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Research Paper

DESIGNING AN INTEGRATED ON-BOARD CHARGER TO EFFICIENTLY CHARGE ELECTRIC 2-WHEELER VEHICLES

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ABSTRACT

An on-board charger for efficiently charging multiple battery-operated electric vehicles (EVs) is introduced. It has evolved as a single-input dual-output (SIDO) integrated boost-single ended primary inductor converter (SEPIC) fly-back converter, offering cost-effectiveness, reliability, and higher efficiency compared to conventional chargers with equivalent specifications. The proposed system includes an additional regulated output terminal, in addition to an existing terminal for charging the EV battery of a 4-wheeler, which can be used to charge another EV battery, preferably a 2-wheeler. With the aid of control techniques, unity power factor operations are obtained during constant-voltage (CV)/constant-current (CC) charging for the grid-to-vehicle (G2V) operating mode. Using mathematical modelling analysis, the proposed system is developed in a Matlab/Simulink environment, and the results are validated in a real-time simulator using dSPACE-1104. The proposed system is employed for charging the batteries of two EVs with capacities of 400 V, 40 A·h and 48 V, 52 A·h for the 4-wheeler and 2-wheeler, respectively.

Its performance is investigated under different operating modes and over a wide range of supply voltage variations to ensure safe and reliable operation of the charger.

Keywords — Continuous conduction mode (CCM), CV/CC, electric vehicles (EVs), power factor correction (PFC), single input dual output (SIDO), state of charge (SOC)

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INTRODUCTION

Designing an integrated on-board charger (OBC) for efficient charging of 2-wheeler electric vehicles (EVs) is a critical step toward improving convenience, performance, and energy efficiency in the rapidly expanding EV market. Unlike off-board chargers that require external infrastructure, an OBC is embedded within the vehicle, allowing seamless and flexible charging from standard power outlets. The primary objective of this design is to optimize energy conversion, minimize charging time, and ensure the longevity of the battery while maintaining a compact and lightweight structure suitable for two-wheelers. Key design considerations include high-efficiency power electronics, advanced thermal management, and intelligent control strategies to regulate charging parameters dynamically.

The use of high-frequency converters, such as resonant or soft-switching topologies, can significantly reduce power losses and enhance overall system efficiency. Additionally, implementing bidirectional charging capabilities enables features such as vehicle-to-grid (V2G) and vehicle-to-home (V2H) power transfer, allowing the vehicle's battery to serve as an energy storage unit. Ensuring compatibility with different grid voltages and incorporating robust safety mechanisms like overvoltage, overcurrent, and thermal protection are also essential to enhance reliability and prevent potential hazards. Furthermore, integrating smart communication protocols, such as CAN or IoT-based monitoring, allows real-time data tracking and remote diagnostics, improving user experience and system maintainability. As the demand for electric two-wheelers rises, developing an efficient, cost-effective, and scalable OBC will play a crucial role in accelerating EV adoption while addressing challenges related to energy consumption, infrastructure limitations, and overall sustainability in the e-mobility sector.

METHODOLOGY

Step 1:

Research problem Problems faced with off board chargers ▪ Limited Accessibility (only at charging stations) ▪ Higher Installation Cost ▪ More complex design and control ▪ May introduce EMI challenges Solution proposed: Designing an Integrated on board charger by using two power train transistors (Totem pole converter).

Step 2:

Methods of Data collection

▪ Secondary data collection

▪ Tools: Matlab/Simulink

▪ Technique: Power electronics system, Control algorithms, and Modelling

▪ Variables focused: Power, AC voltage, Battery voltage, Battery Capacity, Charging current.

Step 3:

Method of analysis The OBC charger a two-stage charger consists of a PFC rectifier to get a good power factor and DC–-DC converter to control the output voltage and provide galvanic isolation charger

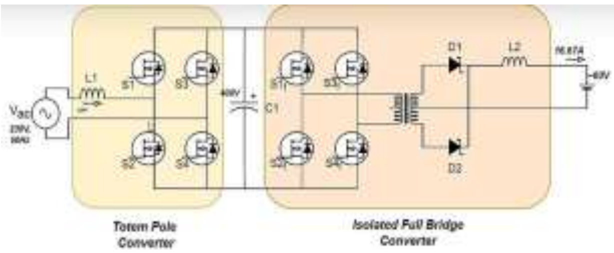

Fig.1: Circuit diagram of totem pole and isolated full bridge converter

Step 4: Evaluation & Justification

A **totem-pole** converter is a type of power electronics circuit commonly used in on-board chargers (OBCs) for electric vehicles (EVs). Its primary purpose is to efficiently convert AC power from the grid into DC power to charge the vehicle's battery. The totem-pole PFC (Power Factor Correction) topology is particularly popular in modern OBC designs due to its efficiency and performance benefits.

