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MULTI-CRITERIA SELECTION FOR LOAD SHEDDING SCHEME USING ANALYTICAL HIERARCHY PROCESS (AHP) IN ELECTRICAL POWER SYSTEM

NOOR ZAIHAH BINTI JAMAL

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Universiti Tun Hussein Onn Malaysia

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ABSTRACT

This report was written to present a methodology of multi-criteria selection for load shedding scheme for power system using Analytical Hierarchy Process (AHP). The AHP is a method to derive ratio scales from paired comparisons which obtained from actual criterias and alternatives and has been identified as a suitable technique for dealing with complex decision making especially during emergency happened. In this report actual data from Terengganu Advanced Technical University College (TATiUC) have been chosen as a study site. The idea of proposing this methodology to the TATiUC power system came out when the large contingency occurs and had effected to major shutdown to one of the system ring which had happened in 2008. During that time to maintain the operation of the effected system ring, the person in-charge had to select load which is essential to be powered up and what not by using their own experience and knowledge to the system without any proper guidance. By using AHP, it can be one of the solutions scheme to the system and also guidance to the person in-charge. Several conventional methods of load shedding also being discussed under literature review chapter and why the AHP has been selected as the most suitable method to be applied to the TATiUC power system. The detail background and history of the TATiUC system were also enlightened in an easy to understand schematic complete with legends. The application of Microsoft Excel Software have been used to analyzed the actual data and it is very reliable software to be amended in future if any data have been updated. The result and discussion also being discussed and well justified using graphs,pie charts, tables and flow charts for better understanding on the finding results. As a conclusion, the AHP is a very reliable method to be used for load shedding scheme and several recommendations was proposed to ensure the reliability of the method will be paralled with the upgraded power system in future.

ABSTRAK

Laporan ini membentangkan kajian berkenaan salah satu teknik membuat keputusan berdasarkan kriteria-kriteria yang dipilih yang mana boleh digunakan untuk merangka satu skema pengurangan beban dalam sistem elektrik kuasa. Teknik tersebut adalah teknik proses penstrukturan atau hirarki secara analitikal dimana teknik ini membandingkan kriteria atau pilihan yang dipilih secara berpasangan untuk menghasilkan nisbah skala untuk setiap perbandingan secara berpasangan yang dibuat. Teknik ini sangat sesuai digunakan untuk membuat sesuatu keputusan yang kompleks. Data yang digunapakai dalam laporan ini adalah data sebenar sistem elektrik kuasa di Terengganu Advanced Technical Universiti College (TATiUC). Cadangan untuk menggunapakai data dari TATiUC setelah mengambilkira masalah yang pernah berlaku di sana pada tahun 2008 dimana berlaku masalah kepada sistem relung-1 yang telah menyebabkan kepada berlakunya kegagalan pada sistem elektrik kuasa pada relung tersebut. Semasa keadaan ini berlaku, sistem elektrik ke bangunan-bangunan yang kritikal atau penting perlu mendapat bekalan kuasa secara berterusan dan sesetengah beban yang tidak kritikal perlu dimansuhkan daripada sistem elektrik kuasa tersebut. Oleh itu, operator yang bertugas perlu membuat keputusan segera untuk memilih beban-beban yang bersesuaian mengikut pengalaman dan pengetahuan sedia ada tanpa rujukan yang sesuai. Oleh itu, teknik ini amat bersesuaian untuk dijadikan penunjuk aras jika berlaku sebarang kecemasan pada sistem tersebut pada masa akan datang. Teknik-teknik pengurangan beban secara tradisional juga diterangkan untuk memberi pemahaman yang lebih baik berkenaan dengan teknik yang dicadangkan. Latarbelakang dan sejarah sistem bekalan elektrik kuasa di TATiUC juga diterangkan secara mendalam dalam bentuk skematik mudah untuk memberikan pemahaman yang lebih baik. Dalam kajian ini, data yang diperolehi dianalisa mengunakan perisian excel untuk memudahkan kerja-kerja pengiraan beban yang terlibat. Keputusan dan perbincangan telah diterangkan dalam bentuk graf, carta pi, jadual dan carta alir untuk memberi pemahaman mendalam. Beberapa cadangan telah diutarakan untuk penambahbaikan kepada sistem pada masa akan datang.

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AHP	Analytical Hierarchy Process
Alt	Alternatives
RMU	Ring Main Unit
SS	Substation
HV	High voltage
LV	Low voltage
CI	Consistency index
RI	Random index
CR	Consistency ratio
MW	Mega-watt
$\sum$	summation

CHAPTER 1

INTRODUCTION

1.1 Project background

Electrical power system is a network or structured of electrical equipments which used to supply the electrical power to the consumer. In peninsular Malaysia, the high voltage of electrical power was being transmitted via nasional grid which operated and owned by Tenaga Nasional Berhad (TNB) as the largest electric utility company in Malaysia. The generated power will be transmitted to the distribution substation and distributed to the industry or consumer. During the early stages of the development of a new power system infrastructure for any industry, the designer or consultant has to consider the developed infrastructure is able to cater any future development for at least for next five years ahead. During this stage, the master planning of the area is very critical to be done to avoid any under sizing equipment which leads to the extra cost consumption to the consumer to replace the expensive equipment in a short duration. So the feasibility studies on the master plan for five years ahead is very importance. The designer should also came out with the idea on how to maintain the power supply to the essential load during any faulty condition occurs. The supplied power to the area should be increased in proportion to the increased in numbers of loads. If less power supplied than consumed the frequency would decline and vice versa. Even small deviations from the nominal frequency value would damage synchronous machines and other appliances. In order to ensure the frequency is remain constant, any minor or major disturbances need to be attended and solved in a very short period of time to avoid any further system collapsed. The very short cut way to stop further declining of system frequency is by removing or shedding any load that is non-essential. Load shedding is defined as amount of non-critical load that must be cut-off from the power system network to maintain the operational of the system to the critical load[1]. Lightning strike during a thunderstorm, faults, switching errors, major generation outages are the most common problem which leads to the system tripped[1]. Thereupon, by removing a certain amount of load can ensure the remaining portion of the system continually operational. That remaining portion should be only the most essential and most critical loads in the system. And the substances amount of load to be shed or switched off should be from any non-essential loads available in the same disturbed system. By switching off that non-essential load, the equality between the power supplied and power consumed 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 essential and most critical loads in the system. The module begins with non-essential loads and follows by semi-essential loads removal. The essential loads can only be removed if the system is disturbed by large disturbances such as major generation outages.

