INTEGRATION OF ELECTRIC VEHICLE, UTILITY GRID, AND RESIDENCE POWER FLOW CONTROLS

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Abstract: Various electric vehicle charging and discharging strategies (EVs) and V2G technologies are discussed in this article as their impacts on energy distribution networks. The V2G application that can be used on vehicles offers many benefits, as demonstrated. Features such as active power regulation, reactive power support, load balancing, and current harmonic filtering are incorporated into this technology. Although V2G technology has many benefits, there are also several challenges. These challenges include reduced battery life, communication overhead between EVs and grids, and changes in distribution network infrastructure. The article briefly discusses the effects of electric vehicle penetration levels, charging profiles, and various other aspects of controlled charging and discharging from a performance perspective. This includes overloading, deteriorating power quality, and power loss. A comprehensive analysis of controlled and uncontrolled charging–discharging methods, delayed charging–discharging methods, indirect controlled discharging methods, bidirectional charging–discharging methods, and intelligent scheduling is presented in this study.

Keywords: V2G technology, Electric Vehicle, Comprehensive analysis

1.0 INTRODUCTION

Electric vehicles (EVs) are becoming increasingly popular as a result of their low emissions and less reliance on fossil fuels. The number of EVs on the road has risen significantly in recent years, partly due to their increasing efficiency and range. The increasing use of EVs, especially when supplied through RES, may significantly contribute to the moving towards a minimal-carbon economy and to achieve the EU's goal of decreasing greenhouse gas emissions by 80–95% by 2050. Incorporating EVs into the electrical grid may provide a significant response to the problem of the intermittency of RE resources. This intermittency may be addressed by deploying an EV fleet for providing backup power or energy storage. In this context, the EV has the potential to enhance the cost-effectiveness of RE production. Energy flow from an EV to the grid (V2G) and the power flow from grid-to-vehicle (G2V) are two functionalities that allow EVs to have a bidirectional relationship with the electrical grid The performance of a power system may be enhanced by the use of the V2G technology, which can also increase system stability, dependability and efficiency A distributed storage system can be implemented with EVs and can be used for charging. The battery of the vehicle, especially during peak times, can be used to provide electricity to a grid, which improves system reliability

2.0 RELATED WORKS

In the literature, in a new hybrid AC/DC MG clustering architecture is proposed. This architecture is both scalable and reconfigurable, and utilizes a decentralized control strategy for coordinated operation. The architecture involves a hierarchical clustering approach that allows MGs to operate autonomously while being coordinated with other clusters. In a comprehensive review of EV integration and vehicle-to-grid (V2G) operation in active distribution grids is investigated [1]. It covers a range of topics related to power architectures, grid connection standards and typical applications provided. In a proposed MG architecture integrates both AC and DC power sources, and provides autonomous power flow control. The system is designed to be reconfigurable and can adapt to changing energy needs and supply sources. The architecture is based on a hierarchical control structure, with multiple levels of control to ensure efficient and reliable operation [2]. Microgrids are small networks composed of different distributed energy resources, frequently linked to an integrated national grid that is able to operate in grid connected or islanded mode, and can be controlled by different control techniques such as traditional droop controller, modified droop controllers, and PQ controllers technology discharges energy back to the grid to improve grid utilization, level demand, and improve reliability for utilities of the future [3]. It can be used to support the utility grid services with stability increase and reliability of the network [4]. The control of active power (P), and reactive power (Q) between electric vehicles (EVs), and microgrids through bidirectional energy flows make them to be considered distributed energy storage (DES) units [5]. The owner of electric vehicle is able to control the charging and discharging times and, thus, can be used as sources of income because they can sell excess energy to the utility grid operators. V2G enables energy to be pushed back to the utility grid while Grid-to-Vehicle (G2V) is the process in which electric vehicles are charged via the power grid [6]. Therefore, it is very easy to control and monitor power flow in Vehicle-to Home (V2H or V2B), and its implementation is not difficult compared to Vehicle-to-Grid because the reverse power interface is not required, but islanding detection capability and other power quality delivery detection interfaces [7]. Different models of charging are considered depending upon the software package. Meanwhile, in energy planning, the four models considered include a dumb battery charger, flexible demand, smart charger, and V2G charging that contains EVs charging control based on different electricity tariff models [8,9]. As the United Nations set guidelines for climate change and greenhouse gas emission limitations, many industries and researchers are still carrying out research on the development of different electric vehicles based on emissions and consumption.

