

ASSET MANAGEMENT DECISION MAKING OF POWER TRANSFORMER  
WITH INSULATION AGIENG KNOWLEDGE

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A project report submitted in partial fulfillment of the  
requirement for the award of the degree  
Master of Electrical Engineering



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Faculty of Electrical and Electronic Engineering  
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JANUARY 2013

## ABSTRACT

Transformer represents a substantial asset. Transformer's ageing has recently become a great concern and challenge to all electric utilities around the world. Utilities today face the twin challenges of satisfying increasingly high standards for reliability and service quality while at the same time reducing costs and improving earnings. Asset management has been recognized as their framework for allocating capital and operation/maintenance budgets. The challenge is to align the business requirement and the scientific and technical knowledge of the assets in order to make business decisions. There are various management concepts, maintenance methodologies and asset technical evaluations that are currently exist and practiced in the industries. The focus of this project is to align transformer ageing knowledge to the business process of asset management. The methodology employed to produce the decision making process is through integration and application of existing knowledge in asset management with PAS 55 as a benchmark. As a result, an asset manager's decision making process is proposed, which link the business requirement and technical knowledge of asset condition, using risk-based management. By linking these requirements, asset managers will be able to quantify risk, justify expenditures which will meet the technical requirement of asset condition and in line with the business plan.



## ABSTRAK

Pengubah mewakili asset yang besar. Penuaan pengubah menjadi suatu kebimbangan dan cabaran yang besar terhadap pembekal elektrik seluruh dunia. Kini, pihak organisasi menghadapi cabaran dalam memenuhi pencapaian piawaian yang tinggi bagi kebolehpercayaan dan kualiti perkhidmatan manakala pada masa yang sama menitikberatkan pengurangan kos dan penambahan pendapatan. Pengurusan Aset telah di perkenalkan sebagai rangka kerja bagi melakukan peruntukan belanjawan modal dan operasi/penyelenggaraan. Cabarannya adalah dalam melakukan penyelarasan keperluan perniagaan berkadaran dengan pengetahuan saintifik dan teknikal aset dalam usaha untuk membuat keputusan perniagaan. Terdapat pelbagai konsep pengurusan, kaedah penyelenggaraan dan aset penilaian teknikal yang wujud serta diguna pakai oleh pihak industri. Tujuan utama projek ini adalah untuk menyelaraskan pengetahuan mengenai penuaan pengubah dengan proses perniagaan berdasarkan pengurusan aset. Kaedah yang digunakan untuk menghasilkan proses membuat keputusan adalah melalui integrasi dan penggunaan pengetahuan yang sedia ada dalam pengurusan aset dengan menjadikan PAS 55 sebagai penanda aras. Berikutan itu, proses membuat keputusan pengurus aset adalah dicadangkan, dengan menghubungkan keperluan perniagaan dan pengetahuan teknikal keadaan aset, berpandukan pengurusan berasaskan risiko. Oleh itu, dengan menghubungkan keperluan ini, pengurus aset akan dapat menganggar risiko, memberikan ramalan perbelanjaan yang akan memenuhi keperluan teknikal keadaan aset dan selaras dengan pelan perniagaan.



## CONTENTS

<b>TITLE</b>	<b>i</b>
<b>DECLARATION</b>	<b>ii</b>
<b>DEDICATION</b>	<b>iii</b>
<b>ACKNOWLEDGEMENT</b>	<b>iv</b>
<b>ABSTRACT</b>	<b>v</b>
<b>ABSTRAK</b>	<b>vi</b>
<b>TABLE OF CONTENT</b>	<b>vii</b>
<b>LIST OF FIGURES</b>	<b>viii</b>
<b>LIST OF TABLES</b>	<b>x</b>
<b>LIST OF SYMBOLS AND ABBREVIATION</b>	<b>xi</b>
<b>CHAPTER 1 INTRODUCTION</b>	
1.1 Transformer	1
1.2 Asset Management	2
1.3 Problem Statement	3
1.4 Aim and Objective of the Project	5
1.5 Project Scope	5
1.7 Outline of the Thesis	6
<b>CHAPTER 2 LITERATURE REVIEW</b>	
2.1 Introduction	8
2.2 Asset	8
2.3 Asset Management	9
2.4 Business Process	10
2.5 Asset Management Standard – PAS 55	10
2.6 Previous Research	14
2.6.1 A Framework Linking Insulation Ageing and Power Network Asset Management.	14
2.6.2 Smart Asset Management of Ageing Devices in	



PT TAA UTHM  
PERPUSTAKAAN TUNKU TUN AMINAH

Energy System: A Case Study of Transformers.	15
2.6.3 Asset Management Techniques.	16
2.6.4 Incorporating Ageing Failures in Power System Reliability Evaluation.	16
2.6.5 Asset Management Techniques for Transformers	17
2.7 Comparison between the previous researches	18
<b>CHAPTER 3 METHODOLOGY</b>	
3.1 Introduction	21
3.2 Research Flow Chart	21
3.3 Asset Condition, Maintenance and Ageing	23
3.4 Maintenance methodology	25
3.5 Ageing Process and Condition Assessment	28
3.6 Ageing effect to reliability evaluation	29
3.7 Health Index	31
<b>CHAPTER 4 ASSET MANAGEMENT DECISION MAKING</b>	
4.1 Introduction	34
4.2 Asset Deterioration and Ageing Processes	35
4.2.1 How equipment ageing	35
4.2.2 Expected life and factors that affect it	36
4.3 Risk Management	38
4.4 Condition Based Risk Management (CBRM)	40
4.5 Criticality assessment	41
4.6 Life cycle cost	44
4.6.1 Net Present Value	44
4.7 Optimization	45
4.8 Business Perspectives on Asset Management	47
<b>CHAPTER 5 CONCLUSION</b>	
5.1 Asset Manager's Decision Making Process	50
5.2 Linking Business Plan and Asset Knowledge	50
5.3 Asset Management Decision – Consume, Prolong, Replace	52
5.4 Example of evaluation method	56
5.5 Case studies	58
5.5.1 Case 1: Consequence of Failure (COF)	



