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Transactive Energy System Concept in Power Distribution System- A Review

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Abstract: The power sector is undergoing evolution towards more effective, dependable, and resilient systems. The adoption of distributed energy resources (DER), particularly renewable DER (RDER), signifies a groundbreaking transition. DER offers a multitude of benefits to power systems, such as decreased emissions, environmental advantages, improved safety, reliability, and network connectivity. Nonetheless, a high level of penetration presents challenges, leading to confusion and impediments in the seamless operation of electrical systems. This paper explores delivery systems crafted to tackle these challenges. The distribution platform incorporates an interactive distribution system that provides synchronized control to address the demand-supply gap and monitor uncertainties linked to DER. Transactive Energy (TE) incorporates business and management techniques to achieve the dependability, stability, and efficiency of smart grids (SGs). This analysis underscores the potential of TE operations in prolonging the overall lifespan of distribution transformers. Additionally, the cooperative approach equips DER with the ability to navigate and oversee the electricity market, fostering collaboration among market participants.

Keywords: Power Market, Demand Response, Distributed Generation, Distribution System

1. Introduction

1.1 Literature survey

The grid has come a long way since Thomas Edison’s invention of the first electric generator in 1882 Ambrosio (2016). Today, the energy sector has undergone a significant transformation, with the shift from a monopoly structure to a restructured electricity system. This system is monopolised and vertically controlled, with the operator ensuring system consistency and protection while reducing energy costs for all products by sending out the energy produced. The energy industry was restructured in 1990, dividing it into three parts to provide unique energy products and create competition to reduce service costs. This restructuring created a market that enables competition and offers consumers a wide range of energy products. Gan et al (2014); Zhang (2010); Rahimi and Ipakchi (2012).

The current trend in electricity development involves a shift from centralized electricity to a demand-driven model. Distributed Energy Source (DER) is a promising energy production source that offers numerous economic and technological benefits Daneshvar et al (2021a). The decentralized power model enables local energy usage, ensuring the safety and reliability of the power supply and network operation. This approach also reduces transmission losses from generation to consumption. Furthermore, renewable energy sources (RER) generate less carbon than conventional power plants and use vestige-based fuels. From an economic standpoint, as the energy infrastructure evolves, energy postpones the need for large-capacity facilities, providing more affordable and stable prices Pinto et al (2015); Knight (2016); Bowes and Beehler (2015). However, the growth of DER can lead to reliability or operational issues if not appropriately managed. Increasing RER installation could change the underlying supply and create duck load curves, forcing reductions. For example, in California, this happened and caused wind disruptions in the Pacific Northwest region Hammerstrom (2016). To tackle these challenges and guarantee the effective operation of the energy system a novel distributed client (DSO) and telecommunications paradigm are required to manage the transmission and distribution management system, respectively, by ISO and DSO Ambrosio (2016); Rahimi et al (2016); Rahimi and Ipakchi (2016). The concept of Total Energy (TE) can be defined as a useful factor in balancing power generation and load. Kristov et al (2016); Widergren and S (2016). TE is a combination of procedures that ensure the visibility, reliability, stability, and efficiency of the energy grid with a high penetration of DER, depending on business and management points of view Rahimi et al (2016).

TE can be viewed as the fundamental principle for the amalgamation of DER, particularly renewable DER, to the grid (SG), where end customers also take a pivotal position. Thus, to establish a transparent market devoid of market power, the focus of all market regulations should be on market utilization. However, in practice, certain factors contribute to an increase in charges within the electricity market. In such a scenario, the concept of TE can enhance operational efficiency by bolstering control over work management. Furthermore, the restructured TE policy reduces the need for a controlling entity or any other entity capable of disrupting the business pattern. Within the TE framework, all products within SG are exposed to business and market information through secure communication channels. Consequently, all distribution controls and end users can monitor the impact on business operations. Additionally, the coordinated operation of all components within the entire power system is crucial to ensure the effective and reliable functioning of the entire structure. As a result, TE can establish a binding entry pattern within the market. Kristov et al (2016); Widergren and S (2016)

This study investigates microgrids (MGs) and transactive energy (TE) through a systematic review. The research indicators reveal a growing interest in MGs worldwide, driven by the pursuit of alternative energy generation using renewable energy sources (RES). Additionally, the integration of blockchain technology in the energy market shows promise for decentralized and secure virtual transactions. The study sheds light on interactions between prosumers and utility providers, emphasizing sustainability in MG communities through self-supply and RES utilization Rodrigues and Garcia (2023)

Transactive energy is a powerful method for peers to exchange and trade energy resources. Within the transactive energy framework, various interconnected components including generation businesses, prosumers, the energy market, energy service providers, and transmission and distribution networks play crucial roles. This article provides an in-depth exploration of transactive energy concepts, primary drivers, architecture, energy market dynamics, control and management strategies, network management, emerging technologies, and the flexibility of power systems. Researchers will find valuable insights to navigate this multifaceted field Gupta et al (2022). This paper proposed an innovative transactive energy approach as a viable option for coordinated distribution system planning over a specific time horizon. The approach is evaluated using a multi-looped (meshed) test system, considering load growth and prosumers actively participating in the electrical market. The evaluation focuses on techno-economic aspects. The proposed framework was validated using the IEEE 69-bus system Tariq et al (2024). Transactive energy systems (TESs) represent a fusion of economical and control mechanisms, offering promising solutions for integrating distributed energy resources (DERs) into modern power grids. TESs foster a fair and efficient energy ecosystem, benefiting both participants and the grid Hai et al (2023).

1.2 Contributions of this paper

Examining the issues outlined in the preceding section, this paper assesses the Transactive Energy (TE) based Distribution System Operator (DSO) framework, concentrating on the merging of the transmission and distribution sectors. The necessity to establish a background for this analysis becomes the foundation for the overall platform's crucial requirements. The approach involves physically balancing energy within the electrical grid by comprehending diverse types of Distributed Energy Resources (DER). While the persistent presence of DER emphasizes the need for a TE-enabled framework in forthcoming electricity grids, existing literature should highlight a collective initiative to establish an energy partnership between Independent System Operators (ISOs) and DSOs.The collaboration between ISOs and DSOs plays a pivotal role in ensuring customers receive a secure, well-organized, and reliable power supply. This study introduces a novel perspective by employing the TE paradigm to manage energy interactions, specifically addressing the challenges posed by renewable energy. It establishes a new foundation for the dependable operation of existing energy systems. Consequently, the roles and responsibilities of DSOs are thoroughly explored to demonstrate how innovative systems should be devised to resolve these challenges. Subsequently, TE-based DSOs are examined, considering the interactions between bulk and consumer energy markets. The relevance of this framework to TE design and its system is carefully analyzed to validate its capability to foster interactions across various layers of the Smart Grid (SG). To evaluate the suitability of TE in the existing energy system, a comprehensive investigation is undertaken, exploring widespread implementation, addressing multiple challenges, and targeting various objectives. The novel TE framework contributes to the future structure of the energy network, involving numerous transmission and distribution stakeholders to ensure the provision of reliable and cost-effective energy.

1.3 Organisation of paper

The following sections of the paper are organized as outlined below: In Section 2, the Transactive Energy concept, along with the roles, responsibilities, and different types of Distribution System Operators (DSOs), is elucidated. Section 3 provides an in-depth exploration of the Transactive Energy approaches implemented in the Distribution system. The classification of Transactive Energy Systems is covered in Section 4. Section 5 outlines the various Management Levels integral to Transactive Systems. Sections 6 and 7 delve into the architectures employed in Transactive Energy Control and the associated trading mechanisms, respectively. Section 8 is dedicated to the implementation scheme of Transactive Energy. Section 9 offers a detailed examination of the application of transactive energy in smart grid operation. Concluding the paper, Sections 10 and 11 present the derived conclusions and outline the future scope of this work.

2 Transactive Energy scheme

2.1 Concept and Definition

The business models were first developed for the wholesale market in the 1990s. In the electricity market's transmission level business environment, ISO works to reduce the cost of electricity, including safety restrictions. ISO uses a market-based method, the Locational Marginal Pricing (LMP), as the market price, which is just one of the options for choosing the price of electricity in the TE system Kristov et al (2016). The TE framework extends the transactive network to the distribution level, providing demand-side management capabilities and the ability to drive customers involved in electric sales or purchases Rahimi and Ipakchi (2016). Therefore, among Transactive Energy functions in the retail and wholesale markets, Ref. Kristov et al (2016) projected the idea of TE," homeostatic control," in 1987 Knight (2016). It emphasises the need for automated and decentralised decision-making to deal with uncertainty and electrical power system changes. In this homeostatic management system, usage is based on changes in the field price, similar to dynamic price applied in management today.

