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Study of Recent Trends and Topology of Electric Vehicle Charging Through DC Microgrid

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Abstract: This article analyses the DC microgrid used for electric vehicle charging. The development of the DC microgrid concept has improved electric vehicle charging performance and minimized charging duration. This article outlines the DC microgrid, with its design and control strategies for managing and protecting energy. Focus is given on research of the EV charging station and its topology on the basis DC microgrid.

Keywords: Electric vehicles, DC microgrid, DERs, Charging station, Islanded mode

1. INTRODUCTION

Changes in climate and the dependence of the auto industry on fossil fuels have caused severe ecological challenges. With strict regulations in countries worldwide regarding carbon dioxide and other harmful carbon emissions, this is the worst situation. Alternative solutions have been explored concerning plug-in hybrid (PHEV) and plug-in (PEV) electric vehicles. Predictable growth in electric vehicles requires their charging systems to be simultaneously developed. A lack of proper loading stations currently exists. Also, current charging stations have different effects on the grid, including fluctuations, interruptions in voltage, harmonics, etc. Additional charges will be imposed, particularly during peak hours, by integrating electric vehicles in the current grid. All those factors have increased scientists' interest in using renewable energy sources for electric charging stations as an alternative energy source. Recent literature research has shown that photovoltaic materials are the first choice for charging electric vehicles. Microgrids' concept has recently been predicted as a distributed power generation integration method, owing to the increased penetration of renewable energy systems. Improvements in power electronic circuits have further enriched this prospect.

V.A. Juliet et.al.[5] analyzes technical problems such as the energy management strategy and the DC bus voltage maintenance, regardless of overloaded grid. MATLAB/Simulink modeled the proposed Energy Management Strategie (EMS), and its different operating modes were checked. Also, a test prototype of a lab scale has been developed and achievement from the suggested prototype charge station was examined. This paper contributes greatly to the EMS algorithm development in different scenarios for the Multiport Battery Electric Vehicle (BEV) charge station and experimented in MATLAB / SIMULINK.

B Aluisio. et al. [6] proposed a linear, mixed-integer procedure to determine optimum DC supply infrastructure operational planning. As per the PV and EV mobility forecasts, the process is intended to optimize the daily operation cost, including the operator and owners of EV microgrid several EV usage indicators are drawn. The approach is applied during various operating days compared to a non-linear DC microgrid resolved by using a genetic algorithm

F Locment et al. [7] have suggested that the EV charging stations should be supported by a direct current microgrid algorithm for real-time, regulatory-based charging stations. This paper focuses on an EV charge station for power management strategy under power constraints and considers most drivers' choices. This article examines an EV charge station's real-time management strategy with power limitations. It takes most drivers' needs into account from combining theory and practice in which driver choices, disconnecting, standby, shedding, and restoration are included. The arrival time for the electricity transmitters, the original State of Charge EV, and the drivers' choice is random, emphasizing an uncertainty concerning EV charging behavior. Smart shedding and restore operations are suggested according to the same theory as the computer stack.

Benedetto Aluisio et al. [8] implemented a techno-economic assessment procedure for the Electric Vehicle Supply Infrastructure (EVSI) microgrid configuration of DC. It aims to reduce economic investment efforts and lifetime microgrid management. Real spatial and technical constraints and various operational conditions based on EV requirements and availability of nonprogrammable renewable sources are mainly taken into account. The analyzed configuration consists of feasible combinations with an excellent interface to the low-voltage AC distribution network, converters, modular panels, Energy Storage Systems (ESS) elements, and electricity loading stations. In the area of the Port Authority (Italy), the proposed process is applied to the dimensioning of a microgrid.

