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Design and Analysis of Bidirectional Battery Charger for Electric vehicle

Vrushali S. Londe
Department of Electrical Engineering,
WCEM, Nagpur (INDIA).
londevrushali4@gmail.com

***Abstract*— Electric Vehicles (EV) are increasingly adopted by consumers in the U.S. and around the world. However, the EV draw lots of power from supply feeders for charging, leading to increased power losses in the power lines and depressed feeder voltages. The EV charging also interferes with normal operation of other motor-based equipment such as residential appliances. This study seeks a solution to mitigate the EV adverse impacts while improving its value for the owners. Specifically, the study investigates a technique to enable bi-directional charging (i.e. both charge and discharge) functions for the vehicles using ACDC-AC converters. These functions can create additional benefits for the EV owners. They can make use of the EV battery power for running other appliances when desired, such as for camping trips. The bi-directional functions are also useful for the grid as the EV can inject their battery power to support the grid under emergency conditions.**

Keywords— ATmega328p, Inverter, Relay

I. INTRODUCTION

A. Background

The rapid growth of electric vehicles (EVs) is transforming the transportation and energy sectors. Conventional EV charging systems are typically unidirectional, meaning electrical energy flows only from the grid to the vehicle battery. While effective for charging, this approach underutilizes the potential of EV batteries as distributed energy storage systems.

A bidirectional electric vehicle battery charger enables power flow in two directions: from the grid to the vehicle (G2V – Grid-to-Vehicle) and from the vehicle back to the grid (V2G – Vehicle-to-Grid). This technology allows EVs to act not only as loads but also as mobile energy storage units, contributing to grid stability and energy management.

Bidirectional chargers are based on advanced power electronics, typically involving AC-DC and DC-AC converters with controlled switching devices such as IGBTs or MOSFETs. These systems are designed to maintain high efficiency, ensure power quality, and comply with grid standards. Intelligent control strategies are implemented to manage charging, discharging, and synchronization with grid conditions.

The concept of vehicle-to-grid (V2G) plays a crucial role in modern smart grid systems. During peak demand periods, EVs can discharge stored energy back to the grid, helping to reduce load stress and improve reliability. Conversely, during off-peak hours, vehicles can be charged when electricity demand and cost are low. This capability supports renewable energy integration by storing excess energy generated from sources like solar and wind.

In addition to V2G, bidirectional charging also enables Vehicle-to-Home (V2H) and Vehicle-to-Load (V2L) applications. These allow EVs to supply power to residential homes or external electrical loads during outages or emergencies, enhancing energy resilience.

Despite its advantages, bidirectional charging faces several challenges, including battery degradation concerns, high system cost, complex control requirements, and the need for regulatory and infrastructure support. However, ongoing research and technological advancements are steadily addressing these issues, making bidirectional charging a key component of future sustainable energy systems.

The following block diagram showing the all components we have used in this system

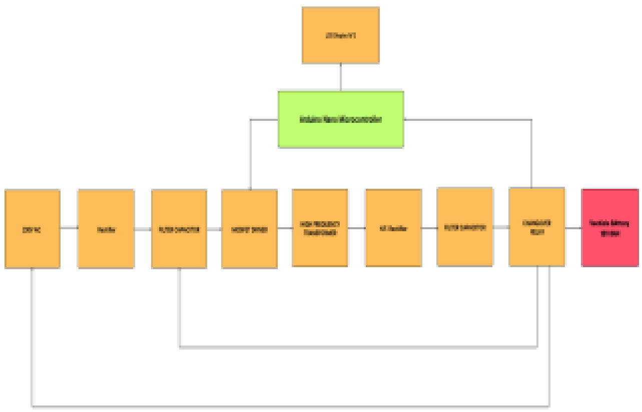

Fig. Block diagram of the system

B. Necessity

The necessity of bidirectional EV chargers arises from their ability to support advanced grid functionalities associated with the Smart Grid. With increasing penetration of renewable energy sources such as solar and wind, power generation becomes highly variable and unpredictable. Bidirectional chargers allow EV batteries to function as distributed energy storage units, thereby stabilizing fluctuations through mechanisms aligned with Demand Response strategies.

