Identification and Elimination of Faults Occurrence in sub-systems by using Resistance Switching for Linear Loads through Distribution Statcom (D-STATCOM)

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Abstract

This Paper presents the orientation procedure for diagnosing the power quality problems in different fault occurring conditions by using Distribution STATCOM (D-STATCOM) with linear loads. Here the resistance switching is used to get the pure sinusoidal voltage compensation. This modelling and simulation of D-STATCOM is achieved by using pure sinusoidal Pulse Width Modulation Technique. The major problem is that, during fault conditions there is a probable disturbance in the load side and this problem is diagnosing by utilizing the D-STATCOM at load side, as well as in between source and load. This custom power device is an effective and efficient is used in major portion of power distribution networks. D-STATCOM injects a reactive power to correct the fault conditions at end users. Here the SPWM Technique helps to keep controlling the Voltage Source Converter (VSC).The overall proposed topology is modeled and simulated.

Keywords: *Distribution STATCOM (D- STATCOM), Fault Conditions, Linear Loads, Resistance Switching, Sinusoidal Pulse Width Modulation (SPWM) Technique, Voltage Source Converter (VSC)*

1. Introduction

The modern devices are mostly made by the electronic based equipment and some programmable devices. Mostly the electronic devices are less tolerant to power quality problems, and highly effective and efficient such as fault conditions. Reasonably, these problems are related to incremental and detrimental changes in voltage levels of the sinusoidal wave forms at load side [1]. At fault conditions the voltage levels are disturbed and deviated effectively can be achieved by injection of reactive power at the common coupling of the load. D-STATCOM injects a shunt current to correct the fault condition. Here the custom power device is connected in series or parallel to the digital controlled device for modifying the fault conditions [8]. The fast response of D-STATCOM makes it efficient solution for improving the power quality in distribution system. A D-STATCOM basically VSC based FACTS controller sharing many similar concept with that of STATCOM used at transmission level. The main application of STATCOM is D-STATCOM exhibit high speed control of reactive power to provide voltage stabilization in power system [3]. The D-STATCOM protect the distribution system from voltage sags, flicker caused by reactive current demand. Effectively, this proposal explains one of the major problems at the distribution or load side can be identified as a fault. By using D-STATCOM may diagnoses these problems like unaltered currents occurring at loads side can be compensated as a proper currents. This topology initiated the difference between the faults occurring in linear and non-linear loads are identified and eliminated by D-STATCOM to enhance the power quality [5].

2. Power Quality Problems

Recently the most power quality problems are due to fault conditions at different loads like linear and non-linear loads. Effectively, a power voltage spike can damage valuable components. Power quality problems encompass a wide range of disturbances such as voltage sags, swells, flickers, harmonic distortion, impulse transients, and interruptions. Power system faults are categorized into open-conductor faults and short circuit faults .Open-conductor fault which is nothing but at blowing of fuse or burning of a jumper conductor in that phase [1]. The common types of short circuit faults occurring in a Power System are line to ground faults and line to line faults, double line to ground faults and three-phase faults. In 11KV distribution systems most of them are line-earth or often open-conductor with fuse blow (*i.e.*, conductor in that phase opens), remaining account for the rest. When any of the above fault occurs in the system it creates the voltage drop in the other feeders connected to the system.

2.1. Sources of Power Quality Problems due to System Faults

i. High currents and large drop in lines are due to lightly inductive loads leads to different faults in system.
ii. Short Circuits in Sub Systems are due to the combination of resistive combining with capacitive or resistive combining with inductive loads and in some special cases transients in power systems will be produced due to short circuit faults in sub systems [3].

