International Journal for Innovative
Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Title: Operating Modes Of Seamless Transfer Control Strategy For Fuel Cell Uninterruptible Power Supply System.

Volume 06, Issue 05, Page No: 1536 – 1543.

Paper Authors

*** DR PAGIDIMARRI KRISHNA, C V VIJAY KUMAR, BALANAGU SUSHMA.**

* Dept of EEE, Nalla Malla Reddy Engineering College.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

OPERATING MODES OF SEAMLESS TRANSFER CONTROL STRATEGY FOR FUEL CELL UNINTERRUPTIBLE POWER SUPPLY SYSTEM

***DR PAGIDIMARRI KRISHNA, **C V VIJAY KUMAR, ***BALANAGU SUSHMA**
*Professor, Dept of EEE, Nalla Malla Reddy Engineering College (NMREC), Hyderabad.
**Assistant Professor, Dept of EEE, Nalla Malla Reddy Engineering College (NMREC), Hyderabad.
***Assistant Professor, Dept of EEE, Nalla Malla Reddy Engineering College (NMREC), Hyderabad.
pagidimarrik@gmail.com cvvijay93@gmail.com sushma.vidyapuram@gmail.com

ABSTRACT:
Uninterruptible power supply (UPS) systems provide uninterrupted, reliable, and high-quality power for vital loads. They, in fact, protect sensitive loads against power outages as well as overvoltage and under voltage conditions. UPS systems also suppress line transients and harmonic disturbances. Applications of UPS systems include medical facilities, life support systems, data storage and computer systems, emergency equipment, telecommunications, industrial processing, and on-line management systems. A seamless transfer control strategy, which is suitable for FC-UPS, is proposed. The power conversion architecture of FC-UPS is presented with the characteristic analysis of PEMFC and the requirements of UPS. Then, the scheme of the seamless transfer control strategy is investigated. The proposed seamless transfer control strategy is not only capable of guaranteeing the uninterruptible load voltage, but also protecting FC against the power demands beyond its allowable bandwidth during the transition for long lifespan and safety a line-interactive fuel-cell powered uninterruptible-power-supply system. A three-port bidirectional converter connects a fuel cell and a supercapacitor to a grid-interfacing inverter. A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices. The system can operate in both stand-alone and grid-connected modes. are being verified using MATLAB/Simulink software based on a detailed system model.

Index Terms: Uninterruptible power supply (UPS) systems, fuel cell (FC), seamless transfer, PV system

I. INTRODUCTION

Generally, an ideal UPS should be able to deliver uninterrupted power while simultaneously providing the necessary power conditioning for the particular power application. Therefore, an ideal UPS should have the following features.

- Regulated sinusoidal output voltage with low total harmonic distortion (THD) independent of the changes in the input voltage or in the load, linear or nonlinear, balanced or unbalanced.
- On-line operation, which means zero switching time from normal to backup mode and vice versa.
- Low THD sinusoidal input current and unity power factor.

- High reliability.
- Bypass as a redundant source of power in the case of internal failure.
- High efficiency.
- Low electromagnetic interference (EMI) and acoustic noise.
- Electric isolation of the battery, output, and input.
- Low maintenance.
- Low cost, weight, and size.

The advances in power electronics during the past three decades have resulted in a great variety of new topologies and control strategies for UPS systems. The research has been focused mainly on improving performance and expanding application areas of UPS systems. The issue of reducing the cost of converters has recently attracted the attention of researchers. Reducing the number of switches provides the most significant cost reduction. Another form of cost reduction is to replace active switches such as IGBTs, MOSFETs, and thyristors with diodes. Not only are diodes more reasonable than the controlled switches, but there is also a cost reduction from eliminating gate drivers for active switches and power supplies for gate drivers. Another way of reducing cost is to develop topologies that employ switches with lower reverse voltage stresses and lower current ratings, which means less silicon and smaller switching losses resulting in lower cost and higher efficiency. In past research works, a variety of high-efficiency converter topologies were proposed for FC power systems [6]–[10]. In former literature works focusing on the FC dynamics compensation, the power management unit (PMU) with the energy storage component was utilized to supply the dynamic power when the load steps [11], [12]. In [13]–[15], the super capacitor (SC) was used as the auxiliary power source and an efficient power management system for hybrid electric vehicles was presented. However, how to ensure the FC safety in the transition between different operating modes for FC-UPS systems was not extensively investigated in former studies. The authors extended the PMU function to deal with low-frequency current ripples under unbalanced load conditions to guarantee the FC lifespan, the PMU acts as dc-bus capacitors to suppress low-frequency current ripples, thus large dc-bus electrolytic capacitors can be eliminated and the lifespan and reliability of the system can be enhanced consequently.

