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Performance of Dual Llc Bridge Converter for Battery Charging Applications

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ABSTRACT
This paper proposes a double extension (DB) LLC resounding converter for wide info applications. The topology is a coordination of a half-connect (HB) LLC circuit and a full-connect (FB) LLC circuit. The fixed-recurrence pulse width-tweaked (PWM) control is utilized and a scope of double the base information voltage can be secured. Contrasted and the customary pulse recurrence modulation (PFM) controlled HB/FB LLC full converter, the voltage addition range is free of the quality factor, and the magnetizing inductor has little influence on the voltage gain, which can improve the parameter determination process and benefit the structure of attractive segments too. Over the full load extend, zero-voltage exchanging (ZVS) and zero-current exchanging (ZCS) can be achieved for essential switches and optional rectifier diodes, separately. Nitty Gritty examination on the modulation plan and working rule of the proposed converter is introduced alongside the converter execution. At long last, all hypothetical examination and characteristics are verified by test results from a 120-V to 240-V input 24 V/20 an output converter model.

Index Terms—Dual Bridge (DB), fixed frequency, LLC, wideinput voltage range.

I. INRODUCTION

In numerous applications, power transformation circuits are required to work with a wide info voltage run. For instance, the yield voltage scope of module and battery electric vehicle (EV) on-board chargers is wide (e.g., 200– 450 V), which implies the input-voltage scope of on-board dc/dc converters that condition power between the high- and low-voltage batteries is wide too [1]– [4]. Along these lines, building up a dc/dc converter with high efficiency over a wide voltage run is fundamental. LLC resonant converter, which is fit for acknowledging delicate changing from zero to full loads and accomplishing high efficiency what's more, high power density, has turned into an exploration hotspot as of late [5]– [12].

Regularly, ordinary half-and full-connect LLC converters work with variable recurrence control. The working recurrence run must be expanded or the inductor proportion must be diminished so as to get a wide info voltage run [13], [14], which is trying to plan and streamline attractive segments [15]. This may cause numerous undesired issues, for example, low power density and high conduction misfortunes. In this manner, the customary LLC converter isn't appropriate for wide info applications [14]. Consolidating the three-level circuit with a LLC resonant tank, numerous kinds of three-level LLC (TL LLC) full converters equipped for accomplishing a wide information go have been proposed in [16]– [21].

A straightforward TL LLC resonant dc/dc converter with just a single attractive segment is proposed in [16], which can accomplish a wide information/yield go inside a tight recurrence go on account of the two-arrange reverberation. Not quite the same as the TL LLC resonant converters with one resonant tank, the topology talked about in [17] is a TL LLC full converter comprising of two half-connect (HB) LLC arrangement full converters in arrangement, yet, having the equivalent resonant inductor and transformer. As an augmentation of [17], another TL LLC converter with one resonant tank is proposed in [18], where the full recurrence is twice as high as the exchanging recurrence, diminishing the measure of resonant parts and expanding the power density. Be that as it may, the recurrence varieties of these previously mentioned converters are still generally enormous, e.g., 88–150 kHz in [16], which is trying for the streamlining of attractive parts.

By utilizing the new modulation systems, a TL confined FB LLC converter that can work at a fixed recurrence is introduced in [19], which can work in whole two-level or three-level modes depending on the voltage run. In any case, various changes must be utilized and the structure is intricate. Jin and Ruan [20] proposed a cross breed FB TL LLC converter equipped for working under both three-level and two-level modes. In spite of the

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fact that this converter can understand a wide voltage gain extend with the fixed-recurrence control, two working modes suggest progressively refined control and not every one of the switches persevere through portion of the info voltage under the three-level mode.

A fixed-recurrence TL LLC converter with helper switches and windings on the auxiliary side is introduced in [21]. Be that as it may, extra windings are included the optional side of the transformer and the auxiliary assistant switches can't understand ZVS turn-on.

