Energy Proceedings
Vol 28, 2022
ISSN 2004-2965

Building Blocks of Peer-to-Peer Energy Trading in a Smart Grid

Kamini Singh[1*], Anoop Singh [1]

1 Center for Energy Regulation, Department of Industrial and Management Engineering

Indian Institute of Technology Kanpur

ABSTRACT

The various power market challenges of the conventional power system are projected to be addressed by a smart grid. It entails a synergy between the three pillars of electricity trading, 1) energy market economics, 2) power network balancing, and 3). market policies and regulations. This paper explores an overview of peer-to-peer (P2P) trading under a smart grid milieu from these three pillars' perspectives. The first pillar delineates the energy user's role flipping between the consumer and prosumer due to behind-the-meter distributed energy resources integration to maximize their payoffs. At the power network, P2P trading necessitates a). robust and sophisticated network infrastructure, and b). bi-directional Internet and communication technologies for successful electricity trading in the distributed electricity market. This is defined as physical and virtual levels of P2P architecture under the second pillar of P2P. Lastly, the third pillar is essential for adequately constructing an optimal business strategy to maximize the player's profit function.

Keywords: Distributed electricity market, distributed energy resources, market economics, market regulation and policies, P2P, prosumer, power network, smart grid, virtual and physical level

1. INTRODUCTION

The conventional power system with asset aging and faltering, brown-out and dwindling, lack of transparency and price volatility, etc. all are imposing an intense challenge for its sustainable survival. And, increasing energy demand among consumers is posing an intensive burden on the existing network. It is forbidden to meet up a current and unforeseen rising energy demand in the time to come with conventional grid infrastructure. These grids have started showing their age. Broadly, a country's economy is highly subject to the increasing energy demand [1]. In a developing to developed countries, people born after the 1980s-90s consider electricity ubiquitous. Daily life is hard to imagine for them without electricity. However, some of them may find it interesting to live without electricity but not so long as it comes to losing their living comfort [2]. Electric energy becomes crucial in deciding the countries' economy. Roughly, most of the industries and multi-stories buildings consume 73% of the total energy covering 39% total share in the U.S. economy [3] than other sectors.

Indeed, an infrastructure up-gradation in the existing power system is inevitable to accommodate the integration of advanced emerging technologies. This helps to cope up with the existing techno-barriers of the power system. However, in parallel, a change in the power market structure is equally necessary to minimize the demand-supply gap with technological advancements in the system. As per [4] and [5], electricity demand in developing countries is expected to grow more rapidly than in developed countries owing to the historical pattern of electricity access and its availability. Therefore, the outdated market structure of the wholesale power market is ought to be reshaped.

Further, in the retail power market, localized electricity generation and demand at importing and exporting trading nodes in the transmission and distribution network leads to the congestion during peak hours. This allows the retailer to fake congestion in the system to play with the consumer tariffs spatially and temporally under politicized energy market regulations and policies. Therefore, due to the lack of transparency in the system under such a scenario, the entirely grid-dependent consumer has to pay more during the peak hours.

Whereas the disintegration of the existing vertical electricity supply chain into a horizontal structure allows small market stakeholders to emerge as an investor. The integration of distributed renewable energy resources (DERs) behind-the-meter enables the consumer to play a twin role of consumer as well as generator, known as prosumer [6]. They could emerge as an energy, capital, or technology provider or act as an energy aggregator in the distributed electricity market (DEM). This can be seen as a solution to construct a realistic and viable consumer-friendly electricity market at the distribution level. The profit maximization from electricity trading between the peers at the distribution level deals with the first pillar of the power trading which is knowledge of market economics.

Smart grid is the future of the power grid. It acts as second pillar providing the smart technological setup required for local power trading [6] [7]. It ensures the grid-efficiency and reliability at a minimum network loss. Further, the defined pre-setup rules and policies helps to shape the business model for any future disputes. Therefore, the energy regulation and policies is explored as a third pillar of the electricity trading in this work between the peers.

