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CATALOG NUMBERS

Media Type Requested	Part Number	ISBN
XPLORE COMPLIANT	CFP24UZ6-ART	979-8-3503-8520-5
PRINT	CFP24UZ6-PRT	979-8-3503-8519-9

89	517	Acquisition and Detection of Eye Movement Using Electrooculography Sruthilaya Gajendiran, Yuvaraj Sivagnanam
90	550	Identifying and Analyzing Toxic Behavior in Ecommerce Industry through Reddit Discussions Using BERT and HateBERT Anoop Kumar, Arpita Soni , Rajeev Arora , Dheerendra Panwar
91	551	Enhancing E-Commerce through Transformer-Based Large Language Models: Automating Multilingual Product Descriptions for Improved Customer Engagement Anoop Kumar
92	554	Enhancing Multilingual Table-to-Text Generation with QA Blueprints: Overcoming Challenges in Low-Resource Languages Arpita Soni
93	557	Enhancing Agricultural Decision-Making through an Explainable AI-Based Crop Recommendation System Surendra Kumar, Mohit Kumar
94	571	IoT Based ECG Monitoring System for ICU Mohammad Maroof Siddiqui, Abdullah Abdulrahman Qureshi, Khalid Salim Al Mashani, Haitham Awadh Shajannah
95	573	IRVD-NAS: A Lightweight Backbone for Infrared Vehicle Detection Wang Yongjun
96	585	LLC Resonant Converter Design for Fast Charging of Electric Vehicles <u>Sunil Kumar Choudhary, Arindam Mondal, M Prakash</u>
97	594	Read Right: Empowering the Blind to Read the World Vempati Lakshmi Prasuna, Sk.Fathimabi, Apoorva Adusumilli, Bandaru Veera Venkata Rajesh
98	615	Forecasting of Solar Irradiance using Machine Learning Techniques Saumya Mishra, Deependra Pandey, Saurabh Bhardwaj
99	623	Resource Allocation in Backscatter NOMA Network with Optimum Throughput Shilpi, Sachin Kumar, Sudhanshu Tyagi
100	628	Transforming Aspect-based Sentiment Analysis to Domain-Specific Mining by Integrating Machine Learning Ensemble (MLE) Model Deena Nath, Sanjay Kumar Dwivedi
101	632	Dynamic Speed Control of Axial Piston Pump Using Adaptive Model Predictive Control with Kalman Filter Vivek Verma; Sachin Kumar; Apurva Anand
102	639	Enhancing CNN Classification with Lamarckian Memetic Algorithms and Local Search Akhilbaran Ghosh, Rama Sai Adithya Kalidindi
103	640	Performance Estimation of Pattern Matching Algorithms Employing DNA Sequence Pooja Khanna, Neelam ,Manohar ,Pragya, Kumud Tiwari
104	641	Review Paper of Metal Insulator Metal and Metal Oxide Metal Capacitors for Improved Capacitance and Overall Performance Anjali Bharti, Bindu Bhardwaj, Richa Yadav, Vandana Niranjana, Sylvia Keisham, Komal Duggal
105	658	Mortality Prediction through Machine Learning: Insights from XGBoost and Random Forest Model Praveen Kumar Mishra, Varnika Tiwari, Rahul Gupta, Barkha Gupta
106	659	Prediction of Share Price by Using Machine Learning Algorithm: Multiple Linear Regression Model Praveen Kumar Mishra, Ritika Dubey, Barkha Gupta
107	660	Diabetes Prediction using Logistic Regression and Support Vector Machine (SVM) Classifier Praveen Kumar Misra, Rahul Gupta, Barkha Gupta
108	663	PneumonXNet - A Deep Learning Model for Pneumonia Detection Harshit Aditya, Anchita Ramani, Nilesh Kumar, Kasturi, Vandana Bhattacharjee
109	665	Facial Emotion Recognition using Image Filtering Techniques Anjali Sachan, Deependra Pandey, Neha Mittal
110	666	Optimized Machine Learning Model for Alzheimer's Disease Classification Goutami Das, Ritunsa Mishra, Saumendra Kumar Mohapatra, Mihir Narayan Mohanty
111	667	Design, Utilization, and Performance Enhancement of Instrumentation Amplifiers in Biomedical Applications Ritik Singh, Kamlesh Kumar Singh
112	671	Controlled Quantum Teleportation in Asymmetric Noisy Ambience Nidhi Singh, Ravi S. Singh

