

Study on the Detection Method of Space Electric Field based on UAV

Liqian Wang^{1,a}, Geng Liang^{1,b}

¹School of North China Electric Power University, Beijing 10054, China.

^awlq0124@foxmail.com, ^bliangeng@ncepu.edu.cn

Abstract

This paper proposes a new method for the detection of space electric field. The method based on the use of drones carries the electric field sensor to measure the space electric field, and uses wireless transmission equipment to transmit data to the ground, then processes to make the data on the ground display visually, and the structure and working principle are introduced in detail. Also the method describes the influence of the UAV on the safety of transmission and distribution line and the spatial electric field value of the measurement. In the case of accurate detection of space electric field, the operation mode is the most simplified, real time measurement data, greatly improving the processing efficiency and reliability. It has important significance for the safe operation and environment protection of electric power equipment.

Keywords

UAV; Space Electric Field; Transmission and Distribution Lines; Electric Field Sensor.

1. Introduction

In recent years, with the rapid development of the national economy and the increasing demand for electricity, the development of the power industry plays an important role in the whole energy pattern. China has built the world's largest and most complex power grid, which will inevitably increase the difficulty of the safe operation and detection of the power grid [1]. At the same time, the impact of electromagnetic pollution caused by high-voltage power equipment on the residents and equipment along the line has attracted the attention of all aspects of society, and more and more studies show the harmfulness of electromagnetic pollution [2]. Therefore, the study of space electric field has become an important issue in the field of environmental protection and electromagnetic compatibility technology. Accurate measurement of space electric field and its changes around power equipment is of great significance to the safe operation of power equipment and environmental protection.

Nowadays, the most common method to measure the spatial electric field is as follows:

a) Using the capacitive voltage divider based on the principle of space electric field effect, the high-voltage part of the measurement system is suspended on the high-voltage line to be measured through the high-voltage lead, and the low-voltage part is placed on the ground of the studio or measurement site. By controlling the operating switch of the low voltage side of the measuring device, the transient high voltage signal of the line to be tested can be measured and recorded [3]. The workload of this way is huge, and it needs to check the lines one by one manually. In places with bad terrain, it also poses a great threat to the life and safety of operators.

b) The use of hand-held field strength instrument and professional near-field probe can make the test more convenient and fast. Pmm8053a comprehensive field strength measurement analyzer produced by PMM company in Italy [4] and hi-3604 power frequency electromagnetic field strength tester produced by Holladay company in the United States [5] are the most

commonly used ones. The test instruments are small in size, easy to carry, large in detection range and high in accuracy. However, the handheld field strength tester is limited by optical fiber and expensive. When using the handheld field strength tester, the tester should be far enough away from the probe of the handheld field strength tester to avoid large electric field distortion near the probe. Moreover, the handheld field strength tester can only test the field strength on the ground or far away from the transmission line, and can not detect the electric field in close space.

c) Mechanical electric field sensor and optical electric field sensor are used to measure the space electric field of high-voltage power equipment, and UAV and other equipment are used to carry the sensor. Although it does not need to contact the high-voltage line directly, this kind of sensor has high cost, large volume, heavy weight and complex structure. When measuring, it needs to carry the sensor to take off. Excessive volume and weight will bring extra power consumption, and it is difficult to measure the low-frequency field or electrostatic field.

2. Measurement of space electric field by UAV

In recent years, the application and research of unmanned aerial vehicle (UAV) have been paid more attention. With the rapid development of embedded processor, sensor technology and control theory, UAV technology has been widely used in various fields.

Due to its ability to land vertically and hover freely, rotorcraft can adapt to flight conditions of various speeds and flight profiles [6]. UAV has the following characteristics:

- a) Small size, light weight, simple structure, easy to carry, no need for professional airport take-off and landing, suitable for multi platform, flexible take-off and landing on the ground;
- b) It is convenient, efficient and safe to perform tasks;
- c) The flying altitude is low, and it has strong maneuverability. The flying altitude of micro UAV is several meters to several hundred meters, and the speed is several meters to tens of meters per second.

These characteristics make rotor UAV can be used in complex environment, and can also carry portable devices, such as cameras, to provide accurate and real-time target information.

