On-Line Monitoring Analysis of Aeolian Vibration of Jiangmen-Tongtangjia 220kV Transmission Line

Wenping Xie[1], Tian Peng[2], Kai Xiao[1], and Jian Zhang[2]
[1] Electric Power Research Institute of Guangdong Power Grid Co., Ltd., Guangzhou, China
[2] Civil Engineering Department, Tongji University, Shanghai, 200092, China
Email: {309577110, 993139097}@qq.com, {pt0796, 13928750816}@163.com

***Abstract*—The Aeolian vibration of coastal overhead transmission is a well-known phenomenon which leads to fatigue damages of conducts. This paper introduces the information and the arrangement of on-line monitoring equipment for Jiangmen-Tongtangjia 220kV transmission line, analyzes the data acquired by on-line monitor and advises the improvement of the selection or install location of stock-bridge damper of conducting wire, which prevents the breakage of conducting wire due to Aeolian vibration.**

***Index Terms*—overhead transmission line, Tongtangjia line, Aeolian vibration, on-line monitoring**

I. Introduction

The damages caused by Aeolian vibration in transmission line [1], such as breakage of conductor strands, insulator strings, and the loosening of parts, have become a problem to be solved, since the large-scale development of transmission line. Especially the effect of sea wind on transmission line is very frequent, and the damages mainly happened at the concentrated stress point of contact such as the suspension clamp [2]-[4].

Aeolian vibration of electrical transmission line conductors due to oscillatory life force actions caused by vortex shedding gives rise to material fatigue in a wide wind speed range (1-10m/s) [5], [6]. The subject has invited a great number of investigations. Earliest research about vortex characteristics are found with the two persons: Karman and Strouhal, as vortex also called Karman vortex. The type of high frequency-low amplitude vibration, fluid-solid coupling, resulting due to wind of low velocities, are called the characteristic of Aeolian vibration. And now, the research about Aeolian vibration mainly concentrated on the studies of the vibration mechanism, anti-vibration theory, anti-vibration device, laboratory test, on-line monitoring, and numerical simulation analysis, etc. [7]-[9]. But those studies cannot settle down the anti-vibration design of conductors due to the character, small amplitude, fluid-solid coupling, non-linearity of conductor and messenger of damper of Aeolian vibration. Moreover, the fact that the theory analysis and laboratory experiments can't completely simulate the actual wind field which are influenced by the site environment and actual design, made on-line monitoring as an important means to analysis Aeolian vibration [9], [10].

The regulation of DL/T741-2010, operating code for overhead transmission line, ruled that a long-span transmission tower-line should be conducted a regular measurement of conductors and ground wires. But on-line monitoring of transmission line is limited especially lack of on-line monitoring data analysis of transmission line in the coastal areas, from the recent 20 years research of transmission line [11]-[15]. Based on these facts, this paper introduces the information and the arrangement of on-line monitoring equipment for Jiangmen-Tongtangjia 220kV transmission line, analyzes the data acquired by on-line monitor and advises the improvement of the selection or install location of stock-bridge damper of conducting wire, which prevents the breakage of conducting wire due to Aeolian vibration.

II. Monitoring System of Aeolian Vibration

A. Actual Situation of Line

The monitoring system installed on the transmission line of Taishan power plant to Guanghai town named Jiangmen-Tongtangjia 220kV transmission line which distance from the coastline in the range of 5km. The data got from the monitoring of A6 and A7 tower to analysis the Aeolian vibration situation, and then got the evaluation of anti-vibration measures. The type of conductors are LGJ-500/45, the type of ground wires are JLB-40 and the two towers adopted stock-bridge dampers to protect the line.

B. Monitoring System

The data obtained from the monitoring system which consists of data acquisition unit of conductor and ground wires which supply by solar power and data concentrator through the wireless way to upload to the main station system. The two measuring work mainly includes the following two aspects: bending amplitude in the vicinity of clamps and vibration frequency. There are three measuring point of Aeolian vibration as shown in Fig. 1 and Table I, and the details of point are as shown in Fig. 2.

