CHAPTER 1
INTRODUCTION

1.1 Background of Study

Lightning is an atmospheric discharge of electricity, usually accompanied by thunder, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms. In the atmospheric electrical discharge, a leader of a bolt of lightning can travel at speeds of 60,000 m/s (220,000 km/h), and can reach temperatures approaching 30,000 °C (54,000 °F), hot enough to fuse silica sand into glass channels known as fulgurites which are normally hollow and can extend some distance into the ground. There are some 16 million lightning storms in the world every year. For an American, the chance of being struck by lightning is approximately 1 in 576,000 and the chance of actually being killed by lightning is approximately 1 in 2,320,000. Lightning can also occur within the ash clouds from volcanic eruptions, or can be caused by violent forest fires which generate sufficient dust to create a static charge.

Lightning can strike anywhere on earth - event the North and South Poles! In any U.S. geographical location, lightning storms occur as few as five times or as many as 100 times per year. The Northeast United States has the most violent thunderstorms in the country because of the area's extremely high earth resistivity. High earth resistivity (the earth's resistance to conduct current) increases the potential of a lightning strike. If struck, structures in these areas will generally sustain more damage when there is no lightning protection system present.

1.2 Problem Statement

Each year, thousands of homes and other properties are damaged or destroyed by lightning. It accounts for more than a quarter billion dollars in property damage annually in the United States. Lightning is responsible for more deaths and property loss than tornadoes, hurricanes and floods combined.

Nowadays, LPS play a prominent role in order to protect plant and its equipment from lightning strike. Most industries provide several amounts of money in order to install LPS at their premises. Unfortunately, not many people understand how it is work and does not have basic idea on what LPS is all about. Usually, the task regarding LPS installation will be hand over to the contractor or consultant.

1.3 Objective and Scope of Study

The objective of this project is to redevelop the tool already designed by Mr Lokman in more practical software which is Microsoft Office 2003. Another objective of this project is to make significant improvement regarding the tool that already designed by Mr Lokman.

Mr Lokman's tool still far from complete as it needs several improvements. The tool need to be improve in term of interface as the current interface may let the user change or modify instruction or function easily. It can be improve using Microsoft Office Excel Macros.

The tool also need to be improve in term of including shape of structure as one of the parameter used in assessing the LPS. In addition, the tool also needs to be improved in term of having extra part that assess on soil condition.

CHAPTER 2
LITERATURE REVIEW

2.1 Lightning Protection System

A **lightning protection system** is a system that protects a structure from damage due to lightning strikes, either through safely conducting the strike to the ground, or preventing the structure from being struck. Most lightning protection systems are composed of a network of lightning rods, metallic cable conductors, and ground electrodes designed to provide a low impedance path for the lightning to travel through towards the ground.

The majority of lightning protection systems in use today are of the traditional Franklin design. The fundamental principle used in Franklin-type lightning protections systems is to provide a sufficiently low impedance path for the lightning to travel through to reach ground without damaging the building. This is accomplished by surrounding the building in a kind of Faraday cage. A system of lightning protection conductors and lightning rods are installed on the roof of the building to intercept any lightning before it strikes the building.

2.1.1 Lightning Rod (Air Terminals)

Air Terminal is a metal rod mounted on top of a building and electrically connected to the ground through a wire, to protect the building in the event of lightning. If lightning strikes the building it will preferentially strike the rod, and be conducted harmlessly to ground through the wire, instead of passing through the building.

An effective air terminal is one which is much more likely to generate a successful propagating streamer than is a part of the structure it is protecting. It has been known that tall objects are more likely to get strike than the shorter objects. Taller object will provide shorter distance for the streamer to reach the approaching stepped leader compare to shorter object [3].

There are lots of types of air terminal installed nowadays. Recent research conducted based on twelve years field study suggested that the most effective air terminals is lightning rod with moderate diameter around 19mm and blunt tipped [3].

Air terminals generally are made of solid copper, aluminium, or stainless steel. Stainless steel air terminals are used in high corrosive area. For the size, air terminals will be a minimum of 10 inches (254 mm) in height, at least 0.5 inch (12.7 mm) in diameter for copper and 0.625 inch (15.9 mm) in diameter for aluminium [4].

Air terminal will extend at least 10 inches above the protected structure unless they are mounted on walking surfaces. In this case, the tip of the air terminal will not be less than 5 feets above the walking or working surface. For the air terminals that exceeding 24 inches (600 mm) in height above the protected structure, additional support need to be installed at the point that not less than half of their height. Air terminals will be placed on the ridges of the pitched roofs and around the perimeter of flat or gently sloping roofs at intervals not exceeding 20 feets (6.1 m). Air terminals will be bonded to the nearest roof or down-conductor, and connected to the plant earth ring. Each air terminal must be connected to at least two paths to ground [4].

2.1.2 Down-conductor

The function of down-conductor is as connector between air terminals and grounding system. Down-conductor will instantaneously transfer the discharge current to the grounding system. To minimize the risk during carrying the discharge current, down-conductor must have very low resistivity and reactance and have no sharp bends or loops in order to ensure the discharge current can be carried safely to the grounding system [5].

The down-conductors are specially design cables which made from copper or aluminium that provide low resistance path to the ground. Each structure requires at least two down-conductors at the opposite corner of the structure. Based on Petronas Technical Standard, the conductor should have cross sectional size of 70 mm^2 [6].

Building with parameter of 76 m or less should have not less than two down-conductors. The down-conductors should be installed as far as possible from each other. For the building that has diameter more than 76 m the average distance between down-conductors must not exceed 30.5 m (100 feet) [4].

Any down-conductor subject to mechanical damage or displacement must be protected with a protective molding or covering for a minimum of 1.83m (6 feet) above grade. If a down-conductor runs through a ferrous metal tube or pipe the conductor must be bonded tom both ends of the tube. Down-conductor connector should not be paint unless there is the high-compression or welded type. Each down-conductor must be connected at its base to a grounding electrode [7].

2.1.3 Grounding System

Proper grounding of a lightning protection system is critical for the protection of a structure. Failure to provide sufficient grounding could result in the damage or loss of property and lives. The most common methods for grounding a lightning protection system include ground rods and ground plates. The proper design of a grounding system starts with testing to identify the site's resistance ground. In most cases, resistance of 5 ohms or less is required for proper grounding. If that threshold is not met, additional design elements must be used [11].

Ground rod must be at least 3.05 m (10 feet) long, made of not less than 19.05 mm (0.75 inch) diameter solid rod made of copper or copper clad steel. Ground rod must penetrate 3.05 m into soil. It is recommended that ground rods should be installed with it tops at least 0.31 m (1 foot) below grade. The spacing between ground rods should be at least two times a single rod length. Nominal spacing between rods should be between two and three times a single rod length (e.g., 10 feet ground spaced at 20 feet apart). Ground rods should be located 2 to 6 feet (0.6 to 1.8 m) outside the foundation or exterior footing of the structure [5].

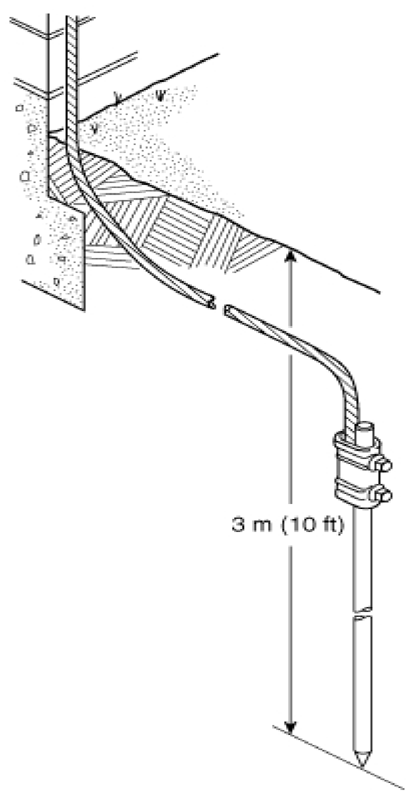

Figure 1: Typical Single Ground Rod Installation. [5]

2.2 LPS Designing Methods

There are several methods used in designing LPS. We only will be interested in the major methods which are:

1. Cone of Protection
2. Mesh method (Faraday Cage)
3. Rolling Sphere

2.2.1 Cone of Protection (Franklin Rod) Method

This method which is known as the Franklin rod or catching end systems is a method of protection from lightning made up of a simple metal end, landing conductor and earthing sections used to protect tower type places from lightning. It is able to protect an area determined with a fixed protection angle.

The area that can be considered safe from direct lightning strike is called protection zone area. The protection zone is determined by the high of the lightning rod. The area of protection is the area that been cover by protection angle of 45* from the top of the lightning rod to the ground. The radius of the area is the same as the high of the lightning rod.

