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Investigation of Development of Micro Grid with Electric Vehicles to Manage Network Energy to Manage Costs

Sergushina Elena Sergeevna

Organization: National Research Ogarev Mordovia State University, 68, Bolshevitskaya Str., 430005, Republic of Mordovia, Saransk, Russia

Abstract

The increasing penetration of scattered energy sources in electricity distribution systems, on the one hand, and environmental and economic concerns on the other hand, has led to the emergence of a new concept called micro grid in modern power grids. In addition to the economic, technical and environmental benefits, optimal operation of the micro grid can increase the resilience of the power system, that is, its ability to predict and limit the effects of various events that can lead to the power outage of part of the network. Also, with the increase in the number of electric vehicles as an environmentally friendly transport system, it has been possible to use them as energy storage in micro grids; this can be exploited by their presence in micro grids to mitigate the negative effects of fluctuations in renewable energy sources as well as to supply part of the energy required by the micro grid in island operation. In this dissertation, a model is developed for developing a micro grid of Electric Vehicles. The purpose of the proposed problem is to minimize the total cost of operating the grid, including the cost of locally sourced production, the cost of purchasing energy from the main grid with a demand response plan.

Keywords
Electric Vehicle, Micro grid, Cost Management, Clean Energy

1. Introduction

Due to advances in technology, government incentives to use clean energy, and concerns about the high and rising price of fossil fuels, scattered energy sources have become a viable approach to producing clean, sustainable and clean local energy. This has led to the tendency to employ micro grids as a set of electric charges and various scattered energy sources. In recent years, much research has been done on micro grids power and their exploitation debate (Boglou et al., 2022; Zhang et al., 2018; Farsangi et al.,

***Corresponding author:** Sergushina Elena Sergeevna, Organization: National Research Ogarev Mordovia State University, 68, Bolshevitskaya str., 430005, Republic of Mordovia, Saransk, Russia

E-mail address: press@researchub.org

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2018; Vahedipour-Dahraie et al., 2018; Shams et al., 2018). In (Boglou et al., 2022) the microgrid economical program, note to the configuration of plug-in hybrid electric vehicles (PHEVs) is proposed and the impact of various charge patterns on microgrid performance was presented. In (Mehrjerdia and Hemmati, 2020) designed optimal charging ability for electric vehicle (EV) charging station. The charging facility is designed based on three levels fast, intermediate, and slow speeds. They found that fast charging energy is 30% more than the intermediate one and the normal mode needs up to 40% more energy than slow one.

In order to maximize the benefits of using distributed generation resources in a micro grid, it is necessary to optimize the use of the micro grid and to manage the consumption side to increase efficiency. On the other hand, by increasing pollutions, electric transport system plays a prominent role in advancement system. The development of systems like the EV proposes different chances for next systems. In (Crozier, 2020) investigated the economical analysis to the optimal performance of network by the bi-directional charges compared to uni-directional one. In addition to increasing system efficient and how they are operated, energy consumption and pollutions will be deduced in transportation systems. It has been discussed in (Marilyn, 2019) regarding the integrating the electricity and transportation industries to cover their disadvantages and improve their performance and efficiency in the coordinated system. In recent years, demand response has been extensively studied. The demand response has been investigated in various sources. In (Shafie-khah et al 2016), a model is provided to show the effects of various demand response systems on the operation performance of a PEV parking complex, utilizing random programming in both cost and incentive based demand response programs and the level of parking complex participation is optimized in any demand response system. It also addresses the uncertainties of the PEVs and the electricity market. In (Zhang et al., 2018), a robust two step optimization model is developed to solve the issue of guaranteed robustness against the uncertainties of reproducible distributed generation and demand response. A concurrent two-step micro grid strategy is proposed that adjusts one-day price-demand response and hourly distributed distribution output to maximize profit against system uncertainties.

In researches (Coelho et al., 2016; Xiong et al., 2018; Mortaz, 2017) the PVs were used as the energy storage for the Micro grid. In (Coelho et al., 2018), the power system scheduling of an intelligent Micro grid was analysed utilizing PVs and seeking to minimize batteries application. In (Farsangi, 2018), energy control strategy of a micro grid containing wind turbines, photovoltaic (PV) modules, combined heat and power, fuel cells, single power systems, heating units, electric transportation and thermal power system sources for the supply of electric and heat is provided. To achieve better demand-side management, cost-based and incentive-based demand response programs (DRPs) were employed and their effects on reducing the costs of operating a micro grid in network and island modes are investigated. Also, uncertainties in cost, load, wind speed and solar radiation were considered to obtain real results. By dividing the probability distribution functions for per uncertain factor, a set of scenarios is developed.

