COMPENSASION FOR VOTAGE SAG IN LINE TO LINE FAULT USING SILICON OXIDE FUEL CELL BASED D-STATCOM

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Abstract

This work presents a study on the use of a Non-Conventional Energy Source using Silicon Oxide Fuel Cell in shunt with a Distribution Static Compensator (D-STATCOM), where the voltages are unbalanced due to LL fault. In this paper, the growing scale of the power system and the applications of non linear load increase the complexity of the system and also make it difficult to control and results the instabilities of the systems in terms of voltage and frequency. The new system feature gives enhancement in terms of power quality, reliability and voltage sag compensation. A detail analysis has been carried out on a passive stand by SiO2- DSTATCOM. Simulations and analysis are carried out in MATLAB/SIMULINK with this control method for proposed systems. The experimental result can be easily extended to other possible system on similar lines.

Keywords: *Instabilities, Line to Line Fault, Non-Conventional Energy Source, SiO_2-DSTATCOM, Voltage Sag.*

1. INTRODUCTION

Power quality issues can be divided into short duration, long duration, and continuous categories.Electric power quality (PQ) has become the concern of utilities, end users, manufacturers, and all other customers. Power quality is the set of parameters defining the properties of power supply delivered to the users in normal operating conditions in terms of continuity of supply and characteristics of voltage (magnitude, frequency, symmetry, waveform etc.). Modern electronic equipment's and devices, such as microprocessors, microcontrollers, telecommunications equipment and sensitive computerized equipment's etc. are susceptible to PQ problems. Poor PQ has become a more important concern of both power suppliers and customers.

Application of deregulation policy in power systems results in growing attention regarding power quality issues. Although much efforts and investments are done by utilities to prevent power interruptions, it is not possible to completely control disturbances on the supply system. Many disturbances are due to normal operations such as switching loads and capacitors or faults and opening of circuit breakers to clear faults. Faults are usually caused by events outside the utility's control. These events include acts of nature such as lightning, birds flying close to power lines and getting electrocuted, and accidental acts such as stress or equipment contacting power lines [1],[2]. In industrial and commercial facilities, disturbances may be caused by the operation of arc welders and the switching of power factor capacitors and inductive loads such as motors, transformers, and lighting ballast solenoids. Moreover, fluorescent lamps, CFLs, and other devices that use power electronics such as switch-mode power supplies, television sets, light dimmers; and adjustable-speed drives can also inject harmonics into the power system [3].

In recent years, the custom power technology, the low voltage counterpart of the more widely known flexible ac transmission system (FACTS) technology, aimed at high voltage power transmission applications, has emerged as a credible solution to solve many of the problems relating to continuity of supply at the end-user level. Both the FACTS and custom power concepts are directly credited to EPRI. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications [4].

Voltage support at a load can be achieved by reactive power injection at the load point of common coupling. The concept of custom power devices is introduced few years back improves the power quality in industrial plants. Different custom power devices have been proposed, many of which are based on the Voltage Source Converter e.g. Dynamic Voltage Restorer (DVR), Static Synchronous Compensator (STATCOM), D-STATCOM.

The D-STATCOM applications are mainly for sensitive loads that may be drastically affected by fluctuations in system voltage. The functions of proposed SiO_2-DSTATCOM to compensate reactive power, absorbing harmonics and therby compensating the voltage dip[5]. The simulations in this paper are based on the Matlab/ Simulink. A SiO_2FC based D-STATCOM is implemented to mitigate Line to Line faults.

1. 1 voltage sag determination

The basis of voltage sag determination is fault analysis. With accurate information of all impedances including positive, negative and zero sequence resistances and reactances of the power components, and fault impedances, the system can be simulated to predict the sag characteristic at the node where the sensitive load is connected. To quantify sag in a radial system, the voltage divider model is shown in Fig.1.

