RISK ASSESSMENT IN POWER SYSTEM USING MULTI-CRITERIA DECISION MAKING (MCDM) METHODS

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For my beloved family and friends

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ABSTRACT

In recent years, immense power system outage events have happened across the world. This is not exceptional to the Malaysia power system whereby on 27 Jun 2013 the system blackout occurred in the state of Sarawak, due to sudden dropping of frequency. Hence, power system risk assessment has become an important and mandatory task in planning, operation, maintenance and asset management of utilities. There have been efforts devoted in searching for new methods and procedures that effectively evaluate the risk of a power system. The objective of this study is to rank and determine the most common cause of power loss outages in the grid. This study implements multi criteria decision-making methods such as Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). For data collection, it employed interviews of key participants, review of documents including unpublished official reports and annual reports. From the data collected there are four criteria identified, namely Duration Time (min), Estimated Maximum Loss of load (MW), Estimated Energy No Supplied (MW-min) and System Minutes. On the other hand, seven causes of power loss outages are identified, they are Treat To System Security, Equipment Failure, Fire or Explosion, Switching Risk, Tower Collapse, Accelerated Ageing of Equipment and Supervisory Control System Failure. Results of data analysis show that both methods have identified that Equipment Failure is the major cause, followed by Supervisory Control System Failure.

ABSTRAK

Beberapa tahun kebelakangan ini, beberapa gangguan bekalan elektrik yang besar berlaku di seluruh dunia. Negara Malaysia tidak terkecuali daripada perkara ini di mana pada 27 Jun 2013, gangguan bekalan elektrik yang besar berlaku di negeri Sarawak yang melibatkan penurunan frekuensi bekalan. Maka, penilaian risiko untuk sistem kuasa telah menjadi satu usaha yang penting dan wajib diadakan semasa perancangan, operasi, penyenggaraan, dan pengurusan aset untuk sistem elektrik. Pelbagai usaha telah dilakukan untuk mencari kaedah dan prosedur baru untuk menilai risiko ke atas sistem kuasa . Objektif kajian ini ialah untuk membuat penarafan dan mengenalpasti punca utama berlakunya gangguan bekalan elektrik pada grid. Kajian ini menggunakan kaedah penentu-keputusan pelbagai kriteria seperti *Analytic Hierarchy Process* (AHP) dan *Technique for Order Preference by Similarity to Ideal Solution* (TOPSIS). Bagi pengumpulan data, kaedah temubual dengan pihak yang terlibat dan rujukan dokumen yang berkaitan seperti laporan rasmi dan laporan tahunan telah dilakukan. Daripada data yang diperolehi, empat kriteria berkenaan gangguan bekalan elektrik telah dikenalpasti iaitu *Duration Time (min), Estimated Maximum Loss of load (MW), Estimated Energy No Supplied (MW-min)* dan *System Minutes*. Selain itu, tujuh punca bagi gangguan bekalan elektrik turut dikenalpasti iaitu Ancaman kepada Keselamatan Sistem, Kerosakan peralatan, Kebakaran atau Letupan, Risiko Pensuaian, Keruntuhan Menara, Peralatan yang telah berusia, dan Kegagalan Sistem Kawalan Penyeliaan. Analisis data yang diperolehi menggunakan kedua-dua kaedah yang dinyatakan (AHP dan TOPSIS) menunjukkan Kerosakan Peralatan sebagai punca utama gangguan, diikuti oleh Kegagalan Sistem Kawalan Penyeliaan.

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LIST OF SYMBOLS AND ABBREVIATIONS

UTHM	-	Universiti Tun Hussein Onn Malaysia
C_n	-	criteria
A_n	-	alternative
r_{ij}	-	normalized decision matrix
x_{ij}	-	rating A_i with respect to criterion C_j
v_{ij}	-	weight normalized decision matrix
w_{ij}	-	criteria weight
S_i	-	ideal solution
S_{ni}	-	negative ideal solution
RC	-	relative closeness
W_c	-	criteria weight
CR	-	consistency ratio
λ_{max}	-	criteria in risk assessment
CI	-	consistency index

