# Project Review 3

# Smart Grid


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# Transactive Energy Management System


**Abstract**

Due to the increasing population, there is an increase in penetration of our normal grid system as more demand is required. Also in our country India, Union ministry of power has promulgated rules laying down the rights of power consumers in the country through the rule "Electricity (Rights of Consumers) Rules,2020". Basically, in this rule, a citizen can ask for an electricity connection and the utility have to provide the connection within the limited days i.e., 7 days for a Metro city, 15 days in other city and 30 days in rural areas. As a result, in future which will somehow lead to the destruction of our normal grid system. So, in order to avoid that condition in future, we need a local energy market with distribution grid which should be bidirectional. This type of system is also known as the transactive energy management system in which there are prosumers (consumers as well as producers). So, this paper is basically focusing on building the algorithms for making this local market stable and the locality can reduce the load on our normal grid and can relay on this transactive energy so that our main grid does not collapse.



Keyword – Local electricity market, Rights of consumers, smart grid, utility, transactive energy.

## Introduction

Our National Grid is the high-voltage electricity transmission network in India. It connects power stations to the different major substations present in different region of states to satisfy the demand requirement everywhere possible. The National Grid is maintained and owned by the state-owned Power System Corporation of India and operated by the state-owned Power System Operation Corporation. So, Power Grid Corporation of India Limited is an Indian statutory corporation under the jurisdiction of Ministry of Power, Government of India and the headquartered in Gurugram, India. This corporation mainly deals with the bulk energy transmission between different states of India and maybe even transmitting and selling the power to the neighboring countries. So, this Power Grid transmits about 50% of the total power generated in India on its transmission network.

India is one of the largest operational synchronous grids in the world with 371.054 GW of installed power generation capacity as of 30 June 2020. India’s grid is connected as a wide area synchronous grid with nominally running at 50 Hz. The permissible range for the nominal frequency is around 49.5-50.5 Hz, effective 17 September 2012. The country sells the energy to the neighboring countries at a higher price if they want the transmitted energy at a lower frequency. There are some of the synchronous interconnections to Bhutan and asynchronous links to Bangladesh, Myanmar and Nepal. An undersea connection to the Sri Lanka has also been proposed which will be the high voltage direct current interconnection. A proposed interconnection between the Myanmar and Thailand would facilitate the creation of power pool and which will enable trading among all BIMSTEC nations.

In the current scenario, our country is coping with the increase demand of the electricity due to the increase in population and also the smart IoT devices near us which requires continuous power from the grid. Due to this increase in demand, whenever the substation is malfunctions, the adjacent substation has to fulfil the demand of the area which first gives priority to the hospitals and other sensitive areas. Because of this the power is cut for the normal house and residential building which also affects the common people a lot. Taking the example of the electric vehicle, the technology of electric vehicle is new to the market but it is rapidly getting accepted by the society which also makes a big challenge for the electricity power grid and its transmission to distribute the energy to the charging stations for the electric vehicle. This issue is not a hype right now but can be in future so we need to work to reduce the connections to the power grid. If we reduce the connections to the power grid, how the demand will be fulfilled for the removed connections?

Start relaying on the renewable energy source can only be the solution to these issues but as per the reports, the global electricity demand is growing faster than the introduction and implementation of renewable energy sources. New IEA report sees 5% rise in the electricity demand in 2021 with almost half the increase is met by fossil fuels, notably coal, threatening to push $CO_2$ emission from the power sector to record levels in 2022. Renewable energy is expending quickly but not as quickly as to encounter the increasing demand by the society so the remaining energy is still generated by burning the fossil fuels which produce the harmful effects to the environment. As per the stats, 1% of the energy demand reduced in the year 2020 due to the COVID-19 pandemic as most of the IT hubs were not working as well as the shops and malls and ports were closed and guess these things just reduced 1% electricity! The demand is set to grow in the year 2021 by 5% and then it reduced to 4% grow in the year 2022. Due to the expected increase in the energy, the extra power is transmitted and bought from the Asia Pacific region, primarily China and India. The renewable electricity generation is mainly from the hydropower, wind and solar panel. The energy by these renewable energy sources is grown by 8% in 2021 and by 6% in the year 2022. The Fossil Fuel based power generation has cover the 45% of the demand in the year 2021 and 40% in the year 2022 with the nuclear power encountering with the rest of the energy demand. As a result, the $CO_2$ emission in the year 2020 have reduced due to the COVID-19 pandemic as most of the vehicles were not working so there was reduction in the air pollution but for the year 2021, it increased by 3.5% and in year 2022 it increased by 2.5%.