Ref. Widergren and S (2016), homeostatic control is the idea of balance between generation and load based on the economic process obtained from the energy market as per the time-varying prices Forfia et al (2016). According to this background, producer consumers and other DERs are armed with smart devices called transfer agents. Trade can occur using bilateral or wholesale interactions between merchants, DERs, microgrid operators, wholesalers and other DSOs Forfia et al (2016).

TEs are a great way to increase the efficiency of various sources at the transport and delivery level. TE enables business and management systems to access DER effectively while maintaining a wholesale microgrid-organised transport system that proposes top-down optimization, two-way safety and trustworthiness of the system Rahimi et al (2016). The combination of finance and management leads to a reliable, stable, and efficient network Collier (2016). GWAC proposes Transactive Energy as" an economic and energy management system that balances energy supply and demand for economic value while determining reliability" Kristov et al (2016); Widergren and S (2016) and seeks to create a place in the room to add work and effort. Grid Wise Architecture Council (GWAC) organised a workshop as the first project in the field of TE in May 2011. Smart grid quality control is divided into four groups, using the following idea Rahimi et al (2016) to illustrate the nature of the transactive approach based on quality control Rahimi and Albuyeh (2016).

Figure 1 illustrates these classifications: top-down control, Price reaction, Centralized optimisation, and Transactive control. It indicates whether it is based on one-way or two-way communication. The line divides the different paths into two categories according to the decision of the set of local problems: local decision or central decision. In this picture, interactive management is the best way to integrate changing materials into the electronics business. The business mechanism uses two communication methods: price and energy as quantity. Transactive

Operators react by receiving Transactive Incentive signals (TIS) and transmitting corresponding Transactive feedback signals (TFS) appropriate for load estimation. Schweppe et al (1980); Olken (2016). This two-way communication provides greater security for responses and business transactions through appropriate incentive signals. Additionally, the local decision-making process leads to negotiation utilising all available DER and response capacity and protecting end-user confidentiality. The market manager allows consumers to participate in the market and regulate their consumption/production, accordingly, deciding the consumption/production amount they want and the price they are ready to pay or bid. Ref. Chandler et al (2014) elucidate the operation of the transactive exchange market and contrast it with active and interactive markets. An active market refers to a commercial setting where the price is manipulated, prompting the end customer to respond to the initial price set by the central authority. Interactive marketing is the broadcasting of calls and marketing environment for medium optimisation that allows the customer to feed the data back to the central control to set the starting price. The transactive business sector is the best place for business management, providing automatic and decentralised control for end customers. Considering the features of these business markets, active, interactive and transactive environments are appropriate for short, medium and long-term work Jin et al (2012).

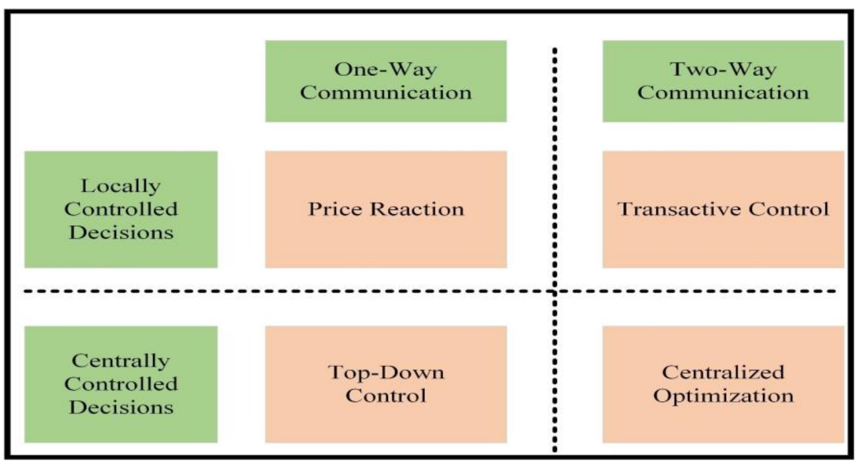

Fig. 1: Smartgrid Quality Control Widergren and S (2016)

2.2 Transactive systems

The Transaction System (TS) is a collaborative policy that enables the exchange of business and value. The TS can simultaneously achieve many functioning and business aims, some of which are illustrated in Figure 2.

There are two different perspectives on the features of a TE system. The first opinion is the minimalist view. In this, there exist only the processes that make the system interactive. According to this view, TE schemes are presently used in wholesale, demand-response, and other DER plans. An additional perspective assumes that TE systems must have special features such as two-way navigation and communication to exchange management and financial information. From this perspective, TE systems still need to be accomplished and are an upcoming need for the energy industry. In the next view, there are three ways to participate in the TE system.

Again, wholesale participation in the TE system is sufficient considering the theme. However, another view is that there is a change in the distribution stage required for TE systems. According to one of the perspectives, the" equipment price" is a significant fragment of the TE system. Apparatus and materials must be properly and directly controlled for the job.

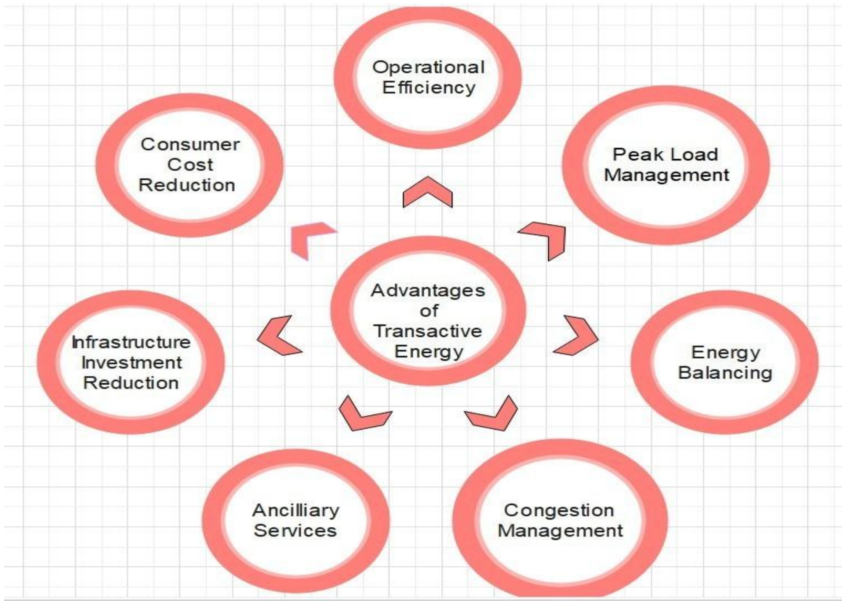

Fig. 2: Benefits of Transactive Energy Hammerstrom (2016)

2.3 Distribution System Operator

As DERs enter the distributed grid and smart consumer systems such as the building energy management system (BEMS) is increasingly used, decentralised production requires a management system. Distributed generation and load control in the distribution network is accomplished by hosting a microgrid. A microgrid is a self-contained distributed system with a local generation that transmits and controls DERs in response to required market signals and controls the demand/output of electricity from/to the grid. Microgrids engage in the wholesale energy market and disrupt the equilibrium and standardized prices in the marginal area. Rahimi and Ipakchi (2012); Collier (2016). However, with the rise of DERs and other requirements for networks, such as load management, microgrids must be adequate to improve the economical use of DERs. Therefore, a new outline and improved methods are needed to address the development of DERs in a coordinated manner. Today, this management is done by a single DSO, balancing supply and demand for every regional distribution zone (LDA) Kabiri Renani et al (2019). Therefore, as a substantial component of the Transactive Energy framework, DSO has the advantage of negotiation by providing a unified management system and connecting wholesale and retail markets, making people engage in the electronic market Renani et al (2017a).On the other hand, this method enables DSO to meet different customer needs Schweppe et al (1980).In central management, all processes are optimised by a central supervisory or regulatory body (such as ISO), which must know the process running with data from individual DERs and customers in the private network. Analysing and processing large amounts of data is difficult, causing great difficulties and computational load on the system. However, managing multiple DERs improves the stability and reliability of the network by reducing reaction time to outages.

In the control system, the optimisation is done by the respective DSO. DSO needs information about individual DERs and clients in LDA. Each LDA is modelled as a virtual source at the communication port (T-D interface) to improve the power transfer of the T-D interface by the ISO. Kristov et al (2016); Cazalet (2014); King (2014); Ghatikar et al (2016); Syed et al (2015) .