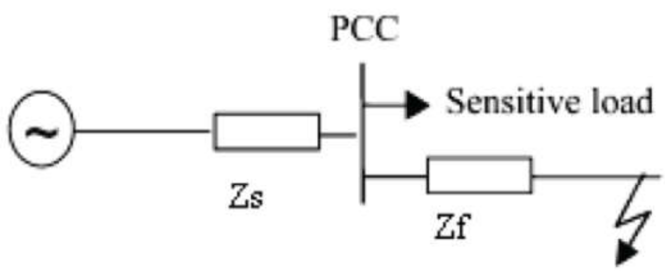

Fig.1: Voltage Divider Model

In this figure Zs is source impedance at the point of common coupling (PCC) and Zf is the impedance between PCC and the fault.

The PCC is the point from which both the fault and the load is fed. In the voltage divider model the load current before as well as during a fault is neglected. The voltage at the PCC, which is the voltage at the terminal of sensitive equipment, will be as in (equation 1)

$$\bar{V}_{sag} = \bar{E}\frac{\bar{Z}_f}{\bar{Z}_f + \bar{Z}s} \tag{1}$$

With the assumption that the pre-fault voltage is 1 pu, E=1. Now the expression of sag will be as equation 2

$$\bar{V}_{sag} = \frac{\bar{Z}_f}{\bar{Z}_f + \bar{Z}s} \tag{2}$$

Here the fault impedance is included in feeder impedance Zf.

Equation 2 can be used to calculate sag as a function of the distance to the fault

Let Zf = zl, with z as the impedance of the feeder per unit length and l as the distance between the fault and the PCC as equation 2 will be now.

$$\bar{V}_{sag} = \frac{\bar{Z}l}{\bar{Z}l + \bar{Z}s} \tag{3}$$

In the above equation Vsag, Zf, Zs and zl are complex quantities.

Form the equation (3) the magnitude of the sag voltage at PCC will be

$$V_{sag} = \frac{Zl}{Zl + Zs} \tag{4}$$

And the phase angle jump associated with voltage sag at PCC is given by

$$\Delta\phi = \arctan\frac{X_f}{R_f} - \arctan\frac{X_s + X_f}{R_s + R_f} \tag{5}$$

Where $z_f = X_f + jR_f$ and $z_s = R_s + jX_s$

Thus the phase-angle jump will be present if the X/R ratio of the source and the feeder are different. Duration of sag is determined by the fault clearing time which is considered constant for this study.

For the three phase to ground faults, i.e. balanced faults, the voltage sag (during fault voltage) will be balanced in all phases and its calculations can be carried out on a single phase basis sing positive sequence values of all parameters. But for unbalanced faults the voltage divider model has to be split into its three components: a positive-sequence network, a negative-sequence network and a zero sequence network. The three component networks have to be connected into equivalent circuits at the fault position. The connection of the component networks depends on the fault type [2].

1.2 Custom power devices

Custom power is a strategy, which is intended principally to convene the requirement of industrial and commercial consumers. The concept of the custom power is tools of application of power electronics controller devices into power distribution system to supply quality of power, demanded by the sensitive users. These power electronics controller devices are also called custom power devices because through these valuable powers is applied to the customers. They have good performance at medium distribution levels and most are available as commercial products. For the generation of custom power devices VSI is generally used, due to self-supporting of dc bus voltage with a large dc capacitor. The custom power devices are mainly divided into two groups: network reconfiguring type and compensating type.

1.1.1 Use of Custom Power Devices to Improve Power Quality

In order to overcome the problems such as the ones mentioned above, the concept of custom power devices is introduced recently; custom power is a strategy, which is designed primarily to meet the requirements of industrial and commercial customer. The concept of custom power is to use power electronic or static controllers in the medium voltage distribution system aiming to supply reliable and high quality power to sensitive users. Power electronic valves are the basis of those custom power devices such as the static transfer switch, active filters and converter -based devices. Converter based power electronics devices can be divided in to two groups: shunt-connected and series-connected devices. The shunt connected devices is known as the D-STATCOM and the series device is known as the Static Series Compensator For lower voltage sags, the load voltage magnitude can be corrected by injecting only reactive power into the system. However, for higher voltage sags, injection of active power, in addition to reactive power, is essential to correct the voltage magnitude. Both DVR and D-STATCOM are capable of generating or absorbing reactive power but the active power injection of the device must be provided by an external energy source or energy storage system. The response time of both DVR and D-STATCOM is very short and is limited by the power electronics devices. The expected response time is about25 ms, and which is much less than some of the traditional methods of voltage correction such as tap changing transformers [6-10].

