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Comparison of Configurations of Bidirectional Converters Suitable For V2G Technology

Ganesh M [1], Polly Thomas[2], Sreekanth P K[2], Athira M Thomas[2], Pooja Maria James[2]

Amrutha Maria Mathew[2]

PG Student, Saintgits College of Engineering, Kottayam, Kerala, India [1]

Assistant Professor, Dept. of EEE, Saintgits College of Engineering, Kottayam, Kerala, India [2]

Assistant Professor, Dept. of EEE, Sree Buddha College of Engineering, Padanilam, Kerala, India [2]

PG Student, Saintgits College of Engineering, Kottayam, Kerala, India [2]

PG Student, Saintgits College of Engineering, Kottayam, Kerala, India [2]

PG Student, Saintgits College of Engineering, Kottayam, Kerala, India [2]

ABSTRACT: The major challenge faced by our power sector is peak demand meeting. V2G technology can reduce the impact of this deficiency in peak demand and can facilitate DSM. For V2G capable vehicle to facilitate interchange of power between grid and vehicle bidirectional converters are inevitable. This work explains the configuration, simulation and design of 2 types of single phase bidirectional converters. Then it compares the two configurations. Simulations are performed using Matlab – Simulink background.

KEYWORDS: Electric Vehicle, Vehicle to Grid, Pulse Width Modulation, Zero crossing Detection, Demand Side Management.

I.INTRODUCTION

Inappropriate peak load management specifically peak power deficiency results in frequency declination, poor power quality, poor voltage regulation etc. It can lead to low reliability and continuity of supply, poor system stability and eventually most severe blackouts like the one which occurred 3 years before in India. Renewable energy resources meet 28% of peak demand. [24] Electric vehicles, using Battery energy storage systems, can be used as a distributed energy resource . In foreign countries there are many charging stations and parking lots where this concept is implemented. But its charging may sometimes create a peak load in the power grid. Even then there is a possibility of injecting energy back to the grid by the Vehicle to Grid technology (V2G). But it needs an Independent Source Operator, Aggregator and communication network to control EVs as distributed generating sources.[1-5].

This paper explains the design with simulation of V2G bidirectional converter suitable for single phase application. Design is based on the EV model , Mahindra Reva and the simulations were done in the Matlab – Simulink platform. Two configurations are simulated and compared for selecting the better configuration. The second section explains the block diagram and the base model details. Third section explains the design of the converters. Then converters are compared on the basis of THD analysis.

II.SYSTEM MODEL AND DESIGN

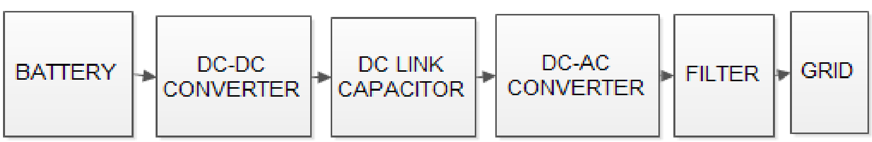

Fig: 1: Block diagram

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Fig:1 shows the system configuration.Since most of the people those who own EV are having charging outlets at their homes which is single phase, this paper considers the design of single phase converters with bidirectional capability. Here we are considering Mahindra Reva as our base model or EV for design and simulation purpose. It uses an arrangement of 8 cells in series; each cell is having a rating of 6volts and the capacity of each cell is 200 Ampere hours.

OUTPUT POWER:

As we are using the vehicle for injecting power to grid and also since we have to use the battery power to drive the motor of the vehicle, which is the primary purpose, we are limiting the battery power usage by 30% for grid injection. Remaining 70% is for driving purpose. This means that before delivering the power to grid for DSM the SOC of the battery is checked. It should be greater than 70% for grid injection as we have limited. So the calculation of total power that can be delivered is as follows:

Battery Voltage = 6V   Number of cells = 8
Ampere Hour capacity = 200Ah   Total capacity of battery bank = 200x6x8 = 9600Wh
Power that can be delivered to grid = (100 - 70)% of SOC = 30% of 9600 = 2880Wh

