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Design and Implementation of Flexible D-Statcom for Mitigating Power Quality Problems and Improve the Distribution System Performance

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Abstract
This paper gives a detailed information about flexible D-STATCOM, which is used to mitigate and reduces all types of faults and operate as a Distributed Generation. When the main source is disconnected it supplies power to sensitive loads and doesn't interrupt the supply power to the loads. Thus D-STATCOM operates same as a flexible D-STATCOM and hence is known as Flexible D-STATCOM. The performance of Flexible D-STATCOM system is to mitigate power quality problems and improve distribution system performance under all types of system related disturbances and system unbalanced faults, such as Line-to-Line and DLG faults under islanding condition. 12-pulse D-STATCOM configuration is utilized with IGBT which is designed and is used in determining the graphical representation of the D-STATCOM using the software PSCAD/EMTDC electromagnetic transient simulation program. The reliability and robustness of the control schemes in the system is determined by the voltage disturbances occurred by Line to line and double line to ground faults and islanded operating condition are thus verified in the results obtained in simulation.

Index Terms— D-STATCOM Voltage Sags, Distribution System, Faults, Energy Storage Systems, Islanding Condition.

I. INTRODUCTION

The electrical utilities systems for transmitting and distributing Powers are entering a sudden period of change. Their operation is due to be fine-tuned, to an unprecedented degree, by the application of power electronics, microprocessors and microelectronics in general and communications. Between these technologies will make the transmission and distribution of electricity more reliable, more controllable and more efficient.

At present many transmission facilities confront one or more limiting network parameters plus the inability to direct power flow at will. The distribution static synchronous compensator (DSTATCOM) is a facts controller, can be used Various methods have been applied to mitigate voltage sags. The conventional methods use capacitor banks, new parallel feeders, and uninterruptible power supplies (UPS). However, the power quality problems are not completely solved due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but also for a host of

other power quality solutions such as voltage stabilization, flicker suppression, power factor correction, and harmonic control. D-STATCOM is a shunt device that generates a balanced three-phase voltage or current with ability to control the magnitude and the phase angle. DG provides many benefits, such as peak shaving, fuel switching, improved power quality and reliability, increased efficiency, and improved environmental performance. There is a high demand for utility DG installations due to their advantages upgrading the distribution infrastructure. Most DG units are connected to the distribution system through a shunt nonlinear link such as a VSI or a Current Source Inverter (CSI).

There are many types of Distributed Generation. Among them are wind, biogas, fuel cells and solar cells. Generally, these sources are connected to grid through inverters and their main function is to deliver active power into the grid. The to control the real power and reactive power independently. There are many methods for reducing the faults, but due to losses in the system they are not suitable for operating. Due to less efficiency and losses occurring in the system other methods are not preferable.

A flexible D-STATCOM system designed to operate in two different modes. Initially, it can mitigate voltage sags caused by LL and DLG faults. Secondly, it can mitigate voltage sags caused by three-phase open-circuit fault by opening the three phases of a circuit-breaker and disconnecting the main power source (islanding condition). Reactive power compensation is an important issue in the control of distribution systems. Reactive current increases the distribution system losses, reduces the system power factor, shrink the active power capability and can cause large-amplitude variations in the load-side voltage.

DGs are designed to supply active power or both active and reactive power.

The new trends in power electronics converters make the implementation of such multiple functions feasible. A DG is islanded when it supplies power to some loads while the main utility source is disconnected. Islanding detection of DGs is considered as one of the most important aspects when interconnecting DGs to the distribution system. With the increasing penetration and reliance of the distribution systems on DGs, the new interface control strategies are being proposed.

This paper proposes a flexible D-STATCOM system designed to operate in two different modes. Initially, it can mitigate voltage sags caused by LL and DLG faults. Secondly, it can mitigate voltage sags caused by three-phase open-circuit fault by opening the three phases of a circuit-breaker and disconnecting the main power source (islanding condition). Reactive power compensation is an important issue in the control of distribution systems. Reactive current increases the distribution system losses, reduces the system power factor, shrink the active power capability and can cause large-amplitude variations in the load-side voltage. Various methods have been applied to mitigate voltage sags.

