A Novel Stress Reduction Technique Using Switched Capacitor with Coupled Inductor Based High Gain Converter for Electric Green Transport Scheme

A. Peer Mohamed and K.R.M. Vijaya Chandrakala

Department of Electrical and Electronics Engineering, Amrita School of Engineering, Coimbatore, Amrita Vishwa Vidyapeetham, India.

Abstract: This article showcases a new unique high gain step up DC/DC converter which is the future of interfacing to fully green electric vehicle scheme. This technique optimally integrates four diodes, three capacitors and a modified coupled inductor connected to electric vehicle motor, which is three -phase Brushless DC motor. The developed converter topology has reduced conduction losses, improved the conversion range, functionality with switched capacitor method with which reduced voltage stress during the switching period of the converter is achieved. Due to utilization of energy from leakage inductance of the new topology, mutually joined inductor will support to improve the efficiency and power concentration. Also, grouping of parallel inductor and diode L–D in series with the power switch helps in decreasing the switching stress current. When compared to existing converter topologies, the developed converter topology helps to produce output voltage of 505V for an input DC voltage of 30V, improved the voltage gain to 16.8 achieving the output power of 525W and efficiency to 97.74%. The voltage stress on the switch, diode and capacitor is 170 V, which is 34 % of the converter output voltage. The designed converter is simulated using MATLAB/Simulink and the performance of the new topology is compared with different converter topologies.

Keywords: L-D technology coupled modified Inductor, Less Stress Switch – High Gain, High Step–Up Single Switch Converter, Fuel cell, Brushless DC Motor.

1. Introduction

The energy consumption in upcoming periods is going on increasing with diverse segments. So, it is the time to increase the power generation but profoundly depletion of non-renewable energy sources has become the key issue which is getting depleted day by day. Therefore; power production is now relying on the renewable energy sources to extract the available power. Hence; power extraction from green energy sources is the forthcoming focus in all area of electrical applications. These apprehensions made by the authors would help to overcome global warming by employing solar radiation energy system, energy from wind system and energy from fuel stack system [1]. The power tracked from sunlight pattern is constant one, environmental - welcoming, nearer to nil conservation and satisfactory price which is extremely suggested by the authors for energy generation equated to conservative energy scheme domain [2].

Trendy current ecosphere where industrial and domestic solicitations proposes to follow power electric policies. The request concerning custom of DC/DC circuit converter topology is operated efficiently by the mix of hybrid power bases and great renovation is essential for the best use of electric energy application. Therefore; to extract available low power from renewable energy sources and to operate...
electrical application which is of high voltage level, suitable converter topologies are required which bridge the gap. Between the dissimilar arrangements, Single End Primary Inductor (SEPI) converter arrangement is basically preferred owing to practice as buck, boost process without inverting polarity, compact current output and input, with less stress density throughout during ON/OFF switching period as mentioned by the authors [3].

Since the energy derived out of the renewable source, say solar is very intermittent in nature and the voltage need to be maintained within limits to drive electrical appliances. In addition, this can be overcome by connecting DC–DC converters. Hwu suggested photovoltaic module, boards underneath dissimilar hotness differences, mist transient and fractional covering are accountable for abridged power production [4]. Additional key distress is the cost which is greatly aimed towards small application where power requirement is less as introduced by the authors [5]. Photovoltaic panels for area requirement on small power claims appropriate converter to boost the energy and with great compactness [6]. Newly, great well-organized and supreme based topology are extensively applied. Conversely, standard stage up converter harvest alone 40 V to 80 V to the field of application.

Also, the conventional technique uses wounded coil turns with high variation and operate with extraordinary ON/OFF period. The topology like step down, step up, step up – down, single end primary inductor and cuk converters are moderately fit to transport motor energy requests are presented by the authors [7]. Converter functionality below exciting ON/OFF period with more coils turns may result energy retrieval difficulties, leakage energy inductance, winding losses, time intermission losses and persuade great current to the device strategies [8]. For wide power applications and to shape the output voltage to ten eras of regular value, using regular step up technique is not promising [9]. Hence, great gain voltage is required for wide high power applications to operate.