The prime role of a DSO is to operate, organise and provide telecommunications services to the distribution network, similar to that of the company. It is liable for the working of the distribution network consistently. They manage the distribution network and work for the security of the LDA. The current inclusion of distributed resources into the grid requires the optimal utilization of these resources to offer working and planning profits to the grid and prepare results. The DSO monitors the demand-side aggregation before the power market is established at the distribution level. It introduces advanced programs with incentives for the consumer side for the efficient work functioning of the distribution system, thereby postponing the processing of expansion planning. Cazalet (2014); Rahimi and Mokhtari (2014) Fuller et al (2011). As more distributed energy resources enter the grid, DSO needs advanced functions to enable Distributed Energy Resources to take part in the process and scheduling of the electric power market. To equalise the power of the LDA and manage the demand and supply, the DSO links the wholesale and the retail markets and safeguards the effective and safe action of the electric system Olken (2016). These novel responsibilities are related to the DSO interaction process, as discussed in more detail. With high penetrating DER in the distribution network, the part of the DSO is involved in the development and action of the distribution network, guaranteeing that demand is fulfilled. DSOs provide producers with long-term and short-term economic signals, encouraging appropriate investment and operating decisions. The functioning of DSO should include mechanisms like demand response (DR), photovoltaics on the rooftop, electric vehicles and various DERs in LDA to facilitate their participation in the industry Rahimi and Ipakchi (2012). DSO is similar to ISO for distribution links. They are liable for the viable and unfailing process of LDA and have an equivalent role to ISO at the distribution level. For example, managing distribution level restrictions is a function of DSO, just like ISO at the transmission/transport level. However, DSO experiences matters like distribution losses and phase imbalance Forfia et al (2016). ISO wholesales and DSO retails and maintains a healthy life in LDA, including its restrictions and limitations. Wholesale-level businesses such as GENCO and freight collectors are eager to increase profits. In contrast, market players, including microgrids, producer consumers and other DERs, provide optimum performance Xia et al (2012). DSO, as the electricity market operator, completes all bilateral tenders and tenders based on the determination of the DER operation plan.

DSO determines the trade balance and calculates the marginal distribution cost (DLMP) in its LDA by specifying the power flow (ac or dc), adjusts the local supply and demand balance in its LDA, controls and manages the different functions of the DER, and communicates with the transmission network for the unfailing and protected functioning of the distribution grid. The Distribution System Operator is liable for providing eligible products based on retail prices to reflect the customer's product value. The new DSO enables DERs to meet their needs by delivering market distribution using TE. In addition, collective agreements for the wholesale market will be introduced by the DSO, allowing DERs in the LDA to trade among other LDAs and the wholesale market. Therefore, this novel platform will enable customers to engage in the wholesale market and provide necessary auxiliary services of rotating/non-spinning reserve, control and frequency response at the transmission level, and facilities required for distribution operations like level measurement and avoiding overload in the distributed network Xia et al (2012).

Fig. 3: Various types of Distribution System Operators (DSO) Kabiri Renani et al (2022)

Ref. Rahimi and Mokhtari (2014) explained the Distribution System Operator as a connection connecting the wholesale and retail markets. It contained various DSO models, as illustrated in Figure 3. The diagram correlates the function of the transactive Distribution System Operator (DSO) with additional less deterministic models. As per the figure, the roles of the transactive DSO comprise of:

1. Planning of the network for LDA

2. Safety of LDA

3. Timed Processing (Load, DR and DER Estimate, Load Side Capacity Accumulation, Arranging of already present DERs or Wholesale Market Auction),

4. Scheduling and Real-Time Control of DR and Interconnection control of DERs

5. Measurement and reconciliation (timing measurement, reconciliation with wholesaler, coordination with retailers),

6. Management of retail stores (provide DER solutions such as DR), content DER DSO's competition to create the tender DERs use to deliver or bid for wholesale and bilateral contracts for DERs).

The first two roles are the primary role of each DSO model, and the other roles are the DSO's role in connecting wholesale and retail.

2.3.1 Types of Distribution System Operators

The simplest type of DSO is DSO lite, which is responsible for limiting and controlling the operation of DERs, microgrids and consumers and for exchanging electricity with the network connection to improve the economy of LDAs and ensure security and is a reliable method.

In minimalist mode, DSO does not directly control DER, only the entire DER, time and control are controlled by ISO. A simple form of DSO is the Balanced Area DSO (BA DSO). In this model, the DSO directly manages the DER and the operation of these resources, including the effects on the system and the security of the LDA. In addition, the DSO has the authority to eliminate this market and determine the quality and efficiency of the wholesale market, DERs and exchanges, including the credible LDA market. In this model, DSOs deal with retailers and customers and ISOs deal with suppliers. Hence, in the typical scenario, the Distribution System Operator (DSO) presents numerous opportunities for Distributed Energy Resources (DERs) to participate in the market. Typically, entities operating DERs, microgrids, and external load systems are referred to as DSOs. The DSO assesses all received bids to organize or execute a competitive tender process, facilitating access to the Independent System Operator (ISO) wholesale as a service. Moreover, in situations of complete connectivity, the DSO is not the exclusive customer for DERs. Consequently, they have the option to submit bids and transact with DSOs or engage in direct bilateral trading agreements.

3. Transactive Energy Approach for Distribution System

Due to the variability and unreliability of these resources, the continuous use of these resources in multiple generators and distributed networks leads to a lack of supply, use and demand. The diffusion of resources in the distribution network continues to increase, posing problems for the system's effective operation due to the development of management needs and the participation of consumers in the workforce, interconnection and overproduction. Therefore, the system requires adaptability and coordination mechanisms on the demand side to dynamically align the equilibrium between supply and demand. and adapt to quick changes in renewable energy generation. Schweppe et al (1980).

In the new landscape, many consumers have generation resources like solar panels on the roof and energy-efficient storage systems. These new projects in the distribution grid require proper management and control of demand to ensure efficient and safe operation. Therefore, another DSO must effectively operate (Local Distribution Area)

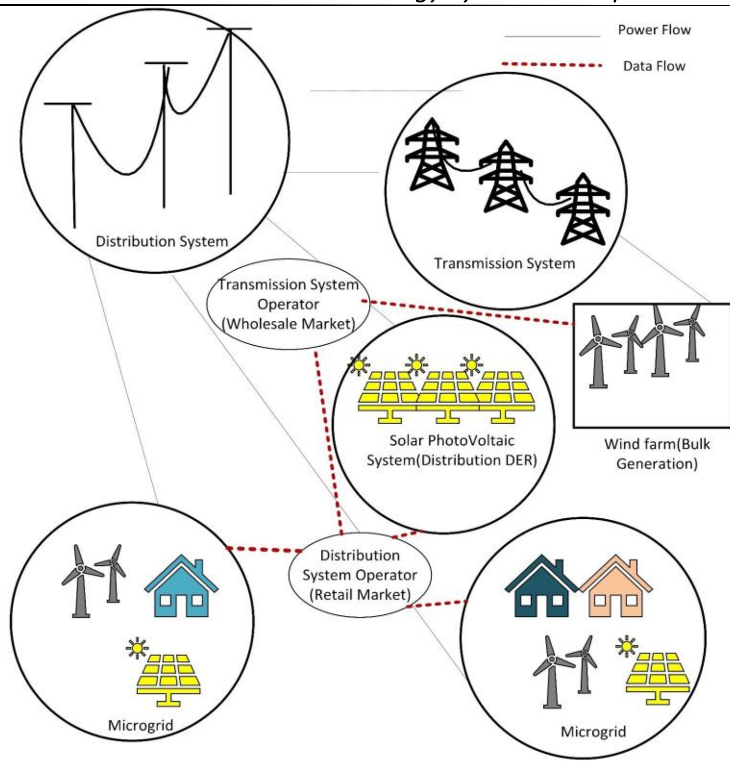

Fig. 4: Schematic Diagram of Transactive Energy Concept in Smart Grid Kabiri Renani et al (2022) Zia et al (2020a)

(LDA) while upholding its consistency and safety. This DSO will use the TE method to enable transmission operators to improve the business performance of all DERs in the market while maintaining normal operations. Rahimi et al (2016); Forfia et al (2016); Cazalet (2014). The TE frame demonstrates the benefits of intelligent design, including reduced power consumption, improved power efficiency, and frequency and voltage regulation. It also allows greater use of renewable energy in the distribution grid, reducing carbon emissions from power generation and increasing energy efficiency. Ghatikar et al (2016). Additionally, TE is one of the essential resolutions to achieve distribution integration, especially with the advancement of Distributed resources and customers.

