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A REVIEW ON OPTIMIZATION OF ELECTRICITY DEMAND FOR ENERGY MANAGEMENT SYSTEM

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Abstract

One of the best strategies to lower energy usage and electric costs is to employ a demand control management system to use electricity more effectively. Effective monitoring and management of power use is accomplished through the use of an electrical demand control system. Additionally, it's a helpful tool to help you prevent fines above the negotiated value of power demand with each electricity provider. In this research, we will create a predictor based on Taguchi-Grey to estimate the value of power demand online.The most recent information on systems for managing energy (EMS) and prosumer structure of organizations is provided in this review. When sustainable energy sources (RES) are integrated into a home, recent difficulties arise for power system stability, optimal operation, power quality, and market involvement. Creating an EMS with unique prosumer organisational structures is a common way to handle these problems. Several facets of observation must be included in the interdisciplinary process of developing an emergency management system. In addition to input parameter prediction strategies, optimisation methodologies, goal roles, constraints, and market conditions, this study provides an overview of the types, components, organisational, and control systems of prosumers. To mitigate the effects of market prices, creation, and consumption uncertainties associated with renewable energy sources running at maximum efficiency, Particular care is taken in forecasting input parameters. And the optimisation framework, which exhibits development potential.

Keywords: *Energy management system[1], Prosumer[2], Organizational structure[3], Renewable energy sources[4], Prediction method[5].*

1. Introduction

Because of the influence of global competition, national and multinational enterprises have tried very hard to reduce their expenditures in order to increase their competitiveness. Optimizing energy expenditure presents an alternative approach to mitigating operational overheads without recourse to human capital reduction. Frequently, manufacturing entities can recalibrate their primary operational windows from daytime to nocturnal cycles to leverage advantageous off-peak electrical tariffs. This strategic shift can result in a substantive reduction in utility outlays. These days, energy management concerns are heavily focused on electricity demand control systems [1, 2]. In most cases, balancing electrical supply and demand through proactive load shaping, resource allocation, and intelligent control systems to achieve enhanced operational efficiency, cost reduction, and grid resilience may be accomplished efficiently to avoid going above the agreed-upon the power company requires the demand value of electricity thanks to the advanced predictive model for electricity demand management system. Prediction procedures typically make use of artificial intelligence techniques, regression analysis, and time series analysis. However, the time series approach needs a vast amount of previous data to make good predictions. Despite requiring comparatively little data, the short linear model of regression analysis sometimes results in unsatisfactory prediction accuracy. Though they don't require many limitations, artificial intelligence techniques like expert systems and neural networks rely heavily on the experience of the specialists and the quantity of historical data repositories used to train the artificial intelligent framework [3, 4]. Unlike other methods, the grey prediction does not assume a sequential arrangement of delayed data and requires as few as four data pieces. Studies of the social sciences, agriculture, reproduction, electricity consumption, and management have also made extensive use of the Grey prediction [5]. This document introduces an advanced Taguchi-Grey predictor, specifically engineered to forecast electricity usage for effective energy oversight. The Grey-based electricity demand forecasting algorithm was devised and integrated into a personal computer-driven automated monitoring and and control electrical system (AMCES) at the National Kaohsiung First University of Science and Technology (NKFUST) for real-time electricity governance. The AMCES offers a robust approach to challenges in electricity management. Nevertheless, the configuration of Grey's parameters can significantly impact the precision of its predictions. To accurately anticipate electricity demand, we employed Taguchi's experimental design methodology to fine-tune the parameter settings for the Grey prediction model. The diagram provides an idea of how energy is controlled via power distribution networks. Limitations, challenges, and upcoming initiatives have been explored, along with the establishment of objective function-based classifications, energy management systems, and optimisation strategies.

2. Methodology

The intension of this analysis this article objective is to furnish the most recent advancements in prosumer EMS and address the questions of future research directions and areas for development. Despite the fact that there are review publications on the prosumer EMS topic, this research closes the optimization framework gap. A thorough analysis of prediction techniques and electrical market participation is also conducted. As the above illustrates, the scope of this work is an attempt to investigate every facet required for creating and Building a precise model for prosumer optimisation that intends to participate in the electricity industry in order to lower costs or boost profits. Thus, this paper's analysis will give readers particularly those who are just starting to learn about the field a comprehensive perspective on the condition of EMS for prosumers in the modern era.

