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Power Quality Improvement of Fuel Cell Integrated With Grid System

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ABSTRACT:- This paper discusses some crucial energetic, environmental and sustainability issues and the role of fuel cell. The fuel cells are none but they are a no-conventional energy resource which enhances the overload capabilities of existing power system and makes old power system comparatively efficient technologies as one of the potential solutions to these issues. The commercialization plans in various industrialized countries for these technologies have started by identifying the most likely early markets for fuel cells as power producing devices from micro- to macro-applications, and set realistic near-term and mid-term goals for selected market penetration. The plans outline the major barriers to achieving those goals. This paper proposes a simulink model of integrated system. These systems are fuel cell and conventional generating station. The performance of integrated system improved by using the FACTS devices.

KEYWORDS: Fuel Cell,STATCOM, Energy, Integrated System .

I.INTRODUCTION

In the past, centralized power generation was promoted. The power generation units were generally built away from the populated areas but close to the sites where the fuel (i.e., fossil fuel) was available. This kept the transportation cost (of the fuel) to a minimum and eliminated the possibility of pollution in populated areas. Such schemes remained quite popular until recently despite drawbacks such as Ohmic (I_2R) losses (due to transmission of electricity through transmission lines over long distances), voltage regulation problems, power quality issues and expansion limitations. With the power demand increasing consistently, a stage has come when these centralized power generation units can be stressed no further. As a result, the focus has shifted to generation (and consumption) of electric power "locally" leading to "distributed power generation systems" feeding the micro grids. These distributed power generation systems associated with micro grids covering small areas have become popular nowadays. The pollution and global warming issues have put a stress on the importance of clean environment. Also vanishing fossil fuels have given force to the idea of local power generation by the renewable energy sources (e.g., fuel cells (FC), geothermal, tidal, pumped hydropower, wind energy, photovoltaic (Solar) cells, etc.) which may suit a particular region or remote areas and provide power at various load centers along the main power grid. Most of these sources are pollution-free and abundant. Unfortunately, they are not so reliable due to their mere dependence on the weather conditions. For example, the PV source is not available during the night hours or during cloudy conditions. Wind energy may or may not be available and is less prevalent in winter conditions. Other sources, such as fuel cells may be more reliable, but have monetary issues associated with them. Because of this, two or more renewable energy sources are required to ensure a reliable and cost effective power solution. The integration of renewable energy sources (RES) with new technologies (fuel cells and hydrogen) will lead to situations involving different equipment with different electric interfaces, opening clear paths for more suitable devices and techniques to be implemented [4]. In this paper an integrated system comprising of solar and wind energy as primary sources with fuel cells acting as a backup system has been proposed. Microgrids [2] offer the possibility of coordinating the distributed resources in a more or less decentralized way, so that they behave as a single, controlled entity. In this way, distributed resources can provide their full advantages in a consistent way. Microgrids comprise Low Voltage (LV) distribution systems with distributed energy sources, such as micro-turbines, fuel cells, PVs, etc., together with storage devices, i.e. flywheels, energy capacitors and batteries, and controllable loads, that behave as a coordinated entity, thus offering considerable control capabilities over the network operation. These systems are interconnected to the Medium Voltage Distribution network, but they can be also operated

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isolated from the main grid, in case of faults in the upstream network. Thus, Microgrids can provide network support in times of stress by relieving congestions and aiding restoration after faults. From the customer point of view, Microgrids provide thermal and electricity needs, and in addition enhance reliability, reduce emissions, improve power quality by supporting voltage and reducing voltage dips, and potentially lower costs of energy supply.

II. FUEL CELL

Although fuel cells have been around since 1839, it took 120 years until NASA demonstrated some of their potential applications in providing power during space flight. As a result of these successes, in the 1960s, industry began to recognize the commercial potential of fuel cells, but encountered technical barriers and high investment costs— fuel cells were not economically competitive with existing energy technologies. Since 1984, the Office of Transportation Technologies at the U.S. Department of Energy has been supporting research and development of fuel cell technology , and as a result, hundreds of Companies around the world are now working towards making fuel cell technology pay off. Just as in the commercialization of the electric light bulb nearly one hundred years ago, today's companies are being driven by technical, economic, and social forces such as high performance characteristics, reliability, durability, low cost, and environmental benefits.

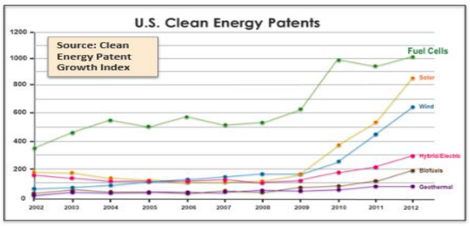

Fig.1Clean Energy Patent Growth Index

A fuel cell is like a battery in that it generates electricity from an electrochemical reaction. Both batteries and fuel cells convert chemical energy into electrical energy and also, as a by-product of this process, into heat. However, a battery holds a closed store of energy within it and once this is depleted the battery must be discarded, or recharged by using an external supply of electricity to drive the electrochemical reaction in the reverse direction.

