Dam Safety Instrumentation Data Acquisition, Monitoring, and Data Visualization Improvements at the Rocky Mountain Hydroelectric Plant

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Abstract--Collection, organization, and presentation of instrumentation data can be a daunting task for dam owners. Historical data may be stored in multiple locations and formats, surveillance and monitoring programs may include numerous types of instruments with varying methods of data collection, instrumentation from different vendors may run on separate and often incompatible software, and dam safety instrumentation reporting is often time consuming. Dam owners such as Oglethorpe Power Corporation (OPC) have implemented improvements to their monitoring program utilizing new technology in data acquisition, database management, and reporting. OPC's Rocky Mountain Hydroelectric Plant surveillance and monitoring plan includes a combination of automated and manually read instruments that are synchronized into a single data management database platform. Integrated data management software allows OPC to quickly access charts and reports, set alarm notifications, and use templates to easily generate instrumentation reports.

I. Introduction

Collection, organization, and presentation of instrumentation data can be a daunting task for dam owners. Historical data may be stored in multiple locations and formats, surveillance and monitoring programs may include numerous types of instruments with varying methods of data collection, instrumentation from different vendors may run on separate and often incompatible software, and dam safety instrumentation reporting is often time consuming. Add in the challenges of limited manpower and remote sites, and running an effective dam safety instrumentation program can become overwhelming. Dam owners such as Oglethorpe Power Corporation (OPC) have implemented improvements to their monitoring program utilizing new technology in data acquisition, database management, and reporting. OPC's Rocky Mountain Hydroelectric Plant surveillance and monitoring plan includes a combination of automated and manually read instruments that are synchronized into a single data management database platform. Integrated data management software allows OPC to quickly access charts and reports, set alarm notifications, and use templates to easily generate quarterly and yearly instrumentation reports.

II. Instrumentation Challenges

Located in northwest Georgia, OPC's Rocky Mountain Hydroelectric Plant is a pumped-storage facility with an upper reservoir contained within an impervious core earth and rock fill embankment dam at the top of Rocky Mountain, and lower and auxiliary reservoirs impounding Heath Creek with a series of rock fill/earth embankment dams. The project was dedicated in 1995 and upgraded to allow additional capacity in 2011. Dam safety instrumentation data at Rocky Mountain are collected both automatically and manually and instrumentation includes piezometers, weirs, and settlement monuments.

Automated instrumentation at Rocky Mountain includes piezometers in the powerhouse tunnel, upper reservoir dam, Dam A, and lower reservoir main dam. By 2012 the original Automated Data Acquisition System (ADAS) was unreliable and in need of replacement. Manually read instruments include open standpipe piezometers, weirs, and settlement monuments. The combination of automated instruments, manually read instruments, and level surveys complicated data acquisition, data organization, and data display. Preparation of OPC's annual dam safety surveillance monitoring report was labor intensive and was complicated by the numerous sources of data.

OPC's challenges at the Rocky Mountain plant are similar to what many dam owners face. Older ADAS setups often use equipment that is no longer being supported or is based on outdated technology. Many systems have been built in a piecemeal fashion and may not be expandable to meet current monitoring needs. In OPC's case, the original ADAS equipment was outdated and the system was prone to damage from lightning which caused costly telemetry failures.

Differing format and data acquisition rates of various dam safety instruments as well as relevant operational and weather information complicates the ease of presentation, review and comparison of data. Automated instrument readings are collected at a rate set by the project owner or engineer and may vary by instrument function. Some instruments at a given dam may be monitored hourly while others are recorded daily. Manually read instruments could be monitored weekly, monthly, or quarterly. Alignment and level survey might be completed yearly. A dam owner might end up with survey data provided in one spreadsheet, manually recorded piezometer data on another, and automated piezometer data in yet another spreadsheet. Compilation of data for ease of use becomes even more complicated when you add in weir measurements, crack meters, extensometers, inclinometers, and other types of instruments.

