WIRELESS POWER INTERFACING USING AN ADAPTIVE DC LINK AMONGVEHICLE-GRID-HOME

B Pavan babu Assistant professor, Department of EEE, Narayana Engineering College (Autonomous), Gudur, SPSR Nellore, AP, India
Sk Husna Banu, Y Prathima , I Sai Pooja , J Vani , K Sai Divya , Sk Mamola UG Students, Department of EEE, Narayana Engineering College (Autonomous), Gudur, SPSR Nellore, AP, India

Abstract
Electric vehicles (EVs) that offer grid services using the V2G concept essentially require an interfacethat allows for directional power flow. This paper presents a wireless bidirectional grid power interfacefor EVs that facilitates power flow between the grid, EV and homes with nonlinear loads. The proposed wireless vehicle-grid-home power interface (WVGH-PI) uses the grid side low frequency to DC converter, used in typical wireless bidirectional chargers only to facilitate the two-way energy flow, toimprove power quality by compensating for the harmonic and reactive power of nonlinear household loads. To improve the overall efficiency of the interface, an adaptive DC-link voltage controller is alsoproposed
Keywords: Electric vehicle (EV), inductive charging, wireless power transmission (WPT), adaptiveDC-link voltage, wireless Vehicle-Grid-Home power Interface.

Introduction
Strong momentum in electric vehicle markets despite the pandemic. There were 10 million electric carson the world's roads at the end of 2020, following a decade of rapid growth. Electric car registrations increased by 41% in 2020, despite the pandemic-related worldwide downturn in car sales in which global car sales dropped 16%. Around 3 million electric cars were sold globally (a 4.6% sales share),and Europe overtook the People's Republic of China ("China") as the world's largest electric vehicle(EV) market for the first time. Electric bus and truck registrations also expanded in major markets, reaching global stocks of 600 000 and 31 000 respectively.
The energy sector is facing a drastic shift towards a greener future. While traditional energy productionis more stable, renewables are volatile and energy production becomes less predictable. The simultaneous rise of ELECTRIC VEHICLES (EV's) raises questions about the capacity of the ELECTRICAL GRID. In fact, EVs are not a threat but rather big batteries of wheels. A massive rebuilding of the electrical grid is not needed if smart charging services are being used. With smart charging, energy utilities can realize the full potential of electric vehicles as a part of the energy system. EVs, with recent advances in battery charging technologies, can also be utilized as grid-integrated distributed energy storage systems to manage energy with greater flexibility or to provide grid servicesin an efficient and cost-effective manner. The grid services are offered through the vehicle-to-grid (V2G) concept, which uses batteries of EVs as an energy storage.
The V2G concept requires EVs to be essentially equipped with bidirectional chargers, and various systems have been proposed to demonstrate the feasibility of these chargers, exploring several converter topologies and control strategies. Control strategies have also been reported on bidirectional hard-wired V2G chargers to improve efficiency, power factor and stability. V2G concept can be extended to vehicle-to-grid-to-home systems (VGHs) to offer more services, but require further additional functions and considerations. The hard-wired power interfaces (chargers) are simple, they are not consumer friendly, requiring physical connection, and must also include isolation to prevent the risks of shock hazards, particularly under wet environments and harsh weather conditions, such assnow and ice. To mitigate these issues and as an alternative, wireless power interfaces, through which EVs can be charged without any physical contacts, have recently been proposed. In contrast to hard- wired charges, wireless EV chargers are more attractive, offering the advantages of inherent higher galvanic isolation, convenience and robust operation unaffected by harsh weather conditions.

In typical wireless charging system, charging can be done in one direction that means it is a uni-directional wireless charging. Here in typical wireless charging the operation is as follows that is fromthe grid we get the supply which is given to the AC/DC converter which converters ac supply into dcsupply. After conversion of supply we get output as Vdc output voltage which is further given to the H Bridge which acts as inverter. The operation of H bridge is to switch the polarities and here H bridgeis acting as inverter that is dc supply is converted ac supply by using MOSFET as bridge.

