Evolution of Microgrid and Hierarchical Control of Microgrid

HS Pranavi Peddada, Tatwamashi Panda, Annika Gupta, Sriramalakshmi P, Balamurugan

Vellore Institute of Technology, Chennai

Corresponding author: Sriramalakshmi P, Email: sriramalakshmi.p@vit.ac.in

A microgrid is a local energy grid with control capability, which means it can disconnect from the traditional grid and operate autonomously. This survey article focuses on the technical control solutions for various levels of the Microgrid organization. An electric grid is an interconnected network where electricity is delivered by producers to consumers. Grids vary in size and consist of: power stations, electrical substations, electric power transmission and electric power distribution. The difference between a traditional grid and a microgrid can be clarified using an example. In a traditional system, if the power transmission source and load are out of balance, the power is instantly balanced by the system's rotational inertia, modifying the intensity, which is the simple concept of the P-f droop control method. The microgrid, on the other hand, lacks inertia because most of the microgrid's sources are renewable, making the microgrid control system architecture complex and difficult. This resulted in the development of a new control technique for microgrids called Hierarchical Control (HC), which has three levels: main control, secondary control, and tertiary. This survey mainly mentions how the grid structure is complicated and the role of microgrids to address this issue. Electric grids are vulnerable to malicious attack and cyber threats. Hence, their security is a must. They are large in size and are frequently found far from densely populated areas.

Keywords: Electrical grid, Transmission, Hierarchical Control, Coupling.

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1. Introduction

An interconnected network where electricity is delivered by producers to consumers is called an electric grid. Grids vary in sizes and consist of:
i) power stations that are close to an energy source but distant from densely inhabited regions.
ii) electrical substations that help to scale the voltage up or down; and
iii) electric power transmission that transports electricity over large distances.
iv) electric power distribution, in which the voltage is scaled down and distributed to individual consumers according to their needs. The conventional grid follows a unidirectional network where electricity flows unidirectionally from the generators to the substations over the transmission lines and then to the customer’s outlets.

An electrical grid serves as a conduit for delivering electricity from generators to consumers. Mass reception of EVs have various effects and advantages, remembering the capacity to help in implementation of environmentally friendly power into existing electric lattices [1]. According to the research, as of 2021, about a billion individuals distributed across various places are unable to connect to the power grid due to a variety of issues. Prior to the 1880s, electric energy was generated close to the equipment or place that required it [2]. During the 1880s, power contended with coal gas, which was created close to where clients resided, and ventures involved organizations of funnelled gas for lighting. During the 1990s, a few nations changed energy guidelines, bringing about the power transmission business being controlled independently from the conveyance business [3].

2. Functionalities of a Grid

2.1 Frequency

All generators in a coordinated grid should run at a similar recurrence and be intently in stage with one another network. Since energy is consumed as it is created, utilization should be adjusted across the entire lattice. An entire coordinated matrix works at similar recurrence, adjoining networks, regardless of whether they work at a similar ostensible recurrence, wouldn't be synchronized. To interface two exchanging current interconnection networks that are not synchronized, high-voltage direct current lines or variable-recurrence transformers can be used. This takes into account interconnection without requiring the synchronization of a bigger region.

2.2 Voltage

Grids are built to provide power to clients at a relatively steady voltage. This must be accomplished in the face of fluctuating demand, changeable reactive loads, and even nonlinear loads, with electricity supplied by generators and distribution and transmission infrastructure that isn't always reliable. To alter the voltage and keep it within specification, grids frequently use tap changers on transformers near the customers.

2.3 Demand

Baseload is the least burden on the framework at some random time, though top interest is the most elevated. Baseload was previously met by gear that was somewhat economical to work and could run consistently for weeks or months all at once, however this is turning out to be less predominant around the world.

