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Energy Procedia 105 (2017) 2227 – 2232

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

Feasibility of peer-to-peer energy trading in low voltage electrical distribution networks

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Abstract

Peer-to-peer (P2P) energy trading is referred to as flexible energy trades between peers, where the excessive energy from many small-scale Distributed Energy Resources (DERs) including those in dwellings, offices, factories, etc., is traded among local customers. To assess the feasibility of P2P energy trading, where local electricity demand and supply balancing is desired, a so-called P2P index was developed. By clustering the historical smart metering data using the *k*-means method, customers were categorized by their electricity consumption patterns and representative demand profiles of low voltage electrical distribution networks were produced. A linear programming optimization was carried out to find the optimal capacity of different DERs to maximize the local demand and supply balancing. PV systems and combined heat and power units were considered as the renewable resources. This work provides network planners with guidelines of appropriate shares of DERs for better constructing their future networks, and facilitates a P2P energy trading market paradigm.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

Keywords: Peer-to-Peer energy trading, demand and supply balance, PV system, Combine Heat and Power, optimization

1. Introduction

Existing electrical energy systems were designed and built to accommodate large-scale generating plants, with demand traditionally considered as uncontrollable and inflexible, and with centrally controlled operation and management. Recently, there has been a revival of interest in connecting Distributed Energy Resources (DERs) to distribution networks, and microgeneration and flexible loads at the premises of end users. DERs suffer from the issues of uncertain availability due to varying weather conditions. Flexible loads are not currently utilized for balancing local generation. Thus, a challenge for the Distribution System Operators (DSOs) to provide a secure network to meet peak demand, and to

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Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.632

move to more active DSO roles with new business models, is increasingly critical. However the current changes cannot be effectively implemented within the existing technical schemes and market frameworks, and may result in a degradation of economic and environmental performance. There is a vital challenge to the DSOs, and new business models are essentials for their survival under this energy revolution.

A large penetration of DERs also creates operational problems in distribution networks. For effective operation of the distribution networks, different approaches are being considered. One approach would be to break the network into smaller entities such as Microgrids and CELLs [1]. These investigations of Microgrids, CELLs, etc. were mainly focused on the technical issues. However the challenges that DSOs are facing with the energy revolution were not fully addressed. Radical decentralised systems and regional market solutions are clearly required to bring the end users and DSOs at the heart of system operation, and to provide effective technical and new market arrangement and business models for DSOs.

Peer-to-Peer (P2P) energy trading might be a way forward to provide these market and technical solutions. P2P energy trading is defined as flexible energy trades between peers, where the excessive energy from many small-scale DERs is traded among local customers. Recently, some work has already been carried out on the P2P concept of trading local energy resources with other customers. Several projects, such as "Piclo" in the UK [2], "Vandebron" in Netherland [3], and "SonnonCommunity" in Germany [4] each proposed a possible business model for P2P energy trading considering from suppliers' perspective. However, it would be necessary to assess the portfolios of these renewable resources as well as the electricity consumptions and to evaluate the feasibility of balancing them.

2. Peer-to-Peer Energy Trading

The P2P approach promotes regional energy trading and demand response to available resources in local areas, and this increases the efficiency, flexibility and responsiveness of local resources. Due to the hierarchical nature of the distribution networks, the P2P energy trading will be carried out in three levels: Level 1: P2P within a Microgrid; Level 2: P2P within a CELL (multi-Microgrids); and Level 3: P2P among CELLs (Multi-CELLs), as shown in Figure 1. In Level 1, each customer (normally in an low voltage (LV) network) is considered as a peer, in Level 2 each Microgrid is a peer (Level 2 is normally a medium voltage (MV) distribution network), and each CELL from Level 2 is a peer in Level 3.

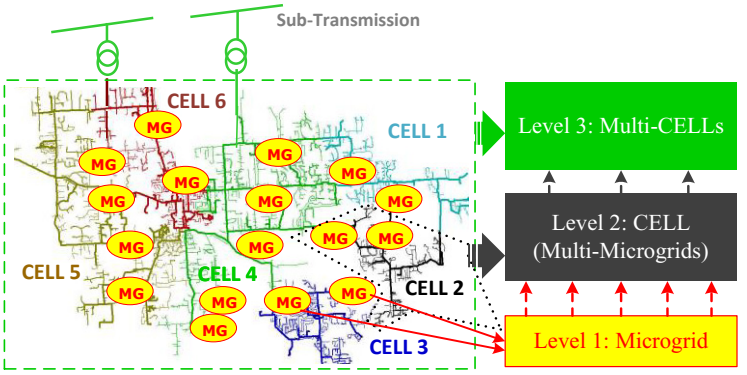

Fig. 1. Structure of peer-to-peer energy trading

3. Clustering Customer Demand

In the UK, a number of generic profile classes (PCs) are provided by Elexon for residential, commercial and industrial customers, and are derived based on the average of all customers contained within a single PC [5]. Although these PCs are suitable for settlement, in reality they are not reflective of how electricity is actually consumed within the home. Individual households may use electricity in very