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A Literature Review on Bilateral Contracts in Electricity Markets; Perspectives and Challenges

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ABSTRACT

Academics and practitioners are becoming increasingly interested in the role and function of bilateral contracts in the complex and ever-evolving landscape of electricity markets. Bilateral contracts in the electricity sector involve two parties trading goods and services between themselves, which is accompanied by a unique set of advantages and challenges. A significant portion of energy transactions are governed by this distinctive form of contract, which serves as a mechanism for hedging against price volatility, ensuring supply security, as well as facilitating market stability. Here, we provide a comprehensive analysis of the state-of-the-art research and developments in bilateral contracts in the electricity market. In this paper, we discuss the importance of bilateral contracts in the future of electricity markets, how these contracts can be evaluated, how they contribute to market stability, and the challenges and perspectives associated with them. The purpose of this paper is to review new studies related to bilateral contracts, as well as to analyze and review the models used in these contracts. By emphasizing the technical, economic, and regulatory aspects of such contracts, this paper aims to direct researchers, policymakers, and participants toward effective decision-making.

1. Introduction

1.1. Motivation and background

Humans have built one of the largest and most complex machines in history, the electric power system. It is imperative to maintain a balance between supply and demand at all times. There has been a profound transformation in the global electricity market over the past decade, affecting energy generation, transmission, and consumption in profound ways. A number of factors have contributed to these changes, including an increasing demand for clean energy sources, rapid technological advancements such as renewable energy and smart grids, as well as changes in energy consumption and distribution patterns. International trade in electricity is regulated and facilitated by bilateral contracts within the dynamic environment of electricity markets. Since the 1980s, many electric power industries have been deregulated to change the traditional structure of system operation and planning. In electricity markets, energy and ancillary services are traded in the competitive environment to achieve efficiency [1].

In the electricity market, bilateral contracts are defined as agreements between government entities or energy companies that are designed to facilitate the exchange of

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electricity and related services between two countries or entities. There is a great deal of significance to these agreements. As a first step, they regulate commercial relations between nations, ensure energy security, regulate electricity production and distribution, and even meet environmental commitments. Bilateral contracts can also serve to foster technical, technological, and engineering collaborations among nations, thus improving global electricity networks' quality and efficiency. By allowing multiple buyers and sellers to participate in bilateral contracts, the electricity market is made more competitive. The result of this competition may be lower prices for consumers and increased market efficiency. Furthermore, bilateral contracts can encourage investments in new generation capacity by ensuring revenue certainty for generators, which is essential for financing new developments [2].

Based on the points mentioned and the studies conducted, it is of great importance for market participants, policymakers, and researchers to understand the dynamics and implications of bilateral contracts in the electricity market. So, the purpose of this review paper is to examine the intricacies of these mechanisms, including their impact on market dynamics, pricing, risk management and overall market efficiency. By analyzing the existing literature thoroughly, this paper provides valuable insights into the role of bilateral contracts in shaping the modern electricity market.

1.2. Methodology

Our framework for presenting a comprehensive literature review on bilateral contracts study included five steps: (i) searching online databases and clustering information, (ii) refining citations and samples, (iii) refining abstracts, (iv) refining full-text reviews, and (v) final sorting. Identifying the papers involved searching the Web of Science database, one of the most comprehensive multidisciplinary content search platforms for academic researchers.

This paper delves into the intricacies of bilateral contracts in electricity markets, mapping their evolution and elucidating the mechanics of bilateral contracting. It provides a nuanced exploration of their role in enhancing market efficiency and stability, while also considering the challenges and criticisms that accompany their use. Through a comparative analysis with other market models and a review of various bilateral contract templates and examples, the discourse extends into the future perspectives and developments anticipated in this domain. In navigating these areas, the article aims to offer a comprehensive understanding of bilateral contracts, serving as both a source of practical insights for industry stakeholders and a scholarly reference for academic research.

The remainder of this paper is organized as follows. After Section 1 and 2, which have the definitions and basis of bilateral contracts, a complete review of the literature on the subject, are given in Section 3. After reviewing recent studies, Sections 4, 5, and 6 address the using bilateral contracts by dominant market participantss, mechanics of bilateral contracting, and the role of bilateral contracts in market efficiency and stability, respectively. In the Section 7, some of the most important legal and technical challenges related to bilateral contracts are stated. The Section 8 deals with the findings of the paper, and finally, the paper's general conclusion is given in section 9.

