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Distribution planning with reliability options for distributed generation

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ABSTRACT

The promotion of electricity generation from renewable energy sources (RES) and combined heat and power (CHP) has resulted in increasing penetration levels of distributed generation (DG). However, large-scale connection of DG involves profound changes in the operation and planning of electricity distribution networks. Distribution System Operators (DSOs) play a key role since these agents have to provide flexibility to their networks in order to integrate DG. Article 14.7 of EU Electricity Directive states that DSOs should consider DG as an alternative to new network investments. This is a challenging task, particularly under the current regulatory framework where DSOs must be legally and functionally unbundled from other activities in the electricity sector. This paper proposes a market mechanism, referred to as reliability options for distributed generation (RODG), which provides DSOs with an alternative to the investment in new distribution facilities. The mechanism proposed allocates the firm capacity required to DG embedded in the distribution network through a competitive auction. Additionally, RODG make DG partly responsible for reliability and provide DG with incentives for a more efficient operation taking into account the network conditions.

1. Introduction

In the context of the European Energy Policy, ambitious targets have been set concerning improvements in energy efficiency and the use of renewable energy sources (RES) [1]. The electricity sector is meant to play a major role in the achievement of the aforementioned goals. Different economic support schemes for the production of electricity from RES and combined heat and power (CHP) have been implemented at national level. As a consequence of these support schemes, new generation technologies have been developed over the last years. Several of these technologies are generally applied on medium and small-scale installations. This fact has brought about a new concept in the context of electricity production called distributed generation (DG). Other terms used with similar meanings are embedded generation, distributed energy resources, dispersed generation or decentralised generation.

The definition of the term DG has been analysed in detail [2]. In this paper, DG will be considered as electricity generation systems connected to distribution networks, characterized by their reduced size and located near consumption points.

Distribution networks were not originally designed to accommodate generation. Hence, increasing penetration levels of DG are causing profound changes in the planning, operation and maintenance of distribution networks. In order to integrate DG effectively and efficiently, the electricity distribution networks should no longer be passive elements that transmit electricity in one direction. They should become active elements where control, safety and flexibility are very relevant factors.

The impact of DG immersed in distribution networks is currently being analysed in detail. Various aspects are being considered: network planning [3], operation and maintenance [4], ancillary services [5,6], quality of service [7] and regulatory aspects [8].

This paper focuses on the possibility to substitute new network investments thanks to the contribution of DG to meet peak demand. Article 14.7 of the European Electricity Directive [9] states that DSOs shall consider DG as an alternative to network upgrading or replacing network elements. However, this challenge is not exempt of difficulties. In some countries, DSOs may own DG. Therefore they have the possibility of installing either new network elements or new generation units [10,11]. Nevertheless, under the current European regulatory framework, DSOs must be at least legally and functionally unbundled from other activities in the electricity sector. Electricity distribution remains a regulated activity, whereas generation has become a liberalised one. Therefore, DSOs have no direct control over the location and operation of DG.

Two main problems are derived from this situation. On the one hand, the responsibility of continuity of supply resides 100% on

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DSOs. Thus if DG is not producing during hours of peak demand, then DSOs are made responsible for possible interruptions. On the other hand, DG perceives no incentives to guarantee production during high demand periods. Therefore, specific mechanisms that ensure DG production during key system periods and allow DSOs to consider DG as an alternative to new facilities are deemed necessary.

Several schemes of this kind, such as capacity payments or reliability options, have been developed concerning large-size generation connected to the transmission grid [12,13]. These have three main objectives: ensure the existence of sufficient power generation installed to provide a suitable reserve, achieve a stable income for existing generators and new market entrants, and guarantee that generation may meet demand at all times. Nonetheless, these mechanisms generally do not take into account the grids. It is assumed that the network is not an obstacle to achieve this balance, since transmission grids are deemed to be sufficiently robust and meshed.

However, balancing DG and local demand in distribution networks is a very different situation. Distribution networks are generally either radial or operated this way. Hence, the network plays a key role within the generation-demand balance, as the presence and/or absence of this generation may cause overloads in the distribution network.

