IMPROVEMENT OF THE SAG AMPACITY CARRYING LEVEL OF EXISTING 275 KV OVERHEAD LINE TOWER BY USING THE RE-CONDUCTORING APPROACH

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ABSTRACT

This project presents a methodological approach, suggestions and information in uprating the existing 275kV transmission overhead line by using the re-conductoring approach. Overhead transmission line conductors were given priority in information. Calculation regarding the maximum sag and maximum current at maximum operating temperature were the core of this project as to suggest a novel conductor available in the current market. The aim of this project is to provide more current and less sag with the new conductor proposed in comparison with the existing. In addition, the conductor will not in any way infringe the minimum safety clearance. Smart Draw, Matlab and Excel were used as a medium in the data analysis. Therefore, the apparent power of the overhead transmission line when applied with the new conductor can be calculated as to achieve the objective of this project. In Malaysia, ACSR Zebra is used as the conductor for the 275 kV L3 tower. Thus, four other conductors were chosen in order to make comparison between the maximum sag and current at maximum operating temperature. These conductors are the 3M Drake, AAC Narcissus, AAAC Greeley and ACCC 415 mm^2 which have similar characteristics to the ACSR Zebra in terms of weight, maximum rated strength ratio and size. By using the calculations provided in this project, it is determined that the 3M Drake conductor is better to the ACSR Zebra in comparison of the maximum sag and the curent at maximum opertaing temperature.

ABSTRAK

Projek ini menerangkan pendekatan metodologi, cadangan dan maklumat dalam meningkatkan voltan talian penghantaran 275 kV sedia ada dengan menggunakan pendekatan menukar-ganti konduktor. Maklumat berkenaan konduktor voltan talian penghantaran diberi keutamaan. Pengiraan berkaitan dengan pengenduran maksima konduktor dan arus elektrik maksima pada suhu operasi maksima adalah teras projek ini di samping mencadangkan konduktor baru di pasaran semasa. Matlamat projek ini adalah untuk menghasilkan arus elektrik yang lebih tinggi dan pengenduran konduktor yang lebih rendah apabila menggunakan konduktor baru yang dicadangkan. Tambahan, konduktor tersebut tidak akan memasuki jarak selamat minima antara konduktor dengan objek-objek lain di sekitarnya. Smart Draw, Matlab dan Excel adalah perisian yang digunakan untuk menganalisa data. Adalah dengan itu, kuasa ketara (*apparent power)* boleh dikira bagi konduktor baru yang telah digantikan untuk mencapai objektif projek ini. Di Malaysia, konduktor ACSR Zebra digunakan untuk voltan talian penghantaran 275 kV. Oleh itu, empat jenis konduktor yang lain telah dipilih bagi memperoleh keputusan perbandingan bagi tahap pengenduran konduktor dan arus pada suhu operasi maksima. Konduktor-konduktor tersebut ialah 3M Drake, AAC Narcissus, AAAC Greeley dan ACCC 415 mm^2 di mana ia mempunyai ciri-ciri yang hampir sama dengan konduktor ACSR Zebra dari segi berat, nisbah maksima kekuatan dan saiz. Pengiraan menggunakan rumus yang disediakan dalam projek ini membuktikan bahawa konduktor 3M adalah lebih baik berbanding konduktor ACSR Zebra daripada segi pengenduran talian dan juga arus pada suhu operasi maksima.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

kV	-	kilovolt
kN	-	kilo Newton
kg	-	kilogram
AAC	-	All-Aluminium Conductor
AAAC	-	All-Aluminium Alloy Conductor
ACAR	-	Aluminium Conductor Aluminium-Alloy Reinforced
ACSR	-	Aluminium Conductor Steel Reinforced
AAAC	-	All Aluminum Alloy Conductors
AACSR	-	Aluminum Alloy Conductor Steel Reinforced
ACSS	-	Aluminium Conductor Steel Supported
GTACSR	-	Gap-Type Thermal-Resistant ACSR
ACCR	-	Aluminium Conductor Composite Reinforced
ACCC	-	Aluminium Conductor Composite Core
IACS	-	International Annealed Copper Standard
TW	-	Trapezoidal Wire / Trapwire
HTLS	-	High Temperature Low Sag
GUI	-	Graphical User Interface
CEGB	-	Central Electricity Generating Board
MWT	-	Maximum Weight Tension
W	-	Watt
Ω	-	Ohm
°	-	Angle in Degree
°C	-	Temperature in Celsius
ft	-	Feet
m	-	Meter
mm	-	Milimeter

mm^2	-	Milimeter square
ms	-	Milliseconds
s	-	Second
hr	-	Hour
lbs	-	Pound
I	-	Current in Ampere
V	-	Voltage in Volt
MVA	-	Apparent Power
Hz	-	Hertz

TA LE OF CONTENTS

CHAPTER	TITLE	PAGE

CHAPTER 1

INTRODUCTION

1.1 Project Background

Electricity plays important role in modern day routine. No matter the time and place, without the electricity to lighten up the bulb, to operate the fan or such electrical devices, it will definitely affect our life. For the past years, new overhead transmission lines had been very few in many countries. Though, such countries had been experiencing an increasing amount of power consumption in which these overhead transmission line may not be able to supply enough electricity to these urban cities in few years more [3]. Thus, the purpose of this project is to increase the current capacity of the existing overhead transmission line by using reconductoring method. Building new transmission lines cost huge amount of money including long term time planning while as reconductoring only cost a portion from it [5].