“Renewable power is growing impressively in many parts of the world, but it still isn’t where it needs to be to put us on a path to reaching net-zero emissions by mid-century,” said Keisuke Sadamori, the IEA Director of Energy Markets and Security. “As economies rebound, we’ve seen a surge in electricity generation from fossil fuels. To shift to a sustainable trajectory, we need to massively step-up investment in clean energy technologies especially renewables and energy efficiency.”

Even with the continuation in the increase of these renewable energy sources, this generated energy will only be able to complete half of the energy requirement. But still it will reduce the 50% load on the Power Grid so it will become more efficient and stable. This issue can be solved by going through this paper and start depending upon the transactive energy distribution system using the smart grid and renewable energy sources.

## Literature Survey

**A review on distributed generation allocation and planning in deregulated electricity market** [1], A.K. Singh, S.K. Parida et al. worked currently on the distribution generation (DG) based on conventional energy source and renewable energy source have played an important role in satisfying the demand of the electricity over the globe. As there is an increase in the load rate growth per year, the power grid is in stress to provide the load demand. To overcome this problem, the paper has worked upon the robustness, sustainability and reliability of the distribution generation and also discussed various aspects including different contingency scenario. This contingency analysis of the power system is the major block in power system planning and operation. This review covers the recent works done in the area of integration of DGs with various scenarios in electrical power systems. The fundamental goal of this research is to figure out how to better integrate variable demand as demand response, demand side management (DSM), and distributed generation (DGs) into the grid. After that, it goes over some of the most important findings in this discipline. The importance of addressing some of the intriguing research problems is also highlighted.

**Electricity Markets and Power Supply Resilience: An Incisive Review** [2], Ekundayo Shittu, Joost Reyes Santos et al. review's objectives are the developments in the resilience of electrical networks and energy markets are the subject of this article. The goal is to determine how advancements in system resilience may impact market rules while also identifying gaps in the research.

Three conclusions are summarised in this review. First, tremendous progress has been made in the design and configuration of resilient power systems. Second, topological and architectural breakthroughs appear to be separate from market activities. Third, there is space for self-healing resilience to be integrated into power systems, bridging the gap between enhancing network resilience and having the market value resilience appropriately.

Clearly, the number of disturbances to electrical networks is increasing, necessitating a shift from a merely dependable energy network to one that is resilient and adaptable. This study emphasises the qualitative importance of procedures that improve adaptive resilience while also encouraging the necessary signals for power market integration.

**A Framework from Peer-to-Peer Electricity Trading Based on Communities Transactions** [3], Ricardo Moreno, Cristian Hoyos, Sergio Cantillo et al stated that several writers and reports have recently published articles regarding peer-to-peer goods and service transactions. Normally, electrical markets are used to trade energy. In wholesale power markets on a huge scale Given the integration of dispersed energy resources like solar panels and small-scale storage, there are new possibilities for trading energy at a small scale by focusing on the producer-consumer interaction, such as demand response and electric cars. This stems from energy trading options based on peer-to-peer (P2P) power marketplaces, which make use of tools like the blockchain and the implementation of smart contracts. Energy resources that are spread (DERs). This research proposes a framework for small-scale energy trading based on a flexible hybrid P2P paradigm. Each peer can alter its function for each period of time in transactions between communities and peers. Prosumer and producer peers can share the energy they've created. Based on price and quantity, consumer peers might modify their purchasing behaviour. As a result, the function of the community manager as a mediator between the community and the grid comes into play. As a result, for various structures and sales prices, a model of transactions with P2P offers was developed. Finally, for different situations, the framework for trading energy in a hybrid P2P model is tested in a demand curve over a 24-hour period.

