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Probability Occurrence of Estimated Lightning Surge Current at Lightning Rod before and after Installing Dissipation Array System (DAS)

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Abstract: Lightning surges in a telecommunication building were observed before and after installing a dissipation array system (DAS) for lightning in winter. A portable digitizing oscilloscope and a multichannel digitizing oscilloscope with an optical fiber system were used for the observation. The observed results from winter 1991 to winter 1996 show that the peak value occurrence probability at an antenna tower leg was not changed before and after installing the DAS and the occurrence at a pillar of the building was decreased a bit by installing the DAS. The peak value of the lightning current at the lightning rod of the building was estimated from the surges observed at the lightning rods, at a leg of each telecommunication tower, and at a building pillar. The occurrence calculated from this value was almost the same before and after installing the DAS.

INTRODUCTION

Direct lightning strikes to telecommunication buildings can cause malfunctions in the equipment. Recent telecommunication systems use high speed semiconductor devices that are easily damaged by lightning surges. The protection system in these buildings should be improved to protect more susceptible equipment. Improving the grounding systems in the buildings is effective to reduce the lightning surge to the equipment. International Electrotechnical Commission and Telecommunication Standardization Sector of International Telecommunication Union have published a technical report how to protect equipment in these buildings [1], [2]. According with these publications, a grounding system for telecommunication building has been developed [3].

The prediction of the lightning surges induced in the buildings is effective to determine the optimum grounding system for each telecommunication system. Calculations using the building reinforcement structure model have been reported [4], and an experiment using a real building and an artificial lightning surge has been reported [5]. Observation of lightning surges induced in the buildings is also important because it is difficult to model the lightning's direct strike phenomena. The lightning surge observation system and the results

were also presented [6]. The grounding route searching method has also been presented to optimize the route and reduce the lightning surge to the equipment [7].

Preventing the lightning surge by improving the grounding system in the building reduces the surges to the equipment to equalize the potential in the buildings. However, this method can not reduce the elevation of the potential around the buildings. This causes malfunctions because the telecommunication lines are extended so long from the buildings and are connected to equipment at both ends. So, the ideal protection method is to prevent the direct lightning strike [8].

A dissipation array system (DAS) [9] was recently developed to reduce the likelihood of lightning directly striking to the building. However its effectiveness has not yet been confirmed.

This paper describes the investigation results of this system by comparing the estimated lightning current at a lightning rod before and after installing a DAS in winter. The observation place and the lightning characteristics in a winter lightning surge are explained, and the configuration of the DAS and the observation system are described. The observation results are shown as the occurrence probability of the peak value before and after installing the DAS. Finally, the peak value of the lightning current at the lightning rod is estimated from the observation data and the occurrence is also compared before and after installing the DAS.

OBSERVATION PLACE AND ITS GEOMETRICAL CONDITION

Lightning occurs when some region of the atmosphere attains an electrical charge sufficiently large that the electric fields associated with the charge cause electrical breakdown of the air. The occurrence probability of lightning is affected by geometrical conditions. The frequency of thunderstorms occurring in Japan is shown in Fig. 1. The malfunction locations are indicated as circles. Thunderstorms frequently occur at the center and the Japan sea side of the island. The malfunctions are mainly located where many thunderstorms take place.

Lightning at the center of the island appearing is caused by thundercloud in summer. Lightning at the Japan sea coast occurs not only in summer but also in winter. Figure 2 shows the number of thunderstorm day at Wazima city located on Japan sea coast. Around 50% of the thunderstorms occur in winter.

Figure 3 illustrates the difference of thundercloud in summer and winter in Japan. Summer thunderclouds grow vertically, whereas winter thunderclouds grow horizontally because of strong seasonal winds from the Japan sea. This means that lightning in winter is affected by geometrical conditions where strong seasonal winds exist, and lightning appears to concentrate some places such as tall telecommunication tower and buildings. In addition, both negative and positive leaders existing in this lightning. Lightning strikes appears several times per year in telecommunication buildings in such place. So the countermeasures for lightning strikes is therefore an significant problem.

A dissipation array system (DAS) was installed in one of the such building to study its effectiveness.

