The Micro-Nano Technology Sol-Gel Corrosion Sensor System

Final Project Report

July 15, 2015

Abstract

This report provides a detailed result of the Army sponsored project entitled "The Micro-Nano Technology Sol-Gel Corrosion Sensor System." It was prompted by awareness of the rising costs of U.S. Army corrosion prevention and control for Army material. The outcome of this project includes the design and implementation of an early-stage corrosion monitoring system using sol-gel corrosion and A36 steel carbon based sensors, a RS485-based local sensor network, and Internet access for remote data and system access through WiFi infrastructure for determining the degree of early-stage corrosion level of steel and steel structure during service. This corrosion monitoring system was deployed at the U.S. Army's bridge at Rock Island, IL since May 2013. Major project tasks include design, testing, field work and deployment, and data collection and monitoring activities. Overall, corrosion is reflected by higher capacitance readings of the sensors, including both sol-gel and cylindrical sensors. The field results are consistent with the lab testing results. The lessons learned from problems and issues found at various phases of the project provide valuable knowledge and guidelines for corrosion, environmental monitoring and sensing applications needed in the Army program on corrosion prevention and control for Army materials.

Executive Summary

The Micro-Nano Technology Sol-Gel Corrosion Sensor System project was awarded by the U.S. Army Construction Engineering Research Lab (CERL) in 2011. As a result, an early-stage corrosion monitoring system (CMS) using innovative sol-gel corrosion sensor and A36 steel rod-based cylindrical corrosion sensor was successfully designed, built, deployed and tested. This CMS designed for monitoring and determining the degree of early-stage corrosion level of steel and steel structures during service. This CMS provides such capabilities as automatic data collection, processing and evaluation of the early-stage environmental corrosion which is very important to maintain the integrity and safety of the structures and systems that were built with such metal materials as carbon steel, aluminum, zinc and copper. The design team at Purdue University Fort Wayne campus (IPFW) conducted various stages of multi-discipline activities, including design, testing, deployment, and maintenance activities in the areas of sensor materials, electronics signal processing circuits, power supplies for the system, computer hardware architecture, software system, communications and networking architecture. The CMS was finally built and deployed to Army's Rock Island Arsenal bridge at Rock Island, IL, in May 2013 and continuously operational to collect corrosion data for analysis. From May 2013 to the final report date as of June 30, 2015, the IPFW design team has been continuing to fine tune the system, which consists of the following subsystems: (a) Six Corrosion Sensor Nodes (three sol-gel and three cylindrical types): each sensor node consists of a weatherproof packing and a sensor connector, a sensor electronics PCB board, a commercial off-the shelf data acquisition module which includes a RS485 link (set at 9600 bps), 16-bit analog-to-digital converter, and an embedded computers with preconfigured functions for RS485 communication and data acquisition; (b) One CMS Server Unit Box, a Windows XP-based embedded computer unit with a thermal-cooling unit for maintaining a desired operating temperature; (c) Power Supply System for the CMS includes one 24V DC 2.5A for the embedded computer inside the CSM server unit box, and two 24V, 1.7A delivered, via Cat 6 cables, to all six corrosion sensor boxes, and an uninterruptible power supply (UPS) unit for power reliability; (d) Wired RS485-based star sensor network: Cat 6 heavy-duty, weather proof cabling system (up to 250 feet) and RJ45 connectors for corrosion data sensing and collection at six predetermined locations on the Army steel bridge; (e) Three cellular network-based Wi-Fi hotspots (one AT&T WiFi Mobile Hotspot with two-year service purchased and two InterNetOnTheGo WiFi hotspots without contract) for wide area networking and remote access to the CMS server computer; and (f) A cloud-based remote system service through LogMeIn for accessing the CMS using web-based service and the Dropbox cloud storage.

This report gives, in Section 2, a detailed description of the technology overview, field investigation and deployment work, and system validation through testing, commissioning, inspection, and fine tuning. Section 3 presents performance measurement, demonstrated results, and lessons learned throughout various phases of the project execution. Section 4 provides an economic analysis of life-cycle cost and predicted return-on-investment (ROI). Section 5 gives the conclusions and summary, and highlights on major accomplishments related to project related paper publications and technical presentations.