Chapter 3

Future of Microgrids with Distributed Generation and Electric Vehicles

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http://dx.doi.org/10.5772/intechopen.68819

Abstract

This chapter examines the current energy scenario for microgrids over the world and discusses the challenges and opportunities due to the increasing penetration of distributed power generation systems and electric vehicles (EVs) into the microgrids. Wind power and solar power can be generated by wind turbines and photovoltaics, respectively, while these are intermittent in nature. EVs and hybrid EVs use a battery energy storage system and charging facilities while the latter also include an Internal Combustion Engine (ICE) to provide an extra energy source. The features of these systems in the context of microgrids are studied in detail, in terms of their components, efficiency, reliability, charging and discharging arrangements, active and reactive power control. The chapter provides a reference to the development of microgrid systems especially for developing countries.

Keywords: Batteries, Carbon Free Generation, Charging and Discharging, CO_2 Emissions, Electric Vehicles, Microgrid, Renewable Energy

1. Introduction

Currently, air pollution is a serious issue, especially in heavily populated cities, such as London, Paris, Beijing, and Tokyo. Approximately 25% of global CO_2 emissions are due to passenger road and air travel, and the transport of goods. In addition to CO_2, Sox and Nox are also generated. Although, cars and trucks are responsible for the bulk of these of emissions, about 75% worldwide emissions due to aviation and shipping are growing rapidly too, and the energy used in transport could double by 2050 [1]. The chart of projected overall CO_2 emissions by different countries is depicted as shown in **Figure 1** [2], and particularly CO_2 emissions by electric cars by different countries are shown in **Figure 2** [3, 4].

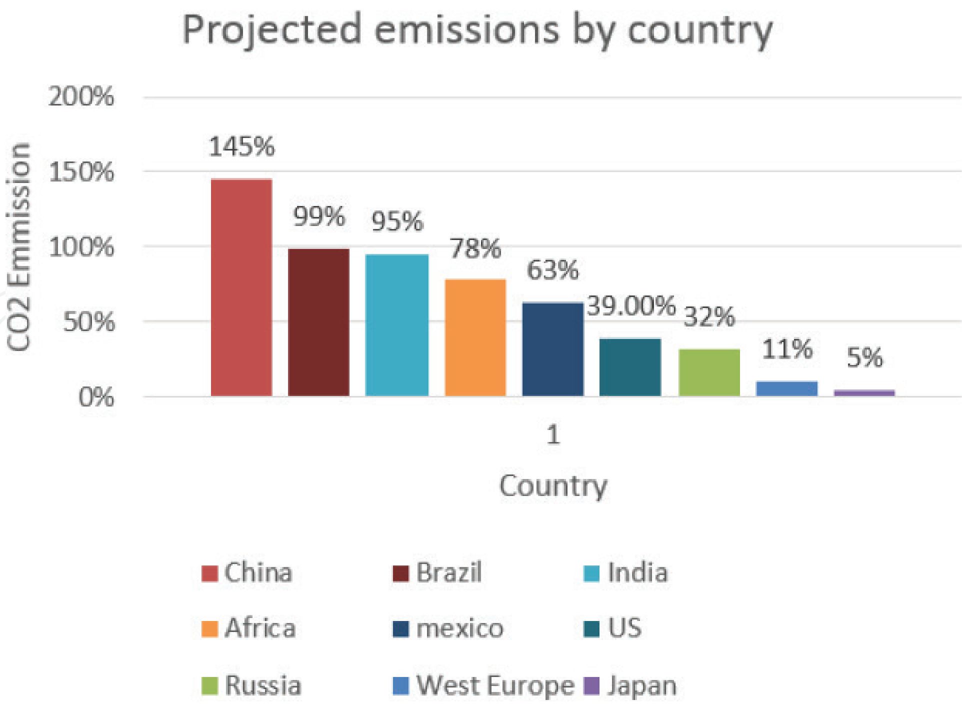

Figure 1. Projected emissions by country.

Therefore, CO_2 emissions need to be cut by approximately 50%. Priority should be given first to research technologies and practices that are mostly cost effective. Microgrid and E-propulsion systems have the capability to enable this; thus, bringing about a revolution in

