ANALYTIC HIERARCHY PROCESS & TOPSIS METHOD TO EVALUATE LOAD SHEDDING ANALYSIS IN RANAU POWER STATION

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ABSTRACT

Load shedding is a type of protection to prevent total blackout for electrical power system. It is the best method available to counter power imbalance between generator and load demand. There are many load shedding schemes implemented by industries in tackling this problem such as manual load shedding, under frequency load shedding and under voltage load shedding. This paper discuss one of that implementation through AHP and TOPSIS approach as an analysis tool in giving out an additional information for the operator to determine which load should be shed first. AHP and TOPSIS are part of Multi Criteria Decision Making (MCDM) in solving complex decision marking based on alternatives and criteria given. Therefore in this study, the analysis outcome in interest is to remove loads by ranking them according to their priority. By earning the first rank means that the priority is less as the load shedding module aim is to ensure power continuity to only vital and most critical loads in the system. With the result obtain from this analysis it can be used by the operator with an assumption that the efficiency of load shedding scheme can greatly increase.

ABSTRAK

Pembuangan beban adalah satu kaedah perlindungan untuk mengelakkan pemutusan bekalan kuasa secara sepenuhnya bagi sistem kuasa elektrik. Ia adalah kaedah terbaik dalam mengimbangi kuasa penjana dan keperluan beban. Terdapat pelbagai cara yang dilaksanakan oleh industri dalam menangani masalah ini seperti pembuangan beban secara manual, pembuangan beban berdasarkan frekuensi, dan pembuangan beban berdasarkan voltan. Kertas ini membincangkan salah satu pelaksanaan tersebut melalui pendekatan AHP dan TOPSIS sebagai alat analisis dalam memberikan maklumat tambahan kepada pengendali untuk menentukan beban yang mana perlu dibuang dahulu. AHP dan TOPSIS adalah sebahagian dari kaedah (MCDM) dalam menyelesaikan masalah kompleks berdasarkan kriteria dan alternatif yang diberikan. Oleh itu dalam kertas kajian ini hasil keluaran yang ingin dicapai adalah dengan membuang beban mengikut keutamaan. Beban yang berada pada kedudukan teratas bermaksud keutamaan semakin kurang dan seharusnya menjadi beban yang pertama untuk dibuang. Ini kerana pembuangan beban adalah bertujuan untuk memastikan kesinambungan kuasa hanya kepada beban yang penting sahaja. Berdasarkan keputusan yang didapati dari analisis ini, pengendali boleh mengguna pakai dalam menjalankan kerja seharian dan diharapkan kecekapan system pembuangan beban akan meningkat.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
MCDM	-	Multi Criteria Decision Making
MADM	-	Multi Attribute Decision Making
PIS	-	Positive Ideal Solution
NIS	-	Negative Ideal Solution
CI	-	Consistency Index
CR	-	Consistency Ratio
RI	-	Random Index
MW	-	Mega Watt
SESB	-	Sabah Electricity Sdn Bhd
UTHM	-	Universiti Tun Hussien Onn Malaysia

CHAPTER 1

INTRODUCTION

1.1 Project background

Load shedding is defined as an amount of load that must almost instantly be removed from a power system to keep the remaining portion of the system operational [1]. This load removal is in response to the system that was disturbed which causes a generation deficiency condition and if not properly executed can leads to a total system collapse. Common disturbances that can cause this action to occur include major generation outages or important power transmission line outages, faults, switching errors, lightning strikes, etc [1-2].

Thereupon, by removing a substances amount of load can ensure the remaining portion of the system operational. That remaining portion should be only the vital and most critical loads in the system. And the substances amount of load in discussed to be shed or switched off should be from any non-vital loads available in the same disturbed system [3]. By switching off that selected load, the balance between the power generated and load demand could be brought back. Hence, the skill to properly differentiate what load to be shed first and so forth is important in achieving an ideal load shedding module. The process of differentiating can be done by ranking them in hierarchy.

Therefore in this study, the analysis outcome in interest is to remove loads by ranking them according to their priority. By earning the first rank means that the priority is less as the load shedding module aims is to ensure power continuity to only vital and most critical loads in the system. The module begins with non-vital loads shedding and follows by semi-vital loads removal. The vital loads can only be removed if the system is disturbed by large disturbances such as major generation outages.

Foremost, the analysis is begins by setting a goal and identifies the criteria. These two will frame out the shedding process. And to aid or to simplify the selecting process comprising multiple criteria condition can be chosen from the variety multi-attribute or multi-criteria decision making (MADM/MCDM) technique. Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are two best known and most widely applied techniques MADM/MCDM problems in the real world [4-5]. They have been known to solve problems in areas such as engineering, government, industry, management, manufacturing, personal, political, social and sports [6].

In this study, the AHP is used to obtain the criteria weight while the TOPSIS method is used to rank the selected load into series of sequences. AHP technique acts as a decision maker systematically evaluating several data or elements by comparing one and another at the same time. Then the TOPSIS acts as an agent searching for the best set of load to be shed in recovering the shortage of the electrical power availability. Details of the complete analysis can be read in **Chapter 3 – Methodology**.

1.2 Problem Statement

Problem statement or motivation can be understood as a presentation of the study's argument of selecting such research. As mention before, the interest outcome of this study is to rank the load in hierarchy according to their priority. This is as to assist or illustrated the flow of one load shedding. Load shedding can be initiated whenever a stability of a power system is affected by any disturbances. It can be shed through control theory and manual load shedding operation.

Control theory is defined as the methods and principles to control different systems, processes and objects using system analysis. And for the system to analyse effectively, it requires information about the state of the system. The more information about the system is available, the more accurate and efficient operation will be committed [7]. For example, under frequency relay scheme and programmable logic controller-based load shedding (PLC) are two kinds of control theory approach of shedding load. They rely solely on the data from the frequency measuring systems. These kinds of load shedding principles cannot be programmed with the knowledge gained by the power system engineers. They have to perform numerous system studies that include all of the conceivable system operating conditions and configurations as to correctly design the power system load shedding [1]. Because of numerous variables involved, it is usually difficult, if not impossible to obtain precise frequency characteristic. This unavailability of information for future changes and enhancement of the system will significantly reduce the protection system performance.

Meanwhile, manual load shedding operation relies on the system operator. He will select a contingency in which the system is affected. The shedding will be carried out after the operator confirms the execution. The arrangement of shedding which load is made based upon a hierarchy load shedding module [3]. This kind of shedding is suitable for equipment overloading like generators, grid transformer of a reactor and 33kV bus under frequency. And it is known as slow load shedding and the algorithm is framed on a symptom-based approach.

Even though the first example is known as the primary load shedding which is framed on generation deficit and the shedding command is generated through fast actuating relays, but it does not means it is more reliable. For any reliable load shedding, ensuring of data validity is a must. The data is in terms digital and analog inputs come through a field interface which is validated before using in a program [3].