Manuscript received August 22, 2016; revised December 12, 2016.

doi: 10.18178/ijoee.4.3.179-183

And Install location of Aeolian vibration device is 89mm distance of clamp, because the international norms rule the amplitude of 89mm (3.5in) distance of clamp as measurement standards [16]. And A7 tower was shown in Fig. 3.

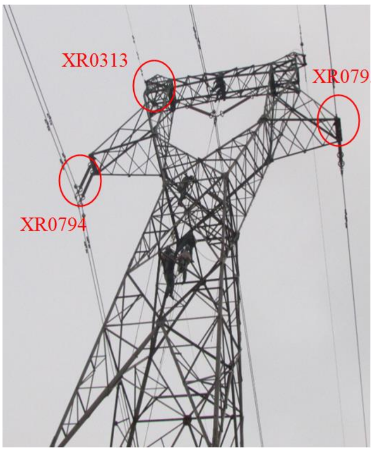


Figure 1. Installation diagram of A6 tower

Figure 2. Installation diagram of monitoring point XR0795

Figure 3. A7 tower

C. Monitoring Status

The data received from the XR0313 rarely, while the other two device got abundant data. The total monitoring time was 12 hours and the condition of data reception was shown in Table II and Table III shows XR0313 device failed to acquire data and the last two devices were considered to work well. The local average wind is 2.6m/s, and the wind speed is subject to Weibull distribution.

D. Monitoring Status

The data received from the XR0313 rarely, while the other two device got abundant data. The total monitoring time was 12 hours and the condition of data reception was shown in Table II. Table III shows XR0313 device failed to acquire data and the last two devices were considered to work well. The local average wind is 2.6m/s, and the wind speed is subject to Weibull distribution.

TABLE I. INSTALLATION LOCATION TABLE

Numbers	Device types	Device number	Install location	Taking electricity ways
1	Aeolian vibration device	XR0313	89 mm distance of clamp of OPGW of A6 tower	solar power
2		XR0794	89 mm distance of clamp of conductor of A6 tower	elctric power from conductor
3		XR0795	89 mm distance of clamp of ground wires of A6 tower	solar power

TABLE II. CONDITION OF DATA RECEPTION

Numbers	Device number	Data reception	Online rate	Statistic time
1	XR0313	0	0	2014/10/16-20:00---- 2014/10/17—8:00:00
2	XR0795	620	86.1%	2014/10/16-20:00---- 2014/10/17—8:00:00
3	XR0794	616	85.5%	2014/10/16-20:00---- 2014/10/17—8:00:00

III. MONITORING DATA ANALYSIS

A. Monitoring Data

The monitoring system operated in October 2014. The test data was reasonable from the analysis of the captured data of conductors and ground wires. Fig. 4-Fig. 7 were the oscillogram of 1 second (amplitude unit: micrometer). Fast Fourier transformation of waveform can do the spectral analysis, and then got the amplitude-frequency curve (as shown in Fig. 8-Fig. 11).

