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Impacts of direct load control on reinforcement costs in distribution networks

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ABSTRACT

Based on the GreenLys Smart Grid experiment taking place in the cities of Grenoble and Lyon (France), this paper presents a quantitative method to evaluate the benefits of load control for the reinforcement costs of distribution networks. Preliminary results of this experimentation have led authors to develop a linear model that estimates the modification of electric demand caused by direct load control. The impact of demand control on the distribution network reinforcement costs is further discussed. The developed approach highlights the reinforcement costs savings potential of direct load control for urban areas.

1. Introduction

This study has been conducted within the GreenLys project, one of the largest Smart Grid in situ pilot project in France with a budget of 43 M€. It aims at experimenting new technological options in the cities of Lyon and Grenoble while involving most of the stakeholders of the electrical energy chain: Transmission System Operator (TSO), Distribution System Operators (DSO), suppliers, technology providers, universities, research and development (R&D) centers, end-users, local communities, and producers associations. By gathering all stakeholders of the electric system, this full scale demonstrator foreshadows the technologies that could be deployed in future smart grids (self-healing protection scheme, advanced MV/LV transformers, ...). Load control, in particular, was tested on real residential customers. Based on the feedback from these field experiments, a cost–benefit analysis has been performed. According to the framework proposed by the Joint Research Centre of the European Commission [1], the costs and the benefits have been separately assessed, as can be seen in Fig. 1. This paper focuses on determining the benefits of consumers' flexibilities in the distribution networks investments. The economic relevance of direct load control will be later addressed by comparing its benefits to the additional costs.

Distribution networks are designed to meet the power demand while ensuring security and quality requirements [2]. Therefore, by enabling the adaptation of the power demand to the DSO's requirements, direct load control claims to be an opportunity to differ or even to avoid some reinforcements in distribution networks [3,4]. Nevertheless, although many supportive policies [5,6] have already been issued concerning load control, its impacts on distribution networks reinforcement still need to be accurately quantified and evaluated [7].

Many scientific publications have proposed methods concerning optimal direct load control strategies. Some of these aim to reduce the operational costs of the electric system [8–13]. Other methods focus on minimizing the peak demand [14–19]. Nevertheless, few recent scientific studies that have explicitly discussed the impact of direct load control on the investments planning strategy of a DSO [20]. The purpose of this paper is precisely to develop a novel and generic method that quantifies the optimal benefits of direct load control on distribution network reinforcement costs. In this study, the regulatory context will remain out of the scope of this investigation.

The proposed method is based on the assessment of the impact of direct load control on the power demand of HV/MV substations.

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Fig. 1. General framework of the cost benefit analysis performed in GreenLys and developed by the European Commission [1].

The estimation of the consumers' flexibility potential depends on the:

- Amount of power that is consumed by loads that could potentially be controlled (domestic hot water, heating systems and air-conditioning systems)
- Deployment of the equipment that enables the control of a portion of theses loads. In the presented paper, the costs of using consumers' flexibilities will not be discussed.

Fig. 2 presents the power curves of each of these flexibility means within the global electricity demand of an HV/MV substation.

In order to quantify the investment savings linked to the distribution network reinforcement, three questions must be addressed:

- How does load control modify power demand?
- How do such demand changes impact network reinforcement needs?
- What is the optimal control strategy to minimize reinforcement costs?

The first part of this paper is devoted to the description of the field experiment that led to develop the proposed approach. Based

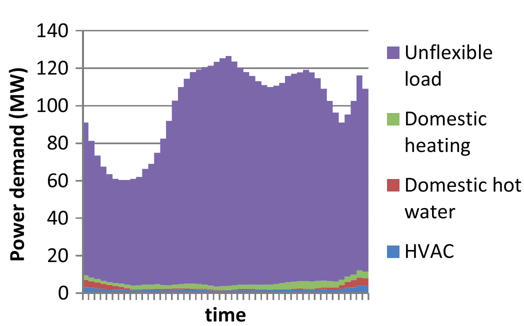

Fig. 2. Illustration of the flexibility potential on a HV/MV substation during a winter day.

on the experimental feedback, the load control model design will be explained: namely physical limitations as well as contractual requirements that need to be taken into account. Furthermore, the method used to evaluate reinforcement needs is discussed and the notion of optimal load control strategy is defined. In the last section, simulation results are presented and discussed.

2. GreenLys experimentation

The GreenLys project is a full scale experiment aiming to involve 1000 residential and 40 tertiary consumers in the cities of Lyon and Grenoble. To do so, an IT infrastructure has been built to test the direct load control system that has been considered in this study. Fig. 3 presents the two-way communication system that collects the load consumption and transmits the load control signals from a remote operating platform to the loads. The deployed components depend on the pre-existing equipment on the consumption site. Therefore, specific IT architecture is designed depending on the type of consumer, residential or commercial.

Currently, all commercial sites involved in the GreenLys experiment were previously equipped with a Building Management System (BMS). The BMS supervises flexible loads. The additional functionalities required to communicate with the operating platform could have been achieved in many different ways. However it has been chosen to add automation servers that are able to communicate with the BMS through open standard protocols and connect to the operating platform using the commercial consumer's VLAN or a specific 3G+ connexion. This choice has considered a compromise between the:

- *Cost of the solution*. The reprogramming of the pre-existing BMS software appeared to be extremely expensive. A turnkey solution is currently searched to decrease the installation costs.
- *Adaptability of the architecture* to the heterogeneity of the consumer sites. The withheld solution can be easily adapted to any site that is not equipped with BMS. In such cases, additional relays will be needed. Besides an existing ADSL connexion could be used without any major change in the IT architecture.
- *Reversibility of the solution*. It ensures the possibility for consumers to recover their initial installation at any time.
- *Compatibility with commercial consumers' security concerns*. The solution has to fit with the security requirements of each consumer site. The security policy may vary from one site to another.

On the contrary, the residential consumers involved in the experimentation were not previously equipped with home automation. Therefore, the flexible loads needed to be equipped with relays. These relays were able to collect the consumption information of the associated load while transmitting the control signals from the Home controller of the consumer sites. This additional component has been designed to use the pre-existing ADSL connexion to communicate in HTTP format with a server that aggregates the data from each residential load. The residential load control operating platform was implemented on a dedicated server. The choice of this architecture has been motivated by the:

- *Range of embedded services* for the benefits of the consumers. In addition to direct load control, the home controller can be used by involved residential consumers to programme or schedule their consumptions.
- *Modularity of the solution*. The deployed architecture can be potentially completed by additional equipment to provide other services (in home display, consumption monitoring, . . .)