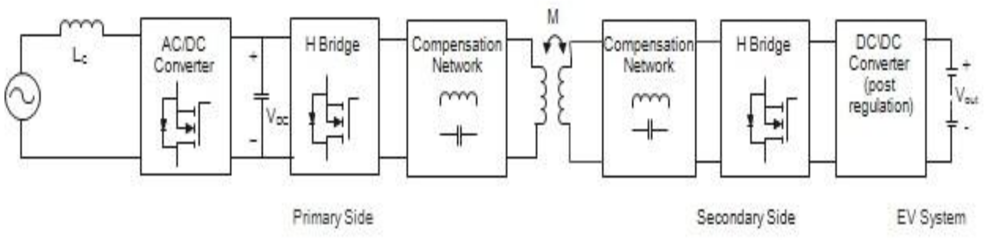


Fig. 1 A typical wireless charging system

Finally, the output of H Bridge is given to compensation network which compensate reactive power and reduce the harmonics.now by using weak magnetic coupling the output of compensation network from transmitter side is transferred to the receiver side with mutual inductances M.

Now from transmitter side the power is received by the receiver in the receiver side and then again given to compensation network to compensate the received power. The output of the compensation network is given to H Bridge and then finally given to the Dc/Dc converter that is post regulation. The output of the converter is given to the E-vehicle and then finally the vehicle is charged. Here the power is transferred in one direction that too by using wireless power transfer technique. So that this typical wireless charging system is called as uni-directional wireless power transfer. The proposed system is advance version of existing system (uni-directional wireless power transfer) that is Bi-directional wireless power transfer with interference of home and also with power quality control.

Statement of the Problem

- A new wireless vehicle-grid-home power interface (WVGH-PI) that regulates energy flow between the grid, EV and home while maintaining power quality within the guidelines.
- The proposed interface is like a typical wireless bidirectional charger, but uses the grid side low frequency to DC converter as a power quality control converter (PQCC), compensating forreactive power and nonlinear household loads.
- The interface employs an adaptive DC-link voltage controller to improve overall system efficiency, minimizing switching losses of both the PQCC and converters used for wireless power transfer.

Objectives of the study

➢ To design and implement a converter with
- Wireless power transfer FOR BATTERY CHARGING
- POWER QUALITY IMPROVEMENT

➢ To optimize the way we transport, use and produce electricity by turning electric cars into "virtual power plants".

➢ To support the power grid during demand peaks.

➢ To use EVs as backup power for homes in situations when the electric grid services has failed.

Review of Literature

A simple high-performance current control strategy for V2G three-phase four-leg inverter with LCL filter proposed by C. Tan, Q. Chen, K. Zhou, and L. Zhang in the year 2019 and it state that Electric vehicles (EVs) can behave as distributed energy storage devices for providing on-demand smart grid support service, that is an emerging Vehicle-to-Grid (V2G) technology. Optimized operational cost reduction for an EV charging station integrated with battery energy storage and PV generation proposed by I. S. Bayram, A. Tajer, M. Abdallah, and K. Qaraqe in the year 2019 and it state that While balancing the real - time supply and demand by adjusting the optimally schedule charge/ discharge of Battery storage grid supply and deferral loads.

Low-complexity charging/discharging scheduling for electric vehicles at home and common lots for smart households prosumers proposed byA. Mehrabi and K. Kim in the year 2018 and it statethat Based on the data from the vehicles, a mixed optimization model is formulated by the central scheduler which aims to maximize the profit of consumers and is then solved using an effective algorithm. A novel boost active bridge based wireless power interface for V2G/G2V applications proposed by G. R. Kalra, D. J. Thirmawithana, M. Neuburger, B. Riar, U. K. Madawala, and R. Zane in the year 2017 and it state that Bidirectional wireless interfaces facilitated energy flow only between the grid and the EV, and without addressing any power quality issues.

Modeling and testing of a bidirectional smart charger for distribution system EV integration proposed by M. Restrepo, J. Morris, M. Kazerani, and C. A. Canizares in the year 2018 and it state that The model can be used efficiently in time-domain simulations that require models of a number ofEV chargers, such as EV integration studies in low-voltage (LV) distribution networks. Plug-in electric vehicle to home (V2H) operation under a grid outage proposed by H. Shin and R. Baldick in the year 2017 and it state that the paper investigates Vehicle-to-Home (V2H) operation that provides backup power under outage of the external electric grid. Modeling bidirectional contactless grid interfaces with a soft dc-link proposed by S. Weearsinghe, D. J. Thrimawithana, and U. K. Madawala in the year 2015 and it state thatIn contrast to existing bidirectional grid converters, the proposed system employs a simpler switching strategy with a lower switching frequency.

