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Innovative network pricing to support the transition to a smart grid in a low-carbon economy

Laura Antonia Faerber[a], Nazmiye Balta-Ozkan[b,*], Peter M. Connor[c]

[a] The Advisory House GmbH, Malkastenstr. 17, 40211 Dusseldorf, Germany
[b] School of Water, Energy and Environment, Cranfield University, Cranfield, Bedfordshire MK43 0AL, United Kingdom
[c] University of Exeter, Penryn Campus, Treliever Road, Penryn, Cornwall TR10 9FE, United Kingdom

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ABSTRACT

This paper outlines how current distribution network pricing can be revised to enable transition to a smart grid in a low-carbon economy. Using insights from expert interviews, it highlights multiple trade-offs between innovative pricing approaches and regulatory principles which might be resolved by a political decision on how the costs should be recovered or socialised. It then identifies four essentials for a successful implementation of a new mechanism: (i) Closer collaboration between TSO and DNO/DSO concerning local dispatch to improve system efficiency. (ii) Installation of smart meters to collect data providing information about the actual contribution to the grid utilisation of each customer. (iii) Intensified cooperation between supplier and DNO/DSO to pass-through the price signal on the electricity bill. (iv) A legislative framework to facilitate data sharing and data management and communication among network stakeholders – essentially a relaxation of current privacy legislation as an enabler for new approaches to network management, and potentially to reduce costs to the consumer. This suggests the focus for future network pricing should be on services and functions provided by the grid rather than on the commodity *power* itself.

1. Introduction

The need to balance environmental sustainability, security of supply and energy equity, the *energy trilemma* (WEC, 2013), are strong drivers for the adoption of high volumes of intermittent and highly distributed electricity sources, thus necessitating a shift to a smarter grid as part of the transition to a low-carbon economy (Ofgem, 2014). A number of technologies affecting the demand- and supply-side of electricity are likely to be significant in this transition: Distributed energy resources (DER) place energy generation closer to demand and necessitate a two-way flow of electricity to maintain local reliability of supply (Hledik et al., 2016). Large-scale intermittent sources such as windfarms require systemic flexibility for balancing purposes. Demand-side response (DSR) has been adopted since the 1970s to influence conventional demand patterns but could be scaled up substantially to allow a future shift to matching demand-to-supply rather than the traditional paradigm of demand-to-supply. Smart meters will monitor the electricity consumption and generation across the grid with a much greater granularity of data than has historically been possible – or feasible (Union of the Electricity Industry, 2013; van den Oosterkamp et al., 2014) and offer the potential to facilitate many network services. Heat pumps are expected to be a major tool in decarbonising heat, essentially via energy savings (Ofgem and DECC, 2014) but their use may increase electrical demand and demand volatility. Storage solutions may increasingly provide enhanced grid utilisation flexibility and improved reliability of supply (Pérez-Arriaga and Bharatkumar, 2014). Finally, any significant expansion in electric vehicles (EVs) will increase electricity demand and may provide mobile storage solutions (Pérez-Arriaga et al., 2013). This study terms these technologies as *low-carbon electricity generation and demand* (LEGD), unless stated otherwise.

The integration of LEGD into the network will affect network stakeholders (Teh et al., 2011) and has already led to calls for the conventional paradigm of the European electricity sector to be rearranged (Union of the Electricity Industry, 2013; van den Oosterkamp et al., 2014). Infrastructure investments are required to balance increasing shares of intermittent electricity generation and to deal with changing demand patterns. This will necessitate the installation of smart information systems, the modernisation of technical standards and reshaping of business models (Picciariello et al., 2015). Recent research calls for the revision of the distribution network pricing mechanism to fund these investments and the associated operation and maintenance (O&M) costs. While some of the studies focus on DER only (Pollitt and

* Corresponding author.
E-mail address: n.ozkan@cranfield.ac.uk (N. Balta-Ozkan).

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Anaya, 2016), others consider only DSR (Wilks, 2011) or look at the system-wide impacts of LEGD (Picciariello et al., 2015). However, to date the options for alternative distribution network pricing mechanism that can be operationalised along the electricity supply chain and consideration of what opportunities and challenges emerge as a result have not been analysed. This work aims to address this gap by taking a whole-system approach which considers policy and consumers across network stakeholders.

There is an ongoing debate over the financing of electricity distribution systems in the future due to an increased number of distributed generators and prosumers and the potential withdrawal of the latter from the need for network services. This paper contributes to this debate through analysis of empirical data collected by the researchers. It argues that a new approach is required for a sustainable financing of distribution networks in the future. It identifies new approaches and draws conclusions as to what alternative pricing mechanisms could look like and what they should reflect. Argument and conclusions are rooted in empirical data collected from key stakeholders from the UK and Germany by conducting semi-structured interviews. More specifically, following a review of the current pricing mechanism, this research aims (i) to develop an innovative pricing mechanism that can address the challenges from LEGD and (ii) to identify barriers and opportunities for the implementation of an innovative mechanism along the electricity supply chain.

