Home Charging for Electrical Vehicles: A Bidirectional Approach Solution

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Abstract

Consumers in the U.S., and all over the world are adopting electric vehicles (EV). The EVs draw a lot of electricity from the supply feeders to charge, which leads to higher power losses and lower feeder voltages. The EV's charging interferes with the normal operation of motorized equipment, such as household appliances. The study aims to find a way to reduce the negative impacts of EVs while increasing their value. The study investigates, in particular, a method to enable bidirectional charging. The study investigates a technique to enable bi-directional charging (i.e. The EV owner can gain additional benefits from these functions. The EV can be used to power other appliances, for example during camping trips. Bi-directional functionality is also beneficial for grids, as EVs can support grids in emergency situations by injecting their battery power.

Introduction

Electric vehicles are becoming more popular, and this is directly related to the increase of applications that utilize their capabilities. The average electric car travels less than zero percent of the time, according to the vehicle travel trends. The use of EVs in the home can be beneficial, particularly to power priority loads when there are blackouts or other emergency situations. EVs are a good way to compensate for renewable energy's intermittent nature and provide ancillary service. Electric vehicles store energy during nighttime when prices are low and then withdraw it during high-priced peak times. Electric vehicles are pumped storage units that allow owners of electric cars to profit from price differences and partially compensate their initial investment. (Alanazi, 2020)

Bidirectional charging enables an electric car (EV) that is equipped with a battery to be used as backup energy for the home**.** It can lead to more cost-effective energy use and a better efficiency.

The bidirectional charger works using an embedded DC-AC converter. The EV can:

- Solar energy can be stored
- Home or Office Power
- Recharge the grid with electricity

The charge can be bidirectional:

- Energy efficiency is possible
- Saving money is possible
- As a mobile storage unit of energy
- Solar energy can be stored
- Home or Office Power

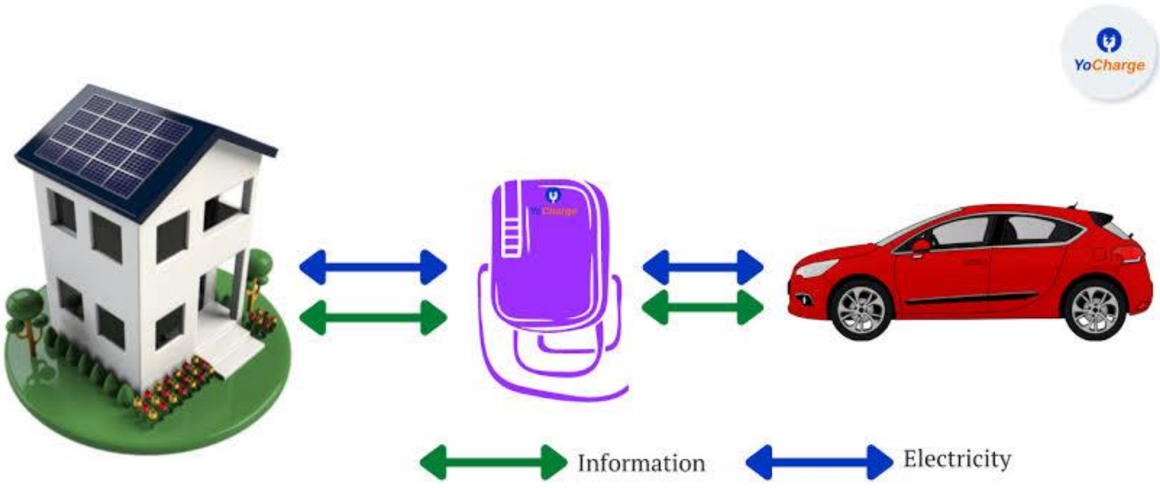

Figure 1: Future charging plans (Source: Tesla.com)

Electric vehicles are growing in popularity, and this is reflected in the research being conducted. Kang Miao begins his article, Bidirectional Battery Charger for Electric Vehicle by explaining four functions that electric vehicles provide the grid. Electric vehicles have limited storage capacity, making it difficult to disperse peak power. However, this problem can be solved if they are grouped together or if refueling is done. Electric vehicles have the ability to provide these services at peak times while using power off-peak. Electric vehicles can benefit from the arrangement because spinning reserves are based on the amount of time that they are in use. Electric vehicles are spinning while connected to the grid, but only for short periods. The use of electric vehicles for backup and storage can help to reduce the need to rely on fossil fuels. (Abraham, 2019)

