A DC-DC CONVERTER WITH INTERLEAVED BOOST STAGE FOR HYBRID ENERGY STORAGE SYSTEM

Harsha.D.R, Student, M.Tech (Power Electronics)
Dept. of Electrical and Electronics Engineering,
Dr. Ambedkar Institute of Technology
Mallathally, Bengalore,-560056

Dayanand T.B, Associate professor
Dept. of Electrical and Electronics Engineering,
Dr. Ambedkar Institute of Technology
Mallathally, Bengalore-560056.

Abstract **- Now a days the human life has become tough because of availability of the non-Renewable sources are reduced. Such as Gasoline, petroleum products, coal, natural gas and other fossil fuels. These resources cannot be recycled again. To overcome this problem IC engine automobiles are replaced by electric vehicles. hybrid energy storage systems are used such as battery, super capacitor and other storage devices in the electric vehicles. This project presents DC-DC converters with Interleaved boost stage for the hybrid storage systems. The interleaved boost converters have may advantages such as less ripple current, high efficiency and faster dynamics. The interleaved boost converter boosts the output voltage up to 350-400v compared to the input voltage. PID controller is the mechanism used to the control the operation of the converter to operate in the safe mode and reduces the stress on the switches. The Simulink diagrams and experimental results are investigated by using MATLAB/SIMULINK software.**

Keywords – Interleaved boost converter, Nonrenewable resources, Hybrid energy storage systems, PID controller

I. INTRODUCTION

The increased environmental pollution has led to the replacement of conventional sources by renewable sources like photovoltaic sources, windmills etc which result in turn an increase in the demand of DC- DC converters. Basically DC-DC converters are used to boost the input voltage to required output voltage and to get the high voltage gain[1]. The converter should be operated with the duty cycle of more than 50% to get higher gain in voltage level. As power densities continue to rise, interleaved boost designs become a powerful tool to manage input currents with increased efficiency. The interleaved DC-DC boost converters are used for the application requiring demands such as low current ripple, high efficiency, faster dynamics, and higher power density. With the help of interleaving technique, the inductor current of interleaved boost converter can be reduced[2].

Multi-input DC-DC converters are widely used to combine various power sources in an efficient way. Hybrid Energy Storage Systems (HESS) which integrates high-capacity batteries with fast-responding ultra-capacitors (UC), is an efficient solution for high-power and high-energy applications. Although batteries can achieve high specific energy up to 500 Wh/kg, their specific power usually does not exceed hundreds of watts per kg. In contrast, UCs have high specific power in the order of kilowatts per kilogram[3],[4]

Recently, HESS has been utilized for Electric Vehicle (EV), Hybrid Electric Vehicle (HEV), and Plug-in Hybrid Electric Vehicle (PHEV) to improve power and energy density, lifetime, and cost of the storage system[5]. In order to use the HESS efficiently, the topology of the system and also the control scheme, should be designed carefully.[5],[6]

By integrating DC-DC converters, multi-input DC-DC converter with reduced size and cost can be achieved. multi-input topologies with multiple energy sources combine desired characteristics of each source (with different voltage levels and power and energy capacity) and also increase the reliability of the system [7],[8]. A wide range of applications can be imagined for multi-input converters including hybrid micro-grids, EV and HEV, and integrated renewable sources[9].. The limitation of this converter is that at a specific time, only one input source can be charged or feed the load. In addition, the input sources cannot share power between each other.

II. BLOCK DIAGRAM DISCRIPTION

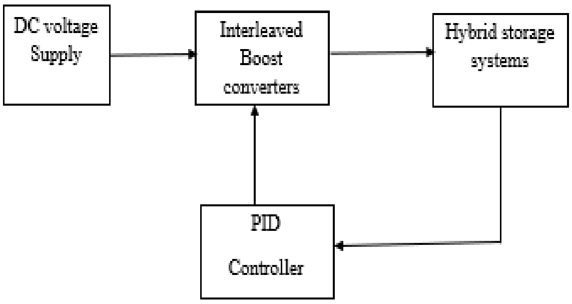

Fig 1: Block diagram of the system

DC voltage supply:

A DC power supply is one that supplies a constant DC voltage to its load. Depending on its design, a DC power supply may be powered from a DC source or from an AC source such as the power mains.

