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An Electric Vehicle-to-Vehicle Wireless Power Transfer System Utilizing Wind and Solar-Powered Battery Systems for Use in Single Phase Induction Motor Drive Trains

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ABSTRACT

This paper presents a groundbreaking electric vehicle-to-vehicle (EV2V) power transfer system that integrates battery storage and renewable energy sources like solar and wind power. The system, designed for single-phase induction motor (SPIM) drive trains, aims to improve the efficiency and sustainability of electric vehicles (EVs) by facilitating wireless power transmission between vehicles. This innovative approach reduces reliance on traditional grid-based charging infrastructure and minimizes carbon emissions associated with vehicle operation. The core functionality of the system is its ability to integrate multiple renewable energy sources and battery storage, enhancing flexibility and reliability in meeting power demands. The adoption of SPIM drive trains also contributes to the overall efficiency and performance of the power transfer process. To evaluate the system's efficacy, comprehensive analysis and simulation studies were conducted using MATLAB. These simulations provided valuable insights into the system's performance under various operating conditions, demonstrating its potential to advance environmentally friendly transportation technology. The integration of MATLAB simulation validates the feasibility of the EV2V power transfer system and offers a platform for further refinement and optimization.

***KEYWORDS:** Electric Vehicle-to-Vehicle (EV2V) Power Transfer, Renewable Energy Integration, Wind Power, Solar Power, Battery Storage, Single Phase Induction Motor (SPIM), Wireless Power Transfer*

1. INTRODUCTION

The switch to renewable energy sources like wind and solar power will have major effects on the transportation sector, notably electric automobiles. Wind turbines convert wind energy into electricity, a clean, scalable alternative to fossil fuels. It grows well in windy coastal locations and broad plains and provides steady energy. Solar power uses photovoltaic cells to directly transform the sun's abundant energy into electricity. Rooftops, automobile exteriors, and road infrastructure may include solar panels to power electric cars [1]. Solar power is ideal for electric vehicles since it may be used when parked, charging, or moving. Electric vehicle (EV) power transfer systems can collect huge amounts of renewable energy from wind and solar. These renewable sources have no greenhouse gas emissions, a little environmental impact, and a nearly endless supply [2]. Wind and solar power decentralise energy production, improving energy security and resilience since they reduce grid dependency. EV-to-V2V systems improve energy autonomy and efficiency by integrating wind and solar energy storage technologies [3]. These devices will power EVs with renewable energy even in bad weather. Renewable energy sources are already very efficient, and they may be much more so with the help of energy management systems and complex control algorithms [4]. Solar and wind electricity synergistically improve efficiency and reliability. Wind and solar power, for instance, often have different peaks, which means that there are complementary patterns of production. Combining the two sources into one EV-to-V2V system reduces power supply variance and increases stability [5]. With wind and solar power in EV-to-V2V systems, sustainable and autonomous mobility has improved. These technologies provide the framework for a more resilient and decentralised energy system that uses wind and solar energy to reduce carbon emissions and fossil fuel reliance [6]. Technology is making wind and solar-powered electric vehicles (EVs) more inexpensive, promising a bright future for transportation. Everyone is talking about electric automobiles nowadays. They are becoming more valuable owing to their lower running costs and environmental benefits [7]. Lack of handy charging facilities and huge distances between them are the major issues with electric vehicle usage. Installing additional network charging stations may boost electric car adoption [8-9]. However, installing charging stations may need expensive grid upgrades. To solve EV range anxiety, V2V charging may be incorporated [10]. The external charger or interface is cumbersome, costly, and heavy, rendering off-board DC quick charging options useless for V2V applications [11]. A V2V charging system must overcome many technological challenges, including preventing automobiles from overloading each other and optimising the charging circuit for power transmission [12]. Using an EV or PHEV, which stands for "plug-in hybrid electric vehicle," is one approach to help with energy and environmental issues. Since they are green and essential to the smart grid, plug-in hybrid electric vehicles (PHEVs) are popular. Fast PHEV charging and discharging infrastructure growth will challenge the household power distribution system [13]. Off-board rapid charging affects PHEV market adoption globally. Peace of mind for customers is increased useful battery life and more time for PEVs to use their batteries courtesy of off-board chargers. Advances in battery technology allow higher-power automotive battery charging [14]. As electric cars grow, batteries become increasingly crucial. EV commercialization is limited by battery life, charging time, weight, energy density, and cost. Unfortunately, battery charger parameters greatly affect charging time [15]. Wireless charging, a novel technology, works with many portable gadgets. The system is popular because it lacks direct electrical connections and is safe and easy to use. This novel technique may help two- and three-dimensional battery charging devices and other wireless power transfer applications. [17]. Use a charging pad instead of a cable if your two-dimensional system doesn't come with one. It can still charge your phone, laptop, etc. This charges multiple gadgets wirelessly, like traditional chargers. Even better, it allows devices to charge in any position or orientation on the charging pad, so it's perfect for charging personal electronics without any problem.[18]. WPT's transmitter and receiver coils are essential. Many different types of coils are used in WPT systems, including square, circular, rectangular, and bipolar coils. [17]. Most automobiles can get along without totally draining their batteries. Every car on the road wastes energy by using more electricity than it requires. If a shorter-distance vehicle was at rest or in motion, it could wirelessly charge a longer-distance vehicle at low power, enabling it to reach its destination quicker. Due to the wireless gearbox coil's resonant induction characteristics, electric cars may exchange power while travelling side by side or in parallel. More recent developments, such as the vehicle-to-vehicle (V2V) charging platform, have helped alleviate some of the concerns associated with charging electric vehicles, such as the limited availability of charging stations and the constant fear of running out of charge while driving [19-20]. Two coupled coils that transmit power via a magnetic field make up the WPT system. As electricity flows through the central coil, a temporally-varying magnetic field envelops it. By intercepting the magnetic field, the secondary coil may generate voltage near the primary coil. The number of turns, air gap length, and magnetic flux (dφ/dt) depend on the induced voltage.