2. Understanding Bilateral Contracts in Electricity Markets

2.1. Definition and Basics

A bilateral contract in an electricity market is defined as an agreement between two parties, typically a buyer and a seller, to exchange electricity, rights to generating capacity, or related products under agreed-upon terms for a specified period. These contracts are pivotal for the functioning of electricity markets, offering price stability and certainty necessary for long-term planning and investments [3]. Bilateral transactions can occur through direct negotiation between parties or via electronic trading platforms, with the intercontinental exchange being a common venue for shorter transactions. The terms of a bilateral trade may include delivery points, volumes, timing, and pricing, with trades often categorized into blocks of time such as peak, off-peak, or round-the-clock, and priced on fixed, indexed, or strip basis [4].

2.2. Types of Bilateral Contracts

There are several types of bilateral contracts utilized within the electricity market [5]:

1) Sale contract: An agreement in which a utility or an entity offers to sell power to the latter at a specific rate or price is called a sale contract. In most cases, these sales are considered to be off-system sales.
2) Purchase contract: It is an arrangement whereby a utility or an entity receives and accepts power from another at a specified price.
3) Energy contract: These contracts may be sales or purchase contracts, but they are limited to only energy, and there is no capacity warranty, which can sometimes result in the loss of energy.
4) Capacity contract: A capacity contract can be either a sale or a purchase contract, however, they require the buyer to guarantee the capacity and to have energy available at all times. These contracts are entered into based on various factors, such as the time period over which they are to be supplied: monthly, daily, summer, winter, etc., and pricing structures, such as fixed, indexed, and strip[4].

2.3. Evolution of Bilateral Contracts

2.3.1. Impact of Deregulation on Bilateral contracts

Deregulation marked a significant shift in the electricity market, particularly affecting bilateral contracts. Traditionally, utilities were vertically integrated, controlling both the generation and distribution of electricity. However, deregulation introduced new dynamics, where utilities might not own generating resources but could still engage in bilateral contracts to manage their energy needs. This shift was particularly evident in regions managed by Regional Transmission Organizations (RTOs), where the emphasis moved towards promoting competition and reducing long-term contract engagements to avoid "locking in" high prices, which was initially thought to hinder the benefits of a competitive market [2].

Despite these changes, the need for stable, long-term agreements remained critical, especially for supporting new and renewable energy resources. Bilateral contracts have thus continued to play a vital role in financing large-scale renewable projects, where developers and utilities agree on prices that ensure project viability and reasonable returns without relying on market scarcity rents [2].

2.3.2. The Transition towards Renewable Energy Sources

The transition towards renewable energy has been significantly supported by bilateral contracts, particularly Power Purchase Agreements (PPAs). These agreements have been crucial for independent power producers, especially in financing capital-intensive projects like wind and solar power plants. By securing long-term, fixed-price contracts, these producers can mitigate the financial risks associated with high upfront costs and lack of fuel and emissions costs during operation. Such arrangements not only facilitate the financial stability of renewable projects but also contribute to hedging against future price volatility in traditional energy markets [6]. From traditional utility-focused agreements to modern, complex market structures supporting renewable energy, bilateral contracts have adapted to meet the changing needs of the electricity market, ensuring stability, competitiveness, and sustainability [7].

Moreover, the evolution of corporate Power Purchase Agreements (CPPAs) has further exemplified the shift towards renewable energy. Large corporations, driven by sustainability goals and the need to secure stable energy prices, have increasingly engaged in CPPAs, significantly impacting the development and funding of renewable energy projects. By 2020, these agreements had covered substantial renewable capacity, demonstrating the growing corporate commitment to renewable energy and its influence on the market dynamics of bilateral contracts [8].

2.4. comprehensive overview of bilateral contracts

To construct and visualize bibliometric networks in this study, the VOSviewer software is used to extract the data for keywords with at least fifteen occurrences were collected from the Web of Science database and individual clusters, which included both a network visualization (Fig. 1) and overlay visualization (Fig. 2) were merged.

Also, the occurrences average year is emphasized by the soft green, yellow and red colors in the overlay visualization shown in Fig.2. These clusters suggest publications with relative use of keywords in their publications. Among a total of 584 observed keywords, 18 meet up the level of 5 occurrences.

