Analysis of a Residential Distribution System with the Application of Conservation Voltage Reduction at House Level

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***Abstract*—With the advancement of communication technologies and big data concept, the conventional grid has been transformed to a smart grid. The smart grid concept provides two-way information flow and dynamic control of the generation and consumption is possible through this information exchange. Within the smart grid, residential customers can also become smart and can be treated as an active demand. Thus, demand response algorithms-such as load shifting, load shedding- are being used to control the residential demand. Recently, the conservation voltage reduction (CVR), which is mainly used at distribution system level, has emerged as another way of demand response application at house level. In this study, the effect of the CVR at house level on a residential distribution system power demand and distribution losses are analyzed for a system with 14 houses. ZIP models of common residential appliances are used to obtain MATLAB/Simulink model of the house level CVR application. Obtained results show that the power demand is reduced by about 20% and the distribution losses is reduced by about 35% when the CVR is applied at house level as a demand response method.**

Keywords*—*Smart home, demand response, CVR at house level, residential distribution system

I. Introduction

'Smart Grid' is an intelligent electrical network that integrates the actions of all connected users and uses advanced information, control and communication technologies to control both the demand and the generation to save energy, reduce cost, and increase reliability [1]. In the smart grid infrastructure, utility companies are exploring Demand-Side Management (DSM) technology to control power consumption on the customer side [2]-[5]. On the demand side, the electricity energy consumed in houses has considerable proportion when compared to total electric power consumption. For instance; in the United States the electrical energy used by residential sector is about 38% [6]. Therefore, more efficient energy use can be achieved by controlling residential electricity consumption. The easy and efficient solution for controlling household electrical energy consumption is to create home energy management systems that can communicate with the smart grid. In Home Energy Management (HEM) systems, the appliances are usually classified as controllable/uncontrollable appliances [3]. Thus load shifting, load shedding and control of the time of use are employed to control the household demand. Although CVR studies are often discussed centrally on distribution systems [7-13], it has been recently used to control the residential power demand. The CVR has been first proposed for improved efficiency of distribution networks by controlling the voltage magnitude at the distribution transformer level so that the power consumption can be reduced based on the relationship between the applied voltage and consumed power. In [14], it is shown that the power consumption of most household appliances can be reduced with the house level CVR and a new Home Energy Management (HEM) algorithm has been proposed for smart homes to reduce peak demand and increase energy efficiency. The experimental results showed that, the proposed HEM algorithm reduces house peak demand by 17.5% with only the voltage control, and 38% with both voltage control and appliance shifting. In [15], a smart transformer design is given for the voltage-controlled HEM system. The applicability of the developed smart transformer structure has been experimentally demonstrated in the Smart Home Laboratory. In [16], a smart plug design that can control the voltage across the plugged appliance with the expense of line current harmonics is given.

With the smart grid concept, each house can be treated as a controllable load by means of communication technologies and the voltage at the house entrance can be dynamically controlled through a smart transformer during the demand response period. The smart transformer could be a power electronics based circuit design [17] or a conventional transformer with taps on the secondary side so that the output AC voltage magnitude can be adjusted based on a control signal. The CVR at the house level can be initiated based on a signal from a utility or based on a threshold limit determined by the customer. It could also be implemented in an autonomous way with a signed agreement between the utility and the residential customer.

This study covers the application of the CVR at the house level and analyzes the effect of such application on the residential distribution system power demand and losses using ZIP models of common house appliances. The considered residential distribution system includes 14 houses with same appliances, whose power consumptions can be reduced with the CVR at the house level. Then, results are compared with the normal operation of the distribution system with no CVR.

This paper is organized as follows: In section II, ZIP models of residential appliances are given. In Section III, simulation study is completed in MATLAB/Simulink and results are summarized for the CVR at house level and no-CVR cases. Section IV, concludes the paper.

II. Load Modeling

Load models are mathematical functions that explains the relationship between active/reactive power and generally

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