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Simulation Investigation of Rolling Sphere Method as Lightning Protection System for Buildings Using AutoCAD - 3D Lightning Software

Yanuar Z. Arief
[1)]*Dept.of Electrical and Electronic Eng.*
Faculty of Engineering
Universiti Malaysia Sarawak
(UNIMAS)
94300 Kota Samarahan, Sarawak, Malaysia
ayzulardiansyah@unimas.my

[2)]*Dept. of Electrical Engineering,*
Faculty of Engineering & Information System
Jakarta Global University (JGU),
16412 Depok, West Java, Indonesia

Jefferson Sait
Dept. of Electrical and Electronic Eng.
Faculty of Engineering
Universiti Malaysia Sarawak
(UNIMAS)
94300 Kota Samarahan, Sarawak, Malaysia
64796@siswa.unimas.my

Aulia
Dept. of Electrical Engineering,
Faculty of Engineering,
Universitas Andalas (UNAND),
Padang, West Sumatra, Indonesia
aulia@eng.unand.ac.id

Naemah Mubarakah
Dept. of Electrical Engineering,
Faculty of Engineering,
Universitas Sumatera Utara (USU),
20155 Medan, North Sumatra, Indonesia
naemah@usu.ac.id

Yulianta Siregar
Dept. of Electrical Engineering,
Faculty of Engineering
Universitas Sumatera Utara (USU),
20155 Medan, North Sumatra, Indonesia
Julianta_srg@usu.ac.id

Hendri Masdi
Dept. of Electrical & Electronic Engineering
Faculty of Engineering
Universitas Negeri Padang (UNP)
Padang, West Sumatra, Indonesia
hendri@ft.unp.ac.id

***Abstract*—A lightning protection system (LPS) is one of the protection systems that has been used to protect structures from fire or mechanical destruction. LPS also prevents the person in the building from being injured or killed during the lightning strikes the ground. The failure to install or design the LPS will increase the hazard to the building, electrical and electronic devices, and humans. Incorrect implementation of LPS can cause the chance of lightning strikes on unprotected parts of the building to increase. The structure that contains toxic, flammable, or explosive products would likely cause the hazard to increase beyond the incident area. To solve this issue, a simulation of the rolling sphere method (RSM) has been performed for the selected buildings of UNIMAS, which are the Faculty of Engineering (FENG) and Chancellery buildings. In this work, two elements will be studied namely lightning protection zone and the area of protection for the building. To study the lightning protection area, the simulation will be conducted by using the 3D lightning application on AutoCAD. The length of the lightning arrester has been manipulated to observe the changes lightning protection zone for every lightning protection level. Furthermore, an improvement on the LPS design for both buildings was been completed based on the simulation result of the original building design. For the FENG building, the best design was to use 2.0 m of lightning arrester rod while the Chancellery building used 1.0 m of lightning arrester rod since the protection zone of 1.0 m was nearly the same as the 2.0 m one.**

Keywords—Lighting protection system, Rolling sphere method, Lightning strike, AutoCAD – 3D lightning software, Lightning protection zone, lightning arrester rod.

I. INTRODUCTION

Lightning is a natural phenomenon that consists of massive electrical discharge. It occurs in the atmosphere between clouds, the air, or the earth. It is the result of the rapid discharge of electricity as the opposite charge that has been built up exceeds the air's insulating ability. Lightning strike also affects metal which makes it melt when struck by lightning. Failure in designing could be inappropriate method use and inaccurate data that has been collected. Choosing the incorrect method to install a lightning protection system (LPS) would cause some zones may be not protected [1-5].

The inaccurate design of the position or length of the lightning arrester on the building was one of the problem statements for this project. A lightning protection system (LPS) needed to be installed on a building especially a tall building that occupied a lot of people and contained electrical and electronic equipment. It was found that the reports regarding to simulation of the lightning protection area of the rolling sphere method (RSM) are few compared with other methods such as the mesh method and protective angle method. This might be due to the limited open-source software available for conducting the simulation of LPS [6-8].

