ABSTRACT

Sarawak Energy Berhad formerly known as Sarawak Electricity Supply Corporation is owned by Sarawak Enterprise Corporation Berhad (SECB) and responsible for the generation, transmission and distribution of electricity in Sarawak. In executing their responsibility in terms of distributing electricity network, Sarawak Energy Berhad also has encountered the problem that distribution network prone to trip due to heavy vegetation growth along their long spur lines. In order to overcome this problem, Sarawak Energy Berhad installed auto - reclosers (AR) at appropriate locations in their network. The objective of this research is to develop a methodology to determine the most suitable location of ARs and their numbers to be installed. In order to do that, Analytical Hierarchy Process (AHP) and Fuzzy AHP will be used where all the data related such as the distribution location, length of feeder, load and composite reliability indexes will be collected. From this criterion the available alternatives chosen are town, village and forest. Both methods have their own method and calculation in obtaining the values that will reflect the ranking of priorities. By using this ranking of priorities, the best location for the placement of AR in the distribution system can be determined.

ABSTRAK

Sarawak Energy Berhad sebelum ini dikenali sebagai Perbadanan Pembekalan Elektrik Sarawak dimiliki oleh Sarawak Enterprise Corporation Berhad (SECB) bertanggungjawab dalam penghantaran penjana dan pengagihan elektrik di Sarawak. Dalam melaksanakan tanggungjawab mereka dalam pengagihan bekalan elektrik di Sarawak, Sarawak Energy Berhad telah mengalami masalah dalam penghantaran elektrik dimana sering berlaku litar pintas disepanjang laluan penghantaran disebabkan wujudnya pokok-pokok besar dan gangguan yang menyebabkan berlakunya litar pintas pada proses penghantaran bekalan elektrik. Dalam usaha untuk mengatasi masalah ini, Sarawak Energy Berhad telah memasang *auto-reclosers (AR)* di lokasi-lokasi yang sesuai dalam proses pengagihan bekalan elektrik mereka. Objektif kajian ini adalah untuk membentuk suatu kaedah untuk menentukan lokasi yang paling sesuai untuk meletakkan AR pada system pengagihan bekalan elektrik. Dalam usaha tersebut, *Analytical Hierarchy Process (AHP)* dan *Fuzzy AHP* akan digunakan dan kesemua data yang berkaitan seperti lokasi pengagihan, jarak penghantaran, beban dan indeks kebolehpercayaan komposit akan dikumpulkan. Dari kriteria ini alternatif yang sedia ada seperti bandar, kampung dan hutan juga diperlukan sebagai rujukan. Kedua-dua kaedah mempunyai cara penyelesaian mereka sendiri dari sudut pengiraan untuk mendapatkan nilai-nilai yang akan menentukan kedudukan utama lokasi AR dalam proses penghantaran. Dengan menggunakan ini, ranking keutamaan dan lokasi yang terbaik untuk penempatan AR dalam sistem pengagihan boleh ditentukan.

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LIST OF ABBREVIATIONS

AHP	-	Analytical Hierarchy Process
AR	-	Auto-Recloser
MCDM	-	Multicriteria Decision Making Method
MPGA	-	Multiple-Population Genetic Algorithm
GA	-	Genetic Algorithm
SAIFI	-	System Average Interruption Frequency Index
C.I	-	Composite Index Reliability
LOC	-	Location
DG	-	Distribution Generation
VoLL	-	Value of Lost Load
TFN	-	Triangular Fuzzy Numbers
kV	-	Kilo Volt

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CHAPTER 1

INTRODUCTION

1.1   Project Background

In electric power distribution system, an AR is used as circuit breaker equipment that can automatically open and close the breaker due to a fault. The faults most common on overhead lines are transient, semi-permanent or permanent in nature and permanent fault [1].

The transient fault, such as an insulator flashover is a fault which is cleared by the immediate tripping of one or more circuit breakers to isolate the fault and which does not recur when the line is re-energized. The lightning is the most common cause of transient faults, partially resulting from insulator flashover from the high transient voltages induced by the lightning [2]. Other possible causes are swinging wires and temporary contact with foreign objects like fruit trees, monkey and birds. Thus, the transient faults can be cleared by momentarily de-energizing the line, in order to allow the fault clear.

Semi-permanent or permanent in nature fault commonly cause by a small branch falling onto the line. An immediate de-energizing of the line and subsequent auto-reclosing does not clear the fault. Instead, a coordinate time-delayed trip would allow the branch to be burned away without damage to the system. The permanent faults are those will not clear upon tripping and reclosing. Main cause due to permanent fault on an overhead line is broken wire causing a phase to open, or the broken pole causing the phase to short together [2]. Fault on the underground cables should be considered permanent. Cable fault should be cleared without auto-reclosing and the damage cable repaired before service is restored.