1.1 Literature Review

Peer to peer (P2P) trading in the distributed electricity market (DEM) is gaining a momentum for its prolific advantages. The researchers worldwide are contributing significantly for the success of P2P business model. The latest recognized work in P2P is presented in the Table 1 to highlight the research gap. In [8], the author has presented an economic model of an energy control and management techniques for prosumers in a P2P trading. The [9]-[10] have studied the effectiveness of optimal designing of bidding strategy for the demand-side, and for a bilateral contracts, respectively. They have used the economic modelling to maximize the economic payoff of prosumers.

In [11]–[13], the authors has reviewed on the synergy between the prosumers and the system operator for a successful P2P trading. It shows the correlation between the first and second pillars of P2P trading, but is limited by ambiguity. However, the [14] explicitly discussed about the role of technical employees ‘support on the network operation, and [15] highlights the significance of optimal bid designing with system reliability in the future distribution system for energy trading.

A smooth communication flow at virtual level is a key for a successful P2P trading. Improper flow of information may trigger the divergence between the mutually agreed players. The author of [16] has presented three types of communication based network to maximize the prosumers reach for P2P trading. And, the [17] has proposed a blockchain based P2P business model elaborating the smart contract for a virtual power plant. The smart contract armor the players from getting into any disputes, but not guaranteed. This emphasizes the need for pre-defined set of business policies as a third and important pillar for P2P trading.

Index / references	Market Economics			Power Network		Regulation & Policies	
	Business model (P2P)	Market operation		Sys. Reliability	Sys. Operation	Dispute management/guidelines	Transaction settlements/ adjustments
		Bidding strategy	Payoff maxi	Physical level	Virtual level		
[17]	Y						Y
[16]	Y		Y		Y		
[8]	Y	Y	Y				
[9], [18]	Y		Y				Y
[14]				Y	Y	Y	
[11] R	Y	Y	Y	Y	Y		
[12]	Y	Y	Y	Y	Y		
[13] R	Y	Y	Y		Y		
[15] R		Y		Y			
PW* R	Y	Y	Y	Y	Y	Y	Y

Table 1: Research gap table; R: review paper; PW*: presented work

Earlier presented works on P2P trading are lacking to establish a corelationship between the three main pillars of energy trading. This paper reviews the P2P trading to unveil its role in empowering the emerging decentralized distributed power market. We debate under a smart grid facilitated improved and healthy power system network the three pillars of P2P are work in a synergy. And, an appropriate knowledge of above provides an equal opportunity to all the market stakeholders. This would help the readers to understand the know-how of the market economics of the emerging digital DEM.

The paper is divided into six sections. Section II describes the offerings of Smart grid to DEM. Section III discusses the twin role of an energy user from being entirely a consumer to becoming an independent prosumer. Section VI and section V demonstrate the two levels of peer-to-peer (P2P) trading and roadways to successful P2P trading in DEM over these levels, respectively. Finally, section VI concludes the paper.

2. P2P REQUISITES: SMART GRID

A smart grid integrated with advanced and intelligent electronic devices (IEDs) and supported by internet and communication technologies (ICT) is a promising solution. It opens up a new prospect for distributed power market, incorporating healthier monitoring and controlling of the grid, asset managing, data security and privacy, leading to improve reliability and efficiency of the system [19]–[23]. Therefore, the nervous system of the smart grid, enabled by IEDs when embedded with ICT, lies in the effective management of mitigating the demand-supply gap. It compliant 1). continuous up-gradation of grid infrastructure to support new technologies, 2). grid decarbonization with renewable integration 3). optimal allocation of generated electricity transmission capacity to avoid the congestion in the network, 4). rapid integration of ancillary services during contingencies at the transmission system operator (TSO) and distribution system operator (DSO) level. The improved network control offers a flexible P2P trading platform to the buyer and seller. The smart grid at the distribution level accommodating P2P trading known as a microgrid. Technically, a microgrid is a subset of a smart grid that functions in an islanded mode. The characteristics of a smart grid/microgrid are given as follows:

