AN APPROACH OF ENERGY GRID BALANCE BY V2G TEHCNOLOGY

Assoc. Prof. Todor Kostadinov, PhD
Burgas Free University

Abstract: *The large amount of renewable energy sources share in the modern power grids affects the ability to maintaining grid stability and reliability due to their variable nature. On the other hand, the increasing amount of battery electric vehicles offers the ability to balance the power grid. To obtain efficient control communication between EV and the grid is required. Vehicle-to-Grid (V2G) technology offers a solution by enabling bidirectional energy flow between electric vehicles and the power grid. This paper presents an approach of energy system balance by V2G. By using EVs as dynamic energy storage units, V2G can support peak load reduction, frequency regulation, and voltage stabilization, enhancing the flexibility of the energy infrastructure.*

Keywords: *V2G technology, power grid balancing, EV, energy storage, powerline communication*

INTRODUCTION

The average power consumption globally has increased almost four times for the past 40 years [9]. This constant increase in consumption demands the production of more energy by using nuclear, thermal and other varieties of powerplants. It leads to increased level of carbon emissions, producing global warming and climate changes [10]. In compliance with the green deal, it is necessary to migrate to green methods of energy production [7] such as renewable energy sources – wind, sun and water energy [8]. In contrast with the conventional methods of power production, the renewable energy is much less predictable and thus effective due to the specifics of the energy sources – the wind and the sun radiation are not constant during the day and the large amount of energy produced for instance during daytime is not present during the night. The same applies to the wind flow – it has a temporary nature. This leads to intervals with high power consumption and low power production, causing strain on the power grid [9]. To reduce the impact of the periodical nature of the renewable energy a balance energy conservation system must be implemented [8]. The nature of power storage can be mechanical or chemical, depending on the type of the harvested renewable energy [7]. Building a power storage is usually expensive, finite in performance and not carbon emission friendly. The scope of this article is focused on implementation of battery electric vehicles (BEV) as a power storage due to the large battery capacity and the capability of utilization to conserve energy while not being in use during the light part of the day / presence of wind movement and provide energy during the night / lack of wind. To provide flexible operation of BEV as a power storage, a V2G communication protocol is taken into consideration for user friendly application of the vehicle in the grid. A balancing approach according to the degree of BEV utilization is proposed.

1. BEV AND ENERGY CONSERVATION

Two of the most common types of renewable energy sources are wind and solar radiation. Solar radiation is the most preferred type as it is accessible all around the globe during the day. The wind energy is mostly used in coastal areas and areas known for good airflow circulation – windy areas that are not that common as the sunlight. Due to the nature of transforming the green to grid energy, the output varies between alternated current - AC and direct current – DC. AC is typically generated by the wind turbines generators as it is more efficient than the DC generators. This type of energy is more suitable to be directly fed to the grid, but not that suitable to be directly stored to a DC battery storage as a AC-DC converter is required increasing the cost and decreasing the efficiency due to losses, while the solar radiation is transformed to electricity by solar panels that result DC power and can be directly stored to a battery array. Considering the latter, from this point of the article on solar systems will be considered as the main source of renewable energy. The battery charge is then performed by a charge controller that monitors the storage state. As mentioned, energy storages type may vary, but battery storage remains the preferred one as it is widely used and well known. The advantages in weight and power density of lithium batteries over the lead-acid ones leads to wide use worldwide, including also the BEVs. According to the size every renewable energy system can generate different amount of energy varying from several kilowatts to several hundred megawatts. However, the energy acquired by the large renewable energy systems can remain unused, especially in moments of peak generation and not sufficient during the lack of energy denoted by the curve denoted as E_{PV} in fig. 1. This issue is resolved by adding power storage – curve $E_{(PV+BESS)}$. in fig. 1.

