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# Distributed generation and distribution market diversity in Europe

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ABSTRACT

The unbundling of the electricity power system will play a key role on the deployment of distributed generation (DG) in European distribution systems evolving towards Smart Grids. The present paper firstly reviews the relevant European Union (EU) regulatory framework: specific attention is paid to the concept of unbundling of power distribution sector in Europe. Afterwards, the focus is on the current state of penetration of DG technologies in the EU Member States and the corresponding interrelations with distribution features. A comparison between the unbundling of the distribution and supply markets using econometric indicators such as the Herfindahl–Hirschmann ($I_{HH}$) and the Shannon–Wiener ($I_{SW}$) indices is then presented. Finally, a comparative analysis between these indices and the current level of penetration of distributed generation in most EU is shown; policy recommendations conclude the paper.



## 1. Introduction

The European electric power sector is undergoing important modifications in response to the three key objectives set by the European Union (EU) within its current energy policy: environmental sustainability, security of supply, and competitiveness (European Commission, 2006a, b, 2007a, b, 2009; European Parliament and Council, 2004, 2006, 2009a, b). Essential herein are the EU's specific targets to be attained by 2020:

- a reduction in greenhouse gas emissions of 20% below the 1990 levels;
- a 20% share of energy consumption covered by Renewable Energy Sources (RES);
- a 20% reduction in primary energy use compared with projected levels, which assume a yearly increase of 1.5% until 2020 (European Commission, 2006c).

Some resulting trends are already more and more apparent, for example, within electric power distribution systems, where several EU countries report a steady increase in the installation of small and medium generation systems with capacities of some tens of MW and generally placed close to the final user. It is obvious to classify these systems under the heading of distributed generation (DG), although there is no globally accepted definition for this concept. In order to create an unambiguous context inside this article, DG is here defined in accordance with the relevant European legislation (European Parliament and Council, 2009b) as based on "generation plants connected to the distribution system" (see also Section 2). It should be noted however that a wide variety of alternative definitions, often more detailed, are used. These are generally based on criteria, such as voltage level, generation capacity, applied technologies, and the like. In general, DG comprises units based on RES, like wind turbines, photovoltaic panels, and hydraulic micro-turbines as well as generators not necessarily based on RES, such as gas micro-turbines, diesel engines, and fuel cells that can be used for Combined Heat and Power (CHP) generation.

Due to its decentralised nature and low environmental impact, DG has the potential to foster the achievement of the EU energy policy objectives. DG is believed to offer concrete benefits to the electric system including increased security of supply, reduced fossil fuel consumption, higher system efficiency, lower transmission and distribution losses, improved quality of supply, new market opportunities, and enhanced system competitiveness. DG may also, indirectly, be the chosen solution in response to apparent social and environmental opposition to the construction of large-size power plants and higher-capacity transmission infrastructures.

It should be stressed however that numerous technical issues have to be addressed in order to allow for a successful increased penetration and integration of DG (including RES) into distribution grids.

However, beyond technical issues, also market and regulatory challenges are to be addressed towards an increased penetration

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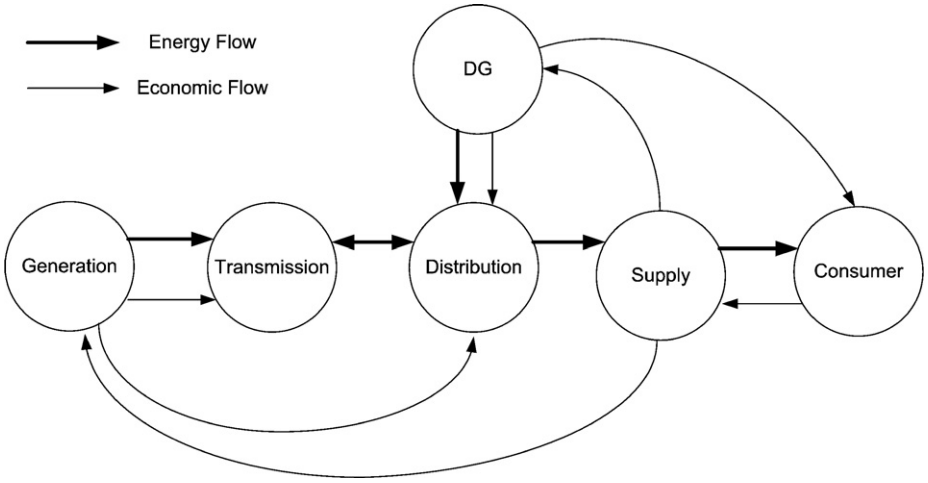


