IJCRT.ORG ISSN : 2320-2882
INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)
An International Open Access, Peer-reviewed, Refereed Journal

SOLAR BASED BI-DIRECTIONAL V2H CHARGING SYSTEM

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Abstract – The increasing adoption of electric vehicles (EVs) has prompted the development of efficient charging infrastructure and innovative vehicle-to-home (V2H) systems. This project presents a solar-based bi-directional electric vehicle charger that enables a V2H system, allowing the transfer of energy between the EV and the home. The proposed charger integrates solar power generation with bidirectional power flow capability, enabling the EV to not only charge from the solar panels but also supply power back to the home during peak demand or in emergency situations. The system incorporates power electronics converters and energy management strategies to ensure efficient and reliable operation. Moreover, the charger is designed to meet safety standards, providing flexibility and grid support. The Solar Based Electric vehicle Charger's efficiency, reliability, and ease of use also make it an attractive option for EV owners and operators, providing a cost-effective and convenient charging solution. As the world continues to shift towards renewable energy sources, the Solar Based Electric vehicle Charger is poised to play a crucial role in shaping the future of transportation and energy.

Keywords – Bi-directional, Vehicle to home, Vehicle to grid, Converters

I. INTRODUCTION

As the demand for electric vehicles (EVs) increases, the need for efficient and cost-effective EV charging solutions is also on the rise. One promising solution is the use of solar energy to power EVs. However, the intermittent nature of solar energy makes it challenging to provide a consistent and reliable source of power.

To address this issue, several innovative systems have been developed that integrate solar energy with other sources of power, such as the Vehicle-to-Home (V2H) system. In this project, we present a solar-based bi-directional EV charger that utilizes a combination of solar energy and lead-acid batteries to power the vehicle, along with a V2H system that allows the EV battery to discharge back into the grid.

Bidirectional EV charging offers more than just environmental benefits. It provides EV owners with various advantages, including the potential to earn money from their vehicles. However, many EV owners may still be unsure about the concept of bidirectional EV chargers and their functionalities. Bidirectional EV charging allows electricity to flow in both directions, unlike unidirectional chargers which only facilitate electricity flow from the grid to the vehicle. With bidirectional charging, EVs can not only receive electricity but also send it back to the grid or use it to power homes. This technology enables EVs to serve as energy storage devices, allowing users to store inexpensive off-peak electricity or harness solar power to reduce household energy costs. Additionally, bidirectional charging empowers EVs to provide backup power during blackouts or emergencies, offering an additional layer of reliability and resilience.

The proposed system offers an efficient and eco-friendly solution to the growing demand for sustainable energy sources in the transportation sector. The system is designed to collect photovoltaic energy using a solar panel and store it in a lead-acid battery. The stored energy is then inverted and stepped up to charge another lead-acid battery, which is assumed to be the EV battery. The same inverted power is then used to power the load, and if there is no power coming from the solar panel, the power stored in the EV battery is again inverted and stepped up to supply the load. In addition to this, the V2H system allows the EV battery to discharge back into the grid during peak demand periods, providing a valuable source of power to the grid.

The use of solar energy for EV charging, coupled with the V2H system, offers several advantages over traditional charging methods. Firstly, solar energy is a clean and renewable source of energy, which reduces the carbon footprint of the charging process. Secondly, the V2H system provides an additional source of power to the grid, which helps to reduce the strain on the grid during peak demand periods. Thirdly, solar-based EV charging systems offer a cost-effective solution, as they eliminate the need for expensive infrastructure and reduce the dependence on fossil fuels. The proposed system utilizes a simple circuit design that consists of a solar panel, lead-acid battery, a transformer, an inverter circuit, an EV battery, and a V2H system. The unidirectional power circuit allows power to flow from the solar panel to the lead-acid battery. The power stored in the battery is inverted using the transformer and inverter circuit to power the load. The same inverted power is then rectified and stepped down to charge the EV battery. If there is no power coming from the solar panel, the power stored in the EV battery is again inverted and stepped up to supply the load. The V2H system allows the EV battery to discharge back into the grid during peak demand periods, providing a valuable source of power to the grid.

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II. PROBLEM STATEMENT

The system addresses the challenge of Electric vehicle charging by conventional methods.