II. NORMAL MODE OF OPERATION UPS

During this mode of operation, the power to the load is continuously supplied via the rectifier/charger and inverter. In fact, a double conversion, that is, AC/DC and DC/AC, takes place. It allows very good line conditioning. The AC/DC converter charges the battery set and supplies power to the load via the inverter. Therefore, it has the highest power rating in this topology, increasing the cost.

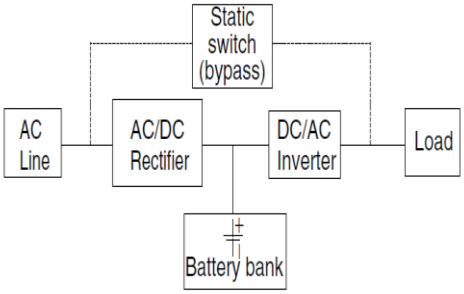


Fig.1 Block diagram of a typical on-line UPS system.

When the AC input voltage is outside the preset tolerance, the inverter and battery maintain continuity of power to the load. The duration of this mode is the duration of the preset UPS backup time or until the AC line returns within the preset tolerance. When the AC line returns, a phase-locked loop (PLL) makes the load voltage in phase with the input voltage and after that the UPS system returns to the normal operating mode.

III. SEAMLESS TRANSFER BETWEEN INVERTER WORKING MODE AND FC WORKING MODE

In the FC-UPS system, FC adopts cold backup to guarantee the long lifespan. However, FC cold start time is long and FC cold start with load is difficult. Besides, the dynamic response of FC is slow and the output power change of FC should be as steady as possible during the transition. Therefore, the transfer control strategy of the FC-UPS is different from the traditional UPS. The proposed control strategy for the transition between inverter working mode and FC working mode is shown in Fig. 2 followed by the detailed analysis including five stages.

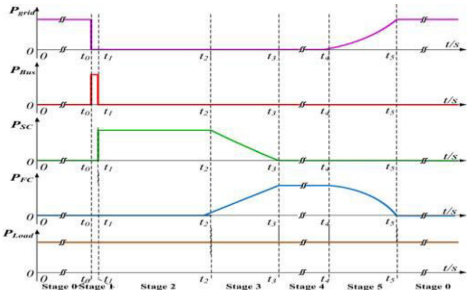


Fig. 2 Schematic diagram of seamless transfer between inverter working mode and FC working mode

Stage 0: Initial state (0–*t*0)

In this stage, the grid is normal and the system operates in the inverter working mode as shown in Fig. 3. The grid feeds the load through the ac/dc converter and the dc/ac inverter, while the dc/dc converter does not work. The dc-bus voltage is maintained by the ac/dc converter and the bi-dc/dc converter operates in current control mode. Under unbalanced load conditions, the bi dc/ dc converter absorbs low-frequency current ripples to support the dc-bus voltage.

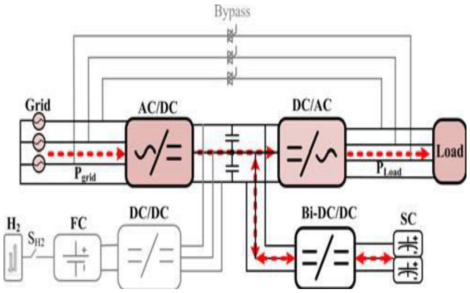


Fig.3. Stage 0 of the seamless transfer control strategy

Stage 1*: Grid failure detection stage* (*t*0–*t*1)
Supposing that the grid fails at *t*0, the dc/ac unit detects the grid failure at *t*1 as shown in Fig. 2. During this period (*t*0–*t*1), the power of the load is supplied by the dc-bus and the dc-bus voltage will decrease, which is shown in Fig. 4. The value of the dc-bus capacitor is determined by the grid failure detection time and the allowable decrease range of the dc-bus voltage.