1.2 Problem statements

The main interest of this study is to rank the load in hierarchy according to their priority as the option to assist the system operator to decide which load to be removed or shed first and next during the disturbances to the power system using one of the multi-criteria selection methods called Analytical Hierarchy Process (AHP).

Normally, before any electrical infrastructure or facilities being developed, the engineer will have a study and research on the load demand for future five (5) years ahead on the area or industry. However, sometimes the demands of the fast growing industry are not able to cater the additional load installed. Any un-equality of the power supplied and load demand will lead to the system disturbances or collapse. To avoid system from down or collapse, some of the non-essential loads need to be removed from the system instantly. In order to select which load to be removed, the idea of using Analytical Hierarchy Process (AHP) pop-up to ensure the removed load is the least important to the system.

1.3 Project objectives

In order to ensure the developed load shedding scheme is ideal for the selected electrical power system. The objectives of this project are as follows:

a) Implement the multi-criteria selection for load shedding scheme using Analytic Hierarchy Process (AHP).
b) Evaluate the Analytical Hierarchy Process (AHP) performance of load shedding scheme by performing a case study in actual case in Terengganu Advanced Technical University College (TATiUC).
c) Identify the weaknesses and disadvantages of the existing load shedding schemes in that particular area.

1.4 Project scopes

The system studies were carried out using Microsoft Excel Software application and only focus on Analytic Hierarchy Process (AHP) method for load shedding scheme. The performance of the AHP method will be evaluated by using the actual relevant input data. Due to the constraint of getting the latest input data, the following salient points will be taken into consideration:

a) The system study is carried out to rank load priority for load shedding scheme as one of the protection system for the power system infrastructure at Terengganu Advanced Technical University College (TATiUC).
b) Due to the constraint of the latest load data availability only a portion of data for year 2010 was taken into consideration.
c) For this analysis, only power supplied and load operating demands were taken into consideration.
d) The type of disturbance considered in this analysis was large contingency thermal breakdown in solid dielectric.

1.5 Thesis overview

The report was layout as follows:

Chapter 1 – Introduction

This chapter is briefly an introduction to load shedding and the importance of the load shedding to the power system. The interest of the research is towards Analytical Hierarchy Process (AHP) and salient points which taken into consideration had also clearly stated at the end of the chapter.

Chapter 2 – Literature Review

This chapter discussed on past researches on several load shedding method and why Analytical Hierarchy Process (AHP) is the most suitable method for this study case compared to the others method. It was properly structured for future reference purposes.

Chapter 3 - Methodology

This chapter discussed on background of the electrical power system at the Terengganu Advanced Technical University College (TATiUC) based on 2010 data and why the system need load shedding in order to ensure the smoothness of the supplied power if any disturbance occurs. Sketches of the system also pasted in this chapter to provide clear introduction to the system studied. Excel Software Application has been used to rank the load by using Analytical Hierarchy Process method according to their weighted average ratings and the results gained can be a reference to the operator in-charge to perform load shedding execution.

Chapter 4 – Result, Analysis & Discussion

The findings of the research were discussed and presented in graphs, pie charts and tabulated data in this chapter 4. The analysis of the results is also being discussed in this chapter for each criteria and alternative selected. And why the findings decision should be that way as the best load shedding scheme to the system approached.

Chapter 5 –Conclusion and Recommendation Works

The final parts of the report discussed and concluded the importance of the finding which definitely is very helpful as a guide to the person in charge for better protection for the power system network during major contingencies. It also focused on the future proposal to improve the findings as the system may change due to the surrounding needs.

1.6 Summary

This chapter was discussed on the introduction to the electric power system and load shedding definition in order to briefly explain on the importance of the load shedding to the power system and how to manage the disturbances happened to prevent further losses to the consumer. During this research performed, several salient points have been considered to ensure that the data was used is suitable with the study case and it is well stated under the section of the project scope

CHAPTER 2

LITERATUR REVIEW

2.1 Electrical power system in Malaysia

Malaysia is currently gearing up towards transparent and efficient electricity supply industry. In 1990s, the Malaysian government has introduced the independent power producer (IPP) and privatization of the national utility as parts of the effort to ensure the supply to be more responsive to the needs of the people and keeping the price to be affordable. Main power producer in Malaysia are Tenaga Nasional Berhad (TNB), Co-Generator such as Petronas Gas Sdn Bhd, Independent Power Producer (IPP) such as YTL Generation Sdn. Bhd., Malakoff Berhad, Genting Sanyen Power Sdn Bhd which generated electricity and sell them to TNB, Sarawak Electricity Supply Corporation (SESCO) which responsible for the generation, transmission and distribution of electricity in Sarawak and Sabah Electricity Sdn Bhd (SESB) which providing reliable generation, transmission and distribution services in the state of Sabah and the Federal Territory Labuan.

In peninsular Malaysia, TNB is the largest utility company whom owned, managed and operated the National Grid which links the TNB power station and IPPs to the distribution network. The grid is connected to Thailand's transmission system in the north and Singapore's transmission system in the south. More than 420 substations in Peninsular Malaysia are linked together by the extensive network of transmission lines operating at 132kV, 275kV and 500kV voltage levels. Highest peak demand in the system which recorded on 20th June 2012 is 15,826 MW and the total installed capacity in Peninsular stands at 21,749MW. The transmission network are divided into four regions i.e. Northern Area (Perak, Pulau Pinang, Kedah and

Perlis), Central Area (Selangor, Federal Territory of Kuala Lumpur and Putrajaya), Eastern Area (Pahang, Terengganu and Kelantan), Southern Area (Johor, Melaka and Negeri Sembilan) which can be shown in the diagram below. The major load centers are in the West Coast where majority of thermal power plants are located. Presently, Bukit Tarek and Lenggeng are the main network gateway for power transfer from Northern and Southern regions to the major load center.