The power transfer capacity of an existing overhead transmission line can be upgraded by either increasing the size or number of conductors or increasing the voltage. By increasing the conductors and retaining the same voltage does not in any way change the electrical parameters. In general, existing structures are not loaded to their structural capacity in which they can accept larger conductors. While increasing the voltage involves in modification of both the electrical and structural aspects of an existing line. The structure can be modified in several ways; from simple to complex depending on the structure types. Though, power transfer capacity by increasing the conductors ampacity is structurally and electrically easier compared to increasing the voltage [5].

1.2 Problem Statement

Rapid urbanization in big cities demand higher power consumption. The needs of electricity had become among the priorities of daily routine. A lot of existing overhead transmission line was built years ago that could barely support today's demand not to mention that power consumption increases 5% each year [5].

Building new transmission tower would most likely violate the rights of way in which it will consume large space of area and disturb civilization. Though, another way of increasing the capacity of current that the overhead transmission line can deliver is by changing the existing conductor into one with higher current capacity without exceeding existing limitations such as sag constraints [5].

Currently in Malaysia, we have 500 kV transmission line built. Considering that the increase in population will soon grow to a huge number, the existing 275 kV transmission line will either be replaced or upgraded. Thus, this project gives suggestion regarding the re-conductoring process by using a novel conductor that is currently available in the market in order to upgrade existing 275 kV transmission line. For this, the weather and climate of Malaysia are considered to design the upgraded transmission line.

1.3 Objective

The main objective of this project is to investigate the potential improvements in the sag ampacity carrying level of existing 275 kV overhead line tower by re-conductoring approach. In order to achieve this objective, work analysis will look at the potential of increasing the ampacity of the line by using suitable novel conductors that are currently available in the market.

1.4 Scopes and Limitation

In order to achieve this project, the following scope and limitations had been followed:

i. Literature review of related issues such as conductor sag, ampacity, etc.
ii. To determine wether the 275kV L3 tower can provide more ampacity than the existing by using the calculations provided in this project..
iii. To provide simulation tools to be used in data collecting by using Matlab and Excel.

Through this, the National Grid 275kV L3 tower is used as the framework for the analysis.

C APTER 2

ITERATURE REVIEW

2.1 Introduction

There are three major parts that contributed into an overhead transmission line, which are the tower, conductor and insulator. The tower can be in variety of shapes which depends on the type of the line [6]. Conductor acts as a medium in which the electric charge moves form one point to another which generally contains metallic attribute such as aluminium or copper. Insulators acts as a support to hold the conductors in place in order to provide sufficient distance between the tower and the conductor. Inheriting the insulation properties, it will resist the flow of electric current. By means of increasing the current capacity using reconductoring method, only the conductor properties will be discussed thoroughly throughout this project.

A. Kikuchi and K. Yonezawa [4] had proposed a paper regarding the application of gap conductor and other special conductors for uprating the overhead transmission line tower. Antiquated, overworked, objection from inhabitants to construct new transmission line and the lack of coordination with IPPs on the grid efficiency seems to be the major problems in rapid urbanization such as the U.S. High growth of electricity consumption faces the problem of limited current supplied, thus increasing the current capacity of existing transmission line would obviously be the solution. This proposal provides such solution by re-stringing the conductor with higher current capacity. In high temperature condition, heat-resistant aluminium alloy was developed so high amount of current can be delivered with the same size of conductor as the previous. Gap conductor leaves a gap between the steel core and aluminium layer filled with heat-resistant grease that will help reducing the friction between the steel core and aluminium inner layer at the time of stringing. It also helps preventing water from entering the gap [4].

Jerome G. Hanson [5] had proposed a paper that provides the overview of the experience from a large utility in upgrading transmission lines. Reasons and methods with advantages and disadvantages are also discussed between upgrading and constructing new transmission lines. Upgrading an existing transmission line is far more economically than creating a new one. Though, upgrading does not seem to be easy in every way. Two different ways of upgrading the existing transmission lines are by increasing the size and number of the conductor or increasing the voltage. The former is structurally and electrically easier compared to the latter. A wood pole H-frame in North Dakota had been upgraded and modified by adding additional cross-arm that costs only 60 percent from the cost of a new line. Thus, upgrading will be implemented in the future in regard of uprating the ampacity of the existing transmission lines [5].