This paper takes advantage of the above characteristics of UAV, carries the electric field sensor on the UAV to detect the line, and after processing by the signal processing module, transmits the data to the ground station in real time through the wireless module, processes and displays the data visually, and uses the navigation system to locate the waypoint and select the route during the flight, The obstacle avoidance module is used to fly with the transmission and distribution lines at a certain vertical distance and avoid obstacles in the route. In the case of accurate detection of space electric field, the operation mode is the most simplified and the measured data is returned in real time, which greatly improves the processing efficiency and reliability.

3. Analysis of influence of UAV on space electric field

Because the UAV itself contains metal materials, and will carry electromagnetic equipment, so when using UAV to measure space electric field, the safety of UAV, the impact on high voltage lines and the impact on the measured electric field value are very necessary.

High voltage transmission line is a three-phase alternating current. The changing electric field produces a changing magnetic field, which is constantly excited around. The closer the distance from the high-voltage line is, the greater the field strength is [7]. Taking UHV transmission line as an example, the 220kV transmission line has Drum Tower, the length of ground wire cross arm A1 is 3.9m, the length of upper phase conductor cross arm A2 is 5.5m, the length of middle phase conductor cross arm A3 is 7m, the length of lower phase conductor cross arm A4 is 6m,

the height of ground wire to ground is 56m, the height of upper phase conductor to ground is 50.5m, and the height of middle phase conductor to ground is 44m, The height of lower phase conductor to ground is 37.5m, the radius of ground wire is 13mm, and the equivalent radius of conductor is 0.1M. In the calculation process, it is assumed that the upper, middle and lower conductors of the transmission line are respectively suspended with a, B and C three-phase conductors, and the phase difference of the three-phase conductors is 120 degrees. Figure 1 shows the tower model.

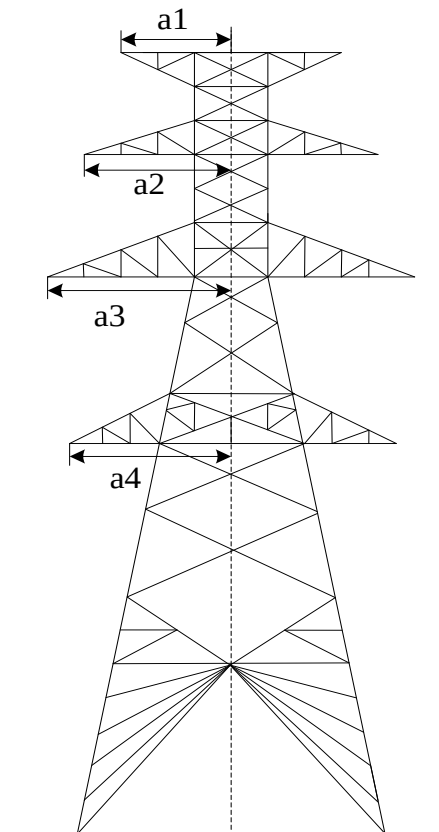


Figure 1. Tower model

Table 1. Calculation of electric field without considering UAV

Assume the initial phase of the upper phase conductor	Potential of upper phase conductor	Potential of middle phase conductor	Lower phase conductor potential
0	127kV	-64kV	-64kV
$\pi/10$	120kV	-94kV	-26kV
0.3π	74.6kV	-126kV	-51kV

To sum up, when the UAV is not considered, the voltage is the highest and the electric field intensity is the highest in the phase with zero phase. So we choose to add UAV when the phase of the upper phase wire is zero to calculate the influence of UAV on the field strength around the transmission line. Figures 2, 3 and 4 show the potential distribution and details of UAV when the dielectric constant is 20, 181 and 10000 respectively.

After many experiments, no matter what kind of material is chosen for UAV. UAV has little influence on the total electric field around the transmission line, only in the local area where the UAV is located. If the UAV chooses metal material, it has a great influence on the electric field. If the UAV chooses insulating medium, the smaller the dielectric constant of the insulating medium, the smaller the influence on the electric field.

