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A stochastic MPC framework for the control of pumping stations in polder systems with regard for uncertainty in inflow and hourly electricity prices

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The Netherlands is a low-lying country situated in the Rhine-Meuse delta. A significant portion of the Netherlands is located below sea level, making the proper management of local and national waterways essential. Polders are used to manage groundwater levels, drain excess rainwater, and store water during times of drought. These polders often have pumping stations that pump water into drainage canals, like the Noordzeekanaal-Amsterdam-Rijnkanaal (NZK-ARK), which receives water from the Rhine river and four local water authorities and connects to the North Sea at IJmuiden through a pumping station and a series of undershot gates.

The operators of the NZK-ARK utilize Model Predictive Control (MPC) to schedule the discharge of water through the gates and pumps. The combination of the pump and gate discharge allows the NZK-ARK to discharge excess water to the North Sea when the sea water level is both higher and lower than the water level in the canal. However, traditional MPC can lead to suboptimal schedules when uncertainty is introduced, resulting from, for example, incoming discharge, fluctuating electricity prices, and the availability of renewable energy. Stochastic MPC allows for the consideration of uncertainty in decision-making, optimizing control actions based on a range of potential scenarios. In the future, the objectives for the control system of the gates and pumps may become more complex and may need to take into account factors like renewable energy availability and electricity prices. Ensuring the effective and efficient management of water in the Netherlands is critical, and the use of polders for water storage and control of groundwater tables, and techniques like MPC and stochastic MPC play important roles in achieving this goal.

In this study, we present a framework that combines probabilistic forecasting, scenario generation and reduction, and stochastic MPC to minimize energy costs associated with pumping at the NZK-ARK. This framework is based on probabilistic forecasts of electricity prices and incoming discharge and is specifically designed for use at the NZK-ARK. By considering the uncertainty present in electricity prices and incoming discharge, our framework allows for the optimization of control actions through the use of stochastic MPC. The ultimate goal of this approach is to reduce energy costs at the NZK-ARK by effectively managing the discharge of water through the pumps and gates while complying with local constraints.