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Research on Intelligent Monitoring System of Intelligent Transmission Line Based on Computer Internet of Things Technology

Abstract: - The author proposes an intelligent early-warning system for preventing external damage of transmission lines. The system uses TI-TMS320DM6446 as the core, the peripheral circuit configuration and video monitoring; The moving objects captured by PTZ camera are detected and identified by using mixed Gaussian model, background difference and minimum tangent matrix, and alarm signals are provided. According to the particularity of the power supply of the equipment on the transmission line, the basic power management of the system is analyzed in detail. A reliable power management scheme is designed. The practical application proves that this method has good real-time performance and has obvious effect on preventing power cable damage by force.

Keywords: Transmission Line; External Force Failure; Mixed Gaussian Model; Background Difference Method.

I. INTRODUCTION

Electricity transmission is the most basic industry of the country. As domestic demand for electricity continues to increase, transmission lines will inevitably pass through cities, villages and other areas. After the country implemented the return of farmland to forests, the material quality of rural people's life has been greatly improved, and illegal planting of trees and illegal building of houses often occur in the corridors of transmission lines. In recent years, human damage to and theft of power facilities are also quite common [1]. As China's transmission lines have more and more wide geographical scope, transmission distance is more and more distant, the transmission lines through the regional environment and weather changes are more complex, therefore, the daily operation, maintenance and repair of the power grid operation and maintenance department of the line put forward severe requirements [2]. In the process of power grid operation, transmission line failure will not only cause power grid accidents, but also bring huge economic losses and bad social impact to the power grid.

Through the analysis of the annual work summary of the State Grid Company, it is found that lightning strike, external damage and ice disaster are the top three causes of power system tripping from 2008 to 2020. Losses from lightning strikes were 11.5 per cent, losses from external causes 33.5 per cent and losses from ice 34.8 per cent. Among them, lightning is uncontrollable, hail is only a warning and power supply to the power grid, and can reduce the loss, only external forces [3]. External damage such as short circuit, crane hit line, illegal construction can be controlled. In recent years, with the deepening of urbanization and urban-rural integration, there are more and more human projects and buildings near the power system, so most of the external damage will appear in the villages and towns passed by the power system [4]. More than half of the external damage was caused by floating objects on construction machinery and greenhouses, and the number of construction line collisions on transmission line corridors from 2008 to 2013 was about 80%, according to statistics. For the occurrence of external force damage, the power operation inspection department usually adopts the mode of inspection and publicity in the transmission line corridor across the countryside, and can also sign security agreements with units or individuals, but this way can not be monitored and prevented outside the inspection period, which is incomplete and not timely. In addition, if there is an accident, the construction workers have been evacuated, then the power company will not have the appropriate evidence to hold them accountable [5]. Therefore, it is of great significance to develop a system that can monitor and collect evidence of damage caused by external factors in real time and efficiently for reducing power grid failure caused by damage caused by external factors. For the real-time monitoring of power lines, many foreign technologies are ahead of China. The detection of wire temperature, vibration, tilt, tension, sag and other parameters is the earliest one.

The United States USI has developed a wire temperature, wire current, wire tilt instrument, which is a contact test method. The wire temperature and tension monitoring system developed by ValleyGroup company in the United States is based on the basic principle of contact detection. The Power Research Society of the United States has developed a Sagometer for measuring the change in distance between wires and the ground using a

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contactless method, and the device can also be used to measure the distance between wires and the ground [6]. In foreign countries, because the development is relatively early, and has a certain market experience, so the things produced are relatively stable and reliable. Compared with the international, China's research on online monitoring of power lines started in the past two decades, and China's research on this started relatively late, and many technologies inevitably lag behind the international. However, with the continuous construction of the national grid, the country's energy requirements are becoming higher and higher, more and more foreign cable testing new products and new technologies have been introduced to China, many universities and power research institutions are also continuing to invest in real-time monitoring of power lines [7]. China's transmission line monitoring has just begun, due to the imperfect communication network in China and the lag of communication equipment, the use of online monitoring products is greatly restricted. Before 3G, the transmission of TV signals over long distances was limited, and many products forwarded the image to the grid through optical cables, which was expensive and unstable. In recent years, due to the wide application of the third generation mobile communication technology and the establishment of large-scale mobile base stations, the development of power system online monitoring technology in power system has been greatly limited [8]. Especially for some video equipment, many are based on 4G, and some companies have carried out real-time monitoring research for 5G transmission lines. Aiming at the detection problem of current moving objects, this project researches the interframe difference method, single Gaussian background construction, multi-Gaussian background construction and other aspects of current video images, combined with the scene features of trees swaying and water wave fluctuation in power line channels, and researches the moving object extraction technology based on multi-Gaussian background model.

II. Intelligent power line monitoring and control system

A. System Architecture

In view of the intelligent alarm device for external force damage of high-voltage transmission lines, the PGND camera is used to shoot the scene picture in real time, the simulated data is simulated and transformed through the video acquisition module, and the data is transmitted to the video processing unit [9]. When abnormal phenomena occur in the field of the transmission lines, The status of the site is sent to the background monitoring center through OPGW/ optical cable + WIFI or 3G network. The main control board of the monitoring extension is based on ARM+ DSP, and ARM is the main control chip. SIP protocol is used to communicate with the video image acquisition and processing module, and the collected video data is transmitted to ARM, which then analyzes the obtained images through the video difference algorithm in DSP. When human violations such as large machinery approaching and pedestrians climbing the tower are found, the software can be linked with the call device to send an alarm to the staff [10]. At the same time, the background monitoring center MMS platform will receive on-site alarm information in the form of MMS real-time sent to the staff, the network server will synchronize the message with the PC, and through the mobile phone login system server for re-query. As the monitoring extension is set outside, it is difficult to obtain power, so the wind-solar complementary + battery power supply mode is used, and the charging and discharging circuit is protected, its overall structure is shown in Figure 1 (the picture is quoted in World Electr.Veh.J.2023, 14(8), 224).

B. Implementation of video monitoring extension system

The system is mainly composed of video acquisition module, video processing module, communication module and power supply module. The analog video captured by the PTZ camera is decoded by the image acquisition module and sent to the video processing module containing the corresponding difference algorithm for analysis and processing. When the risk of the transmission line site is analyzed and judged, Using OPGW/ optical cable + WIFI or 5G networks to send alerts to back-office monitoring centers and staff mobile phones. The entire hardware architecture can be seen in Figure 2 (image cited in World Electr.Veh.J.2023, 14(8), 224).