2.1. Network control and monitoring

Revitalizing the grid through upgrading/replacing the aged energy producing, managing, and distributing assets and technologies improves the overall power systems reliability. The smart power grids embedded with information and communication technologies (ICT) offers real-time data tracking hence, a better control. The real-time monitoring of load pattern improves the overall system efficiency and transparency which is must for P2P trading. The complete automated structure of smart grid allows flexibilities to the electric utilities as well as consumers for their load control. A power network with advance monitoring and control lead the players (buyer and seller) to get engaged easily one-to-one without difficulty for P2P trading.

2.2. Behind the meter technology integration

The embedded technologies advanced metering infrastructure (AMI), meter data management system (MDMS), phasor-measurement unit (PMUs), flexible alternating current transmission system (FACTS), wide area monitoring system (WAMS), energy management system (EMS), etc. enables the real-time flow of information between the utility and consumers. Technology integration at the consumer end allows them to track their real-time energy consumption and generation data for better decision making to participate in a P2P trading. They can also optimize their savings by voluntarily participating in demand response (DR)/demand-side management (DSM) programs. These programs offer them incentives by agreeing to shift their load from on-peak to off-peak hours as directed by the distributed system operator (DSOs) [24],[25]. This assist them in greater savings on their meter bills by altering their load pattern based on the historical data of their consumption. Such arrangements P2P/DR/DSM directly benefits the DSOs in improving the system reliability, demand-supply balancing, bill collection efficiency, removing manual meter reading, and confiscating meter bypassing and energy theft. Therefore, it improves the overall system's revenue.

3. P2P OFFERINGS TO THE SYSTEM

3.1. Decarbonizing the sector through DER integration

The rising concern on decarbonizing the sector to meet the world climate change targets formulated in the Paris agreement at the United Nations climate change conference (COP 21) has enforced the power sector for integration of renewable generations [26]–[28]. Distributed generation, dispersed energy storage with electric vehicles utility-ends and at consumer-end enables the system to work in islanded mode (Micro-grid) without stressing the grid hence, an environmentally sustainable grid. The emergence of Microgrid is still at its nascent level due to a lack in the consolidation of standards and protocols of immature evolving technologies. However, the prospect on evolution of distributed energy market in a Microgrid has already taken place. The P2P trading is one such energy market in which the energy users with DER integration behind the meter participates one-to-one in their neighborhood. The appropriate knowledge of market economics and know-how of trading platform assist them to maximize their personal as well as societal payoffs [29].

3.2. Emergence of distributed electricity market

The development of DEM under a Microgrid milieu enables the consumers (integrated with advanced technologies and DERs) to participate in the decentralized electricity market as a leading market stakeholders. Prosumers producing surplus energy can experience through feed-in-tariff (FiT) or can go P2P energy trading to optimize their revenue using bi-directional communication [11], [30], [31].
They can also opt to be completely off-grid through vehicle-to-home (V2H) integration. Thereby, distributed generation alters the load pattern, making the grid more reliable and robust. Furthermore, the integration of DERs at consumer's-end enables them to contribute to societal benefit by decarbonizing the grid. Whereas, by altering the spatial pattern of generation using distributed generation, DSOs can maintain the grid harmonization during on-peak periods [11], [32].

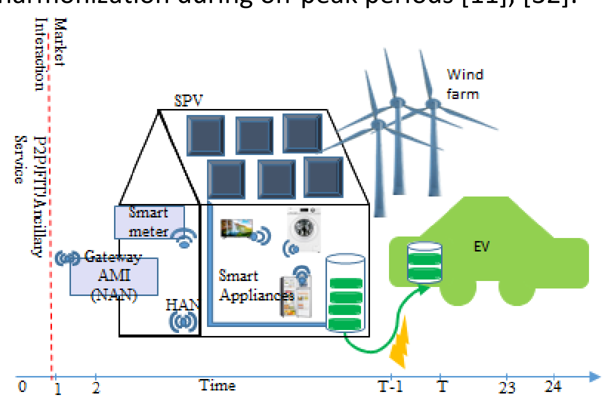

Fig. 1: Transforming role of an energy user from grid-dependent consumer in a wholesale market to grid-independent consumer (prosumer) in DEM

