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STUDY OF BATTERY ENERGY MANAGEMENT FOR EV UNDER CONDITION HYBRID BESS AND V2G IN MICROGRID

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Abstract

This paper discusses the installation of electric vehicles (EVs) integrated with battery energy storage systems (BESS) in the setting of transferring energy from vehicle-to-grid (V2G) to a microgrid distribution system, employing the IEEE 13 bus standard. The EVs have a power rating of 4.8 kilowatts (kW), while the BESS has a power rating of 500 kW. The overall design connects These systems to the three-phase bus, utilizing the daily load profile. Bus settings are available on 632, 633, 634, 671, 675, and 680 buses. The power flow computation in the Open Distribution System Simulation (OpenDSS) program is utilized by the simulation. Results of a research investigation comparing the implementation of EVs and BESS within microgrid systems. The study's findings were compared to both the regular system and the system that was implemented. The highest and minimum values of the per-unit system exhibit equality. The aggregate power distribution for active and reactive power exhibits a negligible disparity of less than 1 %. Regarding the power loss value in both active systems, namely free and reactive, a marginal difference of less than 1 % exists. The presence of the backup power supply does not have any impact on the primary testing system utilized in the experiment.

Keywords : Electric vehicles, Battery energy storage systems, V2G

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Introduction

The rapid advancement of renewable energy technologies and the need for sustainable energy solutions have brought about significant transformations in energy management. The primary modern energy conversion is the integration of electric vehicles (EVs) Y. Fu et al. (2019) Tie, S. F., & Tan, C. W. (2013) M. Al-Muhaini. (2020) K. Yenchamchalit et al. (2021) and battery energy storage systems (BESS) P. Prabpal et al. (2021) M. Noosawad et al. (2023) within microgrid systems. Managing battery energy storage and electric vehicles can significantly change energy generation, storage, and transfer. Microgrids M. Al-Muhaini. (2020), called microenergy systems, are becoming more popular as dependable and successful substitutes for conventional centralized grids. These self-contained networks, which can operate independently or in conjunction with the primary power grid, can meet the energy needs of certain towns, academic institutions, or industrial complexes that rely on microgrids. Integrating EVs and BESS within microgrid systems presents a promising opportunity to realize numerous advantages and effectively tackle critical issues within the energy sector. The EVs have emerged as transformative innovations in the transportation sector, presenting a cleaner and more sustainable alternative to traditional vehicles powered by internal combustion engines. Through recent improvements in battery technology, EVs have acquired the capacity to store and distribute significant quantities of electrical energy efficiently.

The characteristic attribute of EVs allows them to function as portable energy storage devices, enabling them to take advantage of their battery packs to enhance the stability and resilience of microgrids. Integrating EVs into microgrid systems enables the practical storage and utilization of surplus energy derived from renewable sources. This integration reduces dependence on fossil fuels and encourages the adoption of renewable energy. The distinctive attribute of EVs allows them to function as portable energy storage devices, enabling them to utilize their battery packs to enhance the stability and resilience of microgrids. BESS increases the performance of EVs within microgrids by providing stationary energy storage capabilities. BESS utilizes advanced battery technologies to store excess electricity generated during low-demand or high renewable energy output periods. The previous steps' energy stores can be utilized during periods of high demand or inadequate renewable energy generation. Appropriate supply and demand management is critical in enhancing microgrids' stability, reliability, and resiliency, and BESS plays a crucial role in achieving this balance.

Additionally, they contribute to efficiently incorporating intermittent renewable energy sources, optimizing energy utilization, and reducing wastage. Integrating EVs and BESS within microgrid systems promises a paradigm shift in sustainable energy management. The consumption of EVs is not limited to transportation purposes but extends beyond their integration as active elements within the energy ecosystem. Through harnessing the capabilities of EVs and BESS microgrids, we can mitigate the ecological consequences of energy usage, diminish the release of greenhouse gases, and facilitate the shift toward a more sustainable and decentralized energy landscape.