Interleaved boost converters:

A basic boost converter converts a DC voltage to a higher DC voltage. Interleaving adds additional benefits such as reduced ripple currents in both the input and output circuits. Higher efficiency is realized by splitting the output current into two paths, substantially reducing I^2R losses and inductor AC losses.

Hybrid storage systems:

Hybrid energy storage systems (HESSs) characterized by coupling of two or more energy storage technologies are emerged as a solution to achieve the desired performance by combining the appropriate features of different technologies.

PID controller:

A PID controller is an instrument used in industrial control applications to regulate temperature, flow, pressure, speed and other process variables. PID (proportional integral derivative) controllers use a control loop feedback mechanism to control process variables and are the most accurate and stable controller.

III. BOOST CONVERTER

Figure 2 shows the boost converter that raises the voltage of DC input to a given voltage of DC output. The source of input voltage is connected to an inductor. The source connected to the solid-state device works as a switch. A diode is the second switch used. The diode is connected to a capacitor which is in parallel to the load as shown in the figure.

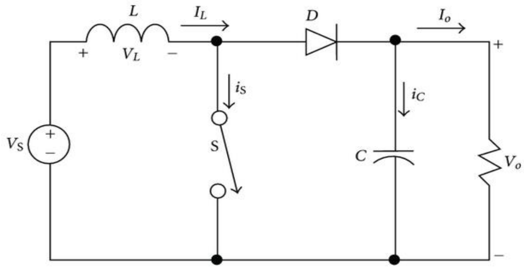

Fig 2: Topology of boost converter

Stage1: Switch is ON, Diode is OFF

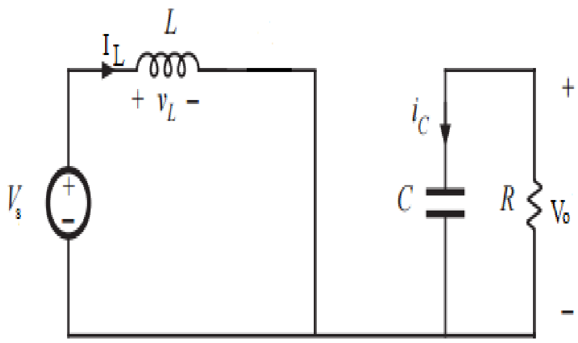

Fig 3: Equivalent circuit for switch closed

When the switch is ON the diode becomes reverse biased and the current will flow through inductor, switch and then back to the source.

Boost converter during steady state operation, for stage 1 operation using KVL.

$$V_L = V_S = L\frac{dI_L}{dt}$$

$$\text{Therefore, } \frac{dI_L}{dt} = \frac{V_S}{L}$$

$$\frac{\Delta I_L}{\Delta t} = \frac{\Delta I_L}{DT} = \frac{V_S}{L}$$

Switch closed for $(\Delta I_L) = \frac{V_S DT}{L}$

Stage 2: Switch is OFF, Diode is ON

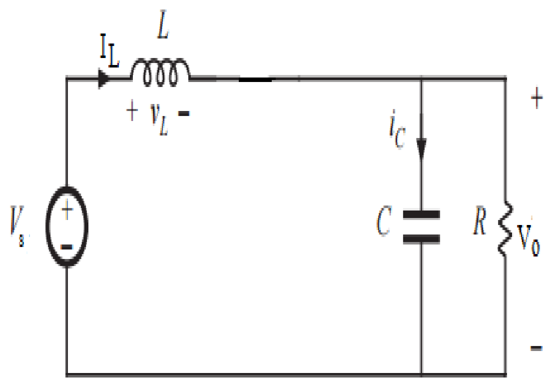

Fig 4: Equivalent circuit for switch open

When the switch is OFF, the diode becomes forward biased to provide path for inductor current. The energy stored in the inductor will dissipate to the load resistance.

