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A Fuel Cell based Hybrid Boost Three-Level DC–DC Converter With High Voltage Gain

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Abstract:-* *The demands of FC technology with high performance is very interesting alternative on supplement the electric system generation, due to the persistent cost reduction of the overall system a lot of works have been done during the design and implementation of high efficiency DC-DC converters applicable in FC . This paper proposes for improving the power-conversion efficiency and to obtain high voltage gain by reducing voltage stresses at a switch node of boost converter by using snubber cell which consists of inductors, capacitor, as well as diodes. In the proposed converter, two inductors with same level of inductance are charged in parallel during the switch –on period and are discharged in series during the switch-off period. Finally the improved boost converter topology results have shown in matlab Simulink.

keywords— FC ,DC-DC boost converter, high voltage gain snubber circuit, high efficiency

I. INTRODUCTION

Fuel cell (FC) energy appears quite attractive for electricity generation because of its noiseless, pollution-free, scale flexibility, and little maintenance. Because of the FC power generation dependence on sun irradiation level, ambient temperature, and unpredictable shadows, a FC based Power system should be supplemented by other alternative energy sources to ensure a reliable power supply.) Wind power emerging as a promising supplementary power sources due to their merits of cleanness, high efficiency, and high reliability. Batteriesare usually taken as storage mechanisms for smoothing output power, improving startup transitions and dynamiccharacteristics, and enhancing the peak power capacity [2], [3]. Combining such energy sources introduces aFC/wind/battery hybrid power system. These converters Have received more attention in the literature because of providingsimple circuit topology, centralized control, bidirectional power flow for the storage element, high reliability and lowmanufacturing cost and size. Two input converters based on flux additively in a multiwinding transformer are reported in[15]. Because there was no possibility of bidirectional operating of the converter, and complexity of driving circuits andoutput power limitation in [16], they are notsuitable for hybrid systems. Three input converter are proposed based onstructure of the dc–dc boost converter. The dc–dc boost converter is useful for combining several energy sources whose power capacity or voltage levels are different.

A novel hybrid boost three-level dc–dc converteris proposed, taking the topology established without a transformeror coupled inductors into account. It is composed of onlyone inductor, two output capacitors in series, and other powersemiconductor components, which are easy to be integrated.This proposed converter cannot only realize high step-up gain,but also avoid extreme duty cycles

II. PROPOSED TOPOLOGY

A. Operation States of Topology

According to, the output pulse voltages of two halfbridges are V_{ag} and V_{bg} , and then the output pulse voltage V_{ab} of the hybrid converter can be described as

$$V_{ab} = V_{ag} - V_{bg}. \qquad (1)$$

As a result, the output dc voltage $Vpg = Vo$ can be obtainedfrom Vab , filtering by capacitors $Cf\,1$ and $Cf\,2$.

The corresponding states of power components for instantaneous Vab of the hybrid converter are listed in Table I, and it is also assumed that the voltages across capacitors $Cf\,1$ and $Cf\,2$ are equal, namely $VCf\,1 = VCf\,2$ .When the power switches $Q1 - Q4$ are turned OFF, the capacitors $Cf\,1$ and $Cf\,2$ in series are charged together by both the dc voltage source Vin and the energy stored in Lf through diodes $D1 - D4$.

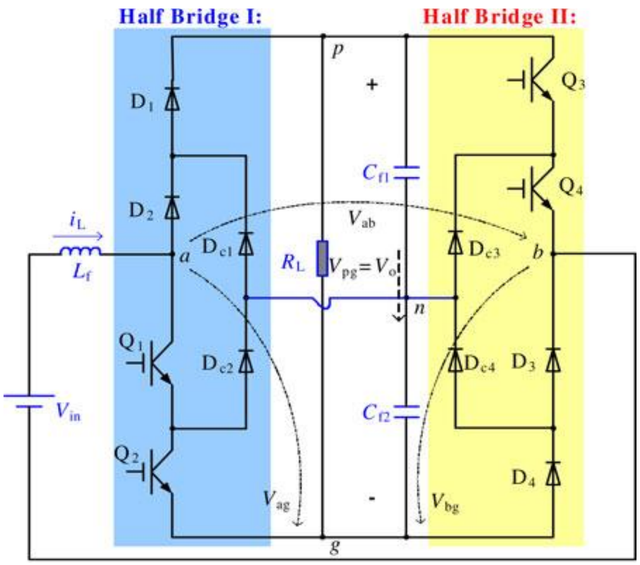

Fig. 1. Proposed hybrid boost three-level dc–dc converter.

