

Research Paper

Design and Simulation of a Renewable-Powered Microgrid with EV Charging Infrastructure

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Abstract –

A growing number of people are turning to electric vehicles (EVs) as a means to combat the increasing pollution levels caused by greenhouse gas emissions and climate change. Electric vehicles have a major impact on grid load and voltage stability since they are increasingly connected to the power grid. Microgrid integration of renewable energy sources with electric vehicles is the focus of this research. The microgrid that is being studied has a diesel generator as its main power source, with renewable energy also being generated via a photovoltaic (PV) farm along with a wind farm. Furthermore, the ability to more easily manage the cycles of charging and discharging of electric vehicles is enhanced by strategically placing Vehicle-to-Grid (V2G) systems close to the microgrid's load. With the ability of renewable energy sources growing, microgrids are becoming more important for addressing the varied energy needs of institutions like hospitals, universities, and EV charging stations, as well as the larger community as well as industrial sectors. Maintaining EV operations, which affect grid stability along with energy management techniques, requires a reliable charging infrastructure. With the nonlinear circuit elements of EV systems in mind, this study investigates the dynamic impacts of microgrid networks including EVs. Additionally, it offers a comprehensive study and modeling of how the integration of renewable energy sources and the adoption of electric vehicles might improve the operation of microgrids, leading to greener energy solutions. In addition, the project presents a summary of the Matlab/Simulink microgrid analysis using EVs.

Keywords – Electrical Vehicle, Microgrid, PV System, RES, Stability.

1. INTRODUCTION

Electricity production, transmission, as well as distribution systems are the three basic components of a conventional electric power system. All of the loads in a certain area get their power from the distribution system, which is linked to the producing stations via transmission lines. Connecting separate power systems to create larger power pools is common practice for several reasons, the most common of which are technical and economic. Although they function autonomously, these area or regional electric grids are linked to create a utility grid. Thanks to technological advancements, new business models, and policy changes, power generating systems are currently going through an evolution toward increasingly complex and interconnected sets of systems on numerous levels. Vehicles driven by fossil fuels or ICEs, or internal combustion engines, have released large quantities of CO₂ into the atmosphere. Electric vehicles may use alternatives to traditional energy sources like gasoline and diesel, which include batteries, fuel cells, even ultra-capacitors. You may maximize efficiency by using these sources alone or in

combination with more conventional methods. For EVs, the battery is the main problem. New research, however, suggests that battery life is essentially a non-issue. To lessen the impact on the environment, electric vehicles are becoming more popular as a replacement for diesel and gasoline engines. Power-to-grid (G2G) and grid-to-vehicle (G2V) are two essential concepts in the electric vehicle industry. The most common way to charge electric vehicles is via the grid-to-vehicle, or G2V, connection. Technology that allows a vehicle to double as a generator is known as vehicle-to-grid (V2G) technology. When plugged into the grid, electric vehicles release their energy. In addition to balancing electrical loads, optimizing costs, combining renewable energy sources, decreasing peak energy usage, while keeping stable voltages and frequencies levels are some of the many uses for V2G technology. In order to achieve load profile flattening, it is very preferable to use the V2G optimal logic control strategy. To make sure the V2G process runs well, an aggregator is used. An aggregator is an online hub that connects service suppliers with customers who are looking to purchase digital services. When it comes to the problem of peak demand on the power

system as well as distribution network, V2G technology provides a workable answer. Many problems with distribution networks may be reduced with the use of good techniques. The impact of EVs on the distribution of electricity use is examined. The unpredictable character of travel patterns is the main problem with vehicle-to-grid technologies. Reducing the costs of electric car battery wear is possible via controlling charging patterns, which in turn reduces the costs of battery cycle life management. Delivering frequency regulation services via electric cars accomplishes the goal. The whole load profile is examined in relation to the effects of EV charging duration and EV battery efficiency. Minimizing environmental pollution and operating transportation and power supply system costs is the primary objective of optimizing V2G system operation. Improving the reliability, consistency, and quality of power supply is also important. In addition to putting a strain on the power infrastructure, the impending EVs will eventually generate electricity independently of the central authority. Electric vehicles (EVs) may serve as both a load and a generator for electrical power. This report presents the results of an investigation into a microgrid that includes the capture of electrical loads, EVs, and non-renewable as well as renewable energy sources. In addition, it will display the amount of energy produced by each source, investigate electric vehicles (EVs) both as a load as well as a means of energy, and determine how EVs affect grid performance and its ability to sustain peak loads. Analysis and modeling of microgrid integration of renewable energy sources with electric vehicles is the main emphasis of this work. The findings of the evaluation of the electrical grid with EVs have been verified using Matlab/Simulink, and this article summarizes those results.

