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Impact and Solutions for EV Charging Stations on National Grids: A Comprehensive Analysis



Abstract: - In recent times, the number of electric cars has been increasing worldwide, and of course, this has led to an increase in the presence of charging stations for these electric cars. Although these cars are environmentally friendly, in some cases they may harm the environment and infrastructure. This paper discusses a plan to reduce the impact of electric car charging stations on the national grid, by combining planning and tremendous technological advancement. However, we may face infrastructure obstacles when starting to implement the construction of these stations. The studies delve into a plan to address any impact that may be associated with electric car charging stations on the national grid. One of the obstacles that the grid may face is determining places to install charging stations based on the real and necessary needs of the user. To reduce the burden on power grids and reduce the damage caused by charging activities on the grid, integrating renewable energy sources such as solar and wind energy enables us to reduce electricity usage and promote environmentally friendly sources. We can also say that our research aims to explore any technical and economic aspects of deploying and charging electric cars on the national grid. It can be argued that the use of EVs positively enhances sustainability, and reduces greenhouse gas emissions, which will impact the energy grid and consumption. Finally, this research paper will study the evaluation and the capital costs associated with charging stations and grid enhancement, in addition to the ongoing costs of energy consumption.

Keywords: Charging stations, electric vehicles, Fast chargers, Slow chargers.

I. INTRODUCTION

In this session, we will discuss mitigating the negative impact of using exclusive charging stations on the campus of Al-Balqa Applied University by following a comprehensive approach. It is important to conduct a comprehensive inventory and evaluate the distribution and accessibility of charging stations on campus. This assessment includes investigating negative impacts such as lack of access or crowding and environmental concerns. We must cooperate with stakeholders such as students, faculty members, and university employees to understand their views and concerns and take them into account.

After that, strategies must be developed to extend the charging infrastructure beyond the campus boundaries to nearby areas or business areas frequented by university members. Also encouraging sustainable transportation options such as cycling, walking, or using public transportation can help reduce reliance on private vehicles and demand for charging stations. To increase awareness of energy conservation and the importance of reducing carbon emissions and using renewable energy sources such as solar or wind energy to operate charging stations to reduce the environmental impact, awareness campaigns can be carried out.

Initially, we will talk about the difference between fast and slow chargers:-

First note that the DC charger is the fast charger and the AC charger is the slow Charger

Why? Because the car battery is DC so there is no need to convert electricity from to. In the case of AC charging, we must convert electricity from AC to DC using a rectifier which of course takes longer. Both charging methods have their advantages and disadvantages and the choice is made based on the user's needs.

Here are some points to consider when choosing between AC and DC chargers

-Charging speed

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Fast chargers reduce the charging time a lot compared to the slow charger which in some cases may take 30 minutes to charge your vehicle up to 80%. So when you are traveling on a travel route and you need to charge your vehicle quickly.

DC fast charging is required. In case you have time to leave your vehicle to charge overnight or during extended periods of parking then AC slow charging is required.

- Convenience

Fast chargers are usually located along highways or in places where quick charging is required

However, slow chargers are often installed at homes, workplaces, and universities, offering the convenience of charging while the vehicle is not in use. [1]

- Battery health

Rapid fast charging can hurry battery damage due to exposure to high temperatures and pressure which impacts the long-term health lifespan of the battery. Slow charging, on the other hand, is gentler on the battery and does not put any additional pressure on it which helps prolong its overall lifespan.

And about Cost

Fast chargers are more expensive to install compared to slow chargers due to their high-quality components and require larger infrastructure and increased maintenance.

- Grid impact

Fast chargers consume higher power demand which puts more pressure and strain on the grid. Slow chargers draw lighter loads. Minimizing demand surges.

This paper describes how, in contrast to gasoline-powered vehicles, electric automobiles are currently more common since they reduce a number of problems and have positive environmental effects. The growing popularity of electric cars has made it necessary to discuss topics such as the various kinds of charging devices, charging technologies, and other topics that shed light on the significance of electric cars and their advantages in the modern world. A thorough guide to electric car chargers and stations is also necessary.

Additionally, Transportation has changed as a result of the rise in electric vehicles, which has also lessened pollution and depended less on fossil fuels. The national electrical system is under stress as a result of the growing demand for infrastructure brought on by the growing number of EVs.