LLC Resonant Converter Design for Fast Charging of Electric Vehicles

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Abstract— Charging the batteries of electric cars (EVs) is the primary problem because electric vehicles (EVs) are becoming the primary mode of transportation all over the globe. While simultaneously charging batteries at a high rate, the electric vehicle charger can flexibly make voltage adjustments over a wide range. By finding a balance between efficiency and gain range, it is difficult to optimize inductor-inductor-capacitor (LLC) converters in a way that is both efficient and effective. Inductances that are resonant and magnetizing are going to be included into the LLC converter. It is possible to make dynamic adjustments to the magnetically attracting inductance depending on changes in the load and the electrical output voltage. A switch-controlled magnetic inductor (SCMI) that is connected in parallel with the secondary side winding of the converter transformer is used to achieve the desired correction. Fast-charging electric vehicles (EVs) increase efficiency by up to 96.4%, minimizing energy waste. The proposed converter's power density makes it small and space-efficient enough for fast-charging stations. Electric vehicle charging is fast with the suggested converter, which can give up to 800 watts of electricity from 80V to 100V on different dynamic conditions. To validate the essential concepts, a functional prototype of the whole LLC-RC bridge, as described.

Keywords— Converter transformer, Electric Vehicles (EVs), efficiency enhancement, LLC resonant converter, Switched controlled magnetic inductor (SCMI)

I. INTRODUCTION

Currently, environmental contamination and air pollution are significant worldwide concerns [1]. Specifically, conventional vehicles powered by both diesel and petrol are the main contributors to respiratory and environmental pollution, mostly due to the pollutants they emit. Consequently, there is a growing need for environmentally friendly electric vehicles. The percentage share of the worldwide automobile market occupied by electric vehicles (EVs) and low-emission vehicles is consistently expanding [2]. Furthermore, electric vehicles (EVs) have the benefit of reduced servicing requirements and lower noise emissions as compared to gasoline- or diesel-powered cars [3]. On the other hand, they need quite a lengthy amount of time to charge. For this reason, it is of the utmost importance to build electric automobiles that are capable of a relatively short charging time. In recent times, there has been a focus on enhancing the power of rapid fast charging technologies [4]. To state it another way, boosting the power implies raising the voltage or current levels and vice versa [5]. When the voltage is increased, there is a difference in the electric potential between the converter's output voltages and the voltage produced by

the battery [6]. As a result, the charging current is increased. High-efficiency converters and quick charging topologies are the subject of a significant amount of research that is now being conducted for the electric vehicle charging system. On the other hand, research on fast charging systems with high efficiency for EVs is far less prevalent in contrast to research on electric vehicles [5-6].

Furthermore, the majority of rapid chargers used by the public for electric vehicles (EVs) are specifically engineered and manufactured to accommodate lead-acid batteries [7]. Because it has a direct influence on the converter's effectiveness, dimensions, density of power, and reliability, the converter transformer is an essential component of the LLC resonant converter (LLC-RC) for charging the batteries, it is responsible for fast charging [8]. In contrast to the phase-shift full-bridge converter, the LLC-RC exhibits a much higher fraction of overall loss while operating at the same power level [9].

The LLC-RC displays a fringing effect due to an air gap inside the iron core of the transformer. This action boosts the corresponding resistance of the windings close to the air gap, which also causes an imbalance in the temperature rise distribution inside the transformer. Another problem contributing to the diminished effectiveness of the LLC resonant converter is the short magnetizing inductance, which contributes to a larger conduction loss and switching loss [10]. Therefore, the efficiency of the converter is impaired.

The LLC-RC technology for full-bridge is commonly utilized in diverse sectors and applications due to its prominent features, including significant excellent efficiency, and cost-effectiveness [11-12]. To enhance the efficiency of the transformers, a variable magnetizing inductance is included in the design of the transformers mentioned in references [13-14]. A step gap in the core column is used to provide a higher magnetizing inductance under low load conditions, which reduces under heavy load conditions [15]. However, the range of magnetizing inductance is non-linear and cannot be controlled. To enable the simultaneous functioning of two transformers in parallel, the authors proposed a power switch that also operates in both directions [16-17]. During periods of high demand, the switch activates and two transformers on the main side operate simultaneously. Even though the magnetically attractive inductance of the resonance chamber is rather low, it is effective enough to provide the required gain during the first phase of the charging process. When there is a low load, the switch is disengaged, resulting in just one transformer being active. The magnetically attracting inductance of the resonant chamber is