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The power quality problems are not completely solved due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to provide not only for voltage sag mitigation but also for a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction, and harmonic control. D-STATCOM is a shunt device that generates a balanced three-phase voltage or current with ability to control the magnitude and the phase angle.

Generally, the D-STATCOM configuration consists of a typical 12-pulse inverter arrangement, a dc energy storage device; a coupling transformer connected in shunt with ac system, and associated control circuits. The configurations that are more sophisticated use multi-pulse and/or multilevel configurations. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system of network through the reactance of the coupling transformer. In this method, Clark and Park transformations are not required.

They have been investigated voltage sag/swell mitigation due to just load variation while no balanced and unbalanced faults have been investigated. In this paper, a new control method for mitigating the load voltage sags caused by all types of fault is proposed. To detect the proportional gain of PI controller is based only on Trial and Error Method. In this paper, the proportional gain of the PI controller is fixed at a same value, for all types of faults, by tuning the transformer reactance in a suitable amount. Then the robustness and reliability of the proposed method is more than the mentioned methods.

In this method, the dc side topology of the D-STATCOM is modified for mitigating voltage distortions and the effects of system faults on the sensitive loads are investigated and the control of voltage sags are analysed and simulated.

II. PROBLEM DESCRIPTION

Power quality is certainly a major concern in the present era; it becomes especially important with the introduction of sophisticated devices. Many problems are occurring in power quality, such as Power Factor, Voltage flickering, Harmonic Distortions, Voltage Transients, Voltage Sags or Dips, Voltage Swells.

These are power quality problems in the distribution system. To improve the power quality these may be applied: Power factor correction, Transient voltage surge suppression, Special line notch filtering, proper earthing systems, Uninterruptable power supplies, Harmonic filtering and control.

Power quality is certainly a major concern in the present era, it becomes especially important with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage swells, and harmonics.

The main purpose of the coupling inductors is to filter out the current harmonic components that are generated mainly by the pulsating output voltage of the power converters. The STATCOM is connected to the power networks at a PCC, where the voltage-quality problem is a concern. All required voltages and currents are measured and are fed into the controller to be compared with the commands. In general, the VSC is represented by an ideal voltage source associated with internal loss connected to the AC power via coupling reactors. In principle, the exchange of real power and reactive power between the STATCOM and the power system can be controlled by adjusting the amplitude and phase of the converter output voltage. In the case of an ideal lossless power converter, the output voltage of the converter is controlled to be in phase with that of the power system. In this case, there is no real power circulated in the STATCOM; therefore, a real power source is not needed. To operate the STATCOM in capacitive mode or var generation, +Q, the magnitude of the converter output voltage is controlled to be greater than the voltage at the PCC. In contrast, the magnitude of the output voltage of the converter is controlled to be less than that of the power system at the PCC on order to absorb reactive power or to operate the STATCOM in inductive mode, -Q. To regulate the capacitor voltage, a small phase shift d is introduced between the converter voltage and the power system voltage. A small lag of the converter voltage with respect to the voltage at the PCC causes real power to flow from the power system to the STATCOM, while the real power is transferred from the STATCOM to the power system by controlling the converter voltage so that it leads the voltage at the PCC.

Voltage dips are considered one of the most severe disturbances to the industrial equipment Electronic equipment’s are very sensitive loads against harmonics because their control depends on either the peak value or the zero crossing of the supplied voltage, which are all influenced by the harmonic distortion. As one of the prominent power quality problems, the origin, consequences and mitigation techniques of voltage sag/swells and interruptions problem. The techniques of correcting the problems in a distribution system by strong power electronics based devices called Dynamic Voltage Restorer (DVR) and the Distribution Static Compensator (D-STATCOM). Voltage from both devices is connected into the system to correct the problems. The performance of the DVR and the D-STATCOM is studied for the power quality problems to be viewed.

Generally two types of VSC-based compensators have been commonly used for mitigation of the voltage sags and swells and regulating the load bus voltage. Those are shunt and series devices which are DSTATCOM and DVR respectively. The performance of the DSTATCOM and the DVR used for the load bus voltage control have been analyzed and compared when a nonlinear load is connected across the load bus. Both of these compensators are used under closed-loop voltage-control mode. The DSTATCOM and the DVR has been obtained for the weak and strong ac supply systems.