Research Methodology

The circuit configuration of the proposed WVGH-PI, consisting of a grid side low frequency full bridge converter and a typical BD-WPT module, comprising two high-frequency full bridge is as shown in the figure 2. A Grid-tied electrical system, also called tied to grid or grid tie system, is a semi- autonomous electrical generation or grid energy storage system which links to the mains to A feed excess capacity back to the local mains electrical grid. When insufficient electricity is available, electricity drawn from the mains grid can make up the shortfall. Conversely when excess electricity is available, it is sent to the mains grid. When the Utility or network operator restricts the amount of energy that goes into the grid, it is possible to prevent any input into the grid by installing Export Limiting devices.

To design and implement a converter with wireless power transfer "*for battery charging and power quality improvemen*t. To optimize the way we transport, use and produce electricity by turning electric cars into "virtual power plants". To support the power grid during demand peaks. To use EVs as backup power for homes in situations when the electric grid services has failed.

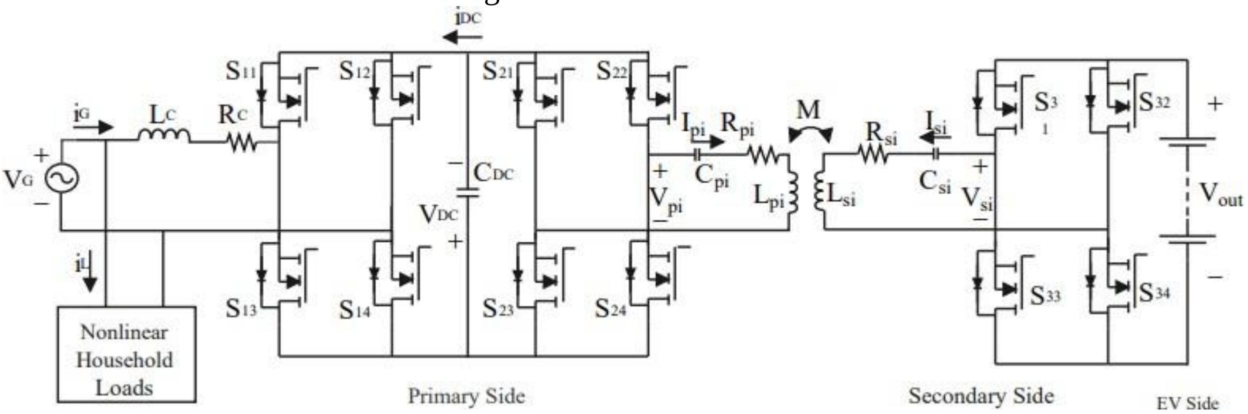


Fig. 2 Proposed WVGH-PI system

Here the designed proposed system is to implement that a converter used for battery charging and also same converter acts as power quality improvement converter with less number of components.To control all the converter micro controllers are used and also for triggering the circuit.in proposed three converters are used. In mopde 1 converter 1,2,3 acts as rectifier, inverter,rectifier as follows and battery gets charged through the concept of G2VH(Grid to Vehicleto Home) technology. Now in mode 2 a distrubance is created on grid side so that the 3leds which are on grid side indicates house load gets turned off. Now from battery, supply is given to house in reverse direction which means bi directional way by using V2GH(vehicle to Grid to Home)technology and converters 1,2,3 acts as inverter,rectifier,inverter as follows.When the supply is given from battery then it compensate the problem which has been occurred in grid as well as it gives power supply to house that means the 3leds gets ON.So here it is clear that the supply is given from vehicle to grid to home through V2GH technology and it is also an bidirectional power transfer that to by using wireless power transfer techniqe.The components required for the proposed system is as mentioned below in tabular column.