At the present time, Sarawak Energy Berhad only provide for distribution electricity at 33kV and 11kV. The numbers of ARs place along a spur lines is not more than 3 to maintain the effectiveness of AR. Besides that, the limitation numbers of ARs also subject to cost constrain where the equipment itself can cost up to RM 60, 000 per AR and the installation can cost up to RM 20, 000. For the time being, there were almost 200 AR place throughout Sarawak where in Kuching itself there were almost 50 AR was installed.

As a general practice, the maximum number of ARs that will be installed for 50km distance line of electricity network is three. This practice is depending on the length of line, distance and also the loading of the line. It is admitted that the more AR installed the better performance of electricity distribution system. However there are several factors that must be take into account when determines the number of ARs that should be placed along the lines. For example, the principle of protection rules that there is time limit to operate between two AR when isolates the affected customer due to fault.

Recently, various methods have been developed to find the location of AR in distribution network such as Genetic Algorithm (GA), Ant Colony System Algorithm, Cost Analysis and Multiple-Population Genetic Algorithm (MPGA). The Multicriteria Decision Making Method (MCDM) has been widely used in power system currently. MCDM identifies and chooses alternative based on the value and preference of decision maker. Making a decision implies that there are alternative choices to be considered, and in such a case not only to identify as many of these alternative as possible but to choose best alternative that fits with our goals, objective, desires, values and so on [3]. In this paper, the MCDM is propose and used to determine suitable location of AR in feeder.

The Fuzzy AHP is one of the MCDM group and extension from AHP to efficiently handle the fuzziness of the data involved in the decision making. It is easier to understand and it can effectively handle both qualitative and quantitative data in the multi-attribute decision making problems. In this approach triangular fuzzy numbers are used for the preferences of one criterion over another and then by using the extent analysis method, the synthetic extent value of the pairwise comparison is calculated [4].

In order to know the condition of the feeder, whether it is critical or not, the numbers of interruption need to be considered. Reliability indexes are used to evaluate interruption and it is divided into six indexes [5]. But in this research only one index are used which is System Average Interruption Frequency Index (SAIFI) [6].

1.2 Problem Statement

The flow of power is always from the substation transformer to the individual customers for the typical radial feeder. For a fault anywhere on the feeder showed in Figure 1.1, only one AR operates which is the closest to the fault typically to minimize the number of affected customers. Assuming that when there is fault occurs on the line, the first AR location at upstream of the fault will operate in the presence of a fault anywhere on the line. Then the customers locate at downstream of the AR will also be affected by this fault. A faulted branch may be energized from both sides and several protection devices may need to operate in order to completely interrupt the current. Having many protection devices in the system required a lot of money. By using Multi-Criteria Decision Making Method (MCDM), it can analyze the system and decide the condition of the area whether it is critical, less critical or normal area. When the condition already being discovered, it will calculate suitable location of AR are needed in each condition area
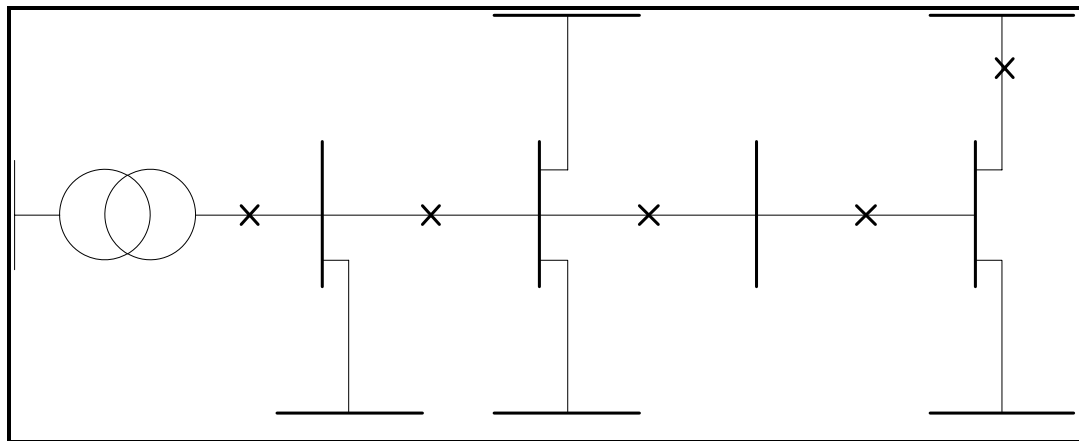
Figure 1.1: Typically Distribution Feeder and AR Location

1.3   Objectives

The objectives of this project are:-

1. To propose the Multi-Criteria Decision Making Method (MCDM) to find the best location of AR in the power distribution system.