This research examined previous scientific works that address the aforementioned topic in order to offer the state of the art of prosumer EMS and address the topic in detail. But with a few restrictions, the writers concentrated on looking through scientific databases:

- Scientific publications that were published during the recent five years were considered, except for highly referenced, more extensive publications that were published more than five years prior and were also considered;
- Articles on the creation of microgrid and prosumer EMS systems were considered;
- ESS, DSM, hybrid EMS, and EV-based EMS development papers were taken into consideration;

- Excluding highly cited publications, review papers published during the last five years that addressed the following issues were considered: the electricity market, microgrid EMS, prosumer EMS, and input data prediction in optimisation issues;
- Basic, excellent works on the subject of RES incorporation and its effects on the grid were taken into consideration;
- Another factors were overlooked, including communication and security technology.

The framework of this review paper was established by the study concept that was given.

- The introductory section presents a thorough and high-quality summary of the study issue, Study of review papers that have been released thus far, and the gap that the current research is intended to address as well as areas for improvement;
- A comprehensive study A comprehensive examination of the EMS is conducted concerning the prosumer control structure of all aspects, and the business landscape are the formats in which the research findings are presented;
- The conclusion, suggestions, and areas for development are derived on a thorough analysis of scholarly reading material.

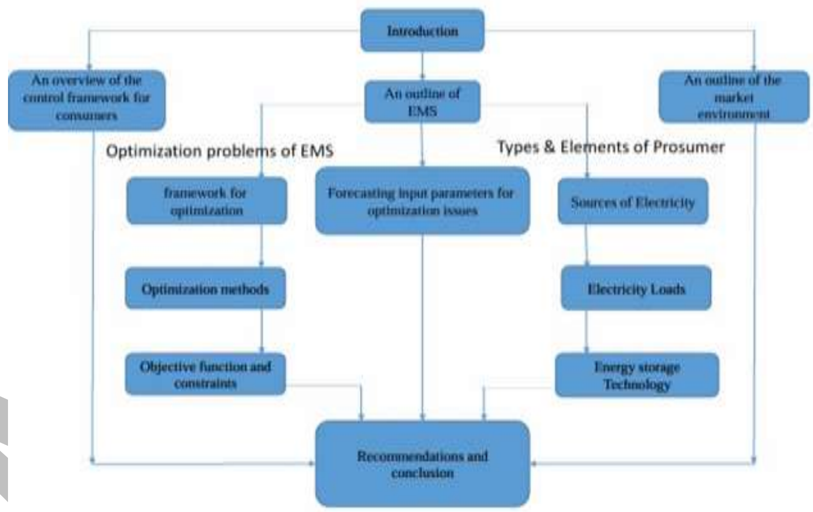

Figure 1 shows a study of this work's structure, including all of its sections and subsections

3. A Synopsis of the Prosumer Control Framework

An analysis of the academic literature indicates that prosumer control mechanisms fall into two general categories: centralized and decentralized. Additionally, RES can be included in a microgrid or prosumer community by integrating them into the distribution grid in the best possible way. Comparing a microgrid to the rest of the electricity system, it can be a controllable unit. As such, it has to have the proper EMS installed. Standardizing solutions for the widespread use of microgrids is problematic, particularly when it comes to standardizing energy management. The scientific literature divides microgrid EMSs into two primary categories based on the level of accountability of each microgrid (element) controller: centralized and decentralized control. Additionally, In the scientific literature, the concept of a hierarchical microgrid EMS is commonly seen because there is no universal notion of The design of a microgrid Energy Management System (EMS) because of Variations in construction dimensions, categories, and historical infrastructure. The hierarchical structure represents a local and a central controller and communication system on the following three levels: A fast local controller is used for primary regulation, which controls just one microgrid element of secondary regulation, which oversees and coordinates all local controllers: tertiary regulation acts as a connection between the central microgrid controller and external parties like aggregated components.

4. A Prosumer EMS Overview

A thorough description of an EMS for prosumers is given in this section. An EMS is crucial because it guarantees the best possible use of available resources. There is a dispute in the scientific literature regarding the classification of prosumers in the field of effective distribution grid-level energy management. The literature review states that all power users with integrated RES can be categorized as microgrids or prosumer communities.