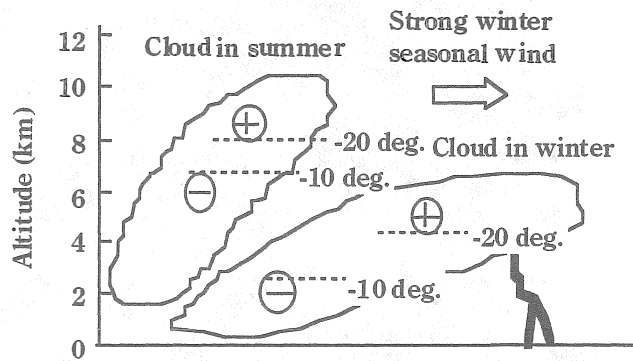


Fig. 3 Difference between summer and winter lightning.



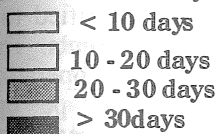
Fig. 4 Observation place.

DISSIPATION ARRAY SYSTEM FOR INVESTIGATION

A dissipation array system (DAS) was installed in a building in Hakui city. Hakui city is on the Japan sea coast near Wazima city in Fig. 4. Thunderstorm day in this area is more than 35 days per year on average, which is one of the most frequent in Japan. Telecommunication equipment in the buildings often malfunctions because of direct lightning strikes.

The structure of the DAS is shown in Fig. 5 and its configuration is illustrated in Fig. 6. Two kind of ionizers are used in this system and they are installed in two antenna towers on the building. This system was not installed per the manufacturer's recommendations as a results of the building construction conditions in Japan.

Thunderstorm days



○ Malfunction locations (1989 - 1994)

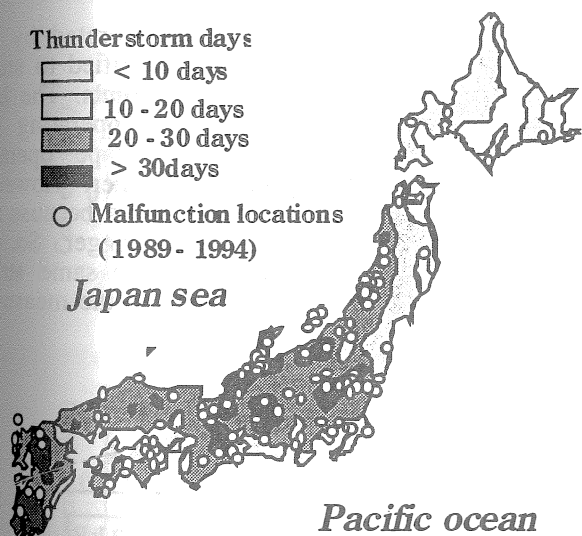


Fig. 1 Malfunction occurrence of telecommunications equipment in buildings caused by lightning surge in Japan.

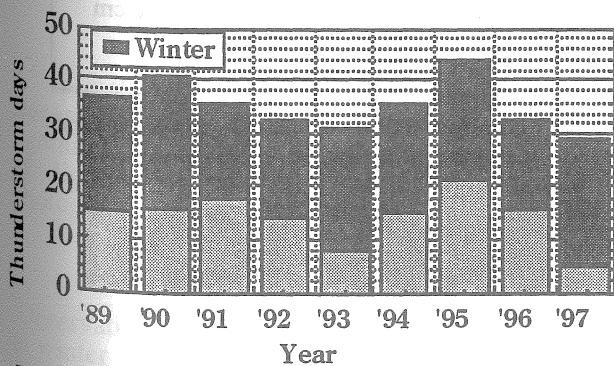


Fig. 2 Thunderstorm days in the observation area.

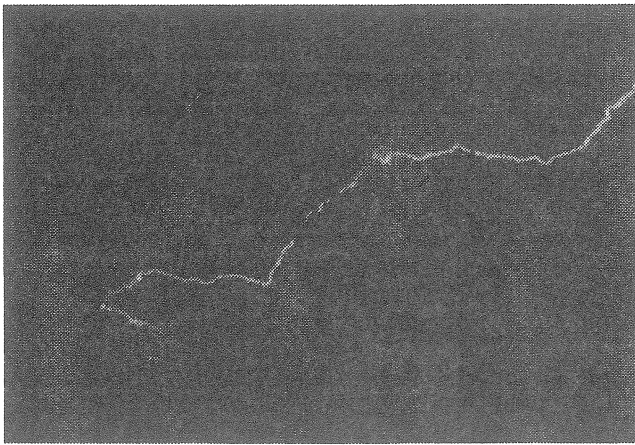


Fig. 5 Lightning and the Dissipation Array System installed in a telecommunication tower.