K. Kopsidas, S. M. Rowland, M. N. R. Baharom, and I. Cotton in [9] had proposed a paper regarding of increasing power demand for power transfer including economic and environment issues had made building new transmission line the second choice or rather not to be chosen at all. Thus, new implementation of technology had been done such as re-tensioning, reconductoring or modifying the tower design in order to supply the needs for electricity. Most of the old lines use re-tensioning to increase the thermal rating or reconductoring that changes the lines a little bigger than the previous lines. Other than that, modification of the tower design can also be done by adding composite cross-arms. Strong as the conventional, the cross arms tend to reduce cost from several angle which are; reducing the painting cost, reduce electromagnetic fields or improve pollution performance of a system. Current and voltage uprating were discussed in this paper. 275kV Lattice tower system was also discussed regarding its existing figure and modified. The cross arm provides insulation between phase and earth in which no further insulator required. ACSR was selected for the first case study as the existing tower uses it while the second comparative case uses ACCR according to the results stated in this paper. For both case studies, twin bundle configuration had been investigated [9].

I. Zamora et. al. [10] had wrote a paper regarding the possible options of upgrading the capacity of a line by means of re-conductoring. A general study of the characteristics of electrical conductors with high temperature performance and low sag were done and applied to the specific overhead transmission line. Technological peak and the quality of life increased which led to a growing demand for electrical power. Existing transmission lines are being forced to transmit increasingly higher power in order to met with this increase in demand. Thus, the ampacity of some transmission lines is close to its critical limit. The most immediate solution state din this paper is the increase in the ampacity of current overhead lines by increasing their nominal voltage or an increase in their maximum accepted current. The first choice came with a problem in the needs for raising or modify the existing supports in order to comply with the minimum safety distances. For the increase in ampacity, it is possible to opt for replacing the conductor by another with a bigger cross section which would mean performing changes or alterations to the supports in order to withstand the greater stresses on them [10].

K. Kopsidas and S. M Rowland [9] in another paper had evaluated the opportunities for increasing the power capacity of existing overhead line systems. In this paper, re-tensioning and re-conductoring are considered as the most popular cost-effective ways to increase the efficiency of power capacity of an existing aerial line. In order to identify the most beneficial method, ampacity and sag calculations are required as to consider all of the system factors that influence its performance. A holistic methodology for calculating such criterion are presented here when different conductors are implemented onto a pre-specified overhead line structure. Analysis done in this paper focuses on normal operating temperatures for novel conductors that can operate at elevated temperatures to avoid the increase in losses and also to allow the comparison with conventional conductors in order to identify potential benefits for the investigated overhead lines system [9]. Table 2.1 represents the summary of the previous work done by other researchers.

Table 2.1: Previous work summary.

Project Title	Author	Method	Outcome
Application of Gap Conductor and Other Special Conductors for Uprating [4]	- A. Kikuchi - K. Yonezawa	- Re-stringing	-Use GTACSR and ZTACIR conductor - Increases current and maintains sag
Evaluating Opportunities for Increasing Power Capacity of Existing Overhead Line Systems [9]	- K. Kopsidas - S. M. Rowland	- Re-conductoring	- Use 33 kV wooden pole structure - AAAC better than ACSR
Power Transfer Capacity Improvements of Existing Overhead Line Systems [11]	- K. Kopsidas - S.M. Rowland - M.N.R Baharom - I. Cotton	- Re-conductoring - Composite cross-arm	- ACSR LYNX and ACCR - Reduced sag and increased current
High Temperature Conductors: A Solution in the Uprating of	- I. Zamora et. al.	- Re-conductoring	- Use GTACSR, ZTACIR and ACSS - Reduced sag and increased current

Overhead Transmission Lines [10]			
ACSS/TW - An Improved Conductor for Upgrading Existing Lines or New Construction [14]	- F.R. Thrash, Jr.	- Re-conductoring	- Use ACSS/TW - Less sag - High temperature operation

2.2 Conductor

The conductor is the overhead cable or line used to transmit power between the two sides. Naturally, strands of relatively pure aluminium are among the material suitable to use is the aluminium which is cheaper and lighter compared to copper [7]. These advantages made aluminium conductor to be favored as overhead transmission line of the transmission system. For example, the All Aluminium Conductor (AAC) is widely used compared to copper due to its price, weight and availability including the strength to weight ratio of AAC that has been improving which provides smaller sags resulting in shorter tower. During the period, modifications had been made which produced All Aluminium Alloy Conductor (AAAC) and Aluminium Conductor Steel Reinforced (ACSR) [1].

