International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 6, Number 3 (2013), pp. 289-299

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Power Quality Enhancement Strategy of Hybrid Distributed Generation System

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Abstract

This paper concentrates on the control of hybrid fuelcell (FC)/energy-storage distributed generation (DG) systems under voltage sag in distribution systems. The proposed control strategy makes hybrid DG system work properly when a voltage disturbance occurs in distribution system, and it stays connected to the main grid. This controller determines the supercapacitor power that should be generated according to the amount of available energy in dc-link. Also, current control strategies for the FCconverter (boost) and supercapacitor converter (buck–boost converter) are designed by proportional-integral and sliding-mode control consequently. Moreover, a complementary control strategy for voltage source converter based on positive and negative symmetrical components is presented to investigate the voltage sag ride-through and voltage control capability. The hybrid system is studied under unbalance voltage sag condition. Simulation results are given to show the overall system performance including active power control and voltage sag ride-through capability of the hybrid DG system.

Keywords: Control, energy storage, fuel cell (FC), hybrid system, smart grid, voltage sag.

Introduction

Today, new advances in technology and new directions in electricity regulation encourage a significant increase of distributed generation (DG) resources around the world. The current electricity infrastructure in most countries consists of bulk centrally located power plants connected to highly meshed transmission networks. However, a new trend is developing toward distributed energy generation, which means that power conversion systems (PCSs) will be situated close to energy consumers and the few large units will be substituted by many smaller ones. For the consumer, the potential lower cost, higher service reliability, high power quality, increased energy efficiency, and energy independence are all reasons for the increasing interest in what is called “smart grids” PCSs accept any source of fuel (coal, sun, and wind) and transform it into a consumer’s end use (heat, light, and warm water) with minimal human intervention. These systems allowsociety to optimize the use of DG and minimize our collective environmental footprint. Hence, proper control of DG systems is essential in keeping them operational within the power distribution systems to which they are connected. Many of the DG systems, such as fuel cells (FCs), photovoltaic, and wind turbines, are connected to the grid via power electronic converters to improve the system integrity, reliability, and efficiency. Therefore, it is important that the control strategies are designed to keep the system stable under any disturbance and parameter variations in the distribution system. The grid-connected power electronic converters are highly sensitive to grid disturbances and it is important to emphasize the necessity to reduce the effects of voltage disturbances on their operation. In spite of the growing number of DG units, their contribution to the total power delivered to the utility grid remains small, as compared to the power generated by the traditional large power plants. However, they can support the grid in case of disturbances provided that they remain connected, which will be possible only through judicious control strategies such as the ones presented in this paper. Among the wide range of power quality disturbances that severely affect the performance of voltage source converters (VSCs) are voltage sags. A voltage sag is a drop in voltage with between DG units and the grid during voltage sag is very important and it must be considered when designing a proper control strategy. This is the objective of this paper, where a control strategy under voltage sag conditions is proposed for a DG system consisting of a FC combined with energy storage. Up to now, an extensive study has not been introduced for FC DG systems and their operation under voltage disturbances. The limitations of active power and reactive power injection to the grid during voltage sag should be considered carefully. During voltage sag, a decrease in voltage magnitude affects the grid-connected converter. In this case, the current controllers limit the power that DG unit can supply to the grid to avoid overloading of the converter. For FC DG systems, the power limitation can be a problem resulting in slow dynamics of FC power sources. Hence, to respond to a transient power demand, usually an energy storage device is combined with the FC. The comparison between battery and supercapacitor energy storages shows that the use of supercapacitor is better than battery for power quality problem studies; also there are some limitations in using a battery. Due to the low power density of the battery, it cannot release its charge or discharge fast enough during voltage sag. Additionally, the main drawback of the batteries is a slow response time, limited by a charging current; in contrast, the supercapacitor can be acted in a short time, depending on the availability of a high-charging power from the main source. Although the batteries are considered to be the main energy storage devices for DG application, their cycle and calendar life still need to be improved. In most of today’s

