Electric Vehicle in Energy-V2G, V2H, V2V

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Electric vehicles (EVs) are inducing revolutionary developments to the transportation and power sectors. Their innumerable benefits are forcing nations to adopt this sustainable mode of transport. Governments are framing and implementing various green energy policies. Nonetheless, there exist several critical challenges and concerns to be resolved in order to reap the complete benefits of E-mobility. The impacts of unplanned EV charging are a major concern. Accurate EV load forecasting followed by an efficient charge scheduling system could, to a large extent, solve this problem. This entry focuses on short-term EV demand forecasting using three learning frameworks, which were applied to real-time adaptive charging network (ACN) data, and performance was analyzed. Auto-regressive (AR) forecasting, support vector regression (SVR), and long short-term memory (LSTM) frameworks demonstrated good performance in EV charging demand forecasting. Among these, LSTM showed the best performance with a mean absolute error (MAE) of 4 kW and a root-mean-squared error (RMSE) of 5.9 kW.

Vehicle-to-Grid vehicle grid integration renewable energy sources

1. Introduction

The last decade has seen tremendous efforts in the direction of climatic awareness, green energy, and a clean environment. The demand for reductions in pollution and green energy has increased. All over the globe, research is happening, and governments are aggressively implementing a plethora of policies to reduce carbon emissions and promote green energy [1][2][3][4]. A major producer of Greenhouse Gas (GHG) emissions is the automobile sector [5]. Decarbonizing the transport sector would be a prominent step that would help the governments achieve their goal.

EVs play a significant role in lowering carbon emissions by replacing conventional Internal Combustion Engines (ICE). These vehicles have drawn a lot of interest recently as an economical and environmentally friendly alternative to conventional ICE vehicles. Also, the low operating cost, energy efficiency, and ease of integration with RES make them more customer-friendly [6][7][8][9]. Poornesh et al. in [10] compare the features of ICE vehicles and EVs and conclude that EVs are better than the former in many aspects.

The research on EVs dates back to the last century. The initial focus of the research was on components such as fuel cells, batteries, machines, drive systems, etc. [11][12][13]. As the adoption of EVs gained momentum, it became important to consider them as part of the consumer load and study them from a load management perspective. The research took a new direction with the introduction of smart grid technology in the power sector. As illustrated in **Figure 1**, the development and acceptance of RES in utility, along with the development of a smart grid, have revolutionized the EV industry. Various studies show that EVs are not just efficient mobility tools but also reliable sources of energy. These support the utility grid by providing a variety of services. Hence, these are also known as Gridable Electric Vehicles (GEVs) and offer significant capabilities, which are collectively known as Vehicle-to-Everything (V2X) services. V2X includes Vehicle-to-Home (V2H), Vehicle-to-Grid (V2G), Vehicle-to-Device (V2D), Vehicle-to-Vehicle (V2V), etc. Among these, V2G, V2H, and V2V are of prime focus in the present energy and power sectors [14][15][16].

