ANALYTICAL HIERARCHY APPROACH FOR LOAD SHEDDING SCHEME OF AN ISLANDED POWER SYSTEM

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Dedicated to my beloved
parents, who sincerely raised me
with their gentle love.

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ABSTRACT

In general, the highly development environment in the society or the natural interruptions can cause loss of the power supply due to the burden of the generator. In industries, this can cause million of losses when the shortage of supply occurs. Usually, the supply will be back-upped in the storage system. If the over demand is uncontrolled, or when there is no decision-making in removing a certain load, there will be a trouble in the power system. Certain loads will be removed depending on some importance or criteria such as operating load and area power. This requires some decision-making in order order to choose the best load(s) to be cut off. In order to do that, Multi Criteria Decision Making (MCDM) can be applied in determination of the load shedding scheme in the electric power system. The objective of this thesis is to justify a load shedding scheme for an islanded power system. This thesis proposes methodologies for load shedding scheme for the islanded electric power system by using Analytic Hierarchy Process (AHP), Fuzzy Analytic Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In this thesis, the load shedding scheme is applied to several systems such as large pulp mill electrical system, IEEE 118 bus test case system, Selangor electrical system and Johore electrical system. Models are built up on the base of analysing correlative factors with examples given to indicate how the AHP, Fuzzy AHP and TOPSIS are applied. From this thesis, a series of analyses are conducted and the results are determined. Analyses are made, and the results have shown that AHP, Fuzzy AHP and TOPSIS can be used in determination of the load shedding scheme in pulp mill system, IEEE 118 bus system, Selangor system and Johore system. Among these three MCDM methods, the results shown by TOPSIS is the most effective solution because of the effectiveness of load shedding is the highest.

ABSTRAK

Secara umumnya, persekitaran pembangunan yang pesat dalam masyarakat atau gangguan semula jadi boleh menyebabkan masalah kehilangan bekalan kuasa yang membebankan penjana kuasa. Dalam industri, keadaan ini boleh menyebabkan kerugian apabila berlaku kekurangan bekalan. Biasanya, bekalan akan disandarkan dalam sistem penyimpanan. Jika permintaan berlebihan tidak dikawal, atau apabila tiada keputusan untuk mengeluarkan beban tertentu, akan menyebabkan masalah dalam sistem kuasa. Beban tertentu akan dikeluarkan bergantung kepada beberapa kepentingan atau criteria seperti beban operasi dan kawasan kuasa. Ini memerlukan beberapa cara membuat keputusan untuk memilih beban yang terbaik untuk diputuskan. Dalam usaha untuk berbuat demikian, *Multi Criteria Decision Making (MCDM)* boleh digunakan dalam penentuan skim penumpahan beban dalam sistem kuasa elektrik. Objektif tesis ini adalah untuk memperbaiki skim penumpahan beban yang sedia ada bagi sistem kuasa yang dipulaukan. Tesis ini mewajarkan kaedah skim penumpahan beban dalam sistem kuasa elektrik dengan menggunakan *Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (Fuzzy AHP)* dan *Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).* Dalam tesis ini, skim penumpahan beban digunakan dalam beberapa sistem seperti sistem elektrik kilang pulpa besar, sistem IEEE 118 bas, sistem elektrik Selangor dan sistem elektrik Johor. Model dibina di atas asas menganalisis faktor-faktor yang berkaitan dengan memberi contoh-contoh untuk menunjukkan bagaimana *AHP, fuzzy AHP* dan *TOPSIS* digunakan. Dari tesis ini, satu siri analisis akan dijalankan dan keputusan akan ditentukan. Analisis dijalankan dan keputusan menunjukkan bahawa *AHP*, *fuzzy AHP* dan *TOPSIS* boleh digunakan dalam penentuan skim penumpahan beban dalam sistem kilang pulpa, sistem IEEE 118 bas, sistem Selangor dan sistem Johor. Antara ketiga-tiga kaedah *MCDM*, keputusan *TOPSIS* memberi penyelesaian yang paling berkesan kerana keputusan keberkesanan penumpahan beban adalah yang tertinggi.

