AN IMPLEMENTATION OF HYDROZEN FUEL CELL AND D-STATCOM BASED EFFICIENT AND LOW-COST GRID POWER TRANSMISSION SYSTEM

Aditi Sharma[1]
M-Tech Scholar
Central College of Engineering and Management,
Chhattisgarh, India

Rahul Verma[2]
Assistant Professor
Central College of Engineering and Management,
Chhattisgarh, India

Abstract—In our previous paper, we review the fuel cell A detailed analysis and implementation of MATLAB/SIMULINK based fuel cell generation has been modeled in this result paper. Along with this generation's topology power electronics-based flexible 3-pahse transmission system (FACTS), D-STATCOM has been introduced. The purpose of the D-STATCOM is to improve the transient stability of the fuel cell system during load availablity. Different fault case situations are tested with the model system in order to verify the effectiveness of DSTATCOM.

Keywords— Fuel Cell, Hybrid Cascaded Multilevel Inverter,Analysis

I. Introduction

Recently the problem of global warming is the matter of different countries to reduce the production of harmful gases due to electricity generation by combusting fossil fuels. Therefore, broad research and investment are already prepared for the efficient utilization of clean, renewable energy as suitable alternative energy. Between the renewable resources, wind, solar, and fuel cells are growing in quality and gain the interest of energy researches. As green renewable energy resources, wind and fuel cells have increased substitution potential for conventional fossil fuels.

In this regard, The vital hardware component of STATCOM is a bidirectional Voltage Source Converter. This device can be used for reactive power compensation, power factor correction, and also for the benefit of voltage fluctuations, swell, voltage sag, etc. For real power compensation, a power source that is capable of supplying real power should be used, and it has to be adequately large enough to provide the necessary power. The active power supplied to STATCOM is also used to compensate for losses occurring in the device. Therefore a renewable energy source such as a photovoltaic cell module is considered. Whenever a PQ problem occurs in the distribution line, STATCOM can supply active and reactive power, for the efficient mitigation of the problem, to the system bus [2]. A controller is required to control the firing pulse of the voltage source converter. Voltage and current of the system bus are supplied to the controller, and required pulses are produced and supplied to the inverter switches. Integrated distributed generation is a valid alternative solution for distributed generation. Thereby, the distribution grid is hybridizing wind energy and hydrogen fuel cells from natural gas. Newly, the generation cost of fuel cells is declined due to the industrial development of the membrane and electrolyte technology. The implementations of fuel cell technology are yet limited to hybrid electric system. Some researchers are dealing with the power system application of fuel cells and their interactions with the different system components. When such distributed generators are connected to the distribution system, it is essential to check the technical constrictions of the voltages at system buses, and power flows along system lines. Therefore, the interaction of fuel cells with wind turbine and power system components, as well as switching electronic devices, are essential to keep these constraints within their permissible levels[6-7]. The wind turbine will generally operate in normal conditions with a voltage level between 90 and 105% and frequency between 49-51 Hz. The penetrations of distributed generation may disturb these operation constraints. Therefore, the active and reactive power supplied to the distribution network should be continuously controlled to regulate the voltage and frequency of the system. Under fault conditions, the wind turbine would experience significant voltage variations. The amplitude and duration of these variations will determine whether the wind turbine should be disconnected or kept in operation during fault conditions. FACTs devices such as STATCOMs can provide the required reactive power for voltage regulation and assist wind farms to continue in supplying active power for a specific time during fault conditions [8]. The main objective of this paper is to simulate the integration of wind turbines and fuel cell stacks into the medium voltage distribution system and investigate the effect of using STATCOM to stabilize the voltage levels in the studied system. The Matlab/ Simulink software packages used to model the distribution system, including the described distributed generators.