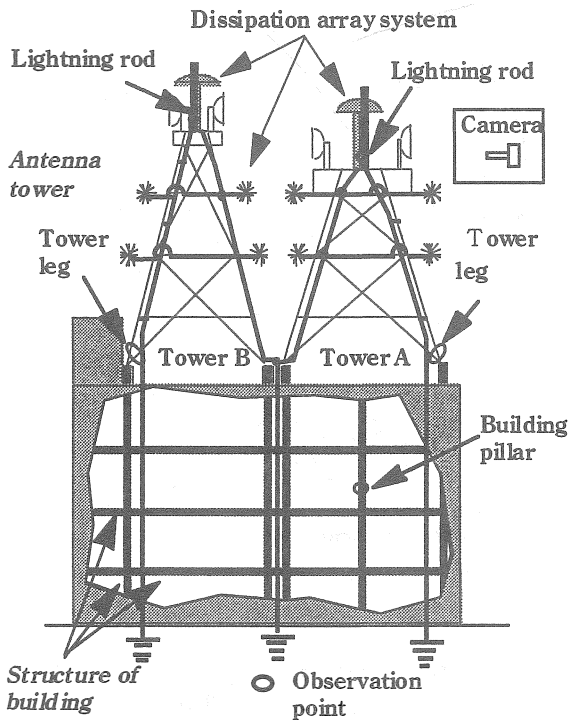


Fig. 6 Configuration of lightning surge observation points.

OBSERVATION METHOD

The lightning surge current was observed at the lightning rods on two telecommunication towers, one leg of the towers, and a building pillar within the building. Two kind of digitizing oscilloscopes were used to measure the waveform. One was a

portable type and the other is the multichannel type.

The configurations of the portable type oscilloscope is shown in Fig. 7. The oscilloscope is battery-operated, has a sampling rate of 4 MB/sec, and a memory size of 12 kB. The measured data and its observed time are stored in a 256 kB SRAM IC card. Current probes were used. This equipment was used to measure the lightning surge at the lightning rod and

the antenna tower legs because these observation points were located outside the building.

The configuration of the multichannel type oscilloscope is illustrated in Fig. 8, and its external view is shown in Fig. 9. The number of channel is the maximum of 16, the sampling rate is 100 MB/sec, and the memory size is 32 kB per channel. A personal computer (PC) controls the oscilloscope, and the measured data is stored on the hard disk in the PC. The PC can be controlled by a PC in the laboratory using the telecommunication line. The current probes were connected to the oscilloscope using optical fiber link. The isolation transformer is inserted at the AC mains terminal of the observation equipment.

The lightning surges which are generated by the same lightning strike should be identified to study the relations between observation points. The best method is to use the oscilloscope operating or-trigger which means each oscilloscope operates other oscilloscope's trigger each other. However, this is impossible to operate or-triggers because the portable type does not operate or-trigger. So, the surges which were generated by the same strike were identified from the similarity of the measured waveform.

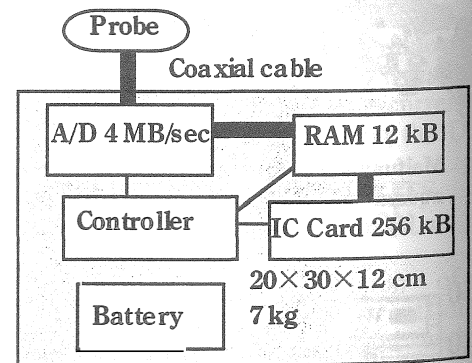


Fig. 7 Configuration of portable lightning surge observation equipment.