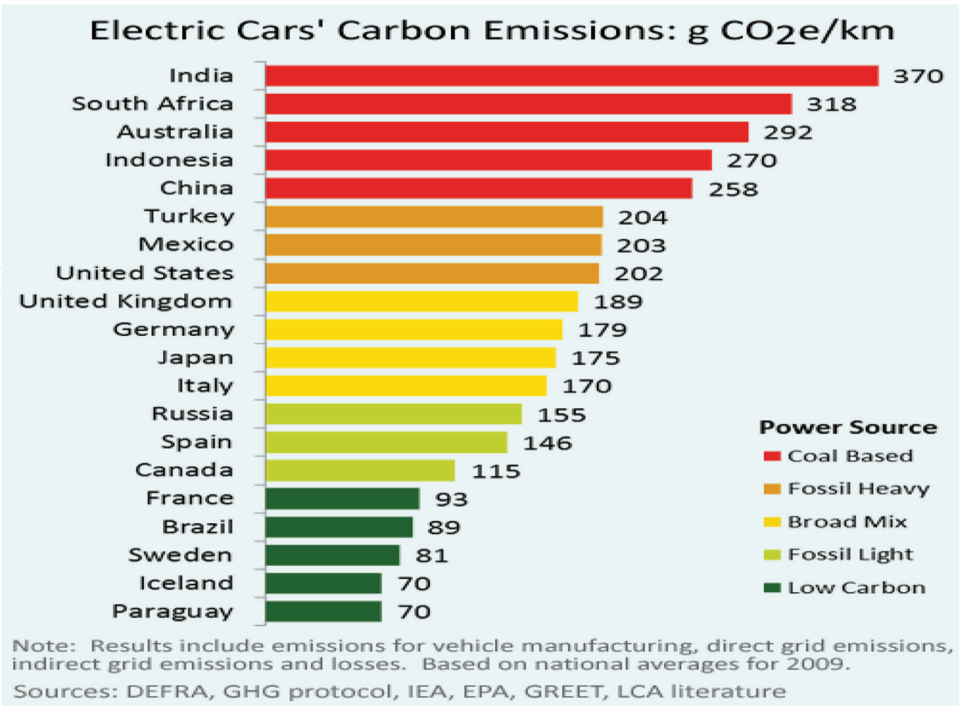

Figure 2. Electric cars' carbon emissions.

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low CO_2 emission technology [5]. Thus, for the developing zero-emission, electric vehicles have become the key logical and scientific research project in many countries around the world in the twenty-first century [6]. The dynamism and energy saving motor drive technology have developed one of the key points to electrical vehicles commercialization [7].

As EVs are suitable, progressively more essential not only because they decrease noise and greenhouse gases but also they are able to diminish the dependency of carrying oil, as the power is generated from fuels other than oil [8]. Electric vehicles can contribute to decrease carbon emissions. The zero release of CO_2 production necessitates that the EV energy should be produced from alternate sources like nonfossil fuel, for example, nuclear and unconventional sources of energy. Actually, the most dangerous situation is that there is merely 40 years of oil supply is left [9, 10] with the rates of current usage. In fact, increasing inadequacy may bring the consequence in the huge amount of rises in price and ultimately the practice of continuous oil usage and extra fossil fuels will never be lavishly practicable, hence sources of oil might be well-maintained, as the procedure of consumption will decline. The production of oil can also be achieved from other fossil fuel sources such as coal [11]. Normally in this way, oil production is deliberated to be round about 10% more costlier.

This chapter provides a brief overview of the recent energy crisis in all over the world and the comparison between an electric vehicle and gasoline vehicle, and the methods by which driving range of electrical vehicle can be enhanced with the help of microgrid. The proposal which actually necessitates the development of microgrid technologies on the basis of different reasons and their implementation with respect to electrical vehicle and issues associated with the energy crisis is also given. The main purpose of this chapter is to lump together plug-in vehicles and electrical vehicles with microgrid.

1.1. Electrical energy scenario and background

The most complex and largest machine which has been ever built by the human brain is actually the electric grid. We found electricity 100 years ago. But still very much a dark planet, still a lot of places in the world there have not had an access of electricity in the last 100 years [12]. Even people living in some places do not know what electricity is [13]. So, just like many others, engineers and a group of some technical persons, if we could create an open source movement, an elaboration to build something and to start thinking about how would we electrify placed out there that governments have forgotten about. The first business should be to plan together and to find the ways to build the future. First of all, one block of location or something nearer and something that would benefit from what we are doing. So if we look at the statistics which is shown as below.

1.2. Energy poverty statistic

One in five people in this world do not have access to electricity today and it is approximately 1.2 billion people globally. If we start to look in depth that where are these people? Three of five in Africa, primarily in the rural population, have no access to electricity today [14]. If we further look at the statistics, where is the growth going to be? Where are all those new children going to be in the year 2100? The statistic of world's energy poverty is shown in **Figure 3**, and the statistic of Africa's energy poverty is shown in **Figure 4** [15].

It will be approximately 10 billion people in the year 2100 [16] and in Africa, it will be 3/2 billion people. Africa's land mass is three times bigger than the United States and Africa's population is 750 million people today and it is 4 times more [15]. The area is full of poverty and full of orphans because of HIV [17]. Now, if we try to figure out how can this community be upgraded? Let's see if we can create an open source collaborative approach to electrify this rural population, and there must be an impact on all of the community. Just for example as the first thing which is needed is an affordable and reachable electrical power, a nice thing in Africa. Everybody has cell phone and people mostly walk 5–10 miles to charge the mobile battery for their cell phone [18], so what if they could do that at home with the help of microgrid and in this way, business of microgrid will be growing. The second point is we have to be sustainable and have to keep the environment green. No greenhouse gases, no nitrous, no methane, and no carbon dioxide. So what do we have to do for alternative sources? We have lot of wind as well as lot of sunshine for photovoltaic (PV). Finally to reduce usage kerosene in homes. As kerosene is the primary source of cooking and lighting in the developing world. It is very dangerous and very polluting.

1.3. Electric vehicles

A vehicle that uses one or more electric motors or traction motors for propulsion.

