Real Time Control of Sewers: US EPA Manual

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U.S. EPA will publish a manual on design and implementation of real time control (RTC) for managing wastewater conveyance networks. The intended audience is the practicing engineers who are considering RTC to enhance the operational aspects of their sewer networks.

Introduction and Definition

The problem of sewage spills and local flooding has traditionally been addressed by large scale capital improvement programs that focus on construction alternatives such as sewer separation or construction of storage facilities. The cost of such projects is often high, especially in older communities where the population density and the value of land is high. In the last few years, Real Time Control (RTC) of conveyance systems has been emerging as an attractive alternative. Although there are still only a few documented implementations of RTC to large urban sewerage systems, this technology has been successfully implemented to large urban systems. One of the goals of this Manual is to provide a guide to RTC technology and facilitate acceptance by the user community.

An RTC implementation includes several different aspects, including hydraulics, instrumentation, remote monitoring, process control, software development, mathematical modeling, organizational issues, and forecasting of rainfall or flows. Addressing each of these issues in detail would require a large document, beyond the scope of this manual. This manual is a broad introduction to these different issues, and the primary objective is to bring these different aspects into view, rather than elaborate on each of them extensively and in great detail.

The main goal of the RTC manual is to introduce RTC to practitioners who had had limited exposure to RTC in the past, and to make this technology more accessible and understandable.

One of the barriers to broader acceptance of RTC is an unfortunate perception that RTC systems are always complex. In a generally risk-averse culture of the public agencies, there is often reluctance to adopt the “bleeding edge” methodologies and tools. In recent years, the term “Real Time Control of Sewer Systems” has often been used to describe control systems that include system-wide (“global”) control rules, and may include such sophisticated components as linear optimization algorithms (Seattle, Hamilton, Quebec City). As some of these complex systems have been reported in the literature, for many in the wastewater industry the term “RTC” has somehow become synonymous with this type of complex system and application.

Therefore, when municipalities consider RTC, they might start from this narrow and specific interpretation of the term as implemented in a “global predictive optimal” configuration. Such a complex system is by no means always the best choice, and therefore a much more appropriate definition of an RTC system is:

A system that performs control actions (e.g., movement of gates, turning pumps on/off) in real time; RTC adjusts the operation of facilities in response to on-line measurements in the field. RTC requires dynamic adjustment of settings for the control elements, and thus the control elements must be capable of adjustments.

Historically, flows and levels in sewer systems used to be only manipulated by static facilities, e.g., weirs, that were not being adjusted in real time. RTC adds the dynamic component, where some of the facilities are actively adjusted in real time based on system conditions.

Possible Applications and Uses of RTC

An RTC system generally performs the following functions:

a. Collects information about the current state of the sewer network

b. Compares the current state of the sewer network with the desired state of the sewer network

c. Determines the settings for the control facilities that will bring the sewer network (closer) to the desired state

d. Implements the settings (determined in step c) into actions of the final control elements (e.g., gates, pumps, inflatable dams)

During the process of designing an RTC system, we must decide what the *desired state* (operational goals) of the sewer system will be. This, however, can be a bit tricky because we may have different operational goals that depend on the system state itself. For example, we may have different operational objectives (definitions and metrics for the “desired state”) during dry weather, in the middle of an intense storm, or during a security emergency.

Examples of operational goals include:

1. reducing or eliminating backups and street flooding

2. reducing or eliminating sanitary sewer overflows (SSOs)

3. reducing or eliminating combined sewer overflows (CSOs)

4. managing/reducing energy consumption

5. avoiding excessive sediment deposition in the sewers

6. managing flows during a planned (anticipated) system disturbance (e.g., major construction)

7. managing flows during an un-planned (not anticipated) system disturbance such as major equipment failure, or security related incidents

To view RTC as only “a way to reduce CSOs” is therefore a bit restricted view, because a well-designed RTC system may need to address a number of different operational goals at different times. Storm events that cause CSOs are not an everyday operational situations: in most cases, storms are “special conditions” that do not happen that frequently (how many times per month can we have a ten-year storm?).

RTC Components Overview

Overview of RTC components is provided below in Figure 1. Description of these components has been provided in a number of RTC publications, and different municipalities are at different points in the implementation of these components.

