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Current Mode Control strategy of switching Regulators for Fuel Cell

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Abstract — *Methods of energy production, storage and conversion have continuously been changing since the last two decades of the 20th century. Before this transient time, human livelihood demanded energy mainly from the fossil sources. But nowadays it is realized that pollution caused by these sources endanger the natural environment on which human beings and other creatures depend on. In addition, today there is a lack of certainty on the amount of the untapped reserves. On the other hand, the increase in world population and desire for high living standards demand more energy. Today there is a realization that fossil fuels have inherent limitations and the future of the societies cannot depend on this forever. For many years, looking for new and alternate energy sources has become a challenge for every country. Some countries have addressed these challenges by utilizing alternate sources of energies like nuclear, solar, wind, tidal and other clean energy resources. The main obstacles in using nuclear energy are nuclear waste and accessibility of nuclear technology to every country. Moreover, other alternate energy sources such as the solar, wind, and tidal energies remain unrealistic when it comes to supplying the world's energy demand. The system proposed by us uses energy system, a fuel-cell power module (polymer electrolyte membrane fuel cells) along with a boost converter delivering a power of 900 W. Results given by experiments confirm that the proposed controller performance for output voltage regulation changes when done via closed-loop gain measurements and step load. Additionally, a comparison between open- and closed-loop measurements is also made, where the controller robustness is tested for large load variations and also for fuel-cell stack output voltage changes if any.*

KEYWORDS: *Fuel-cell; power application; controller performance; load variation; Nonlinear Load.*

I. INTRODUCTION

In today's electrical world, it is usually assumed that the input voltage supply of a switch-mode power offer is constant or shows negligible little variations. However, the last assumption isn't any longer valid once a fuel-cell stack is employed as input supply.

A fuel-cell stack is characterized by low and unregulated DC output voltage. Additionally, this voltage decreases in a non-linear fashion when the demanded current increases. Thus, a suitable controller is required to cope the mentioned above issues. In this paper of implemented system, an average current-mode controller is designed using a combined model for a fuel-cell stack and a boost converter. The implemented energy system uses a fuel-cell power module along with a boost converter. This converter delivers a power of 900 W. Results of experiments confirm the proposed controller performance for output voltage regulation via closed-loop gain measurements and step load changes. The distinguish between open- and closed-loop measurements is made, and robustness of controller is tested for large load variations. Also fuel-cell stack output voltage changes are tested as well.

II. LITERATURE SURVEY

A fuel cell is an electrochemical device and produces electricity by utilizing an electrochemical reaction to combine hydrogen ions with oxygen atoms. A typical PEM fuel cell includes an anode, a cathode, proton exchange membrane (which blocks electrons), and catalysts (which facilitates the reaction of oxygen and hydrogen). Pressurized hydrogen gas (H2) comes in the fuel cell on the anode side. When an H2 accommodated the catalyst, it divides into two H+ions and two electrons (e-). The electrons pass through the external circuits to do electrical work and get in touch with the cathode side of the fuel cell. Meanwhile, on the cathode, O2 forms two oxygen atoms under the catalyst. Each of oxygen atoms combines with two electrons to form ions through the membrane, where they react to generate water molecule which attracts the two H+ 22,3 Some major advantages of fuel cell systems which make them attractive contenders in many applications are:

Unparalleled environmental performance – the conventional generation of electricity produces more particulates, Sulfur Oxides and, Nitrogen Oxides than all other stationary industrial sources combined.4 A PEM fuel cell stack itself operates on hydrogen, thus, water is the only by-product from the stack reaction. Besides minimizing emissions of regulated pollutants, a fuel cell system is also relatively quiet which makes its overall impact on the environment minimal.

High efficiency – the system is nearly double the simple-cycle efficiency of conventional gas turbine and reciprocating engine power generation technologies. Due to the ability to integrate power production in dwelling areas, efficient use of the waste heat is possible. Another feature of fuel cell is the similarity between the efficiencies of small system.

Continuous output – a fuel cell is similar to a battery. The advantage of fuel cells over batteries is their ability to continuously produce electrical output through replenishing their reactants (hydrogen and oxygen). In other words, fuel cells produce electricity from an external fuel supply as opposed to the limited stored energy of batteries.

Fuel diversification – this technology uses hydrogen which can be made not only from fossil fuel sources but also from biomass and some other alternate sources.

Durability and maintainability – a mature unit is typically designed to function for up to 20 years and operates for about 40,000 hrs between overhauls.