2.1 CONVERTER TOPOLOGIES

A double bridge LLC DC-DC converter is in a perfect world suited for high-control, galvanically detached DC-DC transformation. The DAB DC-DC converter has focal points of high power density, Zero Voltage Switching (ZVS), bidirectional power exchange ability, a measured and symmetric structure, and basic control necessities. The DAB DC-DC converter can likewise be utilized for multi-port operation, which is a component that is helpful in interfacing a few DC sources and loads utilizing a solitary converter. Despite the greater part of the benefits of the traditional DAB converter, for applications requiring wide voltage varieties, for example, an interface for vitality stockpiling, power devices, or photo voltaic, the DAB converter has constrained ZVS range and high flowing currents at low loads. The high flowing currents at low loads brings about poor proficiency when the DAB converter is under a low load condition. Accordingly, there is a requirement for an enhanced DAB converter that gives an expanded ZVS run and additionally expanded productivity especially at low load conditions.

To address these issues, scientists at Arizona State University have created novel control plans for bidirectional dc-dc double dynamic extension converters. The proposed control plans consolidate the customary technique for stage move control with Pulse Width Modulation (PWM) of one single H-extension and two converter connects at the same time in a composite control plot that relies upon the contribution to yield voltage proportion and the load condition. One key component is that the plan naturally advances between double PWM, single PWM, and just stage move control by using straightforwardly measured info and yield voltages, and utilizing the load data certain in the required stage move.

2.2 Potential Applications

- Uninterruptible Power Supplies (UPS)
- Grid Tie Renewable Resources (Photovoltaic Energy)
- Fuel Cells

Advantages

- Extends the soft-switching range down to zero load condition
- Reduces RMS and crest currents
- Results in huge size decrease of the transformer
- Lower attractive centre misfortunes
- As an illustration, the proficiency at 3% load and half ostensible yield voltage is expanded from 25% with stage move control alone to 77% with the proposed conspire. The transformer measure is likewise lessened by 33%.
- Hybrid DC/DC Converters Excel in AC Applications

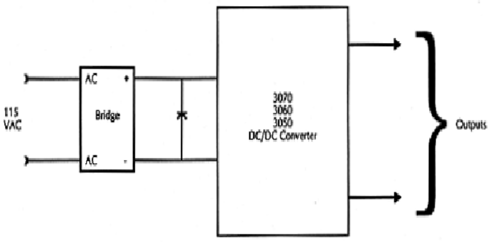

Fig. 2.1: DC-DC converter

This arrangement has great EMI qualities. The high recurrence discharges are controlled inside the DC/DC converter itself. The low recurrence led emanations are limited by keeping the channel capacitance as little as could be expected under the circumstances. Since the DC/DC converter is intended to work over a substantial info voltage run, it can adapt to the high throbbing voltage resultant from a little capacitor.

A regular info waveform is appeared in Figure 2.2. The little capacitor brings about a vast conduction edge. The substantial conduction point gives a powerful factor and permits a moderately quick tumble off of low recurrence music.

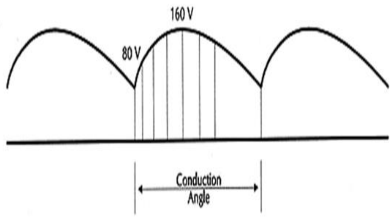

Fig. 2.2: DC-DC Converter output

A significant advantage of having the capacity to work with practically no outer capacitance is the

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little physical measurements of the subsequent power supply.

2.3 Battery Backup Power Supplies

The prerequisite to work from an AC control line with a battery reinforcement is frequently experienced in basic applications. A straightforward design for battery went down power supplies utilizing two half breed DC/DC converters is appeared in Figure 2.3. Exceptionally reduced uninterruptable or battery went down power supplies can be actualized with half and half converters.