- Limited Access to Clean Energy: Many regions still heavily rely on conventional energy sources, leading to environmental concerns and carbon emissions. The problem lies in the limited access to clean and renewable energy alternatives, such as solar power, which can provide sustainable and eco-friendly solutions.
- Insufficient Infrastructure for Electric Vehicle Charging: With the increasing popularity of electric vehicles (EVs), the lack of sufficient infrastructure for EV charging is a significant problem. The limited availability of charging stations and the reliance on traditional power grids contribute to a slower adoption rate of EVs.
- Inefficient Energy Utilization: In conventional systems, energy generated by solar panels is often underutilized. Excess energy is lost or wasted due to inefficient energy storage and distribution mechanisms. This results in missed opportunities to maximize the use of clean energy and reduce dependence on non-renewable sources.
- Inconsistent Power Supply: Fluctuations in solar energy availability pose challenges for uninterrupted power supply. Dependence solely on solar energy can lead to periods of insufficient power supply during cloudy days or at night. Additionally, fluctuations in energy demand and grid availability can disrupt the consistent supply of power.
- Lack of Bi-directional Power Flow: The inability to facilitate bi-directional power flow between the solar panel and the EV battery poses limitations. Without a mechanism to utilize the stored energy in the EV battery for home load supply or vice versa, there is a missed opportunity to optimize energy usage and promote energy sharing within the system.

III. RELATED WORKS

Plug-in electric vehicles (PEVs) have garnered significant attention worldwide due to their advantages over traditional fuel vehicles. The electric vehicle (EV) technology incorporates an efficient on-board battery charger (OBC) to facilitate charging. OBC converters can be categorized into three main types: integrated converters with the machine, two-stage converters, and single-stage converters. These different OBC types are typically designed by balancing factors such as power factor correction (PFC), cost, efficiency, and lifespan. This paper presents a recent survey comparing various available single-stage isolated unidirectional OBC systems, focusing on the aforementioned metrics. Additionally, the review takes into account hardware limitations, performance aspects, and the utilization of semiconductor components[5].

Finally, the different topologies are summarized, considering a range of performance criteria [7]. This study introduces a novel electric vehicle (EV) charger that allows for two-way power flow with excellent power quality from the power supply side. The charger operates in two modes: grid to vehicle (G2V) and vehicle to grid (V2G). During G2V mode, the charger draws power from the grid to charge the EV's battery, while in V2G mode, the charger allows the battery to discharge power back into the grid. To enable bidirectional functionality, a single-phase active bridge converter with sine pulse width modulation (SPWM) control is utilized at the front end of the charger. The charging and discharging processes of the Li-ion battery are managed by a dual active bridge (DAB) converter, employing predictive duty cycle control in both modes of operation. The proposed charger achieves rapid dynamic response by precisely regulating the battery current. To ensure balanced transformer current and eliminate DC bias, the peak value of the winding current is regulated. The charger is specifically designed and simulated for a 230V, 50Hz power supply with a maximum power output of 3kW. Simulation results effectively demonstrate the charging and discharging operations of a 48V, 100Ah Li-Ion battery using the proposed charger.

A proposal is made for a bidirectional electric vehicle charger that allows power transfer between the grid and the vehicle while incorporating an automatic smart energy management system (EMS) [6]. The charger employs a straightforward power electronics design, enabling users to adjust the charger's output using a controller's control signal. Simulation results demonstrate the effective interaction between the charger and the Energy Management System (EMS) in a residential environment. The design consists of a single-phase on-board charger capable of bidirectional Vehicle to Grid (V2G) and Grid to Vehicle (G2V) applications. It primarily consists of a buck converter and a high-gain boost converter configuration. Charging and discharging of the battery are controlled based on the battery's state of charge. MATLAB Simulink software is used for simulations to validate the bidirectional functionality. The simulation results confirm the successful operation of the charger in both directions.

A unique control approach is proposed for a Dual Active Bridge (DAB) bidirectional DC-DC converter, which forms part of a power electronics-based power converter system used for charging high voltage traction batteries in electric vehicles [9]. This bidirectional converter allows the battery to be used as an energy source, enabling power to flow in both directions. The system comprises a bidirectional AC-DC converter at the front end, which controls the current on the AC side to achieve power factor correction and reduce the Total Harmonic Distortion (THD) of the inverted AC voltage. Additionally, an isolated DC-DC converter is employed at the back end to regulate the battery-side current or voltage for Constant Current (CC) and Constant Voltage (CV) battery charging. The proposed control strategy ensures efficient charging and discharging of the battery while also enabling the operation of a standalone AC load powered by the battery.