Other alternate converters with less efficiency:

Bridgeless Boost PFC Converter (Requires complex control algorithms, May introduce EMI challenges)

Vienna Rectifier (More complex design and control)

Dual-Boost PFC Converter (Increased components count)

WORKING

The on-board charger (OBC) for 2-wheeler electric vehicles (EVs) operates on the fundamental principle of power conversion, regulation, and efficient energy transfer from the grid to the EV's battery pack. The primary objective is to ensure that the alternating current (AC) power supplied from the electric grid is effectively converted into a stable and regulated DC voltage that meets the charging requirements of the battery, while also maintaining high efficiency and safety standards.

The charger follows the Constant Current-Constant Voltage (CC-CV) charging strategy, where it initially provides a constant current (CC) mode to rapidly charge the battery and then transitions into constant voltage (CV) mode as the battery approaches full charge, gradually reducing the current to prevent overcharging and battery degradation.

The system integrates multiple stages, including an AC-DC conversion stage, a DC-DC conversion stage, and a battery management system (BMS) to ensure controlled and optimized charging. The working of the integrated on-board charger begins with the AC power input, which is taken from a standard single-phase or three-phase power source. The first stage in the system is the power factor correction (PFC) circuit, which plays a crucial role in ensuring that the current drawn from the grid remains in phase with the voltage, thereby improving power quality and reducing harmonic distortions.

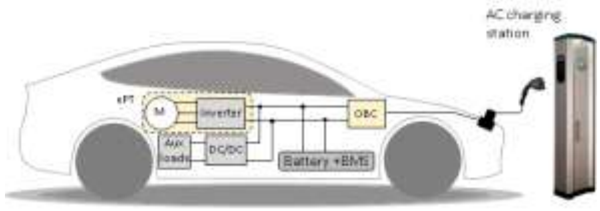

Fig.2: EV-charging

The working of the integrated on-board charger involves multiple stages:

1. **AC Input and Power Factor Correction (PFC) Stage:**
   - The charger takes AC power from the grid (typically single-phase or three-phase).
   - A totem-pole power factor correction (PFC) circuit ensures that the input current remains in phase with the

input voltage, reducing power losses and improving grid efficiency.

2. **AC-DC Conversion (Rectification):**
   - The AC input is converted into DC voltage using a diode bridge rectifier or an active rectifier circuit.
   - This DC voltage is typically at a higher level and needs further regulation before charging the battery.
3. **DC-DC Conversion Stage:**
   - The DC voltage from the rectifier is processed by a DC-DC converter, which adjusts the voltage and current to match the battery's charging requirements.
   - This stage may include a square wave inverter, a tap-changing transformer, and another rectifier stage to step down the voltage to the required battery level.
4. **Battery Charging Process:**
   - The regulated DC power is fed into the battery pack, following the CC-CV charging strategy:
   - Constant Current (CC) Phase: The charger supplies a steady high current to quickly charge the battery up to a specific voltage level.
   - Constant Voltage (CV) Phase: Once the battery reaches a preset voltage, the current gradually reduces to prevent overcharging.
5. **Battery Management System (BMS) and Safety Controls:**
   - The Battery Management System (BMS) continuously monitors voltage, current, temperature, and State of Charge (SOC).
   - Protection mechanisms such as overvoltage, overcurrent, short circuit, and thermal shutdown are implemented to ensure safe and efficient charging.
6. **Final Charging Completion and Cut-off:**
   - Once the battery reaches full charge, the charger reduces the current to a trickle charge or shuts off automatically to prevent overcharging.
   - The on-board charger communicates with the vehicle's system to update the charge status and control further power flow.

SIMULATION

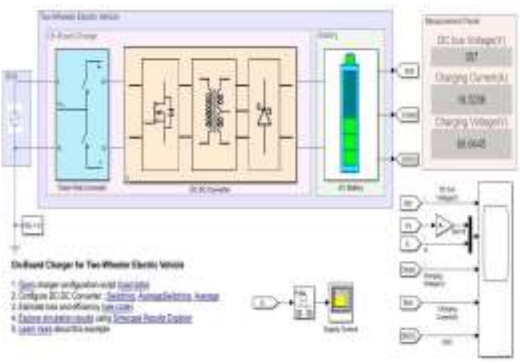

Fig.3: Simulation of On-board Charger

The given image illustrates a simulation model of an on-board charger (OBC) for a two-wheeler electric vehicle (EV), showcasing the charging process from the AC grid to the EV battery.

The system begins with an AC grid input, which is processed through a Totem Pole Converter for AC to DC conversion with power factor correction (PFC). This DC voltage is then further refined using a DC-DC converter, comprising a Square Wave Inverter, Tap Changing Transformer, and Diode Bridge Rectifier, ensuring efficient voltage and current regulation for battery charging.