PTTA AUTHM  
PERPUSTAKAAN TUN TUN AMINAH

effect decision making	59
5.5.2 Case 2: Reliability, Risk and Maintenance Intervention	62
5.5.3 Case 3: Time based vs Condition based Maintenance	63
5.5.4 Case 4: Ageing Effect on Transformer reliability	65
5.5.5 Case 5: Ageing Effect to Maintenance Program	66
5.6 Discussion	67
<b>CHAPTER 6 CONCLUSION</b>	
6.1 Overview	72
6.2 Further studies recommendation	73
<b>REFERENCES</b>	74
<b>APPENDIX A: Consequence of Failure</b>	77
<b>APPENDIX B: Probability of Failure</b>	80
<b>APPENDIX C: Failure Data</b>	82
<b>VITA</b>	



**PTTA UTHM**  
PERPUSTAKAAN TUNKU TUN AMINAH

## LIST OF FIGURES

2.1	APDC Chart by PAS 55	11
2.2	Continual Improvement by PAS 55	12
3.1	Flowchart process of produce decision making	22
3.2	Asset management layer of the model	23
3.3	Two life curves for the same equipment under two different maintenance policies	24
3.4	Life curve of and equipment with different ageing rate	24
3.5	Classification of Maintenance Strategy	26
3.6	Framework to insulation ageing by author	28
3.7	Actual Health Index Results for a group of power transformer	33
4.1	Damage in oil insulation	36
4.2	Influences affecting ageing	37
4.3	Risk Management Process from Risk Management Standard	39
4.4	CBRM systematic and Objective process	41
4.5	Risk Assessment Table	43
4.6	Influence diagram for the option selection problem	45
4.7	Optimization which relates to optimum business impact	46
4.8	Relationship between Business Plan, Asset Manager and Physical Asset by author	47
4.9	Relationship between Business plan and Asset Manager by author	48
5.1	Asset Management and Business Plan (by the author)	51
5.2	Asset Manager's Decision Making Process (by the author)	55
5.3	Relationship between Reliability and Risk	62
5.4	The effect of Time based maintenance to Reliability and Risk	63
5.5	The effect of Condition based maintenance to Reliability and Risk	64

5.6	Ageing effect on reliability of transformer with different age	65
5.7	Ageing Reliability with CBM for 3 year old transformer	66
5.8	Ageing Reliability with CBM for 27 years old transformer	66
5.9	Asset Manager's decision making process flow diagram (By the author)	71



PTTA UTHM  
PERPUSTAKAAN TUNKU TUN AMINAH



## LIST OF TABLES

2.1	Five layers Framework	14
2.2	Decreasing priority of condition monitoring of transformers	15
2.3	Comparison of the previous researches	18
3.1	Health Index and Transformer Expected Lifetime	32
4.1	Example of criticality factors for different consequence	42
5.1	Quantify the “Consequence of Failure”.	56
5.2	Criticality due to Consequence of failure	57
5.3	Severity due age of equipment compared to design age	58
5.4	Estimated Magnitude of Large Power Transformers in 2011	60



PTTAUTHM  
PERPUSTAKAAN TUNKU TUN AMINAH

## LIST OF SYMBOLS AND ABBREVIATION

<b>Re</b>	-	<b>Reliability</b>
<b>Ra</b>	-	<b>Reliability due to ageing</b>
<b>Aa</b>	-	<b>Availability due to ageing</b>
<b>Ua</b>	-	<b>Unavailability due to ageing</b>
<b>Rt</b>	-	<b>Total reliability of the equipment</b>
<b>Pf</b>	-	<b>Probability of transition due to ageing</b>
<b>T, t</b>	-	<b>Age of equipment, subsequent period</b>
<b><math>\Delta x</math></b>	-	<b>Length of each interval</b>
<b><math>\mu</math></b>	-	<b>Mean time of failure</b>
<b><math>\sigma</math></b>	-	<b>Standard Deviation</b>
<b>\$</b>	-	<b>U.S Dollar</b>



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## CHAPTER 1

### INTRODUCTION

#### 1.1 Transformer

Transformers are often the most valuable and indispensable asset in a substation and failures would result in undesirable disturbances and economic losses to energy systems. In order to prevent failures, the common practice in the industry is to monitor the condition of all transformers uniformly and routinely irrespective of the vulnerability of an individual transformer. Since transformers with higher operation years and greater loading condition will deteriorate more, the condition monitoring and maintenance activities should be adjusted taken into account these effect. Transformer asset management is generally considered to be one of the most power system equipment asset managements. This is due to the substantial investments in the power transformers and the importance of the transformers as one of the major factors that affect the system reliability. The un-scheduled outages of the transformers due to unexpected failures are catastrophic in many cases.

Most utilities and some commercial and industrial transformer owners use the expected life of the transformer to evaluate the losses. However, if the transformer is replaced before it reaches its full life due to failure, overloading, or high losses, the

expected replacement time should be incorporated into comparison [1]. There are many factors that affect a transformer's life. Anything that affects the insulating strength inside the transformer reduces transformer life. Such things as overloading transformer, moisture in the transformer, poor-quality oil or insulating paper, and extreme temperatures affect the insulating properties of the transformer. Increased temperature is the major cause of reducing transformer life. Most transformers are designed to operate for 20 years at the nameplate rating. While transformers that are loaded below the nameplate rating have lives longer than 20 years, transformers loaded above the nameplate rating over an extended period of time have lives less than 20 years.

The replacement time of transformers is more than one and a half years for the ordinary transformer customer who has no specially designed contract with the manufacturer. Hence, it becomes important to utilize the transformers as much as possible without unnecessary risk. To do this the study of lifetime models becomes crucial. This, since 30% of all failures is considered to be caused by ageing. Large investments in the electrical power system infrastructure were made during the 1960s and early 1970s making the largest part of the transformer population older than 25 years. According to an IEEE survey, the effect of ageing in transformers is starting to appear around the 25<sup>th</sup> year. Hence a large part of the transformer population is closed to their end of life but they cannot be replaced all at once [2].

## 1.2 Asset Management

Asset management is becoming more important in asset intensive industries recently due to the highly competitive and deregulated markets. Profit margins becomes much slimmer, therefore business are exploring new innovation to improve business performance. There are two distinct aspects in asset management, the business performance and the technical requirement of the asset. However, both these requirement can contradict each other. For example, financial requirement wants asset maintenance to be done at a minimum cost. However, cutting expenditure on maintenance can effect asset performance and consequently effect business revenue.

Therefore, a balancing act is needed between business requirement and equipment performance. This exercise is also called “optimization”.

