Development of Automatic Detection System for Faults in Transmission Lines

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ABSTRACT

Electricity is a resource that we cannot do without to carry out our cultured life. The electric power companies which supply that electricity are building new power plants and transmission facilities in order to cope with the year-by-year increasing demand for electricity. Also, power failure due to accidents directly affects our lives. Therefore, power companies are putting a lot of effort into the maintenance management of power facilities.

Up to now, the inspection of overhead transmission lines was carried out visually by people using binoculars, either walking, or in helicopters. Overhead transmission lines are set up over long distances and wide areas, and are directly affected by the environment, so the inspection has been a time-consuming task, and many faults have been overlooked.

Recently, a method of recording the inspections by video camera from helicopters has been used. However, the detection of faults is done by people checking the video recordings at slow speed, so this takes a great deal of time and manpower.

This paper introduces an automatic detection system in which faults in the power lines are detected automatically by processing the image taken by a HDTV (high definition television) camera. This system has made the detection work more efficient and with increased precision.

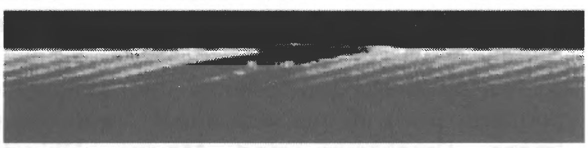

Figure 1. example of fault (broken strands)

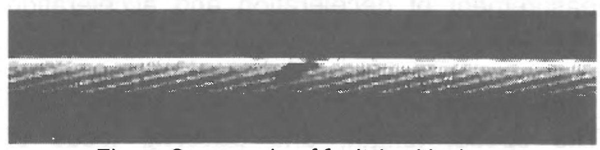

Figure 2. example of fault (melting)

1. Surveying of Transmission Lines

1.1 Purpose of Surveying

Over many years, due to natural environmental factors such as snowstorms, lightning and briny air, power lines develop broken strands (Figure 1), melting (Figure 2), kinking and corrosion, etc. If these are left unattended, they become worse, and can even cause a serious accident such as grounding or shorting. The purpose of surveying is to find these faults at an early stage, and prevent accidents from occurring.

1.2 Overhead Transmission Lines

Overhead transmission lines are constructed as shown in Figure 3. Power lines are made up of the power lines required to send the necessary electric power, and ground wires to protect the power lines from lightning. Ordinary 2-line steel towers have 3 levels of tower arms (top, middle and bottom), at both ends of which 2 sets of 3-layer, 3-wire type power lines are hung by insulators. The ground wires, at the top of the steel tower, have a steel wire in the center with twisted aluminum wires around, as shown in Figure 4, with the steel wire making up for the lack of tension-resistance of the aluminum wires. The diameter of ground wires varies according to the voltage being carried, as shown in Table 1.

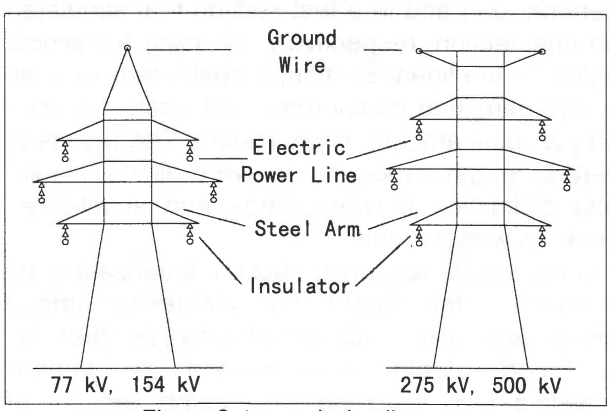

Figure 3. transmission lines tower

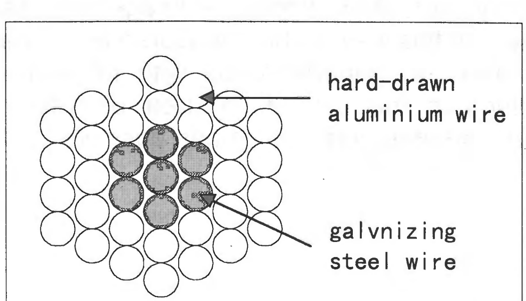

Figure 4. cross section of steel feeling aluminium wire

Power line voltage (kV)	Ground wire diameter (mm)
77	7.8~9.6
154	9.6~17.5
275, 500	17.5

Table 1. Power line voltage and Ground wire diameter

1.3 Method of Surveying

Up to now, there have been problems such as difficulty in getting into places such as mountainous areas, forests or where the lines are crossing straits, or where visibility is restricted by trees or buildings. Also, melting caused by lightning often happens at the top of the power lines, so it is difficult to see from the ground.