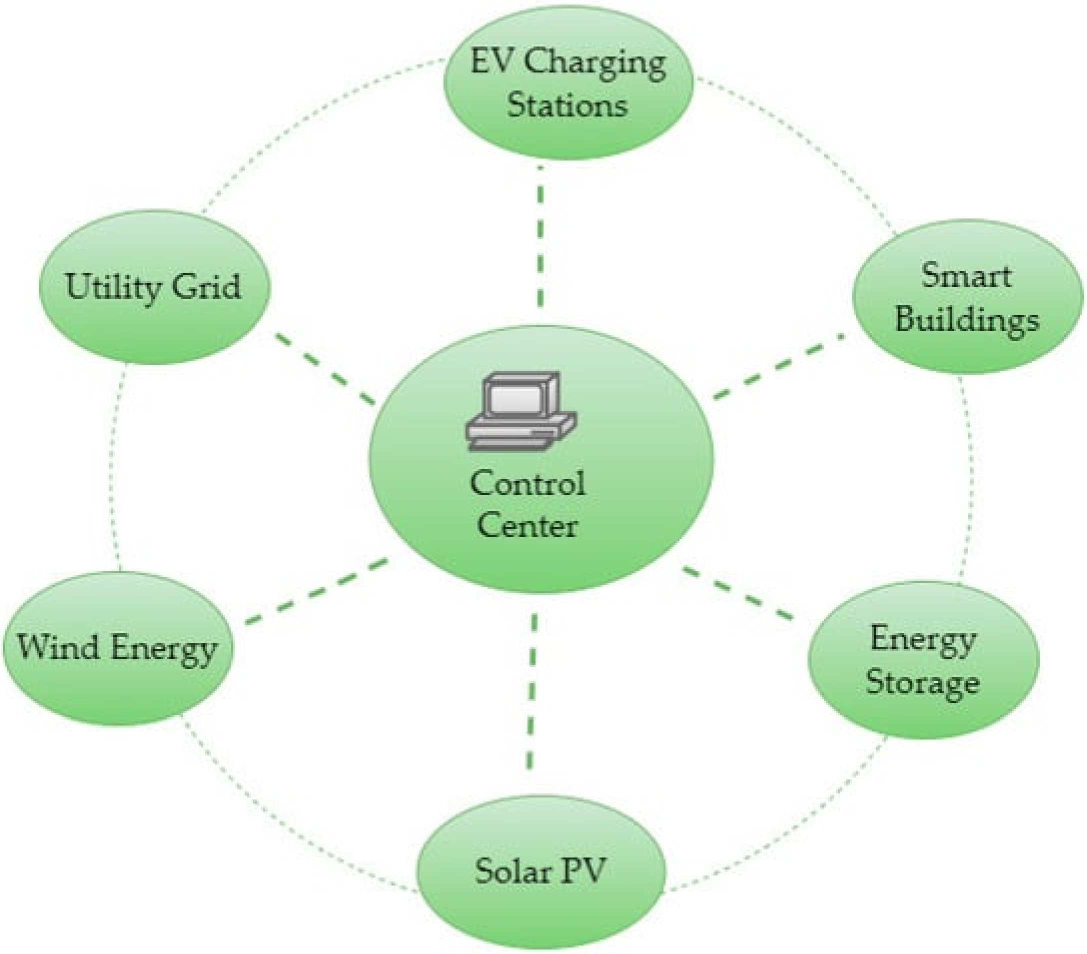

Figure 1. Smart grid with Renewables, Energy Storage, and EV charging stations.

The potential features of EVs welcome governments to undertake heavy investments in EV adoption. EVs are currently viewed as key pillars for economic development. The current automobile market is highly focused on EVs and Plug-In-EVs (PEVs). A study by Canalys shows that EV sales have boomed up in 2020, and by 2030, EVs will represent almost 50% of total cars, globally, as illustrated in **Figure 2** [17].