Moreover, there are advantages and disadvantages to the grid's ability to accommodate EV charging stations. While charging multiple cars at once during peak hours might cause grid disruptions, including greater infrastructure costs and voltage fluctuations, charging during off-peak hours can help reduce grid usage. The extensive installation of EV charging stations may put additional load on the grid, particularly in places with constrained network capacity. This could lead to network inefficiencies and impede the uptake of electric vehicles. It is essential to comprehend how EV charging stations affect the national grid to create sustainable solutions.

This section of the paper will include a concise analytical synopsis of all the findings we have previously presented, as well as a conclusion that will draw attention to any findings and research we have conducted and how they may affect the future of the electrical grid.

We can also state that, following our investigation, visitation, and information gathering, we have given a thorough description of the fast and slow electric chargers and the brands of chargers and charging stations utilized inside Jordan. The report also emphasized how critical it is to reform infrastructure and turn it into a highly sustainable infrastructure to preserve the nation's stability and functional performance as well as its capacity to deal with the rapidly rising number of electric vehicles.

Furthermore, we will review the findings from the earlier sections and examine the statistics regarding the network impact of electric vehicle charging stations. There will be a comparison between slow chargers (AC) and fast chargers (DC), as well as a discussion of the different charger types and how they affect network stability. [2]

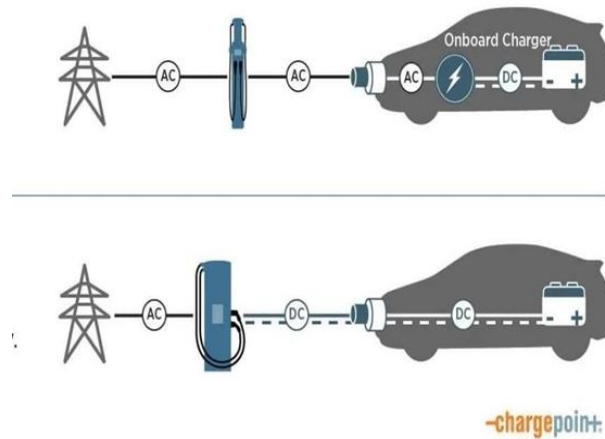
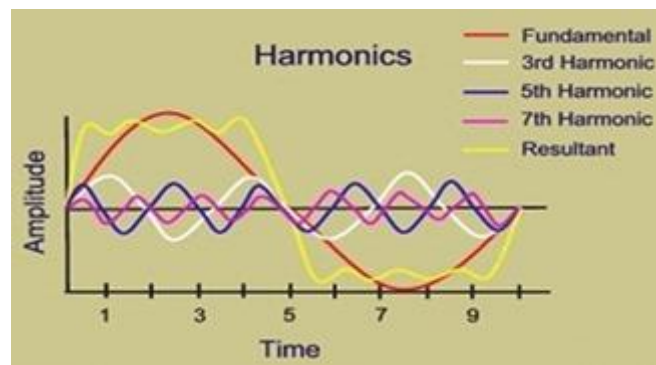


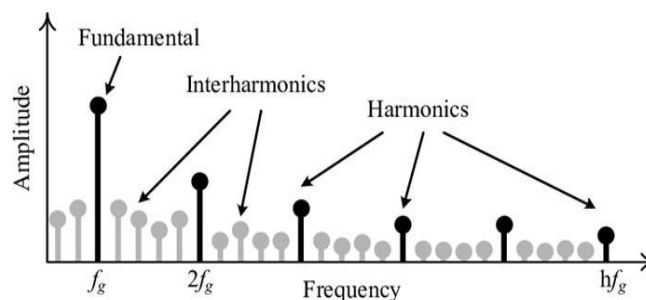
Fig. 1. The difference between fast (AC) and Rapid (DC) charging