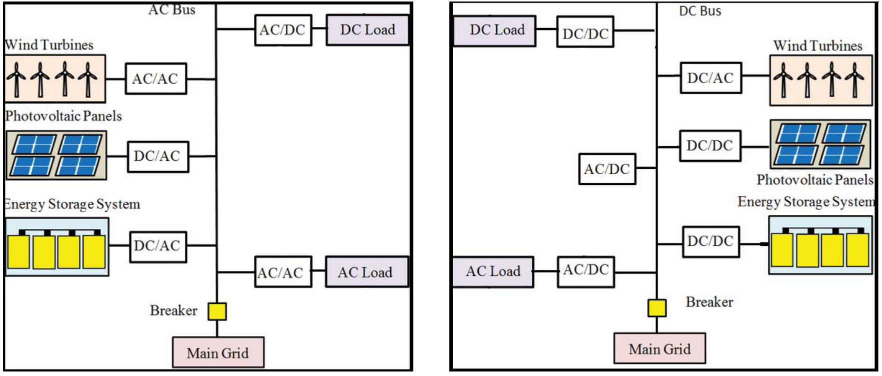
Chao-Tsung Ma et al. [9] focusses on system planning and key technologies review of electric cars' grid-connected charging stations. These current system configurations revise the related design methods, algorithms, and key EV Charging Stations (ECS) technology system. The most popular ECS configuration, based on discussions in the documents examined, was a hybrid system integrating renewable energy generation and various energy storage systems (ESSs), and electricity grid systems. Noteworthy is that by adding an ESS with properly designed control algorithms, rapid fluctuating power demand for charging, smooth intermittent REBP G generation, and the overall efficiency and operational flexibility of the ECS can be buffered time. Also, the importance and potential benefits of portable ESS in ECS networks are verified as a possible research topic in the field of ECS, with many potential applications of portable ESSs on the full technical spectrum of grid-connected ECS.

Microgrid, which is a well-known concept to scientists that allows DC and AC support. Many authors define micro Grid, which integrates power and loads distributed and can work in on-grid or islanded mode, as a small voltage or medium voltage grid [1]. In this paper, much literature is studied on Electric Vehicle (EV) charging through DC microgrid. The detailed discussion of the DC microgrid is given in Section-2, including design, control, and protection. Section-3 describes the EV charging architecture details are provided with some collected user data. The review's conclusion is in Section-4 with the research gap in the general literature study.

2. DC MICROGRIDS

2.1: Overview

A microgrid is typically embedded with distributed generation, load, and energy storage devices confined in closed proximity that utilizes renewable energy for clean and green energy. It includes solar distributed energy, wind power, etc., which can run parallel to the public grid and a specialist energy storage unit and load connection. In the literature on the widespread use of microgrids, microgrids' great benefits for owners and available grids are addressed. Various authors include the design, protection, monitoring, and energy management of microgrids. The primary AC and DC microgrid architecture is shown in Figure 1.



AC DC

Fig.1 Basic Microgrid Architecture

2.2: Design of DC Microgrid

DC microgrid consists of solar photovoltaic (SPV), wind energy with battery storage systems for basically DC loads and home electrification, and EV charging shown in Fig 2. Voltage Source Converter (VSC) integrates wind turbines to DC microgrids to maintain constant DC voltage. For SPV, DC-DC boost converters are used, and the generation is controlled to keep the power balance. Many studies have examined the design of DC microgrids. A simplified model, representing load performance under DC operation, is the first requirement for reliable and effective microgrid design [20]. The process of microgrids in isolated and non-isolated modes was emphasized. DC power systems' feasibility has become clear, mainly when DC loads' penetration rate is high, and highly developed efficient technology for power electronics is available [2].