For instance, electric vehicles (EVs) are a further development in the electric power industry with many profits, comprising eco-friendly benefits. They stabilise different electricity requirement variations and provide safety due to renewable energy sources. Simultaneously, they can also disturb the network due to a lack of coordination and price-dependent charging schemes. In these cases, EVs will become a new load on the grid, causing grid disconnects due to power problems or high voltage. In this case, transactive control combined with least-cost EV charging can avoid overcrowding in the distributed network. King (2014); Khodayar et al (2016).

3.1 Transactive Energy Incentive Criterion

The Transactive Energy System aids Distribution System Operators in integrating DER in the operational and scheduling process of energy that can be obtained by providing the necessary indicators for DER investment and business planning. Financial value is essential in TE.

Therefore, it is required to act as an energy booster and constantly modify it according to the conditions of the system to promote owners of renewable energy devices, such as Distributed Energy Resources (DERs) to use these modifications to achieve multiple goals and improve performance, reliability and efficiency. Therefore, many motivations can work, and it is essential to create a variety of TE methods to support any motivation that will work. Some examples of incentives that can be used in TE systems are environmental incentives other than financial incentives, such as lowering energy costs for certain levels of change, providing monthly or quarterly discounts over program alternatives, or incentives for renewable energy use or carbon reduction. One of the strongest motivations is the dynamic price, which shows the time change of equipment and the expenses linked with the generation, transmission and distribution of electricity. Ambrosio (2016). The average electricity cost for each customer in the United States is higher for generation and distribution than transmission. Therefore, concentrating on the generation and distribution sector will lead to better incentives for Transactive Energy. All suppliers and consumers of DER should be aware of the cost of electricity. They should be motivated to manage their production or use by balancing time in the business to be efficient and collaborative. Ghatikar et al (2016). Finding costs reflect the difference in power generation costs, which are elevated when the resource is unproductive and lower when the resource is available. Therefore, the wholesale price is most relevant in the trading signal. The day-ahead and hourly rates are better than the real-time rates available in the electricity market. This is due to the fact that the day-ahead and hour-ahead rates are established by the ISO and disseminated to the members. Thus, consumers/producers can alter their usage or generation according to identified prices. However, the real-time cost can be obtained by estimation, as estimation errors will lead to uncertainty, and acting upon these projected prices would entail risks.

Two ways to look at distribution costs as another factor in the Transactive Incentive Signal (TIS) are (1) using current selling prices and (2) using market prices. The current electricity selling price is built on the base of the LMP of the T-D interface as well as the numerical information (like loss) matching individual feeders in the LDA. As a result, electricity prices in the existing market are inadequate to take on the future expectations of high DER, change in quantity and direction of electricity flow, and its impact on wholesale and retail prices. Schweppe et al (1980).

The second technique is more efficient as it is a cost-based technique that accurately reflects the delivery costs in various parts of the Distribution Area, including distribution costs. In this way, the Distribution System Operator runs the referral market to ensure that DERs meet their needs, and the bulk offer by DSO will be promoted to the wholesale market, which lets deal of DERs in Local Distribution areas and other Areas and wholesalers. Therefore, the system depends on the wholesale business, and the wholesale price (including mass production and export costs) and export costs must be determined from exchange rates. In the market-based pricing style, the price of individual locations in the LDA can be found from the DSO after the market has been cleared, like obtaining the LMP of the transmission network. Here, customers and producers apply to the DSO as a commercial vendor. These competitions have consumers willing to pay for their products and the prices that manufacturers hope to win. Since all producing consumers bid, the market economy can set prices to balance supply and demand. Exchanges act on behalf of users and set final costs to maximise profits. At the same time, DER is synchronised with the competent working of the complete system.

Rahimi and Albuyeh (2016). The cost of transactions in the distribution system for additional supply is known as "Distribution LMP (DLMP)". It is the rate of offering the consumer demand at various locations of the LDA, equivalent to providing 1 kWh more demand at a given location. The DLMP should include three factors related to the additional cost of electricity generation, electricity loss and grid congestion Fuller et al (2011), which will be affected by all factors affecting LDA costs, including the LMP at the LDA point and the associated communication link, DER categories and features, energy loss and congestion in distribution networks essential to regulators and the much-needed consumer bill benefits and DER credit. The authors of the reference at an initial cost. The cost response has aided customers in reducing costs along with the trustworthiness and productivity of the energy supply. In accumulation, the application of TE methods network. This is because the call encourages all customers to lower costs by changing consumption and help raise capital by increasing production from time to time, from grid congestion to higher prices for congestion periods. As a result, long-term customers will pay less for service delivery, as the allocation of resources must be returned by the customer Schweppe et al (1980).In TS, the application process that supports TE participants in dealing with the target's work and studies is determined according to the TS process used in the TE system. To better understand how TS motivates or determines value, the TS techniques applied in Transactive Energy systems are described below:

Bilateral Exchanges/transactions: This two-way exchange between buyers and sellers, vendors and shipping providers calculates the hourly delivery and shipping costs, respectively. These monetary prices incentivise improving the energy supply and deploying new apparatus in diverse locations.

Double Auction Market: This process establishes the energy cost generated at the point where the demand and supply curves intersect, known as economic equilibrium.

- Nodal Cost: The broker is responsible for equal energy trading at each node in this

approach. These organisations are tasked with aligning supply and demand within their region. They are based on the calculation of representatives, energy costs and the cost of supplying goods from the cheapest sources. This energy can come from domestic production and foreign energy sources Hammerstrom (2016). Considering the product TS, the general schematic illustration of the transactive power system within the smart grid is depicted in Figure 4. . Figure 4 Hu et al (2015) gives the relationship among different fragments of the electricity market. The diagram shows how many people involved are communicating with each other for the body to function well.

3.2 Transactive Energy Systems Classification

In recent years, many reviews of TES have contributed to the deployment and commercialisation of TES. For example, business models for peer-to-peer (P2P), social marketing, and hybrid P2P marketing were compiled using general mathematical models. Sousa et al (2019), but no pricing strategy was specified. Li et al (2020) discussed four major TES problems, including the stable competitive situation, the Stackelberg game situation, the reverse Stackelberg game situation, and the design model situation. But these four have completely different processes for clearing.

Reference Zia et al (2020b) mainly discusses the design of TES and explains various technologies (such as hashgraph, tempo, blockchain, holochain and directed acyclic graph) but does not provide general mathematical models. As per the authors' knowledge, no study has provided a detailed analysis of the TES in a comprehensive pattern. To satisfy this gap, this article delivers a wide-ranging review of different TES based on the involved objects, business models, clearing processes, solutions algorithms, trading products, etc.,

Figure 5 provides each method's basics and then discusses the pros and cons of the different methods. This article can guide TES development as per the latest research update. The TES deployment application is shown in Figure 5. From the market participants' perspective, the operation of TES requires the cooperation of energy suppliers and users. Still, usually, they consider the power users as theoretical users to facilitate the behaviour of various applicants. Power prosumers are unique participants who can be both power and power users. In terms of business model, according to the grade of decentralisation and the topological structure of the communication network, Transactive Energy Systems can be divided into centralised, decentralised, distributed and hierarchical. Blockchain and other decentralised technologies are expanding across the industry to create a safe, fair, and reliable P2P trading environment. Price is an essential factor affecting TES performance and can be determined by many trade-offs. The liquidation of TES can be divided into three types: the distributed marginal pricing (DLMP) method, the auction mechanism method, and the game theory method.

