Full-scale implementation of cloud-based sewer Model Predictive Control in Kolding, Denmark

Mise en place d'une solution 'Cloud' industrialisée de gestion dynamique et prédictive du système d'assainissement de Kolding, Danemark

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RÉSUMÉ

En juin 2011, le gestionnaire de l'eau et de l'assainissement de la municipalité de Kolding au Danemark (approx. 90.000 hab.) – BlueKolding – a mis en place un système de gestion dynamique globale – Sewerflex – des 19 bassins de rétention de son système d'assainissement unitaire (Nielsen et al. 2010). L'objectif était de réduire les déversements au milieu récepteur, minimiser le risque d'inondation en ville et en même temps limiter l'investissement nécessaire en volumes supplémentaires de stockage de 5,000 m^3 à 2,000 m^3 en maintenant le même niveau de service. Ce système fonctionne avec succès depuis 7 ans. Cette réussite a récemment conduit BlueKolding à passer à l'étape suivante avec l'introduction d'une solution 'Cloud' de gestion dynamique globale et prédictive s'appuyant sur une modélisation en temps réel. Le but de cette nouvelle étape est de réduire d'avantage le nombre de déversement (Jess 2018), de faciliter la mise en place et la calibration de nouveaux points de contrôle, d'assurer la maintenance du système, et de préparer les développements futurs. Le développement de la partie prédictive de Sewerflex a été initiée en 2018 et devrait être opérationnelle à l'été 2019.

ABSTRACT

In June 2011, BlueKolding utility in Kolding, Denmark (pop. approx. 90.000) implemented global real time control (RTC) Sewerflex in 19 basins in the combined sewer network. The objective of this implementation was to reduce combined sewer overflows (CSO), minimize the risk of flooding in the city and at the same time reduce the needed extension of basin volume from 5,000 m^3 to just 2,000 m^3 to fulfill the demands and maintain the same level of service. This system has now been running and operated with success for 7 years. BlueKolding has decided to take the next step and introduce cloud-based model predictive control (MPC) in the system (Jess 2018). The goal of this is to further reduce CSO's in the system, make it easier to implement and calibrate new control points, maintain the system and prepare for future developments. The Sewerflex MPC upgrade was started in 2018 and will be operational in the summer 2019.

KEYWORDS

Algorithm; cloud; CSO; MPC; retention basin

Algorithme; cloud; déversement; gestion dynamique et predictive; bassins de stockage

1 INTRODUCTION

The control algorithm used in BlueKolding, was developed in its original form during the Storm- and Wastewater Informatics project, 2008-2013 (Vezzaro and Grum, 2012; Vezzaro et. al., 2013). Since then it has been tested online (Frier et al., 2013) and gone through several upgrades, which have applied more robustness into the algorithm and made the way for easier implementation. The updated cloud-based control algorithm in Sewerflex, is now part of AQUAVISTA™, Veolia Water Technologies' global digital offer for real-time performance optimization of water treatment facilities.

2 METHODS

2.1 The Sewerflex MPC routine

The Sewerflex MPC routine is performing a coordinated "smart" usage of the retention basin volumes in order to minimize combined sewer overflows (CSO's). The control strategy is based on a dynamic risk assessment where the risk of overflow is calculated for every retention basin every 5 minutes, based on:

- Actual retention basin filling and total retention basin volume
- Predicted runoff volume from dry weather- and rainfall forecast (optional)
- The relative cost due to overflow (depending on i.e. recipient sensitivity)
- Possible hydraulic emptying capacity of the retention basin equivalent to fixed gate position and/or pump operation
- The actual hydraulic capacity of the downstream waste water treatment plant (WWTP)

Using a simplified model of the sewer system (Figure 1) together with the genetic optimization algorithm, the total overflow risk (all retention basins combined), is minimized, by changing the emptying capacities of the retention basins. The simplified model contains the retention basins, the catchment to the retention basins, the sewer connections between the retention basins and a downstream boundary (the wastewater treatment plant).

