution must meet or what the solution to the problem must do.

The requirement can be defined as the set of the feasible solutions of the decisions problem. Besides determining the requirement, the decision maker may also *establish goals* to set the minimum essential to meet wants and desires while being a communicator of practical decision solutions. In this stage, decision makers may find the information that relates to the problem, from many sources and also find the information for substitute problem to compare the pros and cons of the problem. For these reasons, decision makers may call upon the process to set the requirements and goals of *obtaining necessary information* (Sven Ove Hansson, 2005). The next step of the decision-making process is called *Production of possible solutions* and refines the possible solutions to a few that should meet the requirement, meaning that the infeasible solutions must be deleted (Screened out) and prevented from achieving future consideration. The possible solutions that are used to solve the problem should be:

- Able to discriminate among the alternatives and support the comparison of the performance of the alternatives.
- Completely include all goals.
- Be operational and meaningful.
- Non-redundant
- Few in number

Then they start to compare the alternatives and make a final decision to select or reject that product. This step is called *evaluation of such solutions* from which the decision maker will make their judgment and use the selected decision-making tools to rank the alternatives or to choose a subset of the most promising alternatives. The last step is called *Selection of a strategy for performance* and reveals the final decision result (alternative) for solving the problem. Therefore, the alternatives that are applied to a complex problem should consider the further goals or requirements added within the decision model. As Witte said in 1972, "*We believe that human beings cannot gather information without in some way simultaneously developing alternatives. They cannot avoid evaluating these alternatives immediately, and in doing this they are forced to a decision. This is a package of operations and the succession of these packages over time constitutes the total decision making process.*" (Marek J. Druzdzel and Roger R. Flynn, 2002).

- Plan, implement, monitor, and evaluate the selected alternative; determine if the problem still exists, and decide on future action.

In the last step of the problem solving process, the decision maker should listen to the opinions and attitudes of the people who apply the final alternative because this can help the decision maker to set up the implementation, develop a contingency plan, and minimize risk. The performance after applying the alternative should also be measured because they need to follow up with regards to the effect of the applied alternative and whether it created a different problem or unintended effects.

On the decision making process, a basic decision problem should have a single criterion or a single aggregate measurement of alternatives. However, complex decision-making may actually have an infinite number of alternatives, which match with an infinite number of decision criteria, so the method used to manage that alternatives is call Multi-attribute Utility Theory (MAUT) (Nikitas-Spiros Koutsoukis, Belen Dominguez-Ballesteros, Cormac A. Lucas and Gautam Mitra, 2000; Malhotra, Y., 2001). The basis of MAUT is the use of utility functions, which can be applied to transform the raw performance values of the alternatives against diverse criteria. A good example of MAUT can be shown in the goal of cost minimization because the associated utility function must result in higher utility values for a lower investment costs. To explain the Multi-attribute decision making methods, focus is placed on the relationship between *m* criteria and *n* alternative, and let $C_1 \ldots C_m$ be the criteria while $A_1 \ldots A_n$ are the set of alternatives as the standard feature of multi-attribute decision making methodology in the decision table, shown below:

		X_1	.	.	X_n
		$\mathbf{A_1}$	.	.	$\mathbf{A_n}$
W_1	$\mathbf{C_1}$	a_{i1}	.	.	a_{m1}
.	.	.	.	.	.
.	.	.	.	.	.
W_m	$\mathbf{C_m}$	a_{m1}	.	.	a_{mn}

Figure 2.15 Decision making formula

As shown in the decision table, the score $a_{11} \ldots a_{mn}$ can assume that a higher score value means a better performance for any minimization goal and can be transformed into a goal of maximization. In this table, the weights $w_1 \ldots w_m$ are assigned to the criteria, which represent the importance of criterion C_i, and is assumed to be positive. While the values $X_1 \ldots X_n$ are also associated with the alternatives A_n, which represent the higher rank, and mean a better performance of an alternative and where the highest ranking value is the best of the alternatives. The simplest form of the MAUT method is called Simple Multi-attribute Rating Technique or SMART, which was presented by Edwards in 1977, stating that ranking value x_j of alternative A_j is obtained simply as the weighted algebraic mean of the utility values associated with it. The formula is as follows:

$$x_j = \sum_{i=1}^{m} w_i a_{ij} / \sum_{i=1}^{m} w_i , \qquad j = 1, \ldots, n.$$

Figure 2.16 Decision making score average

Seen from the formula above, it proposes a simple method to assess weights for each of the criteria to reflect its relative importance to the decision. For large industries, especially for the Electricity System Industry (ESI), the decision alternative finalized by a decision maker is important and affects a wide rank of participants, so the group decision making method is used to aggregate different individual preferences on a given set of alternatives to a single collective preference. The characteristic of group decisions is that they involve multiple decision makers who have different skills, experience and knowledge for setting up the criteria of the same problem, and have a special decision maker (Supra Decision Maker or SDM) who has the authority to establish consensus rules and determine voting power of the group members, for the different criteria. Therefore, the final decision should be derived by aggregating the opinions of the group members according to the rules and priorities defined by the SDM. Referring to the basics of the decision table, a group decision maker considers a problem with *L* group members (decision makers) set in the form of $D_1 \ldots D_l$, *n* with alternatives as $A_1 \ldots A_n$ and *m* are the criteria of $C_1 \ldots C_m$, which can be evaluated differently by the decision maker.