As the worldwide economy originates to strain under the burden of increasing petroleum costs and environmental distresses, studies have encouraged the growth of numerous categories

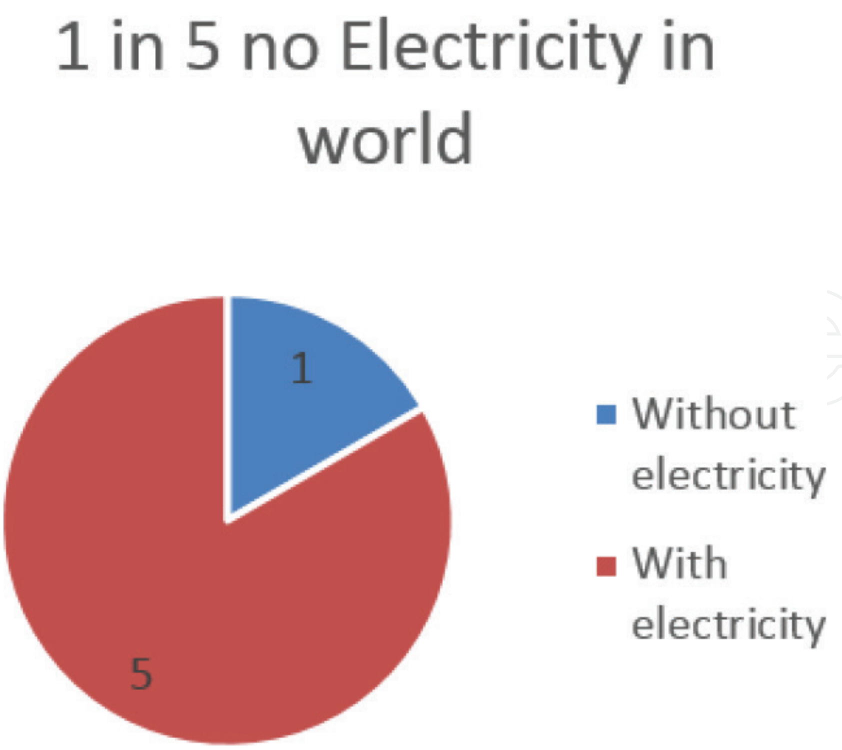

Figure 3. World's energy poverty density.

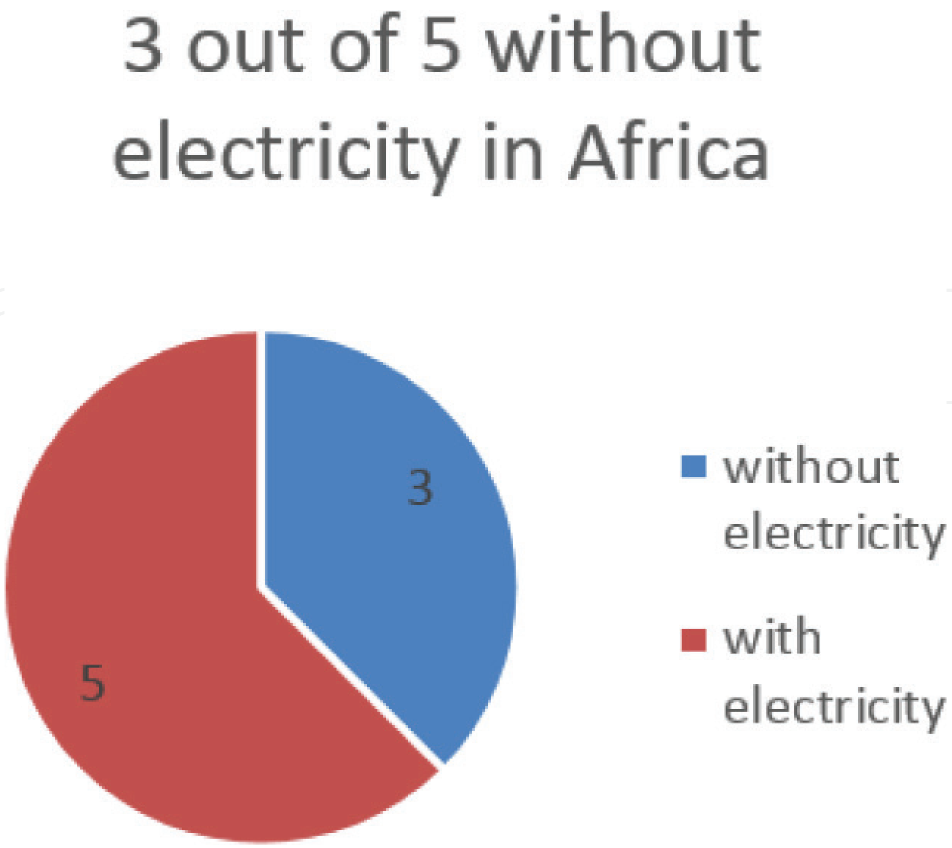

Figure 4. Africa's energy poverty density.

of clean energy transportation systems, for example, hybrid electric vehicles (HEVs), battery electric vehicles (BEVs), and plug-in hybrid electric vehicles (PHEVs).

Plug-in hybrid electric vehicles are already playing an important role in minimizing greenhouse gas emissions, as these emissions are very hazardous and are the main cause of global warming [19]. Therefore, electrical vehicle technology, electric vehicles (EV) and plug-in hybrid electrical vehicles (PHEVs), have gained the momentum in recent years and have become the focal point of research and development in finding suitable replacements for the internal combustion engine [8]. As internal combustion engine vehicles are being converted into EV, increasing amounts of oil will be saved. However, the energy for the innovative EVs will have to be generated in addition to the electricity used for surviving purposes [20]. Furthermore, there is also a need to upgrade the existing power grid if large number of EVs/HEVs are connected to it. To tackle this problem, a current trend is to develop microgrid [21]. This will not only necessitate a considerable enhancement in electricity generation, but also the microgrid distribution will have to be planned for [22]. The electric vehicles by Range Rover Evoque and Jaguar F type are shown in **Figures 5** and **6** [23–25].

