SCADA System Robustness and Accuracy: Looking Beyond the Hardware

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ABSTRACT
Modern, flexible irrigation service inherently results in more demanding operating conditions throughout an irrigation district's delivery system compared to more rigid rotational delivery schemes. Supervisory Control and Data Acquisition (SCADA) systems are commonly used by irrigation districts to provide some of the enhanced management capabilities required for flexible deliveries. In these cases, robustness and accuracy are important SCADA system characteristics.

Achieving robustness and accuracy requires extra attention to detail well beyond specifying good quality hardware. This paper presents specific examples deficiencies commonly identified by the authors in the field that can have real impacts on the robustness and accuracy of SCADA systems. Recommendations for improvement are also presented so that readers might avoid these issues in the future.

INTRODUCTION
Supervisory Control and Data Acquisition (SCADA) systems in irrigation district applications are generally implemented with the following basic capabilities:
1. Remote monitoring of dispersed infrastructure
2. Local automatic control of gates and/or pumps
3. Automated record keeping of key operational data

These capabilities are often supplementary to other modernization efforts. As defined in Burt (1996), modernization is a process of improving water delivery service flexibility, reliability and equity metrics through physical and managerial changes. Operating conditions become more demanding as irrigation district operations shift from rigid rotation deliveries to flexible frequencies, durations and flow rates. More specifically, hour-to-hour management throughout a water delivery system becomes necessary.

Measurement and control capabilities are fundamental prerequisites for management of most industrial processes, including irrigation water delivery systems. It follows that the quality of measurement and control impacts management performance. SCADA systems are typically used to improve performance, but they also bring new complexities when they are added to provide measurement and control functions.

While there are a number of different ways to implement SCADA, this paper focuses on "distributed" SCADA systems where the measurement, signal processing and control logic (when applicable) are executed locally at each SCADA site. Readers may also find this paper's contents applicable to other types of SCADA implementations.

SCADA PERFORMANCE METRICS

In the context of modernization, SCADA systems are expected to exhibit excellent performance under new and more demanding operating conditions. To more clearly characterize SCADA systems, the following performance metrics are presented:

1. Accuracy – The ability to report near real-time and historical data with minimal error
2. Robustness – The ability to continue an expected level of function or performance, both within and outside of, normal operating conditions.

Achieving good performance requires special attention to design and implementation details at each project stage, far beyond good hardware selection.

LOOKING BEYOND THE HARDWARE

As existing SCADA systems expand and new systems are installed, the following tend to occur:

1. Less frequent visits by field staff to SCADA sites, coupled with a growing dependence on the SCADA system for near real-time data and accurate records
2. An abrupt loss of confidence when the SCADA system fails, and sometimes a temporary decrease in the level of irrigation water delivery service

To avoid the negative impacts of unexpected failures and errors in reporting, SCADA systems must be designed to be robust and accurate.

Historically, attention was paid to identifying good-quality hardware because most instrumentation and control devices were initially designed for factory conditions that are less extreme than those found in the field. With relatively recent advances in instrumentation and other individual SCADA component technologies, finding good-quality hardware designed for outdoor, agricultural environments has become easier.

While good-quality hardware such as sensors and programmable logic controllers (PLC) are necessary, good-quality components alone are insufficient to provide a robust and accurate SCADA system. In fact, even with good-quality hardware, the authors continue to identify design and installation deficiencies that can contribute to frustration and real problems for SCADA owners. There are some common issues that even SCADA owners can be unaware of.

The remainder of this paper discusses some specific examples of minor installation deficiencies with potentially major impacts to SCADA system accuracy and robustness. Specific recommendations are also provided so that readers may avoid such problems altogether.

WATER LEVEL SENSOR PLACEMENT

Depending on the application, both the number of sensors and the precise location(s) of sensors are important considerations. Two examples are provided below.

Example 1 – Flow Measurement

The Parshall flume shown in Figure 1 is installed on the main canal in an irrigation district in New Mexico. The Parshall flume is frequently submerged downstream up to 90 percent (the downstream water depth is equal to 90 percent of the upstream water depth relative to the same datum). The site was originally fitted with only a single upstream ultrasonic level transducer and thus the SCADA system was incapable of considering downstream submergence in the computation of flow rate when downstream submergence influences accuracy.

Based on standard Parshall flume tables (USBR, 2001), a failure to consider downstream submergence results in flow measurement error between 5-55 percent of the actual flow for a flume about 8 feet wide. Even with a good-quality sensor, the outcome is performance with unacceptable accuracy.