Denoting the result of the evaluation of decision maker D_k for alternative A_j based on the criterion C_i by ak_{ji}, assuming that the possible problem arising from the different dimensions of the criteria has already been settled, and the ak_{ij} values are the result of proper transformations. The individual preferences on the criteria are expressed as weight where $wk_i >= 0$ will be assigned at criterion C_i by decision maker D_k, I = 1…m and k = 1…l. For the group decision-making, the voting powers of the decision maker can affect the way to weight the criteria and alternatives, especially in the case of subjective criteria that present not only the weights but also the ak_{ij} values and will be modified by the voting power in order to qualify. Therefore, if set $V(w)_{ki}$ is the voting power that is assigned to D_k for weighting on criterion Ci, and $V(q)_{ki}$ is the voting power assigned to D_k for qualifying for criterion Ci, I = 1,…,m; k = 1,…,l. So the method of calculating the group utility of alternative A_j is as follows:

- For weights (Wi) the criterion (Ci) is:

$$W_i = \sum_{k=1}^{l} V(W)^k{}_i W^k{}_i / \sum_{k=1}^{l} V(W)^k{}_i, \qquad i = 1, \dots, m.$$

Figure 2.17 Weight identification formula

- The group qualification Q_{ij} of alternative A_j against criterion Ci is:

$$Q_{ij} = \sum_{k=1}^{l} V(q)^k{}_i a^k{}_i / \sum_{k=1}^{l} V(q)^k{}_i, \qquad i = 1, \dots, m, j = 1, \dots, n.$$

Figure 2.18 Alternative selection formula

- The group utility U_j of A_j is determined as the weighted algebraic means of aggregated qualification values with the aggregated weights is:

$$U_j = \sum_{i=1}^{m} w_i Q_{ij} / \sum_{i=1}^{m} w_i, \qquad j = 1, \dots, n.$$

Figure 2.19 Group selection formula

Finally, the decision maker needs to focus on the factors that affect the decision-making process, especially in-group decision-making, in order to avoid the emotions that lead to faulty decisions.

2.4 Decision Support Information Management and Knowledge Management Tools

When focusing on the decision-making process, it is shown that the quality of information received from any source is an important element for providing the accuracy of the decision result. If a decision maker does not get enough information, they will make their decision uncollected and increase the risk when running their business, which in turn may affect the turnover of the business. Therefore, the study of ways to manage organization information, which may be received from different sources at difference times, is necessary for any organization that needs to make complex decisions in a limited time. Moreover, the decision maker dealing with present situation needs more specific information and sometimes they need to go back to study the information that decision makers used to make decisions at a previous time.

Therefore, *knowledge management* was presented to the decision-making world. Although, when we look at the theory of knowledge management we find that information management or an information science that exists today already provides many of the important foundations for supporting knowledge management, it was claimed by Buckland in 1999 that “the documentation tradition has a long history of developing method and practices for organizing the vast expanses of human knowledge for access by various kinds of user, and the computational side of information science also developed the powerful techniques for retrieving documents through different forms of computer-based processing and search”.

Information management initially dealt with catalogues and bibliographic information and full text documents, which were paper-based. When technology became an important part of people’s lives, IT experts developed computer programs that could support the decisions of decision makers called "decision support systems" or "DSS" that could define the tools that help decision makers to gather information, generate alternatives, estimate the values of alternatives and make choices (Mobashwer Ahmed Chowdhury, Hasan Sarwar and Prof. Shahida Rafique, 2006). So the information management also changed from paper based to network and multimedia information bases. DSS can be separated into many types not only the decision support system for individuals or groups of decision makers but also the decision support systems for optimal solutions. The related tools that are used to support information management in organizations can be shown as follows:

- Ontology

In the general world, each piece of data has its own meaning. However, the way to specify that one data is the subset of another data is also important because it can show the relationship between two forms of data that interest people and can be used to identify where data comes from. One of the important tools used for arranging data is called Ontology. It can be defined as an information structure, which can help to acquire knowledge, share it, and check consistency within that knowledge. Camap (1968) and Bunge (1977) also define ontology as a branch of philosophy concerned with the study of what exists. Gruber (2007) presents a formal definition of ontology, separating it into 5-tuple (*N*, *R*, *D*, *F*, *T*). The first element is N, which is defined as a set of nodes, and another element is *R*<*N* defined as a set of relationship types. In ontology, knowledge is mainly represented by *D* and *T* where *D* is a set of description logic sentences where each sentence can use an element in *N* and 2 variables, subject and object, and indicates respectively the first and third element in the 5-tuple in *T*. *T* as the set of relations, defined as a set of 3-tuple where s is the subject, o is the object that both are an element of *N*, and *r* is the relation presented as an element of *R*. The last tuple is the function that maps elements in *R* and maps onto one element in *D (*Stephen Quirolgico, Pedro Assis, Andrea Westerinen, Michael Baskey and Ellen Stokes, 2004).

- Common information model (CIM) and IEC 61970 standard

In the Electricity System Industry (ESI), the data that decision makers use to support their decision comes from many sources, in different formats and at different times, so people have to focus research on the power system exchange data to help decision makers. IEEE established the first power system exchange data in the year

1968 called Common Format. It represented the line based format for grouping the content of the lines into sections and gave headers to each section, with data items entered in each column. However, this standard did not allow blank items in the columns, which were replaced by a zero. While the ESI was extending, it needed to exchange power data between companies that used different computer based systems connected via web technology (Dr. Alan and W. *McMorran*, 2007). The Common format could not support those technologies because the data was not self-describing and could only to be understood by experts. Therefore, the Common information model (CIM) was developed by the Electric Power Institute as a platform independent model for describing the power system, and was adopted as an IEC standard (IEC 61970) in November 2003. The CIM represents all major objects normally used within an electricity utility enterprise in the structure of a UML based Rational Rose ™ model that is represented as classes having attributes and shows relationships to the other classes (Xiao-Bing Hu, Ezequiel Di Paolo, Shu-Fan Wu, 2007).