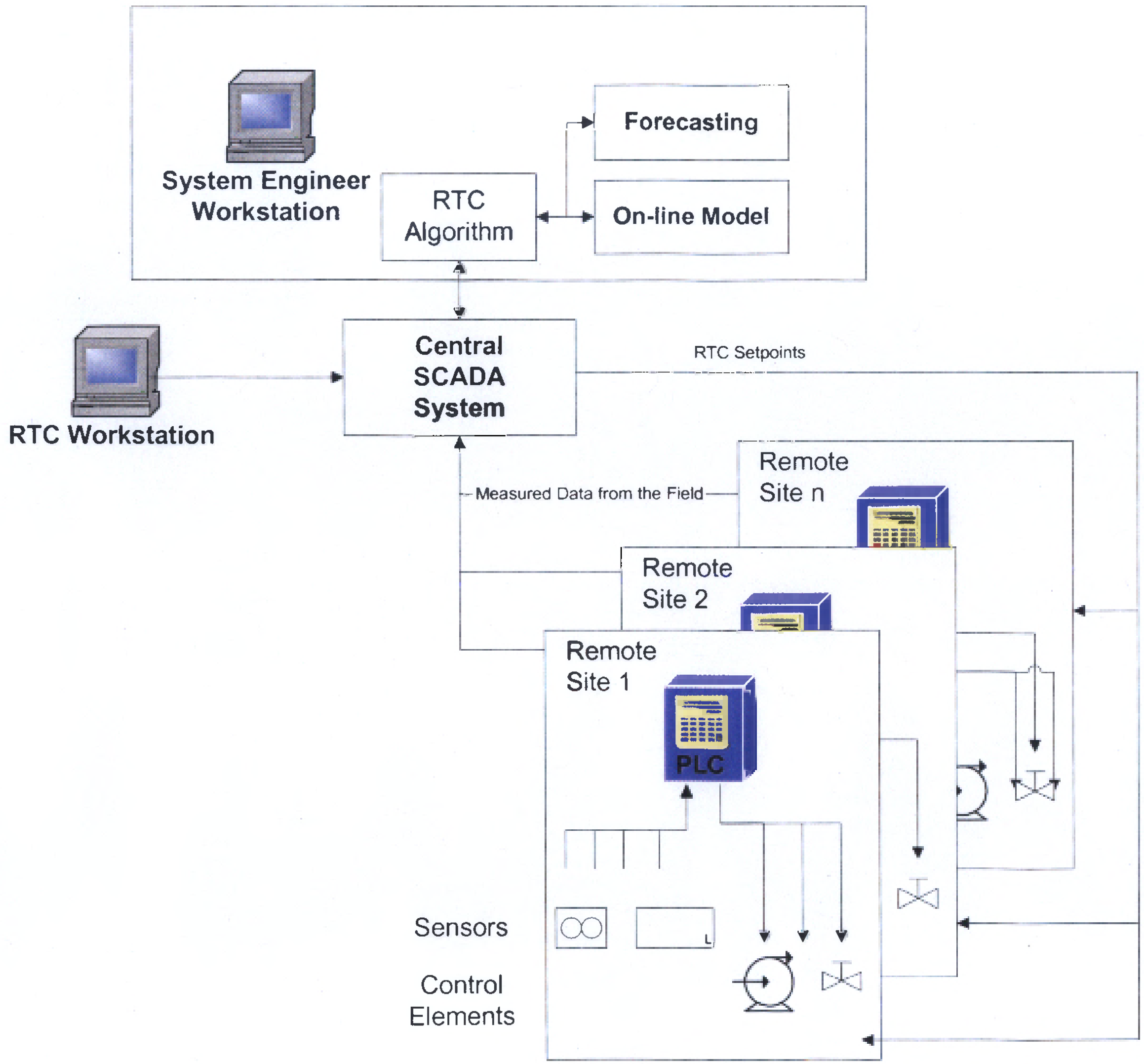

Figure 1. System overview of RTC Components

Measuring the Impact of RTC

In some collection systems, RTC systems can bring about positive impact and improve operation. However, measuring and reporting the benefit of RTC can be done in different ways and sometimes such claims need to be taken with a grain of salt. For example, huge savings may be sited as a result from RTC implementation, because savings from capital projects that might be delayed or declared unnecessary because of RTC. Such statistics may be deceiving, or inaccurately represent the role of RTC.

This can be shown on simple examples. Some agencies have been proactive and competent about managing both their operation and design, and therefore it is not simple to make a huge impact by introducing RTC. In such cases, both the design and the operation of the system infrastructure have been carefully adjusted through the years, and gross inefficiencies are not easy to find. If simply introducing RTC can result in huge savings, it might actually indicate that the agency is in very early stages of understanding how to manage their network, and that significant inefficiencies simply have not been noticed yet.

Managing Control Modes: Fail Safe Operation

Although RTC is increasingly accepted by municipalities, there is still some concern that automation may introduce additional risks. Therefore, it is necessary to structure the RTC systems in such a way that different modes can be handled properly and safely.