2. TECHNOLOGY AND CHALLENGE INVOLVED IN EV

A. PROBLEM FORMULATION

Using the V2G strategy—which is based on the variable load demand—to decrease distribution system losses is the primary goal of the proposed research. The following equation forms the basis of the distribution system's power equations:

1) G2V

2) V2G.

B. V2G TECHNOLOGY

Electric vehicles and the power grid work together to manage energy and power, and both systems benefit from the other. Energy storage is usually not a part of the electrical system. The total capacity of the pumped storage facility is less than 2.2%. To adapt to changing consumer demand, it is essential to maintain efficient control and continuous management of energy production and transmission. Electric vehicles are cars that use electricity to

move, either directly or via a combination of the two. Hence, they are often likened to conventional cars powered by internal combustion engines. One major benefit of electric vehicles is its ability to produce or store electrical energy, even while at rest. They may contribute to the grid's electrical supply if they have strong links to various system auxiliary components. This connection type is known as a V2G connection. Electric vehicles may run on either battery power alone or a combination of battery and fuel cell technology. But the most important thing is to keep the electrical system powered up while it's not moving or parked. Peak power, regulation, and spinning reserves are the three most important characteristics of power markets. Because of the slow charging and discharging rates of batteries, electric vehicles that use them charge their batteries when power demand is low and discharge them when power demand is high, such when the vehicle is accelerating or in driving mode. Vehicles that use fuel cells may run on either gas or liquid fuel. Both of these modes are within the capabilities of PHEVs.

C. CHARGING CONTROL

1) HARMONIC CONTROL

Due to their role in the system's harmonic buildup, converters are essential components of battery charging systems. Using a multilayer functioning of the converter or the pulse width modulation technology may help control or minimize the occurrence of harmonics. To drastically reduce harmonics in the Root Mean Square (RMS) current, increase the pulse count. Furthermore, reactive power mitigation strategies may be used to keep the unwanted harmonics. Further power quality issues inside the system can be caused by harmonics, so it's important to keep an eye on things to deal with any unexpected problems as soon as they arise.

2) COORDINATED CHARGING

Concentrated charging, which may occur as a consequence of widespread EV charging, may affect power grid control. Consequently, we use coordinated charge to control the grid since it is a controlled load. Maximizing economic efficiency while reducing grid impact is the main goal of this technique. With the state of the grid, the peculiarities of the batteries' performance, and the needs of the consumers in mind, we mainly oversee the charging process. It also helps to regulate unwelcome variations in demand for load and prevents new peak loads from being generated. This method has the potential to make the distribution network more dependable, consistent with power, and economically efficient. Coordination of electric car distribution with the grid and charging scheduling are two key components of an efficient coordinated charging system. Since the grid had a hard time managing the billing process directly, the idea of a middleman came up. Using multi-agent technology is another way to accomplish this goal. Electric car integration

with smart energy systems naturally shortens charging times during peak hours.

D. FREQUENCY CONTROL AND V2G CHARGER

To keep the frequency between the permitted range, which is described as $f_0 \pm \Delta f$, frequency control is used to modify the active power output. There are three sub-controls that measure frequency adjustment metrics specifically. With the aim of decreasing the transient frequency with the Rate of Change of Frequency (RoCoF), primary control is a fast regulatory system that operates when a frequency deviation over the permitted threshold. A regulatory system known as secondary control intervenes after main control but has a delayed response time. No matter how far out of range the frequency gets, the objective is to maintain a constant value. After secondary control has been applied, tertiary control is used to fix the frequency and return it to an appropriate range. At present, nuclear or coal-fired power plants, which have great inertia and capacity, are responsible for providing tertiary control. Future power grids will likely use demand response technologies or long-lasting, high-capacity storage to manage tertiary control. After reviewing the research, it is reasonable to assume that V2G charges play a significant role in secondary frequency control. A V2G fleet's main and secondary regulated energy and power must comply with all applicable laws and market procedures. To encourage EV fleets to provide secondary frequency control, a market auction is used to compensate for activation and capacity reserve.