In (Vahedipour-Dahraie, et al., 2018), a risk-constrained random structure is developed to improve the profitability of a micro grid operator with the uncertainties of renewables, load demand and power prices. In the developed approach, the reconciliation between the maximum expected profit of the beneficiary and the low profit risk in the undesirable systems is modeled utilizing the Conditional Value at Risk (CVaR) approach. Impact of consumer participation on Demand Response (DR) programs and their emergency load loss for various amounts of lost load (VOLL) are explored based on requested operating profit, CVaR, demanded power and scheduled micro grid reserves. In (Shams et al., 2018), a two-step random optimization is conducted for short-term performance of micro grids with multi-energy carrier network to determine programmed energy and reserve capability. The problem is determined as an integer linear program. The cost function is to minimize the demanded operating price in the short run. By introducing scenarios with relevant probabilities, uncertainties in renewable generation like the wind and solar photovoltaic generation, and electric and thermal demand are considered. In addition, the efficiency of requested response programs to deduce operating costs and amend security factors is measured. In (Soares et al., 2017), a new random approach with multi uncertainty resources containing load demand variability, PV and wind alternation frequency, location and random demand of Electric Vehicle and market price is introduced. The developed approach helps in minimizing the expected operating cost of an energy collector according to random programming. A case study showed that DR reduces the effect of uncertainties. In (Zakariazadeh et al., 2014), using distributed contingency planning, intelligent distribution system scheduling is planned and subscribers participate in energy and reservation planning. A demand response DRP provider combines load reductions to contribute to small and medium loads in the demand response program. In (Khemakhem et al., 2017) points out the role of demand response DR in power grid smarting. The peak hours of demand can also be changed to off-peak hours by optimizing the performance strategy by setting a dynamic and varied price in the energy management system. In this regard, optimal production planning is based on pricing strategy.

2. Electric Transportation

By progress in the transportation system, shortage of the fossil fuels and their environmental pollution problems, the application of the clean energy sources in the transportation system and especially vehicle such as PHEV and EV is developing rapidly. The EV vehicles performance in the high speeds and their charging is one of the challenging issues in the EV development (Salehpour and Moghaddas Tafreshi, 2020). In (Ghahramani et al., 2018), pure electric vehicle performance for various charging and discharging strategies have been investigated to enhance the optimal performance in various condition. The objective of their research in the charging strategy is to control energy distribution in mechanical parts to enhance a smooth power variation smoothly over a one day trip. In (Aliasghari et al., 2018), an optimal robust technique is used to plan short-term operation of the distribution network in the presence of uncertainty in the electricity market price. The effect of EV parking as an energy storage technology on the purpose function of the distribution system is discussed. In (Karfopoulos and Hatziargyriou, 2016), renewable energy sources according to a micro grid (RMG) is proposed. The issues of optimal energy management of RMGs with the presence of PEVs are discussed. The goal of the RMG owner is to make a minimum cost by generating energy with its local generators and exchanging energy with the electricity market. In addition, RMG can motivate PEV owners to participate in a Response Plan (DR) as a flexible burden. This can be beneficial to owners of both PEVs and RMGs. The uncertainties in the scenario-based framework are modeled. In (Sadati et al., 2018), a concurrent EV distribution management that extracts the bidirectional power distribution potential between the main network and the EV according to short-term forecasts of network request and RES generation, developed charge control, EV demand over They prioritize the clock with RES surplus and take advantage of the V2G capability to minimize system variance. In (Choi et al., 2018), an intelligent distribution system operation planning that evaluates renewable energy sources along with electric vehicle parking lots with demand response programs in place. Also considered are the uncertainties of RER and PLs and a proper charge/discharge planning of EVs. Price and incentive based request responses are employed for operational planning. In (Mohamed et al., 2014), to accommodate the uncertainties of renewable energy sources, loads, market price signals, and arrival times of the Electric Vehicle in the micro grids operation model, a micro grid based on a robust optimization approach is proposed. Specifically, it focuses on the uncertainties of the arrival and departure of the Electric Vehicle. A power distribution pattern is considered for a charging park. In (Rashidizadeh-Kermani et al., 2018), where the grid-connected charging park includes a photovoltaic system as well as hybrid EVs connected to electricity. An EV collector, as an agency between power producers and electric vehicle owners, participates in the Pool and Future market to cater to the needs of the electric vehicle. The problem of optimal decision-making of an automobile picker has been addressed in the medium term under uncertain conditions (Honarmand et al., 2016). The classical longitudinal dynamics equation of the vehicle is used to obtain the required average longitudinal force. This equation, despite its simplicity, is a precise way of describing the straight-line motion of a vehicle.