2.4 Capacity and Firm Capacity

The limit of an electrical grid can be determined as the amount of the most extreme power results of the generators associated with it. Generators might be turned down for support or different reasons, for example, a deficiency of energy inputs (fuel, water, wind, sun, etc) or stresses over contamination. Firm limit is the most extreme power yield on a network that is quickly open inside a specific time-frame hence it is an undeniable.

2.5 Handling Failure

Following a huge blackout in one part of the framework, power might be rerouted to move from generators to customers by means of transmission lines with deficient limit, bringing about extra blackouts.

3. Components

The electrical grid is mainly divided into three main categories like generation, transmission and distribution as shown in Fig 1.

3.1 Generation

At this point in the electrical grid, electricity is created. Electricity may be generated in a variety of ways, including electromechanical generators, combustion-fuelled heat engines, and other methods such as kinetic energy from flowing water or wind. Solar and geothermal energy are now routinely used to generate electricity.Electricity is generated through coal and natural gas-burning power plants, hydroelectric dams, nuclear power plants, wind turbines, and solar panels, to name a few. The distance between these electrical generators and end consumers, as well as the placement of these generators, varies substantially.

These technologies are utilised and managed differently on the power grid. This is further divided into two categories: centralised and decentralised. Large-scale power generation, such as coal, nuclear, natural gas, hydro, wind farms, or vast solar parks, that are located remote from population centres or consumption centres is referred to as centralised power generation. On the other side, decentralised generating happens near consumption centres.

3.2 Transmission and Distribution

Transmission lines are needed to move high-voltage power across enormous distances and to associate sources. Overhead electrical cables and underground force links are the two instances of transmission lines. Overhead force links are not protected and they are more affordable to introduce than underground force wires. Overhead and underground transmission lines are of aluminium combination and steel support. Transmission-level voltages are regularly 110,000 volts or 110 kV or more, with some transmission lines voltages as high as 765 kV. In any case, power generators make power at low voltages. The power should initially be changed to higher voltages through a transformer before it tends to be shipped at high voltages. Electric power transmission is the development of electrical energy from a producing source to an additional a high voltage (EHV) substation. The transmission lines are connected to the distribution network by a network of wires known as the distribution network. These networks, which lead to homes, schools, and businesses, begin with the transformers. State-level distribution is governed by PUCs and PSCs, which regulate retail electricity pricing in each state.

3.3 Consumption

The transmission lines are connected to the distribution network known as the distribution network. These networks, which lead to homes, schools, and businesses. State-level distribution is governed by PUCs and PSCs, which regulate retail power pricing in each state.These consumers might be industrial, residential, or commercial, depending on the needs. The 230V electricity energy that eventually arrives at our home. Electric energy is measured in joules (J) or watt hours (Wh), which is a power unit that stays the same across time. An energy metre, which counts the quantity of energy consumed and is used to compute our electricity bills, delivers power to our home.