II. Literature Review

Many FC based hybrid systems are represented so far. In [1], the authors described a hybrid system using SOFC/UC

Combination. In [9], [10], the authors proposed that the FC/UC combination is used for electric vehicle utilization and has high efficiency. An FC with a diesel engine based hybrid system is proposed in [11]. However, it is not a practical possibility in terms of cost and pollution problems. The dynamic modeling and simulation of a hybrid system consisting of FC/UC are presented in [12]. Robust Control of SOFC with UC is explained in [13], [14]. Similarly, the advantages of FC based generations are explained in [15]–[16]. This paper proposes a hybrid combination of SOFC/UC/PV arrays with a hydrogen storage system for a typical residential load grid-connected applications and the utility grid. The proposed model works under the simple Dynamic Power Control Algorithm (DPCA). The DPCA controlled the power flow and entire power management for the proposed model and handle all the energy sources, storage devices and power converters on the basis of dynamic references.

III. Fuel Cell system

The distributed generation system provides the power to load based on load demand. Power generation should be made available at all the terms and hence even during the period of non-availability of renewable energy sources like wind, hydro, etc. and non - renewable energy sources like thermal, etc. this is probable by energy storage devices, among those, Fuel Cells are widely used to meet load demand during off-grid or absents of other power supplies. The Fuel Cell (FC) is one of the most assuring sources of renewable energy by its merits to reach load demand. The advantages of using fuel cells are as follows:

(a) Fuel cells can generate electricity by using hydrogen and oxygen as fuel.

(b) The resulting performance is more as compared to an internal combustion engine.

(c) Fuel Cells are not emission any pollution.

(d) Fuel cells can have the facility of varying sizes that can be stacked together to meet the required power demand.

(e) Fuel cells are operating very silent due to no moving parts inside the stack except coiling fans.

(f) Fuel cells may give us the prospect to provide the world with sustainable electrical power.

(g) Fuel cells do not produce any hazardous waste products.

Fuel Science and technology are examining a rapid increase in both applied and fundamental studies. The advantages which are common to all fuel cell systems are it has high operating efficiency, and there are no moving parts, it has instantaneous recharge capability in comparison to batteries. SOFC operates at high temperatures around 800-1000ºC .the catalysts that are used are noble metals and raw materials. The advantage of using SOFC are that it is CO tolerant, fuel-flexible, high-quality waste heat. It also has certain disadvantages like the long start-up time, inactivity of electrolyte below 600ºC. Some of the most promising applications of SOFC are stationary power withy cogeneration, continuous power applications. The operation depends on absolute chemical equations. Here hydrogen that reacts with the oxygen to produce water which is given by

$2H_2 + O_2 = H_2O$

For extracting current the above-mentioned equation is separated into two half reaction. One of the reaction takes place at anode and other at cathode.

$H_2 + O- = H_2O + 2e^-$

$O_2 + 4e^- = 2O^=$ Electrons emitted at the anode reaction gives the necessary current and then returns towards cathode for reacting with the molecules of oxygen. 1 volt is produced by one fuel cell so depending upon the requirement of voltage we can use the no. of cells.

The fuel cell produces electricity by combing the hydrogen and oxygen, which separated using a proton conductive membrane. It results in the generation of electricity and water. The efficiency of the fuel cell is higher than the diesel engine and battery. By the outcome of the fuel cell is water; it keeps the environment cleaner. However, it operates like a battery. It can generate power as long as the fuel (hydrogen) is supplied. It consists of two electrodes and electrolyte, and the purpose of the electrolyte is to control the spontaneous combustion of hydrogen and oxygen. While the chemical reaction, the hydrogen is ionized and carries the positive charge and the electrons that are negatively charged flows. The proton exchange membrane fuel cell works with a polymer electrolyte, which is flexible and will not leak or crack. It's a thin solid membrane in the form of a permeable sheet. These cells are operated at a low temperature, so it is suitable for home and car appliances. It can operate around 80 degrees C. in this low temperature, the electrochemical reactions occur slowly, so in each electrode, a thin layer of platinum is catalyzed. The optimized angles are obtained by using the particle swarm optimization technique for reducing the harmonics in the output voltage.

IV. Dstatcom

A static synchronous compensator (STATCOM), also known as a static-synchronous condenser (STATCOM), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of energy, it can also produce active AC power. It is a member of the FACTS family of devices. It is intrinsically modular and electable. These compensators are also used to reduce voltage fluctuations.

