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Review on Power Flow Evaluation of Grid Connected Bidirectional Wireless Power Transfer for EV System

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Abstract: *Wireless Power Transfer (WPT) for Electric Vehicle (EV) battery charging application is one of the key upcoming technologies. The possibility of using EVs to transfer power back to the grid, utilizing the concept of Bidirectional Wireless Power Transfer (BD-WPT) is extensively being explored. The effect of integration of EV on grid is also of concern. This paper presents analysis of complete grid integrated BD-WPT system for controlling power transfer between grid and EV battery, along-with ensuring Unity Power Factor (UPF) at grid side. Mathematical model of each component in the system is presented which is then used to design vehicle and grid side controllers for achieving desired output. Concepts stated analytically are validated by simulation in MATLAB (Simulink).*

Keywords: Photovoltaic (PV), Transformerless, Inverter

I. INTRODUCTION

The increasing global concern over depletion of fossil fuel reserves and their adverse effects on the environoment have resulted in fast development in technologies like renewable energy generation and EVs. Conductive charging has been long introduced but is still not preferred due to tripping hazards, leakage from old cracked cables (particularly in cold zones), risk of electric shock etc. Major drawback of present EVs is the power storage technology, usually battery, which has very unsatisfacotory performance. Long charging time of EV batteries is the main reason for its low popularity among consumers. Introduction of wireless power transfer for EV battery charging is thus being considered as a probable solution for aforementioned issues in conductive charging. Wireless charging technique provides several advantages like galvanic isolation, convenient and safe usage in addition to low maintenance due to no physical contacts or moving parts. Also, the battery capacity of EVs with wireless charging could be reduced to 20% or less compared to EVs with conductive charging. Most of the developments in WPT technology have mainly been in applications requiring unidirectional power transfer. In recent years, BD-WPT systems have become popular for implementing the concept of Vehicle to Grid (V2G) for grid integration of EVs. To reduce the effects caused due to intermittent nature of renewable energy systems and facilitate dynamic demand management, V2G concept can be used as cost-effective alternate energy storage unit.

In this work, a complete system depicting V2G and G2V concept for controlling desired power transfer between grid and EV battery, along-with ensuring unity power factor at grid side has been analyzed and simulated in MATLAB

II. LITERATURE REVIEW

Sr. No	Name of Author & Year	Title of Paper	Methodology	Claim by Author
1	Y. Tang, Y. Chen, U. K. Madawala, D. J. Thrimawithana and H. Ma in 2017	"A New Controller for Bidirectional Wireless Power	In this paper the author has proposed a new controller that uses a measured active power (P) and reactive power (Q) at the resonant network of BD-WPT systems to regulate the power flow in	They claimed that the power transfer of the system as well as they had obtained experimental results for 1

		Transfer Systems"	both directions while providing synchronization between two sides without a dedicated communication interface for controlling of the power transfer of the system as well as they had obtained experimental results for 1 KW prototype system which showed good agreement with the stimulated results.	KW prototype system which showed good agreement with the stimulated results.
2	G. Pandey, and Narsa Reddy T in 2020	"Power Flow Study of Grid Connected Bidirectional WPT Systems for EV Application"	This paper presents the analysis of complete grid integrated BD-WPT system for controlling power transfer between grid and EV battery, along-with ensuring Unity Power Factor (UPF) at grid side. As well as mathematical modelling of each component in the system is presented which is used then to design vehicle and grid side controllers for achieving the desired output.	They claimed the mathematical modelling of each component in the system is presented which is used then to design vehicle and grid side controllers for achieving the desired output.
3	Cristina-Adina Bilatiu, S.I. Cosman, R.A. Martis in 2019	"Identification and Evaluation of Electric and Hybrid Vehicles Propulsion Systems''	This paper deals with identification and evaluation of electric and hybrid propulsion variants for vehicles. The first part of the study identifies and studies the existing variants of propulsion systems for electric and hybrid vehicle whereas the next step involves a comparative study between the systems already analyzed in order to evaluate the performance of different system configurations.	They claimed the comparative study between the systems already analyzed in order to evaluate the performance of different system configurations.
4	S. Li and C. C. Mi in 2015	"Wireless Power Transfer for Electric Vehicle Applications"	This paper basically focused on reviewing the technologies in the WPT area applicable for EV wireless charging, by introducing WPT in EVs, and the obstacles of charging time, range, and cost can be easily mitigated.	Here author claimed that reviewing the technologies in the WPT area applicable for EV wireless charging, by introducing WPT in EVs, and the obstacles of charging time, range, and cost can be easily mitigated.
5	T. Payarou and P. Pillay in 2020	"A Novel Multipurpose V2G & G2V Power Electronics Interface for Electric Vehicles"	This paper basically proposes and analyses a novel multipurpose power electronic interface (MPEI) designed for the new generation plug-in electric vehicles (PEVs), and plug-in hybrid electric vehicles (PHEVs). The proposed topology allows vehicle to grid (V2G) and grid to vehicle (G2V) operation to support the grid in times of high load or	This proposes and analyses a novel multipurpose power electronic interface (MPEI) designed for the new generation plug-in electric vehicles (PEVs), and plug-in hybrid