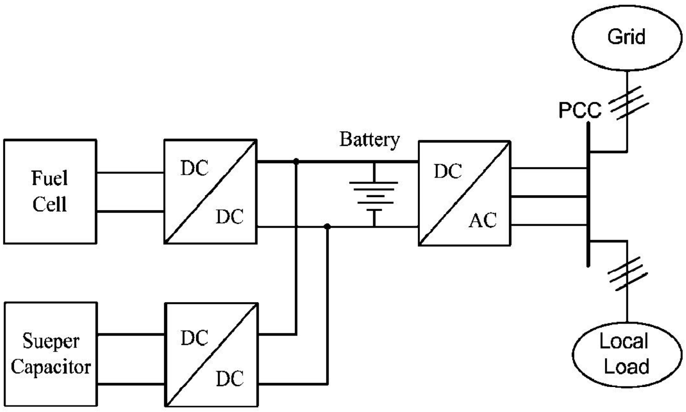
DG applications, batteries are used as an auxiliary power source to deliver power for a long time. On the other hand, the use of a supercapacitor as an auxiliary source is expected to provide very fast power response and can complement the slower power output of the main source (particularly the FC generator). Therefore, it is important to study the operation and the behavior of the whole hybrid FC/energy-storage DG system under voltage sag, not just the response of power electronic converters. Hence, in this paper, a robust control strategy has been presented for hybrid FC/energy-storage DG system during voltage sags.

Description and Modeling of Power Generation System

The hybrid DG system is based on the centralized dc-bus architecture. In this topology, the FC source and supercapacitor are connected to dc bus by boost and buck–boost converters before connecting to the grid as shown in Figure ure 1. To boost the lower output voltage of the FC stack to the level of the dc-link voltage as well as to shape the current output of the FC, a boost converter is used. The hybrid dc power source is then connected to the local ac bus by using a voltage source inverter.

Modeling and Control of FC Subsystem

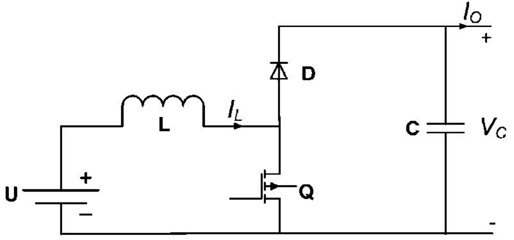
FCs are static energy-conversion devices that convert the chemical energy of fuel directly into electrical energy. The model of FC power plant used in this study is based on the dynamic proton exchange membrane FC (PEMFC) stack model developed in. The performance of FC is affected by several operating variables, as discussed in the following. This model is based on simulating the relationship between output voltage and partial pressure of hydrogen, oxygen, and water. The Nernst's equation and Ohm's law determine the average voltage magnitude of the FC stack. The following equations model the voltage of the FC stack:



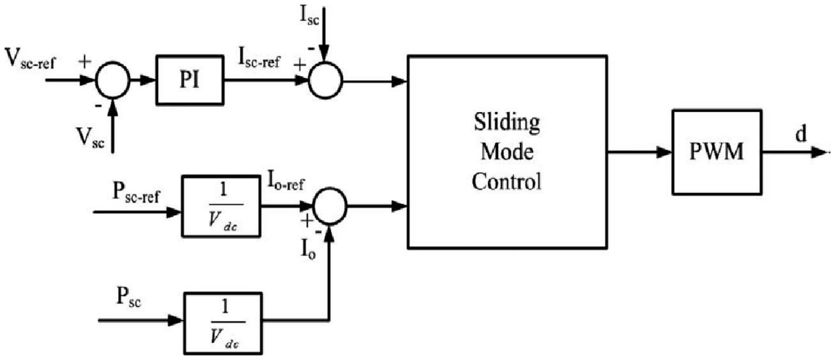
The FC cannot immediately respond to power demand during startup or sudden load changes due to its slow dynamics. Usually to connect a FC to an external power system, it is necessary to boost the FC voltage or to increase the number of cells.

The role of the dc–dc boost converter is to increase the FC voltage, to control the FC power, and to regulate the voltage.

Figure ure shows the dc–dc converter model. This boost converter is described by the following two nonlinear state-space-averaged



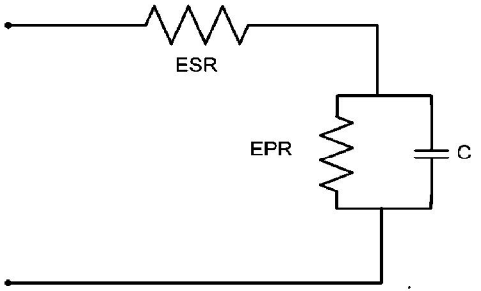
Proposed control structure for buck–boost converter is below.

