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Electricity Market for Direct Current Distribution Systems: Exploring the Design Space

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***Abstract*—Direct current distribution systems (DCDS), which connect local prosumers directly to community grids without AC/DC conversions, are a promising alternative to AC systems. While regulations call for market-based operation, existing markets for AC systems do not meet DC requirements and cannot be applied to a DCDS. This paper develops a design framework for local electricity markets and with it explores possible DCDS market designs. We review the technical requirements and desired properties for DCDS operation, enumerate its market design goals, then identify the design variables influencing the short-term market efficiency. This paper is our first step towards a systematic DCDS market design, and it supports our future work on quantitative analysis of the design choices.**

***Index Terms*—electricity market design, direct current, distribution system, design space, flexibility**

I. Introduction

In future power systems, a high proportion of electric power will be generated by direct current (DC) distributed energy resources (DER) and consumed locally by energy-efficient DC loads. DC distribution systems (DCDS) connect DER, storage systems, and loads directly by avoiding unnecessary power conversions. A DCDS has advantages of energy efficiency and operational flexibility and is a potential competitor to alternating current (AC) systems [1], [2]. Studies on DCDS mainly focus on technical feasibility, optimal dispatch, control, and protection issues [3], [2]. However, few have investigated its operation in a liberalized electricity market [4], [5]. The prosumers who own power devices in a DCDS may be assumed to operate these devices for their benefit without regard for optimal system operation. We aim to design markets that guide prosumers within DCDS network constraints, given prosumers' different use patterns, preferences, and interests.

Although regulations empower consumer participation in electricity markets [6], existing AC markets are not applicable to DC because the latter has little system inertia, strict power limit and a direct linkage of power and voltage [7]. New DC markets must coordinate prosumers for efficient system operation. However, there is no consensus about a general design framework for local electricity markets.

This paper develops a design framework for local electricity markets, and with it explores the space of possible DCDS markets. Adopting a general engineering design process, we review the desired properties of DCDS operation and enumerate the market design goals. Based on these, we identify the design variables that have a crucial impact on market performance, especially on its short-term efficiency.

II. Methodology

To date, there is no consensus on a general design framework for local electricity markets; this article develops such a framework based on literature review and systematic analysis.

Figure 1 illustrates our design framework for local electricity markets. It adopts the general design process of identifying goals, determining the design space, testing, and evaluation [8]. This article focuses on the first two stages. Whereas previous studies focus on single markets, we investigate how the arrangement of sub-markets plays a role [10]. Accordingly, we divide the space into *architecture design*, the choice and arrangement of sub-markets, and the *rule design* for each sub-market [11]. We include a feedback loop and allow future market improvements based on performance. An electricity market involves complex systems and multiple stakeholders, and both the technical systems and the actors change rapidly. Hence, there is no single best market per se, and the designs should be improved during the test and implementation.

III. From DCDS Requirements to Design Goals

A DCDS's unique features require a different market design from AC systems [7]. First, it has strict power limits because converter-driven DC systems cannot overload for seconds. In a few decades, massive DER integration and rapid electrification may push a DCDS towards congestions. Second, a DCDS mainly consists of non-spinning devices, so its system inertia is much lower than AC systems [12] and face severe voltage disturbances. Hence, real-time (RT) congestion management and balancing mechanisms become crucial. Third, nodal voltage is linked to power flow in DC networks [13], so voltage control and economic dispatch are not separable as in AC networks. Upon congestion, a DCDS must maintain the voltage level with prosumer support. To sum up, a DCDS is weakly connected to the main grid and must support the voltage level on its own, for which a DCDS market should exploit prosumer flexibility.

A DCDS's limited scale also sets further requirements. In a low-voltage distribution system, where voltage drops and

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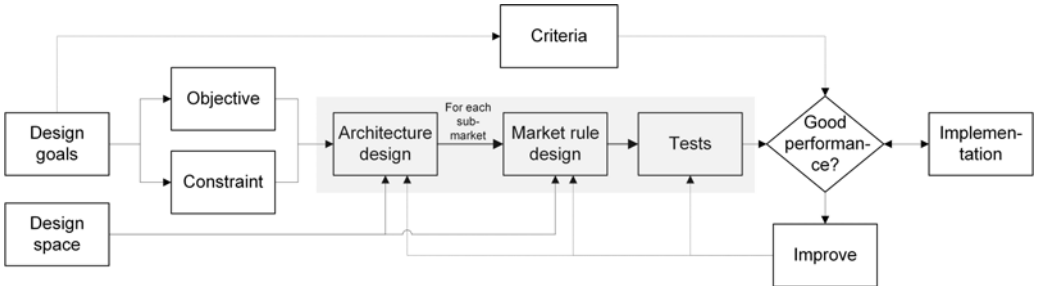