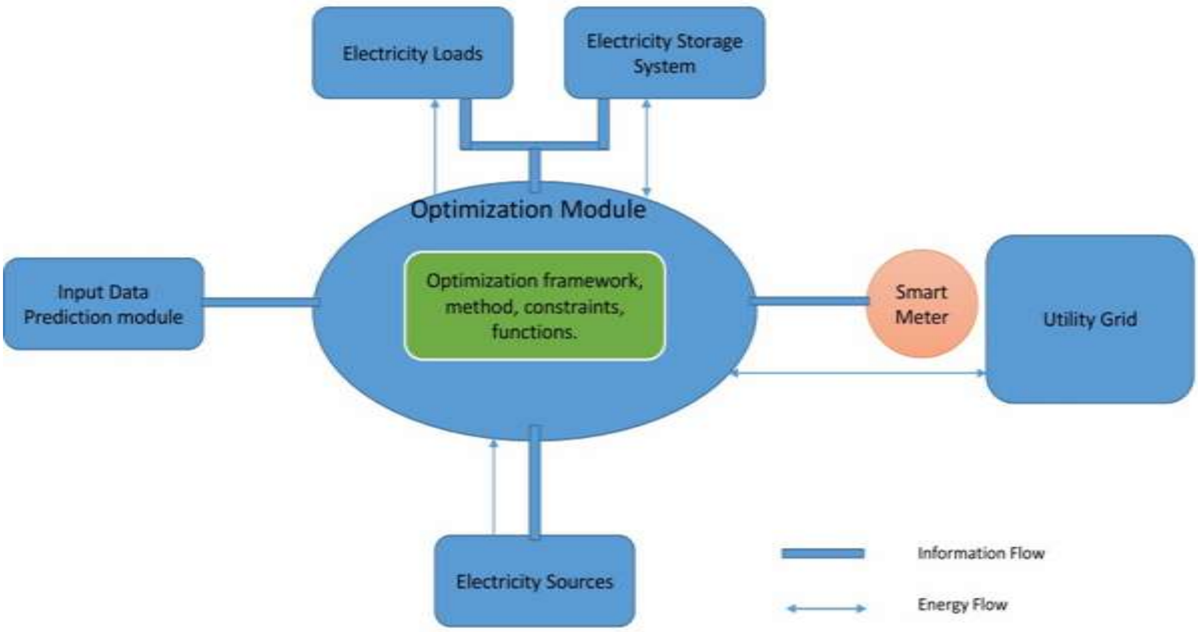

Figure 2: Overview of the prosumer EMS

The entire microgrid can be thought of as a single prosumer, especially if it's linked to the main grid at a point of common coupling (PCC). A generalized EMS system can be derived based on the studied literature, as seen in Figure 2.

The prediction and optimization modules for the input data, which are depicted in Figure 2, are the primary components of the prosumer EMS. EMS modelling is a complex, multidisciplinary task because there are many different potential prosumer design and operating factors. The following elements were considered in a evaluation of the academic literature in order to address every facet of the EMS simultaneously:

- The characteristics of the prosumer and the components they incorporate;
- The marketplace in which prosumers are present;

- Techniques to forecast input parameters in optimization issues;
- Prosumer EMS optimization challenges and optimization frameworks.

One advantage of the prosumer concept is that it may be implemented in a wide variety of topologies and components. Three prosumer topologies have been simulated in the literature: DC (DC prosumer), AC (AC prosumer), and hybrid (AC/DC prosumer). The kind most frequently utilized in the literature is AC (AC prosumers) because of the larger existing infrastructure. Every variety does, however, have benefits. All prosumer elements and characteristics of prosumer functioning must be represented in the EMS's optimization module. There are numerous examples of prosumers in the scientific literature with a range of regulated and uncontrolled components, including:

- Sources of electricity:
  - Uncontrollable sources (RES) and
  - Controllable sources (CS);
- Energy storage systems:
  - Electrochemical systems (secondary batteries),
  - Chemical systems,
  - Electrical systems.