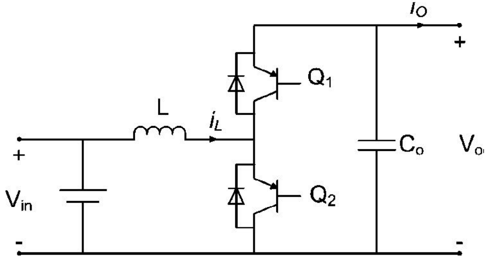


Modeling and Control of Super Capacitor Subsystem

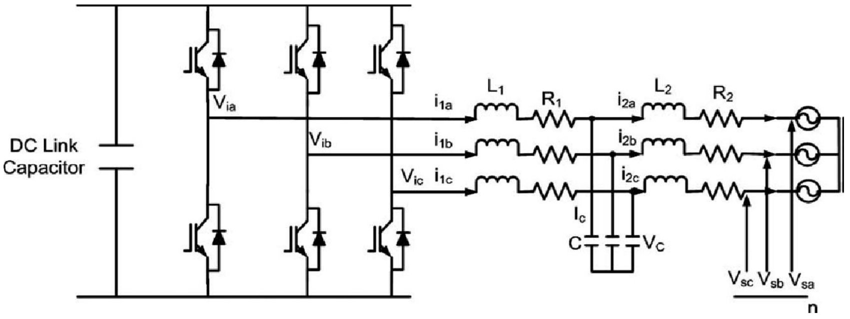
Supercapacitors store electrical energy by accumulating charge on two parallel electrodes separated by a dielectric material. The capacity represents the relationship between the electric charge stored in the capacitor and voltage between the two electrodes of the capacitor. The classical equivalent circuit of the super capacitor is shown in Figure ure Since the EPR models leakage effects and influences long-term energy storage performance of the super capacitor, only the ESR will be taken into account.

The super capacitor energy storage connects to the dc-link by using bidirectional converter. This converter topology is slightly more complex than the boost converter, since it includes one additional switch, but it has the advantage of allowing bidirectional power flow, which means energy can flow from the energy source to the load and back from the load to the energy source. This feature is very convenient for energy storage devices like batteries and supercapacitors. Since it allows recharging the device after each time their energy is used. The schematic of buck–boost converter is shown in Figure





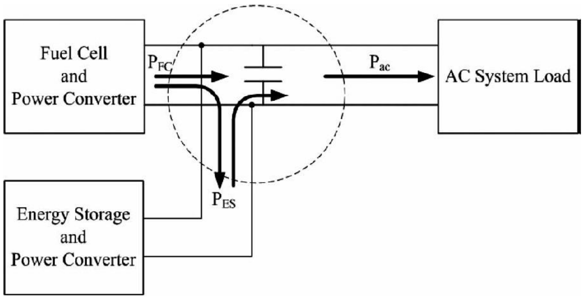
Buck–boost converter model.



Three-phase dc/ac voltage source inverter

Power Flow Control of Hybrid Energy Conversion System during Voltage Sag

In this section, the control strategy of the hybrid FC/energystorage DG system is presented. The term, "power-flow control", refers to the design of the higher level control algorithm that determines the proper power level to be generated, and its distribution between the two power sources. In fact, during voltage sag conditions, the power-flow-control strategy must be designed to stabilize the dc-link power and regulate the dc-link voltage consequently.