**A review of transactive energy systems: Concept and implementation** [4] Qi Huang a,∗ , Waqas Amin b,a , Khalid Umer a , Hoay Beng Gooi b , Foo Yi Shyh Eddy b , Muhammad Afzal a , Mahnoor Shahzadi a , Abdullah Aman Khan a , Syed Adrees Ahmad et al. worked on transactive energy trading is new and much more efficient way of electricity trading among the local. In recent decade with the advancement in smart grid technology the popularity of transactive energy also increases. Transactive energy framework is made of many different types of blocks from market to local buyer to local seller and to know how good is a transactive energy framework we have to see the overall outcome of the system and the outcome of the blocks from which the whole system is made. This paper gives a brief introduction of a transactive energy and how can a transactive energy system can be implemented in the real-world and this paper also discuss about what’s the role of each block of the transactive energy framework and how efficient and effective these blocks are in the transactive energy system.

**Towards transactive energy systems: An analysis on current trends** [5], Omid Abrishambaf, Fernando Lezama, Pedro Faria * , Zita Vale et al. paper mainly focuses the main aspect of the transactive energy system which is “what is transactive energy system which is simply the concept of the TES and implementation of the transactive energy system in the real world. This paper’s work has been shown in three different field of research one of them is the transactive energy management 2nd is transactive control and the last on is peer to peer market. This paper shoes many of the transactive energy model have one same issue which is that the model is ready for theoretical approach but most of them are lacking in the real-world implementation and that’s the reason that many of the model doesn’t have complete validation. For solving this problem, we have to study about both real-world implementation and theoretical approach.

**Transactive energy: A review of state of the art and implementation** [6], Zhaoxi Liu, Qiuwei Wu, Shaojun Huang, Haoran Zhao at el worked on large-scale deployment of distributed energy resources (DERs) and renewable energy sources (RES) is envisaged in future smart grids. New control techniques for power system operations are required to integrate a high penetration level of DERs and RES in the grid while running the system safely and effectively, allowing the flexibility of the responsive assets in the grid to be further explored. In recent years, transactive control, which is regarded one of the most unique distributed control systems for power system operations, has been widely researched and investigated across the world. The study and application of transactive energy ideas and transactive control approaches in power systems are reviewed in this work. The GridWise Architecture Council's suggested transactive energy framework is used to explain the concepts of transactive control. Following that, implementation pilots and research projects on transactive control applications in power systems are examined.

**Microgrid Transactive Energy: Review, Architectures, Distributed Ledger Technologies, and Market Analysis** [7], Muhammad F. Zia, Mohamed Benbouzid, Elhoussin Elbouchikhi et al. worked on microgrid transactive energy systems at the distribution level have the exciting potential of reducing transmission losses, lowering electric infrastructure expenditure, improving reliability, enhancing local energy use, and lowering customers' electricity bills thanks to the prosumer concept and digitilization. For the creation of a decentralised smart grid system, distributed energy supplies, demand response, distributed ledger technology, and local energy markets are essential components of the transaction energy system. As a result, this article examines the notion of transactive energy and suggests a seven-layer architecture for creating a transactive energy system. The suggested design is contrasted to a real-world case study of a microgrid in Brooklyn. In addition, this study examines existing designs and describes the frequently used distributed ledger technologies (blockchain, directed acyclic graph, hashgraph, holochain, and tempo), as well as their benefits and drawbacks. For energy commerce within a transactive energy system, the local energy market idea is given and critically assessed. The promise and constraints of peer-to-peer and community-based energy marketplaces are also discussed in this study. The proposed architecture and analytic assessment of distributed ledger technologies and local energy markets open the ground for advanced transactive energy system research and industrialisation.