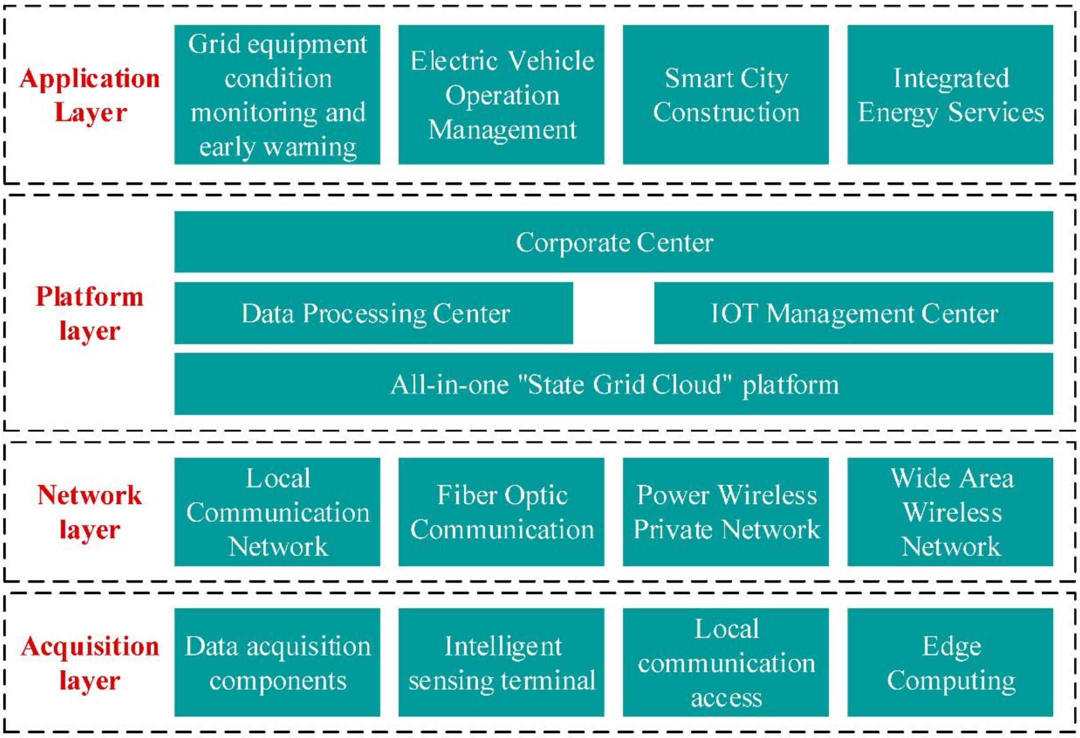


Fig.1 Transmission line monitoring system architecture

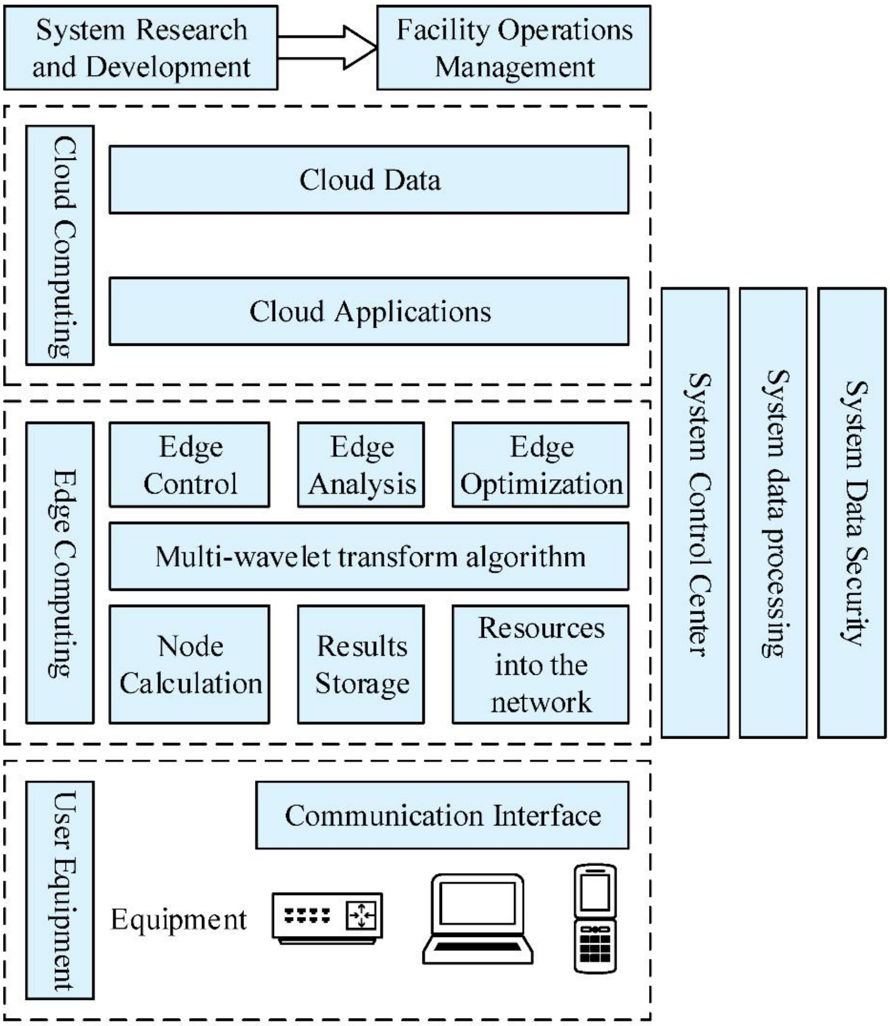


Fig.2 Hardware architecture of video monitoring extension machine

a. PTZ camera

The camera is the most forward device of the resistance destruction intelligent alarm system constructed in this subject. The imaging quality of the camera determines the performance of the system and also determines the performance of the system. Considering the characteristics of the system, the author uses a visual light simulation camera with a head, which can be monitored 24 hours a day.

b. Video capture module

Using TVP5147 encoder of TTI company of TI company, YUV4:2:2 transformation is carried out on the analog image obtained by PTZ camera, and then sent to DM6446 image front end for data processing and transmission.

