Tokyo Electric Power Company Holdings, Inc.
Tokyo Electric Power Company Power Grid, Inc.

Study Committee B2
Overhead Lines

10633_2022

Rationalization of maintenance methods for hot-dip galvanizing transmission tower

Teruhisa TATSUOKA*, Hiromitsu IJICHI, Keiichi YOSHINO / Tokyo Electric Power Company Holdings, Inc.

Tomoaki KAWAMURA, Motoyuki YAMAZAKI, Tomonori SHIRAISHI / TEPCO Power Grid, Inc.

1. Motivation

- Hot-dip galvanizing transmission towers installed in various environments get corrosion and should be painted just before the loss of galvanizing layer.
- Because the corrosion rate and the corrosion product volume of carbon steel are much higher than that of hot-dip galvanizing and the paint system is easy to break by steel corrosion product with increasing of repainting cost (Fig. 1).
- Therefore, the galvanizing layer corrosion rate and paint degradation rate should be investigated accurately to decide appropriate first painting and repainting timings.

Fig. 1 Tower painting.

2. Method/Approach

- Corrosion is accelerated by deposition and wetness such as very thin electrolyte film on the metal surface (Fig. 2).
- Atmospheric corrosion monitor (ACM) sensor can detect the thin electrolyte film and get the corrosion rate of zinc and carbon steel (Fig. 3).

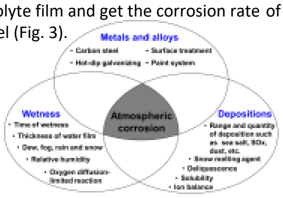


Fig. 2 Acceleration factors on atmospheric corrosion.

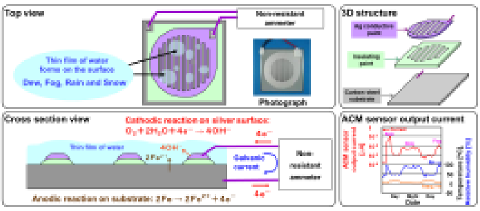


Fig. 3 Schematic diagrams of atmospheric corrosion monitor, ACM, sensor to evaluate corrosion rate.

3. Objects of investigation

- Comparison of corrosion rates of hot-dip galvanizing, hot-dip zinc-aluminum alloy galvanizing was conducted (Fig. 4).
- 3 Pint system lives were evaluated by accelerated degradation test.

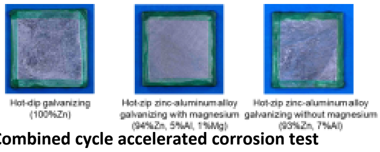


Fig. 4 Combined cycle accelerated corrosion test specimens.

4. Experimental setup & test results

- Corrosion rate maps in Japan were developed by the multiple regression analysis of correlations between the corrosion rates of 150 transmission towers measured by ACM sensors and the 108 environmental factors (Fig. 5).
- Life evaluation and lifecycle cost assessment of hot-dip galvanizing, hot-dip zinc-aluminum alloy galvanizing, and paint system on transmission towers were conducted.

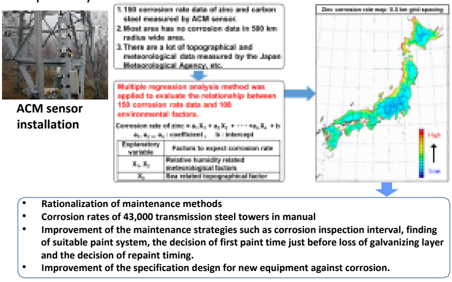


Fig. 5 Corrosion rate map of hot-dip galvanizing.

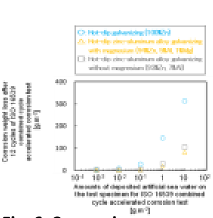


Fig. 6 Comparison between corrosion rates of 3 galvanizing specimens.

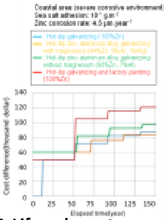


Fig. 7 Lifecycle cost comparison of galvanizing and factory painting on transmission towers in coastal area.