DC – DC CONVERTER:

Battery bank voltage V_{in} = 48V   DC link voltage V_0 =80V
We know that $V_0 / V_{in} = 1 / (1 - D)$ D = 0.4,   Where D is the duty cycle.
Maximum current; I_0 = (W x h) / V_0 = 36A
Take 5 % ripple current = 1.8A   Switching frequency F_s = 10000Hz
Load resistance can be calculated as:

$$R = Vo^2 / W = 2.222\text{ohms.}$$

For controlling the switching of the boost converter PI controller was used. Ki value as 1 and Kp value is taken as 0.01. The voltage error is measured and fed back to the controller for the switching purpose so as to regulate the output voltage.

DC - AC CONVERTER

It includes an inverter, it's control and a filter circuit. IGBT based H-bridge configuration is used. Equations for design are given in the reference.[25] . To eliminate harmonics, filter circuit is included at the output side of the converter. S rated is the kVA rating of the converter. T is the time period corresponding to the grid frequency. Δr is the power variation in watts. Δx is the allowable dc bus voltage change. Ma the inverter modulation index and RAF the Ripple Attenuation Factor.

Boost converter inductance, Ldc = (RD(1 – D2)) / (2Fs)
Take Srated = 2.880kVA   T = 20ms.   Δr = 2880W
Power factor = 0.95   Vdc = 80V   Δx = 8
Ma = 0.9
DC link capacitor Cdc =(Srated x 2n x Δr x pf)/(Vdc^2 x Δx) = 2137uF
Inverter side inductor Lsource

= ($Vgrid^2$ / (THD x Srated x 2∏ x Fs))√(($∏^2$ /18)(1.5 – (4√3 / 11)Ma +(9 Ma 2/8)))
= 0.7073mH
Filter capacitor Cfilter = 71uF   Filter inductor Lsource = 0.13449mH
Rfilter = 0.42527ohms

III. SIMULATION AND DESCRIPTION OF TWO TYPES OF CONVERTERS

Two types of converters are compared in this paper, type-1 which is based on the zero crossings and on off control and the type-2 is based on the Pulse Width Modulation (PWM). Table 1 given below summarizes all the design and simulation parameters.

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Table 1: Circuit Parameters

PARAMETERS	VALUES
Vin	48V
Ldc	46uH
Cdc	2137.5uF
Vo	80V
Kp	0.01
Ki	1
Linv	0.7073mH
Lsource	0.1344mH
Cfilter	71uF
Rfilter	0.42527ohms
AC source voltage(through transformer)	75V
Load	5kW,80V,50Hz

Type-1 Configuration

Fig 2 shows the type 1 switching configuration. In the type-1 converter, the grid voltage is fed back to the switching sub system. Zero Crossing Detectors(ZCD) decides whether to turn on or turn off the IGBT switches by generating pulses. One of the ZCD detects the positive half cycle of the utility grid voltage and other the negative half cycle. The output of ZCDs are again compared with carrier pulses generated by the pulse generators and are used to trigger the IGBT gates. Here the carrier frequency is 10kHz. When both the carrier pulses and ZCD output coincides, corresponding IGBT group gets triggered. H – bridge inverter configuration with 4 IGBTs are used. The main advantage of this converter scheme is that, as the pulses from the ZCDs are used, the converter can easily follow up the frequency changes in the grid in a co-ordinated manner with out any controller aid. When the IGBTs are switched ON, as the dc link voltage (80V)is greater than the grid voltage as seen from the grid/load side, power flows from battery to the load/grid. Same happens during the negative half cycle. Figure 4 shows the Subsystem for Inverter switching using type-1 configuration.