4.1 Consumer Types and Components

Electrical Power Sources

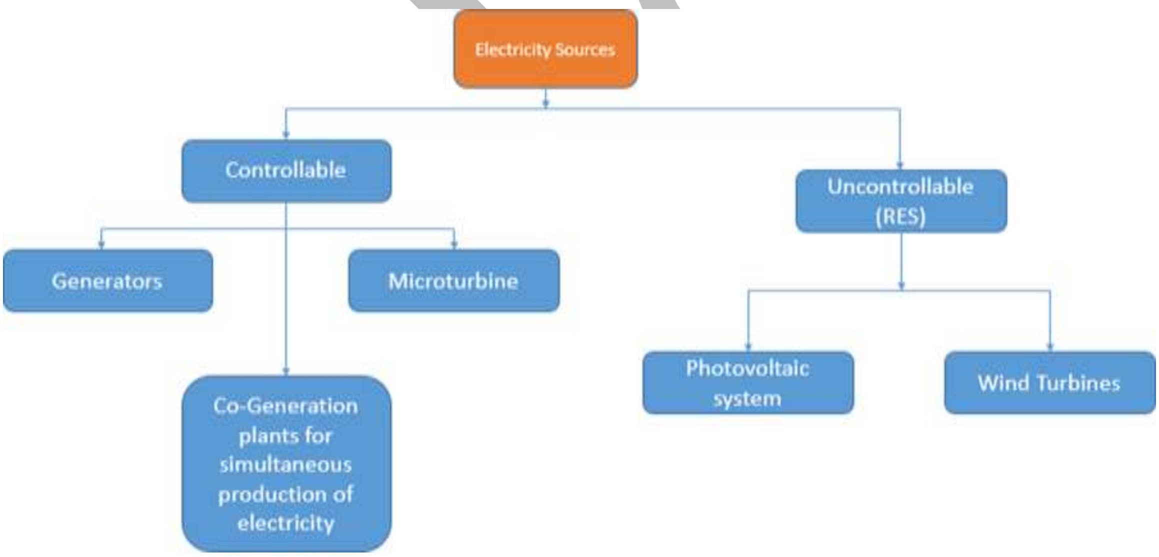

Figure 3: Overview and allocation of power sources

As illustrated in Figure 3, sources of electricity power can be broadly classified as either controllable or uncontrollable. Controllable electrical sources allow power production to be regulated, typically based on the electricity source's principal energy source (fuel). Furthermore, auxiliary (backup) power supply systems that are necessary for the microgrid's island mode functioning are frequently controlled electricity sources. Despite the involvement of various technologies, the mathematical models pertaining to these aspects primarily exhibit characteristics of the unit commitment and economic dispatch optimization problem, subject to the following limitations:

- The aggregator's (electricity power source's) minimum and maximum output power;
- The rate at which the output power ramps up or down;
- The minimum duration of power generation and the minimum duration of electricity generation interruptions, often known as the minimum up/down time;
- The two main categories of expenses for electricity generation (working time) are fuel and startup charges.

The kind and installed power of the generator determine the limitations used in the mathematical model. Some restrictions can be disregarded when using a little generator that is integrated into the microgrid.

Renewable energy technologies are the most common source of uncontrollable electricity, and their power output is contingent upon the availability of primary energy sources, such as solar irradiation and wind speed. When the output power cannot be adjusted across the range as needed, it is said to be uncontrolled. In the scientific literature Wind turbines (WT) and photovoltaic systems (PV) are the most commonly referenced.

Table 1 provides a summary of the scholarly publications pertaining to the authors' sources of electricity.

Ref.	RES	EV/PHEV	ESS	BPEC	CCADE and LCADP
[16]	PV, WT	No	ECS	No	Yes
[17]	PV	No	ECS	No	Yes
[18]	PV	No	ECS	No	Yes
[19]	PV, WT	Yes	ECS	No	Yes
[20]	WT	No	ECS	No	Yes

Loads of Electricity

Managing consumption is an inevitable aspect of the prosumer lifestyle. The installed power and consumption characteristics of electricity loads vary widely. Figure 4 illustrates how the scientific literature most commonly divides electrical loads into controllable and uncontrollable (critical) categories.