The present article aims to explore the diverse facets of integrating EVs and BESS into microgrid systems. This study will examine the subject matter's advantages, technological obstacles, regulatory factors, and possible uses. In acquiring a comprehensive understanding of these interconnected relationships, we can establish a trajectory toward an energy infrastructure characterized by enhanced efficacy, adaptability, and ecological sustainability. It effectively meets the needs of present and future generations. The renewable energy sector has seen significant transformations due to the rapid advancement of renewable energy technology and the increasing need for environmentally sustainable energy alternatives. Integrating EVs and BESS into microgrid systems represents a significant area of progress. The convergence of electric mobility and energy storage could fundamentally transform the methods by which electricity is generated, stored, and disseminated. Microgrids, often denoted as localized energy systems, are gaining popularity as dependable and efficient alternatives to conventional centralized grids. These self-contained networks can fulfill the energy demands of specific communities, universities, or industrial complexes. They can operate autonomously or in conjunction with the primary power grid. Integrating EVs and BESS into microgrid systems allows for leveraging diverse benefits and addressing pressing concerns within the energy landscape. EVs have significantly transformed transportation by offering a more sustainable and ecologically conscious option than traditional vehicles powered by internal combustion engines. Advancements in battery technology have facilitated the capacity of EVs to store and distribute substantial quantities of electrical energy efficiently. As a result of this notable characteristic, EVs are positioned as portable energy storage devices capable of utilizing their battery packs to enhance the robustness and reliability of microgrids. EVs possess the potential to be seamlessly incorporated into microgrid systems, facilitating the efficient storage of surplus energy generated by renewable sources. This research concept of stored energy may subsequently be utilized during periods of demand, thereby diminishing reliance on fossil fuels and fostering the adoption of renewable energy sources. BESS plays a crucial role in augmenting the performance of EVs within microgrids by providing stationary energy storage capabilities. BESS employs advanced battery technology to store surplus electricity generated during low-demand or high-renewable energy production periods. Subsequently, these accumulated energy reserves can be discharged during peak demand or when renewable energy generation falls short. Implementing BESS enhances microgrids' stability, dependability, and resilience by effectively managing supply and demand equilibrium.

Moreover, they smoothly incorporate intermittent renewable energy sources, optimizing energy efficiency and minimizing wastage. Integrating EVs and BESS within microgrid systems is a ground-breaking approach to sustainable energy management. EVs can serve dual purposes by functioning as integral components of the energy system and as means of transportation. Microgrids can mitigate the adverse environmental impacts associated with energy consumption, reduce the emission of greenhouse gases, and facilitate the shift towards a more sustainable and decentralized energy landscape through the effective utilization of EVs and BESS. This discussion will comprehensively examine the various aspects of integrating EVs and BESS inside microgrid systems. This analysis will examine the benefits, technical challenges, legal considerations, and possible applications associated with the subject under investigation. By comprehensively understanding the synergistic relationships involved, it is possible to develop an energy infrastructure that is more efficient, resilient, and environmentally sustainable while meeting the needs of current and future generations.

Problem Formation

Battery Energy Storage System

The main objective in energy management is to maintain constant power flow and minimize losses during the operation of microgrid systems. The power flows from the inlet of the electric vehicle (EVs) and battery storage for V2G to the microgrid. The objective of this research is to investigate strategies for energy management during the installation of 3-phase electric car loads within a microgrid distribution system that adheres to the IEEE 13 bus specifications. The study will investigate the effects of utilizing energy from Vehicle-to-Grid (V2G) technology and its integration with Battery Energy Storage Systems (BESS). This research is centered on the topic of energy management inside microgrid systems and the effects on the distribution system. The active power for EVs loads at the interface with the grid and the storage element is calculated by reducing the power that charges and discharges storage. The OpenDSS M. Noosawad et al. (2023) Dugan, R.; Montenegro, D. (2020) Celso Rocha et al. (2020) calculated power flow simulation at time instant for time-varying over the time interval unit. The charge state can be used if the energy stored (kWh) is less than the capacity storage rated (kWRrated). The power flow within the charge state by the storage element is illustrated in Figure 1.