$$Ft = mgCr + \frac{1}{2}\rho CAV^2 + ma + mg\sin\alpha \quad (1)$$

In equation (1), the first item represents the force needed to deal with the rolling resistance of the wheels, which is independent of vehicle speed. The second item represents the aerodynamic force that the vehicle must deal with at a fixed speed. This force is proportional to the square of the vehicle speed. Air resistance is low at low speeds whilst increases rapidly with increasing speed. The third sentence represents the inertial force caused by the acceleration of the vehicle, which is zero under constant speed conditions.

$$Ftractive = Fa + Faerodynam + Fascend + Frolling \quad (2)$$

$$Fa = (vehicle\_mass + caro\_mass) \times (V - Vpre) / \Delta t \quad (3)$$

$$Fascend = \sin(\arctan(grade)) \times current\_veh\_mass \times g \quad (4)$$

$$Faerodynamic = \frac{(Vavrege)^2 \times Fa \times Cd \times \rho}{2} \quad (5)$$

$$Frolling = [wh\_1st\_rrc + Vave \times wh\_2nd\_rrc] \times (\cos(\arctan(grade) \times current\_vehicle\_mass \times g) \quad (6)$$

The EV with the status of the state of the charge (SOC) and the required power, based on the longitudinal dynamic force can join to the network to regulate its power.

3. Investigation of Micro Grid Structure

3.1. Micro Grid

The power micro grid is part of the distribution grid and has a set of distributed energy sources and loads, both electric and thermal that can operate in either the main or island mode. The micro grid connects to the main grid via a substation by a transformer, called a common connection point, and serves a variety of loads such as: domestic, industrial, commercial, and so on. Although small standalone grids have been around for a long time, the concept of micro grid was first introduced as a solution to maximize the presence of distributed energy sources in the power grid and utilize their benefits to increase efficiency. The environmental and economic benefits of the micro grid and consequently the expansion of the micro grids are closely related to their energy management, intelligent and optimal control. The primary purpose of a micro grid energy management system is to deliver high reliability electrical power to the consumer and optimize power generation to predetermined targets. An energy management program is performed by a central micro grid controller, local distributed controller, or a combination of the two above. At present, the approach of using local controllers has attracted more attention, leading to the emergence of different hierarchical control strategies. In this strategy, the local controllers are highly intelligent and do not need to communicate with the central controller for some of their decisions. An energy management program must determine the optimal power point with respect to all the constraints of the problem so that power consumption can be appropriately distributed across all generating sources and the micro grid will remain stable during disturbances. Therefore, proper utilization of the micro grid according to the stated objectives is the main task of the energy management program (Azadfar, 2015; Gao and Guo, 2019; Bahmani-Firouzi and Azizipanah-Abarghooee, 2014).

3.2. Micro Grid Structure

The micro grid is usually connected to the main grid by a distribution substation via a common connection point and includes a variety of distributed generation sources, energy storage systems and electrical and thermal loads. Figure 1 shows a micro grid with its usual components. The micro grid usually operates in the grid-connected state, but is expected to be able to independently feed its critical vital loads independently of the grid and remain voltage and frequency stable. Therefore, the micro grid can be isolated from the main grid when errors occur and operate in island-independent mode. For the network user, the micro grid is a controllable system with which it can exchange two-way power. One of the essential features of a micro grid that distinguishes it from a set of distributed energy sources that are not managed is the island's micro grid capability. This unique feature of the micro grid allows the micro grid to be disconnected when the power quality of the main grid is not satisfactory. For this reason, micro grid consumers generally have higher quality electricity (Aldosary, 2021).