By means of switched coupled modified inductor coil using voltage multiplier technique many investigators have contributed towards attaining high voltage gain [10]. But it results increase in number of components which may contribute towards increased losses, circuit becomes bulkier and cost also increases. High gain is acquired but there is outflow of energy in mutually joined inductor topology which results high losses [11, 12]. Therefore, by adopting method of switching multiple capacitor is commonly used to recover the gain of the voltage [13]. In switching using multiple capacitor method seems to be compact, insubstantial, better performance; required gain advance can be attained with smallest interfering difficulties owing to electro - magnetics [14]. Since coupled inductance value is less, it causes surge current during steady state and transient period. It will result high current stress across the switches which may give less gain voltage is discussed by few authors [15, 16]. The researchers started focussing towards reducing the current stress to improvise on the voltage gain using three winding technique which has Coupled Inductor (CI) with additional set of Inductor [17].

Adding more Inductor coil will increase the coupling coefficient, increase voltage gain and reduce the stress independently. Whereas, as presented by El Mana Barhoumi [18], interleaved boost converter with buck-boost converter in the form of cascaded topology is developed to minimize the ripple voltage and attain desired voltage regulation. Relatively El Mana Barhoumi demonstrated in [19], parallel combination of two boost converters is used to reduce voltage and current ripple under regulated load voltage. Researchers in [20–24] are using more than three switches which may lead to increased conduction losses, reduced voltage gain, creates manufacturing difficulty and increases the production cost which is not feasible. Hence, to improve standing gain and minimalize switching strain, novel topology proposed in this work uses Switched Capacitor (SC) magnetically CI technique and parallel grouping of Inductor–Diode (LD Technology) associated with the power switch. This technology helps to reduce main switch current and voltage stress and reduces the switching losses. Decreased switching losses here by may reduce the price of the semiconductor components and regulate non-inverting output voltage to increase the converter efficiency.

The work developed is highlighted under the succeeding section. Section 1 presents the circumstantial learning of DC/DC converter. In Section 2 designates Fuel Cell (FC) designing connecting to Electric Vehicle (EV) motor. Section 3 details the functionality of the developed converter. Section 4 explains the developed converter performance. Sections 5 details the simulation results, discussions in comparison with other converter performance. Section 6 highlights the conclusion of the work.

2. Fuel Cell (FC) Designing Connecting to Electric Vehicle (EV) Motor

2.1. Fuel Cell (FC) Modelling

The response of converting one energy to another energy, chemical to electrical energy is possible by using FC. Response of Oxygen (O₂) cathode and Hydrogen (H₂) anode, The output of entire FC is explained using Eq. 1, Eq. 2 and Eq. 3 are listed below.

\[ H_2 \rightarrow 2e^- + 2H^+ \]  \hspace{1cm} (1)

\[ \frac{O_2}{2} + 2H^+ + 2e^- \rightarrow H_2O \]  \hspace{1cm} (2)

\[ \frac{O_2}{2} + H_2 \rightarrow H_2O \]  \hspace{1cm} (3)

Voltage production start to \( E = 1.229V \) from H₂-O₂ of FC [8].

\[ E^o = -\frac{\Delta H_0 - T_{temp} \Delta S}{nF} = 1.29V \]  \hspace{1cm} (4)

In the Eq. 4, \( \Delta S = -0.1641kJ/K/mol, T_{temp} = 298.2K, \Delta H_0 = -284.00 \text{ kJ }/\text{ mol}, n \) quantity of electronics an external circuit aimed at independently molecule filled through hydrogen and \( F = 97.68500 \text{ C }/\text{ mol } \) (persistent) [16]. The output voltage of Fuel Cell (FC) is inconsistency among its internal voltage and its interior voltage droplets. The characteristic of fuel cell system is a non-linear one, because of interior pressure parameter of hydrogen, oxygen and interior temperature. These precipitations of voltage are
considered as non-linear determinations of fuel cell system
warmth produced with biochemical responses. The Eq. 5
states the fuel cell system voltage.
\[ V_o - V_{con} - V_r - V_{at} = V_{FCS} \]  
(5)

Here, \( V_{FCS} \) = output voltage of FC System, \( V_o \) = Open


circuit voltage, where \( V_{at} \), \( V_{con} \) and \( V_{r} \) are the start, the

consideration, then the ohm FC overhead voltage

congruently.