After a field inspection, it was recommended to install the downstream sensor and adjust the internal PLC flow computation to account for submergence.

Figure 1. An existing Parshall flume that is frequently operated with downstream submergence in New Mexico. The initial installation omitted the downstream sensor. The downstream sensor was later added and the flow computation was adjusted to account for submergence when it occurs.

Recommendation. When implementing SCADA on hydraulic flow measurement structures it is critical to first understand and evaluate the structure before installing sensors. In many cases, physical improvements of flow measurement structures are required to achieve reasonably accurate flow measurements.

Example 2 – Automatic Upstream Water Level Control

Automatic upstream water level control is a common SCADA application. In this example, an upstream water level sensor was installed just upstream of the gate in a concrete block-out on a wing wall as shown in Figure 2.

Figure 2. Noticeable head loss at the entrance of an upstream controlled gate structure

While convenient, installing water level sensors within a contraction can be problematic if all of the following conditions exist:

1. The sensor(s) are used as an input for automatic upstream water level control
2. The potential head loss is significant
3. The upstream pool is operated with little to no freeboard, or there are gravity turnouts in the upstream pool that are relatively sensitive to canal water level fluctuations

In this case, the sensor was measuring the water level at the wrong location. As a result, the PLC would adjust the gate to maintain the water level at the measured location rather than the effective pool water level further upstream, as shown in Figure 3.

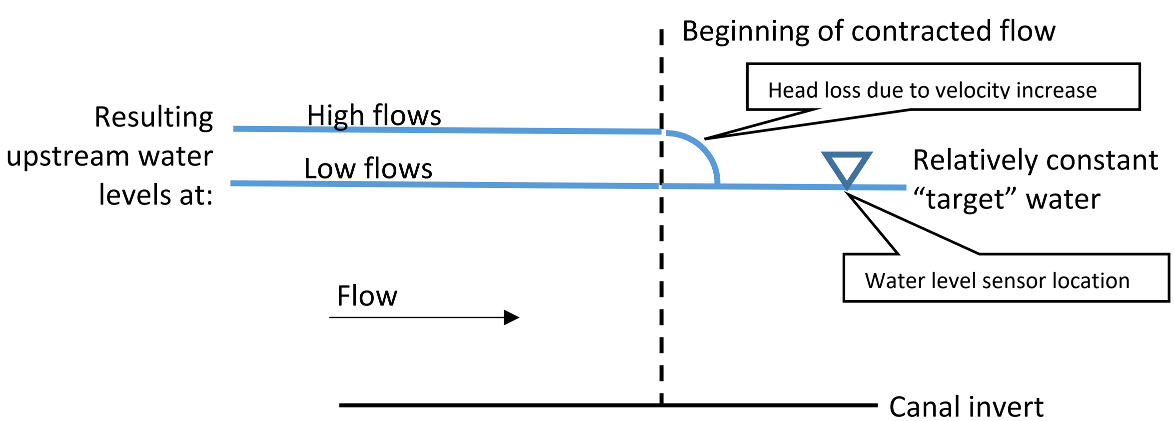

Figure 3. Potential fluctuations in the pool water level due to poor sensor location on a hypothetical automatic upstream control gate (profile view)

Recommendation. Installing the sensors upstream of the contraction will normally produce a more desirable result, as shown in Figure 4.

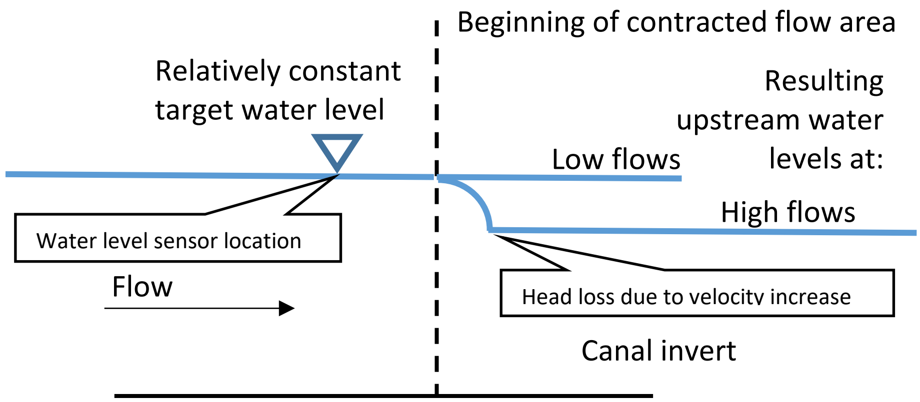

Figure 4. Improved water level control in the pool with a different water level sensor location, with the same amount of head loss due to increased water velocity at an automatic upstream control gate (profile view)

PHOTOVOLTAIC POWER SYSTEMS

Off-grid photovoltaic (PV) power systems are common in irrigation district SCADA systems when utility power is not available. With no shortage of good-quality commercial products, most PV problems experienced in the field are caused by under-sizing and less-than-ideal installation practices.