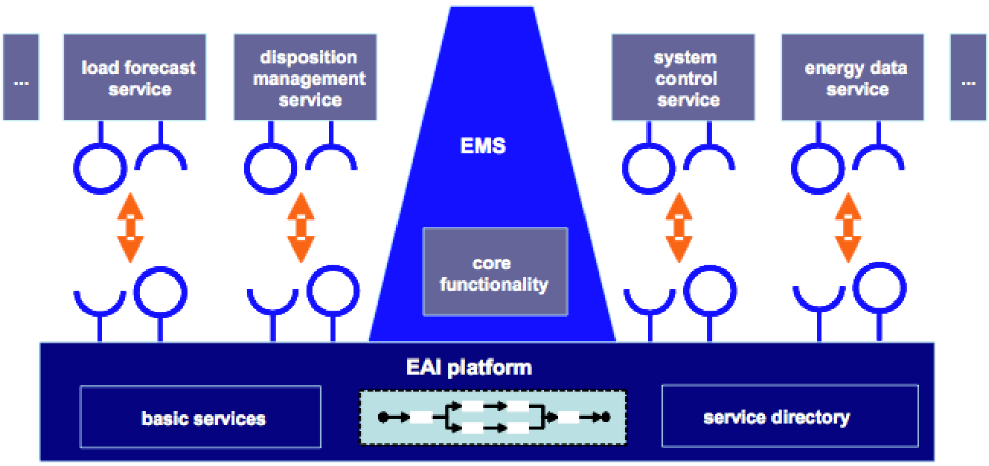

Figure 2.20 CIM and the relationship with EMS

Figure 2.20 shows the example to applying CIM for integrating EMS with many service-oriented subsystems. A communication and nitration platform can be used to provide communication and data exchange between the difference subsystem which applied the CIM for provide the numerous options to support communication between system and provide their internal data such as power grid topology to the EMS.

The figure above shows an example of applying CIM for integrating EMS with many service-oriented subsystems. A communication and nitration platform can be used to provide communication and data exchange between the different subsystems, which apply CIM for providing the numerous options to support communication between systems and provide their internal data such as power grid topology to the EMS.

- Energy Management System (EMS)

The Energy Management System (EMS) was an important tool used in the electricity market because it obtained data and used it to produce the trend analysis and annual consumption forecasts. EMS can be defined as a computer system designed specifically for the automated control and monitoring of the heating, ventilation and lighting needs of a building or group of buildings, such as university campuses, office buildings or factories, and other cases where EMS also provide facilities for the reading of electricity, gas and water meter (Hemanta Doloi and Ali Jaafari , 2002). The benefit of EMS can be shown as follows:

  - Facilitate the management of energy usage in the building or facilities.
  - Trending and monitoring of energy consumption.
  - Automatic and consistent reactions to events.
  - Provide a means to gather and view information quickly.

As a result, EMS is used for a comfortable and safe environment for the building occupants for the lowest possible cost.

- **Knowledge Management tools**
  - CommonKADS

The commonKADS model was established under the objective of capturing the knowledge from experts while they do their work and transforming that into the computerized base, which general people could understand. In order to capture the knowledge from one task, commonKADS separate into two main parts. These are, task templates used to classify the characteristic of the task, and communication models, which are used to identify the information transaction between any agents who are involved in the task (A Waern, K Hook, R Gustavsson and P Holm, 1993). The details will be deeply discussed in chapter 3.

- Balance Scorecard

Balanced scorecards emerged in the USA from Johnson and Kaplan, at the end of the 80's (1987), as a new management control tool to help business make gains in strategic and marketing dimensions. BSCs are most popularly used for mid-term strategies (5 years) and are composed of (Ravi Arora, 2002):

- Four strategic perspectives, which are financial, customer, internal business process, learning and growth
- Ten to fifteen strategic objectives distributed among the four perspectives
- At least two indicators to measure each strategic objective
- Targets and initiatives to reach the targets

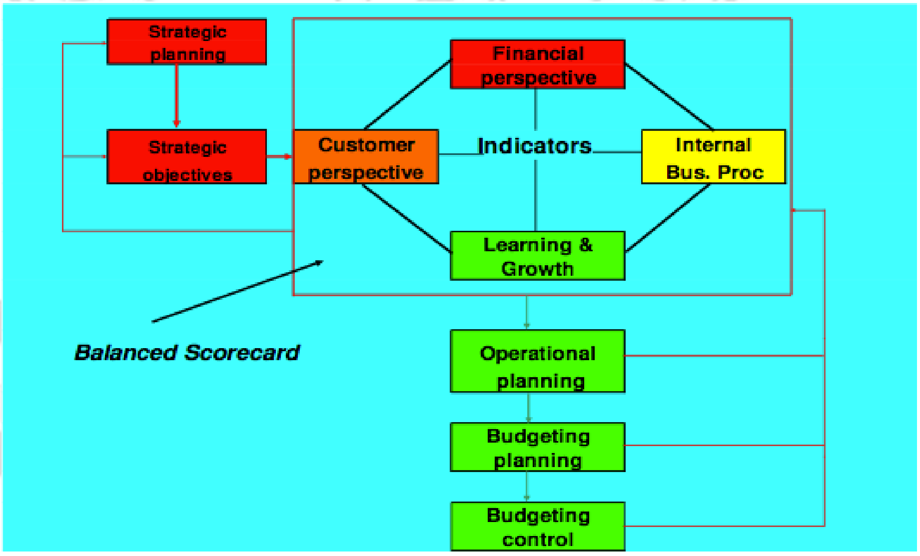

Figure 2.21 Relationship between balance scorecard and organization strategic

From figure 2.21, the four perspectives are designed to balance the organization capitals that are the balancing between financial and nonfinancial, the internal and external, and the current performance with the future performance, and end with the develop of learning and growth level of organization. The relation between BSCs and knowledge management was shown in the parts of capital within the organizational architecture of the firm called "Intellectual Capital Scorecards" and were deployed by the Swedish insurance company Skandia. It means design and identify the measurement of each four parts in balance scorecard can effect with the success of organization strategic can goal because the balance scorecard.