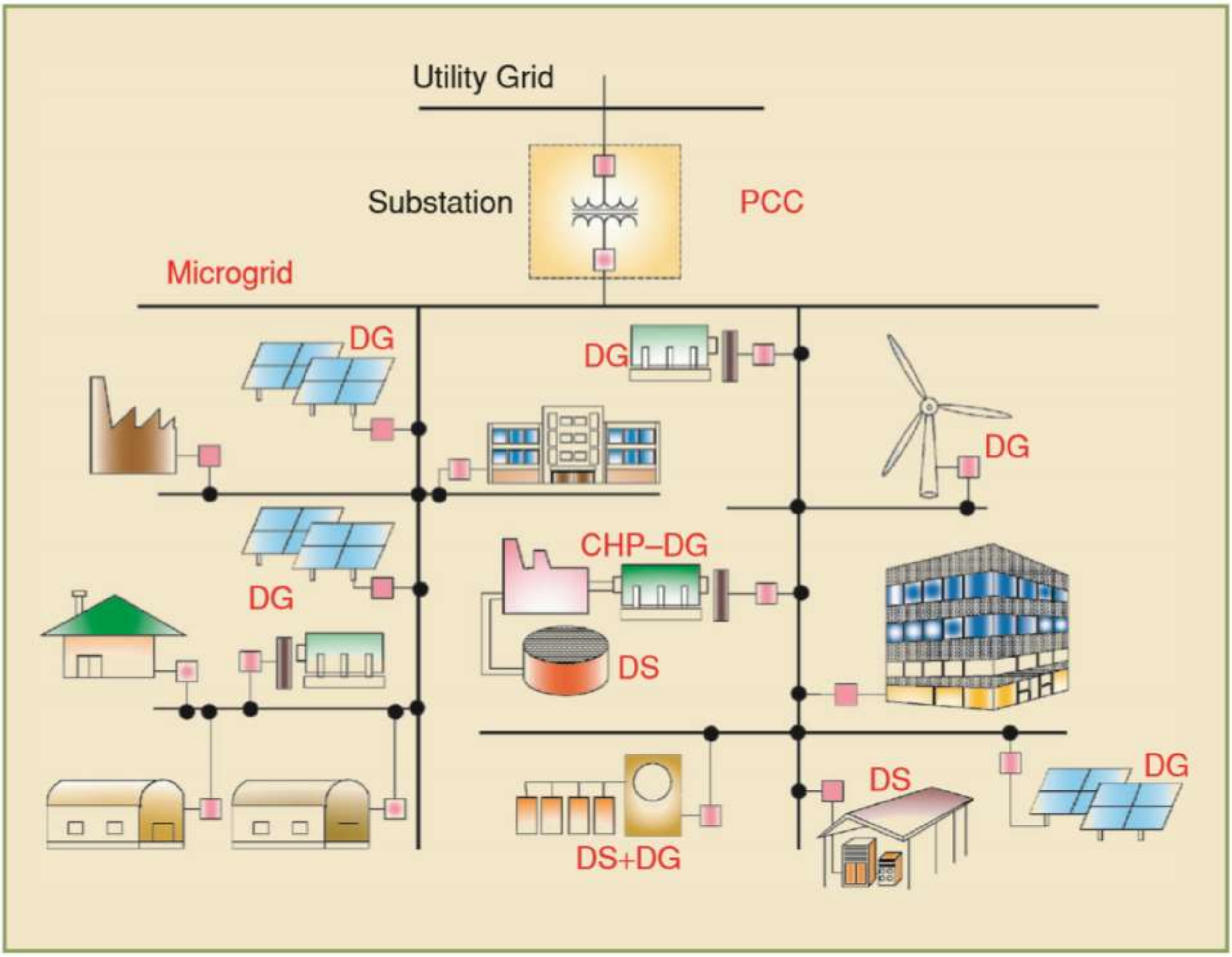

Figure 1: A typical micro grid structure consisting of scattered loads and generating units

Depending on the type and amount of distributed power sources, load characteristics, power quality constraints and market strategies, micro grid management and control strategies can be different from traditional power systems, and the most important reasons for this are:

- Dynamic and steady state characteristics of distributed generation sources with power electronics converter are very different from traditional synchronous generators.
- In the micro grid there is always a great deal of unbalance due to single phase loads.
- A significant portion of the micro grid power supply is of uncontrolled type. For example, the electrical power of a wind turbine or solar cell is completely affected by weather conditions and is highly uncertain.
- Long-term or short-term storage resources can play an important role in controlling and operating the micro grid.
- Economic issues require that the micro grid occasionally cut or plug some energy sources or loads, while traditional systems do not.
- The micro grid is usually responsible for generating heat in addition to generating electricity.