Furthermore, during peak load conditions, these chargers enable energy to be fed back from vehicles to the grid, reducing stress on power infrastructure and minimizing the risk of outages. This capability is particularly important in densely populated regions and developing countries where grid reliability remains a concern.

In addition to technical advantages, bidirectional charging provides economic benefits to both utilities and consumers. EV owners can participate in energy trading by supplying stored electricity back to the grid during high-demand periods. This not only reduces electricity costs but also introduces new revenue opportunities, making EV adoption more financially attractive.

Moreover, bidirectional chargers enhance energy security by enabling Vehicle-to-Home (V2H) operation, where EVs act as backup power sources during grid failures. This feature is increasingly relevant in regions experiencing frequent power interruptions.

From an environmental perspective, bidirectional charging plays a vital role in maximizing the utilization of renewable energy. By storing excess renewable generation and redistributing it when needed, these systems reduce reliance on fossil fuels and contribute to lowering greenhouse gas emissions. Thus, they are essential for achieving sustainable energy goals.

C. Objectives

- Bidirectional charging refers to two-way charging (meaning charge and discharge).
- V2G is a charging technology that allows the one-way flow of energy from the car battery back to the grid (from the vehicle to the grid).
- To enable greed support and demand response.
- To access Renewable energy integration.
- To Emergency and backup power.
- To improve energy management and Power quality

II. LITERATURE SURVEY

1. Kang Miao Tan, Vigna K. Ramachandaramurthy and Jia Ying Yong Power Quality Research Group, Department of Electrical Power Engineering Universiti Tenaga Nasional Kajang, Malaysia,. "Bidirectional Battery Charger for Electric Vehicle":

Increase in electric vehicle mobility has encouraged the growth of vehicle to grid technology. Vehicle to grid technology allows bidirectional power flow between the battery of electric vehicle and the power grid. This allows peak load shaving, load leveling, voltage regulation and improvements of power system stability. Implementation of the vehicle to grid technology requires dedicated electric vehicle battery charger, which allows bidirectional power flow between power grid and electric vehicle battery. In this paper, a new control strategy for bidirectional battery charger is proposed. The proposed control strategy can charge and discharge an electric vehicle battery in both slow and fast mode. The performance of the bidirectional controller is verified by simulation in PSCAD/EMTDC software under different operating modes, which include fast charging, fast discharging, slow charging and slow discharging. The results show that the proposed control strategy performs well in all four modes.Archana Padikar A, Cinmayee C K, Chaithra E, Chethan1India "Health Monitoring and Soldier Tracking System using IOT":

2. Travon Dent Report for CPP McNair Research Program, Summer 2016 "Developing Bi-directional Charging Functions for Electric Vehicles":

Electric Vehicles (EV) are increasingly adopted by consumers in the U.S. and around the world. However, the EV draw lots of power from supply feeders for charging, leading to increased power losses in the power lines and depressed feeder voltages. The EV charging also interferes with normal operation of other motor-based equipment such as residential appliances. This study seeks a solution to mitigate the EV adverse impacts while improving its value for the owners. Specifically, the study investigates a technique to enable bi-directional charging (i.e. both charge and discharge) functions for the vehicles using ACDC-AC converters. These functions can create additional benefits for the EV owners. They can make use of the EV battery power for running other appliances when desired, such as for camping trips. The bi-directional functions are also useful for the grid as the EV can inject their battery power to support the grid under emergency conditions.

3. N. Sujitha, S. Krithiga , School of Electrical Engineering, Vellore Institute of Technology, Chennai Campus, Chennai, Tamil Nadu, India "Grid tied PV-Electric Vehicle Battery Charger using Bidirectional Converter."

Research on renewable energy based Electric Vehicle battery charging system is booming in the automobile industry in the recent years. The intermittent nature of the renewable energy sources leads to the grid connected renewable energy systems for Electric vehicle battery charging applications. Hence, an Electric Vehicle battery charger using grid connected PV system is proposed in this paper. The proposed system is capable of charging the EV battery continuously irrespective of solar irradiations using dc-dc converter and bidirectional ac-dc converter. Sepic converter is preferred for dc-dc converter and Line commutated converter is used as a bidirectional ac-dc converter with the help of the proposed bidirectional configurator in the charging system. During sunshine hours, PV array power generated is used to charge the EV battery alone and during peak sunshine hours, apart from charging of EV battery, the excess PV array power is fed to the single phase utility grid. During low and non sunshine hours, the EV battery charging was supported by the utility grid through bidirectional ac-dc converter. The proposed electric vehicle battery charger is simulated in the MATLAB/Simulink environment and the dynamic response of the system was studied and its results are furnished in this paper