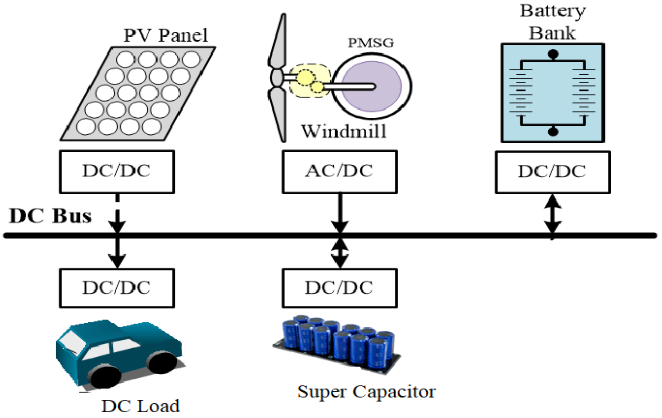


Fig 2: Typical-configuration-of-DC-microgrid

2.3: Control techniques and Energy Management in DC Microgrids

The isolated microgrid is not reliable to a greater extent due to inconsistency. So, diesel generators or gas-operated generators are usually used to increase the remote DC microgrids' reliability. Different optimization techniques and algorithms are used for effective energy management by employing hybrid energy storage systems like batteries and supercapacitors [18]. The progress of DC microgrids and electricity grids primarily depends on applying appropriate monitoring strategies and effective energy management between the different microgrid components. Suitable energy management can ensure minimum voltage fluctuations for high efficiency, efficient energy distribution between power sources and loads, and equal and stable sharing of current among various energy sources and the best economic and technical conditions. There has been a lot of work in the literature about microgrid control strategy and energy management. A new model is used to quickly optimize stable and transient control problems for large-scale power systems [22].

2.4: Protection of DC Microgrids

Implementing a proper protection mechanism for DC microgrids is a very challenging task. The different issues like the rapid increase of DC fault current can lead to sustained arcs, ground fault, fault location, and significant issues [20].

Although DC microgrid is now a perfect network model for distributed power generation, it is essential to solving DC failures' localization and protection. Many protection schemes in the literature have, over the years, been proposed. The unit protection and non-unit protection system can be divided. Unit protection schemes are designed to protect certain areas of the system under fixed constraints such as transformers, generators, busbars, etc. In contrast, non-unit protection schemes are not limited to any such requirements. The proposed system is analyzed to target the distributed ring structure of the microgrid under different fault conditions. The differential current-based solution is used to detect multiple DC photovoltaic microgrids quickly. This study is aimed at detecting and protecting short-run microgrid faults [19].

3. DC MICROGRID BASED EV CHARGING STATIONS

The DC microgrid based charging stations based on photovoltaic, wind with other sources allow the charging of electric vehicles and supply other domestic DC loads [2], shown in Fig 3. The DC microgrid is modelled using a Maximum Control structure (MCS) and Energetic Macroscopic Representation (EMR).

The loading of the energy storage unit is an essential part of the operation of a vehicle. The charging process is conductive or inductive for electric vehicles. The electric contact between the charger and the vehicle's charging point transfers the battery pack's power. Inductive charge uses wireless energy transmission by electromotive force coupling. Charging has been carried out by electric vehicles worldwide, whereas inductive charging remains in the early development stages. Charging systems are split in terms of rated power into standard, medium power, and high power. Slow loading, fast charging, or fast loading can also be divided depending on the loading time [3].

Compared to internal combustion engine vehicles, electric vehicles' charging time should be as short as possible. Therefore, it is evident that electric power vehicles are combined with commercial fast-charging stations, and fast-charging stations consist of several high-performance charging points. FCS presents two topologies such as standard AC bus and DC bus various AC-DC and DC-DC EV chargers [4]. In addition to EV charging relatively minimized to its State of Charge (SOC), quick charging can also increase productivity and reduce operating costs.

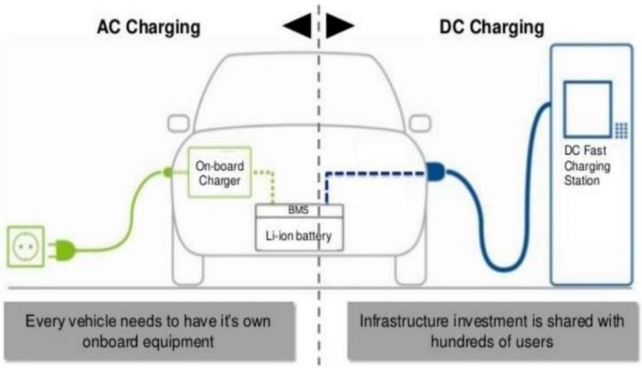


Fig 3: Charging Station for EV

Moreover, it is well-known that fast chargers are more powerful than conventional chargers, and battery efficiency can be improved by charging less overburden [10].

3.1: Renewable Energy Sources

The Distributed Energy Resources (DERs) like solar, wind, and fuel cells are considered the primary sources embedded with batteries and supercapacitors as energy storage devices.