Thus in assisting the shedding to be more effective either to the control theory approach or to the manual load shedding operation, it is best to develop a reliable load shedding module by illustrating the respective loads in hierarchy form. The top load in the hierarchy conveys the meaning of less priority load therefore should be removed first and immediately. In contrast to the bottom of the hierarchy is by far the most important and vital load. The removal of the final load should only be made if the power system is still in jeopardy, as the system main concern is to ensure the continuity of power to that group of load.

In short, the primary purpose of this study is to illustrate a flow or in other words, to form a hierarchy structure of load shedding priority in providing an adequate tool for decision support to the operator calls. And likely, the results of this study may also help in improving load shedding execution so that the areas of weakness or lack of knowledge could be exposed to those who are responsible for shaping and creating a better protection for power system.

1.3 Project Objectives

Structured objectives were developed with an aim of illustrating an ideal scheme of shedding loads upon disturbances effects on any power system. The objectives are:

a) To implement AHP and TOPSIS the multi criteria decision making methods in the load shedding scheme
b) To evaluate AHP and TOPSIS performances by performing a case study in Ranau Power System
c) To illustrate a load shedding flow for Ranau Power System

1.4 Project Scopes

The system study was carried out using the DIGSILENT and Microsoft Excel software application. The following salient points are taken into consideration:

a) The system study is carried out to rank load priority for load shedding scheme as one of the defense scheme/protection system for Ranau Power Station.
b) Due to the limited availability of the latest substation load data and load priority from Kawasan Ranau, only a portion of data from year 2011 and 2012 was used.
c) For this analysis, only power generated and load demand were taken into consideration.
d) The type of disturbance considered in this analysis was large contingency such as major generator outages or important power transmission line outages.

1.5 Thesis outline

The written report was layout as follows:

1. Chapter 1 – Introduction

It briefly discussed on the importance of shedding a portion of load after a power system was hit by any major contingency and how Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) can come in handy in offering a guideline for an operator in charge. It led to a motivation of a research in terms of studying the AHP and TOPSIS and their relationship with the load shedding scheme. The summary of the research was reviewed with its objectives and limitations were clearly listed.

2. Chapter 2 – Literature Review

This chapter reviewed on past researches which have significant link to this study. The associate researches' literature were broke down to AHP and TOPSIS brief discussion, Load Shedding in Malaysia (in particular) and a lengthy discussion concerning the past methodology in load shedding execution before ending it with the AHP and TOPSIS approach in a multi criteria situation. It was structured in a way for easier cross reference in the future.

3. Chapter 3 – Methodology

Chapter 3 touched on the methodology of AHP and TOPSIS solutions derivations in achieving the ultimate objective of this study which was the load shedding priority ranking. The methodology was done accordingly to the AHP technique as to achieve the load in interest their weighted average rating for each decision alternative before calculating the loads' relative closeness to ideal reference point through TOPSIS reference. These solutions were the key in determine the loads' rank in a form of bottom-up hierarchy and in a way guide the operator in charge to perform a load shedding execution.

4. **Chapter 4 – Results**

The findings of this study were presented under the Results section of Chapter 4. This chapter not only showed the graphs and data tables, but brief comments were also given upon the statistical analysis. And on enhancing the results, they were neatly organized under the cases that they were experimented.

5. **Chapter 5 – Conclusion**

Chapter 5 provided the conclusion of this study by restating back the important findings and how beneficial they will be in shaping and creating a better protection for the power network system during major contingencies. It also brought up few potential further works that can be done in improving the research area.

1.6 Summary

The objective of this chapter is to give the readers an understanding of why one should bother much about when a power system was hit by major contingencies such as major generation outages, important power transmission line outages, faults, switching errors or lightning strikes and the importance of shedding a portion of load during that particular time. It also points out the motivation behind the study, giving out its objectives and scope of work before laying out the thesis outline.

CHAPTER 2

LITERATURE REVIEW

2.1 What are AHP and TOPSIS?

In the task of making management decisions and prognoses of possible results, analyst usually has to deal with complex system of interdependent criteria (resources, required results or goals) that has to be analysed. There are a variety of multiple criteria techniques to aid selection in conditions of multiple criteria. Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) are two best known and most widely applied techniques multi-attribute or multi-criteria decision making (MADM/MCDM) problems in the real world [4],[5].

For example, Les Frair et al used the AHP in assisting a development of a new curriculum design [8]. This new curriculum should satisfy the ABET 2000 criteria, University core curriculum requirement and also the appropriate subjects to be offered. The new curriculums involved were Industrial Engineering (IE) Manufacturing Alternative, IE Engineering Management Alternative and IE General Alternative. The decision they were seeking was a curriculum alternative recognized as excellent by all affected parties (students, faculty, alumni, ABET, university, employers and IE Community).

In addition, AHP also helped in analysing a future energy supply infrastructure for a suburb with approximately 2000 households and possible additional industrial demand as studied by Espen Loken et al [9]. The planning involved with five criteria – minimizing investment, minimizing operating cost, minimizing CO2 emission, minimizing NOx emission and minimizing heat dump from CHP plants to the environment. It also has to be analysed from an investment point of view which were – do they have to reinforce the electricity grid with a new supply line or do they have to build a new CHP plant, and the new location for the newly build plant should be either near an industrial site or nearby residential area.

Moreover, AHP analysis not only managed to assist in general field such as management and industry but also succeeded in quantifying power quality level at many loading points with different operating conditions which is in engineering field [10]. This factor was researched by S. A. Farghal et al aiming in identifying whether total harmonic distortion, frequency of under voltage events and load stiffness affected the performance of electric power quality during a steady operation, occasional events and load-related power quality determinant factor (PQDF) modules.

Likewise TOPSIS had successfully helps in deciding manufacturing applications such as selecting a manufacturing process or robotic processes. Process attributes with direct cost implication are not always explicitly identified and their indirect cost and benefits are generally not well quantified. Thus, O.L. Chan and Celik Parkan used TOPSIS in determined the preference ranking with respect to operational benefits [11]. Not only that, TOPSIS also makes way into corporate and financial areas. It has been used in comparing company performances and financial ratio performance within a specific industry [11]. C. M. Feng and R.T. Wang applied the TOPSIS in evaluating the procedure performance for highway buses with the financial ratio consideration affecting the production, marketing, execution efficiency. Pinporn Maikaew and Patcharaporn Yanpirat also made the same approach by means of applying the TOPSIS in a financial market in Thailand such as stock investments taking into account the corporate financial and nonfinancial performances of the firms considered under uncertain environments.

AHP was introduced by Saaty which helps in determining the priority of any criteria has on the overall goal of the problem in interest. The determination was made through a hierarchical decomposition model of the problem. At the top of the hierarchy is the overall goal or prime objective one is seeking to fulfil, while the succeeding lower levels represent the progressive decomposition of the problem [8].