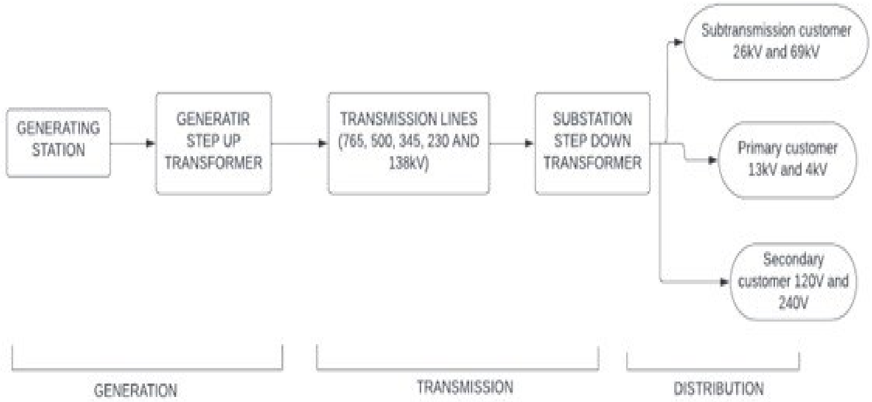

Fig. 1: Components of electrical grid

4. Drawbacks

In order to facilitate power exchange, traditional distribution systems require proper protection. Signalling for resource dispatch becomes increasingly difficult. Contracts for connection and revenue are tough to establish. The main problem of these traditional sources is that they pollute the environment significantly. Air pollution is caused by the burning of firewood and fossil fuels. Using non-traditional sources can assist you in avoiding this. A generator is often a synchronous machine with a small number of poles (two or four) and high speeds (1500–3600 rpm).

The turbine and condenser's inefficiency has a substantial impact on the overall efficiency of the energy conversion from fuel to electricity. Between 30% and 40% of the time, total efficiency is usual.

5. Why Microgrid Came into Picture?

Both conventional and non-conventional energy sources can be used to generate energy. Because conventional sources are reliant on fossil fuel and they can only be used for a limited time. The ever-increasing demand for energy, along with environmental concerns, the emergence of private companies, and more competition, has sparked interest in large-scale development of non-conventional sources. And in order to meet these demands, small-scale grids that can meet the power needs of remote places without requiring large investments in transmission lines. The microgrid can be used to connect a variety of non-traditional energy sources.

Microgrid alludes to a dispersed gathering of electric sources that is utilized to give back-up force during times of substantial requests and in the midst of emergencies like tempests or blackouts [4]. They are regularly upheld by generators or sustainable sources like breeze or sun powered energy. The microgrid fills in as a discrete geographic impression basically in colleges, medical clinics, business focuses or in areas. The power grid is a constantly changing system. It has altered and evolved significantly over the previous century to accommodate new technology, rising electrical demand, and a growing demand for reliable, diverse electricity sources. The system is changing on an hourly basis, with diverse sources of electricity being managed to meet demand at the lowest cost. Significant enhancements to the power infrastructure could be made as technology advances and better solutions become available.

6. Microgrid: How is it different from Conventional Grid?

Microgrid is a term used to describe a dispersed set of electric sources that are used to supply backup power or supplement the main power grid during peak demand periods and emergencies such as storms or power outages. Generators or renewable energy sources such as wind or solar power are generally used to power them. In colleges, hospitals, business centres, and neighbourhoods, the microgrid acts as a discrete geographic footprint. Microgrids can aid in the management of electricity consumption and the reduction of grid congestion. They contribute to system reliability, efficiency, and the postponement or avoidance of electric capacity investments. Microgrids also help in enhancing grid resilience to cyber-attacks. This is due to the islanding functioning of the microgrid. They, indirectly, help the electrical grid recover from a system outrage, i.e., re-energise the main grid.
A microgrid can work in two ways, one, when it is connected to the main grid and secondly, it can also work by delocalising itself from the main grid and operates on its own using local energy generation in necessary conditions. Microgrid controls and administrative frameworks, to carry out different methods of activity (specifically framework associated and islanding), and to guarantee appropriate change between these two fundamental activity modes [5]. This is the main feature of the microgrid and is known as the “island mode” or “islanding”. The microgrid can regain its power and run indefinitely depending upon how it’s fuelled and its requirements. For this purpose, it uses distributed generators, renewable batteries or resources like solar panels, etc. A microgrid is connected to the main grid at a point where the voltage level is maintained at the same level as the main grid and this point is known as the point of “common coupling”.

7. Topology

Medium Voltage network geographies can be circulated into three gatherings:

7.1 Radial Topology

Outspread lines associate essential substations (PSs) to auxiliary substations (SSs), just as SSs to SSs. These MV lines, now and again known as "feeders," can be used to arrive at a solitary SS or numerous SSs. All SSs are heavily influenced by spiral frameworks as depicted in Figure 2.
At the point when these spiral geographies get more confounded, they take on a tree-like construction. They are more affordable to fabricate, work, and keep up with than different geographies, however they are less dependable.