IV. HARDWARE REQUIREMENTS

SOLAR PANEL:

A 12V solar panel is a type of photovoltaic (PV) panel that is designed to generate electrical energy using sunlight. It is a commonly used solar panel variant due to its compatibility with various applications and systems, including small-scale residential setups, off-grid power systems, and portable devices. The 12V designation refers to the nominal voltage output of the solar panel. Under ideal conditions, when exposed to direct sunlight, a 12V solar panel typically produces a voltage output of around 12 volts. However, it's important to note that the actual voltage output may vary depending on factors such as sunlight intensity, temperature, and the load connected to the panel. A 12V solar panel consists of multiple solar cells connected in series and/or parallel to form a photovoltaic module. These solar cells are typically made of silicon, which is a semiconductor material known for its ability to convert sunlight into electricity. When sunlight strikes the solar cells, it excites the electrons in the material, generating a flow of DC (direct current) electricity.

LEAD ACID BATTERY:

A 12V, 1.3Ah lead-acid battery is a type of rechargeable battery commonly used in various applications, including automotive, uninterruptible power supplies (UPS), and small-scale solar power systems. It belongs to the lead-acid battery family, which has been widely used for many years due to its reliability, cost-effectiveness, and robustness. The 12V designation indicates the nominal voltage of the battery, which is typically around 12 volts when fully charged. The actual voltage may vary depending on the battery's state of charge and load conditions. The 1.3Ah (Ampere-hour) rating represents the battery's capacity, indicating how much charge the battery can deliver over a specific period of time. Lead-acid batteries consist of a series of lead plates immersed in an electrolyte solution of sulfuric acid. The plates are typically made of lead (Pb) and lead dioxide (PbO_2), which undergo chemical reactions to store and release electrical energy. The electrolyte facilitates these chemical reactions and provides the necessary ions for charge transfer.

12-0-12V FERRITE CORE TRANSFORMER:

A 12-0-12V ferrite core transformer is a type of transformer that is designed to step down or step up the voltage of an AC power supply. The transformer has three windings, with a center-tapped secondary winding that produces two equal voltage outputs that are 180 degrees out of phase with each other. The primary winding is typically connected to the AC power source, while the two secondary windings are connected to the load circuit. The "12-0-12V" designation refers to the voltage of the transformer's secondary windings. Each secondary winding produces a voltage of 12 volts AC relative to the center tap, for a total output voltage of 24 volts AC when the two outputs are combined. This type of transformer is commonly used in electronic devices that require a low voltage AC power supply, such as audio amplifiers, power supplies for microcontrollers, and battery chargers.

RECTIFIER:

A 220/12V rectifier is an electronic device that is used to convert AC power at 220 volts into DC power at 12 volts. The rectifier consists of a transformer, a bridge rectifier, and a filter capacitor. The transformer is used to step down the high voltage AC power to a lower voltage suitable for rectification. The transformer is designed to have a primary winding that is connected to the AC power source and a secondary winding that produces a lower voltage AC output that is proportional to the turns ratio of the transformer. In this case, the transformer steps down the 220V AC power to a lower voltage AC output suitable for rectification. The bridge rectifier is used to convert the AC voltage to DC voltage. It consists of four diodes that are arranged in a bridge configuration. The diodes allow current to flow in only one direction, so they effectively convert the AC voltage to pulsating DC voltage. The filter capacitor is used to smooth out the DC voltage produced by the bridge rectifier. The capacitor is connected across the output of the rectifier and acts as a reservoir, storing charge during the peaks of the AC voltage and discharging during the troughs. This smoothing action reduces the ripple on the DC output voltage, producing a more stable and consistent output voltage. The 220/12V rectifier is commonly used to power low voltage DC devices such as LED lights, small motors, and electronic gadgets. The output of the rectifier can be further regulated using additional electronic components such as voltage regulators to produce a precise and stable DC output voltage.

INVERTER:

A 12/220V inverter is an electronic device that is used to convert DC power from a 12-volt DC source, such as a car battery, into AC power at 220 volts. The inverter consists of a DC-to-AC converter circuit that uses electronic components such as transistors, capacitors, and diodes to invert the DC power to AC power. The inverter circuit first converts the 12-volt DC power to a high-frequency AC signal, which is then stepped up using a transformer to produce the 220-volt AC output. The transformer is designed to have a primary winding that is connected to the inverter circuit and a secondary winding that produces the 220-volt AC output. The 12/220V inverter is useful in a wide range of applications, including powering household appliances, computers, and other electronic devices from a car battery or other 12-volt DC source. The inverter can also be used in off-grid solar power systems, RVs, and boats, where 220-volt AC power is required but grid power is not available. When selecting a 12/220V inverter, it's important to consider the maximum power rating of the inverter, which will determine the maximum power that can be drawn from the inverter without overloading it. Other factors to consider include the input voltage range, efficiency, and the presence of safety features such as overvoltage and overcurrent protection.