2. SYSTEM CONFIGURATION

As shown in fig.1the electric vehicle to variable voltage power conversion system is compatible with single-phase induction motor (SPIM) drive trains and makes use of solar and wind-powered storage systems. With its intricate design, it aims to improve the efficiency and environmental friendliness of electric cars (EVs). Renewable energy sources, such as solar and wind power, are fundamental to the system. Wind turbines convert the kinetic energy of the wind into electrical energy. These may be either built into the vehicles themselves or placed in locations with particularly strong winds. In a similar vein, solar panels that are flush with the vehicle's exterior turn sunlight into electricity. The main methods for power production in the EV-to-V2V system are these renewable energy sources. Dedicated battery storage systems for wind and solar electricity are integrated into the system to guarantee constant power supply. Onboard batteries store energy from wind and solar sources, ensuring a steady power supply even when the weather is cloudy or the sun isn't shining. Power transfer efficiency inside the SPIM drive trains is optimised, and energy autonomy and resilience are both improved by this complete system setup. The EV-to-V2V power transfer system is a giant leap forward in the quest for environmentally responsible transportation options, thanks to its forward-thinking architecture and use of renewable energy sources

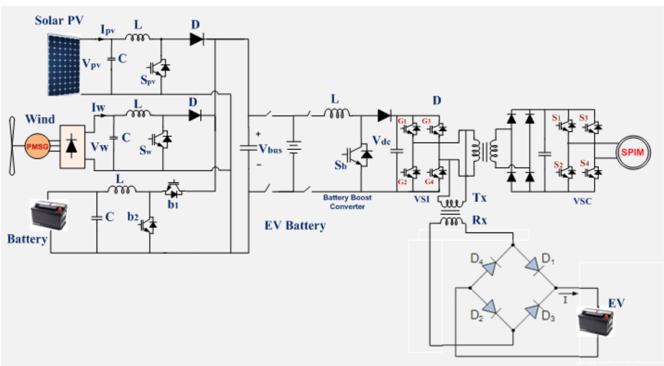


Fig 1: configuration of proposed wireless power transmission for electric vehicle charging