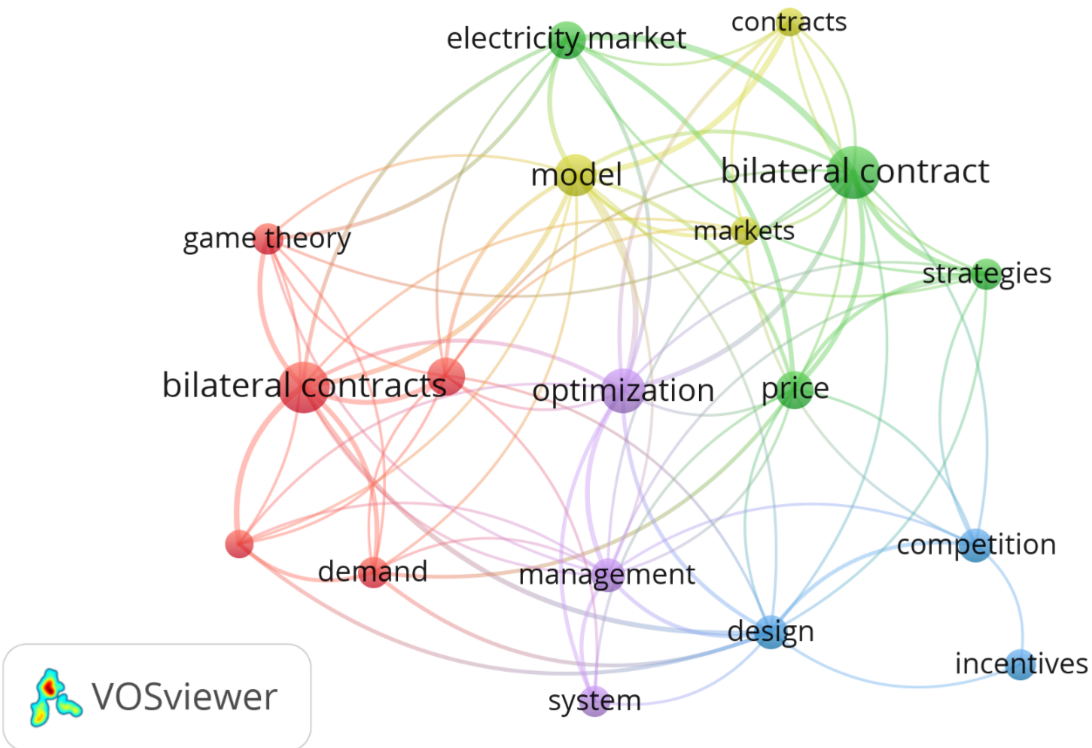

Fig.1. Keywords co-occurrences in the publications related to bilateral contracts research between 2014 and 2024: network visualization

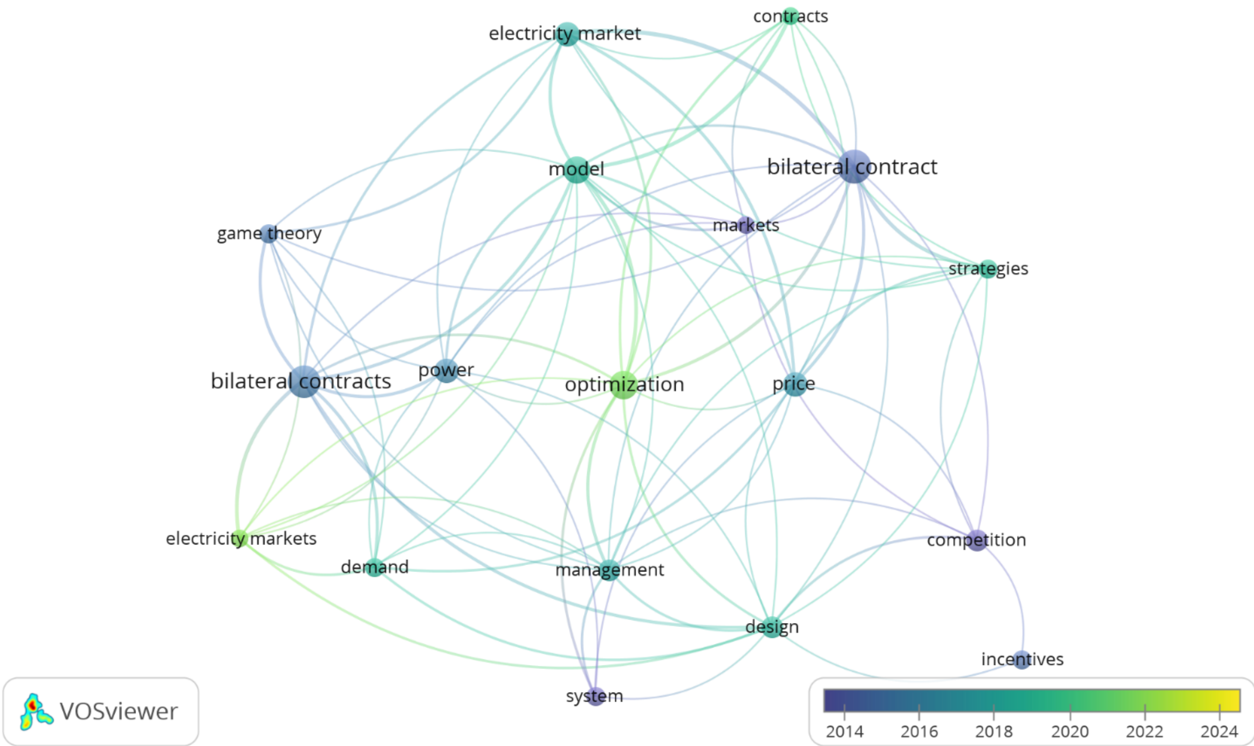

Fig.2. Keywords co-occurrences in the publications related to bilateral contracts research between 2014 and 2024: overlay visualization

