Chapter 1
Introduction

Since electric energy is regarded as the fundamental needs of our present society, it must be therefore made available to every user continuously and undistortedly. The electric power is generated in the power generation plants either a large conventional plants located far away from load centers or a localized distributed generators. The power generated from both sources has to be conveyed to the end users over some means of transportation. This is a transmission and distribution network if such power is produced at conventional plant; or only a distribution network if it is from a distributed generation plant. Either way a power distribution network plays an important role in distributing and supplying electric energy to the end users. The distribution network consists of underground cables, overhead lines, distribution transformers, capacitors, or switching and protection devices. Its primary function is to take power from substation switchgears at medium voltage level and distribute through the medium voltage network to reach the customer points of use. By nature, the performance of distribution network is so important due to its impacts on customer's outage. Furthermore, not only the distribution of such energy must be made in such a way that providing the targeted availability, quality and reliability but also balancing the benefits of all stakeholders at the same time.

The power distribution is asset-based business; huge portion of utility's yearly budget are invested on distribution network. Furthermore, the overall network performance relies heavily on the performance of individual physical asset that forms up the network. Hence, the decision to be made on the network reinforcement investment must be conducted cautiously because it directly affects the welfare of stakeholders. The utilities, for instance, require the maximum profit with the minimum costs whereas the customers want the reliable and quality supply with lowest price. On the other hand, the regulatory body tries to compromise the requirements of both parties. Sociological and environmental concerns such as public safety, people's health, visual impact, or electromagnetic interferences, are other issues that utilities have to be aware of and satisfy the concerned parties with the most appropriate solution. In term of network reliability, the methods that utility usually employed for reliability enhancement include replacement of regular overhead lines by insulated ones, overhead to underground conversion, line reduction by addition of new substation and automatic network reconfiguration and sectionalization using distribution automation system (DAS) [1]. When taking into account the social and environment aspect, utility puts its focus on undergrounding of the network. It has been widely known that the underground distribution system provides a better performance in almost every aspect such as reliability, quality, safety or city aesthetics when comparing to the overhead system but the cost of construction is also very much higher. This is why asset management methodology comes into play.

Asset management has been around to balance the requirements of each stakeholder. Asset management involves systematic and coordinated activities and practices through which an organization optimally manages its physical assets, and their associated performance, risks and expenditures over their lifecycle for the purpose of achieving its organizational strategic plan [2]. This concept is also applied to power delivery business. In essence, the power transmission and distribution asset management involves in the key decision making to maximize the profits, minimize the costs, but still delivering the high service levels to customers, with minimum risks [3]. It thus suggests that the values of distribution network are the maximization of its utilization while maintaining the high reliability and quality, and the minimization of associated costs and risks. To assist the determination of these values, the decision makers need to be equipped with reliable, content specific and up-to-date information on every piece of the assets. Furthermore, the tools that are capable of deriving the knowledge for strategic actions, out of available asset information, must also be made available at hands of the decision makers.

Although asset management discipline has been around for a while and successfully applied to mange generation, transmission, and substation assets; the methodologies developed for distribution network assets mostly focus on the reliability improvement of only either overhead or underground feeders. On the other hand, there do not exist such comprehensive tools to assist the decision making on why, when, and how to convert the overhead distribution lines into the underground ones. The lack of such effective tools not only results in an inefficient decision making in network conversion investment but also, at the same time, places the concerns on social and environmental issues remain unmanaged. This thesis proposes a novel decision support system (DSS) for power distribution network asset management, a conversion of overhead feeder to underground substitution in particular. The proposed tool starts with an asset categorization by classifying of distribution feeder assets, either physical or conceptual into classes as well as defining relationships among them. Using the information contained in asset objects, the DSS attempts to determine the failure risk potential of using existing overhead line, translate this risk into corresponding monetary value. At the same time, the DSS also quantifies the cost figure of the preventive actions if such risk is to be prevented to occur. Distribution network undergrounding is of course one of the preventive solution. These two monetary figures are then assessed against other criteria such as technical constraints, public safety, or city aesthetics in the final decision making process. It shall be however noted that the thesis does not intend to provide a fully computerized automated DSS; it rather offers frameworks for asset categorization, risk and cost assessment, and multicriteria decision making process. In addition, some case studies are presented to show its application practicability.

1.1 Chapter Overview

In this introductory chapter, an overview of electricity power system is presented, followed by the discussion on Thailand electricity supply industry. The power distribution system performance is then addressed in order to justify the ongoing research. The latter section states the research questions and assumption, followed by the explanation of research methods. The novelty contribution and list of publication are addressed in the following sections.