Figure 2-1 : National Grid Map of Peninsular Malaysia

The generated output at 11kV/ 20kV is step up by the transformer to 132kV, 275kV and 500kV to be transmitted via transmission line and distributed to the substation. Some of the Co-Generator will have direct connection to the transmission line and distribute to the customers within specific area such as industrial complexes. Most of the factories received 11kV electricity from the substation to be stepped down with their own built infrastructure for more power reliability. The electricity will be stepped down via transformer to 0.415kV and 0.240V for small factories, individual houses and residential premises.

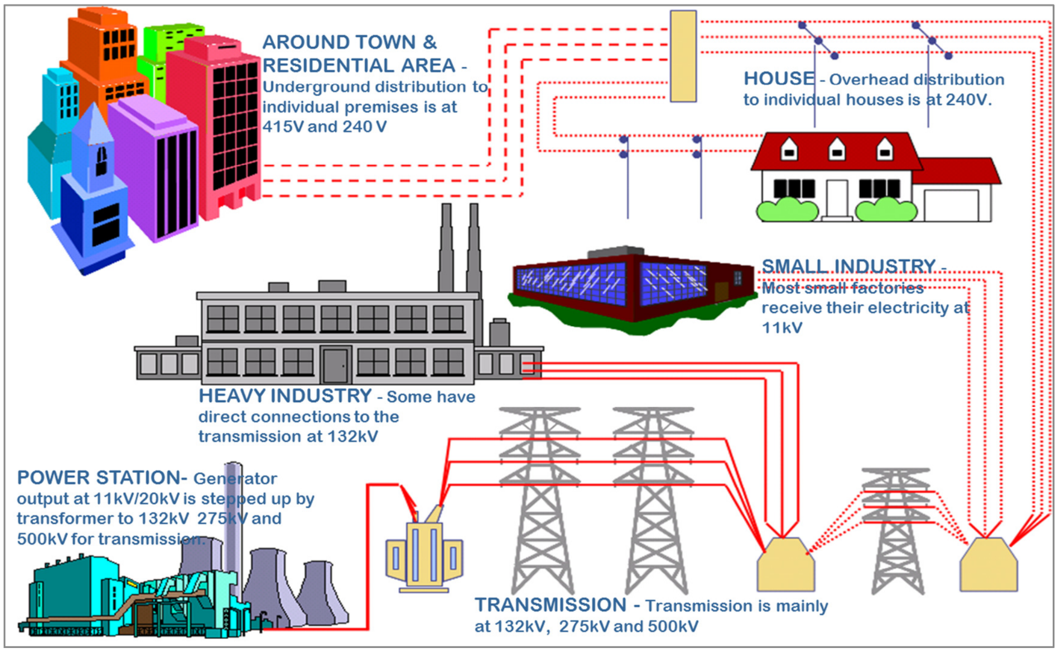

Figure 2-2 : Power distribution to the consumers.

2.2 Electrical power outages event in Malaysia

Malaysia has experienced several tripped event at the main transmission lines which resulted to the major power outages to the affected area.

i. In June 1985, a sudden 600MW load loss tripped transmission line on the east coast which caused a major blackout for several hours to the 11 states. The trip happened on the two lines between Paka, Terengganu and Kampung Awah, Pahang and had tripped all power stations connected to the national grid. The blackout was happened during lunch hour which caused chaos in major towns affected. The backup plans have been introduced to undergo the same outages from happen again which firstly, review the effectiveness of the load shedding scheme. Secondly, construct the alternative route of 275kV transmission line from Paka, Terengganu to Tanah Merah, Kelantan in 1986, for dispatching power to the grid from major plants in Paka and Kenyir, Terengganu. Thirdly, provide power security to Port Klang power plant to avoid major loss.

ii. In July 1992, Lightning during thunderstorm had strike a grid comprising four power lines between Paka and Teluk Kalong in Terengganu which caused massive power failure in the peninsular Malaysia, 15 power station on the west coast were put out of action. The grid is one of the two network supplying power to the west coast and due to this failure affected the Paka power station. The power blackout for almost ten hours in the most affected states. The post actioned to the power failure have been identified which TNB to erect an alternative transmission line between Terengganu and the south of the peninsular, TNB to improve its protection system in the power transmission system and that TNB should allocate 30% spare capacity at any one time in its power generation system. At this time, there is only 10%. TNB to provide portable power stations in densely populated areas to ensure supply will not be cut-out.

iii. In August 1996, a transmission line near Paka Power tripped causing all power stations in Peninsular Malaysia to collapse resulting in a massive power failure. The cascading effect of the trip shut down supply in sequence at all power stations. The post actioned to the outages are TNB recommended that dependence on power generated from these stations be reduced to lower the risk of major system failure and TNB was expected to spend between RM50mil to RM100mil per year in the next five years to improve reliability and security of nation's electricity distribution.

From the power outages happened, one of the solutions to control the huge losses to the industry affected is by having load shedding scheme and the scheme must be effective to ensure the smoothness of the operation during the trip.

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2.3 Previous method of load shedding

This section review on the numbers of conventional method used for load shedding scheme which most famous among the industrial facility.

2.2.1 Breaker Interlock Scheme[1]

This is the simplest method of carrying out load shedding. For example a source breaker would be interlocked via hardwired or remote signals to a set of load breakers that have been pre-selected to trip. When a generator breaker or a grid connection is lost for any reason, signals are automatically sent to load breakers to open. This system is very fast since there is no processing required and all decisions about the amount of load to be shed were made long before the fault occurred.