3.0 METHODOLOGY

V2G' stands for "vehicle to grid" and is a technology developed that allows energy generated by an electric car to be sent back to the power grid through the vehicle's battery. Electric vehicle-to-grid tech, also called car-to-grid, refers to the ability of a car's battery to charge and discharge depending on local energy production or consumption so that a car's battery can be recharged and discharged according to specific signals EDVs can provide electricity to grids even when parked or dormant; vehicle-to-grid power charge generation must occur when the vehicles are in motion. Various electric vehicles exist, such as fuel-cell cars, battery-electric cars, and plug-in hybrids. In order to avoid peak energy consumption, battery electric vehicles can be recharged during slower periods of demand [10]. In electric vehicles, either liquid or gaseous fuel generates electricity Electric-drive vehicles (EDV) may be operated conventionally or in an electric mode if equipped with plug-in hybrid technology. Every vehicle requires the following three components: (a) a network connection for power flow, (b) a logical interface for control with the grid operator, and (c) an onboard instrumentation system that monitors the vehicle.

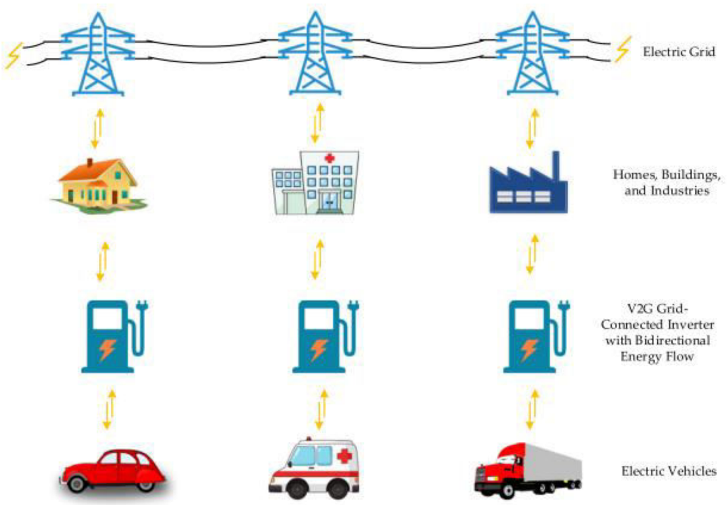

Figure 1: Applications of vehicle-to-grid technology

Proposed system

The proposed system is divided into two distinct subsystems: the on-board EV battery charger and an off-board conversion system that is external to the EV and processes the battery power flow to the network and/or to the residential loads. In addition, local energy

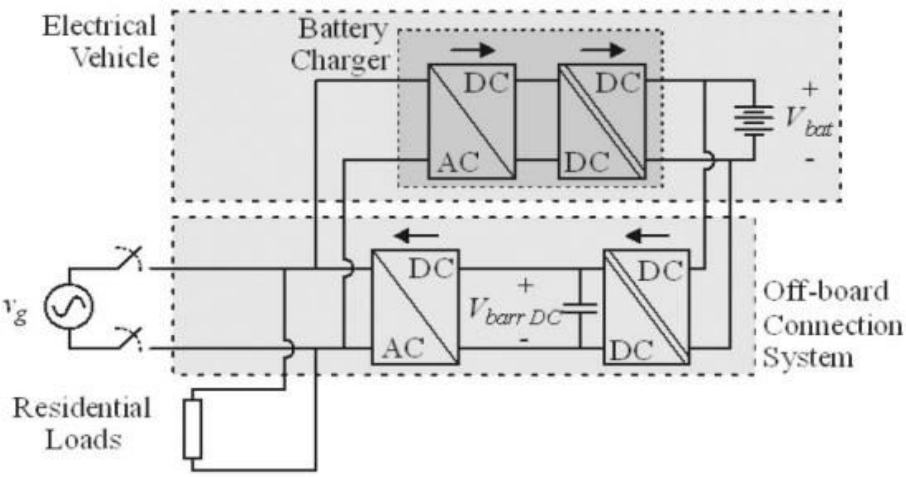

Figure 2: Proposed system with two unidirectional subsystems.