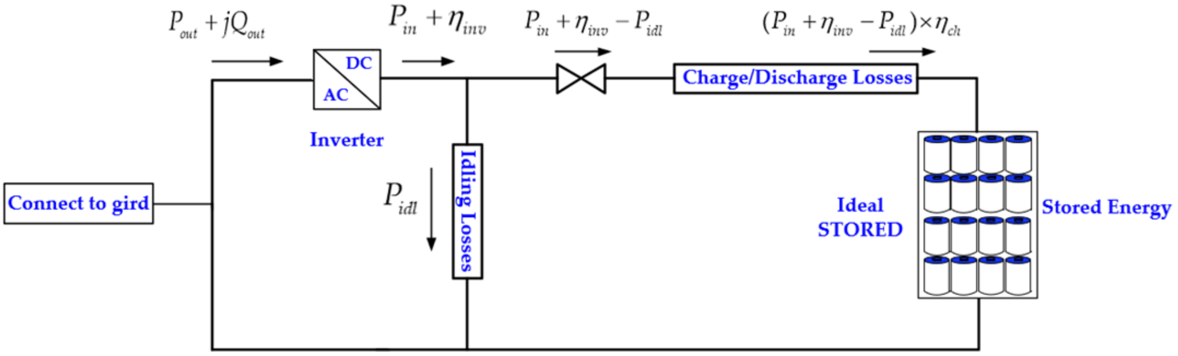

Figure 1. The power flow charging of BESS Celso Rocha et al. (2020).

The power flow solution interfaces with the storage element and has the power ($P_{in}[t]$) to determine the storage inverter losses as shown in Equation (1) Celso Rocha et al. (2020) follows:

$$P^{ch}_{losses,inv}[t]=P_{in}[t]\times(1-\eta_{inv}[t]) \tag{1}$$

Where $P^{ch}_{losses,inv}[t]$ is the power of the storage inverter charge for BESS $P_{in}[t]\times(1-\eta_{inv}[t])$ is the power storage inverter at the DC side, and P_{idl} it supplies the idling losses. The storage inverter losses can be calculated by charging losses analogous as shown in Equation (2) Celso Rocha et al. (2020) follows:

$$P_{losses,ch}[t] = (P_{in}[t] \times \eta_{inv}[t] - P_{idl}) \times (1 - \eta_{ch}) \tag{2}$$

Thus, the total power losses are

$$P^{ch}_{losses,tot}[t] = Losses^{ch}_{inv}[t] + P_{idl} + P_{losses,ch}[t] \tag{3}$$

Where the ideal of storage power effectively is determined by Equation (4) Celso Rocha et al. (2020) follows:

$$P^{ch}_{eff}[t] = (P_{in}[t] \times \eta_{inv}[t] - P_{idl}) \times \eta_{ch} \tag{4}$$

Alternatively, shown as Equation (5) Celso Rocha et al. (2020) follows:

$$P^{ch}_{eff}[t] = P_{im}[t] - P^{ch}_{loasses,tot}[t] \tag{5}$$

The step simulation time at the energy stored is given by Equation (6) Celso Rocha et al. (2020) as follows:

$$E[t + \Delta t] = E[t] + P^{ch}_{eff}[t] \times \Delta t \tag{6}$$

The state of the storage discharging element is a determining factor in the quantity of energy that is stored. The discharge state can be used as capacity energy, the amount of energy stored. The parameter of discharge rate is either defined with a positive value (kW) or a percentage of the kW rate (%Discharge). The power flow state of discharge within the storage element can be seen in Figure 2.

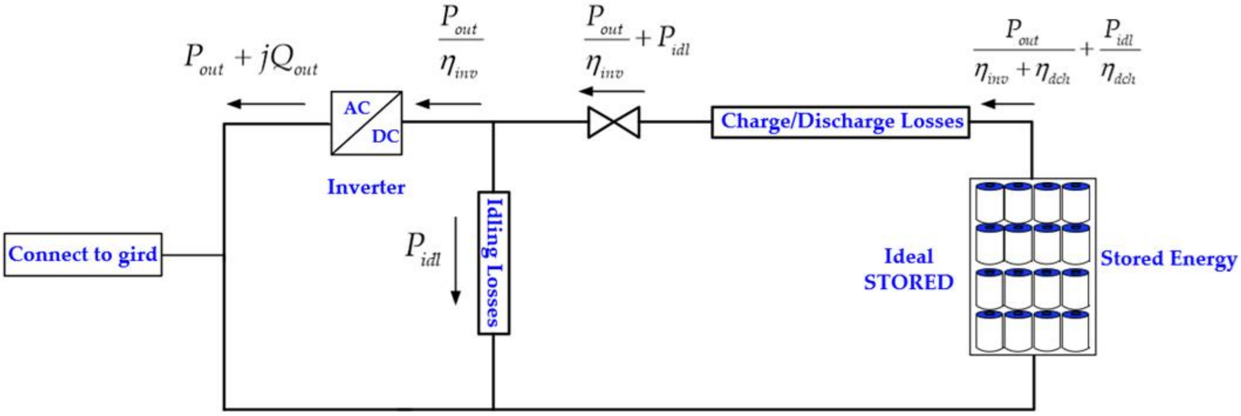

Figure 2. The power flow discharging of BESS Celso Rocha et al. (2020).

