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Modeling and Control of Fuel Cell Based Distributed Generation Systems in a Standalone AC Power Supply

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***Abstract*- This project develops a circuit model and controllers of fuel cell based distributed generation systems (DGS) in a standalone AC power supply. Dynamic model of the fuel cell is considered. To boost low output DC voltage of the fuel cell to high DC voltage and compensate for its slow response during the transient, two full bridge DC to DC converters are adopted and their controllers are designed: a unidirectional full bridge DC to DC boost converter for the fuel cell and a bidirectional full-bridge DC to DC buck/boost converter for the battery. For a three-phase DC to AC inverter, a discrete-time state space model in the stationary reference frame is derived and two discrete-time sliding mode controllers are designed: voltage controller in the outer loop and current controller in the inner loop. To demonstrate the proposed circuit model and control strategies, a simulation test bed using Matlab/Simulink is developed and various results are given.**

Index Terms- Distributed generation systems, standalone, fuel cells, dynamic modeling, isolated full-bridge DC to DC power converter, three-phase PWM inverter, sliding-mode control.

1. INTRODUCTION

Actually distributed generation systems (DGS) are Environmental-friendly such as fuel cell, hydro turbines, wind turbines, or photovoltaic arrays are rapidly increased. The demand of these items is rapidly increasing around the world because they can both environmental regulations and the increasing demand of electric power due to greenhouse gas emissions. Outstanding advances in energy storage devices and Power Electronics for transient backup have accelerated penetration of the DGS into electric power generation plants.

The use of these DGS technologies is in various applications to a standalone, a cogeneration, a grid-interconnection, a standby, peak shavings, etc. and similarly have many benefits such as modular electric generation, environmental friendly, high power quality, increased reliability, cost savings, uninterruptible power services, expandability, and on site generation, etc.

To convert chemical energy directly into electrical energy by the reaction of hydrogen from the fuel, oxygen from the air without respect to climatic conditions there is a use of fuel cells which are also called electro chemical devices. That’s why the fuel cells are one of the most attractive DGS resources for power supply. However battery needs to be placed in series or parallel with fuel cell as a temporary energy storage element to support start up or sudden load changes. This is because the fuel cells can not immediately respond to such abrupt load changes.

For practical analysis of the fuel cell systems, a physical/chemical model or a first/second order model is used to realize the slow dynamics of the fuel cells. In that most of papers does not contain must knowledge on power converter design and control. For a single phase residential applications, the fuel cell is modeled by a DC voltage source to design low cost and small-sized power converters. A unidirectional isolated full-bridge DC to DC power converter can be used to boost low fuel cell voltage. In addition, a bidirectional full-bridge DC to DC power converter can be used for stepping up low battery voltage or stepping down high-voltage-side DC link according to battery discharge or recharge mode.

2. DESCRIPTION

FUEL CELLS:

A fuel cell is defined as an electrical cell, which unlike other storage devices can be continuously fed with a fuel in order that the electrical power can be maintained. The fuel cells convert hydrogen or hydrogen-containing fuels, directly into electrical energy, heat, and water through the electrochemical reaction of hydrogen and oxygen. The fuel such as natural gas, coal, methanol, etc. is fed to the fuel electrode (anode) and oxidant (oxygen) is supplied to the air electrode (cathode). The oxygen fed to the cathode allows electrons from the external electrical circuit to produce oxygen ions. The ionized oxygen goes to the anode through the solid electrolyte and combines with hydrogen to form water. Even though chemical reactions at anode and cathode may be a little different according to the types of fuel cells, the overall reaction can be described as follows:

Overall reaction:
Since hydrogen and oxygen gases are electrochemically converted into water and energy as shown in the above overall reaction, fuel cells have many advantages over heat engines: high efficiency and actually quiet operation and, if hydrogen is the fuel, no pollutants are released into the atmosphere. As a result, fuel cells can continuously generate electric power as long as hydrogen and oxygen are available.