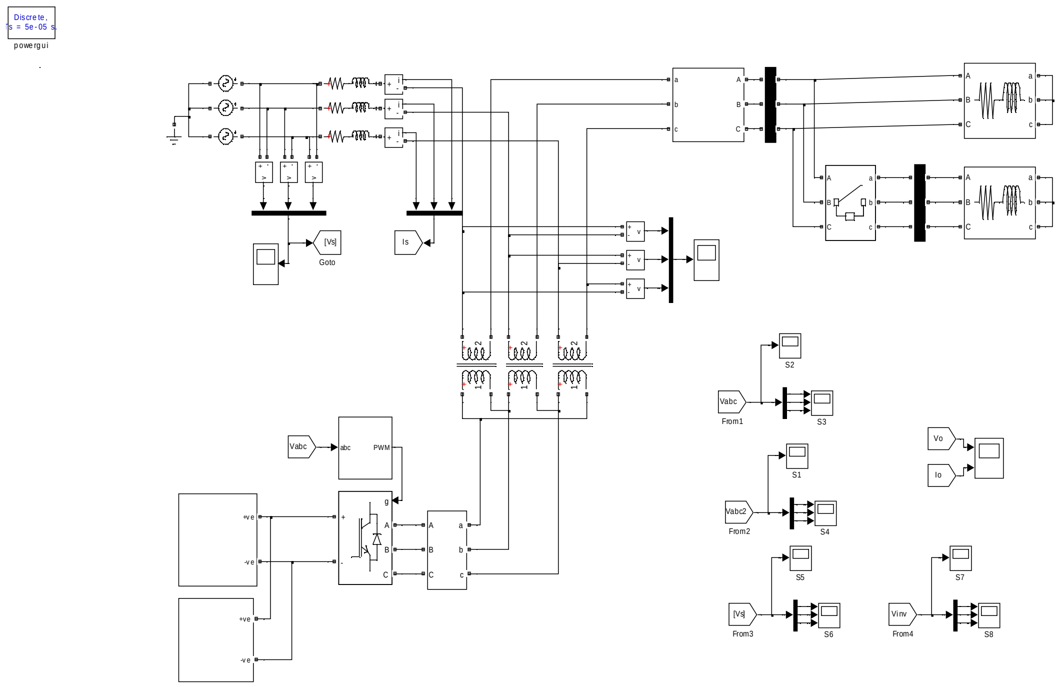


Simulation Results

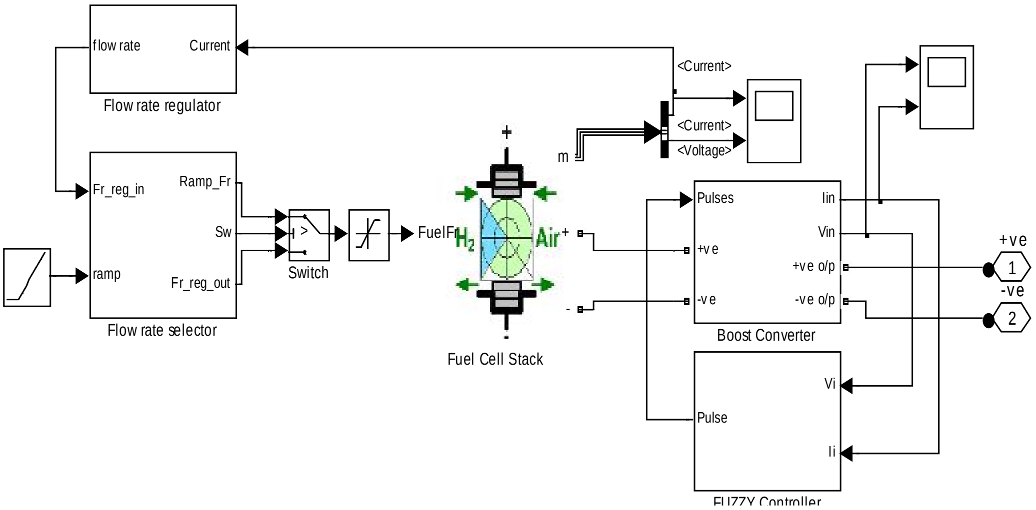
In order to show the effectiveness of proposed control strategy, the simulation model of the proposed hybrid DG system has been built in MATLAB/Simulink environment. The parameters of the hybrid FC/energy-storage DG system in this study are given in Table I. Also, in Table II, the controllers' parameters include reformer controller, and power electronic converters are presented. In this case study, the output power of the FC power system during normal conditioning is considered to be 50 kW