More specifically, the auction process includes an auction, two auctions, and a reverse auction process. Game theory generally has cooperative, non-cooperative, Stackelberg, and mixed games. Solutions used in TES include central optimisation, classification optimisation, and non-deterministic optimisation. Among the many ways to deal with uncertainty, stochastic and robust optimisation are the two most used algorithms. It's also significant to record that machine-learning practices have emerged

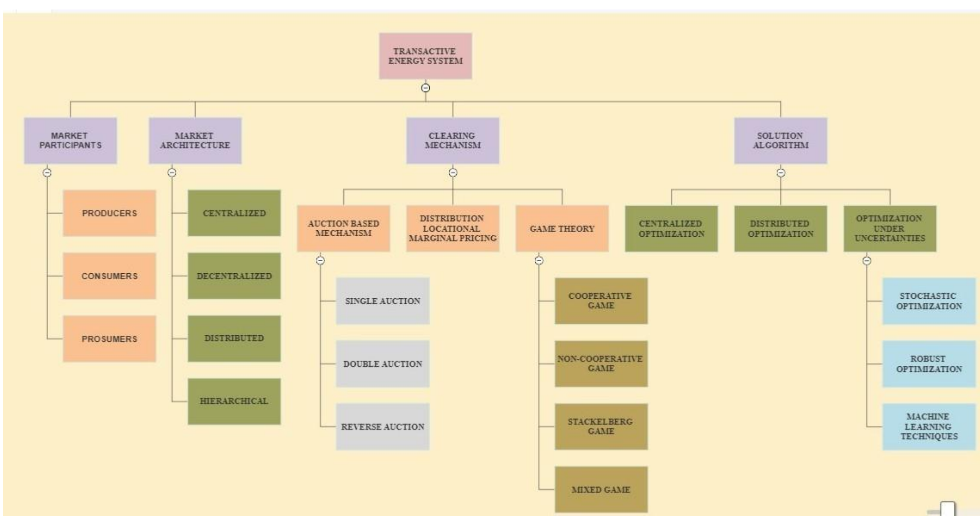

Fig. 5: Transactive Energy System Classification Zou et al (2022)

as a challenge to solve obscure problems by providing some Artificial Intelligence Techniques. Initially, TES products were only available in the electrical market. However, as more energy systems hit the market, they may sell power in multi-energy systems. Finally, fines and loss distribution have been identified as important areas of future research. They are seen as two essential elements to complete TES to ensure the health and integrity of the electricity market.

3.3 Transactive Energy Management Levels

Establishing a sound control system is essential to realise TE's economic and commercial aspects. We propose a hierarchical classification that describes the various stages of TE control approaches available in the classical hierarchical model of large mesh networks. Next, we talk about the differences. TE control input for all control levels.TE controllers are available in different types. It is designed for multiple purposes. In this context, whenever we refer to TE management strategy, we refer to various methods, planning and management processes for Transactive Energy in Smartgrid systems. We propose different software and hardware methods to implement the control strategy considering the TE controller. So, in simple terms, it uses the TE controller and TE control input. So, when we use these two terms, we mean that it is a kind of Transactive Energy control mechanism in the Smartgrid network. To understand the Transactive control concept, it is essential to determine the distribution assembly of the Smartgrid system before moving on to the actual method. In this regard, GWAC Renani et al (2017b) proposed a hierarchical distribution model of the SG system in Lopes et al (2006), and we obtained a model like Figure 6 in this paper. Based on the control hierarchy, the multiple levels of Transactive Energy controllers or control strategies that can be applied, like TSO, DSO, Microgrid, and building level controls, are described below and are shown in Figure 6

3.3.1 Level 1:

This is the first level of the Transactive control scheme, which works at the residential level. This assumes that each building in the Microgrid will have smart devices and DERs connected and controlled by the Level 1 controller.

3.3.2 Level 2:

Level 2 is the Microgrid control level. A microgrid can have many buildings to form a community. Each Controller at this level is called a Level 2 controller, and its function is to store data and check the control code of all controllers at level 1.

3.3.3 Level 3:

At the Distribution System Operator level (like in the city), controllers installed are called level 3 controllers. These controllers aggregate and control business and communication among various level 2 controllers tied to a particular DSO.

3.3.4 Level 4:

This represents the highest management level control in the country. Each controller of this level is called the Level 4 controller, and its role is to manage the operation and communication to/from each controller linked to various DSOs.

3.4 Transactive Energy Architectures

The word architecture discussed in this chapter denotes the various methods to achieve different levels of management. In this case, different levels can affect the architecture depending upon the overall interaction. To this end, this article presents several Transactive Energy architectures that can be categorised according to the participants in the SmartGrid network and the different modes of interaction of these parties.

The term" parties", in this case, refers to the Microgrids and the Microgrid Operator Cazalet et al (2016), Dimobi et al (2020). According to the GWAC, these parties or participants are electronic devices that can serve as human parts, although humans are sometimes present in cycle 212 (2015). Also, Microgrid operators usually include DSOs and TSOs, while Microgrids have customers and prosumers. Therefore, many Transactive Energy models can be classified according to how these participants interact, especially when Microgrid transacts with the DSO or TSO.

Hierarchical and centralised architecture is sufficient when the Microgrid transacts with DSO, but the decentralised and distributed architecture will result when the Microgrid Operator works independently of DSO. Under certain circumstances, a hybrid architecture may work, depending on the needs and aims of the members involved. Therefore, the subsequent subsections will address the following Transactive Energy (TE) architectures, specifically centralised, decentralised, hierarchical, and distributed architecture. We also use two lines, power lines and control lines, to differentiate between dissimilar designs. The transaction line describes the transaction of" value" expressed in financial terms between two parties. This engagement is depicted by the black lines in the diagrams found in Figures 7, 8, and 9, correspondingly. The

Fig. 6: Transactive Energy Management Levels Onumanyi et al (2021)

control line, defined by the red line, represents the difference in direction from one place to another. This method is not limited to physical controls like voltage, power, and frequency but can cause changes on both sides. As an illustration, a control signal is transmitted, featuring a liquidation price that traders can employ for trading.

3.4.1 Centralized Architecture:

Centralised architectures usually have a central control centre that manages data collection from different units and initiates control processes. If the MicroGrid operates in island mode, the microgrid central controller is of control level 2 Sen and Kumar (2018). Therefore, this architecture has only two levels, Level 1 and Level 2. On the other hand, if one Microgrid or several Micrograms are running in the network, there will be a level 3 controller at the distribution level, where the controller instructions are initialised. Three layers will be based on the controllers' level and geographic location. Figure 7 illustrates the centralised architecture's basic structure, showing a line of transaction and management control interaction among the various participants involved in the SG network.

More importantly, it should be noted that individual buildings can have MicroGrid-controlled smart devices and DERs. In this case, data sent to the MicroGrid Controller from various counters will be sent through a high-speed communication channel and processed in the Central Controller at the MicroGrid level, about physical parameters and economic transactions. In this case, the control command is usually sent from the Central Controller to the Level-1 controller in the building (following the control line in Figure 7).

Business lines may be opened amid customers and Microgrid operators, such as paying the electricity bills of the buildings, negotiating with MicroGrid operators and paying prices for DER services. Additionally, in the case of a 3-tier central architecture, it should have a central Level-3 controller present at DSO answerable for issuing commands to the MicroGrid Central Controller for home use. According to the model, all data input from the Microgrid Central Controller from different addresses is sent to the DSO controller, which is answerable for deciding and processing according to the condition of the whole SG network. An exchange line can be operated between the customer and the MicroGrid operator, or a line can be opened between the MicroGrid operator and the Distribution System Operator. Ultimately, all operational and control actions stereotypically occur in the underlying Distribution System Operator. To summarise, Figure 7 shows that in an environment where the transaction line appears in a bidirectional pattern, control information often flows downstream from a single controller to improve the making and use of smart devices and DERs in buildings.

3.4.2 Decentralised Architecture:

In a decentralised architecture, decisions and controls are made at all levels, often based on some measure taken from a mix of local measures and predefined limitations. Decentralised architectures usually only have two main layers: the upper- and lower layers Sen and Kumar (2018). The lower layer has a MicroGrid Central controller, and the upper layer has a MicroGrid Operator. This model can be used with many AI concepts, such as multi-agent Systems (MAS) and swarm intelligence. Multi-Agent System conducts local assessments of different housing units and then sends these assessments straight to the Central Controller at the MicroGrid level for instant action. In addition, the MicroGrid Central Controller may convert its agreement to another Central Controller through the DSO and send the agreement to the Level-1 controller. In this case, the Distribution System Operator guarantees the security and consistency of the whole SG network by recording the clearing price of the different Microgrid Central Controllers.

The TE controller embedded in decentralised architectures is often more difficult than centralised models due to the need to adapt to local decisions. For local decision-making, fog computing technology can distribute Microgrid Central Controllers' data storage and computing power to a proper location, thus reducing complexity. Moghaddam and Leon-Garcia (2018).

Fog computing refers to computing models that distribute, process and store data in the cloud and data centres Yi et al (2015). Therefore, a fully decentralised architecture would need standalone Microgrid Operators running in a dispersed pattern; this regularly leads to a tight relationship between decentralised and distributed architectures. In various situations, it is said that the entire distribution model can be created using distributed ledger technology (DLT), like the technology used in Bitcoin, to obtain a decentralised financial system Zia et al (2020c).