II. GRID IMPACT OF AC VS. DC CHARGING

Adding charging stations increases the electricity demand, especially during peak times, which may lead to increased loads on transformers and local electrical lines. Moreover, charging electric vehicles simultaneously can cause voltage fluctuations, affecting the quality of electricity for other consumers. Also, charging electric vehicles can introduce harmonics into the grid, causing wave distortions and affecting the stability and reliability of the grid. Harmonics are integer multiples of the fundamental frequency and are caused by nonlinear loads. Inter-harmonics are Frequencies between successive harmonics that occur due to changes in load resistance or interactions between nonlinear loads. Both cause distortions in the voltage and current waveforms and require appropriate mitigation techniques. Reason for occurrence, it occurs due to power electronic devices in charging stations that convert Current from AC to DC. Mitigation use of passive and active filters, advanced control techniques, and strengthening of the electrical grid. Additionally, the high power demand of electric vehicle charging stations can cause voltage fluctuations, affecting the stability and quality of the power supply.



(a) Harmonic in power system



(b) Harmonics and inter-harmonics: Frequency Domain Definition

Fig. 2. Power System Harmonics: Understanding Harmonics and inter-harmonics in the Frequency Domain

III. CHARGING STATION BRANDS (DC)

There are many brands of electric vehicle charging stations that provide important elements of the electric vehicle infrastructure. There are also differences between each brand and brand in terms of the type and quality of the station, the speed of charging in it, and the station's location.

A. *Green Parking*

This brand refers to environmentally friendly practices, including reducing carbon emissions. It is important to know that this brand supports all-electric cars on the market, and this brand is famous for providing an application for users to find the nearest electric car charging station to them. [3]

This station includes two types of chargers, while a home charger (slow charger) takes a charging period between 4-8 hours. Or the targeted charger, which is the (fast charger) that is used in all public places and takes only one hour to charge. However, one of the disadvantages of this station is that the charging devices it includes contain only two (2) socket types, so users need to provide their charging cables. Also, one of the famous disadvantages of this station is that it is very expensive. [4]

B. *E-charge*

The charging station is one of the types of charging stations for electric vehicles. E-charge is a high-speed charger that allows electric cars to be charged quickly and efficiently. These charging stations use advanced technologies to transfer energy to the car battery at high speed, providing convenience to electric car owners and increasing their range of use in daily life.

Features of E-E-Charge: - The E-charge charging station has several features, including the ability to charge electric cars quickly and effectively, as the car can be charged to between 80% and 100% of the battery capacity in a short time ranging from 30 minutes to one hour. These stations also provide peace of mind for electric car owners by providing a wide network of charging stations in public places to ensure charging is available easily and conveniently. More this station is considered very safe and ability to read the car's temperature, if there is an increase in the car's temperature, the charger is quickly disconnected. It also has a DC charging method only for charging all types of electric cars because all types of chargers are available such as (European, Chinese, Japanese, American, and Tesla) chargers.

Defects of E-Charge:

Among the disadvantages of an E-charge charging station, some disadvantages can include such as not being available in private places such as homes, thus becoming more difficult for electric car owners to access. Some stations may not be sufficiently available in some areas, which may cause some challenges in the charging process.

IV. TYPES OF CHARGERS

Electric vehicle chargers come in different types and configurations to meet various charging needs. EV owners need to understand these differences to effectively charge their vehicles at home, work, or public charging stations. Factors such as charging speed, compatible car types, and charger capacity vary between different types of chargers.

A. *Zencar*

SAE J1772 from the USA Is an electric vehicle manufacturer that offers simple and easy-to-use chargers, although charging electric vehicles can be relatively slow. The chargers are portable and compatible with most electric vehicles, and some models allow for amperage adjustment. They also come with safety features such as overcharge protection and are weatherproof for outdoor use. The input voltage ranges from 120V to 240V, with output power varying by model. Installation may require a professional for high-power versions. Zencar chargers are ideal for home, workplace, and public charging, providing a reliable and convenient way to charge electric vehicles. [9]

B. *Tesla*

CCS1 from the USA Offers a range of electric vehicle (EV) charging solutions for different needs, including home charging and fast charging on the go. The home charging options include the Wall Connector, which charges at 70 kilometers per hour, and the Universal Cable, which is compatible with most North American electric vehicles. Tesla also operates the world's largest supercharger network with over 50,000 Superchargers, allowing electric vehicles to travel up to 200 kilometers in 15 minutes. The network is designed for quick stops and is located on highways near facilities. Additionally, Tesla partners with hotels, restaurants, and other locations to provide over 40,000 power points for charging. The company also offers features such as the Trip Planner, which helps plan routes by accounting for charging stops, and the Tesla App, which allows users to track charging status, receive notifications, and remotely manage and schedule charging. Overall, Tesla's charging infrastructure supports a wide range of charging needs, providing convenience for both daily and long-distance driving. [10]