Fig. 1. Design Framework for General Electricity Markets, adapted from [8] and [9].

energy losses are main concerns [14] and should be solved by prosumers. A DCDS is typically a radial network linked to one substation, where congestions may happen earlier than a ring or meshed network. Local prosumers are less aggregated, and the power prosumption is more volatile than a transmission network [15]. Meanwhile, they are typically small-scale customers with little experience in energy trading, who are vulnerable to risks and have privacy concerns.

The above requirements call for a fast, complete, and interlinked DCDS market for prosumers. A low-inertia DCDS is vulnerable to RT congestions, so the market requires small, high-frequency transactions. The clearing should be computationally tractable, low in transaction costs, and compatible with technology and regulation. A complete DCDS market should address voltage drops, energy losses, and reliable power supply by remunerating ancillary services. Finally, a DCDS market should coordinate flexible prosumers through user-friendly trading rules that are easy to follow, incentive-compatible, less risky, and transparent in operation.

Energy directives and technical reports have revealed the goals of electricity market design [6], [16], [17]. The primary goal is the *productive and allocative efficiency*, where efficient prices encourage prosumer participation. An efficient power market requires *reliable system operation*. Since power prosumption is more volatile at the local level, network congestions and voltage drops will occur more frequently. Another crucial goal is *prosumer involvement* because local market operation highly relies on them. Finally, the market should be *practical to implement* regarding technical feasibility, scalability, and the role of existing stakeholders and regulations. Some goals inevitably contradict each other and require a trade-off.

IV. Design Space

We now investigate the freedom of DCDS electricity market design. The goal is to limit the space as much as possible without excluding promising designs. Sect. IV-A reviews the design variables for market architecture following the categorization of [10], then lists their feasible options and evaluate their features. Sect. IV-B enumerates the market rule design variables for each sub-market following [18], [19]. Sect. IV-C summarizes the design variables and indicate those with a key impact on market performance.

A. Market Architecture Design Variables

The market architecture describes the choice and arrangement of sub-markets, each serving a unique technical function required for system operation. The variables are the choice of sub-markets, their types, the linkages between sub-markets, and the linkage to wholesale markets. The architecture plays a crucial role in the market operation and lays the foundation for market efficiency; therefore, it should be considered before the market rule design. Table I lists the design variables and their options for market architecture, where the first three variables are identified by [10] and the fourth one is from our analysis.

a) Choice of Sub-markets: The choice of sub-markets determines the commodities a market remunerates. It lays the foundation for the incentive scheme. An efficient DCDS operation relies on various ancillary services, some of which have higher trade-ability and should be remunerated by the market. These commodities include (electric) energy, network capacity, voltage regulation, contingency supply, and the flexibility of local prosumers. Not all commodities are qualified for a sub-market; we evaluate a market's non-discriminatory access, completeness, transaction costs, and operational transparency [10]. By contrast, the barely tradable services for safety, protection, and power quality should be provided by a DSO or be regulated by DC network codes.

b) Market Type: The market type describes the arrangement of trading, and it mainly affects the information available in the market. An organized market, such as a pool (with side payments) or an exchange (without them), adopts central clearing and facilitates information exchange [10], [20]. The standardized contracts also lower transaction costs, but the centralized allocation require investments in computation and communication infrastructure. By contrast, a bilateral market based on a bulletin board or brokers allows peer-to-peer trading and diversified contracts [21]. The information exchange is less efficient and transparent, which potentially affects the economic efficiency and network security.

c) Linkage between Sub-markets: The linkage between sub-markets is "the heart of market architecture", which naturally arises because of time, location, and financial arbitrage [10]. Implicit linkages are found between sub-markets. Due to the power-voltage linkage, network capacity and voltage regulation markets are closely linked in a DCDS, and both of them highly rely on flexible prosumers who can adjust power