Particularly, PHEVs obtain the most consideration because of combining electrical source and conventional engine. This kind of vehicle makes available the buyer a significant pure electrical choice and also an extended range, which is able to perform by means of a conventional internal combustion engine (ICE). The literature reveals that sales in electric cars have been

Figure 5. Range Rover Evoque electric vehicle.

tremendously increased in recent years. The UK growth in electric cars data taken by SMMT from 2011 to 2016 is shown in **Figure 7** [26], and the overall sales in electric cars are shown in **Table 1** [27].

Figure 6. Jaguar F type.

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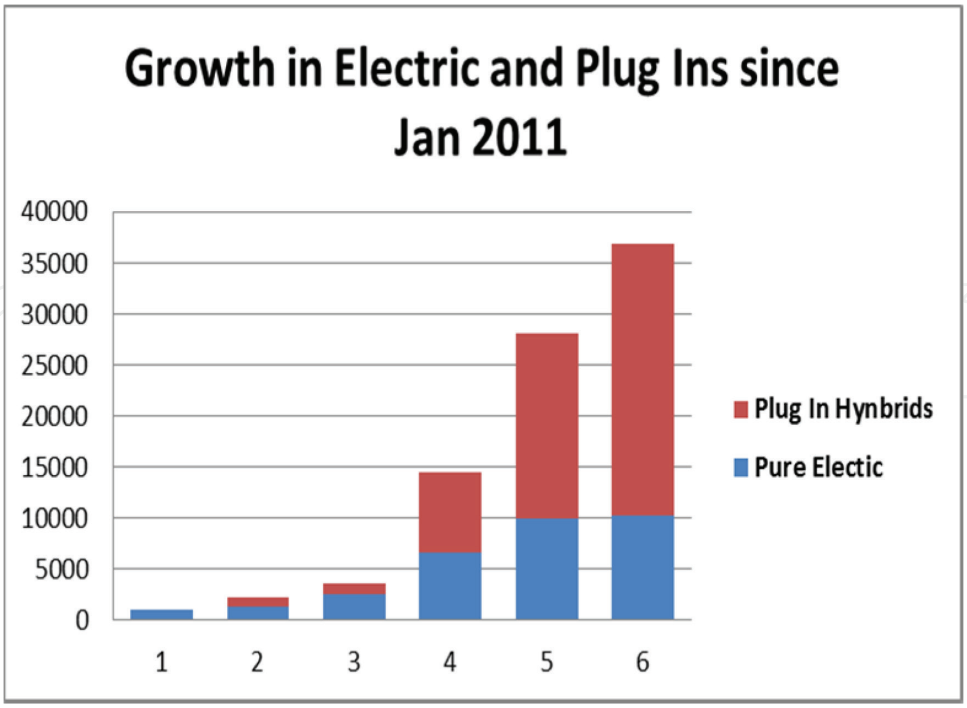

Figure 7. Growth in electric cars in UK.

Year	Number of electric cars on the road
2010	25,000
2011	80,000
2012	200,000
2013	405,000

Table 1. Electric car sale accelerates.

Due to above-rising trend in sales scenario of the electrical vehicle on the road, the demand of power is growing at an approximate rate of 100% per annum for the last 4–5 years and it is obviously anticipated that the growth in average demand over the upcoming decades will be bigger. This is an indication of load demand anxiety and stress on the distribution grid station in the years ahead, and much would be expected from electricity service provider so as to operate in such a way that it can satisfy customer needs and also enable it to stay in effective business.

The establishment of a rechargeable energy storage system (RESS) that has a provision of the output power during acceleration, proficiently use the regenerative energy to achieve a considerable cycle life is the serious aspect to be met by battery technologies.

1.4. Gasoline vs electric vehicles

The comparison between electric and gasoline vehicle is shown in **Table 2** [28].

Electric vehicle	Gasoline vehicle
Requires utility company for charging	Organization of petroleum exporting countries (OPEC)
200+/− mile range	300+ mile range
Zero emission	Huge greenhouse gases/pollution
Hours to charge	Minutes to refuel
2 cents per mile	12 cents + per mile

Table 2. Comparison between electric vs gasoline.

By considering **Table 2**, in contrast to gasoline/patrol vehicle, the electric vehicle has 6× lower cost for a 1-mile drive. However, its driving range is only 1/3 of gasoline vehicle per full charge. And this is the main drawback [29].

1.5. Improvement in driving range

The storage of electricity and resultant mass is shown in **Table 3**. We can enhance the range of driving by the accumulative capacity of the battery. But then, again at what expense? In order to have heavier and bigger battery, there is a need that it must have the greater energy density to be higher, so more costly battery/car hence lesser price charge of a storage battery is required. The trend of battery energy density is shown in **Figure 8** and the cost of electric vehicle battery storage to consumers is shown in **Figure 9** [30].

In **Figure 9**, from the year 2015 onwards, the improvement in rates is further delicate at 5% (as with the case of extraordinary technology battery). Satisfactory for electric vehicle to compete the worth and range of driving of gasoline vehicle, battery cost ($/kWh) necessities to drop by 4 times, which is unachievable even in 2035 [31].