The power flowing out of the storage element has, therefore, been determined from the storage solution, and the determined storage inverter losses are calculated as follows:

$$P^{dch}_{losses,inv}[t] = P_{out}[t] \times \left(\frac{1}{\eta_{inv}[t]} - 1 \right) \tag{7}$$

The power at DC supplies is ideal for storage at the inverter, along with the discharging and idling losses. The discharge losses can be given as follows Celso Rocha et al. (2020):

$$P_{losses,dch}[t]=\left(\frac{P_{out}[t]}{\eta_{inv}[t]}+P_{idl}\right)\times\left(\frac{1}{\eta_{inv}[t]}-1\right) \tag{8}$$

The calculated total losses with the discharge state are as follows Celso Rocha et al. (2020):

$$P^{dch}_{losses,tot}[t]=P^{dch}_{loasses,inv}[t]+P_{idl}+P_{losses,dch}[t] \tag{9}$$

The power of effective discharge ($P^{dch}_{eff}[t]$) in ideal storage is determined as follows Celso Rocha et al. (2020):

$$P^{dch}_{eff}[t]=\frac{P_{out}[t]}{\eta_{inv}[t]\times\eta_{dch}}+\frac{P_{idl}[t]}{\eta_{dch}} \tag{10}$$

So, it is.

$$P^{dch}_{eff}[t]=P_{out}[t]+P^{dch}_{losses,tot}[t]\quad[W] \tag{11}$$

Therefore, the time step following the energy stored is given by Celso Rocha et al. (2020):

$$E[t+\Delta t]=E[t]-P^{dch}_{eff}[t]\times\Delta t \tag{12}$$

Power Flow Controller

The power flow problem is solved in a computer simulation using the Open Distribution System Simulation (OpenDSS) R. Dugan, J. Taylor and G. Delille. (2013) N. Thaitae et al. (2023) B. Yosrueangsak et al. (2023) software. OpenDSS is open-source software for computer simulation in electrical power flow analysis. The solutions of power flow simulation are current flow mode, daily time, snap-shot, dynamics, annual, harmonic, parametric, fault current study, and probabilistic study. The parameters of a microgrid in the OpenDSS R. Dugan, J. Taylor and G. Delille. (2013) are the component generator, transformer, transmission line, capacity, load, electric vehicle (EV) load, battery energy storage (BESS), and vehicle-to-grid (V2G), as shown in Figure 3.

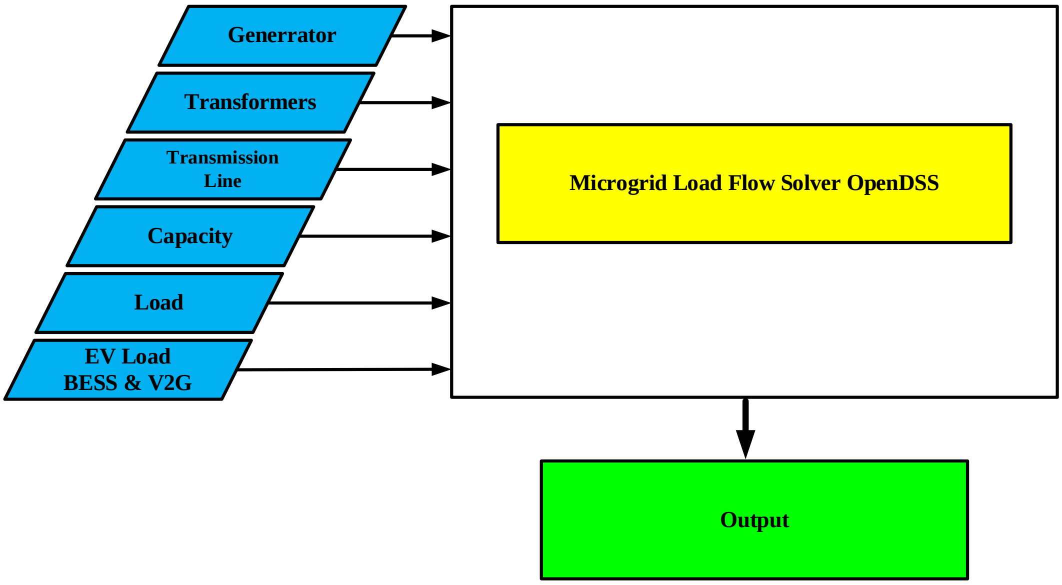

Figure 3. The power flow controller for BESS and V2G for EV loads in the OpenDSS N. Thaitae et al. (2023).