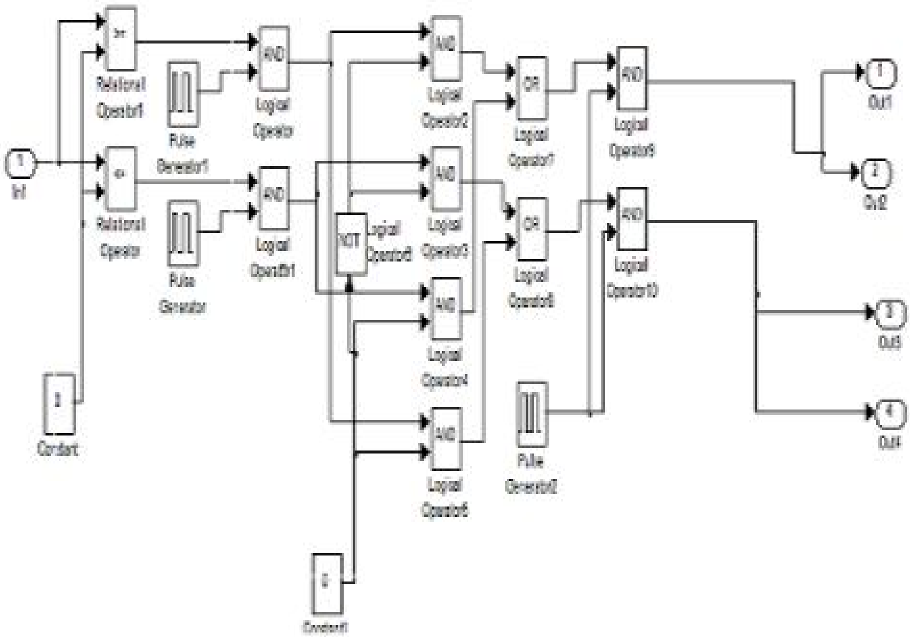

Fig 2: Type-1 configuration – Switching Subsystem for Inverrter

Type-2 Configuration

In order to reduce the THD further and to make the waveform shapes more sinusoidal we can make use of the Pulse Width Modulation in the type-2 configuration. The sinusoidal voltage wave form from the source, which is taken

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through a voltage feed back loop is compared with the a carrier waveform of triangular shape having a higher carrier frequency and the resultant pulses are used for triggering the converter switches. Here the carrier frequency is again set to 10kHz. When the amplitude of the voltage feed back becomes greater than the triangular carrier, corresponding IGBT pair in the H-bridge inverter is triggered ON. Other pair is turned ON after a delay of 10mS which corresponds to the time delay of 1 half cycle. Also a new control circuit is introduced to make the converter operate as an inverter wheb the SOC is above 70% and as rectifier if the SOC is below 70%. Figure 3 shows the Subsystem for Inverter switching using type-2 configuration. Main disadvantage is that, delay must be adjusted according to the change in grid frequency dynamically. Otherwise we will lose the synchronism. Fig 3 shows Type-2 configuration – Switching subsystem for Inverter in which PWM is given importance.