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III. METHODOLOGY

A. Basic Idea

Electric vehicle (EV) has become more competitive compared to the conventional internal combustion engine vehicle due to lower carbon dioxide emissions and rising fossil fuel price . However, EV is not widely adopted into the market due to some limitations, such as high vehicle cost, limited charging infrastructure and limited all-electric drive range. In addition, the integration of EV on the power grid will lead to many challenging issues. For instance, large penetration level of EV charging will increase the power grid loading. Instead of being an additional electrical load, EV battery can be utilized as an energy storage. This potential has led to the new vehicle to grid (V2G) concept. Apart from charging EV battery, V2G allows interaction between the EV owners and the power utility to enable power injection into the power grid according to the predefined schedule and power rates. Interaction of EV and power grid can introduce various benefits to both the power utility and EV owners. From the perspective of power utility, V2G concept can achieve load leveling, peak load shaving, reactive power support, active power regulation, stability improvement and harmonic filtering. On the other hand, EV owners can earn extra revenues by selling power to the grid. Presently, the available EV battery chargers in the market are solely for charging operation. The conventional EV battery charger has unidirectional characteristic, which allows either slow charging or fast charging. The implementation of V2G technology requires dedicated EV charger that allows bidirectional power flow between power grid and EV battery [6], [7]. In this paper, a bidirectional EV battery charger with new control strategy is proposed. The proposed control strategy allows four modes, which are fast charge mode, fast discharge mode, slow charge mode and slow discharge mode. In section II, V2G concept and its advantages will be discussed. Section III presents the modeling of EV battery. The control strategy for bidirectional battery charger is described in section IV. Section V discuss the simulation results. Section VI concludes and summarizes the key points of the paper.

