Wind Turbine Blade Defect Image Acquisition System

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Abstract. The detection of wind turbine blades in service is a difficult problem in wind power operation and maintenance. Wind farms in the quality assurance unit and daily inspection, regular detection of blade is with the aid of SLR camera, then the human recognition, low accuracy and low recognition efficiency. This paper puts forward a set wind turbine blade detection method based on artificial intelligence image recognition system. With the help of high definition camera array and image recognition software, a large number of image acquisition and rapid recognition processing are carried out for wind turbine blades in service, and finally the automatic detection of blade surface defects is realized. The feasibility and applicability of this method are verified through field detection, which can be promoted in the field of wind power.

1. Introduction
In recent years, the domestic wind power industry has developed rapidly. By the end of 2019, China's total installed wind power capacity has reached 210 million kw. At the same time, wind turbines are developing towards large, intelligent and efficient, and blade size is also increasing. The working environment of wind turbine is harsh, and the blade is prone to surface defects such as crack, paint peeling and wear [1]. These blade surface defects, if not repaired in time, may cause serious accidents. There are two main factors that the blade surface defects lead to serious accidents in wind turbines, one is that climate environment in the blade working condition leads to accumulation of surface defects, The second is due to blade of wind turbine connected to the grid workload increase. The consequences are serious if some accident happens. In order to avoid these problems, wind farms will non-scheduled conduct network outage maintenance for wind turbines in grid-connected power generation. The traditional way of testing has many disadvantages, such as the low efficiency, the big blind area, high risk and subjecting to the subjective influence of the human brain, and so on, and will seriously affect the wind farm output and income. Therefore, it is very necessary to conduct on-line health monitoring and defect identification research on blades.

Various sensor detection technologies, such as acoustic emission sensor, vibration sensor, optical fiber sensor and infrared thermal imaging technology, have been applied to the defect detection research of wind turbine blades[2]. Blanch M J et al. applied acoustic emission technology to the blade detection of the wind turbine in service to monitor the failure process of the blade[3]. This technique is one of the common methods used in non-destructive monitoring of wind turbine blades, but it is difficult to separate the stress waves from the clutter due to the interference of electromechanical noise. Vibration detection technology uses vibration sensors installed on the blade surface to monitor the changes of blade characteristics in real time in order to carry on wind turbine blade fault on-line diagnosis[4]. Bin H et al. proposed to establish the damage index and damage form file to achieve the fan blade structure health monitoring[5]. This method has low cost and high sensitivity, so is widely used. Optical fiber sensing detection technology is to diagnose the health status of wind turbine blades through the changes of temperature and strain detected by optical fiber
sensors [6]. The cost of this method is high, so reducing the cost is the key problem of this method. Infrared thermal imaging detection technology has become a common method for nondestructive detection of composite materials due to its good timeliness and accuracy. Dahao Y et al. detected near-surface defects of blades by means of flash light pulse infrared thermal wave [7]. The method is mature for static wind turbine blade detection. However, because the wind turbine in operation is greatly disturbed by the operating environment, the method is difficult to detect the blades in service.

Machine vision detection is a new technology developed in recent years. This method has been paid more and more attention by researchers at home and abroad due to its advantages of fast measuring speed, non-contact and full-field measurement. In this paper, a large number of blade images are collected by using the developed high definition camera array and image processor. Finally, the surface defects of wind turbine blades are detected efficiently and quickly with the help of artificial intelligence image recognition software.

2. Wind Turbine Blade Defect Detection System

The wind turbine blade defect detection system built in this paper consists of two parts: image acquisition system and image recognition system. The image acquisition system includes high definition camera array and image processing server. Main technical parameters of the system are shown in table 1:

| Table 1. Main technical parameters. |
|-------------------------------------|
| **Index name** | **Index parameters** | **Note** |
| Hd Imaging array | x1 | Used to shoot figure |
| Image processing server | x1 | Used for image storage, defect identification, etc |
| Artificial intelligence recognition system | x1 | Used for identification and classification of blade surface defects |
| Holder, tripod | x1 | Supporting camera array |
| Communication cables | x1 | Data transfer cable from camera array to PC |
| The adapter (220V AC->12V DC 200W The adapter) | x1 | Power supply for hd imaging arrays (integrated inside the array) |
| Shooting distance | 65~80m | The distance from the imaging array to the blade |
| Hd array data output port | Billion Ethernet cable | The transmission distance can reach 100m |
| Monitor camera resolution | 12Mp | Color camera |
| Hd array resolution | 72Mp | Black and white |
| Shooting range @65m | 74m*10m | 65m Shooting range |
| Shooting range @80m | 99m*13m | 80m Shooting range |
| Defect identification resolution | 5mm | When shooting the crack, the smallest crack that can be identified is 5mm |

3. Camera Array and Image Processing System

The image acquisition system in this paper includes high definition camera array and image processor. They are shown in figure 1 and figure 2.
In this paper, the connection between image processor and camera array in the blade defect image acquisition system is as follows:

- The high definition camera array consists of two sets of cameras, one for positioning the blade range and the other for identifying defects.
- The image processor and camera array are connected via a communication cable.
- The camera array is mounted on the cradle head to adjust the shooting angle.
- The computer monitor of the image processor is connected to the camera array via a network cable.
- Considering the actual situation in the field, the camera array can be mounted directly under the blade or under the tower barrel, with a shooting distance of 65~75m.