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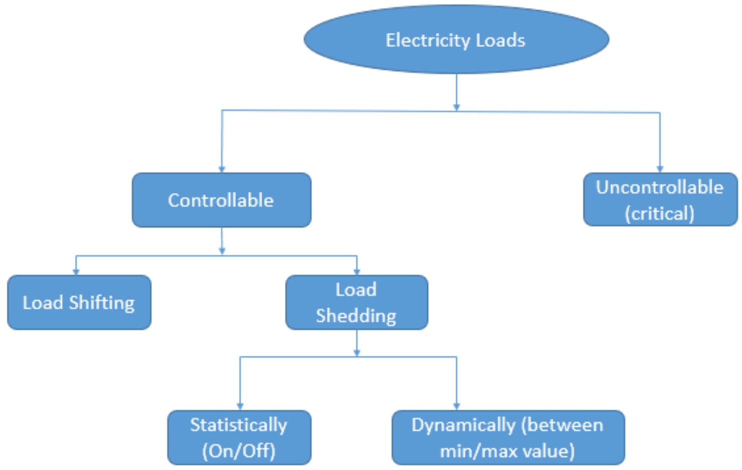

Figure 4: Overview and division of electricity loads.

Most of the time, the EMS does not model controllable electricity loads. The scientific literature does, however, contain a number of instances that simulate either a collection of controllable electrical loads (an aggregate of loads) or each individual controllable electrical load. In Table 1, the abbreviation "Aggr" denotes a group of controlled electrical loads. When controlling the consumption of a group of controlled electrical loads, two outcomes are obtained, depending on the modelling technique: load shedding and/or shifting. They think that the prosumer is involved in DRP while modelling controllable electricity loads. This has the same impact on the prosumer's profile of electricity usage, but with some monetary compensation.

Technologies for Energy Storage

An sophisticated power system must be flexible, and there are more and more published scientific studies on the subject. Because of The volatility of RES electricity generation, especially from wind and sun, and demand, especially for electric vehicles, an advanced power system would fail without flexibility. This is why study in this area is so important. In order to guarantee sophisticated power systems, flexibility is also required for prosumers. There are multiple approaches to achieving a flexible power system, however the following are the most crucial:

- energy management;
- energy storage.

When compared to electrical sources and loads, ESS is a component that has bidirectional power flows. ESS may function both as an electrical supply and a load. thanks to two-way power flows, which guarantees operational flexibility and balances electricity output and consumption in modern power systems for prosumers.

A summary of technologies for energy storage, including following factors:

- Electrical storage (ES), including superconducting coils and super capacitors;
- Mechanical storage (MS), which includes flywheels, compressed air, and pump-accumulation hydropower plants;
- Electrochemical storage (ECS), which includes both immediate and secondary batteries;
- Solar fuel thermochemical storage (TCS);

- Fuel cells for chemical storage (CHS);
- Thermal storage (TS), which includes both high-temperature energy tanks and low-temperature energy storage.

Figure 5 provides a thorough summary and breakdown of energy storage technology. The advanced power system can also make use of mechanical technologies, which were mostly employed in the conventional power system. Other technologies could be employed in the advanced power system, particularly EV batteries with sizable battery capacities and the ability to charge and discharge, as well as stationary battery storage. Optimal ESS sizing and allocation are particularly important because of reduced grid losses, efficient power flows, and initial investment during construction. Nevertheless, this study did not look at optimal allocation and scaling techniques.