3. POWER TRANSFER IN V2V

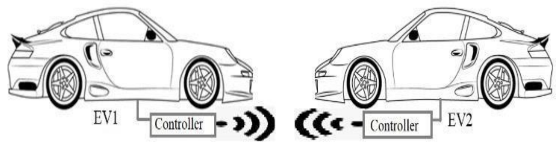


Fig 2: wireless power transmission

Wireless Power Transfer (WPT) technology allows for the transmission of electrical energy from a transmitter to a receiver in a manner that is completely wireless. There are several industrial applications that would profit more from the use of WPT technology, which offers numerous advantages in comparison to the transfer of electricity via wires. Wiring discomfort is reduced and power transmission operations are improved when WPT technology is used. Not too long ago, the WPT has garnered a lot of interest due to the fact that it may be used to recharge the batteries that are aboard electric vehicles. Initiatives to adopt WPT technology and enhance its qualities are being initiated by a number of well-known automobile manufacturers. As a result, WPT may be achieved by means of a low-cost inductive connection between two coils together referred to as a transmitter and receiver coil. For vehicle-to-vehicle (V2V) charging applications, transmitter and receiver coils are installed within the electric vehicle. The inductive WPT of the resonant type is commonly used in applications that need medium-to-high power transmission because of its superior energy efficiency.

4. SOLAR OPERATION

To charge batteries or power extra loads, a DC-DC boost converter that runs on solar energy and using the Perturb and Observe (P&O) Maximum Power Point Tracking (MPPT) algorithm may maximise the amount of solar energy that is generated. In order for the converter to work, it needs certain components like a diode, a capacitor, an inductor, and a switch—typically a MOSFET or an IGBT—. As shown in figure 3, the P&O MPPT algorithm continuously modifies the solar panel's operating point to track its maximum power point (MPP), the point at which the panel's power output peaks. This method, when repeated, ensures that the solar panel will collect as much energy as feasible. When used with a DC-DC boost converter, the P&O MPPT algorithm may help solar-powered systems convert and use energy more efficiently. Because it can maintain operation close to its maximum power output, the system is more efficient and performs better overall. This is achieved by automatically adjusting the converter's operating settings in response to changing conditions in real time.

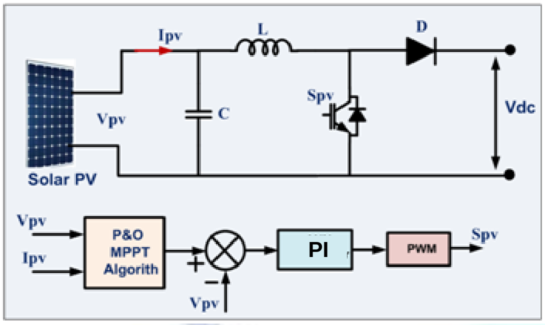


Fig.3 solar MPPT DC-DC unidirectional converter

turbine can always run at its most efficient with the help of this adaptive control system. Consequently, the MPPT algorithm greatly enhances the wind turbine system's overall performance and output.

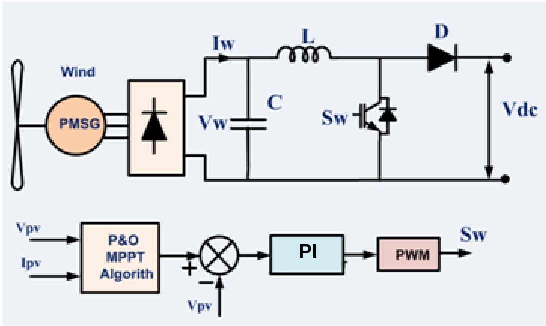


Fig.4 wind power generation with MPPT DC-DC unidirectional converter

5. WIND OPERATION

Permanent Magnet Synchronous Generators (PMSGs) are a kind of wind turbine that convert alternating current (AC) to direct current (DC) by spinning the blades in response to wind energy. A rectifier circuit is used to accomplish this conversion by converting the AC output into pulsing DC voltage. A bridge design of diodes allows current to travel in just one way, achieving this. The rectified DC voltage is still pulsing, however, so it still has ripples. Capacitors store and release electrical energy, which helps to decrease ripples and provide a more consistent DC output. Increasing the DC voltage could be necessary when powering loads that need a higher voltage or while charging batteries. The energy is sent to the load in a separate phase by means of a DC-to-DC boost converter, which stores it in an inductor. Operating the wind turbine at its greatest power point allows for optimal energy extraction using the Perturb and Observe (P&O) greatest Power Point Tracking (MPPT) method. To maximise power production and improve overall efficiency and performance, the MPPT algorithm modifies the operational parameters of the turbine in response to real-time observations of wind speed, turbine output, and other pertinent elements. To top it all off, the MPPT algorithm keeps an eye on the weather and makes adjustments to the turbine's operating position in response to new information, so it can keep up with different wind speeds. The MPPT algorithm aids in optimising energy output and system efficiency by making real-time adjustments to the turbine's settings. No matter how the wind changes, the