			stress. The operation principles of the MPEI in its different modes are explained and practical results obtained using a real-time controller are discussed and validated in this paper	electric vehicles (PHEVs).
6	T. Alagarsamy and B. Moulik in 2018	"A Review on Optimal Design of Hybrid Electric Vehicles and Electric Vehicles"	This paper is structured in a way to propose an optimal design strategy for the various configurations employed in it. The first section provides the brief introduction of the various technologies followed by the various configurations involved in the design of the vehicles. Third section gives a view on the impact of these configuration on the vehicle performance and how it is been managed in real time	In this paper author claimed on optimal design strategy for the various configurations employed in it. The first section provides the brief introduction of the various technologies followed by the various configurations involved in the design of the vehicles.
7	M. Moradpour and G. Gatto in 2018	"A New SiC-GaN-Based Two-Phase Interleaved Bidirectional DC-DC Converter for Plug-In Electric Vehicles"	This paper proposed a two-phase dc-dc converter in which one phase is SiC based MOSFET and the other one is GaN-based transistor. To reach the maximum utilization of the GaN device, the output power will be shared through the two phases, based on the current rating of the GaN device. First, the power stage design and the average model of the converter are presented. Then, power losses and efficiency of the converter is investigated in comparison with an all-SiC converter through spice-based simulations	This paper proposed a two-phase dc-dc converter in which one phase is SiC based MOSFET and the other one is GaN-based transistor
8	Y. Hsieh, Z. Lin, M. Chen, H. Hsieh, Y. Liu and H. Chiu in 2017	"High-Efficiency Wireless Power Transfer System for Electric Vehicle Applications"	In this paper, a high efficiency WPT system for electric vehicle charging application is studied and implemented. Series-series resonant topology with RF feedback design is adopted as the wireless power transfer DC-DC stage due to the advantages of circuit simplicity, easy analysis and control. A 500W laboratory prototype is built and tested to verify the feasibility of the proposed design. According to the experimental results, high wall-to- battery efficiency and unity power factor can be achieved over an air gap of 15 cm and maximum sliding distance of 10 cm under various power conditions and universal input voltage from 90VAC to 264VAC. A	In this paper, a high efficiency WPT system for electric vehicle charging application is studied and implemented. Series-series resonant topology with RF feedback design is adopted as the wireless power transfer DC-DC stage due to the advantages of circuit simplicity, easy analysis and control. A 500W laboratory prototype is built and tested to verify the feasibility of the