In this work, a conventional lightning protection system namely a rolling sphere will be simulated in selected buildings of UNIMAS which were FENG and Chancellery buildings. The suitable design of lightning protection has also been selected based on the result of the simulation and

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its area protection. Using this final design of RSM for both buildings is hopefully able to give better protection to the building compared to the original design which is based on its actual layout. The protective area against lightning will be investigated based on different lightning protection levels (LPL). The improvement of design will also be suggested using this simulation.

II. Method

A. AutoCAD and 3D Lightning Software

AutoCAD 2013 was employed to stimulate the lightning protection zone for RSM of LPS. AutoCAD is a computer-aided design (CAD) type of software created by Autodesk company. It enables the user to create, design, and edit a precise 2D and 3D geometry drawing. The advantages of AutoCAD are easier for the user to edit and manipulate the designs, shortens the time of production, and has better accuracy in design in all dimensions. The reason for choosing the oldest version of AutoCAD is because it is compatible with 3D lightning.

3D lightning is software that uses the RSM and LPS class to calculate and visualize the protected area. This makes it easier to determine the effectiveness of air termination components. For the time being, the software is only applicable to single, double, and multiple rods as well as shield wires. On zero level, the earth's surface is considered the ground plane. The striking distances to the ground, shield wire, and rod are the same.

Fig. 1 shows the flowchart of conducting the simulation for the rolling sphere method. In both buildings, three different lengths of lighting arrester were used which were 0.5 m, 1.0 m, and 2.0 m in order to observe the changes in the protection zone. Each of the designs will be observed in every lightning protection level and the area of the protection will be calculated based on the particular height of the horizontal section. To finalize the design of the protection, the selection and positioning of the lightning arrester was chosen based on the previous result of the simulation which can give the best protection for the particular building.

B. Case Study of Buildings for Simulation

The case study for simulation of the lightning protection method was performed on the building of the Faculty of Engineering (consisting of the administration office, mechanical engineering, and Electrical & Electronic Engineering Department) so-called FENG building, and Chancellery Building, Unimas. The location was located in Unimas campus as shown in Fig. 2.

In AutoCAD, the building model of the case study is designed based on the layout of the blueprint given by the Asset Office, Unimas. The model will be designed in 2D before being converted into 3D by using "Extrude" on AutoCAD's command. Fig. 3 shows the side view of FENG and Chancellery building in AutoCAD software.

The determination of the radius for lightning strikes is based on the IEC standard (IEC 62305). Table 1 shows the radius for the rolling sphere that has been simulated for the rolling sphere method according to its lightning protection level (LPL). The function of the LPL was to decide the capacity for conduction and interception of lightning for the selected protection level [9].

The RSM can be used to establish the proper location for external lightning protection apparatus such as the air termination (Franklin's rod), down conductor, ring electrode, and grounding system [11-12].