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LIST OF SYMBOLS AND ABBREVIATIONS

Σ	-	Summation
α	-	Value of fuzziness
et al.	-	And others
etc.	-	And the rest
m_i	-	Medium
n	-	Number
l_i	-	Lower limit
ui	-	Upper limit
CR	-	Alternative
M_i	-	Pairwise comparison ratio
S_i	-	Fuzzy synthesis extent
W	-	Weight
Y,Z	-	Column
ac	-	Alternating current
adt/d	-	Air-dried tons per day
kV	-	Kilovolt
AHP	-	Analytic Hierarchy Process
AP	-	Area power
CI	-	Consistency Index
CR	-	Consistency ratio
DCS	-	Distributed Control System
ETAP	-	Power system software
GIS	-	Gas Isolated Substation
GWh	-	Giga watt hour
HV	-	High voltage
Hz	-	Hertz
IEEE	-	Institute of Electrical and Electronic Engineers

IMS	-	Information Management System
L	-	Load
LP	-	Load power
LS	-	Load Shedding
LV	-	Low voltage
MCC	-	Motor Control Center
MCDM	-	Multi Criteria Decision Making
MW	-	Megawatt
MVA	-	Megavolt ampere
MVAR	-	Megavolt ampere reactive
NIS	-	Negative Ideal Solution
OP.	-	Operating
OL	-	Operating loads
PIS	-	Positive Ideal Solution
PS	-	Power Supply
RC	-	Relative closeness coefficient
REC	-	Rectifier
RI	-	Random Index
S	-	Apparent power
SCADA	-	Supervisory Control and Data Acquisition
SD	-	System Dynamics
SEM	-	Structural Equation Modeling
TG	-	Turbine Generator
TNB	-	Tenaga Nasional Berhad
TOPSIS	-	Technique for Order Preference by Similarity to Ideal Solution
TP	-	Total Power

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CHAPTER 1

INTRODUCTION

1.1 Project background

Load shedding occurs in places where the total electrical load power demand greatly exceeds the amount of power generated by the local power stations or national network power stations. If the load shedding was not done, the generator's overload breakers would automatically shut down the whole power station to protect its alternators from very severe damage. Such damage would be extremely expensive to repair and would take a lot of time to do it.

In general, load shedding can also be the number of loads that must almost instantly be removed from a power system to keep the remaining portion of the system operational. This load reduction is in response to a system disturbance and consequent possible additional disturbances that result in a generation deficiency condition. Common disturbances that can cause this condition to occur include faults, loss of generation, switching errors, lighting strikes, etc. [1].

In the modern large interconnected power system, there exists the possibility that under the certain condition, the whole system will be suddenly separated into several islands [2]. A sudden loss of generation due to abnormal conditions such as a generator fault or line tripping could disturb the balance between generations and loads resulting in the system frequency decline. The system power deficit could lead dangerously to the low speed of the generating set and might cause failure in turbines' blades [3].

Notifying that several power system blackouts have occurred recently over the world, voltage stability has become a major concern of power system operators.

Voltage stability refers to the ability of a power system to maintain steady voltages at all the buses in the system after being subjected to a disturbance from a given initial condition [4]. System blackout is the state when the system or large areas of it may completely collapse. This state is usually preceded by a sequence of cascading failure events that knock out transmission lines and generating units [5].

Voltage instability, in particular, results from the inability of the combined transmission and generation system to deliver the power requested by loads. It is a dynamic phenomenon largely drove by the load response to voltage changes. Load shedding is well known to be an effective countermeasure against voltage instability, especially when the system undergoes an initial voltage drop that is too pronounced to be corrected by generator voltages [6].

1.2 Problem statement

According to the statistics provided by Suruhanjaya Tenaga [7], the demand of the electric power was increasing year by year from 2005 to 2008. Figure 1.1 shows the total electricity sales of Tenaga Nasional Berhad (TNB) for the year 2005 to 2008. The total electricity sales increased 5.34% from 2005 to 2006, 5.65% from 2006 to 2007 and 3.85% from 2007 to 2008. The sales increased 15.58% within three years of total electricity sales.

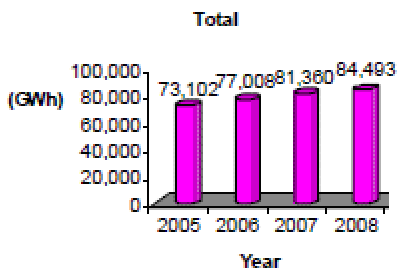

Figure 1.1: The total electricity sales (GWh) of TNB [7]

Figure 1.2 [7] to Figure 1.7 [7] show the electricity sales (GWh) of TNB according to the categories from 2005 to 2008. The sales for the domestic, commercial, industrial, public lighting and agricultural were increasing continuously. The sales increased 18.67% within three years for domestic, 5515 GWh or 25.44% within three years for commercial, 2,957 GWh or 7.97% within three years for industrial, 24.38% from 2005 to 2008 for public lighting and 294.74% for agricultural from 2006 to 2008. On the other hand, only the sales for mining decreased from year 2005 to 2007 but later increased in the year 2008.

