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Lightning Protection of Cable Bridges

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Abstract-- The aim of this paper is to present a lightning protection system for a cable bridge, which was implemented 11 years ago and no damage was ever reported. This cable bridge is manufactured to link the mainland of Hellas with the island of Evia, which is the second largest island of Hellas. In addition a similar design for a smaller scale cable bridge will also be presented. The design was based on the Hellenic standard ELOT 1197 and IEC 61024, which are now replaced by the new EN-IEC 62305 series.

Index Terms-- Cable Bridge, Earthing, Equipotential Bonding, External Lightning Protection System

I. INTRODUCTION

The Chalkida cable bridge took the name of the capital of Evia. The bridge was manufactured 11 years ago and was the largest cable bridge of Hellas before the manufacture of the Rion – Antirion Bridge.

Figure 1 shows the Chalkida cable bridge, which was a total length of 694m, width of 13m and a total height from sea level of 95m. The bridge is supported by two pylons with a height of 90m from the deck and 144 stay cables.

The external Lightning Protection System – LPS of the Chalkida cable bridge was implemented during the manufacture period of the bridge, which as mentioned before was 11 years ago. The design was based on the current standards, the Hellenic ELOT 1197 [1] and the international IEC 61024 [2].

After several inspections over the past 11 years there was no evidence of any damage due to direct lightning strike

on the bridge although the area has a high lightning activity. According to ELOT 1197 the area has 25 thunderstorm days per year.



Fig. 1: Overview of the Chalkida cable bridge

Additionally in 2003 another much smaller cable bridge was manufactured in Athens over a new highway of Attiki Odos. The design of the Attiki Odos cable Bridge shown in Figure 2 was based on the new EN-IEC 62305 series standards [3] – [5]. Metallic parts of the bridge helped to implement a better LPS design. The design of both cable bridges will follow.



Fig. 2: Overview of the Attiki Odos cable bridge

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II. EXTERNAL LPS DESIGN OF CABLE BRIDGES

The protected volume was the deck, the stay cables and the pylons of the bridge. The deck was protected by the pylons and the stay cables with the protection angle principle. The pylons were protected by two Franklin rods, which were installed on a 3m mast.

In total 144 stay cables were supporting the bridge. On the top of every highest stay cable, which is on the external side of the bridge a running LPS hot deep galvanized steel conductor was installed and supported on the stay cable by an appropriate collar/fastener every one meter as shown in Figure 3.



Fig. 3: Protection of the pylons and the stay cables of the Chalkida Bridge

The need of side flash protection was also necessary. The complexity of the cable bridge design was a problem on how to support the side LPS conductors. The solution was given by the contractor of the cable bridge, who suggested using the metallic conductors, which are used as tension and oscillation absorbers. Figure 4 illustrates the natural components of the cable bridge, which were connected to the main LPS for sideflash protection.

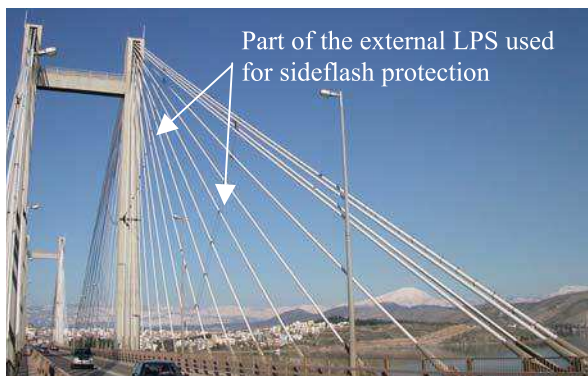


Fig. 4: Natural components of the Chalkida Cable Bridge used as parts of the external LPS.

The rods on the pylons and the LPS conductors on the stay cables were bonded on the top of the bridge. Two down conductors are installed on each pylon connected to the earthing system. Additionally on the deck the LPS conductor of the stay cable was bonded with the metallic support of the stay cable by using a flexible lead so as to allow oscillations to be absorbed (see Figure 5) and not to cause damage to the LPS conductors.



Fig. 5: Flexible lead bonding between the LPS conductor of the stay cable and the support of the stay cable

Along the deck every metallic element such as pipes, fences, lighting towers, enclosures, metallic body of the stay cables are all bonded with each other and with the earthing system (see Figure 6).

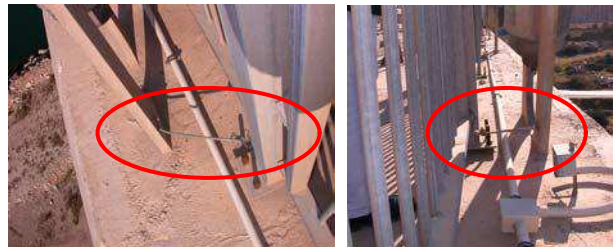


Fig. 6: Equipotential bonding of all metallic parts

The earthing system was installed near the foundations of the pylons at the sea level. The electrodes were made out of copper and the connections with the rest steel LPS conductors were through bimetallic elements to avoid electrochemical corrosion. The earthing system was installed in sea water, which gave a very low earth resistance since the sea water has very high conductivity.

A similar design was also applied for the Attiki Odos cable bridge, which is much smaller in scale as can be seen in Figure 2, but the design principle is similar to the Chalkida cable bridge. The advantage if the Attiki Odos cable bridge was that the top part of the one pylon that was supporting the bridge was made out of metal helping the efficiency of the LPS design. Figure 7 and 8 illustrate the protection of the stay cable and the pylons.