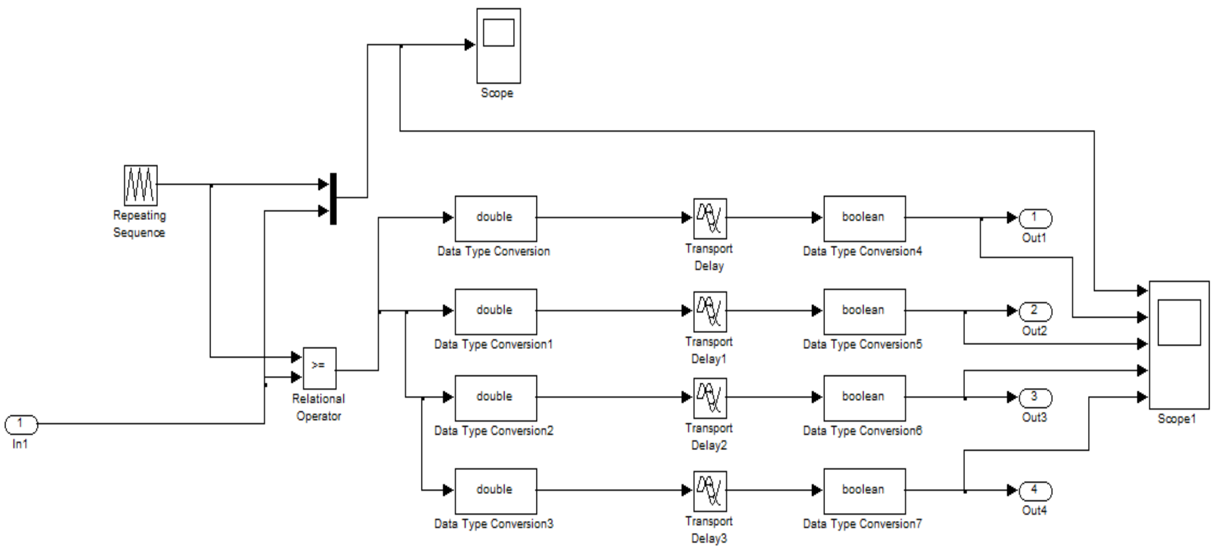

Fig 3: Type-2 configuration – Switching Subsystem for Inverter.

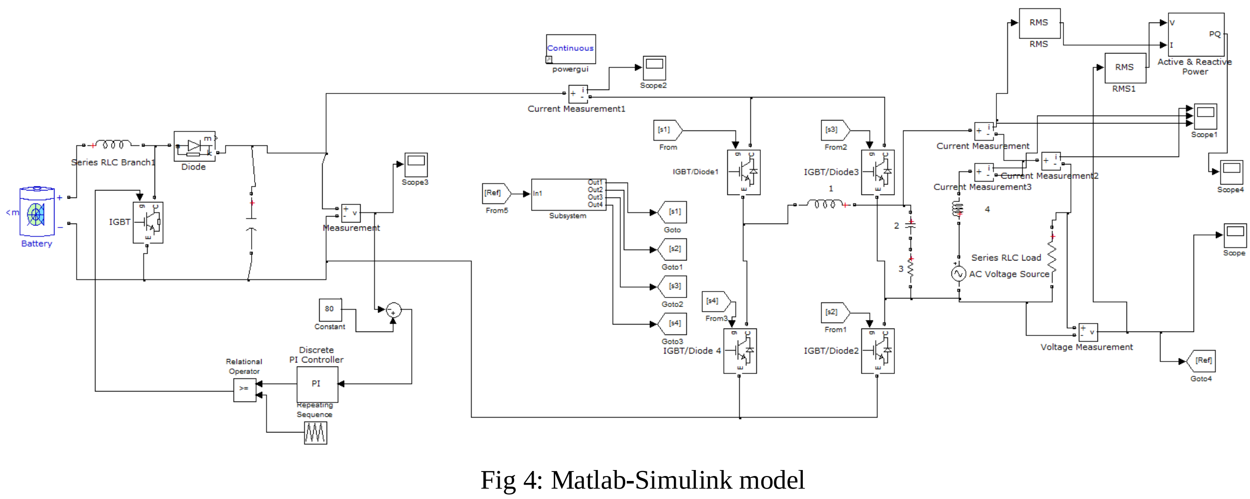

Fig 4: Matlab-Simulink model

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IV. COMPARISON AND RESULTS

We have figure:4 , the Matlab – simulink model for type 1 and 2 converters, in which the differences are only in switching subsystems . Comparisons are made on the basis of current THD analysis, ease of synchronization and charging discharging control. Figures below shows the current waveforms of both type of converters. Type -1 configuration has more distorted current waveforms and greater THD than Type -2 configuration. Table 2 shows the THD analysis results and also compares both types of converters. In type -1, since the pulses generated by pulse generator and ZCD output are the only factors that governs the switching mechanism, it is not possible to control the charge/discharge rate directly. But in case of PWM, current control schemes can be easily done. It must be noted that in both types, mode selection (ie: charging/discharging) can be easily included. Also as power injected increases, THD is also found to be increasing in the case of Type-1 converter to drastic level, which cannot be allowed as per standards. Also in Type -2, as feed back is taken from the grid voltage, distortions in grid voltages can lead to higher THD which is not allowable. In case of Type- 1, grid voltage distortions, noises and spikes can lead to false triggering of ZCDs which further increase the THD.