3. Bilateral contracts in recent studies

Due to the importance of bilateral contracts in the electricity market, a lot of research has been done in relation to this issue in new researches. A detailed analysis of a bilateral agreement between an electricity retailer and a power market operator in a deregulated industry is presented in reference [9]. Energy is purchased by retailers at market clearing prices (MCPs), both in spot markets and through the use of bilateral contracts. It is incumbent upon retailers to estimate their payoffs and quantify the risks associated with these differences at both the buying and selling ends. In order to guarantee a risk-constrained payoff, [9] presents a series of potential bilateral quantities and the corresponding prices for a retailer. The exercises are conducted for a single retailer in the market, as well as for a case of competitive positioning between two retailers. An alternative approach to risk assessment is the use of risk-adjusted recovery on capital (RAROC). For each bilateral price at a fixed tariff of loyal load and fixed value of switching load, the problem is evaluated in order to obtain a range of bilateral quantities.

The presentation of risk-sharing contracts and risk management of bilateral contracting in electricity markets can be found in reference [10]. Spot markets are constituted by day-ahead, intraday and real-time markets, and their prices are characterised by high volatility. Derivative markets comprise both physical and financial products, which are used to mitigate the risk of fluctuations in spot prices. The terms and conditions of private bilateral contracts may be set by the players involved, but these are subject to a number of risks that can be mitigated through the implementation of a risk management process comprising three distinct phases: risk assessment, characterisation and hedging. This paper considers both risk attitude and risk-sharing, and their potential influence on the negotiation of price. [10] presents both the standard and non-standard designs of a new type of contract, the Risk-Sharing Contract (RSC). Furthermore, it outlines the trading process of these contracts and introduces a negotiation strategy for dealing with risk. It also presents case studies of bilateral contracting involving the negotiation of RSCs, where different agents interact and trade according to the rules of an alternating offers protocol.

[11] has investigated impact of bilateral contracts on wholesale electricity markets in a case where a market participant has dominant position**.** It examines different levels of bilateral contracts among producers and demand aggregators, aiming to quantify their effect. In addition, it focuses on markets where bilateral contracts could be used as a tool by market participants with a dominant position. The model in [11] incorporated bilateral contracts with committed generating capacity from producers, as well as dynamic bidding strategy per market participant.

In [12], bilateral contracting was examined in relation to electricity markets with demand response. Curtailment and shifting were examined in relation to time-of-use tariffs and their effects on energy quantity and cost for consumers. According to [13], bilateral contracts in multi-agent electricity markets are important for setting energy prices. A variety of market models were discussed in this study, including pools, bilateral contracts, and hybrid models.

There is a discussion of bilateral contracts in peer-to-peer energy trading in the references [14,15]. A bilateral contract in peer-to-peer energy trading is an agreement between two parties within a decentralized energy market. Through these contracts, prosumers, which include both producers and consumers of energy, are able to directly negotiate and trade energy with each other. Using a system like this may increase the efficiency of the power grid by coordinating small-scale distributed energy resources, which can reduce the need to invest in large-scale power generation and transmission infrastructures [14]. As a special class of coalitional game, [15] proposes a bilateral peer-to-peer (P2P) energy trading scheme under single-contract and multi-contract market setups. Using the proposed market formulation, an efficient market equilibrium can be computed while maintaining the desired economic properties. Their market model also allows buyers to have heterogeneous preferences (product differentiation) over energy sellers.

As discussed in [16], bilateral contracts have a significant impact on offering strategy, particularly when wind power producers (WPPs) are acting as price makers in the day-ahead (DA) market. Market prices can be influenced by bilateral contracts and market power can be exercised. WPPs must consider how bilateral contracts will affect their offering strategy to the DA market when they enter into bilateral contracts. A bilateral contract can have an impact on the transmission margin and the regulation market, which is why they are so important.

[17] presents a joint clearing market for coupled electricity and gas systems taking into account bilateral energy contracts. There is a great deal of complexity involved with this concept in energy economics. By integrating electricity and natural gas markets, it is possible to optimize supply and demand across both sectors, taking into account contractual agreements between buyers and sellers. PLA can be easily applied to market clearing problems based on dual variables or Lagrange multiplier pricing, as well as dealing with bilateral contracting problems, due to the solution proposed in [17].