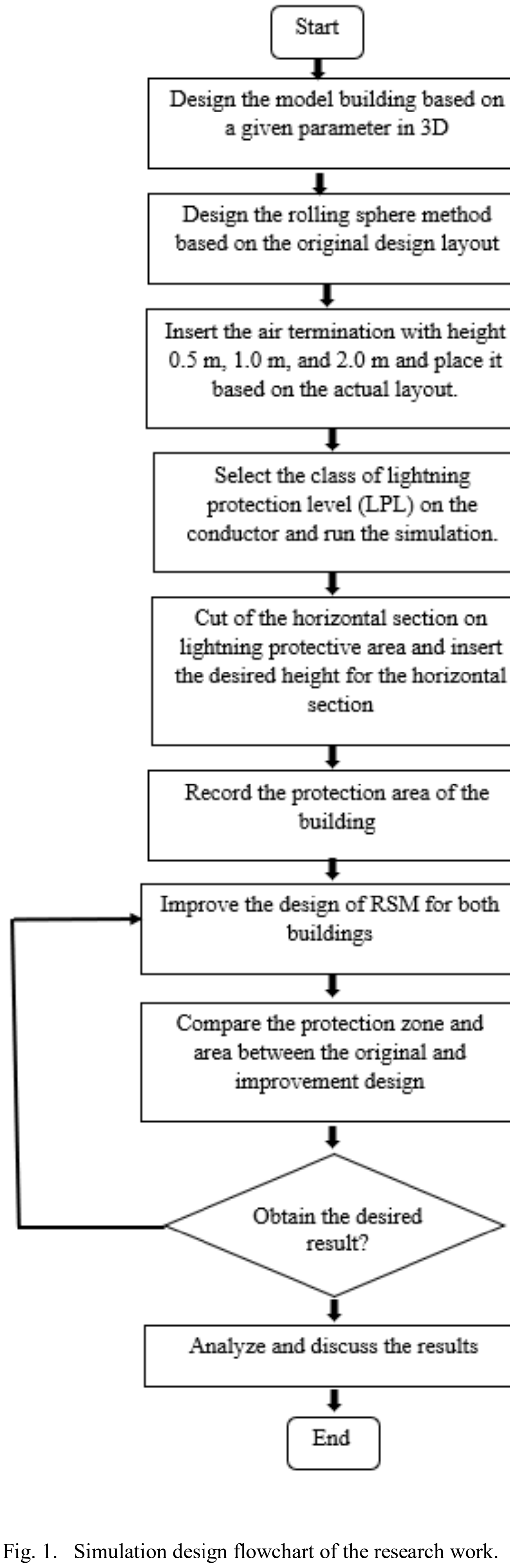


Fig. 1. Simulation design flowchart of the research work.

(a)

(b)

Fig. 2. Case study for the simulation: (a) FENG Unimas building and (b) Chancellery building as seen from Google Map

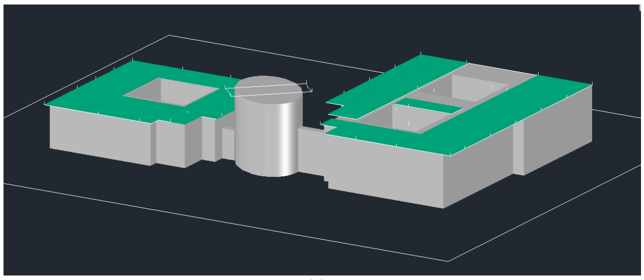
TABLE 1. ROLLING SPHERE RADIUS ACCORDING TO LPL [7].

Lightning Protection Level (LPL)	Rolling sphere radius (m)
1	20
2	30
3	45
4	60

III. RESULTS AND DISCUSSION

The lightning protection area of the rolling sphere has been observed with different lengths of a lightning rod for the FENG building while the Chancellery building will be observed in terms of positioning of lightning arrester. The lightning protection area of the rolling sphere has been observed in two terms which are in a 3D model and the area of the lightning protective zone. The simulation of the lightning protection area was observed for every length of the lightning arrester rod (0.5m, 1.0m, and 2.0m).

Fig. 4 shows the simulation results for the case study at the FENG Building for 0.5 m of lightning arrester rod. The green zone indicates the protected zone for the FENG building. The positioning of the lightning arrester on the FENG building was based on the actual layout with a 0.5m height of the lightning arrester. In this simulation investigation, the length of the lightning arrester was changed from 0.5m to 1.0m and 2.0 m in order to observe the changes in the protection zone.



