

Development of the Corrosion Deterioration Inspection Tool for Transmission Tower Steel Members

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Abstract

Recently, interests for maintenance of transmission tower are increasing to extend life of structures and reduce maintenance cost. However, existing classical diagnosis method of corrosion deteriorated degree on the transmission tower steel members, visual inspection, has a problem that error often due to difference of inspector's individual knowledge and experience. In order to solve the problem, this study carried out to develop the corrosion deterioration inspection tool for transmission tower steel members. This tool is composed of camera equipment and computer-aided diagnosis system. We standardized the photographing method by camera equipment to obtain suitable pictures for image processing. Diagnosis system was designed to evaluate automatically degree of corrosion deterioration for member of transmission tower on the basis of the RGB color image processing techniques. It is anticipated that developed the corrosion deterioration inspection tool will be very helpful in decision of optimal maintenance time for transmission tower corrosion.

Keywords: Transmission Tower, Maintenance, Corrosion Deterioration Inspection, RGB color model, Image Processing

1. Introduction

Transmission towers are constructed and operated in a variety of atmospheric environments over a long period of time, resulting in its deterioration, mainly caused by air pollution. Steel is mostly used as the main member of the transmission tower, and a hot dip galvanizing process technique is generally applied to minimize its deterioration. If the hot dip galvanizing member loses its inherent function, it's repaired by additionally painting the member surface with heavy-duty paint. In general, deterioration of the member not only causes difficulties in maintenance and operation of the equipment, but also reduces reliability of the power supply and is a major cause in hindering public safety. Therefore, accurate assessment of the member's deterioration state simultaneously with suitable repair and reinforcement in a timely manner are needed for economic and reliable operation of the transmission tower.

A reference index for detecting the deterioration state of the currently operating transmission towers is partly set-up, for which visual inspection is usually carried out as an inspection method for the deterioration state in order to determine whether or not to perform maintenance. However, such visual inspection is irrational as the inspector's personal experience and perspective significantly affect deterioration determination of the transmission tower member. Further, since quantitative analysis of the deterioration state is difficult, maintenance time of the transmission towers cannot be efficiently determined. In order to solve these problems, this study developed an inspection tool which can quantitatively analyze the corrosion and deterioration states and also objectively read the deterioration grade of the transmission tower member.

2. Background and Related Work

When hot dip galvanization of the member is subjected to corrosion over time due to transmission tower use, surface of the steel member is painted to prevent additional corrosion.

This is to prevent corrosion by physic-chemically or electrically blocking the steel member from the environment. Currently, painting is the most widely used technique, accounting for approximately 65% of the cost for corrosion prevention measures. Painting is widely used because specific painting equipment is not required for the painting process and it can be done on site, but also due to low cost and maintenance of environment-friendly aesthetics. However, re-painting is required regularly since the paint and film have limited durability.

Thus, studies on paint maintenance measures have been conducted with recognition of the importance of paint management. Economic efficiency of paint maintenance was determined by setting up various painting methods applicable according to the characteristics of the exposed atmospheric environment, evaluating service life for each paint system, and thereby analyzing the life cycle cost [1]. In particular, analysis of the paint repair costs during the life cycle by providing grades for the transmission tower in advance according to occurrence and progression of corrosion, and preparing reasonable repair measures for each corrosion grade showed that there was more than twice increase in costs depending on the differences in repair time of each corrosion grade [2].

Therefore, accurately determining the deterioration state of the member with respect to the operation and maintenance of the commonly used transmission tower is a crucial step in ensuring safety and economic efficiency of the support. Correspondingly to this, various techniques have been developed to inspect and diagnose corrosion deterioration state of the transmission tower and steel structure. By default, evaluation criteria for visual inspection was established for corrosion and paint deterioration of the steel member [3], [4], [5], [6], and a technique for measuring deterioration of the painted member using ultrasound was introduced [7], [8], [9]. In addition, thickness of the remaining galvanized coating for the hot dip galvanizing member was effectively measured using Electromagnetic Thickness Tester and Handheld X-Ray Fluorescence Analysis System [10]. In particular, various techniques for quantitatively measuring deterioration grade of steel structure were developed by image processing of deterioration such as corrosion and flaking based on images taken by CCD (Charge-Coupled Device) Camera of the inspection and diagnosis area of steel structures, and these techniques are currently implemented to inspection and diagnosis processes of steel bridges [11], [12]. Studies have also been partly underway for the transmission towers on deterioration grade determination based on color image processing [13], [14].