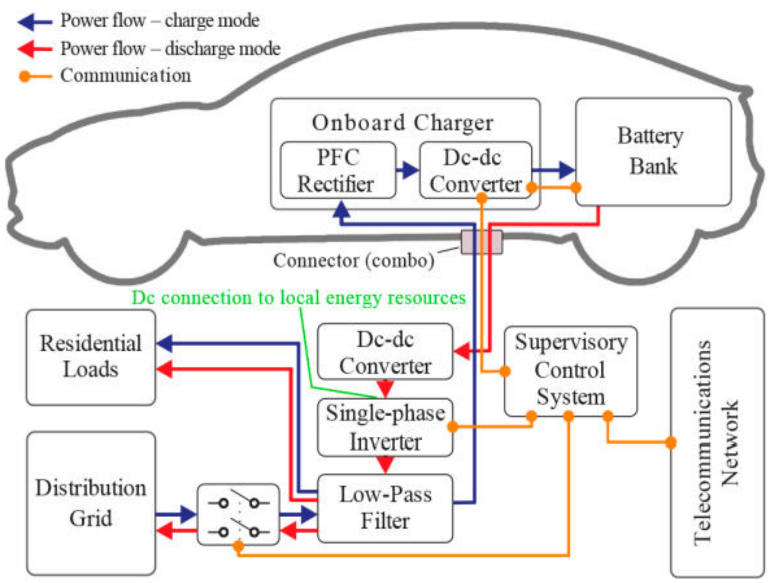

Figure 3: Block diagram and power flows for the proposed system

The possibility to integrate local energy resources could be advantageously connected to the dc-link of the off-board conversion system and, thus provide a way to integrate other power systems with a shared grid-connected/islanding inverter, which is a complex system. The proposal is to add an off-board connection system that is able to process energy from the EV battery to the local loads so that the typical on-board charging system is kept. The proposed system is intended to be used in a single residence application and, thus, a switch is included to provide a separation from other parts of the grid outside the residence

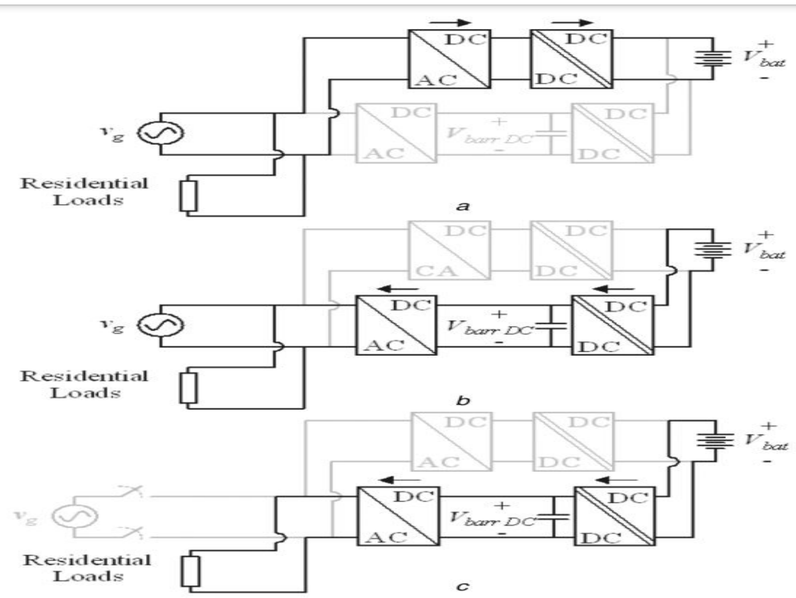

Figure 4: Proposed system operation modes

System converters

with the established voltage and the power levels, the characteristics and topologies used for the performance evaluation of the proposed power system are discussed. The subsystem for charging the EV battery requires reduced volume and weight. Its connection to the utility grid should drain current with low distortion and with a high-power factor. Additionally, for security reasons, it is preferable to use isolated power converters in this way, a two-stage solution is