BIDIRECTIONAL/UNIDIRECTIONAL DC TO DC CONVERTERS:
A DC to DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electric power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission). DC to DC converters are used in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries primarily. Such electronic devices often contain several sub-circuits, each with its own voltage level requirement different from that supplied by the battery or an external supply (sometimes higher or lower than the supply voltage). Additionally, the battery voltage declines as its stored energy is drained. Switched DC to DC converters offer a method to increase voltage from a partially lowered battery voltage thereby saving space instead of using multiple batteries to accomplish the same thing.
Most DC to DC converter circuits also regulate the output voltage. Some exceptions include high-efficiency LED power sources, which are a kind of DC to DC converter that regulates the current through the LEDs, and simple charge pumps which double or triple the output voltage.

BATTERY:
A battery is a device consisting of one or more electrochemical cells with external connections provided to power electrical devices such as flashlights, smart phones, and electric cars. When a battery is supplying electric power, its positive terminal is the cathode and its negative terminal is the anode. The terminal marked negative is the source of electrons that will flow through an external electric circuit to the positive terminal. When a battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and the free-energy difference is delivered to the external circuit as electrical energy. Historically the term "battery" specifically referred to a device composed of multiple cells, however the usage has evolved to include devices composed of a single cell. The main used batteries are
1. Lead-Acid battery
2. Nickle-cadmium battery
3. Sodium-Sulfer battery
4. Zinc-Bromine battery

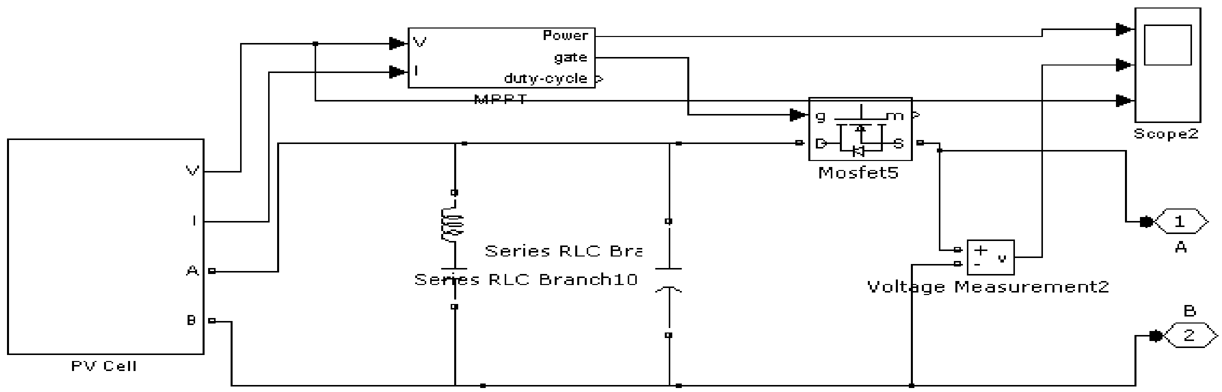
PV CELL:
A Photo voltaic cell (PV) is an energy harvesting technology, that converts solar energy into electricity through a process called the photovoltaic effect. There are several different types of PV cells which all use semiconductors to interact with incoming photons from the Sun in order to generate an electric current.

DC TO AC INVRTER:
The system consists of a DC voltage source (Vdc), a three-phase PWM inverter an output filter (Lf and Cf), and a three-phase load (RL).
Note that the first stage of DGS that consists of a fuel cell, a battery, and two full-bridge DC to DC power converters is replaced with the DC voltage source (Vdc) because during transient the battery fully supports the fuel cell with a slow dynamic response to keep the DC link voltage (Vdc) constant and as a result, the first stage can be considered as a stiff DC energy source