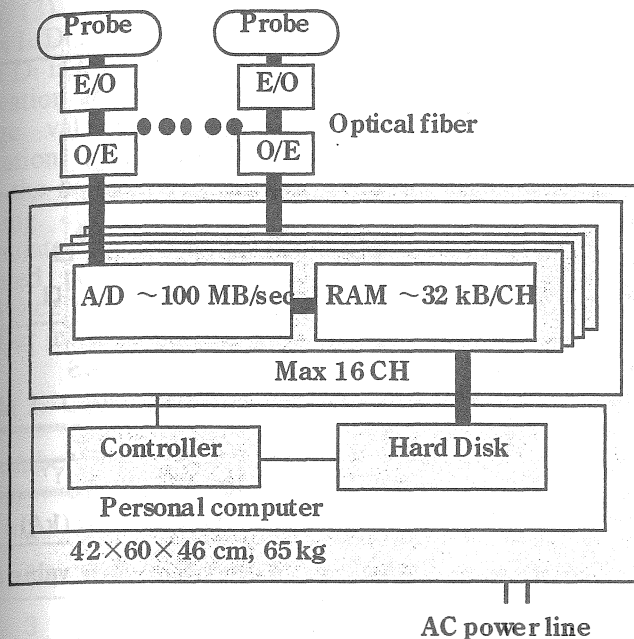


Fig. 8 Configuration of multichannel lightning surge observation equipment.

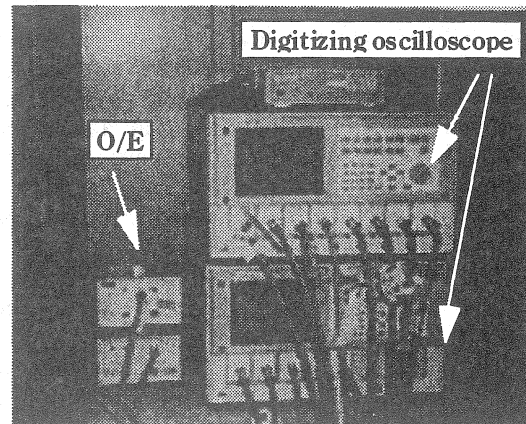


Fig. 9 View of multichannel type equipment.

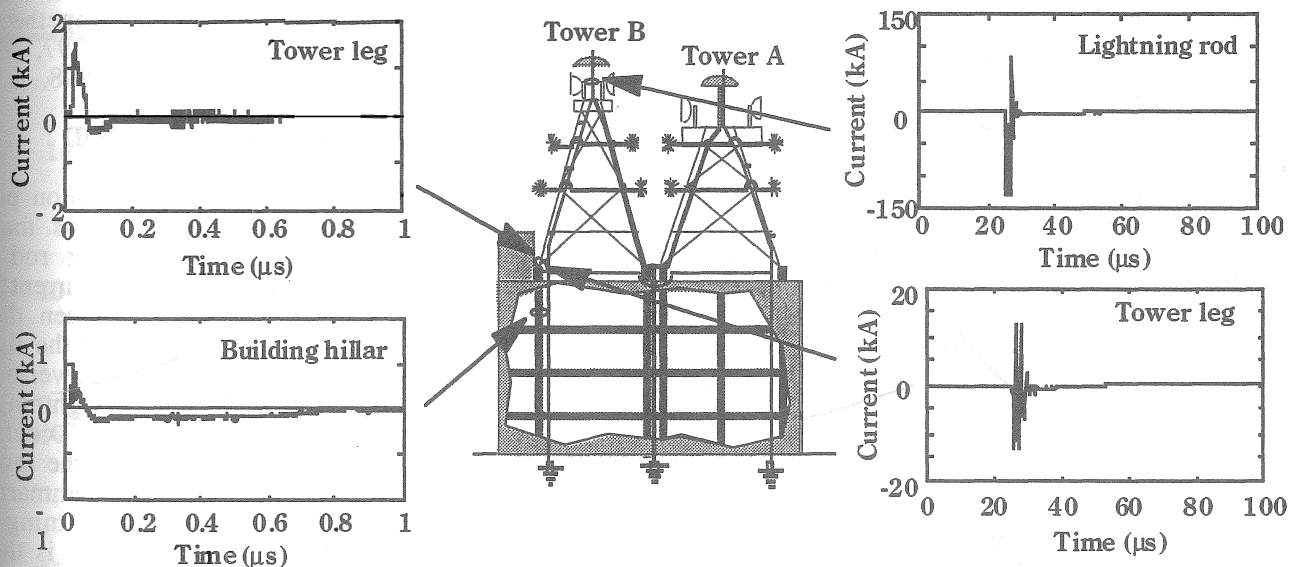


Fig. 10 Example of measured lightning surges for the same lightning strike.

