A Case Study on Lightning Protection System in Term of Collection Volume Method at Faculty of Science Computer and Mathematics UiTM Shah Alam

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Abstract : **Risk assessment is a process in order to detect potential hazard and analyses the possible occurrences happen towards the building and assets by using the suitable lightning protection system (LPS). The study based on the Faculty Science Computer & Mathematics in order to decrease the risk of breakdown to electric and electronic devices because of lightning strikes. The risk of building will be determined based on Malaysian Standard Lightning Protection System MS 62305, which are divided into four parts. The tolerable risk that will consider to the human life that is 10^{-5} can be compared with R_1 (calculated value from equation). If $R_1 > R_T$, the suitable protection measure used in order to decreased risk cause by lightning strikes. The recommended method for this project is Collection Volume Method (CVM). This method had been evaluated and been discussed for any improvement and reliability regarding the risk assessment at respective building.**

Keywords: Lightning Protection System, Collection Volume Method, Faculty Science Computer and Mathematics, risk assessment, tolerable risk.

I. INTRODUCTION

Overhead line faults majority caused by lightning. Lightning strikes present in every day around the world. Faults in permanent damage to power system equipment caused by 5% to 10% of lightning [1]. At Tenaga Nasional Berhad (TNB), lightning also caused power interruptions at Power utility[2]. Lightning strike can reach 20kA to 300kA of stroke for about 1.8 to 18 microseconds. [10].

Basic principles of lightning protection are:

- Intercept the lightning discharge.
- Safety conducts the lightning currents.
- Minimize the effects of lightning currents.
- Dissipate the lightning currents in the earth.

The components of a lightning protection system include:

- Lightning Terminal
- Down Conductor System
- Earth Termination System

Basically LPS used is divided into two types:

- Conventional or standard LPS
- Unconventional or non-standard LPS

The IEC 62305 is comprised of 4 parts:

Part 1: General principles.
Part 2: Risk management.
Part 3: Physical damage to structures and life hazard.
Part 4 : Electrical and electronic system within structure

The possible sources of damage are identified:

- D1- Injury to humans and animals due to touch and step potential
- D2- Fire, mechanical destruction, explosion and chemical release
- D3: Failure of internal electrical/electronic systems due to lightning electromagnetic impulse.

Lightning protection system has 4 level as shown in Table 1 below. Minimum lightning protection level can be determine by this level. Figure 1 shows the types of damage from lightning strikes.

Table 1: Lightning protection level (LPL)

	LPL
LPL I	highest
LPL II	II
LPL III	III
LPL IV	lowest

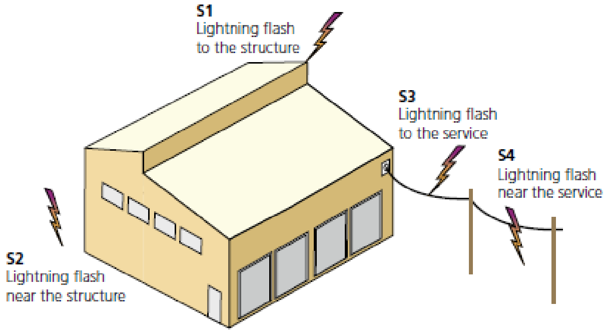

Figure 1: Sources Damage

Risk assessment is required to determine the risk for the structure in order to check whether the lightning protection system is needed or not. It helps people to take proper measures before lightning comes, it also can prevent people, equipment and buildings from being stroke[12]. By using mathematical method, the risk R1 of loss of human life can be obtained before compared with the tolerable value of $R_T=10^{-5}$

Recently, lightning can be divided into two phenomenon which is directly or indirect strike. Lightning that discharge to the power system directly and produce high impulse currents are called direct strike.

Meanwhile, lightning that discharge to the ground and produce smaller voltage and current to power line are called indirect strike. Miss-operation of control, breakdown to the electronic equipment are the effects of the indirect strike. In order to reduce damage when lightning strike, lightning protection system is designed to protect the building from the damage and passing low impedance direct to the ground.

The objectives for this project are:

1. To analyze the collected data obtained at the Faculty of Science Computer and Mathematics building.
2. To study on the lightning protection system used at Faculty of Science Computer and Mathematics based on risk assessment.
3. To purpose suitable method to FSKM building

The CVM was also re-named as the Field Intensification Method (FIM) in 2002 [8]. The collection volume method (CVM) was developed as an alternative ways to the existing air terminal. For the Dynasphere, this CVM was first used as a proprietary method that works on early streamer emission (ESE) air terminal a decade later [7]. This model used the "attractive radius" concept to function.