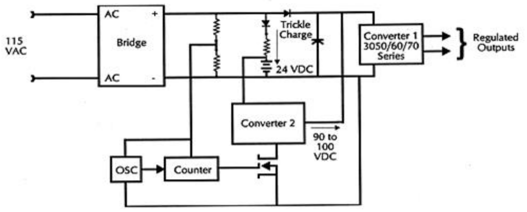

Fig. 2.3: AC-DC converter

2.4 Capacitor Selection

Capacitors ought to have a base voltage rating of 200 to 250 VDC for this application or as de-rating criteria requests. The client can utilize a film, multilayer clay, tantalum thwart or an elite aluminum electrolytic capacitor. These part sorts are accessible in a tallness that is predictable with the stature of the converters.

The dissemination variables of the capacitors ought to be evaluated since they are working with a high swell voltage. A high dissemination factor can cause control dispersal. At 400 Hz it might be alluring to utilize more capacitance than showed to lessen the converter's yield swell voltage.

3070 Family (to 6.5 Watts Output)	
Output with No External Capacitor	External Capacitance for Full Output
1.6 W at 50 Hz	8.7 µf/200 V
2.0 W at 60 Hz	6.5 µf/200 V
6.5 W at 400 Hz	-

(a)

3060Family (to 20 Watts Output)	
Output with No External Capacitor	External Capacitance for Full Output
2.2 W at 50 Hz	49 µf/200 V
2.6 W at 60 Hz	30 µf/200 V
17 W at 400 Hz	3.5 µf/200 V

(b)

3326 Family (to 40 Watts Output)	
Output with No External Capacitor	External Capacitance for Full Output
5.4 W at 50 Hz	64 µf/200 V
6.5 W at 60 Hz	50 µf/200 V
44 W at 400 Hz	3.5 µf/200 V

(c)

3051 Family (to 80 Watts Output)	
Output with No External Capacitor	External Capacitance for Full Output
5.4 W at 50 Hz	125 µf/200 V
6.5 W at 60 Hz	104 µf/200 V
44 W at 400 Hz	6.8 µf/200 V

(d)

Table 2.1: Tables showing the output voltage with capacitance

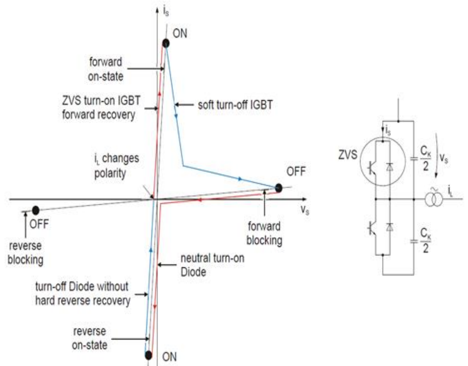

Figure 1.4.: Working point normal for switch current and voltage amid soft/resonant switching as ZVS

- The substitution process is begun by dynamic kill, switching misfortunes are decreased on account of parallel association of recompense capacitance CK
- The substitution process is finished by uninvolved, low-misfortune turn-on at a switch voltage versus ≈ 0
- Before next recompense, the heading of current stream changes in the switch that is turned on with awed di/dt
- Inductance in recompense circuit LK ought to be at the base

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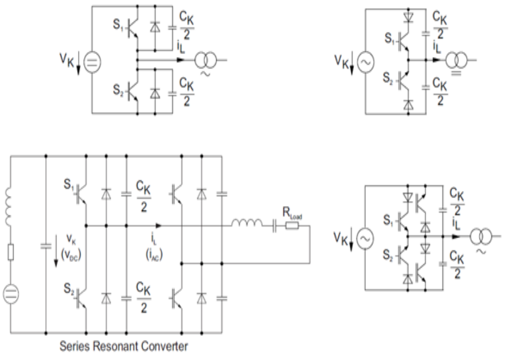

Figure 2.5: Sample circuit diagrams for commutation circuits with ZVS and a series resonant converter

2.5 Zero Current Switching (ZCS)

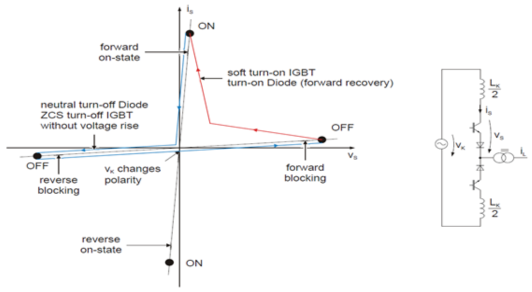

Figure 2.6 Working point normal for switch current and voltage a mid-soft/resonant switching as ZCS

