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A HIGH-EFFICIENCY BIDIRECTIONAL INTERLEAVED DC-DC CONVERTER

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Abstract: This paper presents a high-efficiency digital controlled bidirectional interleaved dc-dc converter is design and implemented to provide a regulated high voltage output for high-power proton-exchange-membrane fuel-cell applications. Ripple cancellation on input current and output voltage can be achieved. This interleaved dc-dc converter reduces hysteresis energy losses inside the fuel-cell stacks and meet battery charging consideration on high-voltage dc bus. Here active-clamped circuit is used to reduces voltage spike on power switches for raising the system reliability.

Keywords: Active-clamped circuit, digital control, fuel-cell, interleaved dc-dc converter, power switches.

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INTRODUCTION

Proton exchange membrane (PEM) fuel-cell is a device that converts chemical fuels into electric power, with many advantages such as clean electricity generation, high-current-output ability, high energy density and high efficiency.

The PEM fuel cell presents a low-voltage output with wide range of variations [1]-[3].As shown in fig. 1 a step-up dc-dc converter is always necessary for providing a regulated high-voltage output to the post stage dc-ac inverter in high-power grid –tied applications. For PEM fuel cell system applications, the dc-dc converter must be considered with following design criteria: large step-up ratio, low-input-current ripple and isolation[4]-[6].Input choke with high inductance is needed at low voltage side because high ripple current may cause undesired hysteresis energy losses inside the fuel cell stacks[7]-[10].Increased power loss and component size on input choke are significant to result in poor conversion efficiency and low power density for the step-up dc-dc converter in high power PEM fuel-cell systems.

In this paper, a digital-controlled interleaved dc-dc converter is designed and implemented to achieve low-input-current ripple and high-efficiency power conversion by the developed ripple cancellation characteristics at the high-voltage side. Because the fuel-cell stack lacks storage ability for electric energy. An energy-storage device such as the Li-ion battery is usually used on the high –voltage output dc bus of the power converter in practical high-power applications[11]-[13].

II. LITERATURE REVIEW

Shih-jen Cheng,Yu-Kang Lo(2013) proposes to design and implemented digital controlled interleaved dc-dc converter which provide regulated high voltage output for high-power –proton-exchange-membrane fuel-cell application. Ripple cancellation on input current and output voltage can be achieved by the studied interleaved dc-dc power conversion technique to reduces hysteresis energy losses inside the fuel-cell stacks and meet battery charging consideration on the high-voltage dc bus. An active clamped circuit is also use to reduce the voltage spike on the power switches for raising system reliability[1].

C.A.Ramos-paja,(2009) proposes a proton –exchange membrane fuel-cell control strategy to produce the power requested by an electrical load, minimizing the fuel consumption and also providing a regulated dc bus voltage to the load. the power system consist of hybrid fuel cell capacitor topology, and control objective is to follow the minimum fuel consumption point for given load power profile. This is done by controlling air pump voltage and regulating fuel cell current through dc- dc switching converter.[2] Jung-Min Kwon (2009) proposes a high-efficiency high-step-up current-fed resonant push-pull converter and a full bridge inverter. The converter conserves inherent advantages of a conventional current-fed push-pull converter such as low input-current stress and high-conversion ratio. also, a voltage doubler rectifier employed in order to remove reverse recovery problem of the output rectifying diodes and provide much higher voltage conversion ratio .the proposed system operates in wide input –voltage range with high-efficiency.[3] Morten Nymand (2010) propose a new design approach achieving very high conversion efficiency in low-voltage high-power isolated boost dc–dc converters is presented. The transformer eddy-current and proximity effects are analyzed, demonstrating that an extensive interleaving of primary and secondary windings is needed to avoid high winding losses.[4] Sangwon Lee, Junsung Park and Sewan Choi (2011) propose a new active-clamped three-phase current-fed push-pull dc-dc converter is proposed for high power applications where low-voltage high-current input source such as fuel cells are used. [5] Antonius Yudi Sendjaja and Vinay Kariwala(2011) proposes a simple yet reliable decentralized proportional-integral-derivative(PID) controllers are systematically designed based on a benchmark nonlinear dynamic model of SOFC.[6] Akshay K. Rathore(2012) a wide range zero-voltage switching (ZVS) active clamped L-L type current-fed isolated dc–dc converter is proposed for fuel cells to utility interface application. The proposed converter maintains ZVS of all switches from full load down to very light load condition for wide input voltage variation.[7] Nobuyoshi Mutoh(2012) proposes the failsafe performance of front-and rear- wheel-independent-drive-type electric vehicles (FRID EVs) is clarified from a practical viewpoint through vehicle dynamics analysis under various road conditions and experiments on a running test course. Dynamic analyses at the time of failure were performed under severe road conditions by comparing the vehicle trajectories of FRID EVs with those of conventional EVs, i.e., two- and four-wheel motor drive-type EVs. The analyzed results show that after failure, FRID EVs continue to run safely and stably.[8] Bo Yuan, Xu Yang, Xiangiun Zeng, Jason Duan, Jerry Zhai and Dongho Li (2012) proposed a high efficiency high step-up current-fed multi resonant converter (CFMRC) for interfacing sub stainable power sources, such as PV channel and Fuel cells, which are characterized by low-voltage high-current output and have strict current ripple requirement.[9] Hunter H.Wu*(2012) proposes the design of a 5 kW inductive charging system for electric vehicles(EVs). Over 90% efficiency is maintained from grid to battery across a wide range of coupling conditions at full load. Experimental measurements show that the magnetic field strength meets the stringent International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for human safety.[10]

III. FUEL CELL POWER CONVERTER SYSTEM

As shown in fig.1 step-up dc-dc converter is always necessary for providing regulated high-voltage output to the post stage dc-ac inverter in high-power grid tied application. for the PEM fuel- cell system applications, the dc-dc converter must be concerned with following design criteria: large step-up ratio low-input current ripple, and isolation. Typically input choke with high inductance is needed at low voltage side because high ripple current may cause undesired hysteresis energy losses inside the fuel cell stacks. Increased power loss and component size on the input choke are significant to result in poor conversion efficiency and low power density for step-up dc-dc converters in high power PEM fuel cell system.