3.3. Transitioning of an energy user: prosumer

A collaborative network with ICT facilitates the power system with significant challenges and opportunities in every arena, particularly in the market sector. The power market structure is changing from wholesale to retail to DEM with increasing behind-the-meter DER integration. Therefore, unlike the energy user in the wholesale market who are used to be A grid-dependent entity for their primary energy need have the opportunity to emerge as a grid-independent entity in DEM through P2P trading. An energy user's capacity of producing behind-the-meter energy with DER integrations has given them an identity of prosumer. Such energy users are self-generating the energy to consume. Therefore, under a smart grid milieu, when a prosumer is producing more power than their need; the DEM market structure allows them to trade the surplus energy to their neighborhood using P2P trading. Fig. 1 shows a house setting of a prosumer in the DEM market under a smart grid milieu. Such that all the players are equipped with home area network (HAN) using IEEE 802.15.4 ZigBee/ local area network (LAN), radio frequency mesh, etc. They communicate using smart metering infrastructure to get informed about real-time market prices and energy transaction data.

Additionally, smart grid enabled bi-directional communication between a supplier and consumer aids them to make more informed decisions. The development of behind-the-meter power generation, storage, and sales of surplus energy to the grid is paving the way for the emergence of prosumers, who can simultaneously play a twin role of producers and consumers. This gives the energy users market power to become a price setter in the smart grid. Thus, every energy user can directly maximize their payoff using DER in DEM, indirectly boosting environmental health and grid reliability. One such study is shown in [33] for EV adoption. A prosumer failing to participate in P2P, e.g., due to unavailability of the buyer, can participate in other DEM markets such as FiT to sell the surplus to the electric utility and/or in a distributed ancillary services for the day ahead or intra-day markets [34]. For distributed ancillary services, a prosumer has to confirm her availability before the slot, and she must not be engaged in any other transaction during the allotted slots.

4. TWO LEVELS OF P2P TRADING

The roadway to decentralized DEM requires interoperability between the engaged market players and between the different functional levels. Players could be buyers, sellers, and network providers as per their role in the DEM market settings. The two primary operational levels that require interoperability are the virtual and physical levels.

4.1. *Virtual level*

The virtual level supported by ICT is further divided into communication and business layers. At the communication layer, players engage with each other using a bi-directional communication network topology. The final P2P trading occurs at the business layer at the negotiated energy prices.

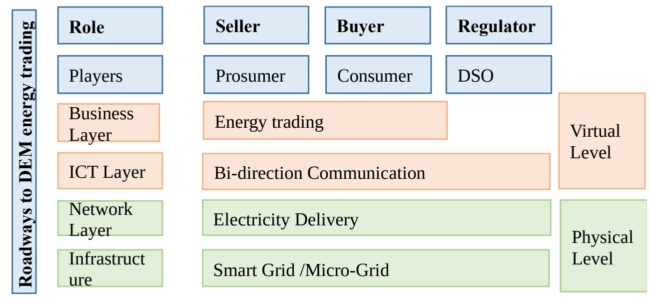

Fig. 2: Roadmap to decentralized P2P energy trading in a distributed power market

4.2. *Physical level*

The physical level supports all the power network infrastructure requirements for the physical delivery of the energy at due time. For example, in today's time (twenty-first era), all the social networking mobile apps allow sender and receiver to communicate using ICT (wi-fi/ZigBee) at the communication layer. If they engage in any payment activities, these apps provide a secure encrypted platform (blockchain, etc.) for transferring the currencies for successful businesses. But, to do so, the buyer and seller both require a physical infrastructure, i.e., a smart device embedded with ICT (mobile/laptop/iPad/ etc.), which represents a physical level. The same goes for electricity trading in the DEM market. Therefore, in this case, the supporting physical infrastructure is facilitated by the emerging smart grid. Fig. 2 depicts the sequential arrangements of these layers with the role of entities involved in DEM.

