Study Committee B2

Overhead Lines

10630_2022

Deterioration diagnosis-imaging technology and deterioration countermeasure technology for overhead transmission line

Kensei YAMAMOTO, Tomoaki OSONO, Hiroyuki MIYOSHI, Tomoaki KAWAMURA, Motoyuki YAMAZAKI, Tomonori SHIRAISHI

TEPCO Power Grid, Inc. (JAPAN)

1. INTRODUCTION

- Our company owns around 43,000 steel towers and around 15,000 km of transmission lines.
- Since equipment near the sea is prone to rapid corrosion, deterioration due to rusting among other issues has become a serious problem.
- Although our equipment is regularly inspected to determine its state from early stage, securing the time and manpower required for such inspections has become problematic.

This poster shows countermeasures to resolve these issues.

- **Image deterioration diagnosis technology.**
- **Deterioration countermeasure technology.**

2. DEVELOPMENT OF A CONDUCTOR DIAGNOSIS-IMAGING SYSTEM USING HELICOPTER VTR and AI

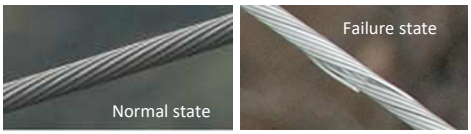

Fig.1 Normal and failure states of conductor

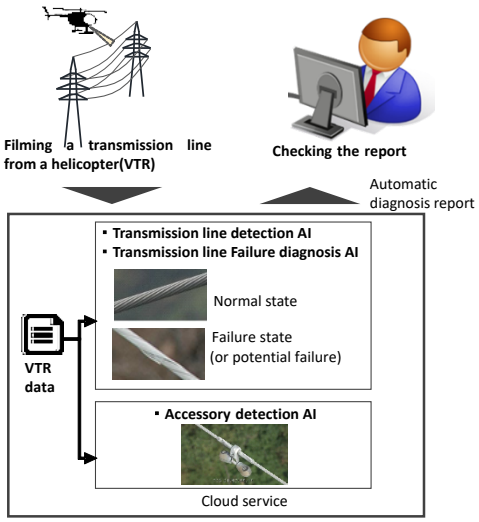

Fig.2 Overview of conductor diagnosis-imaging system

- To streamline VTR inspection by helicopter, which is carried out when inspecting conductor, we have developed a conductor diagnosis-imaging system.
- AI was constructed using deep learning, which is one of machine learning.

3. DEVELOPMENT OF STEEL TOWER DETERIORATION DIAGNOSTIC METHOD USING DRONES AND AI

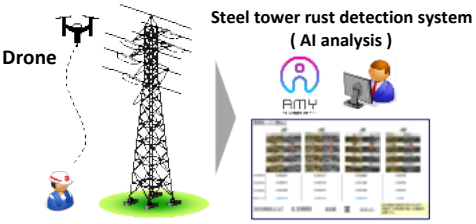

Fig.3 Steel tower deterioration diagnosis method using drones and AI

- To streamline efforts for check the level of deterioration of steel towers, we have established a diagnostic method using drones and AI.
- Utilizing commercially available drones, we have constructed AI using the same deep learning as for conductor inspection.

4. DEVELOPMENT OF TOWER MEMBER REPAIR METHOD USING CARBON FIBER (VARTM METHOD)

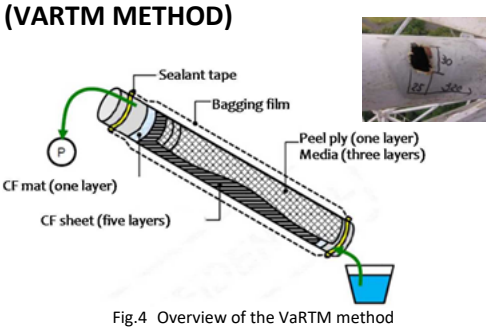

Fig.4 Overview of the VaRTM method

- To repair steel tower members which cannot be easily replaced promptly or economically, we have developed a repair method using carbon fiber.
- This exploits scope to mold high-quality CFRP repair materials used for aircraft and wind turbine blades locally to prepare repair materials in various shapes.