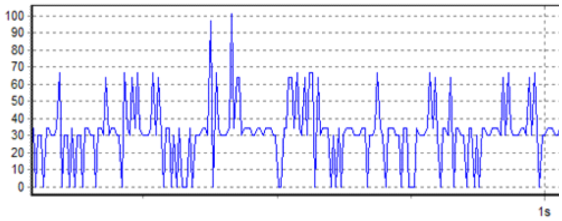


Figure 4. Veform data of XR0794 at 21:00 16th October

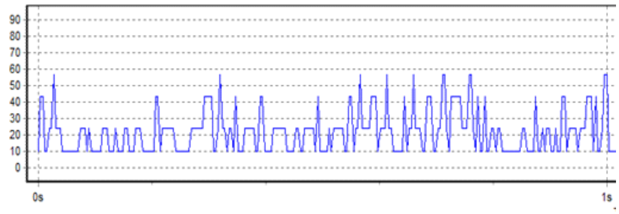


Figure 6. Veform data of XR0794 at 21:02 16th October

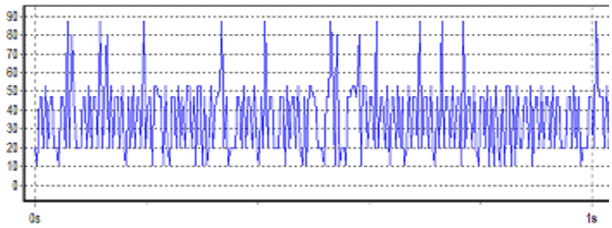


Figure 5. Veform data of XR0795 at 14:04 16th October

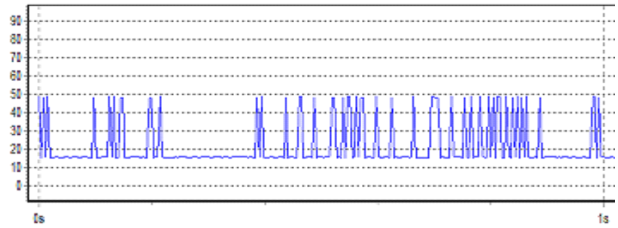


Figure 7. Veform data of XR0795 at 14:06 16th October

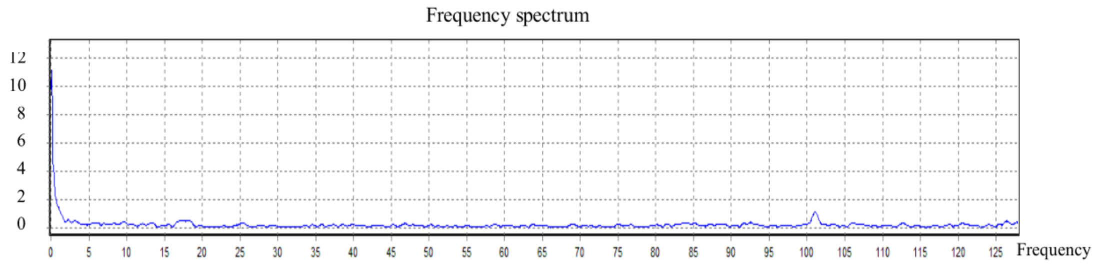


Figure 8. Plitude-frequency curve of XR0794 at 21:00 16th October amplitude-frequency curve

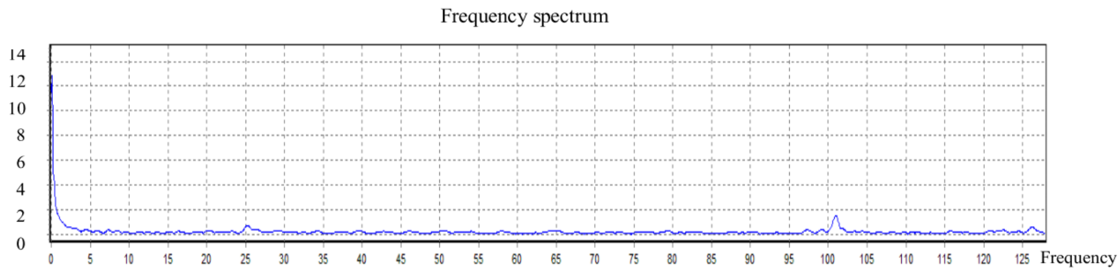


Figure 9. Plitude-frequency curve of XR0794 at 21:02 16th October amplitude-frequency curve

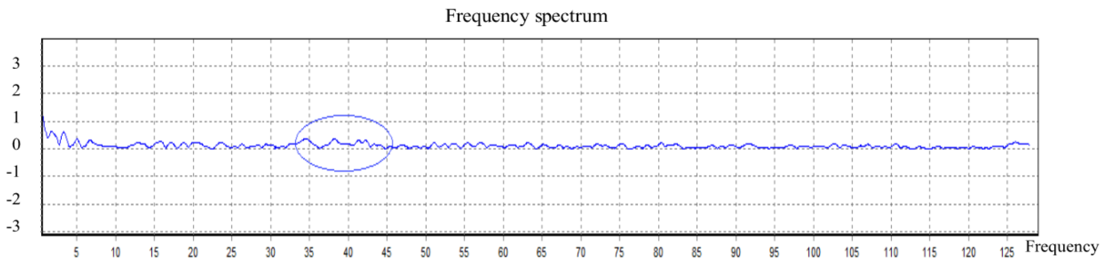


Figure 10. Plitude-frequency curve of XR0795 at 14:04 16th October amplitude-frequency curve