This method might be appropriate for simple and small conventional structure but it will not be effective for modern or tall structure. There were cases on tall structure where the lightning bypass the protection and strike the lower part of the building. Thus, rolling sphere method is applied for higher and bigger structure or building.

2.2.2 Mesh (Faraday Cage) Method [13][14]

Michael Faraday, a British physicist, discovered that a metal cage would shield objects within the cage when a high potential discharge hit the cage. The metal, being a good conductor, would direct the current around the objects and discharge it safely to the ground. This process of shielding is widely used today.

A Faraday Cage Lightning Protection System consists of Strike Termination Devices (air terminals) along the ridges, flat-roof portions and perimeters, interconnected with specialized lightning protection conductor coursed throughout the building, terminating at grounding locations.

For protection with the Faraday Cage, the building that is to be protected is going to be wrapped around together with all its collateral sections from the highest places of the building to the ground in a way that will form a constant and continuous conductive path. This cage which possesses many catching ends made up of conductors completed with horizontal connections, is going to be connected to an earthing system

The lightning protection systems are going to be installed in a way compliant to the project which is going to be prepared in accordance to the lightning risk report, the protection level for the lightning risk report which is to be prepared is going to be determined by taking Table 1 as basis.

Table1: Protection Level for Lightning Risk Report

Protection level for Faraday Method	Lightning Protection System Efficiency, “E”
	E > 0,98
Level 1	0,95 < E < 0,98
Level 2	0,90 < E < 0,95
Level 3	0,80 < E < 0,90
Level 4	0 < E < 0,80

2.2.3 Rolling Sphere Method

A sphere of radius equal to the striking distant is usually employed to visualize the likely stroke termination point, the so-called Rolling Sphere Method (RSM). Application of RSM involves rolling an imaginary sphere of a prescribed radius over the air termination network. The sphere rolls up and over (and is supported by) air terminal, shield wires, and other grounded metal objects intended for direct lightning protection. A piece of equipment is protected from a direct stroke if it remains below a curved surface of the sphere by virtue of the sphere's being elevated by air terminals or other devices. Equipment that touches the sphere or penetrates its surface is not protected [12].

Rolling sphere theory based on two assumptions [2]:

1. Lightning strikes the nearest earth object from the orientation point so its worst position is the center of a sphere which attaches several earth objects.
2. The point of strike of lightning is determined when the downward leader approaches the earth or structure with a striking distance.

The theory concludes that no structure will be strike by lightning if the striking distance is greater than the radius of the sphere.

Protected Distance Formula:

$$D=\sqrt{h_1(2R-h_1)}-\sqrt{h2(2R-h_2)}$$

D = horizontal protected distance

R = rolling sphere radius [30m (100ft)]

h_1 = height of strike termination device (air terminals)

h_2 = height of object to be protected

The 'D' in the equation referred to the distance between the air terminal and the edge of the zone of protection provided by the air terminal. Thus, in order to expand the area cover by zone of protection for the LPS it is best to locate an air terminal at that location. The process of calculating the distance and installing new air terminals need to be continued until the zone of protection for this LPS cover the whole structure.

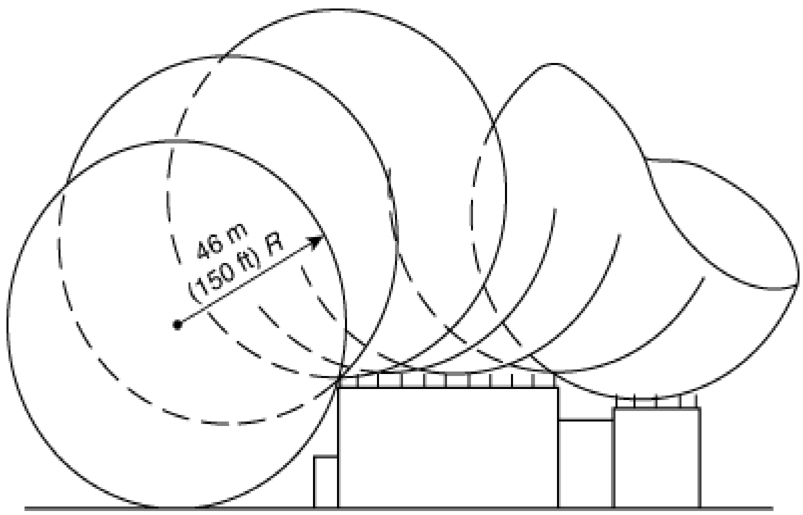

Figure 2: Zone of Protection Depicting Rolling Sphere. [7]

2.3 Standard Used In Designing LPS

2.3.1 PETRONAS Technical Standard (PTS 20.181) [6]

(a) General

According to PTS 20.181, LPS shall be installed if required in accordance with local regulations. In the absence of such regulations, the need for LPS shall be determined and the system where required shall be designed and installed in accordance with the standards.

For the purpose of facilitating a low impedance lightning discharge to earth, earth electrodes shall be located near the base of elevated structures requiring LPS. The electrodes shall be connected to the structure to be protected and interconnected with the plant earth ring by 70 mm* earth cables.

The combine resistance to the general mass of earth of the electrodes provided for LPS shall not exceed 5 Ω (8 Ω for rocky soils) when isolated from the plant earth ring.

(b) Protection of Equipment and Structures

The metallic enclosures of electrical equipment shall be bonded to the plant earth ring. The metallic enclosures of non-electrical equipment, for example vessels shall also be bonded to the plant earth-ring or be provided with their own duplicate earth electrodes; in the latter case the combined resistance to the general mass of earth shall not exceed 5 **Ω**. Plant grounding ring conductors shall have a cross sectional area of 70 mm^2. The cross sectional area of branch conductors connecting equipment and structures to the plant earth ring shall be:

1. To metallic enclosures of HV electrical equipment – 70 mm^2
2. To metallic enclosures of LV electrical equipment having a supply cable with a conductor cross section of 35 mm^2 and more - 70 mm^2
3. To metallic enclosures of LV electrical equipment having supply cable cross sectional area less than 35 mm – 25 mm^2
4. To control panels; etc - 25 mm^2
5. To non-electrical equipment exposed to lightning, e.g. tanks, columns and tall structures - 70 mm^2
6. To other non-electrical equipment - 25 mm^2

*2.3.2 IEEE Std. 142-2007 (IEEE Recommended Practice for Grounding of Industrial and Commercial Power System**)** [5]*

(a) Practice for LPS

Building and structures that store hazardous liquids, gases or explosives require additional protection. For this type of structure it is better to avoid using its exposed metal body as down-conductor. Thus, separately mounted LPS should be applied to this kind of structure.

The separately mounted LPS will be either mast or catenary system. Catenary system is made from combination of at least two masts and overhead ground wire. For structures containing flammable liquids and gases, the radius of the sphere of protection used is 30 m (100 feet). To prevent side flashes the minimum distance between a mast or overhead ground wire and the structure to be protected should not be less than the side flash distance as describe in NFPA 780.

2.3.3 National Fire Protection Association (NFPA 780) [7]

(a) Tanks Protection According to NFPA 780

NFPA 780 has specified the requirement protection for the above ground tanks at atmospheric pressure containing flammable vapors or liquids that give off flammable vapors. The tanks are divided into three groups according to the type of the roof; fixed-roof tanks, floating roof tanks, and metallic tanks with non metallic roof.

(b) Fixed-Roof Tanks

Metallic tanks with steel roofs of riveted, bolted, or welded construction, with or without supporting members, that are used for the storage of liquids that give off flammable vapors at atmospheric pressure shall be considered protected against lightning (inherently self-protecting) if all requirements below are met:

1. All joints between metallic plates shall be riveted, bolted or welded
2. All pipes entering the tank shall be metallically connected to the tank at the point of entrance
3. The roof shall have a minimum thickness of 4.8 mm (0.1875 inch)
4. The roof shall be welded, bolted or riveted to the shell

(c) Floating-Roof Tanks

Where floating roofs utilize hangers located within a vapor space, the roof shall be electrically bonded to the shoes of the seal through a direct electrical path at intervals not greater than 3m (10 ft) on the circumference of the tank. There are several requirements needs to be met in order to protect the tanks effectively:

1. The metallic shoe shall be maintained in contact with the shell and without openings through the shoe
2. Tanks without a vapor space at the seal shall not require shunts at the seal
3. Where metallic weather shields cover the seal, they shall maintain contact with the shell
4. The shunts shall be spaced at interval not greater than 3 m (10 feet) and shall be constructed so that metallic contact is maintained between the floating roof and the tank shell in all operational positions of the floating roof.

(d) Metallic Tanks with nonmetallic Roofs

Metallic tanks with wooden or other nonmetallic roofs shall not be self-protecting, even if the roof essentially gastight and sheathed with thin metal and with all gas openings provided with flame protection.