Boost converter during steady state operation, for stage 2 operation using KVL.

$$V_L = V_S - V_O = L\frac{dI_L}{dt}$$

Therefore, $\frac{dI_L}{dt} = \frac{V_S - V_O}{L}$

$$\frac{\Delta I_L}{\Delta t} = \frac{\Delta I_L}{(1-D)T} = \frac{V_S - V_O}{L}$$

Switch closed for $(\Delta I_L) = \frac{(V_S - V_O)(1-DT)}{L}$

The net change in inductor current,

$$(\Delta I_L)_{closed} + (\Delta I_L)_{open} = 0$$

$$\frac{V_S DT}{L} + \frac{(V_S - V_O)(1-DT)}{L} = 0$$

Solving for $V_O = \frac{V_S}{(1-D)}$

IV. INTERLEAVED BOOST CONVERTER

The proposed system interleaved boost converter is used as charging stage for hybrid storage systems such as battery and super capacitor. This converter is used to get high voltage gain compared to the existing system. In the proposed interleaved boost converter additional inductor and two diodes is used to get high voltage gain and super capacitor is added for additional charging storage. PID controller is used to provide pulses and to get better performance of converter. The additional switch S3 is added for the connection to the super capacitor. The super capacitor starts to charge after the completion of battery charging. The switch S3 turns on after battery charges to 100% to charge the super capacitor.

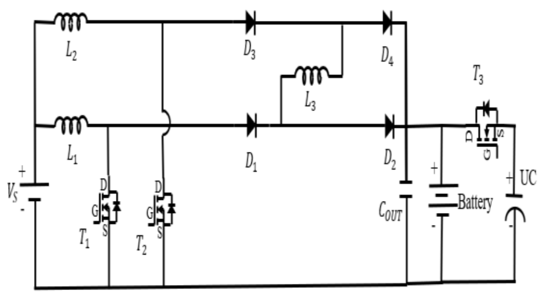

Fig 5: Toplogy of interleaved boost converter

Mode 1:

during this mode, switch T1 is turned on and T2 is turned off. Diodes D2 and D3 are in the forward condition. D1 and D4 are reverse biased. the inductor L1 stores the energy and L2 and L3 transfers the energy to the load through the diodes D2 and D3.

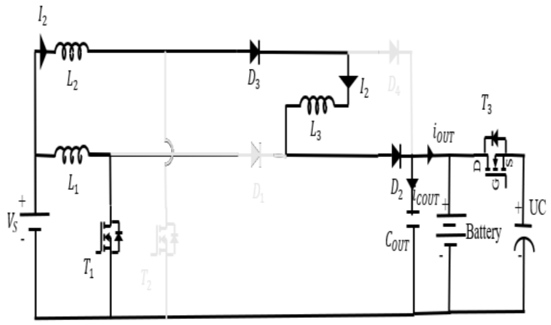

Fig 6: Equivalent circuit for switch closed

Mode 2:

During this mode, switch T1 is turned off and T2 is also turned off. Diodes D1 and D4 are in the forward condition. D2 and D3 are reverse biased. the inductor L1 and L3 transfers the energy to the load through the diodes D1 and D4

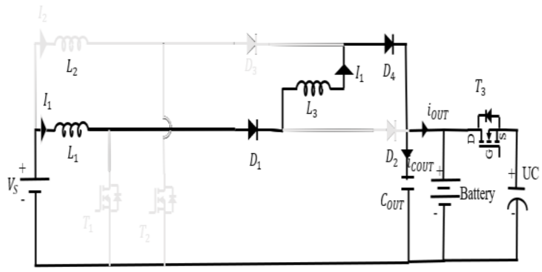

Fig 7: Equivalent circuit for switches open

Mode 3:

During this mode, switch T1 is turned off and T2 is also turned on. Diodes D1 and D4 are in the forward condition. D2 and D3 are reverse biased. the inductor L2 stores the energy and L1 and L3 transfers the energy to the load through the diodes D1 and D4.