The non-linear distinguishing of FC power is labelled by

the formulation assumed through Eq. 6 [25].

\[ V_{cell} - I_{ FC}R_{in} - \ln\left| \frac{I_{ FC}}{i_q} \right| - \frac{RT}{2F} \ln\left| \frac{I_{ FC}}{i_q} \right| - \frac{RT}{2\alpha F} = \frac{V_{FCS}}{12} \]  
(6)

Where \( I_{ FCS} = \) Fuel cell output current, \( i_q = \) current limiting, \( \alpha = \) co–efficient of transfer charge, \( i_q = \) current density and

\( R_{in} = \) inner resistance. The stack of fuel cell is planned by
determined model of 1.261 kW PEMFCS (proton exchange
membrane fuel cell System) in Simulink/ MATLAB, stack
device has exposed in below Table 1.

<table>
<thead>
<tr>
<th>Table 1. Parameter of fuel cell [9]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameters of Fuel Cell</td>
</tr>
<tr>
<td>Supply of Air Pressure</td>
</tr>
<tr>
<td>Fuel supply</td>
</tr>
<tr>
<td>Fuel Flow Maximum</td>
</tr>
<tr>
<td>System Temperature</td>
</tr>
</tbody>
</table>

2.2. Brushless DC (BLDC) Motor Modelling

Voltage based Source side Inverter (VSI) powers the
Brushless Direct Current (BLDC) motor using the switching
sequence.

The three phase star coupled non brush DC motor can be labelled by the following Eq. 7, Eq. 8, Eq. 9 and Eq. 10 [26].

\[ V_{pq} = v_p + L \frac{d}{dt}[i_p - i_q] - v_q + R[i_p - i_q] \]  
(7)

\[ L \frac{d}{dt}[i_q - i_r] - v_r + R[i_q - i_r] + v_q = V_{qr} \]  
(8)

\[ R(i_p - i_q) + v_r + L \frac{d}{dt}(i_r - i_p) - v_p = V_{rp} \]  
(9)

\[ K_{fme} - v_p + T_L + J \frac{d\omega_m}{dt} = T_E \]  
(10)

\( T_l \) then \( T_E \) stand for load torques and electrical torque
consistently. I, V and E means phase current, phase voltage
and back EMF consistently.

\( J \) and \( T \) is the rotor inertia, frictional constant is \( k \) and \( F \) is
the electrical torque which is calculated as mentioned Eq. 11, Eq. 12, Eq. 13, Eq. 14.

\[ v_p = \frac{k}{2} \omega_m F(\theta_m) \]  
(11)

\[ v_q = \frac{k}{2} \omega_m F(\theta_m - \frac{2\pi}{3}) \]  
(12)

\[ v_r = \frac{k}{2} \omega_m F(\theta_m + \frac{2\pi}{3}) \]  
(13)

\[ T_E = \frac{k}{2} \left[ F(\theta_m) + F(\theta_m - \frac{2\pi}{3}) + F(\theta_m + \frac{4\pi}{3}) \right] \]  
(14)

The motor voltage calculation is a straight combination
of the double additional voltages.

The current in the three phases are assumed to be balanced and represented in the Eq. 15 [27].

\[ i_p + i_q + i_r = 0 \]  
(15)

The voltage Eq. 16 and Eq. 17 becomes;

\[ v_p + L \frac{d}{dt}(i_p - i_q) + R(i_p - i_q) - v_q = E_{pq} \]  
(16)

\[ v_q + R(i_q - i_r) - v_r + L \frac{d}{dt}(i_q - i_r) = E_{qr} \]  
(17)

<table>
<thead>
<tr>
<th>Table 2. BLDC Electric motor factors [9]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poles (number)</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Voltage</td>
</tr>
<tr>
<td>Inductance</td>
</tr>
<tr>
<td>Torque</td>
</tr>
<tr>
<td>Resistance</td>
</tr>
</tbody>
</table>

The three phase BLDC motor is controlled in a dual
stage mode, however the 3rd phase is off. The hall effect
sensors located across the 3- phases vary the signals each by 60° (electrical) as shown Fig.1.

Table 3. describes the six switches that get energies or
d–energies whose switching sequence is shown. At the
respective voltage switching interval is the hall sensors are
positioned in the sequence to generate sequence pulses to
produce three phase current to drive theBLDC motor. The
motor scheme driven by the three phase switching sequence
switching is shown in Fig.1.
Table 3. Inverter switching sequence [9]

<table>
<thead>
<tr>
<th>Voltage Switching Interval</th>
<th>Seq. No. A</th>
<th>B</th>
<th>C</th>
<th>Sensor Position</th>
<th>Switch</th>
<th>Phase Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>0° - 60°</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>Q3</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>60° - 120°</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>Q3</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>120° - 180°</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>Q6</td>
<td>OFF</td>
</tr>
<tr>
<td></td>
<td>180° - 240°</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>Q6</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>240° - 300°</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>Q6</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>300° - 360°</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>Q6</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Fig. 1. Simplified BLDC motor drive schemes

3. Design of Proposed DC-DC Converter with Coupled Inductor (CI) – Inductor Diode (LD) Technology

The FC system generates low voltage output and to step up the voltage for the required applications DC-DC converter is used. New DC-DC converter proposed technique generates high voltage gain with reduced switching stress. The static gains of the developed converters are compared with other conservative DC converters similar boost, SEPIC and M – SEPIC.