A specially designed camera was installed in December 1997 to take a photograph of the lightning. This camera operate by detecting a flash of lightning. Figure 5 was the example of photograph taken by this camera.

OBSERVATION RESULTS

Observations before the DAS was installed started in winter 1991 and ended in winter 1994. The DAS

was installed in summer 1994. Post-installation observations started in winter 1995, and are now continuing.

Twenty-six lightning surges, 8 with positive polarity and 18 with a negative polarity, were observed from winter 1991 to winter 1994. Sixteen surges, 8 positive and 8 negative, were observed from winter 1995 to winter 1996.

An example of the measured result is shown in Fig. 10. Similar surge waveforms were obtained. This

means that lightning surges generated by the same lightning strike may be identified from the waveform.

Surge current at tower leg

The occurrence probability is used to investigate the efficiency of the DAS. The peak value occurrence probability at the leg of tower A is shown in Fig. 11. The horizontal axis is the peak value of the surge and the vertical axis is the occurrence probability exceeding abscissa values normalized by the thunderstorm day for each month in this area. Four surges observed from winter 1991 to winter 1994 can be identified as the surges by the lightning strike at tower A and three surges observed from winter 1995 to winter 1996 can be identified. These observation data indicate that the occurrence probability does not change before and after installing the DAS.

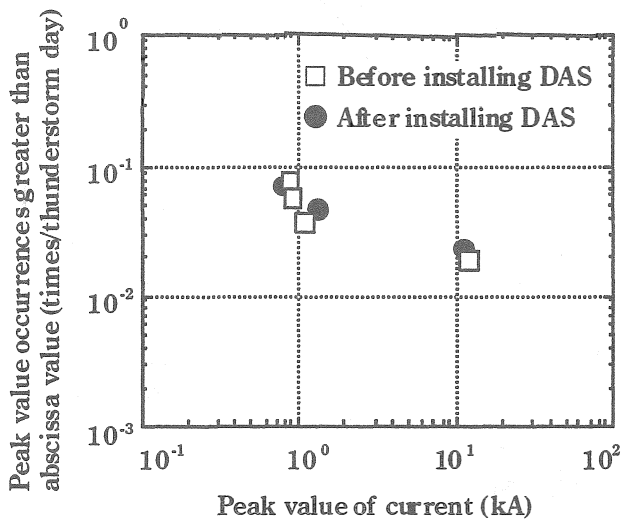


Fig. 11 Occurrence probability of peak value at leg of antenna tower.

Surge current at pillar

The occurrence probability is used to investigate the efficiency of the DAS. The peak value occurrence probability at the pillar in the building is shown in Fig. 12. Thirteen surges observed from winter 1991 to winter 1994 can be identified as the surges in the pillar and nine surges observed from winter 1995 to winter 1996 can be identified. These observation data indicate that the occurrence probability after installing the DAS is a bit lower than that before installing the DAS. This is thought to be because the lightning surge current is divided into the grounding of the DAS and the building reinforcements and ground after installing the DAS because the grounding resistance of the DAS is lower than 1Ω , and this value is sufficiently low to influence the lightning surge current in the pillar.

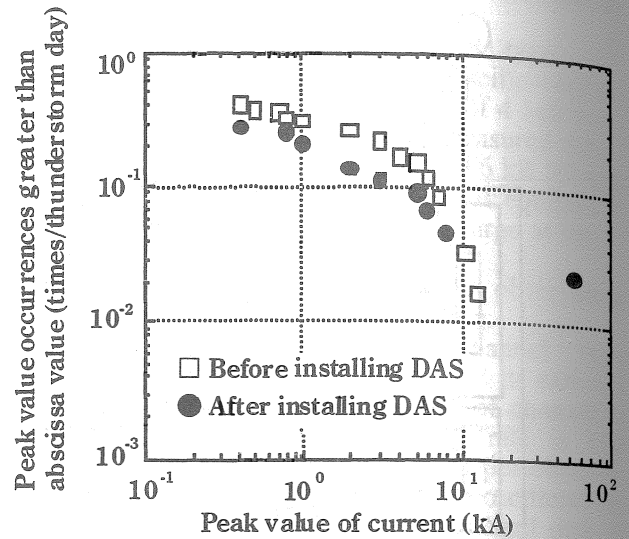


Fig. 12 Occurrence probability of peak value at pillar in the building.