5. CONCLUSION

- In future, we plan to study the feasibility of further expanding the applicable scope of AI (conductor accessories, insulators, conductor fittings) and developing construction methods that allow repairs to be done more economically and promptly.

Study Committee B2
Overhead Lines
10630_2022

Deterioration diagnosis-imaging technology and deterioration countermeasure technology for overhead transmission line continued

2. DEVELOPMENT OF A CONDUCTOR DIAGNOSIS-IMAGING SYSTEM USING HELICOPTER VTR and AI

Development of conductor diagnosis-imaging system

- Helicopter VTR inspection involves a worker checking and inspecting the VTR via slow-motion playback at 1/10 normal speed, which normally takes around 1,330 hours a year.
- We developed a conductor diagnosis-imaging system.
- Helicopter VTR footage is uploaded to this system, diagnosed by AI and a report is then automatically issued on parts deemed to have failed.

Development AI model

- The conductor detection AI was trained and constructed based on U-Net.
- Conductor failure diagnosis AI was trained and constructed by performing transfer learning based on the general-purpose image recognition model VGG16.
- For conductor failure data, 594 cases were extracted from VTRs. 471 of such cases were used for an AI learning model and 123 cases were used for verification.
- As normal images, 133,000 normal parts were randomly extracted from filmed VTRs and then used for an AI learning
- Fig.5 shows the procedure of the conductor failure diagnosis.

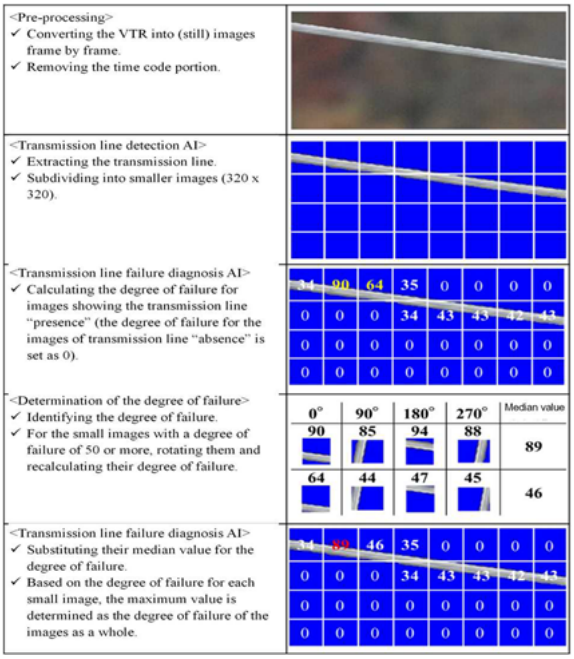

Fig.5 The procedure of the conductor failure diagnosis

Judgment rate

The indicators of the judgment rate were categorized as the non-detection and false detection rates (Tab.1).

- The changes in the non-detection and false detection rates with respect to the degree of failure in 123 cases for verification are shown in Fig.6.
- The threshold value to determine the degree of failure was 62 or less when the non-detection rate was set to 5% or less
- In this case, the falsedetection rate was 6%

Tab. 1 Items to judge the conductor failure diagnosis

		Predict	
		Failure	Normal
Actual measurement	Failure	TP (True Positive)	FN (False Negative)
	Normal	FP (False Positive)	TN (True Negative)

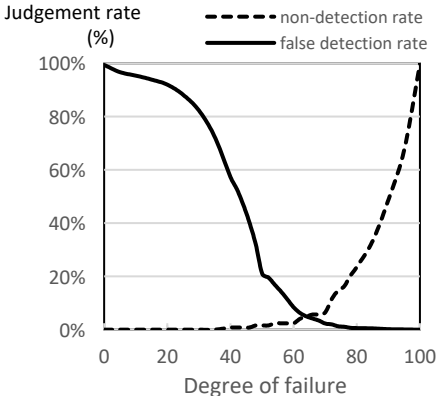

Fig.6 Judgment result of the conductor failure diagnosis

Study Committee B2

Overhead Lines

10630_2022

Deterioration diagnosis-imaging technology and deterioration countermeasure technology for overhead transmission line continued

3. DEVELOPMENT OF STEEL TOWER DETERIORATION DIAGNOSTIC METHOD USING DRONES AND AI

Traditional steel tower deterioration diagnosis

We carry out work to check the deterioration of all steel towers.

