Lightning Risk Assessment for Canseleri UiTM Building and Interface with GUI

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Abstract –**This paper presents the lightning risk assessment for Canseleri UiTM building based on Malaysian Standard MS 62306. Based on assessment R_1 shall be determined and compared with tolerable risk value $R_T = 10^{-5}$. Protection is required if the risk R_1 is higher than tolerable risk, R_T lightning protection required for structure. This paper also presents the result of Zone 3 (office building) in GUI method using MATLAB software as an alternative to mathematical method.**

Keyword: GUI method, risk assessment, Canseleri UiTM building, tolerable risk.

I. INTRODUCTION

Malaysia is one of highest records of lightning strikes among the countries in the world [1]. Lightning strike is a natural phenomenon with potentially devastating effects and represents one of the important causes of deaths from environmental phenomena. Lightning flashes to earth may be hazardous to structures and to services.

The risk to a structure can result in:

a) Damage to the structure and to its contents.
b) Failure of associated electrical and electronic systems.
c) Injury to living beings in or close to the structure.

The risk to services can result in:

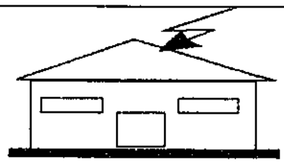
a) Damage to the service itself.
b) Failure of associated electrical and electronic equipment.

Flashes to the structure may cause physical damage and life hazards and flashes to the service may cause failure of electrical and electronic systems due to overvoltage from resistive and inductive coupling of systems with the lightning current.

There are **three type of damage** of lightning strike that is Injury to living beings (due to step and touch voltages), Physical damage (due to fire, explosion and mechanical destruction) and Failure of internal system (due to LEMP - lightning electromagnet impulse). When lightning strikes there are **four type of loss** associated with the structure namely loss of human life, loss of services to the public, loss of cultural heritage and loss of economic. Loss of human life, loss of services to public and loss of economic may be classified as social loss and loss of cultural heritage may be treated as economic loss [2].

There are 4 types of source damage and distinguished by the strike point in the Table 1.0

TABLE 1.0 – STRIKE POINT OF LIGHTNING

Source of damage	Point of strike
Flashes to a structure	
Flashes near a structure	
Flashes to a service	
Flashes near a service	

The lightning risk assessment is carried out to determine the risk for the building by using Malaysian Standard MS 62306 in order to determine the structure whether lightning protection device is required or not. This is for the purpose of reducing the risk and to protect the Canceleri UiTM building. Hence, the protection measures will reduce the risk for the structure into the safe condition.

II. METHODOLOGY

The procedure to assess the risk consists of 4 main steps mainly:-

1) Identify the structure to be protected and its characteristic
2) Identify the tolerable risk, R_T and all type of losses in the object and calculation of risk R_1
3) Evaluate the risk R_1 for each type of loss using mathematical method and GUI method.
4) Evaluate the need of protection, by comparing the risk R_1 for a structure with the tolerable risk, R_T [2].

Such steps are shown in Figure 1.

