Participation in demand response (DR) has been explored for many large energy-using assets based on day ahead electricity markets. In this manuscript, we propose the use of multiple electricity spot markets to enable price-based DR for open canal systems in the Netherlands, where many large pumping stations are used for flood mitigation and control of groundwater levels. In the new strategy for pump-scheduling, we combine the day ahead and intraday electricity markets to be used in a hierarchical receding horizon economic Model Predictive Control (MPC). We formulate the decision problem as a Mixed-Integer Quadratic Problem (MIQP), to be solved to near global optimality. A cost-potential analysis was performed for multiple market strategies and the automatic Frequency Restoration Reserves (aFRRs), using actual market and water system data. We show new insights into the trade-off between CO2 emissions and operating cost, the difference between the German and Dutch markets, and temporal changes in market conditions due to renewable energy integration. We observe that the German energy market is rewarding DR more than the Dutch equivalent, due to the higher renewable energy market penetration. The proposed multi-market strategy leads to a cost decrease of 10 and 16% in the Netherlands in 2017 and 2019, respectively. When applying German market scenarios, we found a cost-saving potential of 56 and 50% in 2017 and 2019, respectively. The cost-saving potential for the aFRR market was found to be up to 12% in the Netherlands and 28% in Germany, through a conservative analysis. The results suggest that the proposed control system, optimizing costs over the day ahead, intraday and possibly the aFRR markets, is profitable compared to the current strategy in both the current and future electricity market.

Keywords: Demand Response, electricity markets, open canal systems, pump-scheduling, water resource management

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