TABLE I
DESIGN VARIABLES FOR LOCAL ELECTRICITY MARKET ARCHITECTURE

Design Variable	Design Options
Choice of sub-markets	energy / network capacity / voltage regulation / contingency supply / flexibility
Market type	bilateral / organized
Linkage between sub-markets	explicit / implicit
Linkage to wholesale markets	complete / partial

*ancillary services include voltage regulation, contingency supply, and flexibility.

prosumption. Implicit linkages usually lead to more frequent information exchange (adding to the operational complexity) and arbitrages between sub-markets. By contrast, an explicitly-linked market [22] integrates various commodities into one. An example is the locational energy market, which links the network capacity to energy market via locational prices.

d) Linkage to the Wholesale Markets: The above design variables are identified in wholesale markets. For local markets, we recognize the linkage to wholesale markets as the fourth design variable, indicating if a local sub-market is connected to a corresponding wholesale market [23], [24]. A local market should facilitate prosumer participation in the wholesale market, and local resource allocation should aim at the global optimum. Here the design criterion is the completeness [25], i.e., if each sub-market in a DCDS is linked to a corresponding wholesale market, and each local commodity has a counterpart in the latter. A partial linkage prevents globally efficient resource allocation and becomes prosumers' barrier to the wholesale market.

B. Market Rule Design Variables

Properly designed market rules yield competitive prices and prevent gaming [18]. These rules regulate the information flow and the prosumer behavior in the market. Table II lists the design variables of DC electricity market rules, and for each identified variable, the table shows the corresponding options and choices. The selection of variables is based on general power markets [26], [18], balancing markets [27], [28], and flexibility markets [29], [23]. Based on operation stages [19], we further categorize the variables into general organization, bid format, allocation, payment, and settlement. The *general organization* decides buyers and sellers. The *bid format* regulates the information gathered from prosumers. The *allocation rules* determine the economic efficiency, while the *pricing rules* sets monetary incentives for such an allocation. Finally, the *settlement rules* guarantee the delivery of commodities.

a) General organization: The general organization decides who are buyers and sellers, and which market information is available. The design variables are the buyer-seller arrangement, entry requirements, and information disclosure. The buyer-seller arrangement sets the supply and demand of a commodity [30]. It has a strong influence on the market structure, i.e., different parties' market share and their competition. The entry requirements decide whether (1) all prosumers have equal access to a market, and (2) the market participation is voluntary or mandatory [31]; they decide non-discriminatory access and liquidity of a market. The information disclosure decides to which detail prosumers should reveal private information. Further information disclosure yields more efficient allocation [29], yet disclosing truthful information should be safe and beneficial to prosumers [32].

b) Bid Format: The bid format determines the information gathered for efficient allocation. The design variables are the bid information, bid resolution, gate closure time and locational information. The bid information decides the information a prosumer submits to the market. Comprehensive information potentially increases market efficiency but challenges computational tractability [33]. The bid resolutions refer to the fineness of allocation and payment in time [28], price [34], and quantity [35]. They determine the fineness of market efficiency and incentives at the cost of simplicity and metering requirements. The gate closure time is the deadline for bid submission. A later gate closure allows the use of more accurate, updated information [26], whereas an earlier one provides more system flexibility. The locational information describes whether a prosumer's location is included in a bid [33]. This information, either zonal or nodal, indicates the spacial scarcity of energy resources [36], [28], [33].

c) Allocation: The allocation rules determine the market efficiency and, together with payment rules, decide the incentives for such an allocation. The design variables are the objective function, risk measure, uncertainty model, and settlement steps. The objective function quantitatively describes the optimality of the allocation. It is a crucial design variable that decides the direction of the resource allocation. The uncertainty model describes how an allocation takes uncertainty into account and it has a crucial impact on system reliability and the risk level [37]. A risk measure describes the (monetary) risk associated with a given allocation [37] and facilitates risk-averse decisions. More steps offer further hedging opportunities at the cost of market complexity and gaming opportunity [38]. Electricity transactions can be settled in one or multiple steps. More steps offer hedging opportunities at the cost of market complexity and gaming opportunity.

d) Payment: Once the allocation is decided, the payment rules should adequately reward the accepted bids in this round, thereby influencing the bids submitted in future. The design variables are the pricing rules, price caps, and taxes & levies. The pricing rule defines at which price a deal is closed [39], and it lays the basis of the incentive scheme. In general,