At the Rocky Mountain plant, various forms of data were organized into spreadsheets and automated data could be viewed using a custom software interface. Data was accessible by plant personnel, but the data organization did not facilitate ease of comparison from a dam safety perspective. Owners of older facilities frequently encounter an even more complex collection of historic data. Data may be collected in field books, report hard copies, spreadsheet files, and text files. This historic data may not be useful until it is organized and formatted.

A final instrumentation-related challenge is the ability to access data for review and reporting. Instrumentation reporting can be time consuming and monotonous. Engineers might spend days importing data into spreadsheets, creating and formatting charts, illustrating trends, and organizing appendices. OPC recognized that its staffing level demanded a more efficient and effective method for reporting. Additionally, OPC needed a method to immediately identify and review data that exceeded alarm levels.

III. SOLUTIONS USING NEW TECHNOLOGY

Advances in automated data collection and development of software for integrating geo-monitoring data from numerous sources offer solutions to the instrumentation challenges facing dam owners. The best examples of data management software provide a single platform that accepts and integrates data from multiple data sources including automated collection systems, operations data platforms, and manually collected data. And there is no reason to remain tethered to a desktop computer when current software and improvements in network security allow viewing of the entire project database in a web browser via the internet using portable devices.

The best practice for implementing an ADAS or data monitoring software platform is to first establish the design criteria. Questions such as what types of instruments will be monitored, will all or some of the data acquisition be automated, what telemetry is required for automated instruments, what additional monitoring will be required in the future, what alarm types and notifications are needed, and what viewing capability is needed should be asked and answered. The designer should consider re-using existing hardware that meets project requirements. OPC approached its system upgrade by defining the required system performance; working with their instrumentation consultant to design the data acquisition system, database management, and software interface; and scheduling the deployment to minimize instrument down time. The three main implementation phases were: 1) improvements to automated data acquisition equipment, 2) data management and presentation improvements, and 3) development of field applications for manually read instruments and custom annual instrumentation reporting templates. Phases one and two required integration and were implemented concurrently and phase three was implemented with the monitoring system in place and functional.

Outdated acquisition hardware at the Rocky Mountain plant was replaced with a combination of dataloggers and vibrating wire interfaces integrated with new multiplexers and radio/fiber optic communication devices to improve the performance of the ADAS. Transient voltage protection devices for defense against lightning damage were already in place, and OPC was able to successfully integrate this existing protection system into the new ADAS design. The installation was designed to allow for system expansion in the future and OPC has since added a weather station and seismic monitoring equipment.

OPC uses an integrated suite of software for datalogger programming, automated collection of data from the dataloggers, and database management. The software suite consists of a group of software applications, a database server, and a web client. Before configuring the software, a plan for organizing the various types of data, instrument naming, database normalization, and importing existing data was developed. The Rocky Mountain plant instrumentation database was then organized with hierarchical relationships that make data storage and viewing efficient. With the database organized, historical data from spreadsheets and other database systems was imported using tools included within the software. Owners in need of operational data such as headwater and tailwater elevations may link to another existing database and write scripts to acquire data from the shared source.

A challenge faced by OPC and shared by many dam owners is the difficulty of synchronizing automated and manually collected data. OPC deployed a mobile application to bridge the gap between data collection in the field and the hosted project database. This app runs on iOS or Android devices and is used by a field technician for performing a survey of instruments. Using a mobile device with the app configured and running, the technician visits each instrument location, scans the instruments Quick Response (QR) code to identify it, then manually takes a reading which is entered and saved to the mobile device. Along with data, notes or photographs may be recorded and saved along with the data point. Moving from instrument to instrument, the technician proceeds through the survey, saving data to the mobile device after each data entry (or at the end of the survey). The survey is finished by synchronizing the data, notes, and photos saved on the mobile device with the project database.

The mobile app allows seamless collection and storage of manually read instrumentation data, and has the additional advantage of allowing error identification in the field instead of in the office. The app will display the previous readings and will notify the user when the current reading is outside of the normal range of values. The field technician can then immediately take another reading instead of re-mobilizing to the instrument later for data verification.

