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A review of Reactive Power Compensation using Vehicle to Grid enabled EV Battery Charger

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ABSTRACT: This study examines several technological methods for grid power quality assurance, including reactive power compensation and power grid support techniques such grid voltage management and power factor correction. Electric Vehicles (EVs) use back-end DC-DC bidirectional converters and grid-facing AC-DC cascaded H-Bridge bidirectional converters for managing the power flow between the grid and the batteries. An additional topology includes a three-phase AC-DC boost rectifier that will run in four quadrants. The charger of Electric Vehicle (EV) with bidirectional power capabilities which can perform charging and discharging operation. Above all the problems are resolved by using accurate voltage regulation.

Keyword: Electrical Vehicle, V2G Technology, G2V Technology, Reactive Power Compensation

INTRODUCTION:

Because they consume less petrol and emit fewer ozone depleting substances, electric vehicles (EVs) have received a lot of attention in developed countries during the past several years [1]. With draining petroleum product saves and expanding metropolitan air contamination, transportation oil utilization should be all the more viably controlled, and elective vehicle advancements ought to be created. Since public attention was drawn to the electrification of the automotive industry, the number of charging stations for EVs has increased dramatically. The installed commercial EV charging station had 100,000 units worldwide as of July 2017 [2]. The unidirectional topology only transmits the power from grid or utility to the vehicle battery and operates near unity power factor with less hardware and simple communication method [3]. While G2V and V2G are the two ways that bidirectional topologies depict active power transmission. The battery degrades when electricity is transferred between the vehicle to the grid, which is a serious issue with batteries [4]. Off-board chargers have an advantage over on-board chargers in terms of adjustable power levels [3]. The vehicle is DC linked to the charging station, which at the vehicle end converts AC electricity into DC.

The energy source supplies reactive power in a traditional electrical system. This causes a voltage drop that lowers the system's voltage quality by adding to the reactance losses in lengthy transmission and distribution networks. The voltage character of the frame is diminished by a greater voltage drop across the line reactance. Therefore, it is preferable to

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produce the reactive load close by. EV batteries control the DC link voltage, which has an impact on battery life, in order to provide continuous power factor adjustment. The page discusses several grid electric car charging types.

For the recent lectures the study of control technique for the V2G is a well-known point. For instance the author in ref. [5] offers a concept for a single-phase on-board charger that is capable of charging the car's battery and compensating the power grid for reactive power. Similarly, author in ref [6] design a fuzzy battery charger which can be operate near unity power factor.

In order to offer reactive power compensation anytime the grid is required, an effective control approach for a reversible autonomous electric car battery charger is studied in this paper.

VEHICLE TO GRID CONCEPTS AND POWER GRID MODELLING:

V2G refers to the management and monitoring of EV loads by utilities or aggregators through communication between cars and the power grid. There are three basic ideas behind grid-connected electric vehicle technologies: vehicle-to-home (V2H), vehicle-to-vehicle (V2V) and vehicle-to-grid (V2G) [7]. There are three types of power exchanges, in V2H the power is exchange between Vehicles to home where the battery of Electric Vehicle acts as a power storage for the home appliances [8]. In contrast, V2V is a local body that has the ability to charge or discharge the battery of an electric vehicle depending on the situation. Similarly, V2G uses energy from the local electric vehicle and resells it to the grid [9].