2.2.2 Under Frequency Relay Scheme. [1]

Frequency relays do not detect disturbances but react to the disturbances. They detect either a rapid change in frequency or gradual frequency deterioration and initiate staged operation of interlocked breakers. When the first stage is reached, the relay waits a predetermined amount of time, to avoid nuisance tripping, and then trips one or more load breakers. This is done to allow the frequency to recover. If the frequency continues to decay, the relay will wait for the next stage to be reached and after an additional time delay, opens other load breakers.

2.2.3 Programmable Logic Controller-Based Load Shedding. [1]

The use of Programmable Logic Controllers (PLCs) for automatic sequencing of load has become an important part of substation automation in recent years. The application of PLCs in industrial load management and curtailment schemes started in the early 1980s. However, it wasn't until power management systems were combined with microprocessor based PLCs that distributed fast load shedding systems became a reality. With a common type of PLC-based load shedding scheme, load shedding is initiated based on the system frequency deviations and/or other triggers. The circuit breaker tripping can be programmed based on the system loading, available generation, and other specific logics. Each subsystem is equipped with a PLC that is programmed to shed a preset sequence of loads. This static sequence is continued until the frequency returns to a normal condition. Modification of the logic requires changing of the latter-logics that are programmed in the PLCs.

PLC-based load shedding scheme offers many advantages over the frequency-based scheme since they have access to information about the actual operating status of the power system. However monitoring of the power system is limited to the sections of the system that are connected to the data acquisition system. This drawback is further compounded by the implementation of pre-defined load priority tables in the PLC. These load reduction tables are executed sequentially to curtail blocks of load until a preset load shedding level is achieved. This process may be independent of the dynamic changes in the system loading, generation, or operating configuration. The system-wide operating conditions are often missing from the PLC's decision-making process resulting in insufficient or excessive load shedding. In addition, the load shedding systems response time (time period for which the load shedding trigger is detected by the PLC or relay up to the time when the trip signal is received by the circuit breaker) during transient disturbances is often too long requiring for even more load to be dropped. The state-of-the-art load shedding system uses real-time system-wide data acquisition that continually updates a computer based real-time system model. This system produces the optimum solution for system preservation by shedding only the necessary amount of load and is called Intelligent Load Shedding.

2.4 Why analytical hierarchy process (AHP) is selected

During the literature review stages, several method have been taken into consideration and finally the AHP method has been selected due to the below reasons:

i) For Breaker Interlock scheme, the exact amount of the load consumed during that fault maybe differ due to extension work to the system or etc. So the scheme is no longer reliable to the system.

ii) Under Frequency Relay scheme, the well managed coordination between relay breakers upstream and downstream is needed. If the relay coordination system is not well coordinated to ensure any disturbance happened to the downstream system will not trip the upstream relay breakers, this situation will cause huge losses to the industries and affected the daily routine of the un-effected area. This situation will happen if any upgrading work performed to the system but the relay coordination did not re-coordinate well because to perform this job, the consumer need to hire specialist in that field to perform the study and calculation which cost huge amount of money.

iii) By using the Programmable Logic Controller-Based Load Shedding to system will incurred higher cost to the customer in the beginning to set-up the system and not all the system customer are good in handling the PLC based load shedding scheme. The person in-charge have to be well knowledge on PLC system and maintenance so the engineers have to attend special courses on handling the PLC based load shedding scheme. The customer also needs to spend huge amount of cost for schedules maintenance to maintain good performance of the PLC operation.

In other way, AHP method is better in terms of cost and time incurred. Rather than selected ‘correct’ decision, the AHP helps decision makers to find one that best suits their objective and their understanding of the problem.

In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. [2], [10]

2.5 Analytical hierarchy process (AHP) technique in a multiple criteria situation

The analytic hierarchy process (AHP) is a structured technique for organizing and analyzing complex decisions. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. It has particular application in group decision making and is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education. Rather than prescribing a "correct" decision, the AHP helps decision makers find one that best suits their goal and their understanding of the problem. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals, and for evaluating alternative solutions[2],[10].
Once the hierarchy is built, the decision makers systematically evaluate its various elements by comparing them to one another two at a time, with respect to their impact on an element above them in the hierarchy. In making the comparisons, the decision makers can use concrete data about the elements, but they typically use their judgments about the elements' relative meaning and importance. It is the essence of the AHP that human judgments, and not just the underlying information, can be used in performing the evaluations. [2],[10]

The AHP converts these evaluations to numerical values that can be processed and compared over the entire range of the problem. A numerical weight or priority is derived for each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. This capability distinguishes the AHP from other decision making techniques. In the final step of the process, numerical priorities are calculated for each of the decision alternatives. These numbers represent the alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action. [2],[10].

The basic procedures of AHP as follows: [9]

a) Develop the weights for the criteria by

- developing a pairwise comparison matrix for each criterion
- normalizing the resulting matrix
- averaging the values in each row to get the corresponding rating
- calculating and checking the consistency ratio

b) Develop the ratings for each decision alternative for each criterion by

- developing a pair wise comparison matrix for each criterion
- normalizing the resulting matrix
- averaging the values in each row to get the corresponding rating
- calculating and checking the consistency ratio

c) Calculate the weighted average rating for each decision alternative. Choose the one with the highest score.