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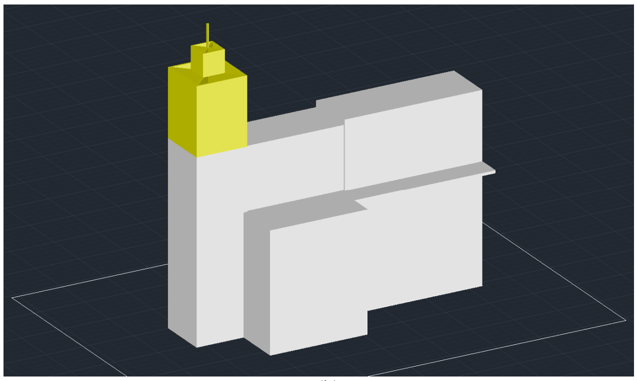

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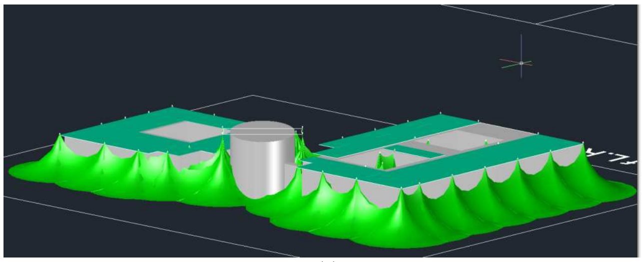
Fig. 3. Side view of the case study building in AutoCAD simulation: (a) FENG Unimas building, (b) Chancellery building.



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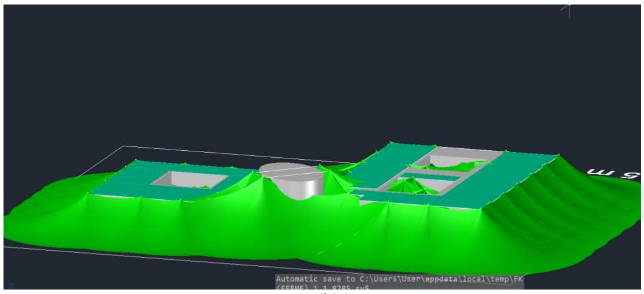

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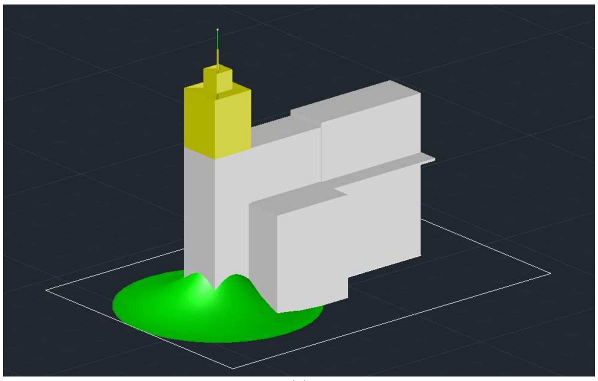
Fig. 4. Simulation results for FENG Unimas building for 0.5 m of lightning arrester rod: (a) LPL Class I, (b) LPL Class IV.

Based on the simulation results, the green zone in Class III and IV almost covered the lower part of the building which was from the lower part of the roof to the ground. The lightning strike makes direct contact with the roof part and some small regions on the wall of the building for Class III and IV. In Class I and II, it was observed the green zone doesn't cover the wall of the building. It shows that the lightning strike is able to make contact with the wall of the building which is called a side flash. Since the side flashes in Class I and II rarely to be happen which about 2-3 percent of all lightning flashes, this class will be neglected as the focus was only on Class III and IV.

Fig. 5 shows the simulation results for the case study at Chancellery Building with 4.0 m of lighting arrester protective are rod. As can seen from the figure, the arrester doesn't protect the building completely. For Class IV (Fig. 5(c)), only a certain part of the building below the lightning conductor was fully protected by the arrester. Although the lightning arrester that was used was taller than the previous building (FENG building), the lightning was still able to strike the unprotected part of the building since the zone of protection was only below the lightning arrester.