The next steps: matrix of pairwise comparisons constructing, vector of priority calculating, consistency ratio evaluating, alternative perceptibility analysis [12]. An AHP hierarchy has at least three level:

a) **Level-1:** The main objective or goal of the problem at the top.
b) **Level-2:** Multiple criteria that define alternatives in the middle.
c) **Level-3:** Competing alternatives at the bottom.

On the other hand, TOPSIS introduced by Hwang and Yoon determined the priority of any criteria based on the shortest distance from the (positive) ideal solution (PIS) and the farthest from the negative ideal solution (NIS) [11]. The principle behind TOPSIS is simple: The chosen alternative should be as close to the ideal solution as possible and as far from the negative-ideal solution as possible. The ideal solution is formed as a composite of the best performance values exhibited (in the decision matrix) by any alternative for each attribute. The negative-ideal solution is the composite of the worst performance values. Proximity to each of these performance poles is measured in the Euclidean sense (e.g., square root of the sum of the squared distances along each axis in the attribute space), with optional weighting of each attribute.

As the variety of AHP and TOPSIS application extended into engineering field, an approach in utilising both techniques in offering an alternative to load shedding method is introduced.

2.2 Load shedding events in Malaysia

Load shedding as previously defined in Chapter 1 is said to be an amount of load that must almost instantly be removed from a power system to keep the remaining portion of the system operational [1]. This protection action is in response to the system that was disturbed by either major generation outages or important power transmission line outages, faults, switching errors or lightning strikes which causes a generation deficiency condition and if not properly executed can lead to a total system collapse [1-2].

Thereupon, through tremendous studies it has been proven that by removing a substances amount of load can ensure a portion of the system operational. That remaining portion should be only the vital and most critical loads in the system. And the supposed loads that were shed or switched off should be from any non-vital loads available in the same disturbed system [3]. This fast mitigation helps in bringing back the balance between the power generated and load demand.

With that intention in interest, load shedding has been practiced by electric utility company around the world as early as ones could remember. It is known as the last-resort measure used by an electric utility company in avoiding a total blackout of the power system. Load shedding is common or even a normal daily event in many developing countries where electricity generation capacity is underfunded or infrastructure is poorly managed. On the other hand, in developed countries this kind of measure is rare because demand is accurately forecasted, adequate infrastructure investment is scheduled and networks are well managed; such events are considered an unacceptable failure of planning and can cause significant political damage to responsible governments.

Malaysia is one of the developing countries and is not exempted from this practice. As shown in Figure 2.1, by practicing the load shedding the numbers of tripping events in Peninsular Malaysia were much less compared to the tripping taken by non-load shedding action. The average is null to 5.6 in 2007-2009 alone.

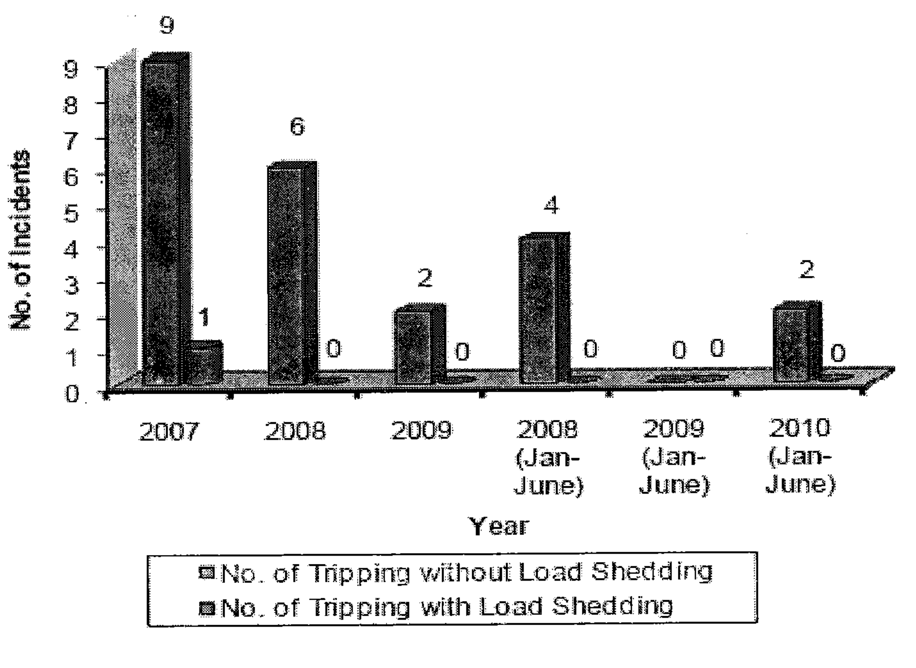

Figure 2.1: Number of Transmission System Tripping in Peninsular Malaysia with a Load Loss of 50MW and above for first half year of 2008 – 2010 and in the year 2007-2009 [13]

Table 2.1: Statistics of transmission system tripping with a load loss of 50MW and above for the first half year of 2010 [13]

Perkara / *Indicators*	Jan	Feb	Mar	Apr	May	June
Bilangan Pelantikan *No. of Tripping without Load Shedding*	0	1	0	0	0	1
Bilangan Lucutan Beban *No. of Tripping with Load Shedding*	0	0	0	0	0	0
Kehilangan Beban Maksimum (MW) *Maximum Load Loss (MW)*		56				61.5
Tenaga Yang Tidak Dibekalkan Semasa Pelantikan (MWj) *Unsupplied Energy due to Tripping (MWh)*		112.1				57.3
Purata Tenaga Tidak Dibekalkan Setiap Pelantikan (MWj) *Average Unsupplied Energy per Trip (MWh)*		112.1				57.3
Purata Tempoh Setiap Pelantikan (Jam:Minit) *Average Duration per Trip (Hour)*		2:00				0:56
Tenaga Tidak Dibekalkan Semasa Lucutan Beban (MWj) *Unsupplied Energy During Load Shedding (MWh)*	0	0	0	0	0	0

By referring to Table 2.1, in the first half of 2010 Peninsular Malaysia experienced tripping events only twice without load shedding action compared to none when with load shedding. A 56MW and 61.5MW loads were shed in February and June, respectively which caused a discontinuity of 112.1 MW/h and 57.3 MW/h supplied energy to the customers as seen in Table 2.1. The causes were numerous; with process and quality of works hold the majority of 56.7% in contrast to the least cause natural disaster with only 0.1% (refer to Figure 2.2). But still, they only caused two tripping events in the first six months of 2010.

On the other part of the sea, in Sabah the unscheduled interruptions which include load shedding events for the same period of time were 9203 incidents, a 4% increment from the previous year. This data can be referred to Figure 2.3 and in Figure 2.4 shows the causes of those events. The installations/faults were the main contributor to the interruptions holding 37.2% and surprisingly the second most contributors were trees with 15.9%.