6. DC-DC BIDIRECTIONAL CONVERTER

Figure 5 shows how the bidirectional DC-DC converter improves grid efficiency and reliability in vehicle-to-grid (V2G) operations by drawing on the energy stored in electric vehicle (EV) batteries to stabilise the grid during times of high demand or crises. The converter offers useful grid services while actively managing bidirectional power flow using clever management algorithms, keeping EV batteries charged within set limitations. In order to optimise grid performance and decrease dependence on conventional power production based on fossil fuels, these services may include frequency management, voltage assistance, and peak shaving, among others. Furthermore, unique grid services like vehicle-to-home (V2H) and vehicle-to-building (V2B) capabilities are made possible by bidirectional converters. This means that EVs can power houses or buildings even when the power goes out or when the energy rates are too high. A dependable backup power supply and community energy resilience are both fostered by these systems, which draw on the energy stored in EV batteries. A key component of grid-to-vehicle (G2V) operations, bidirectional converters allow for efficient grid-based EV charging. These converters minimise losses while ensuring rapid and dependable charging of electric vehicle batteries by converting grid AC power to DC power. Smart charging techniques including load balancing, demand response, and time-of-use charging are made possible by bidirectional converters, which enable bidirectional communication between the grid and the EV. Optimal charging efficiency, reduced infrastructure costs, and less grid congestion are all outcomes of these skills. In general, bidirectional DC-DC converters play a crucial role in facilitating the shift to a more intelligent, robust, and environmentally friendly energy system. In the future, when transportation and energy systems are intimately linked, there will be more efficiency, dependability, and environmental sustainability. These converters make this possible by easily connecting EVs to the grid and making full use of vehicle-to-grid capabilities. When charging the battery (buck mode) or powering the car's systems (boost mode), a bidirectional DC-DC converter is an essential part of an electric vehicle (EV) since it allows for the efficient transfer of energy from the EV battery to external power sources (such charging stations).

Mode 1: Battery Charging (Buck Mode)

- **Switch S1 and Diode D2 Operation:** This mode is characterised by a forward bias on diode D2 and a closed switch S1. The electric vehicle's battery receives electricity from an external source (such a charging station) via the closed switch, and diode D2 guarantees that the current can only travel in one direction.
- **Buck Mode Operation:** When the converter is in buck mode, it reduces the voltage from the outside power source so it may be used with the lower voltage of the electric vehicle's battery. To charge the battery efficiently, it is essential to make sure it gets the right voltage.
- **Charging the Battery:** The electric vehicle's battery is charged effectively when electricity is transferred from an external source to it. When operating in buck mode, regulating the switch's duty cycle is key to getting the voltage conversion ratio you want. The following are the main formulae for buck mode:

  Voltage Conversion Ratio (Duty Cycle, D): D = $\frac{V_{out}}{V_{in}}$

  Inductor Current (I_L): $V_{out} = \frac{V_{in}\times(1-D)}{D\times(1-D)\times I_L}$

  Output Power (Pout): Pout = $V_{out} \times I_L$

  Efficiency (η): η = $\frac{P_{Out}}{P_{in}} \times 100\%$

Mode 2: Battery Discharging for Power Delivery (Boost Mode)

- **Switch S2 and Diode D1 Operation:** Here, diode D1 is biassed forward and switch S2 is closed. Diode D1 guarantees one-way current flow, and the closed switch permits current to flow from the EV battery to the load, such as electric motors.
- **Boost Mode Operation:** When the converter is in boost mode, it raises the voltage from the electric vehicle's battery to meet the voltage requirements of the load. Even if the load voltage is greater than the battery voltage, this is critical to ensure that the vehicle's systems get enough power.
- **Power Delivery:** The electric vehicle may move and function as needed since energy is transferred from the battery to the load. In boost mode, you may obtain whatever voltage conversion ratio you choose by adjusting the switch's duty cycle. Some of the most important boost mode formulae are:

  Voltage Conversion Ratio (Duty Cycle, D): D = $\frac{1}{1-\left(\frac{V_{out}}{V_{in}}\right)}$

  Inductor Current (I_L): Vout = $\frac{V_{in}}{(1-D)\times I_L}$

  Output Power (Pout): $P_{Out} = V_{out} \times I_L$

  Efficiency (η): η = $\frac{P_{Out}}{P_{in}} \times 100\%$

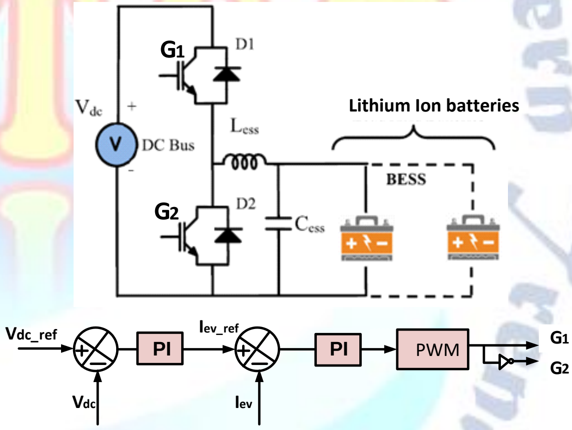


FIGURE 5. Bidirectional DC-DC converter configuration for Electric Vehicle Battery charging.

7. DC-DC UNIDIRECTIONAL CONVERTER

The power converter type seen in figure 6 is a DC-DC unidirectional boost converter, which, as the name implies, increases the input voltage beyond the output voltage. Its purpose is to transfer energy in a straight line, usually from a lower-voltage source to a higher-voltage load, from the input source to the output load. In a boost converter, the main components are an inductor, a switch (often a MOSFET), a diode, and an output capacitor. Permitting current to flow through the inductor while the switch is left closed allows the magnetic field to store energy. When the switch is opened, the inductor can tolerate fluctuations in current flow, which causes a voltage to be inducted across itself on the other side of the switch. When this voltage is added to the input voltage, it raises the voltage across the output capacitor. Current may flow from the inductor to the output capacitor and load because the diode is forward-biased. The output voltage of the boost converter may be fine-tuned by adjusting the duty cycle of the switch. Among the many common uses for the unidirectional boost converter are power supply, LED drivers, and renewable energy systems. In order to satisfy the load requirements, this kind of converter is usually used when the input voltage has to be increased.

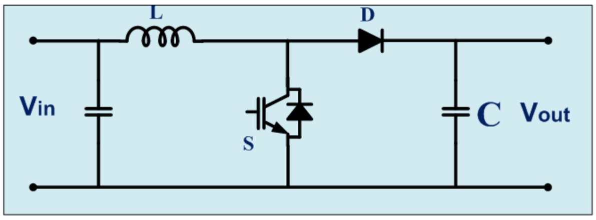


Fig.6 DC-DC unidirectional boost converter

- **Output Voltage (V_{out})**: The output voltage of a boost converter can be calculated using the following formula:

$$V_{out} = \frac{V_{in}}{1-D}$$

Where Vin is the input voltage and D is the duty cycle of the converter.

- **Input Current (I_{in})**: The input current of the boost converter can be calculated as:

$$I_{in} = \frac{I_{out}}{1-D}$$

Where I_{out} is the output current of the converter.

- **Output Current (I_{out})**: The output current of the boost converter can be approximated as: $I_{out} = \frac{P_{out}}{V_{out}}$

Where P_{out} is the output power.

- **Efficiency (η)**: The efficiency of the boost converter can be calculated as the ratio of output power to input power:

$$\eta = \frac{P_{out}}{P_{in}} \times 100\%$$

Where Pin is the input power.

- **Inductor Current Ripple (ΔI_L)**: The peak-to-peak ripple current flowing through the inductor can be approximated as:

$$\Delta I_L = \frac{V_{in} \times D \times T_{on}}{L}$$

where Ton is the on-time of the switching device and L is the inductance.

- **Output Voltage Ripple (ΔV_{out})**: The peak-to-peak ripple voltage at the output can be approximated as:

$$\Delta V_{out} = \frac{V_{in} \times D \times T_{on}}{C}$$

Where C is the output capacitance.

