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THEORETICAL MARKET FRAMEWORK FOR MARKET-BASED TSO–DSO IN REAL-WORLD IMPLEMENTATIONS

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ABSTRACT: This paper introduces a Theoretical Market Framework (TMF) for conceptualizing and designing electricity markets, integrating Transmission System Operator And Distribution System Operator (TSO–DSO) coordination mechanisms. The TMF represents a comprehensive tool that formalizes new, innovative market concepts and their impact on existing markets, and outlines fundamental categories and decisions essential to market design. This paper, through the TMF, addresses the integration challenges posed by new mechanisms for system services. Utilizing the TMF, the study maps 13 European demonstrators' TSO–DSO coordination solutions, identifying real-world challenges in designing and implementing novel system services markets. Drawing on these real-world insights, the paper offers market design and policy recommendations to address and overcome the specific challenges in market-based TSO–DSO coordination. Hence this system shows the results efficiently and accuracy.

KEYWORDS: TSO–DSO Coordination; Real-World Demonstrators; Electricity Market Design; System Services

I. INTRODUCTION

Marketing management refers to the control and operations of various marketing activities and the people involved in those activities, such as managers, marketing management professionals, contractors, and more. Relevant actives often include: Setting goals and developing marketing strategies Performing market research, devising marketing campaigns identifying a company's target market. Managing content on various channels (e.g., social media, email marketing, etc.) and across different mediums (e.g., copy, images and videos, and podcasts). Execution of marketing strategies and marketing plans.

The climate and policy goals driving the ongoing energy transition and decarbonization of our society call for the electricity sector to contribute through the massive use of renewable energy sources and energy efficiency [1]. With the considerable presence of intermittent energy sources and the need to maximize the use of existing infrastructure, it is increasingly important to adopt a more interactive approach to operating the electric power system [2]. Addressing the power system transformation at a reasonable cost, without harming the electricity supply security and quality, calls for unlocking the support from the already connected resources and fostering new resources availability [3]. In this context, cooperation and coordination among SOs are crucial for efficiently managing resources and infrastructures; nevertheless, the involved actors' coordination procedures must be carefully designed to strive for economic efficiency. In order to promote investments in Renewable Energy Sources (RESs) and enable coordinated procurement of system services by both DSOs and TSOs for secure system operation, efficient, integrated, coordinated, and scalable markets are essential in future power systems. These markets should include balancing services, non-frequency ancillary services, and congestion management services[4]. Ultimately, such markets aim to provide real choice for all end-customers and contribute to energy supply security and sustainability.

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Market design is a complex task that encompasses the interplay of multiple markets and policy instruments [5]. The current market designs for electricity face barriers that hinder the efficient integration of Renewable Energy Sources (RESs), leading to a slower and more expensive energy transition. Several studies in the literature have highlighted these barriers and proposed alternative market designs mainly focusing on wholesale electricity markets, capacity auctions for system adequacy, and balancing.

The identified hotspots mainly concern time and spatial granularity, market timing, market sequence, traded products, market power risks, and price settlement rules. To outclass the identified challenges, a market architecture having a novel market sequence for electricity and balancing is proposed for Colombia, and improvements for the capacity markets of Chile, Brazil, and Europe. An alternative design for the European balancing market considering different timing is investigated [6]. A novel market design for North America based on differentiating the wholesale transmission service and retail end-use service and introducing the concept of demand subscription service with fixed cost recovery. Auction design for congestion management markets. The reviewed proposals cover part of the entire electricity market architecture and consider the integration of large-scale RESs. The emergence of mid- and small-scale RES and new actors (i.e., prosumers, demand response customers, aggregators, and energy communities) and the operators' need for system services drive the creation of flexibility markets to engage them as FSPs. Hence, the consequent power system decentralization calls for integrating those markets into the entire electricity market architecture and enhancing TSO–DSO coordination.