Thus the performance of FD-STATCOM system is to mitigate power quality problems and improve distribution system performance under all types of system related disturbances and system unbalanced faults, such as Line-to-Line (LL) and Double Line to Ground (DLG) faults and supplies power to sensitive loads under islanding condition. The 12-pulse D-STATCOM configuration with IGBT is designed and the graphic based models of the D-STATCOM are developed using the PSCAD/EMTDC electromagnetic transient simulation program. The reliability and robustness of the control schemes in the system response to the voltage disturbances caused by LL and DLG faults and islanded operating condition are obviously proved in the simulation results.

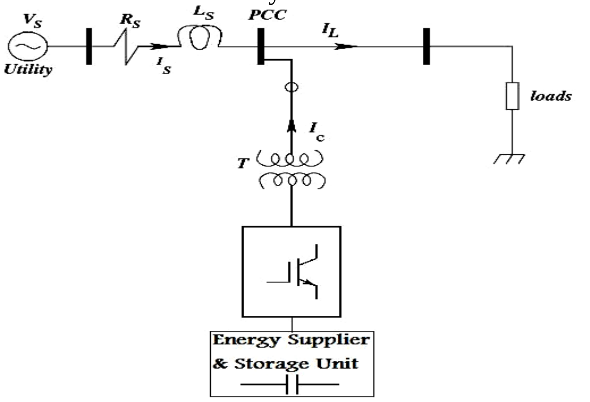
III. STRUCTURE OF FD-STATCOM:

The STATCOM is the solid-state-based power converter version of the SVC. The concept of the STATCOM was proposed by Gyugyi in 1976. Operating as a shunt-connected SVC, its capacitive or inductive output currents can be controlled independently from its connected AC bus voltage.

There are different techniques used for implementing and for mitigating faults are:
FD-STATCOM is operated by using Unified Power Flow Controller (UPFC), Insulted Gate bipolar transistor (IGBT), Super capacitor energy storage system (SCESS) Step up and step down transformer connected in Y-Y and Y-Δ connection.

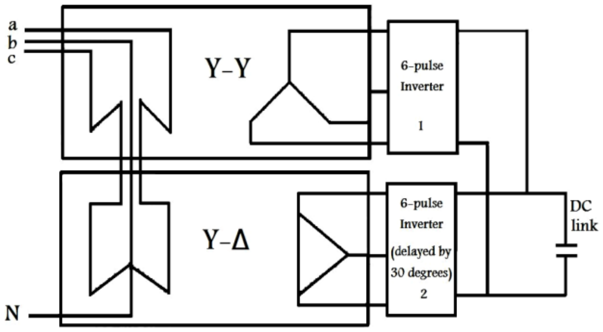
Unified Power Flow Controller

Unified Power Flow Controller (UPFC) consist from two parts, series and shunt, to manage the flow of active power from one part to the other, but FDG consist of one part only, because it has a supply of the active power from DG system.. The basic electronic block of the FD-STATCOM is the voltage source inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency. 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 FD-STATCOM output voltages allows effective control of active and reactive power exchanges between the FD-STATCOM and the ac system.



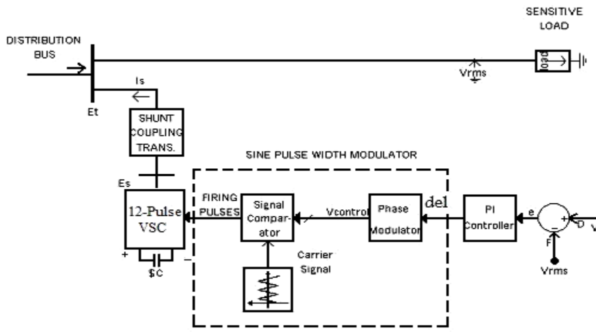
Schematic representation of the FD-STATCOM

A typical 12-pulse inverter arrangement utilizing two transformers with their primaries connected in series. The first transformer is in Y-Y connection and the second transformer is in Y-Δ connection. Each inverter operates as a 6-pulse inverter, with the Y-Δ inverter being delayed by 30 degrees with respect to the Y-Y inverter. The IGBTs of the proposed 12-pulse FD-STATCOM are connected anti parallel with diodes for commutation purposes and charging of the DC capacitor. This is to give a 30 degrees phase shift between the pulses and to reduce harmonics generated from the FD-STATCOM. The FDSTATCOM is connected in shunt to the system.