8. SINGLE PHASE DC-AC VOLTAGE SOURCE CONVERTER

A single-phase DC to AC voltage source converter is crucial in electric power systems for driving single-phase induction motors. These converters, usually set up as H-bridge inverters, convert direct current (DC) voltage from batteries or DC link capacitors into alternating current (AC) voltage for induction motors. The controlled switching of semiconductor devices, typically MOSFETs or IGBTs, generates an AC waveform with adjustable voltage magnitude and frequency, essential for efficient motor driving. The output voltage magnitude is controlled through the duty cycle of a pulse width modulation (PWM) signal, which determines the proportion of time switches are in the ON state relative to the total switching period. The relationship between the duty cycle and output voltage magnitude is linear, with Vout being a fraction of the DC input voltage. The switching frequency of the inverter determines the output frequency of the AC waveform, typically half of the switching frequency in a single-phase system. Control of these converters often involves sophisticated modulation techniques like PWM or SPWM, ensuring precise control over output voltage and frequency, optimizing induction motor performance across various operating conditions. Overcurrent and overvoltage protection are also essential for reliable and safe operation in real-world applications.

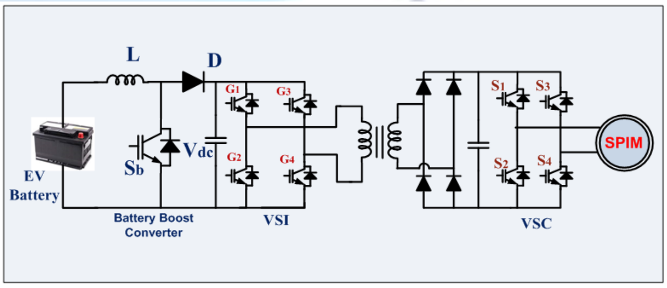


Fig.7 electric vehicle power supply to SPIM drive system

1. **Output Voltage Magnitude (V_{out}):** The output voltage magnitude (V_{out}) is directly proportional to the duty cycle (D) of the PWM signal and the DC input voltage (V_{dc}).

$$V_{out}=D\times V_{dc}$$

2. **Output Frequency (f_{out}):** The output frequency (f_{out}) of the AC waveform is half of the switching frequency (f_{sw}) of the inverter.

$$f_{out}=\frac{f_{sw}}{2}$$

Where:

V_{out}= Output voltage magnitude

D = Duty cycle of the PWM signal (ratio of ON time to total time)

V_{dc}= DC input voltage

f_{out} = Output frequency of the AC waveform

f_{sw} = Switching frequency of the inverter

9. SIMULATION RESULTS AND DISCUSSION

1. Electric vehicle battery variation with renewable energy sources

Renewable energy sources are crucial for generating power for electric vehicle charging stations, reducing greenhouse gas emissions and promoting sustainability in the transportation sector. Advancements in battery technology enable efficient energy storage for electric vehicles, further enhancing environmental benefits. Smart grid technology optimizes energy usage and distribution, making charging stations more reliable and cost-effective. However, renewable energy power generation depends on climate change, with wind and solar relying on air and sunlight, which can be unpredictable. This variability highlights the need for robust energy storage solutions to ensure a stable power supply from renewable sources. Energy storage systems can balance supply and demand by storing excess energy during peak production and releasing it during low production. As shown fig.8 to make renewable energy sources as efficient and reliable as possible for transportation and other uses, it is essential to use modern energy storage technology. From 0 seconds to 0.4 seconds, As shown fig.8 the battery will drain to provide a steady supply to the loads; this is unaffected by climate change. On the other hand, wind power is generated by capturing the kinetic energy of wind. We can maximise the use of renewable energy and lessen our dependency on fossil fuels by combining wind power production with energy storage technologies. This will lead to a more sustainable future. Even solar panels can't reliably power loads from 0.4 to 0.7 seconds; during that time, the battery must deplete. Capturing sunlight and transforming it into energy using photovoltaic cells is the source of solar power. Renewable energy sources may be even more efficient and reliable when combined with energy storage technologies to generate solar power.