On the other hand, when surveying is done by helicopter, if the weather conditions are good it can be done at slow speed along the power lines, and is extremely effective because it is not affected by the geographic conditions. In recent years, the surveying of power lines has been conducted by a method in which a television camera and a VTR are carried in helicopters, and by using a joystick, a cameraman has filmed the transmission lines. After returning, by looking at the slow replay on a monitor, defects can be found visually. However, the problem with filming from a helicopter and checking the film later is that it has to be done by human eyes, and this puts a heavy burden on the people, and takes an extremely long time to find any defects.

Our company has developed an Auto-sighting Video System (see Figure 5) equipped with a HDTV camera and VTR, a laser scanner and PC control unit into helicopters. This system can follow and film power lines automatically, and be able to reduce the work of the cameraman and increase the flight speed and the safety of the flight (Inoue, 1997). Furthermore, we have developed an Automatic Transmission Line Faulty Detection System, which automatically detects faults in the power lines from the recorded videos.

2. Automatic Transmission Line Faulty Detection System

2.1 System Construction

The construction of the system is shown in Figure 6. The system is made up of an HDTV-VTR to play back the recorded video, a frame-buffer to digitally store the played back images, and an EWS (engineering workstation) to control the VTR and analyze the images.

The HDTV-VTR controls the play back and stopping of the video from signals sent to it from the computer. The played back images by this control are fed into the frame-buffer at suitable intervals. The images memorized by the frame-buffer are then fed into the EWS and analyzed.