ACSR and AAAC are commonly used in medium and high voltage lines. Aluminium conductors have better resistivity over weight compared to copper as well as being cheaper. Though, some cooper cable are still used especially at lower voltages and grounding. On equal diameter basis, AAAC has a better corrosion resistance and better strength to weight ratio including improved electrical conductivity than ACSR [7-8].

Among all of the conductor characteristics, the thermal rating of conductor stands out the most. ACSS had been used as an example study for reconductoring options in order to upgrade the current carrying capacity of transmission line. The ACSS can be operated continuously at high temperatures up to 200 °C without being damaged and that it exhibit less sag at equivalent tension [2]. As increasing current implies, the conductor temperature should be increased as well. In high temperature condition, heat-resistant aluminium alloy was developed in order for high current to be delivered with the same size conductor as the previous [3]. Heat-resistant alloy can be divided into two groups, namely; heat-resistant aluminium alloy and super heat-resistant aluminium alloy in which it can be operated to 150 °C and 210 °C respectively [4].

2.3 Conductor Selection

Choosing the most appropriate conductor type and size is essential due to it being one of the major cost components of a line design [9][10]. Among the considerations that can be made are the tension loads, ice and wind loads, the current loading of the line, voltage stability, environmental effects, electrical losses, ambient conditions and many others. The objective is to select a conductor that inherits the best conductivity-to-weight ratio or strength-to-weight ratio at minimal cost for the application. Other key factors in choosing the conductor types are the electrical and mechanical properties, thermal properties, and stress-strain relationship of the conductor type and size for a given line design problem [1].

2.4 Types of Conductor Materials

Relatively pure aluminium (1350-H19), an aluminium alloy (6201-T81), 1350-H19 and 6201-T81 combined or 1350-H19 or 1350-O combined with one or more steel core wires are the common types of phase conductors used in overhead transmission lines. These conductors are well-known as All-Aluminium Conductor (AAC), All-Aluminium Alloy Conductor (AAAC), Aluminium Conductor Alloy Reinforced (ACAR), Aluminium Conductor Steel Reinforced (ACSR) and Aluminium Conductor Steel Supported (ACSS) respectively. Each of the aluminium materials have different advantageous characteristics.

2.4.1 Aluminium and Aluminium Alloy Wire

Aluminium and aluminium alloys can be divided into two major groups, namely the non-heat-treatable and heat-treatable. The first type can only be hardened and strengthened by some form of plastic deformation, such as rolling, drawing, swaging and etc. Generally hardness and strength increase proportionally with the deformation process as opposite to the electrical conductivity. The 1350 pure aluminium used in overhead conductors falls into the non-heat-treatable class. Greatly deformed as it is in which it had undergone the wire drawing process called tempering, it is labeled as H19. Thus, in order to indicate both the material and temper, the wire is referred to as 1350-H19. Smaller wire requires greater deformation during the wire drawing process which makes it contains a higher tensile strength [1].

After the hardening process, both the non-heat-treatable and heat-treatable materials can only be softened by subjecting them into a thermal treatment. The only softened temper used in overhead conductors is a full-soft, or O-temper which also made it fully annealed. Used only in one of the steel-reinforced composite cables, ACSS, the

1350 wire in this state is designated 1350-O. Being compared with 1350-H19, 1350-O wire has a much lower tensile strength, but much greater ductility and slightly increased conductivity [1].

Heat treatable aluminium alloys can be strengthened in many ways, such as; plastic deformation, thermal treatments, or a combination of the two. The deformation takes place during the wire drawing process of wire. Solution-heat-treatment (SHT) and aging treatment are the two thermal treatments required. SHT gives the materials the potential to be strengthened which consists of an elevated temperature-time cycle followed by a quench. SHT can be done during the manufacturing of the redraw rod or separately after the manufacturing process. After the wire is drawn, it is subjected to an elevated temperature-time aging treatment. This means that the wire will achieve two times strength from the process it had undergone. The state of the finished wire is designated as being in the T81 temper [1]. Table 2.2 describes the summarization of the aluminium and aluminium alloy classes summarization.

Table 2.2: Aluminium and aluminium alloy classes summarization.

Non-heat-treatable	Heat-treatable
- Aluminium and aluminium alloys are hardened by plastic deformation.	- Can be strengthened by plastic deformation, thermal treatments or the combination of the two.
- 1350 aluminium is in this category.	- 6201 aluminium alloy is used when higher strength is required.
- H19 is the temper process.	- T81 is the temper process
- Can be softened with full-soft or O-temper.	

2.4.2 Coated Steel Core Wire

One of several types of coatings that impart good corrosion resistance is used to form the core in overhead lines. The coatings include the following ingredients; zinc, zinc-5% aluminium-mischmetal alloy, aluminium coated and aluminium clad.