MATLAB Circuit Diagram Simulation

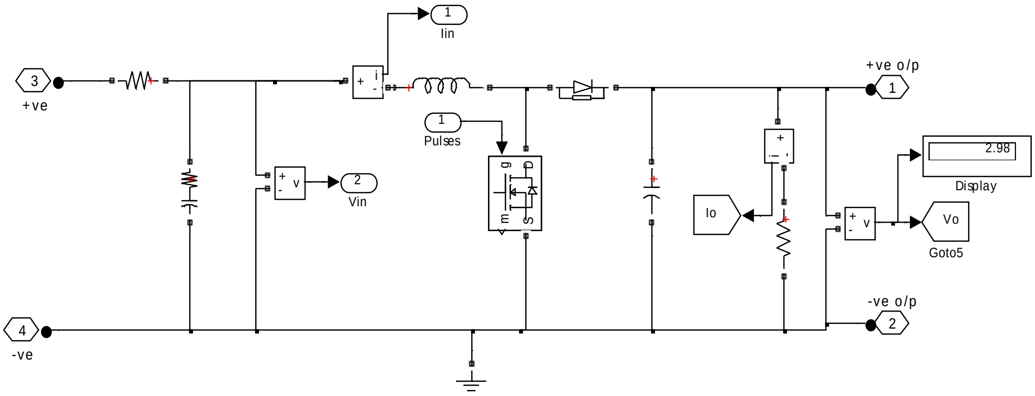
Over all system line diagram



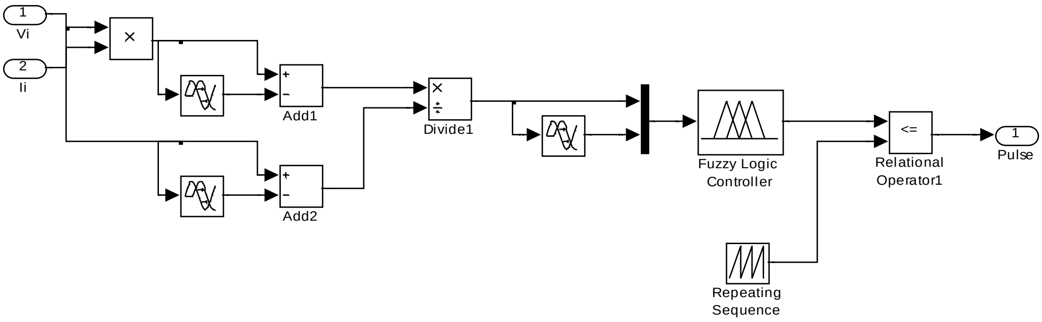
Fuel cell subsystem.



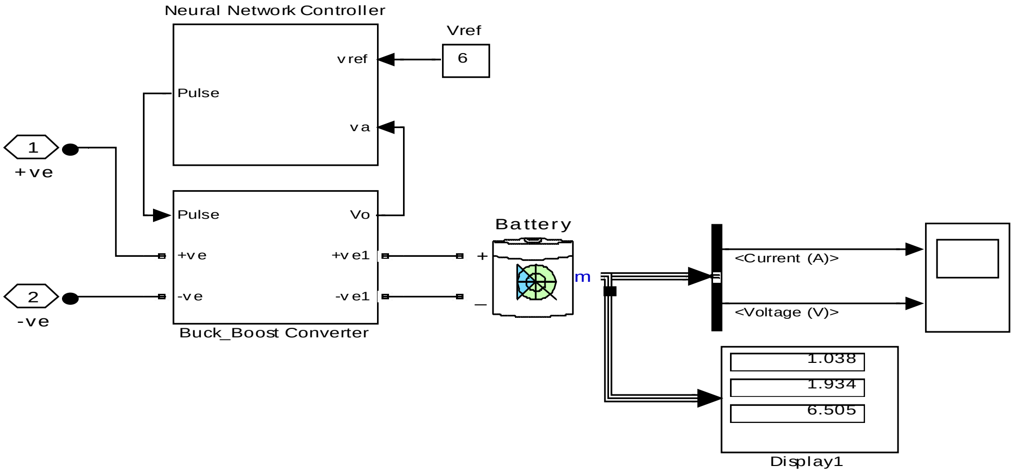
Boost converter arrangement.



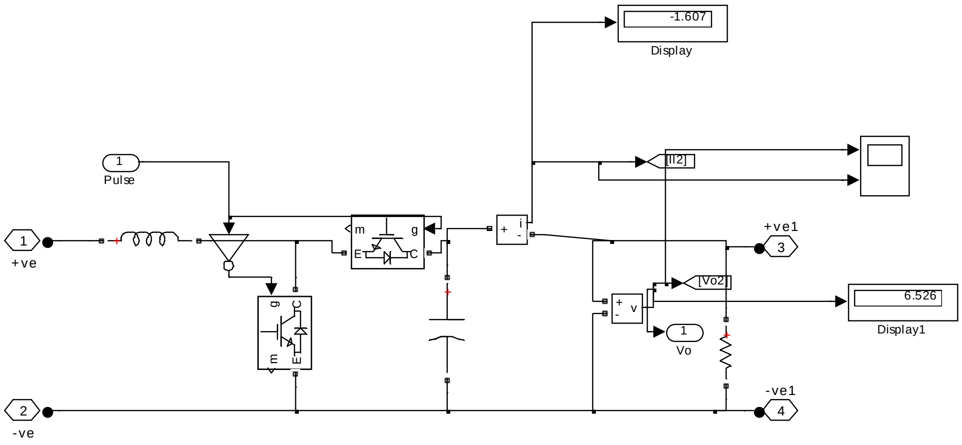
Fuzzy optimized PWM generation.