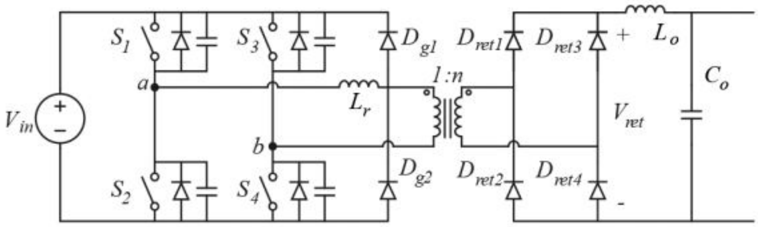

Figure 5: Topology used in the FB-CH and FB-OCS converters

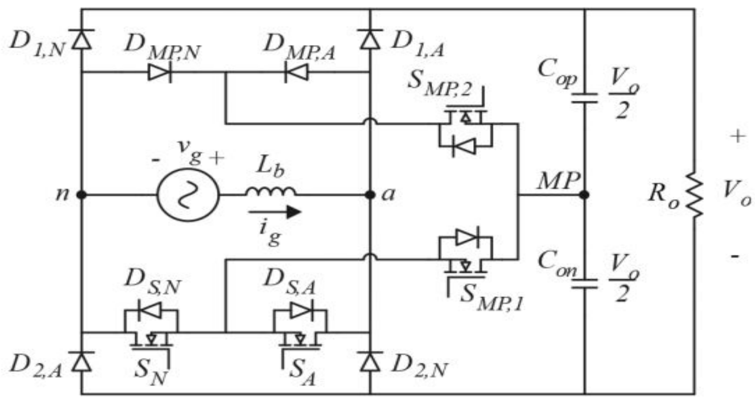

Figure 6: Topology used in the PFC-3L converter

Numeric simulations:

To validate the proposed system, numerical simulations were performed with the PSIM software (version 9.0), considering the state modes of the main system. The parameters used in the simulations are given in Table In these simulations the whole system was designed to be able to process 2 kW, in any of the operation modes, i.e. V2H, V2G and charge mode (from the utility grid to the EV and residential loads). A battery voltage of 300 V is used in the simulations. A resistive ac load, equivalent to half of the rated power, and the reference power for injection in the grid equal to the nominal power, i.e. 2 kW are the other simulation.

Table 1: System parameters

Utility grid and battery	220 Vrms
effective network voltage (Vg, ef)	60 Hz
Network frequency (f g)	264 Vdc
Nominal battery voltage (Vbat)	231–315 Vdc

Table 2: Full-bridge single-phase inverter

DC-link voltage (Vin,Inversor)	**380 Vdc**
utility grid voltage (Vout,Inv)	220 Vrms
switching frequency (fs,Inv)	50 kHz
nominal power (Pnom,Inv)	2 kW

The simulation results are transition between the EV charging mode to the isolated mode is seen in Figs. where the grid goes down at 3.8 s since, both, the grid voltage vg in Fig. and the PFC rectifier input voltage vin,PFC in Fig. 10 go to zero at this time. Before 3.8 s the battery current ibat is increased from zero to +6 A, i.e. the battery is charged, right after the onboard charger converters are started, first the PFC The load voltage vLoad is the same as the vg while the grid is on and the external dc–dc converter is off since its current Iin, FB−SCV and voltage Vo,FB−SCV are null up to 4.2 s.

4.0 Experimental results:

Full bridge inverters are conventional converters, exhaustively studied in the literature, and therefore, it was decided that experimental results related to this inverter would not be included in this study.

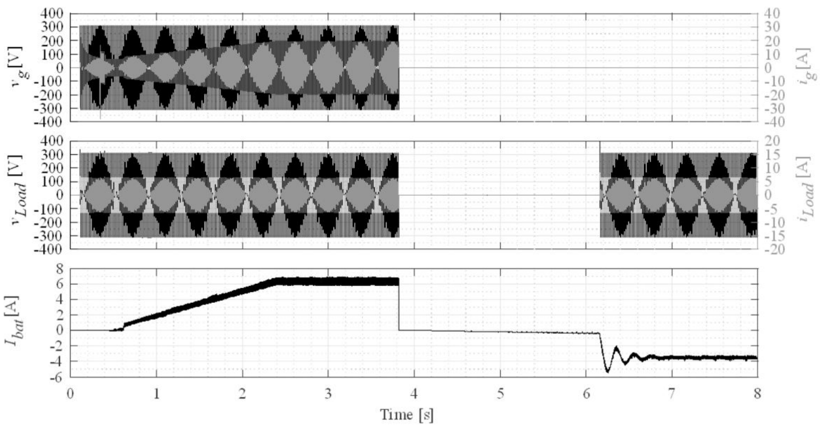

Figure 7: Transition between the EV charging mode to the isolated mode.