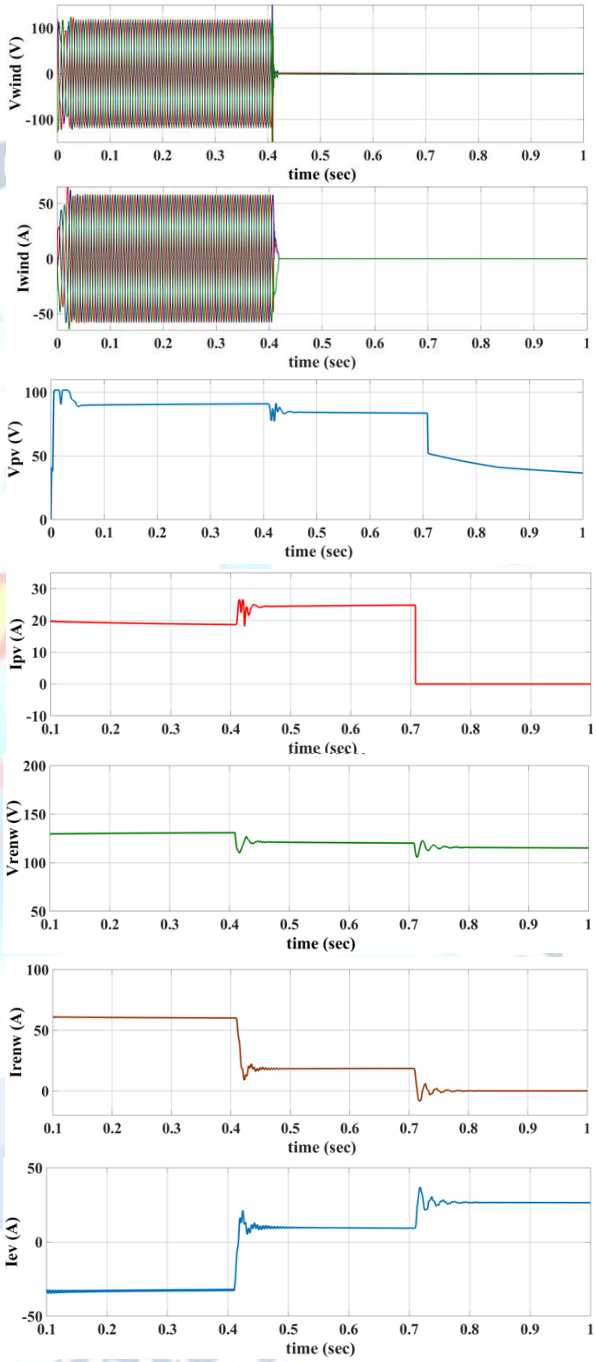
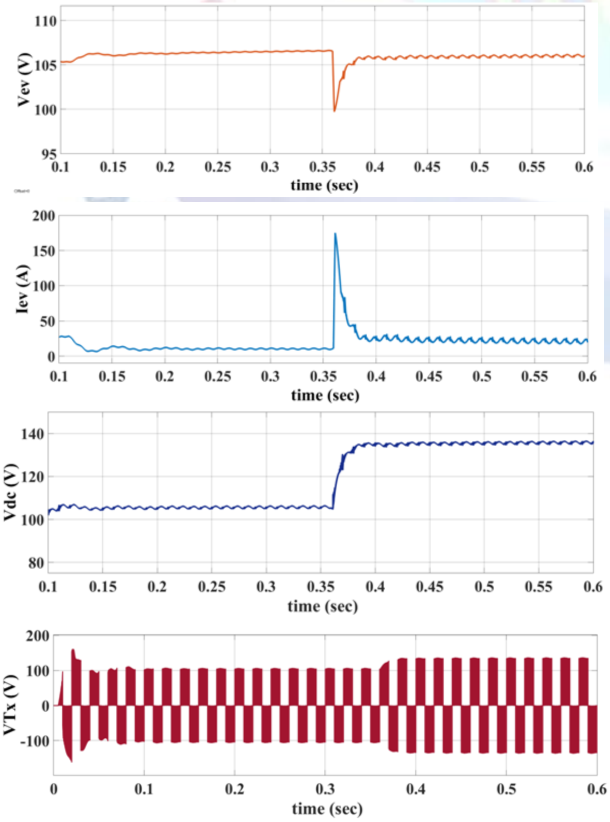