Electric vehicles can store renewable energy during daytime hours, which they then use during non-peak times. Authors discuss electric battery complexity and develop a model which can be used in calculation and design of batteries. The model takes into account all the dynamic properties of the battery: from its nonlinear voltage and current in open circuit, to temperature, storage capacity, time-dependent storage, as well as cycle number. (Jones, 2018) This type of work is further developed in the Bidirectional Battery Charger with Grid-toVehicle (G2V), Vehicle-toGrid (V2G) and Vehicle-toHome technologies. Pinto presents a bidirectional portable battery charger with a control algorithm, hardware, and design. (Sharma, 2021)

To synchronize the grid, two sine waves of unitary amplitudes are shifted 90 degrees. In the G2V mode of operation, the bidirectional full-bridge ACDC converter functions as an active rectifier using sinusoidal current with unitary power factors. In order to provide the battery the required voltage, the buck section of the DC DC link also operates. In V2H or V2G modes, the boost circuit takes over the role of the rectifier to bring the DC-link voltage up to its rated level. In discharge mode the voltage levels drop. To maintain the power, a proportionate increase in current is made. A PI controller adjusts its duty cycle to a PWM modulator. (Rohten, 2022)

To prevent safety issues, rooftop photovoltaic systems must shut down when the grid's power fails. A V2H is capable of maintaining functionality for an islanded load. These homes have been fitted with a variety of meters that track electricity, gas and water usage. In the study, there are 185 homes with rooftop solar panels. Power production is measured separately from demand for electricity. Data collected from the study over the course of a year was used to test the vehicle and system models. (Song, 2018)

A PV-PEV/PHEV system was used. BEVs were tested at 19.2 and 32 kWh. The values are based on the Nissan Leaf and the entry-level Tesla. The PV portion was used first, then if the load demand was less than what the PVs could produce the BEV's maximum charge was applied. The PEV is used until the PHEV's reserves are exhausted. The excess energy from the PHEV used for charging the BEV allowed the authors calculate the relationship between the amount of gasoline and the charge state. The PV generator complements the PHEV during off-peak periods to extend the backup time from just a few to almost 25 days. (Sanguesa, 2019)

Literature review

Mukesh Gupata and Kadlag Somnatha talk about different chargers, charging methods and their topologies. They also discuss the advantages and disadvantages of each. This article also provides insight on the efficiency and construction of electric vehicle battery chargers. The article explains the different types of converter topologies, such as bidirectional and unidirectional as well non-isolated or isolated. These can all be used to construct an onboard charging circuit for electric vehicles. Battery management systems are discussed in EVs. (Alex, 2021)

Xu Xiao and He Molin discuss circuit topologies, control algorithms, and component models for an unidirectional, single-phase, onboard electric vehicle charger. Modeling an onboard charger level one for EVs can be done using the presented method. Full circuit model of EVBC (Electric Vehicle Battery Charger). This circuit consists of a battery, a DC-DC converter with full bridge, a Boost converter and a PFC control. The circuit is a-PFC and uses a boost converter that keeps the inductor current in continuous conduction. Galvanic isolation is achieved using a high-frequency converter. Battery is charged in two different modes, which are controlled by the DC-DC circuit at the rear: Discussions on the importance of active PFC and control are presented with circuit diagrams, complete with equations. Validation of results against actual EVBCs is done for both ideal and distorted waveforms. (Vijayakumar, 2022)

Morris Brenna, Federica Foiadelli, Carola Leone1 and Michela Longo discuss an overview of the different EV Battery Chargers based upon power level, power direction, charging strategy, etc. The article discusses the advantages and disadvantages of inductive and conductive charging. It lists the characteristics of chargers at level 1, 2, and 3. It is necessary to explain the need for vehicle-to grid power flow. Two-stage charging systems consist of AD-DC and DC-DC stages. AC-to DC stage can be built using a half-bridge diode, full-bridge diode or a multilevel bridge with PFCC converter. In the second stage, resonant converters are employed with an LLC configuration. The constant voltage-constant current method is used to discuss a suitable Li-ion battery charging technique for EVs. The charging progress is represented by a graph that plots current against time. The Five-Step Charging Pattern is a method that can be used to charge batteries faster and more safely. (Eltoumi, 2020)

Mingyue Zhi and Xiaobin FAN, in a review article describe that battery technology has been one of the biggest obstacles to electric cars. Battery management research, whether in theory or reality, is crucial, especially for estimating battery charge. Battery management research is critical, whether in theory or reality, particularly for estimating the battery state of charge. It is therefore difficult to determine the exact level of charge. This paper was chosen because it examined a variety of patents and articles relating to the estimation of state-of-charge of an electric car battery.