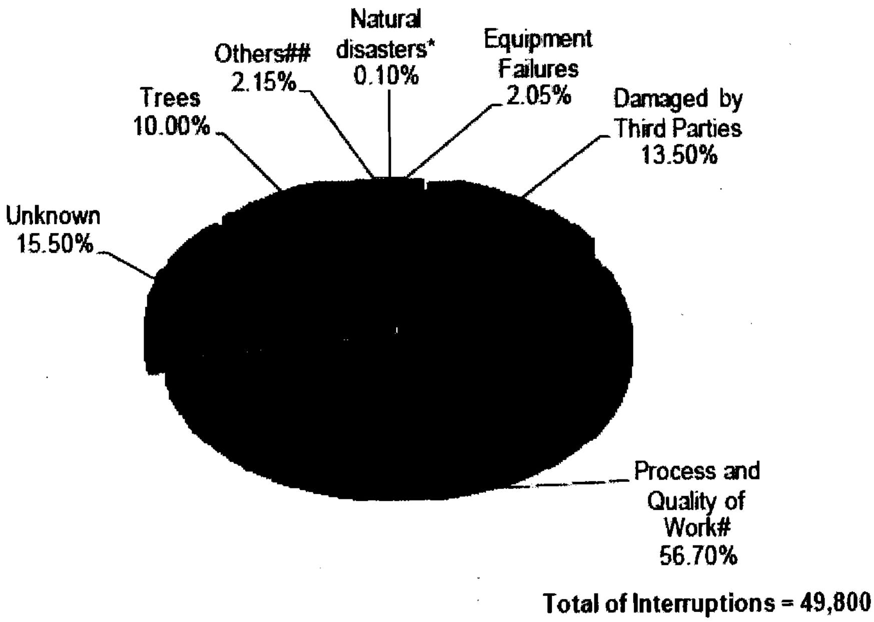

Figure 2.2: Causes of unscheduled electricity supply interruptions in Peninsular Malaysia [13]

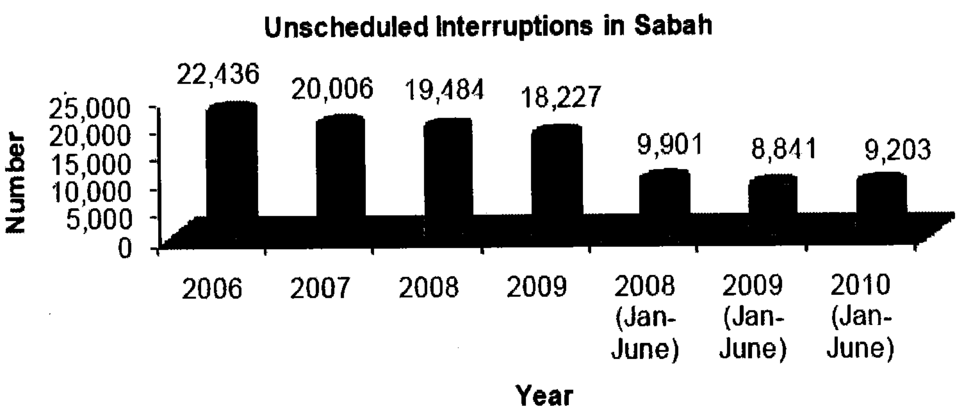

Figure 2.3: Numbers of electricity supply interruptions in Sabah for first half year of 2008-2010 and in the year of 2006 – 2009 [13]

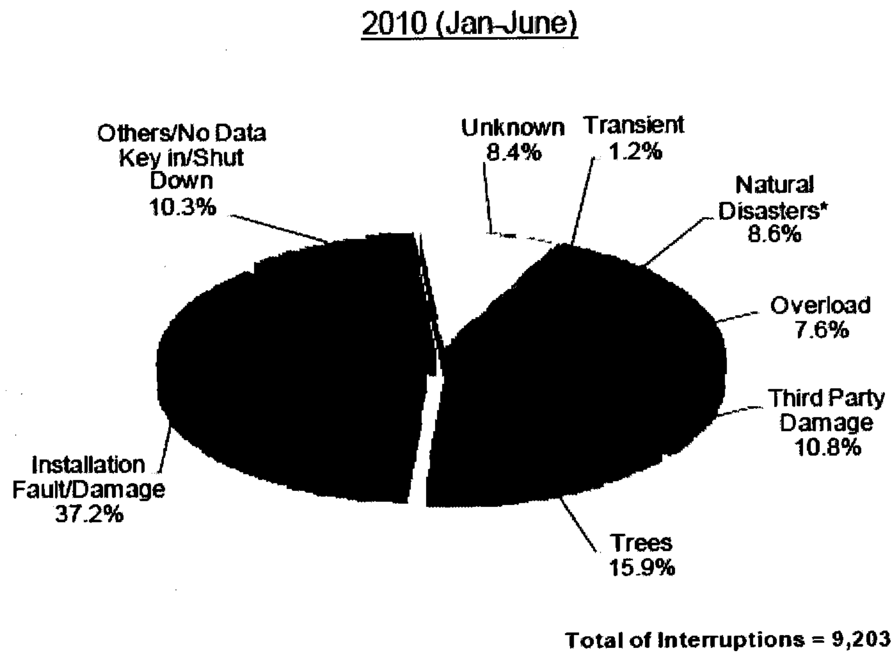

Figure 2.4: Causes of Unscheduled Electricity Supply Interruptions in Sabah [13]

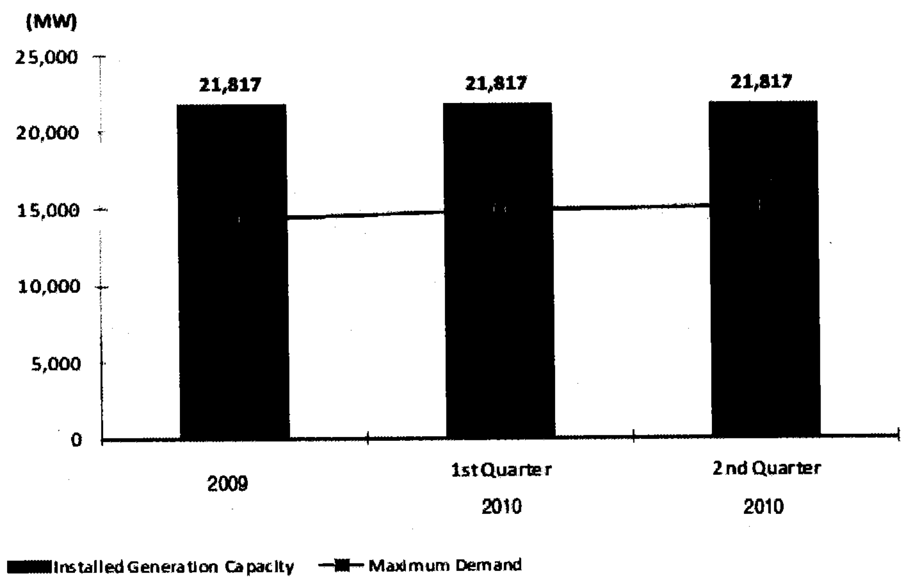

Figure 2.5: Maximum demand and installed generation capacity in Peninsular Malaysia for the first half year of 2010 [13]