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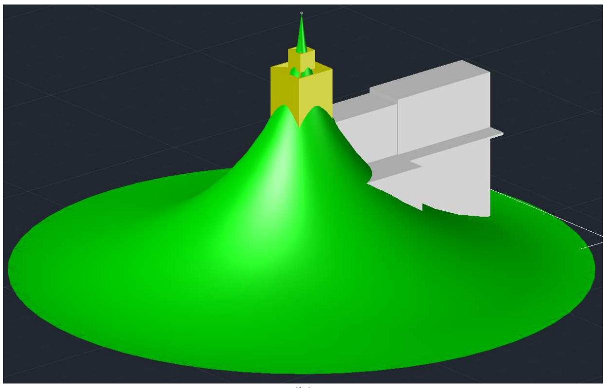

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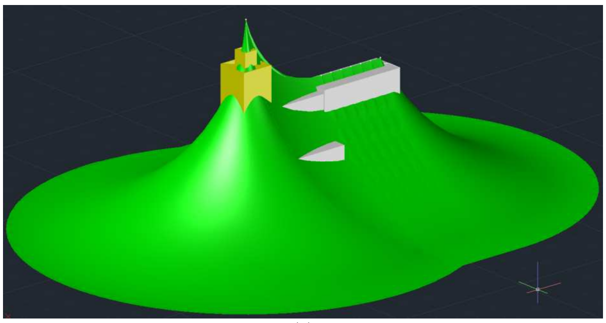


(c)

Fig. 5. Simulation results for Chancellery with the lightning protective area rod of 4.0 m : (a) LPL Class I, (b) LPL Class IV, (c) addition with 2.0 lightning arrester rod for LPL Class IV

In order to solve this problem, an additional 0.5, 1, and 2 m lightning arrester rod was added to the simulation. As the length of the arrester increased, the protection zone of the building improved which is shown in Fig. 5(c).

Fig. 6 shows the protection area of the FENG building for each lightning protection level (LPL). The area was measured at a height of 13.7 m which peak of the Electrical and Electronic Engineering Department, Unimas. As can be seen from the figure, the protection area increases as the length of the lightning arrester increases. Increasing the length of the lightning arrester makes it as tallest object surrounding the building. Due to the tendency of lightning to strike tall objects or buildings, it will strike on the arrester instead of the building roof. It shows that the trend of the graph increases for every lightning protection level (LPL).

Similarly, the investigation for another case study, the area of lightning protection for the Chancellery building was also collected for further study of the simulation.

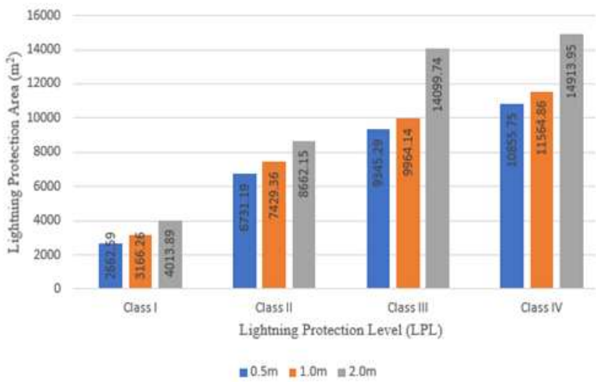


Fig. 6. Graph of lightning protection area (m2) against lightning protection level (LPL).

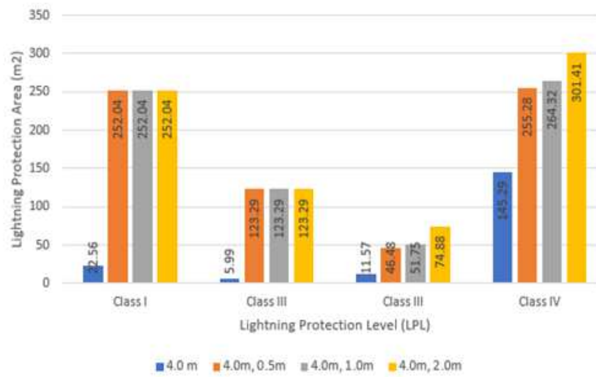
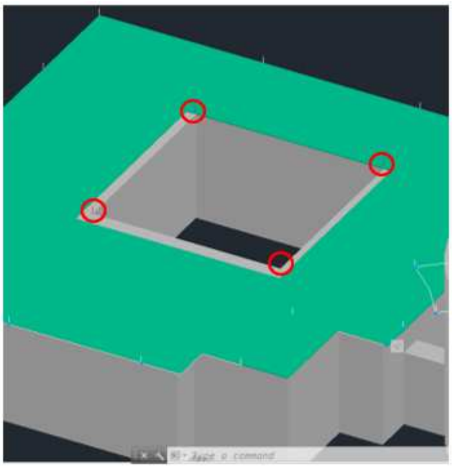


Fig. 7. The graph of lightning protection area (m2) against lightning protection level (LPL).