The 12-pulse FD-STATCOM arrangement

The block diagram of the control scheme designed for the FD-STATCOM is based only on measurements of the voltage VRMS at the load point.



Control scheme designed for the FD-STATCOM

The block diagram of the control scheme designed for the FD-STATCOM. It is based only on measurements of the voltage VRMS at the load point. The voltage error signal is obtained by comparing the measured VRMS voltage with a reference voltage, VRMS Ref. A PI controller processes the difference between these two signals in order to obtain the phase angle δ that is required to drive the error to zero. The angle δ is used in the PWM generator as the phase angle of the sinusoidal control signal. The switching frequency used in the sinusoidal PWM generator is fsw=1450 Hz and the modulation index is Ma ≈ 1. The modulating angle δ is applied to the PWM generators in phase A. The angles of phases B and C are shifted 120 and 240 degrees, respectively.

IV. OPERATION OF FD-STATCOM:

In order to mitigate voltage sags caused by LL and DLG faults and to supply power to sensitive load, a new method is proposed in which the FD-STATCOM and Super Capacitor Energy Storage system (SCESS) are integrated. Different types of faults may occur in distribution system, controller system must be able to mitigate any types of voltage sags. The integration and control of SCESS into a FD-STATCOM is developed to mitigate such problems, enhance power quality and improve distribution system reliability. The new method develops the control concepts of charging and discharging the SCESS by DSTATCOM, and validates the performance of an integrated DSTATCOM SCESS for improving distribution system performance under all types of system related disturbances and system faults, such as LL and DLG faults and under islanded operating condition. The SCESS is explained as following:

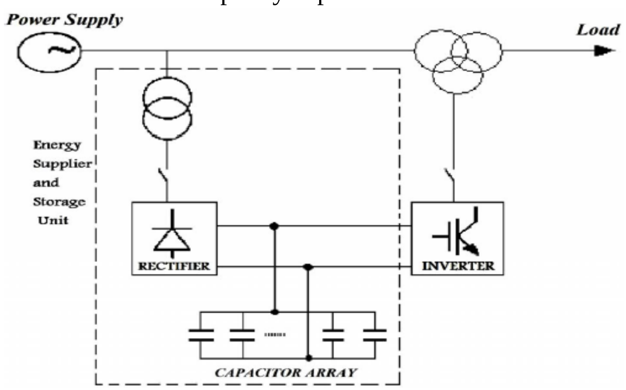
SCESS:

Super capacitor is a new energy device emerged in recent years. It is also known as double-layer capacitor. The electrical double-layer capacitor is a novel energy storage component. the super capacitor does not have electrochemical reaction and only have electric charges adsorption and desorption when it is charged and discharged. It has many merits such as high charge/discharge current, less maintenance, long life and some other perfect performance. At the same time, its small leakage current enables it has long time of energy storage and the efficiency could exceed 95%.

The structure of SCESS, Its circuit is mainly composed of three parts:
(a) Rectifier Unit
(b) Energy Storage Unit
(c) Inverter Unit.

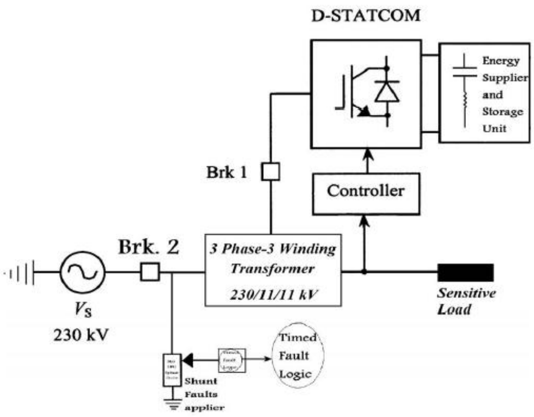
- Rectifier unit adopts three phase full bridge rectifier to charge super capacitor and supply dc power energy to inverter unit.
- Inverter unit adopts three phase voltage inverter composed of IGBTs, it connects to power grid via transformer.