c. Video processing module

The system uses the TMS320DM6446 designed by Da Vinci of TI company as the image processor. Its role is to carry out in-depth analysis, processing, storage and transmission of the digital video signal transmitted from the video acquisition module, and can also cooperate with the video differential algorithm in the ARM call DSP, encode and compress the parsed data, and save it on the hard disk [11]. The memory part consists of two parts, memory connected to the DDR2 controller and SRAM and NOR/NANDFlash connected to the EMIFA. DDR2 memory is used as the memory block of DM6446 processor. The operation of system code, image data transmission, etc. are all using DDR2.NANDFlash is a special software used to store boot programs and data, but also can store information such as file system.

d. Power Module

The power module is composed of five components, including wind generator, solar panel, power charge and discharge control circuit, current and voltage acquisition circuit, and heating circuit (Figure 3 is quoted in Appl.Sci.2019, 9(5), 892). In the charging process, if the battery voltage reaches the upper limit, then the protection circuit will stop charging the battery when the battery is charging, so as to avoid the battery explosion; In the discharge process, if the battery voltage drops to the lowest critical value, then the protection circuit will automatically terminate the discharge, thus avoiding the loss of the battery [12]. In addition, the power supply system also has the function of heating, in winter, if the outdoor temperature is lower than a set temperature, and the battery has enough power, the excess solar energy or wind will be heated for the entire system, thus ensuring the quality of the battery and the efficiency of discharge.

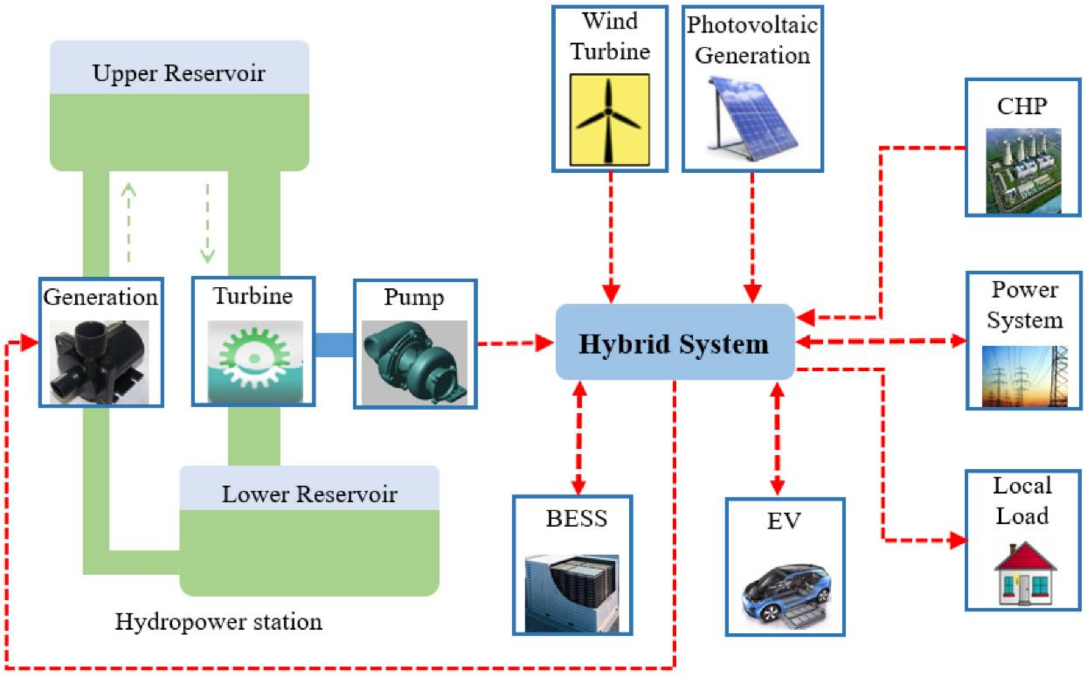


Fig.3 Structure block diagram of wind-solar complementary power supply system

The front-end device is placed on the transmission tower, and the power obtained by solar energy and ground wire induction is very limited. In the design of each component of the entire system, the power consumption of each component must be fully taken into account, only in this way, can ensure the stable work of the entire system [13]. Because there are many complicated calculations in image processing, we should pay special attention to its power consumption when designing graphics processor. Among them, in the digital signal processor (DSP), because the digital signal processor is dominant, it is necessary to strictly control its power when selecting the digital signal processor. In the design process, the first thing to consider is the energy consumption of the system, followed by the speed of calculation. TI's C6000 series DSP takes image processing as the core, using DSP core + ARM core, and these chips have relatively high energy consumption. In 2012, TI Corporation released a digital signal processor based on the TMS320C665x, which has a lower power consumption and a lower price. TI's C665x integrates three chips internally, and all pins are fully compatible for easy development and design [14]. The TMS320C6657, for example, uses two 1.25GHz DSP cores to reach 80 GMAC capacity and 40 GFLOP. In general, the power of the TMS320C6657 is only 3.5W, which is much lower than the DSP chips commonly found in Da Vinci processors, and is very suitable for external interference.

e. Programming of the extension

The system is divided into two parts: one is based on ARM chip system development, the other is based on DSP differential intelligent recognition technology. Among them, ARM mainly completes DSP subsystem, VPSS subsystem, peripheral machine, external memory and other hardware. Among them, the part of image pre-processing realizes the acquisition and processing of image information, and can directly input the existing image information from the front end to the front end. The system includes a CCD controller, a preview engine, a histogram module, and a focus/exposure/white balance module [15]. The video back end includes two main parts, in which the OSD engine can operate on two separate video Windows and two OSD Windows, and can also superimpose the second video window on the first video window, so as to achieve the effect of painting, OSD can superimpose the volume, icon equipotential map or picture on the video screen. Among them, the image compression part realizes the output of digital and analog signals. The decoder chip is transmitted to ARM, and ARM analyzes the captured images in real time through the differential intelligent identification algorithm built in DSP, and feeds back the analysis results to ARM, which transmits data to the background server through 5G module or optical fiber and other communication means [16]. It then syncs with the expert software's photo library and Web client and sends an alarm message to the set up worker's phone. The specific component interactions can be seen in Figure 4 (the image is referenced in Heterogeneous Information Fusion and Visualization for a Large-Scale Intelligent Video) Surveillance System). Figure 5 shows the software design flow of ARM when the monitoring branch selects 5G communication mode (the picture is quoted in Understand the tech).