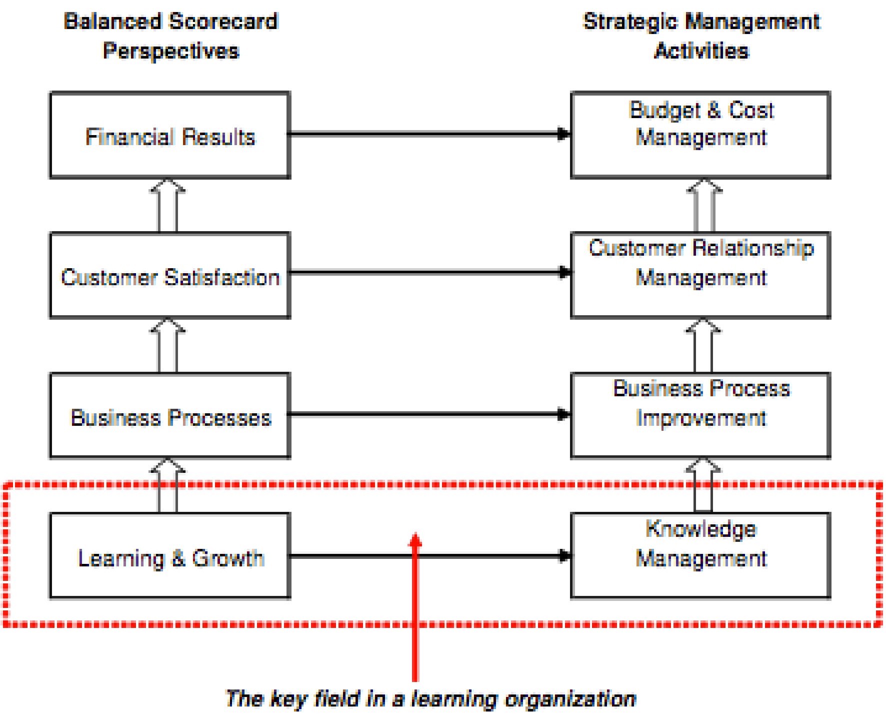

Figure 2.22 Balance scorecard perspective and strategic management activities

Therefore, figure 2.22 shows the methodology to transfer the strategy from top-level organizations to their partner has revealed that the sub units select some strategy from their headquarters and transform it into their own strategy and indicators, which can be a measurement of the drive to commit their goal.

In creating the balance scorecard for Thailand's power system, it starts from analysis of the strategy of organizations, and creates the strategic map that shows the strategic themes, which also shows the relationship, the cause and effect, between the themes (Ajith Abraham, 2005). The strategic theme can be presented in four main parts and the cause-effect between those parts. The strategic map can be seen in the figure, as follows:

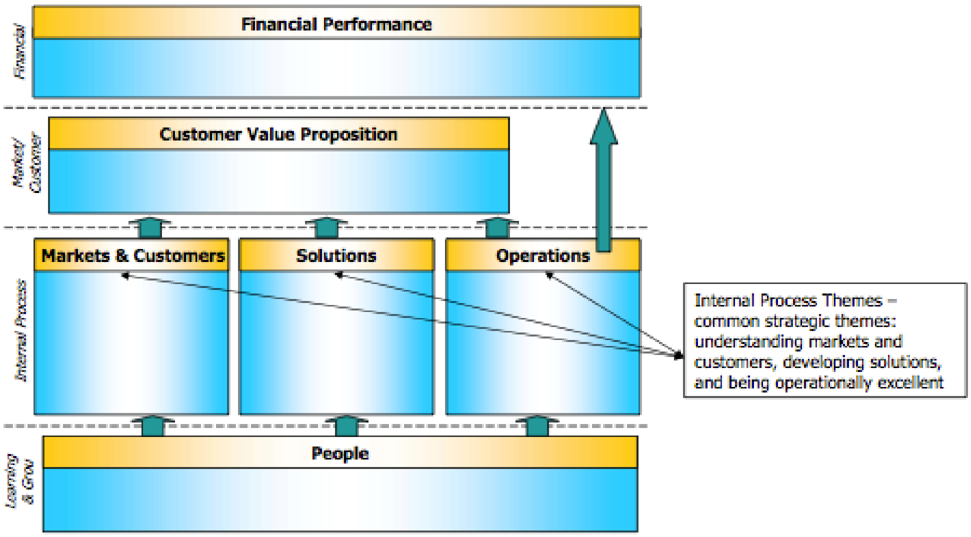

Figure 2.23 Balance scorecard framework

Figure 2.23 has described the detail of function in 4 main area of balance scorecards. First is finance, showing the strategic theme, objective and indicator concerning financial aspects by separating into three main aspects; increase the organization revenue, decrease organization investment costs or increase the quantity of production and organization asset utilization. The second is the theme concerning customers, focusing on the aspects concerning customer satisfaction with the market share, which directly affects the profitability of customers. The third aspect presented concerns internal business processes that analyses the strategic indicator by starting from innovation processes and business operation processes. The last aspect presented concerns the learning and development of people, such as their attitude towards work or training, and business processes of organizations, such as adding ICT or reducing the redundancy of organization business processes (Dr. Alea M. Fairchild, 2002; Jean Baptiste K. Dodor, Rameshwar D. Gupta and Bobbie Daniels, 2004).