**Fig. 1.** Energy and economic flows.

and integration of DG into distribution networks in Europe. Firstly, there is a clear need for appropriate policies and associated regulatory instruments that support the integration of DG into distribution networks. A particularly relevant aspect for DG integration is the unbundling requirement for DSOs (Distribution System Operators), which is laid down in European legislation (European Parliament and Council, 2009a). Successful implementation of unbundling at the distribution network level is generally seen as an important requirement for fair and non-discriminatory network and market access for new DG entrants (L'Abbate et al., 2007).

A model integrating both the economic and energy flows in the power sector can be observed in Fig. 1. In order to highlight the interactions of DG operators in both the network and the market, micro-generation is not considered.

In terms of energy flow one can observe the axial role of the distribution networks, interconnecting DG, transmission, and supply. The emergence of reversed flows between transmission and distribution, due to the integration of DG, is showed there. The possibility of reversed flows demands a special attention, since neither of the networks, nor the connection points between them, were usually designed for such situation.

In terms of economic flows, the supply sector acquires, on the electricity market, the energy either from the traditional generation operators or from DG operators. These operators will pay to the network operators, the usage of their networks. This payment can be done applying Use of System charges and/or Connection charges.

As highlighted in this article, a diversified electricity distribution market may offer the most favourable circumstances for large penetration of DG. Alternatively, a heavily concentrated distribution market is assumed to generally limit the deployment of DG. Naturally, various additional factors influence the level of DG penetration and thus complicate the context analysis.

The present article aims at addressing some market and regulatory issues related to DG integration in the European electricity system. Particular attention is given to the relation between the unbundling level of the distribution market sector and the penetration of DG.

## 2. Vertical unbundling and DG in the EU regulatory framework

DG is considered in several European Directives that address technical, economic, environmental, and regulatory aspects of the EU electricity market. An overview of these Directives and of their contents is given in Fig. 2.

Concerning both DG and unbundling, the principal act of the EU is the Directive 2009/72/EC (European Parliament and Council, 2009b), which is part of the Third Electricity and Gas Liberalisation Package, focusing on the common rules for the internal electricity market. This Directive introduces the principle of proportionality in the authorisation procedures for DG connection, it allows EU Member States (MS) to promote DG based on RES, waste or CHP, and it requires DSOs to consider DG when planning the development of distribution networks as an alternative for upgrading or replacing electricity network capacity.

Furthermore, it regulates the whole process of unbundling transmission and distribution from generation to supply in the EU. Several possibilities do exist in order to achieve the desired unbundling of the entity in case, which include functional, legal, operation, and full ownership unbundling. The functional unbundling is the simplest form of it, in accordance with the minimal requirements of Article 9(1) for transmission, and consists on setting independent organisation and decision making. The legal and functional unbundling demands a more complete separation of the former vertical integrated companies. It is the minimum requirement for distribution, as defined by Article 26. The usage of independent system operators and the separation between network ownership and its operation is defined starting from Article 13. Finally, the complete separation between companies is the ultimate form of unbundling. In Fig. 3, it is possible to observe the different categories of unbundling.

For the unbundling of distribution systems, EU MS can define thresholds of exceptions for companies with a limited number of clients (100,000 customers or less) or small isolated systems, as stated in Article 26(4), and for companies operating closed distribution systems, as stated in Article 28.

Although quite common, the separation between transmission and distribution is not mandatory. However, the rules set in Article 29 concerning the combined operator have to be respected. Concerning network ownership unbundling, it may belong to the same entity or not. A comparison between some of the different possibilities of unbundling – from Vertical Integrated Undertaking (VIU) scheme to fully vertically unbundled company – is displayed on Fig. 4.

The success of the unbundling process of the distribution sector is considered to be an important condition for high DG penetration levels. In actual fact, the aim of unbundling is the creation of a non-discriminatory and transparent environment for all energy market stakeholders and to eliminate the potential