To contribute to the design of integrated electricity markets, this paper proposes a Theoretical Market Framework (TMF) for describing and designing innovative electricity markets. The TMF allows studying the market-based TSO–DSO coordination as well as the challenges of integrating the novel market mechanisms with existing energy and service markets. Regulatory frameworks, such as promote market-based mechanisms for procuring system services, fostering the need for dedicated research on the market-based mechanism for TSO–DSO coordination. Previous work has been conducted on coordination between TSOs and DSOs. Researchers proposed five different service-agnostic coordination schemes (CSs) that define each system operator's roles and responsibilities when procuring and using system services provided by the distribution grid. This analysis was further extended who developed seven CS. Then, more specifically for the joint procurement of balancing ancillary services and congestion management services, distinguished three market models for coordination while identified five market design options. Finally, focused on congestion management describes TSO–DSO coordination under different systems states. However, while these papers and reports describe conceptual market designs concerning flexibility allocation.

II. LITERATURE SURVEY

Z. Anqing, L. Yuming and G. Quanlong, et.al [7] channel management model of China Unicom-Channel Management Mode of Service Provider, and aims at its characteristics, combined with the need of full informationization of China Unicom, puts forward the function model of Service Marketing Management Sytem For Social Channel(referred to as SMMS) and deeply analyses each module and their significance of market, which foundation is the successful construction and summary of SMMS for China Unicom of Guangzhou City, Wuhan City, Guangxi Province and Sichuan Province.

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R. Zhang, K. -y. Wang and L. -k. Xia,et.al [8] analyzed theories of market knowledge competence and summarized the structure of the market knowledge competence firstly. It puts forward that market knowledge competence is made up of three aspects: customer knowledge management capability, competitor knowledge management capability, and interior knowledge integration capability. Secondly, this study analyzed the relationship between market knowledge competence and organizational performance, and developed a theoretical model. Furthermore, this paper made an empirical investigation to test the model. The result shows, customer knowledge management capability and competitor knowledge management capability are positively related to interior knowledge integration capability, and the market knowledge competence has a positive effect on marketing capabilities. As a result, marketing capabilities plays a moderate role in the relationship between market knowledge competence and organizational performance.

Y. Hu, et.al [9] Knowledge Management (KM) is extremely valuable for competitive advantage. However, we know little about the influence mechanism of KM on performance. The main purpose of this study is to examine the inter-relationships between KM, marketing performance and financial performance. Building on extensive literature, a path model was developed and empirically tested using survey data from China's firms. Data were analyzed with confirmatory factor analysis and structural equation modeling. Empirical results support the positive and significant link between KM and financial performance. Meanwhile, the findings also confirm that the indirect effect of KM on financial performance (with marketing performance playing a mediating role) is stronger. Finally, this study discusses managerial implications and highlights some directions for future research.

Y. Z. Ayele and A. Barabadi, et.al [10] competitive market, large businesses & small and medium size enterprises (SMEs) compete with each other. Further, the regulatory requirements are often the same for SMEs and large enterprises. However, SMEs have usually fewer resources to develop strategic marketing management and business plan. These include market research (market segmentation, targeting, competitive environment, etc.) and tactical marketing (market positioning & strategy, marketing & selling model, etc.). The purpose of this paper is to study the main marketing management challenges of the SMEs operating in the Nordic region. Furthermore, the other objective is investigating the factors that may influence the SMEs' international competitiveness. To fulfil the objectives, we have developed a questionnaire; and, carried out a survey for a selected number of local SMEs. The questionnaires are aiming for evaluating the effectiveness of the local SMEs marketing strategies; and, consequently to help local SMEs in developing a smarter marketing management strategy.

V. P. Semenov, A. S. Sokolitsyn and N. A. Sokolitsyna, et.al [11] elaborates marketing activity management improvement mechanism for small-series production enterprises, differed with choosing the best marketing activity variant on base of several possible variants imitation. This elaborated mechanism includes method of defining marketing activity effect, taking into account profit, clients satisfaction and market impact, which allow making more backgrounded and effective management decisions.