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CHAPTER 1

INTRODUCTION

1.1 Project background

Power system is a complex and large-scale nonlinear dynamic system. With the improvement of the functions of modern power system, the structure of the system is increasingly moving towards high degree of automation and involves with high-voltage, long distance and large-capacity power. However, random failure sometimes appear in the system components, causes the system to function with some or all loss. Therefore, the risk prevention of power system operation has become an important and complex task

The application of power system risk assessment has drawn ever-increasing interest in the electric utility industry, particularly since massive power outage events have occurred across the world in the past years. According to an EPRI (Electric Power Research Institute) report based on the national survey in all business sectors, the U.S. economy alone is losing between $104 and $164 billion a year due to power system outages. Severe power outage events have happened frequently in recent years. For instance, a major system disturbance separated the Western Electricity Coordinating Council (WECC) system in the west of north America into four islands on August 10,1996, interrupting electricity service to 7.5 million customers for period of up to nine hours. The 1998 blackout at the Auckland central business district in New Zealand impacted 30 square blocks of the downtown area for about two months, resulting in lawsuits totalling $600 million against the utility. On August 14, 2003, the massive blackout in the east of North America covered eight states in the United States and two provinces in Canada, bringing about 50 million people into darkness for periods ranging from one to several days. This is not exceptional to the Malaysia power system whereby on January 13, 2005 the system blackout occurred due to cascading overloads (The STAR, 2005). In Sabah, on April 21, 2008, a transmission tower collapse triggered a major power blackout throughout the state (The STAR, 2008) and recently, a massive power outage caused by frequency dip occurred in Sarawak on June 27, 2013 (The STAR, 2013).

Due to this, risk assessment has become a challenge and an essential business in the power utility industry today.

1.2 Problem statement

According to the statistics Figure 1.1 provided by *Suruhanjaya Tenaga* 2011 report, system minutes of the grid system in Sabah has been increased significantly from 98.6% to 40.13 minutes and thus affecting the reliability of the whole supply system.

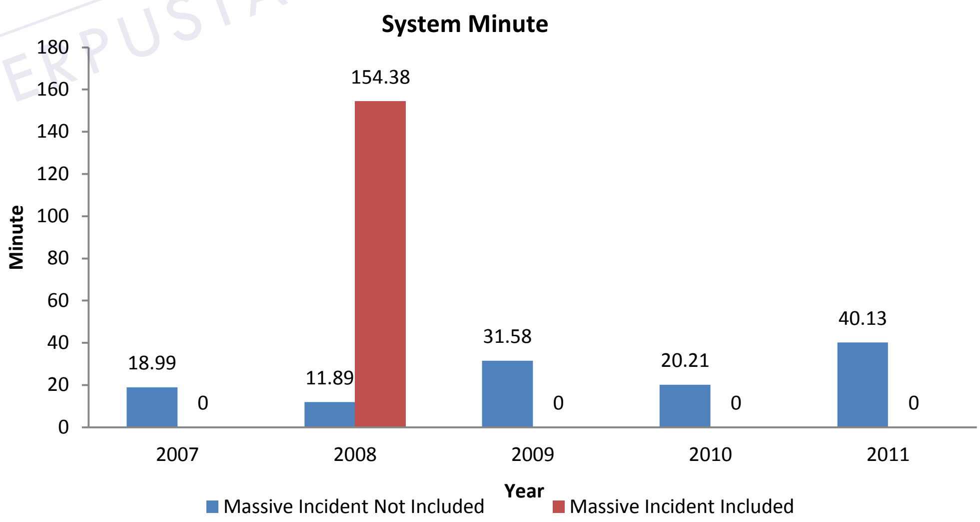

Figure 1.1 : System minutes in Sabah

Figure 1.2, Figure 1.3 and Figure 1.4 shows that the number of unplanned interruptions per 1,000 customers has increased by 5.0% to 50.4% in Sabah for year