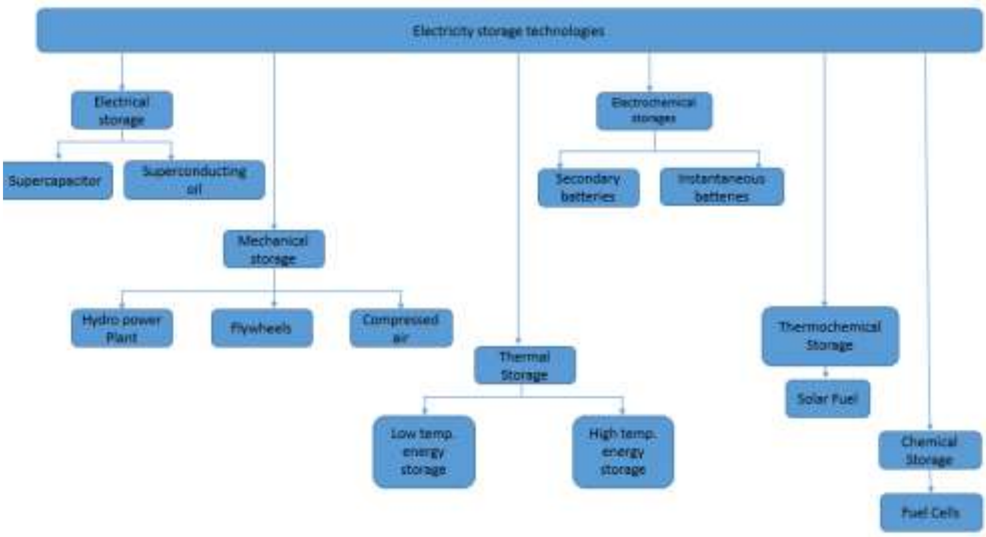

Figure 5: Overview and division of electricity storage technologies.

The most commonly used ESS in micro grids are electrical ESS (ultra capacitors), chemical ESS (fuel cells), and electrochemical ESS (secondary batteries). The two electrochemical ESS types that are most technologically advanced are lithium-ion and lead-acid batteries. Even though lead-acid batteries are the most widely used kind of energy storage because they are inexpensive and simple to recycle, they have the drawback of having capacity that is dependent on lead usage, energy density, and discharge depth and power. Conversely, lithium-ion batteries, whose sales doubled between 2013 and 2018, are the battery technology with the quickest rate of growth. The remainder is in stationary battery storage, with the majority being put in EVs and consumer electronics. The main characteristics of lithium-ion batteries are their high energy density, high efficiency, high discharge power, and extended battery life cycle. Nevertheless, because of their strong temperature sensitivity, they lack safety safeguards. Table 1 provides a summary of the scientific publications that the authors have used in relation to energy storage technologies and EVs or PHEVs.

4.2. Estimating Input Parameters for Prosumer Optimization Issues:

In the optimization process, which is conducted for a discretized future period (a scheduling horizon), one operating point of the optimization problem is represented by a discrete step (an optimization time step) If the input data for prediction is not accurately forecasted, the optimality of the optimization results is questioned because the optimization process depends on the value of data expected in the future. Based on the aforementioned, it is imperative to guarantee input data accuracy in order to get the best possible outcome for resource allocation in the future. This demonstrates robustness, or resilience to uncertainty, one of the characteristics of the EMS. If we look at the profiles of energy generation and consumption (particularly from RES), we can say that they depend on a number of frequently surprising factors. Consumer characteristics (households, business sector, industry), weather (outdoor temperature, wind speed, air pressure, humidity), user habits (departure/arrival patterns, shifts, working hours), the geographic size of the facility whose consumption is monitored (distribution area, feeder, neighbourhood, street, building, household), the time of day, the type of day (working day, weekend, holiday), and the day of the week, month, and year are some of the factors influencing electricity consumption.. The forecasting procedure is further complicated by the fact that many other unpredictable Meteorological components that impact the RES producing profile also influence meteorological features.

4.3. Optimization Framework with Prosumer EMS Optimization Issues:

There are many different points of view while modelling, according to an examination of the scientific literature. Using approximations, some points of view are prioritized while others are disregarded or only partially considered. Different approaches in the scientific literature can be attributed to the intricacy of EMS modelling. To provide a thorough understanding of the optimization framework areas and optimization issue properties utilized in the EMS, The following points of view will be considered:

- optimization framework;
- optimization method;
- objective function and constraints.

A thorough summary and categorization of optimization frameworks, optimization techniques, objective functions, and constraints of optimization issues used in the scientific literature are provided in Figure 6. A thorough summary of the research articles on optimization frameworks and the characteristics of optimization problems applied to consumer EMS is provided below.

Optimization Framework

There are two types of optimization frameworks: online and offline (Figure 8). The majority of EMS employ offline optimization, which involves only one optimization run—that is, prior to the start of the observed scheduling horizon. Online optimization entails running the optimization procedure at each time interval or whenever fresh input data predictions become available. The EMS is more resilient (adaptable) to uncertainty when it is optimized online. In the scientific literature, the rolling horizon strategy (RHS), which is frequently employed in model predictive control (MPC) to reduce the influence of uncertain parameters, is one of the most widely utilized tactics that applies online optimization. MPC is utilized for discrete control, meaning that during the one-time step, the control quantity levels remain constant.