Fig. 7 shows the graph of the lightning protection area (m^2) against the lightning protection level (LPL). The area was measured at a height of 32 m which is from the ground level to the roof part of the building for Class III and IV. As for Class I and II, different height was applied for each class since no protection area when measured at 32 m. For Class III and IV, the data collected showed that increase in area protection as the length of the arrester increases. To compare the lightning protection area for Class III and IV, it was shown that the area increases drastically based on class level. For Class II, the protection area was invalid for 32m. Thus, the height that was used to measure for this class was 21m where the protection zone was able to be calculated. Although the arrester length has been increased, the protection area remains constant for Class II due to the rarity of Class I and II which have been considered as side flash to occur, so these classes have been neglected in this simulation as shown in Fig. 7.

For the FENG building, a few lightning arresters had been added to the Electrical and Electronic Department since the top level of the building was a laboratory for electrical and electronic students. These were the places where electrical and electronic devices were kept. In order to prevent this equipment from being affected by the electromagnetic pulse caused by lightning, the additional lightning arrester rod was placed on a certain part of the building that has been indicated by red circles as shown in Fig. 8 (a). For this design, the height of the lightning arrester was 2.0 m since it gave the best protection area based on the results as shown in Fig. 8 (b).



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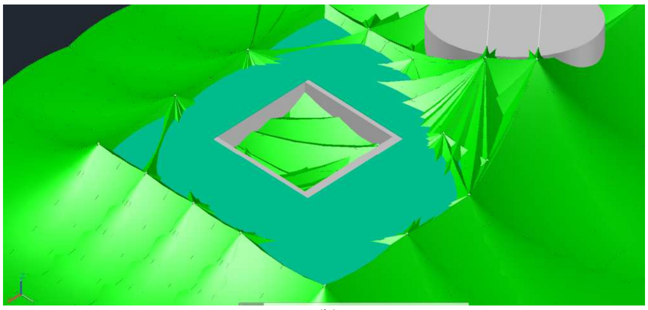

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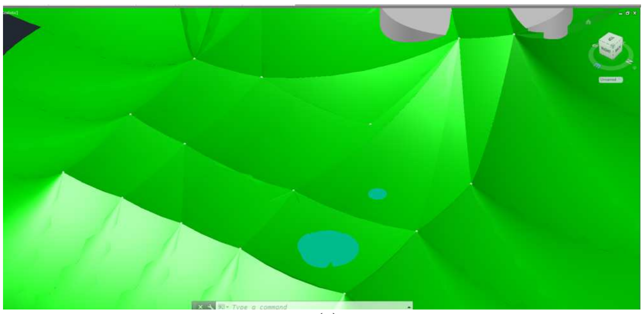
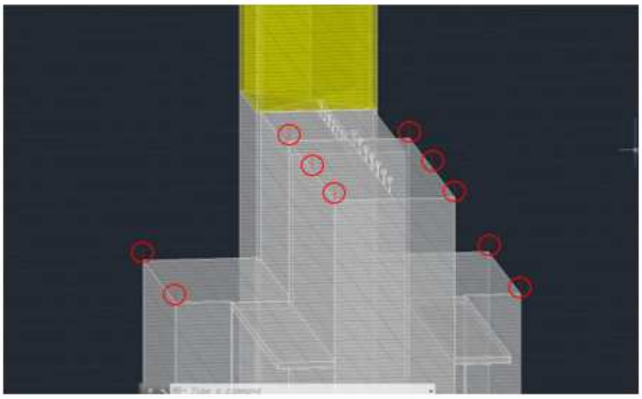


(c)

Fig. 8. Improvement of protection zone for FENG Unimas building: (a) a new design by adding additional lightning arrester rods, (b) simulation results of original design, (c) simulation result with the new design.