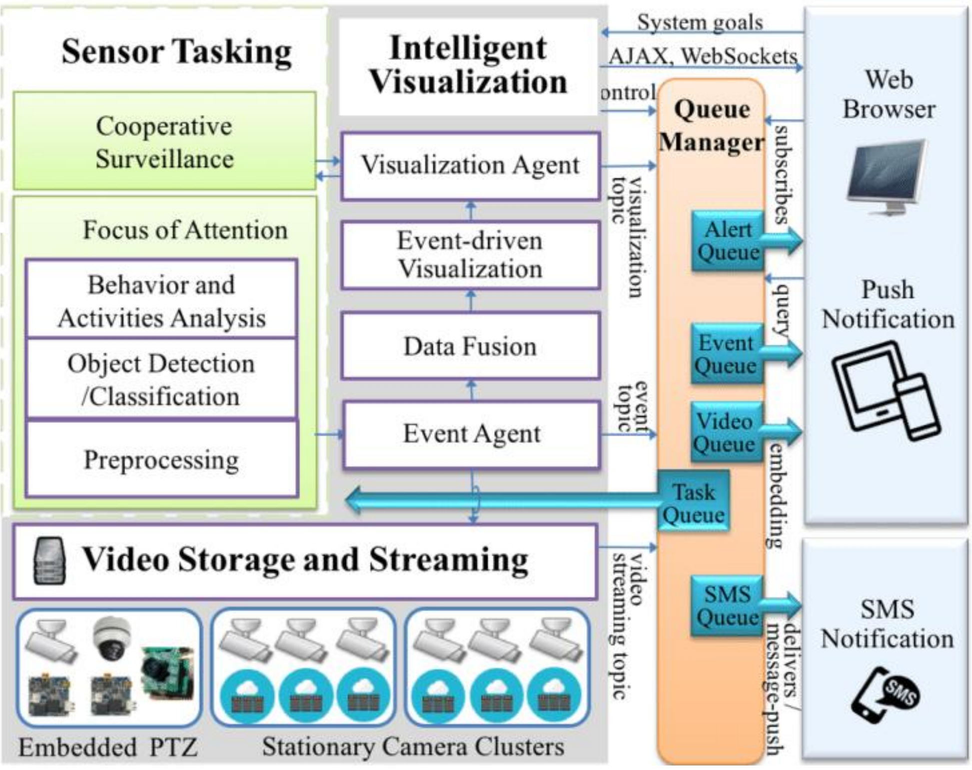


Fig.4 Interactive block diagram of the front-end modules of intelligent video surveillance

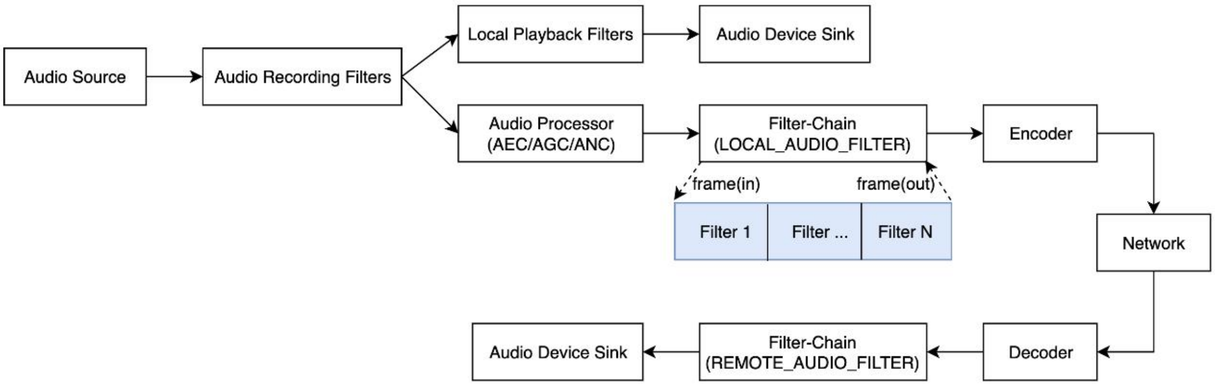


Fig.5 Program flow chart of video monitoring extension

C. Communication network planning

The communication network transmits the analytic data obtained from the forward monitoring extension to the background monitoring center [17]. According to the characteristics of the power system, the use of GPRS/CDMA/ 3G/cable /WIFI and other communication modes, for different use scenarios, these communication modes can be combined to achieve the purpose of data transmission.

a. GPRS/CDMA/5G communication mode

The monitoring device uses an existing wireless transfer module to transfer data over a public network or a virtual private network, the network architecture of which is shown in Figure 6 (image is referenced in Time Full Duplex Radios). This method is suitable for the field without optical cable, and the communication conditions such as GPRS/CDMA/ 3G are good.