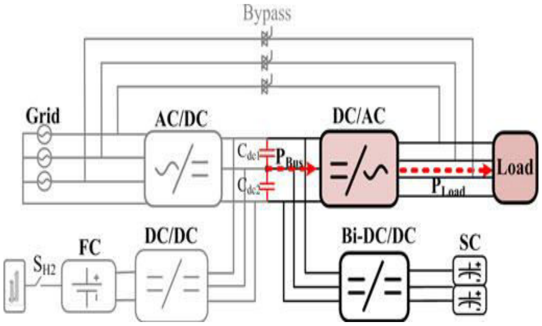
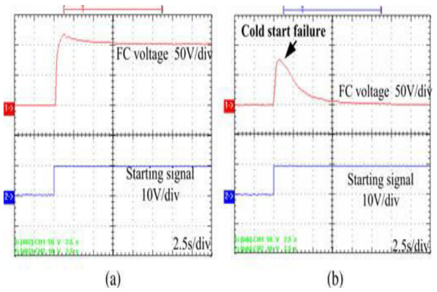


Fig. 4 Stage 1 of the seamless transfer control strategy

Stage 2*: Fuel cell cold start stage* (*t*1–*t*2)
When the dc/ac inverter detects the grid failure, a signal could be sent via the controller area network communication to the ac/dc and dc/dc converters. Once the ac/dc receives the signal, it blocks the insulated gate bipolar transistor (IGBT) drive. The dc/dc converter receives the signal and turns on the electromagnetic valve *SH* 2 to let hydrogen into FC, so that FC can start to set up output voltage. The waveforms of FC cold start with no load and with heavy load are shown in Fig. 5.



(a) (b)

Fig.5. FC cold start with no load and with heavy load
(a) Cold start with no load. (b) Cold start with heavy load.

There will be startup failure. Therefore, the PMU operates in boost constant-voltage mode to control the dc-bus voltage and provide power to the load shown in Fig. 6. With this control strategy, FC can cold start with no load and the safety of FC can be guaranteed. there will be startup failure. Therefore, the PMU operates in boost constant-voltage mode to control the dc-bus voltage and provide power to the load shown in Fig. 6. With this control strategy, FC can cold start with no load and the safety of FC can be guaranteed.

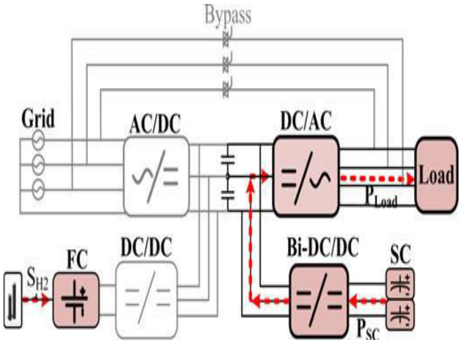


Fig.6. Stage 2 of the seamless transfer control strategy

There will be startup failure. Therefore, the PMU operates in boost constant-voltage mode to control the dc-bus voltage and provide power to the load shown in Fig.6 with this control strategy, FC can cold start with no load and the safety of FC can be guaranteed.

Stage 3: PMU aiding fuel cell to power load stage (t2–t3)

At *t*2 in Fig. 2, FC finishes the cold start. From Fig. 7, the dc/dc converter starts and operates in boost constant-voltage mode to control the dc-bus voltage. Meanwhile, the PMU transfers to operate in current mode to control the output current of the bi-dc/dc converter. The current reference value of the bi-dc/dc converter decreases slowly from the initial value at *t*2 . Under this control, the power provided by the SC decreases slowly and the power provided by FC increases accordingly as shown in Fig. 2, which guarantees the safety and lifespan of FC.