Such tanks shall be provided with strike termination deices. The strike termination devices shall be bonded to each other, to the metallic sheathing, if any, and to the tank shell. If any of the following strike termination devices shall be permitted to be used: conducting masts, overhead ground wires, or a combination of masts and overhead ground wires.

(e) Grounding Tanks

Tanks shall be grounded to conduct away the current of direct strokes and the buildup and potential that causes sparks to ground. A metal tank shall be grounded by one of the following methods:

1. A tank shall be connected without insulated joints to a grounded metallic piping system
2. A tank shall be bonded to ground through a minimum of two grounding electrodes, at maximum 30 m (100 ft) intervals along the perimeter of the tank
3. A tank installation using an insulating membrane beneath for environmental or other reasons shall be as in (2)

2.4 Risk Assessment [7]

The Lightning Risk Assessment Methodology is provided to assist the building owner or architect/engineer in determining the risk of damage due to lightning. Once the risk has been determined, deciding on the need for protection measures is much easier. The methodology considers only the damage caused by a direct strike to the building or structure to be protected and the currents flowing through the lightning protection system.

This risk assessment method is a guide that takes into account the lightning and the following factors:

(1) Building environment

(2) Type of construction

(3) Structure occupancy

(4) Structure contents

(5) Lightning stroke consequences

The methodology use lightning strike frequency (N_d) and tolerable lightning frequency (N_c) as the measure to determine the needs of LPS. The yearly lightning strike frequency (N_d) to a structure is determined by the following equation:

$$N_d = \left(N_g\right)\left(A_e\right)\left(C_1\right)\left(10^{-6}\right)$$

Where:

N_d = the yearly lightning strike frequency to the structure

N_g = the yearly average flash density in the region where the structure is located

A_e = the equivalent collective area of the structure (m^2)

C_1 = the environmental coefficient

The tolerable lightning frequency (N_c) is a measure of the damage risk to the structure including factors affecting risks to the structure, environment, and monetary loss. The tolerable lightning frequency is expressed by the following formula, where

$C = (C_2)(C_3)(C_4)(C_5)$.

$$N_c = \frac{1.5 \times 10^{-3}}{C}$$

2.5 Bond [8]

There are two different conditions to determine the requirement for a bond.

2.5.1 Condition 1

Long vertical metal bodies 18.3 meters (60 ft) in vertical length

This condition addresses long, vertical metal bodies, grounded and ungrounded, exceeding 18.3 meters in vertical distance. For steel framed structures these long, vertical metal bodies must be bonded as near as practical at their extremities to structural steel members. For reinforced concrete structures where the reinforcement is interconnected and grounded, these long, vertical metal bodies must be bonded to the lightning protection system (unless inherently bonded through construction) at their extremities. For other structures bonding is determined the same as condition 2.

2.5.2 Condition 2

Grounded metal bodies

a. Structures 12.2 m (40 ft) and less

b. Structures more than 12.2m (40 ft) in height

(1) Within 18.3 m (60 ft) from top of structure

(2) Below 18.3 m (60 ft) from top of structure

This condition addresses bonding of grounded metal bodies not covered by Condition1. Where grounded metal bodies are connected to the lightning protection system at only one extremity, use the following formula to determine if additional bonding is necessary:

$$D = \frac{hK_m}{6n}$$

D = the distance between a grounded body and a down conductor at which a bond becomes necessary.

h = he greatest vertical distance between the bond being considered and the nearest other lightning protection system bond (or to ground level if no other bond is present).

n = 1 where only one down conductor is within a 30.5-meter (100-foot) radius of the bond in question.

n = 1.5 where only two down conductors are within a 30.5-meter radius of the bond in question.

n = 2.25 where three or more down conductors are within a 30.5-meter radius of the bond in question.

For grounded metal bodies in structures more than 12.2 meters (40 feet) in height and where the bond in question is within 18.3 meters (60 feet) from the top of the structure, the following definitions apply.

h = the greatest vertical distance between the bond being considered and the nearest other lightning protection system bond (or to ground level if no other bond is present).

n = 1 where only one down conductor is within a 30.5-meter radius of the bond in question. Down conductors must be spaced at least 7.6 meters apart.

n = 1.5 where two down conductors are within a 30.5-meter radius of the bond in question. Down conductors must be spaced at least 7.6 meters apart.

n = 2.25 where three or more down conductors are within 30.5 meters of the bond in question. Down conductors must be spaced 7.6 meters apart.

2.6 Mast [7]

The zone of protection of a lightning protection mast shall be based on the striking distance of the lightning stroke, that is, the distance over which final breakdown of the initial stroke to ground or to a grounded object occurs.

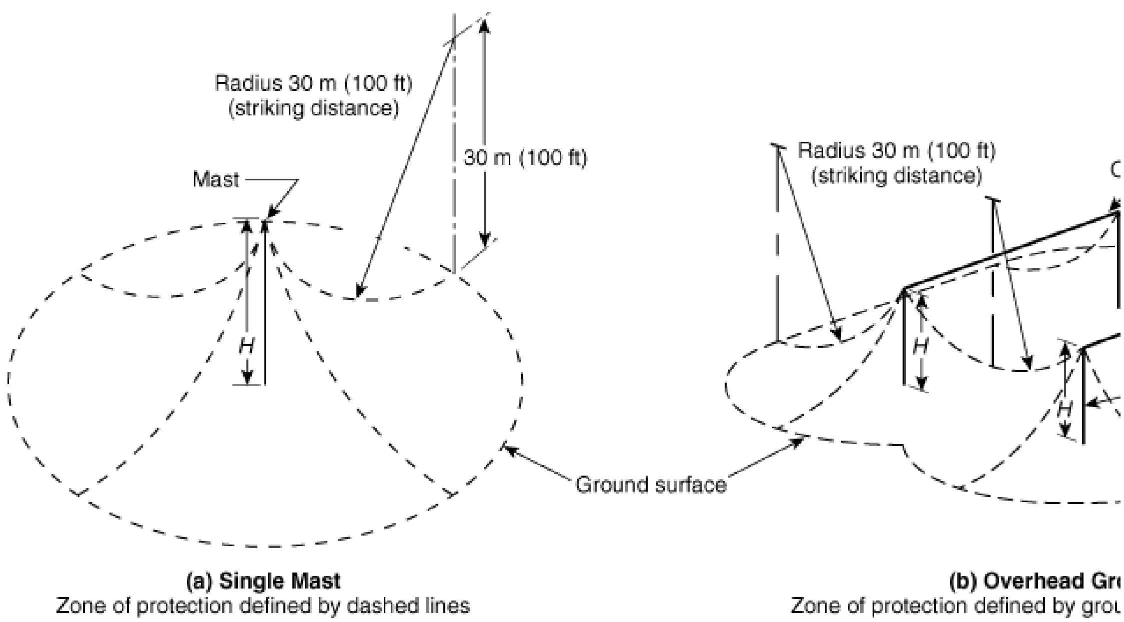

Figure 3: the ground radius covers by mast zone of protection [7]

The zone of protection of an overhead ground wire shall be based on a striking distance of 30 m (100 ft) and defined by 30 m (100 ft) radius arcs concave upward. The supporting masts shall have a clearance from the protected structure. To prevent side flashes, the minimum distance between a mast or overhead ground wire and the structure to be protected shall be not less than the bonding distance or side flash distance.

Side flash distance from a mast shall be calculated from the following formula:

$$D = \frac{h}{6}$$

Where:

D = side flash distance from a mast

h = height of structure (or object being calculated)

2.7 Catenary System [7]

This LPS consists of two masts driven into the ground supporting an overhead ground conductor. The zone of protection is defined by a circular arc concave upward. The radius of the arc is the striking distance, and the arc passes through the tip of the masts and is tangent to the ground.

Catenary system is installed as a LPS that is separated from the structure. It is to avoid the lightning current use the metal structure as down-conductor in order to reduce the risk of accident.