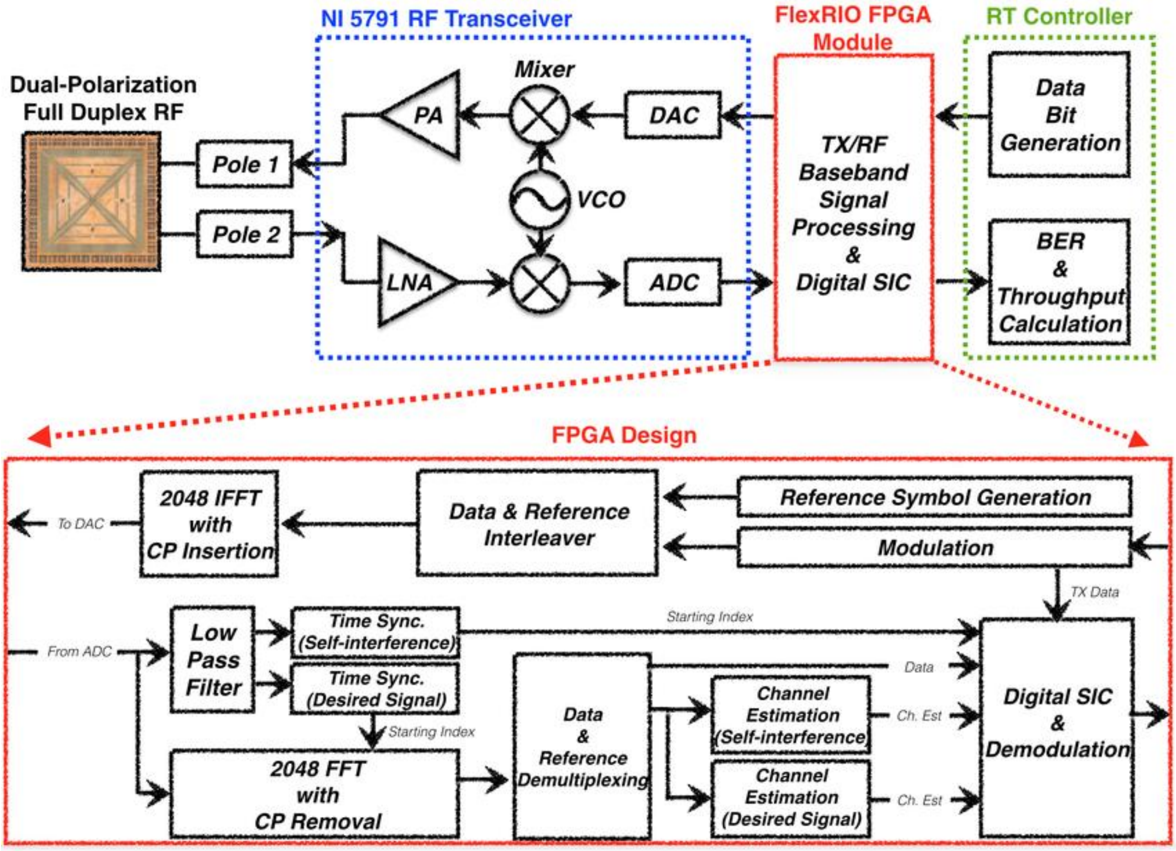


Fig.6 Schematic diagram of radio communication network architecture

b. Optical cable/Optical cable communication mode

The monitoring equipment uses optical fiber and optical cable to communicate, and is transmitted to the substation private network through the fiber channel switch, connector box and OPGW optical fiber, and finally reaches the substation communication system within the jurisdiction of the line [18]. Its network structure is shown in Figure 7 (the image is quoted in Collaborative stochastic expansion planning of cyber-physical system considering extreme scenarios). This method is generally used when the wireless communication conditions such as GPRS/CDMA/ 3G are not good, but there is a cable transfer box.

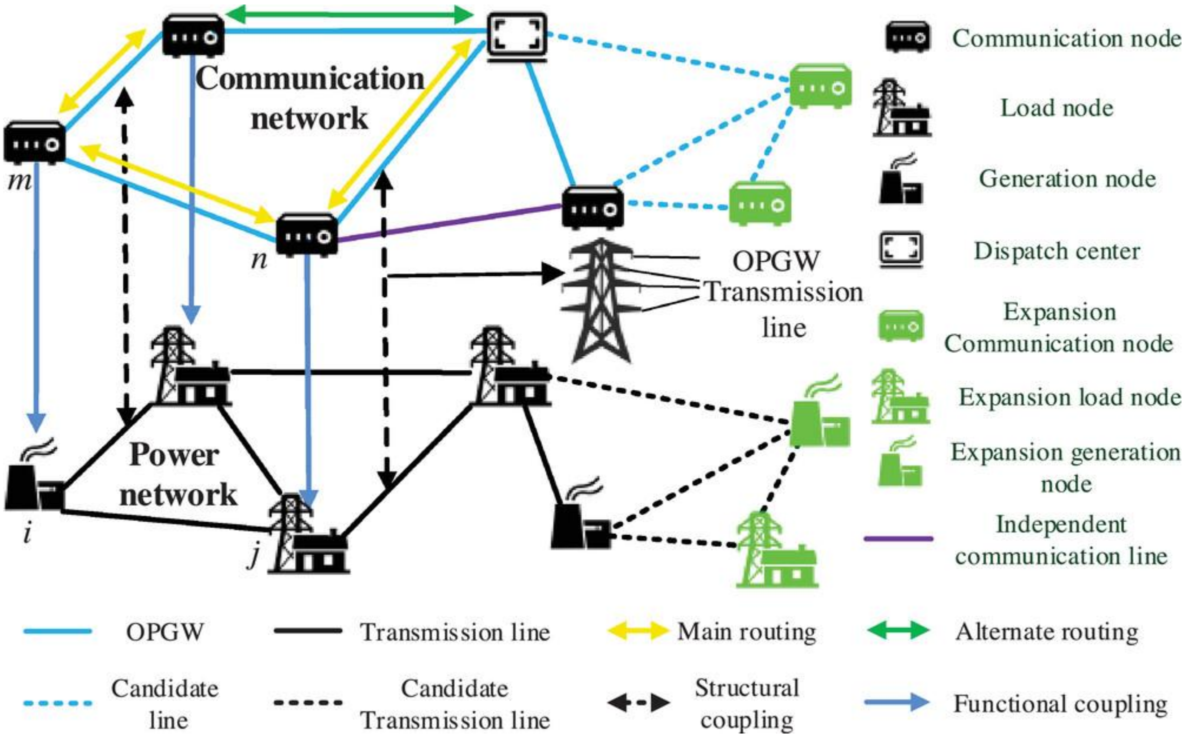


Fig.7 Optical fiber /OPGW communication network structure

c. Optical guide + Wireless communication mode

When there is no optical fiber connection box in the field, and GPRS/CDMA/ 3G communication conditions are poor, the monitoring branch will use wireless AP relay to transmit data to the device equipped with OPGW cable connection box, and then transmit it to the private network of the substation through the optical fiber switch, transfer box, OPGW cable, etc. Finally reach the substation communication system within the jurisdiction of the line. Its network structure is shown in Figure 8 (image cited in Metals 2023, 13(4), 697).