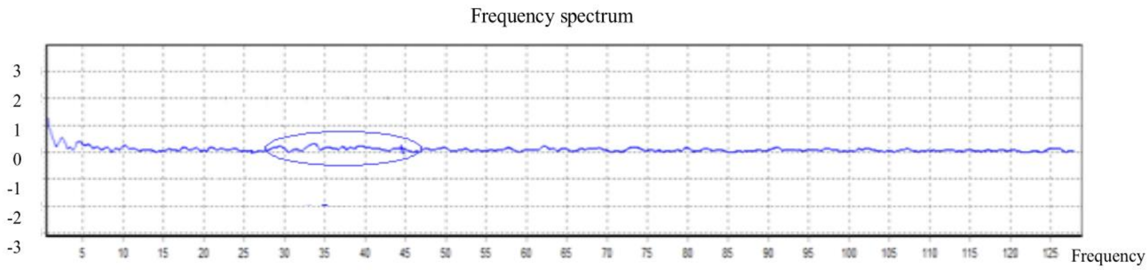


Figure 11. Plitude-frequency curve of XR0795 at 14:06 16th October amplitude-frequency curve

Table III and Table IV were given the feature information of Aeolian vibration of the conductor and ground wire.

TABLE III. FEATURE INFORMATION OF XR0794

Amplitude (μm)	***Frequency (Hz)***	***Time***
8.58	101	21:00
5.16	101	21:02
10.55	101	21:04
8.46	101	21:05

TABLE IV. FEATURE INFORMATION OF XR0795

Amplitude (μm)	***Frequency (Hz)***	***Time***
3.09	41	14:04
3.03	41	14:06
2.99	41	14:08
7.33	41	14:10

B. Data Analysis

The following conclusions are inferred from the analyses.

1) It was safety of conductor and ground wire from the waveform of measure point. The maximum vibration amplitude of XR0794 at 21:00 is 101.82 micrometer and of XR0795 at 14:04 is 48.38 micrometer.
2) It can be seen from the waveform that the vibration signals of conductor were denser than vibration signal of ground wires.
3) From the Fig. 7-Fig. 10, the conclusion can be draw that the main vibration frequency of conductor was 101*Hz* and the main vibration frequency of ground wire was 40*Hz*.
4) Peaks of amplitude-frequency curve (Fig. 7-Fig. 10) coincided with the frequency in Table III and Table IV. Obviously, it is credible directly to upload the feature data.

IV. CONCLUSION

The Aeolian vibration of transmission line in coastal areas of Guangdong influenced by sea wind. The frequency of Aeolian vibration ranges from 30 to 150Hz, and in theory the main frequency of ground wires is higher than the conductor. Therefore, the phenomenon that the main frequency of conductor is higher than the ground wires is possibly due to the energy input of sea wind at 21:00 is more than 14:00.

The Aeolian vibration of transmission line is restricted by many factors, such as the site environment, climate, design, micro-geography and so on. Hence, on-line monitoring is the only way to know the spot circumstance, and the analysis of the data get from it play an irreplaceable role for the operation of the real line, improving design of transmission line, and life assessment.

ACKNOWLEDGMENT

The financial support from Guangdong Electric Power Company Research Institute is gratefully acknowledged.

This work was supported in part by Electric Power Research Institute of Guangdong Power Grid Co., Ltd, Guangzhou, 510080, China and Tongji University, Shanghai, 200092, China.

REFERENCES

[1] Q. Y. Zhen, *Aeolian Vibration of Transmission Lines*, Beijing: China Hydraulic Press, 1987, ch. 2.

[2] O. Barry, D. C. D. Oguamanam, and D. C. Lin, "Aeolian vibration of a single conductor with a Stockbridge damper," *Journal of Mechanical Engineering*, vol. 227, no. 5, pp. 935-945, May 2012.

[3] O. Barry, J. W. Zu, and D. C. D. Oguamanam, "Forced vibration of overhead transmission line, analytical and experimental investigation," *ASME J. Vib. Control*, vol. 136, no. 4, p. 041012, May 2014.

[4] O. Barry, J. W. Zu, and D. C. D. Oguamanam, "Nonlinear dynamics of Stockbridge dampers," *Journal of Dynamic Systems, Measurement, and Control*, vol. 137, pp. 0610171-0610177, 2015.