V. METHODOLOGY

The proposed system for the Solar based bi-directional electric charger is as shown as block diagram in the Fig 1. When an electric vehicle (EV) is being charged, the electricity received from the grid, which is in the form of alternating current (AC), needs to be converted to direct current (DC) in order to be utilized by the car. This conversion process is performed either by the car's own converter or a converter within the charging station. However, in the case of using solar panels as a charging source, we are implementing bidirectional EV chargers equipped with internal converters. These converters have the capability to convert DC power back to AC, enabling it to be used for various purposes. We are using relay and microcontroller for control the output based on solar power available. Microcontroller will check this using voltage regulator and it will switch control the output inverter using relay section.

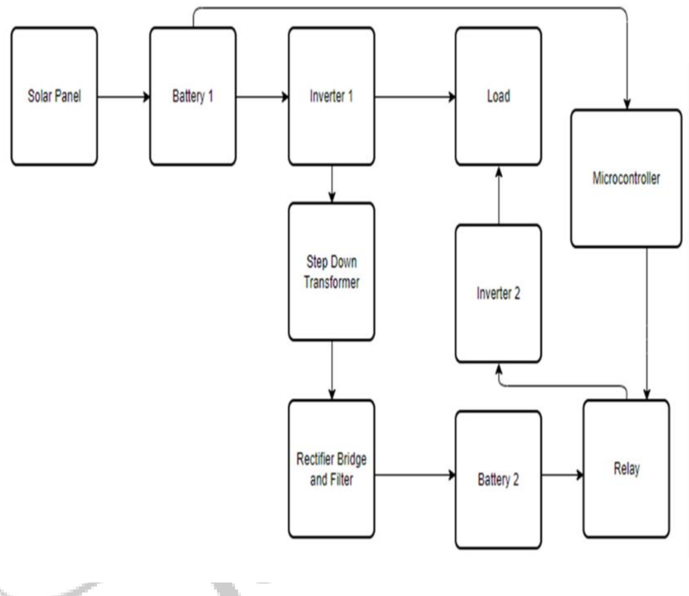

Fig 1: Block Diagram of Proposed System

To begin with the detailed methodology firstly the optimal location for installing the solar panel was determined, considering factors such as maximum sunlight exposure and accessibility. Once the ideal location was identified, the solar panel was installed, ensuring proper alignment and orientation to maximize its efficiency in capturing sunlight. Next, the solar panel was connected to a diode to allow for unidirectional power flow from the panel to the battery. This diode prevented any reverse current flow, ensuring that the collected solar energy was efficiently directed towards the battery for storage. The design and implementation of the inverter circuit were based on the IC CD4047. The necessary components, such as resistors and capacitors, were selected and connected to the IC to achieve the desired frequency of the AC output. The implementation of the bridge rectifier circuit for EV battery charging involved selecting suitable diodes and capacitors to convert the AC power from the grid or inverter output to DC power. The circuit was assembled and connected to facilitate efficient and reliable charging of the EV battery. Lastly, the power inversion mechanism from the EV battery to home load was implemented. This involved designing and assembling a separate inverter circuit specifically for power inversion. The DC power from the EV battery was converted to AC power using this circuit, enabling the stored energy in the battery to be utilized for home load supply.

After successful completion of the project one can get greener access to renewable energy to supply home load which also facilitates charging of electric vehicle and the battery of electric vehicle will acts as inverter to provide supply to home load uninterruptedly.

VI. IMPLEMENTATION

The implementation of the solar-based bi-directional electric vehicle charger involves several key steps to ensure the proper functioning of the system.