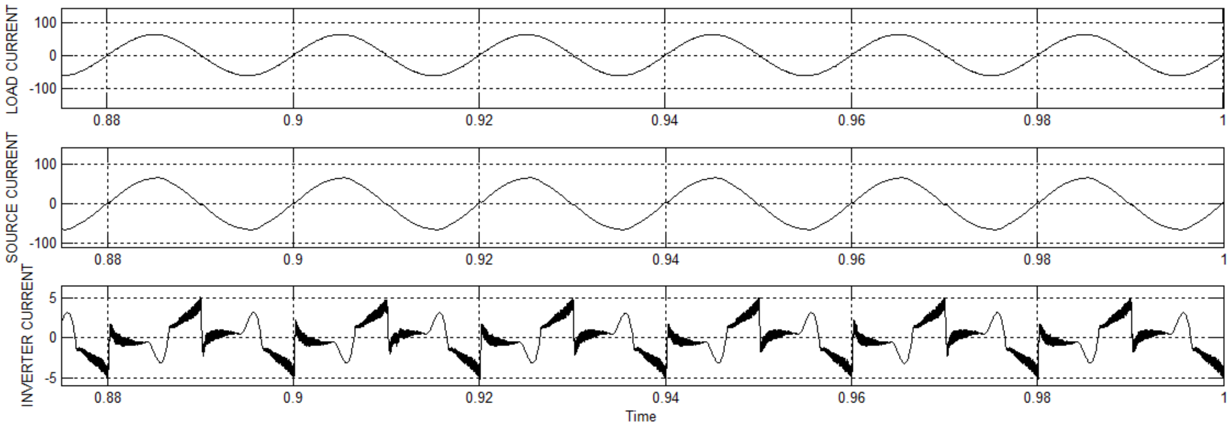

Fig 5: Current Waveforms for load,source and inverter in type-1 converter

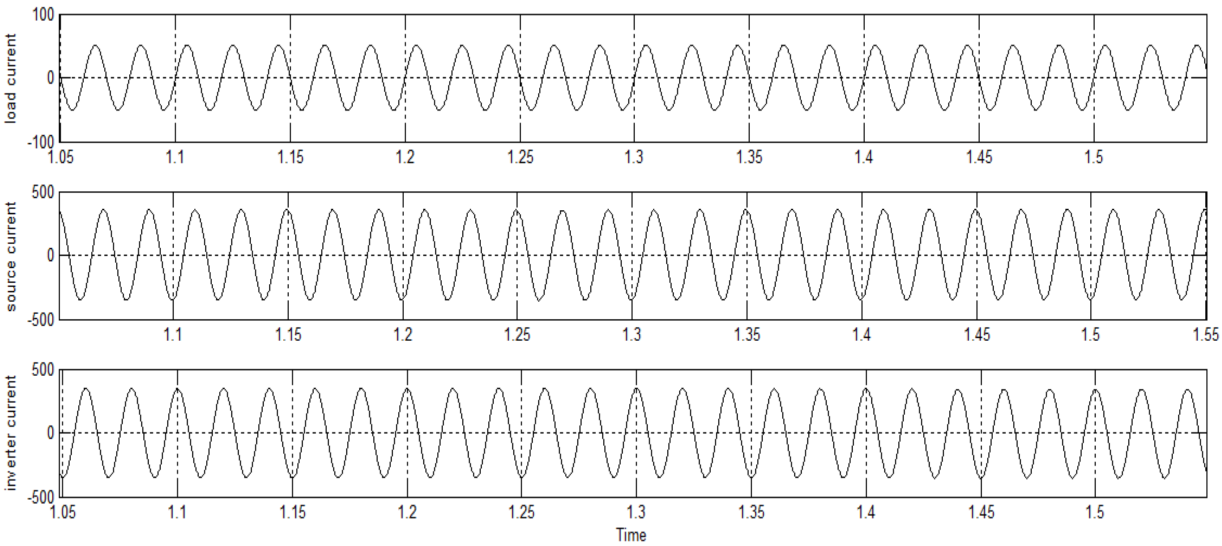

Fig 6: Current Waveforms for load,source and inverter in type-2 converter.