2011. The unplanned interruptions scored the highest percentage of 92% from the total interruption in year 2011.

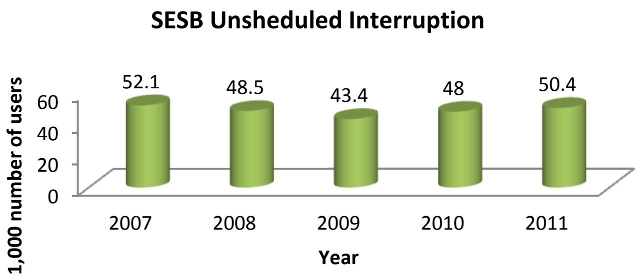

Figure 1.2 : Unplanned interruption per 1,000 customers

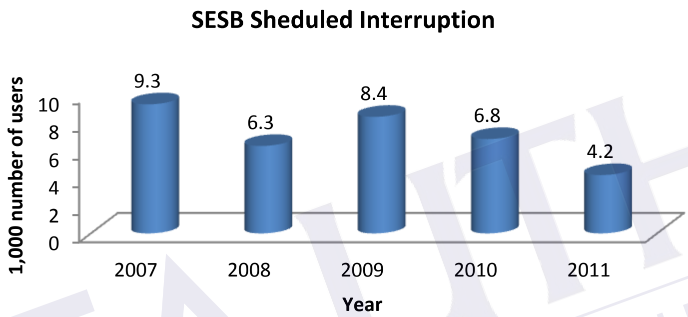

Figure 1.3 : Planned interruption per 1,000 customers

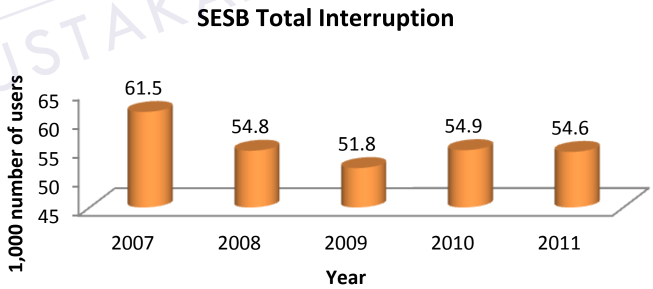

Figure 1.4 : Total interruption per 1,000 customers

There are various causes of the electricity supply interruptions such as natural disasters, equipment failures, overload, damaged by third parties, process and quality of work, trees, unknown causes, and others. If the most common cause of the electricity supply interruption can be identified, SESB could take preventive action to reduce the interruptions, as consumers demand to have an uninterruptable power supply.

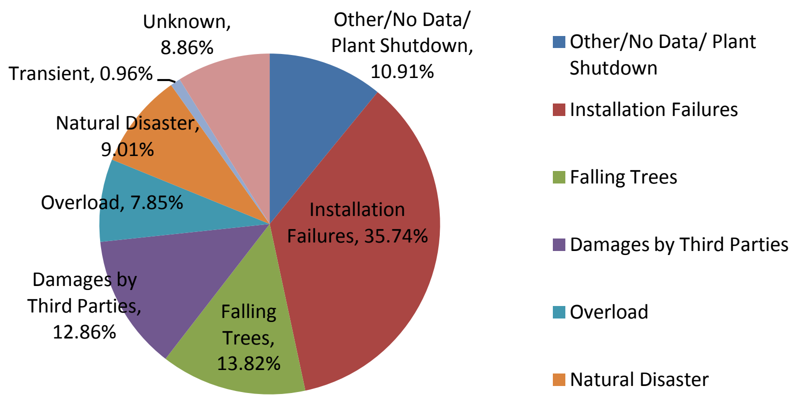

Figure 1.5 : Causes of Unscheduled Supply Interruption

This thesis will identify the most common cause of power outages and identify the most suitable method of risk assessment in the transmission power system.

1.3 Project objectives

There are two objectives for this project:

(i) To determine the most common cause of power outages in the grid

(ii) To implement multi criteria decision-making methods such as AHP and TOPSIS

1.4 Project scopes

The purpose of this thesis is to determine the most common cause of power system outages in the grid using multi criteria decision making. This thesis will only focus on the risks in transmission line of the power system. The data analyzed is obtained from SESB. Consequently, it will develop a systematic approach to identify the priority based on the risk impact of the power system.

1.5 Contribution and claims of originality

The research has identify the most common cause of power system outages in the grid, thus SESB should take preventive action to reduce the interruptions as maximum as possible.

1.6 Thesis outline

The subsequent chapters of the thesis are organized as follow :

Chapter 1 highlights the occurrence of power-outages events in several countries around the world, statistics of an unplanned electricity interruption in Sabah, and the various causes of the electricity interruption in year 2011. The objectives of this thesis are stated in this chapter.

