CORRWIND: A LIFE CYCLE COST COMPARATIVE FOR THE WIND ENERGY INDUSTRY USERS MANUAL

BY INTERNATIONAL ZINC ASSOCIATION

IZA has developed the cost model CorrWind to calculate life cycle costs for different corrosion protection systems, such as thermal sprayed Zn, organic coatings and duplex systems of paint supplied over thermal-sprayed zinc.

The software is Excel-based. The CorrWind software allows users to determine the sensitivity of total corrosion protection system costs over the expected lifetime of a wind energy structure to input factors, such as the initial cost of the corrosion protection system, expected maintenance costs, rate of inflation over the expected surface life of the structure, financial discount rate and the relationship of initial and maintenance costs to the cost per KWh of the wind energy-generating unit, including the capacity factor of typical wind power units. CorrWind should provide the wind industry with an advisory tool for cutting costs and provide users a way of seeing how the life cycle costs are derived. It is also expected that the model will help provide data for developing corrosion-protection standards tailor-made for the wind energy industry.

FIRST SHEET - BASIC PROJECT DATA

The tab, "First Sheet," of the software asks for basic data about the size (square meters or square feet) of the structure that will be analyzed. This is normally the area of the structure above the average sea level. For this analysis, only the outside area of the tower is considered; however, the model can be adapted to consider the inside area of the tower if corrosion costs and maintenance schedules can be predicted. The area of the outside of the structure to be coated is entered in either square meters or square feet in the indicated boxes. Default values are shown using a widely-used design, the Siemens SWT-3.6-107 3.6 MW wind turbine. For this model, the minimum rotor height is 80m and the maximum is 96m, so a figure halfway between these of 88m was used as the tower height. A typical bottom diameter for this kind of tower is 7m with a top diameter of 2m. The area of the outside of the tower is thus calculated using the formula for the area of a truncated cone. The other choice to be made on the first page is the years of the project life to be analyzed. This will be a number between 1 and 25 years. A default figure of 20 years is also indicated on this sheet.

DEVELOPING INITIAL CORROSION PROTECTION COSTS: PAINT-ONLY IN-SHOP WORKSHEET

The tab, "Paint-Only In-Shop," calculates the total cost of applying a paint-only coating to the outer surface of the tower in a land-based facility, such as a shipyard. A typical paint system specified for offshore conditions in Reference 1 is used as an example and default costs in terms of either euros per square meter or U.S. dollars per square foot are shown. The default costs shown here are derived from the NACE 2008 paper.[2] The costs in that paper were adjusted using published USA inflation rates to derive 2013 figures. Use of these figures in future years will require them to be adjusted to reflect actual costs during the year of study. All costs shown in this table are a one-time application cost for preparation of the corrosion protection system onshore, before the tower is transported offshore. Information from References 2 and 3 was combined to develop the template for materials and application costs. Grit blasting of steel to SP3, using automated equipment, is typical in onshore surface preparation procedures. The various layers of paint applied over the surface are then typically sprayed, giving the dry film thicknesses shown in each case, in both microns and mils. Typical spray paint costs and application costs are taken from Reference 2. A "job multiplier" for in-shop application is indicated in the NACE 2008 Paper[2] and typical values of job multipliers are shown in call-up boxes embedded in the worksheets. The job multiplier depends upon the total area of the job and a corresponding multiplier is found in the call-up boxes. The total preparation and application costs are then calculated in the "Paint-Only In-Shop" worksheet, allowing for a total cost of applying the coating to be determined when the cost per unit area is multiplied by the total area to be coated.

DEVELOPMENT OF INITIAL CORROSION PROTECTION SYSTEM COSTS: THERMAL SPRAY ZINC + PAINT IN-SHOP

A separate tab then shows a worksheet for the "TS Plus Sign Paint In-Shop" costs. Like the paint-only cost calculation, this uses anticipated costs to be incurred onshore, in a shipyard or similar type of fabrication and surface treatment facility. Like the paint-only system, grit blasting to an SP3 finish using automated equipment is shown. The materials costs involve application of the sealer over the thermal-sprayed coating, together with paint systems recommended in ISO The zinc thermal-spray system is assumed to be a 100-micron (3.9 mil)-thick thermal-sprayed layer. This is sealed with a vinyl Ester coating, followed by the two layers of primer and one layer of top coat consistent with Reference 1. As with the paint-only system, a job multiplier is used, based on the total area of the tower, and this is found in the call-up box indicated. This "TS + Paint In-Shop" worksheet allows for the cost-per-unit of area to be obtained. This is then multiplied by the area of the tower to determine the total cost of the thermal spray zinc plus paint corrosion protection system. As with the other calculations, default values are shown for materials and application costs that are based on 2013 costs. These were derived from Reference 2 and other sources and adjusted to 2013 costs, using appropriate inflator calculations. These costs will need to be adjusted for use in future years so that accurate costs can be used in the analysis.