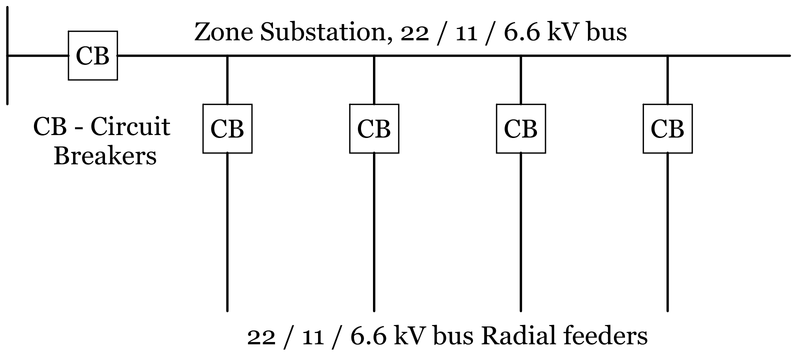

Fig 2.: Radial Topology

7.2 Ring Topology

The network is worked radially paying little heed to the actual design, however in case of a feeder issues, different components are controlled to adjust the framework so that blackouts are stayed away from as shown in Fig 3.

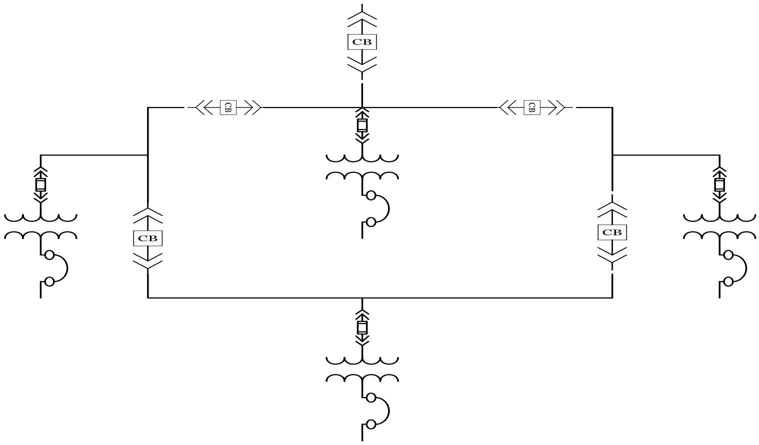

Fig 3. : Ring Topology

7.3 Networked Topology

Essential and auxiliary substations are connected by a few Middle Voltage lines in a well-organized topography. As a result, there are a variety of reconfiguration options for overcoming the shortcomings, and in the event of disappointment, different responses for reconfiguring power may be discovered.

Low Voltage (LV) dispersion frameworks are available in single-stage or three-stage configurations. Three-stage, 230V/400V frameworks are common in Europe, for example (i.e., each stage has a rms voltage of 230V and the rms voltage between two stages is 400V).

The topologies of LV matrix networks are more complicated and varied than those of MV networks as shown in Fig 4. A SS (secondary substation) normally feeds electricity to at least one LV line with at least one MV-to-LV transformer in a similar area. Although LV structures are typically dispersed, with a few branches associating with extended feeders, LV organisations have seen organised matrices and, in any case, ring or double taken care of plans.