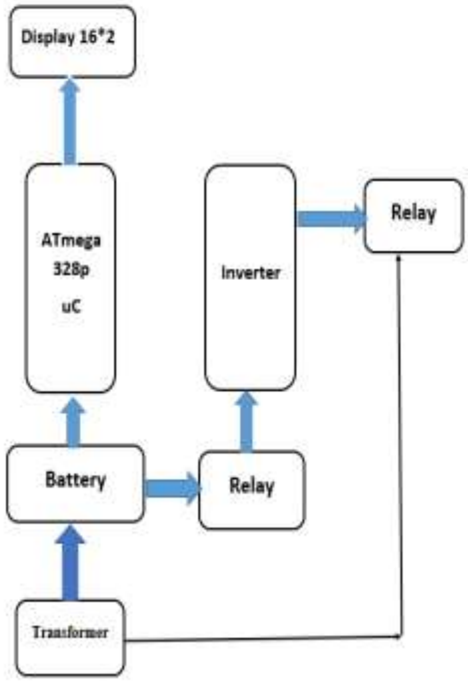


Fig. Block diagram of the system

B. Working of the System

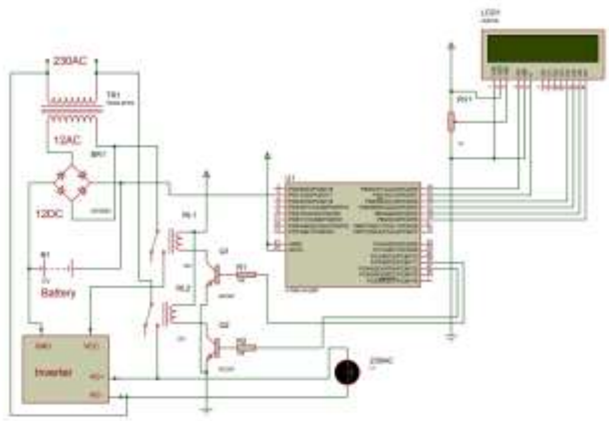


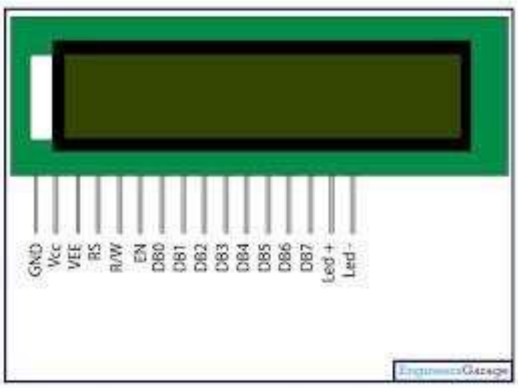
Fig. Bi-Directional EV Charger

In charging mode the main task is the transformation from the 1- phase AC mains power to DC power as input for the battery. To fulfil the grid requirements, a mains filter and an active rectifier is necessary. Further a DC/DC converter to adapt the rectifier output to the battery's needs. In case of an AC charging system, the charger is on board of the vehicle. In case of a DC charging system, it is inside the charging station. Both competing systems are available today, but either the car manufacturer or the public utility wants to avoid its additional cost. Reusing the inverter for this function is proposed in. In the presented BCTS all three functions are included in components, which are already on board of the vehicle: The E-Machine stator is used as the AC mains filter, the inverter as the 1- or 3-phase rectifier and the DC Booster adapts the DC-Link voltage to the Battery-Link voltage for battery management. In principle, this solution could support AC charging with power as high as the installed continuous traction power depending on additional filter efforts. Counting both, vehicle and charging station, the system cost is optimized. The first area is Driving with the use cases traction and regeneration. In traction mode the battery is discharged via the Battery-Link, the DC Booster converts the voltage to the DC-Link in the range of battery voltage and 800 V output. The DC-Link supplies the energy flow to the inverter which converts the DC to AC for the E-machine. In regeneration mode the direction of the energy flow and the energy conversion in the BCTS components is reverse. Between high SOC and regeneration mode3 to low SOC and full acceleration4 the battery voltage has roughly a ratio of 2 (typically 450 V to 270 V). This wide range is covered by the DC Booster and no margin in the Inverter is necessary.

The AC charging mode is split into the sub modes 1-phase charging. 1-phase charging uses the standard interfaces at every home. It is possible at both, 230 V and 110 V. The charging power hereby is limited to some kW only, depending on local regulations. All kinds of AC charging modes require a mains filter, a rectifier and a DC voltage adaptation on board. The maximal power is mainly limited by the onboard charger. The energy flow in the BCTS is as following: From the charger plug socket the 1- phase AC current is fed through the E-Machine via the opened star point. The inductance of the E-Machine is used as filter. Via the DC-Link the AC current reaches the inverter, which rectifies the current. The DC Booster sets the voltage down to the battery needs on the Battery-Link. For the DC charging mode we propose the connection of the DC socket to the DC-Link so that the energy flow is going through the DC Booster towards the battery. This is beneficial since on the one hand the BCTS gives flexibility for different DC voltages in charging stations. Especially both, 400 V and 800 V charging stations can be supported without any modification on charging station side. On the other hand, the charging time is decreased by using a DC Booster on board. For this use case the charging power is not limited at low battery voltage (Pcharge = Icable · Vbat), since a high voltage is always used between car and station (Icable < Ibat).

C. Related Components

1. Liquid Crystal Display (LCD): It is one kind of electronic display module used in an extensive range of applications like various circuits & devices like mobile phones, calculators, computers, TV sets, etc. These displays are mainly preferred for multi-segment light-emitting diodes and seven segments. The main benefits of using this module are inexpensive; simply programmable, animations, and there are no limitations for displaying custom characters, special and even animations, etc.



2. MICROCONTROLLER: Various functions of the microcontroller are as follows:

. To read the data from ADC which is the data received from the LDR sensor.

. To turn on LED light if the signal is sense by the sensor.

. To turn Off LED light if the object does not sense by the sensor.

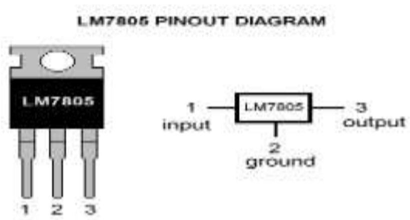
3. Inverter: The basic role of an inverter is to change DC power into AC power. The AC power can be supplied to homes, and industries using the public utility otherwise power grid, the alternating-power systems of the batteries can store only DC power. In addition, almost all the household appliances, as well as other electrical equipment can be functioned by depending on AC power.