2. To determine the appropriate location for the placement of AR in power distribution system based on the priority ranking.

3. To increase the reliability of protection in distribution network.

1.4   Scope of Work

The scopes of this project are:-

1. Research only cover for the radial system at 11kV on distribution network.

2. The research only focuses on suitable location to place AR in the Sarawak distribution system.

3. Using the parameter such as composite reliability indexes, loads and distance to determine the location to place AR in distribution network.

1.5   Thesis Outline

This thesis consists of five chapters. The current chapter mainly presents the background, the objective and the significance of this study. It also provides the general development of method used in determining the location of AR in distribution system and its benefiting contribution towards electricity distribution globally.

Chapter 2 consists of previous studies and research that are relevance in determining the placement of AR in distribution system. As this study uses multi criteria decision making method, Analytical Hierarchy Process (AHP) and Fuzzy AHP is also discussed in this chapter.

Chapter 3 discussed the methodology that is used for this study. It details the process that has been carried out for the short listing of alternatives and the steps taken in building the AHP and Fuzzy AHP model for this study.

Chapter 4 details the analysis and the result of the study. Every chosen criteria and alternatives is assessed individually and related detailed calculation is executed to see their values in the ranking of priorities for the determination of the placement of AR. Pairwise comparison and the results are also discussed in this chapter.

Chapter 5 discusses and concludes the findings of this thesis, and review the parameter of the future development.

CHAPTER II

LITERATURE REVIEW

2.1   Previous Researches

A.Pregelj [7] explained that the placement of protection devices in a conventional feeder is often performed so as to minimize traditional reliability indices. Distribution generation (DG) and storage unit located on the feeder may constrain in term of power and energy capacity, and may include renewable DG unit whose input is dependent on the meteorological condition. Those sources may reduce the number of fault and fault durations for customers residing within their protection zones, thus increasing the reliability of service. This research proposes using the Genetic Algorithm (GA) to find the optimal recloser position on the feeder equipped with power constrained distribution generators. An advantage of this research is to improved the distribution system reliability using distributed generator by providing energy to some of the customer even after fault in distribution system. For its disadvantage, the less information about the benefit of energy constrained sources and storage system and renewable distributed generator.

Then, S. Jamali [8] explained that the optimal placement of recloser and sectionalizers in overhead distribution network to reduce Non-Distributed Energy cause by permanent fault. This research proposed the Numbering Method to reduce the non distributed energy and describe for optimal placement of recloser and sectionalizer in the network. For the advantage of this research is location of recloser and sectionalizer on a distribution feeder to balance the non distributed energy including the energy cost and installation cost and the disadvantage is the research limit for the Iranian distribution feeder and other country using the same power distributed only.

In the research by Lingfeng Wang [9] proposed the new method named Ant Colony System Algorithm in order the find the optimum recloser placement in distribution generation. The advantage of this research is the optimal recloser locations define by minimizing a composite reliability index to enhance power system reliability in distribution network. Then, the disadvantages of its are limit for small range power distribution system and the operational cost by minimizing customer interruption cost should be incorporated see the comprehensive reliability indices.

Research in recloser placement by SA.Pregelj [10] explained that the radial distribution feeder protection strategy is first present in this paper without consideration for distribution generation. Then, the addition of DG across the feeder is introduced in the model. If islanded operation of these DG sources is allowed on a feeder subjected to a disturbance, DG may reduce the number of interruptions and durations for customers residing within their protection zones, thus increasing the reliability of service. The research propose is Genetic Algorithm same with the previous research in order to improved the placement of the recloser. The advantages of this research is the actual reliability improvement factor such as feeder parameter, frequency of fault, fault restoration times, number of protection devices and size of Distribution Generation can be determined. Then, the advantages will be incorporated in the propose method and

other method may be used to planning new DG-enhance feeder design in order to improve power system distribution networks.

For the research by Amir Hisham Hashim [11] proposed the Sabah Electricity (SESB) operates a vertically integrated electricity utility in East Malaysia. It is currently embarking on an initiative to improve the reliability of its 11KV distribution network which is prone to tripping due to vegetation growth along their long spur lines. Apart from that, another proposed solution is to install auto reclosers.(AR) at appropriate locations in their network. This work deals in developing a methodology to determine the most economic location of ARs and their numbers to be installed. In order to do that, data in the form of customer types, load levels and network topology were collected from site visits at SESB.