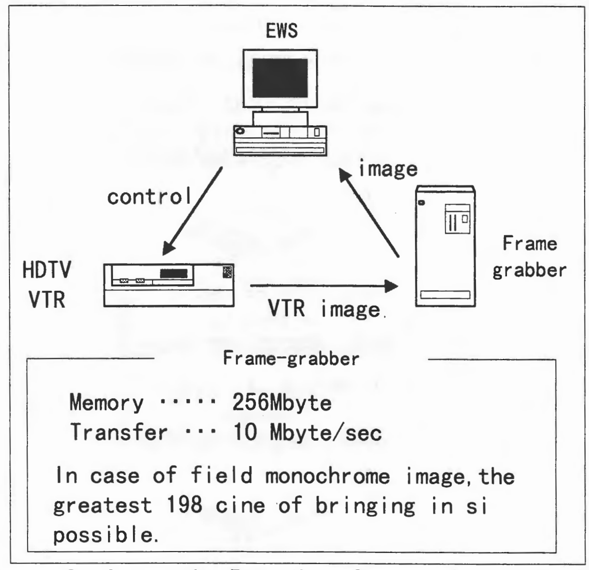

Figure 6. Automatic Detection System for Faults in Transmission Lines

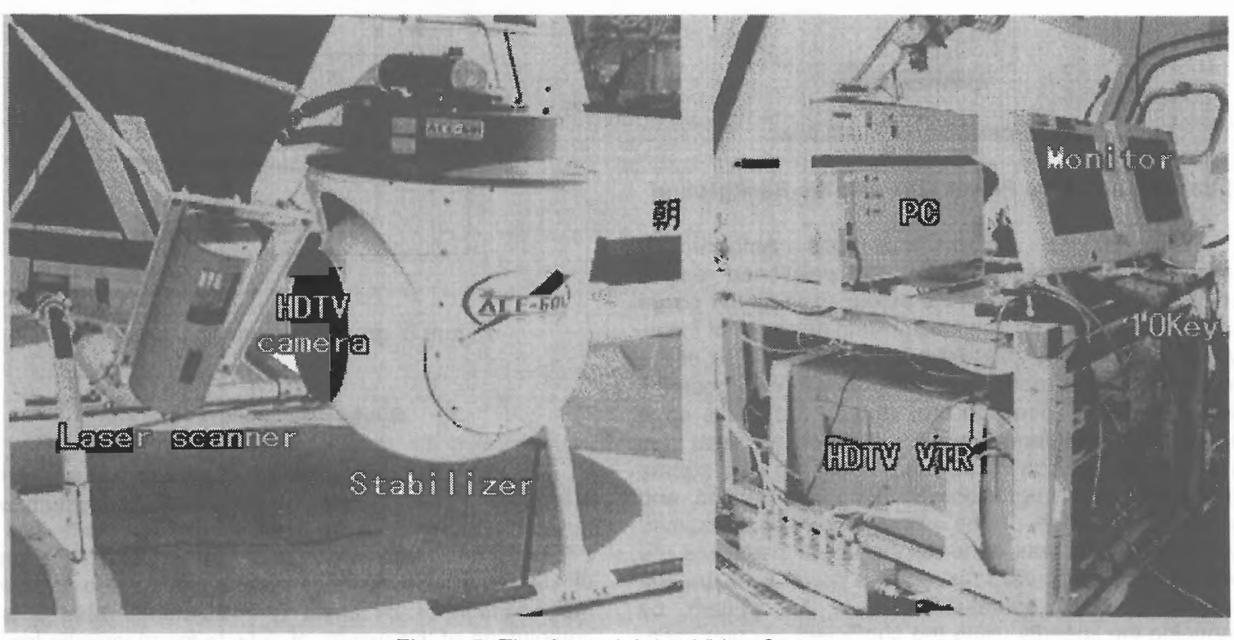

Figure 5. The Auto-sighting Video System

2.2 Analytical Method

The flow of the detection of faults in the power lines is shown in Figure 7. To increase the accuracy of finding faults, the following steps are necessary: (1) separate the power line and the background, and find the position of the outer insulation of the power line, (2) detect faults in density of the inside using that position of the outer insulation as the basis, (3) detect faults in shape of the power line.

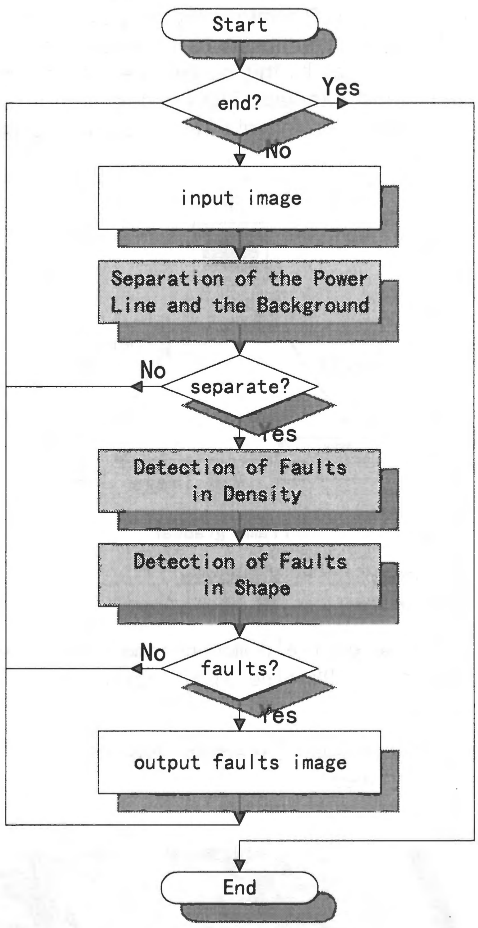

Figure 7. detection of faults flow

(1) Separation of the Power Line and the Background

The images taken with the Auto-tracking Transmission Line Video System are positioned roughly horizontally in the middle of the screen, and as the power lines are put into focus, the background goes out of focus. By using this feature, the detection of the position of the power lines was done by using edge enhancement method in the `y` direction only (Figure 8-a). This edge enhancement was done in every set search step, and from the power line position in each step, using the least square method, the linear regression equation was derived, and the outer insulation of the power line was presumed (Figure 8-b). This was done for the upper parts and the lower parts of the power lines, and the power lines and the background were separated. Also, in this system, by examining the linearity using the coefficient of correlation, it is possible to judge whether or not the images were taken without any problems (separation is possible), and wrongly detected faults can be avoided beforehand.

(2) Detection of Faults in Density

Faulty places with corrosion or melting are shown up on the screen as areas with different colors. By detecting these places by faults in density alone, wrong detections may be made due to twisting of the power lines. For this reason, in this system, the power lines were smoothed out beforehand, thereby doing away with any influence of twisting of the power lines. Then, places with faults were found from changes in density in the entire part of the power lines, with the threshold being set from the standard deviation. Therefore, in this system, places with fault density can be detected, even with different images due to different video recording conditions.

(3) Detection of Faults in Shape

Faulty places with broken-strand can be read as a part protruding out into the background from the outer insulation. The detection of this part was handled on the screen by using edge enhancement method, as described above. The detection of faults in shape was done by getting the standard deviation from the results of edge enhancement of all the steps for the outside area of the power line outer insulation and setting a threshold. From this, as in the case of detecting places with fault density, even with different images due to different video recording conditions, good detection can be undertaken.