V. CALCULATION REGARDING STATION PRICES

The pricing of electric vehicle (EV) charging stations is influenced by factors such as service fees, electricity costs, charger type, pricing structure, access fees, additional services, per kWh charging, and demand-based pricing. Understanding these elements is crucial for EV owners and operators to effectively manage costs and promote sustainable transportation practices. Charging costs can vary significantly based on location, type of charger, and service offerings, making it important for users to be aware of the pricing structure to make informed decisions. [11].

Therefore, the price calculations for the construction of charging stations can be studied with the following equations:

A. *Cab Capacity*

The cab is the point of contact between the charger and the car, as the charging cable is connected to the car through the cab to transfer electrical energy from the station to the battery for charging, the internationally approved unit (KWh) through the equation (1) it can be calculated:

$$\text{Cab Capacity (KWh)} = \text{Electrical capacity (KW)} \times \text{Time (hour)} \quad (1)$$

For case in point:-

If we have a charging station that provides a battery with a capacity of 100 amp-hours, and a voltage of 240V, what will be the cab capacity?

$$\text{Cab Capacity (KWh)} = [\text{Number of Amp-hours} \times \text{Voltage}] / 1000$$

$$\begin{aligned} \text{Cab Capacity (KWh)} &= [100 \times 240] / 1000 \\ &= 24 \text{ KWh} \end{aligned}$$

- (This means that the cabins can provide 24KWh of energy)

B. *Shipping Cost*

And to calculate the shipping cost use equation (2):

$$\text{Shipping cost (\$)} = \text{the energy used (KWh)} \times \text{Price of kilowatt-hour} \quad (2)$$

For case in point:-

If the car needs to charge its battery with a capacity of 30KWh and the price of KWh is 0.20\$, then the shipping cost will be?

$$\begin{aligned} \text{Shipping cost (\$)} &= \text{the energy used (KWh)} \times \text{Price of kilowatt-hour} \\ \text{Shipping cost (\$)} &= 30 \times 0.20 = 6\$ \end{aligned}$$

C. Charger Capacity

The charging capacity of a charger is a critical factor in determining how quickly an electric vehicle can be charged and how convenient the charging process is for the vehicle owner. [12]

To calculate charger capacity use equation (3):

$$\text{Charger capacity (W)} = \text{Voltage (Volt)} \times \text{current (Amp)} \quad (3)$$

For case in point:

If the charger operates at a voltage of 240V and a current of 10A, the capacity of the charger will be?

$$\text{Charger capacity (W)} = \text{Voltage (Volt)} \times \text{current (Amp)}$$

$$\text{Charger capacity (W)} = 240 \times 10$$

$$= 2400\text{W} / (2.4 \text{ KW})$$

VI. IMPACTS OF CHARGING STATIONS FOR ELECTRIC VEHICLES (EVs) ON THE NATIONAL GRID

A. Distribution Network Overloading

EV charging stations concentrated in specific locations can overwhelm local distribution networks, leading to voltage drops, increased line losses, and the necessity for infrastructure upgrades to handle the increased load. This can cause strain on the distribution network and require additional resources to support the demand from charging stations.

- *Transformer Overloading*

The text notes that charging multiple electric vehicles at the same time close can place a heavy burden on electrical inverters. Inverters are designed to handle a certain capacity of electrical flow, and the additional load from electric vehicle charging stations can exceed the rated capacity of the inverter, which can cause overheating, voltage drops, and reliability problems. [15]

- *Voltage Regulation Challenges*

Distribution grid load due to charging of electric vehicles can pose challenges to voltage regulation. Excess demand from charging stations can cause voltage fluctuations and transitions beyond acceptable limits, affecting the quality of power supply to consumers. Grid

Operators need to implement voltage control measures to mitigate voltage problems and ensure grid stability. [18]