Among the asset management decisions that arise in dealing with transformers are the following:

1. Determining what level of maintenance to apply to a transformer over its lifetime;
2. Determining how frequently to inspect or test transformers and what types of inspections or tests to perform (e.g., visual checks for oil leaks, assessment of general condition [corrosion of external metal work, tanks, pipe work, radiators, etc.], annual infrared surveys, dissolved gas oil sampling, and others);
3. Determining which transformers to repair and what repairs to apply to individual transformer components, such as the radiator or the pumps or the bushings;
4. Determining whether and when to overhaul a transformer, thereby rejuvenating it;
5. Determining when to replace a transformer.

### 1.3 Problem statement

Ageing infrastructure of electrical energy systems such as transformer has recently become a great concern and challenge to all electric utilities around the world. This concern is common to current as well as future grids [3]. Most of power transformers in developed countries today were installed during the 1960s. Although some of these transformers may still be operating satisfactorily, they are approaching factor to past the designed lifetime. Ageing equipment is a serious contributing factor to poor system reliability and high operating costs in many utilities [4]. The effects of ageing power transformers can be described as follows [5].

1. The end-of-life failure tends to increase with age.
2. Maintenance and breakdown-repair costs tend to increase with age.

### 3. Replacement parts can become difficult and expensive to obtain.

The demand for higher efficiency and better reliability, encourage electric utilities to support asset management programs, including operation, maintenance and capital planning and risk management and budgeting. However, the decision is accompanied by risk. In the asset management decisions are made, the distribution companies develop strategies for maintenance and reinvestment, where cost effectiveness and risks of different dimensions are balanced [6]. A business may choose to maintain the set point of the new business. They may want to increase business costs and improving quality performance for higher yields. Some problems detected, when we want to improve performance quality results, it can take a lot of cost and sometimes can make the risks more to the company or employees. As such, asset managers must be able to produce or make the best decision to make the process by analyzing the data.

Asset management means operating a group of assets over the whole technical lifecycle guaranteeing a suitable return and ensuring defined service and security standards. Distribution and transmission network operators are facing many different and partly even competing targets. It is their task to find a balance between the requirements of the customers concerning product and service quality at affordable prices as well as shareholder demands for suitable returns on the capital they invest. To optimize between these demands network operators have to develop and extend „best practices“ in asset management. The main question is not „Which network design will provide the best service quality?“ but instead, „Which network design will provide better-than-required service quality while maximizing financial performance?“ Asset management in electrical grid companies plays a key role in the detection and evaluation of decision leading to long-term economical success and best possible earning [5].

Asset management includes not only those who represent the financial interests of certain people but also against any kind of profession that can be implemented or those who are operating history, inspection and maintenance information that should be maintained. Asset management is really understand what the risks are followed by the development and applying the right business strategy and the right model to solve

problems and set, all supported and served by the organization, processes and technology [7].

#### **1.4 Aim and Objective of the project**

The objectives of this research are:

- I. To produce a flow chart or process flow in decision making, power transformer with insulation ageing knowledge while linking with the business strategy in order to assist Asset Managers to make a decision.
- II. Investigate the failures of transformer within collect revenue and survey of transformer's ageing and life assessment.
- III. To study the measurement of the reliability evaluation of the transformer ageing.

This linkage is important for Asset Manager to make decision on investment plan for managing the physical asset in order to support the business strategy.

#### **1.5 Project scope**

Asset management is therefore one important aspect when developing solutions for sustainable grids. Catastrophic breakdown or any failures of ageing transformers can cause interruptions which incur both social and economic losses. Intuitively, the likelihood of a transformer's failure escalates with its operating condition and service duration. The transformer's lifetime depends on how and when the transformer has been maintained, repaired, or even replaced. A timely inspection and maintenance practice not only extends the transformer's lifetime but also help to prevent such catastrophic failures. However, too frequent inspection and maintenance maybe too costly while too little maintenance may lead to poor service and reliability [3].

There are two different aspects of the performance of the asset management business and the needs of technical assets. However, both these requirements can



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contradict each other. For example, the financial requirements like maintenance of assets that should be done at a minimal cost. However, cutting maintenance expenses can affect the performance of the asset and income affect the business. Therefore, a necessary balancing act between business needs and performance of equipment assets must be developed. Therefore, the asset manager must choose the best process for determining the results of the asset management process flow [5].

Flow chart or process flow in decision making will be produced in order to link the knowledge of insulation ageing of power transformer with the business strategy to assist Asset Managers to make a decision. Of decision-making process, asset managers will generate a table for managing the lifetime of aging transformer to increase the operational life cycle of the transformer. Instead of that, it will optimize the management of aging and the future assets to consider the ratio of network performance for the renewal cost. When the asset management using the term more of an asset, it can increase a profit to other companies and more cost savings.

## 1.6 Outline of the Thesis

This thesis organization has shown the sequence and step to produce a decision making process flow linking the knowledge of insulation ageing of power transformer with business strategy in order to assist Asset Manager to make a decision. This thesis classified into five chapters with follows outline:

First chapter describes on the research induction. The introduction is describing what this project is all about. Aside from that, there are also definition of proposed objectives and scopes for this project, deciding the methods to conduct the study and developing the plan of the research.

In chapter 2, the main aspect of asset management is explored. Since there are various asset management techniques recommended and proposed to industries, a Publicly Available Standards on Asset Management: PAS-55 has been developed as a guidelines for industries in applying suitable Asset Management program. PAS-55 requirement will be reviewed in this section.



In chapter 3, evolution in maintenance methodology is discussed. The main maintenance strategy such as preventive maintenance and corrective maintenance has evolved to Reliability Centered Maintenance (RCM), Condition Based Maintenance (CBM). Further to the normal maintenance requirement, the issue of ageing equipment is also crucial. Ageing equipment requires replacement or major refurbishment which involves huge costs. Ageing knowledge of equipment has been continuously improved. This can give benefits to asset management in order to plan expenditure and timing for asset replacement exercise.

In chapter 4, Asset management decision making process is explored. The main direction to which industries are moving towards is risk based asset management. A method explored is Condition Based Risk Management (CBRM) of assets. A method to quantify risk to business performance is reviewed. Criticality of an equipment or system to overall performance of business is employed. This method helps decision making in asset management.