The main components of the micro grid are distributed energy sources including distributed generation (fuel cell, photovoltaic system, wind turbines, micro turbines, CHP, etc.), distributed storage (batteries, flywheels, super capacitors, compressed air storage) and Electrical and thermal loads, including controllable loads and critical loads

3.3. Role of Electric Vehicle in Networking

With increasing the global emissions, electric transportation plays a prominent role in sustainable development. For this purpose, EVs and demand response have inevitable effects on the next intelligent grids. Therefore, the integration of PEVs into the grid is a main factor in achieving sustainable energy process (Boglou et al., 2022). EVs, as a new emerging electric charge and a fundamental technique to smart grid, have gained more attention worldwide and are stimulated as a next way to energy management problems due to their properties and storage power emerged (Honarmand et al., 2022). It is anticipated that the using of renewable DER and EV techniques will fundamentally improve the requested profile of energy systems and impacts on the way distribution networks are managed and operated (Bahmani-Firouzi and Azizipanah-Abarghooee, 2014). The conventional power grid faces major challenges due to increased demand and aging infrastructure. From economical concerns, it is not reasonable to increase production capability indefinitely to meet demand. So the smart grid has emerged to increase the energy grid's tolerance for future potential demand, namely Electric Vehicle Charging (EVs), and alternating renewables, wind and solar energy. The smart grid make it possible for the active role of users through Demand Response (DR) that take an active participation in load planning. With the rapid usage of EVs, vehicles will undergo major changes in the upcoming. As EVs gradually infiltrate our daily lives, they will consume enormous amounts of electricity (Aldosary et al., 2021). Electric Vehicle may offer potential benefits for operating power systems, depending on their charging schedule (Coelho et al., 2018). EV can be used as the main source of the electricity application in the energy market to transfer the energy in the distribution system. For this purpose and application of the EVs in the energy markets, collectors and micro grids can act as an interface. One collector collects the demand for the EV fleet and on the other hand buys electricity from the energy market. A micro grid can also act as a collector and integrate EVs into the system. As is obvious, the EV will become another important element of the future power system, as they can reduce emissions and fossil fuel shortage and limitations (Gao and Guo, 2019). The goal is to reduce emissions by optimally and efficiently utilizing vehicles as loads and energy storage in MG with RESs (Pal and Kumar, 2018). The Vehicle-to-Grid (V2G) systems relates to electrical power resource technology, which is capable of allowing two-way power distribution between an electric power grid and a car battery (Nisar, 2017). Depending on the V2G competency, the charging status of a car storage can be increased or decreased depending on the demands and revenues of the network. The widespread use of EVs collected in (Chao-Tsung, 2019) is suggested to overcome the low EV storage capacity. EV parking lots are considered as the portable systems to collect EVs to obtain significant storage capacity from EVs' small battery capacity in the event of conditions.

3.4. Micro Grid Production Planning

The micro grid production program is an optimization problem, and this optimization problem involves two sub-problems in unit circuitry and economic distribution of load. Solving these issues in the micro grid varies according to its operating modes and the variety of energy sources available, as well as the uncertainty in the ability of renewable energy sources with the traditional power system. Micro grid generation resources are smaller than traditional power systems, which makes switching these resources easier and more flexible in production planning. Power exchange with the main grid, charging and unloading of storage resources is another feature of the micro grid. Due to the micro grid properties, all the issues should be considered in solving the production planning problem in order to achieve economical, safe and reliable operation of the power supply to the consumer. Common objective functions in micro grid production planning include: minimizing costs or maximizing operating income, maximizing use of renewable energy sources, minimizing environmental pollution and power received from the main grid.

3.5. Examination of types of Demand Response

In restructured energy pattern, a two-way market is simply an entity that supplies a process for the market to find buyer and seller, and carry out energy transactions based on their needs and wants. A market without active consumer input is still a one-way market. Figure (2) indicates how a one-way market with inactive and passive need related to get higher costs than a two-way market with needs and active production.