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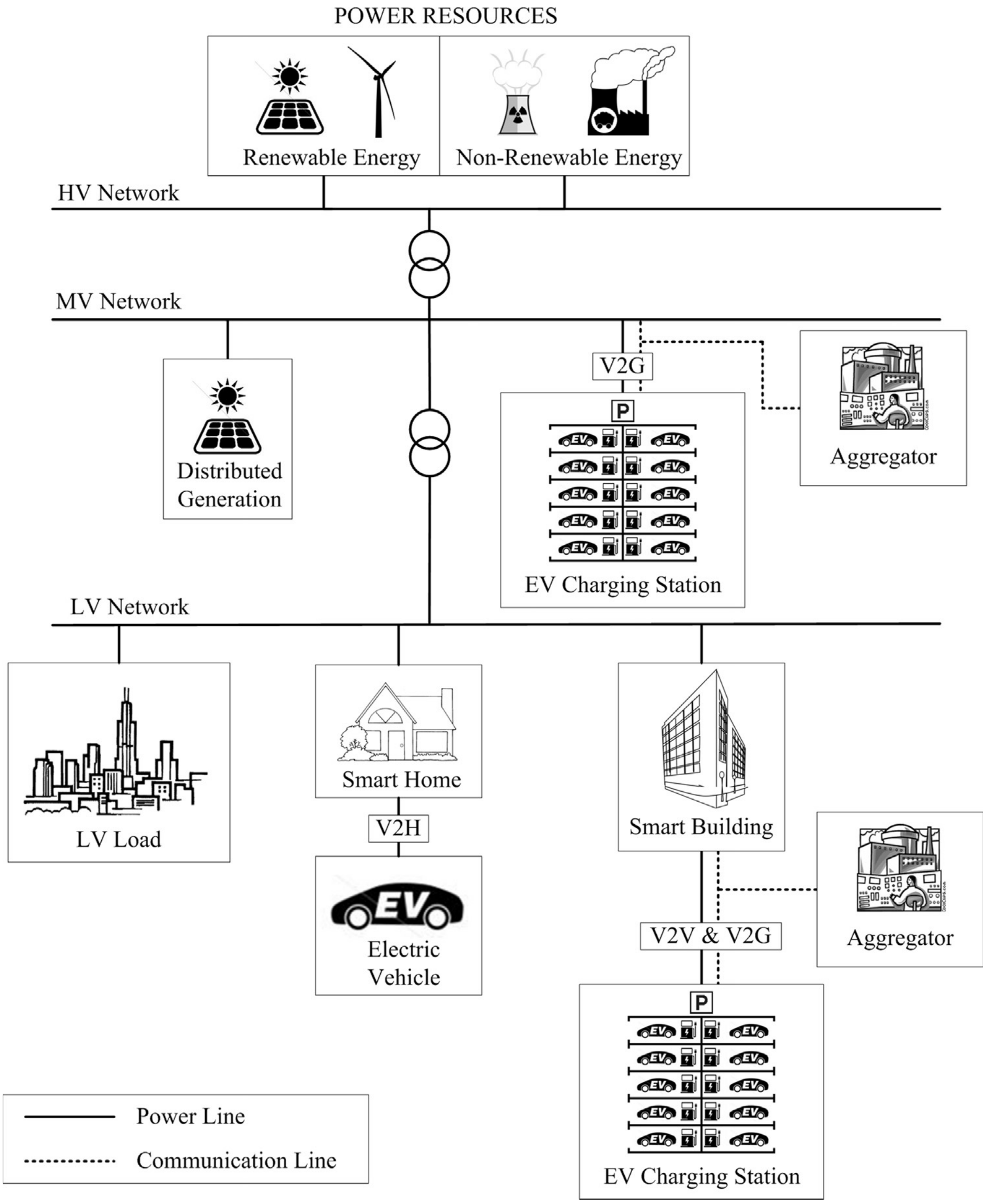

Fig. 1 Framework of V2H, V2V, and V2G Technologies [7]

The figure consists the connectivity of all the three types of EV technologies. Now for the V2G technology there are two types of charger technology present one is unidirectional V2G and other is bidirectional V2G.

UNIDIRECTIONAL V2G: With the use of a technique called unidirectional V2G, an electric vehicle's battery charging rate may be managed in just one way between the grid and the EV [3]. In order to deploy unidirectional V2G, there must be a compelling energy trading strategy that ensures EV owners will get payments for charging their vehicles off-peak and restricts EV charging while on-peak times. [10]. Unidirectional V2G may also enhance revenue and reduce emissions by using optimization techniques [11].