The study then used an estimated Value of Lost Load (VoLL) to quantify the financial losses that customers suffer given a loss of supply. The proposed method to determine the recloser location in this research is Cost Analysis and its advantages is demonstrated for selecting an optimal location of Auto-Recloser placement, the location determines using minimizing risk levels of the feeder and the impact of the tripping and probabilities of tripping implemented in this paper. The disadvantages of this research is this method can be confine to Sabah Electricity Distribution Network only and to determined the location the Auto-Recloser in distribution network. This method has no impact in improving power system distribution networks and useful for the first approximation for real Auto-Recloser placements.

Finally, the research by Zhang Li [12] proposed that the optimization method to identify the optimum recloser placement to improve system reliability for distribution networks with distributed generators (DG). DG may reduce the number of interruptions and/or durations for customers residing within their protection zones, thus increasing the

reliability of service. A composite reliability index is defined as the objective function in the optimization procedure. Then, the zone-network method is introduced for reliability evaluation. The proposed method used in this research is Multiple-Population Genetic Algorithm (MPGA) and the advantages of the research is using the MPGA to improve reliability of power system distribution network and optimization method used to seek the optimal recloser location. However there are few area need to be improved when using this method such as investigate the simultaneous placement of both reclosers and distributed generators hich are dependant on each other. Besides that the operational cost should be incorporated by minimizing the customer interruption cost.

As a conclusion all the findings from the previous method will be accumulatively used to gain more knowledge on the topic and at the same time improving the result by identifiying the weaknesses from the previous research. By revisiting the previous research, the quality of this thesis can be improved and give more impact in the development of distribution system.

CHAPTER III

METHODOLOGY

3.1 Introduction

This chapter will discuss on overall method involved on selecting the best placement of AR in distribution system. The Multicriteria Decision Making Method (MDCM) such as AHP method and Fuzzy AHP method will be used in order to identify the best placement of AR in distribution system.

3.2 Project Flow Chart

Figure 3.1 shows the guidelines on how to execute the project practically to ensure overall project implementation will be run smoothly and succeed. The flow chart

also describes the phases of project achievement from beginning until the end of this project.

Figure 3.1: Project Flow Chart

START

GE I:
LITERITURE REVIEW FROM
PREVIOUS RESEARCH

GE II:
DATA COLLECTION

STAGE III:
UNDERSTANDING METHOD ARE
USED
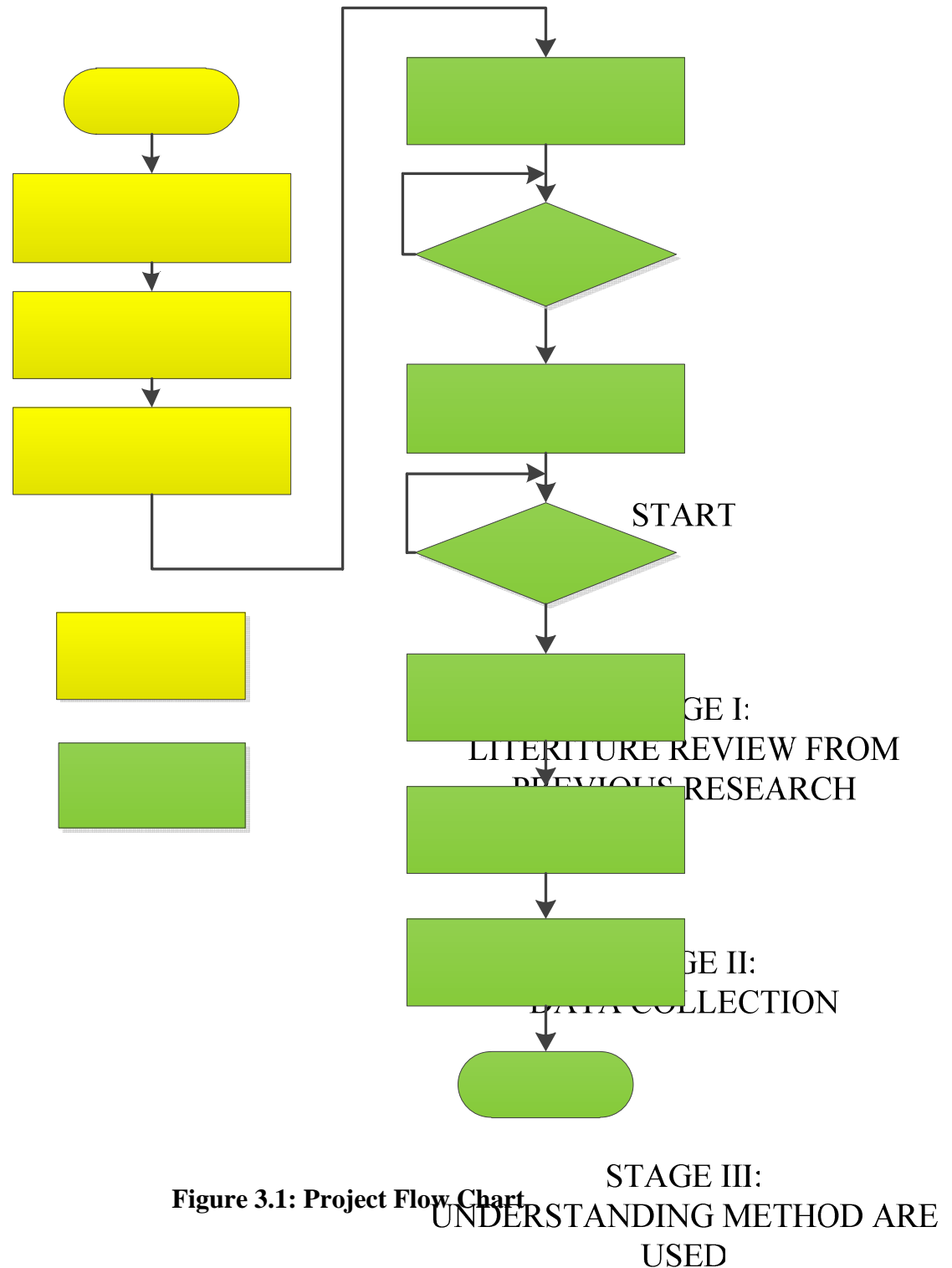
3.3   Project Review