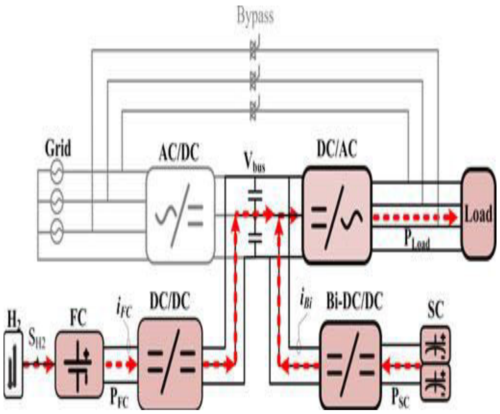


Fig.7. Stage 3 of the seamless transfer control strategy

Stage 4: Fuel cell working mode stage (t3 –t4)

At *t*3, stage 3 is completed and FC-UPS begins to operate in FC working mode. The load power is provided by FC as shown in Fig.2 This stage continues until the grid recovers. As shown in Fig. 10, in this stage, the dc-bus voltage is maintained by the dc/dc converter and the PMU operates in current control mode. The PMU provides dynamic power for FC dynamics compensation. Under unbalanced load conditions, the PMU absorbs low-frequency current ripples to reduce the dc-bus voltage fluctuation.

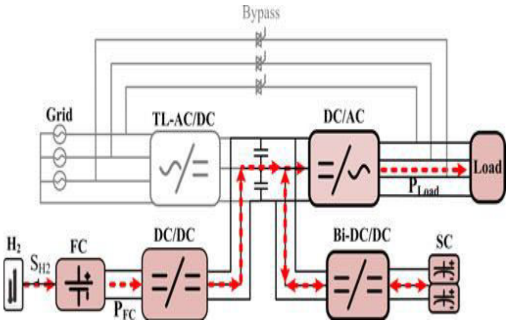


Fig.9 Stage 4 of the seamless transfer control strategy

Stage 5*: ac/dc starting stage* (*t*4 –*t*5 *)*
At *t*4 , the dc/ac unit detects the recovery of the grid and sends a startup signal to the ac/dc converter. As shown in Fig. 10, the ac/dc converter starts and operates in boost constant-voltage mode to control the dc-bus voltage. At the same time, the dc/dc converter is switched to operate in current mode to control the output current of FC. The current reference value decreases at the rate less than 25 A/s from the initial current value at *t*4 .When the FC current decreases to zero, the electromagnetic valve *SH* 2 is shut down and FC is stopped. Consequently, the power provided by FC decreases slowly and the power provided by the grid increases slowly as shown in Fig. 6, which accommodates FC characteristics and guarantees the safety of FC.

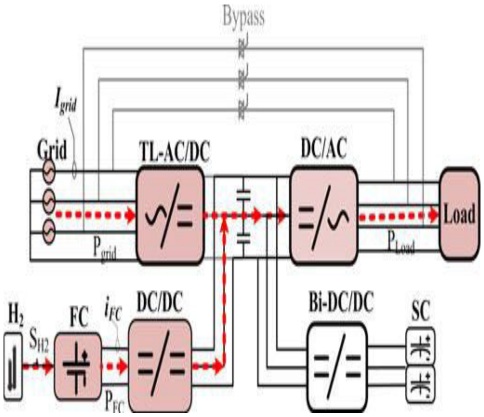


Fig. 10 Stage 5 of the seamless transfer control strategy

From the previous analysis, it can be seen that during the transition from inverter working mode to FC working mode, the PMU maintains the dc-bus voltage to aid FC cold start with no load. After FC finishes cold start, the PMU operates in current mode to ensure slowly increasing of the FC power. During the transition from FC working mode to inverter working mode, the ac/dc converter maintains the dc-bus voltage and the dc/dc operates in current mode to ensure that the FC power decreases slowly. Therefore, the proposed control strategy realizes FC cold start with no load and ensures that FC output power changes slowly during the transition, which accommodates FC characteristics.

IV. PHOTOVOLTAIC SYSTEM

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices.