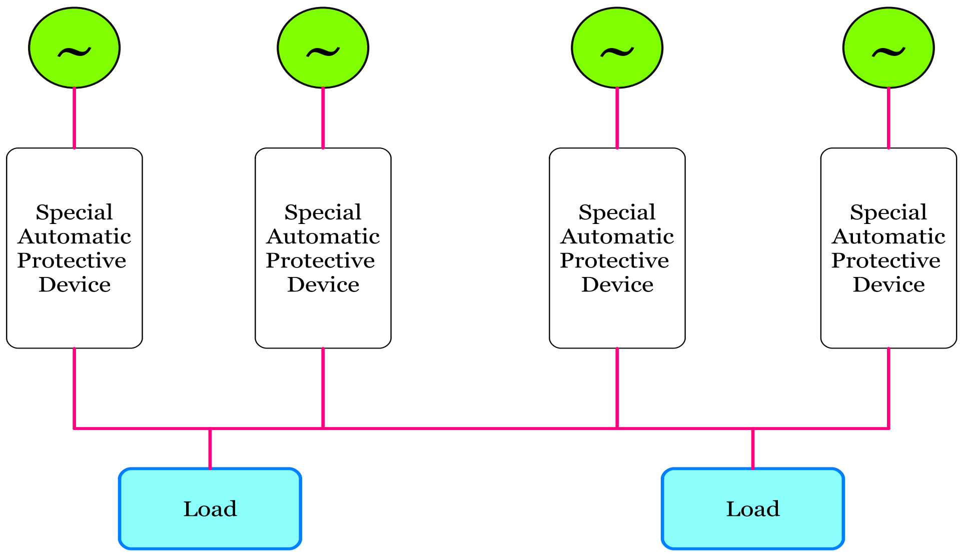

Fig. 4.: Networked Topology

8. Micrograds

Microgrids have gained popularity as a viable framework for integrating renewable energy sources, energy storage devices, and loads. They can be treated as a local distribution system with distributed generators in a grid-connected or islanded condition, and have the potential to increase power quality, reliability, and energy efficiency for their customers. However, considerable challenges, notably in terms of security, must be overcome in order to build microgrids or distribution networks using DGs. Traditional protective systems may be rendered ineffective due to the numerous operating modes and the presence of scattered energy supply.

9. Hierarchy control architecture of microgrid

The rules underlying the microgrid control system differ greatly from those governing the regular grid power system, making research into it difficult [6]. The difference between a traditional grid and a microgrid can be clarified using an example: in a traditional system, if the power transmission source and load are out of balance, the power is instantly balanced by the system's rotational inertia, modifying the intensity, which is the simple concept of the P-f droop control method[7].Their fundamental trademark is the organized control of the interconnected dispersed energy assets (DER), which can be acknowledged by different techniques, going from decentralized correspondence free ways to deal with unified ones, where choices are taken at a main issue. The microgrid, on the other hand, lacks inertia because most of the microgrid's sources are renewable, making the microgrid control system architecture complex and difficult. In [8] a few control strategies utilized in MG are introduced focussing on their different functional modes. This resulted in the development of a new control technique for microgrids called Hierarchical Control (HC), which has three levels: main control, secondary control, and tertiary control as shown in Fig 5.

9.1 Primary Control

The execution is done in two modes: PQ Mode and Voltage Control Mode shown in **Figure 6**. In the Voltage Control Mode, the energy sources that work as voltage-controlled sources and the reference voltage is dictated by hang qualities.