Figure 3.1 shows the overall processes involved in executing this project. The process will be divided into eight stages accordingly.   The first stage is to study literature review from previous research to gain the knowledge and information required of AR placement.   The comparisons from previous research are used to get better improvement in this project. The project will be followed by the second stage which is data collection. All the data required to get the best placement of AR will be identify in this stage.   Once the data is collected, the third stage will begins where the understanding of the method need to be practiced in order to identify the best placement of AR in distribution system.

Next, stage four refers to the evaluation of the data using AHP method and stage five involved the evaluation of data using the Fuzzy AHP method. The Microsoft Office Excel is used in this stage. The result and analysis of the effectiveness placement of AR will be explained on stage six, and then the comparisons between both methods will be elaborated in stage seven, thus suggesting which one is the best method used in terms of the placement of AR in distribution system.   Finally, the conclusions for the whole process involved in this project will be explained in stage eight.

3.4   AHP Method

The Analytic Hierarchy Process (AHP) provides an effective means of dealing with complex decision making. AHP has been used in many application areas including site selection problems and group decision making [7]. In AHP, preferences between

alternatives are determined by making pairwise comparisons. In pairwise comparison, the decision maker examines two alternatives by considering one criterion and indicates a preference [8-9]. These comparisons are made using a preference scale, which assigns numerical values to different levels of preference. The standard preference scale as show in Table 3.1, used for AHP is 1-9 scale which lies between "equal importance" to "extreme importance" where sometimes different evaluation scales can be used such as 1 to 5. In the pairwise comparison matrix, the value 9 indicates that one factor is extremely more important than the other, and the value 1/9 indicates that one factor is extremely less important than the other, and the value 1 indicates equal importance [10].

Table 3.1: AHP 1-9 Scale

INTENSITY OF IMPORTANT	DEFINATION
1	EQUAL IMPORTANT
3	MODERATE IMPORTANT
5	STRONG IMPORTANT
7	VERY STRONG IMPORTANT
9	EXTREME IMPORTANT
2,4,6,8	FOR COMPROMISES ABOVE

Therefore, if the importance of one factor with respect to a second is given, then the importance of the second factor with respect to the first is the reciprocal. Ratio scale and the use of verbal comparisons are used for weighting of quantifiable and non-quantifiable elements. AHP proposed as a decision aid to help solve unstructured problems in economics, social and management sciences [11]. AHP has been applied in a variety of contexts: from the simple everyday problem of selecting a school to the complex problems of designing alternative future outcomes of a developing country, evaluating political candidacy, allocating energy resources, and so on [12-14].