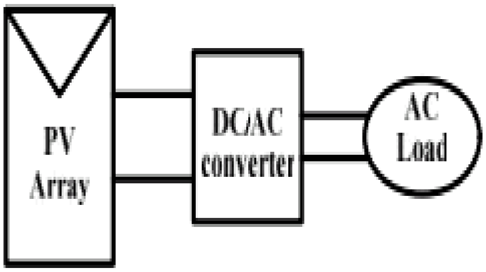


Fig.11. Block diagram representation of Photovoltaic system

This photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter. The Block diagram of the PV system is shown in Fig.11. A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited1

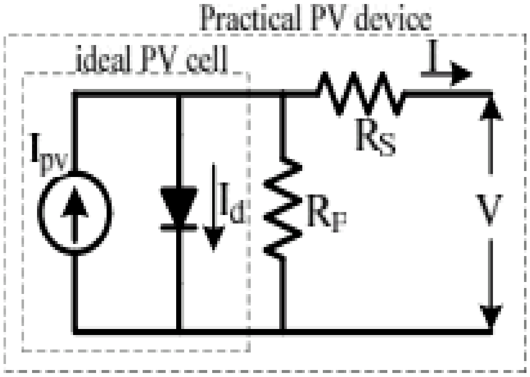


Fig.12. Practical PV device

The equivalent circuit of PV cell is shown in the fig.12. In the above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-V characteristics of PV cell are shown in fig.13. The net cell current I is composed of the light generated current IPV and the diode current ID.

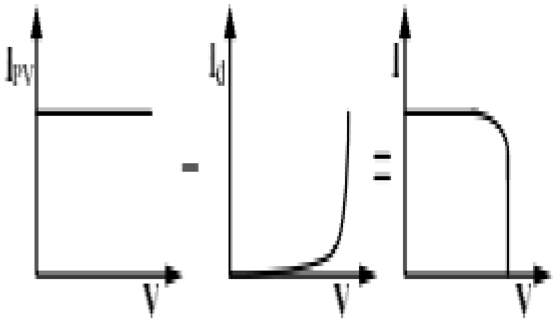


Fig.13. Characteristics I-V curve of the PV cell

V.

VI. MATLAB/SIMULINK RESULTS

Here Matlab/Simulink modeling is done with different conditions, in that, 1). Proposed Fuel Cell Uninterruptible Power Supply System, 2). Proposed Photovoltaic Cell Uninterruptible Power Supply System.

Case 1: Proposed Fuel Cell Uninterruptible Power Supply System

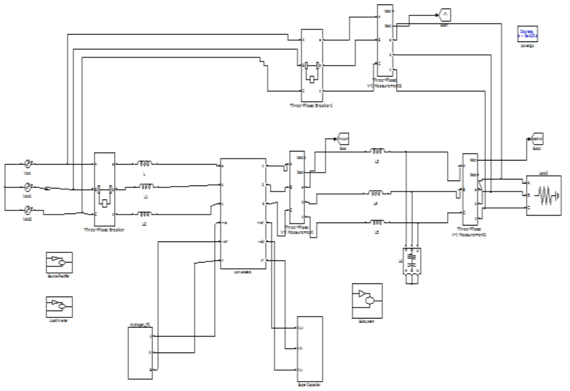


Fig.13 Matlab/Simulink Model of Proposed

Fuel Cell Uninterruptible Power Supply System Fig.13 Matlab/Simulink Model of Proposed Fuel Cell Uninterruptible Power Supply System using Matlab/Simulink Platform.

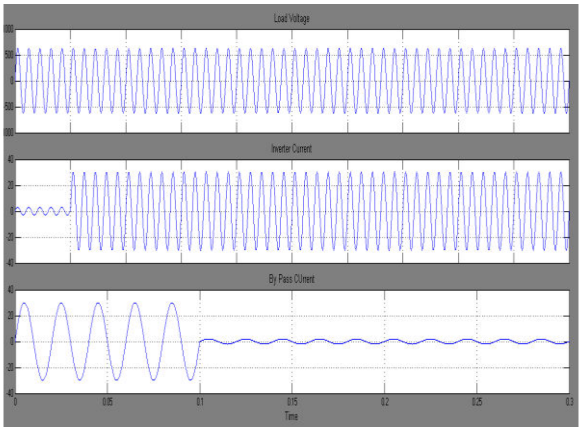


Fig.14 Load Voltage, Inverter Current, By Pass Current

Fig.14 Load Voltage, Inverter Current, By Pass Current of Bypass mode to inverter working mode.