However, there are limits to applying the existing inspection and diagnosis techniques for the corrosion deterioration state of structures to deterioration grade determination of transmission towers. That is, quantitative evaluation of the deterioration grade is impossible through visual inspection, and even though the measuring technique for the remaining thickness using non-destructive equipment has a high measurement accuracy it is merely a localized result for the inspected member, thus there are problems of decreased efficiency in inspection and diagnosis processes when applied to the overall structure. Accordingly, deterioration grade determination technique based on digital image processing has been applied recently, but most are for the use in steel bridges and therefore image processing techniques have been optimized for the deterioration characteristics of the painted member, and as a result cannot be applied to hot dip galvanizing member such as the transmission tower. In addition, recently developed deterioration grade determination technique for transmission towers based on digital color image processing is an image processing technique taking into account the deterioration nature of the hot dip galvanization. Thus, it is difficult to provide suitable inspection and diagnosis results for the deterioration state of the painted member when paint repair is performed over

time according to transmission tower use.

In this study an inspection tool was developed, capable of quantitatively analyzing the paint deterioration and steel corrosion of the painted member and hot dip galvanizing member of the commonly used transmission tower and objectively classifying the deterioration grade of the transmission tower, based on evaluation criteria for the transmission tower deterioration state by the Korea Electric Power Corporation. Camera Equipment and Computer-Aided Diagnosis System of Corrosion Deterioration were developed to allow deterioration grade determination of the transmission tower based on digital color image processing, by utilizing RGB color values for the paint deterioration and corrosion of the transmission tower member.

3. Development of the Inspection Tool

3.1 Criteria of Deterioration Grade for Transmission Tower

Criteria for deterioration grade of the transmission tower may be different by country or maintenance subject. The Korea Electric Power Corporation selects subject members for corrosion protection painting using color change characteristic of the steel surface according to deterioration of painted member and hot dip galvanizing member of the transmission tower, and conducts diagnosis and evaluation of the corrosion state according to the overhead transmission operation business standard [15].

Table 1 shows the criteria for corrosion prevention painting measure of the overhead transmission operation business standard, illustrating the exterior state of the transmission tower's hot dip galvanizing member according to the corrosion progression. Table 2 shows the exterior state of the transmission tower's painted member according to corrosion progression. The diagnosis evaluation is conducted by classifying the deterioration grade into grades of 1(good) ~ 5(poor) for each exterior state.

Table 1. Criteria of Deterioration Grade for Hot Dip Galvanizing Member

Deterioration Grade	Visual Characteristic
1	Light gray in color. Surface is in good condition, with no corrosion and discoloration.
2	Shows faint rusting due to exposure to alloy layer with galvanized coating, and overall surface is pale yellow in color. Less than 10% area ratio of red or black discoloration region.
3	Alloy layer is exposed on all surfaces. Rusting or localized corrosion of dot sized area. Starts to show red color. Less than 20% of rusting area ratio within a section of a horizontally 1 meter long member.
4	Alloy layer and steel material are extensively exposed, causing red and black color change in a wide area. 20%~40% of rusting area ratio within a section of a horizontally 1 meter long member.
5	Steel material is more extensively seen than for deterioration grade 4, and extensive black discoloration is seen. Over 40% of rusting area ratio within a section of a horizontally 1 meter long member.

Table 2. Criteria of Deterioration Grade for Painted Member

Deterioration Grade	Visual Characteristic
1	Shows intrinsic color (green, orange, etc.) of the first paint. Surface is in good condition, and shows no discoloration, checking, flaking, swelling and base metal exposure.
2	Shows slight change in color of the paint, but overall surface is in good condition, and damaged area ratio of checking, flaking, swelling and base metal exposure, etc. is less than 5%.
3	Paint surface shows checking, flaking, swelling and base metal exposure, and base material, etc. Rusting occurs at the exposed base metal area. Less than 20% of damaged area ratio within a section of a horizontally 1 meter long member.
4	Paint surface shows extensive checking, flaking, swelling and base metal exposure, etc. Rusting occurs at the exposed base metal area. 20%~40% of damaged area ratio within a section of a horizontally 1 meter long member.
5	Checking, flaking, swelling and base metal exposure, etc. occurs more extensively on the paint material surface than at deterioration grade 4. Rusting occurs at the exposed base metal area. Over 40% of damaged area ratio within a section of a horizontally 1 meter long member.

