Research on small lightweight electromagnetic interference measurement system based on patrol unmanned aerial vehicle

Pingyuan Liu, Nian Wu, Junwen Yao, Xianbin Ke, Shiguang Bie, Feng Liu

1Guangdong Power Grid Co., Ltd, No. 757 East Dongfeng Road, Yuexiu District, Guangzhou City, Guangzhou and 510000, China
2Electric Power Research Institute Wuhan Nanrui Co., Ltd, No. 143 Luoyu Road, Hongshan district, Wuhan City, Wuhan and 430074, China

Abstract—Unmanned aerial vehicle (UAV) has been widely used in power system inspection. Most of the existing UAVs are equipped with visible and infrared cameras for fast full spectrum photography and fault monitoring of transmission lines. When the transmission line has defects such as aging, broken strand and serious corrosion, the traditional image recognition, infrared and other observation methods can not identify these defects well. In order to realize the rapid detection and judgment of broken strand, this paper analyzes the characteristics of electromagnetic interference of transmission line, and constructs the electromagnetic interference measurement system based on patrol UAV. The research results of this paper can realize the real-time detection and alarm of broken strand, and provide technical support for line inspection.

1. Introduction
Transmission line inspection UAV has the ability of high-altitude, long-distance, fast and self-operation. It can cross mountains and rivers to quickly inspect the transmission line, greatly improving the speed and efficiency of transmission maintenance and repair[1]. As an important technical means of intelligent machine inspection, UAV inspection has been widely used in the system. The application of UAV inspection technology in power industry provides a new method and means for power line inspection and large-scale disaster prevention and mitigation inspection. When the transmission line has defects such as aging, broken strand and serious corrosion, the traditional image recognition, infrared and other observation methods can not identify these defects well, but the change of electromagnetic interference level is an important characterization of the defects[2].

Therefore, combined with the large-scale application of existing UAV and the research on corona characteristics of transmission line wire, this paper studies the correlation between broken strand defect of transmission line wire and high-frequency electromagnetic spectrum distribution, establishes a lightweight integrated communication system for receiving and processing electromagnetic interference information applied to small UAV, and realizes the positioning of serious corona discharge parts of wire, and real-time detection of aging, broken strand and serious corrosion defects can not be distinguished by image.
2. Measuring Principle

2.1. Electromagnetic interference characteristic
Within a certain distance, the height of the line wire nearest to the measuring point has an impact on the speed of the electromagnetic interference level decreasing with the distance. The lower the height of the line wire, the faster the attenuation. The transverse attenuation rate of electromagnetic interference is a complex function, which is related to the frequency and the distance from the interference source. For the extremely low frequency (3-30 kHz) and low frequency (30-300 kHz) bands, the measurement antenna will be in the near field or induction field, and the attenuation rate of electromagnetic interference is \( \frac{1}{R^2} \), \( R \) is the distance from the wire to the antenna. For the intermediate frequency (300-3000kHz) band, with the antenna gradually away from the line, the electric field formed by corona pulse gradually changes from the induced field to the surface wave field at the radial distance \( \frac{\lambda}{2\pi} \) from the wire, where \( \lambda \) is the wavelength, and the unit is m. The attenuation rate of the surface wave field is \( \frac{1}{R} \). When the frequency is from 3 MHz to 30 MHz, the electric field is the combination of surface wave field and radiation field.

The transverse attenuation near the line can be expressed by the following formula:

\[
E = f(R) = E_0 + 20k \log\left(\frac{R_0}{R}\right)
\]

Where, \( E \) is the electric field component level of electromagnetic interference field strength at the linear distance \( R \), expressed by dB(\( \mu V / m \)). \( k \) is the attenuation coefficient, which is 1.65 in the frequency band of 0.5mhz-1.6mhz ; \( E_0 \) is the electric field component level of electromagnetic interference field strength at the reference distance \( R_0 = 20 \text{m} \), expressed by dB(\( \mu V / m \)).

2.2. Detection principle
Based on the analysis of electromagnetic interference characteristics of transmission line, when the transmission line is in normal operation, the magnetic field signal detected around the line is also normal. When the transmission line fails, the fault point will produce the relative difference of fault signal, which will lead to the change of the current of the transmission line in the transmission process. When the EMI antenna is close to the high-voltage transmission line, the broken line will produce the alternating magnetic field, and then produce the interference signal, and the signal will fluctuate in a large relative difference, Therefore, the wire surface state can be judged by detecting the radio signal.