- The compensation process is begun by dynamic turn-on, switching misfortunes are decreased because of arrangement association of substitution inductance LK
- The replacement process is finished by aloof, low-misfortune kill at a switch current $i_S \approx 0$,
- Before next replacement, the voltage heading changes in the switch that is turned on with awed di/dt
- Capacitance in replacement circuit CK ought to be at the base

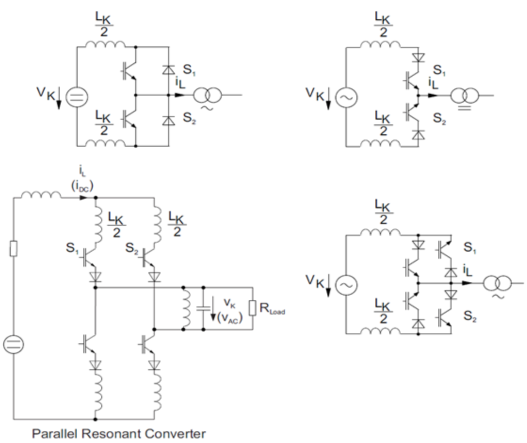

Figure 2.7. Test circuit charts for replacement circuits with ZCS and a parallel full converter

Consistent soft switching depends on the condition that just a single sort of compensation process - either inductive recompense/ZCS or capacitive substitution/ZVS – happens in the replacement circuit of the converter. Inferable from this confinement, the loss of one control probability when contrasted with hard switching has with be acknowledged. This is just accomplished if the polarities of the driving replacement voltage Vk or the commutated yield current Ir are turned around between two indistinguishable compensation forms.

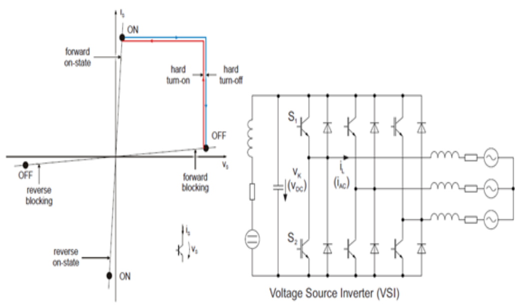

Figure 2.8: Working point normal for switch current and voltage for hard switching (IGBT, MOSFET) and regular circuit graph for voltage source inverter

The IGBT, MOSFET and diodes accessible today were produced and streamlined solely for hard switch applications and show practically identical highlights for this zone of use (Figure 2.8).

2.6 Operation as a Buck Converter

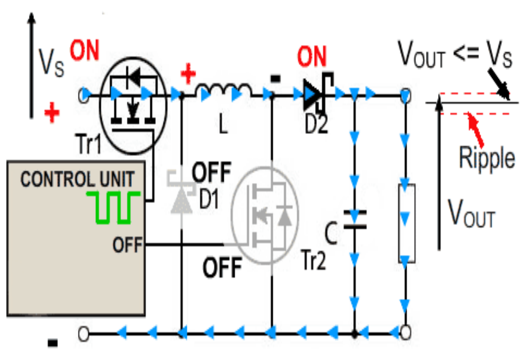

Fig. 2.9 Operation as a Buck Converter during Tr1 'on' Period

Fig. 2.9 demonstrates the circuit working as a Buck Converter. In this mode Tr2 is killed, and Tr1 is switched on and off by a high recurrence square wave from the control unit. At the point

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when the door of Tr1 is high, current streams however L, charging its attractive field, charging C and providing the load. The Schottky diode D1 is killed because of the positive voltage on its cathode.