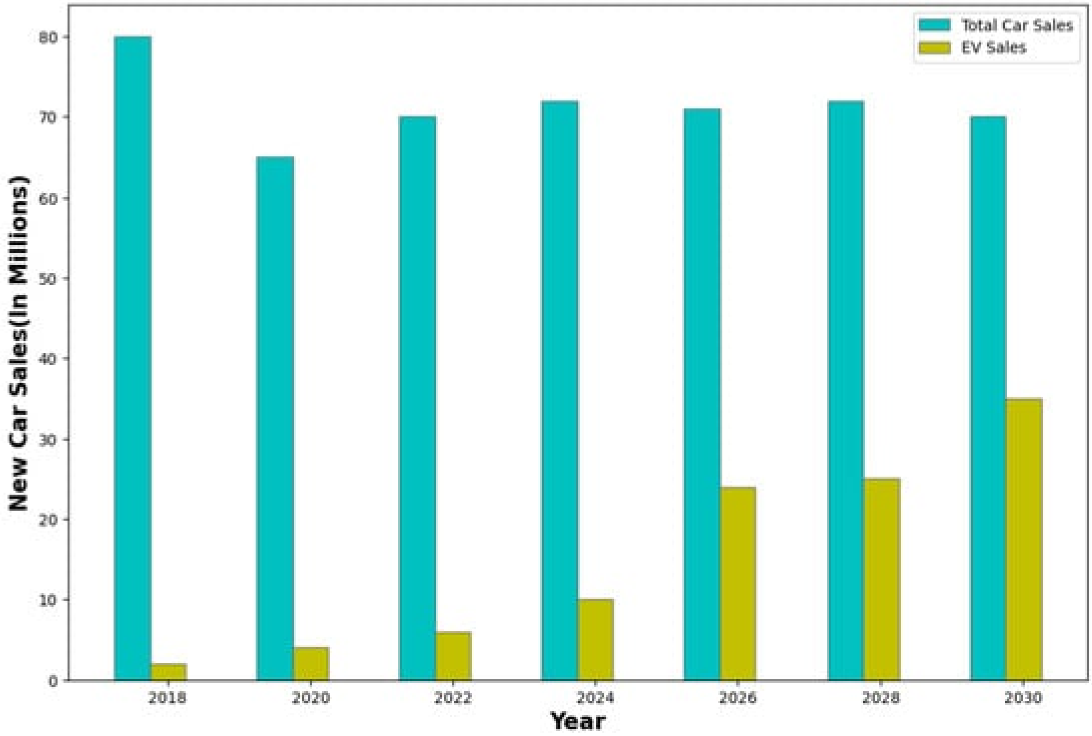

Figure 2. Projected Sales of EV by 2030 as per Canalys Report [17].

However, even with all the benefits, certain barriers hinder the adoption of EV technology. The major problems slowing the adoption of EVs include range anxiety, inadequate infrastructure for charging, cost of ownership, and a lack of consumer awareness [18][19][20].

2. Categories of EVs

The major categories of EVs are Battery EVs (BEV), Hybrid EVs (HEV), Plug-In Hybrid EVs (PHEV), and Fuel Cell EVs (FCEV).

2.1. BEV

Figure 3 shows the diagram of a BEV. These vehicles also referred to as All-Electric Vehicles (AEV), run entirely on a battery. Connecting to the utility grid, the big battery pack may be charged, which can power single or multiple electric motors. These do not produce any tailpipe emissions caused by conventional ICE vehicles. BMW i3, BMW i4, Chevrolet Bolt EV, Nissan Leaf, etc. are BEVs.

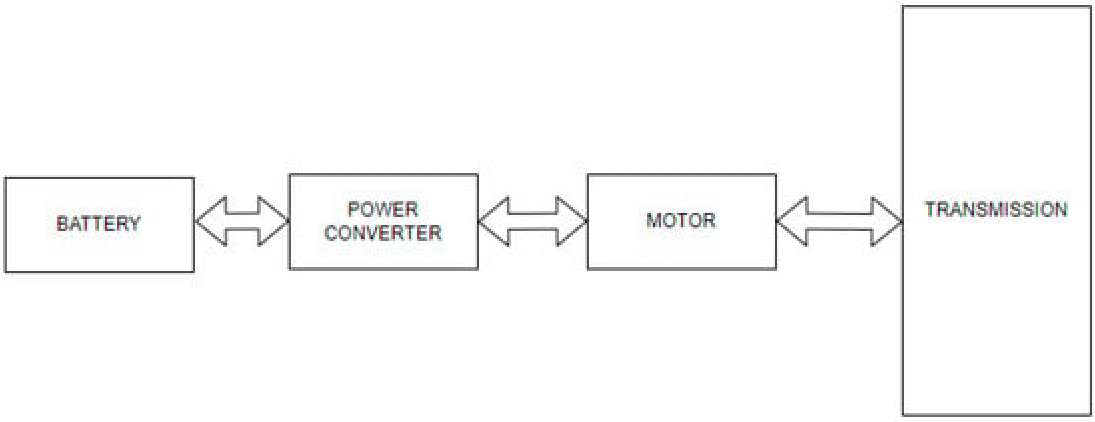

Figure 3. Battery EV.

2.2. HEV

Here, both the engine and electric motor are present, as given in **Figure 4**. The battery obtains energy through regenerative braking. The transmission can be rotated by both the engine and an electric motor. Regular HEVs cannot be recharged from the utility grid.

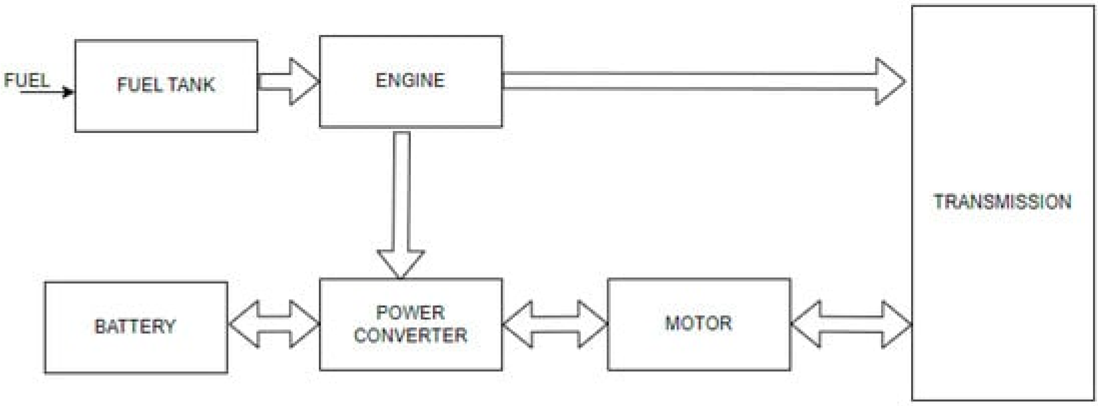

Figure 4. Hybrid EV.