3.1. Camera Array Imaging Principle

The principle of optical lens imaging is shown in figure 3. Among them, $f'$——Focal length, $\eta$ —— Object field of view, $\eta'$——Image field of view, $l$——Object distance, $l'$——Image distance.

![Figure 3. Optical lens imaging schematic.](image)

The imaging formula of the optical system [8] is formula 1:

$$\frac{1}{f'} - \frac{1}{l} = \frac{1}{\eta'}, \quad \frac{\eta}{l} = \frac{\eta'}{l}$$  \hspace{1cm} (1)

The camera array built in this paper consists of 7 lenses. The camera array built in this paper consists of 7 lenses.

Take the central lens of the camera array, for example. The focal length of the lens $f'$ used in the device is 85mm, the working distance $l$ is 73m, the image field of view $\eta'$ is 13.13mm. According to the above formula, it can be calculated that the object field of view $\eta$ is 11.28m. Each lens is arranged at an Angle of 7.5°, and the total field of view of the 7 lenses after splicing and fusion is 74.3m.

The high definition camera array for blade image acquisition developed in this paper is shown in Figure 4. Now take the height of the tower barrel of the wind turbine as an example to illustrate the shooting principle of the camera array, as shown in figure 5. The camera array is generally located...
about 5.5m away from the tower barrel of the wind turbine, 1.26m away from the ground, and the included Angle with the ground is 71.65°. At this point, the included Angle between the blade and the tower barrel is 71.65°. The vertical distance between the camera array and the blade is 73m, and the total field of view is 74.3m. The field of view of a single camera is 12.79m (two), 11.69m (two), 11.09m (two) and 10.9m, respectively. The fusion areas between cameras are 1.24m, 1.27m and 1.37m.

Figure 4. Camera array configuration

Figure 5. The principle of camera array

3.2. Image Processing System

In this system, 7 gigabit cameras in the camera array are simultaneously used to image acquisition, and can adjust the gain and exposure of the image. The system can save the images from the camera in real time and detect them.

When shooting, the wind turbine unit needs to stop, and the blade is rotated to an angle of 72±10° from the tower barrel. The surface of the blade faces toward the ground. The camera array tripod holds the camera device above 1.3m in height. and the camera array is within 5.5m of the tower barrel. Adjust the Angle of the tripod, so that the camera in the middle is perpendicular to the blade surface. At the same time, all the blades should appear in the field of view of 7 cameras.

Pay attention to the direction of the sun in the shooting, and avoid direct sunlight on the camera. The working process of the system is shown in figure 6.

Figure 6. Working process of the system.
The image output page in the image processing software is shown in figure 7. The pictures are saved according to the wind field-unit/blade serial number/front and back. The software needs to be used with 7 gigabit cameras and binds the MAC addresses of 7 cameras and 7 network cards. When the number of connected cameras is less than 7, the serial number of unconnected cameras will be detected as "Unknow Device". At this point, data can be collected from other cameras, but there will be no image transmission in the unconnected camera display window.

The image acquisition system uses an high definition camera array to take multi-angle pictures of the stopped wind turbine blades and store them in the image processor. The stored images are compared with the defect database in the system through the artificial intelligence identification software, and finally the automatic detection of blade defects is realized and the detection report is issued.

![Image Output Interface](image.png)

**Figure 7.** Image output interface.

4. Analysis of field test results

To verify the applicability of the blade image acquisition system developed in this paper, members of the research group conducted spot sampling tests of blade surface defects in a wind farm in Zhejiang province in August 2019. The wind farm was put into operation in October 2018. In the wind farm a single fan capacity is 2.2MW, blades length is 58m and a tower barrel height is 90m. According to the inspection records of the wind farm, 3 fans with more problems were selected for inspection. The image collection time of each fan was about 20 minutes, and the collected images were as many as 200. Finally, the artificial intelligence image recognition software was used to identify the defects in the pictures, and the types and parts of the detected defects were checked one by one manually. The detection results were shown in Table 1.

By comparison, it can be seen that there is a certain difference between the number of defects detected in the detection system and the number of defects recorded in the wind farm patrol inspection. Influenced by the shooting Angle and resolution of conventional detection methods, more defects can be identified by the detection method in this paper. After rechecking, it was found that the accuracy of crack detection was close to 100%, while the accuracy of corrosion and paint peeling was relatively low, which was mainly related to the lack of defect samples in the early training of image recognition software. With the continuous enrichment of the defect fault library of artificial intelligence recognition software, the detection accuracy would be improved continuously. The field test fully verified the feasibility of the blades image acquisition system developed in this paper.
### Table 2. Detection results of blade surface defect types.

| Defects types          | Check out the number | Inspection records number | Recheck number | Accuracy /% |
|------------------------|----------------------|---------------------------|----------------|-------------|
| Surface cracks         | 9                    | 8                         | 9              | 100         |
| Paint peeling off      | 10                   | 9                         | 8              | 80.0        |
| Surface corrosions     | 7                    | 8                         | 9              | 77.7        |

#### 5. Conclusion

This paper uses the developed wind turbine blade image acquisition system to detect blade defects in wind farms that have been put into operation. In the detection process, 3 blades which were found defects in the patrol inspection were selected. The camera array and image processor are used for image acquisition. Then the image recognition software is used to automatically recognize a large number of collected images. The accuracy of the identification results depends on the existing defect database in the identification system. Finally, the results are compared with those obtained by the patrol inspection method. The feasibility and applicability of the image acquisition system combining camera array and image processor developed in this paper in wind turbine blade defect detection are verified. It has certain promotion value in the field of wind power.

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