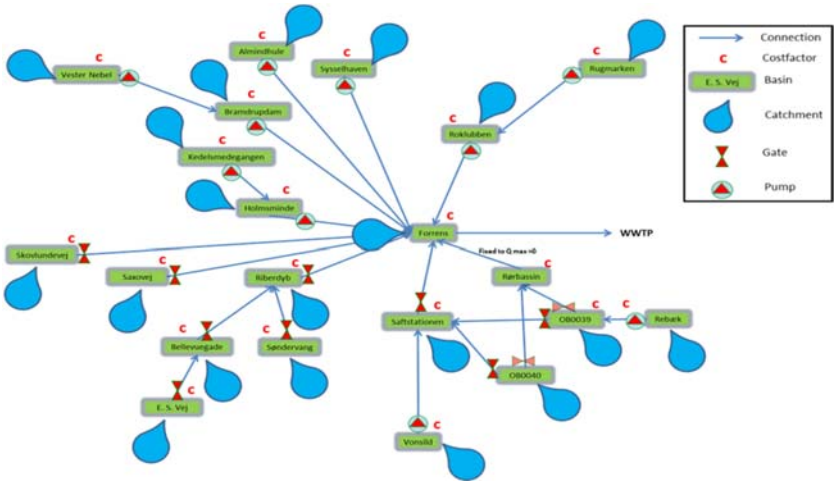

Figure 1: Sewerflex MPC model of the sewer system in Kolding.

By using a relative cost for overflow [cost/m^3] at each location, the optimal solution - predicted optimal flows in connections between retention basins - takes into account which retention basins are more "expensive" to use than others. This will try to locate any un-avoidable combined sewer overflows at "low cost" locations – being the most environmentally robust locations. These settings can be changed at any time by the operator, allowing different CSO priority during the year to prioritize eg. bathing waters and beaches in the summer time.

The identified set of predicted optimal flows (setpoints) between retention basins are carried out using

on/off pump operation and predefined gate positions. The setpoints are presented in an intuitive user interface (SewerView).

3 FULL SCALE IMPLEMENTATION

The implementation at BlueKolding is made in 3 steps, each step adding knowledge to the overall performance of the system; test environment setup -> offline cloud operation -> online cloud operation.

3.1 Setup of test environment

As the first step in the implementation, Sewerflex performance is being evaluated from a number of rain events, in an offline test environment where the MPC interacts with a hydraulic model representing the sewer network of Kolding. A schematic representation on how the test environment calculates setpoints and interacts with the model is shown in Figure 2.

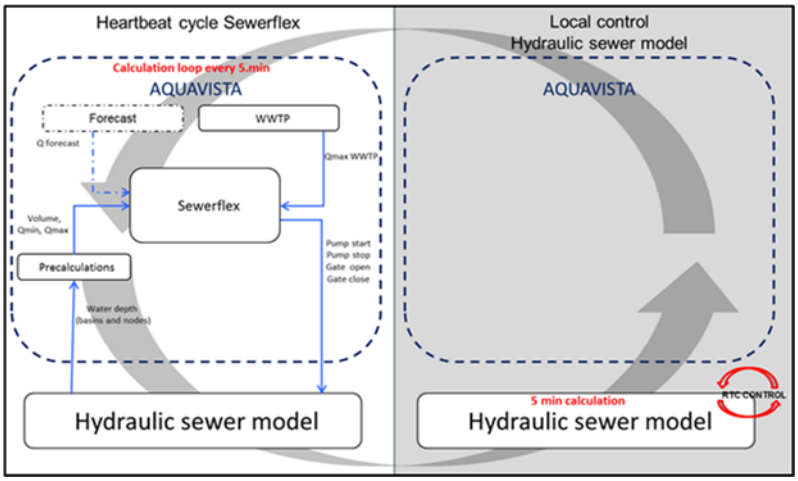

Figure 2: The Sewerflex MPC test environment. Every 5 min the hydraulic sewer model (to the right) is paused in order to extract water depths from the model. These are used to calculate inputs for the Sewerflex MPC. When setpoints have been calculated by Sewerflex (to the left) they are sent back into the hydraulic sewer model and the calculation continues for another 5 min.