5. THREE ROCKS OF P2P TRADING

The roadways to P2P trading rely on the knowledge of the three pillars of the DEM market 1). energy market economics, 2). system network balance, and 3). clearly defined market regulation and policies. Fig. 3 depicts the three pillars of P2P trading in the DEM.

5.1. Energy Market Economics

The energy market economics deals with the knowledge of distributed market functioning to find a personalized business model. The DEM market economics answers the questions related to P2P trading, such as 'how,' what,' and 'why.' The 'how' and 'what' defines the market operation of how a prosumer can participate in P2P and what are the pre-requisite she has to have the knowledge of. Whereas the 'why' defines their business model, which maximizes their payoff. For example, knowing 'how' assist the prosumer whether she should participate in standalone mode or hybrid or a coalition mode, 'what' informs them about their action set, which is finding a suitable bidding strategy, and 'why' allows them to find an optimal trading model that maximizes their profit against their rivals. Generally, appropriated knowledge of market economics aid players in the prior communication between them (buyers and sellers) to negotiate the buying/selling prices to have an optimal business model. Therefore, one can cite these dimensions of P2P on a virtual level of the P2P roadmap, Fig. 2.

5.2. Power Network

Smart grid/ Microgrid (under section 2) discusses the mandatory infrastructure support for successful P2P trading. The availability of network capacity for any energy transaction heavily relies on the system's reliability without losing the grip on power quality and frequency control. Any disturbance in the up and down frequency regulation can damage the system severely. This justifies the involvement of DSO in P2P to oversee the energy transaction between the players in the allotted time. This requires sending transacting signals first to DSO by the players to confirm the availability of network capacity for any future P2P trading. This might lead the players to pay a fixed service fee to DSO to avail the network capacity. Additionally, like the P2P market economics, this dimension of P2P can be cited on the physical level of the P2P roadmap, Fig. 2.

5.3. Regulation and Policies

Simply the power system policies and regulations can be divided into two segments as per the levels of the power market, 1). A business layer at the virtual level, and 2). Physical level, Fig. 2.

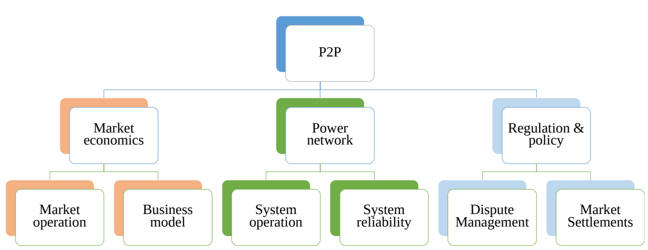

Fig. 3: Three pillars of P2P trading in DEM

5.3.1. Business layer

Business layer policies deal with the conductance of the market operation. This policy defines a set of rules known as regulations to be followed by the market players (retailers/aggregators/prosumers) while designing their market economics. The existing market regulations and policies are designed per the convenience of prominent market players participating in the wholesale market for optimal resource allocation. However, with proposed P2P trading and the emergence of prosumers as price setters in DEM requires a redesign of market policies and regulations centric on the distributed level. These policies should support behind-the-meter DER integration in prosumer's premises such that if a prosumer is participating in P2P, she should be guided by these policies to minimize the dispute between the players. Such issues need to be clearly directed before the actual market takes place. Therefore, a vaguely designed market policies may fail to address the dispute management regulations. Dispute management deals with the rift between the players during market settlement or due to a breach of contract.

5.3.2. Physical layer

The physical layer policies deal with the set of rules for large generators, wires, substations, etc., at the wholesale market level. This deals with another side of the power market. Simply, the physical policies are designed to minimize network congestion and maximize transmission and distribution efficiency. However, with the proposed Microgrid, offsetting these policies and regulation is necessary to accommodate the emerging technologies and power market to achieve a sustainable grid from an economic, environmental and social standpoint. The improvements in the existing regulation would ensure success in achieving a sustainable future grid.