[18] shows a Raiffa-Kalai-Smorodinsky (RKS) bargaining solution for bilateral contracts in electricity markets. The bilateral contract is used in the electricity market as a hedge against price volatility on the spot market. In order to price these contracts as profit-maximizing as possible, either the buyer or seller must schedule their actions. In order to solve this problem, Nash Bargaining Solution (NBS) equilibrium and Raiffa–Kalai–Smorodinsky (RKS) bargaining solution can be used. [18] shows that the RKS approach can achieve better results than the Nash equilibrium method when applied to a case study.

A model based on the Raiffa-Kalai-Smorodinski (RKS) approach and the Nash Bargaining Solution (NBS) approach is introduced in [19] to find the best equilibrium. During each iteration, holes are created around an existing equilibrium in the feasibility set, resulting in a new (smaller) feasibility set. There are two players in this research: a generation company (GC) and an electricity supplier company (ESC), each aiming to maximize their profit.

Using competitive trading bilateral contracts market (CTBCM), [20] examines the future direction of Pakistan's electricity market. The purpose of this study is to analyze the design and implementation phase of CTBCM in order to ensure its timely and effective implementation. In Pakistan, the main goal must be to provide electricity at an affordable price to all sectors.

Agent-based technology has the potential to help address several important issues related to market models, as described in [21]. A particular focus of the paper is the management of risk in bilateral electricity contracts. Interactions and trades between two agents are governed by alternating offers protocol. Asymmetric risk and risk attitude are considered in relation to price negotiations in the [21].

A bi-level interactive model in bilateral electricity contracts is proposed by the authors in [22]. During the first level of this interaction, the retailer selects customers and determines the duration of their bilateral contracts with them. The second level involves minimizing customer costs by introducing new interactive parameters to maximize interaction. By using the proposed bi-level model, an optimal amount of energy is also sold to each customer.

An iterative exchange of offers and counter-offers is the underlying model of [23], which is devoted to bilateral contracting. There is here a focus on coalitions of energy communities. There are two types of negotiation models: team negotiations and single agent negotiations, in which each consumer has a distinct strategy, and a distinct tactic, and a distinct decision model. There is an intra-team strategy and a decision protocol in place for coalition agents. An analysis of bilateral contracts involving a seller agent and a coalition of energy communities is also presented in [23]. The levelized cost reduction for energy communities was 19% when they allied into a coalition and reduced their average electricity costs between 2% (large consumers) and 64% (small consumers).

An innovative decision strategy for selecting a bilateral price for both seller and buyer is presented in [24]. A more efficient strategy and energy trading scheme than those proposed in traditional work requires fewer rounds of negotiations between buyers and sellers to reach a mutually acceptable price. [24] also shows that bilateral energy trading has more benefits for both the seller and buyer when it involves single sellers and single buyers.

Based on the equilibrium of coupled natural gas and electricity distribution markets, [25] studies marginal price-based bilateral energy trading. Multiperiod optimal power flow problems are solved using convex relaxation to clear the electricity market. In order to clear the gas market, a successive second-order cone programming approach is utilized.

[26] proposes a stochastic-based two-stage scheduling method for multi-energy microgrids with electric and hydrogen vehicles charging stations. It considers transactions through the pool market as well as bilateral contracts. This paper proposes a multi-energy microgrid optimized trading and business model based on bilateral

contracts between producers and consumers and pool electricity markets.

Forward contracts are bilateral agreements between a producer and a consumer under which the producer will supply a certain amount of power to the consumer at a fixed price in $/MWh for a predetermined period of time. Since market players participate in both forward and day-ahead markets, their actions in each market have an impact on the other. Therefore, day-ahead and forward markets are interconnected. The behavior of market players in forward and day-ahead electricity markets in the presence of large-scale wind farms is examined in [27]. For this purpose, first the contracting period is modeled considering various outcomes, and then the delivery period is modeled considering those outcomes. For each model, equilibrium models are presented. During the modeling process, both uniform and pay-as-bid pricing models for the day-ahead market are considered.

[28] presents a principal-agent model for designing bilateral contracts to encourage residential demand-side flexibility. To increase residential DR, this study designs economic contracts that maximize the utility's/load serving entity's (LSE) net benefit while considering the utility of individual customers. To develop optimal demand curtailment contracts between the LSE and customers based on their willingness-to-pay (WTP), authors propose a principal-agent model. It is important to design contracts that offer critical peak rebates (CPRs). As a result of these contracts, LSE is able to reduce demand for heating, ventilation, and air conditioning (HVAC) systems by remotely altering the thermostat settings of individual households.

A reliable model based on Lagrangian constrained optimization is presented in [29] for calculating the cost of breaching bilateral contracts in an electricity market system. To determine the share of the difference between the actual consumption amount and what is stated in the contract, a new mechanism based on the Lagrange multipliers method is presented in this paper. Using this mechanism, the excess consumption amount of each buyer will be related to the extra production of each seller, minimizing the sum of squared errors between them.