Requirments	**Ranges**
Battery	12V/1.3A
PIC16F877A	2.0V to 5.5V
Gate Driver(FAN7392)	3.3V to 20V
MOSFET	500V/8A
Resistance	0.25 ohms
Inductance	10mh
Capacitance	10µF
Mutual Inductance	4.9µH
LED	50 ohms
Coupling factor(k)	0.377
Diode	IN4007

Table- 1: components required

The output voltage equation for the rectifier is as followsOutput Voltage

$$Vo = \frac{V_m}{\pi}(1 + cos\alpha)$$

Here Vo is output voltage of rectifier

$$Vm = \sqrt{2}V.$$

And the fundamental RMS output voltage of inverter is

$0.4\,Vs$

$$V01 = \frac{\sqrt{2}}{\pi} = 0.9Vs$$

The turn ON time of MOSFET is 38ns and turn OFF time is 70ns.the total time period of mosfet is 108ns.the drain source voltage Vds is 6.8V

Results and Discussion

To verify the effectiveness of the proposed system, a hardware prototype has been implemented using PIC16F877A for controlling and modulating high switching speed Silicon Carbide (Sic) MOSFETs (IRF840) and Sic diodes (1N4007). To demonstrate the applicability of the concept, a scale-down isolated gird was used in the experimental set-up. This is particularly because the limitation of the '5 A current rating' of the non-linear house hold load that was available for the experiments in thelab.

The grid current is about 1A at 12V, such that the power source reaches its maximum output power 12W. The L_C of the PQCC was designed to be 10mH to reduce ripple in the compensation current. Theboth coils were designed with 30 turns each and the inductances L_{pi} and L_{si} of 1.93H according to the rating and the capacitors C_{pi} and C_{si} were selected as 0.19f to resonant 32 kHz. Here the figure represents the hardware kit of the proposed system.

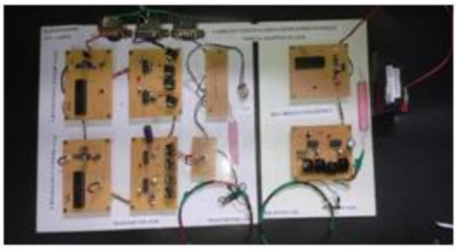


Fig. 7 Hardware setup

In the proposed system two modes of operation exists i.e., in first mode the power will be transferred from grid to vehicle and in second mode of operation the power will be transferred from vehicle to grid.

A. MODE- 1 OPERATION:

The mode 1 operation is represented as G2VH mode (grid to vehicle to home) in which the power is transferred from grid to vehicle and home (3 LEDs in the transmitter side) through wireless power transfer technique and the power is stored in the battery of e-vehicle. Here the supply from grid is given to home at the same the E vehicle's battery also gets charged that too using wireless power transfer technique.

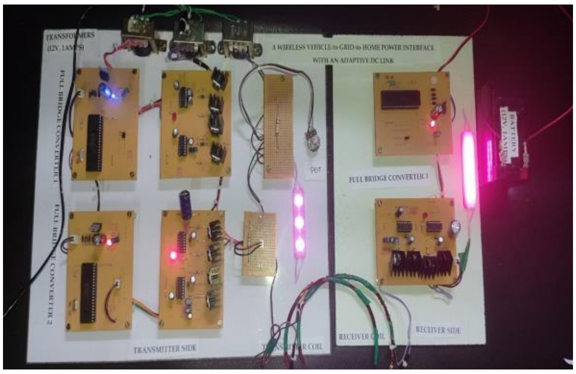


Fig. 8 G2VH mode of operation.

B. MODE- 2 OPERATION

In mode 2, a disturbance is created in the grid so that the 3 LED's get turn OFF that represents the power cut in home.

Now by using V2GH mode (vehicle to grid to home), the stored power in the battery of E-vehicle is transferred to home that means in the power is transferred in the absence of grid supply through wireless power transfer technique.

So, finally it represents Bi-directional power transfer and the power quality is also improved which is clearly observed in the output waveforms.