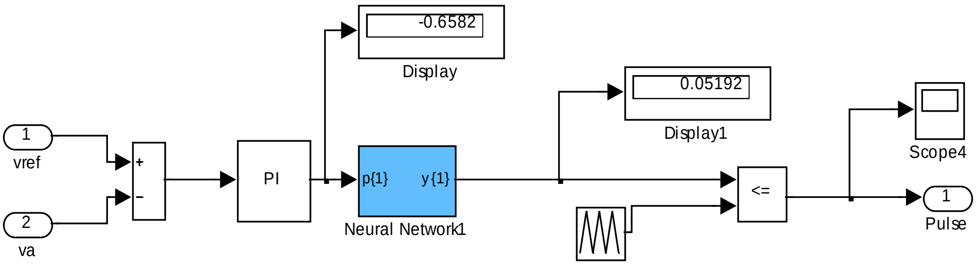
Super capacitor subsystem

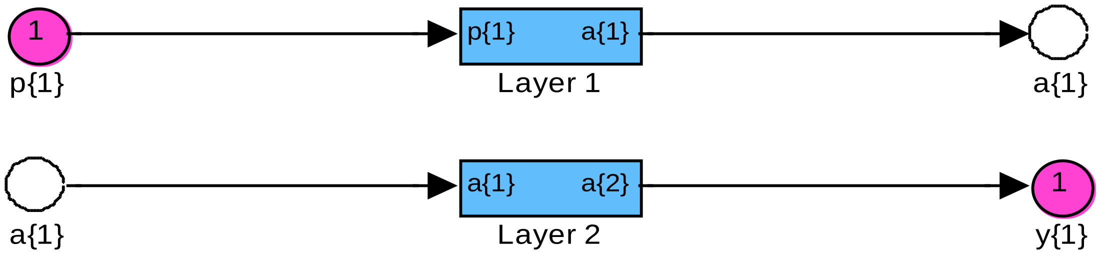


Buck boost converter arrangement



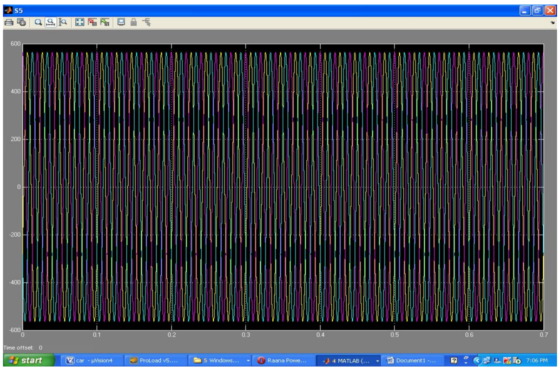
Neural network functional block set



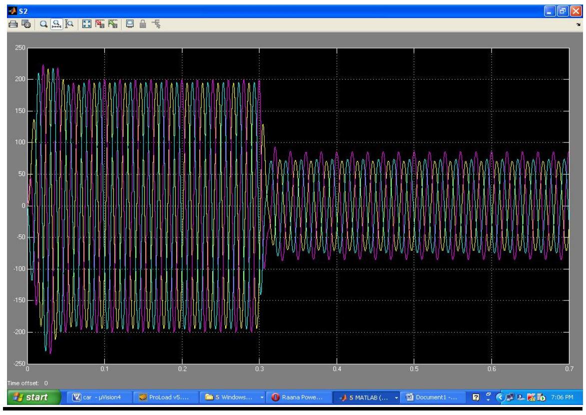


Simulation Waveforms

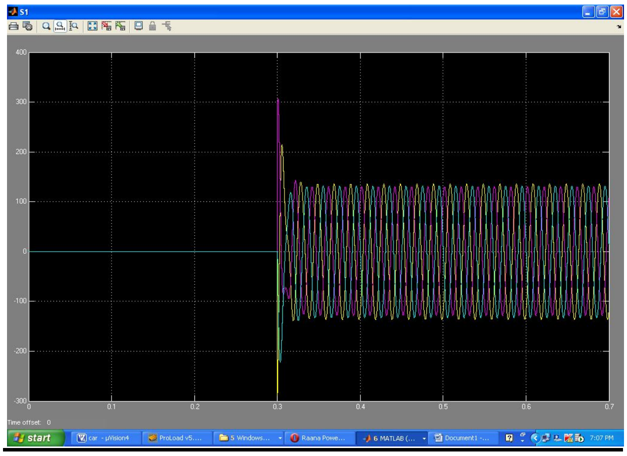
Input Waveform



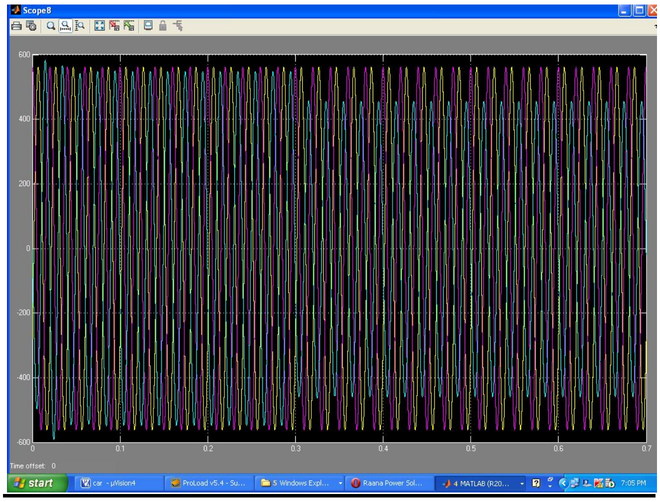
OCCURANCE of Sag



Over Load Output



Output



Conclusion

This paper presents the dynamic modeling and control of hybrid FC/energy-storage DG system under different operating conditions. For this purpose, complete model of Hybrid PCS is presented, and then by designing control strategy for each component, the power control problem of the proposed system is studied under unbalanced voltage sag. Simulation results show that the proposed control strategy is able to tolerate under various voltage sags and keep the system performances like active power control and stability of dc-link.

References

[1] A. Mohd, E. Ortjohann,W. Sinsukthavorn,M. Lingemann, N. Hamsic, and D. Morton, "Supervisory control and energy management of an inverterbased modular smart grid," in Proc. IEEE PSCE, 2009, pp. 1–6.

[2] B. Wojszczyk, R. Uluski, and F. Katiraei, "The role of distributed generation and energy storage in utilities of the future," in Proc. IEEE PES Gen.Meet., 2008, pp. 1–2.