Side flash distance from a catenary shall be calculated as

$$D = \frac{l}{6n}$$

Where:

D = side flash distance from a catenary

l = length of lightning protection conductor between its grounded point and the point being calculated

n = 1 where there is a single overhead ground wire that exceeds 60 m (200 ft) in horizontal length

n = 1.5 where there is a single overhead wire or more than one wire interconnected above the structure to be protected, such that only two down conductors are located greater than 6 m (20 ft) and less than 30 m (100 ft) apart

n = 2.25 where there are more than two down conductors spaced more than 7.6 m (25 ft) apart within a 30 m (100 ft) wide area that are interconnected above the structure being protected

Side flash distance from a mast shall be calculated from the following formula:

$$D = \frac{h}{6}$$

Where:

D = side flash distance from a mast

h = height of structure (or object being calculated)

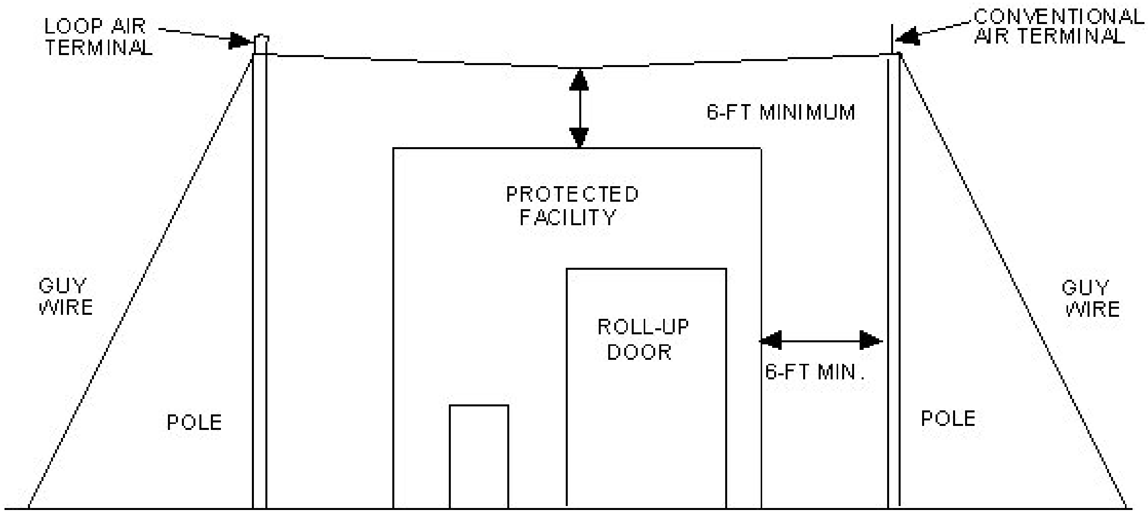

Figure 4: Catenary System [7]

CHAPTER 3

METHODOLOGY

3.1 Procedure Identification

The project activities are as follows:

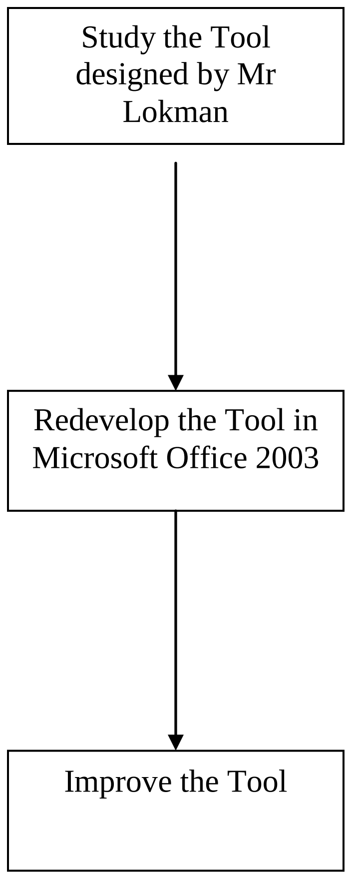

Figure 5: Flow chart of the project

3.2 Study the Tool designed by Mr Lokman

The objective of Mr Lokman's tool is to help the user to design and verify LPS. The tool only focuses on installation of LPS for industrial gas tanks. The tool is designed based on recognized standard, NFPA780, Standard for Installation Lightning Protection Systems, 2004 Edition. It will only involve in conventional LPS matters. This tool can be a good reference as it offers only necessary information regarding LPS installation and designing.

The tool is developed using Microsoft Office 2007. It involves logical function and mathematical equation. The LPS designing tool consist of eight parts; introduction, risk assessment, air terminals assessment, air terminals, down-conductor, catenary system, grounding system and proposed design requirement.

Mr Lokman's tool still far from complete as it needs several improvements. The tool need to be improve in term of interface as the current interface may let the user change or modify instruction or function easily. It can be improve using Microsoft Office Excel Macros.

The tool also need to be improve in term of including shape of structure as one of the parameter used in assessing the LPS. In addition, the tool also needs to be improved in term of having extra part that assess on soil condition.

3.3 Redevelop the Tool in Microsoft Office 2003

The tool needs to be redeveloped in Microsoft Office 2003 as the software is more practical and user friendly. Author manage to redevelop it in Microsoft Office 2003 with almost similar to Mr Lokman's tool in terms of designation and function of the tool.

The designation is similar as the current tool also consists of eight parts; introduction, risk assessment, air terminals assessment, air terminals, down-conductor, catenary system, grounding system and proposed design requirement.

However, the tool is quite far from complete as several functions and result can not be obtained specifically in Risk assessment part. This may be happen due to some error in inserting mathematical and logical function. Nonetheless, the tool still can be utilize and worked as it did not affect much on the other part of the tool. Proposes design requirement part still can display and suggest the best option for installation requirement for the protected structure.

3.4 Improve the Tool

Mr Lokman's tool still far from complete as it needs several improvements. The tool need to be improve in term of interface as the current interface may let the user change or modify instruction or function easily. It can be improve using Microsoft Office Excel Macros.

The tool also need to be improve in term of including shape of structure as one of the parameter used in assessing the LPS as structure shape effect the streamer propagation and the possibility of the structure to be strike by lightning. Besides, the shape also gives effect to the arrangement of air terminals on the structure.

In addition, the tool also needs to be improved in term of having extra part that assess on soil condition. The part may assess the type of soil and soil resistivity where the structure is build on. The data may be important as it may lead to more specific requirement for grounding system design.

However, none of above improvement can be made by author due to author's limitation and weaknesses.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Tool Description

The objective of this tool is to help the user to design and assess LPS. Currently the tool only focuses on installation of LPS for industrial gas tanks. The tool is designed based on recognized standard, NFPA780, Standard for Installation Lightning Protection Systems, 2004 Edition. It will only involve in conventional LPS matters. This tool can be a good reference as it offers only necessary information regarding LPS installation and designing.

The tool is developed using Microsoft Office Excel 2003. The tool involves logical function and mathematical equation in order to assess situation and solve the given equation. Data validation function also being applies to ensure the input columns are filled with the suitable input parameter. Besides, it also helps providing the list of input selection at the input columns.

The LPS assessment tool is consist of eight parts; introduction, risk assessment, air terminals assessment, air terminals, down-conductor, catenary system, grounding system and proposed design requirement. Except introduction, all parts can be grouped into three; assessment, input and output. Assessment group consist of risk assessment and air terminal assessment parts. Air terminals, down-conductor, catenary system and grounding system part will be in input group. The output group consists only proposed design requirement part.

4.2 Overview of the LPS assessment tool function

The assessing process starts with risk assessment part. This part will evaluate whether it will be necessary to install LPS or not. Besides, it will help in determining which LPS is appropriate for the structure; typical LPS or separately mounted LPS. If the structure is suitable to use typical LPS, the process will continue with the next part which is air terminals assessment part.

Air terminals assessment part will evaluate whether the building need lightning rod or otherwise it may employ it metal body as air terminals. If the assessment shows that lightning rod is not needed, the process will pass over the air terminals part and continue with down conductor part. If it shows that lightning rod is needed, the process will proceed with the normal procedure with the air terminals part and then followed by down-conductor part. After assessing the down-conductor part, the process will continue with grounding system part.

However, if the assessment of the structure shows that it suitable with separately mounted LPS, the process will continue with catenary system part rather than air terminals assessment part. After that, the process will continue with the grounding system part.

The grounding system part will be the center point between structure that used typical LPS and separately mounted LPS. The grounding system evaluation can be applied by both types of LPS as it aligns with recognized standards and manual.

Finally, after carrying out all assessment in input groups, all the data will be summarized in the final part which is proposed design requirement part. The result will only display one part, either typical LPS or separately mounted LPS.