Solar energy collection: Firstly, for solar energy collection, a solar panel is installed in a location that receives maximum sunlight exposure. This ensures that the solar panel can efficiently capture solar radiation and convert it into electrical energy. The solar panel consists of multiple photovoltaic cells that generate DC (direct current) electricity when exposed to sunlight. To control the power flow from the solar panel, a diode is connected in series between the solar panel and the battery. The diode acts as a one-way valve for electric current, allowing it to flow in only one direction while preventing reverse current flow. In this case, the diode ensures that the current flows from the solar panel to the battery, creating a unidirectional power flow. The 12V, 1.2Ah lead-acid battery is connected to the diode. This battery serves as the storage medium for the collected solar energy. As the solar panel generates electricity, the current flows through the diode and charges the battery. The battery stores the electrical energy in the form of chemical potential, which can be later used to power various loads or devices. The lead-acid battery is a commonly used type of rechargeable battery known for its relatively low-cost, high-energy density, and robustness. It consists of lead and lead oxide plates submerged in an electrolyte solution of sulfuric acid. The chemical reactions within the battery during charging and discharging processes enable the storage and release of electrical energy. By connecting the solar panel to the diode, and then to the lead-acid battery, the system ensures that the solar energy collected by the panel is directed towards charging the battery in a unidirectional manner. This configuration allows for efficient utilization and storage of the solar energy for future use. It's important to note that the size and capacity of the solar panel and the battery depend on various factors, including the power requirements of the system, the geographical location, and the desired energy autonomy. Proper sizing and selection of these components are essential to ensure optimal performance and reliable operation of the solar-based bi-directional electric vehicle charger system.

Inverter configuration: An inverter circuit is designed and constructed to convert the stored DC power from the battery into AC power suitable for supplying home loads. This involves selecting appropriate components, such as power transistors, capacitors, and control circuitry, based on the desired power output and efficiency. The inverter circuit is then assembled on a circuit board, ensuring proper connections and following safety guidelines. The output of the inverter circuit is connected to the home load. Figure 2 shows the block diagram of inverter.

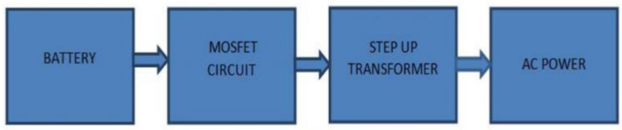

Fig 2: Block Diagram of inverter

Figure 3 shows the circuit diagram of inverter. The IC CD4047 is connected in an astable mode of operation using the 22k ohm resistor and 0.22 microfarad capacitor. This generates the required oscillating signals for the inverter. The output of the IC CD4047 is connected to the gate terminal of the IRFZ44 MOSFET. The source terminal of the MOSFET is connected to the ground or common reference point.

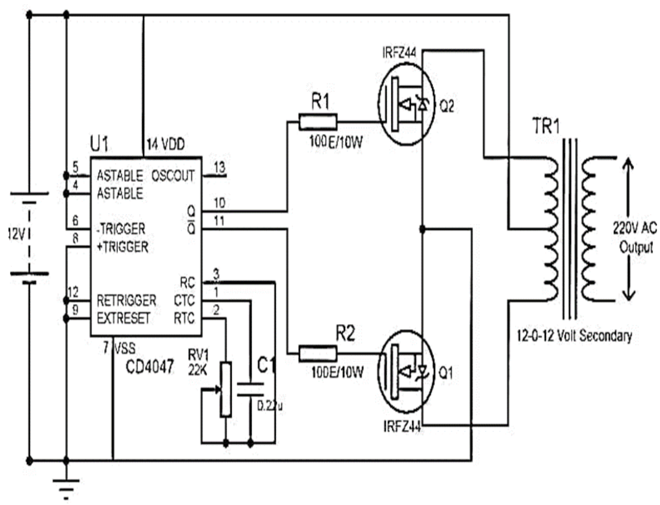

Fig 3: Circuit diagram of Inverter

The drain terminal of the MOSFET is connected to the primary winding of the step-up transformer. The other end of the primary winding is connected to the positive terminal of the DC power source (12V). The negative terminal of the DC power source is connected to the ground or common reference point The secondary winding of the transformer is connected to the load, which represents the AC output terminals. The load can be any device or equipment that requires the AC power output. When the IC CD4047 generates the oscillating signals, it drives the gate of the MOSFET. The MOSFET acts as a switch, allowing current to flow from the DC power source through the primary winding of the transformer. As the current passes through the primary winding, it induces a voltage in the secondary winding, resulting in the generation of AC power. The step-up transformer increases the voltage from the 12V DC input to the desired 220V AC output. This AC power is then available at the secondary winding of the transformer and can be utilized to power various loads or devices connected to the output terminals.