3. ANALYSIS OF THE MICROGRID WITH EV

There are two parts to an electric vehicle. Electric cars are propelled by an electric motor and their batteries are powered by an internal energy source. To power their batteries, electric cars need to be connected to an external power source. In these conditions, charging the vehicles is essential. Electric vehicles charge using a variety of methods. Different types of charging stations are distinguished by the voltage and speed with which they charge. Improvements in electric vehicle range and reductions in charging times are two of the biggest obstacles to the industry's continued growth. To address these challenges, researchers are now undertaking thorough experiments that are continuing. It is recommended to charge an electric automobile utilizing DC in order to speed up the charging process. For electric vehicles, we shorten the charging time by increasing the ability output of the stations. As a result, there is a steadily increasing number of charging facilities with powers more than 350 kW. At the charging stations, you may charge numerous cars at once thanks to the various plugs. Major problems may arise inside the microgrid as a result of charging several cars at once. The growing demand for grid services is a major

concern. Figure 4.2 shows a concept of a microgrid that incorporates RES and electric vehicles. There are four parts to the microgrid that are being studied. Renewable energy is produced by a PV plant that incorporates wind turbines, while diesel generators are the primary source of electricity. Additionally, we use the V2G technology to place a strain on the network. One hundred electric vehicles and one thousand energy-efficient homes make up the microgrid load in this area. One out of ten homes have an electric vehicle. A step toward environmental preservation is increasing the production of renewable energy. Energy production from renewable sources, however, is very sensitive to external factors. Precise control of basic values, like as current as well as voltage, which are shown by 50 Hz sinusoidal waveforms, is essential to microgrid systems.



Fig. 1: Minimization objective functions of electrical vehicle integration into the distribution system.

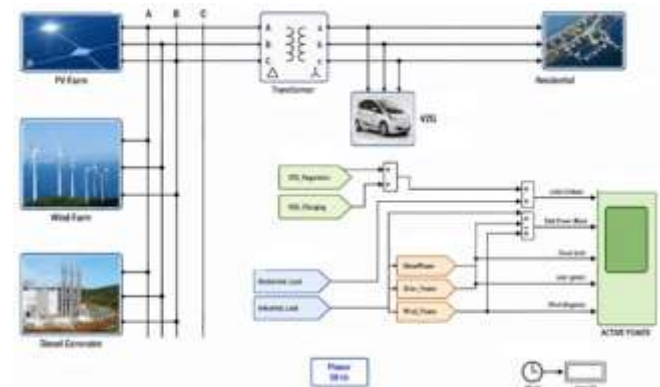


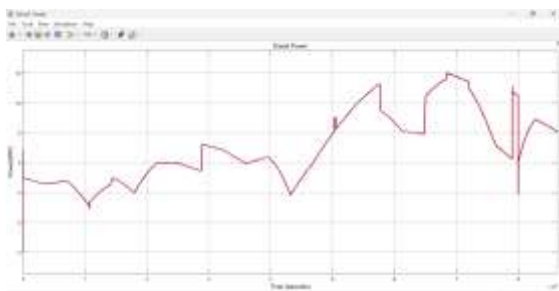
Fig.2: Microgrid and electrical vehicles.

Nevertheless, the introduction of undesirable harmonic components into the microgrid system occurs when these fundamental factors lose their sinusoidal characteristics for a variety of reasons.

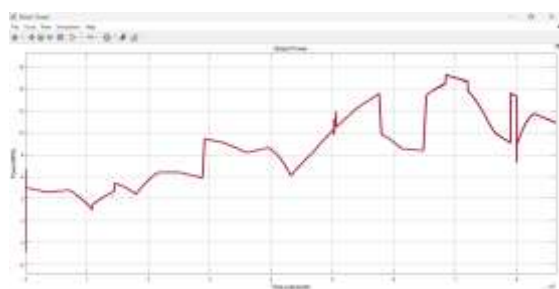
4. SIMULATION RESULTS

With an analysis of load modifications to the system modeling, the simulation results here show the current and suggested waveforms. Nevertheless, the

introduction of undesirable harmonic components into the microgrid system occurs when these fundamental factors lose their sinusoidal characteristics for a variety of reasons. An already straining microgrid is going to be much more so as the number of EVs continues to skyrocket. The microgrid becomes more unpredictable as a result. In order to keep the microgrid's power consumption and generation in balance, a diesel generator is installed. Finding the difference between the grid frequency and the synchronous machine's rotor speed will reveal the source of the frequency differential.