The assumptions considered for the modeling of the new topology are semiconductor device components are considered idyllic and the switching frequency is persistent. In developed converter, input DC voltage source is ‘VIN’ and combination of two inductors ‘L1’ and ‘L2’ are in the form of Coupled Inductor Module (CIM). The source ‘L1’ is connected to the adjacent winding which decrease input ripple current. The single switch ‘SPW’ is connected in series to ‘L2’ to extend the voltage gain which forms the tributary of the CI. The turn ratio coupled inductors are the same, which is 1:1. The combination of three diodes are DCA, DCB, and DCC, three capacitors are CCA, CCB, and CCC, output diode is DOUT, and capacitor output is COUT to form voltage lift module (VIM). Since the inductor turn ratio numbers remains very small, the stress current on the switch develops high value. To diminish the stress current of the technique, a parallel combination of Inductor – Diode remains additional in sequence through the key power switch which is shown in the Fig. 1. The method agrees dropping stress current in the main switch. The ON and OFF time duty period cycle near to Mc = 0.860. Speculative study states that all (semiconductor diode and capacitor) devices are considered as a voltage performance source and ideally unique.

The voltage lift module converter with magnetically coupled wounded inductor shown in Fig. 2. The modified SEPIC technique achieve gain twice of with same input voltage and switching period. High power density and large gain is desired for green transport system and aimed at such applications. The output voltage, switching period, voltage gain, stress voltage across switch, efficiency and losses is designed and intended as follows. Converter switching period ‘Mc’ is given in Eq. 18.

$$M_c = \frac{V_{OUT} - V_{IN}}{V_{OUT} + V_{IN}}$$  \hspace{1cm} (18)

Where; Mc is called switching period. The gain output of the converter ‘Gc’ is achieved by seeing converter time intermission with turns N by means of Eq. 19.

$$\frac{2N}{1 - M_c} = \frac{V}{V_{IN}} = G_c$$  \hspace{1cm} (19)

From Eq. 18 and Eq. 19; the static voltage gain is attained to be 14.280 with N=1.0 and duty cycle of Mc=0.86. In this work, the capacitor voltage is calculated using Eq. 20.

$$\frac{N}{1 - M_c}V_{IN} = V_{ca} = V_{cc} = V_{CC}$$  \hspace{1cm} (20)

Assuming same capacitor value; CCA = CCB = CCC = Cc for the recommended system which is calculated using Eq. 21.

$$C_c = \left(\frac{I_{OUT} \times n}{\Delta V_C \times f_s}\right)$$  \hspace{1cm} (21)

The charge variation ΔQC, alteration in minimal voltage across the capacitors ΔVC is identical to 15% of the normal CC is considered. The voltage ripples across the capacitor is designed using the Eq. 22.

$$\Delta Q_C = \frac{I_{OUT} \times M_c}{f_s} \quad \text{and} \quad \Delta V_C = \left(\frac{V_{IN}}{1 - M_c}\right) \times 15 \%$$  \hspace{1cm} (22)

Capacitor ‘COUT’ across the load is determined by means of voltage ripple ΔVC using Eq. 22 with switching frequency, output current ‘IOUT’ output is expressed below in Eq. 23.

$$C_{OUT} = \left(\frac{I_{OUT} \times 2n}{\Delta V_C \times f_s}\right)$$  \hspace{1cm} (23)
Where; \( I_{OUT} = \left( \frac{V_{OUT}}{R_L} \right) \) The resistance across the load is \( R_L \). The converter output voltage \( V_{OUT} \) is highlighted in Eq. 24.

\[
V_{OUT} = \frac{2N}{1-M_C} V_{IN}
\]

(24)