3.2 Camera Equipment

As shown in Tables 1 and 2, deterioration grade of a transmission tower is determined according to rusting or damaged area ratio within a section of a horizontally 1 meter long member. Thus, it is necessary to develop the equipment for determining deterioration grade of a transmission tower to be able to photograph a horizontally 1 meter long member. However, as shown in Figure 1(a), it is very difficult to photograph a 1meter long member at one time by climbing the transmission tower. Thus, in this study, 0.5meter long member was consecutively photographed to evaluate and diagnose deterioration grade of the transmission tower as shown in Figure 1(b).



(a) Safety Inspection Scene



(b) Camera Equipment

Figure 1. Camera Equipment for Corrosion Deterioration Inspection Tool

As shown in Figure 1(b), the camera equipment was produced in a blue rectangular frame shape so that the region of interest (ROI) of the photographed transmission tower member could be automatically extracted by image processing technique, and the yellow marker in the upper right side of the rectangular frame was used to set the width of the transmission tower member for image processing. In particular, the color chart on the left side of the rectangular frame provided a standard RGB information for compensating image distortion due to change in illumination.

A magnet was installed on the lower bottom of the rectangular frame for convenience of operating the camera equipment, and the digital camera support was designed to be detachable at the center of the rectangular frame. The digital camera used for the camera equipment was attached to the vertical support in the center of the rectangular frame such that the transmission tower member was photographed with identical angle of view and ratio at regular intervals to always obtain a standardized deterioration image.

3.3 Color Image Processing Solution

Color characteristics of rusting, painting and hot dip galvanization must be obtained in order to carry out color image processing for determining deterioration grade from the deterioration images using the characteristic color change of the steel surface according to the deterioration of painted member and hot dip galvanized member of the steel tower transmission. In this study, images were taken from commonly used transmission towers to analyze RGB color values of rusting, paint and hot dip galvanization. The results are shown in Figure 2, Table 3.

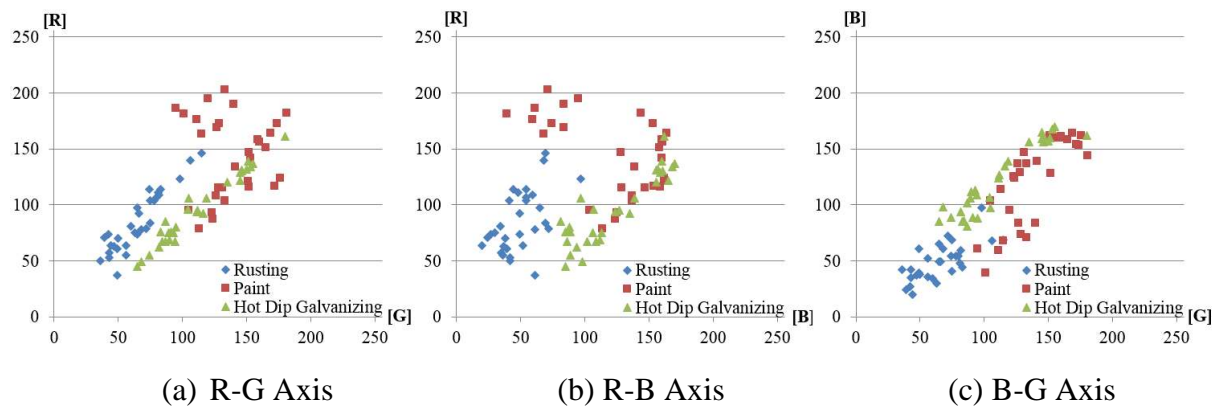


Figure 2. RGB Value of Transmission Tower Steel Member

Table 3. RGB Value Analysis of Transmission Tower Steel Member

Division	Rusting			Paint			Hot Dip Galvanizing		
	R	G	B	R	G	B	R	G	B
Max.	146	115	97	203	181	164	161	180	170
Min.	37	36	20	79	95	39	45	65	81
Mean	85	65	49	144	139	122	96	112	123
Variance	719	386	273	1,229	554	1,412	946	937	949
Standard Deviation	27	20	17	35	24	38	31	31	31