The zinc coated steel wire can be differentiated into three classes of A, B and C with the thickness of coating being the measurement. The coating thickness increases from class A to class C which also means that class C has the highest resistance towards corrosion.

Aluminium coated and aluminium clad are the two types of aluminium coatings available. The first type yields a thin coating of aluminium while the latter has a thicker layer of aluminium coating. ACSR/AZ and ACSR/AW are the terminology used in order to distinguish both types respectively.

2.5 Conventional Round Wire Conductors

There are mainly five common conductor used in the utility industry, namely: All-Aluminium Conductor (AAC); All-Aluminium Alloy Conductor (AAAC); Aluminium Conductor Alloy Reinforced (ACAR); Aluminium Conductor Steel Reinforced (ACSR) and Aluminium Conductor Steel Supported (ACSS). All of this conductor types had been proven to be worthy of its usefulness under a variety of conditions.

2.5.1 All-Aluminium Conductor (AAC)

Composed entirely of 1350-H19 aluminium wires, it is a low cost conductor with good corrosion resistance, moderate strength and a conductivity of 61.2% IACS, minimum. AAC has the highest conductivity-to-weight ratio of all the overhead conductors, making it ideal for installations in urban areas limited in space where short spans with maximum current transfer are required. Figure 2.1 shows the physical appearance of the AAC conductor.

Figure 2.1: AAC conductor [15].

2.5.2 All-Aluminium Alloy Conductor (AAAC)

When steel was in short supply, AAAC is developed in order to make up for the insufficiency of ACSR conductors. Yielding the high strength of 6201-T81 aluminium alloy with a minimum conductivity of 52.5% IACS, it can be compared with ACSR and AAC under certain situations. AAAC have comparable thermal ratings, improved strength-to-weight ratio, lower electrical losses and superior corrosion resistance to the

ACSR. Such factors favor the AAAC for distribution installations on the seacoast, farm and industrial areas which faces high corrosion problems. Figure 2.2 represents the physical appearance of the AAAC conductor.

Figure 2.2: AAAC conductor [15].

2.5.3 Aluminium Conductor Aluminium-Alloy Reinforced (ACAR)

Being a mixture of 6201-T81 and 1350-H19 strands of the same diameter, ACAR has an excellent balance between mechanical and electrical properties. The 1350-H19 aluminium strands are usually located on the outside layers of the conductor. In order to provide the necessary strength, the 6201-T81 aluminium wires are primarily used in the center of the conductor in lieu of steel. Not only the alloy wires provide strength, but it also adds conductive cross-sectional area to the complete conductor. Other than that, ACAR exhibit excellent corrosion resistance and utilize simple termination hardware which making it favored for many transmission line applications. Figure 2.3 is the physical appearance of the ACAR conductor.

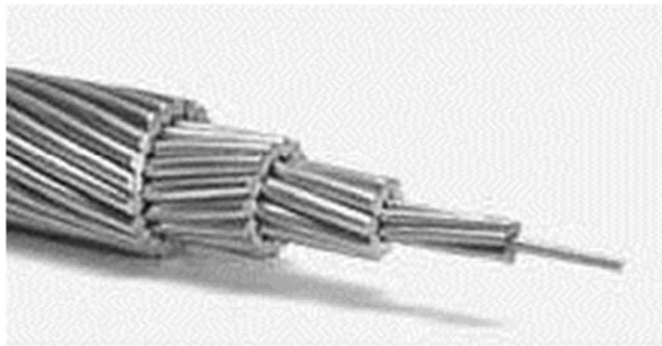

Figure 2.3: ACAR conductor [16].

2.5.4 Aluminium Conductor Steel Reinforced (ACSR)

For many years, ACSR had been dominating the transmission and rural distribution circuits. Extensively, it is used on long spans as both ground and phase conductors because of its high mechanical strength-to-weight ratio and good current-carrying capacity. The use of 1350 aluminium in ACSR gives it equivalent, or higher thermal ratings in comparison with equivalent sizes of AAC. Figure 2.4 describes the physical appearance of the ACSR conductor. The dependability of its high tensile strength combined with good conductivity provides several advantages:

I. ACSR elongate lesser than other conductors due to its steel core which result in less sag at a given tension. This will then increase the maximum allowable conductor temperature as to allow a higher thermal rating when replacing other standard conductors with ACSR.

II. Extreme ice and wind loading areas will affect the ACSR in a minor manner due to its high tensile strength.

III. ACSR is less likely to be broken by falling tree limbs.

Figure 2.4: ACSR conductor [15].

2.6 Trapezoidal-Shaped Wire Conductors

Trapezoidal wire (TW) is also called Trapwire which differs from the conventional round wire conductor construction by taking the shape of a trapezoid as its strands. Homogenous Trapwire constructions have trapezoid shape for all its strands except for the round center core wire. As for non-homogenous conductors, the multi-strand core is usually composed of round strands of one material surrounded by the trapezoidal strands of another. Another difference between this wire and the traditional round wire construction is the interstices elimination between the strands and layers. Figure 2.5 shows the physical appearance of the ACSR/TW conductor.