On applying input voltage \( V_{IN}=30V \), the output voltage \( V_{OUT} \) found from the novel technique converter with switching duty period is 505 V and \( M_C=0.860 \) respectively. The voltage stress across semiconductor gets reduced much as such it improves the converter overall efficiency. For the (CCM) continuous conduction mode, the power switch voltage stress is calculated using Eq. 25.

\[
V_{PS} = \frac{V_{IN}}{1-M_C}
\]

(25)

Similarly, stress across the diodes; \( D_{CA}, D_{CB} \) and \( D_{CC} \) is calculated using Eq. 26.

\[
D_{CA} = D_{CB} = D_{CC} = \frac{N}{1-M_C} V_{IN}
\]

(26)

The half of the total output voltage \( V_{OUT} \) is the stress voltage across capacitor and diode. By using below Eq. 27 the overall efficiency of system calculated.

\[
\eta_C = \frac{P_{C,OUTPUT}}{P_{C,INPUT}} = \frac{V_{OUT} I_{OUT}}{V_{IN} I_{IN}}
\]

(27)

The developed converter is well suited for the driving vehicle, which uses three phase BLDC motor powered by renewable energy sources. The designed values of the proposed DC-DC converter are shown in Table 4.

Table 4. Designed parameter of the proposed converter [15]

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Input Voltage; ( V_{IN} )</td>
<td>30.0 V</td>
</tr>
<tr>
<td>2.</td>
<td>Frequency; ( f_s )</td>
<td>24.0 kHz</td>
</tr>
<tr>
<td>3.</td>
<td>Capacitor ( C_{CA}, C_{CB}, C_{CC} )</td>
<td>220.0 ( \mu F )</td>
</tr>
<tr>
<td>4.</td>
<td>Capacitor ( C_{OUT} )</td>
<td>440.0 ( \mu F )</td>
</tr>
<tr>
<td>5.</td>
<td>Load Resistance</td>
<td>360.0 ( \Omega )</td>
</tr>
<tr>
<td>6.</td>
<td>Duty Cycle</td>
<td>0.860</td>
</tr>
</tbody>
</table>

4. Results and Discussions

Proposed topology shown in Fig. 2 is connected to the BLDC motor shown in Fig. 1 with the Table 1 that shows the designed components details is developed using MATLAB Simulink. The voltage 30 V is fed to front end of the developed topology and the converter produced the output voltage \( V_{OUT} \) of 505 V. The calibrated values of the measuring devices such as voltmeter is of \( \pm 2\% \), ammeter is \( \pm 0.01\% \) and wattmeter of \( \pm 2\% \) is taken into account which measures the voltage, current and power across the vehicle motor and converter. The \( V_{OUT} \) of the developed technique is compared w.r.t without LD technology and classical chopper [15] which is shown in Fig. 3.

Fig. 3. Input-output voltage response of the proposed DC-DC converter

From the Fig. 3, it clearly states that for the same input voltage \( V_{IN}=30V \), switching frequency \( f_s=24 \) kHz and \( M_C=0.860 \) as switching period, the voltage output of the converter is producing 505 V. Fig. 4 displays the comparison of developed converter current ‘I_out’ at output with traditional technique producing current of 1.18 A for \( R_L=360\Omega \) of load resistance.

Fig. 4. Output current response of the proposed DC-DC converter

Fig. 5 displays the switching ripple of the proposed converter across the switch \( S_{PW} \).

Fig. 5. Ripple current response across the proposed DC-DC converter

From the above result, the proposed L-D technology reduces the ripple current across the switch from 14.79 to 12.69 A than compared to existing technology [15]. The switch stress voltage is shown in Fig. 6, which highlights the
capacitor voltage, diode voltage and switch voltage stress of 170 V.

**Fig. 6.** Voltage Stress response across the proposed DC-DC converter

Fig. 7 shows the performance of BLDC motor which is driven by the developed converter with LD technique topology where in which the stator back emf and stator current of three phases are shown.

**Fig. 7.** BLDC motor Back emf and Stator Current analysis

The current and emf in all the phases are symmetrical. Fig. 8 shows the BLDC motor speed and torque characteristic of rated speed achieving to 1500 RPM and rated torque to 2.5 Nm.