2.2. Effects of Faults on Power Quality

The improvement of power quality during faults can be achieved in several different ways. Like any other problem that has to be solved, we need first to understand the nature of the problem and its effect on sensitive users. The most common short circuit faults in the system – single-phase to ground faults – are characterized by the fact that they introduce a voltage sag in the faulted phase, and at the same time they result in a voltage swell in the two healthy phases. In the case of two or three-phase faults is quite different. For three-phase faults all phases experience a voltage sag, while for a two-phase fault - the two faulted phases will have lower voltages, with the healthy phase without a significant change compared to the pre-fault levels [7]. Another factor to be considered in the analysis of short circuit faults is the automatic reclosing. The difference there is that when the fault is on the transmission system or on a distribution feeder, all loads are exposed to voltage sag during the duration of the fault. As soon as the fault is cleared, all loads, except the ones connected to the faulted circuit, will have their voltage go back to normal. At the same time during the reclosing interval the loads connected to the faulted line will experience a voltage interruption [1].

3. Distribution Statcom (D-Statcom)

A D-STATCOM (Distribution Static Compensator), which is shown in Figure 1 consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages.

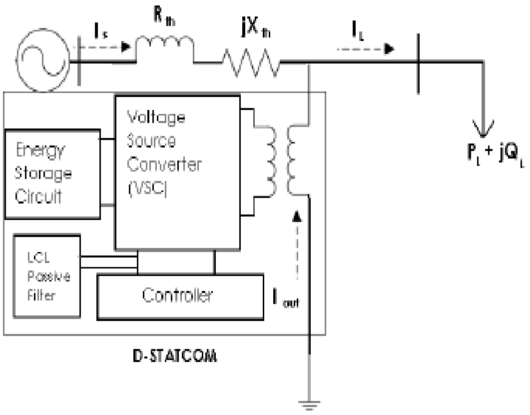


Figure 1. Schematic Representation of D-STATCOM with Linear Load

These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter. In this paper D-STATCOM used to regulate the current and voltage where the fault is occurring. The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

a) Voltage regulation and compensation of reactive power;
b) Correction of power factor; and
c) Elimination of current harmonics.

3.1. Mathematical Modeling

DSTATCOM is a shunt device which hast the capability to inject or absorb both active and reactive current. The reactive power output of a D-STATCOM is proportional to the system voltage rather than the square of the system voltage, as in a capacitor. This makes DSTATCOM more suitable rather than using capacitors [2]. Though storing energy is a problem for long term basis, considering real power compensation for voltage control is not an ideal case. So most of the operations are considered steady state only and the power exchange in such a condition is reactive [3]. To realize such a model, it can be said that a DSTATCOM consists of a small DC capacitor and a voltage source converter.

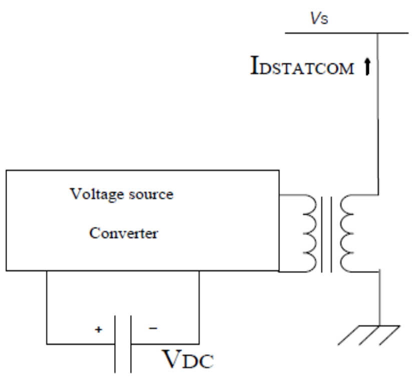


Figure 2. Diagrametic Representation of Modeling of D-STATCOM

3.2. Governing Equations of D-STATCOM

From the injected shunt current component I_{OUT} correct the faults by adjusting the impedance component $Z_{TH}= (R_{TH}+JX_{TH})$. The value of I_{OUT} controlled by the converter output voltage [1],

The injected shunt current component I_{OUT} can be written as follows.

$I_{OUT} = I_L - I_S$…… …… .. (1)

Where

$I_S = (V_{TH} - V_L)/Z_{TH}$………… … (2)

$I_{OUT} = I_L - I_S = I_L - \{(V_{TH} - V_L)/Z_{TH}\}$ ……………. (3)

The complex power injection expressed by the D-STATCOM is given by

$S_{OUT} = V_L I_{OUT}^*$ ……… … (4)

The above equation expressed as the effectiveness of the D-STATCOM in the elimination of fault condition depending up on the value of the Z_{TH} .Similarly when the injection of the I_{OUT}, the load voltage V_L will be minimized and if there exisists a low value of reactive current injection the total complex power at the fault decreases. So, in order to increase the voltage level during fault condition, injection of shunt component I_{OUT} should be must and Z_{TH} should be minimized.