**Transactive Energy Pricing in Power Distribution Systems** [10], Mahdi Ghamkhari et al. stated that demand response has been developed in recent years as a mechanism for dealing with intermittency in the power supply of renewable sources. However, one of the biggest disadvantages of depending on demand response systems is the unpredictability of demand response providers' responses to the price of power. Transactive Energy is a new framework that aims to overcome the aforementioned flaw. In this work, a power market for power distribution systems is designed, allowing power users to exchange transactive energy in real-time distribution system operation. Furthermore, the real-time value of transactive energy is calculated utilising the law of supply and demand.

**Blockchain-based Peer-to-Peer Transactive Energy System for Community Microgrid with Demand Response Management** [11], Hanumantha Rao Bokkisam, Student Member, IEEE, Shashank Singh, Ritesh Mohan Acharya, Student Member, IEEE, and M. P. Selvan, Senior Member, IEEE et al. stated that because of the present smart grid paradigm, interest in transactive energy frameworks (TEFs) is growing. This study suggests a TEF that uses auction theory, contains a system of agents, and uses an auctioneer to support a transactive energy market (TEM). It also allows for peer-to-peer (P2P) energy exchange among residential buildings in a community microgrid for potential monetary gains. There are three actors in this framework: auctioneer, participants, and utility. The auctioneer is a managerial agent whose job it is to determine day-ahead internal market-clearing price and quantity using auction theory. The participants are self-sufficient and logical decision-makers who want to reduce their power costs by managing demand response (DR). Two types of architectures are described, one with a third-party agent displayed in MATLAB and the other with a virtual agent (without a third-party) implemented in the blockchain environment. The simulation findings show that each market member receives large monetary advantages, as well as increased community self-sufficiency, self-consumption, and less dependency on the utility grid.

**A Survey and Evaluation of the Potentials of Distributed Ledger Technology for Peer-to-Peer Transactive Energy Exchanges in Local Energy Markets** [12], Pierluigi Siano, Giuseppe De Marco, Alejandro Rolan, Vincenzo Loia et al. worked on renewable Energy Sources (RESs) inject unpredictability and intermittency into power networks, which may result in unplanned peaks in energy output that differ from energy demand. Proper communication between prosumers (users with RESs that can either inject or absorb energy) and active users (users who consent to have their loads altered according to system demands) is essential to address these mismatches. Because both prosumers and active users want to participate in energy transactions, the centralised strategy utilised in traditional power systems is no longer feasible, and a decentralised approach based on transactive energy systems (TESs) and peer-to-peer (P2P) energy transactions should be used. In this regard, Distributed Ledger Technology (DLT), which is based on the blockchain idea, appears to be the most promising approach for enabling smart contracts between prosumers and active consumers, which are securely stored in blocks with cryptographic hashes. The purpose of this study is to present an overview of decentralised TES deployment and to propose and debate a transactive management architecture. In this context, Proof of Energy is presented as a novel consensus mechanism for DLT-managed P2P energy transfers. The proposed infrastructure is discussed in conjunction with a Virtual Power Plant (VPP) aggregator and household prosumers who are equipped with a novel transactive controller to manage the electrical storage system.

**Algorithm 1-**

- Let the fixed price be ₹u / units
- Let person selling price be ₹v /units
- Let n be the total number of houses as consumers with request demand of p units.
- Let m be the total number of houses as sellers with supply of q units.

  Demand $= \sum_{j=1}^{n} pj$

  Supply$= \sum_{j=1}^{n}$ qj

  Rule 1: v ≤ u-0.5

  Rule 2: First the units will be consumed of the seller with least selling price.

  Rule 3: The extra units produced will be sold to the utility as per their price i.e., whatever they buy at fixed price.

  Rule 4: The person who sell for highest price, he will be given lowest priority for selling the units and if the units remain unsold, he will be making profit at the buying price of the utility.