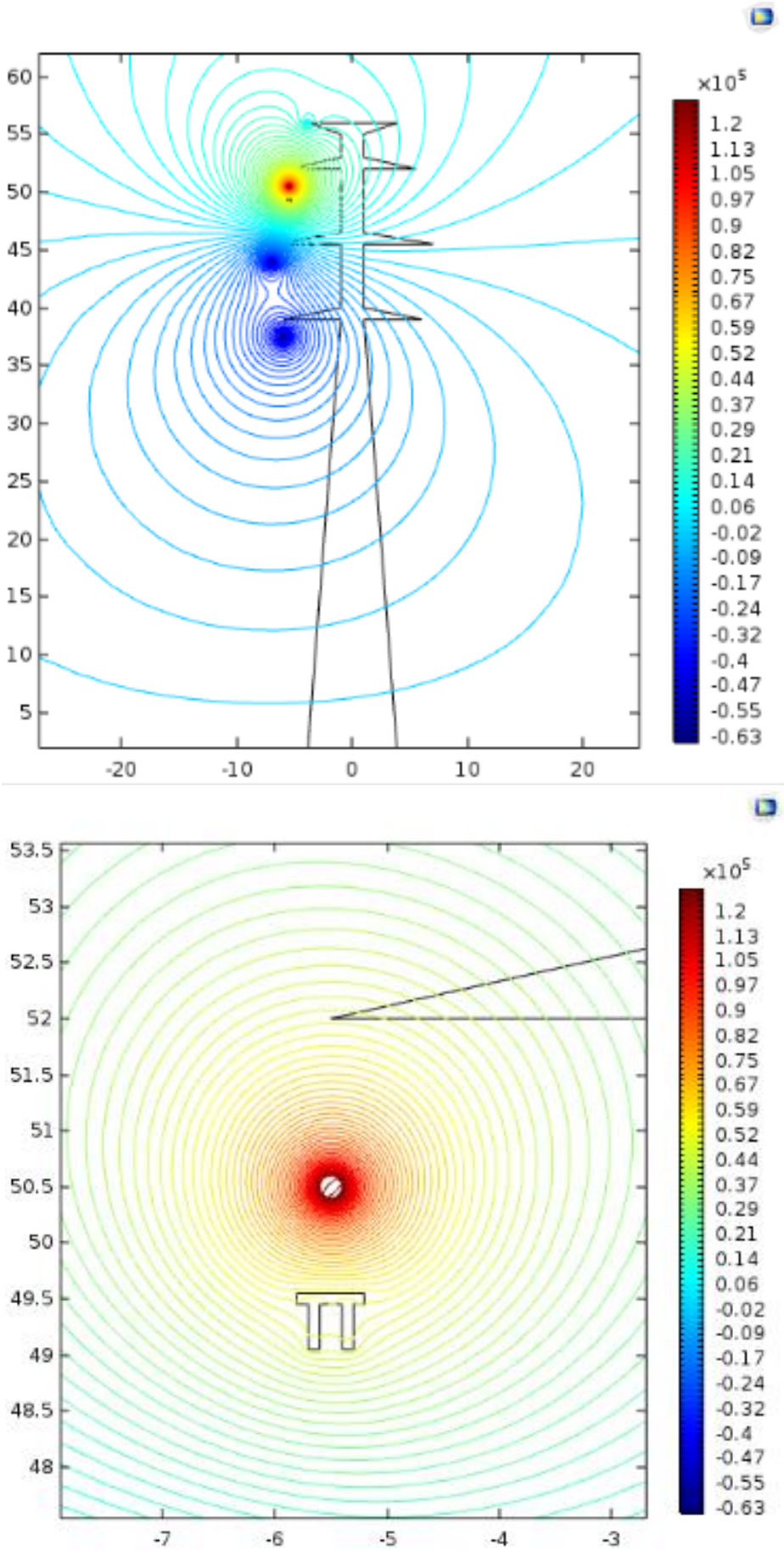


Figure 2. UAV dielectric constant of 20, the potential distribution maps and details of the plan