Diesel and gas generators are integrated to increase the system's reliability and efficiency, leading to better energy management. Solar and fuel produce DC power directly, whereas wind turbines with an induction generator or Synchronous Generator converted to DC with a power electronic interface [2].

PV systems use solar panels, and multiple solar cells are generated in each solar panel. Solar cells are the fundamental components of solar panels, able to work efficiently at lower ambient temperatures. By the principle of the photoelectric effect, light electricity is converted directly to electricity. After installation, photovoltaic solar power generation will not cause pollution and harmful greenhouse gas emissions; therefore, it has special advantages as an electricity source and simple power requirement scalability. Also, the earth's crust contains lots of silicon. With increasing temperatures, solar cells' energy efficiency changes little. With this change of temperature and radiance, results are non-linear curves between voltage-current and power-voltage. There is only one maximum power point that varies with radiance or temperature at any point in time. For this reason, to extract full power in all weather conditions, the DC-DC converter needs a maximum power point tracker. The MPPT technique is used to match the maximum power point at operating voltage and current [8].

So far, many MPPT policies have been tracked. You can divide them into processes that are offline, online, and hybrid. This paper reviews offline methods, including OC voltage methods, SC current methods, and artificial intelligence methods; P&O methods are involved in online methods. The MPPT algorithm for perturbation and observation (P&O) is widely used because of its easy application. MPPT technology, where the MPPT parameters can alter the converter performance

under dynamic conditions. This method enables the efficient use of P&O MPPT to be improved with stable oscillations reduced and the algorithm to lose its tracking direction eliminated. The MPPT algorithm closes the MPPT and minimizes oscillation and raises the amount of interference phases. This technology provides an improved performance dynamic response with a convergence period of 12ms (approximately 99,6%). Other writers have listed many other literature techniques [11].

3.2: DC Bus Arrangement

DC bus connects photovoltaic arrays, power storage units, battery packs for electric vehicles, and electric circuits. The DC bus can improve system efficiency and reliability in comparison with the AC bus. Also, the required power conversion steps are reduced, losses are reduced, and the control algorithm is simplified [7]. The DC bus provides faultless energy management and encourages opportunities to integrate more renewable sources of energy. Fig 4 shows the DC bus arrangement for EV charging to incorporate renewable energy sources such as solar, wind, and ESS in islanded mode.

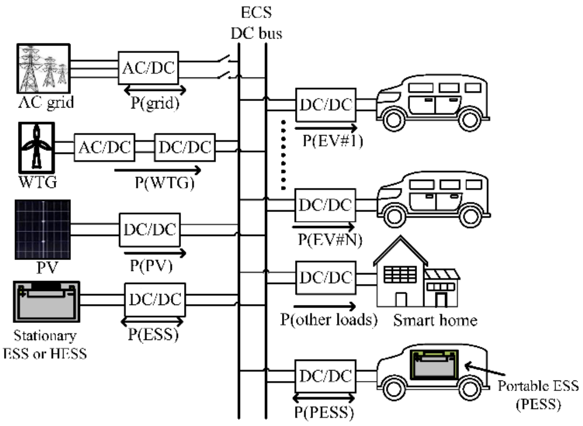


Fig 4: DC Bus Arrangement for EV Charging

3.3: Power Electronic Circuitry

With reduced losses and simplified control algorithms, the DC bus can provide full energy management and promote more renewable energy sources.

Diverse factors, such as rated current and voltage, loss of power while switching, and several other dynamic characteristics, are used to select power-electronic circuits for charging vehicles. Charging facilities of electric vehicles should be improved effectively. The various power electronic equipment electric vehicle required is described in Figure 2.

Earlier, the traditional DC-DC boost converter was preferred by most researchers for high-voltage applications. The output voltage of the power converter is, however, limited due to the transmission gain ratio. Also, the self-parasite properties of the power supplies reduce the voltage and efficiency of the output. Boost technology today includes further components of the driver or inducers [20], and different converters are shown in Fig 5.