OFFSHORE MAINTENANCE COSTS: PAINT-ONLY SYSTEM

The tab, "Maintenance Paint-Only," shows the worksheet that allows calculation of the maintenance costs of a paint-only system using a reference paint system conforming to offshore conditions as described in Reference 1. Columns are provided for each year of the project life, with a maximum of 25 years, defined by the chosen service life in the first worksheet. Based on the experience reported in Reference 4, default values for the percent of total coated area on the outside of the tower above the mean sea level that requires maintenance for each of the maximum of 25 years, is shown. Default values are 1% of the total area, requiring maintenance for the first 12 years with 5% of the total area then requiring maintenance for years 13-20. The total coated area of the project is shown below the percent maintenance assumptions, being carried over from the initial reporting of this figure. This is multiplied by the percent area to be maintained each year, for each year of the project life, allowing calculation of the area requiring maintenance each year. As with all aspects of this software, this can be calculated in either square meters or square feet. The inflation rate during the years of service life of the structure must then be input. The default value for this software is 2% per year; however, different rates can be input by the user. These will influence the cost of both materials and labor in the future, because this inflation rate is applied to the current cost of maintenance and labor, for the base year. The current materials costs for the different components of the paint system, together with current costs of surface blasting and other application costs are then input based on current-year costs. Paint and application costs offshore are based on brush/roll painting, in contrast to spray painting that is used for the initial materials and applications cost of the coating onshore. The job multiplier for field maintenance is then found in the indicated call-up box. Three different levels of job multiplier are shown for onshore maintenance. These usually result in a multiplying of the basic costs by a factor of between 1.35 and 1.5, reflecting the higher cost of working off the ground, onshore. However, offshore maintenance costs are significantly higher costs and job multipliers of 100 times the base costs are not unusual for offshore work[5]. A default value of 100 is shown in this software; however, the user can adjust it to determine the actual maintenance costs for offshore work that are thought to be most accurate. After materials and application costs, together with the job multiplier are input, the total preparation and application costs are determined for each year of the project. The financial discount rate is then used to compare future costs with present values. A default discount rate of 3% is used in the software; however, the user can use any value of discount rate that is desired. It is noted that the discount rate is always higher than the inflation rate to account for investment risk; for example, the default values in the software use a 2% inflation rate and a 3% discount rate. The net present value of the maintenance costs for each year are then calculated using the discount rate, for each year that costs are incurred. These are then summed to give a total net present value for the maintenance costs over the life of the project. Analysts often use a figure termed "average equivalent annual cost (AEAC)" to compare a single figure for each corrosion-protection system with that of other candidate systems. The AEAC combines the present costs of applying the corrosion-protection system with all future costs of maintaining the system, determining a net present value and distributing net present value at equal annual costs over the life of the project. The AEAC of the paint-only system is $224,314.67, or €173,795.87.

MAINTENANCE COSTS: THERMAL SPRAY PLUS PAINT SYSTEM

The tab, "Maintenance TS Plus Sign Paint," allows calculation of the maintenance costs for each year during the life of the project. Following the recommendations of Reference 3, the percent total area requiring maintenance over the life of the project is shown. First, the default value is 1% of the tower outer surface requiring repair each year, with a project life of 20 years. This is multiplied by the total outside tower area, above the mean sea level, to determine the total coated area requiring maintenance each year. A column is provided for each year of the project life, with a maximum of 25 years of service life. After determining the total coated area to be maintained each year, an inflation rate is then selected for each of the years of the project. A default inflation rate of 2% per year is used; however, the user can input selected inflation rates for each of the years over the life of the project, as desired. These inflation rates are then applied to the base costs of paint and application costs offshore. Present costs for each of the components of the paint systems, together with their application, are then inputted for the year zero values. No thermal spraying is assumed to be used in the offshore maintenance of these structures. Only brush/roll-applied paints are used to maintain the corrosion-protection system. The job multiplier for field maintenance is taken from the "Call-up Boxes," shown in a separate tab. For maintenance of onshore windmills, typical job multipliers are between 1.35 and 1.5 of base costs; however, for offshore maintenance the job multiplier is often 100%, as recommended by Reference 1. After determining total preparation, materials and applications costs for each of the years of maintenance of the tower, the discount rate is then determined for each of the years of the project life. A default discount rate of 3% is shown. The financial discount rate is always higher than the rate of inflation to account for investment risk. In the default examples shown in this software the inflation rate is 2% and the discount rate is 3%. The discount rate is then used to determine the net present value of the maintenance costs for the thermal-spray-plus-paint system, for each of the years of the project life. The net present values for each of these years are then summed, to give a total net present value of maintenance for the entire project.