3.4. Voltage Source Converter (VSC)

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. The VSC is used to either completely replace the voltage or to inject the ‘missing voltage’. The ‘missing voltage’ is the difference between the nominal and the actual voltages. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage sag/swell mitigation, but also for other power quality issues, *e.g.*, flicker and harmonics. By implementing the VSC in our proposed topology, we can get the pure voltage at sub systems and the reactive power injection will be in proper manner [9].

4. Sinusoidal Pulse Width Modulation (SPWM)

The main purpose of the control strategy is to maintain the constant voltage magnitude from point to point of sensitive load which connected under disturbance. This will measure the voltage at load point and the voltage source converter switching yields that there may be a good response in non-linear load [12].

4.1. Control Strategy

Here the PI Controller in the test system identifies the error signal and generates the required angle drive the zero. The load voltage is brought back to load rms value and the PWM Generator, the sinusoidal signal V_{ref} compared against the carrier signal in order to generate the signal operation in VSC Valves [1].
The main parameters of the PWM Generator have two important parameters, they are

i. Frequency of Carrier Signal.

ii. Modulation Index of PWM.

4.1.1. Frequency of Carrier Signal

The PWM Carrier signal generates the frequency by choosing a signal from the reference signal. This signal will provide a proper magnitude for the voltage obtained from VSC. Finally the load rms voltage will be equal to required output control voltage.

4.1.2. Modulation Index of PWM

In order to control the output voltage of VSC, the frequency of Carrier signal and V_{ref} should required. Suppose if the frequency set 300HZ then the frequency of modulation index is given as

$M.\, I_f = F_{Switching}/F_{fundamental} = 300/50 = 6$ … .. (5)

Where M.If is the frequency of modulation index.
F_s is the switching frequency.
F_f is the fundamental frequency.

In this technique, if the modulation index is improved or increases then there is slide change in output voltage and magnitude.

5. Modelling Of D-Statcom Operating With Linear Loads Using MATLAB/ Simulink

Figure 3 shows the D-STATCOM Connecting to 3 phase subsystem presented in various sections. Here the D-STATCOM is fed to linear loads with less fault resistance. Whenever a different fault condition was occurring, there is a less fault resistance presenting in system the system performance was modified by increasing fault resistance for each fault. In uneven conditions also when a Distribution STATCOM Presenting in system, load is linear in that case also the system will performed very poor. In order to increasing the performance and good damping conditions connecting the D-STATCOM and increase the fault resistance in each phase fed to linear loads.