RESULTS & DISCUSSION

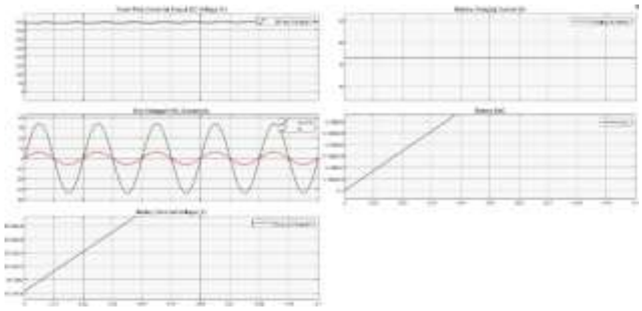

Fig.4: Output graphs of On board charger

The output of modelling an EV battery pack can provide a comprehensive view of its performance under various conditions. Key outputs typically include:

Totem pole converter DC output voltage:

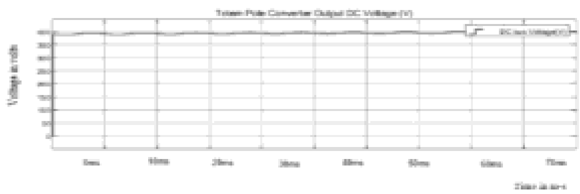

Fig.5: Totem pole converter Output DC voltage(V)

Totem-Pole Converter can be used as a Power Factor Correction (PFC) circuit to efficiently convert 230V AC (input) to approximately 400V DC (output).

Grid voltage(V/10), Current(A):

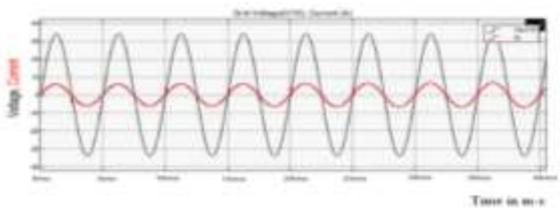

Fig.6: Grid Voltage(V/10), Current(A)

Actual Voltage (Van) = (Van/10) * 10

RMS Voltage (Van) = Peak Voltage / √2

Actual Voltage (Van) = 32 * 10

RMS Voltage (Van) = 320 Volts / 1.414

Actual Voltage(Van)=320Volts

RMS Voltage (Van) ≈ 226.3 Volts

Battery Terminal Voltage(V):

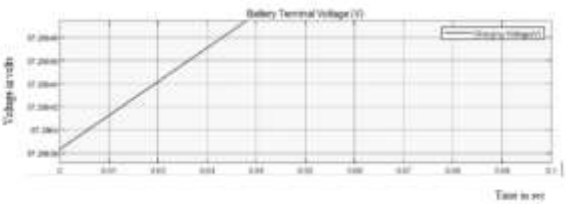

Fig.7: Battery terminal Voltage(V)

Battery Charging Current(A):

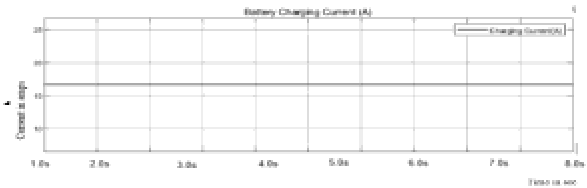

Fig.8: Battery Charging current is 16.67A

Battery SOC:

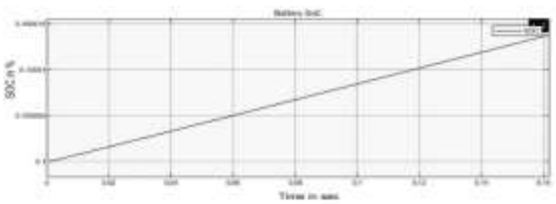

Fig.9: Battery SOC

SoC in the graph represents a change from 10% to 10.0015% with respect to time in sec

CONCLUSION

The development of an integrated on-board charger for efficiently charging two-wheeler electric vehicles presents a significant step forward in enhancing the convenience, accessibility, and sustainability of electric mobility. By allowing users to charge their vehicles from standard power outlets, this solution eliminates the dependency on dedicated charging stations, making electric two-wheelers a more practical choice for everyday transportation. Additionally, the project contributes to environmental sustainability by reducing carbon emissions and reliance on fossil fuels, aligning with global efforts to promote clean energy solutions.

The integration of intelligent charging mechanisms ensures optimized power management, leading to improved battery life and efficiency, thereby enhancing the overall performance and reliability of electric two-wheelers. Furthermore, this technology has the potential to integrate with renewable energy sources and smart grids, enabling sustainable off-grid charging and bidirectional energy flow. The cost-effective and scalable nature of the design makes it particularly beneficial for rural and semi-urban areas where EV charging infrastructure is limited, thereby encouraging wider adoption of electric mobility. Overall, this project serves as a foundation for further research and innovation in the electric vehicle sector, fostering advancements that will shape the future of sustainable transportation.

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