Scheduling Demand Response on the French Spot Power Market for Water Distribution Systems by Optimizing the Pump Scheduling

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1 Introduction

The control of peak electricity demand is more and more important in a context of massive integration of renewable energies and some new uses of electricity: electric vehicles, heat pumps, etc. Balancing in real time load and generation is a difficult task for Transmission System Operators (TSO) because they are facing several uncertainties: weather change, unavailability of production plants, network congestions, etc. In France, electricity consumption is highly driven by weather conditions, especially in winters because of the preponderance of electric heating in households. In cold winters, a decrease of 1 degree Celsius of temperature implies an increase of 2300 MW of electricity demand, it is the Thermo-Sensibility phenomenon. The peak of consumption occurred on the 08^{th} February 2012, estimated to 102 GW at 7 pm, alerted the French TSO RTE (Réseau Transport d'Electricité), and showed the need to develop efficient methods for the active management of demand. Demand Response (DR), defined as the change in the power consumption of an electric utility customer in response to a given signal, brings flexibility to the electric grid by adapting consumption to production. Industrial processes are believed to be the best candidates for Demand Response, especially those with storage units: warehouse, electric batteries. They can adapt their energy consumption to the needs of the electric network, in return for remuneration. Water systems, thanks to reservoir storage and pipe transfer capacities, are electrically flexible industrial processes that can contribute to balance the electric grid, allowing electricity production with low greenhouse gas emissions.

In this talk, we present the opportunities and constraints for water systems to participate in efficient Demand Response mechanisms in France, providing flexibility for

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the electric grid by reducing peak consumptions. We evaluate the economic benefits for water utilities for optimizing pump scheduling and Demand Response trading operations on the French spot power market (NEBEF Mechanism), under time of use (ToU) electric contracts. We formulate the problem as a non-linear mixed integer optimization problem, and propose a linearization approach to make it tractable. Then, we solve the problem using a branch and bound algorithm for a range of water demand scenarios and electricity prices on the French spot market. Using a real water system in France, the financial reliability of the NEBEF Demand Response mechanism is shown to allow for up to 50% of savings on the total energy bill.

2 Context and Objective

The NEBEF mechanism is applicable since April 2016 in France. It allows to sell energy curtailment of an energy consumer, called a DR bloc, in day ahead on the spot market via a DR operator. The DR bloc is sold at the market price, which is the intersection of the supply and the demand curves. The DR operator must then compensate financially the supplier of the site with energy curtailment for the energy injected into the network and valued by the DR operator on the market [1]. The amount of compensation is regulated and depends on the type of the day: season, time, working or non-working days. The final incentive for the DR operator is the difference between the spot price and the compensation. Since it is a recent mechanism, no study has been carried out in this field to our knowledge. Furthermore, France is the only country in Europe to allow DR to participate directly to Day Ahead (D-1) markets as a resource [2]. However, some authors have been interested in water systems and their participation to some other DR mechanisms around the world: Demand Response and water distribution systems in UK [3], Demand Response in California Agricultural Irrigation [4]. These studies present the design of the local Demand Response Markets, and evaluate the potential, the benefits and the constraints for water systems to take part of these markets.

In this talk, we formalize the optimization problem resulting in participation of water systems in the Demand Response NEBEF mechanism. We model Demand Response in the objective cost function of a water utility aiming at:

1. minimizing the total electricity cost due to pumping operations (*) ;
2. maximizing the revenues earned from trading DR blocs on the spot market (**) ;
3. respecting all the physical and operational constraints of the water distribution system;
4. respecting all the NEBEF constraints as described by RTE [5].

3 Mathematical formulation

We denote by :

1. $x_{i,t}$: the binary variable indicating the state of the pump i at time t.
2. $C_{i,t}$: the electric cost when pump i in ON at time t.

3. d_t: the binary variable indicating if we participate in the spot market at time t or not.

4. $P_{dr,t}$: the electric power (DR bloc) put on sale at time t.

5. r_t: the market spot price at time t (in €/ MWh).

We write the objective function ensuring (*) and (**) as follows:

$$\min_{x_{i,t}, d_t, P_{dr,t}} \sum_{i,t} C_{i,t} * x_{i,t} - P_{dr,t} * d_t * r_t \ .$$

The objective function aims at making, for each step time t, a trade-off between electric consumption by activation of pumps, and energy curtailment by selling the energy not consumed on the spot market in day ahead.

In this talk, we will first deal with the modeling aspect of the NEBEF constraints: minimum DR blocs per event, shape of the load curve for a DR event, maximum duration of an event, etc. Then, a mathematical approach will be proposed to linearize some of these constraints and the second term of the objective function. We will use a branch and bound algorithm to solve the optimization problem for a range of water demand and electricity price scenarios. The model has been tested on a real network composed of more than 120 pumps and 70 storages. The numerical results show that the NEBEF mechanism is the most reliable in winter for both the water utility and the electric grid, between 18:00 and 20:00:

1. the DR blocs are the most profitable for the water utility in terms of economic gain: 3% to more than 50% of gain compared to the normal optimal pump planning, according to scenarios;

2. 10 to 15 MW of peak power demand reduction per DR event, which corresponds to 7 to 10 Kg of CO_2 emissions avoided per event.

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