E. Lakić, T. Medved, J. Zupančič and A. F. Gubina, et.al [12] Market power and its possible abuse by market participants is one of the main issues in electricity trading and a lot of work is done on establishing

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trading rules for fair and transparent electricity market. The focus of this paper is to present market power detection techniques which have been proposed in literature with detail review of the tools which could be used in monitoring units of organised electricity market places such as power exchanges. Electricity markets are disposed to collective or collusive market power exercise because of their characteristics and additionally susceptible to the potential exercise of unilateral market power. There have been many insight researches on topic of market power in the deregulated wholesale electricity markets with arising questions how to define, exercise and detect market power. The paper distinguishes between different models for market monitoring and surveillance and the outcomes of the paper can serve as a recommendation and orientation for further tests and researches in the field of the monitoring of market power.

J. Thomsen, A. Roulland, M. Kellermann, N. Hartmann and T. Schleg, et.al [13] German energy transition, several challenges arise. Shifting electricity supply from a centralistic, unidirectional system towards a decentralized, bi-directional system with a significantly increased number of stakeholders and thus conflicting interests leads to a number of technical, political, social and economic debates. However, there is an overall agreement that the importance of distribution grid operation, decentralised energy generation and flexible generation technologies will be essential elements of future energy systems. This paper presents the concept of a new market role, the “Decentralised Market Agent” (DMA), which optimizes the system operation and expansion on distribution grid level. To do so, one of the potential flexibility technologies is Demand Side Management (DSM), which is analysed in more detail in this paper. With regard to the tasks and objective of the DMA, the requirements and potentials of DSM are discussed and evaluated qualitatively. Based on this, an analysis of applicable DSM measures in households as well as for an industrial consumer is conducted. This serves as a basis for the evaluation of the technical and economic potential DSM might hold for the DMA.

E. Mengelkamp, P. Staudt, J. Garttner and C. Weinhardt, et.al [14] Increasing renewable energy sources and innovative information and communication systems open up new challenges and opportunities to integrate distributed generation into the energy supply system. Formerly centralized energy systems need to be adapted to take full advantage of the immense potential of decentralized energy generation and smart, interconnected energy end users. We introduce a local electricity market on which prosumers and consumers of a community are able to trade electricity directly amongst each other. This local electricity market supports the local integration of renewable energy generation. It facilitates a local balance of energy supply and demand and hence reduces the need for extensive electricity transmission. We introduce, evaluate and compare two local market designs, a direct peer-to-peer market and a closed order book market, as well as two agent behaviors, zero-intelligence agents and intelligently bidding agents. We derive four scenarios by combining each market design with each agent behavior, respectively. All market scenarios offer similar economic advantages for the market participants. However, the peer-to-peer market with intelligent agents appears to be the most advantageous as it results in the lowest average overall electricity price.

B. Richter, E. Mengelkamp and C. Weinhardt, et.al [15] Local energy markets (LEMs) are a highly discussed topic in the academic community. In this paper, we address one of the most critical challenges for these markets. In recent years the

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valuation of energy sources by the consumer became more differentiated. Today many consumers prefer various energy sources (e.g. PV or Wind) in different degrees. Taking this distinction into account causes several challenges in the market design as energy becomes a heterogeneous good. We show that already existing auction mechanisms cannot provide a satisfactory solution to represent these differences. As a result, we propose a two-step mechanism specifically tailored for the differing consumer valuations. It introduces a merit-order based market for each type of energy. Thus, each separate market deals with one source of energy and is cleared separately. With that, the determination of the chronological order of the different markets becomes essential. The proposed mechanism aims at taking the various preferences of all consumers into account by using the Borda count voting mechanism. The theoretically presented market mechanism is supported by a real-life data case study with data from the Landau Microgrid Project.

III. METHODOLOGY

The proposed TMF is used in this paper to describe the OneNet demonstrators' market architecture to support identifying the corresponding gaps and strengths. The TMF is a tool for bottom-up market architecture analysis and design. Starting from the description of every single market-based interaction, the TMF allows for a comprehensive description of the entire market architecture. This section describes the application of the TMF to OneNet demonstrators. This section provides proof of concept of the application of the TMF. The application of the TMF to the OneNet demonstrators follows the following five steps:

1. Identification of buyer–seller interactions;
2. Definition of sub-markets of the market architecture;
3. Description of each sub-market using the TMF features;
4. Description of the interactions between sub-markets using the TMF features;
5. High-level description of the market architecture.