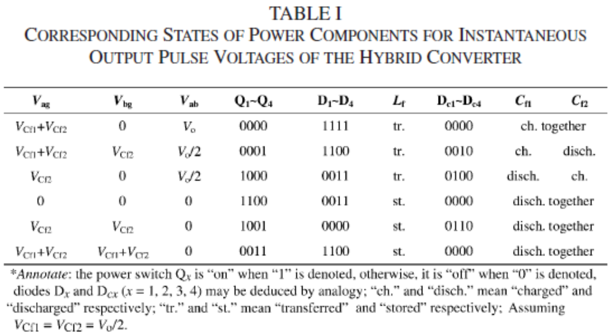

TABLE I
CORRESPONDING STATES OF POWER COMPONENTS FOR INSTANTANEOUS OUTPUT PULSE VOLTAGES OF THE HYBRID CONVERTER

V_{ag}	V_{bg}	V_{ab}	Q_1~Q_4	D_1~D_4	L_f	D_{c1}~D_{c4}	C_{f1}	C_{f2}
$V_{Cf1}+V_{Cf2}$	0	V_o	0000	1111	tr.	0000	ch. together	
$V_{Cf1}+V_{Cf2}$	V_{Cf2}	$V_o/2$	0001	1100	tr.	0010	ch.	disch.
V_{Cf2}	0	$V_o/2$	1000	0011	tr.	0100	disch.	ch.
0	0	0	1100	0011	st.	0000	disch. together	
V_{Cf2}	V_{Cf2}	0	1001	0000	st.	0110	disch. together	
$V_{Cf1}+V_{Cf2}$	$V_{Cf1}+V_{Cf2}$	0	0011	1100	st.	0000	disch. together	

**Annotate*: the power switch Q_x is "on" when "1" is denoted, otherwise, it is "off" when "0" is denoted, diodes D_x and D_{cx} (x = 1, 2, 3, 4) may be deduced by analogy; "ch." and "disch." mean "charged" and "discharged" respectively; "tr." and "st." mean "transferred" and "stored" respectively; Assuming $V_{Cf1} = V_{Cf2} = V_o/2$.

Then, the instantaneous Vab of the hybrid converter is Vo . While $Cf\,1$ is charged by Vin , as well as the energy stored inLf through diodes$D2$,$D1$, and $Dc3$ when only $Q4$ is turned ON. At the same time, $Cf\,2$ is discharged for the load, and the instantaneous Vab is $Vo\,/2$, which is the voltage across $Cf\,1$. In addition, the redundant state for the instantaneous $Vab = Vo\,/2$ is that $Cf\,2$ is charged by Vin and the energy stored in Lf through diodes $Dc2$,$D4$, and $D3$ when only $Q1$ is turned ON. Meanwhile, $Cf\,1$ is discharged for the load, and Vab is the voltage across $Cf\,2$. When the power switches $Q1$ and $Q2$ are turned ON, the energy is stored in Lf through diodes $D4$ and $D3$, while $Cf\,1$ and $Cf\,2$ are discharged together for the load. Then, the instantaneous Vab is zero. Moreover, the other two redundant states for $Vab = 0$ is that power switch pairs($Q1$,$Q4$), or ($Q3$,$Q4$) are turned ON, respectively, the energy is stored in Lf by Vin through the corresponding diodes, while $Cf\,1$ and $Cf\,2$ are discharged together for the load.