V2G Electric Vehicle model

Amidst mounting apprehensions over climate change and the imperative for sustainable energy alternatives, the EV sector has experienced swift expansion and notable technological progress. Propelled by rechargeable batteries, EVs have become a crucial element in the worldwide shift towards a more environmentally friendly and sustainable energy landscape. Simultaneously, integrating intermittent renewable energy sources into the electrical grid has prompted advancements in grid management and energy storage techniques. V2G technology emerges as a potentially disruptive approach to effectively tackle the difficulties mentioned above. V2G signifies a fundamental transformation in the dynamic between EVs and the electrical grid, as it bestows upon EVs the ability to serve as energy consumers and prospective energy providers. V2G technology empowers electric cars to engage in bidirectional communication with the electrical grid. It allows them to discharge their stored energy into the grid during periods of high demand and absorb surplus energy during off-peak hours. The bidirectional communication between electric vehicles EVs and the electrical grid can improve the stability and dependability of the grid, as well as optimize energy consumption, lower expenses, and enable the seamless integration of renewable energy sources. The use of V2G technology in the broader context of electric mobility and energy management poses a range of complex obstacles and potential advantages. There has been significant interest among researchers, politicians, and industry players in gaining a thorough knowledge of the consequences of V2G deployment. It includes assessing its viability and examining its influence on the electrical grid, energy economics, and environmental sustainability. This scholarly model provides a valuable contribution to the ongoing discussion by giving a methodical and analytical framework for evaluating the incorporation of V2G technology into the electric grid. Our proposed model aims to examine fundamental inquiries of the implementation of V2G technology, encompassing its technological feasibility, economic viability, and environmental advantages. Moreover, the primary objective of this study is to provide a comprehensive understanding of the ramifications of V2G technology on the stability of electrical grids and its capacity to optimize energy use within the framework of dynamic energy environments. In the forthcoming sections of this scholarly framework, we shall explicate our research methodology, elucidate the constituents of the V2G model, show our empirical results, and provide a whole discourse on our study's ramifications and potential uses. Our model aims to offer significant insights that can guide decision-making processes, contribute to sustainable energy solutions, and facilitate the development of a more resilient and efficient electrical grid as electric mobility and smart grid technologies progress.

Proposed Methodology

This paper explores the methodologies employed in constructing system simulations utilizing the IEEE 13 bus standard systems. The standard system parameters include the generator, transmission line, transmission line distance, voltage regulator, and load. The installation of EV and BESS is being implemented in the IEEE 13 bus model, as depicted in Figure 4. The simulation is an essential component of the research study. The EV size was set to 4.8 kW, and the BESS size was set to 500 kW using the OpenDSS software. The EV and BESS were implemented in a phased manner across multiple bus loads, specifically on buses 632, 633, 634, 671, 675, and 680. The power flow simulation entails the analysis of a daily load profile that incorporates three-phase demands originating from EV and BESS.

Result and Discussion

The study analyses the implementation of EVs and BESS within a microgrid system. The base case parameters from the system are max-min p.u. of the system, active-reactive power, and active-reactive loss. The next step of the simulation is to install the EV load and BEES test under the condition that the EV size is set to 4.8 kW and the BESS size is set to 500 kW. Set EV and BESS to 6 bus conditions. There are buses 632, 633, 634, 671, 675, and 680. The results are categorized into typical system testing, serving as the foundation case for studying, data collection, and comparison between systems with EVs and BESS installations. Table 1 displays the study's parameter analysis outcomes, which examined the variables influencing the system. Table 2 presents a comparative analysis of the discrepancies observed among bus setups compared to the standard system. The study's results on the factors impacting the system suggest that the active voltage present in EVs and BESS throughout a 24-hour load scenario could be represented by the voltage supply and demand, as shown in Figure 5 the active power. Figure 6 illustrates the reactive power generated by EVs and BESS.