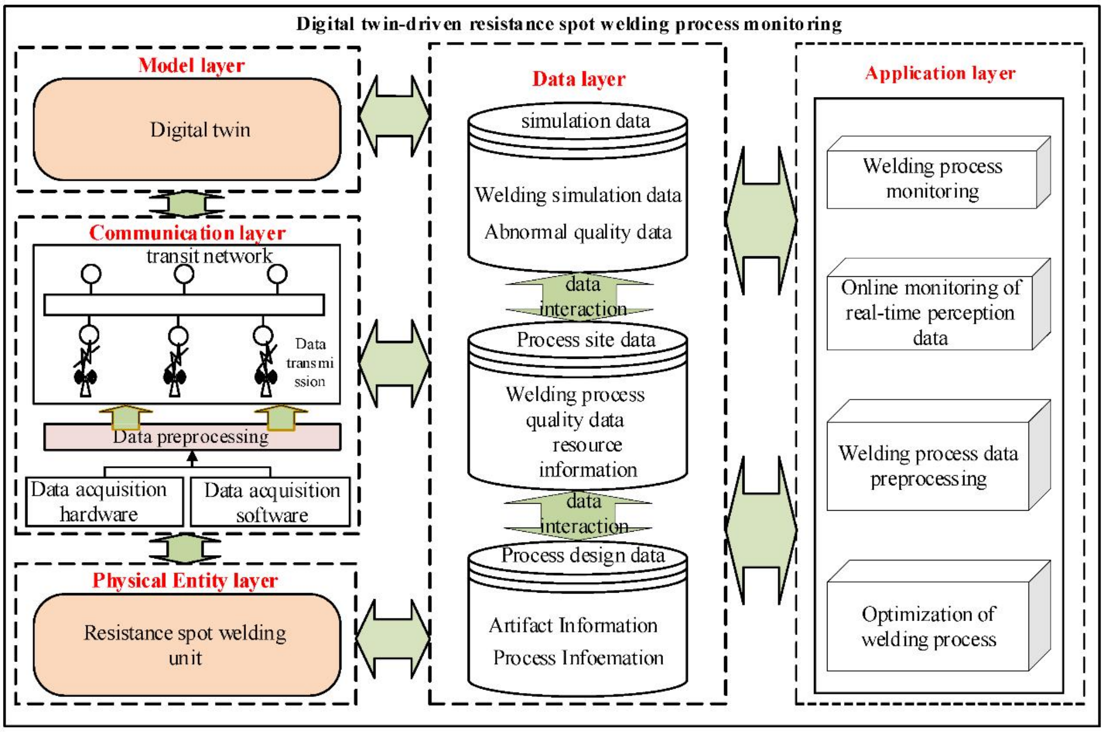


Fig.8 Schematic diagram of the field communication network structure

D. Background monitoring center expert software

The software mainly includes two aspects: power transmission and transmission network monitoring and protection technology (Figure 9). The expert analysis system configured in the back end receives a specific early warning signal generated by the front collection terminal, and sends the early warning signal to the handheld terminal, the web browsing client, and sends an early warning to the relevant staff.

a. PC client program development

The software interface and Web client of the expert analysis system are shown in Figure 9 (image cited in Water 2016, 8(5), 201). The system realizes the acquisition and processing of the acquired image, and the processing of it. Web browsing user interface, with video monitoring interface, can be real-time observation of the scene, and can see the previous alarm image and processing process.