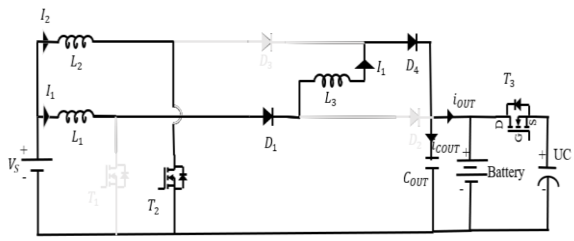

Fig 8: Equivalent circuit for switch T2 closed

Mode 4:

During this mode, switch T1 is turned off and T2 is also turned off. Diodes D3 and D2 are in the forward condition. D1 and D4 are reverse biased. the inductor L2 and L3 transfers the stored energy to the load through the diodes D3 and D2.

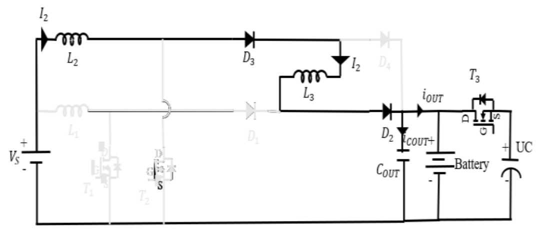

Fig 9: Equivalent circuit for switches open