Using the approach of game theory and government intervention, [30] examines the issues of implementing bilateral contracts in order to increase bilateral interaction between members of the supply chain of co-production and co-distribution. Through the application of game theory to these two members of the chain and the intervention government, this research is seeking to maximize production and distribution by utilizing excess production and distribution capacity. Two ways are therefore available to the producer to utilize his surplus capacity: one is produced by the producer directly and entered into the market by the distributor, and the other is a product that the distributor orders from the producer, which is different from what the producer produces. This product is produced directly by the distributor and given to the consumer.

An optimal electricity procurement model for hydrogen fuel stations (HFSs) with responsive hydrogen demands is developed in [31]. The developed model allows the HFS operator to procure its required electricity through the day-ahead market (DA), bilateral contracts, a contract with a withdrawal penalty (CWP), and balancing markets. It has been developed as a two-stage model, where the first stage is the decision variables related to bilateral transactions, and the second stage is the decision variables related to the other transactions. Based on the results, bilateral contracts reduce expected costs and CVaR by 6% and 3%, respectively.

To strike a balance between wholesale and retail interests in a multi-agent electricity market, [32] proposes a dynamic two-layer game. In the first step, a bilateral contract-based master-slave game for the wholesale market is developed to investigate generator-supplier relationships. In the lower layer, a nonlinear reward and punishment mechanism is presented for suppliers to guide users' electricity consumption. In addition, [32] uses the evolutionary game to model the dynamic selection process of users. In a multi-agent market, bilateral contracts are able to achieve the balance between supply and demand, and the nonlinear dynamic reward and punishment mechanism can achieve the balance between interests.

Table I shows the classification and summary of recent studies related to bilateral contracts in the electricity market.

Table I. Bilateral contracts in recent literature review

Refrences	General subject	Detailes
[9 , 10 , 21]	Risk management of bilateral contracts	[9] Risk guarantee
		[10] Risk sharing and management
		[21] Asymmetric risk and risk attitude
[11,12,13,16,32]	Impact of bilateral contract on electricity market	[11] Wholesale electricity market
		[12] electricity market with demand response
		[16] Offering strategy in electricity market
		[13,32] Multi-agent electricity market
[14,15]	Bilateral contracts in peer to peer energy trading	-
[17,25]	Bilateral contracts in Integrated Gas and Electricity Networks (IGEN)	-
[18,19]	Solution to bilateral contracts	[18] RKS
		[19] RKS and NBS

[20]	Real case study	Bilateral contracts in Pakistan
[22,23,26,28-32]	Presenting a model for bilateral contracts	[22] Bi-level model
		[23] Model as negotiation process
		[26] Two-stage stochastic model
		[28] Principal agent model
		[29] Reliable model based on Lagrangian constrained optimization
		[30] Model based on game theory and government intervention
		[31] Stochastic risk averse MILP model
		[32] Dynamic two-layer game

4. Using bilateral contracts by dominant electricity market participants

In this section, it has been discussed how dominant electricity market participants utilize the bilateral contracts assessing the analysis with the scopes of market dynamic, competition theory, and influence of regulation. In these ways, dominant market participants can manipulate bilateral contracts as the means and end for entrenching and prolonging the dominance in the market, setting the price signals and driving investments in the sector, mitigating the regulatory and operational risks, and delivering their strategic vision of the future market. Due to the often subtle application of these contracts, this mastery can be the product of an equally profound comprehension of market possibilities and of local regulation; they may therefore be characterized as a highly efficacious tool when wielded by large, well-established stakeholders in the electricity markets [11,16].

4.1. Strategic Forward Contracting and Market Signaling

The large market players in electricity markets use bilateral contracts not only for covering the revenues, but also for signaling. Due to their large input that is procured at fixed prices for a long-term contract with other market firms, these firms may be in a position to influence other players in the market through adjustments of their inputs in relation to the existing future conditions. This may be a low key strategy that changes the market sentiment and puts pressure on competitors and may discourage other competitors from entering the market or even push them out.

4.2. Capacity Withholding and Price Manipulation

Bilateral contracts can be a tool for strategic capacity withholding. A dominant player could commit a part of its output through long-term contracts and hence appears to leave a part of the total production which could otherwise have been offered to the spot market. This artificially created scarcity most often impacts the spot prices and the remaining uncontracted output proves beneficial to the dominant player. This kind of strategic behaviour needs to be watched more closely as it is likely to distort the market and force end consumers to pay a lot more [33].

4.3. Cross-Market Hedging and Integration

Electricity markets are embedded in other commodity markets especially in natural gas markets, coal markets, and carbon markets. The dominant electricity players may employ this form of contractual arrangements to manage risk exposures that are derived from the interconnected markets [34]. For instance, a utility that has many gas fired power stations might adopt hedge strategies by signing long-term power purchase deals pegged on natural gas prices to reduce on the risks of fluctuating fuel costs. This form of cross market hedging can be of great importance in as much as it helps provide stability in the financial results and well defined profit margins.