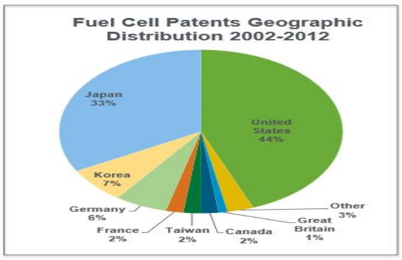

Fig.2 Fuel Cell Patents Geographic Distribution 2002-2012

A fuel cell, on the other hand, uses an external supply of chemical energy and can run indefinitely, as long as it is supplied with a source of hydrogen and a source of oxygen (usually air). The source of hydrogen is generally referred to as the fuel and this gives the fuel cell its name, although there is no combustion involved. Oxidation of the hydrogen instead takes place electrochemically in a very efficient way. During oxidation, hydrogen atoms react with oxygen atoms to form water; in the process electrons are released and flow through an external circuit as an electric current. Fuel cells can vary from tiny devices producing only a few watts of electricity, right up to large power plants producing megawatts. All fuel cells are based around a central design using two electrodes separated by a solid or liquid electrolyte that carries electrically charged particles between them. A catalyst is often used to speed up the reactions at the electrodes. Fuel cell types are generally classified according to the nature of the electrolyte they use. Each type requires particular materials and fuels and is suitable for different applications.

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III. CIRCUIT DESCRIPTION FUEL CELL

The system consists of a SOFC which is connected to a three-phase infinite bus through an IGBT inverter. The inverter uses hysteresis switching and controls active power by manipulation of direct-axis current while holding reactive power at 0VAr.The three phase output of inverter is fed to the existing power system to develop a grid.

A Distribution Static Synchronous Compensator (D-STATCOM) is used to regulate voltage on a 25-kV distribution network. Two feeders (21 km and 2 km) transmit power to loads connected at buses B2 and B3. A shunt capacitor is used for power factor correction at bus B2. The 600-V load connected to bus B3 through a 25kV/600V transformer represents a plant absorbing continuously changing currents, similar to an arc furnace, thus producing voltage flicker. The variable load current magnitude is modulated at a frequency of 5 Hz so that its apparent power varies approximately between 1 MVA and 5.2 MVA, while keeping a 0.9 lagging power factor. This load variation will allow you to observe the ability of the D-STATCOM to mitigate voltage flicker.
The D-STATCOM regulates bus B3 voltage by absorbing or generating reactive power. This reactive power transfer is done through the leakage reactance of the coupling transformer by generating a secondary voltage in phase with the primary voltage (network side). This voltage is provided by a voltage-sourced PWM inverter. When the secondary voltage is lower than the bus voltage, the D-STATCOM acts like an inductance absorbing reactive power. When the secondary voltage is higher than the bus voltage, the D-STATCOM acts like a capacitor generating reactive power.

The D-STATCOM consists of the following components:
a 25kV/1.25kV coupling transformer which ensures coupling between the PWM inverter and the network. a voltage-sourced PWM inverter consisting of two IGBT bridges. This twin inverter configuration produces fewer harmonic than a single bridge, resulting in smaller filters and improved dynamic response. In this case, the inverter modulation frequency is 28*60=1.68 kHz so that the first harmonics will be around 3.36 kHz. LC damped filters connected at the inverter output. Resistances connected in series with capacitors provide a quality factor of 40 at 60 Hz. a 10000-microfarad capacitor acting as a DC voltage source for the inverter a voltage regulator that controls voltage at bus B3 a PWM pulse generator using a modulation frequency of 1.68 kHz anti-aliasing filters used for voltage and current acquisition.

The D-STATCOM controller consists of several functional blocks:

- a Phase Locked Loop (PLL). The PLL is synchronized to the fundamental of the transformer primary voltages.
- two measurement systems. Vmeas and Imeas blocks compute the d-axis and q-axis components of the voltages and currents by executing an abc-dq transformation in the synchronous reference determined by sin(wt) and cos(wt) provided by the PLL.
- an inner current regulation loop. This loop consists of two proportional-integral (PI) controllers that control the d-axis and q-axis currents. The controllers outputs are the Vd and Vq voltages that the PWM inverter has to generate. The Vd and Vq voltages are converted into phase voltages Va, Vb, Vc which are used to synthesize the PWM voltages.
- The Iq reference comes from the outer voltage regulation loop (in automatic mode) or from a reference imposed by Qref (in manual mode). The Id reference comes from the DC-link voltage regulator. an outer voltage regulation loop.
- In automatic mode (regulated voltage), a PI controller maintains the primary voltage equal to the reference value defined in the control system dialog box. a DC voltage controller which keeps the DC link voltage constant to its nominal value (Vdc=2.4 kV).

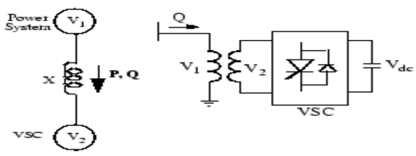

Fig.3 Circuit diagram of statcom.