2. SOFC Based D-STATCOM Test Systems

Electrical circuit model of SOFC Based D-STATCOM test system is shown in Fig.2 [11]. MATLAB/Simulation diagram of the test system is shown in Fig.3. This system comprises of 11 kV, 50 Hz generator, feeding distribution line (usually known as feeder) through a 3-winding transformer connected in Y/Δ/Δ, 11/132/11 kV. System parameters for this model are listed in Table 1.

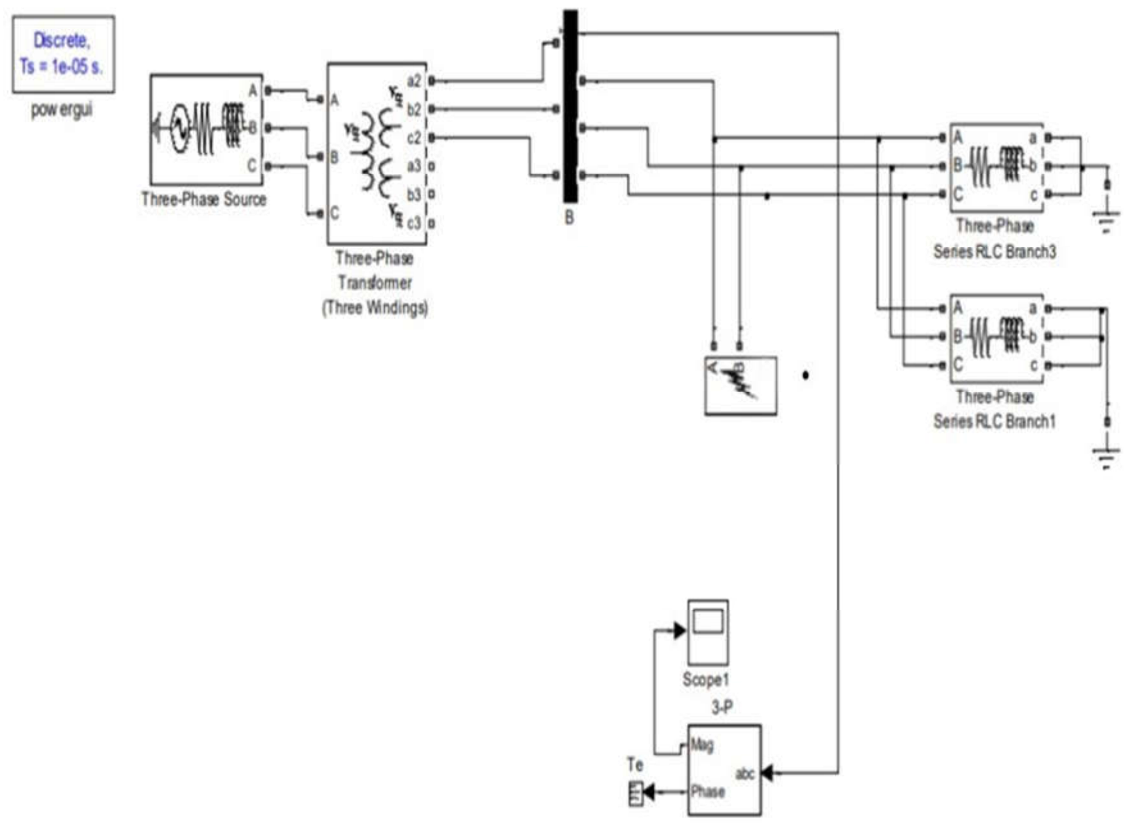

Fig.2: Test system for voltage Sag Without DSTATCOM

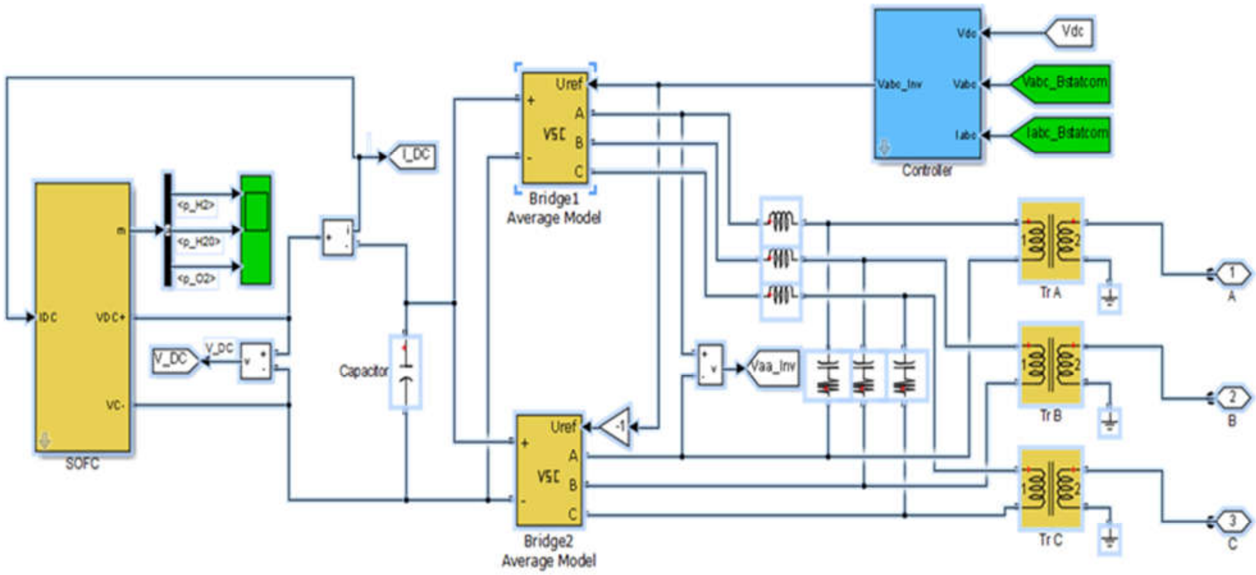

Fig.3: A SOFC Based D-STATCOM Model

Table 1: D-STATCOM Test System Parameters

System Quantities	Standards
Inverter Specifications	IGBT based, 3 arms, 6 Pulse, Carrier Frequency =1080 Hz, Sample Time = 5 μs
Load	R = 0.1 ohms, L = 0.1926 H
Transmission Line Parameters	R = 0.01273 (ohms/km) L = 0.9337 (mH/km) C = 12.74 (nF/km)
Transmission Line Length	6 km

2.1 Compensation of Sags with SOFC Based D-STATCOM System for Power Quality Enhancement

Detailed simulations are performed on the D-STATCOM test system using MATLAB/Simulink. System performance is analyzed for compensating voltage sag (for PQ improvement) with different fuel cell rating so as to achieve rated voltage at a given load feeder. Line to Line (LL) fault is considered to analyze the impact of fuel cell rating on sag compensation. Line to Line (LL) fault at 11 kV distribution line are discussed below:

2.2 Case 4: Line to Line (LL) Fault at 11 kV Distribution Line

The D-STATCOM is designed to compensate for voltage sag at the load side. To illustrate voltage sag compensation by the D-STATCOM, a voltage sag condition is generated by initiating a LL fault at time t = 0.4 s, the duration of the fault is 0.2 s and the sag is 26% in which case the voltage drops from 1.0 to 0.74 p.u. (11 kV=1 p.u.). In this situation, the system needs 26% of voltage from D-STATCOM to inject into the system. Transition time for the fault is considered from 0.4 s to 0.6 s. The simulation results with and without D-STATCOM compensation technique are shown in Fig.4.