- Ratio of power required by houses is:

$$\frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} + \frac{p2}{\sum_{j=1}^{n} \mathrm{pj}} + \frac{p3}{\sum_{j=1}^{n} \mathrm{pj}} + \cdots + \frac{pn}{\sum_{j=1}^{n} \mathrm{pj}}$$

- Available power delivered ratio:

$$\frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj} + \frac{p2}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj} + \frac{p3}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj} + \cdots + \frac{p4}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj}$$

- Now the charge per unit of each seller:

$$\frac{q1}{\sum_{j=1}^{m} \mathrm{pj}} + \frac{q2}{\sum_{j=1}^{m} \mathrm{pj}} + \frac{q3}{\sum_{j=1}^{m} \mathrm{pj}} + \cdots + \frac{qm}{\sum_{j=1}^{m} \mathrm{pj}}$$

- For calculating the money constant:

$$k = \frac{q1v1}{\sum_{j=1}^{m} \mathrm{qj}} + \frac{q2v2}{\sum_{j=1}^{m} \mathrm{qj}} + \frac{q2v3}{\sum_{j=1}^{m} \mathrm{qj}} + \cdots + \frac{qmvm}{\sum_{j=1}^{m} \mathrm{qj}}$$

- For consumer 1, bill will be given as:

$$=\left(\frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj}\right) * k$$

$$=\left(\left(\frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj}\right) * k\right) * \left(\left(\frac{1}{\sum_{j=1}^{m} \mathrm{qj}} * \sum_{j=1}^{m} \mathrm{qj}\, vj\right)\right)$$

$$=\left(\frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj}\, vj\right)$$

And similarly, it will be calculated for other consumers.

- Simplifying:

Let

$$k1 = \frac{\sum_{j=1}^{m} \mathrm{qjvj}}{\sum_{j=1}^{m} \mathrm{pj}}$$

- So now the price for the consumers will be given by the simplified formula:

=pi * ki

- This above-mentioned rule is valid if the supply is greater than the demand.

- If demand is greater than the supply, we will repeat the above procedure and in order to provide him with complete demand, the remaining demand will be at the price of utility i.e.,

$$= \left( pi - \left( \frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj} \right) \right) * u$$

- Now the total bill for the $i^{th}$ consumer will be:

$$= pi * k1 + \left( pi - \left( \frac{p1}{\sum_{j=1}^{n} \mathrm{pj}} * \sum_{j=1}^{m} \mathrm{qj} \right) \right) * u$$

- If two sellers are selling the energy at different cost, one may get profit so in order to make that fair, the person to make less profit can be given the concession of some amount on the seller who buys from utility gets satisfied.