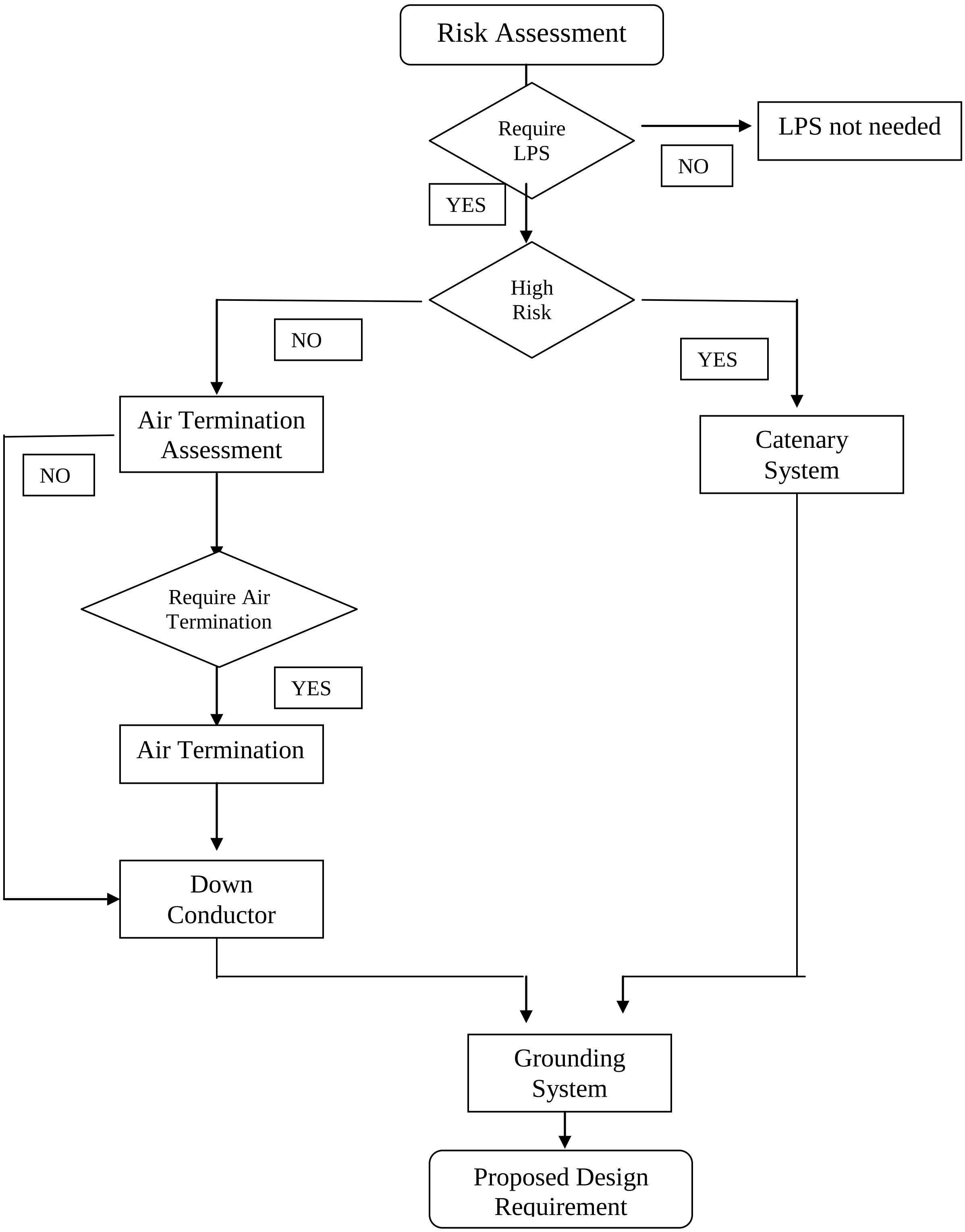

Figure6: Flow of LPS assessment tool operation [2]

4.3 LPS designing tool parts

4.3.1 Risk Assessment part

The objective of this part is to evaluate whether LPS is necessary or optional for installation. The Lightning Risk Assessment Methodology is provided to assist owner or engineer in assessing the risk of damage due to lightning. It will be much easier deciding on the need for protection after the risk has been assessed. The methodology will only considers damage from a direct strike to the building or structure to be protected and the currents flowing through the LPS.

The risk assessment is applied by comparing the value of lightning strike frequency to the structure (Nd) and the value of tolerable lightning frequency (Nc). If the value of lightning strike frequency (Nd) is less or equal to tolerable lightning frequency (Nc), LPS is not nacessary to be installed but if lightning strike frequency (Nd) exceeds tolerable lightning frequency (Nc), LPS should be installed.

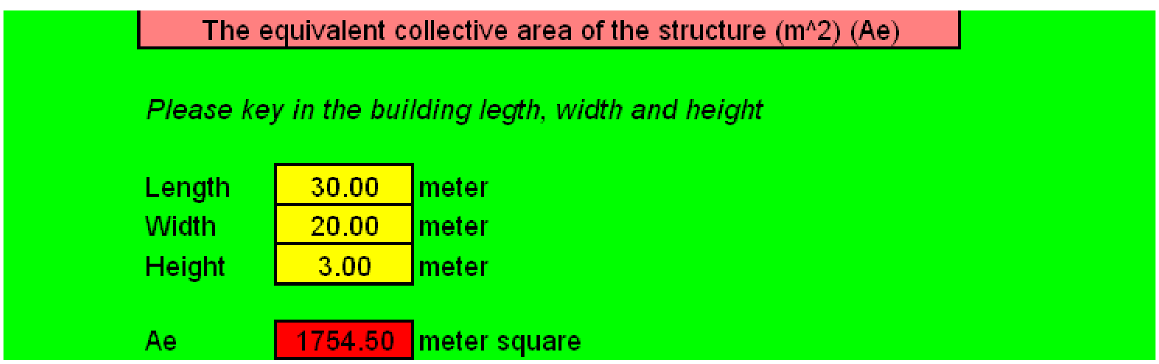

Figure 7: Equivalent collective area (Ae)

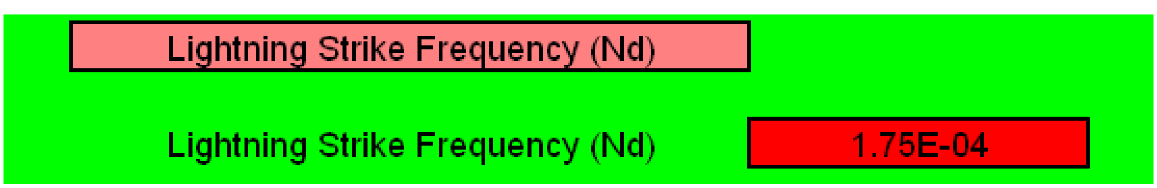

Figure 8: Lightning strike frequency (Nd)

In order to obtain lightning strike frequency (Nd), users need to key-in three parameters; lightning flash density (Ng), the equivalent collection area of the structure and environmental coefficient. Users may get the value of the lightning flash density (Ng) from Isokeraunic map. Users need to calculate the area of the structure that exposed to lightning in order to obtain the equivalent collection area of the structure. While for the constant, it can be obtain from the manual.

There are four elements involved in getting the value of tolerable lightning frequency; structural coefficients, structure contents, structure occupancy, and lightning consequence. Each element has assigned value that will be used in calculating the tolerable lightning frequency.

However, author cannot get the exact desired value for tolerable lightning frequency. This result may happen due to error in inserting wrong mathematical and logical function. However, the tool still can be used as it still can suggest to the user what type of LPS should be used and may proceed to next part.

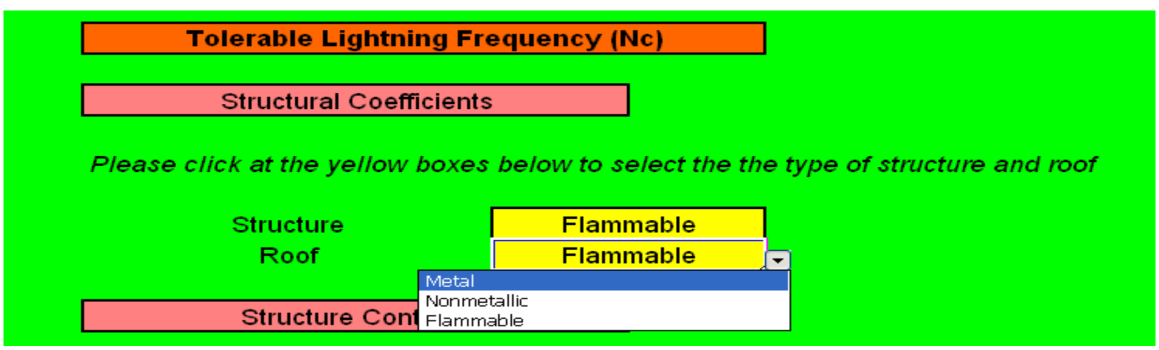

Figure 9: Structural Coefficient

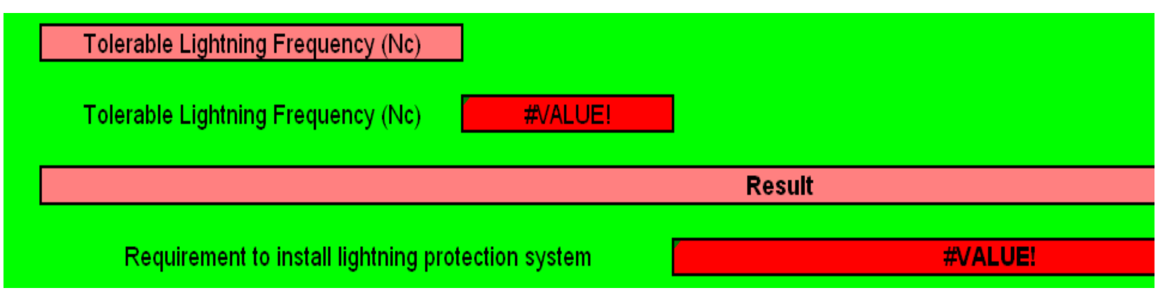

Figure 10: Output of risk assessment

4.3.2 Air Terminals Assessment part

The objective of this part is to evaluate whether lightning rod should be used as the air terminals or it is allowable to use tank exposed metal body as air terminals. There is option for metal structure such as tank whether wants to use lightning rod as air terminals or its exposed metal body as air terminals. However certain requirements need to be met if user wants to use the tank exposed metal body as air terminals. The requirements are different based on the type of tank. No evaluation needed for metallic tanks with nonmetallic roof since it certainly needs lightning rod as air terminals.