Installation

The example shown in Figure 5 illustrates opportunities for improvement. The solar panel, located in western Nevada, is installed in such a way that partial shading from the fence structure will occur on most days. Anand et al (2014) and others report substantial reductions in PV panel output (20-40%) with even minor shading. In fact, the relationship between the percent of panel area shaded and the percent reduction in PV panel output is not directly proportional.

Figure 5. Partial shading of a photovoltaic (PV) power system can be problematic and can sometimes be corrected with minor modifications. This PV panel in western Nevada is shaded most of the time by an adjacent fence structure.

Recommendations. When practical, shading of the PV panel should be completely avoided..

Under-Sizing of Components

Under-sized PV and battery systems are also commonly found in irrigation district SCADA systems. Common symptoms of undersized PV systems include low (2-4 year) lead-acid battery lifespans and frequent power failures. In addition to evaluating the possibility of decreasing the design load of the PV system, good designs are based on worst-case criteria, including the following major considerations:

1. Daily sun-hours change throughout the year, but a typical worst-case scenario is an extended, cloudy storm or perhaps even localized air particulates from forest fires and smog.
2. Most irrigation district PV power systems for SCADA sites are mounted on a fixed position bracket. Therefore, the PV panel will not be pointed in the optimum position most of the time.
3. PV panels are cleaned infrequently – meaning most of the time the panel will have some amount of dust and bird droppings on it.
4. PV panel output decreases with both higher ambient temperatures and age.
5. Battery capacities decrease with time and use. Furthermore, it is not uncommon to have the batteries sized to autonomously power a SCADA site without PV panel charging for multiple (2-5) days.

Recommendations. A variety of helpful literature is available from good-quality battery and PV panel manufacturers. Additionally, design standards for off-grid PV systems can be purchased from the Institute of Electrical and Electronics Engineers (IEEE). Specific standards publications include IEEE 937, 1013, 131 1526, and 1562.

RADIO TOWER GROUNDING AND BONDING

Radio antennas installed on 10 to 60 foot masts and towers are common solutions for SCADA communication at remote field sites. The authors routinely identify inadequate grounding and bonding at these radio tower sites. An example of a deficient 50 foot, aluminum self-supporting radio tower installation is shown in Figure 6.

Figure 6. The base of a 50-foot SCADA radio tower fitted with a single and undersized grounding conductor (seen in the lower right of the frame).

Proper grounding and bonding is important to minimize a number of important issues:
1. Human safety – good grounding practices are important for general worker safety
2. Radio frequency interference (RFI) and static discharge
3. Lightning protection

While these topics are well documented in academic and practical literature (NAB, 2011), the justification for good grounding and bonding practices beyond building code requirements for human safety may not be widely understood. In general, more advanced grounding practices than stipulated by building codes are required to minimize RFI and lightning strike issues, which can affect SCADA system robustness.

For example, in 2018 a direct lightning strike event in Poston, AZ resulted in a complete and catastrophic failure of all SCADA site equipment. Grounding practices at the site were similar to the installation shown in Figure 6. In the professional broadcasting sector, radio towers regularly experience direct lightning strikes without incident (NAB, 2011) – so it is clear that effective lightning protection is possible.

On the other hand, RFI and static discharge issues can be difficult to identify. However, if the grounding and bonding system is designed for lightning protection, it is more than likely adequate to mitigate both RFI/static discharge and human safety concerns.

Recommendations
Special design attention should be paid to grounding and bonding at SCADA radio sites to increase SCADA system robustness, above and beyond building code stipulations. Excellent standards and guides are available from associations such as IEEE and others. For the most critical SCADA sites, it may be worthwhile to contract with a specialized grounding and bonding engineer for technical assistance.

DISCUSSION

Robustness and accurate SCADA systems require extra attention to detail during both design and implementation phases of a SCADA project. Specific examples of commonly identified deficiencies and alternative recommendations for improvement have been provided. While numerous other examples of deficiencies could also have been provided, the authors' intent is to highlight the potential negative impacts of design and installation details that some may consider negligible.

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