6. CONCLUSION

The presented work highlights the basic frameworks of emerging decentralized power market structure. The role of the smart grid in the emergence of prosumers as independent market stakeholders and P2P trading is discussed. As per the infrastructure requirements for a decentralized power market, P2P trading is break-up into two levels of interoperability operations. And three pillars of P2P over these virtual and physical levels are put forth to develop a clear picture of successful P2P trading to the readers.

REFERENCES:

[1] C. E. Perspectives and I. Collection, "The power of working smarter," 2005.
[2] W. Strielkowski, "Social and Economic Implications for the Smart Grids of the Future," *Economics & Sociology*, vol. 10, no. 1, pp. 310–318, 2017, doi: 10.14254/2071-789X.2017/10-1/22.
[3] The Economist, "Building the smart grid," vol. 391, pp. 1–6, 2009.
[4] C. Report, "Growth 18," 2018.

[5] IEA (2017), "'World Energy Outlook 2017', https://www.iea.org/reports/world-energy-outlook-2017," *IEA, Paris*.

[6] C. Sasse, G. Manager, and T. Areva, "Electricity Networks of the Future," pp. 1–7, 2006.

[7] R. R. K. R. K. Sharma and K. Singh, "SMART GRID : A MANAGERIAL PERSPECTIVE," *Procedings of the International Conference on IEOM*, vol. 2018, no. JUL, pp. 972–974, 2018.

[8] K. O. A. M. A.-M. HAILING ZHU, "Peer-to-Peer Energy Trading in Smart Energy Communities: A Lyapunov-Based Energy Control and Trading System," *Renewable and sustainable energy review*, vol. 15, no. 2, pp. 1–22, 2022, Accessed: Apr. 24, 2022. [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9758722

[9] "Assessing the competatitveness of demand side bidding," *IEEE*, Accessed: Apr. 24, 2022. [Online]. Available: https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=744498

[10] T. Morstyn, A. Teytelboym, and M. D. McCulloch, "Bilateral contract networks for peer-to-peer energy trading," *IEEE Transactions on Smart Grid*, vol. 10, no. 2, pp. 2026–2035, 2019, doi: 10.1109/TSG.2017.2786668.

[11] W. Tushar *et al.*, "A motivational game-theoretic approach for peer-to-peer energy trading in the smart grid," *Applied Energy*, 2019, doi: 10.1016/j.apenergy.2019.03.111.

[12] C. Zhang, J. Wu, Y. Zhou, M. Cheng, and C. Long, "Peer-to-Peer energy trading in a Microgrid," *Applied Energy*, vol. 220, no. December 2017, pp. 1–12, 2018, doi: 10.1016/j.apenergy.2018.03.010.

[13] H. Mohsenian-rad, T. Saha, H. V. Poor, and K. L. Wood, "Networks via Peer-to-Peer," *IEEE Signal Processing Magazine*, vol. 35, no. July, pp. 90–111, 2018.

[14] M. E. Honarmand, V. Hosseinnezhad, B. Hayes, and P. Siano, "Local energy trading in future distribution systems," *Energies*, vol. 14, no. 11. MDPI AG, 2021. doi: 10.3390/en14113110.

[15] J. Collins and W. Ketter, "Smart Grid Challenges for Electricity Retailers," *KI - Künstliche Intelligenz*, vol. 28, no. 3, pp. 191–198, Aug. 2014, doi: 10.1007/s13218-014-0311-6.

[16] T. Baroche, F. Moret, and P. Pinson, "Prosumer Markets: A Unified Formulation." [Online]. Available: https://gitlab.com/fmoret/P2PApp.git.

[17] S. Seven, G. Yao, A. Soran, A. Onen, and S. M. Muyeen, "Peer-to-peer energy trading in virtual power plant based on blockchain smart contracts," *IEEE Access*, vol. 8, pp. 175713–175726, 2020, doi: 10.1109/ACCESS.2020.3026180.