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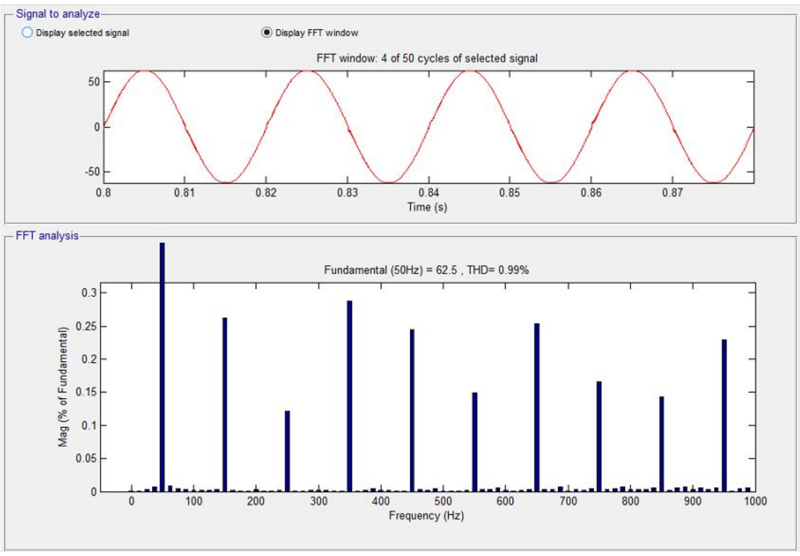

Fig 7: THD analysis result of source current waveform of type-1 configuration.

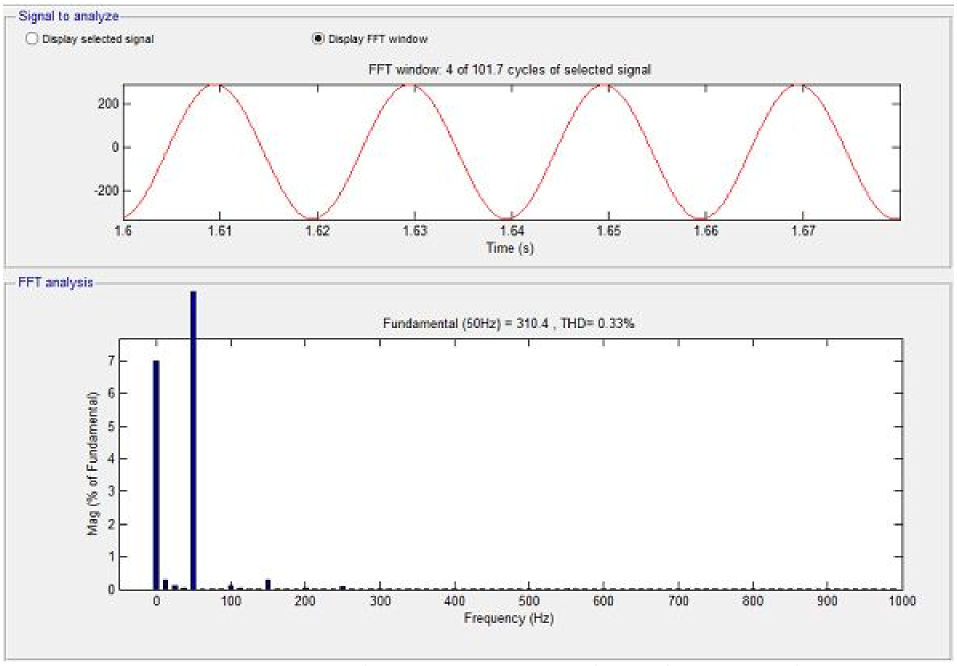

Fig 8: THD analysis result of source current waveform of type-2 configuration.