4.4. Regulatory Compliance Strategy

Thus, from the perspective of regulatory requirements, bilateral contracts can be employed in a way that meets or exceeds the standards with regard to the environment and operations. For example, a power company with limited tolerance on emission levels could undertake bilateral contracts through which power can only be purchased from the renewable concrete assets, thus providing the renewable power business with a ready market and satisfying the emission standards at the same time. They may help to 'freeze-in' compliance and potentially obtain regulatory goodwill/penalties.

4.5. Market Power Consolidation through Vertical Integration

Bilateral contracts may be utilized by the dominant firms to vertically integrate to acquire control over the production as well as distribution channels. For instance, a generation company may engage in a bilateral contract with a retail firm which is affiliated with it, or vice versa, we have a large retail company which source their power from a generation firm which is within the same company group. These integrative contracts lock the supply chain in a vertical line and may be disadvantageous to the small players in that they fail to command similar supply chain owning companies [35].

5. Mechanics of Bilateral Contracting

5.1. Negotiation and Development of Contracts

Contracts in the electricity market through bilateral negotiations require a careful study of the terms between the GenCo and the LSE. This process makes use of positive outcome game theory which is bargaining theory with special focus on Nash theory, which used to make sure that result obtained during bargaining is both fair and efficient. The theory also enlightens whether or not parties can fail to agree on certain facets, with offering a systematic way to bargaining [36].

5.2. Pricing Mechanisms and Cost Structures

Cost or pricing data is essential in bilateral contracts and must contain factual and complete current data that are certified and valid at a certain date prior to the execution of the contract. This makes certain that the agreed price reflects a mutual understanding to do the job as also the various components of the offeror's technical bid. Another sharing options are also usual where the contractor incurs some of reasonable, allocable, and allowable contract costs. Direct costs, which can be readily associated with a contract, usually have a major part in the financial arrangements of these contracts [37].

5.3. Risk Management and Hedging Strategies

Bilateral contracts are one of the tools that can be used to hedge risks in the electricity market. They offer revenue and cost stability, thus helped the sellers and buyers in managing the unstable fluctuation in retail prices. This is especially the case with utility scale renewable resources which are cost intensive and are tied to long term power purchase agreements, which help to mitigate for future fuel and emission price uncertainty. Also, there is understanding in the negotiations about managing the risk and return wherein risk is quantified using tools such as the Nash bargaining theory and the Conditional Value at Risk (CVaR) [10,21,36].

6. Role in Market Efficiency and Stability

Bilateral contracts are fundamental in electricity markets because they enhance efficiency and market stability. These contracts offer structures that guarantee competition, stability of prices and supplies, and the reduction of prospective power and control of market power. The analysis showed that bilateral contracts are essential in achieving efficiency and stability in electricity markets. Not only do they help fund the economic and operational needs of the market participants but also play a crucial role in the development of renewable energy resources, thus bringing about a change in the global energy mix towards more sustainable one.

6.1. Promoting Competition and Innovation

Bilateral contracts foster a competitive environment by allowing buyers and sellers to negotiate terms that best suit their needs, independent of market operators. This allows parties to negotiate the specifics of an agreement according to the quantity, price and duration of the relationship, which will help to increase competition and innovation in the market [12]. Some organized wholesale electricity markets such as those of PJM have relied on competition to generate a resilient, cheaper and cleaner grid. The auction-based clearing price mechanism means that only the lowest bids capable of satisfying demand are used, making these markets both economically efficient and innovative [38].

6.2. Providing Predictability in Pricing and Supply

Bilateral contract enables the control of price with the ability for both generating companies as well as consumers to have an inclination to the future prices to be charged. Key benefits of these contracts, include the fact that they help participants avoid the daily showed market fluctuations since prices and quantity are agreed in advance [39,40]. Such predictability is particularly advantageous when it comes to funding and project development and scheduling, since large-scale renewable energy projects require large initial investments and are required to be economically feasible given the absence of fuel and emissions costs during the use of the product. These cost savings, however, are assured through long-term, fixed-price contracts, and keeping rates affordable ensures that ratepayers reap these benefits depending on a stable financial foundation while supporting the renewable energy transition in the long run [2].

6.3. Mitigating Market Power and Manipulation Risks

Enhance of the bilateral market can decrease the risk which connected with abuse of market power due to presence of more than one procurement option, inclusively the self-generation and the spot market. This diversity of options makes it very hard for any single seller to monopolize the market and thereby—one way or the other—manipulate price. Furthermore, the forward bilateral contracts in cross-products/ mixed-pool/ bilateral markets provide a hedging negotiation model that will fairly distribute the opportunities and threats of the future spot prices. It also minimize buyers' risk; thereby exerting a balanced and favorable impact on the prices and other contractual conditions to be offered [41].