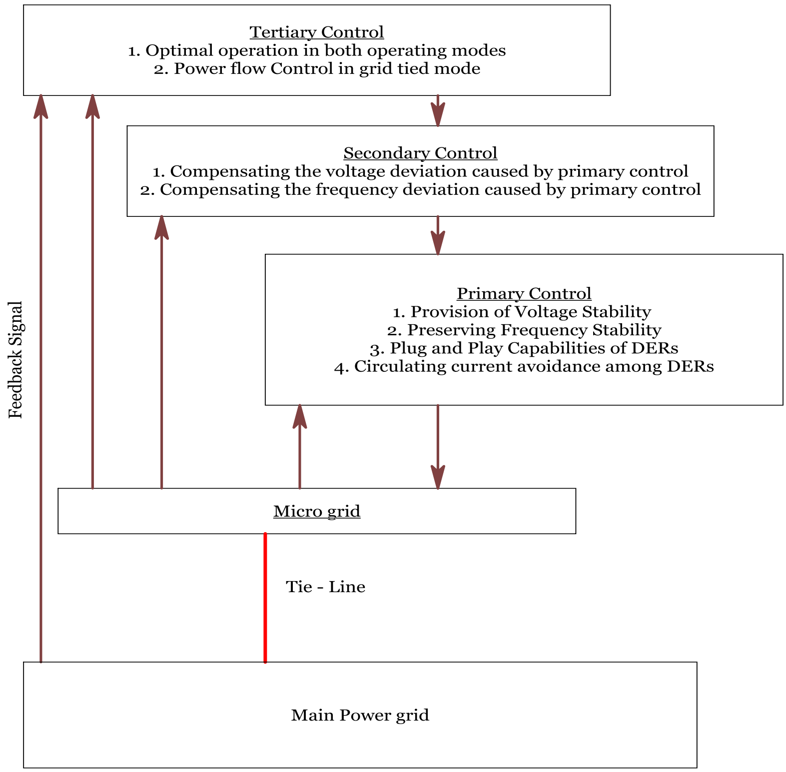

Fig. 5.: Basic Hierarchical Control Structure

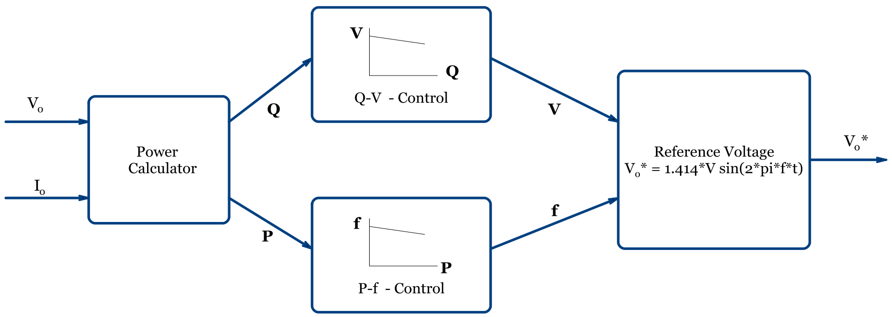

Fig 6.: Determination of Reference Voltage for the Voltage Control Mode

9.2 Secondary Control

The regulator utilizes a Microgrid Central Controller which holds the control insight that considers the microgrid all in all and furthermore advances the whole microgrid activity which is conversely, with the essential control that works in island mode [10].

9.3 Tertiary Control

It ensures financial streamlining based on energy cost and power market. The tertiary regulator expands the trading of information with the dissemination framework administrator in order to streamline the microgrid activity inside the utility grid. The power stream between the principal network and the microgrid by changing the sufficiency of the appropriated energy sources at the Point of Common Coupling is overseen by the tertiary regulator in the matrix tied mode.

Hierarchical Control guarantees a prudent and secure activity by keeping up with the recurrence and voltage in microgrids. Administrative Control and Data Acquisition (SCADA) is utilized to screen voltage in microgrids. Droop Control is a control mode in which the voltage output decreases as the line frequency rises. In traditional power systems with many parallel generating sources, it is utilised for load sharing. The load is shared by drooping the frequency of each dispersed source with the real power delivered. Examination in the field of Microgrid Control Technology is a continuous interaction and its possibilities improve its viability and activity proficiency remembering the expanding utilization of inexhaustible wellsprings of energy. This will help in the change and advancement of the current Microgrid Control Technology into a more productive and wiser Microgrid System.

10. IoT remote monitoring system in microgrid

Microgrids join IoT-empowered innovation with power framework hardware to empower neighbourhood organizations to convey additional administrators on top of the fundamental stock of power to nearby organizations that capacity in corresponding with or freely of the territorial matrix. Various advancements, designs, and applications that utilize the Internet of Things as a critical part and guidelines are being created to refresh and further develop productivity, versatility, and financial aspects [11],[12]. Microgrid applications can be found in a wide scope of energy utilization situations. The Internet of Things plays a major role in Microgrid design. The complete operation of microgrid is shown in Figure 7.

