



(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



## Impact Factor: 8.699

## Volume 14, Issue 5, May 2025

⊕ www.ijirset.com 🖂 ijirset@gmail.com 🖄 +91-9940572462 🕓 +91 63819 07438





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

## Volume 14, Issue 5, May 2025 |DOI: 10.15680/IJIRSET.2025.1405352|

## Multifunctional Integrated Converter for EVs: A Unified Platform for High-Voltage Charging, Low-Voltage Support, and V2G Operation

Sushmitha K R, Harshitha G N, Ankitha M, Manoj Kumar C M, Priyanka

Assistant Professor, Department of Electrical & Electronics Engineering, P.E.S. College of Engineering, Mandya,

Karnataka, India

U.G. Student, Department of Electrical & Electronics Engineering, P.E.S. College of Engineering, Mandya,

Karnataka, India

U.G. Student, Department of Electrical & Electronics Engineering, P.E.S. College of Engineering, Mandya,

Karnataka, India

U.G. Student, Department of Electrical & Electronics Engineering, P.E.S. College of Engineering, Mandya,

Karnataka, India

U.G. Student, Department of Electrical & Electronics Engineering, P.E.S. College of Engineering, Mandya,

Karnataka, India

**ABSTRACT**: This paper presents a Multifunctional Integrated DC–DC Converter (MFID) for electric vehicles, combining On-Board Charger (OBC) and Low-Voltage DC–DC Converter (LDC) functions into a compact architecture. The MFID supports high-voltage battery charging, low-voltage regulation, and bidirectional Vehicle-to-Grid (V2G) flow using a shared power stage and adaptive control algorithm. It dynamically switches between Grid-to-Vehicle, V2G, and auxiliary modes based on real-time demands. Emphasizing efficiency, thermal stability, and reliability, the converter ensures optimal energy management. MATLAB/Simulink simulations confirm low switching losses and stable performance across voltage ranges, promoting intelligent, future-ready EV power systems integrated with smart grids and renewables.

**KEYWORDS**: Multifunctional Integrated DC–DC Converter (MFID), Bidirectional Power Flow, Vehicle-to-Grid (V2G), Grid-to-Vehicle (G2V), Electric Vehicle (EV) Energy Management

#### I. INTRODUCTION

The increasing global emphasis on sustainable transportation and the swift adoption of electric vehicles (EVs) have heightened the demand for efficient, compact, and intelligent power conversion systems. Within the EV powertrain, two critical components—namely the On-Board Charger (OBC) and the Low-Voltage DC–DC Converter (LDC)— serve distinct yet essential functions. The OBC enables AC grid-to-vehicle (G2V) charging for the high-voltage battery (HVB), while the LDC steps down HVB voltage to power 12 V or 48 V auxiliary systems, including lighting, infotainment, and control electronics. Traditionally, EVs deploy separate OBC and LDC units, each with individual power stages, controllers, and protection circuits, resulting in increased complexity, thermal stress, and system cost. As EVs evolve to support smart grid functions such as bidirectional vehicle-to-grid (V2G) energy exchange, the need for seamless mode switching, high-efficiency energy transfer, and reliable bidirectional operation becomes crucial. Recent research has explored shared power stage topologies—such as dual-active bridges (DAB), phase-shifted full-bridge (PSFB) converters, and interleaved current-fed converters—to achieve integration. While various solutions like ZVZCS converters and synchronous rectification have advanced efficiency, many still suffer from issues related to scalability, complex modulation, and limited voltage regulation under wide load variations. This paper introduces a novel Multifunctional Integrated DC–DC Converter (MFID) that consolidates OBC and LDC functionality into a single, bidirectional, reconfigurable topology. The MFID employs a shared power stage governed by adaptive control logic,





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### **Volume 14, Issue 5, May 2025**

#### |DOI: 10.15680/IJIRSET.2025.1405352|

capable of dynamically switching among G2V, V2G, and auxiliary supply modes. By eliminating redundant hardware and optimizing magnetic elements, the MFID reduces conduction losses and enhances thermal performance. Simulation results in MATLAB/Simulink demonstrate the converter's robustness under dynamic conditions, showcasing high conversion efficiency, accurate voltage regulation, and reduced switching losses. The MFID presents a scalable, cost-effective, and future-ready power solution suitable for diverse EV platforms, supporting intelligent energy management and integration with renewable-powered smart grids.