[3] A. Bayod-R´ujula, "Future development of the electricity systems with distributed generation, energy," J. Energy, vol. 34, no. 3, pp. 377–383, 2009.

[4] A. Hajizadeh, L. Norum, and M. A. Golkar, "Robust power control of hybrid distributed power generation system during voltage sag," in Proc.IEEE IECON, 2009, pp. 791–797.

[5] M.H. Bollen, Understanding Power Quality Problems: Voltage Sags and Interruptions. New York: IEEE Press, 1999.

[6] A. Hajizadeh and M.A. Golkar, "Control of hybrid fuel cell/battery distributed power generation system with voltage sag ride-through capability,"

[7] G. Saccomando and J. Svensson, "Transient operation of grid connected voltage source converter under unbalanced voltage conditions," in Proc. IEEE IASA, 2001, vol. 4, pp. 2419–2424.

[8] B. Renders, W.R. Ryckaert, K. De Gussem´e, K. Stockman, and L. Vandevelde, "Improving the voltage dip immunity of converter-connected distributed generation units," Renewable Energy, vol. 33, pp. 1011–1018, 2008.

[9] K. Sahay and B. Dwivedi, "Energy storage technology for performance enhancement of power systems," *Electr. Power Qual. Util. Mag.*, vol. 4, pp. 1–12, 2009.

[10] A. Hajizadeh and M. A. Golkar, "Intelligent power management strategy of hybrid distributed generation system," *Int. J. Electr. Power Energy Syst.*, Vol. 29, pp. 783–795, 2007.