III. CONTROL STRATEGY

PWM Control of Topology

According to Table I, the switching functions of Vag and Vbg for both half-bridges can be described as follows:

$$V_{ag} = (1 - S_1 \cdot S_2) \cdot (V_{Cf1} + V_{Cf2}) - (S_1 - S_2) \cdot V_{Cf1} \qquad (2)$$

$$V_{bg} = S_3 \cdot V_{Cf1} + S_4 \cdot V_{Cf2} \qquad (3)$$

where Sx (x = 1, 2, 3, 4) = "0" or "1" is the function of theswitching state of the corresponding power switch. Accordingto (1)–(3), the switching function of Vab for the hybrid convertercan be written as

$$\begin{aligned} V_{ab} = {} & [(1 - S_1) \cdot (1 + S_2) - S_3] \cdot V_{Cf1} \\ & + (1 - S_1 \cdot S_2 - S_4) \cdot V_{Cf2}. \end{aligned} \qquad (4)$$

Then, the PWM control method can be depicted in according to (2)–(4) and the consideration that switching actionsare the least between two adjacent switching states ($S1S2S3S4$) in one carrier period, as well as the required balancing principlefor charging or discharging of $Cf\,1$ and $Cf\,2$.

In ma and mb are the modulation indexes for thedouble modulation waves, and carrier_1, carrier_2 are designedas π phase-shifted carriers due to the two half-bridges structureof the hybrid converter. In addition, the PWM control law can be described as

$$\begin{cases} m_b > V_{\text{carrier\_1}}, S_1 = 0 \\ m_a > V_{\text{carrier\_2}}, S_2 = 1 \\ m_a > V_{\text{carrier\_1}}, S_3 = 1 \\ m_b > V_{\text{carrier\_2}}, S_4 = 0. \end{cases} \qquad (5)$$

As a result, the PWMcontrol signals of$Q1 - Q4$ are obtainedin Fig. 5(b) to (e), and then the three-level pulse voltages $Vag$and Vbg can be achieved according to the operation states ofthe topology, as shown in, as well as *Vab*shown in Fig 1.When *Vab* = 0, the energy is stored in *Lf* , and the inductor current *iL* increases otherwise it decreases. According to Table I, there are such threeswitching states in each carrier cycle, namely “0000”, “1100”and “0011” that *Cf* 1 and *Cf* 2 are charged or discharged together in respective switching state.Then, the voltage balancing of *Cf* 1 and *Cf* 2 would not be affected bythese three switching states. However, in the switching states“1000” and “0001,”*Cf* 1 is discharged during the first half-cycle, while *Cf* 2 is done in the second half-cycle. If the dischargingtime (*t*1 + *t*2) shown in is not equal to (*t*3 + *t*4), the voltage balancing of *Cf* 1 and *Cf* 2 will be affected seriously.

In *t*on1 − *t*on4 are the turn-on time of*Q*1 − *Q*4 respectively, while the carriers are about *t* = *T*/4 or *t* = 3 *T*/4symmetric in each half-carrier period according to the discharging time of capacitors can be written as

$$\begin{cases} t_1 = t_2 = \dfrac{t_{\text{on}1} - t_{\text{on}2}}{2} \\ t_3 = t_4 = \dfrac{t_{\text{on}4} - t_{\text{on}3}}{2}. \end{cases} \quad (6)$$

In addition, while the carriers are about *m* = 0.5 symmetricin each carrier cycle, the turn-on time of*Q*1 − *Q*4 can be written as

$$\begin{cases} t_{\text{on}1} = t_{\text{on}4} \\ t_{\text{on}2} = t_{\text{on}3}. \end{cases} \quad (7)$$

Therefore, the discharging time (*t*1 +*t*2) of*Cf* 1 , and (*t*3 +*t*4)of *Cf* 2 can be equal by means of (6) and (7), namely

$$t_1 + t_2 = t_3 + t_4. \quad (8)$$

Fortunately, the load current could be considered constant ineach carrier cycle (*T* is small enough) [20], and the alternatingdischarging time of *Cf* 1 and *Cf* 2 are identical, and then thevoltages across *Cf* 1 and *Cf* 2 can be self balanced.