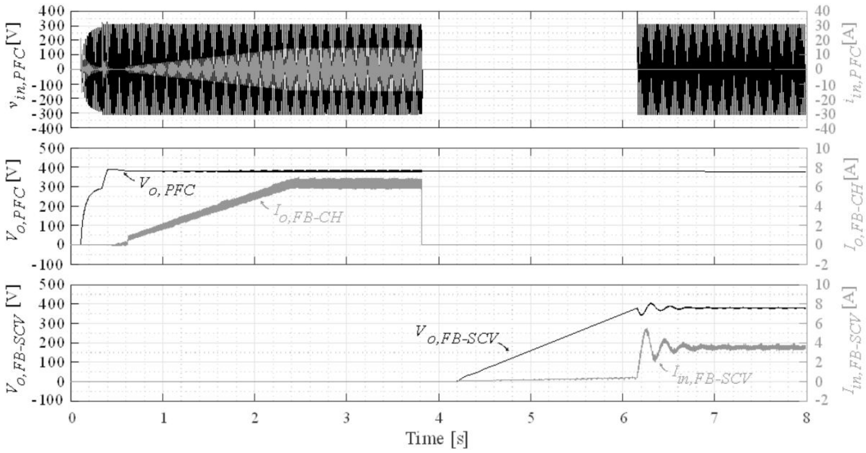

Figure 8: Transition between the EV charging mode to the isolated mode. Simulated waveforms of the voltage and the current on the EV converters.

During the tests, only ten battery modules were available for use, limiting the voltage range from 210 to 287 V, with a nominal value of 240 V. For this reason, a bi-directional converter was used between the designed converter and the battery bank. The intermediate converter was configured to maintain the voltage at 300 V and all the tests presented were made considering this operating voltage.

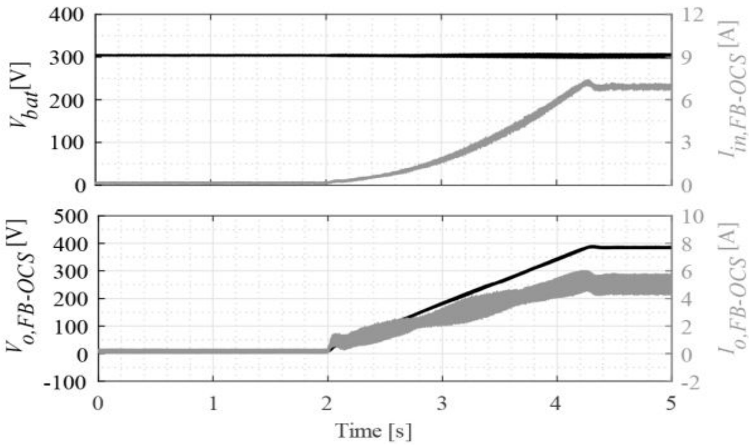

Figure 9. Experimental waveforms of the full-bridge ZVS phase-shift OCS starting ramp

Conclusions

A system based on an external device that incorporates V2H characteristics could be useful for EVs. This setup aims to reduce the EV's overall cost, weight, and complexity by eliminating the need for expensive and bulky bidirectional converters located inside the car. Further, by employing a two-step approach to connecting to the grid, renewable energy sources from the surrounding area can be incorporated. Such V2H systems have the potential to be useful, but their implementation is hindered by the fact that they will primarily be used in individual homes rather than huge structures. There are two primary methods for running such systems when many are networked together in a single building or the area: (i) this can be managed by a central controller/optimiser; (ii) a local controller acts with its own autonomy. V2H and V2G management systems, as stated, for example, provide for the deployment of these choices. Another consideration before installing a system is whether or not the homeowner plans to make use of the V2H idea and whether or not the additional costs of the external power conversion equipment are worthwhile. Simulations of the various operational modes of the system were shown, along with an explanation of how they meet the needs of the system. The prototypes were constructed for experimental verification, and the findings of these experiments were gathered. The results reveal that the system is able to switch modes by supplying ramp-like transients at the battery current, allowing for smooth transitions between all operational modes. Additional capabilities are provided by the system's expansion through the incorporation of solar panel generation systems and local energy storage systems, among other forms of distributed energy resources.

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