**Fig. 8.** BLDC motor Speed and Torque analysis

**Table 5.** Proposed Converter with other converters Comparison

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Input Voltage $V_{IN}$</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
<td>30 V</td>
</tr>
<tr>
<td>2.</td>
<td>Input Current $I_{IN}$</td>
<td>13.3 A</td>
<td>12 A</td>
<td>9 A</td>
<td>17.2 A</td>
<td>17.9 A</td>
</tr>
<tr>
<td>3.</td>
<td>Input Power $P_{IN}$</td>
<td>399 W</td>
<td>360 W</td>
<td>270 W</td>
<td>516 W</td>
<td>525 W</td>
</tr>
<tr>
<td>4.</td>
<td>Output Voltage $V_{OUT}$</td>
<td>225 V</td>
<td>300 V</td>
<td>300 V</td>
<td>425.5 V</td>
<td>505 V</td>
</tr>
<tr>
<td>5.</td>
<td>Output Current $I_{OUT}$</td>
<td>1.050 A</td>
<td>9.950 A</td>
<td>0.830 A</td>
<td>1.100 A</td>
<td>1.18 A</td>
</tr>
<tr>
<td>6.</td>
<td>Power Output $P_{OUT}$</td>
<td>125 W</td>
<td>500 W</td>
<td>250 W</td>
<td>505 W</td>
<td>575 W</td>
</tr>
<tr>
<td>7.</td>
<td>Frequency in kHz</td>
<td>24.0</td>
<td>24.0</td>
<td>24.0</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>8.</td>
<td>Duty cycle</td>
<td>0.860</td>
<td>0.860</td>
<td>0.860</td>
<td>0.860</td>
<td>0.860</td>
</tr>
<tr>
<td>9.</td>
<td>Voltage gain</td>
<td>6.9</td>
<td>10</td>
<td>10</td>
<td>14.2</td>
<td>16.8</td>
</tr>
<tr>
<td>10.</td>
<td>Voltage stress on Switch, Diode and Capacitor</td>
<td>200 V</td>
<td>258.2 V</td>
<td>200 V</td>
<td>190 V</td>
<td>170 V</td>
</tr>
<tr>
<td>11.</td>
<td>No. of Switch, Inductor, Capacitor, Diode</td>
<td>1,2,4,3</td>
<td>2,2,4,4</td>
<td>1,2,4,3</td>
<td>1,2,4,4</td>
<td>1,2,5,5</td>
</tr>
<tr>
<td>12.</td>
<td>Ripple Current</td>
<td>14.5 A</td>
<td>15.2 A</td>
<td>13.8 A</td>
<td>12.75 A</td>
<td>11.75 A</td>
</tr>
<tr>
<td>13.</td>
<td>Efficiency</td>
<td>74.8 %</td>
<td>93 %</td>
<td>95.8 %</td>
<td>96.34</td>
<td>97.74 %</td>
</tr>
</tbody>
</table>
From the above Table. 5 and the results on comparison with [13, 14, 15 and proposed converter], the developed topology with LD technique produced output voltage of 505V, output current of 1.18A, power output of 525W at an operating frequency of 24kHz, voltage stress being reduced to 170V which is half of the output voltage, ripple current of 11.75A for duty cycle of 0.86 supplied with an input voltage of 30V. The proposed topology with LD technology resulted voltage gain of 16.8 achieving the converter efficiency of 97.74%. Therefore; the impact of the coupled inductor, switched capacitor with LD technology as proposed converter is an efficient methodology to achieve more gain, less stress voltage and more efficient converter. Thus, the developed converter with LD technique is suitable to integrate the green energy springs to transport electric vehicle-based applications.

5. Conclusion

The present converter topology without adopting isolated technique has produced maximum gain, high voltage conversion and is fit for renewable energy integration operating on low voltage-based system. In this article, an integration of a coupled inductor, a single switch and a module for voltage lift consists of capacitors and diodes is proposed. The developed L–D technique can be suitable for CI converters where the winding turn ratio is less. The reduced value of drain to source resistance ‘RDS(ON)’ will minimize the conduction power leakage losses and maximize the performance of the system. This topology produced even reduced current stress on the switch by 15–20% which helps to increase the lifespan period of the components farther. Because of the hassle decrease, the switch grade is compact enough to add and thus will lessen the cost of the total system. The developed switch with coupled inductor DC–DC converter fed to BLDC electric vehicle motor produced desired power output with recommended output voltage of 525 W, 505 V correspondingly with 97.74 %, output efficiency. The switching stress on the current and voltage is reduced which helped to achieve better static gain and proficiency to drive electric vehicle. The proposed topology is suitable for application demanding high efficiency with high voltage gain electric vehicle system.

References