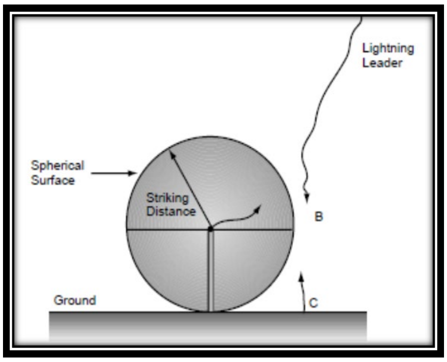

Figure 2: Spherical Surface Protection Method

From figure 2 above, a lightning leader approaching an isolated ground point. At this point, striking radius was ready. Radius will excite the electric field strength at the charge that ready to initiate upward leader. For initiation of the upward leader, that lightning leaders with weak electric charge approach closer to the ground point before achieving the critical conditions. Critical condition happened at the higher the magnitude of charge. Designing of hemisphere radius according to the level protection [13]

II. METHODOLOGY

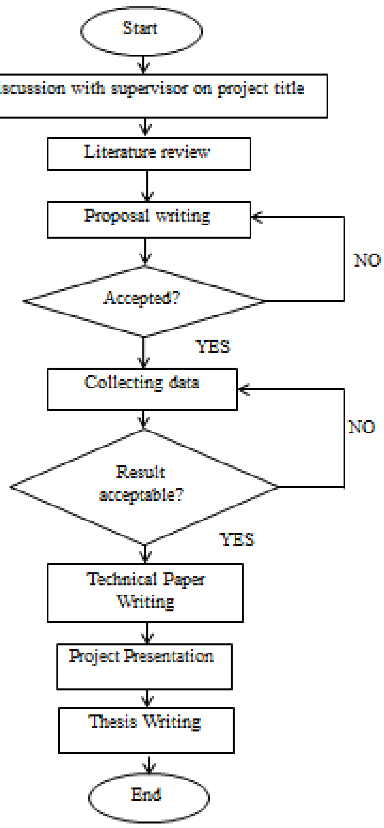

Figure 3 : Flowchart of the Project

Figure 3 shows the flow chart of the project. Firstly discuss with supervisor on project title. After that , search the journals, articles, and manual to proceed with literature review on the structure of building, effect, types and how lightning works. Apart from that, also need to study the Malaysian Standard MS IEC 62305. Next step is collecting data. Data was collected in order to determine and analyze the environment characteristics and the building itself and also study the building plan. Collect data by site visit at the building also is one of the ways. The result then tabulate in order to carry on to the next step. Figure 4 shows the flowchart of risk assessment.

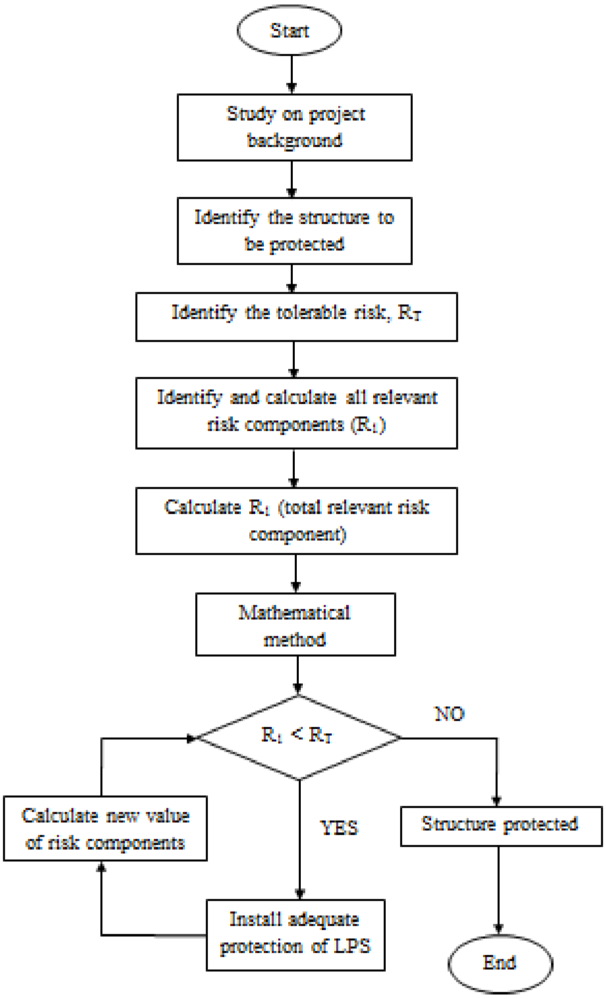

Figure 4: Flowchart of Risk Assessment

A. Identify the building to be covered and its Characteristics

The building that must covered is Faculty of Science Computer & Mathematics as shown in Figure 5. The location of this building is located on the hilltop, near the main road that all students take to pass by. The structure, internal power system and internal telecommunication system are the characteristics that need to be considered. Meanwhile, the location of the earth grounding also need to be identified.