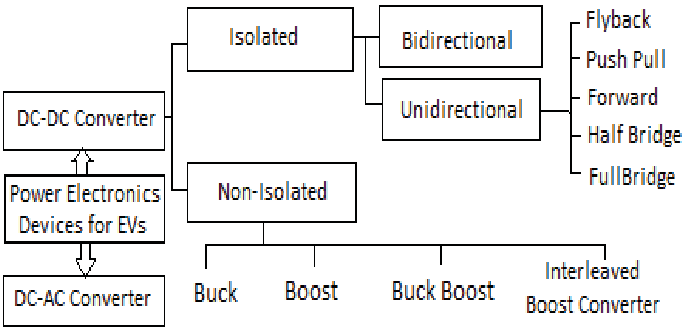


Fig.5: Classification of Power electronic devices used in EVCS

Many hypothetical solutions are provided to increase the output voltage, particularly to isolate the load-side to ensure that the DC-DC converter operates with high voltage. By using the closed-loop PI control technology, the DC-DC boost converter greatly increases the output voltage. A bidirectional DC-DC half-bridge converter model is proposed, suitable for the electric drive unit's power-electronic interface and the primary hybrid electric vehicles energy storage system. The bi-directional DC-DC conversion topology for EV batteries connected to the DC microgrid with an HV conversion ratio. Charging and discharge rates were 96% and 95%, respectively, with high efficiency. For MW-level DC charge of PEV through grid-connected neutral dot clamp converter, Sebastian Rivera et al. proposed an architecture. The proposed converter reduces the DC-DC fast charger's step-down work. It also offers a mechanism to balance the DC load with any changes.

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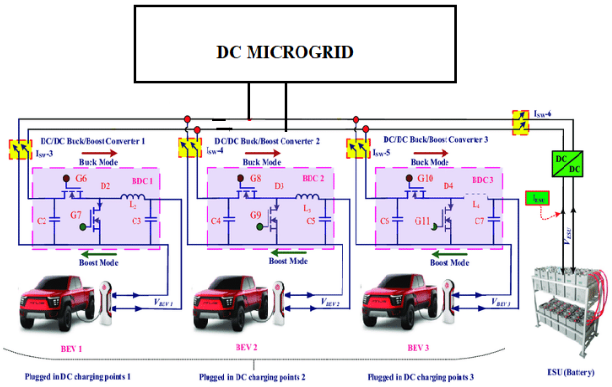

Fig 6: Power Electronic Interface for EV Charging through DC Microgrid

3.4: Impacts of Charging Station on Grid

In every country/region of the world, PEV and PHEV are adopted. The electricity generation or plug into a power outlet may charge these vehicles. However, charging electric vehicles will have different effects on the power distribution network. They consume a large quantity of electric power, contributing to additional burdens and unwanted high demands. These effects are divided into positive and negative effects. Increasing demand, voltage instability, reduced power quality, transformer overheating, and overload all have adverse effects. Vehicle advantages to grid technology include positive impacts. The impact of the electric vehicle charging power system on voltage stability was discussed in this study. The researchers described different problems of electric vehicles' energy quality. The integration of high-speed electric charging reduces grid stability in steady-state. Further studies on the impact of vehicle charging on peak demand and the grid were performed in the literature [5].

4. CONCLUSION

A stable platform can be replaced by critical electric vehicles worldwide in the coming decades due to worldwide concerns about global climate change and the degradation in air quality due to exhaust emission, the rapid deterioration in crude oil worldwide, and the noise pollution caused by fossil fuel-based automobiles—cars based on Noisy ICE. The objective is to develop charging equipment using DC microgrid devices for electric vehicles. This paper reviews and discusses different aspects of DC microgrid solutions for control, protection, and energy management. The researchers examined many facets of electricity charging stations' efficient and reliable operation. The study shows that integrating electric vehicles and renewable energy into the DC microgrid is an emerging and successful technology to meet electric vehicle charging needs. The DC microgrid can be seen as providing high voltage, short charge time, and space for future research for electric cars. Various optimization techniques and Homer Grid Software, EV charging software, and OPAL-RT emulation and simulation software can be used for the fast charging of electric vehicles with cost analysis for stable and reliable operation in the islanded well grid-connected mode.

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