A Novel Approach on Hydrogen Fuel Cell Based Efficient and Low-Cost Grid Power System

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Abstract: ***Fuel Cells are an upcoming technology that has promise in future clean and efficient transportation. More specifically, use in conjunction with batteries in electric scooters as a hybrid system is an attractive option due to its ability to provide clean, efficient power while maintaining quick refueling times that traditional combustion engines possess. Fuel cells maximize the advantage, an intelligent control system must be developed. Additionally, regenerative braking using capacitors can also be used to allow farther range and longer battery life, especially in city environments. Thus, different topologies that utilize battery, capacitor, and fuel cell technologies with regenerative braking have been examined to find an efficient design. In this study, we using MATLAB/Simulink®, these systems can be executed, resulting in a tool to characterize both the electrical system and the overall dynamics of the scooter, aiding in the part selection, design, and simulation.***

Keywords: Fuel Cell, Hybrid Cascaded Multilevel Inverter, Analysis

1. Introduction

Recently the problem of global warming is the matter of different countries to reduce the emission 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 vehicles. 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 constraints 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 violate 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.

2. 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.

3. 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 opportunity 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.

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

$O_2 + 4e^- = 2O^{2-}$

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, and 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.

4. Proposed Methodology

The goal of the Farm Credit System management the disadvantage is to effectively regulate the chemical ingredient consolidation within the cathode by quickly and accurately replenishing chemical element consumed throughout the power generation. The options and limitations of various management configurations and consequently the impact of varied measuring on the management performance square measure examined. As an example, associate degree observability analysis recommends exploitation of the stack voltage measuring as feedback to the observer-based controller to improve the control system performance. The DSTATCOM is a custom power device connected in shunt, which can act as a variable current source, as shown in Figure 1. A VSC using high speed switching IGBT is connected to the PCC through a coupling transformer. The dc voltage at the dc bus is held by the capacitor Cdc [2]. Fuel Cell maintains the dc voltage of the Capacitor constant, and there is a real power exchanged between the fuel cell and the grid by proper control of DSTATCOM. The DSTATCOM can behave as a variable inductor or Capacitor and can compensate for the reactive power demand by the nonlinear and unbalanced load and also supports active power interaction through Fuel Cell. The DSTATCOM uses closed-loop current control to ensure the injection of desired compensating current. The dc bus voltage of DSTATCOM is supported by the Fuel Cell and varies over a narrow range due to the charging and discharging process, and dedicated dc voltage control is not necessary. The charge and discharge of the Fuel cell can be controlled by the active power controller that controls the fundamental component of DSTATCOM current, which is in phase with the PCC voltage. The quadrature component current drawn by the DSTATCOM is controlled by the PCC voltage controller. The load is modeled as unbalanced and nonlinear, which draws unstable and nonlinear current. The presence of DSTATCOM ensures that only fundamental components of the current are supplied by the source, and harmonic component is provided by the Capacitor with the support of Fuel Cell. Also, the Fuel Cell supports the source when there is an excessive load demand. Figure1 shows the schematic diagram of the integrated DSTATCOM/Fuel cell system installed at the PCC of a power transmission system through a coupling transformer. Rdcis included accounting for the switching losses of the inverter.

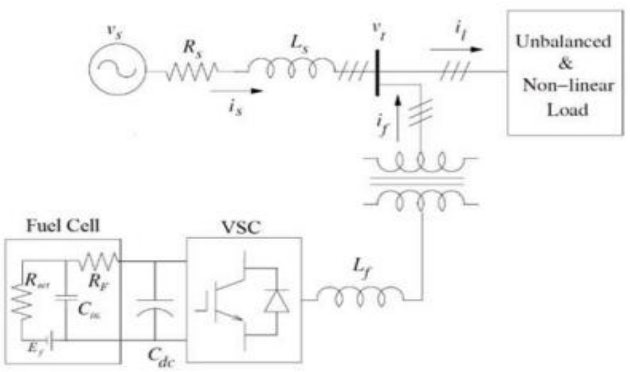

Figure 1: DSTATCOM with Fuel Cell System Diagram

The control scheme is extended to generate reference filter current for the VSC, which will be added to the PCC current such that source has equitable sinusoidal current and is in phase with the PCC voltage. The control scheme should be produced such that the injected current should have the harmonic, quadrature, negative, and zero sequence components of the load current. The DC side fuel cell voltage is variable over a narrow range depending on the charge and discharge cycle. The DC capacitor, along with parallel fuel cell, ensures minimal dc voltage outings during transient changes in operating conditions. In steady-state DSTATCOM needs to be controlled to utilize the active power of fuel cells to partially meet the active power demand of the load. The differential in-phase component of load current needs to be provided by the source.

5. Expected Outcomes

Grid-connected fuel cell will be examined and proposed a novel controller to work system with excellent power quality during all the possible conditions at the distribution point. In this paper we propose an inverter, which is used to transfer real power to the grid from fuel cell, is operating a DSTATCOM also. Hence, it can control good power quality at PCC. From these results, it can be inferred that the system with DSTATCOM regulates the voltage and power at its reference values. The great results will be presented with MATLAB/SIMULINK and satisfactory in all the conditions.

6. Conclusion

This paper propose the establishment of the cell system will make sure the constant power offer aboard the conventional energy sources. Fuel cells have an encouraging demand within the field of renewable energy. But the steadiness sweetening has been the primary concern. This stability is often performed by exploitation, totally different FACTs devices that area unit pricey stabilization schemes. This treatise shows, however, the stabilization of the cell system is usually ensured exploitation price-effective stabilization theme DSTATCOM.

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