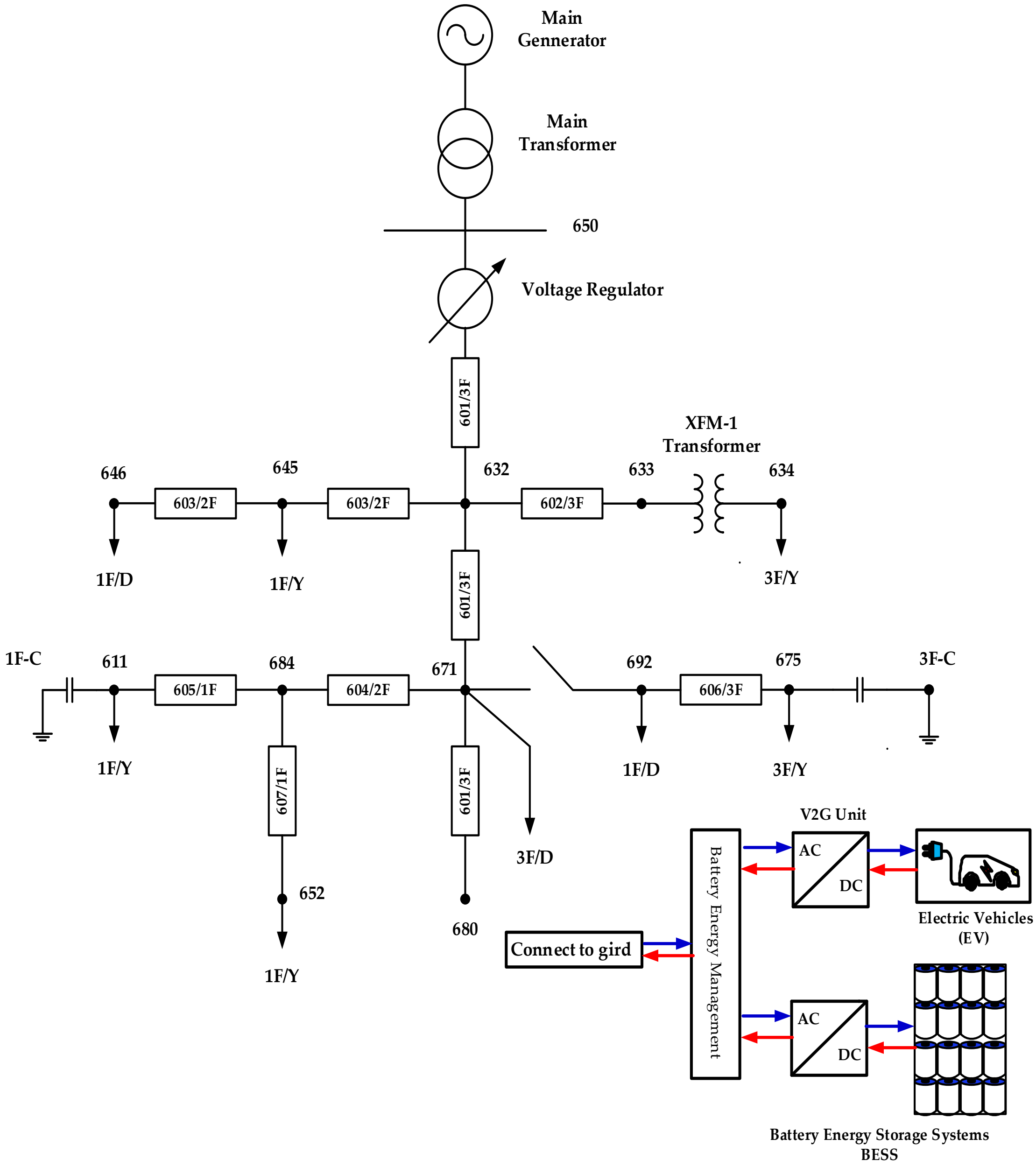

Figure 4. IEEE 13 bus test system.

This paper provides a comprehensive overview of the research findings of the impacts of integrating Vehicle-to-Grid (V2G) technology in conjunction with Battery Energy Storage Systems (BESS) into a microgrid distribution system. Following examination, it becomes evident that when comparing the outcomes of regular systems, one will observe that the maximum and minimum values of the per-unit system exhibit a resemblance, with a discrepancy of no more than 1 % the total active power. The active power contribution of the bus is less than 1 % of the total. However, the reactive power values of buses 632, 633, 671, 675, and 680 exhibit a reduction, while bus 634 has a comparatively more significant gain.