Figure 2.5: ACSR/TW conductor [17].

2.7 High Temperature Conductors

The high temperature conductors were constructed as the need to move larger quantities of power through existing right-of-ways (ROW). Another name for this type of conductor is the High Temperature Low Sag (HTLS) conductor. All HTLS conductors require special installation procedures and hardware except for the ACSS and ACSS/TW conductors.

2.7.1 Aluminium Conductor Steel Supported (ACSS)

ACSS was designed to operate at higher temperature as a comparison to the ACSR in which it will increase the current capacity at reduced sags. The construction cost for ACSS is low and in addition, ROW is easily obtained as ACSS do not have a large impact on the design of transmission line when it was originally introduced. ACSS consists of a core composed of coated steel wires surrounded by one or more layers of fully annealed, 1350-O aluminium round wires. It is also available in three constructions which are; round wire, area equivalent Trapwire and diameter equivalent Trapwire. Figure 2.6 represents the physical appearance of ACSS/TW and ACSS conductors.

Figure 2.6: ACSS/TW and ACSS conductor [18].

2.7.2 Gap-Type Thermal-Resistant ACSR (GTACSR)

This type of conductor is constructed with a gap between the galvanized steel core and innermost shaped aluminium layer. The gap is filled with a heat resistant grease to reduce friction between the steel core and aluminium and to prevent water penetration. This will allow the conductor to be tensioned by gripping the galvanized steel core only. Full advantage of the lower thermal elongation properties of steel can be taken. Figure 2.7 shows the physical appearance of GTACSR conductor.

Figure 2.7: GTACSR conductor [19].

2.7.3 Aluminium Conductor Composite Reinforced (ACCR)

Constructed with Al-Zr alloy wires over a reinforcing core consisting of stranded ceramic filaments, this conductor is typically rated from 210 °C to 240 °C. Each filament consists of ceramic fibers encased in an aluminium matrix. The composite core has a lower thermal elongation and equal or greater strength than galvanized steel. Figure 2.8 represents the physical appearance of ACCR conductor.

Figure 2.8: ACCR conductor [20].

2.7.4 Aluminium Conductor Composite Core (ACCC)

This conductor has a core consisting of polymer-bound carbon-fibers encased in a fiberglass tube. The so-called core represents a figure of a rod. ACCC is typically constructed using trapezoidal shaped, fully annealed 1350-O aluminium wires over a single rod composite core. Limited service application had been recorder to date. Figure 2.9 shows the physical appearance of ACCC conductor.

Figure 2.9: ACCC conductor [21].

2.8 Clearances

Safe distances from buildings, people and objects underneath the conductor must be taken into consideration when designing overhead lines. Information regarding the shape of the terrain along the right-of-way, the conditions of wind, ice and temperature and also the height of the conductor are needed as to avoid any infringement to the minimum ground clearance. As the terms applied in Fig. 2, the span length is the distance horizontal distance of the conductor, everyday sag is the sag of the conductor on daily operating basis, the maximum electrical loading sag is the maximum allowable conductor length on maximum operation and the minimum clearance to ground is the safety clearance that should not be violated [1][9][13].

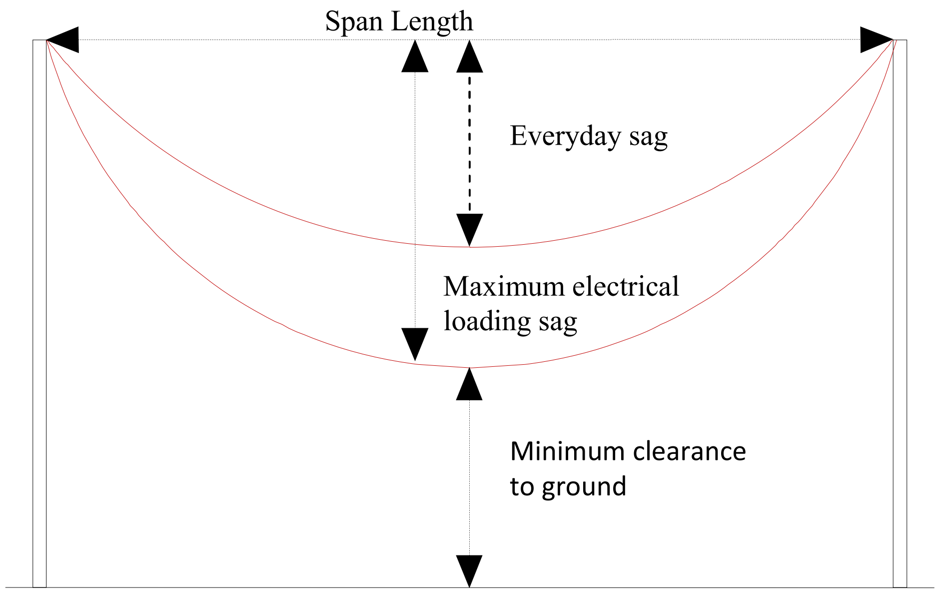

Figure 2.10: The visualization of safety clearance and other types of sag.