This paper divides the estimation techniques into three categories based upon their experimental and theoretical characteristics. These are: Traditional methods using battery tests; Current methods that use control theory; and Alternative methods, based upon novel concepts and a focus on algorithms based in control theory. The management of electric vehicle batteries is crucial for safety, cost reduction, increasing range, and prolonging the battery's life. A typical Battery Management System is composed of sensors, actuators and controllers. The level of charge in a battery management system is similar to the fuel meter on a petrol vehicle.

Hariprasad explains to his students that in Electric Vehicles (EVs), battery management systems are used for monitoring and controlling the charging and discharge of rechargeable batteries. This makes the operation more efficient. Battery management systems keep the battery reliable and safe while increasing its senility. The basic functionality of a Battery Management System is discussed in this paper, including the analysis of battery health and life expectancy, along with the maximum capacity. To maintain battery status, different monitoring techniques, such as voltage, current and ambient temperature, are used. Monitoring is done using different analog/digital microcontrollers and sensors. The battery management system is critical in electric cars because the batteries should never be overcharged, or excessively depleted. The battery can be damaged in this case, as well as the temperature rising and the battery life being reduced. The battery can also be used to increase the range of the vehicle.

Methodology

I'll start by looking at the limitations and specifications of the lithium-ion and nickel-metal-hydride batteries, since they are the most commonly used for electric cars. I will be able to get the rated performance as well as load drawing specs to optimize my design. With this data I can design an electronic replica using circuit design software like MultiSim. It allows me to gain a better understanding of the overall design, so I can improve data flows and make a compact design. Once the design of the electronics is complete, I'll begin testing it with software. Matlab's toolboxes

(Stateflow and Control System), which allow me to simulate, will be used by me to check the efficiency of my control system. (Rangarajan, 2021)

After the system is designed, I'll integrate the battery charge/discharge system and the control system for power loads. Then, I'll perform simulations and analyses of the system. This analysis will evaluate how well the system manages the interaction between the EV and household appliances, as well as the grid. It will enable me to monitor input and output voltages and currents and visually observe how components work within the design. This data allows me to identify phase differences in voltage and current and correct them to minimize reactive power and maximize power transmission. (Xing, 2018)

MODELING OF BI-DIRECTIONAL Charging Function: Specifications

An EV can be viewed from the power grid's perspective as both a charge and a discharge. To accurately reflect the characteristics of an electric vehicle battery, a battery model must be used. In the same way, the control system must include a State of Charge (SOC), which allows the user to choose between two different scenarios. It is the best to use an electric circuit model because it can accurately represent the electrical characteristics of a cell. Shepherd developed an equation to describe the controlled voltage source. (Uzair, 2022)

This model can calculate the state of charge (SOC) of a Li-Ion battery:

$SOC = 100\ (1-it/Q)$

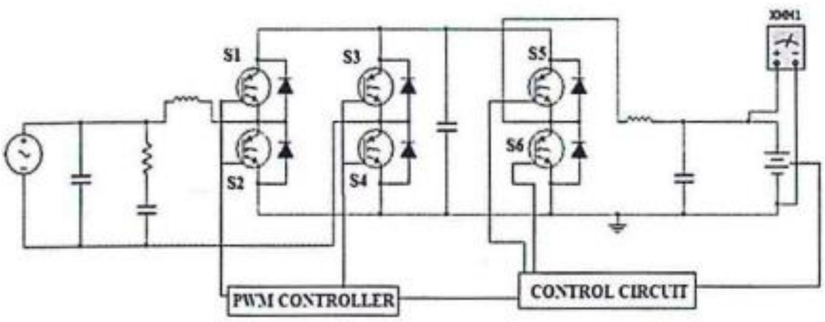

Figure 2: Design of circuit

Direction of current can represent the flow of energy. The direct current technique is employed in this paper to control bidirectional power flows for the V2G implementation. The DC/DC Converter is controlled by this strategy. It acts as a booster converter when IGBT2 triggers and as a buck convertor when IGBTI triggers. The DC/DC converter controller is divided into two parts: the discharging and charging controls. (Merhy, 2021)