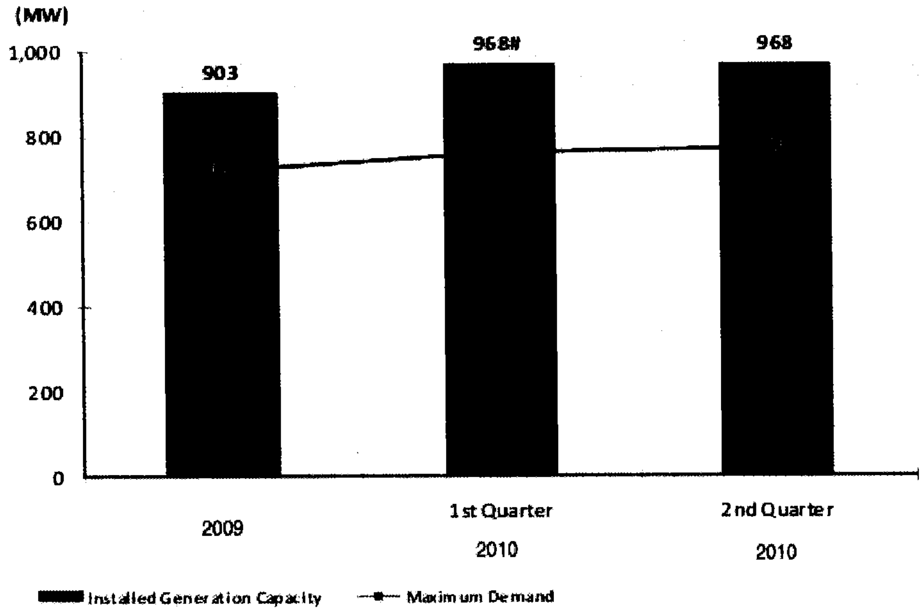

Figure 2.6: Maximum demand and installed generation capacity in Sabah for the first half year of 2010 [13]

Thus, by analyzing the data from Figure 2.5 and Figure 2.6 one can clearly comes to a conclusion that customers demand continues to grow with each year despite the unscheduled interuptions event. Therefore, it is the duty of Tenaga Nasional Berhad (TNB) and Sabah Electricity Sdn Bhd (SESB) to ensure the continuity in load feeding as the progress of the industrial and technological relies in the reliability and credibility of such companies. Any contingency that could bring catastrophic impact to the power system either to Peninsular Malaysia power network or to Sabah power network has to be prudently mitigated. There are many ways for the companies to mitigated the problem and among them is the famed load shedding. By far load shedding is a last-resort measure taken by the company if and only if prior precaution steps fail to balance back the supply (power generated) and demand (loads/customers). Load shedding can be implemented by many ways, which will be explained next.

2.3 Previous Methods

The security of power supply relies heavily on the reliability of the electric utility company in continuing feeding electricity to the end user even if the system was hit by the most catastrophic events. Major contingencies such as generation outages or important power transmission line outages are two of the most contingencies an electric utility company should look out for. They should be tackled wisely. These two contingencies if are not tackled properly can bring down a power system; in other words a total black out. And load shedding is known to be the most suitable mitigation method for these two events.

Load shedding has been practiced by many and through various techniques and approach. The simplest method is the breaker interlock scheme [1]. Signals are automatically sent to load breakers to open when a generator breaker or a grid connection is lost for any reason. It acts very fast since there is no processing required and decisions about the amount of load to be shed were made long before the fault occurred.

In addition, the more common method is through under frequency relay scheme [1]. This scheme does not detect disturbances as the former method, but it reacts to the disturbances. It detects either a rapid change in frequency or gradual frequency deterioration and initiate staged operation of interlocked breakers. For example, a sudden loss of generation capacity on a frequency will be accompanied by a decrease in system frequency. The characteristic of that decrement will be selected as the settings frequency limit for the relays and is sets in few stages. If certain limit is reached as the system frequency goes down, the relay trips a sizeable load. And when the first stage is reached, the relay waits a predetermined amount of time as to avoid nuisance tripping before trips one or more load breakers. The shedding is staged accordingly to the rate-of-change-of frequency.

Through recent year, the evolution of load shedding method and approach has become better and more sophisticated. For example, the use of Programmable Logic Controllers (PLCs) for automatic sequencing of load has become an important part of substation automation [1]. They were used in industrial load management and curtailment scheme in early 1980s but it was not until power management systems were combined with microprocessor based PLCs that can distributed a fast load shedding systems became reality. In spite of that, the PLCs and under frequency relays share a common ground. Their load shedding scheme is initiated based on the system frequency deviation [1]. The scheme requires a pre-programmed circuit breaker in shedding a pre-set sequence of loads. Similar to under frequency relays, the sequence is executed in staged manner. The sequence is continued until the frequency returns to a normal condition.

The evolution of this scheme does not stop here. Recently, the electric power networks have become more and more automated, interconnected and computerized [14]. While interconnection and advanced technologies lead to greater efficiency and reliability, they also bring new sources of vulnerability through the increasing complexity. For example, executing the PLCs load shedding scheme is limited to the sections of the system that are connected to the data acquisition system [1]. Furthermore in Japan, Chubu Electric Power Co. (CEPCO) also depends on telecommunication network and performs stability calculations using on-line network model based on the collected data [15]. The effectiveness of the on-line network depends heavily on the information gathered to determine precisely the amount of generator shedding. Also in PT Newmont Batu Hijau, a mining plant in Indonesia a so-called Intelligent Load Shedding (ILS) server is installed in the power plant control room [1]. This server which served as a processor and calculator for the network data acquisition, circuit breaker status and other pertinent information in determine the optimum load shedding.

Other approaches such as Smart Load Shedding System [7] and Comprehensive Load Shedding System [3] also utilize the information technology in improving the operation and functionality of the existing system. For example, in Smart Load Shedding System each district is equipped with interactive measuring device, a device which receives information about active power consumption and generation as well as load shedding and restoration control [7]. And while in the Comprehensive Load Shedding System, the network selected to be tested has a supervisory control and data acquisition system (SCADA) and network management system. These communication systems monitor the system network status on an online basis [3]. Henceforth, the evolutionarily of load shedding will continues to evolved around the ever-increasing complexity and sophisticated interconnected and advanced technologies power network.

