A Study on High Performance Converter Topology for Hydrogen Gas Generation Electrolysis System

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Abstract

This paper investigates a high performance converter topology for hydrogen gas generation electrolysis system. The proposed converter topology consists of full-bridge inverter, medium frequency transformer, and diode rectifier. Hydrogen gas generation electrolysis process considered in the paper is analyzed and characterized by its equivalent circuit. The electrolysis cell is modeled as effective resistance, capacitance, inductance, and internal emf voltage source. The proposed converter topology provides enhanced efficiency of hydrogen gas generation process under the operating condition of dc output voltage with high frequency ripple on it. The high performance operation of proposed converter is confirmed through the simulation with the electrolysis cell considered in the equivalent circuit model.

1. Introduction

Environmentally clean energy production is an important issue nowadays. Renewable energy sources such as solar and wind are available in a certain amount at all territories. But due to their sporadic behavior, long-term energy storage is necessary in order to provide reliable and continuous electric power to the commercial power transmission grid. Hydrogen has the property of high mass energy density which can be stored for a long period without energy loss. This makes hydrogen suitable for energy storage. Moreover, hydrogen is best suited where the conventional fossil fuel is expensive [1].

Among many different methods to produce hydrogen gas, direct discharge of pulsed high voltage in water has been regarded as a new advanced oxidation process, which may induce complex reaction and production of high active species such as hydroxyl [2]. The proper power converter topology which provides a pulsed high voltage output of optimal shape for hydrogen electrolysis cell is indispensible for the efficient generation of hydrogen gas.

This paper investigates a high performance converter topology for hydrogen gas generation electrolysis system. Hydrogen gas electrolysis cell is characterized and modeled by the electrical equivalent circuit. Based on the proposed equivalent circuit of electrolysis cell, hydrogen gas generation process is investigated. Also, the most optimal shape of output voltage and current applied to the electrolysis cell in order to produce maximal amount of hydrogen gas is proposed. The high performance operation of proposed converter topology and its control algorithm is confirmed through the simulation with the electrolysis cell considered in the equivalent circuit model.

2. Power conversion configuration for hydrogen generation system

The proposed hydrogen generation system is described in Fig. 1. Front-end wind turbine generates electricity required for the hydrogen gas electrolysis. The small amount of battery is integrated into the output of wind turbine to flatten the power fluctuation ripple out of the wind generator. Power converter topology consists of full-bridge inverter, medium frequency transformer, diode rectifier and output filter. The simplified control algorithm is also explained in Fig. 1. The load current in the electrolysis cell is regulated to the given reference value using PI control of full-bridge inverter. Unipolar switching scheme rather than bipolar switching scheme is adopted for the pwm control of full-bridge inverter in this paper. The overall system specifications for the proposed hydrogen generation system are given in Table 1.

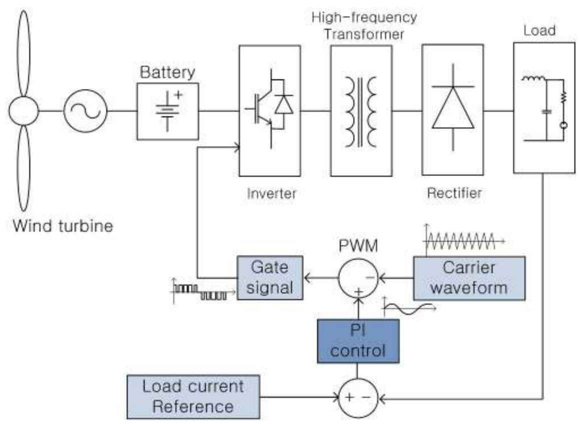

Fig. 1. Block diagram of hydrogen generation system

TABLE 1
HYDROGEN GENERATION SYSTEM SPECIFICATION

Specification	Values
Output power	240W
Output voltage	24Vdc
Unit cell power	30W
Unit cell voltage	3V
Unit cell current	10A
Multiple cell connection scheme	8 unit cells connected in series

3. Modeling of hydrogen electrolysis cell

The complete load of hydrogen gas generation system is made up of series-connected multiple electrolysis cells. The series connection scheme is suitable to boost the load voltage, thereby increasing the output power while maintaining the reasonable amount of load current. The particular configuration of multiple electrolysis cells employed in this paper is shown in Fig. 2. The total of eight electrolysis cell units is connected in series to form the complete load set. The proposed electrical equivalent circuit characterizing the performance of electrolysis cell is also described in Fig. 2. It contains output capacitance between the metal plates, leakage inductance, loss resistance modeling heat dissipation, and electrolysis generated back emf. The equivalent circuit of each unit cell is connected in series to produce the complete model. The final equivalent circuit of eight series-connected cells is integrated into the power converter system as described in Fig. 3.

Load configuration is comprised to set eight series for decrease ohm loss in pole and water. Input power to load is DC power included ripple. This ripple made from full bridge inverter switching.