Optimization Methods

Figure 6 illustrates how a survey of the scientific literature distinguishes between two main categories of optimization techniques deterministic and stochastic that are applied in the formulation of optimization issues. All of the input parameters for the optimization problem are thought to be known with some degree of accuracy in the deterministic approach. A stochastic programming approach is most commonly utilized in the scientific literature to describe such optimization problems, even though a stochastic approach incorporates the notion of probability. The strategies employed to forecast the input parameters of optimization problems largely determine the methodology that is chosen. Using probability density functions, stochastic techniques produce an arbitrary number of potential outcomes based on past data, which are then used to optimization problems.

Objective Functions and Constraints

Figure 6 shows the various numbers and kinds of optimization objectives found in a thorough examination of the prosumer EMS and a review of the scientific literature. Papers with a single objective function are typically found using this method, but examples with multiple goal functions are less common. Regarding the optimization goals that need to be met, they can be divided as follows:

- economic objective;
- technical objective;
- a combination of technical and economic objective;
- a combination of environmental and economic objective;
- a combination of all three objectives, i.e., economic, technical and environmental.

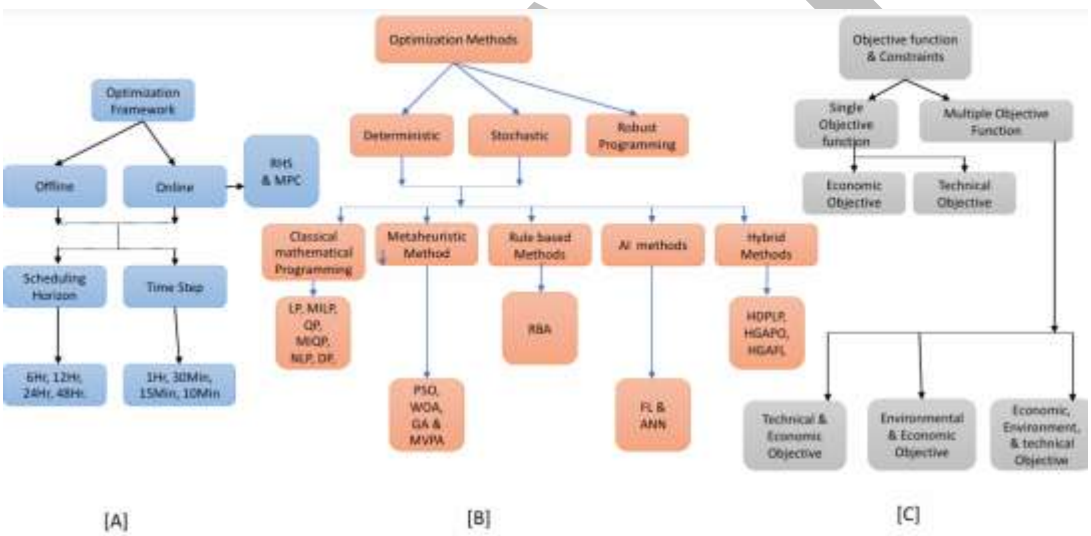

Figure 6: Overview of optimization frameworks, optimization methods, objective functions and constrains of optimization problems.

Different numbers and kinds of optimization objectives are displayed in Figure 6. The constraints in optimization issues are determined by the operating aspects and modelled elements, and the optimization method largely determines the constraints' shape. The most prevalent limitations, while taking into account prosumer components, are those related to the physical components. But in the case of mathematical programming techniques, in addition to physical limitations, the prosumer's power balance must also be defined as a constraint.