The study is structured as follows: Section 2 presents the electricity system landscape, its tariff design principles, and broad characteristics of the current pricing mechanism in the European Union. Section 3 demonstrates the shortcomings of this mechanism. Section 4 describes the research methodology while Section 5 presents the results. Sections 6 and 7 are devoted to discussion and conclusion, respectively.

2. Current network pricing and the role of distribution network stakeholders

Distribution networks are natural monopolies because of their physical characteristics and high investment costs for the construction of the required infrastructure. Networks follow the economic principle: the more end users one has, the merrier the benefit from the economics of scale (Vivek and Parsons, 2010). In the European Union (EU), distribution networks are usually owned by Distribution System Operators (DSOs) (Anaya and Pollitt, 2015; Union of the Electricity Industry, 2013). While the United Kingdom (UK) currently has Distribution Network Operators (DNOs), some initiatives are underway by individual DNOs and their trade association[1] for transition to a DSO model.

Across Europe, distribution networks used to be integrated at the national level in a centralised electricity system consisting of large power plants from which the electricity was transmitted on high voltage levels via transmission networks to local distribution networks (Pérez-Arriaga et al., 2013). From the local level, the electricity was supplied to the customer. It was common that companies along the electricity supply chain were vertically integrated, had no competitors and could set the electricity price (Jamasb and Pollitt, 2005).

Following national and pan-national efforts to privatise electricity the EU started to reform the energy sector (EP, 2009) as a competitive energy and retail market with regulated distribution and transmission networks. Four key actions were taken to liberalise the energy sector (Jamasb and Pollitt, 2005):

(1) Unbundling of generation, transmission, distribution, and retail as well as a horizontal division of production and supply.
(2) Establishment of competition in the wholesale market and in trading hubs.
(3) Authorisation of an independent regulator and third-party access to network infrastructure.
(4) Support of privatisation of state-owned companies.

Economics dictates that a distribution network remains a natural monopoly (Lavrijssen et al., 2016; Union of the Electricity Industry, 2013) while the decisions about the network's structure and services affect every network customer. Sakhrani and Parsons (2010) argue that distribution networks should be considered as a shared resource and a public good since the costs for users must be shared to maintain their benefits to all. A big part of network costs is socialised (Pérez-Arriaga and Bharatkumar, 2014), effectively recovered through elements of network tariffs that each customer has to pay (Anaya and Pollitt, 2015; Union of the Electricity Industry, 2013).

Based on the experiences before the liberalisation process and because of the network's characteristic as a natural monopoly, the costs distribution businesses can pass to consumers are regulated (Union of the Electricity Industry, 2013), based on the allowed CAPEX and OPEX of the DNO/DSO. Regulatory authorities consider these costs (Table 1) in the revenue estimation when setting the allowed revenue for DNOs/DSOs.

Rodríguez Ortega et al. (2008) identified three main drivers of network costs:

- a basic network as soon as a user exists,
- one user can affect the structure of the distribution network at all voltage levels by injecting power in times of excess supply or by consuming power at times of excess demand,
- network losses.

2.1. Tariff level and the role of regulators in tariff design

National Regulatory Authorities (NRAs) regulate the operations of Transmission System Operators (TSOs), DSOs/DNOs, and system owners (EP, 2009). NRAs set the allowed revenues for the period in question and have the authority to approve pricing methods and allowed returns on investment where good management is deemed to have been applied (EP, 2009). The calculation for the allowed revenue is based on the requirements of each DSO/DNO to cover the network costs listed in Table 1 (Union of the Electricity Industry, 2013). The responsible NRA also determines the level of the interest rate and handles the depreciation process, known as ratemaking. Thus it is important that the revenue counterbalances the costs and generates a rate of return on capital investment (Union of the Electricity Industry, 2013). NRAs should set this with the perspective that effective network management is required to achieve the rate of return.

Moreover, the framework for tariff design of NRAs across Europe is guided by the following competing principles (Reneses and Rodríguez Ortega, 2014):

(1) Revenue adequacy: The tariff should provide a full cost recovery for the DNO/DSO and should also enable reasonable/necessary future investments.
(2) Cost representation of induced cost: The tariff should represent the cost contribution of each customer.
(3) Economic efficiency: The tariff should pass-through price signals.
(4) Cost allocation and transparency: The methodology used to determine the price should be transparent. The tariff should protect customers from price discrimination.
(5) Predictability: Based on the tariff, future costs should be projectable.
(6) Tariff additivity and intelligibility: The tariff structure should be

[1] Western Power Distribution is running a consultation at time of writing: (https://www.westernpower.co.uk/About-us/Our-Business/Our-network/Strategic-network-investment/DSO-Strategy.aspx) while another DNO, UK Power Networks, has ended its consultation in September 2017 (http://futuresmart.ukpowernetworks.co.uk/). Sectoral trade association, the Energy Networks Association, has published a plan to enable this transition (http://www.energynetworks.org/assets/files/electricity/futures/Open_Networks/TSO-DSO%20Project%20Framework%20v6.pdf).