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$$P = \frac{V1V2\,sin\delta}{X}$$

Where V_1 and V_2 = Line to Line voltage

X= reactance of interconnection transformer and filters.

$$\delta = angle\ of\ V1\ with\ respect\ to\ V2$$

In steady state operation, the voltage V2 generated by the VSC is in phase with V1 (δ=0), so that only reactive power is flowing (P=0). If V2 is lower than V1, Q is flowing from V1 to V2 (STATCOM is absorbing reactive power). On the reverse, if V2 is higher than V1, Q is flowing from V2 to V1 (STATCOM is generating reactive power). The amount of reactive power is given by

$$P = \frac{V1(V1 - V2)}{X}$$

A capacitor connected on the DC side of the VSC acts as a DC voltage source. In steady state the voltage V2 has to be phase shifted slightly behind V1 in order to compensate for transformer and VSC losses and to keep the capacitor charged.

IV. BLOCK DIAGRAM OF STANDALONE SYSTEM

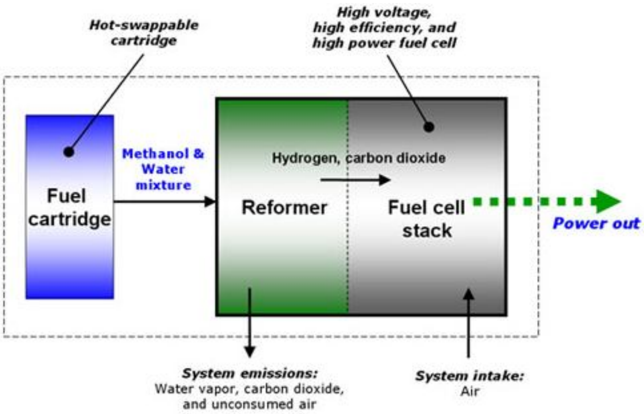

Fig.4 block diagram of fuel cell

There are many types of fuel cells, but they all consist of an anode, a cathode and an electrolyte that allows charges to move between the two sides of the fuel cell. Electrons are drawn from the anode to the cathode through an external circuit, producing direct current electricity. As the main difference among fuel cell types is the electrolyte, fuel cells are classified by the type of electrolyte they use followed by the difference in startup time ranging from 1 second for proton exchange membrane fuel cells (PEM fuel cells, or PEMFC) to 10 minutes for solid oxide fuel cells (SOFC).

V. RESULT AND DISCUSSION

The figure 5 shows the output of fuel cell. The waveform represents three phase ac voltage. This wave form also represent s the sending end voltage and output of inverter.

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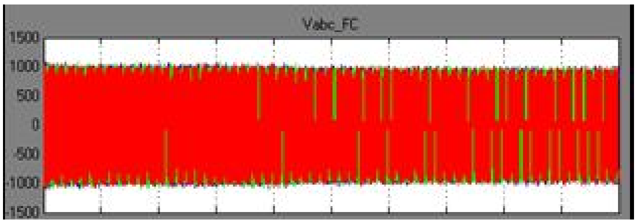

Fig.5 fuel cell three phase output voltage

Figure 6 shows the infinite bus voltage. The fuel cell generating plant is integrated with conventional power grid system.

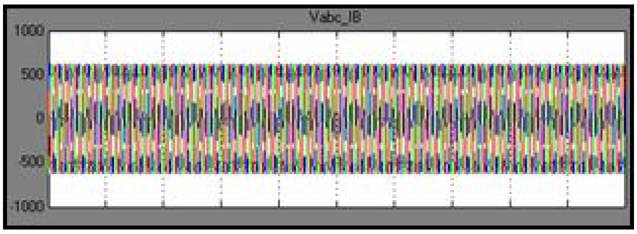

Fig.6 Infinite bus voltage.

The figure 7 shows fully regulated and compensated output at load end from figre it is concluded power qulity improved.

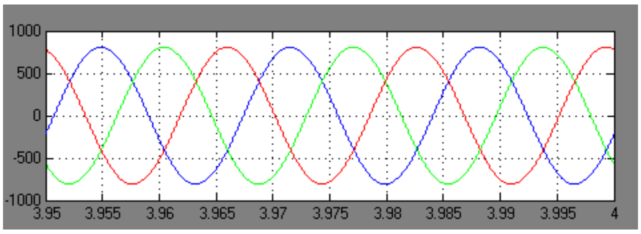

Fig.7Load side three phase AC voltage.

The above waveform represents three phase ac voltage waveform at the consumer end. It is the final output of integrated system which consists of fuel cell and convention a power plant. The power quality is improved by using D-statcom.

By using D-STATCOM the THD is reduced 76% and we get a regulated output.

VI. CONCLUSION

from above results it can be concluded that a fuel cell and conventional generating station can be integrated successfully and the performance and power quality can be improved by using FACT device like D-STATCOM.

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