4. Battery: A battery is a device that converts chemical energy contained within its active materials directly into electric energy by means of an electrochemical oxidation-reduction (redox) reaction. Batteries are the most common electrical energy storage devices in electrical vehicles. The performance of a battery when it is connected to a load or a source is based on the chemical reactions inside the battery. The chemical degrade with time and usage that reflect the gradual reduction in the energy storage capacity of the battery. The battery depreciation process needs to be reduced by conditioning the battery in a suitable manner by controlling it's charging and discharging profile, even various load conditions.

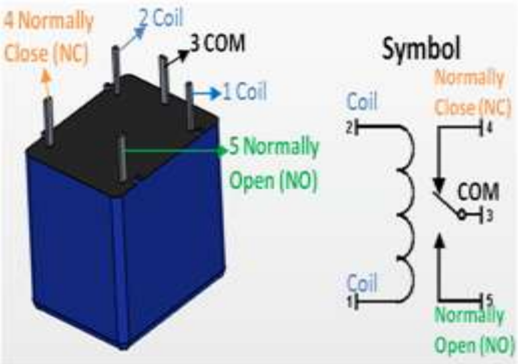
5. LM 7805Voltage Regulator

Voltage regulators ICs are the ICs that are used to regulate the voltage. IC 7805 is 5V Voltage regulators that restrict the voltage output to 5 volt and draws 5V regulated power supply. It comes with provision to add heat sink.

The maximum value for the input to the voltage regulator is 35V. It can provide a constant steady voltage flow of 5V for higher voltage input till the threshold limit of 35V. If the voltage is near to 7.5V then it does not produced any heat and hence no need for heat sink. If the voltage input is more, then excess electricity is liberated as heat from 7805.



6. Relay: A relay is an electrically operated switch. It consists of a set of input terminals for a single or multiple control signals, and a set of operating contact terminals. The switch may have any number of contacts in multiple contact forms, such as make contacts, break contacts, or combinations thereof.



D. System Components Specification

Components	Rating
Microcontroller	ATmega328
Input voltage	5V
Input voltage (recommended)	7-12V
Digital I/O pin	14(Of which 6 provide PWM output)
Analog Input pin	6
DC Current per I/O pin	40mA
DC Current for 3.3V pin	50mA
Flash Memory	32Kb of which 0.5Kb used by boot loader
EEPROM	1Kb
Clock Speed	16MHz

IV. CONCLUSION

The flexibility of the system for uninterruptable charging of EV battery in constant voltage charging method irrespective of the irradiation conditions. The proposed system is capable of charging EV battery and supply power to the grid with the help of bidirectional configurator during peak sun-shine hours and also EV battery gets charged from the grid during low and non sun-shine hours.

The proposed work can be expanded in the future in many directions. After high efficiency is maintained, I plan to introduce varying passive components for a wide range of EV battery voltages before beginning the physical design. At which point I plan to create a program with a user interface which will monitor, initiate, and cease power transmission.

REFERENCES

[1] Kang Miao Tan, Vigna K. Ramachandaramurthy and Jia Ying Yong Power Quality Research Group, Department of Electrical Power Engineering Universiti Tenaga Nasional Kajang, Malaysia,. “Bidirectional Battery Charger for Electric Vehicle”

[2] Travon Dent Report for CPP McNair Research Program, Summer 2016 “Developing Bi-directional Charging Functions for Electric Vehicles”New Delhi, 2020.

[3] N. Sujitha, S. Krithiga , School of Electrical Engineering, Vellore Institute of Technology, Chennai Campus, Chennai, Tamil Nadu, India “Grid tied PV- Electric Vehicle Battery Charger using Bidirectional Converter.”

[4] Electric Vehicle Technology Explained – by James Larminie

[5] " Power Electronics – by Muhammad H. Rashid

[6] “A Review of Bidirectional On-Board Chargers for Electric Vehicles” IEEE Access 2021 by Jiaqi Yuan et al.

[7] "Introduction to Embedded systems" Shibu K. V

[8] Muhammad Ali Mazidi. "The 8051 microcontroller and Embedded Systems", Second edition 2020

[9] www.chipswinner.com

[10] www.datasheetcatalog.com