In chapter 5, an overall view of asset management and business process from Asset Manager's perspective is presented in a chart. This is then expanded and developed into a process flow diagram to assist asset manager in making asset management decisions. In which will be based on technical and financial aspects of the issues. A few case studies are presented in relation to asset management. The first case study is looking into the cost of failure of equipment, such as transformer or system to the business. Then the different between time based and condition based maintenance is presented together with its risk to the business. The impact on ageing is shown in case study 3, which can alter maintenance decision and also assist decision making on ageing equipment.

In a nutshell, the issue of asset management decision making is discussed as a whole which try to target the value that can be created from proper asset management practice and decision making process. Finally, in chapter 6, conclusion will be drawn from the issues discussed in this project.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Introduction

There is various asset management techniques recommend and proposed by other researchers. Each technique has its own method which contains advantages and disadvantages. The purpose of the technique is to produce a decision making process flow in order to assist Asset Manager. Furthermore, main aspect of asset management is explored in this chapter.

#### 2.2 Asset

Ageing infrastructure of electrical energy systems has recently become great concern and challenge to all electrical utilities around the world. Due to the rapid development nowadays, electric energy consumptions are increasing. Consequently, according to those situations, it will affect the proportion of business today. The main aim of the business is to utilize its assets as much as possible. For the industries to sustain

continuous operation and utilization of the asset, require continuous investment in terms of management and maintenance of these assets.

An asset is something that has value and is owned by an entity. Assets add to the net worth of the entity that owns it. The entity that owns an asset can be a person, a company, or any other type of organization. In financial accounting, assets are economic resources. Anything tangible or intangible that is capable of being owned or controlled to produce value and that is held to have positive economic value is considered an asset. Simply stated, assets represent ownership of value that can be converted into cash. Without assets, the company is unable to generate profit generating products to the company. Examples of assets are the transformer, wire, electrical appliances and others.

### 2.3 Asset Management

Asset Management has become the new business ideology for the electric utilities. This business environment puts increasing pressure on asset managers. They have to balance system performance and cost/risk with constrained budgets and mitigating risks within this environment. Asset managers need to use as much information as possible to forecast the many uncertain events.

The following characteristics of Asset Management are stressed in its definition:

1. Centralization: to ensure an overview over the whole network and the whole business
2. Key decisions: focusing on the more strategic decisions rather than all (operational) decisions
3. Decision making: focusing on more than developing a strategy; it also includes the implementation of the policy
4. Network business: focusing on the business of the network rather than on the network as an object
5. To maximize profits: focusing primarily on the business point of view

6. Long term profits: focusing on more than short-term cost minimization to maximize short-term profit by stressing management accountability for several decades
7. High service levels: focusing on all business values and measures including safety, the environment and services other than just delivery point performance alone
8. With acceptable and manageable risk: focusing on the fact that 100% guarantees are not required; but that the risk level has to be clearly under control in relation to the risk appetite of the stake holders.

## 2.4 Business process

A business process is „a collection of related, structured activities that produce a service or product that meet the needs of a client“ [8]. These processes are designed to add value to the business by either reducing cost from increased efficiency, or generate revenue from increased effectiveness. The main aim of a business is to utilize its assets as much as possible. Businesses want to „squeeze the asset“ continuously, in order to generate maximum revenues. This however could deteriorate its condition.

For the industries to sustain continuous operation and utilization of the assets, they will require continuous investment in terms of management and maintenance of these assets. This is important to ensure continuous operation and prolong the life these assets. Therefore, a balancing act is needed, where optimum utilization of the assets, at a minimum cost and with an acceptable risk to the business.

## 2.5 Asset Management Standard – PAS 55

The methodology employed to produce the decision making process is through integration and application of existing knowledge in asset management with PAS 55 as a benchmark. *Publicly Available Standard*, PAS 55 are using as a guideline. Overall asset

management is defined in PAS 55 as a „Systematic & coordinated activities and practices through which an organization optimally manages its physical asset and their associated performance, risk and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan.“ [9].

The process flow chart proposed is simplified in nature, simplifying complex assessment method to a practical model. It might not cover all aspect of management but covers the critical decision making factors.

The main element is to balance between:

- Risk
- Cost
- Performance

To facilitate Asset Manager’s maintenance strategy such as

- Budget
- Priority
- Scheduling

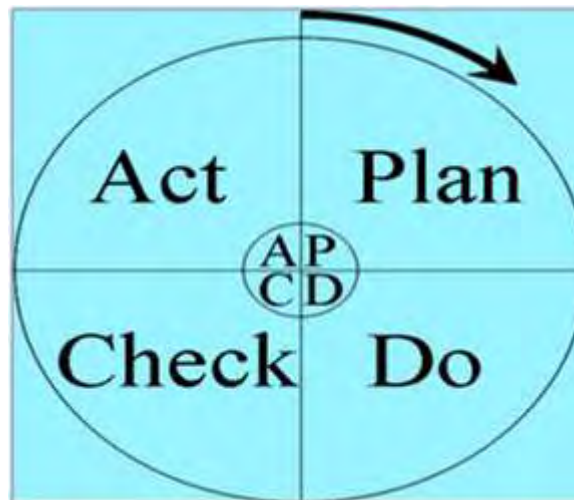
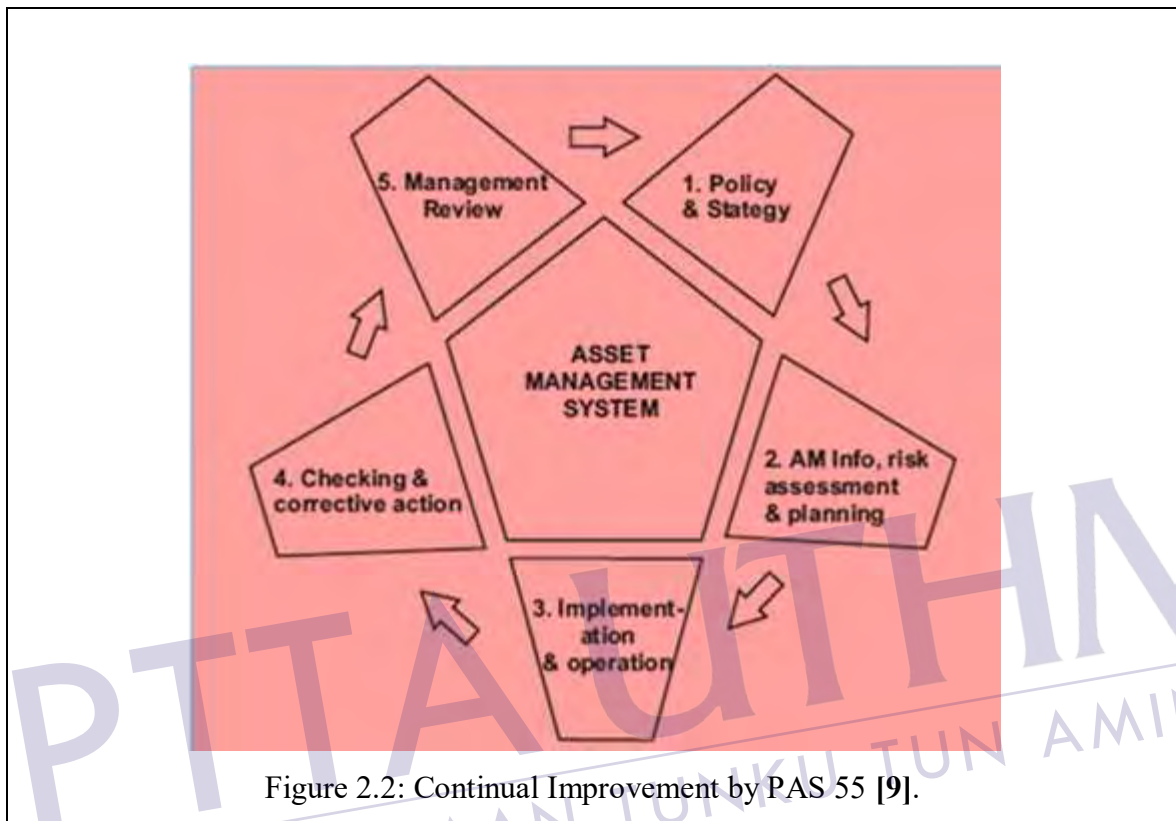