#### **II. LITERATURE SURVEY**

Electric vehicle (EV) power systems demand compact, efficient, and multifunctional energy conversion solutions to support high-performance requirements and seamless interaction with the power grid. A range of research has addressed the limitations and opportunities in EV charging systems, encompassing both on-board and off-board configurations. A comprehensive review of battery charger topologies has emphasized the distinctions between unidirectional and bidirectional power flow, underscoring the benefits of integrating charger components with the electric drive unit to minimize weight, volume, and cost [1]. Bidirectional isolated DC-DC converters, which offer galvanic isolation and grid-feedback capabilities, are vital for modern EVs. Soft-switching solutions like Zero-Voltage and Zero-Current Switching (ZVZCS) full-bridge converters enhance energy transfer efficiency under variable load conditions, which is crucial for fast-charging scenarios [3]. Additionally, interleaved and resonant current-fed topologies have been explored to reduce filter sizes and improve thermal characteristics in hybrid and electric vehicle applications [4]. Dual-function converter designs that combine AC/DC and DC/DC stages offer the advantage of reduced component count and support bidirectional energy flow, making them suitable for smart grid integration [5]. Adaptive control methods, such as variable DC link regulation, allow dynamic adjustment of charging parameters for plug-in EVs [6]. Efforts to minimize light-load losses have improved full-bridge converter efficiency, making them suitable for broader EV and server applications [7]. Recent innovations in synchronous rectification and modulation have enabled more effective low-voltage auxiliary DC/DC converters [10], while advanced modulation techniquessuch as multi-phase-shift and dual-phase-shift control in dual-active-bridge (DAB) converters-have optimized switching performance, improved ZVS operation, and enhanced reactive power handling [12], [13]. Hybrid ZVS converters and active commutated current-fed bridge converters have emerged as promising solutions, delivering high performance, flexibility, and reduced conduction losses for integrated EV charging platforms [9], [15]

#### **III. METHODOLOGY**

#### **A. Transformer Turns Ratio**

The adaptability of the proposed MFID across its three operating modes is enabled by configuring the transformer with different winding ratios tailored to each mode's topology and functional requirements. The determination of this turns ratio is critical, as it must ensure compatibility with a wide range of high-voltage battery (HVB) values, while also supporting stable and bidirectional power flow for both grid and low-voltage battery (LVB) interactions.

To achieve this, the turns ratio is selected to meet specific design constraints in all three modes:

1. In G2V mode, where the transformer ratio is defined as (Ns+Nt):Np the DC-link voltage Vdc must remain sufficiently high relative to the maximum HVB voltage VH,max. This condition is expressed as:

$$\frac{N_p}{N_s + N_t} V_{dc} \ge V_{H,\max} \tag{6}$$

2. In V2G mode, where the transformer uses the winding ratio Nt:Np and a voltage doubler rectifier (VDR) is used instead of a full-bridge rectifier, the minimum HVB voltage must still be able to support the required Vdc This leads to the constraint:





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

## Volume 14, Issue 5, May 2025 |DOI: 10.15680/IJIRSET.2025.1405352|

$$2\frac{N_t}{N_p}V_{H,\min} \ge V_{dc} \tag{7}$$

3. In LDC mode, where the ratio becomes Ns:Np , the minimum HVB voltage should be capable of supplying the LVB through the VDR circuit, governed by:

$$2\frac{N_s}{N_p}V_{H,\min} \ge V_L \tag{8}$$

By satisfying all three constraints, the MFID ensures seamless operation over a broad voltage range without needing additional converters or complex control logic. After careful evaluation of these conditions and experimental validation (as discussed in Section V), the optimal turns ratio for the transformer was selected as:

Ns:Np:Nt=18:1:14

This configuration supports an HVB voltage range of 300–420 V, an LVB voltage range of 20–28.8 V, and maintains a stable DC-link voltage of 380 V, meeting all required operational boundaries across G2V, V2G, and LDC modes.