When SCESS works normally, voltage at dc side is converted into ac voltage with the same frequency as power grid through IGBT inverter. When only considering fundamental frequency, SCESS can be equivalent to ac synchronizing voltage source with controllable magnitude and phase. Energy storage unit i.e. super capacitor energy storage arrays are composed of many monolithic super capacitors. If a large number of super capacitors are placed in parallel, at the same time it improves capacity of power electronics devices in power conversion system thus it can be easily composed of more large capacity SCESS, Thus the operational reliability and control flexibility will not be affected. Super capacitor is very easily modularized, when required, and it is very convenient in capacity expansion.



Structure of SCESS

SCESS based on DG connected to power grid can be divided into three function blocks: super capacitor arrays components stored energy, power energy conversion system in energy transformation and transmission, and an integrated control system. SCESS stores energy in the form of electric field energy using super capacitor arrays. At the lack of energy emergency or when energy needed, the stored energy is released through control system, rapidly and accurately compensating system active and reactive power, so as to achieve the balance of power energy and stability control. Determining the number of energy storage module can save super capacitors, and further reducing volume, quality and cost of the energy storage unit. the FD-STATCOM supplies reactive power to the system.



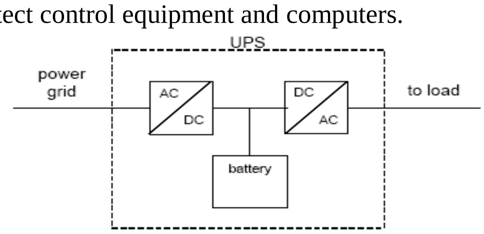
Distribution system with FD-STATCOM integrated with SCESS and controller.

Inverter based solutions:

Inverter based solutions all have in common that they are based on power electronic rectifiers, converters or inverters to help the equipment to withstand a voltage dip. Most of the solutions use some kind of energy storage.

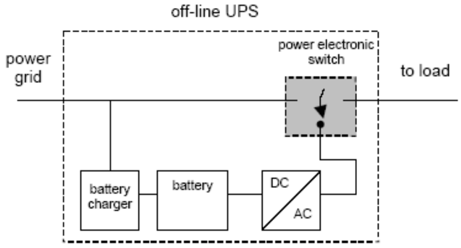
Uninterruptible Power Supply

The most common mitigation device is the UPS. The reason is the low investment, simple operation and control. It is usually connected between the network and the equipment to protect, but other configurations exist. The UPS is usually made of a diode rectifier, a battery and a converter. Other configurations with other energy sources than batteries exist, but are not as common. The UPS is used for rather limited power requirements since the cost caused by the losses in the two converters and the maintenance of the batteries are relatively high. In industrial environments UPS are normally used to protect control equipment and computers.



Example of a standard UPS

An improvement of the UPS is the off-line UPS. These units are often smaller and designed for shorter interruptions. The UPS is normally not connected to the load. Instead a power electronic switch controls the connection between the grid and the load. The total time from sensing a voltage dips and switch to the battery source is 2-4 ms in average. As soon as the utility voltage returns, the UPS switches load back and the batteries recharge.



Example of an off-line UPS.

Voltage source converters (VSC):

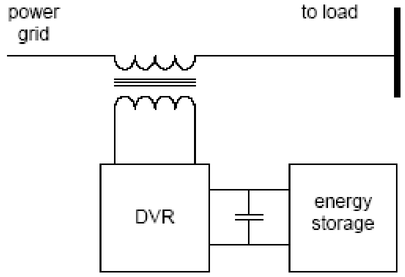
A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual.

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 dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

Series Voltage Controller [Dynamic Voltage Restorer, (DVR)]:

The series voltage controller is connected in series with the protected load. Usually the connection is made via a transformer, but configurations with direct connection via power electronics also exist. The resulting voltage at the load bus bar equals the sum of the grid voltage and the injected voltage from the DVR. The converter generates the reactive power needed while the active power is taken from the energy storage. The energy storage can be different depending on the needs of compensating. The DVR often has limitations on the depth and duration of the voltage dip that it can compensate. Therefore right sized has to be used in order to achieve the desired protection. Batteries for longer but less severe magnitude drops and super capacitors in between. There are also other combinations and configurations possible.