System service procurement and provision require coordinating the power system actors involved (i.e., TSO, DSO, and FSP). The TMF studies this coordination by relying on the interaction concept since the set of interactions in the market architecture defines the coordination between actors. The interaction between provider and beneficiary can be classified as technical-based or market-based. As shown in Figure 1 in market-based interactions, the actors interact through a market architecture which may include the interaction with the actor that plays the market operator and, eventually, the market platform. The technical-based interaction is characterized by information exchange and control actions. These interactions are facilitated by a technical architecture, including interoperable platforms, communication protocols, etc., whose complexity may vary. This focuses on market-based coordination, hence, on the set of market-based interactions tested in the OneNet project.

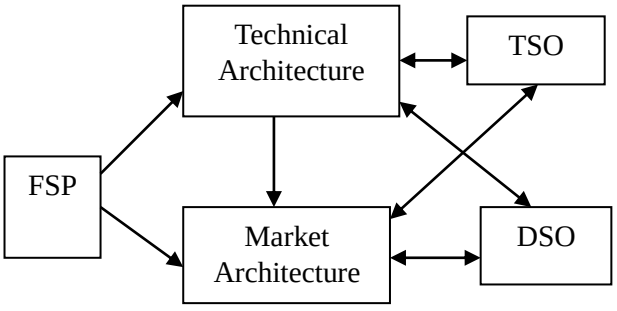

Fig.1: Technical-Based Interactions

IV. RESULT ANALYSIS

The performance analysis of theoretical market framework is observed in this section.

Table.1:Performance Analysis

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Parameters	Coordination Schemes (CSs)	TMF
Accuracy	89	95
Efficiency	90	97

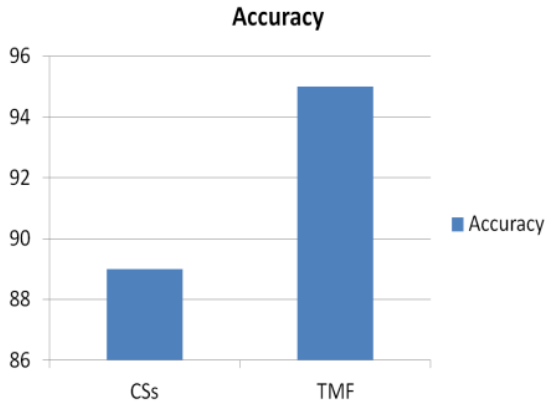

Fig.2: Accuracy Comparison Graph

In Fig.2 accuracy comparison graph Coordination Schemes (CSs) and TMF.

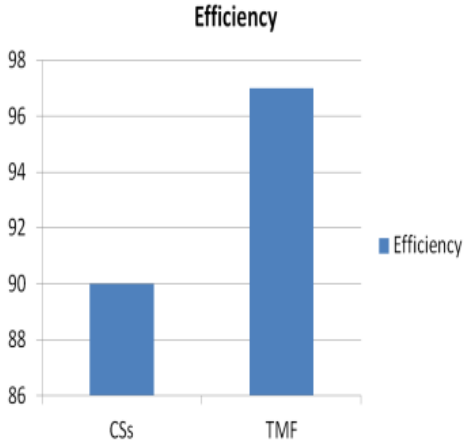

Fig.3: Efficiency Comparison Graph

In Fig.3 efficiency comparison graph Coordination Schemes (CSs) and TMF.

V. CONCLUSION

This analysis contributes to the power system evolution by addressing the perspective of integrating markets for system service products (also known as flexibility markets) into the electricity market architecture. The proposed TMF is an instrument to guide market design activities. Furthermore, the TMF supports policymakers in identifying challenges, barriers, and gaps that characterize a particular electricity market architecture. The TMF is a descriptive tool to analyze the market-based TSO–DSO coordination and a valuable prescriptive tool to guide market design and integration. It represents a single tool to describe the great variety of TSO–DSO markets by using fundamental parameters and aspects for designing coordinated and integrated markets. The TMF supports market analysts and designers by pointing out a comprehensive set of categories with possible choices that need to be made while devising an electricity. Hence this model shows better results interms of accuracy and efficiency.

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