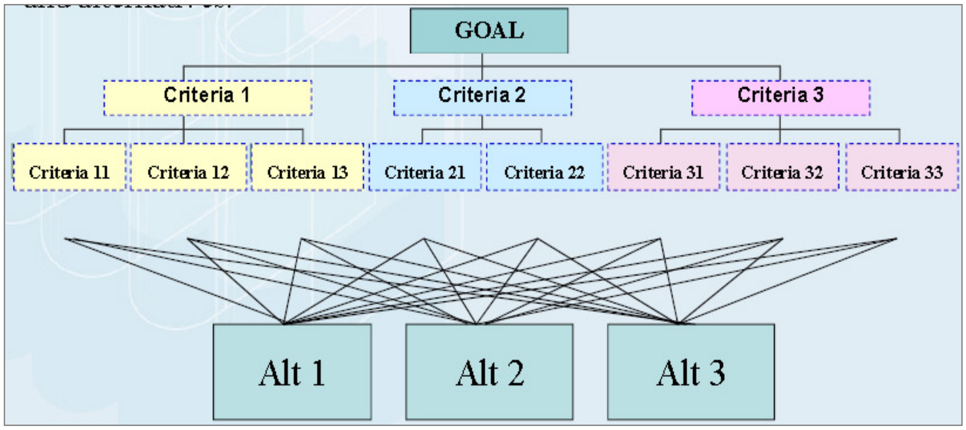

Figure 2-3 : Structure of the hierarchy

Level-1: The goal of the analysis.

Level-2: The multi-criteria that consist of several criterions, you can also add several other levels of sub-criteria.

Level-3: The last level is the alternative choices

Scale	Degree of preference
1	Equal importance
3	Moderate importance of one factor over another
5	Strong or essential importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Values for inverse comparison

Figure 2-4 : The example scale for comparison (Saaty & Vargas, 1991).

2.6 Summary

This chapter has been highlighted on the previous method used in order to achieve the goal or objective to build a consistence power system and to avoid further declining of the system frequency and why the research is implemented Analytical Hierarchy Process (AHP) method to the study cas

CHAPTER 3

METHODOLOGY

3.1 Background of the system

Figure 3-1 : Location of Terengganu Advanced Technical University College (TATiUC)

Terengganu Advanced Technical University College (TATiUC) is an educational institution which have been developed on June 1993 (formerly known as Terengganu Advanced Technical Institute (TATI) and have been upgraded as University College end of 2007) . TATiUC is located under district of Kemaman, Terengganu and 30km from the Kerteh oil and gas industry. This education institute is developed to fullfill the higher scale of education on technical based.

During the early years, the electrical infrastructure at TATiUC was fed by TNB via single 11kV 200/5A incoming to a 11kV consumer switchgear room (known as MD Room) to substation 1 (SS1). The Substation 1 have been installed with one (1) no. of SF6, 11kV, 20kA, 63A Ring Main Unit (RMU), two (2) nos of 11/0.415kV, 750kVA oil immerse transformer, one (1) no. of Main Switch Board with 1250A busbar coupler and one (1) no. of standby generator set to accommodate power supply to Bangunan Pentadbiran 1, Bangunan Asrama Fasa 1, Bangunan Akademik 1 and Kafeteria 1.

On the middle of 2001, TATiUC have upgraded the electrical infrastructure with additional Substation 2 (SS2) which have been installed with one (1) no. of SF6, 11kV, 20kA, 80A Ring Main Unit (RMU), two (2) nos of 11/0.415kV, 1000kVA oil immerse transformer, one (1) no. of Main Switch Board with 1600A busbar coupler and one (1) no. of standby generator set. This Substation 2 have been fed via second outgoing feeder and both Substation (SS1 & SS2) have been interconnected through high voltage power cable to be a one ring system. The equipments installed at each substation is summarize in a table below:

Substation 1		Substation 2	
i)	One (1) no. SF6, 11kV, 20kA, **63A** Ring Main Unit (RMU)	i)	One (1) no. SF6, 11kV, 20kA, **80A** Ring Main Unit (RMU)
ii)	Two (2) nos of 11/0.415kV, **750kVA** oil immerse transformer	ii)	Two (2) nos of 11/0.415kV, **1000kVA** oil immerse transformer
iii)	One (1) no. of Main Switch Board with 1250A busbar coupler	iii)	One (1) no. of Main Switch Board with 1600A busbar coupler
iv)	One (1) no. of standby generator set	iv)	One (1) no. of standby generator set

Table 1 : List of equipment for each substation

The outgoing load from the substations have been re-arranged to ensure that the load is under the acceptable radius and to avoid higher cost on power cable.

Some of the load need to be fed through new substation to accommodate the building extention such as Bangunan Pentadbiran which previously fed from Substation 1 but need to be re-routed to Substation 2 to cater the extention of Bangunan akademik 1 with additional Bengkel and Bilik Kuliah. The summarize of outgoing load from the substations is as follow:

Substation 1		Substation 2	
i)	Bangunan asrama & kafeteria fasa 1	i)	Bangunan pentadbiran Utama
ii)	Bengkel	ii)	Bangunan asrama & kafeteria fasa 2
iii)	Bangunan akademik & kuliah 1	iii)	Bangunan pentadbiran 2
		iv)	Bangunan akademik & kuliah 2

Table 2 : Outgoing load from each substation

On 2007 TATiUC have been honoured from Technical Institute to Technical University College, to accommodate the increased of intake students, development at the TATiUC had rapidly increased. So the infrastructure of the electrical system need to be revised and upgraded. Since the existing substation had fully occupied, TATiUC had appointed external consultant to re-consider on the power system infrastructure. After several meetings and discussions with the TATiUC and consultants for each project package, the appointed infrastruture consultant during that time had came out with better planning. The existing system is maintained with some modification on the cable route and additional two (2) substation (Substation 3 & Substation 4) were developed as another one ring system. To save the cost incurred in this project during that time, TATiUC has agreed to maintain the existing ring so the system is having two (2) different ring system. Any additional load in future as refers to the master plan development will need additional substation.
The system is as follows figure 3.2,

However, this study will only only focus on **substation 1 & 2** since the system had experienced major disturbance and facing a huge problem if any incoming feeder need to have a major shutdown.