Reliability and flexibility – fuel cells contain very few moving parts; therefore these systems have much higher reliability than combustion engines, turbines or combined-cycle systems. Because of the less number of rotating parts, fuel cell systems will not be prone to various breakdowns, unlike combustion engine systems; this also makes fuel cell systems inherently silent.

High power density – new technologies in material science and novel fuel delivery mechanisms have allowed power density of fuel cells to exceed that of lithium ion (Li-ion) batteries.7

Wide ranges of applications – fuel cells have a variety long ranging potential application. Environmental considerations are increasing worldwide, so utilities are increasingly forced to deal with the trade-offs between power generation and the associated environmental consequences. Because of the environmental concerns, fuel cells can also be an attractive choice for the transportation industry. On the other hand, the market for very low power applications (around 1-5W) has more potential when considering relatively high costs, weight and power density of batteries.

Slow dynamic responses under sudden load changes – mechanical components are involved in fuel cell operation. Consequently, a conversion device having fast dynamic response is necessary as part of a fuel cell application.

III. PROPOSED SYSTEM

In the past two decades, there has been a rapid development in the area of power electronics. However, new switching power supplies have to be developed in response of the modern needs of the electrical industry and day to day life. Some of these include very high conversion efficiency, high power density, elimination of EMI and RFI emissions, fast dynamic system response and, elimination of undesired harmonics which cause problem to the utility system.
To address some of the shortcomings of traditional converters, new power electronics circuits are being designed based on resonant and soft switching technologies. A resonant converter uses semiconductor components and resonant L-C circuits to 'naturally' change current routes instead of only using semiconductor components to force currents to change their flowing loops. In other words, L-C circuits cause voltages/currents in semiconductor switches to cross zero as the semiconductor switches are turned on or turned off.

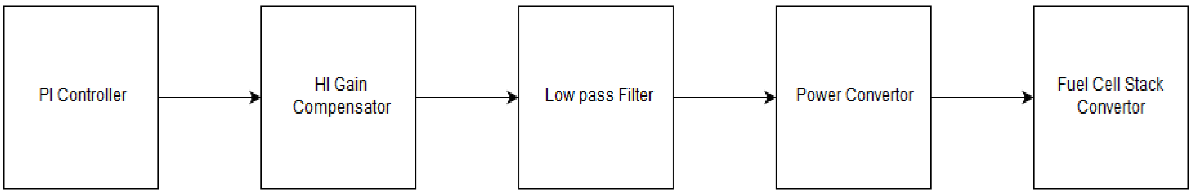

Fig. 1 System Architecture

IV. SIMULATION RESULT

4.1 Open-Loop Test:

The simulation open-loop time response of the system is shown in Fig. 2a. Using the MOSFET S 2 (trigger voltage Vg), step changes of 2 Hz are applied to the output load which ranges from 2.56 to 17 Ω. Following Fig 2b shows the resulting output voltage, which changes for about 33 V. On the other hand, Fig. 4c shows the step changes on the PV side.