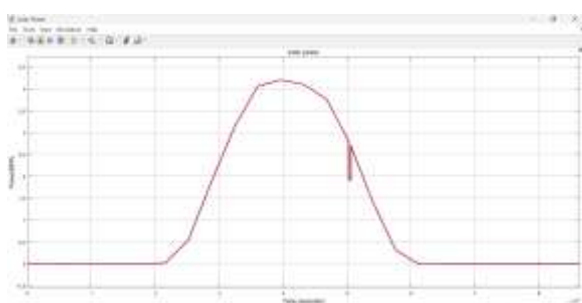


Existing system

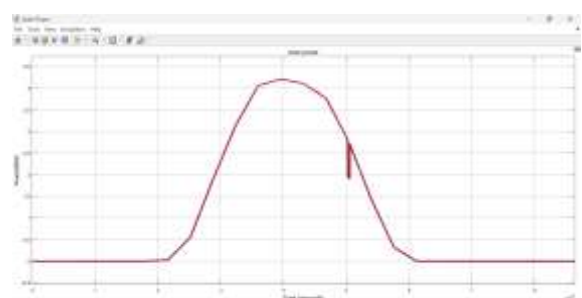


Proposed system

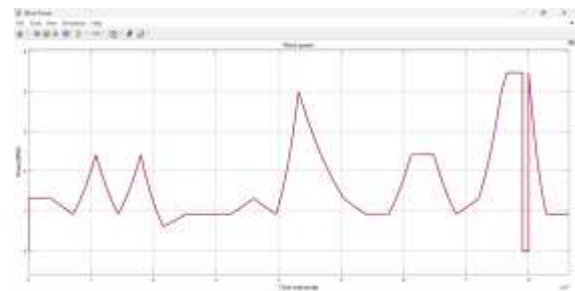
Fig. 3: Power generated by the generator throughout the day.



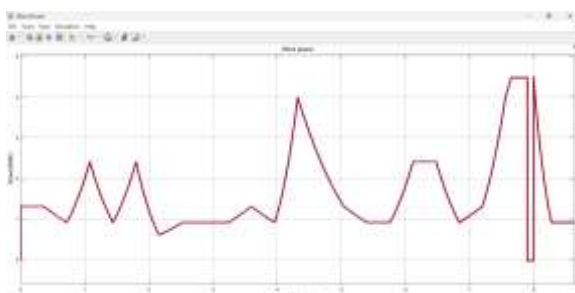
Existing system



Proposed system
Fig. 4: Power generated by the solar throughout the day.



Existing system

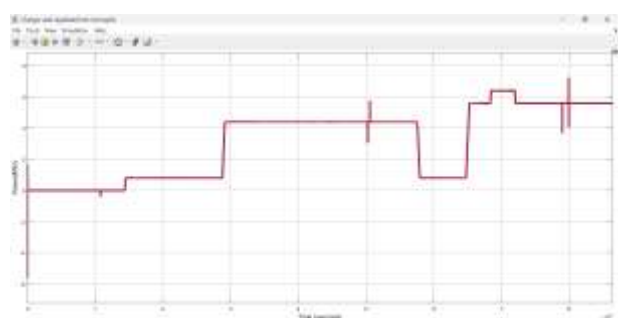


Proposed system

Fig.5: Power generated by the wind throughout the day.

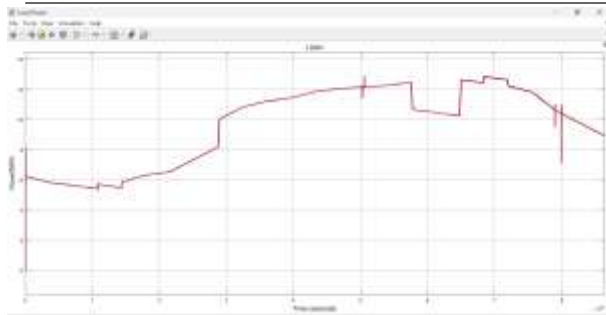


Existing system

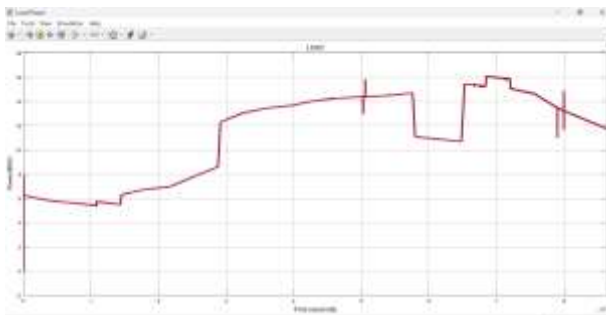


Proposed system

Fig.6: Charged and regulated into the microgrid throughout the day.