			500W laboratory prototype is built and tested to verify the feasibility of the proposed design. According to the experimental results, high wall-to-battery efficiency and unity power factor can be achieved over an air gap of 15 cm and maximum sliding distance of 10 cm under various power conditions and universal input voltage from 90VAC to 264VAC	proposed design. According to the experimental results, high wall-to- battery efficiency and unity power factor can be achieved over an air gap of 15 cm and maximum sliding distance of 10 cm under various power conditions and universal input voltage from 90VAC to 264VAC
9	C. Mi and C.T. Rim in 2016	"Modern Advances in Wireless Power Transfer Systems for Roadway Powered Electric Vehicles"	The methodology is the mobile, cable-free re-charging of electric vehicles, smart phones and laptops to collecting solar electricity from orbiting solar farms, wireless power transfer (WPT) technologies offer consumers and society enormous benefits. Written by innovators in the field, this comprehensive resource explains the fundamental principles and latest advances in WPT and illustrates key applications of this emergent technology	This is a book providing information regarding mobile, cable-free re-charging of electric vehicles, smart phones and laptops to collecting solar electricity from orbiting solar farms, wireless power transfer (WPT) technologies offer consumers and society enormous benefits.
10	M. S. A. Chowdhury, K. A. A. Mamun and A. M. Rahman in 2017	"Modelling and simulation of power system of battery, solar and fuel cell powered Hybrid Electric vehicle"	The Permanent magnet synchronous motor drive system is used in the Simulink model. The simulation results like rotor speed, electromagnetic torque, current, DC-DC converter current, voltage, state of charging, grid charger performance, photovoltaic panel performance and mechanical torque are discussed and compared with the state of the art methods	This paper analyzed an electrical system for the powertrain of Hybrid Electric vehicle which is powered by Fuel cell, Battery and PV panel. A Simulink model is prepared and simulated successfully.
11	A. Saleki, S. Rezazade and M. Changizian in 2017	"Analysis and simulation of hybrid electric vehicles for sedan vehicle"	The modeling and simulation of two different vehicles topologies (parallel hybrid electric vehicle and series hybrid electric vehicle) using the ADVISOR (Advanced Vehicle Simulator). An accurate analysis of the performance of a hybrid electric vehicle, as well as of its consumption and pollution level, requires a dynamic analysis of its behavior	This paper presents a modeling and simulation of two different vehicles topologies (parallel hybrid electric vehicle and series hybrid electric vehicle) using the ADVISOR (Advanced Vehicle Simulator)
12	B. Song, J. Shin, S. Lee, S. Shin, Y.Kim, S. Jeon and G. Jung in 2012	"Contactless power transfer systems for On-Line Electric	Inductive power pickup was developed using series capacitor with ferrite cores and multi-windings and was tested for its ability to transfer electricity wirelessly.	This paper, proposed inductive power pickup was developed using series capacitor with

		Vehicle (OLEV)"	When tested for output power and efficiency of pickup, output power of 20kW and efficiency of 86.7% were achieved at 20 kHz and 250mm air gap.	ferrite cores and multi-windings and was tested for its ability to transfer electricity wirelessly.
13	C. Liu, K.T.Chau, D. Wu, and S. Gao in 2013	"Opportunities and Challenges of Vehicle-to-Home, Vehicle-to Vehicle, and Vehicle-to-Grid Technologies"	In this the investigates and discusses the opportunities and challenges of GEVs connecting with the grid, namely, the vehicle-to-home (V2H), vehicle-to-vehicle (V2V), and vehicle-to-grid (V2G) technologies.	In this author claims, investigates and discusses the opportunities and challenges of GEVs connecting with the grid.

III. PROPOSED METHODOLOGY

A block diagram broadly describing the elements of a bidirectional wireless power transfer system is shown in Fig. 1. It consists of two sides: primary and secondary. Primary side is connected to the utility grid via a dc link and is usually embedded under the road in places like traffic signals, bus stops, vehicle charging stations etc. The secondary side is connected with EV battery and is placed at the bottom of electric vehicle. As can be seen in Fig. 1. both sides consist of coupling coils, high frequency (HF) converters, compensation circuit and dedicated controllers. When power flows from grid to EV battery (forward direction), primary converter acts as an inverter (DC/AC) and secondary converter acts as a controlled rectifier (AC/DC). Similarly, when EV battery supplies power to the grid (reverse direction), the role of converters is reversed. As already mentioned, there are compensation networks on both primary and secondary sides.

This is the concept used by researchers to increase the power transfer efficiency in WPT system. Primary side resonance is used to reduce the Volt-Ampere(VA) rating of the power electronic converter and secondary side resonance to reduce VA rating of the coil [2]. Based on application, suitable converter topology, compensation technique and control technique are chosen. In this work, full bridge Voltage Source Converter (VSC) with LCL compensation topology at both primary and secondary sides will be analyzed. Following are the parameter considering while design the proposed system.