1.2 Electricity Supply Industry

This section is dedicated to provide the grounded idea of electricity power system infrastructure and Thailand electricity supply industry (ESI).

1.2.1 Overview of Electricity Power System

Electric power system infrastructure typically comprises of three main parts: generation, transmission and distribution. Each part plays different role and features with different characteristics. In short, the generation plants generate electric power at a certain voltage level, and then this power is sent through the transmission network at higher voltage level to the load center where many customers are located; after that the voltage is then reduced to medium voltage level and distributed through the primary distribution network; and it is finally further stepped down to low voltage level and brought to the customer's point of uses where the electric appliances are to be connected, via the secondary distribution network. In this viewpoint, the distribution network is thus segregated into the primary and secondary network. The general view of power system configuration is illustrated in figure 1.1 and more description is given as follows:-

Generation Plant consists of a set of generators to convert a mechanical power to an electric power. Mechanical power or prime mover is typically the force of water, steam, or hot gasses on a turbine; this force spins an electromagnet, thus generates large amounts of electrical current with a constant voltage at terminal of generating unit. It is obvious that the best geographic location of the generating plants would be close to the electrical load center where the major load demand exists. However, the locations of the primary conventional energy sources, e.g. water, gas, coal, etc, do not coincide with the population center. From the technical, economical and environmental point of view, it is rather more beneficial to build the power plants close to the energy source and then transport the electric energy to the load than centers to build the power plants close to the load center and transport the fuel from the sources [4]. The electric power is typically generated at 10,000, 12,000, or 15,000 volts.

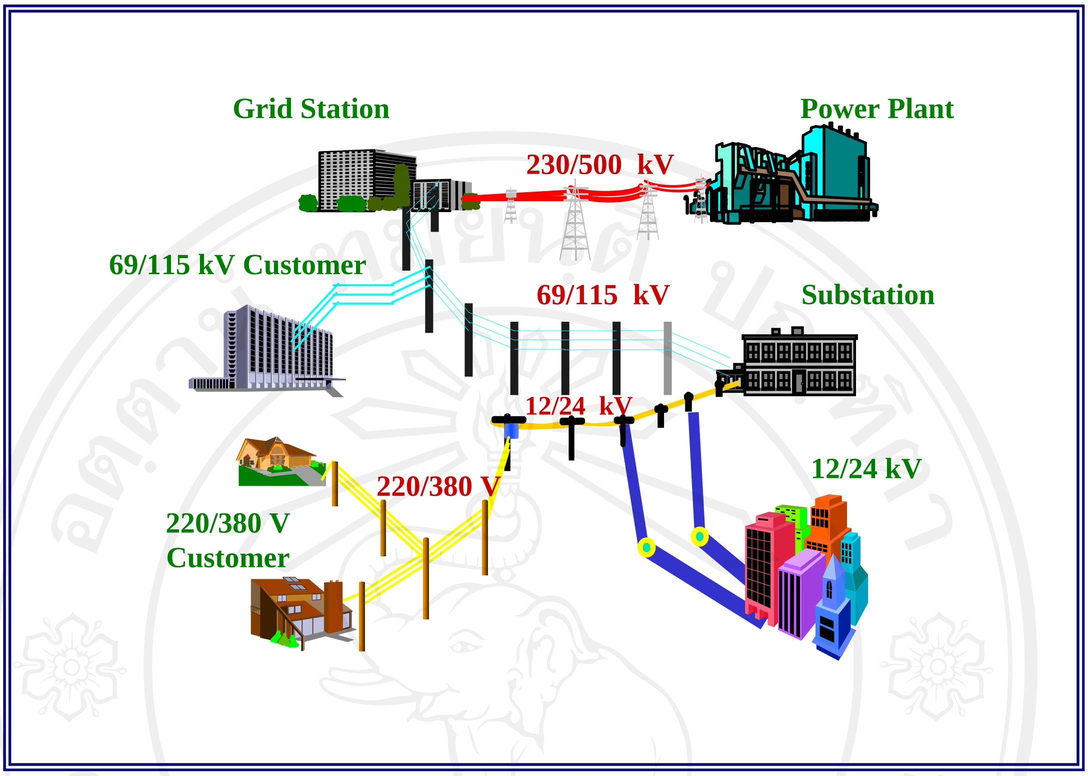

Figure 1.1 The general configuration of electric power system (MEA)