2.3. PHEV

As shown in **Figure 5**, PHEVs have an engine as well as a motor, similar to HEVs. However, there are differences. PHEVs generally include a larger battery pack and powerful motors compared with HEVs. The battery packs get recharged automatically by regenerative braking, like HEV. In addition, these can also be plugged into the grid for charging.

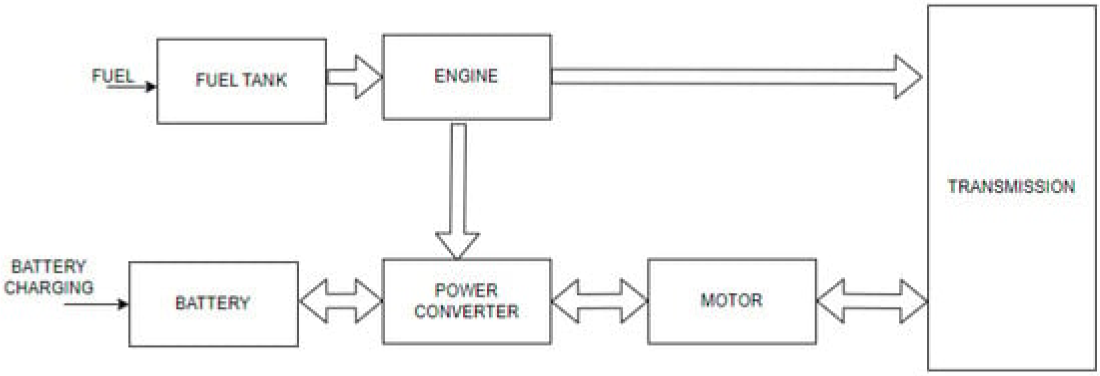

Figure 5. Plug-In Hybrid EV.

2.4. FCEV

These are vehicles with zero emissions, as shown in **Figure 6**. FCEV is similar to BEV in that they also use electrical energy to drive the vehicle. However, they do not store electrical energy like BEV but instead generate electrical energy using hydrogen, through a chemical reaction. These do not need charging from the utility grid.

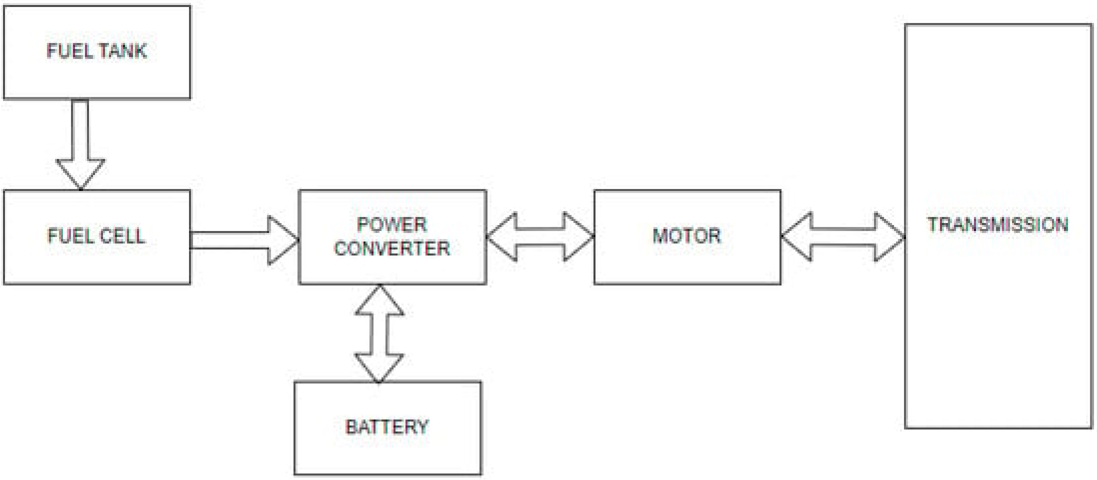

Figure 6. Fuel Cell EV.