Chapter 2 is the literature review of this project. This review begins with the fundamental concepts of power system security and progresses through security assessments of different time frames. The deterministic and probabilistic approaches to security assessment are addressed and the limitations of each of these approaches are highlighted. The literature on the risk-based security assessments is also reviewed.

Chapter 3 discusses about the project procedure and also approach used to implement the project.

Chapter 4 shows the results and data analyses. The risk assessment monitoring in electrical power system by using the Analytic Hierarchy Process (AHP) and TOPSIS is discussed in this chapter.

Chapter 5 presents the project discussions, conclusions and recommendations. This chapter will discuss about the conclusions of the project and also some future recommendations.

1.7 Summary

This chapter of this thesis discusses about the introduction for the whole project. Firstly, the power-outages events are introduced in the first part. Next, the problem statement is discussed. Then, the next part is about the objectives and scopes of the project. Lastly, the thesis outline is discussed which will give an overview for the reader about the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The fundamental objective of an electric power system is to supply its customers with electrical energy as economically as possible and with a reasonable assurance of continuity and quality. To maintain such security standards the power systems are required to be reliable.

Power system reliability reflects the adequacy and security in a power system (Billinton & Li, 1994), (Billinton, Firuzabad & Aboreshaid, 1997). Adequacy with regard to composite generation and transmission relates to the existence of both sufficient generation capacity to supply the energy demand and of the associated transmission facilities required to transport the energy to the major system load points. Security relates to the ability of the system to withstand unexpected failures and continue operating without interruption of supply to the consumers (Kirschen, 2002), (Knight, 2000). Security assessment is a major concern in planning and operation of electric power systems.

The following sections of this chapter, review the literature relevant to this exploration of security issues. In particular, it covers the fundamental concepts of power system security, the deterministic and probabilistic approaches to security, and the techniques used in adequacy and security assessments. It focuses mainly on the probabilistic framework for system security, in the context of power system operation.

2.2 Power System Security

Power system security is usually assessed on the basis of security standards, i.e., the relationship between outages of generation and transmission plant and the level of any acceptable loss of demand. An 'N-1' security standard requires the system to work satisfactorily following loss of any one of its N elements (Strbac, 2001).

Loading on transmission system under normal operating conditions must be limited to levels that permit any "credible contingency" to occur without exceeding acceptable power quality, component or system limits (Strbac, 2001).

Contingencies may be external or internal events (for instance, faults subsequent to lightning versus operator-initiated switching sequences) and may consist of small/slow or large/fast disturbances (for example, random behaviour of the demand pattern versus generator or line tripping) (Wehenkel, 1997).

Usually, numerical simulation of the contingency scenario is used to assess the effect of a contingency on a power system in a given state. However, the non-linear nature of the physical phenomena and the growing complexity of real-life power systems make security assessment difficult. For example, monitoring a power system every day calls for fast sensitivity analysis to identify the salient parameters driving the phenomena, and suggestions on how to act on the system so as to increase its level of security (Wehenkel, 1997).

On the other hand, increasing economic and environmental pressures make the conflicting aspects of security and economy even more challenging as instead of building of new transmission lines and generation facilities, operators tend to operate power systems more closer to the critical limits (Wehenkel, 1997).

Every small change in load is a disturbance that causes a change in system conditions. However, system security is assessed for larger changes that cause major changes in system conditions. These changes are mainly caused by contingencies. Most commonly contingencies result in relay operations that are designed to protect the system from faults or abnormal conditions. Typical relay operations result in the loss of a line, transformer, generator, or major load (McCalley, 2000).

Various components in a power system respond to changes that occur and may reach an equilibrium condition that is acceptable according to some criteria. Mathematical analysis of these responses and the new equilibrium condition is called security analysis (McCalley, 2000).

The decision drivers of security can be classified as shown in Figure 2.1 and the corresponding time frames for making security related decision are given in Table 2.1.