Transmission Grid is a superhighway system where a large block of electric energy is transported from generating plants which usually located far away to the load center [4]. This does not only make the close-to-resource location of generating plants feasible but also lessen the concerns of environmental impact. The current is sent at very high voltage, e.g. typically 230,000, 400,000, 500,000 or 750,000 Volts. This is for the sake of transmission capacity maximization and electrical loss minimization. Transmission grid is designed in such way that interconnects all the generator station and all major load points in the system. The energy can be routed, generally, in any desired direction on the various links of the transmission system in a way that corresponds to best overall operating economy or best serves a technical objective. In a certain geographical area, the subtransmission line is introduced to distribute energy to a number of substations. It is called subtransmission line because it operates at high voltage level but acts as distribution feeder. A large customer (industrial) is allowed to connect his loads to the subtransmission circuit.

Primary Distribution Network spreads throughout certain geographical area where the load center is situated. Distribution feeder is fed from substation power transformer; transport the power to various local distribution transformers. It carries electric currents at medium voltage level, e.g. 6,600, 12,000, 24,000, or 36,000 Volts. Feeder may be overhead or underground construction or combination of both. It is usually 10-20 km long, and with a few tens of transformers per feeder [5]. Feeders may be segregated into many feeder sections with the provision for connecting and disconnecting by various kinds of switches. A number of large (small industrial and commercial) customers are possible to connect to the distribution circuit.

Secondary Distribution Network is where every small customer being able to connect to electric power. The power that distributed through the distribution network is stepped down into the voltage levels where normal electric appliances can operate correctly and safely. The secondary distribution network or often called *low voltage network* sends electricity at normal household voltages from local distribution transformers to individual customers. The electric power supplied to customers shall be made with the voltage drop and waveform distortion falling within standard limit.

1.2.2 Electricity Supply Industry in Thailand

Previous section described the physical infrastructure of electric power system; in this section the business entities of power system will be discussed. Thailand power industry is used to describe the business entities.

Electricity supply industry (ESI) in Thailand has essentially operated in a monopolistic manner. It consists of four main activities: generation, transmission, distribution and retailing. Transmission and distribution activities are characterized by natural monopoly, thus prompting regulation. Although generation and retailing can technically be competitive business, they are operated by the state-owned monopolists [6]. The current structure of ESI in Thailand, as shown in figure 1.2, is called the enhanced single buyer model [7]. In this model, the state-owned enterprise, the Electricity Generating Authority of Thailand (EGAT), is a major power producer, a single buyer of electricity from private power producers and a natural monopolist in transmission business. With an attempt to promote competition in this industry, the government has promoted private sector participation in the generation business in the form of Small Power Producers (SPPs) and Independent Power Producers (IPPs) since 1992. Under the power purchase agreements both SPPs and IPPs are required to sell electricity to EGAT that subsequently transmits to the distributors. The distribution and retailing activities are the responsibility of other two state-owned enterprises, namely the Metropolitan Electricity Authority (MEA) and Provincial Electricity Authority (PEA), in the areas under their jurisdiction. Essentially EGAT generates and supplies electricity to the MEA and PEA for further distribution to consumers. With the current structure, the majority of consumers nationwide have to depend on the services of the three utilities: EGAT, MEA and PEA, as there is no direct competition in their activities. Although the ESI is operated in a monopolistic manner, the three utilities must comply the regulatory standards and stakeholders' requirements.

In the current structure, the distribution networks are operated under the responsibility of MEA and PEA. The MEA takes care the customers in Bangkok Metropolitan area and two adjacent provinces, whereas the PEA is responsible for the rest of the country. Market share between these two utilities, in terms of power demand, is, MEA around 35 % and PEA 65 % out of which the country's demand of around 16,000 MW. Although the nature of business is the same but the two utilities operate their network in different environment. MEA runs its network in an urbanized environment while PEA operates in mostly rural location. Although there a number of large cities to be served in PEA jurisdiction area, they are not as crowded as MEA's.