As shown in Figure 2 and Table 3, RGB values of rusting is distinguishable from the RGB values of painting and hot dip galvanization. Further, the paint applied to the transmission tower is various in color (green, orange, white, ivory, etc.) according to the objective so the RGB values are widely distributed. Figure 3 shows the distribution state of the RGB values for rusting. Therefore, the key in color image processing for determining deterioration grade of the transmission tower is to distinguish the RGB value of rusting and the RGB value of painting from the deterioration images of the hot dip galvanizing and painted members.

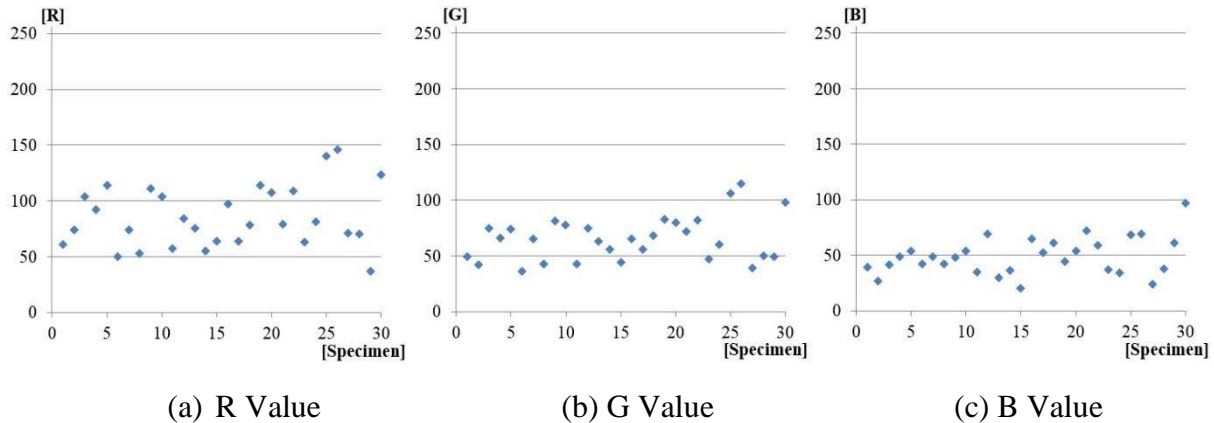


Figure 3. RGB Value of Rusting for Transmission Tower Steel Member

3.4 Computer-Aided Diagnosis System

Color image processed corrosion deterioration diagnosis system was prepared for determining deterioration grade from the deterioration images of the hot dip galvanizing and painted members of the transmission tower. User accessibility was improved by developing it for web-based use in a Windows environment. Figure 4 illustrates deterioration grade detection process of the transmission tower member in the color image processed corrosion deterioration diagnosis system. Transmission tower deterioration detection process of the corrosion deterioration diagnosis system is dualized for hot dip galvanizing member and painted member, but the main processing process is identical. That is, deterioration image of the transmission tower member is taken, inputted into the corrosion deterioration diagnosis system, and region of interest is extracted from the inputted image. Image compensation is performed for the region of interest using the color chart, then hot dip galvanizing member and painted member are separated to carry out color image processing, and rusting and damage area ratio is calculated to evaluate deterioration grade for hot dip galvanizing member and painted member according to deterioration grade criteria.

Difference in image processing for the hot dip galvanizing member and painted member is due to hot dip galvanizing member having inherent RGB value, while painted member has RGB values varying according to the applied paint. Therefore, color image processing for evaluating deterioration grade of the painted transmission tower member requires the process of defining RGB value of the painted member, and color image processing is conducted based on the determined RGB value of the painted member to carry out image processing of the damaged region. Figure 5 shows a graphic user interface (GUI) of the corrosion deterioration diagnosis system, and Figures 6 (a) and (b) respectively show the deterioration grade

classifying of hot dip galvanizing member and painted member of the transmission tower using the corrosion deterioration diagnosis system.