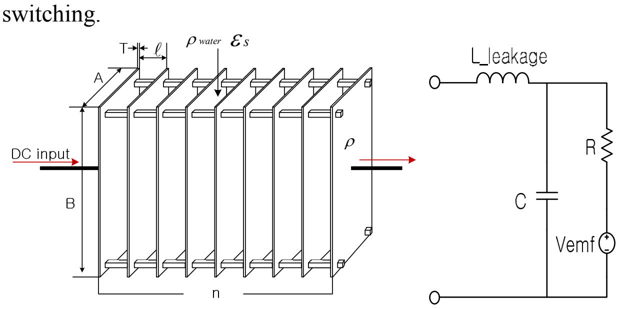

Fig. 2. Load modeling of hydrogen electrolyzer cell

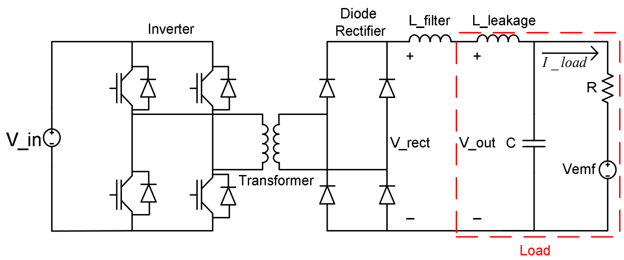

Fig. 3. Hydrogen generation system circuit

TABLE 2
SIMULATION PARAMETERS

Specification	Values
V_in	24Vdc
Transformer_ratio	1:2
L_filter	1.84mH
C	0.001F
L_leakage	10uH
R	0.72Ohm
PWM modulation signal frequency	200Hz
PWM carrier frequency	15KHz
Vemf	16.8Vdc

4. Simulation result

The proposed power converter topology and its control algorithm along with the equivalent circuit of electrolysis cell are simulated using Matlab Simulink and Plecs. The circuit parameters utilized in the simulation is summarized in Table 2. Figure 4, 5, and 6 show the load voltage, load current, and rectifier output voltage, respectively. The variation of ripple size in the output voltage and current against the frequency of pwm modulating signal of full-bridge inverter is presented in Fig. 7. This output ripple plays a significant role in determining the optimal operating point of hydrogen gas generation system.

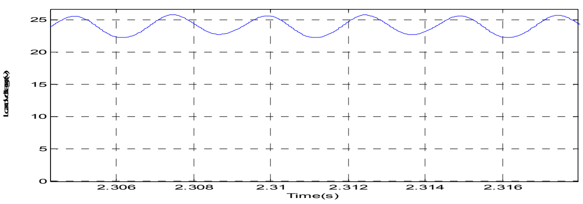

Fig. 4. Total output load voltage(V_out)

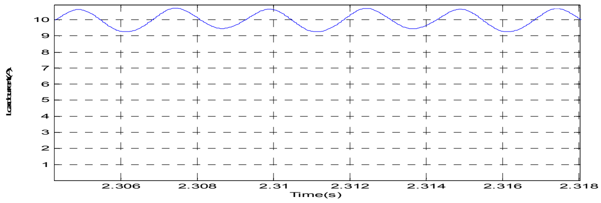

Fig. 5. Total output load current(I_load)

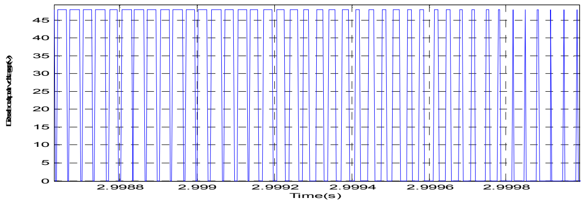

Fig. 6. Diode rectifier output voltage(V_rect)

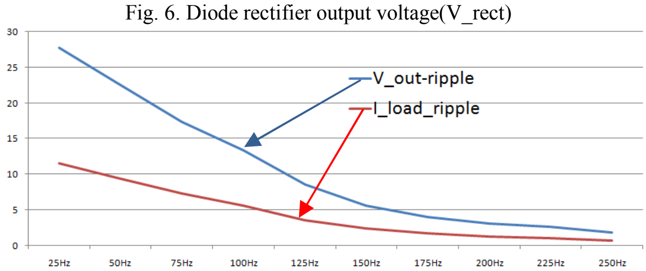

Fig. 7 Variation of voltage and current ripple against PWM modulating signal frequency

5. Conclusion

In this paper, hydrogen gas generation system using direct discharge of pulsed high voltage is investigated. A high performance converter topology for hydrogen gas generation system is proposed. The converter topology consists of full-bridge inverter, medium frequency transformer, and diode rectifier. The load current in the electrolysis cell is regulated to the given reference value using PI control of full-bridge inverter on the basis of unipolar pwm switching scheme. The total of eight electrolysis cell units is connected in series to form the complete load set. The proposed electrical equivalent circuit contains output capacitance between the metal plates, leakage inductance, loss resistance modeling heat dissipation, and electrolysis generated back emf. The performance of proposed power converter topology and its control algorithm along with the equivalent circuit of electrolysis cell are verified through the simulation. The ripple contained in the load voltage and current plays a significant role in determining the optimal operating point of hydrogen gas generation system. The proposed power converter topology provides a cost effective and highly productive solution for hydrogen gas generation system. Experimental verification of the proposed concepts will be reported in future publications.

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