[5] C. H. Williamson and R. Govardhan, "Vortex-induced vibrations. Annual Review of Fluid," *Mechanics*, vol. 36, pp. 413-555, 2004.

[6] G. Diana and M. Falco, "On the forces transmitted to a vibrating cylinder by a blowing fluid," *Mechanics*, vol. 6, no. 1, pp. 9-22, 1971.

[7] IEEE Committee Report, "Standardization of conductor vibration-measurements," *IEEE Transactions on Power Apparatus and Systems*, vol. 85, no. 1, pp. 10-22, 1966.

[8] C. B. Rawlis, "Wind tunnel measurement of the power imparted to a model of vibratioing conductor," *Transactions on Power Apparatus and System*, vol. 4, pp. 936-971, Oct. 1983.

[9] S. Meng and W. Kong, *The Design of Transmission Lines*, Beijing: China Electric Power Press, 2013, ch. 11, pp. 181-199.

[10] Y. Liu, H. Zhang, Z. Jin, Z. Li, and D. Zhang, "On-line monitoring analysis of Aeolian vibration of Songhua River long span of Hegang-Mulan 220kV transmission line," *Heilongjiang Electric Power*, vol. 2, pp. 121-125, Feb. 2011.

[11] Y. Yang, "An on-line measurement system of Aeolian vibration of 500kV transmission line crossing," *Anhui Electric Power*, vol. 2, pp. 29-32, June 2006.

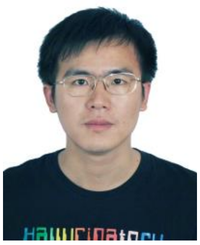
[12] Y. Liu, T. Li, X. Zhu, Y. Fu, and Z. Long, "On-line monitoring analysis of Aeolian vibration of Songhua River long span of Yongyuan-Xingfu 550kV transmission line," *Heilongjiang Electric Power*, vol. 6, pp. 512-514, Dec. 2013.

[13] X. Huang, L. Zhao, J. Shu, S. Ji, and Y. Zhang, "Online monitoring concuctor Aeolian vibration of transmission lines," *High Voltage Engineering*, vol. 38, pp. 1863-1870, August 2012.

[14] M. Liu and X. Zhang, "The design and implementation of the on-line monitoring system for Aeolian vibration of transmission lines," *Application of Technology*, vol. 6, pp. 26-31, Dec. 2012.

[15] M. Kraus and P. Hagedorn, "Aeolian vibration: Wind energy input evaluated from measurements on an energized transmission lines," *IEEE Trans. Power Delivery*, vol. 6, no. 3, pp. 89-106, 1991.

[16] *IEEE Guide on the Measurement of the Performance of Aeolian Vibration Dampers for Single Conductors*, IEEE Committee pp 664-1993, 1980.



Wenping Xie was born in Jiangxi Province, China, in 1986. He received the Master degree in engineering mechanics from Huazhong University of Science and Technology, Wuhan, China, in 2012. Currently, he works in Electric Power Research Institute of Guangdong Power Grid Co., Ltd, Guangzhou, 510080, China. His currently research interests include structure fatigue research, structural optimization of power equipment and power system overvoltage analysis.

Tian Peng was born in Jiangxi Province, China, in 1992. She is a second-grade postgraduate in civil engineering in Tongji University, Shanghai, China. Her currently research interests include structure fatigue research, Aeolian vibration research of transmission lines, wind resistance of transmission lines.

Kai Xiao was born in Hunan Province, China, in 1986. He received the Master degree in materials science and engineering from Zhejiang University, Hangzhou, 310000, China in 2011. Currently, he works in Electric Power Research Institute of Guangdong Power Grid Co., Ltd, Guangzhou, 510080, China. His currently research interests include structural optimization of power equipment and power system overvoltage analysis and monitoring technology of transmission lines.

Jian Zhang was born in Inner Mongolia, China, in 1992. He is a first-grade doctoral students in civil engineering in Tongji University, Shanghai, China. His currently research interests include wind resistance of transmission lines, transmission tower strengthening, transmission tower-line system analysis.