The AHP enables the decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment in confliction [15].

3.5   Application of AHP Method

The application of the AHP to the complex problem usually involves four major steps. The major steps as shown in Figure 3.2:-
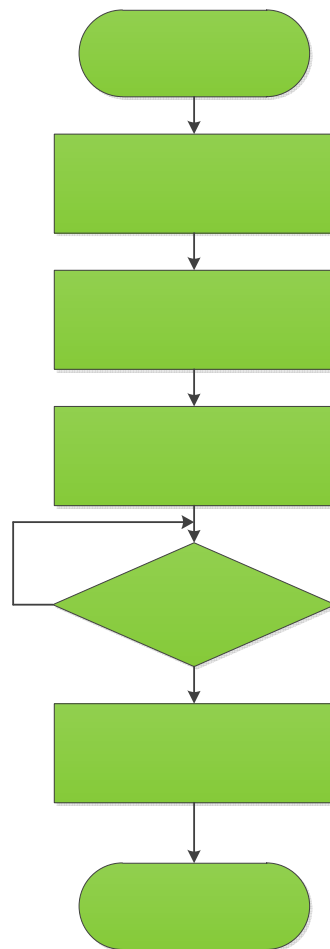
Figure 3.2: AHP Major Step Flowchart

Step 1: Break down the complex problem into a number of small constituent elements and then structure the elements in a hierarchical form.

Step 2: Make a series of pair wise comparisons among the elements according to a ratio scale.

Step 3: Use the eigenvalue method to estimate the relative weights of the elements.

Step 4: Aggregate these relative weights and synthesize them for the final measurement of given decision alternatives.

3.5.1   Built up Hierarchy

The AHP is a powerful and flexible multi-criteria decision-making tool for dealing with complex problems where both qualitative and quantitative aspects need to be considered. The AHP helps analysts to organize the critical aspects of a problem into a hierarchy rather like a family tree as shown in Figure 3.3 :-
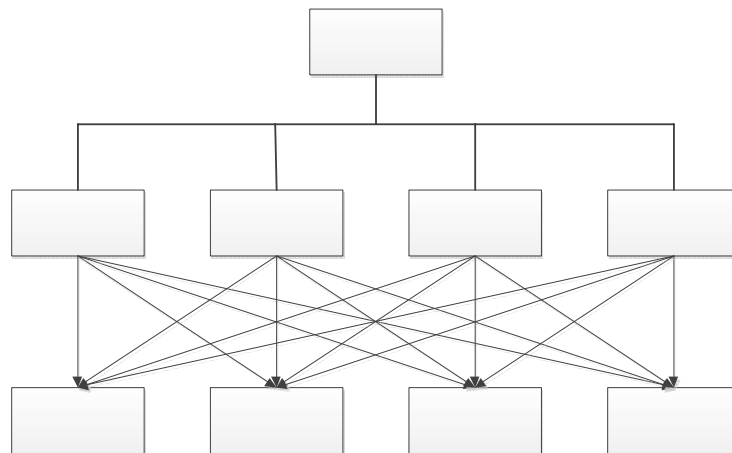
Figure 3.3: AHP Hierarchy

The essence of the process is decomposition of a complex problem into a hierarchy with goal (criterion) 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.

3.5.2 Pairwise Comparisons

To elicit pairwise comparisons performed at a given level, a matrix A is created in turn by putting the result of pairwise comparison of element I with element j into the position a_{ji} as Figure 3.4 :-

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

Figure 3.4: Pairwise Comparisons Matrix

Where:-

n = criteria number to be evaluated

C_i = i. criteria,

A_{ij} = importance of i. criteria according to j^{th} criteria

3.5.3   Eigenvalue Method

The elements at given hierarchy levels are compared in pairs to assess their relative preference with respect to each of the elements at the next higher level. The method computes and aggregates their eigenvectors until the composite final vector of weight coefficients for alternatives is obtained. The entries of final weight coefficients vector reflect the relative importance (value) of each alternative with respect to the goal stated at the top of the hierarchy. A decision maker may use this vector according to his particular needs and interests.

3.5.4   Aggregate Weight

After obtaining the weight vector, it is then multiplied with the weight coefficient of the element at a higher level that was used as criterion for pairwise comparisons. The procedure is repeated upward for each level, until the top of the hierarchy is reached. The overall weight coefficient, with respect to the goal for each decision alternative is then obtained. The alternative with the highest weight coefficient value should be taken as the best alternative.