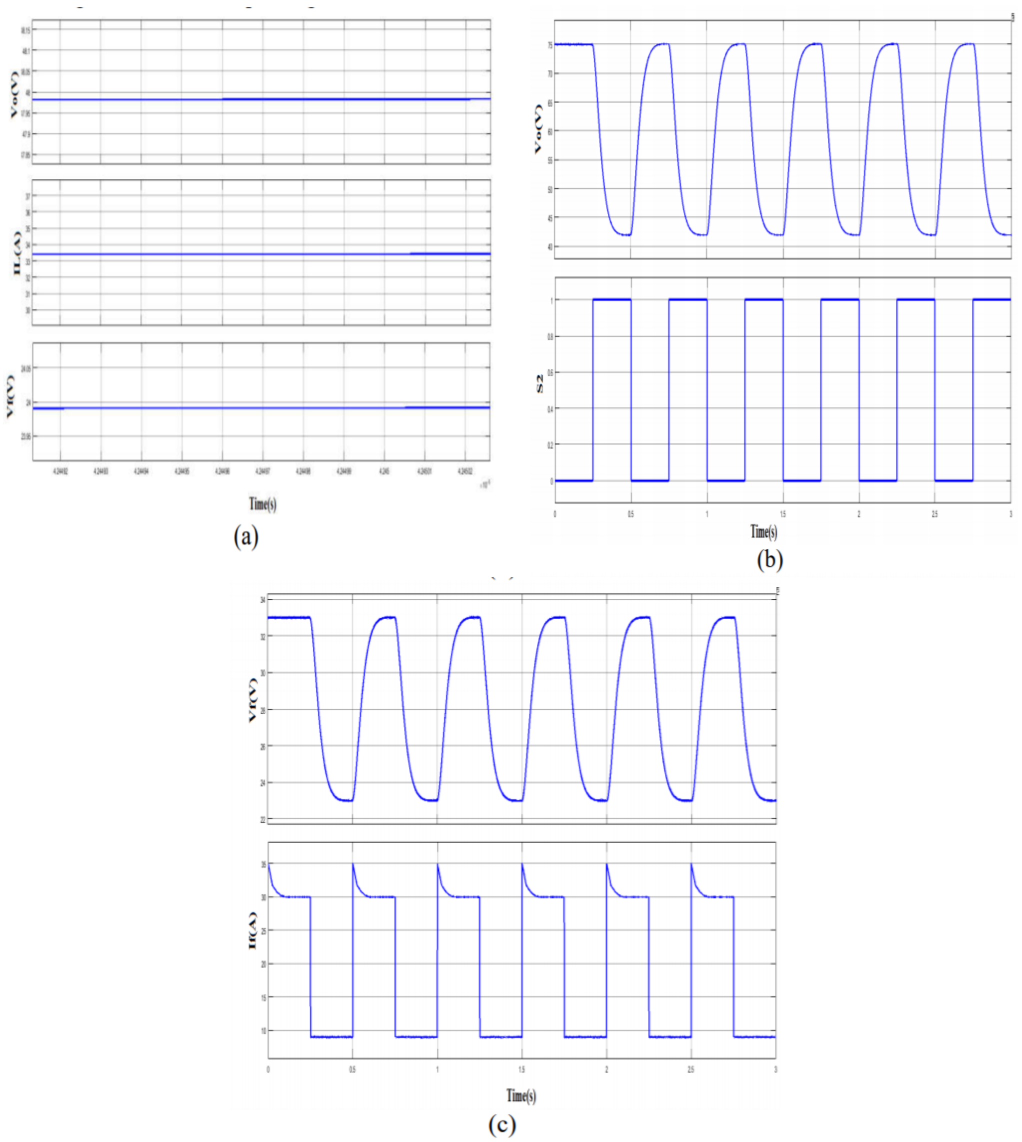

Fig. 2 simulation results in open-loop response for step changes in the load between 2.56 and 17 Ω (a) (From top to bottom) output voltage vO (20 V/div), inductor current iL (25 A/div) and PV voltage VPV(20 V/div) (time: 10 µs/div), (b) (From top to bottom) output voltage vO (20 V/div) and gate voltage Vg of MOSFET S2 (20 V/div) (time: 200 ms/div), (c) (From top to bottom) output voltage of the PV VPV (20 V/div) and output current of the PV IPV (10 A/div) (time: 200 ms/div)

4.2 **Closed-Loop Test**:

The switching regulator operating condition corresponding to 48 V output voltage at nominal load (no load changes) is shown in Fig. 3a. At this operating condition, the PV is delivering a voltage of 24 V. When output load changes are introduced, the resulting load voltage remains at 48 V**.**