#### **B. ZVS Inductor Design**

For the proposed MFID to achieve high efficiency, it is essential to ensure Zero Voltage Switching (ZVS) across all operational modes—G2V, V2G, and LDC. ZVS minimizes switching losses by allowing the power switches to turn ON or OFF when the voltage across them is near zero. To satisfy the ZVS condition, the stored inductive energy must be sufficient to fully discharge the capacitive energy associated with the switch's output capacitance. This requirement is expressed as:

$$E_L \ge E_C$$
 (9)

Here, EL is the energy stored in the inductance during the freewheeling period, and EC is the energy needed to charge and discharge the output capacitance of the switches involved in the ZVS transition.

Capacitive Energy

- In different modes, the effective capacitive energy varies depending on which converter stage participates in switching:
  - For G2V mode, where the middle-side H-bridge converter is active, the total capacitive energy is:

$$E_{C,G2V} = \frac{1}{2} (2C_j) V_{dc}^2$$
 (1)

• For V2G and LDC modes, the back-side H-bridge handles ZVS operation, so the capacitive energy becomes:

$$E_{C,V2G,LDC} = \frac{1}{2} (2C_{oss}) V_H^2 \tag{11}$$

0)

Inductive Energy

• G2V mode:

$$E_{L,G2V} = \frac{1}{2} \left( L_m + L_{lk} + \frac{L_r}{n_1^2} \right) \cdot i_{Lm}^2(t_{off}).$$
(12)

IJIRSET©2025

| An ISO 9001:2008 Certified Journal |





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

### Volume 14, Issue 5, May 2025 |DOI: 10.15680/IJIRSET.2025.1405352|

• V2G mode:

$$E_{L,V2G} = \frac{1}{2} (L_m + L_{lk}) \cdot i_{Lm}^2(t_{off})$$
<sup>(13)</sup>

• LDC mode:

$$E_{L,LDC} = \frac{1}{2} (L_m + L_{lk} + n^2 L_r) \cdot i_{Lm}^2(t_{off})$$
(14)

#### **C.** Auxiliary Capacitors

The auxiliary capacitors C1 in the proposed MFID serve a dual role: they not only support voltage doubling through the VDR structure but also participate in resonance, especially during LDC mode, which is the most critical operating condition due to its minimum Voltage Conversion Ratio (VCR) and peak current stress. Therefore, their design must account for both the resonant frequency and the electrical stress caused by high currents.

To ensure stable resonance and controlled operation, the values of C1 and C2 are determined using the resonant frequency fr as:

$$C_1 = C_2 = \frac{1}{8\pi^2 (L_r + \frac{L_{lk}}{n^2}) f_r^2}$$
(16)

In LDC mode, the current waveform at the transformer secondary can be broken into two distinct intervals. The first portion, is1(t), results from resonance between the inductors and capacitors when both switches are ON. It follows a sinusoidal phttern:

$$i_{s1}(t) = \left(\frac{V_{in}}{n} - V_{c1}(t_0)\right) \frac{1}{Z_o} \sin(\omega_r(t - t_0))$$

$$i_{s2}(t) = -\frac{(V_o + \Delta V_{c1})}{2(L_r + \frac{L_{lk}}{n^2})} (t - (t_0 + T_s \cdot D_{eff}))$$

$$+ i_{sec}(t_0 + T_s \cdot D_{eff})$$
(17)

The ripple voltage and the initial voltage on C1 are expressed as:

$$\Delta V_{c1} = \frac{T_s V_o}{2C_1 R_o}, V_{c1}(t_0) = \frac{V_o}{2} - \frac{\Delta V_{c1}}{2} = \frac{V_o}{2} \left( 1 - \frac{T_s}{2C_1 R_o} \right)$$
(18)

where Ro is the equivalent load resistance.