Table:2 Comparison at a glance.

CRITERION	TYPE-1	TYPE2
THD (source current)	0.99%	0.33%
THD (load current)	3.33%	0.22%
THD (inverter current)	44.33%	0.34%
Synchronization	Automatic	Delay adjustment
Charge/discharge rate control	Not possible	Possible
Charge/discharge mode selection	Possible	Possible
Effect of distortions in grid voltage	False triggering	THD increases

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V. CONCLUSION

Design and simulation of two types of single phase bidirectional converters suitable for V2G and G2V applications were done using Matlab – Simulink platform. Results shows that the that type-2 PWM converter current is having less THD, better wave form and smoother controls than type-1 converter based on ZCD and pulses. Neverthless we get easier synchronization in case of type-1 converter.

REFERENCES

[1] Mukesh Singh, Praveen Kumar and Indrani Kar, "Analysis of Vehicle to Grid Concept in Indian Scenario", 14th International Power Electronics and Motion ControlConference, EPE-PEMC 2010.
[2] Zhenpo Wang, Member, IEEE, and Shuo Wang, "Grid Power Peak Shaving andValley Filling Using Vehicle-to-Grid Systems", IEEE Transactions on power delivery,vol. 28, no. 3, july 2013
[3] Bill Kramer, Sudipta Chakraborty, Benjamin Kroposki, "A Review of Plug-in Vehicles and Vehicle-to-Grid Capability", National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, CO 80401, USA ,2008.
[4] Murat Yilmaz, Member, IEEE, and Philip T. Krein, Fellow, IEEE"Review of the Impact of Vehicle-to-Grid Technologies on Distribution Systems and Utility Interfaces", IEEE Transactions on power electronics, vol. 28, no. 12, december 2013.
[5] Y. Ota, Member, IEEE, H. Taniguchi, Member, IEEE, T. Nakajima, Member, IEEE K. M. Liyanage, "Autonomous Distributed V2G (Vehicle-to-Grid) considering Charging Request and Battery Condition", Scientific Research (KAKENHI) (B)(22360122), University of Tokyo, 5-1-5, Kashiwanoha, Kashiwa, Chiba, 277-8568,Japan.
[6] Koichiro Shimizu,Taisuke Masuta, Yuyaka Ota, Member, IEEE, and Akihiko Yokoyama,Member,IEEE,"Load Frequency Control in Power System Using Vehicle-to-Grid System Considering the Customer Convenience of Electric Vehicles.",2010 International Conference on Power System Technology.
[7] North Bay Chapter of the Electric Auto Association,"Electric Vehicle Batteries", Posted at: http://www.nbeaa.org/presentations/batteries.pdf
[8] Ahmad Pesaran, Ph.D. Principal Engineer National Renewable Energy Laboratory Golden, Colorado, USA," Battery Requirements for Plug-In Hybrid Electric Vehicles Analysis and Rationale", NREL/PR-540-42469.
[9] ianshu Wei, Taeyoung Kim Sangyoung Parky Qi Zhu ,Sheldon X.D., Tan Naehyuck Changy Sadrul, Ula Mehdi Maasoumyx, University of California at Riverside, Seoul National University C3 Energy, "Battery Management and Application for Energy-Efficient Buildings", Permissions@acm.org. DAC14, June 01 05 2014, San Francisco, CA, USA. 2014.
[10] Atsushi Baba and Shuichi Adachi,"State of Charge Estimation of Lithium-ion Battery Using Kalman Filters",2012 IEEE International Conference on Control Applications (CCA) Part of 2012 IEEE Multi-Conference on Systems and Control October 3-5, 2012. Dubrovnik, Croatia.
[11] Milad Falahi, Member, IEEE, Hung-Ming Chou, Student Member, IEEE, Mehrdad Ehsani, Fellow, IEEE,Le Xie, Member, IEEE, and Karen L. Butler-Purry, Senior Member, IEEE, "Potential Power Quality Benefits of Electric Vehicles", IEEE Transactions on sustainable energy, 2013.