But still, even with the high-tech and edge technologies an electric utility power company should always have a backup system just in case if the technologies failed on them. Thus, the designed backup systems cannot follow the technological evolution of the load shedding scheme. This system should adopt a conventional control to be unique in switching off the selected loads. This can be executed by the help of an operator. The operator will shed the load by defining its priority up. The priority to be shed is calculated based on the accumulated load table of the selected contingency [3].

There are a few examples researchers have done concerning this matter. ARGOS, a computer program has been developed and uses a bottom-up approach in simulating both single family and large-area daily load profiles, starting from the electric energy end uses [16]. In addition, a 0-1 Knapsack Problem method also uses the priority up approach by developing a systematic procedure that can be followed by setting priority coefficients for utility maximization in feeding loads during times when the available power is limited [16]. The latter method has been widely used in wide application field for such as logistics, finance for investment mix, medicine for the control of the skin, for the elaboration of the DNA self-assembly model, neural networks and electrical power systems [16]. This methodology was chosen foremost because it does not use statistical considerations and is to arrive at a mathematical formulation that could be effectively be implemented in a control-system software.

By far, 0-1 Knapsack Problem is not the only mathematical technique that can be employed in producing a priority up output. The ever famed method is the AHP and TOPSIS. These two also have been known to be used in areas such as engineering, government, industry, management, manufacturing, personal, political, social and sports [6]. And until recently, AHP usages have been extended into load shedding. If 0-1 Knapsack Problem sees the load shedding as an optimization problem [16[, AHP and TOPSIS see the load shedding as a multi criteria decision making problem [4],[5].

Load shedding is not a one criterion problem. In executing an ideal load shedding, more than one criterion has to be considered. For example, total generation, total load to shed for each triggering event, generation capacity, total spin reserve, minimum load to be shed for each triggering event and optimal combination of circuit breakers [1]. Not only that, load shedding module also has to takes into consideration the types of faults or contingencies that have impacted or causes disturbances to the system [2]. Thus, in offering a guide for an operator in executing a load shedding module outside from the primary execution, the AHP and TOPSIS are the most suitable techniques as they can take in multiple criteria in assisting the operator to make a prompt and right decision.

For example, in a shipboard power system load shedding, AHP is used as load priority selection [17]. It was used as to calculate the weight factor of each system criterion and its effectiveness. On the other hand, in an electrical power system load shedding scheme; AHP was used to value the importance between frequency, voltage and stability [17]. And yet, the usage of AHP in load shedding scheme has not been fully utilised by many. The lack of such information represents a gap in this study. Therefore, it became the interest of this study, to research more on these two techniques in performing a load shedding module. And likely, the results of this study may also help in improving load shedding steps so that the areas of weakness or lack of knowledge could be exposed to those who are responsible for shaping and creating a better protection for power system.

2.4 AHP and TOPSIS techniques in a multiple criteria situation

AHP, as repeatedly said throughout this study is a method in ranking decision alternatives for a decision maker who has multiple criteria to ponder upon [18]. In helping the decision maker to decide, the preferences among alternatives are determined by making pairwise comparisons. By pairwise comparison, he will examine two alternatives by considering one criterion and indicates a preference.

These comparisons are made using a preference scale; assigning numerical values to different levels of preference. The standard preferred scale is 1 to 9 scales which lies between equal preferred to extreme preferred; but sometimes evaluation scales of 1 to 5 is also preferred [18 -19] as shown in Table 2.2.

Table 2.2: The fundamental scale of absolute numbers [18-19]

Intensity of importance	Definition	Explanation
1	Equal preferred	Two activities contribute equally to the objective
2	Equally to moderately preferred	
3	Moderately preferred	Experience and judgment slightly favour one activity over another
4	Moderately to strongly preferred	
5	Strongly preferred	Experience and judgment strongly favour one activity over another
6	Strongly to very strongly preferred	
7	Very strongly preferred	An activity is favoured very strongly over another; its dominance demonstrated in practice
8	Very to extremely strongly preferred	
9	Extremely preferred	The evidence favouring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If activity *i* has one of the above nonzero numbers assigned to it when compared with activity *j*, then *j* has the reciprocal value when compared with i	A reasonable assumption

These comparisons are later mapped out in a form of a matrix. In a pairwise comparison matrix, a value 9 indicates that one alternative is extremely more important than the other, while a value 1 indicates equal importance and on the other hand a value 1/9 indicates that one alternative is extremely less important compared to the other. Therefore, if the importance of one alternative with respect to the second alternative is given, then the importance of the second alternative with respect to the first is the reciprocal. And in selecting the best preference among all preferences, these pairwise comparisons are structured in a form of a simple hierarchy.

AHP comes in at this stage helping to evaluate a large number of quantitative and qualitative factors in a systematic manner and it usually involves four major steps [18].

a) The complex problem is break down into a number of small constituent elements and structured them in a hierarchical form, with the goal at the top of the hierarchy, criteria and sub-criteria at levels and sub-levels of the hierarchy, and decision alternatives at the bottom of the hierarchy as shown in Figure 2.7.

b) A series of pairwise comparisons is made between the elements according to a ratio scale.

c) An eigenvalue method is used to estimate the relative weights of the elements.

d) And lastly, the relative weights are aggregated and synthesised for the final measurement of given decision alternatives

Through the formation of the matrix, the comparison of each alternative is a lot easier. Alternatives at a given hierarchy levels are compared in pairs; assessing their relative preference to each of the alternative at the next higher level respectively. The matrix is then being computed and aggregated their eigenvectors until the composite final vector of weight coefficients for alternatives are obtained. The entries of the final weight coefficient vector reflect the relative importance of each alternative to the goal stated at the top of the hierarchy [18]. The decision maker may use this vector according to his particular needs and interests.

In eliciting the performance of the pairwise comparisons at a given level, matrix A is created in turn by putting the result of pairwise comparisons of element i with element j into the position a_{ji} as given in Equation (2.1) [18].