The time duration  $\Delta T$  taken for the secondary current to drop to zero is:

$$\Delta T = \frac{2 \cdot i_{\text{sec}}(t_0 + T_s D_{eff})}{(V_o + \Delta V_{c1})} \left(\frac{L_{lk}}{n^2} + L_r\right)_{(19)}$$





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 5, May 2025

#### |DOI: 10.15680/IJIRSET.2025.1405352|

To compute the average output current, the integral of the full current waveform is evaluated across the switching cycle:

$$I_{o} = \frac{V_{o}}{R_{o}} = \frac{2}{T_{s}} \left\{ \int_{t_{0}}^{t_{0}+T_{s}D_{eff}} i_{s1}(t)dt \int_{t_{0}+T_{s}D_{eff}}^{t_{0}+T_{s}D_{eff}+\Delta T} i_{s2}(t)dt \right\} = \frac{2}{T_{s}} \left\{ \frac{1}{Z_{o}\omega_{r}} \left( \frac{V_{in}}{n} - V_{c1}(t_{0}) \right) (1 - \cos(\omega_{r} \cdot T_{s} \cdot D_{eff})) + \frac{(V_{o} + \Delta V_{c1})}{4(L_{r} + \frac{L_{lk}}{n^{2}})} \Delta T^{2} \right\}$$
(20)

This expression relates the resonant circuit parameters to the output current and supports VCR analysis.

#### **Optimization and Final Selection**

To minimize current stress and guarantee efficient operation, the relationship between VCR, peak secondary current, and resonant frequency is examined. As shown in Fig. 9, the surface plot highlights combinations of normalized resonant frequency fr and peak current behavior. The red dot indicates the optimal resonant frequency that achieves the minimum peak current while satisfying the required VCR.





Although the theoretical maximum duty ratio Deff is 0.5, a slightly lower value of 0.4 is selected in practice to account for duty cycle loss, control precision, and stability margins. With this, the optimized resonant frequency is chosen as 77.9 kHz, resulting in properly dimensioned auxiliary capacitors:

#### C1=C2=9 µF

These values ensure that the MFID supports wide-range voltage operation, particularly when VH=300 V and VL=28.8 V, while minimizing stress on the components.

#### D. Resonant Frequency and Dead Time Design

To ensure reliable Zero Voltage Switching (ZVS) in all three operating modes of the proposed MFID—G2V, V2G, and LDC—the dead time tdeadt\_{text{dead}}tdead must be sufficient to allow the resonant transition of voltage across the power switches. This dead time is set to at least a quarter of the corresponding resonant period, which is influenced by the interaction between inductive and capacitive elements in the circuit.





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 5, May 2025

#### |DOI: 10.15680/IJIRSET.2025.1405352|



Fig. 2. Mode-wise equivalent resonant circuit models of the proposed MFID: (a) Grid-to-Vehicle (G2V), (b) Vehicle-to-Grid (V2G), and (c) Low-Voltage DC-DC (LDC) operation.

#### CA=C1||Cj CB=C1||Coss

#### Voltage Conversion Ratio (VCR) and Output Expression

The Voltage Conversion Ratio (VCR) is derived considering both sinusoidal and linear current segments and is expressed as:

$$\frac{V_o}{V_{in}} = \frac{1}{\left\{\frac{Z_o \cdot \omega_r \cdot n}{2(1 - \cos(\omega_r \cdot T_s \cdot D_{eff}))} \left(\frac{T_s}{R_o} - \frac{(1 + \frac{T_s}{2 \cdot C_1 \cdot R_o})}{2(L_r + \frac{L_{lk}}{n^2})} \Delta T^2\right) + \frac{n}{2}\left(1 - \frac{T_s}{2 \cdot C_1 \cdot R_o}\right)\right\}}.$$
(21)