[12] Yuchao Ma, Tom Houghton, Andrew Cruden, and David Infield, Senior Member, IEEE,"Modeling the Benefits of Vehicle-to-Grid Technology to a Power System", IEEE Transactions on power systems, vol. 27, no. 2, may 2012.
[13] Sanzhong Bai, Student Member, IEEE, and Srdjan M. Lukic, Member, IEEE,"Unified Active Filter and Energy Storage System for an MW Electric Vehicle Charging Station.", IEEE Transactions on power electronics, vol. 28, no. 12, december 2013.
[14] HaoyuWang, StudentMember, IEEE, Serkan Dusmez, StudentMember, and Alireza Khaligh, Senior Member, IEEE Power Electronics,"A Novel Approach to Design EV Battery Chargers Using SEPIC PFC Stage and Optimal Operating Point Tracking Technique for LLC Converter", Maryland Industrial Partnerships Program, IEEE 2014.
[15] A. T. Al-Awami, Member, IEEE, and E. Sortomme, Member, IEEE,"Electric Vehicle Charging Modulation Using Voltage Feedback Control", A. T. Al-Awami is with King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia,IEEE 2013.
[16] Suk-Ho Ahn, Ji-Woong Gong Dept. of Energy Conversion Technology University of Science Technology Chang-Won, Korea," Implementation of 60-kW Fast Charging System for Electric Vehicle.", IEEE 978-1-4799-0224-8/13, 2013.
[17] Qinglai Guo, Senior Member, IEEE, Shujun Xin, Student Member, IEEE, Hong-bin Sun, Senior Member, IEEE,Zhengshuo Li, Student Member, IEEE, and Boming Zhang, Fellow, IEEE,"Rapid-Charging Navigation of Electric Vehicles Based on Real-Time Power Systems and Traffic Data", IEEE Transactions on smart grid, vol. 5, no. 4, july 2014
[18] Chenrui Jin, StudentMember, IEEE, Jian Tang,Member, IEEE, and Prasanta Ghosh, SeniorMember, IEEE"Optimizing Electric Vehicle Charging: A Customers Perspective",IEEE Transactions on vehicular technology, vol. 62, no. 7, september 2013.
[19] G. M. Asim Akhtar, Student Member, IEEE, A. T. Al-Awami, Member, IEEE,E.Sortomme, Member, IEEE, M. A. Abido, Member, IEEE,M.Waqar Ahmed, Student Member, IEEE"Autonomous Electric Vehicle Charging Management over Real Time Digital Simulator", 978-1-4799-6415-4/14, 2014 IEEE.
[20] C.Kalavalli, K.ParkaviKathirvelu, R.Balasubramanian Department of Electrical & Electronics Engineering, SASTRA UNIVERSITY," Single Phase Bidirectional PWM Converter for Microgrid System", International Journal of Engineering and Technology (IJET), Vol 5 No 3 Jun-Jul 2013
[21] Yutaka Ota, Haruhito Taniguchi, Tatsuhito Nakajima, Kithsiri M.Liyanage Koichiro Shimizu, Taisuke Masuta, Junpei Baba, and Akihiko Yokoyama,"Effect of Autonomous Distributed Vehicle-to-Grid (V2G) on Power System Frequency Control", 2010 5th International Conference on Industrial and Information Systems, ICIIS 2010, Jul 29 - Aug 01, 2010, India.
[22] C. Pang, Student Member, IEEE, P.Dutta, Student Member, IEEE, and M. Kezunovic, Fellow, IEEE,"BEVs/PHEVs as Dispersed Energy Storage for V2B Uses in the Smart Grid",IEEE Transactions on smart grid, vol. 3, no. 1, march 2012
[23] www.wikipedia.org
[24] Website of Power Grid Corporation of India. Ltd.
[25] Arnaldo Arancibia and Kai Strunz,School of Electrical Engineering and Computer Science Technical University of Berlin,"Modeling of an Electric Vehicle Charging Station for Fast DC Charging", IEEE Transactions on power electronics, vol. 3, no.1, march 2011.