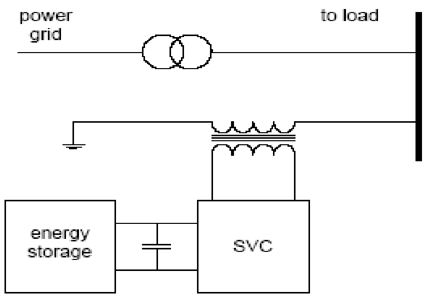
There are configurations, which can work without any energy storage, and they inject a lagging voltage with the load current. There are also different approaches on what to inject to obtain the most powerful solution. The main advantage with this method is that a single DVR can be installed to protect the whole plant (a few MVA) as well as single loads. Because of the fast switches, usually IGBT's, voltage compensation can be achieved in less than half a cycle. Disadvantages are that it is relatively expensive and it only mitigates voltage dips from outside the site. The cost of a DVR mainly depends on the power rating and the energy storage capacity.



Example of a standard configuration for a DVR.

Shunt Voltage Controller [Distribution Static Compensator (DSTATCOM)]:

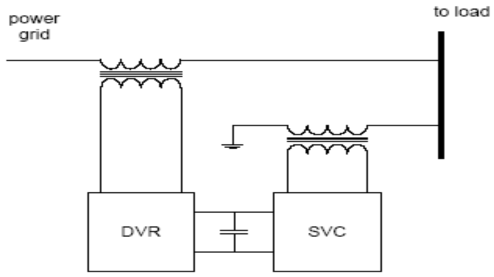
The shunt voltage controller is a voltage source converter connected in parallel with the load bus bar through a transformer or a reactor. The difference between the DVR and the SVC is that instead of injecting a voltage, the current through the reactance is controlled. The shunt voltage controller is normally used for power factor correction, voltage flicker, active filtering, etc., rather than voltage mitigation. For faults originated close to the SVC, on the same voltage level or close to the load, the impedance seen by the SVC will be very low. Since the contribution to the bus bar voltage equals the injected current multiplied by the impedance, a very high reactive current will be drawn during such a fault. Even if the SVC can be used for voltage dip mitigation purpose, it is not the better alternative compared to DVR.



Example of a standard configuration for a shunt voltage controller.

Combination of a DVR and a SVC:

A development of the voltage source converters is a combination of the DVR and the SVC. By using them together, the SVC will during a voltage dip use the remaining voltage to obtain the required energy to the DVR by taking a current from the power grid. The DVR will then inject the missing voltage as described before thus compensating the voltage dip. Using this configuration shown in figure18, no energy storage is needed except for a small capacitance to stabilize the DC-link. The main disadvantage with the SVC and large currents during faults still remains.



Combination of a DVR and SVC without energy storage.

Energy storage:

The energy required during a disturbance through voltage source converters; rectifiers, inverters, UPS, can be stored electrically, kinetically, chemically, or magnetically. These can be implemented by capacitors, flywheels, batteries or superconducting magnetic coils (SMES). The development of new storage medium results in increased capability of those devices.

Capacitors:

Capacitors can be used as energy storage to produce active power. The amount of energy stored on the capacitor is proportional to the square of the voltage. To supply a constant dc-voltage there must be a dc-dc converter to regulate the voltage, since the capacitor voltage decreases when the capacitor is discharged. Capacitors can normally be used up to a few seconds ride-through, depending on the load.

Batteries:

Batteries have a higher energy density than capacitors and supply power for a longer time than capacitors, but at a slower rate. Batteries have a few disadvantages compared to capacitors; they may contain substances, which are not environmentally friendly, a limited lifetime, and they require maintenance to operate as intended.

V. SIMULATIONS AND RESULTS

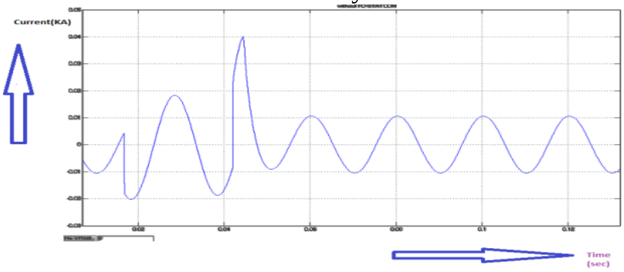
This section describes the PWM-based control scheme with reference to the D-STATCOM. The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power is a relatively low-power application. PWM methods offer a more flexible option than the fundamental frequency switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve on the efficiency of the converter, without incurring significant switching losses.