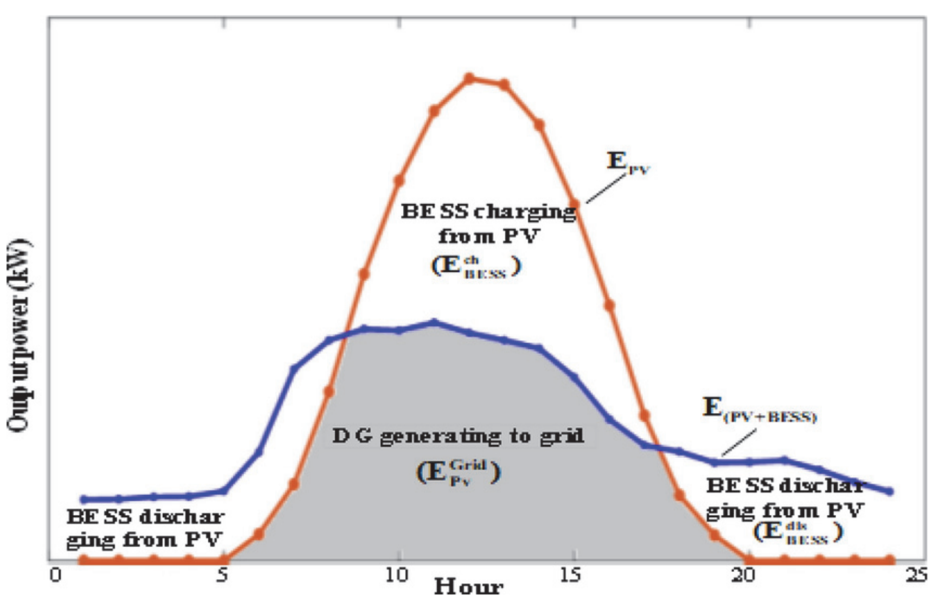

Figure 1. Renewable power sources with and without battery storage

The minimal output power depends on the battery storage capacity – the larger the storage, the less the power shortage demanded from the grid. Nevertheless, it is not justified to provide 100% energy backup in terms of cost, as the battery storage is the most expensive part of a renewable energy system. And the power consumption is neither predictable nor constant. The concept of dynamical or shared energy storage seems feasible in terms of multiple storage usage. This can also lead to improved performance of a renewable system and reduced costs due to shared expense. BEVs are ideal for that purpose a BEV battery storage is generally lithium type. Along with the fact that every BEV has an individual battery management system – BMS, no charge controller is required from the energy system. It can also provide the main grid voltage. The increased number of BEVs on the road is also a factor that can allow the implementation of every electric vehicle as a storage, especially in the moments that the vehicles are not in use. This makes the BEV an ideal source of energy during renewable energy outage, especially for low amount of consumption – for instance a household. To provide larger amount of power, an EV must be equipped with a high performance charging port such as CHAdeMO, CCS or CCS2. To properly utilize the EV battery, a two-direction communication to the vehicle is required to suit the vehicle capacity according to the EV user. In case a vehicle is parked and not used for a long period of time, the battery can be charged and discharged to states close to minimal and maximal levels allowing better energy grid utilization. To achieve such productivity and not sacrifice the end user necessities, a dynamic scheduling is required in order to preserve the excessive energy from the grid as a battery charge and provide it on high energy demand from the grid.

2. COMMUNICATION WITH THE GRID, V2G PROTOCOL

The early BEV use unidirectional communication to the grid, allowing carrier sense and charging infrastructure recognition. In that case the energy is transferred from the grid to the vehicle battery only. The vehicle onboard computer is used only to control the amount of incoming power according to the battery state.

PP	Proximity pilot pre-insertion signalling
CP	Control pilot post-insertion signalling
PE	Protective earth full-current protective earthing system – 6-millimetre (0.24 in) diameter
N	Neutral single-/three-phase AC / DC-mid
L1	Line 1 single-/three-phase AC / DC-mid
L2	Line 2 three-phase AC / DC-mid
L3	Line 3 three-phase AC / DC-mid
DC+	high-power DC couplers including thermal sensing
DC-	high-power DC couplers including thermal sensing

Figure 2. European type 2 + CCS/CCS2 charging interface

The signals PP and CP are used for communication between the Electric Vehicle Supply Equipment – EVSE and the EV / PHEV, these two low-voltage signals are referenced against the protective earth. The CP signal servers as a communication line for interactions between the EV and the charging station (EVSE). It enables the negotiation of charging parameters, like the maximum current the vehicle can draw, and facilitates the start and stop of the charging process. Essentially, it's a bi-directional communication channel using a 1 kHz square wave signal with a ±12V amplitude, modulated by the EVSE to convey information. It can help in the negotiation process for supply power, but cannot state the vehicle state of charge – SOC and the availability of the EV as a power source.

To provide a feature supported by the battery electric vehicles (BEVs) that allows to use the stored energy to power other devices – a mobile power source the Vehicle-to-anything (V2X), part of ISO-15118-2 [2-4] technology is introduced. In broad term it describes the energy storage of an EV and the ability to interact and supply power for end users out of it based on the open system interconnect, presented on fig. 3.

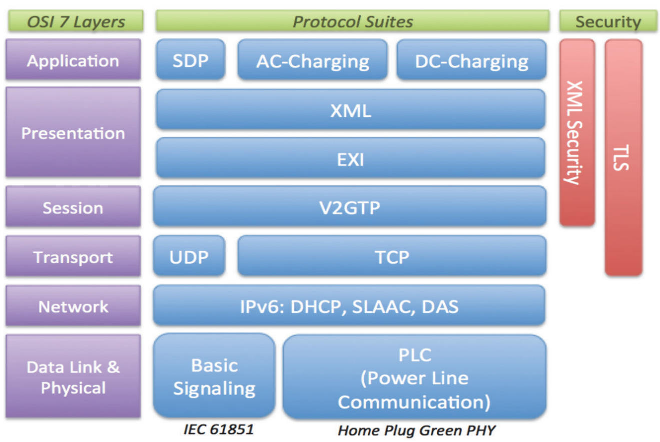

Figure 3. ISO-15118-2

There are several varieties of this protocol – apart from Vehicle-to-Grid (V2G) used mainly as a power exchange, it can also be applied as Vehicle to Vehicle (V2V), Vehicle to Load (V2L), Vehicle to Home (V2H), Vehicle-to-Building (V2B), Vehicle to Emergency (V2E). Some of the varieties of this technology allows EVs to output power up to 3.5 kw to power camping equipment, and / or some domestic appliances – for example V2L. For that purpose, an inverter to convert DC power to AC is required. Then the power is transferred to an existing AC plug. To transfer larger amount of power the varieties V2B and V2H can be implemented along with a building energy management system that can control battery state of charge SOC conditions of the vehicle, managing the needs for better performance and benefits [1, 2].