With the ADAS developed and the database organized, OPC next moved to develop monitoring and reporting views and templates. The integrated monitoring software allows viewing of the entire project database in a web browser via the intranet (as well as the internet, subject to security requirements). It presents views in a number of layers, including instrument locations, alarm status, uploaded images and documents, as well as quick access to the associated output. The software features support for ArcGIS map server layers including satellite data overlays. Figure 1 shows an example project interface with drill downs for various types of instrument charts. OPC has found that a big advantage of its software interface architecture is the flexibility to create custom graphical interfaces that allow the viewing of data from different types of instruments in a general area. For example, if a vibrating wire piezometer in one of the dams has an abnormal reading, data charts from other nearby instruments, such as open standpipe piezometers or toe drain weirs, can easily be observed on the same graphical view.

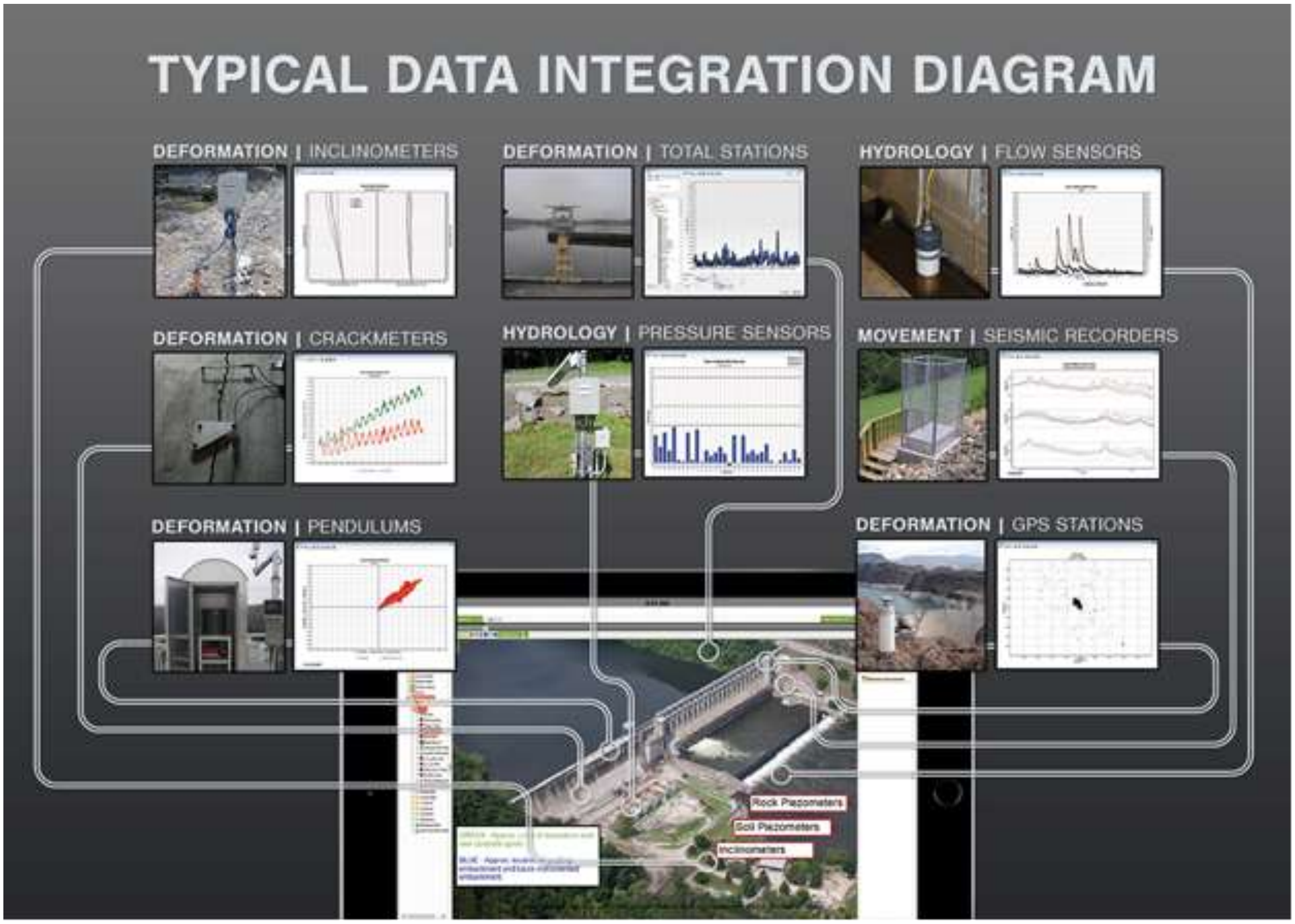

Figure 1. A typical software interface presents views in a number of layers, including instrument locations, alarm status, uploaded images and documents, as well as quick access to the associated output.

An important feature of data management software is the ability to set multiple levels of alarms for each instrument. For example, piezometers might be assigned alarms that correspond to piezometric elevations within an embankment correlating to slope stability factors of safety less than 1.5. Typical alarms are assigned based on high or low values or on rates of change. Notifications are configured to automatically alert assigned personnel by email or text when the alarm values are met or exceeded. The notification email can even be configured to include a chart or data report from the instrument. The user can then log into the system at the site or remotely to check dam instrumentation performance. Another key feature of OPC's system is an automated notification email with a predetermined output each time new data is added to the database. This provides a prompt to the engineer to double-check manual data entries for errors and to quickly check the ongoing performance of critical automated instruments.