A DSTATCOM is a shunt compensation device that provides an effective solution for reactive power compensation and voltage regulation. It comprises of a Voltage Source Converter (VSC), a DC capacitor, a coupling inductor or coupling transformer and a controller. The main function of DSTATCOM is to provide reactive power as demanded by the load. Therefore, with the help of DSTATCOM source currents are maintained at unity power factor and reactive power burden on the system gets reduced. Due to the compensation of the reactive power by DSTATCOM source has to supply only real power.

V. METHODOLOGY

Fuel Cell Systems for Telecommunication Backup Power Implementing a backup power system for a cell tower will add costs for telecom companies; however, the benefits of reliable cell service may outweigh the increased cost. The figure shows a fuel cell backup power system integrated with a cell tower. The system consists of a power generator (e.g., fuel cell stack, typically within a protective enclosure), hydrogen from renewable sources, grid power supply, electric connection to the base station, and the integration with a cell tower.
The fuel cell backup power is rated between 4 and 6 kW to cover the baseload with 40% excess capacity. The product line from fuel cell manufacturers can supply power packages from 2 to 30 kW. Fuel cell stack can be fabricated in a modular unit that is flexible to scale within a wide range. Fuel cells generate DC electricity, and their electric output can connect directly to telecom equipment from 12 V to 48 V without using a DC/AC inverter, thus reducing the system cost. The fuel cell modules are enclosed in power cabinets with formed and welded metal construction that can withstand all weather conditions (-40°C to +50°C).

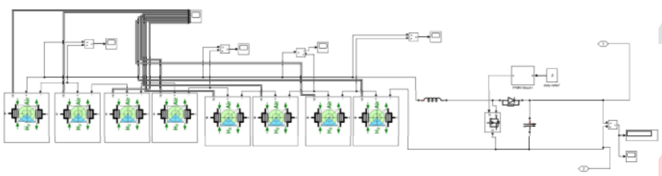

Figure 1: Fuel Cell Storage system in Distribution Network

A fuel cell is an electrochemical cell that converts a source fuel into an electrical current. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate continuously as long as the necessary reactant and oxidant flows are maintained.
The stability of the cell system will make sure the continuous power offer aboard the traditional energy sources. Fuel cells have a promising demand within the field of renewable energy. This paper described the autonomous control strategies of inverters connected in parallel, especially load share for isolated operation of a micro grid configured with various new energy generators. In the verification test, the system was isolated from the utility grid, and inverters connected in parallel deternined the micro grid bus voltage and frequency. Various new energy generators and the D-Statcom were operated synchronously.

VI. SYSTEM DESIGN AND APPROACH

MATLAB model is designed for the distribution system. The figure shows the MATLAB model for the distribution system. In this system, the three-phase ideal source is supplying power to a load. The DSTATCOM is an IGBT based three-phase voltage source converter. This converter is controlled to supply needed reactive power and harmonic current into the system. To interface DSTATCOM to the distribution system, filter inductors are used. These inductors are used to limit circulating current flowing in the system. To control the amount of power flow from DSTATCOM is designed in simulation. We connected Fuel cell (Hydrogen Cell) with DSTATCOM to maintain the impedance in source and load.

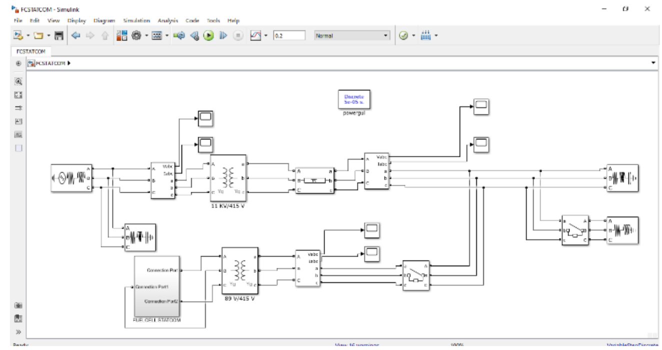

Figure 2: Simulink presentation of Fuel cell & D-Statcom based distribution network