The working principle and basic structure of the inspection UAV for detecting broken strand defect of transmission line by electromagnetic interference are shown in the block diagram in Fig.1:
When the transmission line is running normally, the magnetic signal detected around the line is also normal. When the transmission line is in fault, the relative difference of the fault signal will be produced at the fault point, and the current of the transmission line will change during transmission. The detected radio around the transmission line will reflect the change of the current in the line in real time, therefore, by detecting the radio signal, we can get all kinds of characteristic information of the line signal, and determine the position of the fault by the GPS positioning system, at the same time, image the fault point.

After the ground operator starts the UAV through the remote control device, along with the patrol UAV’s movement in the high-voltage transmission line, the radio interference receives the transmission line status signal which the antenna detects, the signal is processed by the amplification denoising analysis system, with the threshold value for decision, the problem line is automatically executed beyond the threshold interval photo storage, and at the same time the signal is sent to the ground control end to remind. With the flight of the patrol UAV, the detection can be completed on the high-voltage transmission line abnormal fault detection points for a detailed Quantitative analysis, diagnosis of high-voltage transmission line broken, damage fault.

3. System Design
As a fault detection and diagnosis system for high-voltage transmission lines, it has the functions of real-time monitoring, collecting, processing, transmitting and storing the radio interference signals generated by transmission line faults, combined with the recording information of the radio test data, it can be used to detect and diagnose the faults such as broken and scattered strands, which is convenient for the staff to find and analyze the fault points. The communication function of the system makes the detection information more comprehensive and the diagnosis position more accurate. In addition, the
system has the storage function of the time information and the location information, it provides a great help to the follow-up data processing and analysis.

The small lightweight EMI measurement system based on patrol UAV is composed of data acquisition unit, central processing unit and data transmission unit. The overall structure of the system is shown in Fig. 2:

Fig. 2 Overall system structure diagram

(1) Data acquisition unit: MCU is used as the main controller in the front-end acquisition part, which mainly completes the front-end processing of electromagnetic interference signal input, A/D analog-to-digital conversion, data storage and transmission and other functions. The hardware is divided into three parts, the first part is the antenna, the second part is the front-end signal processing circuit, including signal conditioning and trigger acquisition circuit, etc.

(2) Central processing unit: the central processing platform based on ARM mainly uses the ARM microprocessor as the main control unit, designs the corresponding peripheral circuit modules of the chip, transplants the embedded Linux operating system, and realizes the control of the front-end acquisition circuit of the MCU, as well as the reading, analysis and processing of the collected data, photo execution, fault location, fault detection, fault detection and so on Alarm, memory and other functions[7]. Hardware design ARM the most simple system, including ARM processor, SDRAM circuit, as well as the system involved in the expansion of applications, mainly SD card memory module, serial port module, Positioning Module, warning module. The software part includes porting the embedded Linux operating system platform, controlling the acquisition path of the front-end acquisition part, the functions include real-time storage of data with time information and location information, serial transmission, integrated fault diagnosis and analysis of fault data record information combined with radio interference, taking photos of fault points and warning.

(3) Data transmission unit: composed of RF chip, related circuit and antenna. Taking the RF chip as the main control unit, the corresponding peripheral circuit module of the chip is designed. The modulated digital signal is converted to digital analog, converted and filtered, and then sent to the ground flying hand through the antenna to remind the failure point.

The hardware is divided into two parts, the first part is the RF chip and signal processing circuit, including signal conditioning and trigger transmission circuit, analog-to-digital Conversion Circuit, etc. . The software part includes the trigger transmission program, the analog-to-digital Conversion Program, the Signal Processing Code, the fault warning program and so on.

4. Conclusions
Conclusion based on the analysis of electromagnetic interference characteristics of transmission line, combined with the large-scale application of existing UAV and the research on corona characteristics of transmission line wire, this paper studies the correlation between broken strand defect of transmission
line wire and high-frequency electromagnetic spectrum distribution, establishes a lightweight integrated communication system for receiving and processing electromagnetic interference information applied to small UAV, and realizes the positioning of serious corona discharge parts of wire, and real-time detection of aging, broken strand and serious corrosion defects can not be distinguished by image.and provides strong technical support for the condition assessment of transmission line conductor. In the future, this technology can be used in line maintenance and repair to improve the level of intelligent power grid inspection.

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