Three types of tanks that will be considered in this tool are fixed-roof tank, floating roof tank and metallic tank with nonmetallic roofs. Users are needed to pick the type of tank that need to be assessed. Fixed-roof tank has five criteria that need to be met. It is considered that the tank require lighting rod as air terminals if the criteria is not met. For floating roof tank has six criteria that need to be met to avoid using lightning rod as air terminals. For metallic tank with nonmetallic roofs, lightning rod required for air terminals.

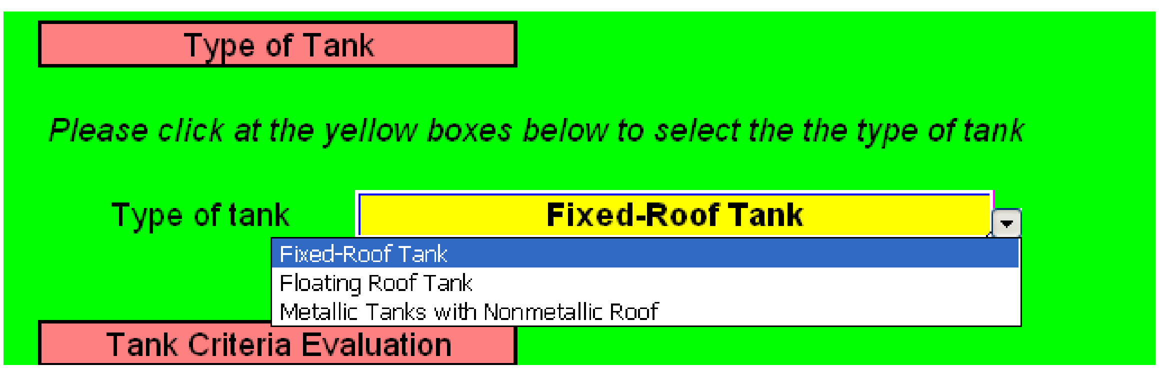

Figure 11: Type of tank selection

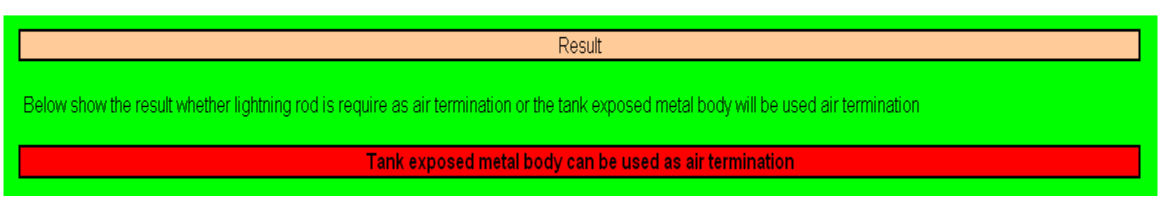

Figure 12: Output of the air terminal assessment part

4.3.3 Air Terminals part

The purpose of this part is to assess the arrangement, size and material used for the lightning rod. The lightning rod arrangement will be according to Roller Sphere Method (RSM). Users are required to key in certain parameter in order to determine the distance between two lightning rods, specifically height of the protected structure and the height of the lightning rod tip to the ground. The striking distance is set to be 30 meter.

Please key in height(meter) in the yellow box

Parameters	Input	
Height of lightning rod tip to the ground (h1)	30.00	Meter
Height of the protected structure (h2)	34.00	Meter
Striking distance (R)	30	Meter
Distance between two lightning rods	0.54	Meter

Figure 13: Parameters to determine distance between two air terminals

Besides that, users need to select what is the material used for lightning rod. There are only two material selection at present; solid copper and solid aluminum. The size of the lightning rod will be determined based on the material chosen.

Please click at the yellow boxes below to select the material for lightning rod

Material Solid Aluminium

Size of lightning rod according to the material selected

For **Solid Aluminium** lightning rod:

Length min 10 inch (25.4 mm)

Diameter at least 5/8 inch (15.9 mm)

Figure 14: Air Terminals material selection and its sizes

4.3.4 Down-Conductor part

The purpose of this part is to assess number of down-conductor, spacing between down-conductor, type, size and material of cable. Besides, the side flash distance between down-conductor and the protected structure will also be able to determine. This part has two major sections.

The first section purposely provides the tool to find out the numbers of down-conductor needed and the distance between the down-conductor. User need to key-in input variable which is the parameter of the tank and two output variables which are the number of conductor and the distance between down-conductor will be obtained. The output calculation is according to the standards which declare that for a building with parameters less than 76m minimum two down-conductors are required. For building with parameter more than 76m there must be at least one down-conductor for every 30.5m.

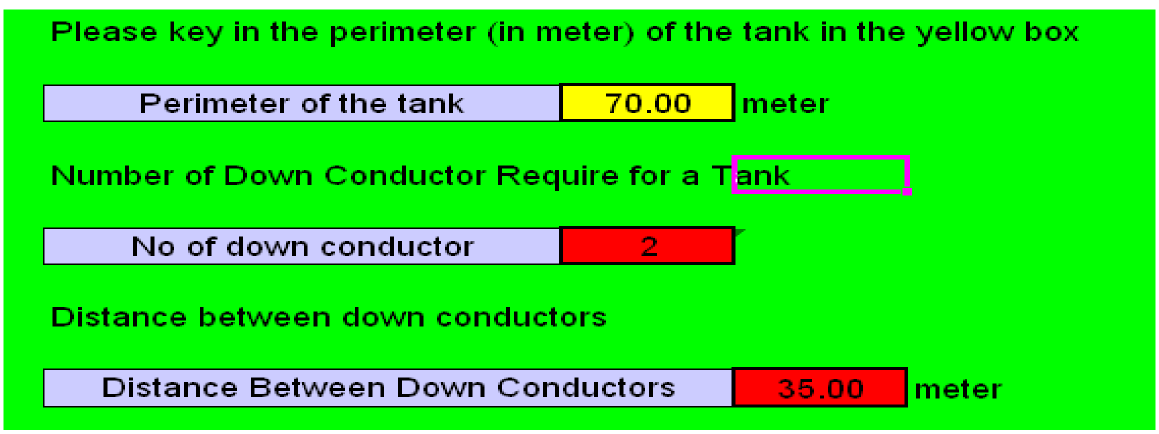

Figure 15: Number of down conductors and distance between it.

The second section purposely provide the tool is to assess the distance between down-conductor and grounded metal body. A bond needs to be made between the down-conductor and grounded metal body if the actual distance less than calculated distance. There will be three input variable. One of it requires the users to key any value according to the point that want to be investigated. Selection list will be provided for the other two.

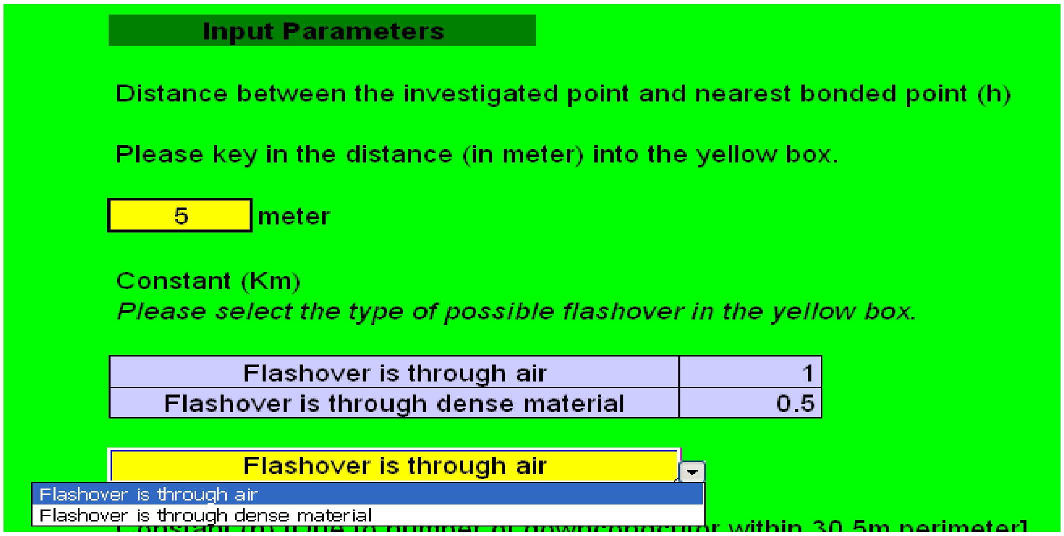

Figure 16: Input parameters for side flash distance

4.3.5 Catenary System part

The catenary system is a separately mounted LPS which considered as an alternative LPS for high risk structure. The purpose of this part is to provide the data regarding the distance require between two catenary systems, the side-flash distance between catenary (overhead ground wire) and protected structure, and the side-flash distance between catenary (mast) and protected structure.