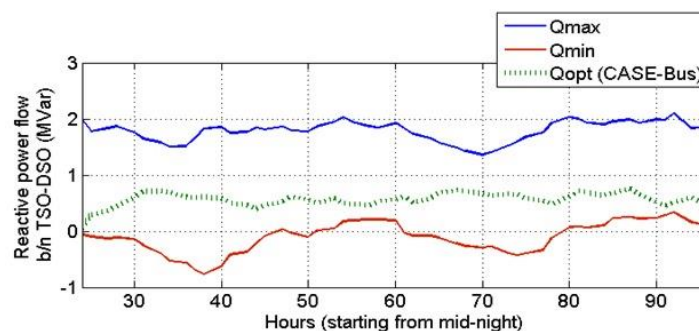


Fig. 3. Voltage Regulation Challenges

B. Harmonic Distortion and Power Quality

Charging electric vehicles can lead to harmonic distortion and power quality problems in the grid due to the high-frequency currents drawn by EV chargers. This can result in harmonics that affect the overall quality of the electricity supply and may interfere with other connected loads. Charging stations for EVs can have a significant impact on harmonic distortion and power quality in the grid, Here is a more detailed explanation of how charging stations for EVs can impact harmonic distortion and power quality.

- *Voltage and Current Harmonics:*

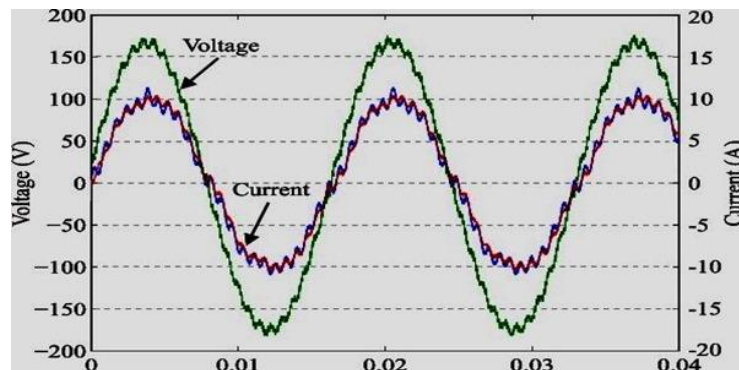
The charging process of electric vehicles means that they may generate electrical currents and voltages at multiple frequencies that are twice the fundamental frequency of electricity (50 Hz or 60 Hz). Multiple components can interfere with the operation of networked electrical equipment, such as motors, transformers, and sensitive electronic devices. Excessive harmonics can lead to overheating, increased power consumption, and decreased equipment life. [15]

- *Harmonic Distortion:*

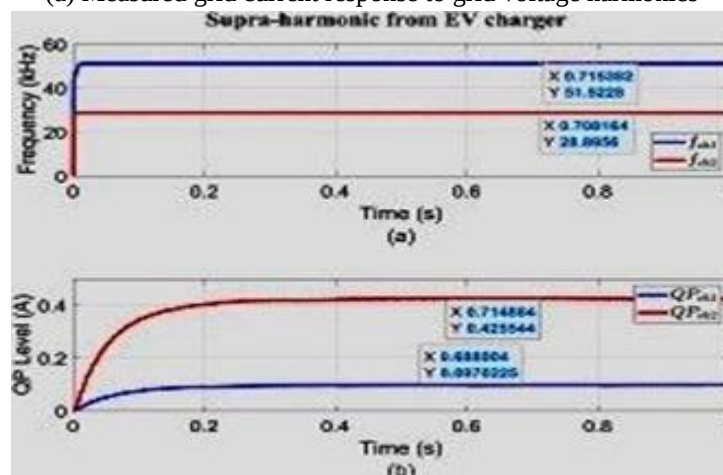
Electric vehicle chargers, particularly fast chargers, can create harmonic distortions in the grid because of their non-linear power electronics. These distortions result in deviations from the normal sinusoidal waveform of grid voltage and current, causing irregularities that can lead to higher losses, decreased efficiency, and possible damage to grid equipment. [13]