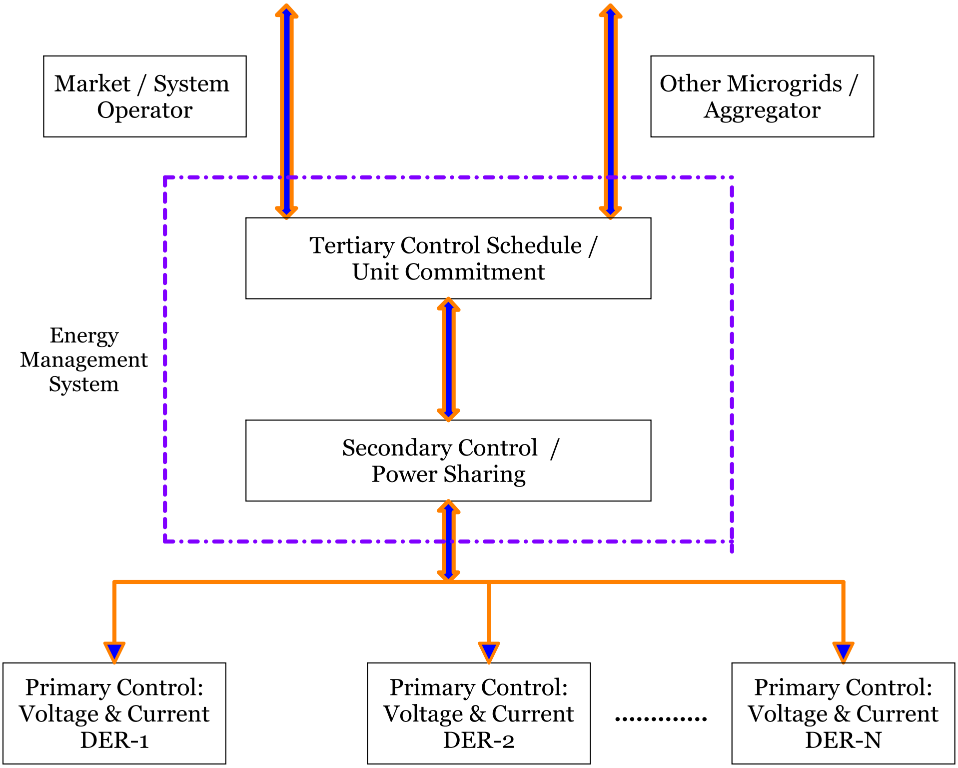

Fig. 7.: Operation of Microgrid

13. Conclusion

Dynamic network executive frameworks require information from across the lattice to wrap up their jobs. This is the place where IoT innovation sparkles: it makes it simpler to gather and dissect information from old lattice assets, circulated energy assets, and option electrical resources, permitting utilities to react all the more rapidly once associated. IoT-driven framework will actually want to execute essential capacities utilizing this data, for example:

- Improving line voltage to decrease energy losses and damage to source lines;
- Tracking down the source of sags, surges, and outages;
- To speed up uploading and restoring services, as well as to make safer override judgments;
- Define the supply of technical and nontechnical issues inside the system in order to lower service charges;
- Uninflected fault locations reduce outage investigation times.

With the fast increase of renewable energy resources in microgrids, IOT might be used to secure and command them. The system's continuous operation and automation, enable energy optimization and system status monitoring. The Internet of Things empowers the framework to remotely screen and deal with the organization. In this article, the Internet of Things was utilized in microgrids to screen and protect the organization in both matrix associated and islanded methods of activity.Soon, an extended result for IoT-based microgrids will help us in all aspects. Microgrids with IoT will disperse environmentally friendly power assets in every network in an appropriate and complete way. The versatility of microgrids will be generously expanded if we can utilize IoT to work with them. The strategy should be worked on sooner rather than later.

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