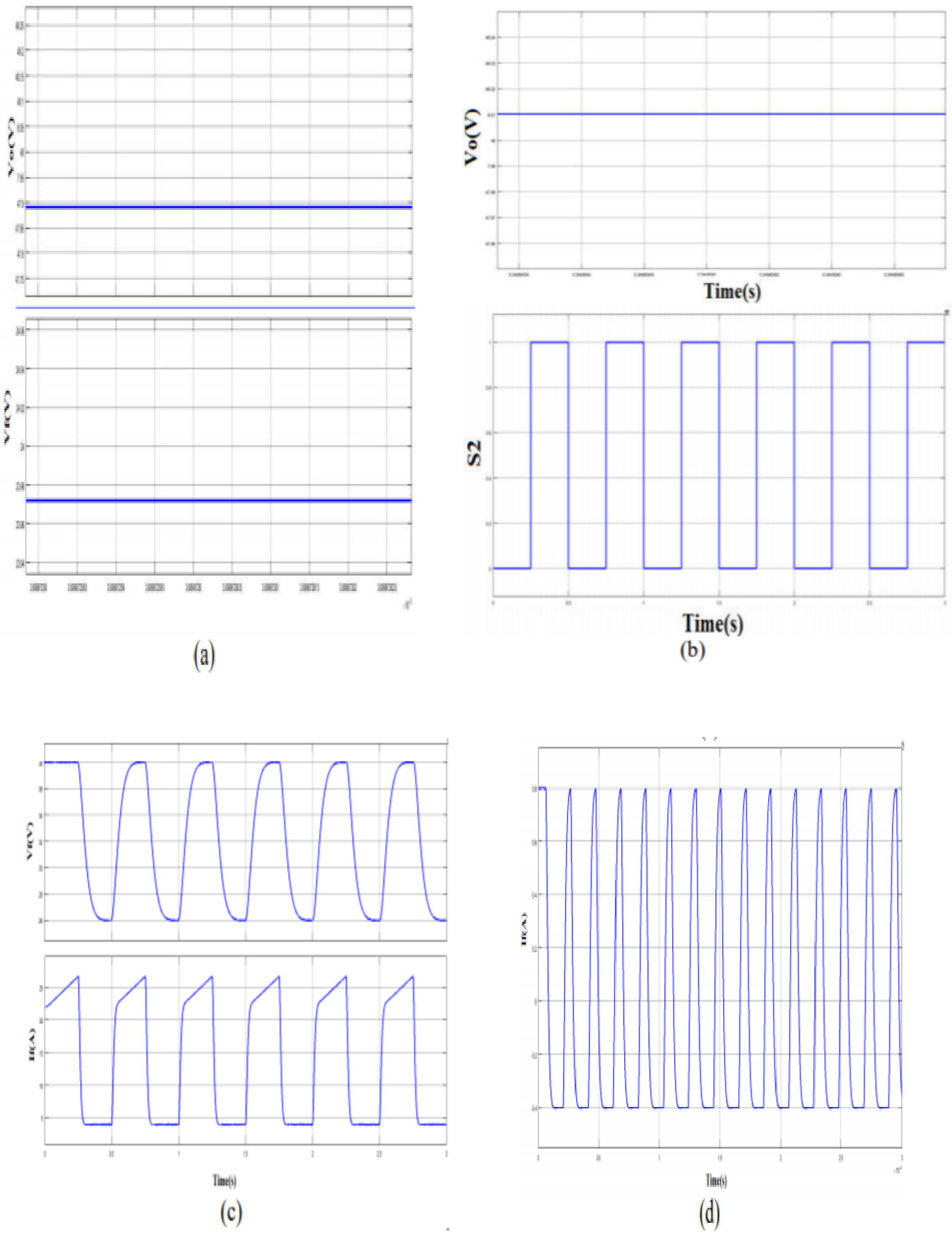

Fig. 3 Closed-loop response (a) Response at nominal load (2.56 Ω). (From top to bottom) output voltage vO (20 V/div) and PV voltage VPV (20 V/div) (time: 200 ms/div), (b) Response to step changes in the load between 2.56 and 17 Ω: (from top to bottom) output voltage vO (20 V/div) and gate voltage Vg of MOSFET S2 (20 V/div) (time: 200 ms/div), (c) Response to step changes in the load between 2.56 and 17 Ω: (from top to bottom) PV voltage VPV (20 V/div), and output current of the PV IPV (10 A/div) (time: 200 ms/div), (d) Output current ripple of the PV IPV (1 A/div) (time: 10 µs/div)

V. APPLICATIONS

1.Manages the output voltage regulation of a power module stack/boost converter system.

2.This control technique was executed utilizing low cost operational amplifiers, reasonable for commercial applications.

3.A boost converter model show great robustness to huge variations on the load

4.Fuel cells prefer small current ripple which will result in prolonged life time of the fuel cell system.

VIII. SYSTEM REQUIREMENT

Sr. No.	Parameter	Minimum Requirement
1	Processor	Core I3 and above
2	RAM	1 GB and above

Hardware Requirements

Sr. No.	Parameter	Minimum Requirement
1	OPERATING SYSTEM	Windows 7/8.
2	SIMULATION SOFTWARE	MATLAB

Software Requirements

VIII. CONCLUSION

In this paper we focus on the output voltage regulation of a fuel-cell stack/boost converter system. The proposed system control strategy is directly based on average CMC. Here two loops are implemented which are basically the inner loop where the inductor current is again fed back using a high gain compensator and a low-pass filter. The outer loop where the output voltage is fed back via a PI controller for steady-state error regulation. The selection procedure is very important and also the criteria given which ensures system stability and output voltage regulation. The operating switching frequency of the converter are set using the poles and zeros for the controller. Additionally, the converter performance is less sensitive due to the high-gain compensator of the inner loop parameter uncertainties and variations of the fuel-cell stack voltage. This control strategy used over here is implemented using low cost operational amplifiers, suitable for commercial and multipurpose applications. This control technique was executed utilizing low cost operational amplifiers, reasonable for commercial applications. Thus, we have also implemented a boost converter model show great robustness to huge variations on the load.

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