Performance of Sewerflex MPC is evaluated based on stability of calculated setpoints and from calculated CSO volumes compared to similar calculations based on the current Sewerflex RTC implemented in Kolding.

3.2 Off- and online cloud operation

Following the test environment, the algorithm will be launched in “offline cloud mode”, meaning live visualization but no optimisation of the sewer network. This phase of the project will allow for everyone to feel comfortable with the informations given before online operation. The online operation is expected to be carried out in steps, allowing a slow transformation from the current online control to the cloud based algorithm. The current RTC control will be kept as a fallback strategy for control safety reasons.

The design of the user interface (UI) has been created with inputs from both operators and hydraulic specialists from BlueKolding in order to make the user interface show relevant information, be intuitive and easy to use. The design is not finished yet, but Figure 3 indicates the current state of information.

In the beginning, the algorithm will run as “reactive”, based on measurements from the system, thereafter upgrading with weather forecast information to allow “proactive” control, where the algorithm can prepare the sewer network for future rain events before they occur (Water Smart Cities 2016).

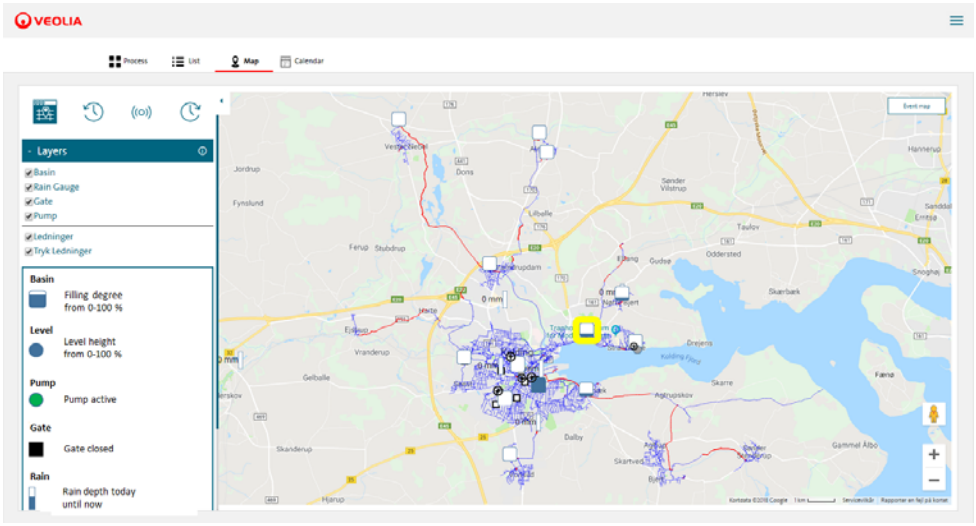

Figure 3: Basic live view of the sewer network (SewerView). In yellow marking the control algorithm indicates a possible overflow within the forecast horizon at a basin in the northern part of the sewer network.

As default, the SewerView map gives basic live information about the state of the sewer network. After each rain event, a report will be available to present key data (rain amount, cloud burst, overflow etc.). When adding Sewerflex MPC, an extra layer of information is included, to inform about the locations being optimized by the algorithm and which locations are in the risk of having an overflow in the near future. This is also illustrated using SewerView in Figure 3.

A presentation at the conference may include more information about the implementation.

3.3 Further upgrades

The downstream WWTP is also upgraded to a cloud based real-time performance optimization using AQUAVISTA™ Plant, thereby achieving a holistic solution of a full optimized waste water system.

In dry weather, an ongoing development project (2017-2020) called “BlueGrid” will, among other things, add the functionality of flexible power consumption using demand/response at both the WWTP and sewer network, thereby achieving a flexible “all weather optimization” which minimizes CSO during rain events and reduces costs for power consumption during dry weather (BlueGrid 2017).

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