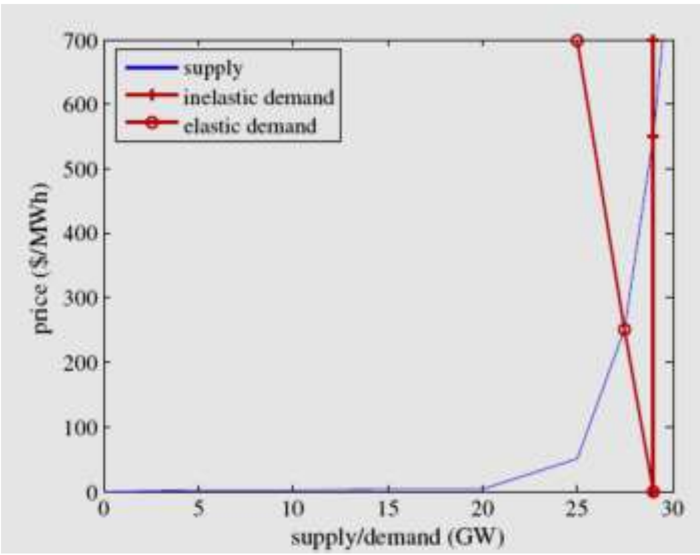

Figure 2: Influence of load on cost of electricity (in a bidirectional market)

In general, DR programs can be classified in two main groups:

- Time and Incentive category

Each of these groups contains several applications, as shown in Figure (3).

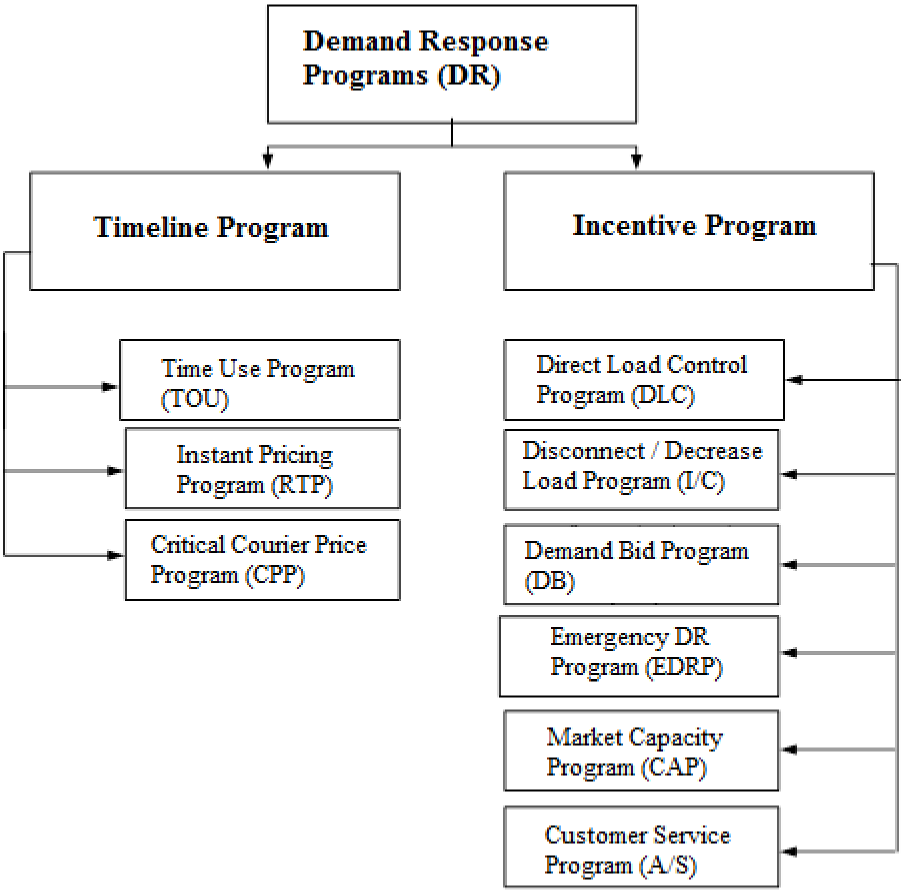

Figure 3: Classification of DR programs

4.6. Electric Vehicle (EV) Model

The concept of micro grid refers to distributed power sources, various loads and power resources that are linked to a medium voltage network in a geographical area (Shafie-khah et al., 2016). The micro grid can be used in both island and grid statues by improving the flexibility and reliability of power grids (Boglou et al., 2022). Electric Vehicle is predicted to have major part of the automotive markets in the coming years. Extra power needs for batteries charging may influence network utilization in terms of reliability and performance, when they coincide with peak system demand. This poses challenges for power system users to effectively integrate Electric Vehicle into power systems by discovering their capabilities, such as controllable loads. Modeling of electric vehicle operation is described in Equations (7-12) (Pal and Kumar, 2018).