A three-phase alternator of 42.5 kVA, 50 Hz, 400V (L-L) rating feeds power to isolated distribution system. The alternator is coupled to the diesel engine with governor as prime mover. The load considered on the system represents an induction motor load. The synchronous machine output voltage and frequency are used as feedback inputs to a control system, which consists of the diesel engine with governor as well as an excitation system. The basic diagram of DSTATCOM connected as shunt compensator. It consists of a three-phase, current controlled voltage source converter (CC-VSC) and an electrolytic DC capacitor. The DC bus capacitor is used to provide a self-supporting DC bus. The test system comprises a 230 kV transmission system. A balanced load is connected to the 11 kV, secondary side of the transformer. Brk. 1 is used to control the operation period of the FD-STATCOM. A 12-pulse FD-STATCOM is connected to the tertiary winding by closing Brk. 1 at 0.2 s, for maintaining load RMS voltage at 1pu. A SCESS on the dc side provide the FD STATCOM energy storage capabilities. The simulations are carried out for both cases where the FDSTATCOM is connected to or disconnected from the system.

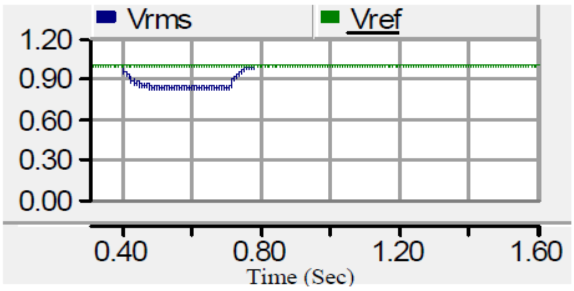
The simulations of the FD-STATCOM in fault condition are done using LL and DLG faults and under islanded operating condition. In LL and DLG faults the faulted phases are phases A and B while in islanded operating condition, three conductors open by Brk. 2 in 0.4 – 0.5 s. The duration of the islanding condition are considered for about 0.1 s and the LL and DLG faults are considered for about 0.3 s. The faults are exerted at 0.4 s. The total simulation time is 1.6 s. In this paper, the FD-STATCOM uses the proposed control method to mitigate the load voltage sags due to all types of faults. The simulations are done for all types of faults introduced in the 11kV distribution systems as follows:

Simulation results for Line-to-Line fault:

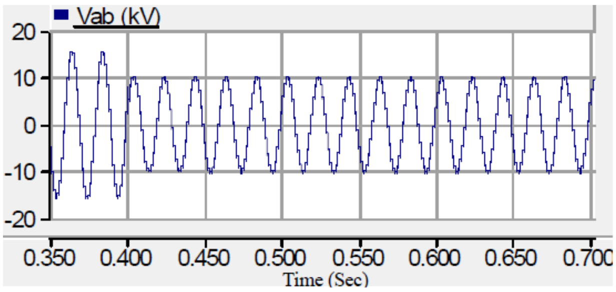
When the system operates without FD-STATCOM and under LL fault. In this case, the voltage drops by almost 20% with respect to the reference value. Int = 0.2 s, the FD-STATCOM is connected to the distribution system. The voltage drop of the sensitive load point is mitigated using the proposed control method. The mitigated RMS voltage using this new method a very effective voltage regulation is provided the RMS voltage and Vab (line voltage) at the load point in interval 0.4 - 0.7 s, respectively, for the case when the system operates without FD-STATCOM and under LL fault. The Vab frequency spectrums during mitigation of voltage sag that is presented in percent. The THD in percent for Vab in during mitigation of LL fault occurrence is 0.034%. Because of a 12-pulse FD-STATCOM STATCOM is used in this paper, and then the THD for Vab is very small.