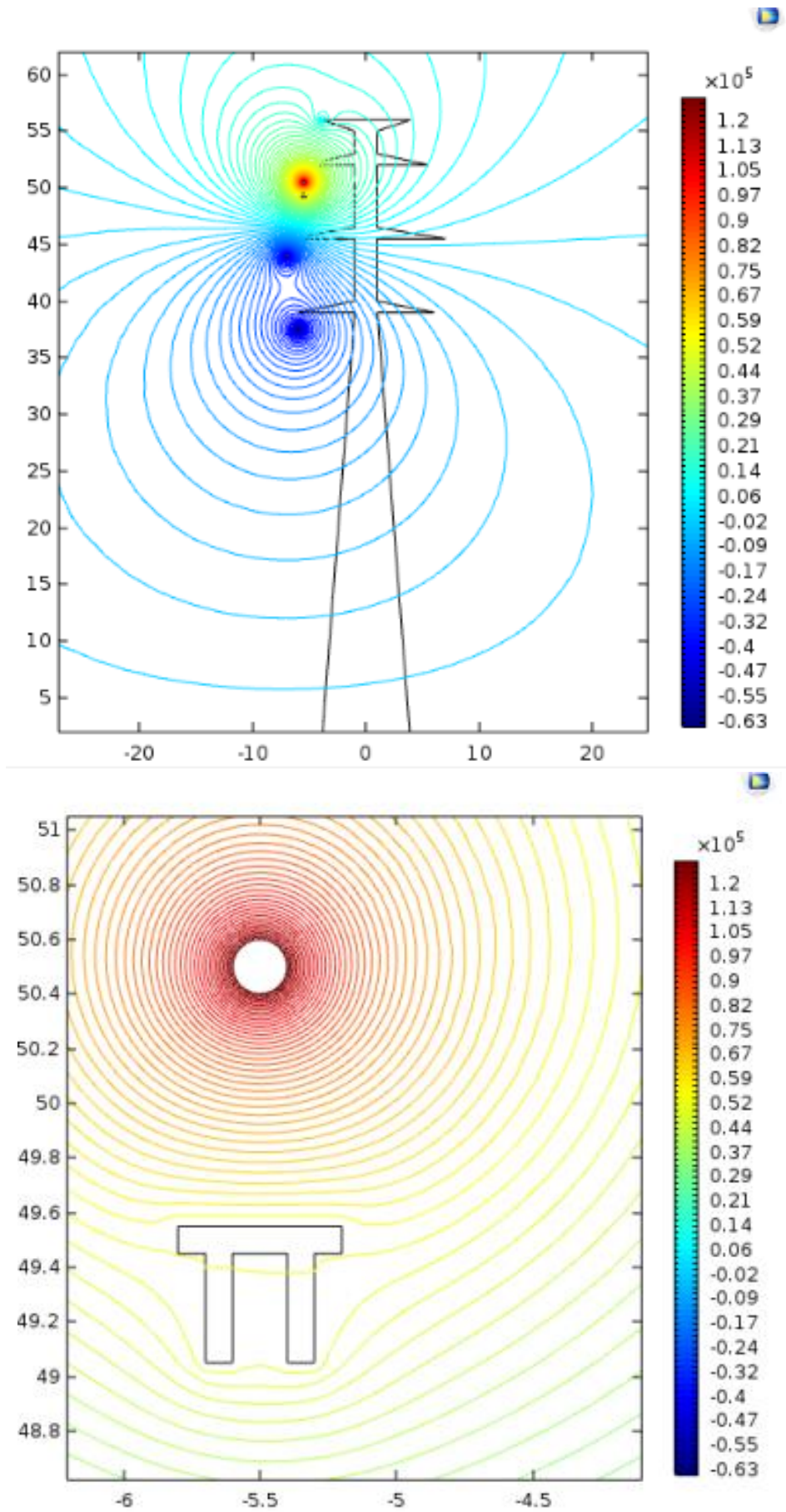


Figure 3. UAV dielectric constant of 181, the potential distribution maps and details of the plan