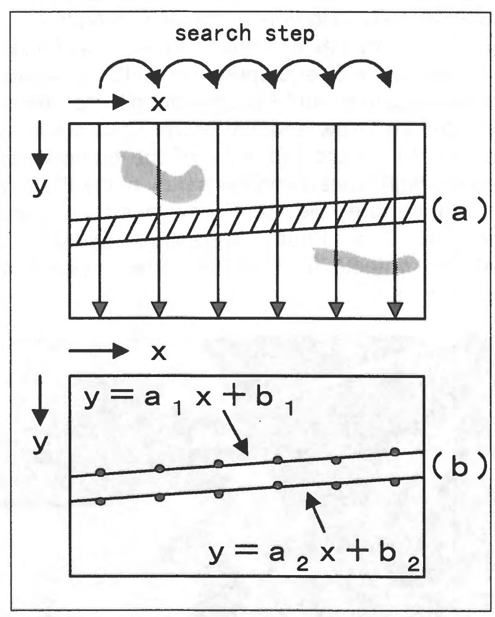

Figure 8. ground wire detection method

3. System Suitability Results

Using data from a survey of ground wires taken in March, 1997, the detection accuracy of this system was tested. As shown in Table 2, the survey was conducted on 275kV ground wires (diameter of 17.5mm) at a flight speed of 15km/h from a distance of 25m, at a video recording magnification of 24 times (f = 204mm). Table 3 is a comparison of the results of defects found visually from a slow speed playback of 3 spans (about 1km) of the survey area, with the automatically detected results using this system. Melting, kinking, and corrosion could be differentiated in the visual survey, while automatically these were all detected as faults in density. The ratio of detection in Table 3 is the ratio of places detected automatically in comparison to those detected visually.

The results of this verification test show that the results using automatic detection system were about twice as many as with visual detection, and there were no misses in detection. Among the places that were detected automatically but not visually, the places with fault shape were places where the sun was shining on the top of the power lines, especially the bright places, and the places with fault density were places where the power lines were twisted.

Recording Date	1997/03/27
Power Line Voltage	275 kV
Ground Wire Diameter	17.5 mm
Camera Magnification	× 24
Distance to Ground Wire	25 m
Velocity	15 km/h

Table 2. verification data

4. Conclusion

From the data used here, automatic detection using this system did not have any misses in detection, and furthermore the time spent processing compared to visual detection was about half, so the effectiveness of this power lines survey was confirmed.

5. Subject for Further Consideration

Because the filming of the power lines can be affected by the weather conditions, one cannot expect the filming to be done under the same. Especially, the position of the sun in relation to the power lines has a big the influence. From the test results, we can see that even places with no faults can be detected as fault. From now on, more tests need to be undertaken, to consider a method of detecting fault places without being affected by the filming conditions.

6. References

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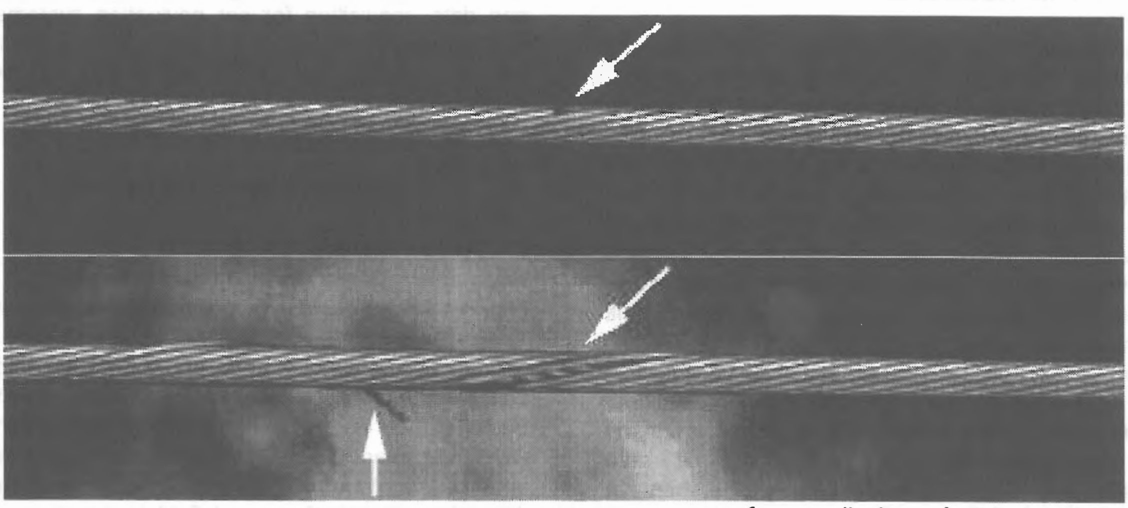
	detection result by slow speed playback	detection result by this system	detection rate (%)
broken strands	2	5	100
melting	3		100
kinking	0	8	100
corrosion	1		100
processing time (minute)	40	24	

Table 3. verification result



arrow of perpendicular fault in density
arrow of diagonal fault in shape

Figure 9. detection example