Table 1. Simulation result.

Result data	*Base case*	*Bus 632*	*Bus 633*	*Bus 634*	*Bus 671*	*Bus 675*	*Bus 680*
1. Max p.u. voltage	*1.0545*	*1.0538*	*1.0538*	*1.0588*	*1.0553*	*1.0555*	*1.0553*
2. Min p.u. voltage	*0.9973*	*0.9923*	*0.9923*	*0.9906*	*0.9936*	*0.9936*	*0.9936*
3. Total Active Power (MW)	*2.4109*	*2.4089*	*2.4087*	*2.4100*	*2.4097*	*2.4098*	*2.4097*
4. Total Reactive Power (Mvar)	*0.8556*	*0.7609*	*0.7611*	*0.8809*	*0.7707*	*0.7735*	*0.7706*
5. Total Active Losses (MW)	*0.0526*	*0.0524*	*0.0522*	*0.0531*	*0.0523*	*0.0525*	*0.0524*
6. Total Reactive Losses (Mvar)	*0.1215*	*0.1431*	*0.1429*	*0.1453*	*0.1433*	*0.1435*	*0.1434*

Table 2. The compare data form installs EVs and BESS.

Result data	*Base case*	*Bus 632*	*Bus 633*	*Bus 634*	*Bus 671*	*Bus 675*	*Bus 680*
1. Max p.u. voltage	*1.0545*	*-0.0664*	*-0.0664*	*0.4078*	*0.0759*	*0.0948*	*0.0759*
2. Min p.u. voltage	*0.9973*	*-0.4993*	*-0.4993*	*-0.6728*	*-0.3720*	*-0.3760*	*-0.3720*
3. Total Active Power (MW)	*2.4109*	*-0.0830*	*-0.0896*	*-0.0361*	*-0.0518*	*-0.0465*	*-0.0506*
4. Total Reactive Power (Mvar)	*0.8556*	*-11.0725*	*-11.0490*	*2.9535*	*-9.9280*	*-9.5995*	*-9.9357*
5. Total Active Losses (MW)	*0.0526*	*-0.4490*	*-0.7540*	*0.9352*	*-0.4842*	*-0.1553*	*-0.4397*
6. Total Reactive Losses (Mvar)	*0.1215*	*17.7737*	*17.5992*	*19.6033*	*17.9630*	*18.1136*	*18.0255*