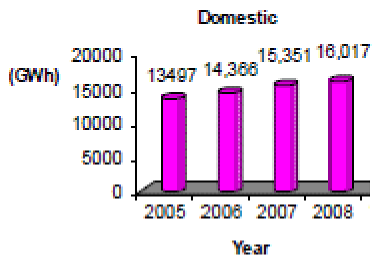

Figure 1.2: The total electricity sales (GWh) of TNB for domestic category [7]

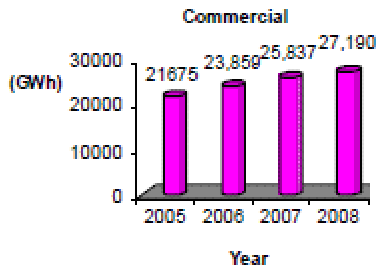

Figure 1.3: The total electricity sales (GWh) of TNB for commercial category [7]

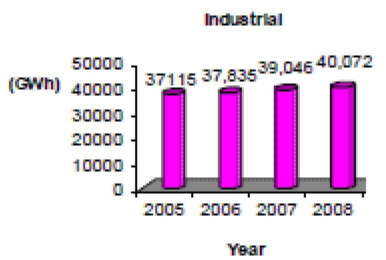

Figure 1.4: The total electricity sales (GWh) of TNB for industrial category [7]

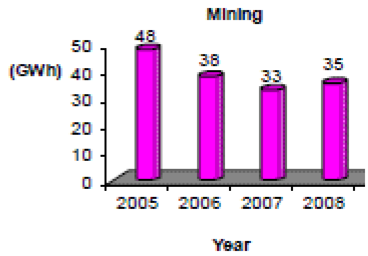

Figure 1.5: The total electricity sales (GWh) of TNB for mining category [7]

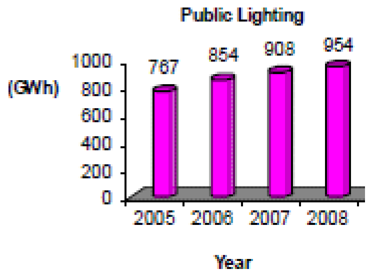

Figure 1.6: The total electricity sales (GWh) of TNB for public lighting category [7]

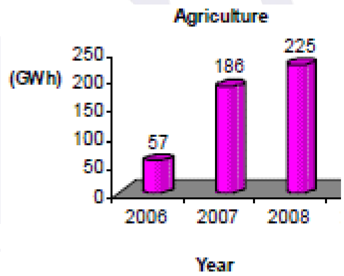

Figure 1.7: The total electricity sales (GWh) of TNB for agriculture category [7]

Figure 1.8 [7] shows the number of transmission system tripping in Peninsular Malaysia with a load loss of 50 MW and above for 2006 to 2008. There were six incidents of tripping without load shedding and one incident with load shedding in 2006, where as nine incidents of tripping without load shedding and one incident with load shedding in 2007. In 2008, six incidents of tripping without load shedding and no incident with load shedding. Therefore, load shedding is important in reducing the incidence of tripping.