The first section provides the assessment that determines the safe distance between two catenary systems. In order to determine the zone of protection, catenary system used similar equation that used to determine the distance between two air terminals. This part needs three input variables. User will only need to key-in the value for the height of catenary and the protected structure. The striking distance will be obtained automatically from the level of protection selected at air terminals worksheet.

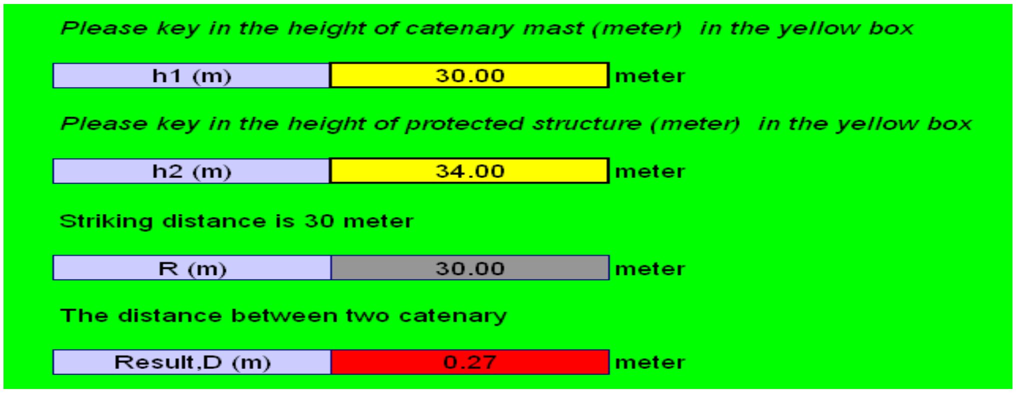

Figure17: Distance between two catenary systems

The second section need the tool to compute the minimum distance needed between catenary system (overhead ground wire) and protected structure. Two input variable will be needed which are the length of lightning protection conductor to the protected point and the constant. User will be needed to key-in the desire LPS conductor length. A selection list for the constant will be provided.

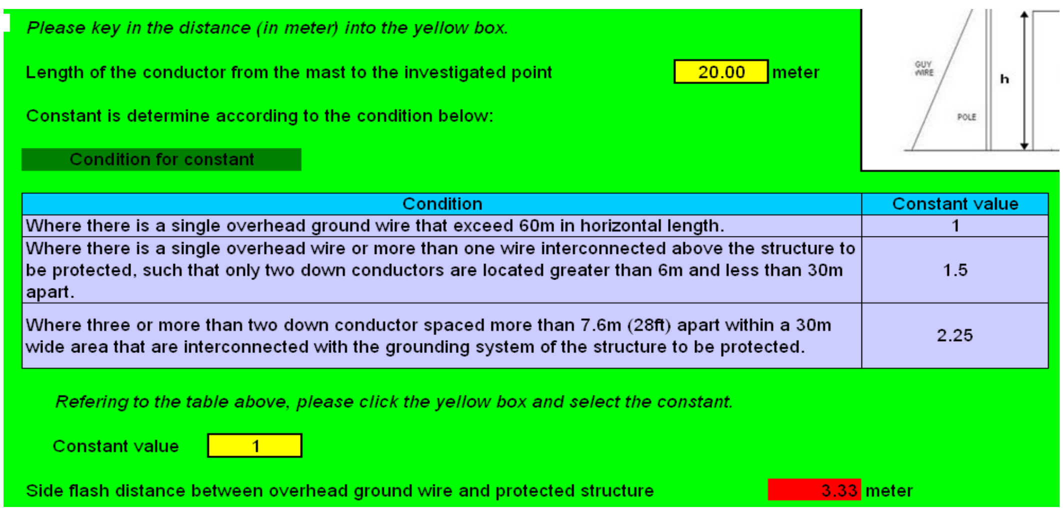

Figure 18: Input parameters for side flash distance

The third section needs the tool to compute the side flash distance between catenary systems (mast) and protected structure. Only one input variable needed which is the height of the protected structure. In order to obtain the output, users need to key-in the height of the protected structure.

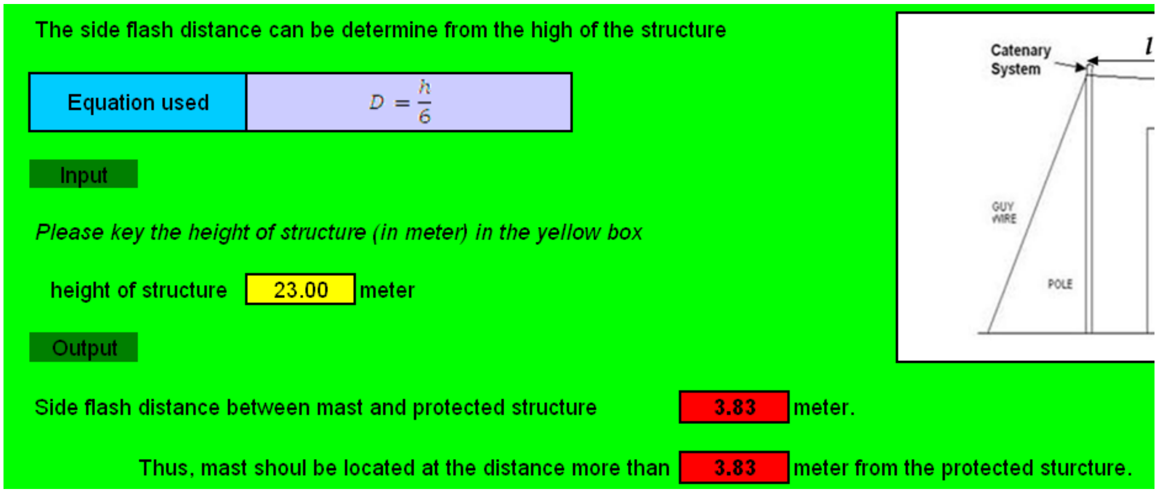

Figure 19: Side-flash distance (Between mast and protected structure)

4.3.6 Grounding System part

The purpose of this part is to assess the type of grounding system, size and material for grounding terminal, and the arrangement and installation requirement of grounding rod.

The first section needs the user to select the type of grounding system. There are five types of grounding system list in the tool at present; grounds rods, concrete-encased electrodes, ground ring electrode, radials and ground plate.

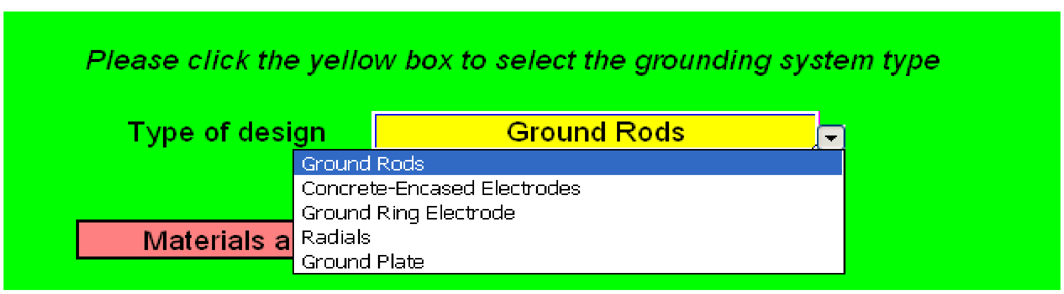

Figure 20: Types of grounding design selection

The second section will show the result of size and material for grounding terminal according to the selected type of grounding system. The grounding terminal may be in the form of ground rod, bare copper conductor and ground plate.

The third section will show arrangement and installation requirement of the selected grounding system type. Most of the output will be in the form of word and sentence.

4.3.7 Proposed Design Requirement part

This part is the output for the tool. It summarizes all the data from the earlier parts. This part is separated into four sections. The first section consist the result for the risk assessment and air terminal result. For example, if the risk assessment gives the result that LPS is not needed, only this section will be highlighted.

The second and third section is for typical LPS and separately mounted LPS case. Air terminals and down-conductor parts are in the second section and the catenary system will be in the third section. There is only one section will be highlighted at a time among this two sections. For example, when separately mounted LPS are selected for the design, only the third section will display the result and the second section will display null.