From the view of floor plan and surveying at this building, the FSKM building has five floor including ground floor. This building also built in spherical surface.

Figure 6 shows the two earth chamber located at Faculty Science Computer & Mathematics

Figure 5: Faculty Science Computer and Mathematics

Figure 6: Earth Chamber at Faculty Science Computer and Mathematics

The building is divided into two zones. Zone 1 is outside building while Zone 2 is inside building as indicated at Table 2. The total of risk is the summation of these two zones.

Table 2: Zones of Faculty Science Computer and Mathematics

Zones	Characteristics
1	Outside building
2	Inside building

B. Identify the value of Tolerable Risk, R_T and Risk R_1

Table 3 indicate the typical value of R_T. The tolerable risk that considered is $R_T = 10^{-5}$ which is risk of human life for each type of loss.

Table 3: Typical values R_T

Type of loss	R_T (y^{-1})
Loss of human life	10^{-5}
Loss of service to the public	10^{-3}
Loss of cultural heritage	10^{-3}

The risk of R_1 can be calculated from equation. R_U and R_V consist of power line and telecom line.

$$R_1 = R_A + R_B + R_U + R_V \text{.......... [12]}$$

C. Protection Measurement

The value of R_1 that have been calculate is compare with the value of R_T which is 10^{-5}. If $R_1 < R_T$, the FSKM building does not need to be protected. The FSKM building need to be protect if the value of $R_1 > R_T$. The IEC standard regulation are:

a) Lightning protection system (LPS)

LPS can protect structure or building by conduct, intercept and disperse the lightning current to the earth. The purpose is to limit surge by suitable surge protection devices that include in LPS and to minimize the potential differences.

b) Surge protection device (SPD)

SPD is located at the point of entry of incoming services. Resistive coupling is used in order to minimize the overvoltage.

D. Risk Assessment for a structure

To achieve lightning risk assessment, mathematical method of statistic was used based on Malaysia Standard MS 62305.The value of R_1 was been calculated based on the data that obtain from FSKM building.

III. RESULT AND DISCUSSION

The data and characteristic of Faculty of Science Computer and Mathematics (FSKM) was recorded below. Table 4 shows the structure characteristic, Table 5 shows the internal power system characteristic, Table 6 shows the internal telecommunication system characteristic , Table 7 shows the zones characteristic, Table 8 shows the collection areas of structure and line, Table 9 shows the expected annual number of dangerous event and Table 10 shows the risk components of zones.

Table 4: Structure data and characteristic

Parameter	Symbol	Comment	Value
Dimension(m)	W_b L_b H_b	Width Length Height	74 85.6 35
Lightning flash density	N_g	1/km²/year	4
LPS	P_B	None	1
Soil resistivity	p	mΩ	500
Location factor	C_d	Isolated object on a hilltop or a knoll	2

Table 5: Power line and internal system

Parameter	Comment	Symbol	Value
Height	Buried	H_c (m)	-
Length	None	L_c (m)	1000
Probability injury to living being	None	P_U	1
Environment factor	Urban with tall building	C_e	0
Location factor	Isolated object on hilltop	C_d	2
HV/LV transformer	Two winding transformer	C_t	0.2

Table 6: Telecom line and internal system

Parameter	Comment	Symbol	Value
Height	Buried	H_c(m)	1
Length	None	L_c(m)	1000
Location factor	Isolated object on a hilltop	C_d	2
Probability injury to physical damage	None	P_V	1
Probability injury to living beings	None	P_U	1

HV/ LV transformer	Two winding transformer	C_t	0.2
Environment Factor	Urban with tall building	C_e	0

Table 7: Zone Z_2(Inside the building) characteristic

Parameter	Comment	Symbol	Value
Loss by touch and step voltages	Yes	L_t	10^{-4}
Fire protection	None	r_p	0.2
Loss by physical damages	Yes	L_f	10^{-1}
Special hazard	Difficulty of evacuation	h_z	5
Risk of fire	low	r_f	10^{-3}
Floor of surface type	marble	r_u	10^{-3}

Table 8: Collection areas of structure and line

Symbol of area	Equation for collection area	Value m^2 ($x10^5$)
A_d	$A_d = \{L_b \, x \, W_b \, x \, 6H_b \, x \, (L_b + W_b) + \pi \, x \, (3H_b 2)\}$	74486.459005828
$A_{l(p)}$	$A_{l(p)} = \sqrt{\rho} + [L_c - 3H_b]$	20012.808398623
$A_{i(p)}$	$A_{i(p)} = 25 \, x \sqrt{\rho} \, x \, L_c$	559016.994374947
$A_{l(t)}$	$A_{l(t)} = \sqrt{\rho} + [L_c - 3H_b]$	20012.808398623
$A_{i(t)}$	$A_{i(t)} = 25 \, x \sqrt{\rho} \, x \, L_c$	559016.994374947