OPC is required to provide a yearly summary report to the Federal Energy Regulatory Commission (FERC). Prior to system and software upgrades, OPC's annual report preparation was complex and time-consuming. A major feature of OPC's data management software is the ability to create report templates which can be re-used each time a report is needed. With the click of a button, OPC can now generate a comprehensive multi-page report that includes text, data charts, and pictures. Instead of spending days creating charts and collating appendix pages, the OPC engineers and geotechnical specialists can concentrate on identifying data trends and verifying dam performance. Report content and formatting is consistent from year to year and additional instrument charts are easily added to the template.

IV. CONCLUSION

Dam Safety instrumentation monitoring challenges, whether a fairly straightforward problem such as organizing historical data or a more complex issue like synching multiple automated and manually read data sources, can be surmounted. Advances in automated data collection and development of software for integrating geo-monitoring data offer solutions to these and many other instrumentation challenges. OPC provides a good example of using technology to optimize an instrumentation monitoring program for reliability, flexibility, and efficiency. Database management and reporting software offers obvious advantages for relatively complex systems such as the one at Rocky Mountain Hydroelectric Plant, but dam owners with simpler needs may also reap advantages. Mobile applications for recording manually read instruments and the ability to develop automated report templates make database management software attractive to owners with instrument inventories that may or may not include automated data acquisition. Technology that can be scaled to meet the individual dam owner's needs is recommended and available.

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Daryl Jordan has a combined 33 years of hydroelectric experience, mostly in operations. He has served for the last eight years as the Geotechnician/Geotechnical specialist for Oglethorpe Power Corporation at the Rocky Mountain Pumped Storage Facility in Rome, Ga. His responsibilities include instrumentation data collection, data review, facility inspection, generation of instrumentation reports, and operation and maintenance of the instrumentation system.

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Vann Newell earned his bachelor's and master's degrees in civil engineering from the University of Tennessee. He was with the Tennessee Valley Authority (TVA) for 32 years before retiring and joining Oglethorpe Power Corporation as the civil engineer for the Rocky Mountain Pumped Storage Facility in Rome, Ga. Dam safety was Mr. Newell's focus for much of his career at TVA and he has brought that experience to the Rocky Mountain facility for nearly seven years.