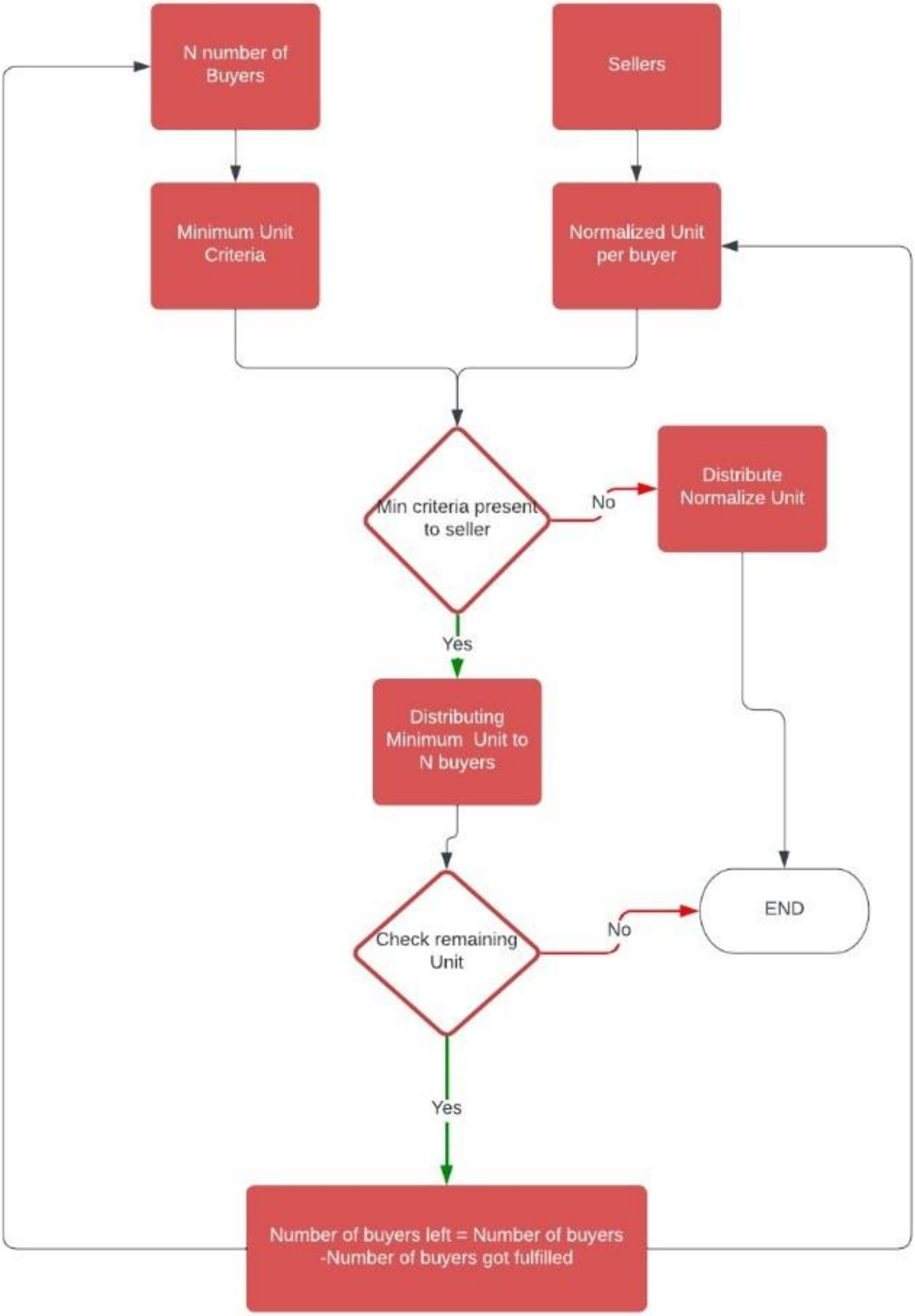
    After few years, their will be a good competition between the seller and the price difference of seller will be very less or even maybe zero which will stabilize the even maybe zero which will stabilize the market and let it work fluently.

**Java Code for the Algorithm 1:**

Google Drive link:

https://drive.google.com/file/d/1s26_iKv3kRorp7gSR7wToMfEH5M5e88H/view?usp=sharing

**Algorithm 2:**


N number of Buyers
Sellers
Minimum Unit Criteria
Normalized Unit per buyer
Min criteria present to seller
No
Distribute Normalize Unit
Yes
Distributing Minimum Unit to N buyers
Check remaining Unit
No
END
Yes
Number of buyers left = Number of buyers -Number of buyers got fulfilled

**Java Code for the Algorithm 2:**

Google Drive link:

https://drive.google.com/file/d/129Huc03l7pYfJsxM-GwZAxhcE1e9sZWM/view?usp=sharing

**Conclusion for Algorithm 1:**

**Advantage:**

- The seller gets the choice for the price he wants to sell the units.
- The algorithm is simple to understand by the consumers.
- The person selling the units at lower price will be benefited first.

**Disadvantage:**

- The consumer with maximum demand in the society will affect the society and consume most of the stored energy.
- The buyer doesn't have a choice for concession of price.
- The data taken in the code is static.

**Conclusion for Algorithm 2:**

**Advantage:**

- The distribution will be fair in the society.
- The consumer consuming the most power will be penalized and which will help reduce the electricity loss.
- The data taken in the code is dynamic.

**Disadvantage:**

- The buyer doesn't have a choice for concession of price.
- It is complicated to understand by the consumers and the society.
- The system may dissolve at high demand time.