- Multiple workers climbing up to the towers and visually assessing the deterioration.
- The evaluation of the deteriorated state was left to the judgment of the worker.

Development AI model

We established a new diagnostic method by using AI and drone to replace the work involved in checking.

- This new diagnostic method involves filming steel towers using commercially available drones, then using AI to quantitatively evaluate the deterioration from the footage(Fig.4).
- This AI can detect deteriorated (rusted) portions of a steel tower from images, in pixel (px) units. Any rust detected in pixel units from the image is color-coded and visualized in three stages according to the degree of rusting.
- This AI includes a function allowing steel towers to be determined from imagery irrespective of the background.

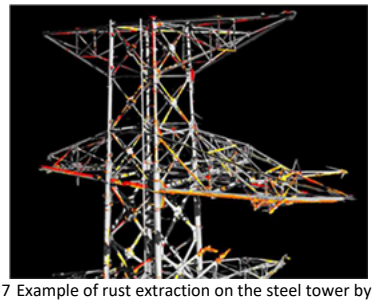

Fig.7 Example of rust extraction on the steel tower by AI

Accuracy of AI

- It has been confirmed that the accuracy of this AI involves a recall rate of 97% or more and precision of 91% or more.
- Although around 1,490 hours a year have been required for such work to date, we predict scope to reduce such inspection time to 315 hours a year, which represents an efficiency improvement of about 80%.

Tab.2 Accuracy of AI

Recall rate (probability of finding rust without missing it)	97.66%
Conformity rate (probability of the existence of actual rust in target points where existence is predicted)	91.91%

4. DEVELOPMENT OF TOWER MEMBER REPAIR METHOD USING CARBON FIBER (VARTM METHOD)

Repairing method using carbon fiber

Repairing method using carbon fiber-reinforced plastic (CFRP) has been adopted for concrete structures since the 1990s, with many current examples.

- We examined the applicability of a repair method applying VaRTM (Vacuum-assisted Resin Transfer Molding) to form high-quality CFRP on site.
- A carbon fiber-reinforced plastic is formed by enclosing a reinforcing fiber film on the outside of a steel pipe subject to pitting, then injecting a liquid resin via vacuum suction.

Examination toward application

With the application of the VaRTM method in mind, we organized and examined.

- Examination of the repairing effect
  - ✓ We conducted test to determine tensile proof strength and compressive proof strength.
- Examination of the applicable scope.
- Examination of construction method.

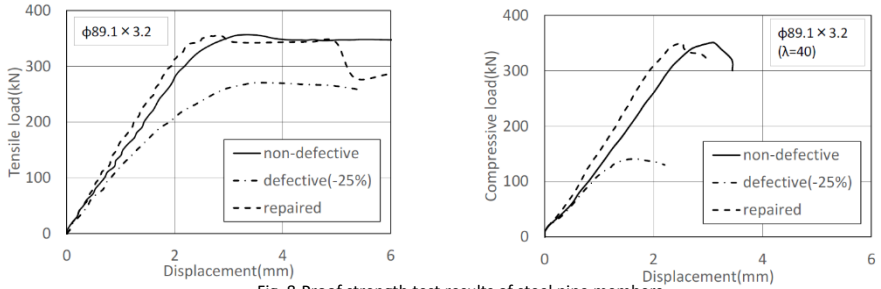

Fig. 8 Proof strength test results of steel pipe members