5. Discussion

- The corrosion rate and paint degradation rate of transmission towers strongly depend on their environments (Figs. 6, 7)

6. Conclusion

- Corrosion accelerated tests with ISO 16539 provide that corrosion resistances of hot-dip zinc-aluminum alloy galvanizing with the deposited sea salt were approximately 2,3 to 7,0 times higher than hot-dip zinc galvanizing.
- 3 paint systems lives having a fluorocarbon polymer-based top coating and an epoxy-based under coating were estimated to be over 40 years.
- In severe corrosion environment, of hot-dip zinc-aluminum alloy galvanizing was cost effective.

cigre | PARIS 2022

TEPCO
Tokyo Electric Power Company Holdings, Inc.
Tokyo Electric Power Company Power Grid, Inc.

Study Committee B2

Overhead Lines

10633_2022

Rationalization of maintenance methods for hot-dip galvanizing transmission tower

continued

7. Corrosion resistance of hot-dip galvanizing and hot-dip zinc-aluminum alloy galvanizing

- This hot-dip zinc-aluminum alloy galvanizing has about twice or thrice higher corrosion resistance than the hot-dip galvanizing.
- Two different types of hot-dip zinc-aluminum alloy galvanizing with and without magnesium (94% Zn, 5% Al, 1% Mg, and 93% Zn, 7% Al) have been applied for the ISO 16539 corrosion accelerated tests (Figs. 8, 9).
- It was assessed that corrosion resistance of hot-dip zinc-aluminum alloy galvanizing with the deposited sea salt was approximately 2,3 to 7,0 times higher than hot-dip zinc galvanizing (Fig. 10).

Fig. 8 Specimens of hot-dip galvanizing and hot-dip zinc-aluminum alloy galvanizing with and without magnesium for combined cycle accelerated corrosion test.

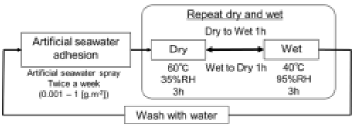
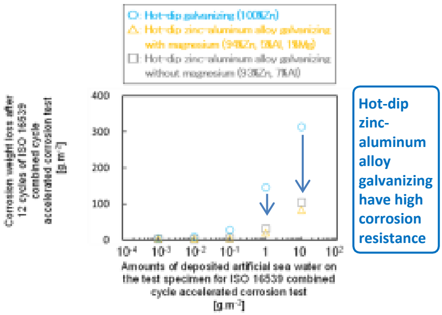


Fig. 9 Combined cycle accelerated corrosion test condition according to ISO 16539.



*: Amount of deposited artificial sea water equals the amount of NaCl assumed that the total chloride ion Cl^- in the artificial sea water is combined with sodium ion Na^+.

Fig. 10 Assessment of corrosion weight loss of hot-dip galvanizing and hot-dip zinc-aluminum alloy galvanizing after 12 cycles of ISO 16539 combined cycle accelerated corrosion test.

8. Life assessment of organic coating for transmission towers

- The long-term under-film corrosion resistance performance and appropriate repaint timing of the standard coating had still not been identified, or in other words the paint system life was not expected precisely.
- An UV irradiation accelerated degradation test was performed in metal halide weather meter (Figs. 11, 12).
- Paints A and B which contain the same base polymer and component and made by different manufacturers and Paint C is used in the past.
- The lives of these 3 corrosion-proof paint systems having a fluorocarbon polymer-based top coating and an epoxy-based under coating were estimated to be 40 to 50 years (Table 1).

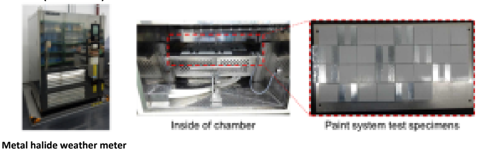
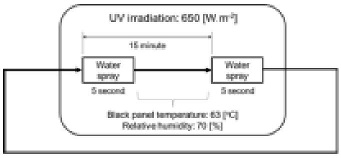


Fig. 11 Metal halide weather meter type UV irradiation accelerated degradation test equipment and test specimens.



1300 hours of the UV irradiation accelerated degradation test in metal halide weather meter corresponds to 10 years in normal outdoor environments in Japan.