Figure 2.1: APDC Chart by PAS 55 [9].

PAS 55 adopted the Plan-Do-Check-Action (PDCA). It also can use as quality control for asset.



The asset management system depicted in figure 2.2 is a continue process to ensure the achievement of the organizational strategic plan. This system consists of five elements:

1. *Policy and strategy* describe the framework for the operational planning, in essence a long-term direction and plan for the organization.
2. *Information, risk assessment and planning*. In this phase, information will be gathered and stored. The information is essential to monitor risks, legislation, standards, objectives, performance, conditions and available plans.
3. *Implementation and operation* is the phase where the plans are implemented in a structured way. To get these plans implemented and in operation, training is necessary for an adequate level of awareness and competence. In this active phase, it is also essential that the gained information is again communicated and stored for future usage.

4. *Checking and corrective action* are done to get insight in the execution status of the plans and correct them if they are not on track.

5. *Management review and continual improvement* ensures that new gained information, about incomplete plans and changing situations, will improve the new formed policies and strategies.

The key criteria for a successful implementation of Asset management system can be identified as follows [5]:

- **Holistic:** looking at the big picture i.e. integrating the management of all aspects of the assets (physical, human, financial, information and intangible assets), rather than a compartmentalized approach.
- **Systematic:** a methodical approach, promoting consistent, repeatable decisions and actions, and providing a clear and justifiable audit trail for decisions and actions.
- **Systemic:** considering the assets as a system and optimizing the system rather than optimizing individual assets in isolation.
- **Risk-based:** focusing resources and expenditure, and setting priorities, appropriate to the identified risks and the associated cost/benefits.
- **Optimal:** establishing the optimum compromise between competing factors such as performance, cost and risk, associated with the assets over their life cycles.
- **Sustainable:** considering the potential adverse impact to the organization in the long term of short term decisions aimed at quick wins. This requires achieving the optimum compromise between performance, costs and risks over the assets.
- **Life cycle or a defined long term:** This would be difficult to achieve with separate capital and operating expenditures and annual accounting cycles.



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## 2.6 Previous Research

### 2.6.1 A Framework Linking Insulation Ageing and Power Network Asset Management.

The journal of S. M. Rowland and S. Bahadoorsimgh entitles ‘**A Framework Linking Insulation Ageing and Power Network Asset Management**’ is a case study about to manage existing assets and put in place economic and viable asset maintenance and replacement plans. A structured framework is represented through which knowledge of physics and chemistry of ageing phenomena in dielectrics can be used to inform asset manager’s plans. This framework will assist asset managers in identifying appropriate process for rule-setting decision making. There are five layers of this framework.

Table 2.1: Five layers Framework.

<b>Types of layer</b>	<b>Function</b>
<b>Asset management</b>	Decision making processes
<b>Material state</b>	The actual condition of the insulation.
<b>Circumstance monitoring</b>	Monitoring the working environment to determine the stresses at a microscopic level.
<b>Ageing mechanisms</b>	Physics and chemistry controlling microscopic material changes resulting in macroscopic properties.
<b>Condition monitoring</b>	Measurements which enable an understanding of material state.

The framework provides a platform a platform on which to base models of plant reliability, identifying direct relationship between the working environment of the equipment and the ageing and failures processes of the electric systems.



### 2.6.2 Smart Asset Management of Ageing Devices in Energy System: A Case Study of Transformers.

In another project entitle ‘**Smart Asset Management of Ageing Devices in Energy System: A Case Study of Transformers**’ which is written by Lian Zijuan, Saranga kumudu Abeygunawardane and Panida Jirutitijaroen. This paper proposes a smart asset management tool which can be used to prioritize the monitoring and maintenance activities of transformers and to predict a transformer condition state. There are two main contributions of this paper. Firstly, this paper investigates the effect of loading and operating years on deterioration conditions of transformers using field data. Secondly, this paper proposes a state prediction tool based on a state diagram. Such a tool can be useful for the industry to forecast the condition of transformers and to decide when and how to alter the present maintenance policy.

The approach of this work includes data collection from a large group of transformers and data classification according to loading conditions and age. As a conclusion, this paper comes out with hypothesis testing between groups of transformers with high and low winding. In particular, the hypothesis testing results show that a group of older transformers with higher loading, experiences more deterioration than a group of newer transformers with lower loading. State prediction of transformers can be used to forecast the next state of transformers and this enhances the management of transformers as an asset in the grid.