Using invertor we generat required AC voltage form fuel cell. The inverter uses hysteresis switching and controls active power by management of direct-axis current while holding reactive power at 0MVar . The measurement blocks are rated at 50kW. Thus, an active power reference of 1pu =50kW. Ode23tb solver with the configuration parameter discrete sampled at 1e-005s is used. This model undertakes the following: The fuel cell gases are ideal ii. Only one pressure is well-defined in the interior of the electrodes iii. The fuel cell temperature is invariant. There is reverse in pressure of all the reactants after 0.4s.Due to which reactive power output of the fuel cell also increases. Simulation can be extended for dynamic study of fuel cell. After 0.4 s fuel cell able to provide the 50kw Active Power.

VII. RESULT AND DISCUSSION

The stability of the cell system will make sure the continuous power offer aboard the traditional energy sources. Fuel cells have a promising demand within the field of renewable energy. This paper described the autonomous control strategies of inverters connected in parallel, especially load share for isolated operation of a micro grid configured with various new energy generators. In the verification test, the system was isolated from the utility grid, and inverters connected in parallel deternined the micro grid bus voltage and frequency. Various new energy generators and the D-Statcom were operated synchronously.
In the distribution network in grid, we take 3-pahse input voltage for supply. In below we see the simulating graph. This is pure AC voltage.

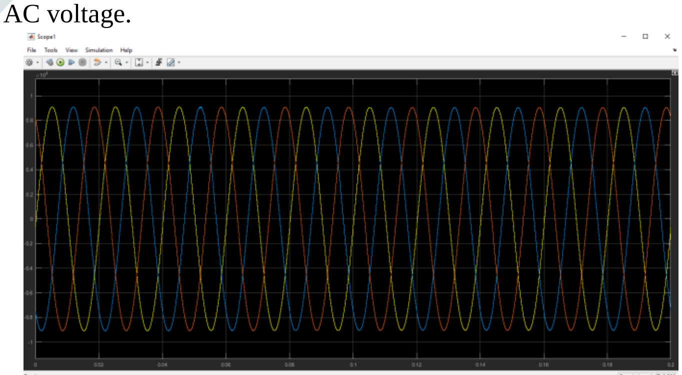

Figure :3 Source Grid Voltage graph

After connecting the sudden load without fuel cell and D-stacom we see the fluctuated variations. In below graph shows the voltage fluctuation.

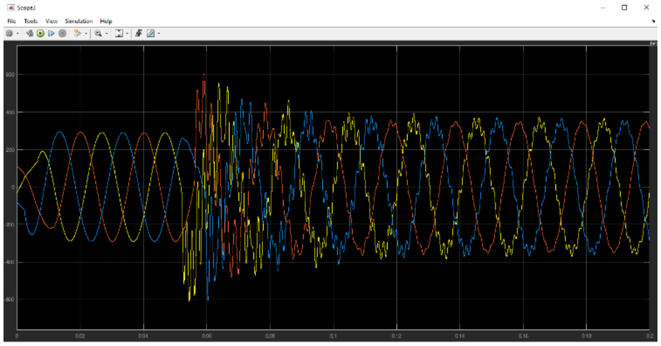

Figure 4: Load side voltage without Fuel cell and D-Statcom

After connecting the Fuel cell and D-Statcom in distribution network the fluctuation is resolved.

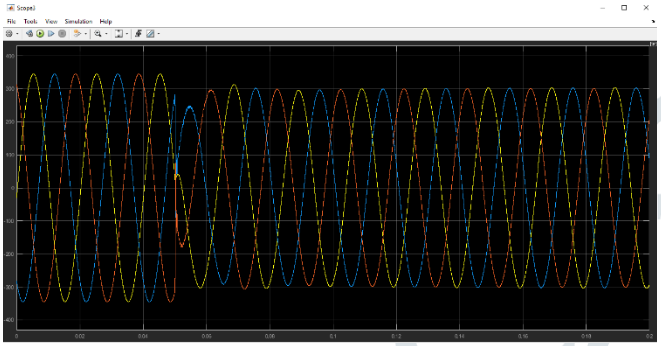

Figure 5: Load side voltage graph with fuel cell and D-statcom

Simulation activities of the proposed system are executed in MATLAB/Simulink to observe the performance of the system under various conditions such as without Fuel Cell & DSTATCOM, with Fuel Cell & DSTATCOM.