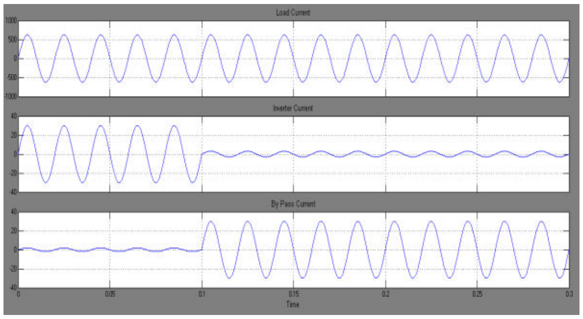


Fig.15 Load Voltage, Inverter Current, By Pass Current

Fig.15 Load Voltage, Inverter Current, By Pass Current of inverter working mode to bypass mode.

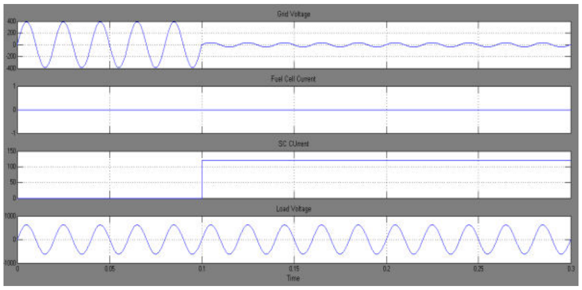


Fig.16 Grid Voltage, Fuel Cell Current, SC Current, Load Voltage

Fig.16 Grid Voltage, Fuel Cell Current, SC Current, Load Voltage from inverter working mode to FC working mode.

Case 2: Proposed Photovoltaic Cell Uninterruptible Power Supply System.

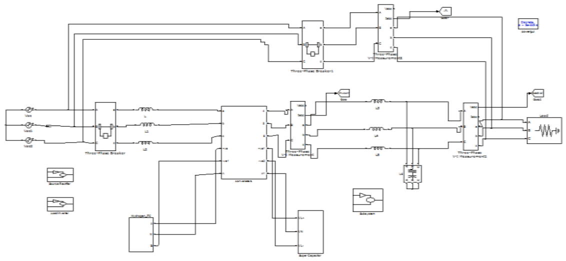


Fig.17 Matlab/Simulink Model of Proposed Fuel Cell with PV Cell Uninterruptible Power Supply System

Fig.17 Matlab/Simulink Model of Proposed Fuel Cell with PV Cell Uninterruptible Power Supply System using Matlab/Simulink Platform.

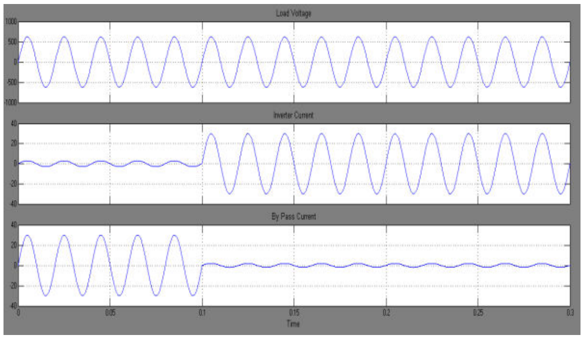


Fig.18 Load Voltage, Inverter Current, By Pass Current

Fig.18 Load Voltage, Inverter Current, By Pass Current of Bypass mode to inverter working mode using Proposed Fuel Cell with PV Cell Uninterruptible Power Supply System.

VII. CONCLUSION

The power industry is experiencing fundamental changes with more renewable energy sources (RESs) or micro sources such as photovoltaic cells, small wind turbines, and microturbines being integrated into the power grid in the form of distributed generation (DG). These RES-based DG systems are normally interfaced to the grid through power electronics and energy storage systems. Due to the long cold start time and the slow dynamics of FC, the transfer control strategy of FC/UPS/PV is different from the traditional UPS with PV Source. This paper proposes a novel seamless transfer control strategy for the FC-UPS/PV system. During the transition from inverter working mode to FC working mode, the PMU supports the dc-bus voltage to aid FC cold start with no load. After FC finishes cold start, the PMU is switched to current control mode to ensure that the FC power increases slowly. During the transition from FC working mode to inverter working mode, the ac/dc converter maintains the dc-bus voltage and the dc/dc operates in current control mode to ensure that the FC power decreases slowly.