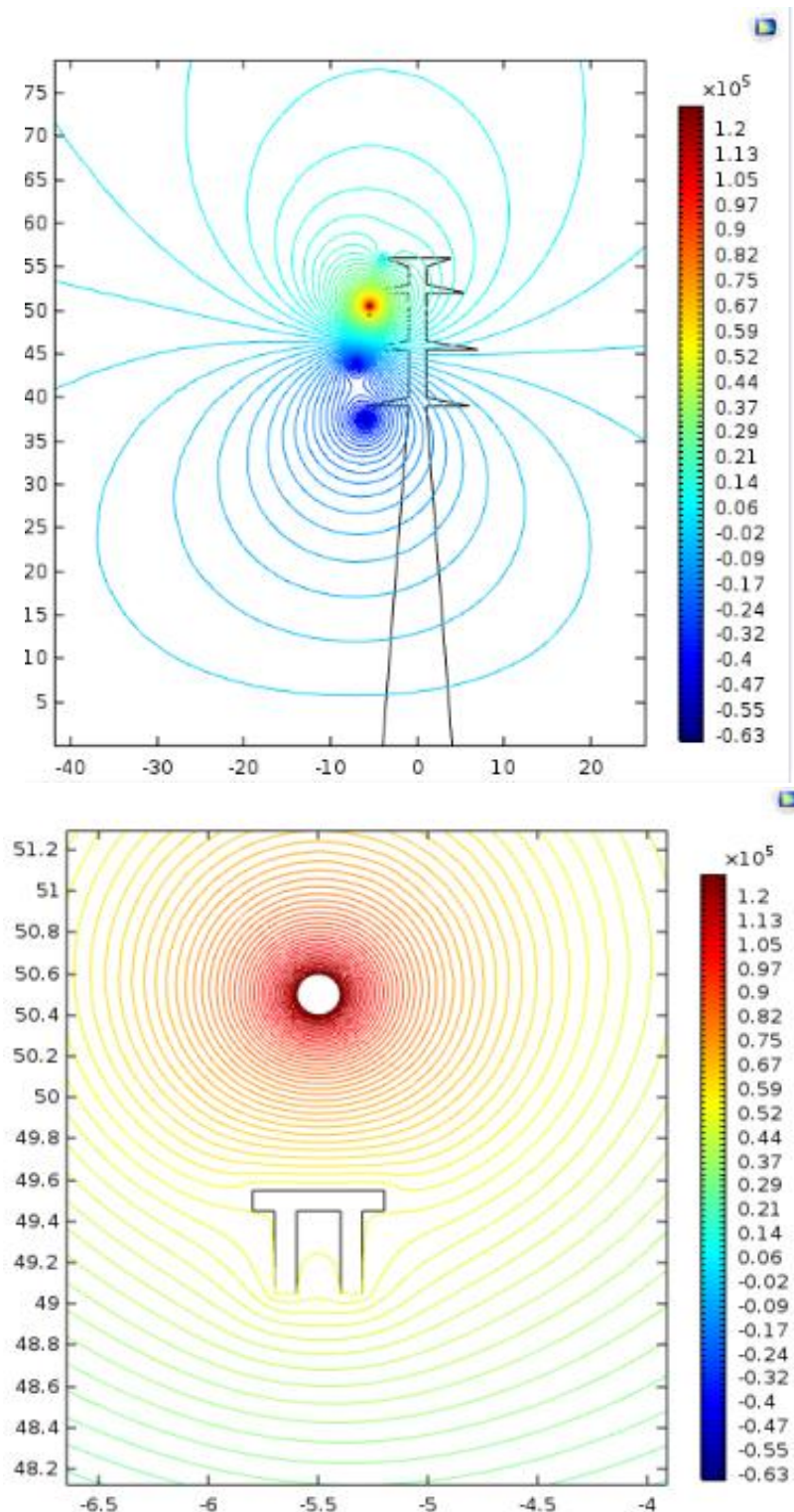


Figure 4. UAV dielectric constant of 10000 (visual unmanned aerial materials for the conductor), potential distribution maps and details

4. Selection of sensors

The measurement of electric field is in the fields of aerospace, electricity, meteorology, biological science, etc., so people have been constantly researching sensors. Many new discoveries and new materials in physics also promote the development of sensors, such as thermoelectric effect, photoelectric effect, electro-magnetic effect and other sensors.

When measuring high voltage transmission lines, the measuring points are located in the high potential and strong field, so the probe of the sensor needs to be well isolated from the signal processing part of the post stage. The response speed of the sensor should be wide in the corresponding range of fast cut frequency. As UAV is needed to measure, the sensor volume should be as small as possible and light.

Based on Pockels effect, photoelectric sensors form strip optical waveguides on crystal surface by proton exchange or titanium diffusion technology, and convert phase change into easily measured optical power change [8].

The sensor is composed of optical waveguide, metal electrode and dipole antenna. LN crystal is cut along the X direction, and the input laser propagates along the Y direction [9]. The electric field of the electrode acts on the optical waveguide along the direction parallel to the z-axis, so as to make full use of the electro-optic effect. The asymmetric M-Z structure with different lengths of the upper and lower branch optical waveguides is used to make the static working point of the sensor in the linear working region [10].