VIII. Conclusion

The design and control of a Fuel Cell & DSTATCOM have been carried out for a three-phase distribution system. A control algorithm based on correlation and cross-correlation function has been found suitable for generating the switching signals of DSTATCOM in a three-phase power system. In this project, algorithms are implemented for the operation of DSTATCOM to eliminate harmonics in source current due to non-linear load, pulse load, and reactive load. Fuel cells convert the chemical energy of a fuel and an oxidant directly into electrical power and heat using electrochemical processes—not combustion. In Fuel Cell water could be split into the hydrogen and oxygen by sending an electric current through process of electrolysis technique. Perhaps the most sincere system, a Proton are Exchange Membrane Fuel Cell (PEMFC), combines hydrogen fuel with oxygen from the air to produce electricity, water, and heat. The MATLAB simulation model is designed for all power loads, and simulated results are analyzed. This system is implemented and compared for harmonic elimination, power factor correction and tracking capability to maintain DC bus voltage. With the effect of source distortion, these three algorithms are analyzed. The next step in the research is to consider Microgrid as a system. It is essential to know more about how the sources interact with each other. More specifically, their relationship to each other needs to be defined. If all goes as anticipated and the Microgrid system is developed, the control of the order will likely be embedded within the electronics. It is possible to use specialized controllers to get a more stable response and to use each power source more efficiently. This should undoubtedly be researched and considered once the power sources interaction and relationship with each other and the mains have been defined. Other aspects that could be developed further are the original sources within the Microgrid. This could be done at two levels. The first is the consideration of other variables for each source.

IX. Acknowledgment

Expression of giving thanks is just a part of those feelings which are too large for words but shall remain as memories of beautiful people with whom I have got the pleasure of working during the completion of this work. I am grateful to Central College of Engineering and Management, Chhattisgarh, which helped me to complete my work by giving an encouraging environment. I want to express my deep and sincere gratitude to the HOD of the department and Central College of Engineering and Management, Chhattisgarh. His comprehensive knowledge and his logical way of thinking have been of great value to me. His understanding, encouraging, and personal guidance has provided a sound basis for the present work.

REFERENCES

[1] Hingorani, Narain G., Understanding FACTS : concepts and technology of flexible AC transmission systems, IEEE Press Marketing.

[2] Arindam Ghosh, Power Quality Enhancement using custom Power Devices, Kluwer Academic Publishers.

[3] H. Akagi, E. H. Watanabe, and M. Aredes, Instantaneous Power Theory and Applications to Power conditioning, Hoboken, NJ: Wiley, 2007.

[4] Kalyan K Sen, "STATCOM - STATic synchronous COMpensator: Theory, Modeling, and Applications", 0-7803-4403-0/98/ 0 1998 IEEE.

[5] Dong Ju Lee , Eun Woong Lee, Jong Han Lee , Jong Gyeum Kim,"Simulation of Static Synchronous Compensator (STATCOM)".

[6] Tariq Masood, R.K. Aggarwal, S.A. Qureshi, R.A.J Khan, "STATCOM Model against SVC Control Model Performance Analyses Technique by Matlab", International Conference on Renewable Energies and Power Quality, Granada(Spain), 23rd to 25th March,2010.

[7] Dong Shen, Wenhua Liu and Zhonghong Wang, "Study on the Operation Performance of STATCOM under Unbalanced and Distorted System Voltage", 0-7803-5935-6/00) 2000 IEEE.

[8] S.H.Hosseini and A. Ajami , "Transient stability enhancement of AC transmission system using STATCOM", Proceedngs of IEEE TENCON02.