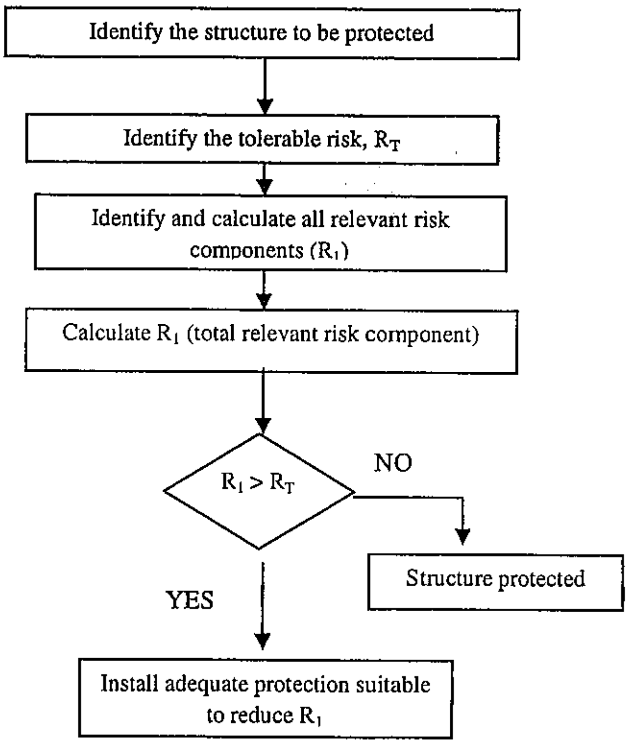


Figure 1. Procedure to find risk R_1

A. *Identify the structure to be protected*

The object need to be protected is the Canseleri UiTM building. The characteristic needed to be identified is the structure characteristic, internal power system characteristic and internal telecommunication system characteristic as well as lightning ground density in the region where the structure is located.

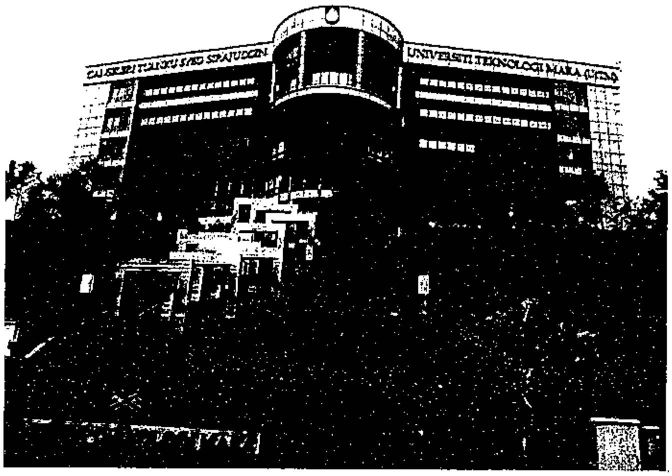


Figure 2. Canseleri UiTM

The Canseleri UiTM building is divided into three zones. Each risk component shall be evaluated for each zone and the total risk is the sum of the risk component related to the three zones. The three zones are in table 1.2.

TABLE 1.2 – ZONES OF CANSELERI UiTM

Zones	Characteristic
1	Entrance area
2	Garden
3	Offices

B. *Identify The Type Of Loss And Calculation Of Risks*

There are three type of tolerable risk in this assessment. The risk to be considered for each type of loss in a structure is **risk of human life** and it will assume as $\mathbf{R_1}$. The table 1.3 shows the type of tolerable risk.

TABLE 1.3 – TYPE OF TOLERABLE RISK

Type of tolerable risk	$R_T (y^{-1})$
Loss of human life	10^{-5}
Loss of service	10^{-3}
Loss of cultural heritage	10^{-3}

The risk of R_1 which is risk of human life can be calculated from equation and the description of other risk show in Table 1.4.

$$R_1 = R_A + R_B + R_U + R_V \qquad [2].$$

TABLE 1.4 – RISK AND DESCRIPTION

Risk	Component description
R_A	Injury to living beings caused by touch and step voltage in the zones up to 3m outside the structure
R_B	Physical damage causes by dangerous sparking inside the structure triggering fire or explosion that may endanger the environment
R_U	Injury to living beings causes by touch voltage inside the structure, due to lightning current inject in a line entering the structure
R_V	Physical damage (fire or explosion triggered by dangerous sparking between external installation at the entrance point of line into the structure) due to lightning current transmitted along incoming services such as telecommunication services

Each risk component R_A, R_B, R_U, R_V may be expressed by following general equation:

$$R_X = N_X P_X L_X \quad [2].$$

Where;

N_X = the annual number of dangerous events

P_X = the probability of damage for structure

L_X = the amount of loss in a structure

C. *Protection Measures*

The purpose calculating of R_1 is to compare with corresponding value of R_T which is 10^{-5}(loss of human). If the result shows $R_1<R_T$, then the structure does not need to be protected. If $R_1>R_T$, the structure need to be protected. The protection should consider the suitable protection measures in order to reduce the risk due to lightning measures, the following are considered in the IEC standard document [3]:

1) Lightning protection system (LPS) – this system have 4 class I,II,III,IV that is to intercept, conduct and disperse the lightning current into earth to minimize the potential differences and to limit surge by Suitable Surge Protection Device (SPD) included in internal LPS
2) SPD System – defines as coordinated SPDs properly selected and erected to internal system against surges. SPD located at the point of entry of incoming services reduces essentially the risk related to the overvoltage by resistive coupling due to direct flashes to the structure and the over voltages transmitted through the line[4].

D. *The Methods Of Risk Assessment For a Structure*

The method that is being used in achieving lightning risk assessment is a mathematical method of statistics based on Malaysia Standard MS 62306 which only uses basic calculation that consists of multiply, add, subtract and divide of this risk assessment calculation.

In statistics, the notion of risk is often modeled as the expected values of some outcome seen as undesirable. This combines the probabilities of various possible events and some assessment of the corresponding harms into a single value [1].

III. RESULT AND DISCUSSION

For this paper, the aim is to calculate the R_1 and compare with $R_T = 10^{-5}$. The data and characteristic of Canseleri UiTM building are recorded in table below:

TABLE 1.5 – STRUCTURE CHARACTERISTIC

Parameter	Comment	Symbol	Value
Dimension	Length (m) Width (m) Height (m)	L_b W_b H_b	64 25 33
Soil of resistivity	Ωm	p	100
Location factor	object same height or smaller	C_d	0.5
Lightning flash density	$1/km^2/year$	N_g	29

TABLE 1.6 – INTERNAL POWER SYSTEM CHARACTERISTIC

Parameter	Comment	Symbol	Value
Length (m)	-	L_c	1000
Height (m)	Buried	H_c	-
HV/LV transformer	two winding transformer	C_t	0.2
Location factor	object same height or smaller	C_d	2
environment factor	Urban with tall building	C_e	0
LPS	None	P_B	0.2
Probability injury to living being	None	P_U	0.03

TABLE 1.7 – INTERNAL TELECOMMUNICATION SYSTEM CHARACTERISTIC

Parameter	Comment	Symbol	Value
Length (m)	-	L_c	1000
Height (m)	Buried	H_c	-
HV/LV transformer	two winding transformer	C_t	0.2
Location factor	object same height or smaller	C_d	2
environment factor	Urban with tall building	C_e	0
Probability injury to living being	None	P_U	0.03
Probability injury to physical dmg	None	P_V	0.03

TABLE 1.8 – ZONES CHARACTERISTIC

Zone Z_1 (entrance area)			
Parameter	**Comment**	**Symbol**	**Value**
Soil of type	Marble	r_a	10^{-3}
Shock protection	None	P_A	1
Loss by touch and step voltage	Yes	L_t	10^{-4}
Zone Z_2 (garden)			
Parameter	Comment	Symbol	value
Soil of type	Marble	r_a	10^{-2}
Shock protection	None	P_A	0
Loss by touch and step voltage	Yes	L_t	10^{-4}
Zone Z_3 (office)			
Parameter	Comment	Symbol	value
Floor surface type		r_u	10^{-3}
Risk of fire	Low	r_f	10^{-3}
Special hazard	Low panic	h_Z	2
Fire protection	None	r_p	0.5
Loss by touch and step voltage	Yes	L_t	10^{-3}
Loss by physical damage	Yes	L_f	10^{-2}

For this sample calculation, the data has been used accordingly to the formulae based on mathematical method statistics.