Participants can access the marketplace with the use of the Brooklyn MG mobile app. Participants can then buy the solar credits through the sales app. Customers can manage their resources and set their daily budgets via mobile software, while customers can agree on whether to trade in their surplus energy. This decentralized

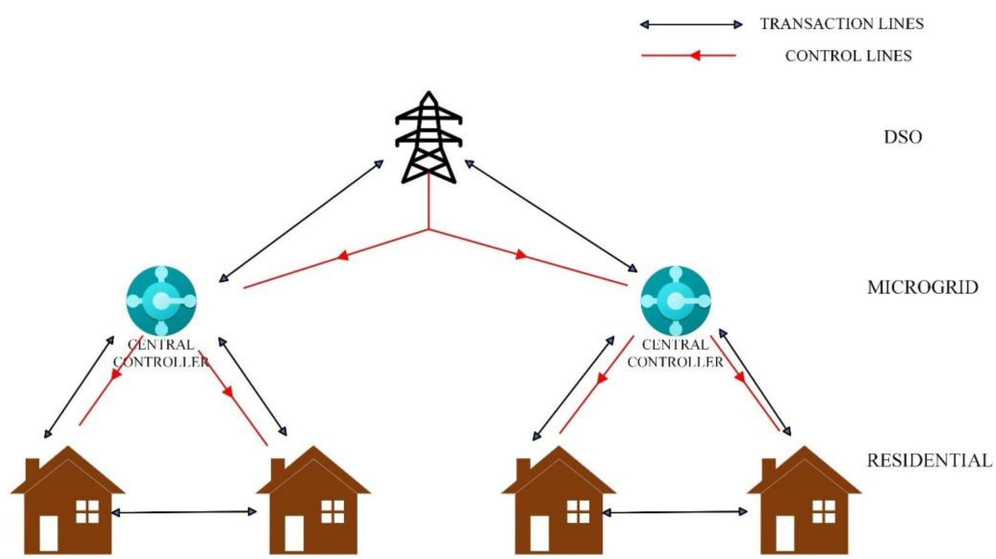

Fig. 7: Centralised Architecture Onumanyi et al (2021)

model has many profits, such as enlightening the local economy and cutting pollution from local stations.

In summary, Figure 8 shows a scatter diagram where lines of business usually appear on both sides of each side. However, control data will be generated independently by different Microgrid Central Controllers to optimise the cost and use of DER and smart devices in the field. It is challenging to decide which is best for Central Architecture and its clients, as the selection will differ per the objectives and needs of the Smart-Grid project.

3.4.3 Distributed Architecture

A distributed model is only an addition to the decentralised model, where essential controllers can collaborate to achieve the goals set by the Smart-Grid project. A decentralised controller will collect local metrics and relate them with nearby controllers to make a reasonable Clearing Price to keep the SmartGrid network safe. There are some crucial aspects of the deployment of the distribution model, for example, the authors in Onumanyi et al (2021) divide the distribution model into lower, intermediate, and upper tiers. However, this is designed to control physical constraints such as voltage, frequency, and power. Also, this management needs to be done on all controllers in the network, so consider the distribution of its architecture.

An architecture named POWERWEB is used in that runs multiple processes on multiple computers using a scalable distributed architecture. These terminal systems are presented as physical models of controllers connected to the internet and positioned in several locations. These models have four types of server-based functions mentioned: web, database, computing, and demand-balancing proxy servers. We have

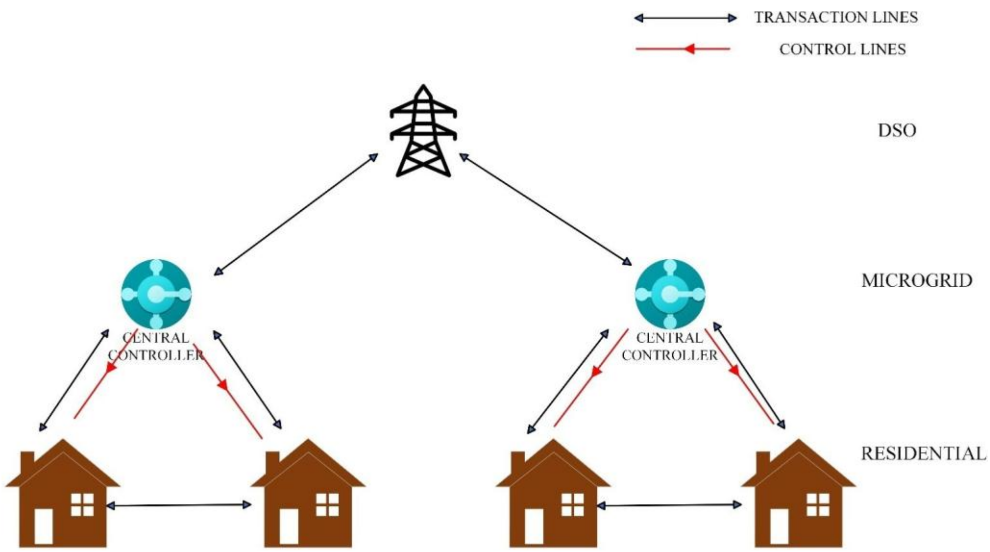

Fig. 8: Decentralised Architecture Onumanyi et al (2021)

noted that a distributed model in Zimmerman and Thomas (2004) can be used as a simulation stage to measure and assess the effectiveness of the Transactive System design. In summary, Figure 9 shows that distributed and decentralised are similar, but all communication partners can communicate with each other at any level to exchange power in distribution architecture. In a few cases, the local MAS can make decisions to control DERs and smart devices in switches at the building level Mengelkamp et al (2018).

3.4.4 Hierarchical Architecture

Hierarchical systems often contain multiple levels of management and processing in a network. The lower control level is intended to account for the status of its variables and additional control limitations to a higher level of advanced control. This interaction uses two-way communication channels where the lower layer transmits data to the upper layer and receives instructions in return. Therefore, it can be said that most central architectures are generally hierarchical in assembly. In addition, decentralised and distributed architectures can also be built in hierarchical layers. Therefore, the hierarchical layers design can be considered a combination of all other architectures, as shown in Figure 7- 9. Schemes regarding power management for TE-SG systems are discussed and proposed in Miceli (2013) and Daneshvar et al (2020a)

3.5 Trading Mechanism in Various Architecture Models

Peer-to-peer (P2P) and centralised transaction schemes can be used as a trading mechanism in different architectures. Distributed ledger technology-based P2P schemes can be used for decentralised or distributed assemblies, while central business schemes are usually sufficient for centralised structures. In a centralised environment, members can

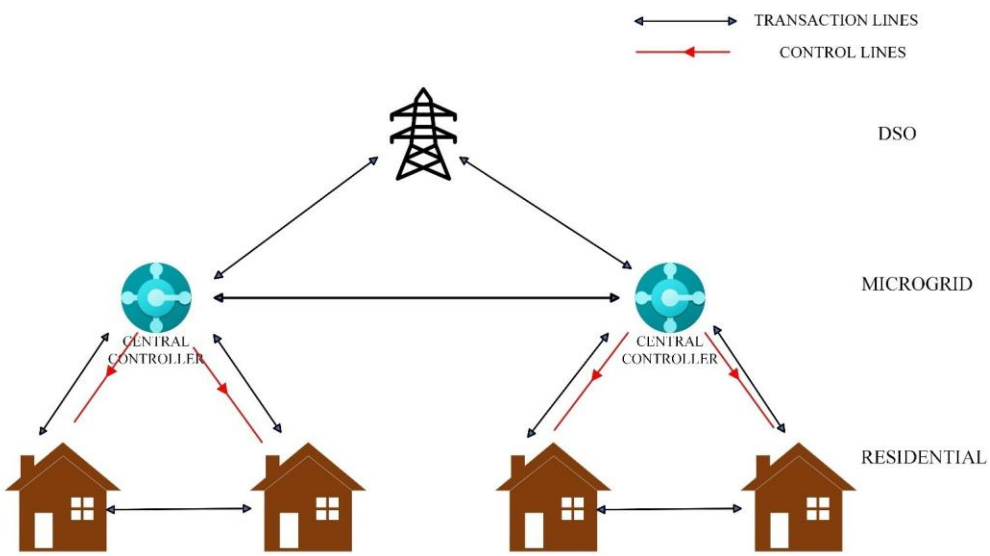

Fig. 9: Distributed Architecture Onumanyi et al (2021)

exchange in island mode employing hierarchical methods Zia et al (2020c). In island mode, the MicroGrid Central Controller usually receives the entire energy bids and offers from various grid members and then sets the Market Clearing Price (MCP) for the MicroGrid usage. In connected grid mode, the Level 3 controller will be liable for getting all offers from the Smart Grid network members. By Market Clearing Price (MCP) determining process, the MicroGrid Central Controller and Level-3 controller will guarantee the technical and operational feasibility. When the Central Controller decides, it sends this value (e.g., control line) to all partners to start electronic trading. In a decentralised or distributed mechanism, different MicroGrid Central Controllers announce the cost of their initial energy to each participant for initiating further bids. Then, they adjust the electricity prices and report them to all members again until they converge. Therefore, the speed of convergence and the optimum solution are the main factors determining the distribution mechanism's efficiency and effectiveness.