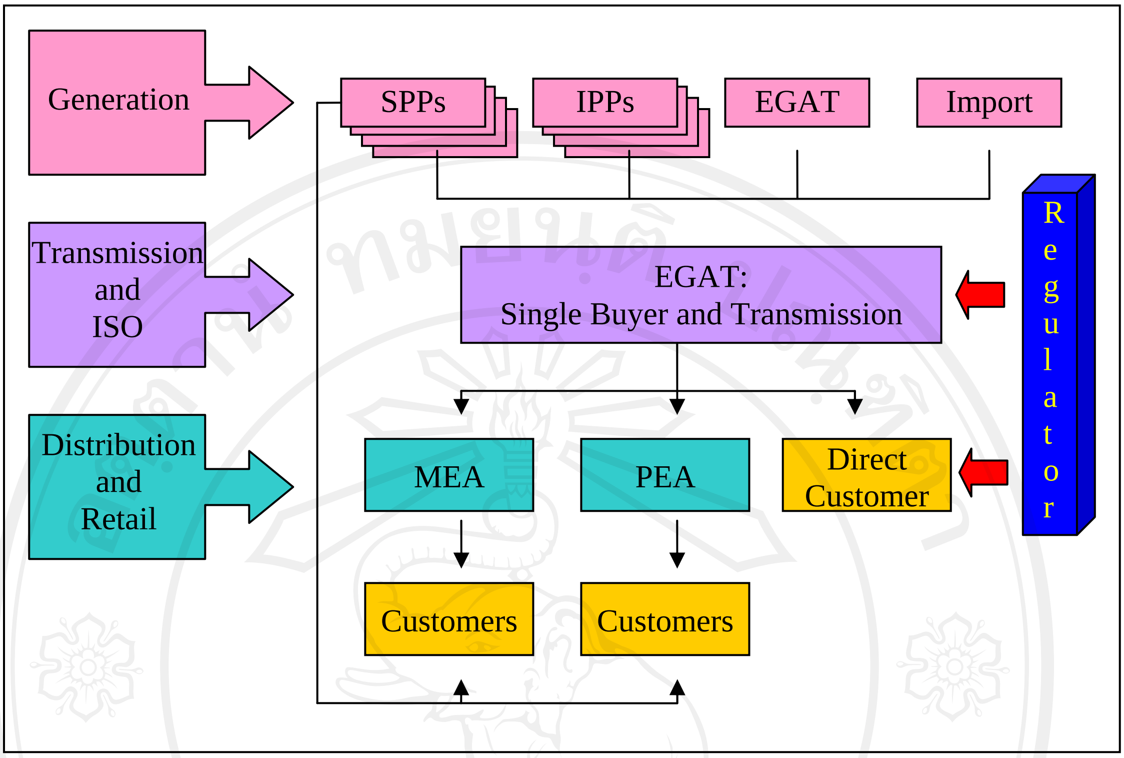

Figure 1.2 The electricity supply industry in Thailand

Although all customers in MEA area have been already electrified, they are still demanding for better performance and services. Furthermore, communities in the area also concern about safety and city beautiful landscape. This makes MEA to consider undergrounding of its distribution network. The conversion of existing overhead network into underground, however, requires diverse knowledge, experiences and expertise in order that utility staff can plan, design, construct, operate and maintain the networks. This thesis thus intends to develop the tool that can assist utility to fulfill such requirement.

1.3 Power Distribution System Performance and Research Justification

Although the power distribution system is regarded as one of the key elements that form of the entire electric power system, its role is crucial in the customer point of view when compare to the others. It acts as a mediator connecting the customers to the generated power via the bulk transmission network or to the distributed generation plants. By their nature, the generation and transmission system differ from distribution system in the way that electric power can be flexibly re-routed to main substations even though some of power stations or transmission lines may be out of service. Such flexibility may not be the case for the distribution system. As a consequence, the performance of the distribution network infrastructure poses a direct impact of customers' daily livings.

The prime concern of both utility and customers is the continuity of electricity supply. The term power system *reliability* involves with the continuity of power supply provided to end users. Reliability to consumers means that power made available to them is fault free and the outage or interruptions are tolerable and do not disturb their normal life. Distribution system interruptions are responsible for approximately 80 percent of outages experienced by customers [8, 9].This fact alone makes distribution reliability an important restructuring issue. However, if taking a closer look into distribution system reliability, it evidently depends on many factors. Followings list some major categories [1].

- *Network design (planning) reliability*- Based on the components that provide a final link between the bulk supply point and the customer's electric system. Major components include breakers, reclosers, circuits, transformers, isolators or fuses.
- *Network operational reliability*- Based on operation and maintenance (O&M) practices followed by a utility, and includes utility switching schemes that minimize the impact of an outage.
- *Environmental factors*- Includes major conditions that are beyond a utility's control; i.e., outages caused by weather conditions, storms etc. Although electric service providers strive to minimize the impact of these major events when they occur, it is obviously too costly and, as such, impractical to design a system for these rarely occurring events.