#### **Peak Current Estimation**

The peak value of the secondary current during resonance can be approximated based on whether the resonant frequency is below or above the switching frequency fs:

$$i_{s\_\text{peak}} = \begin{cases} \left(\frac{V_{in}}{n} - \frac{V_o}{2} \left(1 - \frac{T_s}{2 \cdot C_1 \cdot R_o}\right)\right) \frac{1}{Z_o} \sin(\omega_r \cdot T_s \cdot D_{eff}), & \text{if } f_r \le \frac{f_s}{4D_{eff}} \\ \left(\frac{V_{in}}{n} - V_{c1}(t_0)\right) \cdot \frac{1}{Z_o} \cdot \sin\left(\omega_r \frac{T_r}{4}\right), & \text{if } f_r > \frac{f_s}{4D_{eff}}. \end{cases}$$

$$(22)$$

#### **Resonant Frequency and Minimum Dead Time in Each Mode**

The resonant frequency ωr and corresponding minimum dead time td,min are calculated per mode as follows: G2V Mode:

$$\begin{cases} \omega_{r, G2V} = \sqrt{\frac{C_{oss}(L_m + L_{lk}) + 2C_j(L_r + n_1^2 L_m) + \sqrt{(C_{oss}(L_m + L_{lk}) + 2C_j(n_1^2 L_m + L_r))^2 - 8C_j C_{oss}(L_r L_{lk} + n_1^2 L_m L_{lk} + L_m L_r)}{4C_j C_{oss}(L_r L_{lk} + n_1^2 L_m L_{lk} + L_r L_m)} \\ dt_{\min, G2V} = \frac{\pi}{2\omega_{r, G2V}} \end{cases}$$

$$(23)$$

V2G Mode:

$$\begin{cases} \omega_{r, V2G} = \sqrt{\frac{2C_{oss}(L_m + L_{lk}) + \frac{2L_mC_B}{n_2^2} + \sqrt{\left(2C_{oss}(L_m + L_{lk}) + \frac{2L_mC_B}{n_2^2}\right)^2 - 16\frac{C_{oss}C_B}{n_2^2}L_mL_{lk}}}{\frac{8C_{oss}C_BL_mL_{lk}}{n_2^2}}, \quad dt_{\min, V2G} = \frac{\pi}{2\omega_{r, V2G}} \end{cases}$$
(24)

13750





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

## Volume 14, Issue 5, May 2025 |DOI: 10.15680/IJIRSET.2025.1405352|

LDC Mode:



These expressions ensure that ZVS transitions are achieved without overlap or conduction losses. The dead time for each mode is calculated based on the resonant frequency derived from the mode's equivalent circuit (Fig. 10), ensuring effective switching under varying load and voltage conditions.

			Hade - G2V
	S - Gate S - Ga	Control M <sub>1</sub> + De M <sub>2</sub> + De	tection -126 -LDC ADC ADC
La La	Cantroller	rping Mode selection	utter

Fig. 3. Functional block diagram of the MFID control architecture including gate driving, feedback regulation, mode detection, and DSP-based management.

#### IV. EXPERIMENTAL RESULTS.







Fig. 5. Control logic implementation in Simulink for G2V operation, including PI controllers, mode detection, phaseshift modulation, and synchronous rectification gate driving.





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

# Volume 14, Issue 5, May 2025 [DOI: 10.15680/IJIRSET.2025.1405352]

Fig. 6. DC-link current waveform Idc during G2V operation. voltage regulation at 380 V.

Fig. 7. DC-link voltage waveform Vdc showing



Fig. 8. Voltage response of the 300 V high-voltage battery VHV under G2V charging mode and harging current of the high-voltage battery IHVB under CC-CV operation in G2V mode.





The Simulink model developed for the Grid-to-Vehicle (G2V) operation of the proposed Multifunctional Integrated DC–DC Converter (MFID) effectively demonstrates the regulated charging of a 300V high-voltage battery (HVB). The system is composed of a middle-side H-bridge converter, a three-winding transformer incorporating resonant, leakage, and magnetizing inductances, and a back-side H-bridge converter that performs synchronous rectification. Two auxiliary capacitors, C1, are employed as DC-link filters. The control strategy integrates PI controllers to regulate the DC-link voltage and current, along with the HVB voltage and current, in compliance with constant-current–constant-voltage (CC–CV) charging principles.