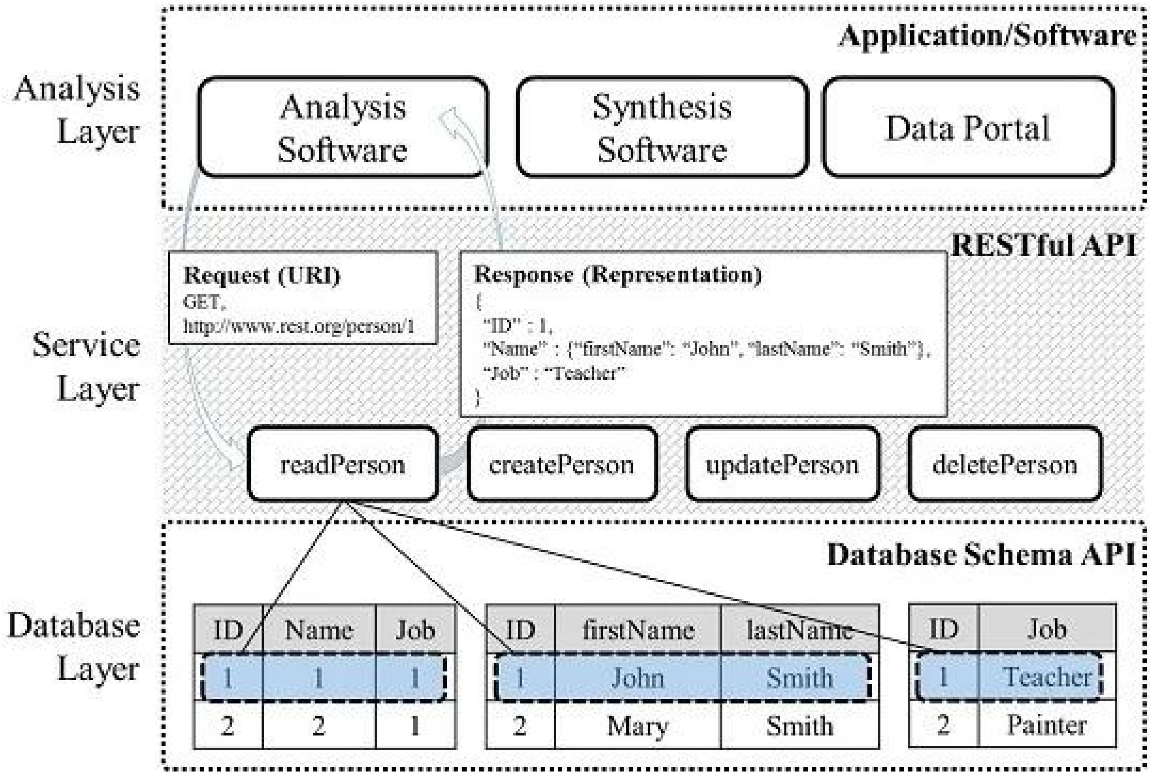


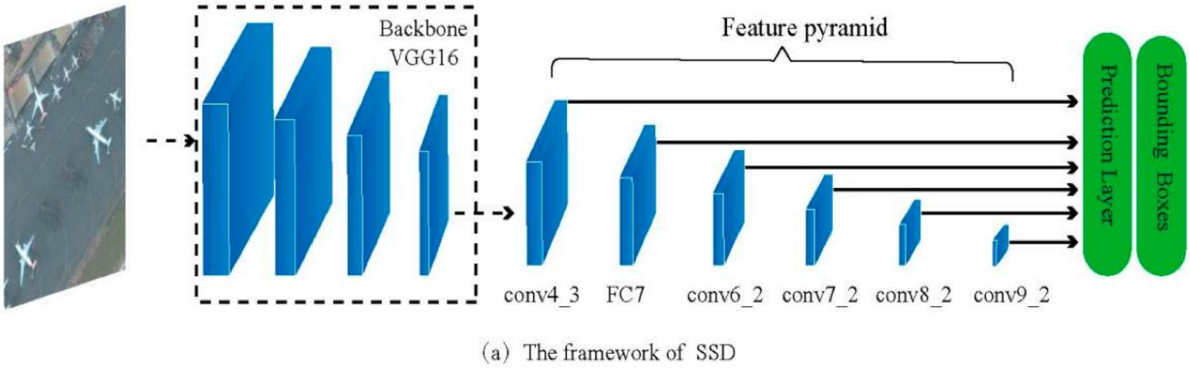
Fig.9 Software interface of Professor Analysis

b. Design of mobile client software

The basic function of the mobile phone client program is: when an alarm is issued for abnormal conditions in the monitoring area, the handheld terminal will pass the early warning image captured by the monitoring node, and send the image to the user through the MMS service, so that the user can make a corresponding response in time. In addition, the handheld terminal of the system also has the monitoring function to realize the real-time monitoring of the scene situation and alarm information through the mobile phone [19]. The system can monitor the suspected personnel, large engineering equipment and other moving objects within the monitoring range in real time. When a suspicious person is detected climbing in an area, the large machine operating in the offline monitoring range will issue a voice warning people not to stay in the safety zone, and will also form an alarm photo of the situation at the scene, and upload it to the network client and mobile terminal for users to view and view.

III. Detection method of weak motion in transmission line

YOLO algorithm was widely used before SSD algorithm was popularized. The algorithm first divides the image, then converts it into a regression object, and then performs the edge box judgment and classification possibility calculation on it. However, the YOLO method only describes the final feature layer, so the accuracy of the calculation results is poor, while the SSD method uses a multi-level feature map. The initial SSD scheme uses VGG-16 mode as the main work, replaces Conv_7 with Fc7, and adds four new dimensions: Conv_8,Conv_9,Conv_10, and Conv_11. SSDS use convolutional networks to extract massive images and generate six kinds of images of different sizes for detection. Advanced perceptual outfield values are larger and have richer semantics, which can be used for large-scale object detection. The original SSD network structure is shown in Figure 10 (image cited in Appl.Sci.2019, 9(20), 4276).



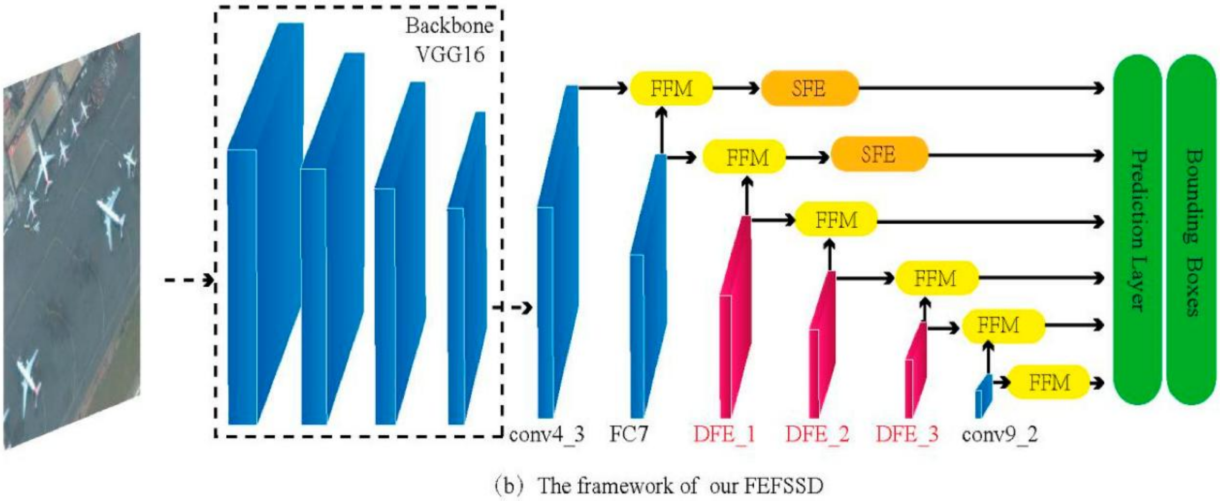


Fig.10 SSD algorithm structure diagram

The overall loss is calculated as follows:

$$S(u,z,s,h)=\frac{1}{M}(S_{conf}(u,z)+\eta S_{loc}(u,s,h)) \tag{1}$$

Where, M refers to the number of boxes matched to the default box, and η controls the weight ratio between the confidence loss and the position loss. The default value is 1.

$$S_{loc}(u,s,h)=\sum_{i\in Pos}^{M}\sum_{m\in(zx,zy,w,h)}u_{ij}^{k}smooth_{S1}(s_i^m-\hat{h}_j^m) \tag{2}$$

For confidence errors, a loss function is used, defined as follows:

$$S_{conf}=-\sum_{i\in Pos}^{M}u_{ij}^{n}\log(\hat{z}_j^n)-\sum_{i\in Meg}\log(\hat{z}_i^o) \tag{3}$$

An anchor-frame based target detection method based on Faster-RCNN is proposed. The regression idea of YOLO mode is introduced, which makes SSD method not only meet the requirement of fast detection, but also maintain high accuracy. This method makes full use of shallow network to detect tiny objects. Using deep neural networks to detect large objects greatly improves the detection efficiency [20]. Because the extracted feature map is incomplete, the semantic loss in the image is caused, and the detection performance is poor. The relationship between the extracted characteristic curve and the initial input characteristic curve under the three swelling rates is as follows: (4) and (5):

$$D_{pzl}(u_t)=ResNet_{pzl}(u_t;pzl) \tag{4}$$

$$Output_{concat}=Concat(u_1,D_1(u_1),D_4(u_1),D_7(u_1)) \tag{5}$$

In Formula 4, pzl is the expansion rate and u_t is the t feature diagram. If u_1 represents the first input feature map, then $u_t\in R^{H\times W\times C},H,W,C$ represents height, weight, and channel size, respectively [21]. The blocks are connected with the initial input value, the dimension of F in Equation 5 becomes G, and through this process, the characteristics of both input and scale context information can be had. Finally, the channels are merged by 1×1 convolution so that the number of channels is the same as the number of channels in the input feature map.

$$Output_{TFM} = Conv_{1\times1}(Outout_{concat}, C) \tag{6}$$

In Formula 6, $Conv_{1\times1}(\cdots)$ is a 1×1 convolution, and C represents the channel size [22]. The result is projected in the channel size and dimension $Output_{TFM} \in R^{H\times W\times C}$. After completing the TFM module, the dimensions of the feature map remain constant; however, only the contextual information on the scale is introduced into the feature map, enhancing the characteristic information for the detection of small targets along the power transmission lines.

