Vibration Characteristics Test and Vibration Reduction Analysis of 220kV Cable Lines on Bridge

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Abstract. More and more high-voltage cable lines are laying on the bridge and in other vibration environments. The impact of vibration on the safe operation of cable lines is increasingly prominent. Therefore, it is necessary to study the vibration characteristics of the cable lines, the layout structure and the influencing factors of the vibration control measures on the bridge. Through the actual test, this paper obtained the vibration characteristics of cable line especially the vibration characteristics caused by the nearby the high-speed railway. The simulation of the cable support spacing and the rubber pad thickness of resonant frequency of cable structure were calculated. The results show that when the cable laid on the bridge. It suffered the continuing vibration caused by the role of external. The amplitude of vibration is relatively larger between 10-50 Hz regions. Because of close to high-speed rail line, the vibration on the cable line is particularly larger. The spacing of cable supports should be determined by the actual measurement of vibration frequency characteristics and calculating, to avoid the resonance and stress concentration. With the increase of rubber pad thickness, it is much more obvious to reduce the vibration effect, so it should be combined with vibration to determine the size of the rubber pad thickness.

Preface

In China, the total length of the 110-500 kV cable line is more than 24000 km. The main laying forms include: pipe, cable trench and tunnel etc. The length of the high voltage and extra high voltage cable on the bridge is close to 150 kilometers. Much more complicated problems are need to face when the cable laying on the bridge than other forms. Not only the cable laying, installation space, carrying capacity, construction and other aspects should to be considered, but also the focus on the expansion and the vibration problem of cable bridge and the bridge expansion compensation and anti-vibration measures need to be considered. For the cable lines on the bridge, the vibration and stress caused by the structural vibration of the bridge directly affect the cable structure layer. Due to the different materials of the cable structure, the ability to withstand vibration and stress is also different. The influences of the vibration and stresses on the cable are the key nodes of stable operation of the cable line. It is necessary for cable installation on the bridge to take proper measures to reduce the influence of vibration on the cable layer.

Vibration Test on 220 kV Cable Lines

For the existence of multiple high-speed railways and road, the two 220 kV cable lines are laying in multiple bridge, tunnel and mixed type. The total length of cable line is 10.8 km, which conclude of 6 bridges. The length of the longest bridge reached 0.75 kilometers. The cable bridges are parallel with the high-speed rail line and the nearest distance is less than 50 m. There are two 220 kV cable lines arranged on the bridge. The conductor section of one cable line is 2500 mm\textsuperscript{2}, and the
conductor section of the other cable line is 1600 mm$^2$. The two 220 kV cable lines are arranged on the two sides of the bridge as vertical snake form. The distance between the cables supports is 6 m, as shown in figure 1.

![Figure 1. Cable on bridge near by high-speed railway.](image1)

Some acceleration sensors are arranged on the outer sheath of the cable to test the vibration of the cable line, as shown in Fig. 2. The waveforms of the vibration test on the cable are shown in Figure 3 whether there is a high-speed train passing or not.

![Figure 2. Vibration test on cable lines.](image2)

Based on the measured vibration waveform analysis, it shows that if there is no high-speed train passes through, the vibration on the cable is caused by load current, the vibration frequency is 100 Hz. When a high-speed train passed, the vibration frequency mainly distributed in the 10-50 Hz area and the vibration amplitude is much greater than that caused by the current. The maximum acceleration of the cable outer sheath (peak to peak) reached 0.1 g by measured.

![Figure 3. Wave form of the Vibration test on cable lines.](image3)

By satisficing the number of high speed trains, it showed that about 10 trains through the high-speed railway line per hour about. If the high-speed operation 12 hours every day, the number of trains per day is about 120 and about 43,000 per year. For the cable line running for 30 years, the cable lines suffered the high speed trains vibration more than $1.3 \times 10^6$ times. Therefore, the bridge vibrations on the cable lines result in the cable structure suffer additional vibration and stress, which seriously affects the life and safe operation of the cable lines.
Calculation and Analyze the Cable Anti-vibration

Calculation of the Cable Vibration under Different Support Space

Through FEM structure modeling, the natural frequencies and mode shapes of cable lines under different support spacing are analyzed and calculated. The influence of external characteristic frequency vibration on the mechanical properties of XLPE cable insulation structure is studied, as shown in Figure 4.

The natural frequency of the cable varies with the spacing of the support can be obtained by calculation. The longer the space of the support, the natural frequency of the cable tends to decrease, as shown in Figure 5. Considering the cable cleat, the natural frequencies of the above 5th orders tend to be consistent with different space changes. The support space reflects on the natural frequency of the structure.

Calculation of the Cable Vibration under Different Rubber Pad Thickness

Figure 4. Vibration of the cable under 6 m support space.

Figure 5. Vibration characteristics of cable structures for different support space.

Figure 6. Vibration of the cable under 6 m support space with 0 mm rubber pad.
Through FEM structure modeling, the vibration characteristics of cable structures with different rubber pad thickness are calculated under the condition of support spacing of 6 m, as shown in figures 6 and 7. The analysis shows that with the increase of the thickness of the rubber pad, the natural frequency of the cable structure is reduced. For example, the thickness of the 15 mm thick pad the natural frequency of the 3rd order will be intended to 50 Hz. The thickness of rubber pad have little influence on the 1st order and 2nd order natural frequencies, while the higher order (above 5th orders) natural frequencies are greatly influenced by the thickness of rubber pad. The higher order natural frequencies decay rapidly with the increase of rubber pad thickness, as shown in Figure 8.

Conclusions

1) The cable line laying on the bridge not only suffered the vibration (100 Hz) caused by the load current but also suffered the continuing external vibration (10-50 in Hz the amplitude is larger). Continuous vibration makes the structure layer of the cable suffered the additional stress which affect the safe operation of cable line;

2) The spacing between cable supports has direct influence on the natural vibration frequency of the cable structure, and the resonance caused by external vibration can be effectively avoided by adjusting the spacing between supports. Therefore, the support spacing for cable lines under vibration condition should be determined through the actual measurement of the vibration characteristic frequency, which can avoid the stress concentration caused by the resonance effect on the cable structure layer more accurately.

3) The rubber pad can reduce the vibration effect for the cable vibration environment. By adjusted the rubber pad to the natural characteristics of frequency of the bracket - cable structure and the vibration effect on the cable structure layer. With the rubber pad thickness increases, reduce the vibration effect is more obvious. The cable under vibration shall be arranged the rubber pad, and combined with the vibration to determine the thickness of the rubber pad.
References