3. EV as a Source and Store of Energy-V2G, V2H, V2V

EVs are not just transportation tools but also resources of energy. EVs with bidirectional chargers can be used to power a home, power another EV, or even feed the utility grid. In V2H operation, as illustrated in **Figure 7**, EVs are wired to the residence by employing a bidirectional charger. Based on the control strategy, EVs can use energy from the home or supply energy back to the home [21][22]. When a PHEV is combined with a rooftop Solar PV system, this can form a small microgrid and provide sufficient power backup for the home. This supports off-grid operation by supplying the home loads in case of a grid power outage [22].

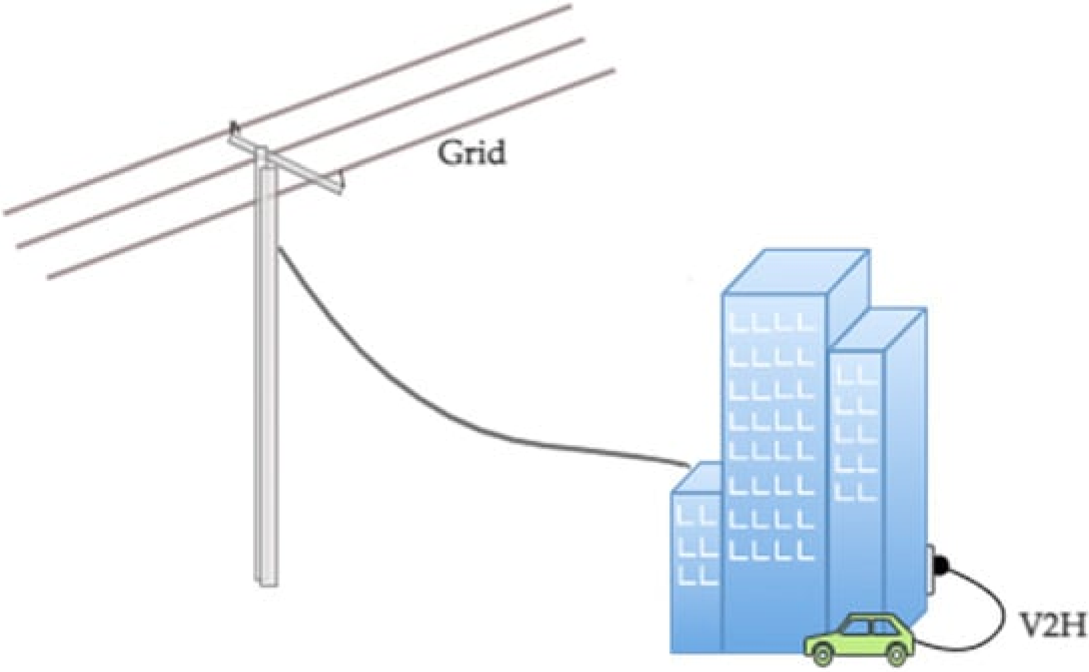

Figure 7. Power flow: V2H.

V2V operation facilitates charge transfer among EVs, as shown in **Figure 8**. This concept allows vehicle owners to share their battery charge with other vehicle owners [23][24].

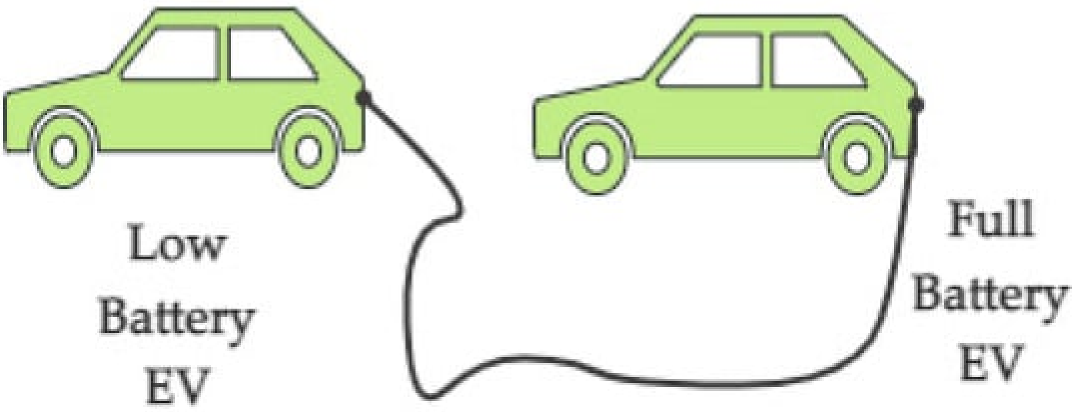

Figure 8. Power exchange between two vehicles.