It is important to determine the next action of the controller. In charging mode, it is necessary to compute the difference between measured and reference battery current. The PI controller will then tune this error. After the PI controller has calculated the error, it will tune the result. SPWM generates the pulses required for IGBT2 using this output. IGBT2 will be turned off during the charging mode. (Baral, 2022)

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The first is for the interface of the grid, and the second is the interface with the traction battery. V2G (Vehicle-to Grid): The Vehicle-to grid (V2G), technology allows users plug electric vehicles directly into the power grid, and use them as a source of electricity to stabilize grid operation. V2G is a concept that includes several key elements such as power utilities, system operators, aggregators, bidirectional charging stations, communication systems, intelligent meters. (Mojumder, 2020)

Simulation and results

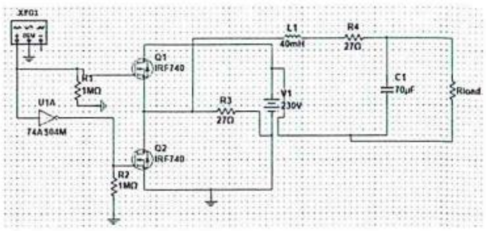

Figure 3: Inverter

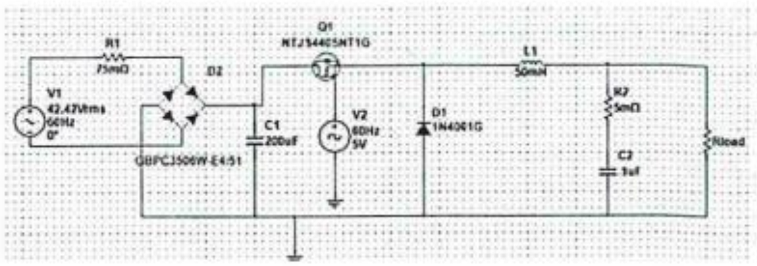

Figure 4: Converter

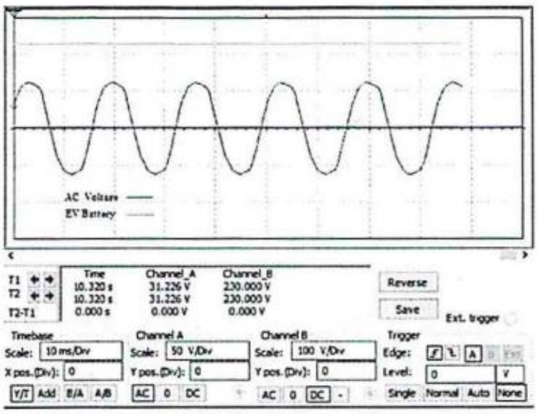

Figure 5: AC Output Vs DC Output

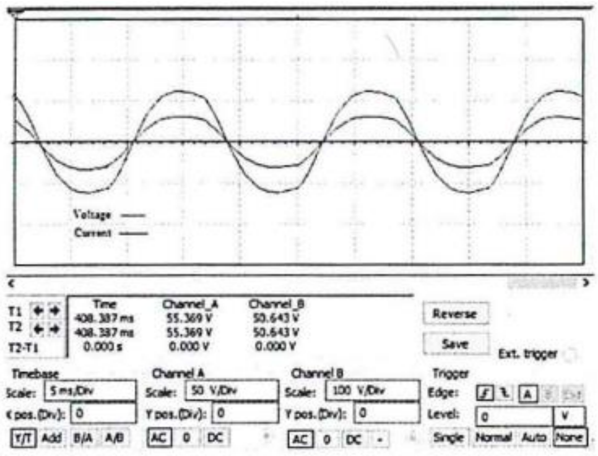

Figure 6: Voltage Vs Current Output

The Fig. above shows the AC sine wave voltage and current in phase, with an amplitude that is similar.

Conclusion

Already, I've completed the circuit design. The high level of efficiency was achieved by using passive components and a low resistance load. We are currently working to find ways to increase efficiency while maintaining a high flow of power.

Future work

Before I begin the actual design, after high efficiency has been maintained, my plan is to add passive components that are suited for a variety of EV batteries voltages. Then I will create a software program that has a user-interface to monitor, start, and stop power transmission.

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