Integration of Smart Grids in Electric Vehicles(2023)

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***Abstract*—*With the threat of global warming, many countries have been working towards achieving a low carbon emission footprint and increasing their use of renewable energy sources. This has caused a rise in the need for electric vehicles (EVs) which in turn has brought challenges to the power grid construction with the main issue being demand for power. It is argued that the use of smart grids could reduce the load on power facilities and allow for the complete switch to renewable energy sources. To ensure the most efficient microgrid interconnection, active customer participation in electricity markets is necessary. In addition, to meet demand, there may be a time where landowners may have to generate energy using technologies and in return, energy companies would pay installation costs or reduce the cost of their own electrical use. Smart grids also allow for better storage of power generated by renewable energy sources and a communication server between the user and the power system.***

# I. INTRODUCTION

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lobal warming has always posed a problem, yet with the unusual weather patterns and increase in natural disasters, the urgency to deal with this issue has never been more important. Many countries have been working towards achieving a low carbon emission footprint and increasing their use of renewable energy sources. In turn, this has caused a rise in the need for electric vehicles (EVs) bringing challenges to the power grid construction. One of the main issues is the demand for power. As the demand for power, renewable energy, and electric vehicles increases, new challenges are faced regarding power reliability.

This paper argues that by integrating smart grids into power stations and charging stations for EVs can decrease the load on the power system. The smart grid allow power stations to increase their functionality and provides a way to communicate between users and the power station. The integration of this technology would allow for the complete switch to renewable energy sources globally.

# II. Background

With the issue of carbon emissions and global warming looming, many countries have taken measures to reduce their carbon footprint by integrating renewable energy sources into their power system, such as wind or solar energy. However, with the introduction of electric vehicles the solution became more commercialized. In the late 1990s, California had ordered the use of zero-emission vehicles (ZEV) which caused car manufacturers to start considering creating EVS. This also brought along the concept of vehicle-to-grid (V2G), the storage of excess energy of EVs back into the grid. However, in 2001, problems within the power grid arose due to the California electricity crisis. In turn, this affected the introduction of EVs as many companies like General Motors began to decommission their EVs. There was a period where EVs were no longer considered a solution, but in the 2010s, Tesla Motors introduced the Roadster. By the 2020s, automakers around the world were producing millions of EVs a year [8, 12].

At the same time, during the 2000s, the United States began research on smart grids under the Electric Power Research Institute in hopes of fully integrating this technology by 2023 [7]. With the 2001 electricity crisis and then the 2003 blackout, the US Energy Department began to take action to improve the power system. The most notable outcome was the introduction of the Smart Grid Initiative by the Energy Independence and Security Act of 2007, which aims to improve the US transmission and distribution grid. The Smart Grid Initiative seeks to accelerate the integration of renewable energy resources, reduce dependence on fossil fuels, and enhance the reliability and security of the electricity grid. This initiative also emphasizes active consumer participation in demand response [12]. In 2009, the smart grid was developed and integrated into energy infrastructure and renewable energy. Many of the power grid facilities have been at the end of their years, with most having a life of 25 years. Smart grids are improving the previous system all while slowly integrating renewable energy sources [4].

Both technologies arriving around the same time was no coincidence. With the goal of completely switching to renewable energy sources, almost all car companies have been introducing their version of electric vehicles to the public. This increase in EVs will cause slight problems within the power industry as the number of charging stations will increase and be introduced worldwide. The use of smart grids can help solve the solution to decrease the load on the power system and serve as a way to communicate between the EVs and the power system.

# III. Brief Technical Overview

The Smart Grid is a complex electric system which uses highly integrated grid infrastructure. This system uses advanced information and communication technologies, control technologies and advanced energy technologies to fulfill the demand for electricity and optimize resource allocation, ensure the security, reliability and economy of power supply, meet environmental constraints, ensure power quality, and adapt to power market development [4].

In addition to creating a more efficient power system, smart grids allow for the shift towards clean and low-carbon energy while improving the utilization of energy resources. Traditional power grids were meant to handle large, centralized power stations and is a rigid system, meaning it is not susceptible to change [8]. These power grids are a one-way communication system where power is generated and sent with nothing sent back to the grid. However, with the advancement of technology, the traditional grid can no longer handle the current needs. Smart grids allow for a two-way communication system, in which the power grid can send and receive information. The flexibility of the power system is increased as well as the adaptivity to new infrastructure, which need more control and monitoring. Smart power systems includes technological upgrades like demand response where the power grid produces an accurate amount of energy for that specific time [4].

The smart grid consists of three main smart features: smart transmission, smart demand, and smart meter [8]. Smart transmission refers to the distribution of power. The main idea of power distribution is that distribution centers receive the power generated by plants and then distributed to local sources such as homes. As mentioned previously, the traditional system is monitored as it is not susceptible to change. With smart grids, real time control and monitoring of the transmission line can be done. This means the system can analyze the data given and can make a decision without human assistance.