[9] Wang Chao and Zhang Yao, "Approach on Nonlinear Control Theory for Designing STATCOM Controller", Proceedings of 2007 IEEE International Conference on Grey Systems and Intelligent Services, November 18-20, 2007, Nanjing, China.

[10] M. Tavakoli Bina, and Ashoka K. S. Bhat, "Averaging Technique for the Modeling of STATCOM and Active Filters", IEEE transaction on power electronics, vol. 23, no. 2, March 2008.

[11] Javid Akhtar, Sinto George, "Modeling and Simulation of STATCOM for a power system network using MATLAB/SIMULINK", IOSR Journal of Engineering (IOSRJEN) ISSN: 2250-3021 Volume 2, Issue 8 (August 2012), pp- 12-17.

[12] Boon Teck Ooi, Gem boos and Xiaogang Huang, "Operating principles of shunt STATCOM based on 3-level diode-clamped converters", IEEE Transaction3 on Power Delivery, Vol. 14, No. 4, Octo ber 1999.

[13] Jianye Chen, Shan Song and Zanji Wang, "Analysis and Implement of Thyristor-based STATCOM", International Conference on Power System Technology, 2006.

[14] Ghosh, Arindam and Majumder, Ritwik and Ledwich,"Power quality enhanced operation and control of a microgrid based custom power park.",7th-IEEE International Conference on Control & Automation (ICCA'09), December 9-11, 2009.

[15] K. Kawasaki, et. Al.: "Dispersed Autonomous Control for a Small Power Grid System", Proc. of the Annual Meeting ofIEE Japan No.6-006 (2005-3) [16] E. K. Sato, et. Al.: "Design of an Autonomous Control for Parallel-Connected Uninterruptible Power Supplies", IEEJ Trans. IA, Vol. 126, No.4 (2006-4)

[17] W. Fujii, T. Yokoyama : "Design of Single Phase UPS Controller for Autonomous Distributed Control based on FPGA", Proc. of the 2006 Japan Industry Applications Society Conference No.1-96 (2006-8)

[18] K. Matsuzaki, et. Al.: "Large Capacity High Performance UPS TOSNICTM-5000", Toshiba Review, Vol. 46, No.6 (1991-6) (in Japanese)

[19] Y. Yamamoto, et. AL. :"Large Capacity Parallel Redundant UPS using IGBT and Current Minor Loop", Proc. of the 1991 Japan Industry Applications Society Conference No.108 (1991) (in Japanese)

[20] J. Sumita, et. Al.: "A Study of Islanding Operation of a Microgrid Configured with Several Inverters", The Papers of Joint Technical Meeting on Power Engineering & Power Systems Engineering, IEE Japan, PE-05-114/PSE05-121, (2005-9) (in Japanese)

[21] J. Sumita, et. Al.: "A Study of Isolated Operation of s Microgrid Configured with New Energy Generators", IEEJ Trans. PE, Vol. 127, No.1 (2007-1)

[22] G. Casaravilla, F. Fnaiech, K. AI-Haddad and S. Rahmani," Adaptive linear combiners a robust neural network technique for on-line harmonic tracking," Proc. of 34lb Annual Conference of IEEE Industrial Electronics, 2008, pp.530-534.

[23] M. E. Baran and N. R. Mahajan, "DC distribution for industrial systems: Opportunities and challenges," IEEE Trans. Ind. Appl., vol. 39, no. 6, pp. 1596–1601, Nov. 2003.

[24] M. E. Ropp and S. Gonzalez, "Development of a MATLAB/simulink model of a singlephase grid-connected photovoltaic system," IEEE Trans. Energy Conv., vol. 24, no. 1, pp. 195– 202, Mar. 2009.

[25] K. H. Chao, C. J. Li, and S. H. Ho, "Modeling and fault simulation of photovoltaic generation systems using circuit-based model," in Proc. IEEE Int. Conf. Sustainable Energy Technol., Nov. 2008, pp. 290–294.