V. SIMULINK MODEL

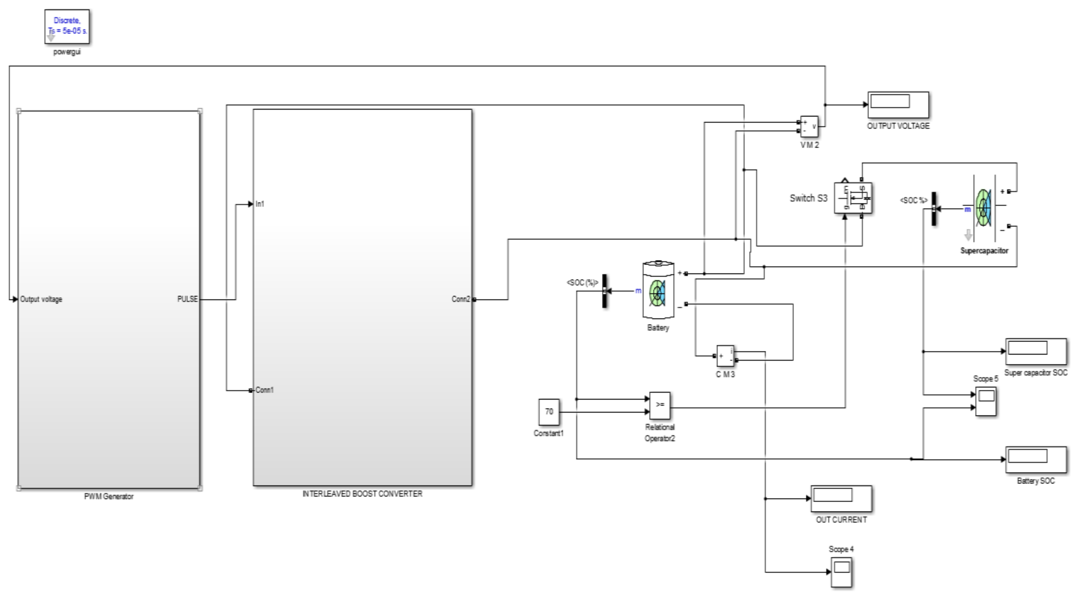

Fig 10: Simulink model of the system

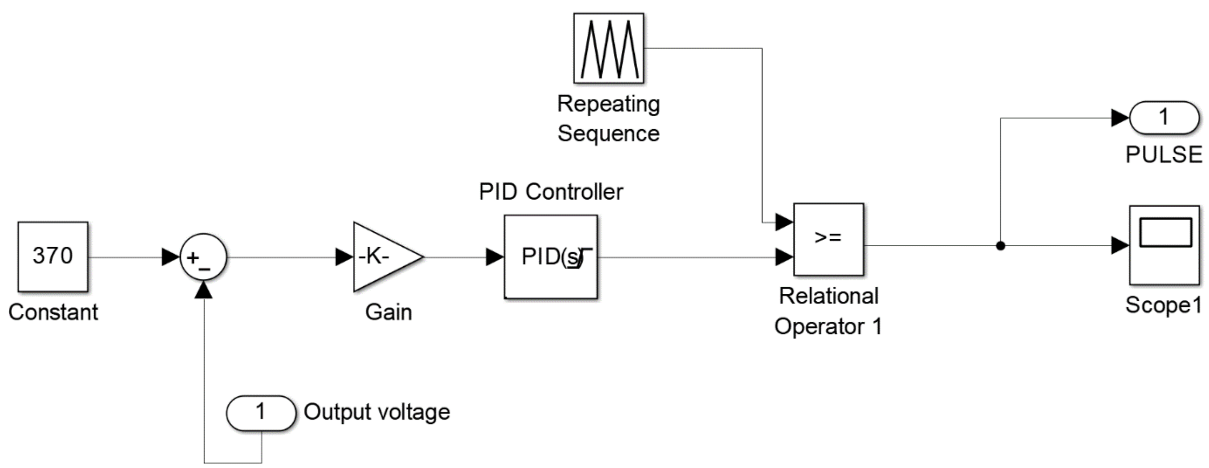

Fig 11: simulink model of PID controller

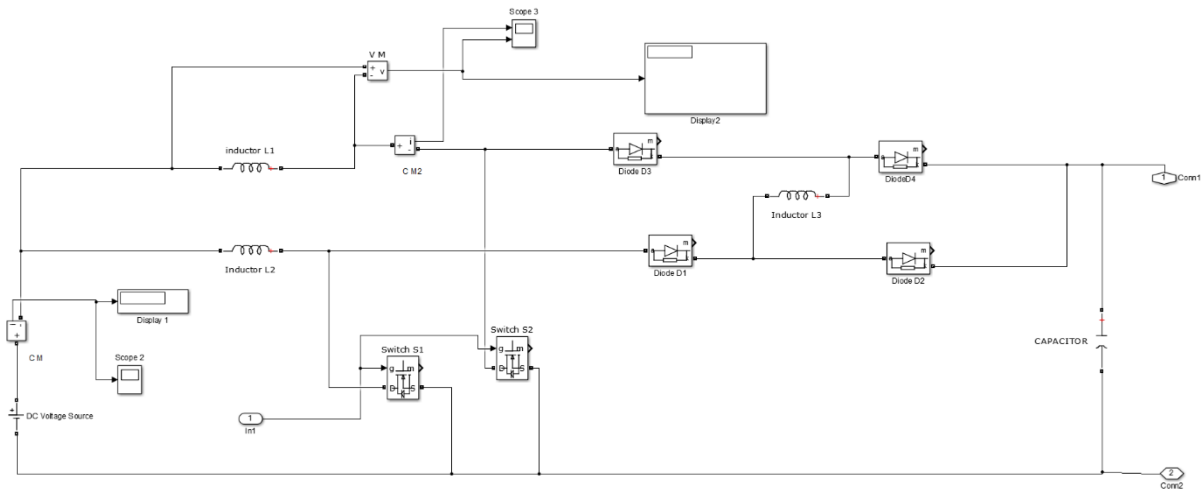

Fig 12: simulink model of interleaved boost converter

PARAMETERS	VALUES
Input voltage	100V
Output voltage	350-400v
Frequency	10KHz
Inductors L1, L2, L3	757μH
Capacitor C	1171μF