Table 2.2: Decreasing priority of condition monitoring of transformers

Priority	Group of Transformer
1	Transformers with high loading and an earlier first year of operation
2	Transformers with high loading and a later first year of operation
	Transformers with low loading and a later first year of operation
3	Transformers with low loading and a later first year of operation

### 2.6.3 Asset Management Techniques.

The journal entitles ‘**Asset Management Techniques**’ which written by Joachim Schneider, Armin Gaul, Claus Neuman, Jurgen Hografer, Wolfram Wellbow, Michael Schwan and Armin Schnettler is related to the project. This article describes the usage of asset management techniques, particularly with regard to asset management and risk management within electrical grids. The essential information needed to set up an appropriate asset management system and differences between asset management system in transmission and distribution systems are discussed.

The ability to assess different scenarios for the whole grid or parts of the grid having the same structure or technology is a major competence in asset management. These assessments provide extensive knowledge about the effects of alternative strategies on the asset base. By using that knowledge asset managers can actively develop the grid and spend the money in a way that the long term goals as well as the short term budgets are met. Furthermore, in this paper consists of the most important strategies and management techniques. These are maintenance strategies, determination of component condition, asset simulation, statistical fault analysis and statistical asset management approach (distribution) and life management (transmission).

### 2.6.4 Incorporating Ageing Failures in Power System Reliability Evaluation.

This journal entitles “**Incorporating Ageing Failures in Power System Reliability Evaluation**” by Wenyuan Li. This paper presents a method to incorporate ageing failures in power system reliability evaluation. It includes development of a calculation approach with two possible probability distribution models for unavailability of ageing failures and implementation in reliability evaluation. Differences between the two models using normal and Weibull distributions have been discussed.

Based on the proposed method and models, the results indicate that ageing failures have significant impact on system reliability, particularly for an „aged“ system. Ignoring aging failures in reliability evaluation of an aged power system will result in an



overly underestimation of system risk and most likely a misleading conclusion in system planning. This paper proposes a method to incorporate aging failures in system reliability evaluation. The paper is organized in presents a definition and a calculation approach with two possible probability distribution models for unavailability of ageing failures. Then, describes implementation techniques in system reliability evaluation.

### **2.6.5 Asset Management Techniques for Transformers.**

The paper titles “**Asset Management Techniques for Transformers**” by Ahmed E.B. Abu-Elanien, M.M.A. Salama. In this paper, a comprehensive illustration of the transformer asset management activities is presented. This paper focuses on the transformer asset management as one of the important power system assets. The transformer asset management can be classified into the following activities:

1. Condition monitoring (CM) and condition assessment (CA) techniques.
2. Performing maintenance plans.
3. Ageing, health, and end of life assessment.



## 2.7 Comparison between the previous researches.

Table 2.3: Comparison of the previous researches

Journal	Objective	Method	Outcome
<b>A Framework Linking Insulation Ageing and Power Network Asset Management.</b>	<ul style="list-style-type: none"> <li>i- Manage existing assets and put in place economic and viable asset maintenance and replacement plans.</li> <li>ii- Assist asset managers in identifying appropriate process for rule-setting decision making</li> </ul>	A structured framework	<p>The five layer framework :</p> <ul style="list-style-type: none"> <li>i. Assist asset managers in identifying appropriate condition monitoring regimes.</li> <li>ii. Provides a transparent process for rule setting for decision making.</li> </ul>
<b>Smart Asset Management of Ageing Devices in Energy System: A Case Study of Transformers</b>	<ul style="list-style-type: none"> <li>i- Prioritize the monitoring and maintenance activities of transformers.</li> <li>ii- Predict a transformer condition state</li> </ul>	<p>Proposes a smart asset management tool.</p> <ul style="list-style-type: none"> <li>i- Hypothesis testing for the condition monitoring.</li> <li>ii- State prediction using simple state diagram</li> </ul>	<p>From the Hypothesis testing:</p> <ul style="list-style-type: none"> <li>i- Effects of maximum loading on DGA Gases.</li> <li>ii- Effects of an age on deterioration.</li> <li>iii- Effects of loading on deterioration.</li> <li>iv- Combined effects of age and loading on deterioration.</li> </ul>

			<p>From state prediction:</p> <ul style="list-style-type: none"> <li>i- Transformer with low loading and an earlier first year of operation.</li> <li>ii- State prediction for transformers with high loading and a later first year of operation.</li> </ul>
<b>Asset Management Techniques.</b>	<ul style="list-style-type: none"> <li>i- Set up appropriate asset management system</li> <li>ii- Give an outlook to future development</li> </ul>	<p>Important strategies and management techniques:</p> <ul style="list-style-type: none"> <li>i- Maintenance strategies</li> <li>ii- Determination of component condition</li> <li>iii- Statistical fault analysis and statistical asset management approach</li> <li>iv- Life management</li> </ul>	<p>Based on the asset management system, differences between asset management system in distribution and transmission systems are discussed.</p> <p>The bulk of costs in electrical grids can be found in costs for maintenance and capital depreciation.</p>
<b>Incorporating Ageing Failures in Power System Reliability Evaluation.</b>	<ul style="list-style-type: none"> <li>i- Incorporate aging failures in power system reliability evaluation.</li> </ul>	<p>Probability distribution models</p> <ul style="list-style-type: none"> <li>i- Normal distribution</li> <li>ii- Weibull distributions</li> </ul>	<ul style="list-style-type: none"> <li>i- Normal model provides a lower estimation of unavailability at a young or mid age and higher estimation at an age around and mean</li> </ul>



			<p>life.</p> <p>ii- Weibull model used in an actual application depends on the match between the parameter of the model and failure data statistics.</p>
<p><b>Asset Management Techniques for Transformers.</b></p>	<p>i- A comprehensive illustration of the transformer asset management activities</p>	<p>Activities of transformer asset management:</p> <p>i- condition monitoring (CM) and condition assessment (CA)</p> <p>ii- performing maintenance plans</p> <p>iii- Aging, health, and end of life assessment</p>	<p>iv- Various techniques used to monitor and assess the condition of the transformer were discussed.</p> <p>v- Transformer lifetime types were classified.</p>



## CHAPTER 3

### METHODOLOGY

#### 3.1 Introduction

It is important to understand the methodology used in this research that contributing to the development of this project. For methodology, before the research can be carrying out the identifying of the methodology is important to aid in implementation process of this research. So, this chapter will discuss about the flow and the procedures when doing this research. They are two major phases from this project. These phases consist of fundamental and data processing to make sure it's fully success.