1.6. Future of Batteries

From the above chart of cost of battery storage per kWh, we can conclude that even up to 2035, price of EV may not be able to match price of gasoline vehicle. Primarily due to cost of

Battery technology	Energy/Weight	Energy/Volume	Power/Weight	Relative	Self-discharge	Recharge time
	Watt h/KG	Watt h/L	Watt/kg	Cost	Rates	Hours
Lead acid	30–40	60–75	180	1	5%	8–16
Lithium/Ion	160	270	1800	4	10%	2–4
Li-Ion Polymer	130–200	300	2800	4	10%	2–4

Table 3. Storage of electricity and resultant mass.

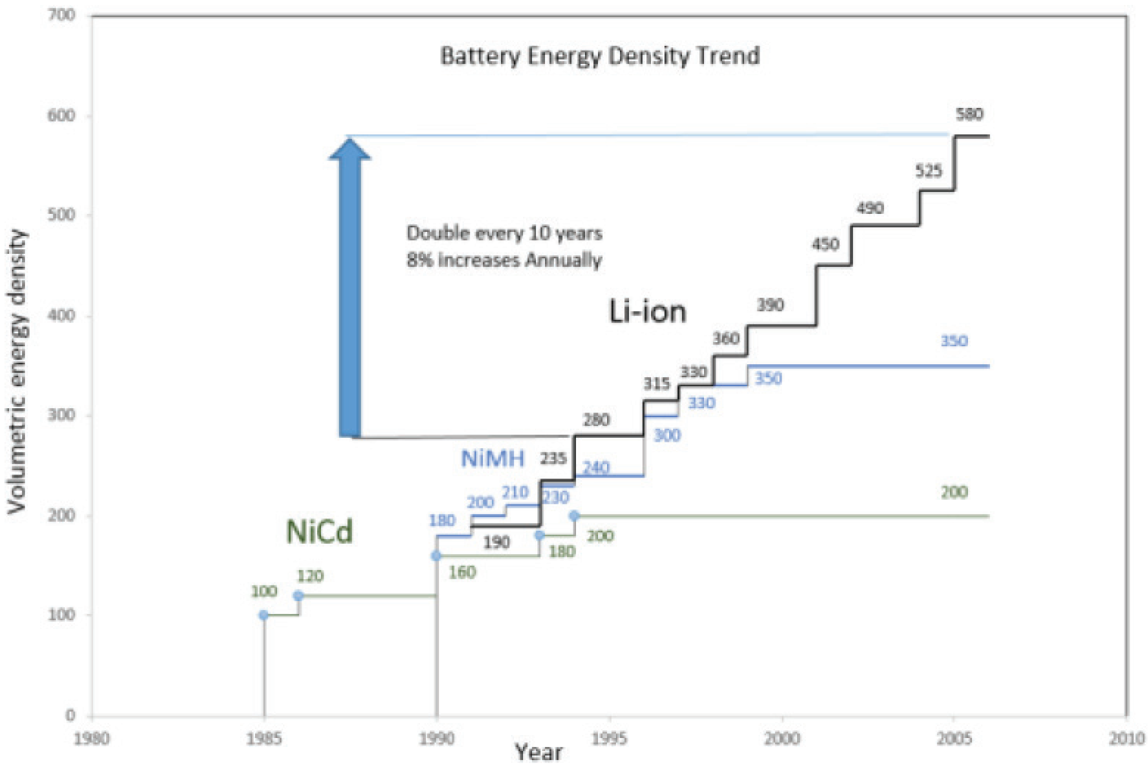

Figure 8. Energy density trend for battery.

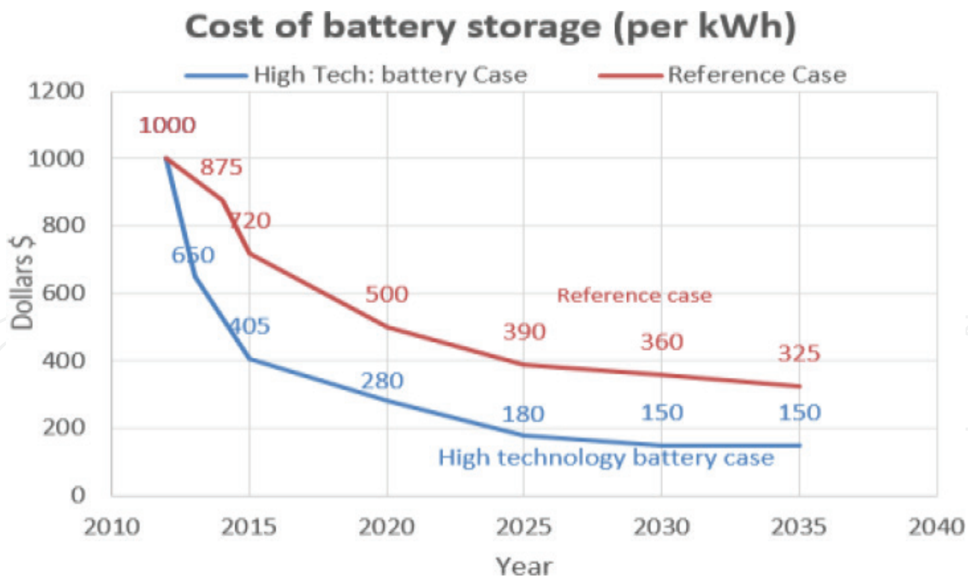

Figure 9. Cost of electric vehicle battery storage to consumers in two annual energy outlook (AEO).

battery only drop by 5% annually. Only in 2047, battery is capable to get closer with gasoline in terms of energy density. Therefore, other choices are needed to drive the penetration of EV to the consumer market.