An important study of the monetary profits of P2P programs for prosumers and consumers by Neves et al (2020). The Transactive Energy business of consumers and solar prosumers in Portugal generated a 28% financial gain for consumers and 55% for prosumers. In another paper by Zia et al (2020c), an elaborated description of the interactive transactive mechanism and its financial consequences. Consequently, we are talking about the specific process related to the P2P approach, specifically suitable for decentralised and distributed models. In this context, Sorin et al (2019) proposed a P2P method based on Multi-binary Economic Dispatch (MBED). The author presents a simple consensus remediation approach for solving the MBED problem in a fully decentralised environment. The paper shows that their arrangements allow customers to use more resources, such as local support and environment-friendly energy products. Another idea, the competitive binary P2P market, is proposed by Baez-Gonzalez et al (2018). This method lets consumers swap between energy sellers and buyers. They claim this scheme increases people's willingness to participate in renewable energy source-based systems. In Moghaddam and Leon-Garcia (2018), the researchers anticipated a consumer-centred P2P trading scheme for home MicroGrids. The aim is to amplify the benefits of DERs while keeping consumer ease in mind. Various studies by Dimobi et al (2020), Hirsch et al (2018), Corn´elusse et al (2019), and Alam et al (2017) concentrate on the development of multiple methods for P2P transactions.

One of the alternatives to the Transactive Energy Market model is the hierarchical system. This is a community-based business planned for centralised models Zia et al (2020c). Microgrid Operators send their respective price values to the central controller to determine the suitable MCP. An illustration of such a method is proposed by Tushar et al (2016) an example of the auction-based approach. Joint ownership of energy storage enables the owners to decide the proportion of energy they want for usage for other consumer participants in the community. The authors suggest that they need to increase and improve the consumers' motivation through incentives. Yoshimura et al (2013) studied the electricity market in the community with multi-agent simulations. The authors assume that communities share a battery from which all households can draw electricity. The central power control model is installed, and the central controller makes the change. Another work proposed a new energy transaction model and an economic exchange market for the community Wiyono et al (2016). The central business market was planned with competent business participants to balance electricity supply and demand.

They demonstrate that it is best to use local electricity to maximise efficiency. More importantly, most community-based approaches (e.g. Corn´elusse et al (2019), Zhang et al (2019), Palizban et al (2014)) concentrate on devising efficient methods to enhance MCP participants' strategies for maintaining equilibrium between energy supply and demand.

3.6 Transactive Energy Scheme Implementation

For the execution of a Transactive Energy (TE) system, control, and administration of the needs and resources of the customers are done using automation. The technology uses smart devices in the distribution network, such as smart meters, energy management techniques, communication and advanced data collection. Homes use a significant share of all electricity (homes in the US use more than 70% of electricity). Therefore, the use of TE systems in buildings is the main step in intelligently controlling the energy consumption of the building, reducing the lack of supply and the need for electricity distribution, and providing service in the power line by changing the power consumption more efficiently. Rahimi and Ipakchi (2016); Pratt et al (2016); Katipamula et al (2016) Rahimi and Ipakchi (2016).

Various types of operations that take place in a TE building can be separated as follows:

Exchange among different devices in a building will contest inadequate resources, reducing their consumption or increasing the comfort of people living in the home.

Local demand measurement or trade between buildings or communities supported by DERs. Trade between buildings and service providers such as energy service companies, retailers or transport bulk goods to share energy-saving electricity and improve business at home. Commercialization of buildings and plans to help power grids make a place to provide more ancillary services Hammerstrom (2016).

Therefore, buildings must have smart energy management to participate in the operation and make keener plans Katipamula (2012). To mechanise DR, Advanced Measurement Infrastructure (AMI) and Data Management System (DMS) are vital to aid two-way communication with customers, as shown in Jin et al (2012).In addition, as users, building owners need an open software interface to facilitate the use of TE systems in buildings and businesses Katipamula et al (2016). To make the power system intelligent, the power distribution equipment must have five capabilities:

1. Capacity control and automatic response to local or remote computer network external control signals.

2. Measurement, power flow, voltage, current etc. It can measure electrical properties at a particular time (measured every hour or every few minutes).

3. Communication is the capability to lead and receive information.

4. The facility may obtain external data related to renewable energy generation, like wholesale prices and weather-related information.

5. Software is the controlling brain of TE; it processes the gathered external data, calculates the output, and makes decisions based on the control strategy and control configuration.

Placement of these smart devices into the distributed grid creates a distributed smart grid of efficient customers, consumers, DERs and microgrids. Smart grids enable collaboration in operations, improve security and economy, and make energy more reliable and sustainable Cazalet (2014); Hu et al (2015, 2016). Today, due to the progress in computer, information and communication technology, the power industry and BEMS use TE systems. In this, customers know the importance of efficiency and intelligent development in systems to see their profits in actual life Knight (2016); Farooq and Zahoor (2015) Knight (2016) A TE is on the list as it is a recently evolving concept, so examples are rare. However, some essential projects use TE systems in the energy sector. The DER-effective TE method in the United States, in collaboration with various organisations including the Department of Defense (DOE), GWAC, Pacific Northwest National Laboratory (PNNL), and IEEE Power and Energy Systems (PES) has been leading three projects to employ DERs, with the consideration of reliability, security and efficiency of the system Widergren and S (2016); Sajjadi et al (2016); Sahin and Shereck (2014) Widergren and S (2016). The work of Hammer Strom et al (2016) provides the past and present research and events in TE to analyse the quality of the Transactive Energy systems.

These projects include

(1) Olympic Peninsula Display Project in Washington State,

(2) The AEP Ohio grid SMART Real-Time Pricing Display Project in Columbus,Ohio, and

(3) The Pacific Northwest Smart Grid Display Project. Also, Power Matcher is the largest TE project in Europe, led by the Dutch Scientific Research Organization TNO.

A brief overview of these projects is mentioned here. The Olympic Peninsula Promotion Project was completed in Washington State from 2006 to 2007. This program uses a 5- 5-minute two-time trading cycle to control DER usage. Bids from public institutions are subject to fixed and variable operating costs. Recommendations for residential consumers are based on a preference for auto response rates, ranging from family non-response rates to high responsiveness rates. The liquidation price is decided and declared to the participants every 5 minutes, allowing them to compare the auction price with their competitors and arrange their expenditures according to the price they bought. Knight (2016). AEP Ohio's grid SMART Real Time Pricing Display in Columbus, Ohio, persisted from 2010 to 2014. Widergren (2014). This project applied RTP-based intelligent decisions to schedule replies. First, each household's competition is summed up according to their preferences to create a demand curve based on the price for the distribution network. The market operator then computes the costs of eliminating and distributing DERs based on the demand curve and the marginal cost function of the wholesale market. The program resulted in a 5% reduction in housing and retail prices. The Pacific Northwest Smart Grid Demonstration Project uses the TE to control the action of DERs to reduce renewable resources and load levels Hammerstrom et al (2016). The control procedure provides incentives for dynamic assets based on their magnitude and adaptability. The impact of Transactive Energy (TE) transmission was assessed using a simulation model, which disclosed that if 30% of the load was responsive to the interactive stimulus, the maximum load would be reduced by 8%. PowerMatcher is a crucial European TE project by the Dutch Scientific Research Organization TNO. The software works like an intelligent agent representing end users and acting according to their rights. To protect the privacy of end users, the information exchanged is local and is only about cost and communication power Rahimi and Albuyeh (2016). However, the genuine practice of TE systems is not restricted to previous projects. In Khorasany et al (2020), the authors tried to comprehend TE-based microgrids using the TE architecture of renewable energy microgrids. In the above study, Transactive Energy (TE) served as a novel energy management system to enhance the electricity market and oversee capacity control within the Monash micro-grid in Australia. The primary rationale for implementing TE schemes in this project is to integrate Distributed Energy Resources (DER) into the grid. The legitimacy of the Transactive Energy model is confirmed in the Monash microgrid, serving as a concrete study showcasing the efficacy of this system for power management within the examined microgrid. In a separate investigation, TE systems were employed to develop home energy management to balance the demand. Pratt et al (2016). Smart Home in Charlotte, North Carolina, emphasises research on the pertinency of TE systems for smart home energy management. This work exhibits the distribution system using the GridLAB- D feeder model. The results ascertain the effectiveness of the Transactive Energy framework to coordinate the air conditioning process with the peak shred.