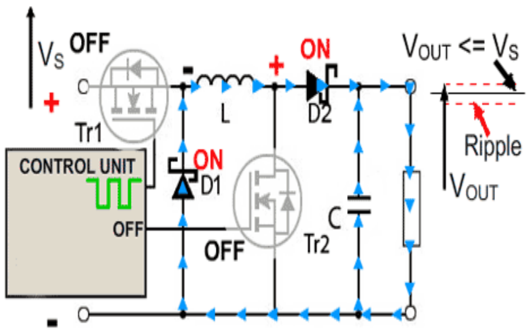

Fig. 2.10 Operation as a Buck Converter During Tr1 'off' Period

Fig 2.10 demonstrates the current stream amid the buck operation of the circuit when the control unit switches Tr1 off. The underlying wellspring of current is presently the inductor L. Its attractive field is falling, the back e.m.f. produced by the falling field inverts the extremity of the voltage crosswise over L, which turns on D_1 and current courses through D_2 and the load.

As the current because of the release of L diminishes, the charge amassed in C amid the on time of Tr1 now additionally adds to the current coursing through the load, keeping V_{OUT} sensibly consistent amid the off period. This helps keep the swell adequacy to a base and V_{OUT} near the estimation of V_S.

2.7 Operation as a Boost Converter

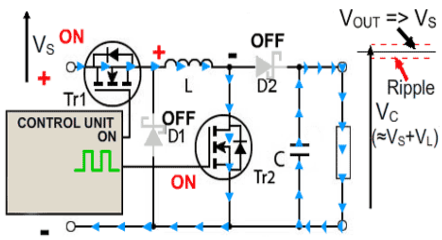

Fig. 2.11 Operation as a Boost Converter During Tr2 'on' Period

In Boost Converter mode, Fig 2.11 Tr1 is turned on consistently and the high recurrence square wave connected to Tr2 door. Amid the on periods when Tr2 is leading, the information current moves through the inductor L and by means of Tr2, straightforwardly back to the supply negative terminal energizing the attractive field around L. While this is occurring D_2 can't direct as its anode is being held at ground potential by the vigorously leading Tr2. For the span of the on period, the load is being provided totally by the charge on the capacitor C, developed on past oscillator cycles. The progressive release of C amid the on period (and its resulting energizing) represents the measure of high recurrence swell on the yield voltage, which is at a capability of roughly $V_S + V_L$.

3.1 Matlab Simulation and Results

In this chapter, various waveforms of DB LLC converter with different input sources are simulated in MATLAB Simulink and various input and output waveforms for the different conditions are shown below.