$$SOC_{t,s}^{v} = SOC_{t-1,s}^{v} + \eta_v^{EV,ch} P_{v,t,s}^{EV,ch} - \frac{P_{v,t,s}^{EV,dis}}{\eta_v^{EV,dis}} - P_{v,t,s}^{EV} \tag{7}$$

$$SOC_{\min}^{v} \le SOC_{t,s}^{v} \le SOC_{\max}^{v} \tag{8}$$

$$P_{v,\min}^{EV,ch} \times U_{v,t}^{EV,ch} \le P_{v,t,s}^{EV,ch} \le P_{v,\max}^{EV,ch} \times U_{v,t}^{EV,ch} \tag{9}$$

$$P_{v,\min}^{EV,dis} \times U_{v,t}^{EV,dis} \le P_{v,t,s}^{EV,dis} \le P_{v,\max}^{EV,dis} \times U_{v,t}^{EV,dis} \tag{10}$$

$$P_{v,t}^{EV} = \Delta D_{v,t}^{EV} \beta_v \tag{11}$$

$$U_{v,t}^{EV,ch} + U_{v,t}^{EV,dis} \leq 1 \tag{12}$$

Equation (1) represents the power balance of the EV. As presented, the charging state of the EV ($SOC_{t,s}^{v}$) is assumed mode of dependent. $P_{v,t,s}^{EV,ch}$ and $P_{v,t,s}^{EV,dis}$ are the charging and discharging. It can be considered that the charge and discharge status of $U_{v,t}^{EV,ch}$ and $U_{v,t}^{EV,dis}$ are as the now - and - here variables, so the charge and discharge status cannot be dependent on the modes. The band rage capacity of the electric vehicle battery are met in relation to (2) and the maximum and minimum power and discharge of the Electric Vehicle are restricted to (3) - (4), respectively. In equation (5), the power consumption of the Electric Vehicle ($P_{v,t}^{EV}$) is determined using the linear equation with respect to the distance. Equation (6) represents the binary level of charge and discharge for EV parts. Figure 4, illustrates the performance of electric motor model in Advisor/Matlab, also for electric vehicle SOC variation for electric vehicle is presented in the figure 5. For a cycle with 8000 second, the battery SOC has been reduced to its lower limit 0.2 which import power to network as the EV.