CHAPT R 3

METHODOLOGY

3.1 Introduction

It is necessary to determine the mechanical loads due to the conductors and their sags before designing the towers. The mechanical loads depend on the span lengths, working strength of the conductor, changes of temperature and changes of loads due to wind and ice. In tower design, the tower height is determined by the conductor sag at its maximum operating temperature. This sag is controlled by specified limits of the conductor tension at lower temperatures.

3.2 Flowchart

The methodology summarized in the flowchart of Figure 3.1 represents the flow of the process in obtaining the suitable novel conductor to be replaced with the existing used on the 275 kV tower. Literature review is done for the basis of information gathering that will be the inputs to the GUI created by using Matlab and Excel. The output of these tools were analyzed and preceded with the report writing.

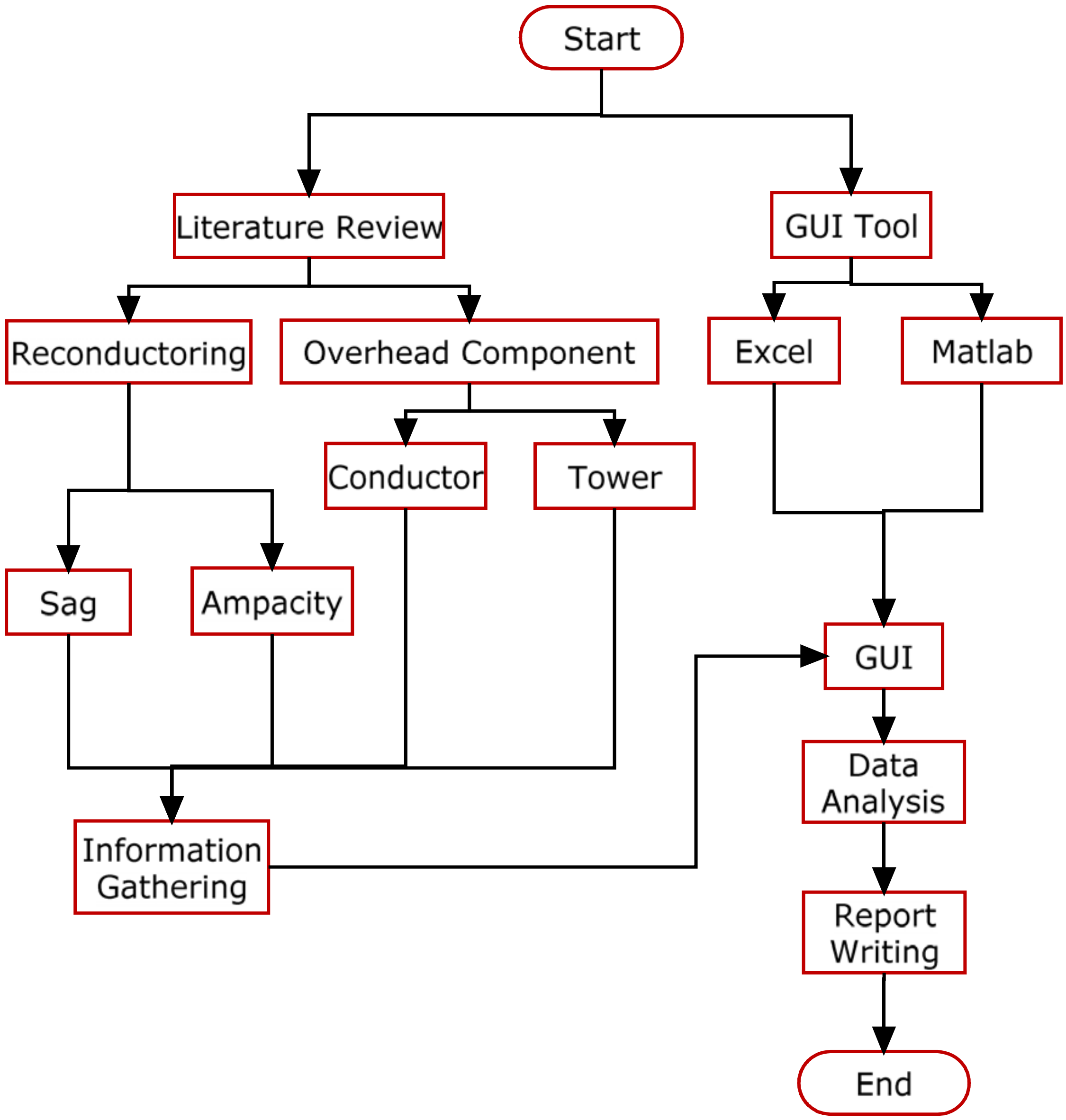

Figure 3.1: The flowchart of this project.