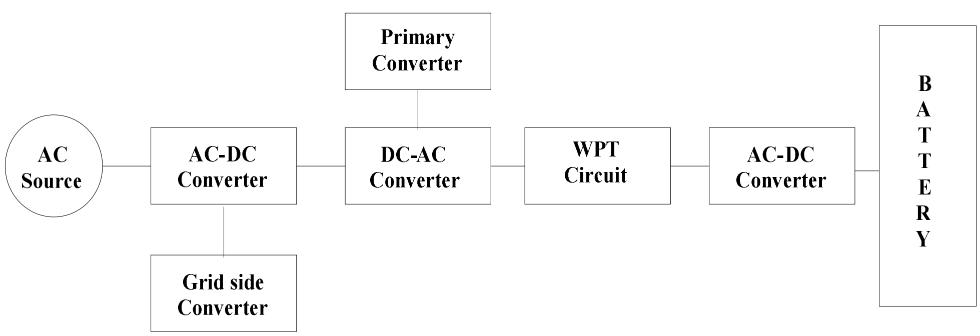

Fig 1: Block Diagram of Proposed System

Wireless Power Transfer (WPT) for Electric Vehicle (EV) battery charging application is one of the key upcoming technologies. The possibility of using EVs to transfer power back to the grid, utilizing the concept of Bidirectional Wireless Power Transfer (BD-WPT) is extensively being explored. The effect of integration of EV on grid is also of concern. This paper presents analysis of complete grid integrated BD-WPT system for controlling power transfer between grid and EV battery, along-with ensuring Unity Power Factor (UPF) at grid side. Mathematical model of each component in the system is presented which is then used to design vehicle and grid side controllers for achieving desired output. Concepts stated analytically are validated by simulation in MATLAB (Simulink)

IV. RESEARCH OBJECTIVES

1. To maintain the power factor of AC supply to unity
2. To improve power quality (Harmonic)-THD
3. To transfer wireless power from grid to vehicle and vehicle to grid

4.1 Wireless Coupler Model

WPT coils can be modeled as a transformer having very large leakage inductance and low mutual inductance since coupling coefficient *(k)* is very less (usually 0.05- 0.4) Fig 3.3.1 shows LCL compensated equivalent model of coupling coils. L_m represents magnetizing inductance,

$$M = \left(\frac{N_s}{N_p}\right)L_m$$

L_{lp}, L_{ls} and L_p, L_s represent leakage and self-inductance of primary and secondary coils, respectively. To reduce additional reactive load on the inverter and coils, system is operated at resonant frequency of the LCL network given by,

$$\omega_r = 2\pi f_r = \frac{1}{\sqrt{L_p C_1}} = \frac{1}{\sqrt{L_s C_2}} \quad (1)$$

Such that,

$L_1=L_p$ and $L_2=L_s$

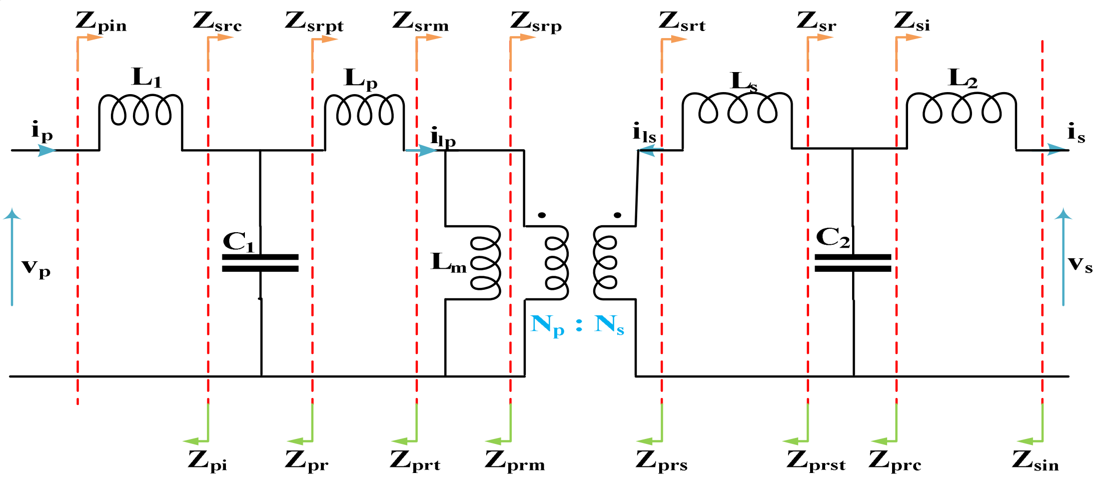

Fig 2: Equivalent circuit of coil with converter

V. CONCLUSION

This paper has considered V2G with a brief description of EV applications worldwide. In technical issues of V2G impacts on stability, the paper has introduced the study of V2G modelling and wireless transfer ciecuits analysis. In future studies, the V2G model will be developed for large-capacity EVs or small fleets.

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