TABLE II
DESIGN VARIABLES FOR LOCAL ELECTRICITY MARKET RULES (FOR EACH SUB-MARKET)

Category	Design Variable	Design Options
General	buyer & seller	one-sided / double-sided
	entry requirements	universal / tech-specific, voluntary / mandatory
	info. disclosure	fully-transparent / anonymous / aggregated
Bid format	bid information	simple / complex
	time resolution	1sec–15min
	gate closure time	1sec–24h
	locational info.	no / zonal / nodal
Allocation	objective function	econ. efficiency / renewable / . . . / fairness
	uncertainty model	deterministic / stochastic
	risk measure	no / LoLP / ELNS / VaR / CVaR
	settlement steps	1 / 2 / 3 / . . . / continuous
Payment	allocation pricing	uniform / discriminatory
	price cap	no / static / dynamic
	taxes & levies	yes / no
Settlement	settlement method	physical / financial
	settlement pricing	one-price / two-price
	time resolution	one (dispatch) interval / multiple intervals

payment is either universal (such as marginal pricing) or discriminatory (such as pay-as-bid) among market parties [26]. A price cap (or floor) sets the maximum (or minimum) price of a commodity. Although it is meant to protect consumers against extreme prices, it affects incentive-compatibility [26]. The taxes and levies refer to the additional payments for the allocation, which include the renewable surcharge, carbon taxes, or VAT. Although they have a profound impact on local markets [40], they are decided by national energy policies and are out of our research scope.

e) Settlement: A market operator must settle the transactions to guarantee the delivery of the traded commodities. The design variables are the method, the pricing, and the time resolution. The settlement method defines the way a commodity is delivered. A settlement is physical if the commodity must be delivered in real time, or it is financial when cash payments are sufficient [31]. The settlement pricing defines whether the deviation of a contract is settled at the same price or different prices for long and short positions [41]. It affects incentive-compatibility and investment incentives. The settlement resolution decides the frequency of the settlement [28] and affects price efficiency. A higher settlement resolution yields more efficient prices [42], but largely increases the computational and communication complexity.

C. Summary

This section listed the design variables and their options for local electricity markets. The market architecture sets the foundation for a market design, based on which we set rules for each sub-market. The variables are the choice of sub-markets, linkages between sub-markets, linkage to wholesale markets, and market type. For each sub-market, rules are set for general organization, bid format, allocation, payment, and settlement. Here the key variables include buyer-seller arrangement, entry requirements, information disclosure, bid information, bid/settlement resolution, gate closure time, and pricing rules for allocation and settlement. Although we analyzed the design options, further quantitative studies should compare the options and suggest suitable choices for DCDS applications.

V. CONCLUSION

This article reviews the market design options for direct current power distribution systems (DCDSs). A DCDS must adhere to strict DC operational requirements, which is challenged by the volatile power prosumption. In a liberalized market, we must coordinate DCDS prosumers using market mechanisms. A DCDS market will be fundamentally different from conventional AC markets: it should be *fast* in response, *complete* in market linkages, and *user-friendly* to small prosumers. We develop a design framework for local electricity markets with which we explore possible DCDS markets from scratch; to our knowledge, we present the first such analysis.

We further identify the design variables that affect a market's short-term economic efficiency. The *market architecture* regarding sub-markets and their linkages is the foundation of the market design. For each sub-market, this article analyzes the design variables for detailed *market rules* and suggest preliminary choices. These variables are categorized into *general organization, bid format, allocation, payment*, and *settlement*.

This article represents the first step towards a comprehensive DCDS market design. While we analyzed the design options, quantitative studies should compare these options and suggest a suitable choice for DCDS applications. Do we have a clear preference over a design variable, or does it require a careful trade-off between different design goals? Future studies should indicate the optimal choice of the DCDS market rules through quantitative analyses and verifications.

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REFERENCES

[1] J. J. Justo, F. Mwasilu, J. Lee, and J. W. Jung, "AC-microgrids versus DC-microgrids with distributed energy resources: A review," *Renewable and Sustainable Energy Reviews*, vol. 24, pp. 387–405, 2013. [Online]. Available: http://dx.doi.org/10.1016/j.rser.2013.03.067

[2] L. Mackay, "Steps towards the universal direct current distribution system," Ph.D. dissertation, Delft University of Technology, 2018.