3.3 The 275 kV Lattice Tower System

This paper studied the typical 275kV lattice tower L3 type with standard suspension tower as shown in Figure 3.2. The maximum sag of the conductor in order to avoid clearance infringement can be calculated from the figure which is 12.23 m. The span length used is 400 m with the maximum loading tension permitted by the strength of the structure is 72 kN and the maximum weight supported by each of the cross-arm is 30 kN [9]. The initial conductor used is ACSR Zebra since Malaysia uses this conductor on the 275 kV L3 tower and comparison was done with other types of conductor of similar characteristic.

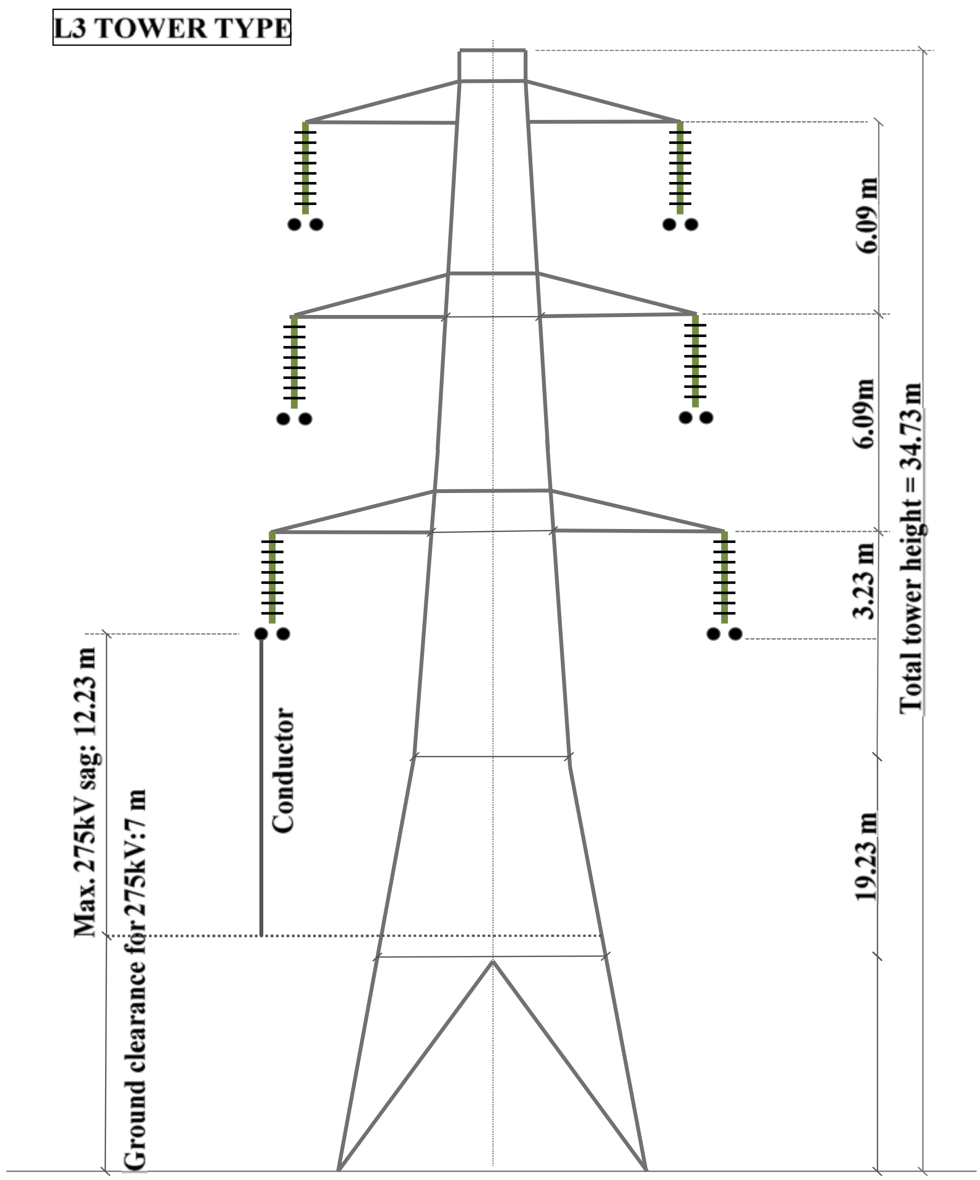

Figure 3.2: The 275 kV L3 type tower.

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