Fig. 12 UV irradiation accelerated degradation test condition.

Table 1. Surface observation result after UV irradiation accelerated degradation tests

	UV irradiation amount				
	10 years equivalent (1300h)	20 years equivalent (2600h)	30 years equivalent (3900h)	40 years equivalent (5200h)	50 years equivalent (6500h)
paintA					
paintB					
paintC					

Study Committee B2

Overhead Lines

10633_2022

Rationalization of maintenance methods for hot-dip galvanizing transmission tower

continued

9. Lifecycle costs comparison of transmission towers

- Based on these results, lifecycle costs were compared using a 275 kV transmission tower of which the weight was 49 ton as a model. In a rural area corresponding to the mild corrosive environment which had 10^{-3} g.m^{-2} of sea salt adhesion and 1,0 µm.year^{-1} of annual zinc corrosion rate, the lifecycle cost of the painting repeated with appropriate timing on the hot-dip galvanizing transmission towers was significantly lower than the others (Figs. 13, 14).
- The initial cost of transmission tower with hot-dip galvanizing was subtracted to deliver the cost differences. The initial costs of hot-dip zinc-aluminum alloy galvanizing with magnesium (94%Zn, 5%Al, 1%Mg), hot-dip zinc-aluminum alloy galvanizing without magnesium (93%Zn, 7%Al), and hot-dip galvanizing (100%Zn) and factory painting also decrease the initial cost of transmission tower.

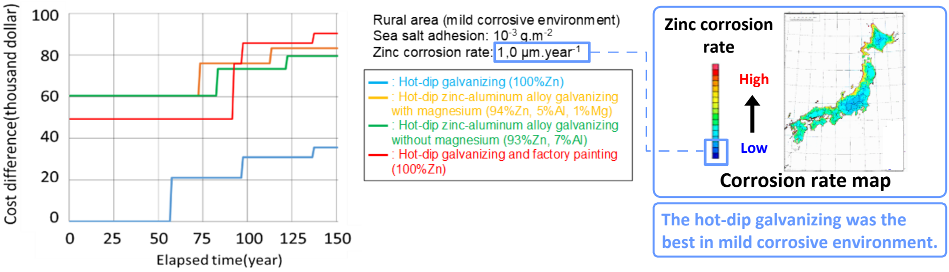


Fig. 13 Lifecycle cost differences comparison of transmission towers with different type of galvanizing and factory painting in rural area (The initial cost of transmission tower with hot-dip galvanizing was subtracted to deliver the cost differences.).

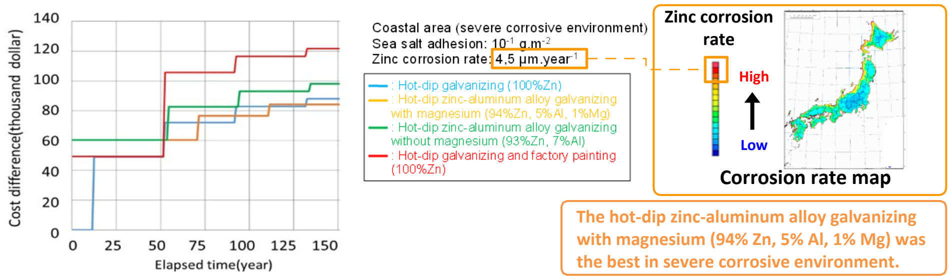


Fig. 14 Lifecycle cost differences comparison of transmission towers with different type of galvanizing and factory painting in coastal area (The initial cost of transmission tower with hot-dip galvanizing was subtracted to deliver the cost differences.).

10. Conclusion

- The corrosion rate maps delivered improvements of the specification design of galvanizing and paint system, maintenance methods, first-paint timing and re-paint intervals.
- Corrosion accelerated tests with ISO 16539 provide that corrosion resistances of hot-dip zinc-aluminum alloy galvanizing with the deposited sea salt were approximately 2,3 to 7,0 times higher than hot-dip zinc galvanizing.
- UV irradiation accelerated degradation tests with the metal weather test chamber provide that the lives of 3 paint systems having a fluorocarbon polymer-based top coating and an epoxy-based under coating were estimated to be over 40 years.