The contribution of DG to cover peak load of distribution facilities has already been assessed by some authors [14,15]. These studies perform probabilistic analyses over DG production profiles. The diverse nature of DG (base generation, intermittent generation, etc.) is taken into account. The most probable net demand, i.e. gross demand minus DG production, is obtained. In order to do this, the impact of vegetative increases of demand and DG production profiles on the system load duration curves is assessed. Net demand, together with the probabilities of failure of network facilities and generators, permit computing the effective capacity of distribution assets and the expected non-supplied energy (ENS). The former information allows DSOs to take more efficient investment decisions. However, these approaches do not encourage active DG involvement in covering peak demand in order to avoid overloads.

This paper proposes a market mechanism based on annual auctions, called reliability options for DG (RODG). This mechanism aims at achieving an active participation of DG in avoiding overloads and substituting new network investments. RODG make DG partially responsible for interruptions and, at the same time, provides efficient economic signals for the operation and localization of DG in the distribution network. Benefits are shared between DSOs, who obtain the firm power offered by DG as an alternative to new network investment, and DG, which is compensated for the provision of this service.

The remainder of this article is organised as follows. Section 2 analyses the current incentives perceived by DSOs when deciding whether to invest in new network facilities. Moreover, the conditions that DG ought to fulfil in order to be considered as an alternative to new network investments are identified. Next, Section 3 describes the RODG mechanism proposed, and assesses this mechanism from the perspectives of DSOs and DG. In Section 4, additional factors that may shape or influence the mechanism proposed are analysed. An illustrative example is provided in Section 5. Finally, the most relevant conclusions of this paper are drawn in Section 6.

2. Distribution planning with DG in a liberalised context

This section presents the alternative mechanisms to remunerate distribution companies, their consequences on distribution network planning, and the requirements to be fulfilled by DG so that DSOs can consider it as an alternative to new network investments.

2.1. The electricity distribution business

The electricity distribution business is a natural monopoly because it presents decreasing average costs and strong economies of scale. Due to its natural monopoly characteristic, the electricity distribution business is regulated in terms of pricing and network access.

After the recent vertical disintegration movements and market deregulation, traditional regulation of distribution, known as cost of service or rate of return regulation, has evolved towards incentive regulation. Cost of service regulation is based on remunerating DSOs according to their costs, thus ensuring profitability of new network investments. On the other hand, incentive regulation pays special attention to increasing efficiency by lowering costs, while reducing energy losses and improving quality of service. The most common incentive regulation approaches used to regulate European distribution utilities are price cap and revenue cap. These formulas establish a 4–5 year regulatory period that decouples actual costs from regulated revenues. This is the basis of the incentives for DSOs to reduce costs [16].

Once the distribution remuneration mechanism has been established, network tariffs are designed. These allow collecting from customers the costs recognized by the regulator, which constitute the revenues of DSOs. In this regulatory framework, the primary mission of a DSO as owner and operator of the distribution network system consists of transporting energy from the transmission grid border points to the end consumers. This mission involves the operation and maintenance of the network together with deciding and carrying out new network investments.

2.2. Deciding new investments with DG

One of the most important activities that DSOs perform is the planning of the grid, by identifying new investments required. DSOs typically analyse load duration curves of distribution facilities and verify that no overload occur (Fig. 1). Furthermore, DSOs assess the reliability of the network and dimension so that the failure of an element does not cause long duration supply interruptions. If additional network capacity is required, new investments are made.

However, DSOs must now face the fact that, when they have large amounts of DG embedded in distribution network, net demand (computed as gross demand minus DG production) is lowered. DSOs have to decide whether to consider this generation to offset existing demand, hence not investing in new facilities, or not to consider it and build new network elements. Moreover, DSOs are fully responsible for continuity of supply, whereas DG perceives no incentives to guarantee firm capacity during peak demand periods. Therefore, DSOs tend not to rely on DG and size distribution networks as if no DG was present, which is not efficient.

Throughout the remainder of this article, for illustrative purposes, we shall base our considerations on the basic distribution

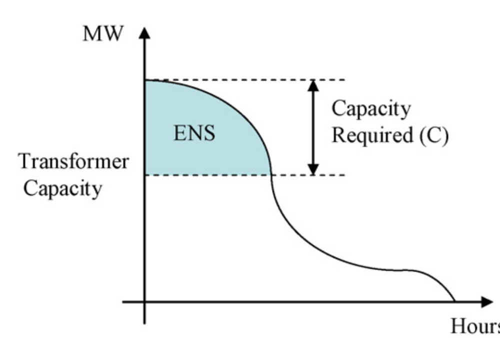

Fig. 1. Generic load duration curve.