3.6   Fuzzy AHP Method

There is an extensive literature that addresses the situation where the comparison ratios are imprecise judgments. In most of the real-world problems, some of the decision data can be precisely assessed while others cannot. Humans are unsuccessful in making quantitative predictions, whereas they are comparatively efficient in qualitative forecasting. Essentially, the uncertainty in the preference judgments gives rise to uncertainty in the ranking of alternatives as well as difficulty in determining consistency of preferences. These applications are performed with many different perspectives and proposed methods for fuzzy AHP [17].

The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP. Despite the convenience of AHP in handling both quantitative and qualitative criteria of multi-criteria decision making problems based on decision makers' judgments, fuzziness and vagueness existing in many decision-making problems may contribute to the imprecise judgments of decision makers in conventional AHP approaches.

So, many researchers who have studied the fuzzy AHP which is the extension of Saaty's theory, have provided evidence that fuzzy AHP shows relatively more sufficient description of these kind of decision making processes compared to the traditional AHP methods.

In complex systems, the experiences and judgments of humans are represented by linguistic and vague patterns. Therefore, a much better representation of this linguistics can be developed as quantitative data. This type of data set is then refined by the evaluation methods of fuzzy set theory. On the other hand, the AHP method is

mainly used in nearly crisp (non-fuzzy) decision applications and creates and deals with a very unbalanced scale of judgment.

Therefore, the AHP method does not take into account the uncertainty associated with the mapping. The AHP's subjective judgment, selection and preference of decision-makers have great influence on the success of the method. The conventional AHP still cannot reflect the human thinking style. Avoiding these risks on performance, the fuzzy AHP, a fuzzy extension of AHP, was developed to solve the hierarchical fuzzy problems [18].

The analysis on fuzzy AHP depends on the degree of possibilities of each criterion. According to the responses on the question form, the corresponding triangular fuzzy values for the linguistic variables are placed and for a particular level on the hierarchy the pairwise comparison matrix is constructed. Sub totals are calculated for each row of the matrix and new *(l, m, u)* set is obtained, then in order to find the overall triangular fuzzy values for each criterion, $l_i/\Sigma l_i$, $m_i/\Sigma m_i$, $u_i/\Sigma u_i$, *(i=1,2,..., n)* values are found and used as the latest $M_i(l_i, m_i, u_i)$ set for criterion M_i in the rest of the process. In the next step, membership functions are constructed for the each criterion and intersections are determined by comparing each triangular fuzzy number.

In fuzzy logic approach in Figure 3.5 , for each comparison the intersection point is found, and then the membership values of the point correspond to the weight of that point. This membership value can also be defined as the degree of possibility of the value. For a particular criterion, the minimum degree of possibility of the situations, where the value is greater than the others, is also the weight of this criterion before normalization. After obtaining the weights for each criterion, they are normalized and called the final importance degrees or weights for the hierarchy level.
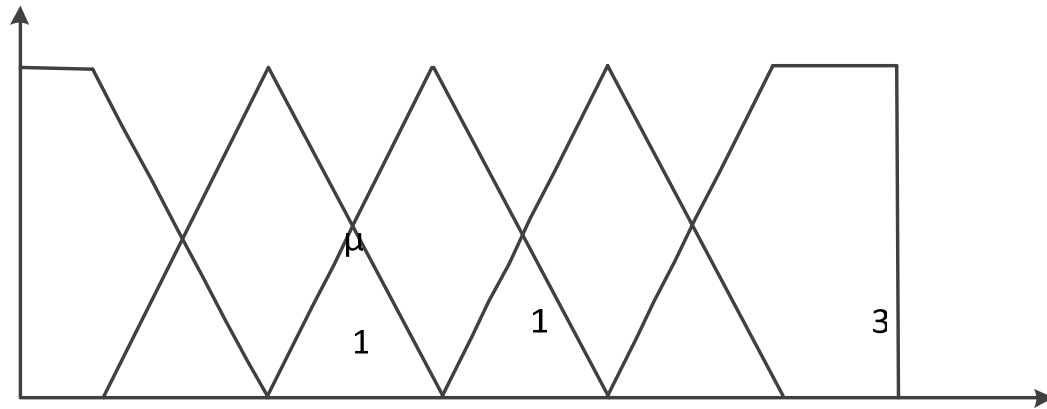
Figure 3.5: Fuzzy Logic Approach