5. An Overview of the Prosumer Market Environment

The market component is given a lot of thought when considering more RES integration. In the markets for electricity and auxiliary services, the market element monitors prosumer profit maximization and/or cost reduction. The scientific literature revealed a number of mechanisms that prosumers use to participate in the electricity market, including intraday and day-ahead markets, a (local) flexibility market, multilevel tariffs, Peer to Peer (P2P) combined with some new distributive technologies like Blockchain), and additional DRP participation. Billing schemes for electricity are mainly established per unit of electricity exchanged, whether the energy is sent to the grid or imported from it. Thus, the objective function of the optimization issue frequently includes this profit or cost. Multi-tariff power billing systems are regarded as DRP by authors in the scientific literature, particularly for prosumers. DRPs are actions done by system operators or aggregators in reaction to a shortage of energy that will soon be available to customers. With a variety of initiatives, these approaches seek to affect end consumers' electricity consumption. From the perspective of the system operator, consumers are superior than traditional end users with controllable loads because of their operational flexibility, which can be triggered by ESS, controlled loads, and controlled sources.

Using time-of-use (TOU) or dynamic pricing, commonly referred to as RTP, the majority of studies incorporate the microgrid into the retail market as an end-user. One illustration of a price based on DRP is this power billing system. Examples of multi-tariff systems include those with a set price over time (one tariff), three-tariff, four-tariff, and seven-tariff systems. The majority of microgrid EMS models dual-tariff systems. Compared to multi-tariff systems, microgrid EMS with dynamic prices exhibit more frequent price adjustments. The present demand for electricity in the electric power system is taken into account while modelling prices. Prices are high when demand is high and vice versa. The same price is charged in the case of the microgrid EMS that uses multi-tariff systems, regardless of whether energy is being exported to or imported from the grid. The price for buying power and the price for selling electricity to the grid are two distinct costs that are typically present in practice. There are examples that use different pricing for importing and exporting power from and to the grid. This is particularly relevant for prosumers who have an integrated system for generating electricity from renewable energy sources that is connected behind the meter. Because the cost of energy purchased from the grid is higher than the cost of energy sent to the grid, it is also crucial to remember that in reality, the retail market is typically encouraged to consume electricity generated by prosumers. A microgrid with the power grid is an example of a detailed cost system of exchanged energy where the price is determined by a number of tariff components. This market environment's implementation is mostly determined by the laws that specify the minimum installed power (microgrid size) needed to take part in these types of energy markets. From the aforementioned, it is clear that involvement in the wholesale power market has been thoroughly studied and is effective in real-world scenarios. forms of the market for electricity.

6. Future Scope

There is potential for improvement in a number of areas based on this review paper's contributions.

- Optimization issues insufficiently detailed EV models that forecast usage trends and cover various forms of energy management throughout charging and discharging cycles.
- In most cases, power converters that are frequently excluded from optimization models are interfaced with EVs, PV systems, and ESS.
- For comprehensive battery models, the charging and discharging power must be taken into account. This power varies over the battery's range and is mostly determined by the battery's charge level.
- Optimisation models rarely employ precise prediction techniques when receiving input data, such as market prices, load, and RES generation.
- Prosumers' involvement in emerging market processes, particularly in local market settings, and the need for more thorough DRP modelling must be addressed.
- In order to reduce the uncertainty around RES generation, load, and market pricing that affect the solution's optimality, optimization frameworks are crucial. The optimization time step must have a

higher temporal resolution due to the high volatility of RES generation and loads, particularly when operating in emerging electricity markets.

7. Conclusions

To find the best way to control prosumer power, the scientific community has seen a lot of research articles. This study explains the challenges associated with integrating RES into residential buildings, the need of maintaining effective energy management, and the need to increase power system flexibility. Several elements that comprise an EMS must be examined in order to demonstrate the prosumer EMS's current level of development. This paper offers a summary of the current body of research on the various types and components of prosumers, their organizational and control structures, input data prediction, optimization frameworks and techniques, objective functions and their limitations, and the market environment. However, this study does not address other topics like communication and security technology. Furthermore, an assessment of review papers revealed that these studies did not examine input data prediction and optimization frameworks, two areas that will only grow in importance in the future. Optimization frameworks are important because of the impact of RES generation and consumption, which alters energy market participation with greater temporal resolution as DRP and resilience to uncertainties. As a result, the authors' optimization frameworks are reviewed in detail in this study together with scientific publications. Furthermore, each component of the EMS's development as well as the areas that authors tend to overlook were the main topics of the scientific paper review. The authors create simpler optimization models without considering the functional interdependence of individual parameters, which they substitute with constant values, according to the findings of the review process. Each section of this report provides a detailed description of the gaps and areas for development, along with specific recommendations for further research.

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