Rectifier configuration: To charge the EV battery, a bridge rectifier circuit is implemented. This circuit is designed to convert the AC power from the grid or inverter output to DC power suitable for charging the EV battery. Suitable diodes and capacitors are selected, and the circuit is assembled on a circuit board, following proper connections and safety precautions. The bridge rectifier circuit consists of four diodes (D1, D2, D3, D4) and a load resistor (RL), arranged in a closed loop configuration. It efficiently converts Alternating Current (AC) to Direct Current (DC) without the need for a costly center tapped transformer. The AC signal is applied across terminals A and B, and the resulting DC signal is obtained across terminals C and D, where the load resistor RL is connected. During each half cycle of the AC signal, only two diodes allow electric current to flow. For instance, diodes D1 and D3 form a pair that allows current during the positive half cycle, while diodes D2 and D4 form another pair that allows current during the negative half cycle of the AC input signal. This configuration reduces the cost and size of the circuit.

In cases where solar energy is not available, a power inversion mechanism is implemented to allow the system to supply home loads using the power stored in the EV battery. This is achieved by designing and constructing an inverter circuit specifically for this purpose. The inverter circuit converts the DC power from the EV battery into AC power suitable for home load supply. Additionally, a switching mechanism is integrated to switch between the solar panel and the EV battery as the power source for home loads based on the availability of solar energy.

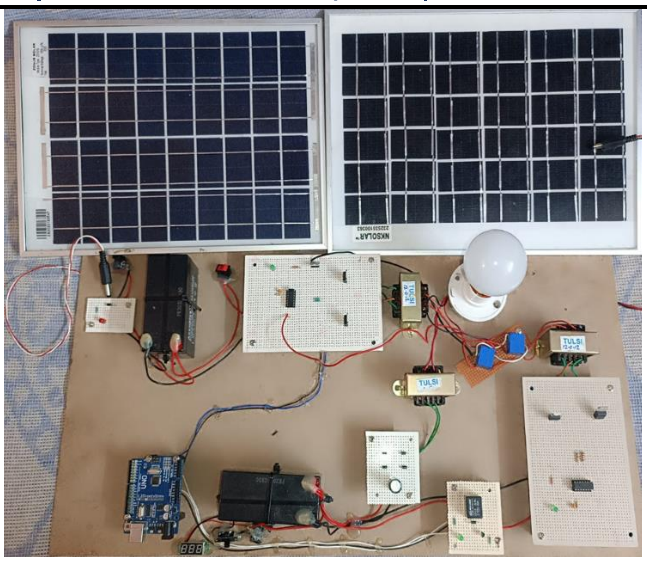

Fig 4: Working Module of the project

Solar panel collects the photovoltaic energy and stores it in the battery provided. The flow of energy from panel to battery is made unidirectional by the use monitoring circuit to avoid power flow back from battery to panel. With the help of inverter circuit design the collected power will be utilized to power home load. And at the same time this power will be rectified from AC to DC by the use of rectifier bridge and filter circuit to charge the Electric Vehicle Battery. If there is no solar power available, an Arduino based controller will trigger the relay section and the power stored in Electric vehicle battery will be inverted from DC to AC to supply home load to get uninterrupted supply to load. By this we can say that the power stored in electric vehicle will flow to and fro based on the requirements.

VII. CONCLUSION

In conclusion, the solar-based bi-directional electric vehicle charger project demonstrates the feasibility and potential of utilizing solar energy for charging electric vehicles. The project successfully implements a system that collects solar energy through a solar panel, stores it in a lead-acid battery, and converts it into usable power for both home loads and electric vehicle charging.

Through the use of a simple circuit design, the unidirectional power flow from the solar panel to the battery is achieved, ensuring efficient energy collection. The power stored in the battery is then inverted using a transformer and inverter circuit to provide AC power for home loads. Additionally, the same inverted power is rectified and stepped down to charge the electric vehicle battery using a bridge rectifier circuit.

The project also addresses the scenario where there is no solar power available. In such cases, the power stored in the electric vehicle battery is inverted and stepped up to supply the home loads, ensuring uninterrupted power supply.

The implementation of the project involves the use of various components such as solar panels, lead-acid batteries, inverters, transformers, rectifiers, and switches. These components are carefully selected and integrated to create a functional and efficient system.
The results obtained from the project demonstrate the successful charging of electric vehicle batteries using solar energy. The system effectively converts and utilizes solar power for both home and electric vehicle applications. The charging process is efficient, and the system is capable of adapting to different scenarios, ensuring continuous power supply.

Overall, the solar-based bi-directional electric vehicle charger project showcases the potential of renewable energy integration into electric vehicle charging infrastructure. It highlights the benefits of utilizing solar energy, such as reduced dependency on the grid, cost savings, and environmental sustainability. The project sets the foundation for further research and development in the field of solar-powered electric vehicle charging systems, contributing to the advancement of sustainable transportation solutions.

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