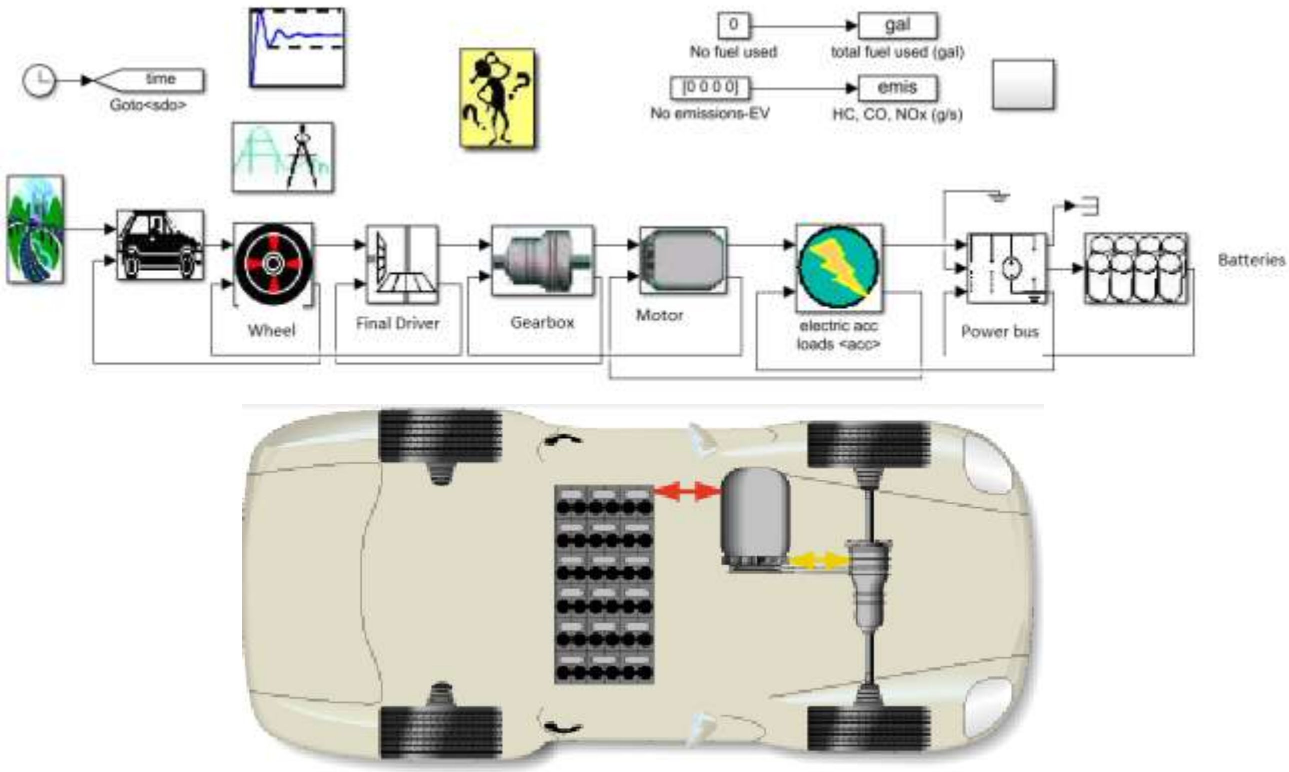

Figure 4: EV model in Simulink

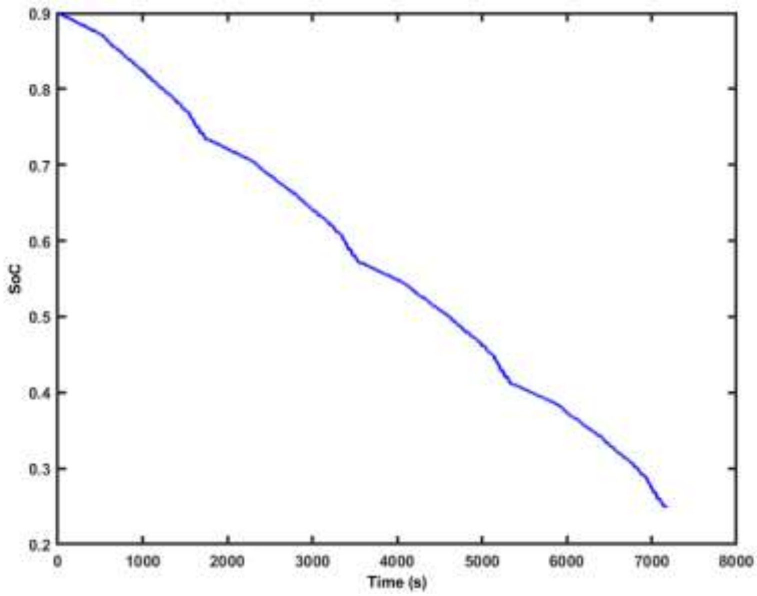

Figure 5: SOC variation

In order to investigate the effect of the electrify level on the performance of the vehicle, in Table 1, the fuel consumption and air pollution factor (based on the HC, Nox and Co) are compared in table 1 for various electricity power range from 0.1 up to all EV (1).

Table 1: Hybridization Effect

Hybridization		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
Fuel (mpg)		29.5	32.6	36.7	38.6	41.7	43.4	47.4	53.1	59.2	65.3
Pollution (gas/mile)	HC	0.94	0.98	0.83	0.71	0.57	0.50	0.36	0.25	0.17	0
	Nox	0.82	0.94	0.81	0.71	0.60	0.55	0.51	0.40	0.28	0
	Co	0.18	0.10	0.18	0.17	0.16	0.17	0.15	0.13	0.13	0

The reduction trend of vehicle mass, fuel consumption and emissions are observed by the degree of hybridization increases. Finally, to investigate the effect of the initial charge level on the performance of the hybrid at three levels of initial charge, 50%, 70% and 90% are considered for a conventional hybrid vehicle.

4. Conclusion

The presence of electric vehicles in a micro grid, taking into account the limitations of the Electric Vehicle night, in addition to being a consumer of electricity, can also be addressed in micro grids by discharging energy from their batteries. It is important to manage the amount and timing of battery charging and discharging, as mobile energy storage systems in micro grids. In addition to the main grid, the network uses distributed generation and storage systems to supply the energy needed by consumers. Electric Vehicle is one of the sources of electricity generation and consumption that can play an important role in network management by connecting to the electricity grid. This paper presents a review and planning analysis for the micro grid with Electric Vehicle and analyzes the use of load response program to overcome the challenges of network management.

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