3.2 Matlab Simulink model for DB LLC converter

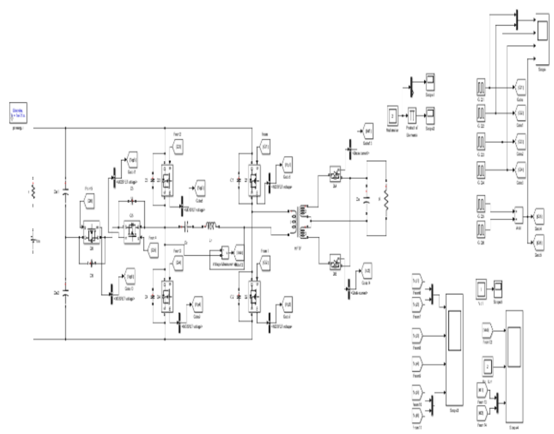

Fig 3.1: Matlab Simulink Model for DB LLC converter

3.2.1 Output voltage of DB LLC converter

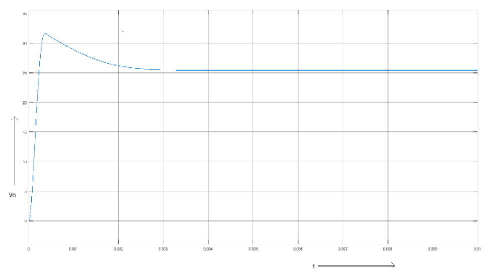

Fig 3.2 Output voltage of DB LLC converter

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3.3 Matlab Simulink model

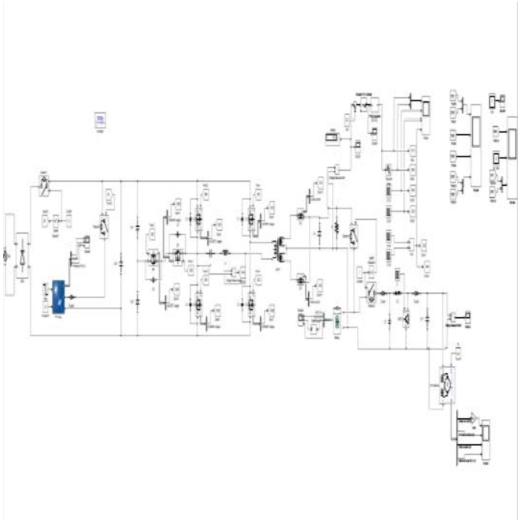

Fig 3.3 Matlab Simulink model

3.3.1 Battery Charging Through single phase AC supply

The above is the Simulink modelling of proposed circuit with two inputs, single phase AC source and PVA. The utilization of these sources depends in solar irradiation. The circuit breakers are triggered alternatively to ensure working of a single source at each time. Both the circuit breakers are connected complimentarily with NOT gate.

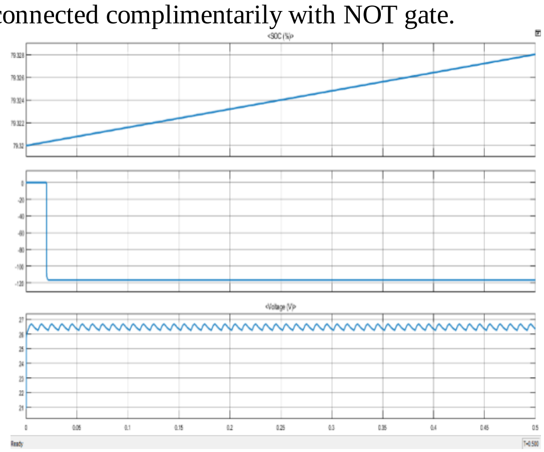

Fig 3.4: Waveforms representing Battery Charging Through single phase AC supply

3.3.2 Battery Charging through PV Array

The state of charge of the battery is raising from 79% as the battery is charged from the proposed converter. The current is in negative direction as the battery consumes current from the circuit output.

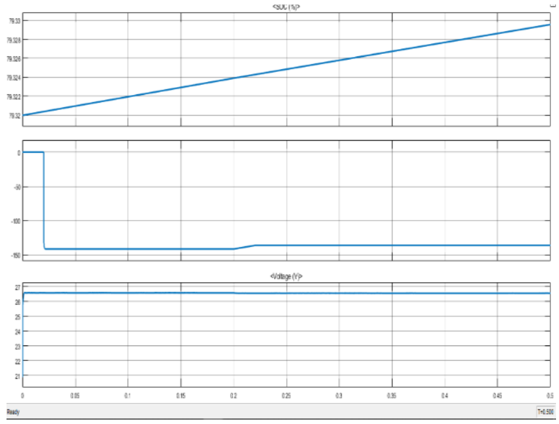

Fig 3.5: Battery charging through PV Array

3.3.3 Battery Discharging

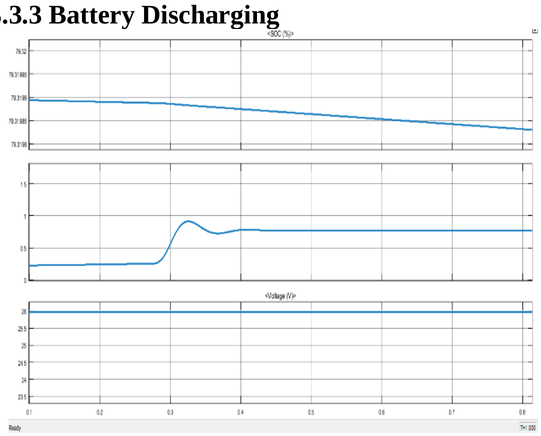

Fig 3.6: Battery discharging Through HEV

The above is the battery discharging mode where the state of charge is dropping. The power from the battery is consumed by the DC motor load. In the above graphs the current is in positive as the current is discharged from battery.