Fig. 7: Protection of the stay cables of the Attiki Odos Bridge

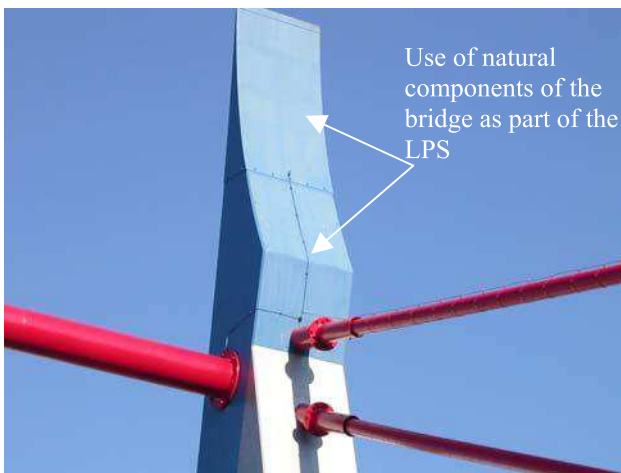


Fig. 8: Protection of the pylons of the Attiki Odos Bridge

III. IMPROVEMENTS OF THE LPS DESIGN

In modern bridges the use of monitoring sensors in order to monitor the strain and the stress of the stay cables, the oscillations and the displacement of the deck, the wind speed, etc, is now very common. All these sensors operate with low voltages and they are very sensitive to surge overvoltages due to lightning discharges. Surge protection is therefore important for all these sensors. The selection and the installation points of the surge protective devices shall be carefully designed by following the current standards [6].

IV. EFFICIENCY RESULTS AND CROSSCHECK OF THE DESIGN DUE TO NEW EVIDENCES

There was an issue regarding the possibility of a flashover between the LPS conductor and the metallic body of the cable strands in the event of a direct lightning strike. This issue has resolved by simulating a part of the bridge and

the LPS conductors as shown in Figure 9 by using the software package CDEGS [7].

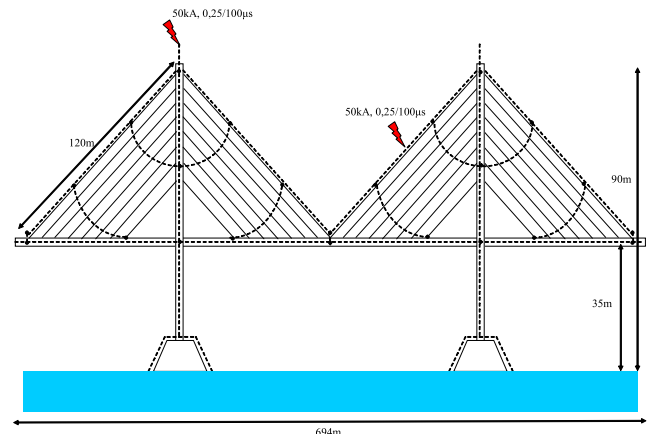


Fig. 9: Chalkida Cable Bridge LPS design as simulated in CDEGS

As shown in Figure 9, two scenarios were considered. In the first one the lightning inception point was set to be the top and a second scenario the inception point was set in the middle of the Bridge. The lightning stroke that was used was the most severe case with respect to the induced voltages due to self and mutual inductance, which is the subsequent stroke model as it is defined in EN-IEC 62305-1 for level I (0,25/100µs, at 50kA).

The potential rise with respect to a remote earth may be high, but this is not important since the potential difference between the LPS conductors and the metallic body of the stay cable has a maximum instantaneous peak value of 450kV, which the insulation of the duct surrounding the metallic stands can sustain. This voltage was observed when lightning was injected in the middle part of the bridge and was measured in middle part as well, since at the top and the bottom the stay cable was bonded with the LPS conductor.

However this voltage figure may be higher for longer stay cables. Repeating the simulation having a double stay cable length (240m) but by using two LPS conductors in a parallel configuration so as to achieve electromagnetic field cancellation, the potential difference was reduced to 350kV.

V. DISCUSSIONS AND CONCLUSIONS

The LPS design of a cable bridge according to EN and IEC standards was presented. This system was installed 11 years ago and no damage has ever been reported. Protection against side flashes shall be considered for such high structures. By using natural components of the bridge the efficiency of the LPS design may be improved.

For the protection against direct lightning strikes on the stay cables the installation of one or more LPS conductors on the top stay cable facing the outer side of the bridge is

preferable since storm usually approaches a structure from the side and not from the top.

The use of surge protective devices shall be considered in order to protect sensors and sensitive electronic equipment, which are now installed in modern bridges.

VI. REFERENCES

- [1] Hellenic Standard EL0T 1197, Protection of structures against lightning
- [2] IEC 61024 – 1, Protection of structures against lightning – Part 1: General principles
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- [5] IEC 62305 – 3, Protection against lightning – Part 3: Physical damage to structures and life hazard
- [6] IEC 61643 – 12, Low voltage surge protective devices – Part 1: Surge protective devices connected to low voltage power distribution systems – Selection and application principles
- [7] CDEGS, Safe Engineering Services (SES) and Technologies Limited, Montreal, Canada