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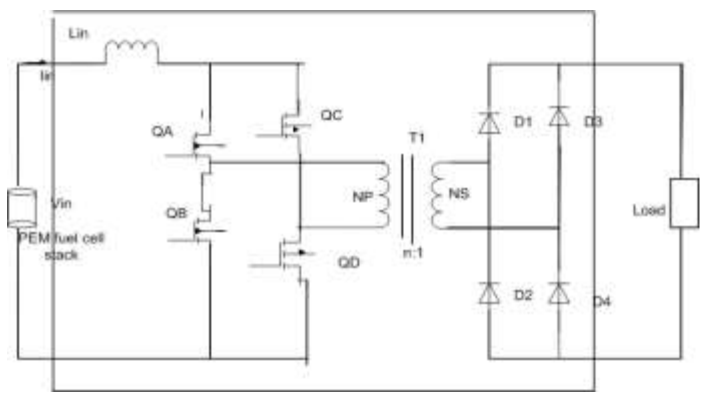

Fig.1 – PEM fuel-cell power converter system

In this paper, a digital controlled interleaved dc-dc converter shown in fig.2 is design and implemented to achieve low-input current-ripple and high-efficiency power conversion by the developed ripple cancellation characteristics at high-current side and voltage -doubler topology at the high voltage side. Because the fuel-cell lacks storage ability for electric energy. An energy-storage device Li-ion battery is usually used on high-voltage output dc-bus of the power converter in high-power applications. A constant-voltage(CV) feedback control with current-limit(CL) protection design is realized to raise reliability of studied fuel-cell power converter. Combined with the studied interleaved operations, output side of current-fed dc-dc converter are connected in parallel to present low-output voltage-ripple that is preferred for battery charging considerations. There is no imbalance problem that exist among the output capacitors of dc-dc converters connected in series. An active- clamped circuit for current-fed dc-dc converter also used to suppress voltage spike on power switches.

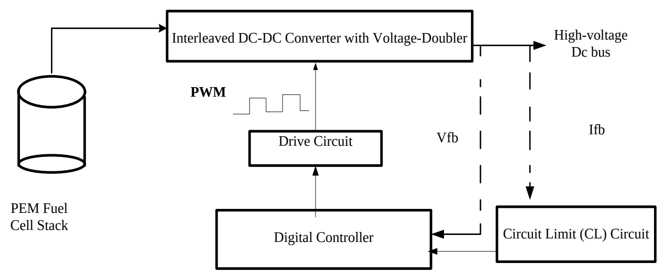

Fig.2 Digital-controlled interleaved dc-dc converter

III. CURRENT-FED FULL-BRIDGE DC-DC CONVERTER WITH VOLTAGE DOUBLER

Fig.3 shows the current-fed full bridge dc-dc converter composed with an input choke Lin, power switches QA ~ QD, a step-up transformer T1, and a secondary voltage doubler. The input choke Lin acts as a boost inductor to store and release the energy from the fuel-cell stack in accordance with the primary switches' operation.

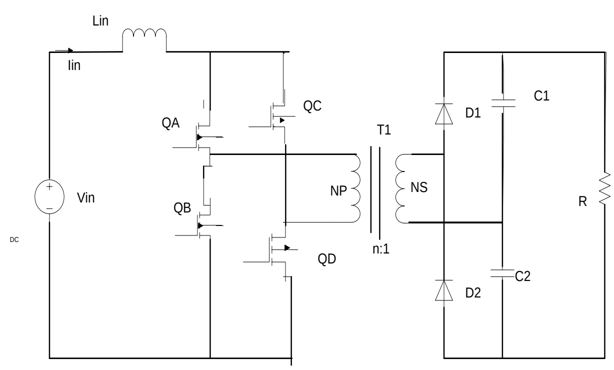

Fig.3- Current-fed full-bridge dc-dc converter

The duty cycle *D* for power switches *QA* ~ *QD* is always higher than 50% to retain the continuity of the input inductor current *I*Lin. The voltage doubler is added at the transformer secondary side to reduce the voltage stresses of the secondary rectifier diodes for the studied high-voltage output applications. *V*Np and *V*Ns represent the transformer primary and secondary voltages, respectively. According to voltage balance second relationship of the input choke Lin, voltage transfer ratio of the current-fed dc-dc converter with voltage doubler can be derived as

Vo/Vin=2/n (1-D)

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Where n represents transformer turn ratio.

TABLE 1: CIRCUIT SPECIFICATIONS

Input voltage	37-80V
Output voltage	365V
Rated power	10KW
Maximum Output Current	27.4A
Switching Frequency	30KHZ

IV. CONCLUSION

This paper has presented a digital-controlled dc–dc converter for High-power PEM fuel-cell applications. High-efficiency performance and low-input-current ripple can be achieved by the studied interleaved current-fed full-bridge dc–dc converter with a secondary voltage-doubler topology.

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