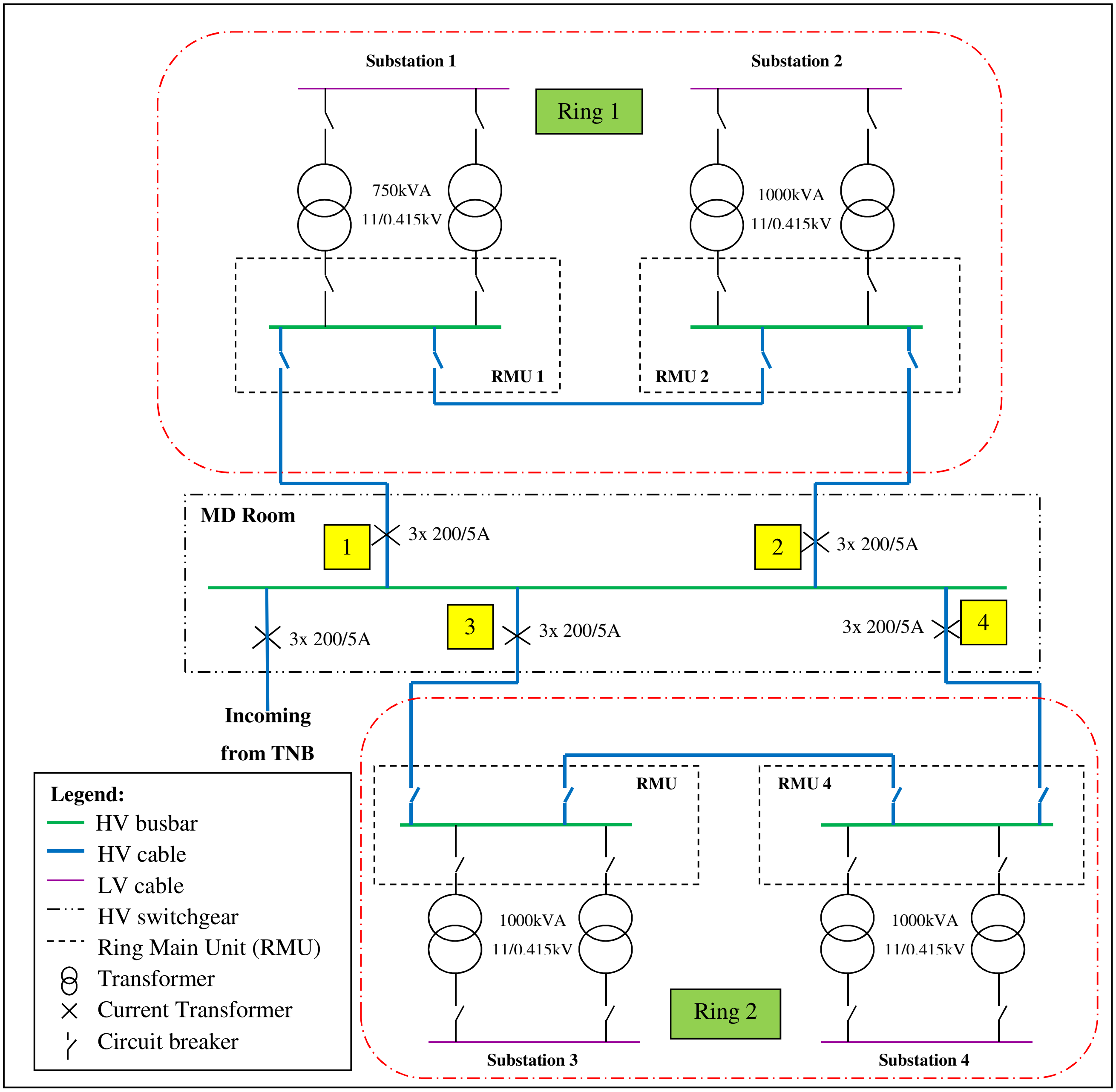

Figure 3-2 : Electrical System at TATiUC

3.2 Why the system need load shedding

In 2008, due to the thermal breakdown in underground HV power cable from MD Room to Substation 2 (the fault is as ilustrated in figure below). This situation had lead to the major shutdown at outgoing feeder 2 to perform cable jointing within 24 hours. During this period, some of the load have to be disconnected and only selected load is feeding by the ring system 1.