3.3.4 Hybrid electric vehicle parameters

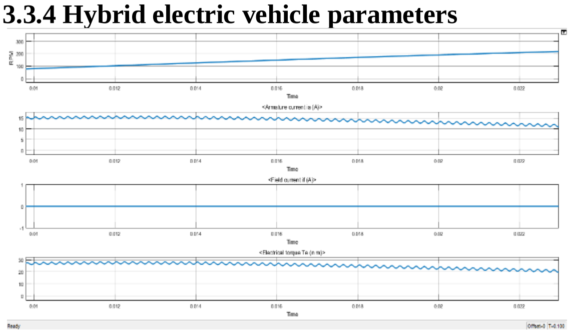

Fig 3.7: Hybrid Electric vehicle parameters

The above are the characteristics of the DC machine with speed, armature current, field current, electromagnetic torque.

II. CONCLUSION

A fixed-recurrence controlled DB LLC resonant converter with a wide info go has been proposed in this paper. In the proposed DB LLC resonant converter, two working modes (HB and FB modes) are identified and used to control the yield voltage inside a wide information voltage run. The modulation procedure, working rule and qualities are researched inside and out. Contrasted and a traditional PFM-controlled LLC converter, the proposed DB LLC full converter embraces the fixed-recurrence PWM control. The voltage gain extend is autonomous of the quality factor Q and the charging inductance has little effect on the dc voltage gain attributes. Hence, the procedure of parameter configuration can be simplified and furthermore a bigger inductor proportion can be picked to diminish the conduction misfortune. The structure and control methodology of the DB LLC resonant converter are more straightforward contrasted and regular fixed-recurrence TL LLC full converters. The exhibition of the proposed DB LLC full converter is tentatively verified on a 120– 240 V input 24 V/20A yield converter model. All essential side switches work with ZVS and optional side diodes turn off with ZCS inside wide info voltage and full-load ranges. Likewise, great unique execution regarding input varieties and load changes can be accomplished under the shut circle control. Thusly, the DB LLC resonant converter is a decent possibility for wide info voltage applications.

REFERENCES

[1]. M. M. Jovanovi´c and B. T. Irving, “On-the-fly topology-morphing control-efficiency optimization method for LLC resonant converters operating in wide input- and/or output-voltage range,” IEEE Trans. Power Electron., vol. 31, no. 3, pp. 2596–2608, Mar. 2016.

[2]. J. Deng, C. C. Mi, R. Ma, and S. Li, “Design of LLC resonant converters based on operation-mode analysis for level two PHEV battery chargers,” IEEE Trans. Mechatronics, vol. 20, no. 4, pp. 1595–1606, Aug. 2015.

[3]. D. Moon, J. Park, and S. Choi, “New interleaved current-fed resonant converter with significantly reduced high current side output filter for EV and HEV applications,” IEEE Trans. Power Electron., vol. 30, no. 8, pp. 4264–4271, Jun. 2015.

[4]. F. Musavi, M. Craciun, D. S. Gautam, and W. Eberle, “Control strategies for wide output voltage range LLC resonant DC–DC converters in battery chargers,” IEEE Trans. Veh. Technol., vol. 63, no. 3, pp. 1117–1125, Jun. 2014.

[5]. C. W. Tsang, M. P. Foster, D. A. Stone, and D. T. Gladwin, “Analysis and design of LLC resonant converters with capacitor-diode clamp current limiting,” IEEE Trans. Power Electron., vol. 30, no. 3, pp. 1345–1355, Mar. 2015.

[6]. B. Yang, F. C. Lee, A. J. Zhang, and G. Huang, “LLC resonant converter for front end DC/DC conversion,” in Proc. IEEE APEC Expo., 2002, vol. 2, pp. 1108–1112.