Distribution system reliability is usually indicated by two common measures: *frequency* and *duration* of power interruption. The indices commonly employed to indicate power interruption are system average interruption frequency index (SAIFI) and system average interruption duration index (SAIDI). Although there are many other indices developed for measuring reliability, but these two indices are most commonly used. SAIFI is a measure of how often an average customer loses supply during one year. A SAIFI of 3 means that the average customers connected to the feeder or supply area being measured on average lost supply three times during the past 12 months. On the other hand, SAIDI is the total of interruption duration in minutes per year per customer experienced by customers for both planned and unplanned interruptions. A SAIDI of 200 minutes means that customers connected to the feeder or supply area being measured experience in average 200 minutes off supply in 12 months.

Due to the new business environment, utilities are now striving for distribution network reliability enhancement. The methods that utilities usually employ include:

- Replacement of regular overhead lines by insulated ones or underground cables.
- Line length reduction by addition of new substations.
- Automatic network reconfiguration and sectionalizing using distribution automation system (DAS) to provide alternative supply capability.

The first and second methods reduce the total number of failures in the network whereas the third method helps to reduce the unsupplied energy caused by failures. Automatic reconfiguration and sectionalizing are the most efficient methods of reducing unsupplied energy.

From the viewpoint of system reliability alone, it has been already worth studying how to implement the stringent power distribution system. When taking into account, the public concerns in terms of public safety and landscape aesthetics it further makes the developed decision support tool for distribution network asset management worthwhile; especially the tool that can assist on overhead to underground investment decision. There are two main grounds for justifying why the distribution feeder is worth for this research; it is the system impact and the social impact.

The first lies in the prime function of distribution feeder of delivering electric power to the end consumers. The failure of distribution feeder creates direct impact, i.e. power blackout, to the customers. The distribution system occupy the largest physical area of the entire power system, they thus extremely susceptible to configuration and environmental problems. Interruption due to adverse weather condition and unexpected system events are unavoidable. In addition, most of distribution feeders are configured as radial network, unlike the transmission counterparts. When breakdown occurs, it is difficult to restore power to customers. The reliability of individual distribution feeder is the utmost important for the sake of customers' benefits.

The second reason may be viewed as a social aspect. The distribution feeders are usually located inside the area where social activities taking place. Examples include residential area, government offices, commercial complex, industrial facilities, etc. The issues such as safety, aesthetics, or health impacted by distribution network are the prime concerns to local community. The feeder construction which satisfies the community's above requirements is of the most importance.

From above reasons, the underground distribution feeder seems to be the best answer. But the cost of obtaining underground network is extremely high, so the decision on whether the distribution feeder shall be undergrounded or not needs to be made cautiously and thoroughly. The thesis is thus attempting to address the problems related to the utilization of the overhead distribution system, quantify the impacts into measurable terms (e.g. monetary value) and propose an alternative resolution options especially replacing with the underground distribution system.

In the related studies [1, 10, 11, 12, 13, 14, 15, 16, 17], although methodologies have been developed to indicate the reliability figure of different alternatives of network realization and translate it into measurable terms and bring about the most suitable implementation action; but none of them addressed the issue on investment decision of undergrounding of power distribution network. Furthermore, those studies are mainly concerned about the reliability as well as the cost to obtain such reliability, neglecting the concerns on social and environment agenda. To have an effective DSS is of paramount benefit to all stakeholders.

The motivation behind this thesis bases on year-long experiences of the author working in the distribution utility that there does not exist in the company the modeling framework to represent the human expert knowledge and in turn apply to assist their daily work. As well, the lack of a comprehensive decision support tool is another issue that makes the decision process more or less inefficiently and ineffectively. From the utility point of view, the knowledge for assessment and decision making tasks that have already existed in the organization. The domain experts use them to run their daily work. But when the assessment and decision making tasks are to be performed, they always require the human experts. It thus impedes the efficiency of the job due to, most of the times, the unavailability of experts. The utility requires a sort of tool to assist performing this job. Moreover, the expert knowledge is valuable assets to utility; not only that it promotes the efficiency of work done but also keeps the utility retain its competitive position. In the academic viewpoint, the techniques that proposed for knowledge representation, risk assessment, cost determination and multicriteria decision making, although recognized by researchers as the prominent techniques that successfully applied for solving the problems in various domains, have never been applied to assemble the comprehensive tool to support the investment decision making, especially in the area of the power distribution network asset management. The methodologies employed and the experiences gained are hence the valuable knowledge to research community.