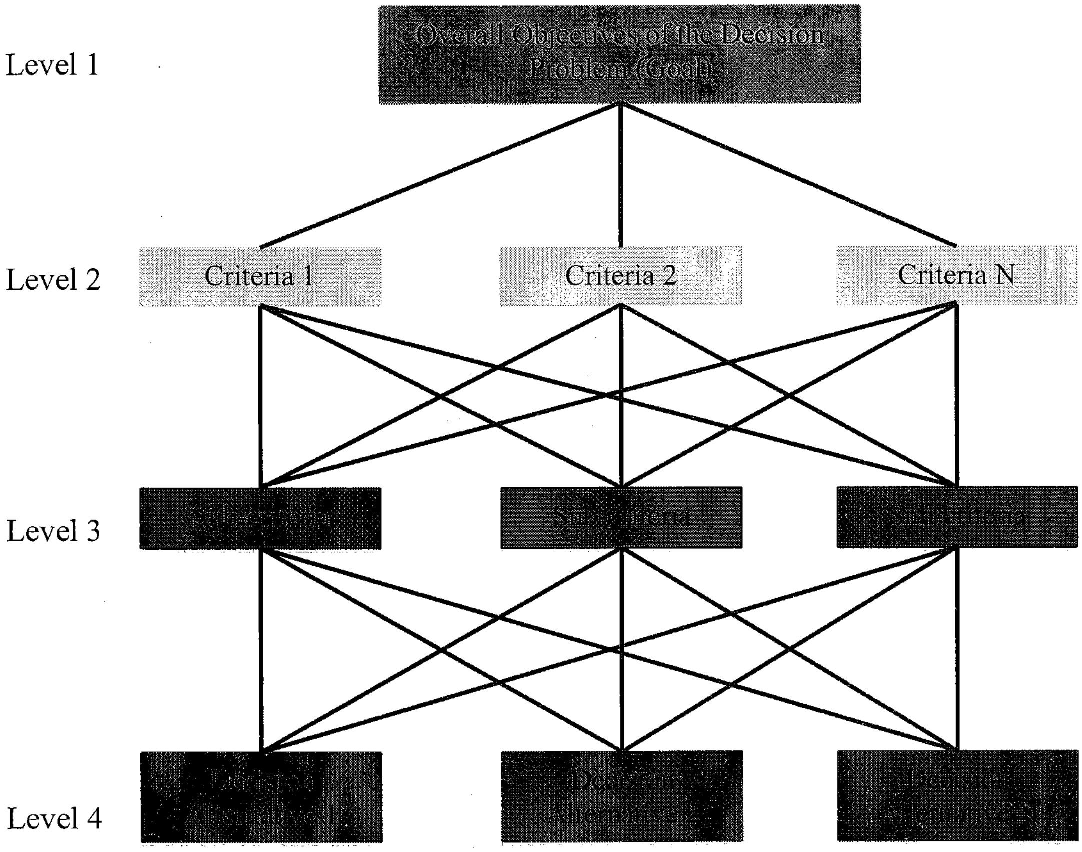

Figure 2.7: Analysis Hierarchy Process scheme [18]

$$
A = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ . \\ C_n \end{array}
\begin{array}{c}
\begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & . & C_n \end{array} \\
\begin{bmatrix}
1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & . & a_{1n} \\
a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & . & a_{2n} \\
a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & . & a_{3n} \\
a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & . & a_{4n} \\
a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & . & a_{5n} \\
a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & . & a_{6n} \\
. & . & . & . & . & . & 1 & . \\
a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5} & a_{n6} & . & 1
\end{bmatrix}
\end{array} . \qquad (2.1)
$$

where

n = criteria number to be evaluated

$C_i = i^{th}$ criteria, $(i=1,2,3,....,n)$

A_{ij} = importance of i^{th} criteria according to j^{th} criteria $(j=1,2,3,....,n)$

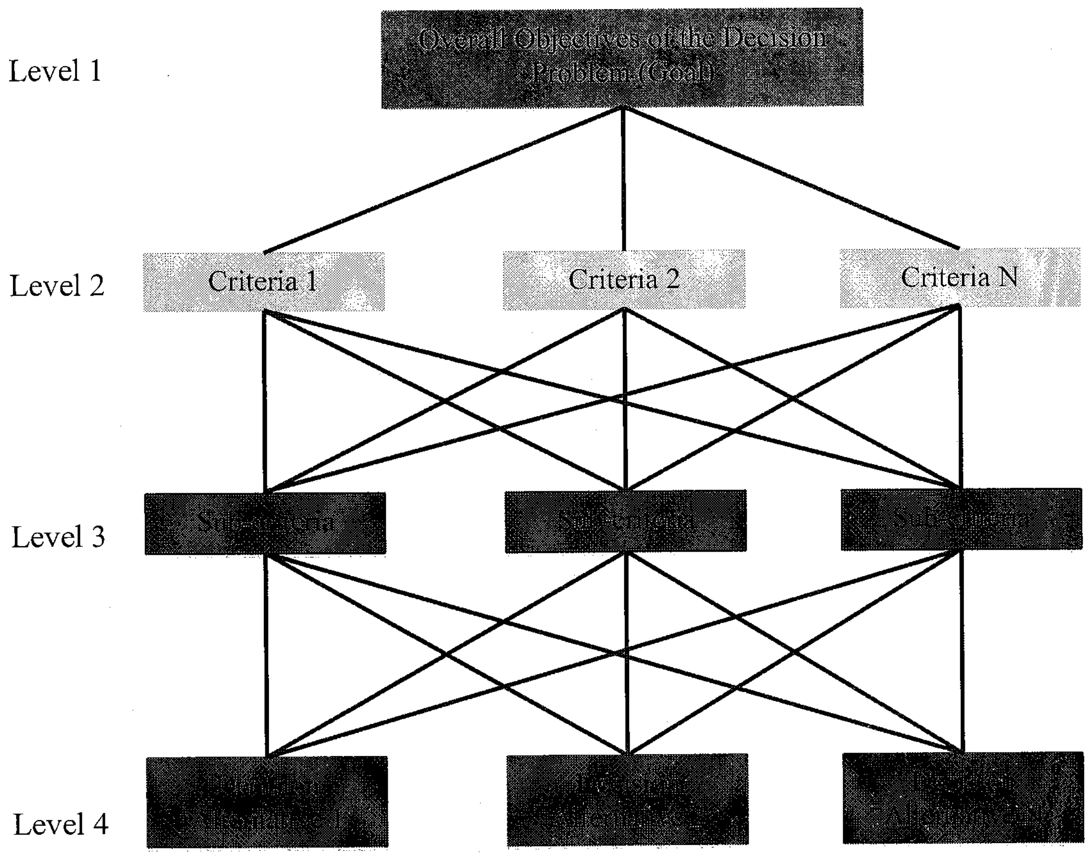

Figure 2.7: Analysis Hierarchy Process scheme [18]

$$A = \begin{array}{c} \\ C_1 \\ C_2 \\ C_3 \\ C_4 \\ C_5 \\ C_6 \\ . \\ C_n \end{array} \begin{array}{c} \begin{array}{cccccccc} C_1 & C_2 & C_3 & C_4 & C_5 & C_6 & . & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} & a_{15} & a_{16} & . & a_{1n} \\ a_{21} & 1 & a_{23} & a_{24} & a_{25} & a_{26} & . & a_{2n} \\ a_{31} & a_{32} & 1 & a_{34} & a_{35} & a_{36} & . & a_{3n} \\ a_{41} & a_{42} & a_{43} & 1 & a_{45} & a_{46} & . & a_{4n} \\ a_{51} & a_{52} & a_{53} & a_{54} & 1 & a_{56} & . & a_{5n} \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & 1 & . & a_{6n} \\ . & . & . & . & . & . & 1 & . \\ a_{n1} & a_{n2} & a_{n3} & a_{n4} & a_{n5} & a_{n6} & . & 1 \end{bmatrix} \end{array} \qquad (2.1)$$

where

n = criteria number to be evaluated

$C_i = i^{th}$ criteria, $(i=1,2,3,....,n)$

A_{ij} = importance of i^{th} criteria according to j^{th} criteria $(j=1,2,3,....,n)$

And after obtaining the weight vector, matrix A is then multiplied by the weight coefficient of the element at a higher level previously seen in Figure 2.7. This procedure is repeated upward for each level, until the top of the hierarchy is reached. Then, finally the overall weight coefficient is then obtained. The alternative with the highest weight coefficient value should be taken as the best alternative.