1.7. Proposed solution

In order to cope with the battery issue, six solutions can be proposed as follows,

Community microgrid–sustainable

Feasibility of charging stations

Provide local residents access to affordable power

Reduced usage of kerosene for lighting

Future for charging stations

Sustainable greenhouse gas free environment

2. Introduction to microgrid

A microgrid is a small-scale power supply setup that is aimed to offer power for a small or private community. The definition of a small community could range from a distinctive housing estate, inaccessible or remote rural communities and societies such as universities or schools, to commercial areas, industrial, and business sites and trading estates or municipal regions. In fact, the Technical and economic viability of the distributed energy resource (DER) technologies for distribution voltage class applications has resulted in the development of the microgrid concept [32]. In other words, the microgrid is a small-scale power grid that is able to work independently or in combination with the area's central electrical grid. Whichever small-scale localized station with its own power resources, generation and loads and definable boundaries be nominated as a microgrid [33], or it is a cluster of interconnected loads and circulated energy assets surrounded by clearly defined electrical boundaries that act as a solitary well-regulated entity with respect to the grid [34, 35]. "The main important point is, it can attach and detach from the grid to allow it to operate in both grid-connected or island mode in a coordinated, controllable way" [36]. The microgrid can also be planned to meet its special needs [37, 38] such as,

Improve local reliability.

Decrease feeder losses.

Support indigenous voltages.

Offer improved efficiency through use waste heat.

Voltage sag adjustment or afford uninterruptible power supply functions.

Microgrids have a provision and flexibility of efficient electric grid by facilitating the integration of growing supplies of distributed energy resources such as renewables like solar and wind [39]. In addition, the practice of local sources of energy to assist local loads helps reduce energy losses in transmission and distribution, further increasing an efficiency of the electric

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delivery system, choices will have to be made whether electricity for transport will come from carbon-free generation or whether the standard combination of energy currently used will be followed to. An assessment of the amount of electrical energy which would be essential throughout the world. If power for transportation from fossil fuels is to be swapped, extensive investment in new methods of power for transport exist in nuclear or unconventional energy will be necessary; therefore, is fairly conceivable to generate electrical power used for transportation and further uses by approaches which should not cause carbon releases or which reduce any further fossil fuels [22]. Now, approximately all such procedures will comprise a mixture of nuclear power generation units and a choice of substitute energy resources. Solar energy from the sun is expected to be the principle substitute of energy [40]; nonetheless, the combination of solar with wind energy, tidal and underwater currents surrounded by others are about to feature intensely. The microgrid architecture and its applications are shown in **Figure 10** [39].

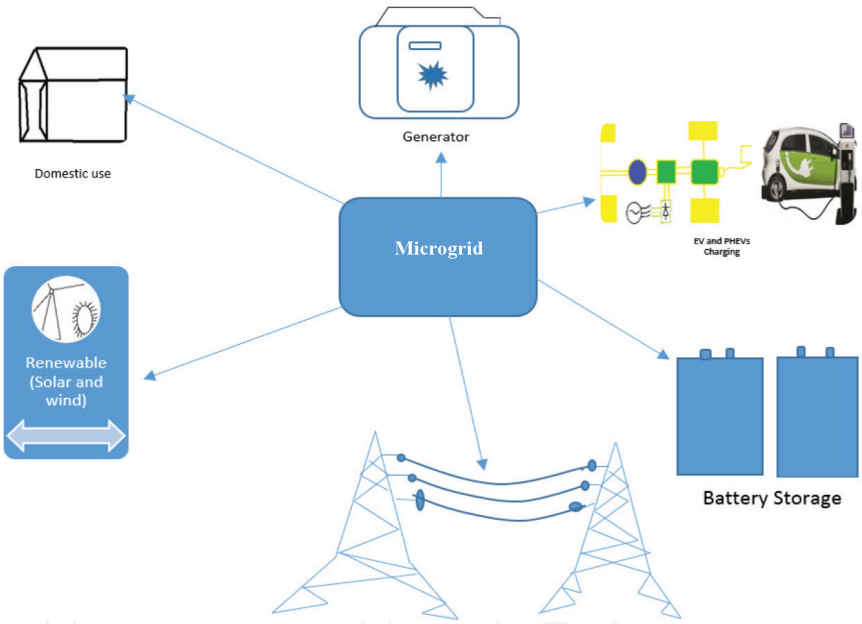

Figure 10. Microgrid architecture and applications.

2.1. Domestic Use

As depicted above, the applications of microgrid are very vast, which can be applied for domestic use, battery storage, electric vehicle charging, utility grid, and renewable energy generation. As most of the appliances are AC power, such as television set, air conditioner, washing machine, refrigerator, microwave oven, and with the implementation of microgrid technologies, these mentioned appliances can easily be operated and can decrease the impact on distribution grid station. Recently, DC power fans are also emerging, which consume very low electricity and have a better performance.