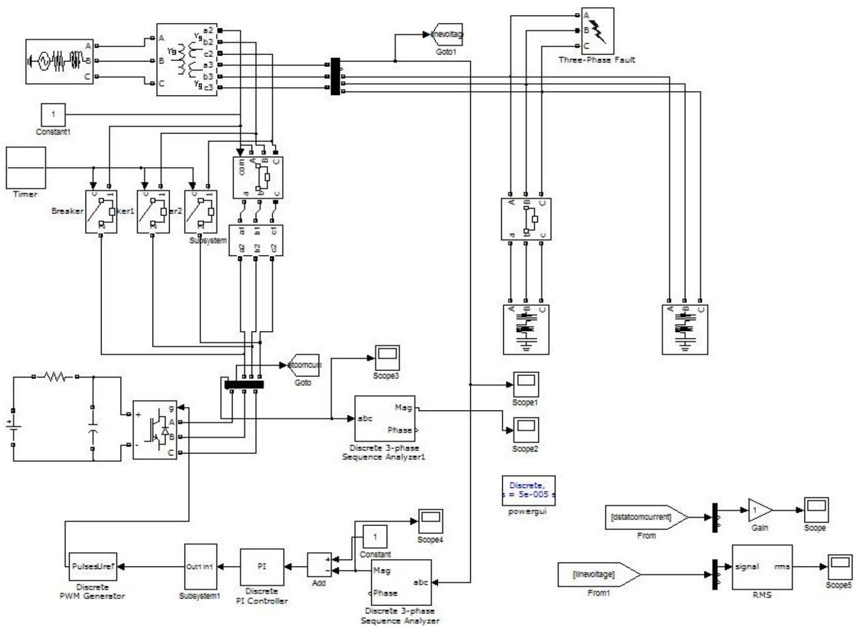
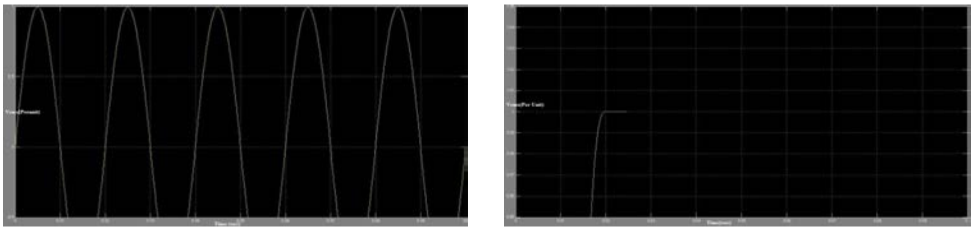


Figure 3. Simulation Diagram for Control Scheme of the D-STATCOM with Linear Load

6. Results and Discussions

i. Figure 4(a) shows a D-STATCOM rms Voltage with three phase fault applied to sub system. With fault resistance 0.66Ω during the simulating time period of 0.1sec.The System performs the fault in various conditions with linear load condition.

ii. Figure 4(b) shows a D-SATCOM rms voltage with same time and with fault resistance of 0.82Ω.Hence by increasing the fault resistance in linear load conditions the three phase-ground faults was modified.

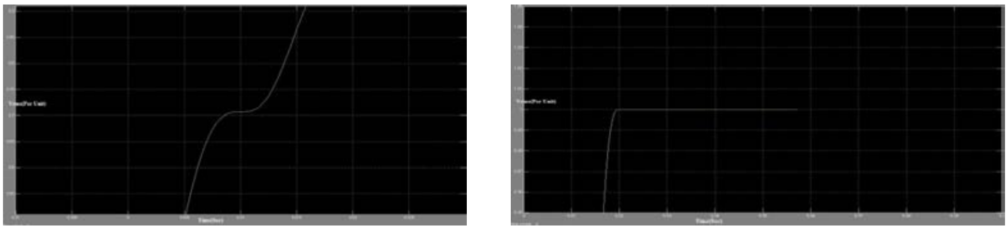


(a) (b)

Figure 4. Volatge V_{rms} through D-STATCOM Connecting to Linear Load with Three Phase-Ground Faults (a) Without Resistance Switching (b) With Resistance Switching

iii. Figure 5(a) shows a D-STATCOM rms Voltage with Line- Ground fault applied to sub system. With fault resistance 0.03Ω during the simulating time period of 0.5sec.The System performs the fault in semi-graphical condition with linear load condition.

iv. Figure 5(b) shows a D-SATCOM rms voltage with same time and with fault resistance of 0.43.Hence the fault condition was modified to linear graphical condition.