- *Inter-harmonics and Supra-harmonics:*

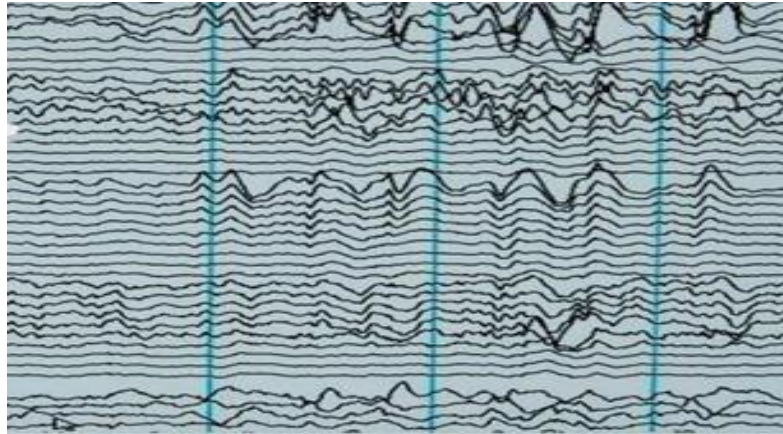
EV charging stations can introduce inter-harmonics and supraharmonics, in addition to harmonic distortions, into the grid. Inter-harmonics are non-integer multiples of the fundamental frequency, while supraharmonics are high-frequency components that can impact power quality. The presence of these can make harmonic analysis and mitigation in the grid more complex. [14]



(a) Measured grid current response to grid voltage harmonics



(b) Supra-harmonics Emission Assessment



(c) Inter-harmonic Effect

Fig. 4. Assessing Grid Current & voltage Response, Supra-harmonics Emission, and Inter-harmonic Effects

VII. SOLUTIONS ABOUT THESE IMPACTS OF CHARGING STATIONS FOR ELECTRIC VEHICLES ON THE NATIONAL GRID

A. Grid-Integrated Energy Storage

When we talk about renewable energy, Solar and wind energy comes to mind. When using this type of energy, we know that it reduces carbon pollution from the use of fossil fuels for cars. The most important use of renewable energy is electric vehicle charging. Therefore, encouraging the use of renewable energy in charging processes reduces strain on the electric grid. [15]

B. Vehicle-to-Grid (V2G) Technology

It is a flexible technology that can be used as solution for the effects of charging stations on the grid, providing a two-way flow of power between the electric vehicle and the grid and thus enabling electric vehicles to charge from the grid (from the grid to the electric vehicle) and at the same time enabling electric vehicles to unload electricity back into the grid when needed (from the electric vehicle to the grid) According to research, V2G can provide other useful network services such as frequency regulation and grid stabilization. [20]

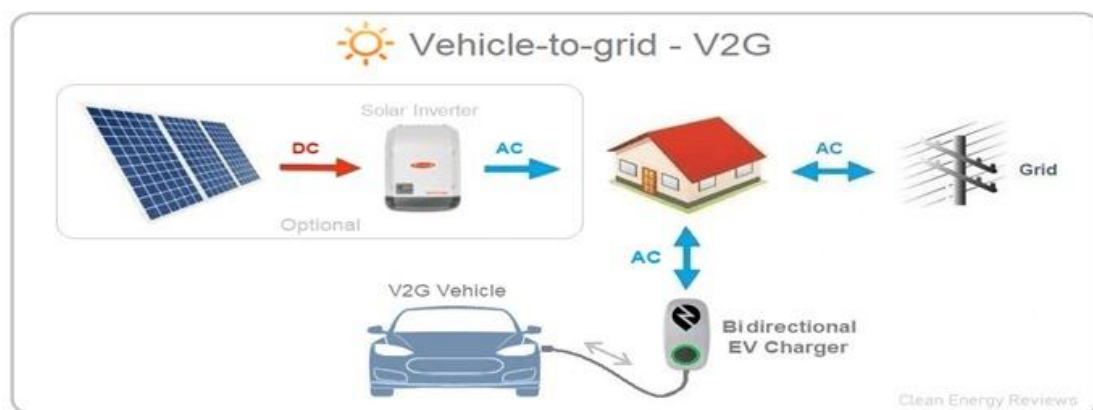


Fig. 5. Understanding Vehicle-to-Grid (V2G) Technology

C. Harmonic Filters

One of the most important solutions used to mitigate the harmonic impact on the network is filters that are used to remove unwanted distortions in the wave resulting from non-linear loads to become formally as close as possible to the sinusoidal waveform.