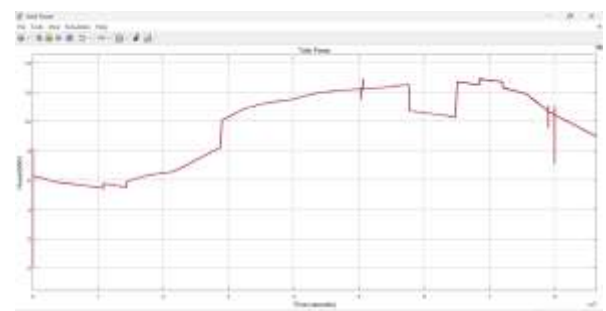


Existing system

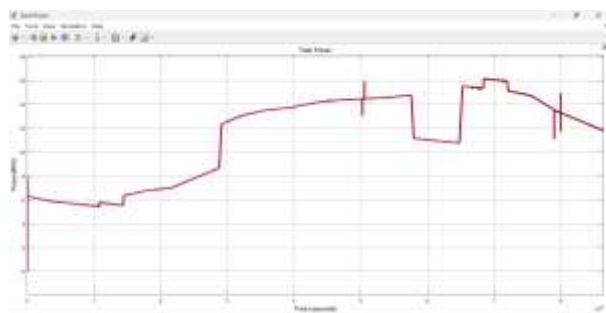


Proposed system

Fig.7: Load drawn power from the microgrid during the day.



Existing system



Proposed system

Fig.8: Total power generation from microgrid during the day.

The cumulative energy production of the diesel generator throughout the day is shown in Figure 3. Diesel generators are problematic due to their high price tag and negative effect on the natural world. However, a diesel generator is needed to provide the appropriate amount of electricity

when sources of clean energy can't fulfill the need. Two different types of renewable energy make up the microgrid. To begin with, the amount of irradiation in the immediate surroundings has a direct correlation to the amount of energy generated by the PV plant. Solar panels display their energy production throughout the day in Figure 4. Microgrid solar farms collect sunlight and convert it into direct electricity. Solar panels' ability to absorb light, the quantity of light reaching them, and the weather all have a role in determining the final energy production. The amount of electricity generated by the wind farm is proportional to the wind speed. When the wind speed hits the set point, the turbine will generate as much electricity as it can. Whenever the wind speed goes beyond a certain threshold, the microgrid switches off the wind power until the wind speed goes back down to a normal level. The microgrid wind farm's daily energy generation is shown in Figure 5. Wind power plants are becoming more popular in microgrids as a result of their efficiency, simplicity, and position as a sustainable energy source. When compared to more traditional power plants, wind farms stand out. The capacity to use vehicle-to-grid (V2G) applications is the main advantage of electric vehicles. Electric vehicles are the only ones that can use this app. What it really does is lets the vehicle feed power into the distribution microgrid. The value of power that the EV regulates and transfers to the microgrid is seen in Figure 6 throughout the day. Transmission of electrical energy from electric vehicle (EV) battery systems to a microgrid is known as vehicle-to-grid (V2G) technology. In an electrical system, EV batteries store energy for later use. Thanks to developments in car-to-grid technology, indications like energy consumption or output may trigger the charging or draining of a vehicle's battery. When the microgrid is experiencing peak energy consumption, the use of electric car charging causes the demand for electricity per transformer to increase. Attaining energy balance is greatly complicated by this. When a large number of electric vehicles are charged simultaneously, it causes a microgrid phase imbalance. Electric vehicle (EV) spontaneous charging causes major problems for the microgrid. There may be a drop in voltage at the charger connections if several EVs are being charged simultaneously. There are power losses in the microgrid since EV charging uses a lot of network active power. There are two main purposes for vehicle-to-grid technology. During transient occurrences, it stabilizes the grid by managing the power source charge and using the available power. The instant availability of existing decentralized energy storage devices is ensured by V2G technology. The market is flooded with a myriad of new battery kinds. Active power received at a certain power factor represents the home load, as shown in Figure 7. The active power

produced by the microgrid is a measure of the overall power generated, which is either more than or equal to the load. Figure 8 shows that demand and generation have reached a balance.

CONCLUSION

As distribution networks continue to grow, the adoption of electric vehicles (EVs) is becoming more inevitable. Distribution system concerns may become more severe as the number of EVs on the road continues to rise. Voltage control in the microgrid is achieved by the decrease of reactive power. Power transmission line power losses may be reduced by reactive power assistance, which also increases the power factor. It also leads to increased productivity. Connected electric vehicles may provide reactive power changes to the microgrid. Examining different EV charging techniques is the main emphasis of the research, which aims to analyze the functioning of a freestanding microgrid. Solar irradiation, wind speed and direction, and the anticipated load demand all feel the pinch of uncertainty. Given the increasing number of electric vehicles on the road, it is critical to study their power quality in depth, paying close attention to harmonic components in particular, and then put measures in place to address these issues. As the number of electric vehicles on the road continues to rise, so does the network of charging stations. A fast evolution of electric vehicles is required to keep up with the current rate of change in the transportation sector; this has far-reaching consequences for the environment and the power grid.

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