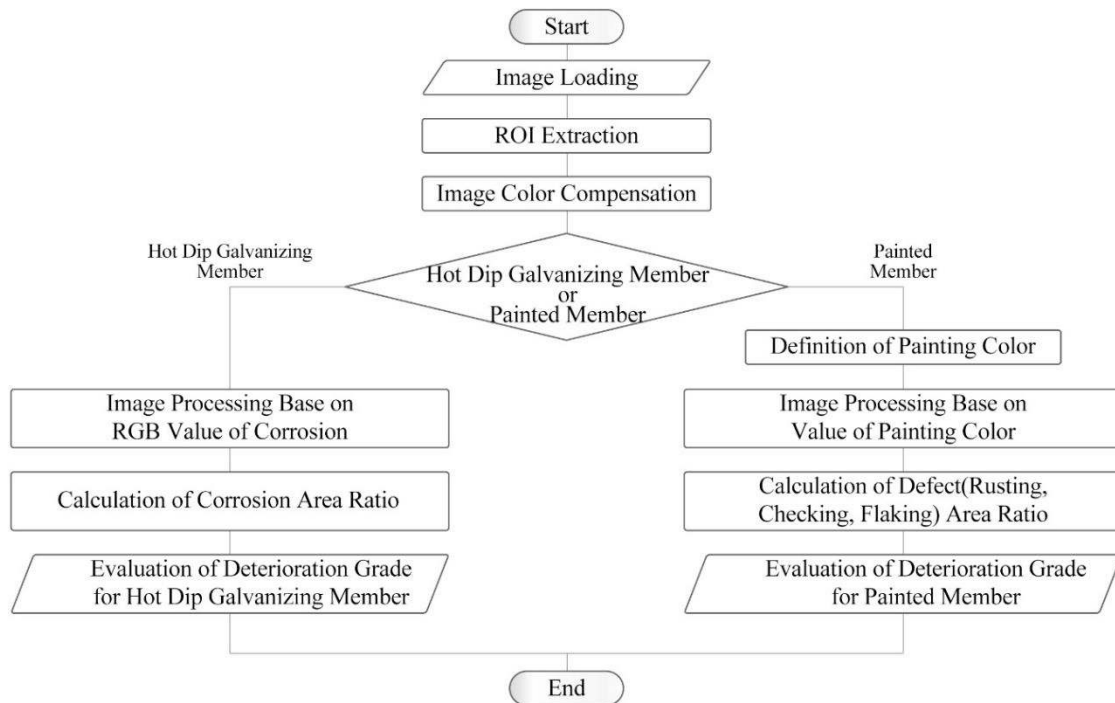
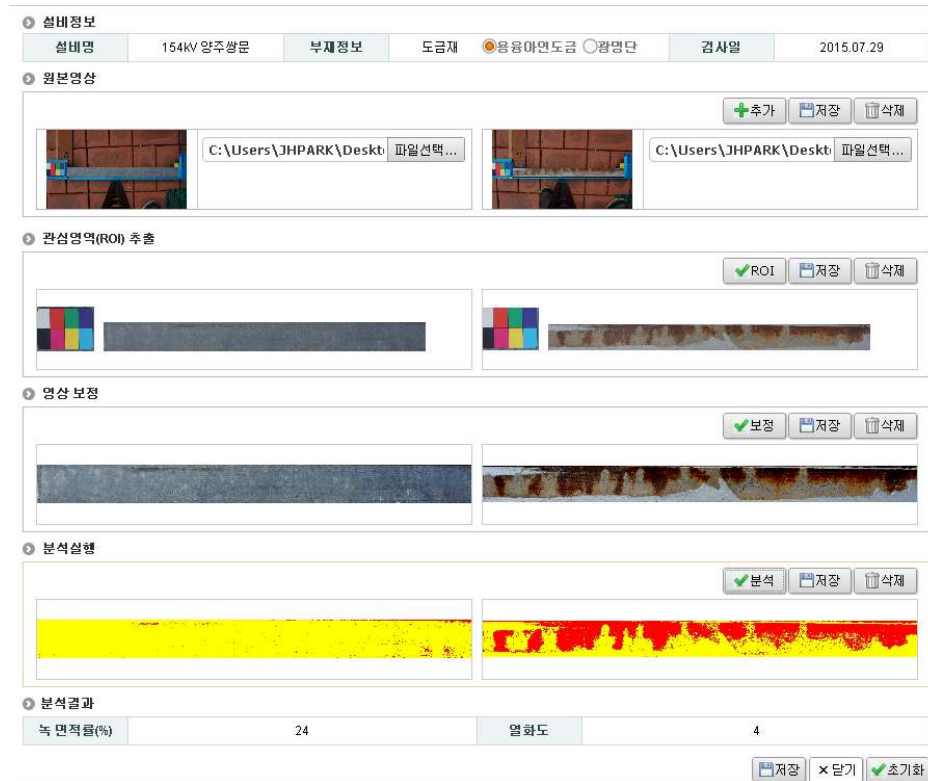