After identify the strategic map, it follows to create the Corporate Balance Scorecard, which is the table to show the description of strategy by presenting the description of strategic objectives, measurements, targets and the initiatives of all strategic themes. These tables are also call "OMTI Models". Next, the organization uses their OMTI to decentralize their strategic theme to sub-unit organizations, as shown in the figure below:

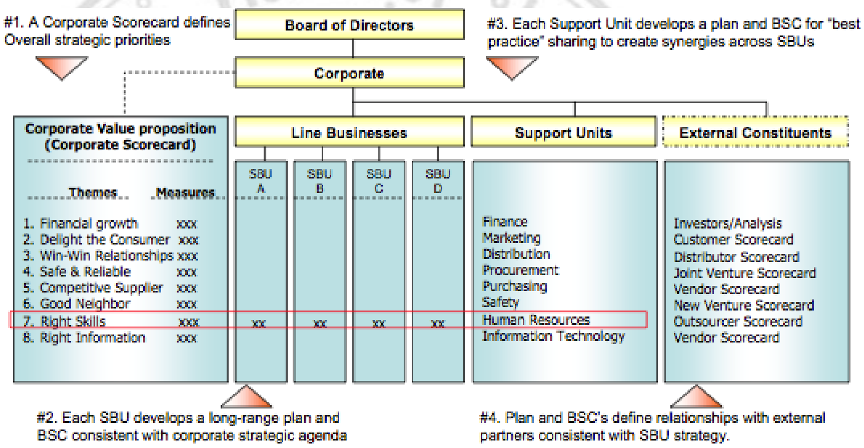

Figure 2.24 Theme and measurement dissemination in balance scorecard

The figure above shows the structure to instruct the strategic themes and measurements from the organization's headquarters to their sub business unit (SBU), and the measurement indicator of the strategic theme that is delivered to their sub business unit (SBU), which has changed to support the SBU private goal. Moreover, the success of that measurement of SBU can lead to success for the strategic theme of the organization's headquarters.

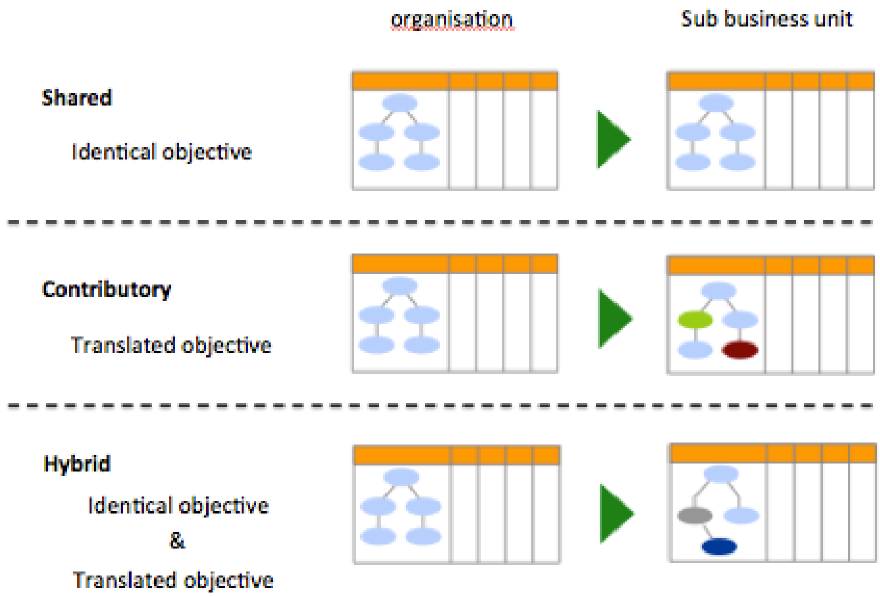

Figure 2.25 Characteristic of measurement dissemination

However, every sub-unit organization also needs to operate their private business to make their own profit, while needing to help achieve the organization's goal for the success of the whole group.

As presented in the balance scorecard in Thailand's power system, we see that each company receives the national plan and develops it own indicator, and this has a structure known as the Contributory Model.

2.5 ESI Task Template and Communication Modelling

To make business successful, many organizations manage their strategy by using many techniques such as balance scorecards, which identify the organizations strategic approach and its attributes related to four main factors, finance, customers, internal business processes and learning and growth. The balance scorecards can also present the key performance indicator (KPI) of each attribute that affects the way organizations complete their strategic objective. However, balance scorecards only present the relationship of each factor and do not include the internal communications, in terms of the transferring knowledge within organization. Therefore people, adopt Knowledge Engineering, involving the science of knowledge capture processing, and will bring the

CommonKADS theory using Knowledge Engineering, from time to time (Tillal Eldabi, Zahir Irani, Ray J. Paul and Peter E.D. Love, 2002). CommonKADS Theory can be explained as the process to capture, extraction or mining of the hidden techniques of specialists or expert parties to create a human knowledge model. Then, the overall solutions that are gathered from the expertise will be analysed and presented in the way of a general concept that ordinary people can understand. The CommonKADS is concerned with answering three questions, which are:

1) Why?

It is used to understand the organization context and its environment to answer the question like "Why Knowledge systems help to create the greater solution"? Or "Which organization impact does it have"?

2) What?

It provides answers for selecting the structure of knowledge and communication involved in the task.