Another feature is smart demand, which is about the energy capacity of the power grid. The current power grid can only generate a specific amount of power, meaning it can only meet the demand of the consumers without being able to store additional energy [8]. This is one of the main reasons why the current grid cannot handle renewable energy sources. Renewable sources depend on the weather and are variable, which means the amount of energy differs at different times. Since the current power system has a maximum capacity, the excess energy produced by renewable sources cannot be used, making this system inefficient.  Smart grid technology allows energy to be stored and used when needed by tapping transformers up and down or managing reactive power.

The last feature is smart metering, which establishes a direct contact between the consumer and the power grid [8]. Mentioned previously, the traditional power grid is a one-way communication system where information is only given, not received. Smart grids allow the consumers to communicate with the power grid by collecting data on the power usage of consumers’ homes and sending it to the grid, allowing for efficient power production. In addition, consumers get a more accurate bill as they are being charged based on various factors like amount of power used and time of use.

# IV. Impacts on the Economy

With the need for electric vehicles rising, there is also an increase in the need for power, which affects the daily load cycle of generated power by the power grid. A solution is to use superconducting magnetic energy storage (SMES) to mitigate this problem as it levels the loads and as a result, steadies the voltage. The output voltage is dependent on the number of electric vehicles charging and the capacity of the SMES [13]. For a certain SMES capacity, the stability of the SMES increases as the smaller the number of electric vehicles is charging. In other words, as the number of vehicles increases, there should be a greater need for power. If this exceeds the capacity of the SMES, then it will not do as good a job in stabilizing the voltage.

This means the charging times must be accounted for when considering using SMES [13]. It was found that about 80% of users have a plug-in time of two hours or less while less than 1% have a plug-in time for more than 5 hours. In addition, the peak charging time was between 3-5 pm [14]. During the peak times, the power needed for charging stations could be split between the main power facilities and energy generated from another source, such as homeowners. The cost could decrease in the long run as there is a smaller load on the power facilities, and the homeowners could profit from their generated energy. However, one downfall may be the installation cost of such technologies for homeowners. The complete switch to EVs would guarantee an increase in vehicles at a charging station. For user accessibility, it is necessary for the charging time to be short to avoid long lines and produce an even greater power load.

This decision to implement smart grids is usually based on two main points, the most cost-effective grid model and the alternative connection methods of microgrids. However, before proposing the use of the minimal cut-set method (MCS), all factors (economic, reliability, etc.) should be considered [6]. This model assigns a probability to each connection between the microgrids and uses this to compare the effectiveness of the microgrids. The higher probabilities correlate with a more effective line. This selection process ensures the most efficient microgrid interconnections, but it may still be costly, leading to the issue of the tradeoff between cost and efficiency [6].

On the other hand, another take is to compare the strategies that are beneficial in perspective to the network operator and the commercial party. The main target is minimizing the network peak loads for the network operator, while charging costs for commercial parties. These strategies can be compared using the net present value (NPV), which is based on cash flow of the investment costs and the energy losses caused by the two strategies. There was approximately a 25% higher NPV when considering electricity prices for charging EVs, in contrast to strategies focused on minimizing network load peaks [2]. These cost differences are due to the variations in grid reinforcements as the prices are dependent on the congestion of the power supply as well as the availability of power during a specific time. Thus, active customer participation in electricity markets, particularly EV owners, is beneficial to the electricity delivery system.

Also, smart grids can be used to communicate between the charger and the power grid, so there is no need to generate additional power to account for electric vehicles through messaging platforms such as SMS text message [11]. Currently, many messaging platforms are available to the public such as email, text message, messenger, etc. Many companies use email to communicate with their customers, but email can be ineffective as the device has to be on for the message to go through. In addition, it reduces the communication between the customer and the power grid because it requires the user to be connected to the Wi-Fi or have cellular data. By using text messages, the user can immediately get an idea of how busy the power grid is and make a decision [11].

# V. Impacts On Society/Global context

Electrifying transport is one of the greatest contributors to reducing carbon emissions. The EU has made it their goal to install around one million charging stations by 2025 to take the first step into switching to sustainable energy sources [10]. As mentioned, the charging stations will create an immense load on the power facilities especially during busy times. There also might be a time where energy created by power facilities is not enough to meet the demand, so landowners may have to integrate some source energy producing technology such as solar panels. The energy produced by these homes could then be transferred to the main power facilities using smart grids [10]. However, this could be an inconvenience to many as some of their land may have to be taken to generate electricity. There would be ways to incentivize landowners, such as paying for installation of solar panels or even reducing the cost of their own electrical use.

Another problem that may arise is not having a place to put these charging stations. In the future, if the switch to EVs was made, all areas would have to have charging stations. This could be a problem in rural areas as it may have to be on homeowners’ property. One method is to find which areas (rural, suburban, and urban communities) could be used to place charging stations [9]. Based on the areas that generate a greater amount of energy during peak times, the energy could be used, and the homeowners paid for their efforts.