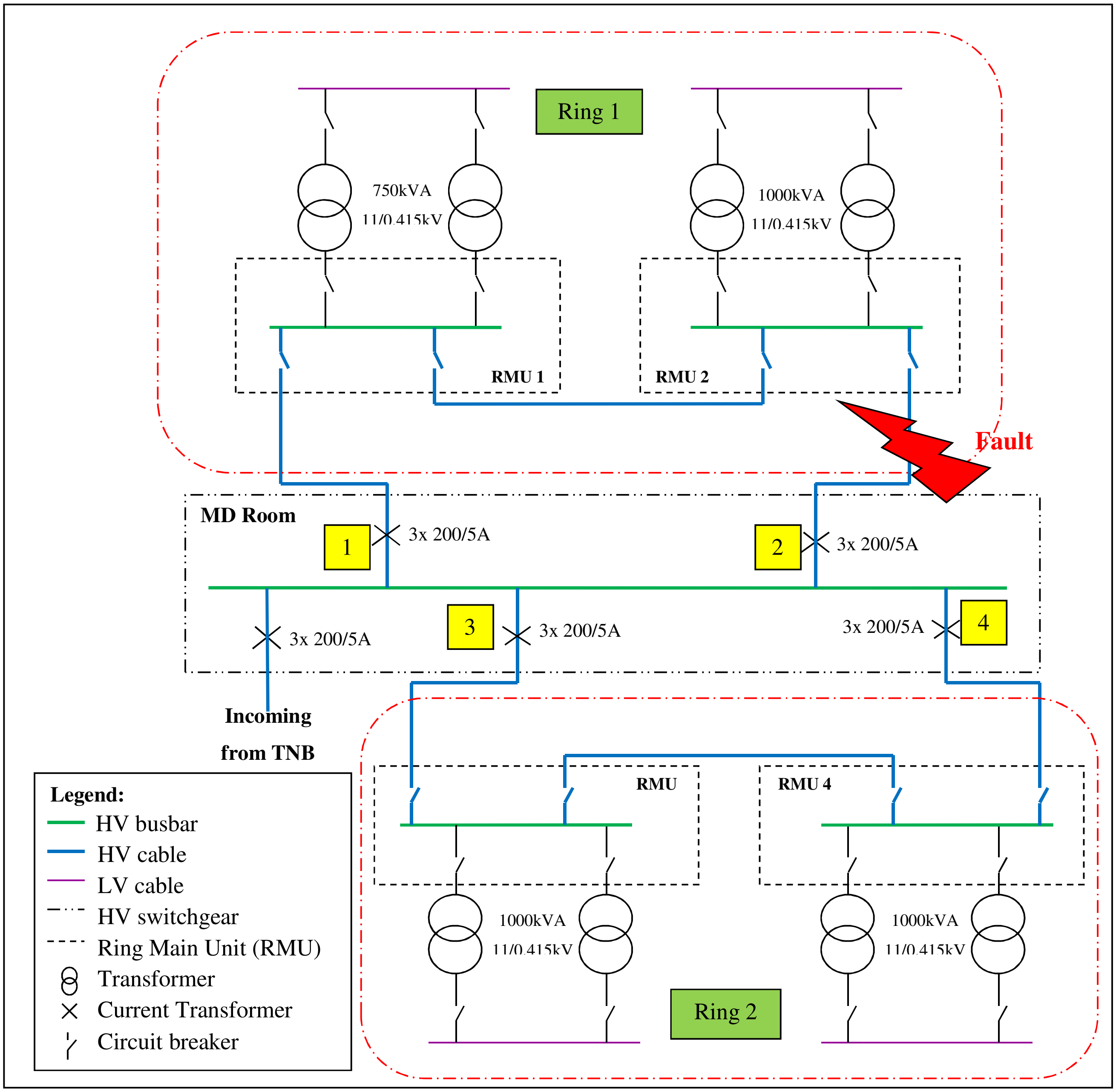

Figure 3-3 : Location of fault occurs.

During this situation, load to be disconnected is selected manually by the person incharge without any proper guideline. So, the Analytical Hirerchy Process (AHP) is the suitable method of doing selection during major similar shutdown in future as a reference to guide the person incharge.

3.3 Analytical hierarchy process (AHP)

Analytical Hierarchy Process (AHP) was developed by Professor Thomas L. Saaty in the 1970s and has been extensively studied and refined since then [19]. It is a method for solving complex decision making based on the alternatives and multiple criteria, as it names stated. It is also a process for developing a numerical score to rank each decision alternative based on how well each alternative meets the decision maker's criteria.

Nowadays, there are many versions of AHP existed. Originally, AHP was designed to calculate the nth root of the product of the pair-wise comparison values in each row of the matrices and then normalizes the aforementioned nth root of products to get the corresponding weights [19]. Meanwhile the modified AHP version normalizes the pair-wise comparison values within each of the matrices and then averages the values in each row to get the corresponding weights and ratings [19].

However both versions give almost the same results. For this research, the original method has been chosen to be implemented as the Multi Criteria Decision Making. Generally process of AHP analysis can be shown in three main steps.

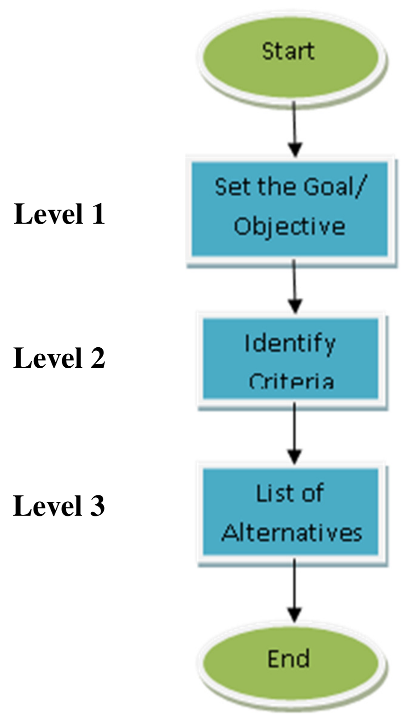

Figure 3-4 : Flow chart of the hierarchy structure

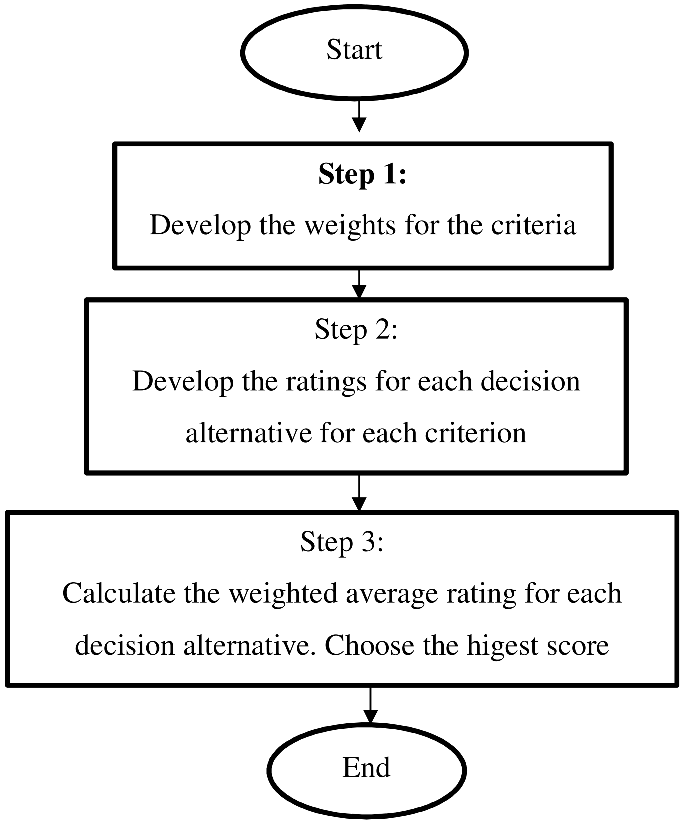

Figure 3-5 : Flow Chart of the AHP method

Step 1: Develop the weights for the criteria: [3],[8],[9]

a) First, develop a single pair-wise comparison matrix for the criteria as shown in the equation below:

$$A_C = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \end{array}, i = 1,2,....n;\ j = 1,2,....n \tag{3.1}$$

where, C1, C2, …,Cn representing the criteria,
aij represents the rating of Ci with respect to Cj

b) Then, multiply the values in each row together and calculates the nth root of the said product as shown in the equation below:

$$n^{th}\ root\ of\ product\ =\ \sqrt[n]{product\ of\ each\ row} \tag{3.2}$$

where n = positive integer number.