7. Challenges of bilateral contracts

After examining the concept of bilateral contracts in electricity markets and the studies done, we divide the challenges of this type of contracts into two categories in this article.

7.1. Legal Challenges

I. Regulatory Compliance: Bilateral contracts should respect national and international regulations, namely concerning the energy market, anti-trust regulation and environmental regulation. This is especially the case when contracts cross national borders with different laws regulating the activities of companies.

II. Contract Enforceability: Problems are seen to do with the extent to which some of these terms can be implemented and complied with specifically the long-term contracts which could take many years given the regulatory periods or the political term. New laws or policies can make a contract less profitable or even unprofitable and therefore question of force majeure, contract alteration and/or contract destruction comes into the picture.

III. Market Manipulation Risks: This is because; bilateral contracts can be tailored for anti-competitive activities such as predation, capacity, or barrier to entry. One of the major difficulties is to make sure that such contracts do not contravene anti-competition laws.
IV. Dispute Resolution: Specifying acceptable ways by which the conflict can be solved is often not easy, especially when working in the international arena. There is the necessity to introduce arbitration and mediation protocols, particularly when the case has international characteristics [42,43].
V.

7.2. Technical Challenges

I. Price formation: Selection of the tariffs in the bilateral contracts can be technically complex due to the tendency of the electricity prices to fluctuate due to a lot of unpredictable factors such as fuel prices, the demand levels and the output from renewable sources of energy.
II. Load forecasting and balancing: The forecast of load and guarantee of proportionality regarding the supply and demand is highly significant when formulating a contract. Errors result in an unequal situation which is both difficult and expensive to correct.
III. Integration with wholesale markets: as there are current operations within the wholesale markets, bilateral contracts have to harmonize well with the existing conditions. This integration is a technical exchange of such a nature that contractual relations can be fulfilled without negative impact on the regularity of the market.
IV. Monitoring and compliance: Measurement and control of the process of technically monitoring the fulfillment of contractual terms needs solid tools of collecting and analyzing data. Meeting the contract provisions particularly the delivery schedules, quantity as well as quality of electricity is a technical exercise.

8. Findings and discussion

This paper has been written considering the importance of discussing bilateral contracts in electricity markets as well as the lack of comprehensive studies that examine these contracts in a specific context. Several studies have used bilateral contracts with different objectives. The following reasons shown in Fig.3, can summarize the findings of this paper in the form of a framework:

Fig.3. Reasons for importance of bilateral contracts as the findings of the paper

- Influencing the on offering strategy of producers.
- Ensuring energy stability: bilateral electricity contracts help to ensure the stability of energy supply. This helps to reduce interruptions in electricity supply and meet the needs of consumers during emergency periods.
- Financial obligations: Such contracts usually define extent or certain financial factors such as debts to pay and debts to receive in electricity tariffs. This is a very positive aspect for the creation of electricity generation and transmission and for the emergence of a more energetic development of countries.
- Environmental obligations: The following are also terms of many of these contracts: environmental terms which assist in protection of the environment. This entails the adoption of renewable energy and decrease in emission of green house gases.
- Security obligations: We can also that in some of these contracts, security issues concerning supply of electricity is addressed. These things assist in safeguarding the energy structures and combating energy security violation mishaps.
- Trade commitments: These contracts are normally useful in trading electricity between countries and in cultivating global energy markets. This in turn facilitates the economic and commercial cooperation that exists between different members of such contracts.

9. Conclusion

An overview of bilateral contracts in electricity markets around the world was provided in this paper. There is a focus in this paper on how to refer to bilateral contracts in recent studies. In order to accomplish this, all databases were searched and the amount of usage of the term "bilateral contracts" in recent years was analyzed by year. In the following stages, the new articles were examined more closely and classified and separated based on their topics. This study of bilateral contracts in electricity markets has traversed the spectrum from their fundamental role in ensuring market stability and efficiency to their evolving dynamics as we transition to renewable energy sources. According to the analysis, these contracts have multiple impacts on fostering competition, ensuring supply security, and enhancing the sector's ability to embrace cleaner energy alternatives.
As a result of a comprehensive examination of bilateral contracts' contributions to the electricity markets, it is evident that their potential is pivotal in steering the sector towards a more resilient and sustainable future. Research and policy development are integral to ensuring that these contracts are in line with the rapidly changing landscape of energy production and consumption. This conclusion, echoing the essence of the paper, not only emphasizes the significance of bilateral contracts within the electricity markets but emphasizes the need for continuous innovation and regulatory foresight in order to maximize their benefits for a sustainable energy future.

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