# VI. Impacts On Environment

Many countries have made it a goal to reduce their carbon footprint, which has caused an increase in demand for electric vehicles. Though using electric vehicles is thought to be using clean energy, the charging stations are still getting power from coal combustion, which is not doing any better for the environment compared to traditional gas cars. Implementing smart grids and renewable energy sources would allow for a better storage system and a communication server between the user and the power system [5]. Solar/wind energy could significantly decrease the carbon emissions compared to coal combustion. The main challenge is to find an efficient storage system for renewable energy. However, by having the smart grid interacting with the users, the prediction of the charging schedule is more accurate, which allows power stations to know which times are the busiest. During stagnant times, renewable energy sources could be used to begin shifting away from coal combustion.

In addition, the increase in EVs has created an issue of power load demand [1]. Some of the methods proposed to counteract this demand is the implementation of methods such as electricity pricing, but this is not the most effective when using it in real time and is counteractive in the long run. In other words, the price of charging vehicles incentives many people to switch to EVs, as it is much cheaper compared to the price of gas. If the charging prices were to increase, there would be no reason to switch. One solution to this problem is to use electric springs to reduce energy storage, which would account for this demand in power [1]. Originally, batteries were proposed as another form of energy storage, but batteries are not the most cost efficient and harmful to the environment.

As mentioned in the previous section, another solution to the power load problem was to consider the use of distribution grids. Distribution grids are not only dependent on the congestion of the power load, but also the weather forecast and the environment [2]. The current transmission grid is very effective as it can transfer power to people, but there are still a few setbacks such as environmental changes (blackouts), customer and market needs (pricing), etc. Transmission grids can be made ‘smart’ by adding three smart components (control centers, transmission networks, and substations) which in turn increases the number of smart features [3]. Two of the many smart features are resiliency and flexibility, which are one of the most important features. One of the main reasons many countries have trouble using renewable energy sources is that it is hard to get to remote locations and is very sensitive to environmental changes. This could be the first step, globally, to make the complete switch to renewable energy.

# VII. Future Of Smart Grids and EVs

Though the current transmission grid is very effective in transferring power to people, there are still a few setbacks such as environmental changes (blackouts), customer and market needs (pricing), etc. The one possible solution is to modify the current transmission grid by adding three smart components (control centers, transmission networks, and substations) to the transmission grids, in turn increasing the number of smart features it has [3]. Out of the many smart features, the two most important ones to consider are resiliency and flexibility because one of the main issues of using renewable energy sources is that it is hard to get to remote locations and is very sensitive to environmental changes. This would also allow many countries to integrate more environmentally friendly power sources and switch to renewable energy.

In addition to the environmental effects on the transmission grid, electric vehicles should also be considered. The switch to fully using EVs means there will be an increase in charging stations available. However, as mentioned in previous sections, the power system is influenced by the charging and discharging of these vehicles [13]. This would create an immense load on the power stations, which would cause long charging times. This is highly inefficient as it would cause large lines at charging stations and customers would also have to make more time to charge. The ability to be at gas stations for very little time is one of the reasons many people may not consider switching to EVs. A possible solution may be to consider using superconducting magnetic energy storage (SMES) as it levels the loads and as a result, steadies the voltage. SMES stability depends on the number of charging electric vehicles and the SMES capacity. No additional load be added on the power system if the number of vehicles charging is close to the SMES capacity [13]. This is where smart grids could come into play. Smart grids can also be used to communicate between the charger and the power grid so that there is no need to generate additional power to account for electric vehicles through messaging platforms such as SMS text message [11]. By using some platform to communicate with the user, the user can immediately get an idea of how busy the power grid is and then be able to decide based on that.

V. Conclusion

With the threat of global warming, many countries have been working towards achieving a low carbon emission footprint and increasing their use of renewable energy sources. This has caused a rise in the need for electric vehicles (EVs), which has brought challenges to the power grid construction. The main issue being power facilities being able to meet the new demand for power. With the integration of smart grids into power stations and charging stations for EVs, the load on the power systems is decreased.

The decision to implement smart grids has to take into account all factors as a whole (economic, reliability, etc.) to ensure the most efficient microgrid interconnection. One solution is to use SMES as it levels the loads and as a result, steadies the voltage. On the other hand, another take is to compare the strategies that are beneficial in perspective to the network operator and the commercial party. However, active customer participation in electricity markets, particularly EV owners, will benefit the electricity delivery system greatly. This also can be implemented using smart grids to communicate between the charger and the power grid, so additional power does not need to be generated to account for electric vehicles through messaging platforms such as SMS text message.

Another perspective to consider is with the increase in EVs, an increase in charging stations available for users will be needed. With the power load in mind, there may be a time power facility may not be able to meet the demand for power, and landowners may have to generate energy using technologies such as solar panels, which can be transferred back to the facilities. However, this could inconvenience many landowners as to generate electricity, some of their land would be used. There would be ways to incentivize landowners, such as paying for the installation cost of solar panels or even reducing the cost of their own electrical use.

Lastly, from an environmental perspective, using electric vehicles is a definite step in using renewable sources. However, the charging stations are still getting power from coal combustion, but by implementing smart grids with renewable energy sources would allow for a better storage system and a communication server between the user and the power system [5]. In addition, this modification allows the current transmission grids to increase the number of smart features such as resiliency and flexibility allowing them to be used in remote places and in harsh weather conditions.

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