#### 3.2 Research Flow Chart

Figure 3.1 below shows the flow chart of this research which shows the important steps that be taken during the research.

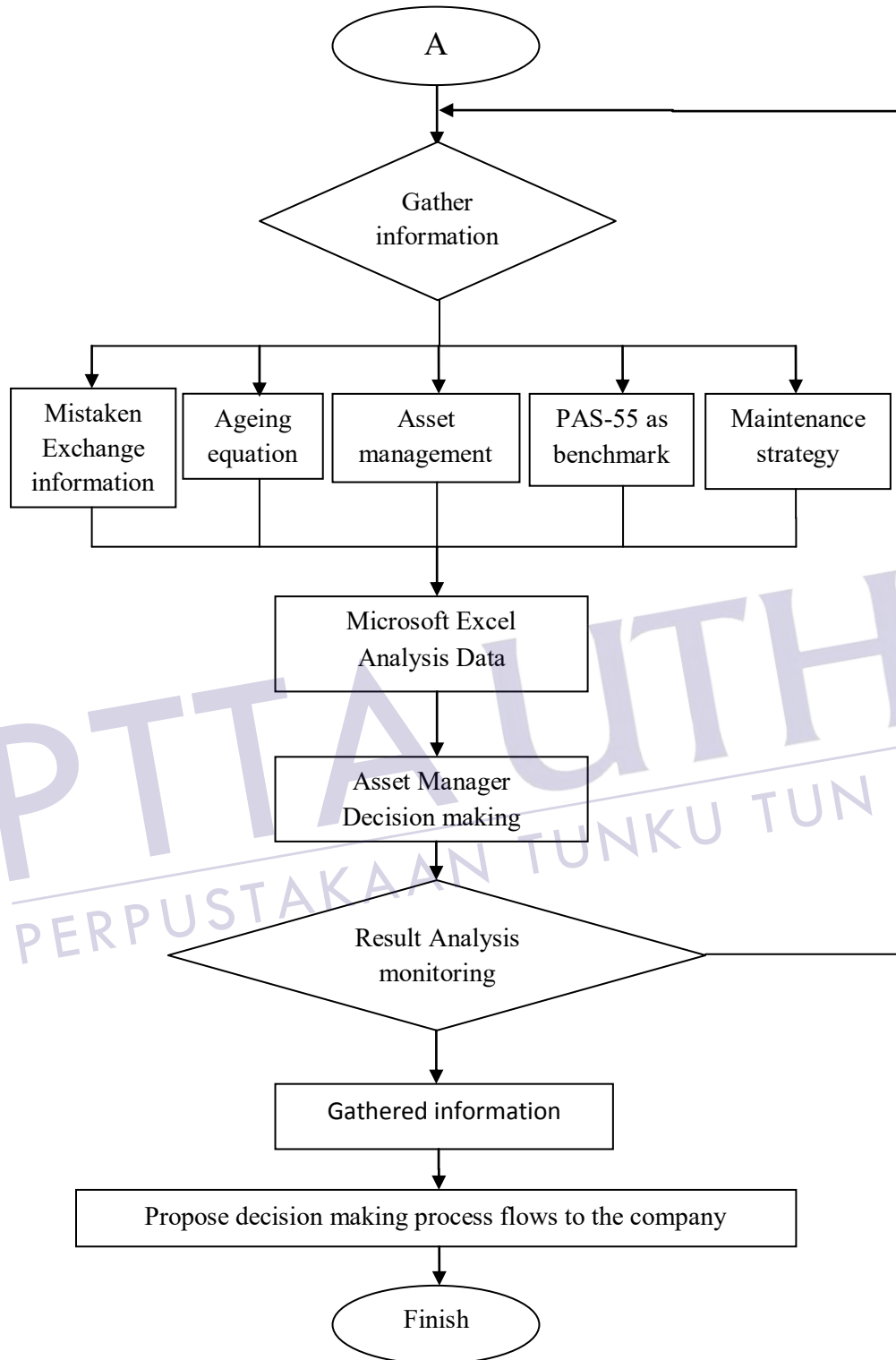


Figure 3.1: Flowchart process of produce decision making.



### 3.3 Asset Condition, Maintenance and Ageing.

The Asset Manager has to decide on a combination of actions which reflect plant loading and stress levels, maintenance schedules, and replacement timetabling. These things are generally interdependent and also depend upon the system requirements of the equipment. It is possible that one route to asset husbandry involves changing the working environment of the item to extend life or reduce immediate failure likelihood.