On the other hand, TOPSIS is known as the Technique for Order Preference by Similarity to Ideal Solution introduced by Hwang and Yoon [18]. It shares the similarity with AHP as it also helps in to identify the ranking of all the alternatives considered. The differences are the decision making matrix and weight vector are determined as crisp values, while the outputs of the decision matrix are a measured distances between the index value vector of each sample and ideal solution along with the negative ideal solution of the comprehensive evaluation known as the positive ideal solution (PIS) and a negative ideal solution (NIS) [18]. PIS is considered as the best value of criteria while NIS is the worst value of criteria.

PIS and NIS are determined through a set of TOPSIS steps. The list of alternatives to a decision maker is classified through the TOPSIS's two artificial alternative hypotheses which are 'Ideal Alternative' and 'Negative Ideal Alternative'. Ideal Alternative represents the best level of all attributes while the Negative Ideal Alternative represents the worst attributes value. Next, sets of calculations using eigenvector, square rooting and summations to obtain a relative closeness value of the criteria are tested. Then through the values of relative closeness, TOPSIS will ranked the whole system by selecting the highest value of the relative closeness as the best attributes in the system.

The uniqueness of AHP and TOPSIS in handling a situation with many criteria to consider to makes these two techniques the best method in offering an alternative to a load shedding scheme. Load shedding scheme is also a situation that has more than one criterion to consider upon before deciding which load to be shed accordingly. AHP and TOPSIS not only capable of offering the ideal alternative load shedding scheme but also these following features [18]:

a) New method

AHP and TOPSIS are considered a new method being practiced in a load shedding scheme for an islanded power system.

b) Simplified

These methods are simpler in concept as the load shedding decision is determined based on the information such as criteria and alternatives. It is also considered to be much faster when it comes to compare alternatives as the previous conventional methods are more difficult and complex.

c) Effective

By applying these two methods to the load shedding scheme, the damage and loss can be reduced to a minimum level. Moreover, the requirement for alternative or additional power supply to the other loads can also be determine in maintaining the situation before it become worse.

2.5 Ranau Power Station Background

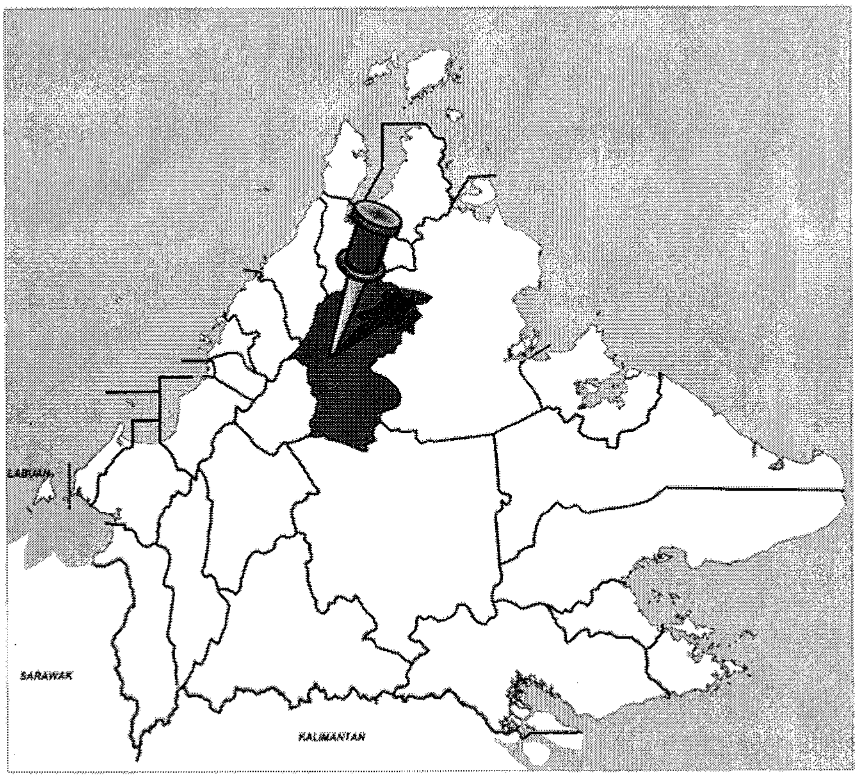

Figure 2.8 Locations of District of Ranau, Sabah

Microgrid with various DER (Distributed Energy Resources).

Energy sources: Diesel Generators

Ranau is a district in Sabah, located 90km from the capital city Kota Kinabalu. History shows that it was supplied with electricity in the early 1960s. During the early years, the supplies were 12-hour system. During that time, consumers served from 0600 hours to 1800 hrs. Unfortunately, only three areas were supplied with electricity namely Lohan, Bundu Tuhan and Kundasang. Each area was connected with its own generators.

The three loads were then interconnected during the mid-1980s. Starting from the 1970s, Ranau district was supplied with 24 hours electricity. At present, the only area serviced with 12-hour system is Matupang. At Paus village, infrastructures are currently developed to supply the village with solar powered electricity. About 80 houses will benefit from this solar powered generator.

According to the Ranau district infrastructure master plan, Rural Electrification Programme (BELB - Bekalan Elektrik Luar Bandar) is currently installing electricity infrastructures at Melinsou, Segindai and Timbua area.

However, up until now Ranau micro grid is only operated on islanded. This is because its power system is still unconnected to the Sabah grid. Even though several attempts to connect the micro grid to main power grid have been done, the results failed and because of that the grid-connected operation are still unavailable.

2.6 Chapter's Summary

The objective of this chapter is to give the readers an overview of previous studies that have direct or indirect influence in shaping the study of this research. All the important categories – AHP, TOPSIS and load shedding practices were briefly discussed in terms of their necessity in one study by associated them with related past researches. Finally, the chapter ends with a highlight of AHP and TOPSIS approach that match to a multi criteria decision making moment.

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