Bi-Directional V2G: To achieve a variety of benefits, the term "bidirectional V2G" refers to the

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bidirectional flow of electricity between an electric vehicle and the power grid [12]. According to Fig. 2 [13], A typical reversible electric car battery charger consists of an AC/DC converter and a DC/DC converter. During the EV's charging mode of operation, the AC/DC converter transforms the AC power from the power grid to DC power before re-transmitting the DC power to the power grid during the EV's discharge state. The DC/DC converter is in charge of employing current control techniques to regulate the bidirectional current flow to the opposite side. Depending on whether it is in a charging or discharging state, the DC/DC converter functions as a buck or boost converter [14].

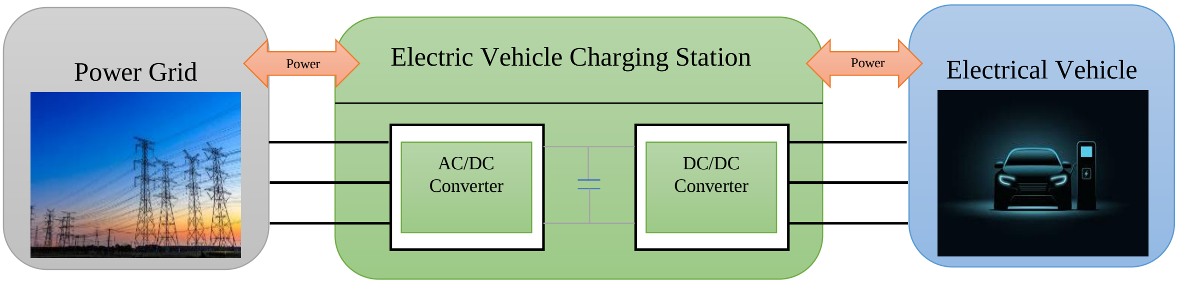

Fig 2. Process of Power Flow

Active power support, reactive power assistance, power factor adjustment, and support for the integration of alternative power sources are the key benefits of reversible V2G systems. By charging the EV during off-peak hours and adding additional EV electricity to the grid during peak hours, these services are made available. Bidirectional V2G gives the capacity to deliver reactive power for grid voltage adjustment in addition to active power assistance [15].

One of the premium services of reversible V2G technology that can lower power losses in the power grid is power factor management [16]. Currently, the V2G bidirectional implementation faces a number of difficulties. The battery's performance degradation is one of the challenges since many cycles of charge and discharge are required to implement the V2G bidirectional system [17].

CHARGER TOPOLOGIES:

Battery chargers for electric vehicles (EVs) rely on current converters to change AC line electricity to DC voltage in order to charge batteries. Using an on-board or off-board charger is the primary factor to take into account when choosing an EV converter. The on-board charger may be installed into any electric vehicle and gives it the ability to be charged at any outlet that is open, [18] despite the fact that off-board chargers could offer more functions and the benefit of no size limitations. This is why the study is concentrated on such converters, as well as the fact that on-board chargers provide more of a challenge in terms of safety and protection limits. One of the finest methods for creating intelligent chargers for electric vehicles has been deemed to be the bi-directional charger architecture [19].

One converter of the dual power converter for electric car discussed in this article converts AC power to DC power, while the other converts DC power to DC power. Table 1 summarizes the various power consumption profiles that should be taken into account, and Figure 3 illustrates the relationship between an anticipated active and reactive power flow and the design of an electric vehicle. It is feasible to charge the batteries concurrently and to use sinusoidal current with a regulated power factor thanks to the construction of the bi-directional power converter and the use of suitable control algorithms. This enables the management of both reactive and active power.

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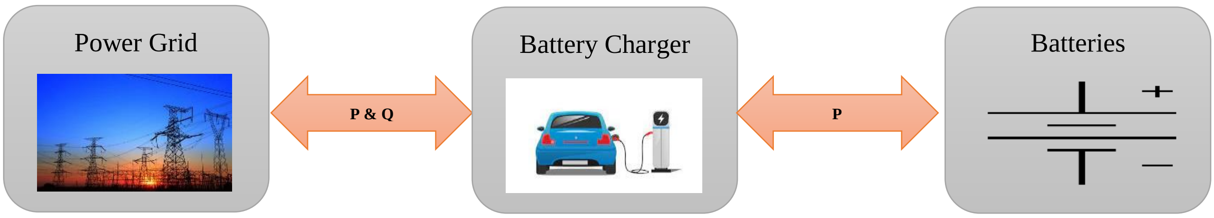