3.7 Transactive Energy Applications in Smart Grid Operation

Currently, the TE system has made the producer more innovative. This problem is mainly due to the need to transition from traditional energy consumption models to intelligent energy consumption. This innovation is the perfect response to hybrid and smart electronic device growth. Due to the solid public decision to use clean energy for power generation, new plans to build energy projects involve high levels of RES in power generation. Papalexopoulos (2021). Even though such strategies reduce the economic and ecological fears in the power generation process, they face optimization problems as they have uneven output Mohseni Bonab et al (2022). Constant changes in renewable energy supply lead to the safety and financial constancy of the system, especially when the grid plans to supply most of its energy from clean energy Kiptoo et al (2020). Therefore, academia and industry are actively working to find practical solutions for increasing high RER in electrical systems. A solution that provides elasticity and efficacy while keeping consistency and security is needed. Placing multiple energy storage and load-side energy management strategies is essential for grid integration of multiple RES. Alhajri et al (2021). However, the higher count of RESs in the overall system requires a large storage capacity, which complicates the implementation of this system. The system must, therefore, be affordable and innovative solutions from an environmental and business point of view. In this case, the energy market is beneficial as it can equalise energy in renewable energy projects. Daneshvar et al (2020b). This tendency has indicated the expansion of more and more types of energy markets to enable smart and justifiable energy use Affolabi (2021). Here, TE is an exchange technique for integrating several RERs in grids. Daneshvar et al (1396). Bearing in mind the critical points of TE as defined in the prior section, it has been applied in recent research as an essential means for the effective working of smart energy. The work presented by Chang et al (2022) used the peer-to-peer scheme to generate an updated trading outline for productive consumers aimed at secure and reliable trading of the distribution grid. A study by Gourisetti (2021) proposes a framework for building a TE business using blockchain as a distribution network skill, taking into account the needs of the global economy to promote good, secure and fair trade. considering the global economy’s needs Although many researchers have benefited from TE based on systems development and stability, its applications are not limited to network operations. This fact was shown in Ref. Toquica et al (2021), propose a TE model for planning built-in automation agents to maintain system homeostasis. Since today’s electricity generation goal is to take full advantage of RER in electricity generation, some researchers have focused on developing functional models that operate with 100% RER using TE technology. Ref. Daneshvar et al (2021b), the authors proposed a new TE control project to support microgrids with 100% RER to achieve energy balance in systems powered by hydrogen energy storage systems. Also, Daneshvar et al (2020c) planned a TE-based model for optimising grids, considering the electric service and thermal load on the Renewable Energy system. There are also various applications of Transactive Energy for transformer life improvement and peak load reduction of the power distribution system. As the usage of electric vehicles (EVs) rises, challenges may arise for the electric grid like peak loading of the system. The need for expanding the electric grid can be avoided or delayed by providing alternatives to consumer goods, such as electric vehicles. Therefore, for the maximum problem, this article emphasises the facility of flexible services in the local market. It includes a background for integrating EVs in the local market, including grid performance constraints. Within the strategy framework, the aggregator interacts with the negotiating power (TE) business owners and the shipping business owner (DSO) in business negotiations to resolve identified business problems. A competitive model is proposed and developed as an optimisation problem for a market-based method. This problem aims at minimising the total cost for DSOs to procure necessary services from EVs. Masood et al (2020)

The work describes household batteries' transactive energy (TE) management to compensate for occupants reprogramming batteries and disconnecting them from the energy store. The TE strategy is evaluated based on the distribution transformer's annual replacement lifecycle loss and the distribution operator's business value, considering the impact of transformer ownership, plug-in, lifespan (TOU) and distributed marginal pricing (DLMP).) concept. The outcomes reveal that using the DLMP pricing scheme, distribution transformer ageing is nearly double compared to the TOU pricing scenario. In addition, using the TE principle can extend the life of the electricity distribution transformer in both pricing schemes. The results also show that when the TOU cost is used, the cost of energy efficiency management is nearly doubled compared to the cost based on the DLMP cost. Lastly, the total energy loss in the system throughout the year is reduced by up to 2% by applying the DLMP value and the TE control framework. Gray and Morsi (2018). This document presents a risk analysis to assess the loss-of-life of a distribution transformer in a commercial building with a charging station for plug-in electric vehicles (PEVs) and on-site photovoltaic generation are considered. Monte Carlo methods are utilized to evaluate uncertainties associated with PEV charging, photovoltaic generation, and parking load. A risk matrix, combining severity with probability, is employed to evaluate the risk of transformer lifespan reduction. The outcomes demonstrate that when connected to photovoltaic generation, the risk of transformer scrapping is reduced, and savings are achieved to prevent transformer obsolescence and premature replacement. Based on the conclusions, the projected plan will be an essential means of determining where risk and investment must be balanced.

Transformers are one of the high-priced products in the distribution system. The role of transformers has not changed in the last few years. Due to their simple construction, they provide a long service life of half a century on average. With the ever-increasing supply of non-linear loads and the concept of distributed generation (DG), new challenges for transformer sustainability are emerging, and ageing is accelerating. In this article, we carefully review the available data on the effect of load and additional elements on the ageing of oil transformers. The latest technology is checked, everything is analysed in detail, and finally, an intelligent transformer protection system like TE is sought to monitor it and protect it from future challenges. Affonso et al (2018)

4. Conclusion

As stated earlier, the growing popularity of decentralised systems, particularly their regenerative procedure, creates problems for coordinating the system and its various components. The electric power market allows manufacturers and consumers to interact and make more independent services. One of the biggest challenges is using renewable energy, which exposes the system to uncertainty. In such projects, it is crucial to establish a central framework for enabling ISOs and DSOs to work together in the wholesale and retail electricity trade to synchronise and accomplish the interaction plan to balance power. However, critical evaluation of this process has received little attention in recent literature, as it is essential to contribute to the safety and reliability of the current electricity consumption network. Therefore, this study carefully examines power distribution systems for efficient and effective operation. The core conclusion of this plan is the implementation of a TE-based background for Independent System Operator (ISO) and Distribution System Operator (DSO) collaboration in wholesale and retail markets, which facilitates the efficient action of the power grid with different DERs. TE product evaluation demonstrates its ability to establish a framework for today's energy use. However, the

TE process requires skilled operators and smart equipment to be safe in practice, but there are limitations to creating these operators and devices.

This article examines the platforms needed to integrate demand-side renewable energy sources like DR, EV, energy storage systems, rooftop Photovoltaic and other renewable energy sources into grid operations. As a combination of management and business, TE systems are the best to solve the problems related to the high inclusion of DER in electrical power distribution, competitive efficiency, and development reliability. Efficiency, safety, and reliability are the primary aims of electrical systems. In a distribution system with advanced DER integration, DSO must offer control and balance concerning supply and demand in the LDA. DSO, the most significant portion of the TE system, connects the wholesale and retail markets and plans the network for transmission. It also guarantees the reliability and protection of the whole system.

5. Future Scope

The future electricity grid will comprise many renewable energy resources and provide clean resources. The main problems related to emissions will be avoided. The emergence of various hybrid power systems indicates the need to analyse the power supply chain and the increase of renewable energy in the system. Therefore, future studies may be designed to clarify the relevant part of Transactive Energy systems in the practical implementation of hybrid energy systems based on renewable sources. Furthermore, the modern use of electricity in TE control and management can be studied in different business processes suitable to accommodate many players from other energy grid infrastructures. For example, a TE-based framework requires skilled operators in practice. These operators act as backbones in TE schemes essential for efficient energy management. Establishing a multi-agent TE system could be used in future efforts to work on modern energy systems. Finally, fines and loss distribution have been identified as important areas of future research. They are seen as two essential elements to complete TES to ensure the health and integrity of the electricity market.

6. Declarations

6.1 Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

6.2 Authors' Contributions

All authors contributed to the development of the concept, writing and finalization of the article. All authors read and approved the final manuscript.

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6.4 Availability of data and materials

No data was used in the preparation of the manuscript.

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