c) After that, normalizing the aforementioned nth root of products to get the appropriate weights by using the formula given in equation 3.3:

$$weight = \frac{n^{th}\ root\ of\ product}{\sum (n^{th}\ root\ of\ product)} \tag{3.3}$$

d) Lastly, perform the Consistency Ratio (CR) by using the formula as shown below:

$$CR = \frac{CI}{RI} \tag{3.4}$$

The value of Random index (RI) can be found using Table 3.1 where Random Index (RI) is a constant and it is a standard for AHP analysis.

Table 3.3: Table of Random index (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45

*Note: Value of C.R must be less than the allowable value of 0.10. Therefore, the consistency of the judgment matrix should be within an acceptable tolerance. But if the consistency ratio is greater than 0.10 then the subjective judgment needs to be revised.

While the value for Consistency Index (CI) can be found by using this equation:

$$CI = \frac{Lambda\_Max - n}{n - 1} \tag{3.5}$$

And for Lambda_Max,

$$Lambda\_Max\ =\ \sum(\sum column_{each\ alternative}\ x\ \ weight_{per\ row}) \tag{3.6}$$

where: *Σcolumn* is the summation of pair-wise values of each alternative vertically and *n* is a positive integer number.

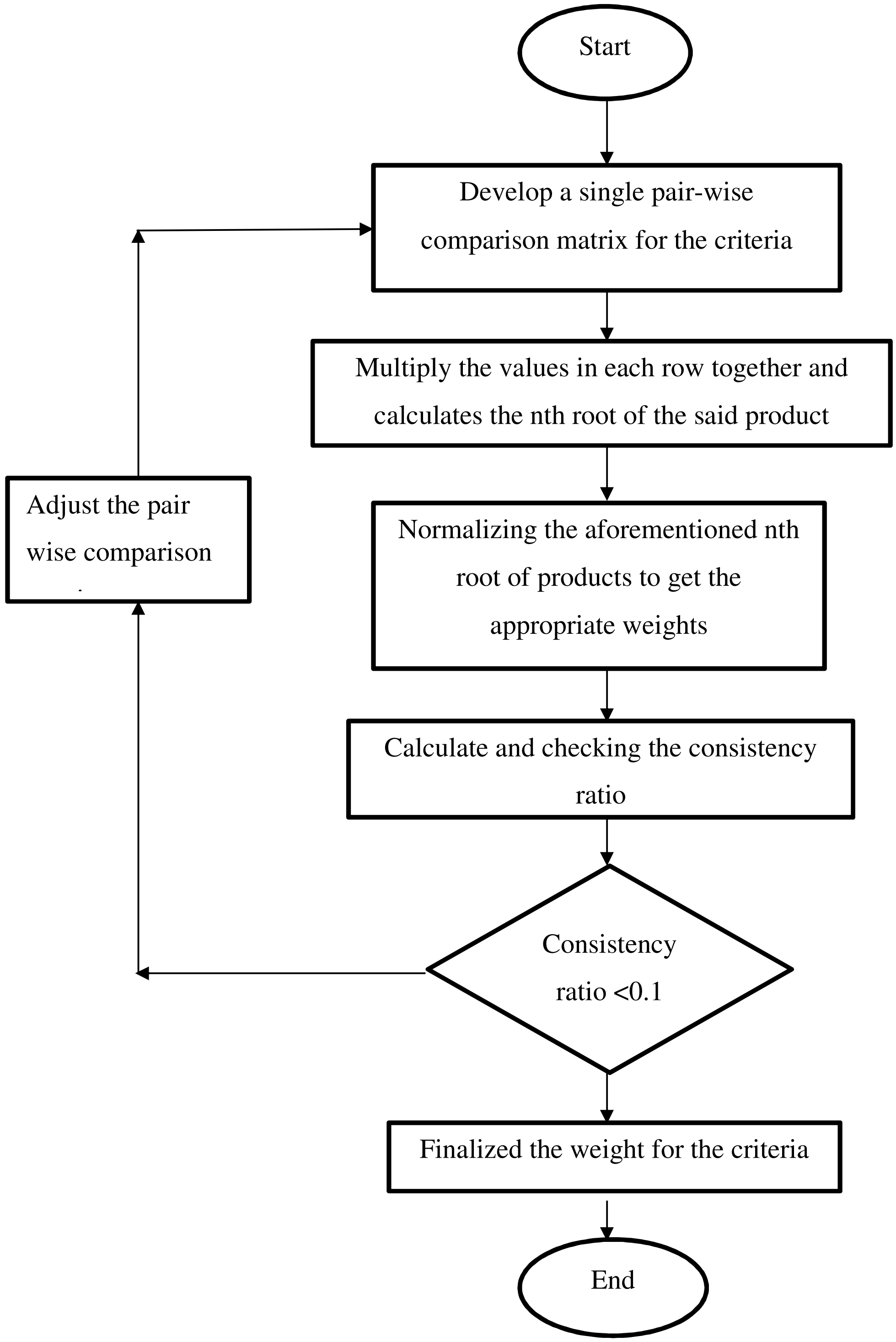

Figure 3-6 : Step 1 in AHP

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