IV. System inspection

The object identification and location are carried out. According to the extracted moving object, the contour line of the object can be obtained, and the easiest way to describe the contour is to use the outer length and width of the contour line. If only the external rectangle in the coordinate system is found, it is very simple, and only the maximum and minimum coordinates of the edge points of the object can be found out the transverse and longitudinal span of the object [23]. However, in practical applications, it is often necessary to first find the length of the target on the axis, and then find the side width perpendicular to it, and this external rectangle is the minimum external rectangle required. One way to estimate the mass error is to rotate a target equidistant at a 90 degree Angle and record an external rectangular parameter in its coordinate system each time. In general, the spindle can be obtained by solving the torque of the workpiece or by obtaining the optimal fitting curve of the workpiece. Through the analysis of the photos of pedestrians climbing the tower under an old tower, the people who are likely to climb the tower are identified. As the transmission line and tower in the power system are located outdoors, this project intends to use finite element method to analyze the target area, rather than global analysis, so as to reduce the complexity of calculation. A set of analysis pictures during field tests are shown in Figure 11.

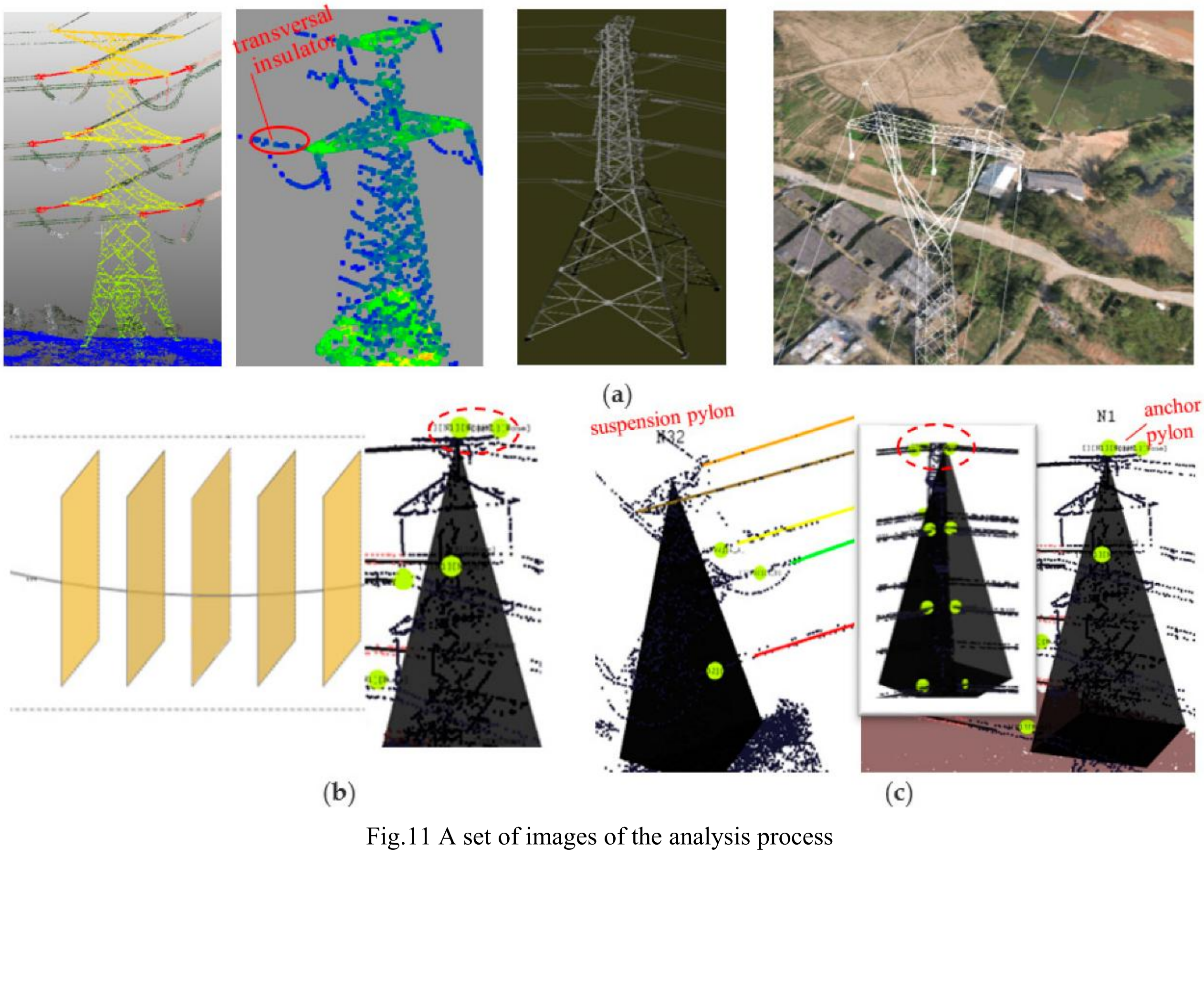


Fig.11 A set of images of the analysis process

V. CONCLUSION

The intelligent video monitoring device installed on the high voltage transmission line tower can collect the environment around the line, and carry out image processing and intelligent identification. And the detected data is transmitted to the background monitoring center and mobile phone through the communication network. In this way, the operator can better understand the actual situation in the production process, so as to formulate corresponding countermeasures. This method can not only reduce or prevent the loss caused by external force on the power line, but also greatly improve the working efficiency. This plays an important role in ensuring the safety and stability of the power system.

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