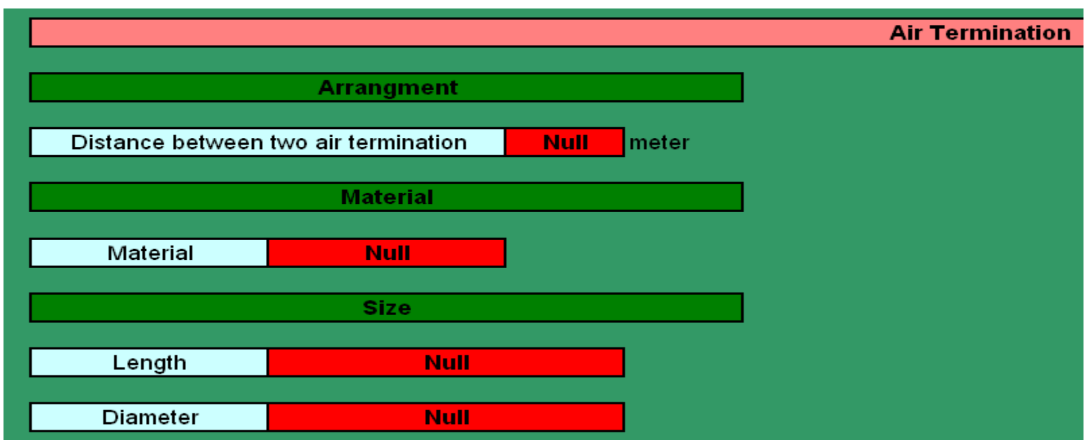

Figure 21: Output for air terminals

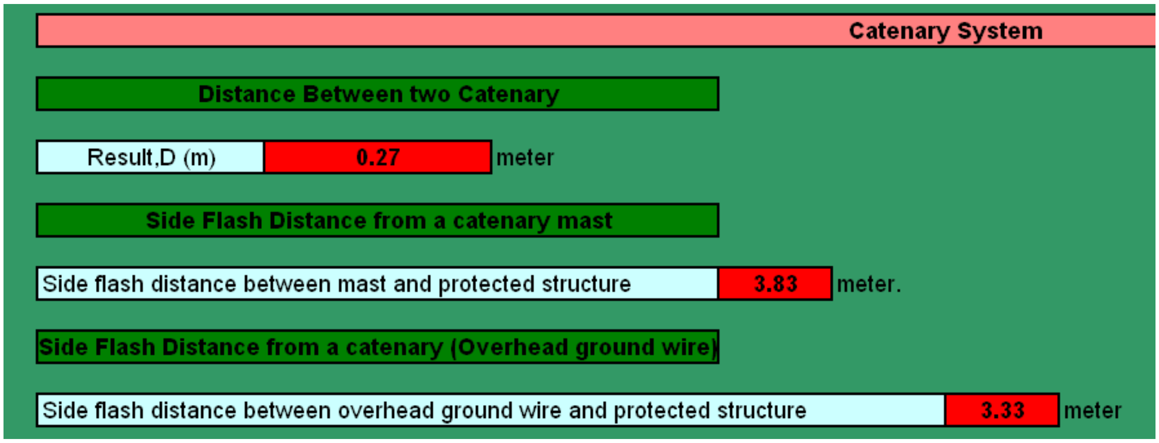

Figure 22: Output for catenary system

The last part is grounding system part. It displays the type of grounding system, size and material for grounding terminal and arrangement and installation requirement.

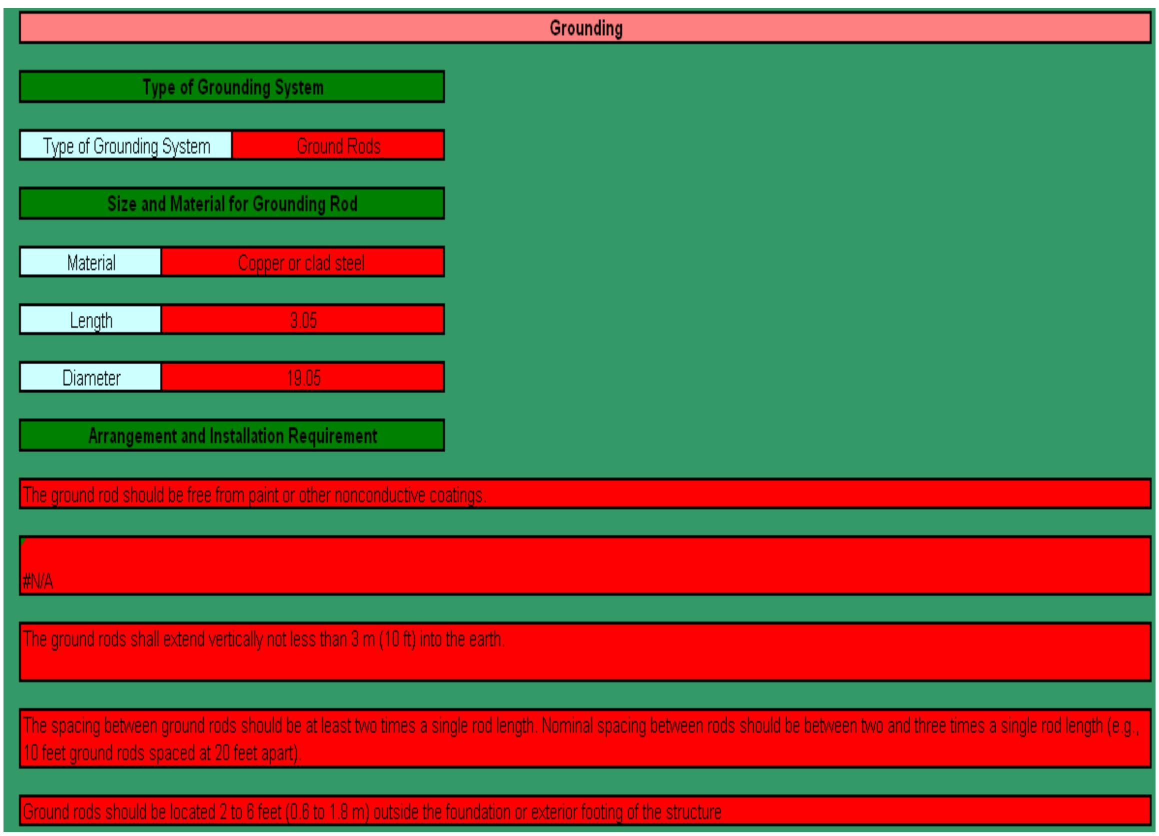

Figure 23: Output for grounding system

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, the main outcomes from this project went to the author himself; the knowledge and information gain by the author. At the beginning, the author has little idea on the topic of LPS. After doing several researches and intensive reading the author manages to understand the concept and theory of LPS. Author manage to identify the general elements of LPS, several types in designing LPS, components needed for LPS, size and material for the components, the parameters involve in LPS design and LPS installation requirement.

Author also manages to develop the LPS assessment tool. The tool is design so that it will be able to be used and handle easily by the user. The tool is able to provide basic information and knowledge on LPS to the user. It provides fundamental idea on how to design LPS and assist user to identify error in LPS design. The tool has simple instruction and well organized of LPS design process. Thus, any background of user may understand and use it effectively. In addition, the tool can be applied broadly without any limitation of software unavailability as we use general software which is Microsoft Office 2003.

However, the tool is still far from complete as several functions and result can not be obtained specifically in Risk assessment part. This may be happen due to some error in inserting mathematical and logical function. Nonetheless, the tool still can be utilize and worked as it did not affect much on the other part of the tool. Proposes design requirement part still can display and suggest the best option for installation requirement for the protected structure.

5.2 Recommendation

As reported from the previous researcher, the proposed design for the tool still far from the actual design. The information provided by the tool is still not enough to perform a complete LPS design.

In order to improve the tool, it is recommend that to correct some errors in inserting some mathematical and logical function specifically at Risk assessment part so that proper result can be obtained from the calculation of tolerable lightning frequency (Nc) as user will get proper suggestion on the next step of LPS installation process.

It is also recommends that to include the shape of structure as one of the parameter used in assessing the LPS as structure shape effect the streamer propagation and the possibility of the structure to be strike by lightning. Besides, the shape also gives effect to the arrangement of air terminals on the structure.

The tool also recommends having extra part that assess on soil condition. The part may assess the type of soil and soil resistivity where the structure is build on. The data may be important as it may lead to more specific requirement for grounding system design.

The tool also recommends to be improving in term of the interface. The suggestion is to use Microsoft Office Excel macros in order to improve the interface as the current interface may let the user to change or modify any of the instruction or function simply without any problem.

In order to get more reliable tool, it need to assemble more parameters and data for more specific requirement of LPS installation. It is suggested to focus on the other type of structure as at present the tool only focuses on industrial gas tank installation requirement.

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