Table 9: Expected Annual Number of Dangerous Event

Symbol of number	Equation for number of flashes ($x10^{-6}$)	Value (1/year)
N_d	$N_d = A_d \, x \, C_d \, x \, N_g$	0.595891672
$N_{L(p)}$	$N_{L(p)} = N_g \, x \, A_{l(p)} \, x \, C_{d(p)} \, x \, C_{t(p)}$	0.032020493
$N_{i(p)}$	$N_{i(p)} = N_g \, x \, A_{i(p)} \, x \, C_{t(p)} \, x \, C_{e(p)}$	0
$N_{L(T)}$	$N_{L(T)} = N_g \, x \, A_{l(T)} \, x \, C_{d(T)} \, x \, C_{t(T)}$	0.160102467
$N_{i(T)}$	$N_{i(T)} = N_g \, x \, A_{i(T)} \, x \, C_{e(T)} \, x \, C_{t(T)}$	0

Table 10: Risk Components of Zones

Symbol of component	Equation for number of flashes	Zone Z_2 (inside building)
		Value ($x10^{-5}$)
R_B	$R_B = N_d \, x \, h_z \, x \, P_B \, x \, r_p \, x \, r_f \, x \, L_f$	59.589167205
$R_{U(power\ line)}$	$R_U = (N_L + N_{DA}) \, x \, r_u \, x \, P_U \, x \, L_t$	0.006279122
$R_{V(power\ line)}$	$R_V = (N_L + N_{DA}) \, x \, P_V \, x \, h_z \, x \, r_p \, x \, r_f \, x \, L_f$	62.791216548
$R_{U(telecom\ line)}$	$R_U = (N_L + N_{DA}) \, x \, r_u \, x \, P_U \, x \, L_t$	0.007559941
$R_{V(telecom\ line)}$	$R_V = (N_L + N_{DA}) \, x \, P_V \, x \, h_z \, x \, r_p \, x \, r_f \, x \, L_f$	75.599413924

Summation of R_1 can be shown by the following:

$R_1 = R_B + R_{U(p)} + R_{V(p)} + R_{U(t)} + R_{V(t)}$

$= 59.589167205 + 0.006279122 + 62.791216548 + 0.007559941 + 75.599413924$

$= \underline{197.993636740 \times 10^{-5}}$

Because of $R_1 > R_T$ (tolerable risk) where $197.993636740 \times 10^{-5} > 1 \times 10^{-5}$, lightning protection for the structure is required. The main contributions to the value of risk are from:

a) $R_{V(Telecom\ line)} = 38.18\%$
b) $R_{V(Power\ line)} = 31.71\%$
c) $R_B = 30.10\%$

To reduce the risk of R_1 to a tolerable value, the protective measure that influenced the component above should be considered. Suitable measure that can be installing is LPS Class 1 which can reduce the value of P_B from 1 to 0.02 and the value of P_U and P_V from 1 to 0.01. Inserting these values into the equations in table 10 above, new values of risk assessment are obtained below

$R_1 = R_B + R_{U(p)} + R_{V(p)} + R_{U(t)} + R_{V(t)}$
$= 1.191783344 + 0.000062791 + 0.627912165 + 0.000075599 + 0.755994139$
$= \underline{2.575828039 \times 10^{-5}}$

Table 11: Summary of Faculty of Science Computer and Mathematics of UiTM Shah Alam building before and After Lightning Risk Protection

Risk component ($x10^{-5}$)	Before	After
R_B	59.589167205	1.191783344
$R_{U(p)}$	0.006279122	0.000062791
$R_{V(p)}$	62.791216548	0.627912165
$R_{U(t)}$	0.007559941	0.000075599
$R_{V(t)}$	75.599413924	0.755994139
R_1	197.993636740	2.575828039

Table 11 shows the summary of lightning protection at FSKM building before and after protection. $R_1 = 2.575828039 \times 10^{-5} > R_T = 1 \times 10^{-5}$, therefore, by selecting the suitable protection measure the objectives has been achieved by because the value of R_1 after changing the type of LPS reduce from the first type of LPS. There is not much difference in the values of R_1 with the R_T, and it is can be said that this value is acceptable between the range.

IV. CONCLUSION

From the research that has been done, the objectives given was achieved. The first objective is to analyze the data collected at FSKM building. The data that was recorded has been analyze in order to continue the project. The recorded data and the calculation method in this case study from MS 62305.

For this building, LPL level I was installed from no protection and the result can reduced the tolerable risk of R_1 from no protection was installed.

Collection Volume Method was proposed as the reliable lightning protection system to the building.

V. RECOMMENDATION

Several methods can be done to the building in order to reduce lightning strike which are by applying more than one of lightning protection system on a building. Besides that, the calculation of the risk also can be improved by using any software related in order to reduce calculation error.

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