1.4 Research Questions and Assumptions

The general aim of this thesis is propose the decision support tool that can assist utility managers in selecting the most suitable alternative option for enhancing power distribution network performance. The approach is based on assumption that the existing distribution feeder is an overhead system and the tool will then try to evaluate the system performance, translate into monetary terms, generate the network reinforcement options and evaluate such options against several criteria which taking into account technical, financial, social and environmental matters.

This leads to an attempt to answer research questions:-

- *How shall the power distribution domain knowledge be modeled?*
  This leads to an attempt to model the power distribution network asset to provide a variety of information and knowledge that required to perform the assessment and decision making task. The model shall offer expressivity, reusability, extensibility interchangeability, and integratability.
- *How can the risks of distribution network failure be efficiently assessed?*
  This leads to an attempt to capture on what information is required and how utility experts conduct a failure assessment of network components. The assessment framework to predict the possibility of failure is accordingly developed by replicating the assessment process implicitly performed by the experts.
- *How can the costs involving network failure and preventive action be quantified?*
  The thesis attempts to quantify two main cost components; that is the cost suffered by stakeholders if the distribution feeder eventually fail and the cost borne by stakeholders if such failure is to be prevented.
- *How can the social and environmental consideration be included in investment decision?*
  This leads to an introduction of the framework for multiple criteria decision analysis. Social and environment impact are very subjective and difficult to measure. The thesis seeks the way to incorporate these two

criteria into the evaluation equation in order that all the related agenda are taken into consideration.

Key assumptions made in the thesis are:

- That the conversion of overhead distribution line into underground feeder is of the prime concern.
- That risk assessment is solely based on the performance of network components, not considering any other aspects such as network configuration, or operating process (e.g. switching philosophy).
- That to allows snap shot comparison, investment cost of network reinforcement at the time of network failure is of interest and compared with the cost of failure.
- That available data are of sufficient quality to enable assessment modules to predict corresponding outputs/outcomes; and
- That the proposed DSS tries to replicate the decision making of human experts so the utility expert's judgment are assumed sufficient to validate the models.

1.5 Research Methods and Proposed Solution

The research is conducted in the following methodological sequences:-

Literature reviews

In addition to author's unremitting long-term professional interests in publications about planning, design, construction, operation and maintenance of the power distribution system, hundreds of relevant publications including technical papers, reports, studies, specification, standards, proposals, fact sheets, catalogues, brochures and books have been reviewed. The main focus is on the domain of power distribution network asset management, assessment methodologies, costing methodologies, knowledge representation and modeling techniques and multicriteria decision analysis.

Data Collection

The main sources of data reside in the distribution utility in Bangkok where the author is currently serving. Two main types of data collection are performed: document exploration and expert interview. The organization document such as specifications, standards, drawings, reports, logbooks, and website have been searched to acquire the required data necessary for development and testing of the decision support system. The field trips to experience the real distribution network sites are also arranged. In addition, the knowledge and experiences related to network asset management used day-to-day job operation are elicited from utility's experts through interviews and work observation. The data about the network assets are collected in forms of informal description of such assets and the assessment knowledge are extracted in forms of knowledge rules.

Selection of Assessment and Modeling Techniques

The objective of this thesis is to propose the decision support framework for distribution network asset management. The underlined task is to present the approaches to model the network asset and employ these modeled data for distribution network risk and cost assessment. A previous and current assessment and modeling methodologies are thus reviewed to see if they are capable of handling the intended job. The Assessment Knowledge Template of CommonKADS, Fuzzy Logic and Markov Chain are selected and investigated if they fit to problem domain of interest and are able to offer the practical solutions to the studied problems. As well, the knowledge representation and modeling techniques are also analyzed. The semantic web technology is a choice of data model. Besides, the advantages and constraints of each selected technique are also evaluated in order that the approaches for resolve will be drawn up.

Analysis of Data

The collected data are analyzed to capture the key concepts of network assets. Attributes of each concept are also extracted. These have been done in such way that the concept and its attributes shall provide information to deduce the asset condition, possibility of network failure, associated cost, and other impact caused by the real implementation of the distribution network. The methods applied for data analysis include the Keyword Search, Mind Mapping and Classification Knowledge Template of CommonKADS. Upon the set goal, the keywords that embedded in the informal description are annotated, sorted and classified. The outputs obtained are the classes, attributes and their relationships.