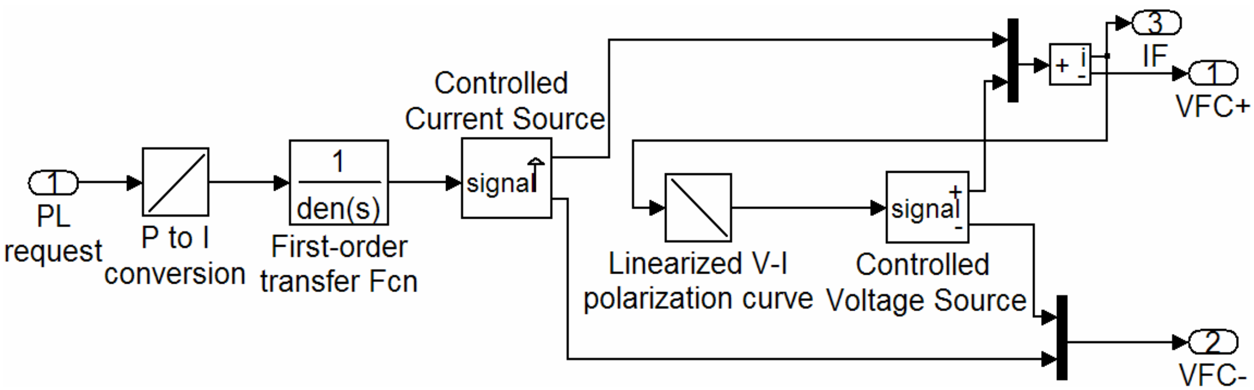
STANDALONE AC POWER SUPPLY:
Distributed generation systems (DGS) used for a standalone AC power plant autonomously supply electric power to local loads without power dispatch

from the grid. For this application, a single DGS unit and two DGS units will be investigated in the following sections.

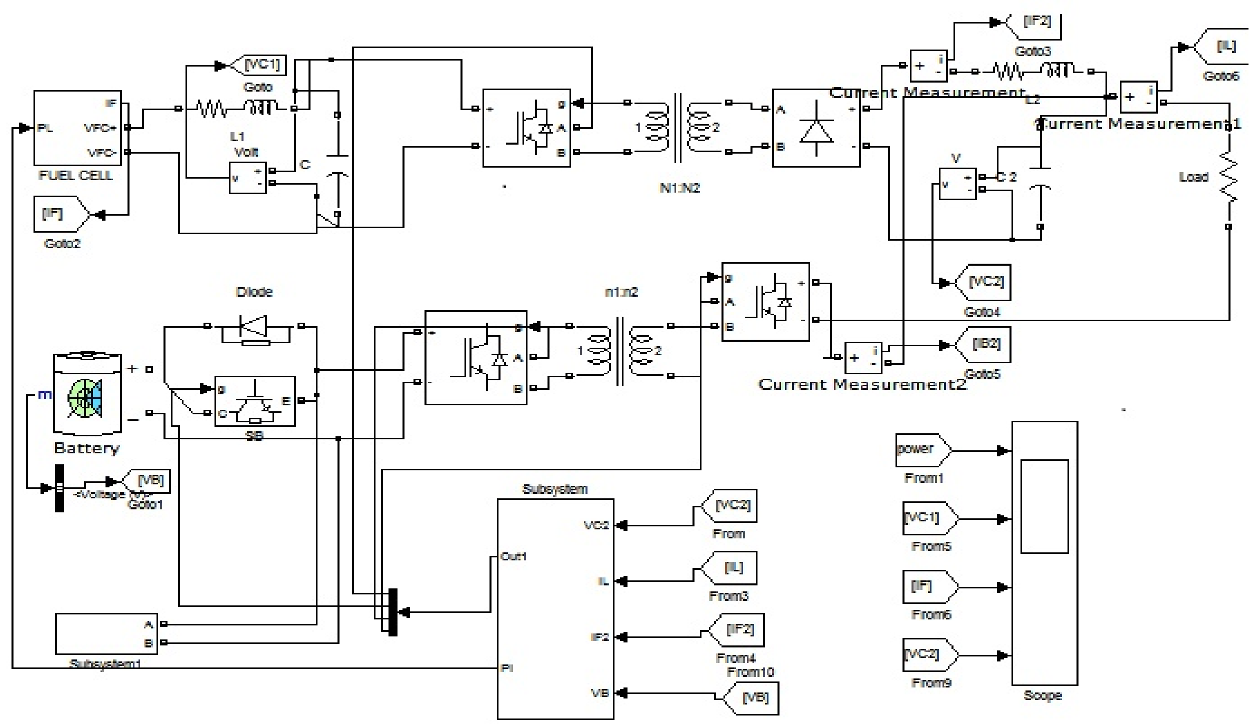
SIMULINK MODEL OF PV CELL:



SIMULINK MODEL OF FUEL CELL:



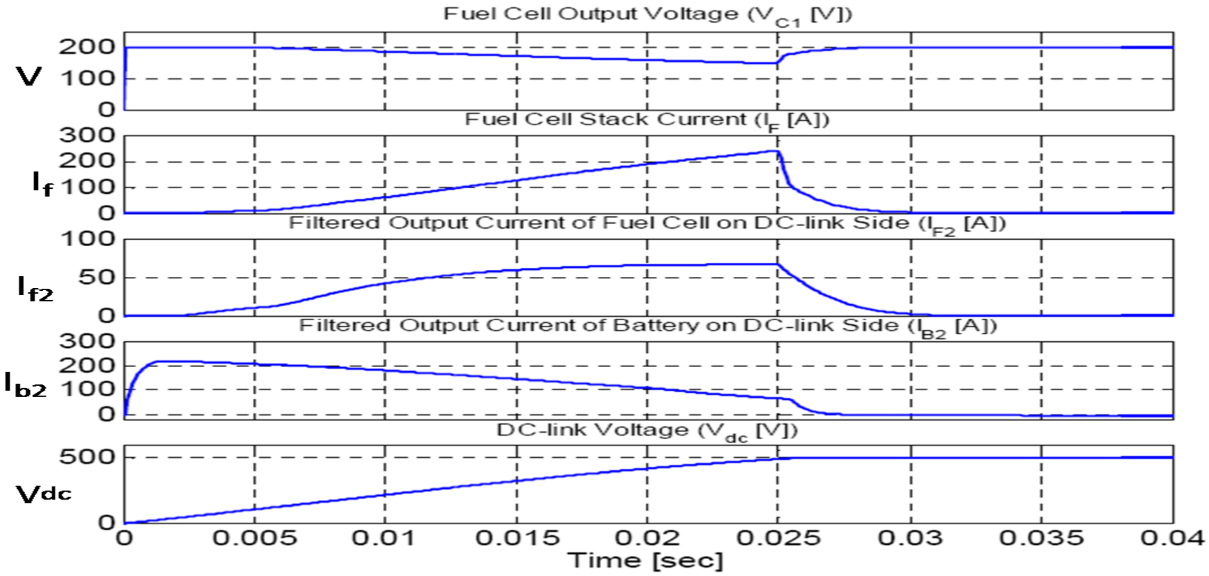
FULL BRIDGE DC TO DC CONVRTERS:



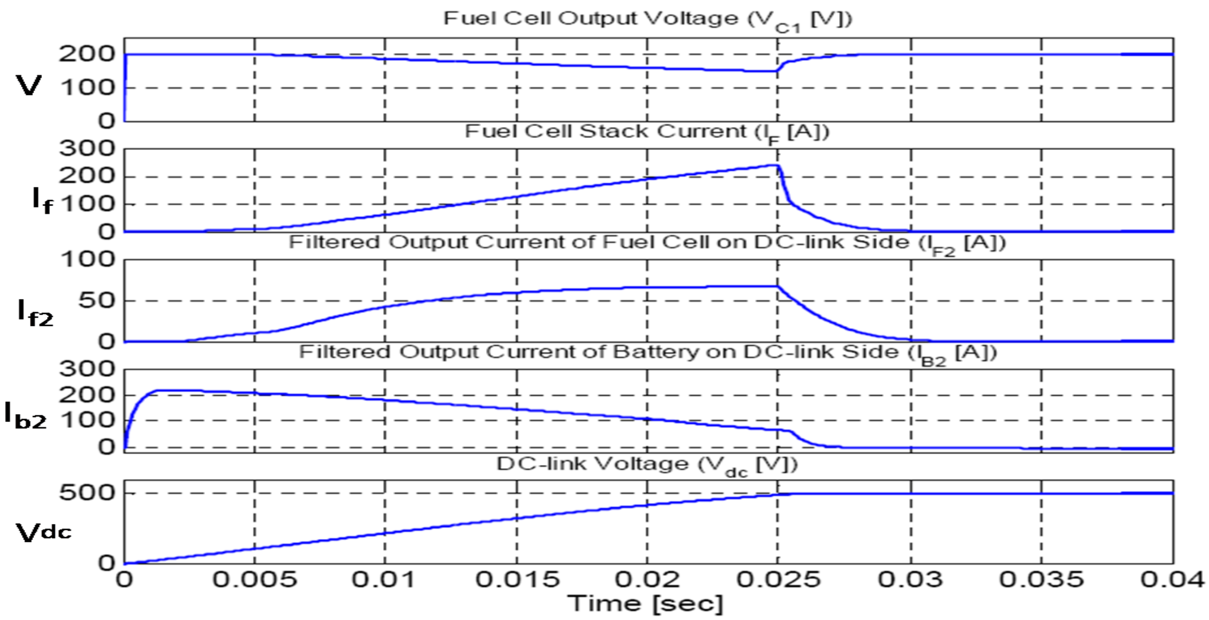
SYSTEM PARAMETERS:

Fuel Cell Output Voltage	88 ~ 200 V
Nominal Battery Voltage	120 V
Turn Ratios (N_1:N_2, n_1:n_2)	1:6.5, 1:6
Input Filters	L_1 = 20 μH, C_1 = 1000 μF
Output Filters	L_2 = 150 μH, C_2 = 10000 μF
Switching Frequency	f_d = 10 kHz
Desired DC Output Voltage	V_{dc} = 500 V

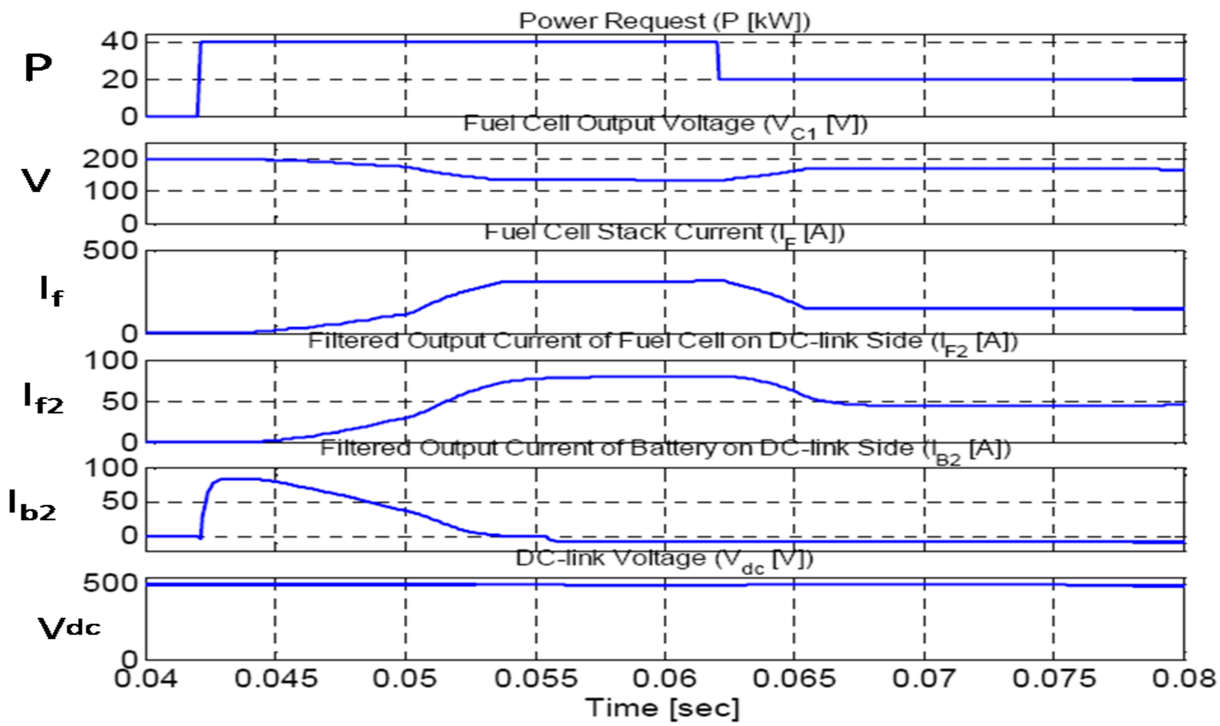
SIMULATION WAVEFORMS AT STARTING:



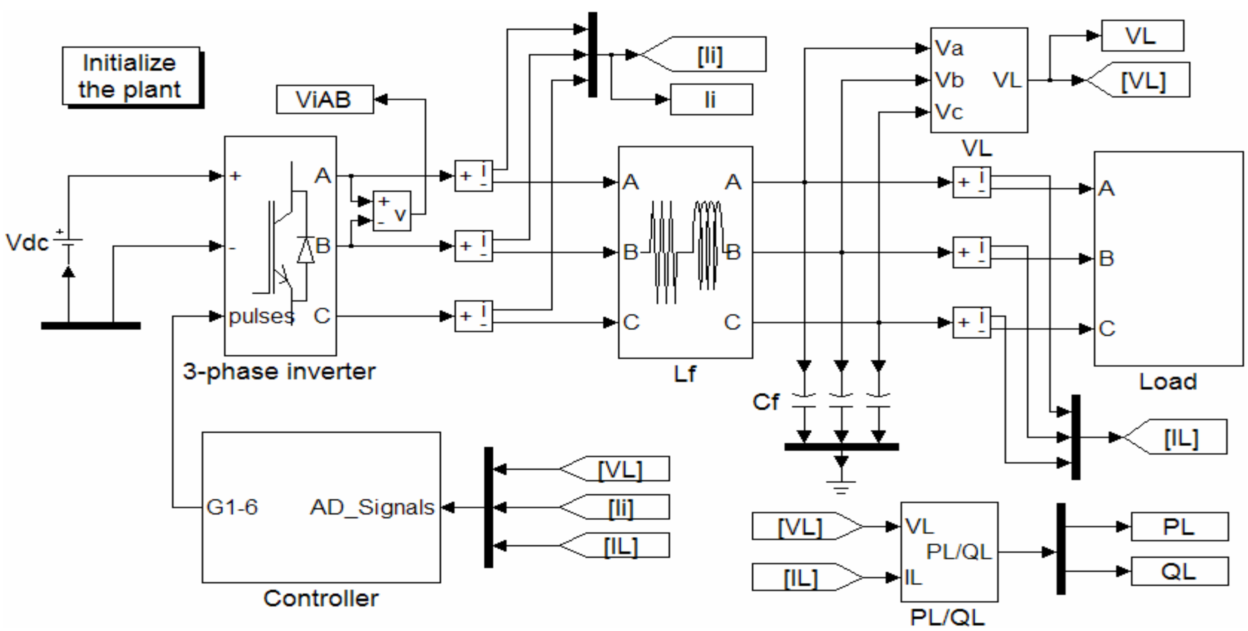
SIMULATION UNDER SUDDEN LOAD INCREASE:



SIMULATION UNDER SUDDEN LOAD DECREASE:



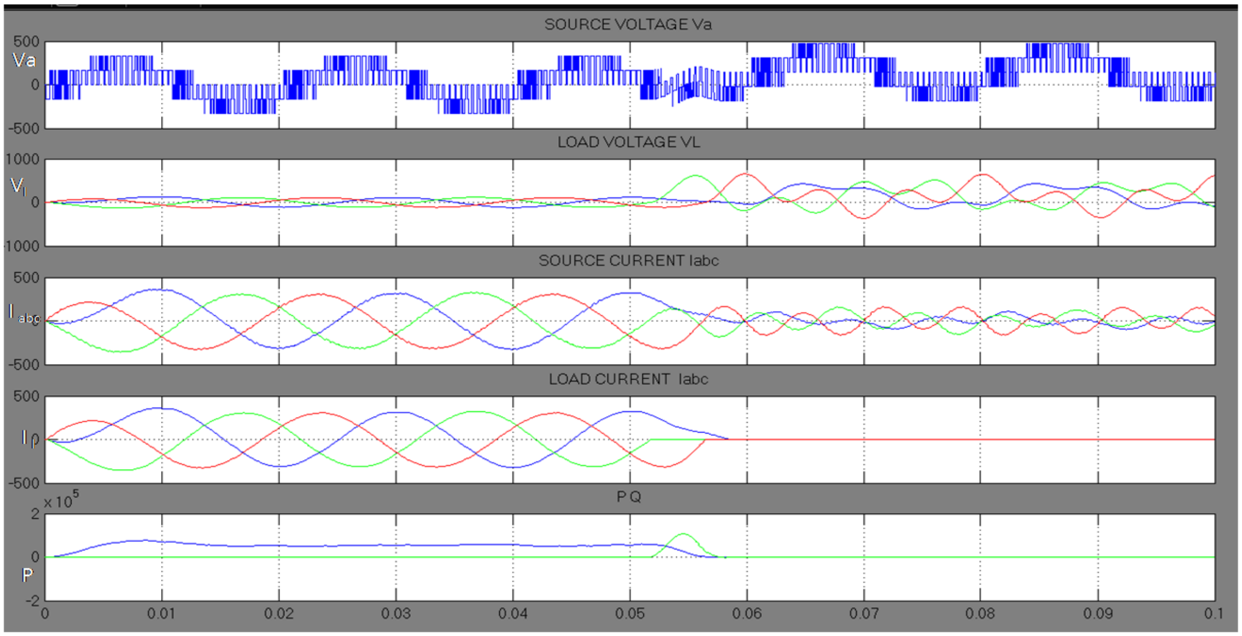
DC TO AC INVERTER:



PARAMETERS:

DC Bus Voltage	V_{dc} = 500 V
Output Power Rating	P_{out} = 50 kVA
AC Output Voltage	$V_{L,RMS}$ = 120 V (L-N), f = 60 Hz
Inverter Filters	L_f = 250 µH, C_f = 580 µF
Switching/Sampling Frequency	f_s = 9 kHz

OUTPUT WAVFORM:



3. CONCLUSION

This paper has described the circuit model and controller design of the fuel-cell-powered DGS to put the battery in parallel to the fuel cell in a standalone AC power supply. A simulation test-bed using Matlab/Simulink is presented, which includes the dynamic model of the fuel cell, the unidirectional full-bridge DC to DC boost converter (fuel cell), the bidirectional full-bridge DC to DC buck/boost converter (battery), and the three-phase DC to AC inverter. Especially, a new topology with a static switch on the side of battery which can control both directional power flows is proposed for the bidirectional full-bridge DC to DC buck/boost converter. For three power converters, the controllers are designed: an adaptive proportional controller for two DC to DC power converters and two discrete-time sliding mode controllers for the three- phase DC to AC inverter.

ACKNOWLEDGEMENT

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REFERENCES

[1] M.N.Marwali and A.Keyhani, "Control of Distributed Generation Systems, Part I: Voltages and Currents Control," IEEE Transaction on Power Electronics, vol. 19, pp. 1541-1550, Nov. 2004.

[2] M.N.Marwali, J. W. Jung, and A.Keyhani, "Control of Distributed Generation Systems, Part II: Load Sharing Control," IEEE Trans. on Power Electronics, vol. 19, pp. 1551-1561, Nov. 2004.

[3] A.A.Chowdhury, S.K.Agarwal, D.O.Koval, "Reliability modeling of distributed generation in conventional distribution systems planning and analysis," IEEE Transactions on Industry Applications, vol. 39, pp. 1493-1498, Sept.-Oct. 2003.

[4] T.Monai, I. Takano, H. Nishikawa, and Y. Sawada, "Response characteristics and operating methods of new type dispersed power supply system using photo- voltaic fuel cell and SMES," IEEE Power Engineering Society Summer Meeting, vol. 2, pp. 874-879, July 2002.

[5] J.L.Del Monaco, "The Role of Distributed Generation in the Critical Electric Power Infrastructure," IEEE-Power Engineering Society Winter Meeting, vol. 1, pp. 144 -145, 2001.

[6] L.Philipson, "Distributed and Dispersed Generation: Addressing the Spectrum of Consumer Needs," IEEE-Power Engineering Society Summer Meeting, vol. 3, pp. 1663 - 1665, 2000.