Observation results by camera

Five direct strikes to the tower A and one direct strike to the tower B were observed by the camera system on the 15th December 1997, the 5th January 1998, and the 6th January 1998.

ESTIMATION METHOD

The number of surges at the observation points in Fig. 6 were not the same. This means that some lightning did not strike the lightning rod or the telecommunication tower where the current probes were placed. The relationships between the peak value of the lightning surge current at the lightning rod of tower A and at the leg of the tower or at the building pillar were calculated from lightning surge data for the same lightning. The coefficients defined by $K_t = I_t/I_r$ for the current at the tower and $K_p = I_p/I_r$ for that at the pillar are summarized in Table 1. I_r is the peak value at the lightning rod, I_t is the peak value at the tower, and I_p is the peak value at the pillar. The calculations for five surges were used to obtain the coefficients. The average value was used as the estimation.

Using these coefficients, the peak value of the lightning current I_s is calculated as follows:

(1) If a current is measured at the lightning rod, I_s is I_r .

(2) If a current is measured at the leg of the tower and at the lightning rod, I_s is calculated using Eq. (1).

$I_s = K_t \cdot I_t$, (1)

(3) If a current is only measured at the pillar, I_s is calculated using Eq. (2).

$I_s = K_p \cdot I_p$, (2)

The peak value appearance probability is calculated by Eq. (3).

$$I_{sp} = I_s/D_t, \quad (3)$$

where D_t is the number of thunderstorm days in the observation area in Fig. 2. D_t of 35, which is the average value for this area, is used for the calculation. The results are shown in Fig. 13, in which the horizontal axis is the peak value of the lightning current and the vertical axis is the accumulated probability of the peak value. The estimated peak value of the lightning current occurrence probability was almost the same before and after installing the DAS.

Table 1. Observed values of K_t and K_p .

Number	K_t	K_p
1	—	2.3E3
2	7.1	5.5E2
3	—	8.7E2
4	6.7	2.0E3
5	7.7	1.1E3
Average	7.2	1.4E3

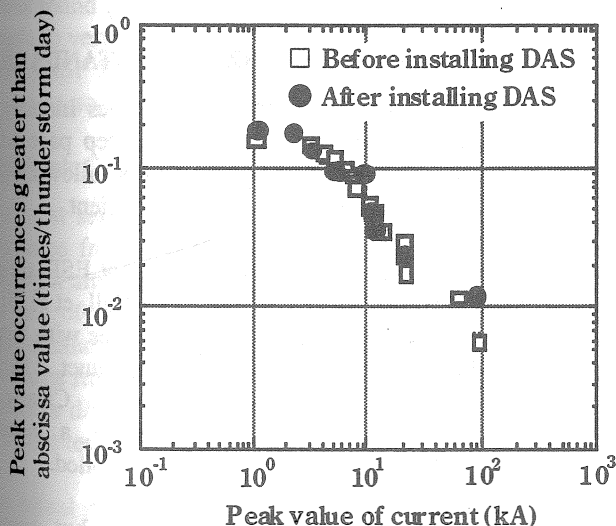


Fig. 13 Estimated probability of peak value.

CONCLUSION

A dissipation array system (DAS) was installed in a telecommunication building to investigate its effectiveness and the lightning surges in the building were observed.

The occurrence probability of the peak value was investigated before and after installing the dissipation array system. The observed data indicate the peak value occurrence at the leg of the tower A does not change before and after installing the DAS, and the occurrence at the pillar after installing it is a bit lower than that before installing it. The Peak value of the lightning current at the lightning rod on the telecommunication tower was estimated. The results show that the probability stayed about the same.

One of the reason is expected that the DAS was not installed for the manufacture's recommendation caused by the conditions in Japan. Further investigation will be needed to adjust this to the conditions in Japan.

Finally, the countermeasures, which were improving the grounding system, improving equipment immunity, and installing the DAS, were carried out in this building in summer 1994. Malfunctions of the telecommunication system caused by lightning direct strike have not occurred in this building since 1994.

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