Then, the design has been compared between the new design with the original design of FENG's external lightning protection system. Based on the simulation result, it shows that the protection zone of the new design is able to cover the unprotected part of the building which not protected by the original design as shown in Fig. 12 (b) and (c). Although there were some small regions not protected, the roof itself can be used as an air termination component based on Table 1 of the IEC standard (IEC:62305-3) [7].

Similarly, to improve the protection zone for the Chancellery building, a few lightning arrester rods were placed on certain parts of the building. Fig. 9 (a) shows the suitable position of the lightning arrester rods in order to improve the protection zone. The design also used the lightning arrester with a height of 1.0 m compared to the FENG building. The reason for choosing the 1.0 m lightning arrester instead of 2.0m was that the protection zone for both lengths was nearly the same. As a result of the simulation, it was shown that the unprotected part of the original design had been covered by the new design of RSM. With 1.0 m of the lightning arrester, it shows that the green zone was able to cover the whole Canchellery building which is shown in Fig. 9 (b).



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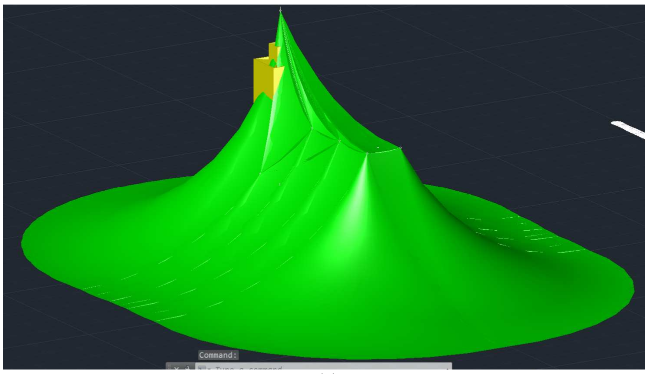

(c)

Fig. 9. Improvement of protection zone for Chancellery Unimas building: (a) Additional lightning arrester rods, (b) the simulation results of improvement design.

IV. Conclusion

The simulation was conducted to simulate the lightning protection system in certain buildings at Unimas. Two buildings were chosen, namely the FENG and Canchellary buildings. The model of the case study building has been created based on the actual layout that has been obtained and simulated the lightning protection system by using 3D lightning software in AutoCAD. For both buildings, the protection zone was observed in three different lengths namely, 0.5, 1.0, and 2.0 m, respectively of lightning arrester in every lightning protection level (LPL).

In the FENG building, the positioning of the lightning arrester on the model was based on the actual LPS of that building. The simulation was to observe the lightning protection zone based on different lengths of lightning arresters. The original design of FENG's lightning arrester was 0.5 m and has been compared with 1.0 m and 2.0 m lightning arrester. For Canselori building, had a steel structure that supported the 4.0m lightning arrester. The simulation was running to observe the protection zone of a 4.0 m lightning arrester. An additional lightning arrester with different lengths (0.5 m, 1.0 m, and 2.0 m) has been added to the model to compare the protection zone generated on the building.

Lastly, the improvement on the protection zone was made in both designs by adding some lightning arresters on certain parts of the building. For the FENG building, the improvement was focused on the Electrical & Electronic Department which laboratory placed on the top level of the building. The lightning arrester that was used was 2.0 m since it protects most of the part of the building compared to 0.5 m and 1.0 m lightning arrester. For the Chancellery building, a 1.0m lightning arrester has been selected for the new design of RSM. The selection length was based on the result of the protection zone of 1.0 m and 2.0 m of lightning arrester were nearly the same in Class IV. Thus, the new design of RSM was able to cover the unprotected of both buildings although there were some small regions not protected in the FENG building.

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