REFERENCES

[1] X. Zhu, X. Li,G. Shen, andD.Xu, "Design of the dynamic power compensation for PEMFC distributed power system," *IEEE Trans. Ind. Electron.*, vol. 57, no. 6, pp. 1935–1944, Jun. 2010.

[2] S. Malo and R. Grino, "Design, construction, and control of a stand-alone energy-conditioning system for PEM-type fuel cells," *IEEE Trans. Power Electron.*, vol. 25, no. 10, pp. 2496–2506, Oct. 2010

[3] W.-S. Liu, J.-F. Chen, T.-J. Liang, R.-L. Lin,and C.-H. Liu, "Analysis, design, and control of bidirectional cascaded configuration for a fuel cell hybrid power system," *IEEE Trans. Power Electron.*, vol. 25, no. 6, pp. 1565–1575, Jun. 2010.

[4] P. Thounthong, S. Rael, and B. Davat, "Control strategy of fuel cell and supercapacitors association for a distributed generation system," *IEEE Trans. Ind. Electron.*, vol. 54, no. 6, pp. 3225–3233, Dec. 2007.

[5] A. Payman, S. Pierfederici, and F. Meibody-Tabar, "Energy management in a fuel cell/supercapacitor multisource/multiload electrical hybrid system," *IEEE Trans. Power Electron.*, vol. 24, no. 12, pp. 2681–2691, Dec. 2009

[6] J. Moreno, M. E. Ortuzar, and J. W. Dixon, "Energy-management system for a hybrid electric vehicle, using ultracapacitors and neural networks," *IEEE Trans. Ind. Electron.*, vol. 53, no. 2, pp. 614–623, Apr. 2006.

[7] R.-J. Wai and C.-Y. Lin, "Active low-frequency ripple control for cleanenergy power-conditioning mechanism," *IEEE Trans. Ind. Electron.*, vol. 57, no. 11, pp. 3780–3792, Nov. 2010.

[8] X. Li, W. Zhang, H. Li, R. Xie, and D. Xu, "Design and Control of Bidirectional DC/DC Converter for 30 kW Fuel Cell Power System," in *Proc. 8th Int. Conf. Power Electron. ECCE Asia (ICPE & ECCE)*, Jeju, Korea, May 30–Jun. 3, 2011, pp. 1024–1030.

[9] X. Li, W. Zhang, H. Li, R. Xie, M. Chen, G. Shen, and D. Xu, "Power management unit with its control for a three-phase fuel cell power system without large electrolytic capacitors," *IEEE Trans. Power Electron.*, vol. 26, no. 12, pp. 3766–3777, Dec. 2011.

[10] M. Harfman-Todorovic, L. Palma, M. Chellappan, and P. Enjeti, "Design considerations for fuel cell powered UPS," in *Proc. 23rd Annu. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, 24–28 Feb. 2008, pp. 1984– 1990

[11] S. B. Bekiarov and A. Emadi, "Uninterruptible power supplies: classification, operation, dynamics, and control," in *Proc. 17th Annu. IEEE Appl. Power Electron. Conf. Expo.*, Dallas, TX, 10–14 Mar. 2002, pp. 597–604.

[12] G. V. Sukumara, A. Parthasarathy, and V. R. Shankar, "Fuel cell based uninterrupted power sources," in *Proc. 2nd Int. Conf. Power Electron. Drive Syst., Part 2*, Singapore, 26–29 May1997, pp. 728–733.

[13] W. Choi, P. Enjeti, and J. W. Howze, "Fuel cell powered UPS systems: design considerations," in *Proc. 34th IEEE Annu. Power Electron. Spec. Conf.*, Acapulco, NM, 15–19. Jun. 2003, pp. 385–390.

[14] T. Haimin, J. L. Duarte, and M. A. M. Hendrix, "Line interactive UPS using a fuel cell as the primary source," *IEEE Trans. Ind. Electron.*, vol. 55, no. 8, pp. 3012–3021, Aug. 2008.

[15] Z. Zhe, O. Ziwei, O. C. Thomsen, and M. A. E. Andersen, "Analysis and design of a bidirectional isolated DC–DC converter for fuel cells and supercapacitors hybrid system," *IEEE Trans. Power Electron.*, vol. 27, no. 2, pp. 848–859, Feb. 2012.