Filters are often installed when charging stations are installed, where filters are usually designed to match specific values of harmonic produced from the chargers at the station during the charging process, filters usually consist of PASSIVE components such as capacitors, inductors, and resistors

An electric circuit of these components is designed according to the specific harmonic value to be disposed of.

When reducing harmonic automatically, the quality and efficiency of the grid are improved because it ensures that both voltage and current remain within the normal boundaries that are important in the proper operation of electric vehicle chargers and the safety of the electric grid at the same time.

Although the addition of the filter is an additional infrastructure cost when comparing the values of the filter with the potential financial value paid when the equipment fails and the duration of the work stop, it is much less than the cost of the filter,

For that filter is one of the effective solutions used to reduce the impact of electric vehicle charging stations on the network. [21]

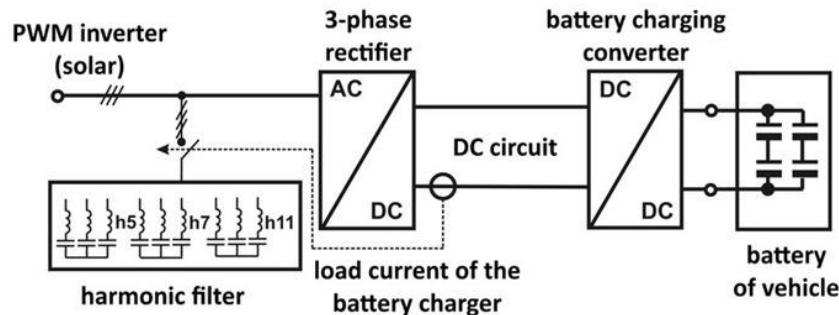


Fig. 6. Block diagram of an EV battery charger with a passive harmonic current filter

VIII. CASE OF STUDY

This case study includes the combined adoption of electric vehicles, solar energy, and battery storage on residential electricity consumption patterns in Arizona. This study analyzes how these technologies impact the time and amount of electricity consumers withdraw from the grid, highlighting shifts in consumption actions and the resulting benefits for both the individual and the environment. The researchers inspected the different electricity consumption patterns of Arizona residents who relied on the three previously mentioned technologies together. They collected data on electricity use before and after adopting these technologies and compared the differences in consumption patterns. They also conducted an analysis.

To identify specific behavioral patterns among consumers. The study concluded that the joint adoption of these three technologies together significantly changed electricity consumption patterns, leading to reduced dependence on the grid during peak hours and increased use during low-demand hours. This change benefited users in terms of reducing costs and also supported environmental goals by reducing energy demand during peak times.

IX. CONCLUSION

We started our talk with the research paper entitled "The Impact of Electric Vehicle Charging Stations on the National Grid". We made a quick comparison between AC (slow) and DC (fast) chargers. We concluded that DC chargers are often faster and more efficient, but require greater investments in infrastructure. We reviewed the impact of these stations on the national grid, the most important of which were harmonic and inter-harmonic with a statement of the negative repercussions of the phenomena on the grid.

With a discussion of possible solutions such as demand management, energy storage, and the use of harmonic filters We also talked about the types of chargers (Tesla, alpha, and Zencar) and the types of charging stations (green parking, E-charge, and Wallbox) With a presentation of the calculations to calculate the cost of building the charging station, thus providing a comprehensive view of any investment required in this field. It is very important to understand the quantitative and qualitative data extracted from the studies we conducted, so we reviewed the results of the graphical analysis and energy for each charger. To provide a clear picture of the challenges. We then discussed the results and challenges facing the project and presented future recommendations with a presentation of a study on the state of Arizona.

Finally, this study indicates the importance of sound planning to ensure sustainable strategies and meet the increasing demand for electric car chargers.

We hope that the results and future recommendations will contribute to guiding governments and stakeholders in achieving a more sustainable future in the field of renewable energy, emphasizing the need to enhance cooperation between different parties to achieve the desired economic and environmental goals that ultimately lead to a strong and sustainable infrastructure.

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