Physical Space carries the physical components like power systems and transportation layers [11]. Power systems layers consist of the chain of the electrical power systems, including bulk power generators, renewable sources of energy, energy storage systems, transmission lines, distribution systems and consumers.

The physical layer of interconnection of the EV and the charging station, and thus the grid is implemented by a greenPHY powerline modem designed for low power communications over the grid components of the next generation power systems including EVs are withing the scope of the cyber physical power systems illustrated in fig. 4

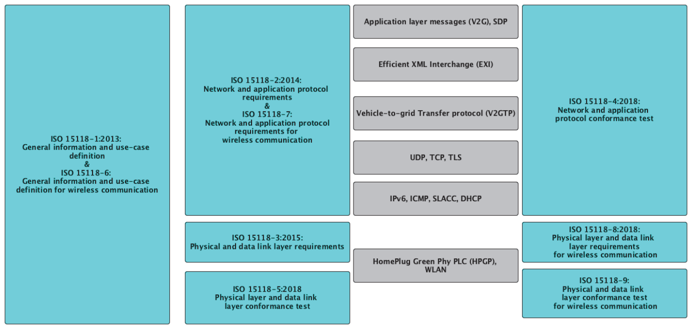

Figure 4. Structure of V2X protocol

Once the greenPHY modem on the EV is connected to the grid, a standard OSI communication including encryption and authentication with the vehicle is started. The V2G protocol [5, 6] is then used to exchange specifics about the vehicle such as protocol revision, request/response message, timestamp, chassis number, ID, battery state of charge – SoC, maximum amount of power output and remaining amount of energy – as shown in the sample XML session below.


```
<V2G_Message>
 <Header>
  <MessageID>XXXXX</MessageID>
  <Timestamp>YYYY-MM-DDTHH:MM:SSZ</Timestamp>
  <Version>1.0</Version>
 </Header>
 <Body>
  <V2G_Request>
   <RequestType>GetSOC</RequestType>
  </V2G_Request>
  <V2G_Response>
   <ResponseCode>Success</ResponseCode>
   <SOC_Info>
    <VehicleIdentification>
     <VIN>12345ABCDEFG</VIN>
     <EVSE_ID>YYYYY</EVSE_ID>
    </VehicleIdentification>
    <SOC_Value>85.5</SOC_Value>
    <SOC_Unit>percentage</SOC_Unit>
```

```
    <Timestamp>2024-07-01T10:00:05Z</Timestamp>
    <RemainingAvailableEnergy>
      <Energy>20</Energy>
      <Unit>kWh</Unit>
    </RemainingAvailableEnergy>
   </SOC_Info>
  </V2G_Response>
 </Body>
</V2G_Message>
```


Using the data sent by the EV it can be easily identified. In order to utilize the vehicle as a ballast a careful planning must be performed.

3. BALANCING TECHNIQUES

As mentioned in the previous paragraph, V2G protocol allows data interchange between the vehicle and the charging infrastructure / grid. To utilize the EV battery as a ballast, further information about the vehicle usage is required. This leads to the need of an individual account for each EV, where the user is supposed to state the amount of time that the battery is landed to the grid, the charge and discharge levels allowed as shown in fig. 5.

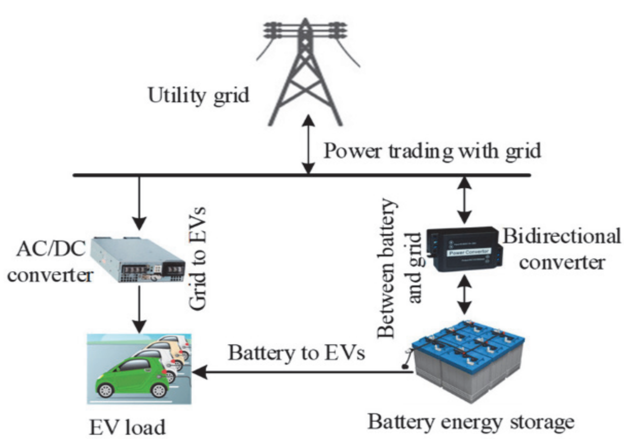

Figure 5. BEV balancing the grid

It is also prior user decision about the timeframe that the vehicle is charging / discharging and the added value to the energy being stored to the EV battery or drawn out of the EV. In case the EV is connected to a building as a power source this must also be specified [12].

The ability of an EV electronic control module to communicate with the grid controller provides flexible schema for utilization of the excessive energy in the grid, generated by the renewable energy sources while not in use and returning that energy in the grid when required to minimize the strain on the supply grid as shown in fig. 1.