Fig 3. Possible Power Flow of Active and Reactive Power by Bidirectional Flow from G2V or V2G

The AC-DC bidirectional power converter was switched using Cyclic Monitoring based on Direct Current Control (DCC) technique. Although this method doesn't function at fixed frequencies, it does set a maximum frequency restriction, in this case 20 kHz. On the other hand, the switching method Pulse Width Modulation (PWM), which operates with a set frequency of 20 kHz, was applied to the DC-DC converter. The IGBTs are properly controlled to provide a bidirectional flow of energy.

Table 1
DIFFERENT CASES OF POWER CONSUMPTIONS

S. No.	PF cos $\propto$	Active Power (P)	Reactive Power (Q)	Unity/ Capacitive / Inductive PF
1	$\propto=0^0$	+ve	0	-
2	$0^0<\propto<90^0$	+ve	+ve	Capacitive
3	$\propto=90^0$	0	+ve	Capacitive
4	$90^0<\propto<180^0$	-ve	+ve	Capacitive
5	$\propto=180^0$	-ve	0	-
6	$180^0<\propto<270^0$	-ve	-ve	Inductive
7	$270^0<\propto<360^0$	+ve	-ve	Inductive

BIDIRECTIONAL ON/OFF-BOARD EV BATTERY CHARGER:

By controlling the switching intervals, IGBT inverter packs may be used to convert a single or three-phase supply into a stable DC voltage at the output (or vice versa due to an on-board charger). This allows the EV battery to be charged and discharged. Due to the necessity for galvanic isolation and grid interface, a Low Frequency Transformer (LFT) and Power Factor Controller (PFC) must be used to link the grid to the EV's inverter. The EV charger is used to test the charger's ability to compensate for reactive power as well as its grid to vehicle or Vehicle to Grid functioning mode. A single-excited voltage-source converter, the AC-DC Front-to-Grid Transmitted H-Bridge Reversible Converter (THRDC) [20].

The EV charger operates in two ways: first, it charges the EV battery using active power from the grid (G2V), and second, it feeds back active power to the grid as necessary (V2G operation). Second, at the request of the distribution grid operator, it supplies reactive power to the grid. For battery charging in

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G2V operation, we take into account constant voltage (CV) and constant current (CC) techniques. The basic battery's charging current is set during the initial charging phase to the proper power and maintained until the battery voltage reaches the manufacturer-recommended allowable nominal voltage. The battery will then continue to charge until it reaches the greatest voltage level while the current is falling. This procedure will continue until the battery voltage and current are at their highest point.

The EV charger transmits electricity from its power source to the grid while it is in V2G mode. When an electric car is linked to the network, the charger's primary duty is to turn on G2V. However, for a while, current flow in either direction could be conceivable with the inclusion of a BBDC. When necessary, the distribution system feeds electricity from the batteries to the grid, which is advantageous for EV owners. By setting the standard power command active power to be negatively weighted and the reactive power on to zero when the system is in this mode, the CHBDC is regulated to maintain a phase shift of 180^0 between the EV current and the grid voltage [21].

CONCLUSION:

This paper provides helpful overviews on reactive power optimization, G2V and V2G modes, and EVs as active components that can store, utilize, and create energy. Electric vehicles (EVs) can be utilized to regulate reactive power and act as nearby energy storage systems (ESS) by using bi-directional battery charging. By assisting the power system in managing the flow of active and reactive current, electric cars will be able to control energy output and consumption.

Based on the transfer of power between the utility grid and the electric vehicle, this technology may be separated into two distinct types, known as one-way V2G and two-way V2G. Both forms of V2G can provide the power grid with a variety of services, such as extra services, peak shaving, load balancing, and a solution to the intermittent nature of renewable energy. The optimization approach is essential because of unquestionable long-term objectives, the electrification of the transportation sector, and V2G technology. V2G technology, on the other hand, is a desirable choice that may enhance the power grid in a number of ways, including influence on the environment.

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