Fig.4 shows that the rated 11 kV voltage is achieved in presence of the D-STATCOM fuel cell (SOFC) parameters as shown in Table 2 with capacitor rating of 750×10^{-6} F and it is also observed that in the presence of SOFC Based D-STATCOM negative sequence component is nearly zero as shown in Fig.4. The approximate fuel cell capacity is 7902 AH.

Table 2: SOFC Parameters-IV

System Quantities	Standards
Absolute Temperature ^{o}K	1273
Initial Current (A)	100
Faradays Constant (C/kmol)	96.487×10^{6}
Universal Gas Constant (J/kmol^{o}K)	8314
Ideal Standard Potential (V) for Each Cell in Volts	1.18
Number of Cells in Series	3700

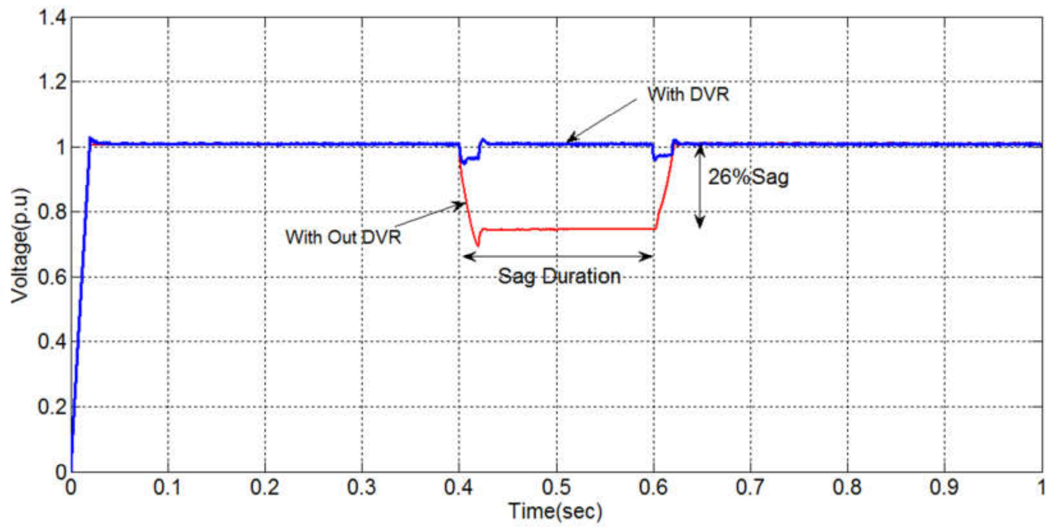

Fig.4: Voltage p.u.at the Load Point with and without SOFC Based D-STATCOM for LL Fault

4. Conclusion

This paper has presented the power quality problem such as voltage sag in Line to Line Fault. Compensation techniques of custom power electronic device with Non conventional energy source (Silicon oxide Fuel Cell) Based D-STATCOM was presented. The SOFC Based D-STATCOM is implemented with a park transformation rotating theory for mitigation of various symmetrical (3-phase faults). The VSI gate is pulsed on the basis of well known Space Vector Pulse Width Modulation (SVPWM) method. It is an advanced, computation-intensive PWM method and possibly the best among the entire PWM techniques controller scheme to control the switching operation of the inverter. A new proposed SOFC Based D-STATCOM has been simulated on various Line to Line fault. It is observed that the proposed method can correctly compensate the voltage sag with high degree of accuracy and reliability. For modeling and simulation of a DSTATCOM by using the highly developed graphic facilities available in MATLAB/SIMULINK were used. The simulations carried out here showed that the SOFC Based DSTATCOM provides relatively better voltage regulation capabilities.

4. References

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