As with the paint-only system, an average equivalent annual cost for maintenance is then calculated. This provides a single figure allowing future costs of maintaining the system by distributing the total net present value of all years of maintenance costs over the life of the project, in equal annual amounts. The AEAC of maintenance for the default thermal spray plus paint system is $89,474.61, or €69,323.67.

SUMMARY OF INITIAL APPLICATION AND PERIODIC MAINTENANCE COSTS:
To compare both initial costs and periodic maintenance costs of selected corrosion protection systems, the tab, "Final Sheet," worksheet is used. This allows the initial costs and maintenance costs of the different corrosion protection systems to be entered. The default values are shown. The initial costs of the paint-only protection system are first shown, followed by the maintenance costs of the paint-only protection system, using the sum of the net present value figures for all years of serviced. The total net present value of the paint-only system is therefore the sum of these because the initial cost of the paint-only protection system is applied during the first year

and does not need to be discounted further. The net present value sum of maintenance costs is a sum of the discounted costs for each of the future years, back to the present year. Their sum provides a total net present value for the paint-only system. Similar entries are then made for the thermal spray zinc plus paint system. The initial cost is first entered, followed by the sum of the net present values over each of the years of maintenance of the system. Their total then allows for a comparison of initial system application costs and periodic maintenance costs. The average equivalent annual cost (AEAC) is then calculated. The life of the project is input here and is shown with a default of 20 years. The average annual costs of the initial coating systems are simply the first costs divided by the project life, without considering depreciation. The maintenance costs use a net present value and the life of the project to determine average annual cost of maintenance, distributed over the life of the project. Similarly, initial cost of the thermal-spray plus paint system is distributed over the number of years of expected service of the system by dividing it by the project life. The sum of net present values for the maintenance costs is then combined with the expected years of service, using the AEAC formula to give the AEAC of the maintenance costs for the thermal spray plus zinc system. Summing the average annual costs of the application of the corrosion-protection system with the AEAC of maintenance provides for a total annual average cost of the thermal-spray-plus-zinc paint system. In the default example, the difference between the total average annual costs is $104,920.52, or €76,898.18. For a wind energy tower generating 13 million kilowatt hours per year, this shows a cost savings of one cent (0.8 euro cent) per KWhy of equivalent annual average cost savings for each kilowatt hour generated over the life of the project, if thermal-spray-plus-paint is used.

REFERENCES

1. ISO 12944, “Paints and varnishes — Corrosion protection of steel structures by protective paint systems —Part 5: Protective paint systems Table A.8 — Paint systems for thermally sprayed metal surfaces for corrosivity categories C4, C5-I, C5-M and Im1 to Im3”, ISO, Geneva, Switzerland

2. J. L. Helsel, R. Lanterman and K. Wissmar, “Expected Service Life and Cost Considerations for Maintenance and New Construction Protective Coating Work”, Proc. NACE Corrosion 2008 Conference and Exposition, Paper 08279, Las Vegas, NV, NACE

3. J. L. Helsel, M. F. Melampy, K. Wissmar, “Expected Service Life and Cost Considerations for Maintenance and New Construction Protective Coating Work,” CORROSION / 2006, paper 06318 (Houston, TX: NACE, 2006).

4. O. Ø. Knudsen, A. Bjørgum, and L.T. Døssland, “Long-Life, Low-Maintenance Coating Systems”, Materials Performance, 51, 6, June 2012, pp.54-59

5. H. Mueller, “Korrosionsschutz von Offshore-Energieanlagen “von der Herstellung bis zur Sanierung” Workshop: “Innovative Beschichtungen von Windkraftanlagen“, October 16, 2012, Fraunhofer Forum Berlin, Gemeinschaftsausschuss Kombinierte Oberflaechentechnik