The sensor used for measuring space electric field by UAV must meet the requirements of non-contact measurement with high field strength and wide frequency band. This kind of sensor is an electric field sensor based on optoelectronic integration technology, which can meet the requirements of measuring space electric field by increasing the distance between optical waveguides and electrodes and reducing the size of dipole.

5. Basic structure and working principle

The space electric field detection system based on UAV includes UAV part, detection part and ground station part.

UAV is composed of UAV, navigation module, obstacle avoidance module, intelligent battery and camera. Among them, navigation module, obstacle avoidance module and camera are all mounted on UAV, which are connected with the flight controller of UAV; UAV, navigation module, obstacle avoidance module and camera are powered by intelligent battery. As the navigation point positioning equipment, the navigation module provides accurate position information for UAV; The obstacle avoidance module enables UAV to automatically detect and avoid external obstacles, and detects transmission and distribution lines by obstacle avoidance module, so that UAV can fly at a certain vertical distance from transmission and distribution lines; The camera is a kind of camera equipped with UAV, which provides more reliable picture of air transmission and distribution line for maintenance personnel, and can find the potential danger that the detection part can not detect. Figure 5 is the schematic diagram of UAV.

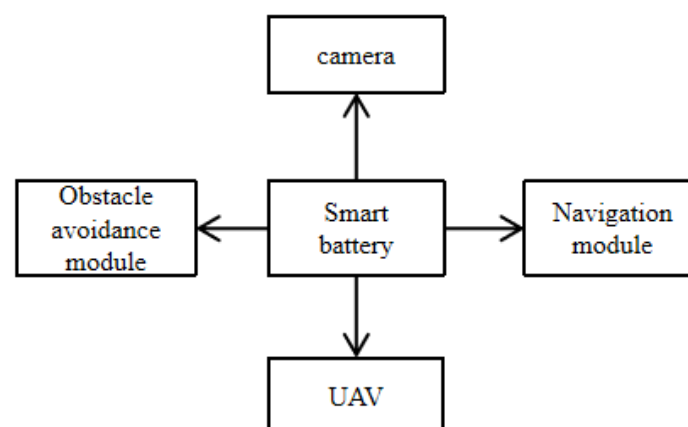


Figure 5. UAV part of the diagram

The detection part consists of control module, electric field sensor, power module, signal processing module and wireless transmission module (unmanned machine end). Among them, the power module is connected with the intelligent battery, which converts the output power to +5v voltage, and then connects with the control module as the input voltage of the control module; The electric field sensor, signal processing module and wireless transmission module (unmanned machine end) are respectively connected with the control module, and the control module supplies power to these devices. Electric field sensor is an important equipment to detect whether the transmission and distribution line leakage and the outer space electric field of transmission and distribution line are connected with the control module as input. Fig. 6 is a schematic diagram of the detection part.

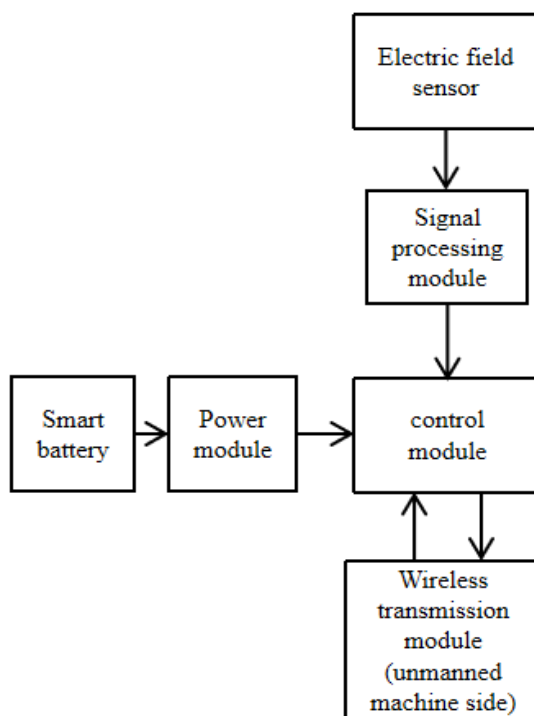


Figure 6. Detection of part of the diagram

The ground station is composed of remote controller and receiving equipment. Among them, the remote controller as ground operation equipment is controlled by maintenance personnel; The receiving equipment also includes a computer, a wireless transmission module (ground station) and data processing software. The wireless transmission module (ground station) is connected with the computer, and the wireless transmission module (ground station) is powered by the power supply equipment of the computer.