3) How?

It presents the way to transform knowledge to a computerized system model.

The three question above are used to develop aspect models, which are shown in the figure below:

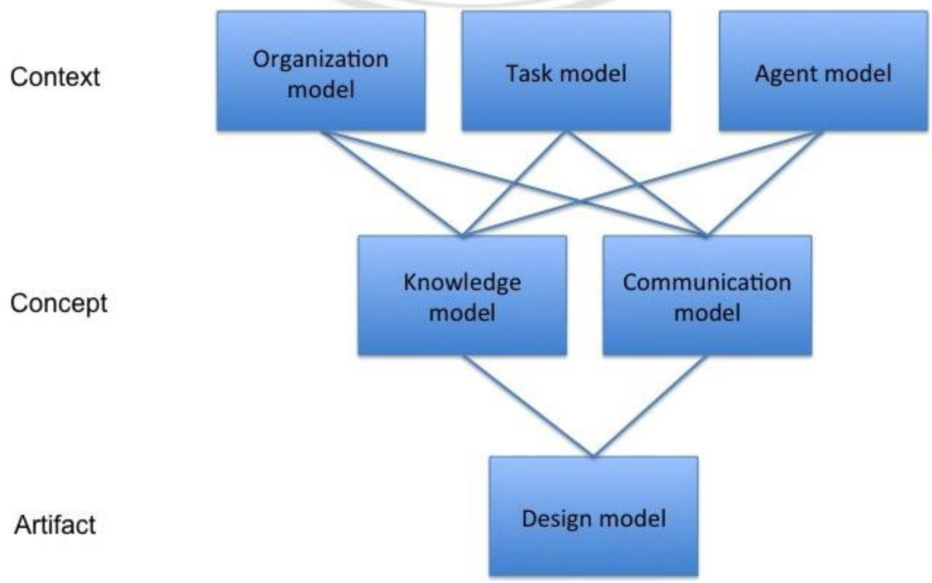

Figure 2.26 CommonKADs development model

Based on the figure above CommonKADS can present the model divided into six types (IEC (2007-08) standard):

1. Organization model: it presents the organisation features to discover the problems, opportunities and impact on the organisation of intended knowledge actions.

2. Task model: it presents the characteristic of the task layout for input, processing and output task, as well as needed resources and competences.

3. Agent model: it presents the characteristics of any elements that participate within the task. Agents can be a human, information systems or any entity.

4. Knowledge model: its purpose is to the detail the type and structure of the knowledge used in performing a task.

5. Communication model: it shows the model of communication transactions of every agent involved in the task.

6. Design model: it uses the implementation of every model above as a requirement in order to create the technical system specification in terms of architecture, implementation platforms, software modules, representational constructs and computational mechanisms.

This research focuses on the two main parts for the model, which are the “Knowledge Model” and “Communication Model”. Knowledge models specify the knowledge and reasoning requirement of the perspective system, and communication models specify the needs and desires with respect to the interface with other agents.

In order to classify and transform the knowledge into a computerized model, the knowledge engineer (KE) mostly uses general models, models to describe the characteristic of the task, called “Task templates” (Neil Gunningham and Robert A. Kagan, 2005). It is defined as the common type of a reusable combination of model elements, and is uses the KE for solving problems of a particular type. Moreover, the task template specifies a typical domain schematic that would be required from the task point of view.

Task templates can be separated into two main groups of task, not only the analytical tasks that are used to classify the object of any task type, but also the synthetic tasks that show the design of a system task to be constructed for some physical artefact. For analysis tasks, the characteristics of each type can be seen in the table below:

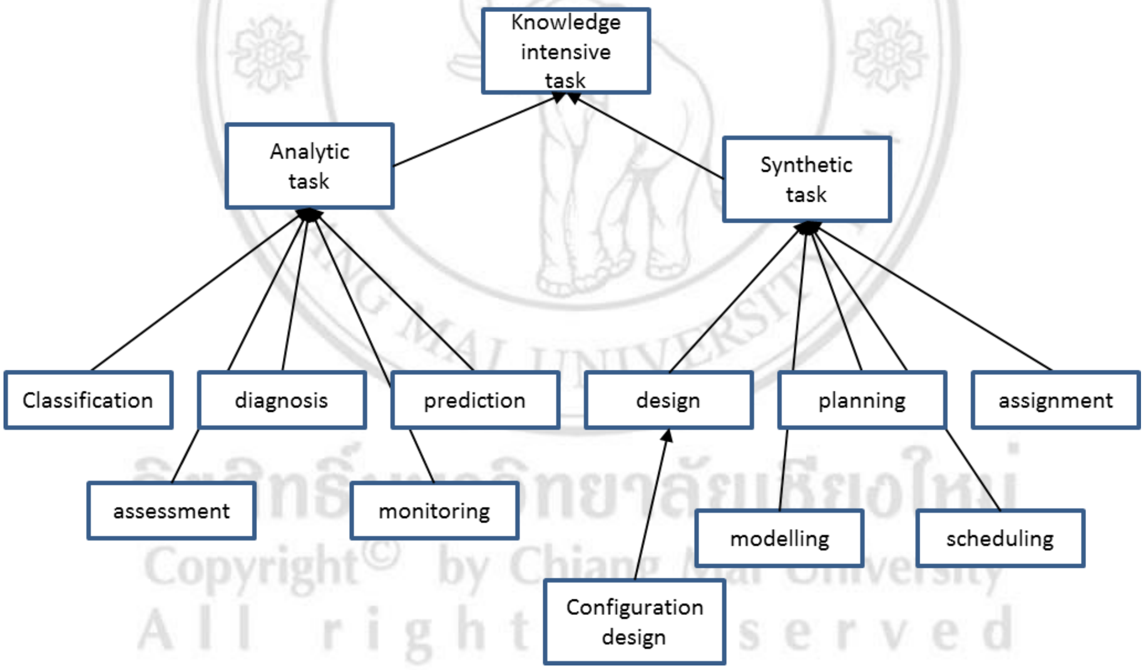

Figure 2.27 Group of task template

The above table shows the characteristics of each task type in the analytical task. The first one is the well-known analytical task type *Classification* that characterizes the object in terms of class, and each class has constraints on the values of the object features. The *Diagnosis* is different from classification because its underlying knowledge typically contains knowledge about system behaviour, and its output can take in many forms, such as faulty components, a faulty state or a causal chain. The next task type is *Assessment*, which is often found in the financial and community service domain (The Energy Group Institute of International Education, 2003; Dieter Fensel and Katharina Siorpaes, 2010). It is used to characterize a case in terms of a decision class. For the *monitoring* task type, it looks similar to the assessment task but the main difference is that the output is simply a discrepancy instead of a decision class. The last task type of *analytic* tasks is a *prediction*, which presents the system behavior to construct a description of the system state at some future point in time. This task is often found in knowledge-intensive modules of teaching systems.

Table 2.4 The characteristics of analysis tasks

Task type	input	output	knowledge	features
analysis	System observations	System characterization	System model	System description is given
Classification	Object features	Object class	Feature-class assisocations	Set of classes is predefined
Diagnosis	Synptoms/ complaints	Fault category	Model of system behavior	From output varies (causal chain, stat, component) and depends on use made of it (troubleshooting)
Assessment	Case description	Decision class	Criteria, norms	Assess,emt is performed at one particular point in time (cf. monitoring)
Monitoring	System data	Discrepency class	Normal system behavior	System changes over time task is carried out sepeatedly
Prediction	System data	System state	Model of system behavior	Output state is a system descriptio at some future point in time

Meanwhile, synthesis tasks also contain many task types. The first task is the *design* task type that constructs some physical artefact, and generally can include the creative designs of components. The next task type is *assignment*, which is consistent with constraints as well as conforming to preferences. *Planning* task type is similar with design but the main difference is the system being constructed and that it is concerned with activities and their time dependencies. Next is the *scheduling* task type, which is used to allocate the activities of resources during certain time intervals, and focuses on the time-oriented character of scheduling. The last task type, *synthesis* task, is modelling that constructs an abstract description of a system in order to explain or predict certain system properties or phenomena. The characteristics of synthesis tasks are shown in the table below:

Table 2.5 The characteristics of synthesis tasks

Task type	input	output	knowledge	Feature
synthesis	Requirement	System structure	Element, constraints, preferences	System description need to be generate.
Design	Requirement	Artifact description	Components, constraints, preferences	May include creative design of components.
Configuration design	Requirement	Artifact description	Components, skeletal designs, constraints, preferences	Subtype of design in which all components are predefined.
Assignment	Two object aets, requirement	Mapping set 1 to set 2	constraints, preferences	Mapping need not be one-to-one
planning	Goals, requirement	Action plan	actions constraints, preferences	Actions are (partially) ordered in time
Scheduling	Job activities, resources, time slot, requirement	Schedule = activities allocate to tome slots of resources	constraints, preferences	Time-oriented character distinguishes it from assignment.
modelling	Requirement	model	Model element, Template models, constraints, preferences	May include creative "synthesis".

2.6 Communication Model

After completing the design of the knowledge model, concerns turn to the other important model, the "Communication model", which is used to specify the information exchange producers use to realize the knowledge transfer between agents. The overview of a communication model and the relationship with other CommonKADS models can be seen in the figure below:

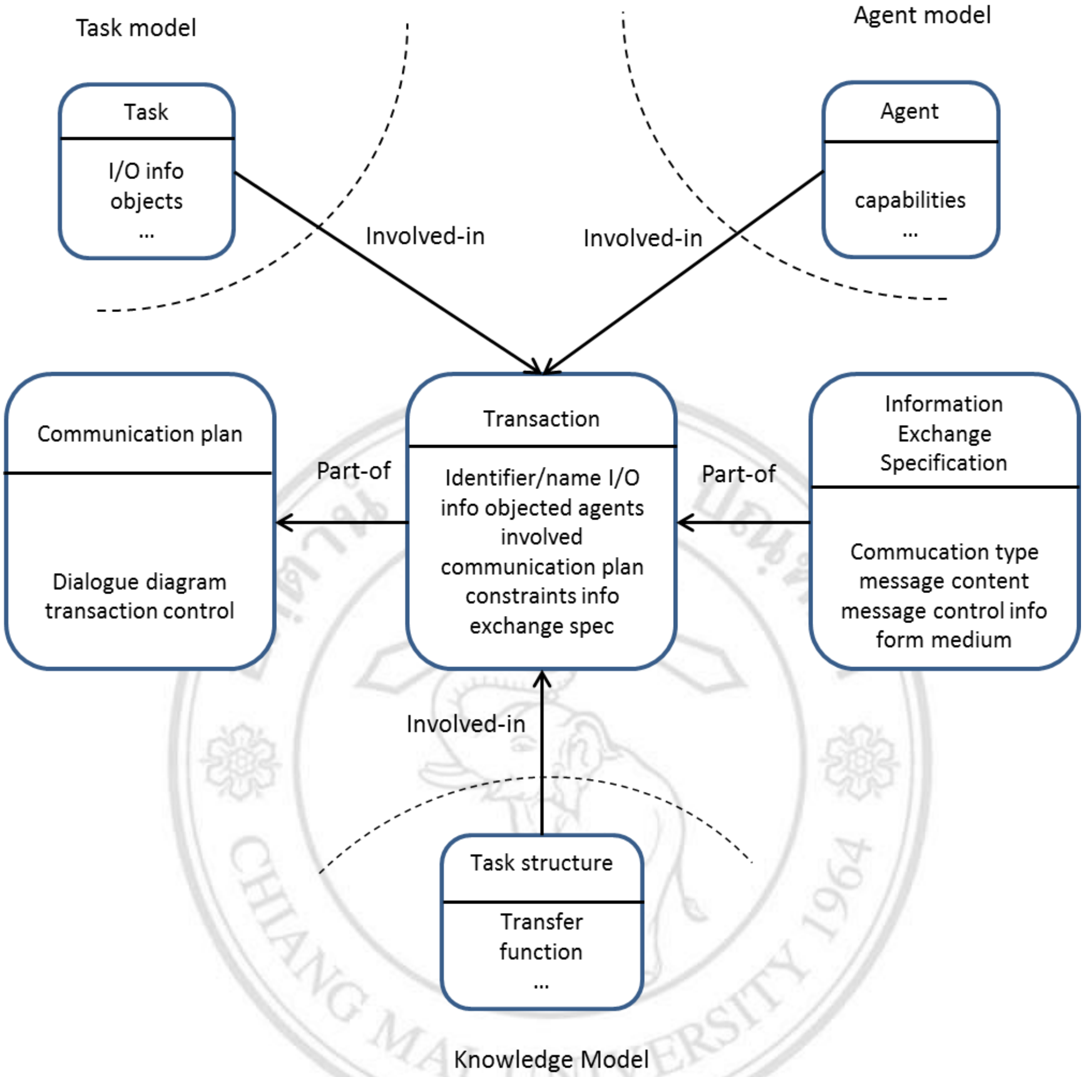

Figure 2.28 A communication model and the relationship with other CommonKADS models

The figure above shows that the key every agent uses for describing a communication act is called a *transaction* and it uses this to tell the information objects exchanged between the agent and the task. Transactions present the building blocks for the full dialogue between two agents and predefine the communication type and pattern. The transaction can describe the communication plan by using a computerized system form such as a UML diagram. This diagram can identify the elements of each task from the first to the last step (Karlheinz Schwarz, 2004; Peter M. Lamb, 2006). Moreover, Knowledge Engineering describes the transaction by using the transaction description (worksheet CM-1), shown in the table below, specifying the transaction name, objective, agent involved, communication plan name and the constraints of each transaction.

Table 2.6 Template for transaction description (worksheet CM-1)

Communication model	Transaction description worksheet CM-1
Transaction identifier/name	A transaction is to be defined for each information object that is output from some leaf task in the task model or in the knowledge model, and that must be communicated to another agent for use in its own tasks. The name must reflect, in a user-understandebele way, what is doe with this information object by the transaction. In addition to the name, give a brief explanation here of the purpose of the transaction.
Information object	Indicate the (core) information object, and between which two task it is to be transmitted.
Agents involved	Indicate the agent that is sender of the information boject, and the agent that is receiving it.
Communication plan	Indicate the comunication plan of whichthis transaction is a component.
Constraints	Specify the requirements and (pre)conditions that must be fulfilled so that the transaction can be carried out. Sometime, it is also useful to state post conditions that are assumed to be valid after the transaction.
Information Exchange specification	Transactions can have an internal structure, in that they consist of several messages of different type, and/or handle additional supporting information objects such as explanation or help items, this is aetailed in worksheet CM-2. at the point, only reference or pointer needs to be given to a later info exchange spec.

Meanwhile, each transaction description also uses information exchange specification (worksheet CM-2). In this worksheet is seen the transaction name and agent involved, identifying the sender and receiver of this transaction. Moreover, it also describes the information item that classifies the layer of each part of the information, separating core and support information, and the message specification, which describes the communication message type that makes up the transaction of each individual message.

Table 2.7 Templates for information exchange specification (worksheet CM-2)

Communication model	Information Exchange Specification worksheet CM-2
Transaction	Give the transaction identifier and the name of which this information exchange specification is a part
Agents involved	1. Sender: agent sending the information item 2. Receiver: agent receiving the information item
Information item	List all information items that are to be transmitted in this transaction. This includes the ('core') information object the transfer of which is the purpose of the transaction. However, it may contain other, supporting, information items, that, for example, provide help or explanation. For each information item, describe the following: 1. Role: weather it is a core object, or a support item 2. Form: the syntactic form in which it transmitted to another agent, e.g., data string canned text, a certain type of diagram, 2D or 3D plot. 3. Medium: the medium through which it is handled in the agent-agent interaction, e.g., a pop-up window
Message specifications	Describe all message that make up the transaction. For each individual message describe: 1. Communication type: the communication type of the message describing its intention. 2. Content: the statement or proposition contained in the message 3. Reference: in certain cases, it may be useful to add a reference to, for example. What domain knowledge model or agent capability is requiref to be able to send or process the message.
Control over message	Give, if necessary, a control specification over the message within the transaction. This can be done in pseudo code format or in a state transition diagram. Similar to how the control over transaction within the communication plan is specified.

Chapter Review

Finally, it can conclude that electricity industry in Thailand has develop in a long way and government need to increase competition in this market for move the market position from monopoly to fully competition, which make the benefit to country resident by reduce the market price and investment cost. Therefore, the next chapter will use the theory such as balance scorecard and commonKADs model to identify industry's task, information and stakeholder for make this industry to have clearly strategic theme.