Fig.8 Variation in renewable sources for charging electric vehicles

2. Electric vehicle power utilizing for SIPM drive and wireless electric vehicle charge

Electric vehicle (EV) technology advances with the vehicle-to-vehicle (V2V) wireless power transformer, which uses renewable energy to fuel sustainable mobility. This revolutionary technology uses single-phase induction motor drives and V2V wireless power transmission to reduce emissions and promote environmental responsibility in the automobile sector. V2V wireless power transformers cut carbon emissions and promote environmental conservation by smoothly integrating renewable energy sources into the EV charging network. Vehicles may use wind and solar energy to reduce their environmental effect. The V2V wireless power transformer provides smooth acceleration and little energy loss as shown in fig.9. This optimisation improves EV driving and maximises energy economy, using every kilowatt-hour, efficiently. This technology's capacity to remove charging stations is revolutionary. The V2V technology simplifies charging by wirelessly transferring electricity between cars, lowering energy usage and removing the need for large charging infrastructure. V2V wireless power transformers also make charging easier for EV owners, fitting into their everyday routines. This technology allows automobiles to charge while driving or parked, giving drivers peace of mind and flexibility. In summary, the V2V wireless power transformer might revolutionise EV technology and transportation. This technology makes energy transfer between cars more efficient and easy, allowing a more sustainable and accessible electric vehicle infrastructure and a cleaner, greener automotive landscape.



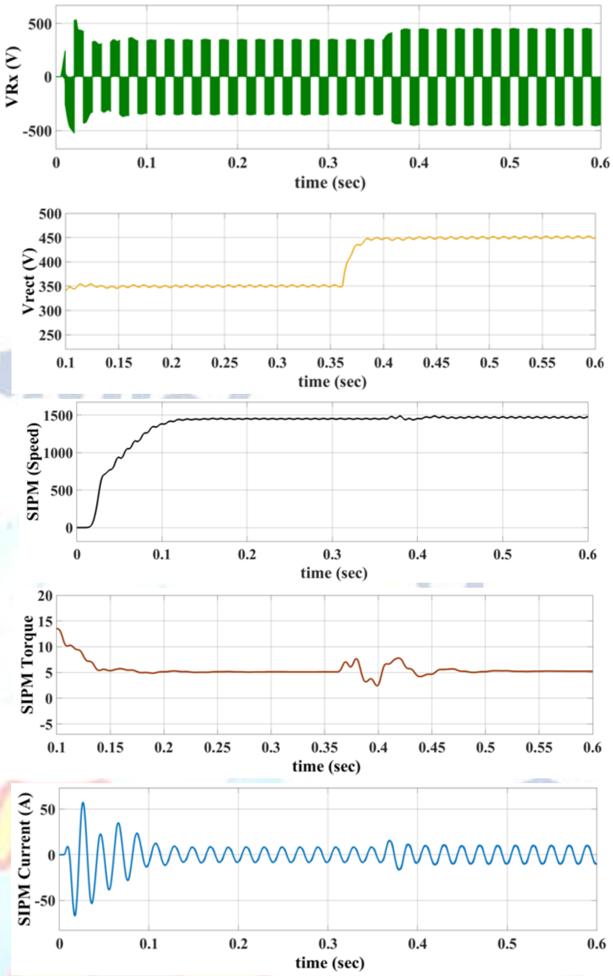


Fig.9 Power conversion from electric vehicle batteries to SPIM and wireless V2V

10. CONCLUSION

The development of an Electric Vehicle-to-Vehicle (EV-to-V2V) power transfer system utilizing wind and solar-powered battery systems for single-phase induction motor (SPIM) drive trains is a significant advancement in sustainable transportation technologies. This system addresses challenges such as range anxiety and reliance on traditional grid infrastructure for electric vehicles. The system uses wind turbines and photovoltaic panels to generate clean energy, while dedicated battery storage systems ensure reliable power supply in variable environmental conditions. The system's effectiveness and feasibility have been demonstrated through detailed analysis and simulation, highlighting its potential to enhance the sustainability and efficiency of EVs. The use of SPIM drive trains further optimizes the power transfer process, contributing to overall energy efficiency and system reliability. This innovative approach reduces carbon emissions, dependence on fossil fuels, and fosters energy resilience and decentralization. The EV-to-V2V power transfer system holds promise for revolutionizing the transportation sector and paving the way for a greener, more sustainable future.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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