2.2. Industrial Use

With the bi-directional information and power flow provided by the microgrid, several novel planning is being promoted to expand and advance the energy usage in diverse settings. One such extension is the concept of microgrids in different industries such as oil and gas exploration industries. These kinds of industries are usually situated at site area where the actual reservoirs are discovered through different seismic surveys and central facility (Plant) is built for gas and oil processing. The actual place from where the oil and gas is explored is called wellhead and is located at far distance (40–100 km away) from the central facility and has no access of electricity, in order to control the process variable like pressure, temperature, flow, and level. There is a need for proper instrumentation for process flow lines and its control variables. So, there are potential benefits of using microgrid especially oil and gas industries which is shown in **Figure 11** [41, 42].

2.3. Benefits of Microgrids

The main benefits of microgrid are listed below.

A more suitable climate

Electric vehicle integration

Better public health

Lower electric bills for consumers growing revenues for utilities

Energy savings–direct DC charging

Renewable energy integration

Figure 11. Flow control valve, pressure gauges, and process flow lines.

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Improved control and monitoring

Improved system reliability

Facilitation of entrepreneurial opportunities

Energy storage systems

Wireless charging

2.4. Locations of microgrid

Residential and commercial buildings consume about 32% of the worldwide energy use, as they are liable for about 30% of the total end use energy-related radiations if the indirect upstream emissions are considered [43]. As the proper renewable energy generation, including photovoltaic arrays or wind turbines, is the main concern in the development of microgrid, in this connection parking facilities are the ideal locations available for systems linking electric vehicles with solar and wind energy sources. Thus, these tactics permit a high number of EVs to be charged at an office building, even with a limited number of charging points, due to the large standstill times [44]. The microgrid with a solar array and windmill is shown in **Figure 12** [45].

A microgrid that mixes renewable generation and vehicle energy storage offers many advantages such as (1) the security of energy, (2) savings in cost, and (3) reliability benefits. The charging stations will work as energy management portals, enabling unidirectional and bidirectional power flow with vehicle energy storage. In the world market 2013–2020, the

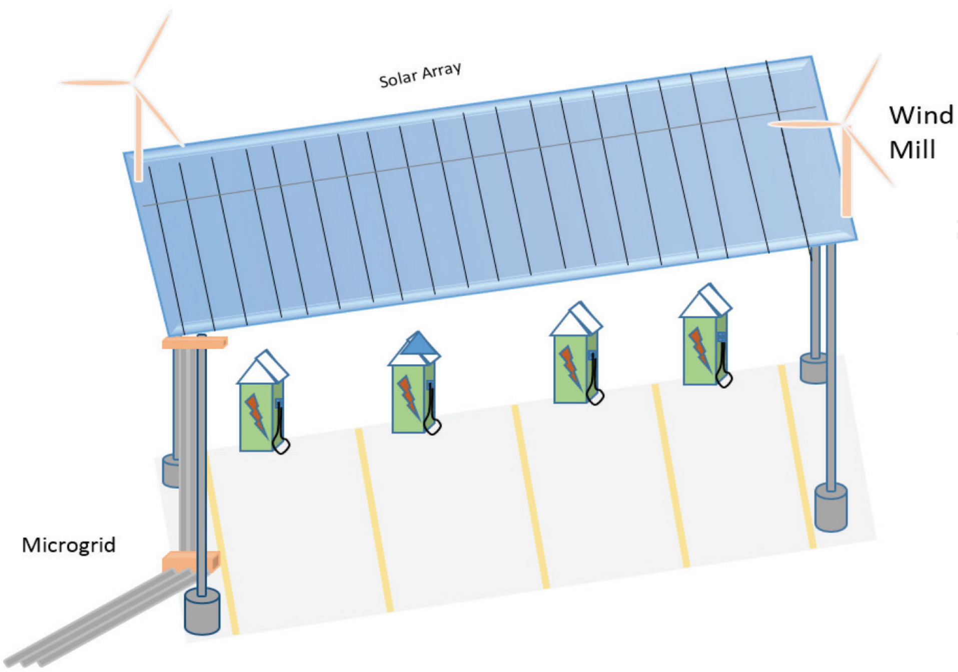

Figure 12. Microgrid with solar array and wind mill.

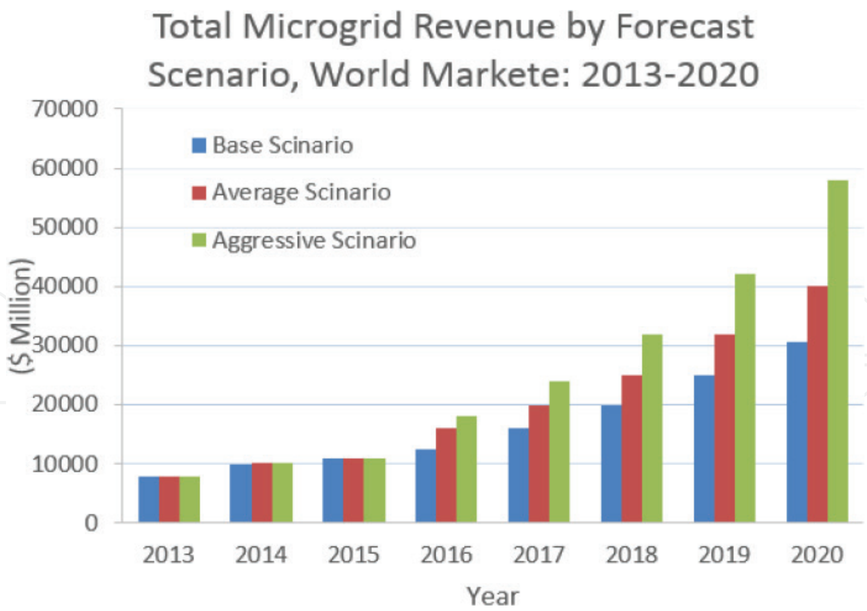

Figure 13. Microgrid revenue by forecast scenario, world market: 2013–2020 [38].

average scenario of microgrid revenue is ($40 billion) and from the aggressive forecast scenario, the revenue is approximately 58,000 $ million, from the world forecast scenario of microgrid revenue in the world market 2013–2020 is shown in **Figure 13** [46], and the charging standard and cost are shown in **Table 4** [47].