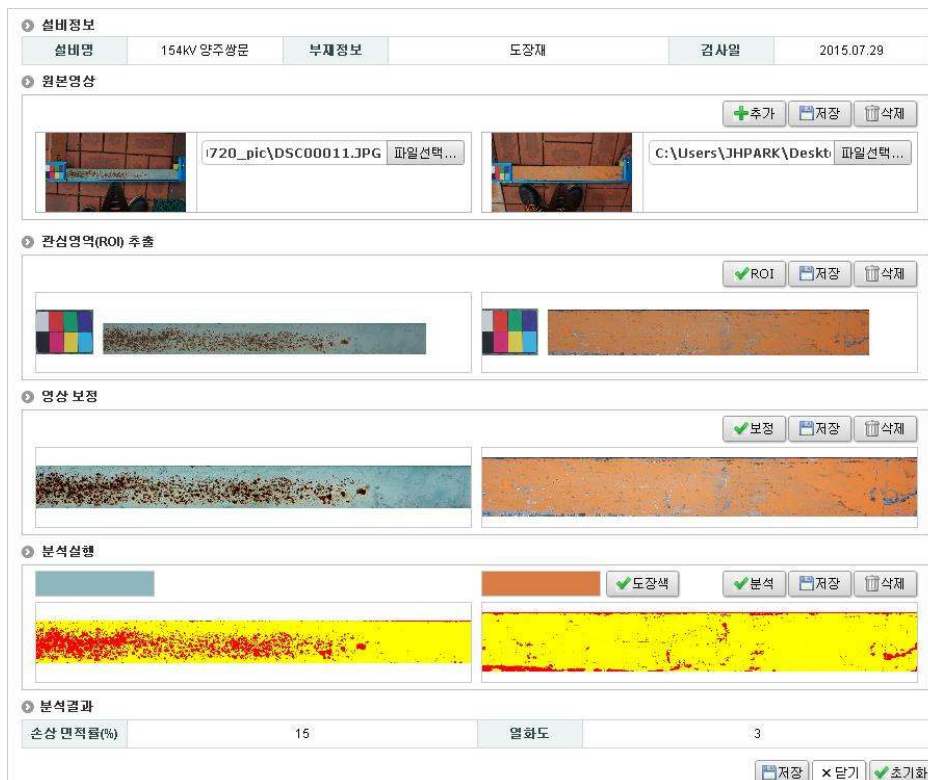
Figure 4. Flow Chart on the Computer-Aided Diagnosis System of Corrosion Deterioration



Figure 5. GUI of Computer-Aided Diagnosis System



(a) Hot Dip Galvanizing Member



(b) Painted Member

Figure 6. Analysis Result of Corrosion Deterioration for Transmission Tower Steel Member

4. Conclusions

In this study, an inspection tool able to carry out quantitative analysis of steel corrosion and paint deterioration of the hot dip galvanizing member and painted member of the commonly used transmission tower, and objectively classifying the deterioration grade of the transmission tower was developed, based on the evaluation criteria for deterioration state of the transmission tower by the Korea Electric Power Corporation. The inspection tool consisted of camera equipment able to obtain standardized deterioration images of the transmission tower member, and corrosion deterioration diagnosis system conducting classifying of the deterioration grade by performing color image processing of the RGB values of rusting, hot dip galvanization and paint from the deterioration images of hot dip galvanizing member and painted member of the transmission tower. The developed color image processing technique based on RGB characteristic values is anticipated for extended application on inspection and diagnosis of deterioration state for similar steel structures.

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