TABLE 1.9 COLLECTION AREA OF STRUCTURE AND LINE

Symbol of area	Equation for collection area	Value m^2 ($x 10^5$)
A_d	To the structure: A_d = Lb x Wb x 6Hb x(Lb + Wb) + $9\pi Hb^2$	50263.234
$A_{l(p)}$	To the power line: $A_{l(p)} = \sqrt{\rho}$ + [Lc – 3Hb]	9010
$A_{i(p)}$	To the power line $A_{i(p)}$ = 25 x $\sqrt{\rho}$ x Lc	250000
$A_{l(T)}$	To the structure: $A_{l(T)}$ = Lb x Wb x 6Hb x(Lb + Wb) + $9\pi Hb^2$	9010
$A_{i(T)}$	To the power line $A_{i(T)}$ = 25 x $\sqrt{\rho}$ x Lc	250000

TABLE 1.10 EXPECTED ANNUAL NUMBER OF DANGEROUS EVENT

Symbol of number	Equation for number of flashes ($x\text{-}10^{-6}$)	Value (1/year)
Nd	Nd = Ad x Cd	0.7281
$Nl(p)$	$Nl(p)$ = Ng x $Al(p)$ x $Cd(p)$ x $Ct(p)$	0.1301
$Ni(p)$	$Ni(p)$ = Ng x $Ai(p)$ x Ct x Ce	0
$Nl(_T)$	$Nl(_T)$ = Ng x $Al(_T)$ x $Cd(_T)$	0.1301
$Ni(_T)$	$Ni(_T)$ = Ng x $Ai(_T)$ x $Ce(_T)$	0

TABLE 1.11 RISK COMPONENTS OF ZONES (ENTERENCE AREA)

Symbol of compone nt	Equation for number of flashes	Value ($x10^{-5}$)		
		Zone 1 Entrance area	Zone 2 garden	Zone 3 office
R_A	R_A = Nd x Pa x ra x Lt	0.0072	0	-
R_B	R_B = Nd x hz x P_B x rp x rf x Lf	-	-	7.281
$R_{U(p)}$	$R_{U(p)}$ = (Nl + NDA) x ru x Pu x Lt	-	-	0.0391
$R_{V(p)}$	$R_{V(p)}$ = (Nl + NDA) x Pv x hz x rp x rf x Lf	-	-	0.1959
$R_{U(T)}$	$R_{U(T)}$ = (Nl + NDA) x ru x Pu x Lt	-	-	0.0391
$R_{V(T)}$	$R_{V(T)}$ = (Nl + NDA) x Pv x hz x rp x rf x Lf	-	-	0.1959

The risk R_1 can be expressed by the following sum of components:

$$R_1 = R_a + R_B + R_{U\,(power\ line)} + R_{V(power\ line)} + R_{U(telecom\ line)} + R_{V(telecom\ line)}$$

$$= 0.0072 + 7.281 + 0.0392 + 0.1959 + 0.0391 + 0.1959$$

$$= 7.75 \times 10^{-5}$$

Since the value of $R_1 > R_T$ (tolerable risk) where is $7.75 \times 10^{-5} > 1 \times 10^{-5}$, lightning protection is required. According to calculation of R_1, the primary contributing factor to the value of the risk R_1 is in zone 3 due to

a) Component R_B (flash to structure) = 97.89%

b) Component R_U (flash to power and telecom line) = 0.56%

c) Component R_V (flash to power and telecom line) = 2.63%

The protective measure could be adopted to protect the building with a LPS Class 1 lightning protection, so the parameter of R_B will change due to PB = 0.02 and Install the coordinate SPD corresponding with the choice of lightning protection level (LPL). Parameter R_V and R_U will change is due to P_V and $P_U = 0.01$.

Therefore, the recalculate values relating to the risk R_1 for Canseleri UiTM building is summarized as follows:

$$R_1 = R_a + R_B + R_{U\,(power\ line)} + R_{V(power\ line)} + R_{U(telecom\ line)} + R_{V(telecom\ line)}$$
$$= 0.0072 + 0.7289 + 0.0130 + 0.0653 + 0.0130 + 0.0653 + 0.0653$$
$$= 0.8857 \times 10^{-5}$$

Thus $R_1 = 0.8857 \times 10^{-5} < R_T = 10^{-5}$, therefore The objective of lightning assessment has been achieved by selecting the appropriate protection measure in order to reduce the risk of loss of human R_T. Table 1.12 shown the summary of Canseleri UiTM building before and after protection adopted.