[18] T. Morstyn, A. Teytelboym, and M. D. McCulloch, "Bilateral contract networks for peer-to-peer energy trading," *IEEE Transactions on Smart Grid*, vol. 10, no. 2, pp. 2026–2035, Mar. 2019, doi: 10.1109/TSG.2017.2786668.

[19] H. Mohsenian-rad and S. Member, "Optimal Demand Bidding for Time-Shiftable Loads," vol. 30, no. 2, pp. 939–951, 2015.

[20] M. Van Den Briel, P. Scott, and S. Thi, "Randomized Load Control : A Simple Distributed Approach for Scheduling Smart Appliances".

[21] J. Yang, J. Zhao, F. Luo, F. Wen, and Z. Y. Dong, "Decision-Making for Electricity Retailers: A Brief Survey," *IEEE Transactions on Smart Grid*, vol. 3053, no. c, pp. 1–1, 2017, doi: 10.1109/TSG.2017.2651499.

[22] M. Erol-Kantarci and H. T. Mouftah, "Wireless multimedia sensor and actor networks for the next generation power grid," *Ad Hoc Networks*, vol. 9, no. 4, pp. 542–551, 2011, doi: 10.1016/j.adhoc.2010.08.005.

[23] W. Wang, Y. Xu, and M. Khanna, "A survey on the communication architectures in smart grid," *Computer Networks*, vol. 55, no. 15, pp. 3604–3629, 2011, doi: 10.1016/j.comnet.2011.07.010.

[24] 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, Nov. 2008, doi: 10.1016/J.EPSR.2008.04.002.

[25] T. C. Chiu, Y. Y. Shih, A. C. Pang, and C. W. Pai, "Optimized Day-Ahead Pricing with Renewable Energy Demand-Side Management for Smart Grids," *IEEE Internet of Things Journal*, vol. 4, no. 2, pp. 374–383, 2017, doi: 10.1109/JIOT.2016.2556006.

[26] U. Series and O. N. Journalism, *Getting the Message Across*. Paris: United Nations Educational, Scietific and Cultural Organisation, 2018.

[27] "Smart Grid Handbook for Regulators and Policy Makers | 1".

[28] IEA, "Technology Roadmap Smart Grid," *Current*, 2011, doi: 10.1007/SpringerReference_7300.

[29] K. Singh and A. Singh, "Behavioural modelling for personal and societal benefits of V2G/V2H integration on EV adoption," *Applied Energy*, vol. 319, p. 119265, Aug. 2022, doi: 10.1016/j.apenergy.2022.119265.

[30] S. N. Islam, "A new pricing scheme for intra-Microgrid and inter-Microgrid local energy trading," *Electronics (Switzerland)*, vol. 8, no. 8, 2019, doi: 10.3390/electronics8080898.

[31] W. Wang, Y. Xu, and M. Khanna, "A survey on the communication architectures in smart grid," *Computer Networks*, vol. 55, no. 15, pp. 3604–3629, 2011, doi: 10.1016/j.comnet.2011.07.010.

[32] V. S. K. Murthy Balijepalli, S. A. Khaparde, and R. P. Gupta, "Towards Indian smart grids," *IEEE Region 10 Annual International Conference, Proceedings/TENCON*, pp. 1–7, 2009, doi: 10.1109/TENCON.2009.5395890.

[33] K. Singh and A. Singh, "Behavioural modelling for personal and societal benefits of V2G/V2H integration on EV adoption," *Applied Energy*, vol. 319, p. 119265, Aug. 2022, doi: 10.1016/j.apenergy.2022.119265.

[34] K. Singh and A. Singh, "To do or not to do: Prosumers strategic decision to participate in the distributed electricity market," *International Conference on the European Energy Market, EEM*, vol. 2020-Septe, 2020, doi: 10.1109/EEM49802.2020.9221877.