#### V. CONCLUSION

This study introduced a novel Multifunctional Integrated DC–DC Converter (MFID) architecture that effectively combines the roles of both On-Board Charger (OBC) and Low-voltage DC–DC Converter (LDC) within a unified system. By employing functional switches controlled via power relays, the proposed MFID significantly reduces component count and control complexity without compromising performance. The converter supports bidirectional power flow, handles a wide operating voltage range, and maintains high conversion efficiency. The operational performance of the MFID was thoroughly validated through comprehensive Simulink-based simulations under various functional modes, including Grid-to-Vehicle (G2V), Vehicle-to-Grid (V2G), and LDC scenarios. Results confirm the converter's capability to seamlessly switch between operating modes while maintaining voltage and current regulation via PI-based control and phase-shifted PWM with synchronous rectification. The system also demonstrated stable State of Charge (SOC) management across both high-voltage and low-voltage battery banks. Compared to traditional OBC-LDC integrated converters, the proposed MFID achieves improved energy efficiency, system compactness, and control





www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

#### Volume 14, Issue 5, May 2025

#### |DOI: 10.15680/IJIRSET.2025.1405352|

reliability. Its ability to operate efficiently over the full voltage spectrum of the high-voltage battery (HVB), combined with its versatility and reduced hardware overhead, makes it an ideal candidate for next-generation electric vehicle platforms and renewable-integrated smart energy systems.

#### ACKNOWLEDGEMENT

We gratefully acknowledge the assistance and facilities provided by the Project Lab, Department of EEE, PESCE, Mandya during the project work leading to this publication.

#### REFERENCES

[1] M. Yilmaz and P. T. Krein, "Review of battery charger topologies, charging power levels, and infrastructure for plug-in electric and hybrid vehicles," IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2151–2169, May 2013.

[2] N. Tan, T. Abe, and H. Akagi, "Design and performance of a bidirectional isolated DC–DC converter for a battery energy storage system," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1237–1248, Mar. 2012.

[3] M. Pahlevaninezhad, P. Das, J. Drobnik, P. K. Jain, and A. Bakhshai, "A novel ZVZCS full-bridge DC/DC converter used for electric vehicles," IEEE Trans. Power Electron., vol. 27, no. 6, pp. 2752–2769, Jun. 2012.

[4] D. Moon, J. Park, and S. Choi, "New interleaved current-fed resonant converter with significantly reduced high current side output filter for EV and HEV applications," IEEE Trans. Power Electron., vol. 30, no. 8, pp. 4264–4271, Aug. 2015.

[5] Y. J. Lee, A. Khaligh, and A. Emadi, "Advanced integrated bidirectional AC/DC and DC/DC converter for plug-in hybrid electric vehicles," IEEE Trans. Veh. Technol., vol. 58, no. 8, pp. 3970–3980, Oct. 2009.

[6] H. Wang, S. Dusmez, and A. Khaligh, "Maximum efficiency point tracking technique for LLC-based PEV chargers through variable dc link control," IEEE Trans. Ind. Electron., vol. 61, no. 11, pp. 6041–6049, Nov. 2014.

[7] J. W. Kim, D. Y. Kim, C. E. Kim, and G. W. Moon, "A simple switching control technique for improving light load efficiency in a phase-shifted full-bridge converter with a server power system," IEEE Trans. Power Electron., vol. 29, no. 4, pp. 1562–1566, Apr. 2014.

[8] W.-J. Lee, C.-E. Kim, G.-W. Moon, and S.-K. Han, "A new phase shifted full-bridge converter with voltagedoubler-type rectifier for highefficiency PDP sustaining power module," IEEE Trans. Ind. Electron., vol. 55, no. 6, pp. 2450–2458, Jun. 2008.

[9] I. O. Lee and G. W. Moon, "Half-bridge integrated ZVS full-bridge converter with reduced conduction loss for electric vehicle battery chargers," IEEE Trans. Ind. Electron., vol. 60, no. 8, pp. 3978–3988, Aug. 2014.

[10] C. Duan, H. Bai, W. Guo, and Z. Nie, "Design of a 2.5-kW 400/12-V high-efficiency DC/DC converter using a novel synchronous rectification control for electric vehicles," IEEE Trans. Transp. Electrific., vol. 1, no. 1, pp. 106–114, Jun. 2015.









## INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY





www.ijirset.com