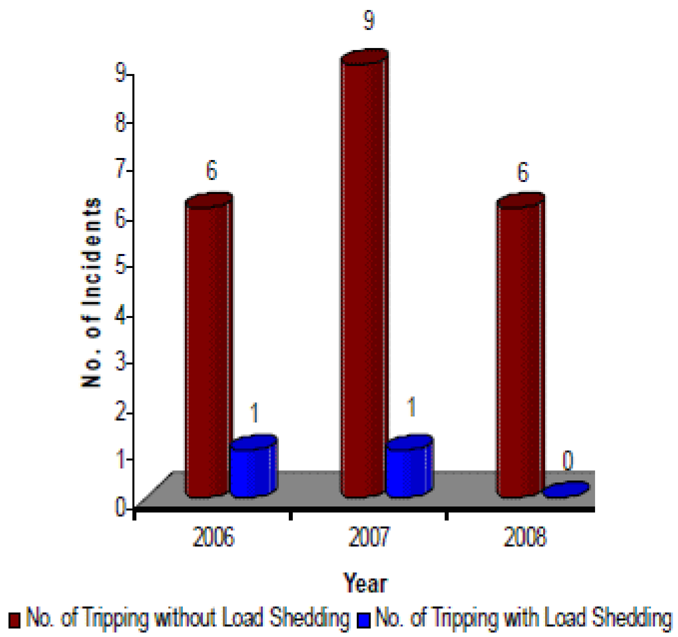

Figure 1.8: The number of transmission system tripping in Peninsular Malaysia with a load loss of 50 MW and above [7]

There are various causes of the electricity supply interruptions such as natural disasters, equipment failures, overload, damaged by third parties, maintenance works, unknown, trees and others. If the interruptions occurred, the electricity Supply Company should take actions to maintain the distribution of the electricity supply of the unaffected area. The company should reduce the interruptions as minimum as possible.

As consumers, people are desired to have continuously distributed electricity supplies without any interruption. For example, the industry will lose a lot of income if there are shortages in the electricity supplies. This thesis will present a system with load shedding scheme for islanded power systems to overcome the problem during electricity interruptions.

This thesis will present a system with load shedding scheme for islanded power system to overcome the problem during electricity interruptions.

1.3 Project objectives

There are three objectives for this project:

(i) To justify a load shedding scheme for the power system.

(ii) To implement multi-criteria decision-making methods such as AHP, fuzzy AHP and TOPSIS in the load shedding scheme.

(iii) To compare the effectiveness of multi-criteria decision making methods in load shedding scheme.

1.4 Project scope

The purpose of this thesis is to identify the load shedding scheme in an islanded power system. A systematic approach is developed to identify the priority based on the impact of the power system state. Therefore, this thesis will focus on the analysis of power system outages.

The criteria for the determination of "worst case" will be the total load shedding in the post-fault system. The contingencies will cover all possible scenarios, including those which will lead to the islanding of the power system.

1.5 Contribution and claims of originality

The research has proposed and developed a systematic approach by identifying the power system dynamic vulnerability under extreme conditions, for example, with the loss of two or more power supplies. The proposed methods have the following unique features:

(a) New method

The Analytical Hierarchy Process (AHP), Fuzzy Analytical Hierarchy Process (Fuzzy AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) under the Multi-Criteria Decision Making (MCDM) methods are the newly methods that have been used in the load shedding scheme for an islanded power system.

(b) Simplified

The methods that have been applied (AHP, Fuzzy AHP and TOPSIS) are simpler in concept as the load shedding decision is determined based on the information such as criteria and alternatives.

(c) Easy

The methods proposed are easily been applied to the load shedding scheme. The calculation from the analysis is quite simple with a few steps only.

1.6 Related research for load shedding

Table 1.1 shows the pervious research about the load shedding. Shokooh *et al.* [1] studies about an intelligent load shedding system application in a large industrial facility. They noticed that the conventional methods of system load shedding are too slow and do not effectively calculate the correct amount of load to be shed. An intelligent load shedding scheme is proposed and comparison is done between intelligent load shedding and conventional load shedding methods.

The disadvantages of Under Frequency Load Shedding (UFLS) with a specific example are illustrated and the factors affecting the frequency dynamics are explained by Shi *et al.* [2]. The concept of Wide Area Measurement System (WAMS)-based load shedding is proposed, and preliminary work on that area is described. Dadashzadeh & Sanaye-Pasand [3] do the simulation and investigation of load shedding algorithms for a real network using dynamic modeling. Several conventional and dynamic load shedding scheme are examined and compared by Dadashzadeh & Sanaye-Pasand.

Amraee *et al.* [4] proposed an improved model for optimal under voltage load shedding. The approach proposed is based in the concept of the static voltage stability margin and its sensitivity value at the maximum loading point or the collapse point. Dola & Chowdhury proposed intentional islanding and adaptive load shedding to avoid cascading outages. The line outages that lead to disastrous consequences are determined, while the intentional islanding scheme and load shedding schemes have been explored.

Cutsem & Vournas [6] provides an overview of emergency voltage stability controls in power systems. Voltage instability mechanisms, countermeasures and system protection schemes are discussed as well as various aspects of emergency

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