Table 4 shows the types of chargers according to different levels; however, the rate of one direct current fast-charge (level 2) is the identical as the cost of one 24 kWh battery, which is used by Nissan LEAF; therefore, constructing additional charging stations will accelerate occasion of opportunities to install lesser capacity of battery, consequently proposing an inexpensive electric vehicle. The domestic electrical vehicle charger is shown (**Figure 14**) [48].

Charging level	Power supply	Charging power	Miles of range for 1 h of charge	Charging times BEV	Charging times PHEV
Level 1	120 VAC Single phase	1.4 kW @ 12 amp (on-board charger)	~3–4 miles	~ 17 h	~7 h
Level 2	240 VAC Single Phase up to 19.2 kW (upto 80 amp)	3.3 kW (on-board)	~8–10 miles	~7 h	3 h
		6.6+ kW (on-board)	~17–20 miles	~3.5 h	~1.4 h
DC fast charger level 2	200–450 VDC upto 90 kW (approx.: 200 amp)	45 kW (off-board)	~ 50–60 miles (80% per 0.5 h charge)	~ 30–45 min (to ~80%)	~ 10 min (to~80%)

Table 4. Charging standards and costs.

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Figure 14. Domestic electrical vehicle charger.

2.5. Suggestions for further improvement in microgrid

- Building the future for EVs
- Licensing of third party activities
- Microgrids for local power generation–peak shaving and commercial prospects for trade of surplus energy back into grid
- EV battery charging, rental, replacement services
- Advertisement on charging stations
- Software and mobile applications to find the nearest charging station

2.6. Future of charging stations

For the future of charging stations, the private companies are already developing their electric vehicles charging solutions [49]. However, building a strong infrastructure for EV charging can overcome the problem of low mile range. Still, there are many efforts and initiatives, which need to be taken for building the case for wireless electrical vehicle charging (WEVC) up to mainstream. The government should distribute its available resources in the favor of research in electrical vehicle demands. Like: (1) low price and availability of power supply to drive electrical vehicle demand, or vice versa. (2) The wireless charging lines on major expressways which are shown below in **Figure 15**, and building the smart metering system with the secure payment for the wired and wireless electrical vehicle charging. Beyond the EV-Extension of Wireless Transmission Applications. Infrastructure availability for EV charging (lowering power supply costs). Directly lowering EV costs (increasing EV demand). With EVs capable to simply and easily locate charging facilities/achieve and get charging on the move when required. Have need of complementary enhancements in smart powering and metering systems for calculation and payment of charging fee.

2.7. Room for Improvements

Rates of enhancements enabling development in use of microgrid, electric vehicle, and expertise in transfer of power without wire: such as

- ICs
- MOSFETs
- Roll printing for thin film substrates

The improvement rates in the above skills exceed the rate of extension in (car) battery skills. Consequently, the task in short mile range of electric vehicle will be overcome more rapidly while smoothing the advance of economical wireless facilities for charging, through powered microgrid. The implementation of the above-mentioned suggestions will lead to a healthier and sustainable life, which is depicted in building the dedicated WEVC on major expressways as shown in **Figure 15** [50].

Figure 15. Building the dedicated WEVC on major express ways.

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3. Conclusion

This chapter has presented the development of microgrids incorporating renewable energy and electric vehicles while the associated energy crisis and their challenges have been extensively discussed. Addressing these challenges would contribute to simplifying the execution of novel renewable technologies in a microgrid. As the microgrid research involves many areas of power systems by considering the latest trend, charging infrastructure can be developed to better cater for EVs in the future. Also, the worldwide anxieties about diminishing fossil energy assets and ever-increasing pollution have augmented significantly in recent years. Distributed generation and EVs have acknowledged enormous consideration because of their environmentally friendly nature as a power source.

The impact on the grid can be reasonably eased by means of developing smart onboard or offboard charging facilities in residential or office areas. These approaches permit a high quantity of EVs to be fast charged with a minor impact on the main grid and an increased DER self-consumption. With the help of microgrids, EVs can reduce the reliance on crude oil fossil fuel energy so as to reduce CO2 emissions. The record numbers of EV chargers based on microgrids and charging infrastructures are anticipated to rapidly increase surrounded by domestic areas in the near future.

The future microgrids will have a huge quantity of distributed generation systems and adaptable power generation from renewable energy resources. As microgrid systems can provide much promise for integrating large numbers of distributed energy resource systems and minimise the impact on the main grids, their future are bright. In addition to the electric vehicle application, microgrid technologies can also be applied to aircraft, rails, ships, submarines or other forms of electrified transportation.

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