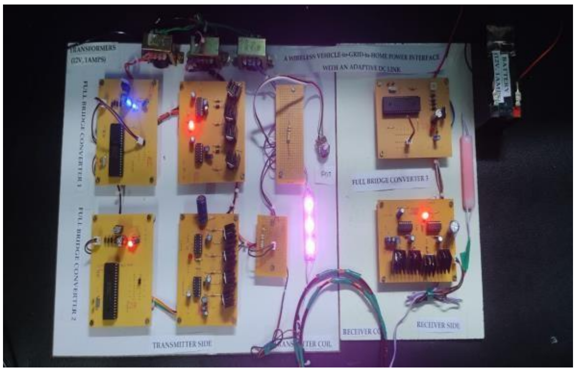


Fig.9 V2GH mode of operation

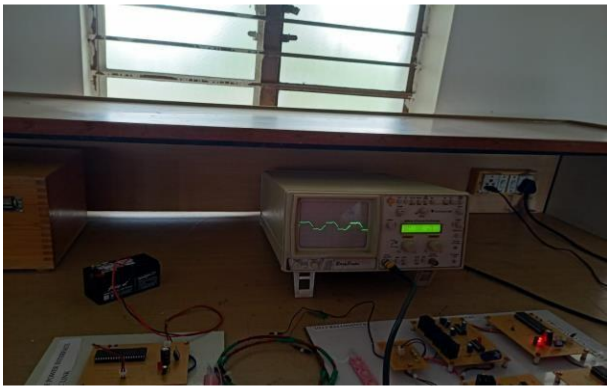
The following are the output values and output waveforms obtained on performing the two modes of operations

A. OUTPUT VALUES

Converters	Mode 1	Mode 2	Outputs	
			M-1	M-2
Converters 1	Rectifier	Inverter	9.4	8.4
Converters 2	Inverter	Rectifier	9.4	8.4
Converters 3	Rectifier	Inverter	9.3	12.2

B. OUTPUT WAVEFORMS

When the distance between two coils is less the voltage profile will be more that is it gets improved and vice versa as it can clearly observed in figures. Here the power quality also improved that is when both coils (transmitter coil and receiver coil) placed on each other that means with zero distance then the voltage waveform is increased as shown in figure 10 and when both coils are spaced some distancethen the voltage waveform gets reduced as shown in figure 11. So from these two figures and statements it is clear that by this proposed system the power quality also gets improved.



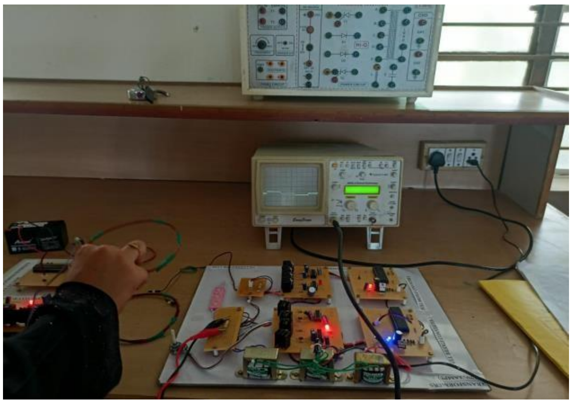


Fig. 10 Waveform obtained in G2V2H mode of operation. Fig.11 waveforms obtained in V2G2H mode of operation

Conclusion

The applications of V2G are vast and provides a wide array of possibilities for reliable power generation and storage. V2G also promises a more sustained approach where the environment is also a major concern. However, it still faces a lot of criticism. The major reasons for this criticism are highinitial cost, lack of government subsidy, resistance to change, be the people and manufacturers. The view of most people can be considered as narrow and negligent as they are only looking at the initial situation, they are ignoring the future prospects of V2G. The recent projects in the V2G implementation have shown promising results and encouraged further research in the field. As and when more durable batteries and cost-efficient grid lines become common, V2G will become a widespread phenomenon. Until then the views of people and manufacturers must be monitored. Lastly,a widespread propagation of the V2G idea, its prospects and opportunities by the governments of developing and developed countries will make the path of V2G implementation much easier. And definitely, smart grid technologies have the latency to meet up the future power demand, which will support V2G.