Proposal of Decision Support Framework

The framework for decision support system is developed in the iterative manner. This phase is started by mocking up a small decision support tool to assess the distribution network risk by entering a certain set of network data into inference engine and drawing up the possibility of network failure. The outage and resolution costs involved with the network failure are then brought into the formula to investigate the financial impacts. And the tool is finally expanded to handle the social and environment issues. The proposed framework is designed in such a way that existing ontologies, network measurement data, historical records, utility standards and practices, operational and environmental stresses, and social concerns can be utilized to form the solutions. Figure 1.3 depicts the decision support framework proposed in this thesis.

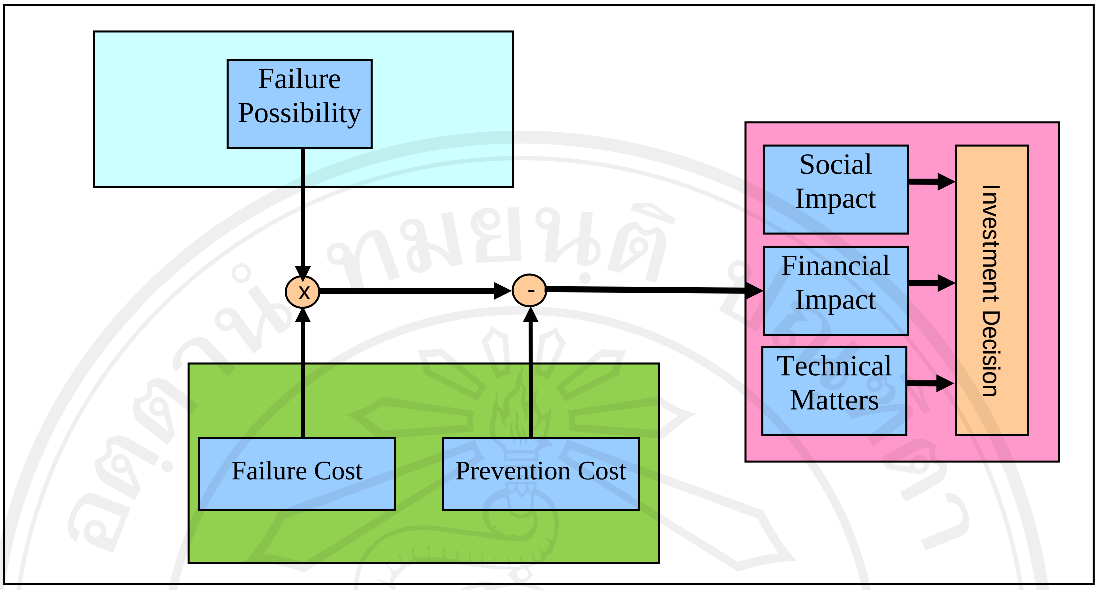

Figure 1.3 Decision support framework

Simulation and testing

The proposed decision support system is tested for proving its robustness. The test scenario was made based on the actual distribution feeder located in utility system. Apart from the mock-up test case, two practical case studies have been performed. One involves the study on failure assessment and its associated cost of overhead feeder in industrial estate area. The other involves the undergrounding of overhead feeder in world heritage site. The results obtained are then brought into the hands of utility's domain experts for evaluation and validation.

1.6 Novel Contribution of Research

The novel contribution of the research can be expressed as the followings:-

- In the knowledge representation context: the asset categorization model facilitates the syntax and semantic interchangeability. This makes it possible for the decision support system to extend its design to cover the other areas of use as well as allows the system to merge (integration) with existing systems of the same modeling framework. It also permits the reuse of existing power distribution domain ontologies.
- In the risk assessment context: the assessment process is comprehensive and rigorous since it takes all key drivers and attributes into accounts and replicate the human reasoning and decision making procedure.
- In the cost evaluation context: the evaluation process takes into consideration cost of reliability
- In the decision making context: the decision framework for distribution utility asset management permits the users to include all the key impacted factors as well as the sensitive issues into consideration in order that the investment decision can be efficiently made and poses minimal adverse impacts to

stakeholders. In addition, the framework also allows, depending on the situation where the investment decision is taking place, the users to define the weight for each criterion to be assessed.

- The decision support system offers the methods to model the distribution network assets, performing failure risk assessment, determine associated cost and comprehensively assist the investment decision making. The system is able to solve the practical problems of why, when, and how to rehabilitate existing overhead distribution feeders. Furthermore, if an undergrounding of the system is of focus; the system can bring about the most suitable undergrounding option.