[3] J. P. Torreglosa, P. García-Triviño, L. M. Fernández-Ramirez, and F. Jurado, "Control strategies for DC networks: A systematic literature review," *Renewable and Sustainable Energy Reviews*, vol. 58, pp. 319–330, 2016.

[4] H. Mohsenian-Rad and A. Davoudi, "Towards building an optimal demand response framework for DC distribution networks," *IEEE Transactions on Smart Grid*, vol. 5, no. 5, pp. 2626–2634, 2014.

[5] C. Li, F. de Bosio, F. Chen, S. K. Chaudhary, J. C. Vasquez, and J. M. Guerrero, "Economic Dispatch for Operating Cost Minimization Under Real-Time Pricing in Droop-Controlled DC Microgrid," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 5, no. 1, pp. 587–595, 2017.

[6] European Commission, "Proposal for a Directive of the European Parliament and of the Council on Common Rules for the Internal Market in Electricity (recast). COM(2016) 864 final/2," 2016.

[7] L. Piao, M. de Weerdt, and L. de Vries, "Electricity Market Design Requirements for DC Distribution Systems," in *IEEE Second International Conference on DC Microgrids (ICDCM)*, 2017, pp. 95–101.

[8] P. M. Herder and R. M. Stikkelman, "Methanol-based industrial cluster design: A study of design options and the design process," *Industrial and Engineering Chemistry Research*, vol. 43, no. 14, pp. 3879–3885, 2004.

[9] S. Stoft, *Power System Economics: Designing Markets for Electricity*. Wiley-IEEE Press, 2002.

[10] ——, "Market Architecture," in *Power System Economics: Designing Markets for Electricity*. Wiley-IEEE Press, 2002, pp. 82–92.

[11] J. Choi, G. G. Lim, and K. C. Lee, "An Agent Based Market Design Methodology for Combinatorial Auctions," *Journal of Artificial Societies and Social Simulation*, vol. 13, no. 2, 2010.

[12] L. Mackay, T. G. Hailu, G. C. Mouli, L. Ramirez-Elizondo, J. A. Ferreira, and P. Bauer, "From DC nano- and microgrids towards the universal DC distribution system - A plea to think further into the future," in *IEEE Power and Energy Society General Meeting (PES-GM)*, 2015.

[13] N. Yang, D. Paire, F. Gao, A. Miraoui, and W. Liu, "Compensation of droop control using common load condition in DC microgrids to improve voltage regulation and load sharing," *International Journal of Electrical Power and Energy Systems*, vol. 64, pp. 752–760, 2015. [Online]. Available: http://dx.doi.org/10.1016/j.ijepes.2014.07.079

[14] S. Deilami, A. S. Masoum, P. S. Moses, and M. A. S. Masoum, "Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile," *IEEE Transactions on Smart Grid*, vol. 2, no. 3, pp. 456–467, 2011.

[15] I. Ilieva, B. Bremdal, and P. Olivella, "D6.1 Market Design," EMPOWER: local Electricity retail Markets for Prosumer smart grid power services, Tech. Rep., 2015.

[16] Federal Energy Regulatory Commission (FERC), "Working Paper on Standardized Transmission Service and Wholesale Electric Market Design," 2002.

[17] G. Strbac and J. Mutale, "Framework and Methodology for Pricing of Distribution Networks with Distributed Generation," *UK Centre for Distributed Generation and Sustainable Electrical Energy (A report to OFGEM)*, 2005.

[18] S. Stoft, "Designing and Testing Market Rules," in *Power System Economics: Designing Markets for Electricity*. Wiley-IEEE Press, 2002, pp. 93–106.

[19] M. J. Morey, *Power Market Auction Design: Rules and Lessons in Market Based Control for the New Electricity Industry*. Edison Electric Institute, 2001.

[20] P. N. Biskas, D. I. Chatzigiannis, and A. G. Bakirtzis, "Market coupling feasibility between a power pool and a power exchange," *Electric Power Systems Research*, vol. 104, pp. 116–128, 2013. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S037877961300165X

[21] E. Mengelkamp, J. Gärttner, K. Rock, S. Kessler, L. Orsini, and C. Weinhardt, "Designing microgrid energy markets: A case study: The Brooklyn Microgrid," *Applied Energy*, vol. 210, pp. 870–880, 2018.