Table I: Parameter values

VI. SIMULINK RESULTS

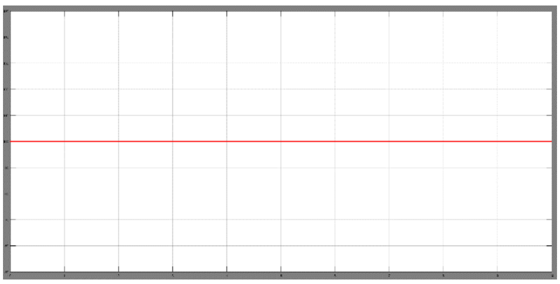

Fig 13: input voltage 100v

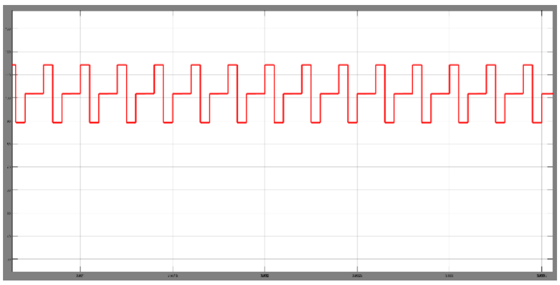

Fig 14: input current

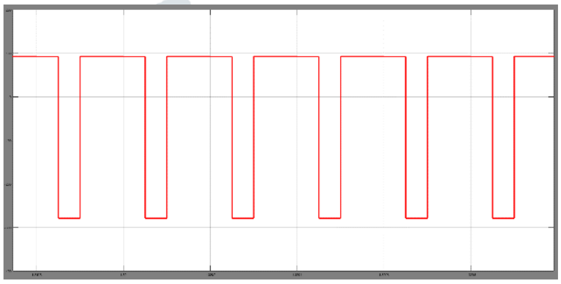

Fig 15: inductor voltage

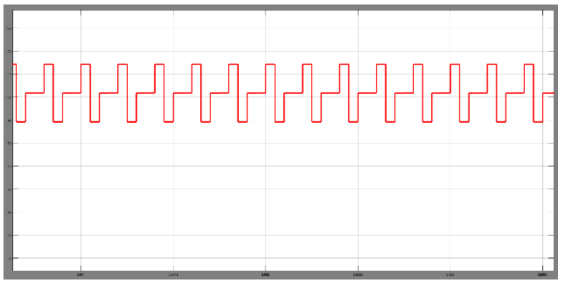

Fig 16: inductor current

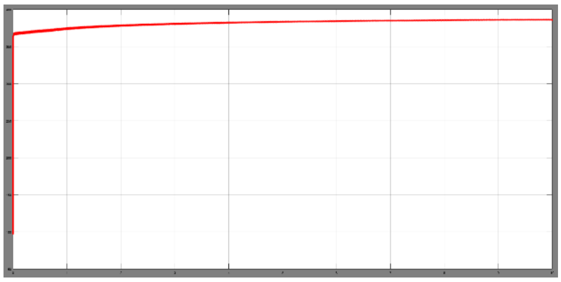

Fig 17: output voltage 385v

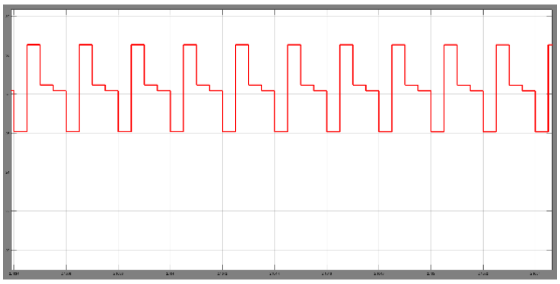

Fig 18: output current

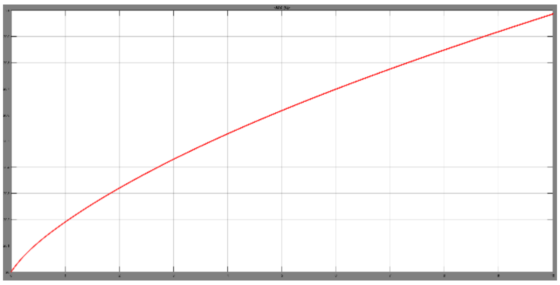

Fig 19: battery SOC

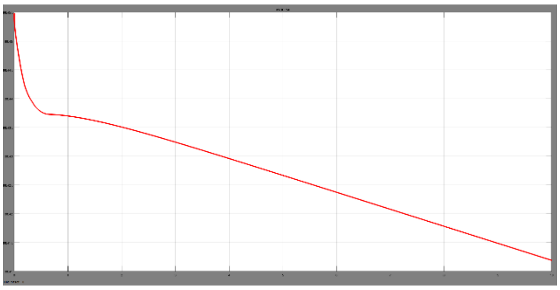

Fig 20: Super capacitor SOC

VII. CONCLUSION

In this project Interleaved boost converter topology is proposed for DC-DC power conversions for electric vehicles with hybrid energy storage systems. The converter operates in all modes including DC-DC battery and super capacitor charging. The converter achieves the output voltage up to 350-400V for the input voltage 100V and duty cycle 75%. The PID controller provides gate pulses and controls the operation of converter. The ripple current is reduced and efficiency is increased. The Simulink results shows the performance and results of the interleaved boost converter including battery and super capacitor charging.

REFERENCES

[1] H. M. Swamy, K. P. Guruswamy, and S. P. Singh, "Design, Modeling and Analysis of Two Level Interleaved Boost Converter," IEEE International Conference on Machine Intelligence and Research Advancement (ICMIRA), pp. 509-514, December, 2013

[2] A. Ghosh, S. Banerjee, M. K. Sarkar, and P. Dutta, "Design and Implementation of Type-II and Type-III Controller for DC-DC Switched-Mode Boost Converter by using K-Factor Approach and Optimization Techniques," IET Power Electronics, vol. 9, no. 5, pp. 938-950, 2016. (doi: 10.1049/iet-pel.2015.0144).

[3] L. Gao, R. A. Dougal, and S. Liu, "Power enhancement of an actively controlled battery/ultracapacitor hybrid," IEEE Trans. Power Electron., vol. 20, no. 1, pp. 236–243, Jan. 2005.