One of the complicating issues about RTC of sewer networks is that the operational goals change depending on the state of the sewer network. During dry weather, for example, the objective may be to minimize energy consumption, while during wet weather the most important goal may be to avoid overflows. Under all conditions, there are critical constraints such as safe operation, avoiding damage to the equipment, and avoiding flooding.

A well designed RTC system needs to effectively manage the different operational objectives and handle the transition between different operational modes in order to provide reliable and efficient operation. An important part of RTC is the management of transitional conditions and operational modes to avoid failure. A reasonable approach to this issue must (at a minimum) address two major categories of risk: failure of equipment, and emergency conditions caused by external factors.

Each control/operational level requires that some components of the overall system are functioning properly. The table below summarizes which components of the overall system have to work properly in order to support different control modes/levels.

Table 1. Components required for different control modes

Note: forecasting may be part of rule-based system, but is not mandatory.

The fail-safe procedures need to be configured so that they are triggered when the requirements for the current operational mode of the system cannot be met. The fail-safe procedures need to be designed to automatically place the system into the next (lower) mode/level of operation that can be fully supported by the current state of the system components.

For example, if the system is operating in the Local Automatic Control mode and the Programmable Local Controler (PLC) malfunctions or loses power, control would need to revert to Local Manual Control; if the system is operating in Regional Automatic Control, failure of the Supervisory Control and Data Acquisition (SCADA) system or the central server should automatically trip the system into Local Automatic Control etc. In case of Global Automatic Predictive control using the optimization algorithm, failure can happen due to problems in any one of the following components:

- sensors (flow meters, level sensors, rainfall gauges)
- PLC malfunction
- loss of communication
- SCADA failure
- Central server problems
- Errors or problems with forecasting
- on-line model failure or errors

Therefore, even if the ultimate goal is to execute a sophisticated control scheme such as global predictive optimization, it is a good idea to develop and test the "lower" levels of control that might need to provide backup in case of emergency or component failure. This layered approach can provide the most appropriate level of control for different conditions and helps to manage the overall risks.

Should RTC be Considered?

A number of municipalities have considered RTC in the recent past, or may be considering it now. The answer (whether RTC is the appropriate solution) is not always straightforward, and this section of the RTC Manual aims to provide some assistance to those municipal managers who are considering whether RTC will provide good value for their specific issues.

First of all, it is important to point out that there are no technological barriers to implementing RTC. RTC technology has been around for at least 20 years, and although RTC implementations remain relatively rare, there are several successful examples of implementation. The report by Schuetze, et al. aims to facilitate a greater acceptance of RTC by the municipal engineers and managers, and suggests a process for evaluating the applicability (suitability) of RTC technology to a specific case.

In practice, enthusiasm for RTC systems sometimes does not originate from those in the "operational front lines," who are directly involved in operations, and would be the primary users of the RTC system. In some cases, application of RTC is suggested from upper management, or from vendors and consultants who are engaged in the development and implementation of RTC.

Municipalities are often risk-averse, and in such environments new or advanced technology (including RTC) may be perceived with some concern. However, since the benefits of RTC can be significant, this Manual aims to demonstrate that this technology can bring such benefits without a great risk.

Apparently, there are still some barriers to broader implementation of RTC. Some of the remaining barriers are as follows:

1. General perception that RTC must always be a complex system, and thus concern about these systems being “fragile” or unreliable. Hopefully, this Manual will show that such concerns can be addressed, and that RTC scope can be adjusted to fit a site specific set of operational needs.

2. Most municipalities are concerned about legal exposure and issues related to regulation; if the sewer system does not include automation, and overflows occur, it is often seen as “act of God” since nothing could have been done. Therefore, the concern is that introducing automation and RTC may will open up “second guessing” and increase scrutiny about operations.

3. RTC is often seen as a complicated “computer project,” and there is general concern because Information Technology (IT) projects have earned a reputation for being late and over budget.

This manual cannot provide a single, simple recipe for overcoming all of the barriers, but it “demystifies” RTC, describes the components, presents a methodology for development, and includes a number of examples. Hopefully, the information provided herein will facilitate the acceptance of this promising technology.

It is also important to note that there are some cases (collection systems) where RTC can provide only very limited immediate benefits, at least in the short term. This could be the case, for example, if the collection system simply does not have any available in-line storage (i.e., if the pipes are close to full even during dry weather, there is little that RTC can do by itself). However, even in those cases, it is prudent to consider RTC during planning of future facilities (e.g., if they provide additional storage capacity).

Conclusions

RTC is gradually making strides to become a more common part of the collection network management. Methodologies for the development of RTC systems are increasingly being improved, and the technology is increasingly accepted by the operators.

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