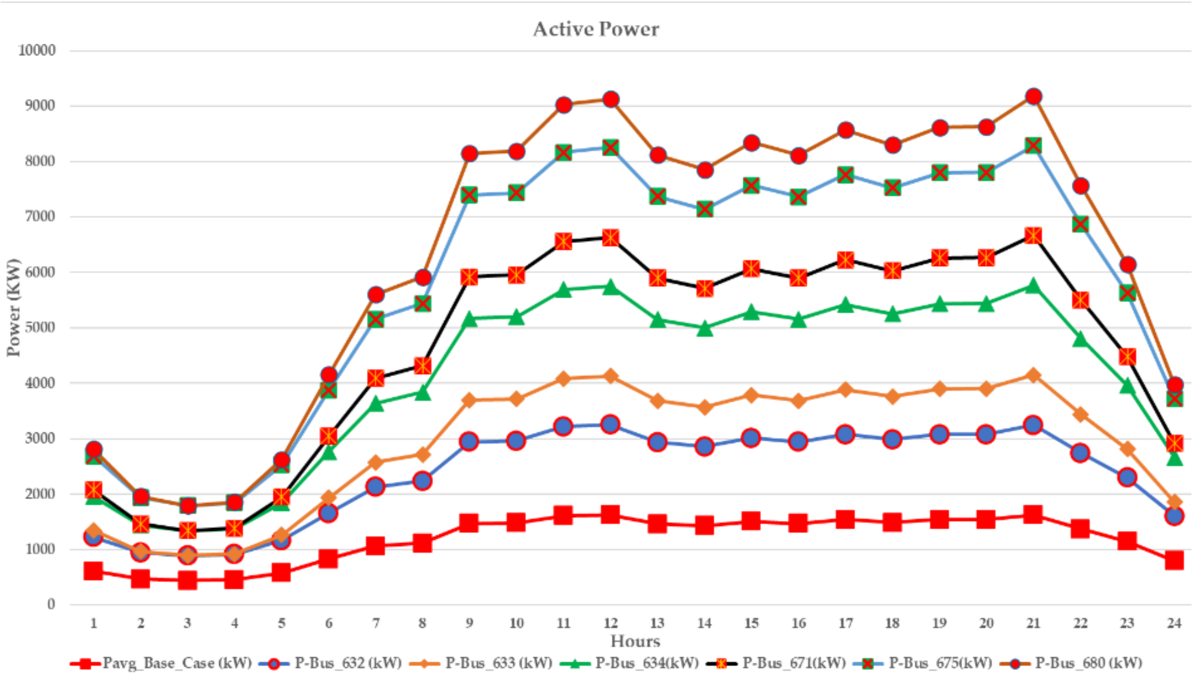

Figure 5. Active power in EVs and BESS.

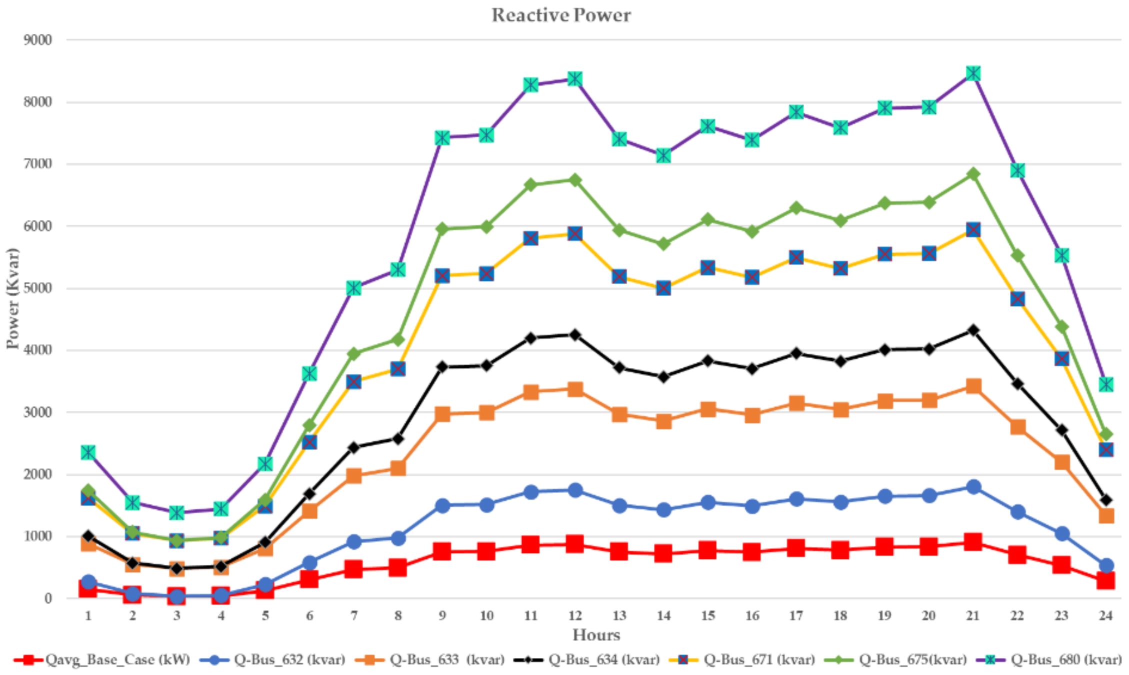

Figure 6. Reactive power in EVs and BESS.

Conclusion

The experimental results indicate that installing EVs and BESS in the IEEE 13 bus standard test system yielded no significant overall outcomes. The system exhibits a minimal fluctuation in values, yet it yields outcomes. The data presented in Figures 5 and 6 demonstrate that the system can effectively provide power with enhanced efficiency. Importantly, this power supply has no adverse effects on the original system. Experimental observations conducted on the final bus of the system indicate that the original system typically experiences losses. The power and power supply exhibit typical functioning, allowing for the utilization of the installed equipment. The research hypothesis and research objectives indicate that the implemented system has the potential to enhance the efficiency of the electrical system. Energy management is employed to enhance energy efficiency by using measurement techniques to assess the performance of energy systems. Installing a power backup system in a research setting can establish a sense of stability within the electrical infrastructure. The system will undergo additional growth and development at other locations to assess the effects of installation and conduct an economic analysis of the investment required for its implementation in the future. It is currently conducting tests and simulations to evaluate the outcomes of installations as a component of forthcoming research endeavors.

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