3.7 Application of Fuzzy AHP Method

To apply the process depending on this hierarchy, each criterion is taken and extent analysis for each criterion, g_i; is performed on, respectively. Therefore, *m extent* analysis values for each criterion can be obtained by using following notation:-

$$M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, M_{g_i}^4, M_{g_i}^5 \cdots\cdots M_{g_i}^m$$

where g_i is the goal set (*I = 1, 2, 3, 4, 5, ...n)* and all the $M_{g_i}^j$ *(j = 1, 2, 3, 4, 5, ..., m)* are Triangular Fuzzy Numbers *(TFNs)*. The steps can be given as in the following Figure 3.6 :-
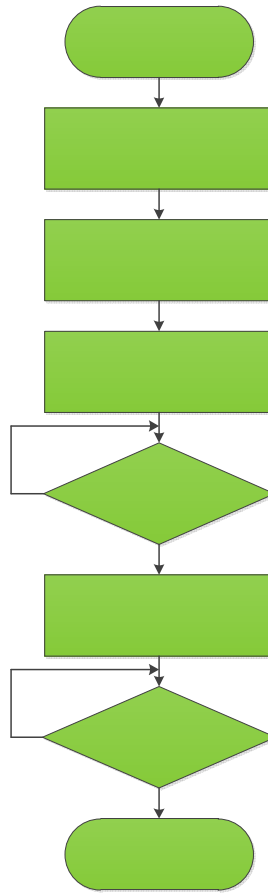
Figure 3.6: Step of Fuzzy AHP Method

Step 1: The fuzzy synthetic extent value (S_i) with respect to the ith criterion is defined as equation 1 .

NO

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{m} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}$$

(1)

To obtain equation 2:

$$\sum_{j=1}^{m} M_{g_i}^j$$

(2)   NO

Perform the "fuzzy addition operation" of m extent analysis values for a particular matrix given in equation 3, at the end step of calculation, new (l, m, u) set is obtained and used for the next:-

$$\sum_{j=1}^{m} M_{g_i}^{j} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j)$$

(3)

Where l is the lower limit value, m is the most promising value and u is the upper limit value and to obtain equation 4:-

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$$

(4)

Perform the "fuzzy addition operation" of $M_{g_i}^{j}$ $(j = 1,2,3,4,5 \ldots \ldots m)$ values give as equation 5:-

$$\sum_{i=1}^{n}\sum_{n=1}^{m} M_{g_i}^{j} = (\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i)$$

(5)

and then compute the inverse of the vector in the equation 5 and equation 6 is then obtain such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} u_i}\right)$$

(6)

Step 2: The degree of possibility of

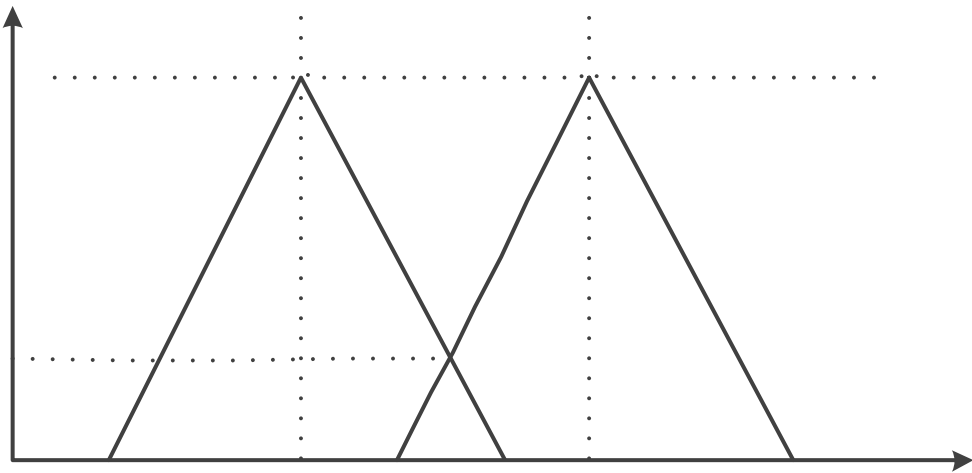$M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ as defined equation 7:

$$V(M_2 \geq M_1) = \sup_{y \geq x}\left[\min(\mu_{M_1}(x), \mu_{M_2}(y))\right]$$

(7)

And x and y are the values on the axis of membership function of each criterion. This expression can be equivalently written as given equation 8:-

$$(M_2 \geq M_1) = \begin{cases} 1, & if\ m_2 \geq m_1 \\ 0, & if\ l_1 \geq u_2 \\ \dfrac{(l_1 - u_2)}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases}$$

(8)

Where *d* is the highest intersection point μ_{M_1} and μ_{M_2} in Figure 3.7:-

Figure 3.7: The Intersection Between M_1 and M_2

To compare M_1 and M_2, we need both the value of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$.

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