IV.SIMULATION RESULTS

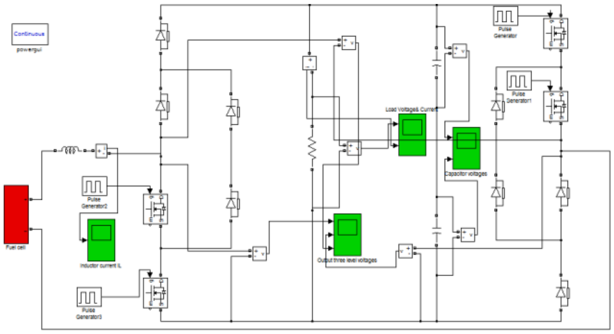

Fig.2 simulation circuit

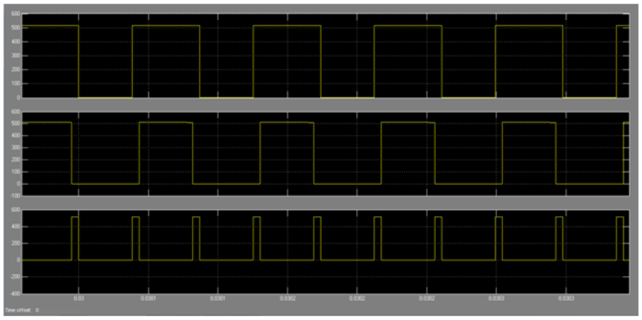

Fig.3 OUTPUT THREE LEVEL VOLTAGES

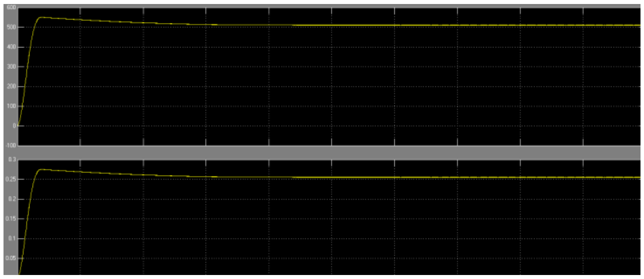

Fig.4 LOAD VOLTAGE AND CURRENT

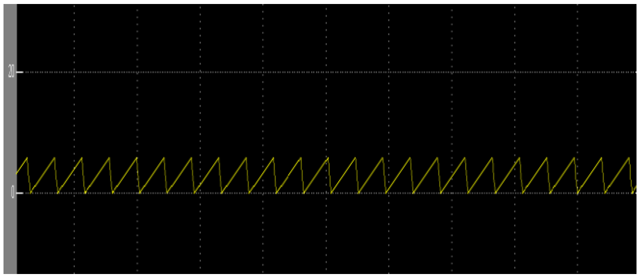

Fig.5Inductor Current

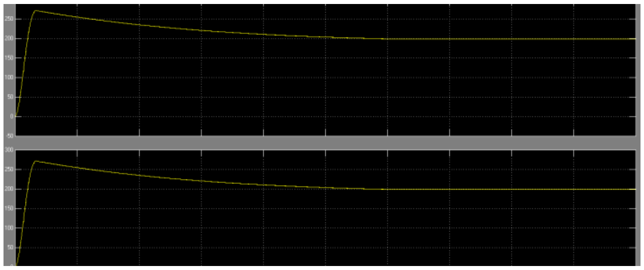

Fig.6 Capacitor voltages

V.CONCLUSION

Renewable energy sources conjointly referred to as non-conventional approach of energy area unit ceaselesslyreplenished by natural processes. With the merits of flexibility, the proposed three input converter shows excellentperformance and potential for various applications including communication systems, satellite, radar systems. Incomparison with the conventional method of hybridizing three input sources with three-boost cells the proposed convertercan economize in the number of inductors, makes use of low-voltage batteries or super capacitors, works in high-stablemarginoperating points and gain access to high-voltage boost factor. the battery can be charged and discharged through theboth power sources individually and simultaneously. Three input boost converter advantages are Simple structure, lowpowercomponents, centralized control, no need to transformer, low weight, high-stability working point, independentoperation of input power sources, and high level of boosting.

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