[4] Hany F. Habib, A.A.S. Mohamed, Mohamad El Hariri, Osama A. Mohammed, "Utilizing supercapacitors for resiliency enhancements and adaptive microgrid protection against communication failures", in Electric Power Systems Research, Volume 145, April 2017, Pages 223- 233,

[5] A. Khaligh and Z. Li, "Battery, ultracapacitor, fuel cell, and hybrid energy storage systems for electric, hybrid electric, fuel cell, and plug-in hybrid electric vehicles: State of the art," IEEE Trans. Vehicle Technol., vol. 59, no. 6, pp. 2806–2814, Jul. 2010.

[6] L. Solero, A. Lidozzi, and J. A. Pomilio, "Design of multiple-input power converter for hybrid vehicles," IEEE Trans. Power Electron., vol. 20, no. 5, pp. 1007–1016, Sep. 2005.

[7] F. Akar, Y. Tavlasoglu, E. Ugur, B. Vural, and I. Aksoy, "A bidirectional non-isolated multi-input DC–DC converter for hybrid energy storage systems in electric vehicles," IEEE Trans. Veh. Technol., vol. 65, no. 10, pp. 7944–7955, Oct. 2016.

[8] K. P. Yalamanchili and M. Ferdowsi, "Review of multiple input DC–DC converters for electric and hybrid vehicles," in Proc. IEEE Veh. Power Propulsion Conf., 2005, pp. 552–559.

[9] B. Dobbs and P. Chapman, "A multiple-input DC-DC converter topology," IEEE Power Electron. Lett., vol. 1, no. 1, pp. 6–9, Mar. 2003.

[10] P. Imbertson and N. Mohan, "A high-performance single-phase bridgeless interleaved PFC converter for plug-in hybrid electric vehicle battery chargers," IEEE Trans. Ind. Appl., vol. 47, no. 4, pp. 1833–1843, Jul. 2011.

[11] 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.

[12] H. Moradisizkoohi and O. A. Mohammed, "A quasi-resonant bidirectional buck-boost converter for Electric Vehicle applications," 2017 IEEE Transportation Electrification Conference and Expo (ITEC), Chicago, IL, 2017, pp. 621-625.