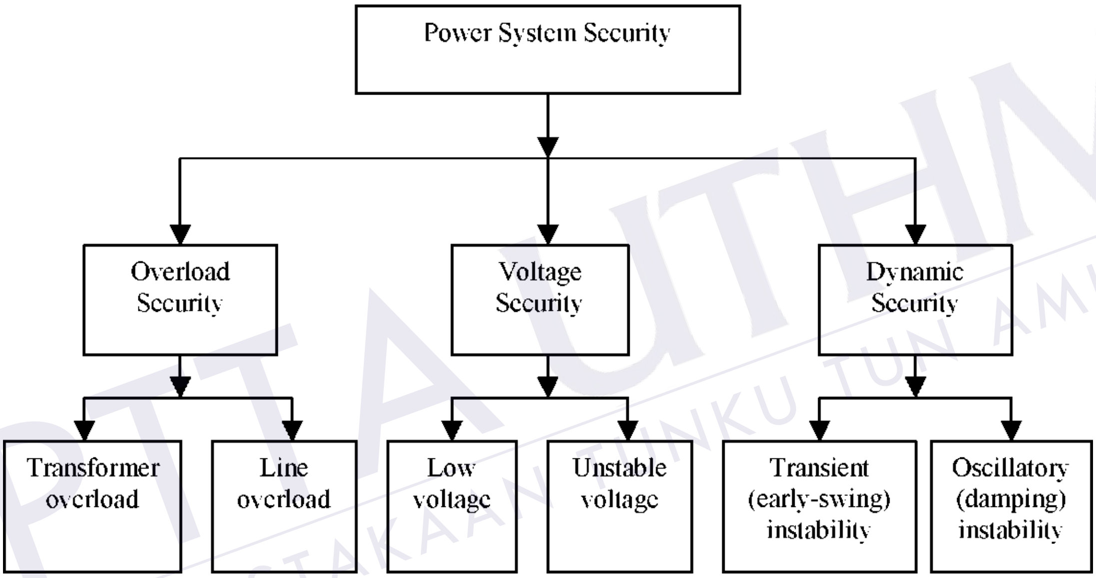

Figure 2.1 : Decision drivers of power system security

Table 2.1 : Security related decisions

Time-frame	Decision-maker	Decision	Basis for decision
On-line assessment (Minutes to hours)	Operator	How to constrain the economic operation to maintain the normal state?	Operating rules, online assessment, and cost
Operational planning (Hours to months)	Analyst	What should be the operating rules?	Minimum operating criteria, reliability, and cost
Planning (Months to years)	Analyst	How to reinforce/maintain the transmission system?	Reliability criteria for system design and cost

If the analysis evaluates only the expected post disturbance equilibrium condition (steady-state operating point), then it is called Static Security Assessment (SSA). Static or steady state security is the ability of the system to supply load without violating operating conditions and load curtailment (Kirshen, 2001), (Kim & Singh, 2002).

If the analysis evaluates the transient performance of the system as it progresses after the disturbance, then it is called Dynamic Security Assessment (DSA) (Grigsby, 2001), (Silva *et al*., 1999), (Ejebe *et al*., 1998). Further, the DSA has been formally defined by the IEEE, Power Engineering Society (PES) working group on DSA as an evaluation of the ability of a certain power system to withstand a defined set of contingencies and to survive the transition to an acceptable steady state condition. Dynamic security considers the ability of the system to supply the load against system dynamic problems of early swing, transient instability and oscillatory instability (Kirshen, 2001), (McCalley, Vittal & Abi-Samra, 1999).

Voltage security is the ability of a system, not only to operate in a stable manner, but also to remain stable (maintenance of system voltage) following any reasonable credible contingency or adverse system change (Kirshen, 2001), (Knight,2000). Voltage security analysis is performed to investigate whether any contingency triggers a voltage collapse (Kirshen, 2001).

SSA can be used quickly to determine if a system is insecure by simply looking at the static outcome of each contingency. However, to know whether the system is fully secured, DSA must be performed. It determines if the associated dynamics of each contingency are acceptable.

A power system always resides in one of four states called normal, alert, emergency, and restorative. The emergency state can be extreme, temporary, or controlled (Fink & Carlsen, 1978). The importance of the four security states is that they provide a conceptual basis for making security-related decisions. This basis rests on the assumption that any normal state is acceptable and any other state is unacceptable. Figure 2.2 shows the power system states and the corresponding actions.

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