In V2G, the GEV can be wired to the utility grid to use energy from the grid or supply energy to the grid, as shown in **Figure 9**.

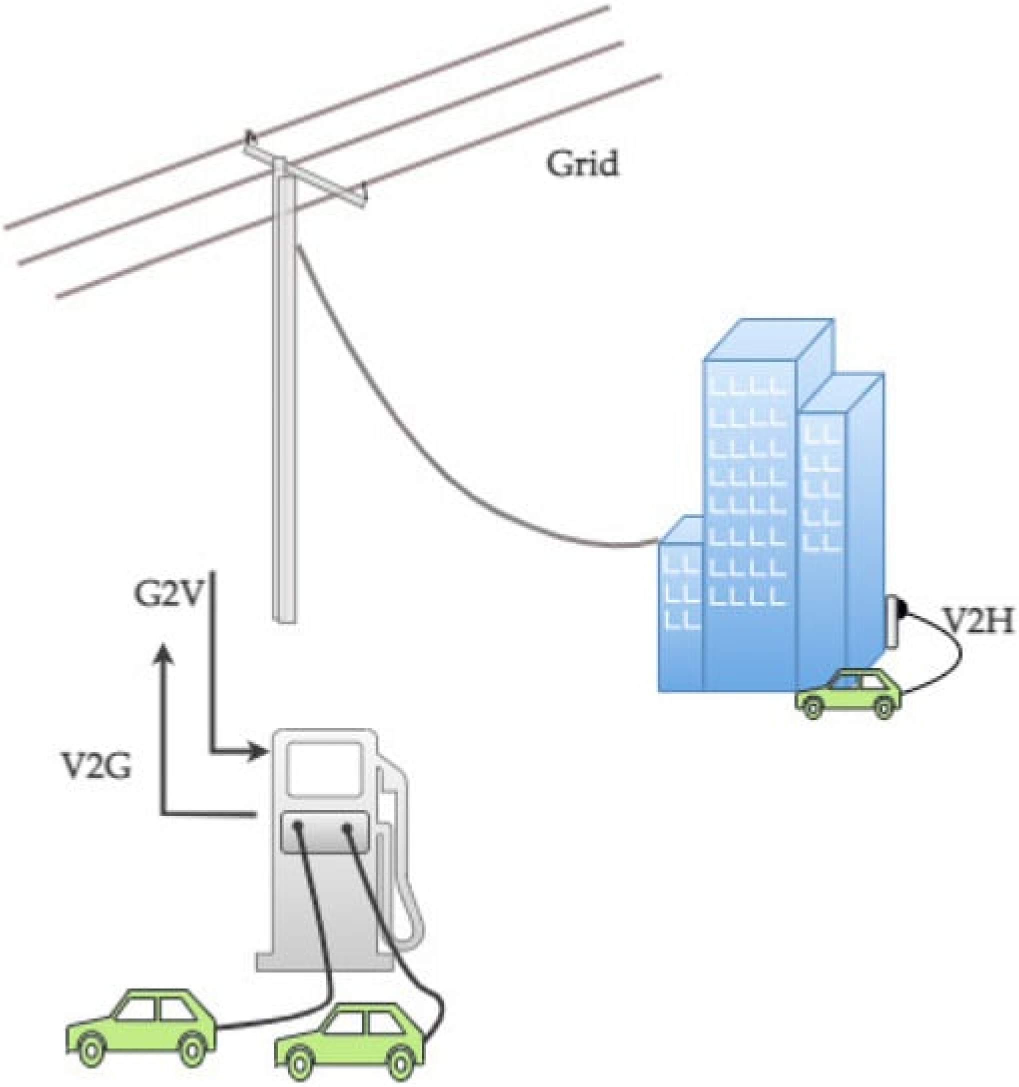

Figure 9. Bidirectional flow of power involving V2G and V2H.

An aggregator is present as a mediator between the Control Center and EVs. The energy associated with an individual EV is very limited. Hence, the aggregator uses a group of GEVs for operations involving charging and grid regulation [25].

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