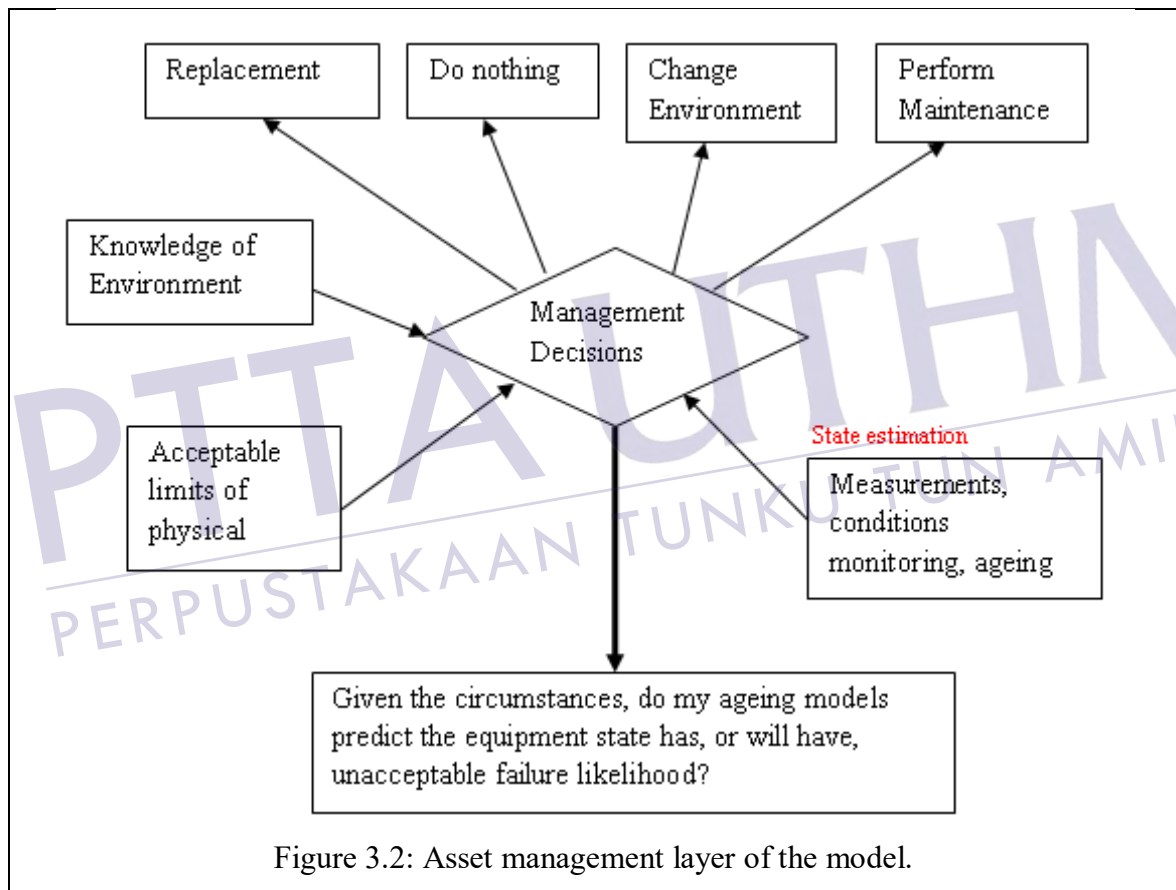


Figure 3.2: Asset management layer of the model.

The asset condition determines the successful operation of the business. Equipment maintenance is a requirement that needs to be performed to maintain desirable output. Ageing of equipment is inevitable that has to be accepted and anticipated to ensure continuous business existence. Equipment ageing is unpreventable. However different maintenance strategy can extend equipment life as shown in figure 3.3. Different

maintenance policy can produce different equipment condition which will then determine its life.

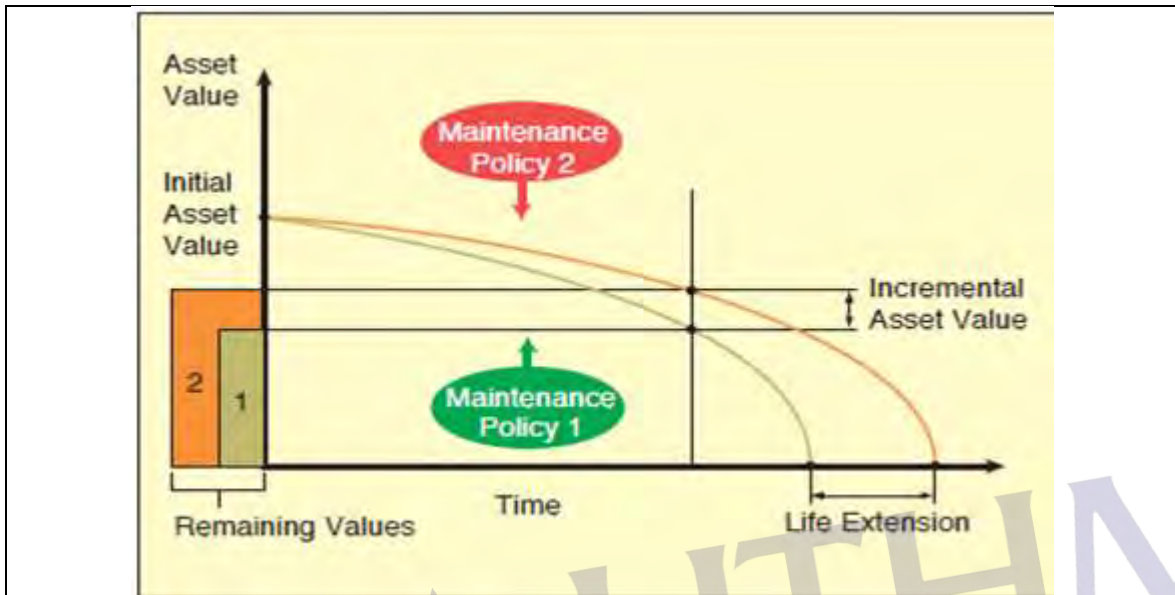


Figure 3.3: Two life curves for the same equipment under two different maintenance policies [10].

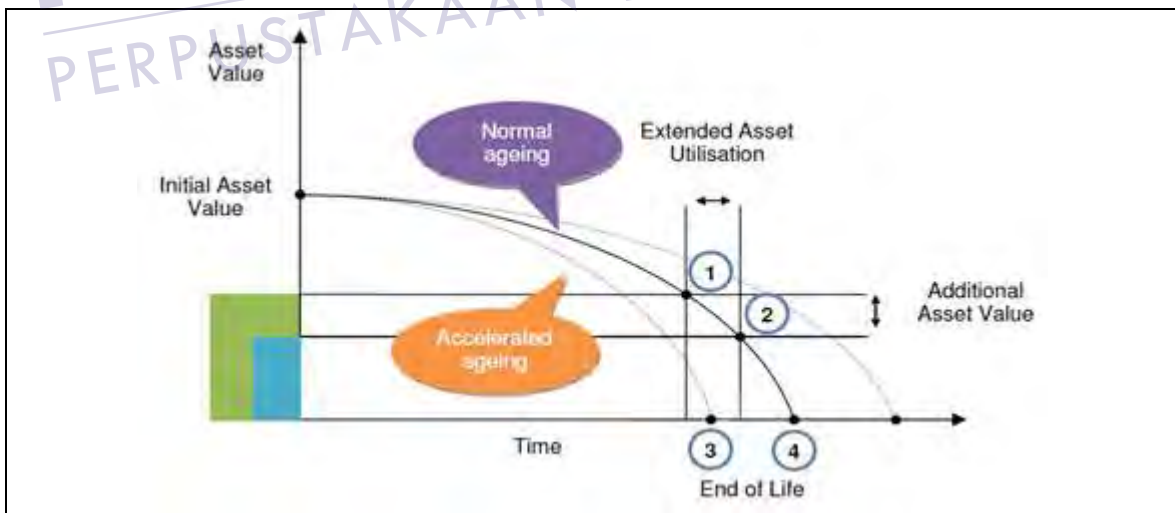


Figure 3.4: Life curve of an equipment with different ageing rate.

[Derived by author from Figure 3.3]

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