[7]. H. Wang, S. Dusmez, and A. Khaligh, “Maximum efficiency point tracking technique for LLC-based PEV chargers through variable DC link control,” IEEE Trans. Ind. Electron., vol. 61, no. 11, pp. 6041–6049, Nov. 2014.

[8]. Z. Hu, Y. Qiu, Y. F. Liu, and P. C. Sen, “A control strategy and design method for interleaved LLC converters operating at variable switching frequency,” IEEE Trans. Power Electron., vol. 29, no. 8, pp. 4426–4437, Aug. 2014.

[9]. K. H. Yi and G. W. Moon, “Novel two-phase interleaved LLC series-resonant converter using a phase of the resonant capacitor,” IEEE Trans. Ind. Electron., vol. 56, no. 5, pp. 1815–1819, May 2009.

[10]. W. Feng, F. C. Lee, and P. Mattavelli, “Simplified optimal trajectory control (SOTC) for LLC resonant converters,” IEEE Trans. Power Electron., vol. 28, no. 5, pp. 2415–2426, May 2013

[11]. G. Yang, D. Patrick, and D. Sadarnac, “Double-phase high-efficiency, wide load rang high-voltage/low-voltage LLC DC/DC converter for electric/hybrid vehicles,” IEEE Trans. Power Electron., vol. 30, no. 4, pp. 1876–1886, Apr. 2015.

[12]. Z. Guo, D. Sha, and X. Liao, “Hybrid phase-shift-controlled three-level and LLC DC–DC converter with active connection at the secondary side,” IEEE Trans. Power Electron., vol. 30, no. 6, pp. 2985–2996, Jun. 2015.

[13]. R. Beiranvand, B. Rashidian, M. R. Zolghadri, and S. M. H. Alavi, “Using LLC resonant converter for designing wide-range voltage source,” IEEE Trans. Ind. Electron., vol. 58, no. 5, pp. 1746–1756, May 2011.

[14]. X. Sun, Y. Shen, Y. Zhu, and X. Guo, “Interleaved boost-integrated LLC resonant converter with fixed-frequency PWM control for renewable energy generation

applications," IEEE Trans. Power Electron., vol. 30, no. 8, pp. 4312–4326, Aug. 2015.

[15]. Z. G. Liang, R. Guo, G. Y. Wang, and A. Huang, "A new wide input range high efficiency photovoltaic inverter," in Proc. IEEE Energy Convers. Congr. Expos., 2010, pp. 2937–2943.

[16]. Y. Gu, Z. Lu, L. Hang, Z. Qian, and G. Huang, "Three-level LLC series resonant DC/DC converter," IEEE Trans. Power Electron., vol. 20, no. 4, pp. 781–789, Jul. 2005.

[17]. I. O. Lee and G. W. Moon, "Analysis and design of a three-level LLC series resonant converter for high- and wide-input-voltage applications," IEEE Trans. Power Electron., vol. 27, no. 6, pp. 2966–2979, Jun. 2012.

[18]. S. Zong, Q. Luo, C. Li, W. Li, X. He, and S. Su, "Three-level frequency-doubling LLC resonant converter with high step-down ratio for high input voltage applications," in Proc. IEEE APEC Expo., 2014, pp. 14–19.

[19]. F. Canales, T. H. Li, and D. Aggeler, "Novel modulation method of a three-level isolated full-bridge LLC resonant DC–DC converter for wide-output voltage application," in Proc. IEEE PEMC Conf., 2012, pp. DS2b.11-1–DS2b.11-7.

[20]. K. Jin and X. Ruan, "Hybrid full-bridge three-level LLC resonant converter-a novel DC–DC converter suitable for fuel-cell power system," IEEE Trans. Ind. Electron., vol. 53, no. 5, pp. 1492–1503, Oct. 2006.

[21]. F. Canales, P. Babosa, and F. C. Lee, "A wide input voltage and load output variations fixed-frequency ZVS dc/dc LLC resonant converter for high power applications," in Proc. 37th Ind. Appl. Soc. Annu. Meeting, Oct. 2002, vol. 4, pp. 2306–2313.