TABLE 1.12 - SUMMARY OF CANSELERI UITM BUILDING BEFORE AND AFTER LIGHTNING RISK PROTECTION

Risk component	Before protection adopted	After protection adopted
R_B	7.28968	0.728968
$R_{U(p)}$	0.0391935	0.0130645
$R_{V(p)}$	0.195968	0.0653225
$R_{U(T)}$	0.0391935	0.0130645
$R_{V(T)}$	0.195968	0.0653225
R_1	7.76	0.885742

For calculation of R_1 in Zone 3, this paper focused on using GUI method as an alternative to mathematical method. The equation of getting R_1 has been inserted in the GUI program as MATLAB code.

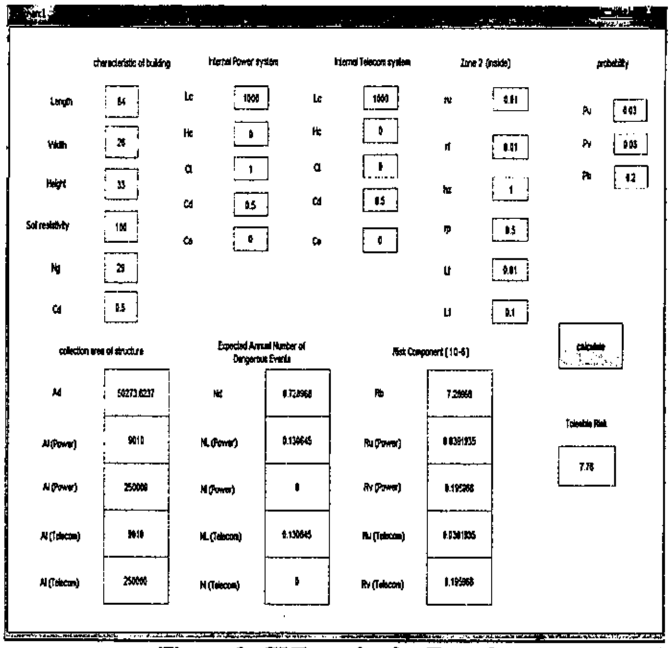


Figure 3. GUI results for Zone 3

To reduce the risk of R_1 is highly recommended to use GUI method. By using this method it can avoid error in calculation and to obtain faster result.

GUI is graphical user interface which is graphical display in one or more windows that containing control, called components that enable user to perform interactive tasks. The advantage of GUI is the user need not to understand the details of how the task is performed. It is because the user does not have to create a script or type commands at the command line to accomplish the tasks. Hence GUI simplifies the process of accomplishing task compared to coding program [5].

The user can manipulate and respond to each action and the user can has one or more user written routines (MATLAB code) known as *callback*. The callback function is triggered by a particular user action such as pressing a screen button, clicking a mouse button, selecting a menu item, typing a string or a numeric value, or passing the cursor over a component. The GUI then responds to these *events*. The user, as the creator of the GUI, provides callbacks which define what the components do to handle events [5].

This kind of programming is often referred to as event-driven programming. In the example, a button click is one such event. In event-driven programming, callback execution is for asynchronous, that is, it is triggered by events external to the software. In the case of MATLAB GUIs, most events are user interactions with the GUI, but the GUI can respond to other kinds of events as well, for example, the creation of a file or connecting a device to the computer [5].

IV. CONCLUSION

In conclusion, the objective of this paper had been achieved. Based on the result of risk assessment, the new lightning protection system has been proposed. There are previous paper suggesting on calculating using new software for more accurate and obtain faster result in calculation of probability. Based on result and discussion of using GUI method MATLAB software, the result seems to be more accurate and can reduce lots of time on calculation. This GUI MATLAB software can also be applied for all building zone (inside).

V. RECOMMENDATION

It is highly recommended to use GUI method MATLAB software in lightning risk assessment for each zone. This would enable the calculation of risk to be more precise.

VI. ACKNOWLEDGEMENT

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