When working, the ground operator selects in the computer interface, the command is sent out through the wireless transmission module (ground station), received and sent to the control module by the wireless transmission module (UAV end), and measured by the electric field sensor. After the detection is completed, the detection signal is transmitted to the signal processing module to convert the analog signal into digital signal, and then the digital signal is transmitted to the ground through the wireless transmission module (UAV end) through the control module. Then the wireless transmission module (ground station) receives the signal, transmits it to the computer, processes the data by the data processing software, and displays the result on the computer screen; Among them, the remote controller only needs to take off and land the UAV, and the automatic flight route, time, altitude and return of the UAV can be set by the computer of the ground station.

The working process of the system is as follows: after the initialization of the system, first manually input the parameters and detect whether the sensor can obtain the data normally, if not, check whether the sensor is connected, and then calculate the field strength and voltage value according to the gear selection to determine whether to save the data, Then the scene of voltage and time axis and the scene of field strength and time axis are displayed. In the process of software design, based on the hardware circuit, structured programming method is adopted to make the software system modular. The overall component diagram of the software is shown in Figure 7:

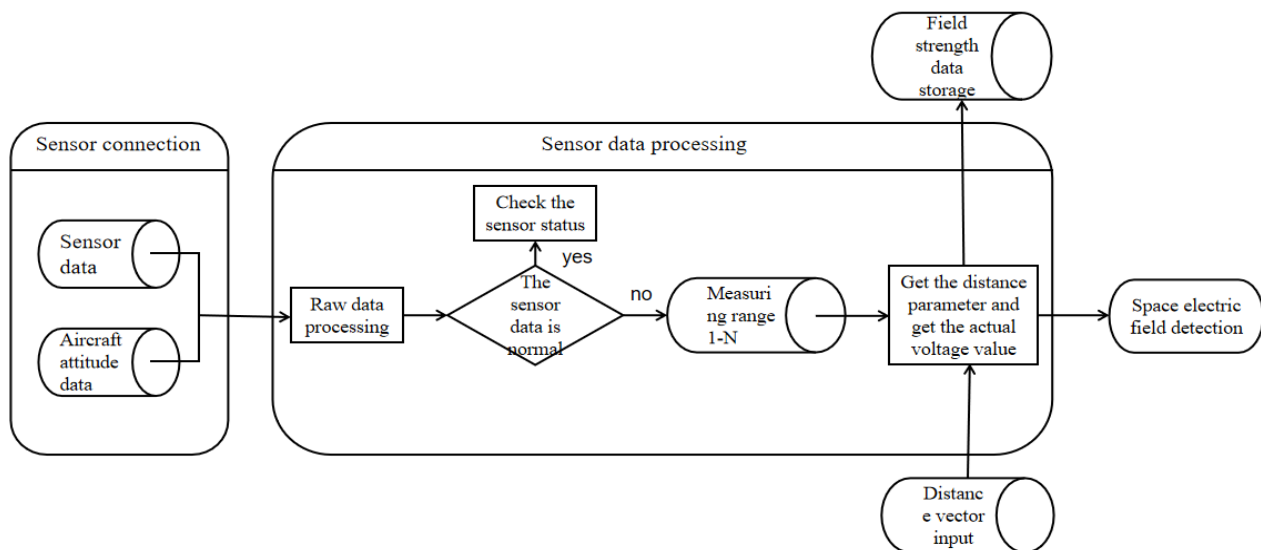


Figure 7. The overall component diagram

6. Summary

This paper designs a space electric field detection system based on UAV, which can realize high automation in UAV flight without professional flight control personnel. In use, the operator can simply take off and land the UAV through the remote control, and the automatic flight route, time, altitude and return of the UAV can be set by the computer of the ground station. At the same time, the self-developed data processing interface is used in the ground station, so the data can be read directly without complicated calculation, which improves the processing efficiency, and the highly precise electric field sensor also greatly improves the reliability of the results. In addition, through the high-resolution camera, it provides reliable photographic images for potential hazards, and provides dual protection for detection with electric field sensor, so as to maximize the reliability of detection and the safety of UAV.

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