[22] S. Ries, C. Neumann, S. Glismann, M. Schoepf, and G. Fridgen, "Rethinking short-term electricity market design: Options for market segment integration," in *International Conference on the European Energy Market (EEM)*, 2017.

[23] A. Ramos, "Coordination of Flexibility Contracting in Wholesale and Local Electricity Markets," Ph.D. dissertation, Katholieke Universiteit Leuven, 2017.

[24] C. Eid, L. A. Bollinger, B. Koirala, D. Scholten, E. Facchinetti, J. Lilliestam, and R. Hakvoort, "Market integration of local energy systems: Is local energy management compatible with European regulation for retail competition?" *Energy*, vol. 114, pp. 913–922, 2016. [Online]. Available: http://dx.doi.org/10.1016/j.energy.2016.08.072

[25] R. P. O'neill, E. B. Fisher, B. F. Hobbs, and R. Baldick, "Towards a complete real-time electricity market design," *Journal of Regulatory Economics*, vol. 34, pp. 220–250, 2008.

[26] J. Hu, R. Harmsen, W. Crijns-Graus, E. Worrell, and M. van den Broek, "Identifying barriers to large-scale integration of variable renewable electricity into the electricity market: A literature review of market design," *Renewable and Sustainable Energy Reviews*, vol. 81, pp. 2181–2195, 2018.

[27] A. Abbasy and R. A. Hakvoort, "Exploring the design space of balancing services markets-A theoretical framework," in *2nd International Conference on Infrastructure Systems and Services*, 2009.

[28] R. A. van der Veen and R. A. Hakvoort, "The electricity balancing market: Exploring the design challenge," *Utilities Policy*, vol. 43, pp. 186–194, 2016.

[29] C. Rosen, "Design considerations and functional analysis of local reserve energy markets for distributed generation," Ph.D. dissertation, RWTH Aachen University, 2014.

[30] R. Madlener and M. Kaufmann, "D5.1b Power Exchange Spot Market Trading in Europe: Theoretical Considerations and Empirical Evidence," OSCOGEN, Tech. Rep., 2002.

[31] H.-p. Chao and R. Wilson, "Design of Wholesale Electricity Markets," *Electric Power Research Institute*, 2001.

[32] A. E. Roth, "The art of designing markets," *Harvard business review*, vol. 85, no. 10, pp. 118–26, 2007.

[33] I. J. Pérez-arriaga, *Regulation of the Power Sector*, I. J. Pérez-Arriaga, Ed. Springer-Verlag London, 2013.

[34] M. H. Albadi and E. F. El-Saadany, "A summary of demand response in electricity markets," *Electric Power Systems Research*, vol. 78, no. 11, pp. 1989–1996, 2008.

[35] V. Alagna, L. Cauret, M. Entem, C. Evens, W. Fritz, M. Hashmi, J. Mutale, P. Linares, M. Lombardi, S. Melin, F. Pettersson, D. Six, M. Trotignon, and C. Yuen, "D5.1 Description of market mechanisms which enable active demand participation in the power system," ADDRES, Tech. Rep., 2011.

[36] F. Roques, D. Perekhodtsev, and L. Hirth, "Electricity Market Design and RE Deployment," IEA Renewable Energy Technology Deployment, Tech. Rep., 2016.

[37] A. J. Conejo, M. Carrión, and J. M. Morales, *Decision making under uncertainty in electricity markets*. Springer, 2010.

[38] S. Stoft, "The Two-Settlement System," in *Power System Economics: Designing Markets for Electricity*. Wiley-IEEE Press, 2002.

[39] L. Maurer and L. Barroso, *Electricity Auctions: An Overview of Efficient Practices*. The World Bank, 2011.

[40] M. P. Rodríguez Ortega, J. I. Pérez-Arriaga, J. R. Abbad, and J. P. González, "Distribution network tariffs: A closed question?" *Energy Policy*, vol. 36, no. 5, pp. 1712–1725, 2008.

[41] R. Scharff and M. Amelin, "Trading behaviour on the continuous intraday market Elbas," *Energy Policy*, vol. 88, pp. 544–557, 2016.

[42] A. Morch and O. Wolfgang, "Post-2020 framework for a liberalised electricity market with a large share of renewable energy sources," Market4RES, Tech. Rep., 2016. [Online]. Available: http://market4res.eu/wp-content/uploads/LR-Market4RES-final-publication.pdf