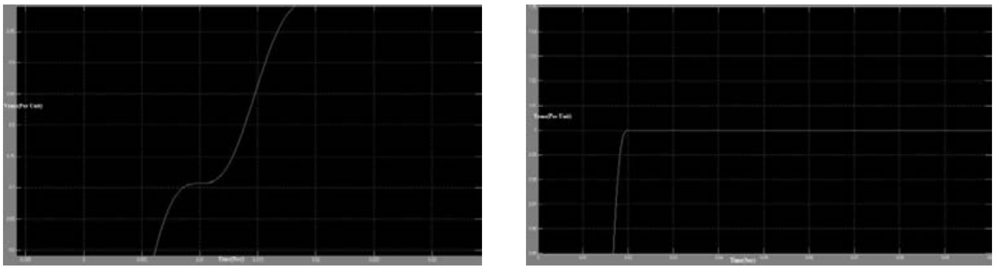


(a) (b)

Figure 5. Voltage V_{rms} through D-STATCOM Connecting to Linear Load with Line-Ground Fault
(a) Without Resistance Switching (b) With Resistance Switching

v. Figure 6(a) shows a D-STATCOM rms Voltage with Line-Line- Ground fault applied to sub system. With fault resistance 0.4Ω during the simulating time period of 0.75sec.The System performs the fault in un damped graphical condition with linear load condition.

vi. Figure 6(b) shows a D-SATCOM rms voltage with same time and with fault resistance of 0.6Ω.Hence by increasing the fault resistance in linear load conditions the Line-Line-Ground fault is modified.

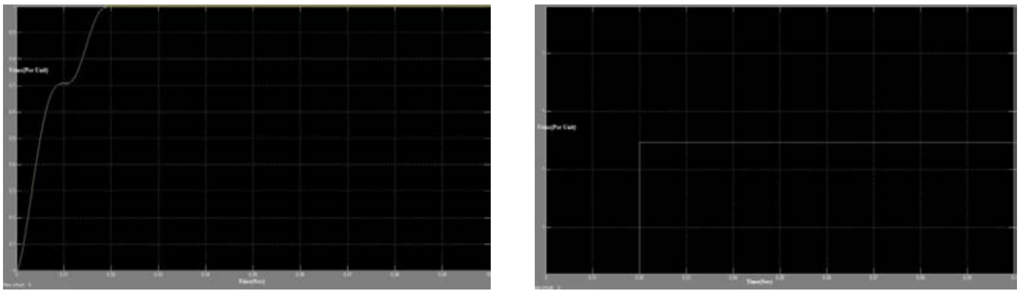


(a) (b)

Figure 6. Voltage V_{rms} through D-STATCOM Connecting to Linear Load with Line –Line-Ground Fault (a) Without Resistance Switching (b) With Resistance Switching

vii. Figure 7(a) shows a D-STATCOM rms Voltage with three phase fault applied to sub system. With fault resistance 0.8Ω during the simulating time period of 1sec.The System performs the fault like second order system performance with linear load condition.

viii. Figure 7(b) shows a D-SATCOM rms voltage with same time and with fault resistance of 1Ω.Hence by increasing the fault resistance in linear load conditions the Line-Line fault was modified.



(a) (b)

Figure 7. Voltage V_{rms} through D-STATCOM Connecting to Linear Load with Line –Line Fault
(a) Without Resistance Switching (b) With Resistance Switching.

6. Future Scope

In advance, Using D-STATCOM eliminates a faults and injecting reactive power is probable happens in sub-system of power systems. By using this topology injecting and switching a resistance parameter in Linear Load Occurrence to obtain pure sinusoidal voltage compensation was Possible. In future, by considering a resistance switching in each fault location leads to diagnosing fault immediately.

7. Conclusions

In this paper, the design and application of D-STATCOM Controlling using SPWM Technique were presented to identify the fault occurrence in each phase of sub-system. The Voltage Source Converter implemented for getting the Voltage Profiles Correction via fault conditions. This topology was investigated, simulated and developed, the identification and elimination of different fault conditions are modified by interconnecting Custom Power device with Linear Load Resistance Switching Methodology. The simulations are carried out for correction of fault condition even in synchronizing of D-STATCOM in linear load conditions due to resistance switching in advance.

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