References

[1] IEA (2021), Global EV Outlook 2021, IEA, Parishttps://www.iea.org/reports/global-ev-outlook-2021.
[2] I. S. Bayram, A. Tajer, M. Abdallah, and K. Qaraqe, "Capacity planning frameworks for electric vehicle charging stations with multiclass customers," IEEE Trans. Smart Grid, vol. 6, no. 4, pp. 1934–1943, Jul. 2015
[3] Q. Yan, B. Zhang, and M. Kezunovic, "Optimized operational cost reduction for an EV charging station integrated with battery energy storage and PV generation," IEEE Trans. on Smart Grid, vol. 10, no. 2, pp. 2096–2106, Mar. 2019.
[4] D. A. Chekired and L. Khoukhi, "Smart grid solution for charging and discharging services based on cloud computing scheduling," IEEE Trans. Ind. Informat., vol. 13, no. 6, pp. 3312–3321, Dec. 2017.
[5] C. Tan, Q. Chen, K. Zhou, and L. Zhang, "A simple high-performance current control strategy forV2G three-phase four-leg inverter with LCL filter," IEEE Trans. on Transport. Electrific., vol. 5, no. 3, pp. 695–701, Sep. 2019.
[6] V. Monteiro, J. G. Pinto, and J. L. Afonso, "Experimental validation of a three-port integrated topology to interface electric vehicles and renewables with the electrical grid," IEEE Trans. Ind. Informat., vol. 14, no. 6, pp. 2364–2374, Jun. 2018.
[7] M. Kesler, M. C. Kisacikoglu, and L. M. Tolbert, "Vehicle-to-grid reactive power operation using plug-in electric vehicle bidirectional offboard charger," IEEE Trans. Ind. Electron., vol. 61, no. 12, pp. 6778–6784, Dec. 2014.
[8] M. C. Kisacikoglu, M. Kesler, and L. Tolbert, "Single-phase on-board bidirectional PEV charger for V2G reactive power operation," IEEE Trans. Smart Grid, vol. 6, no. 2, pp. 767–775, Mar. 2015.
[89] Y. Liao, Z. Liu, G. Zhang, and C. Xiang, "Vehicle-grid system modeling and stability analysis with forbidden region-based criterion," IEEE Trans. Power Electron., vol. 32, no. 5, pp. 3499–3512, May 2017.
[10] M. Restrepo, J. Morris, M. Kazerani, and C. A. Canizares, "Modeling and testing of a bidirectional smart charger for distribution system EV integration," IEEE Trans. Smart Grid, vol. 9, no. 1, pp. 152–162, Jan. 2018.
[11] H. Liu, Z. Hu, Y. Song, J. Wang, and X. Xie, "Vehicle-to-grid control for supplementary frequency regulation considering charging demands," IEEE Trans. Power Syst., vol. 30, no. 6, pp. 3110–3119, Nov. 2015..
[12] D. Liu, Q. Zhong, Y. Wang, and G. Liu, "Modeling and control of a V2G charging station based on synchronverter technology," CSEE J. Power Energy Syst., vol. 4, no. 3, pp. 326–338, Sep. 2018
[13] J. R. Pillai and B. Bak-Jensen, "Integration of vehicle-to-grid in the western Danish power system," IEEE Trans. Sustain. Energy, vol. 2, no. 1, pp. 12–19, Jan. 2011
[14] Wikipedia.: 'Vehicle-to-grid', Wikipedia, San Francisco, CA, Available at: https://en.wikipedia.org/wiki/Vehicle-to-grid.
[15] V. Monteiro, B. Exposto, J. C. Ferreira and J. L. Afonso, "Improved vehicle-to-home (iV2H) operation mode: experimental analysis of the electric vehicle as off-line UPS," IEEE Trans. Smart Grid, vol. 8, no. 6, pp. 2702-2711, Nov. 2017.
[16] V. Monteiro, J. G. Pinto and J. L. Afonso, "Operation modes for the electric vehicle in smart grids and smart homes: present and proposed modes," IEEE Trans. Veh. Technol., vol. 65, no. 3, pp. 1007-1020, March 2016.
[17] J.M. Miller, O. C. Onar, and M.chinthavalli, "Primary- side power flow control of wireless powertransfer for electric vehicle charging,"IEEE J. Emerg. Sel. Topics power Electron. vol.3, no. 1, pp.147-162, Mar. 2015.
[18] Khaligh and S. Dusmez, "compreshensive topological analysis of conductive and inductive charging solutions for plug- in electric vehicles, "IEEE Trans. Veh. Technol., Vol. 61, no. 8, pp.3475-3489, oct. 2012.
[19] G. Buja, M. Bertoluzzo, and K. N. Mude, "Design and experimentation of WPT charger for electric city car," IEEE Trans. Ind. Electron., Vol. 62, no. 12, pp.7436-7447, Dec. 2015.
[20] D. J. Thrimawithana and U. K. Madawala, "A generalized steady -state model for bidirectional IPT system," IEEE Trans. Power Electron., vol.28, no. 10, pp. 4681-4689, Oct. 2013.
[21] F. Musavi and W. Eberle, "Overview of wireless power transfer technology for electric vehicle battery charging ," Power Electron ., IET, vol. 7, no. 1,pp. 60-66, Jan. 2014