1.7 List of Publications

The followings indicate the publications resulting from the research:

- A. Rajakrom, T. Chandarasupsang N. Harnpornchai, and N. Chakpitak, “Improvement of Underground Cable Installation Performance by Knowledge Management,” the Proceedings of the 16th Conference of the Electric Power Supply Industry, Mumbai, India, 2006.
- A. Rajakrom, T. Chandarasupsang N. Harnpornchai, and N. Chakpitak, “Asset Categorization for Enhanced Asset Management Using Object Oriented Approach,” the Proceedings of the 16th Conference of the Electric Power Supply Industry, Mumbai, India, 2006.
- A. Rajakrom, S. Mookdacanthong, T. Chandarasupsang N. Harnpornchai, and N. Chakpitak, “Enhance Decision Making on Underground Power System Implementation Using MCDA,” the Proceedings of the 16th Conference of the Electric Power Supply Industry, Mumbai, India, 2006.
- A. Rajakrom, T. Chandarasupsang and N. Chakpitak, “Underground Power Line Risk Assessment Using Heuristic Approach,” the Proceedings of the 1st Software, Knowledge, Information Management and Applications, Chiang Mai, Thailand, 2006.
- A. Rajakrom, “Fuzzy Risk Assessment for Distribution System Asset Management,” Presented at the Conference of Asian Energy Week 2007, Bangkok, Thailand, 2007.
- A. Rajakrom, “Fuzzy Multicriteria Approach for Power Distribution System Risk Analysis,” Presented at Energy21C: The 10th International Transmission and Distribution Conference & Exhibition, Sydney, Australia, 2007.
- A. Rajakrom, T. Chandarasupsang, N. Harnpornchai and N. Chakpitak, “Determination of Power Distribution Network Risk Using Fuzzy Markov,” the Proceedings of the 2nd Software, Knowledge, Information Management and Applications, Kathmandu, Nepal, 2008.
- A. Rajakrom, “Asset Modeling To Support Cost-Risk Evaluation In Distribution System Asset Management,” the Proceedings of the 17th Conference of the Electric Power Supply Industry, Macau SAR, China, 2008.

1.8 Thesis Organization

The thesis is organized as follows:

Chapter 2 provides an introductory review on risk and asset management as well as an introduction to the novel decision support system developed in this research. It deals with the discussion on definitions, methodologies and standard on asset management; then turns to focus on the utilization of asset management framework in power delivery business in general and the framework proposed by this thesis in particular; and finally discusses on the general concept of risk management.

Chapter 3 reviews the principle and methodologies of knowledge management and engineering. This is done by first introducing the knowledge and knowledge management; then the key methods of knowledge engineering are discussed; followed by the description of knowledge capturing approaches. The techniques for modeling knowledge especially on power distribution system are thoroughly examined and presented in the chapter.

In chapter 4, since the process of categorization, from the beginning till the end, employs numerous steps and techniques; this chapter is thus dedicated to exemplify methods in use. The chapter starts with the objectives of asset categorization, and followed by the terminological description of terms related to categorization. Then the ontology development approach is briefly touched. The languages used for information modeling are subsequently discussed. Finally, the proposed categories of power distribution network assets are focused in the last section.

Chapter 5 deals with risk assessment in power distribution network particularly the failure risk occurred on the feeder. The chapter begins with the literature review on the principle and application of fuzzy logic and Markov chain. It then examines thoroughly on the principle and propose the framework to apply fuzzy logic and Markov chain in determining risk possibility of distribution feeder failure by trying to quantify network component condition rating either at present or future stage first; then conceptualizing fuzzy linguistic variables of network property and stressors; and finally setting the knowledge rules to deduce the percentage of network failure possibility.

Chapter 6 presents the methodologies to evaluate the costs involved in the distribution feeder implementation. There are two major cost components discussed in the chapter: outage cost generated from the feeder failure and resolution cost to prevent the occurrence of feeder failure. The total financial impact which is the cost-benefit evaluation of rehabilitation project candidates is also discussed in the chapter.

Chapter 7 integrates the frameworks presented in chapter 4, 5 and 6 to form the novel decision support system. The principle of multiple criteria decision analysis is reviewed in the chapter. The mock-up case is simulated to test the robustness of the system. The simulation is done step by step to illustrate the flow of information.

Chapter 8 provides the case studies to show the applicability of the novel decision support system on the real system as well as the discussion and analysis on its performance.

Chapter 9 gives the conclusion and future work respectively.