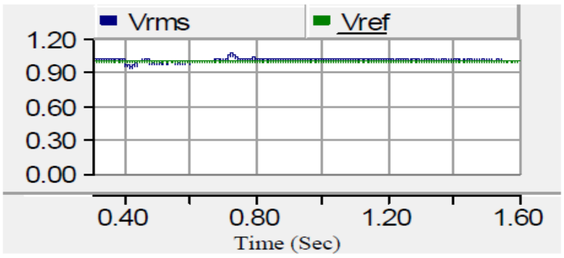
Current waveforms at PCC without FD-STATCOM



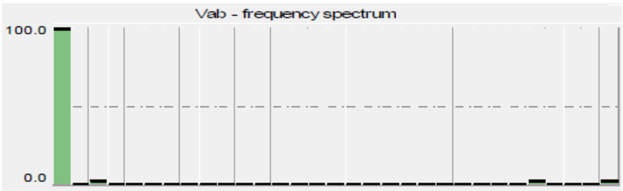
The RMS Voltage (V_{RMS}) at PCC without FD-STATCOM



Vab at PCC Without FD-STATCOM



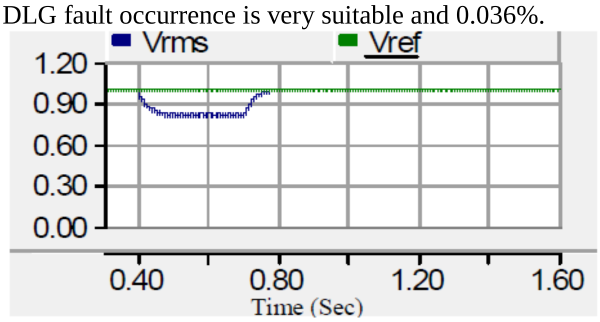
Compensated RMS Voltage under LL fault



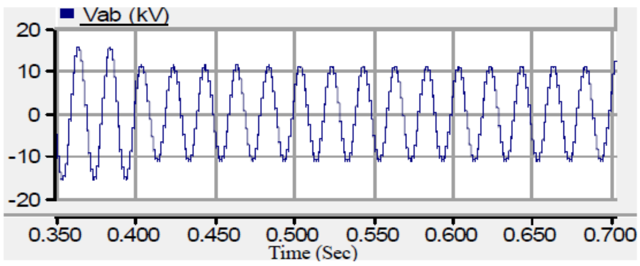
Frequency Spectrum for Vab during mitigation of L-L fault

Simulation results for Double Line to Ground fault:

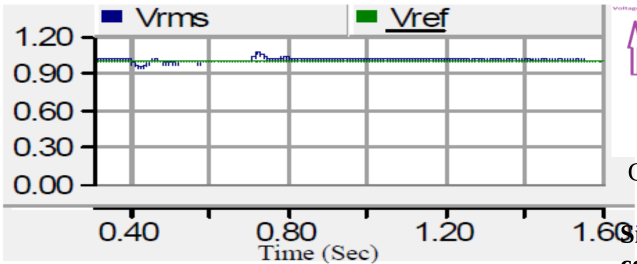
When the system operates without FD-STATCOM and unbalanced DLG fault is occurred. The RMS voltage faces with 20% decrease with respect to the reference voltage. It is observed that the proposed method has correctly mitigated voltage sag. The RMS voltage and line voltage Vab at the load point, respectively, for the case when the system operates without FD-STATCOM and unbalanced DLG fault is occurred. The RMS voltage faces with 20% decrease with respect to the reference voltage. The Vab frequency spectrums during mitigation of voltage sag. The THD of Vab in during mitigation of DLG fault occurrence is very suitable and 0.036%.



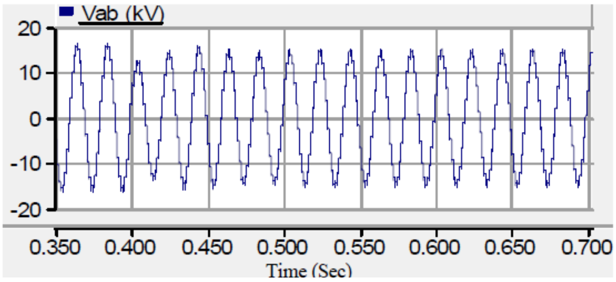
The RMS Voltage (V**RMS**) at PCC without FD-STATCOM



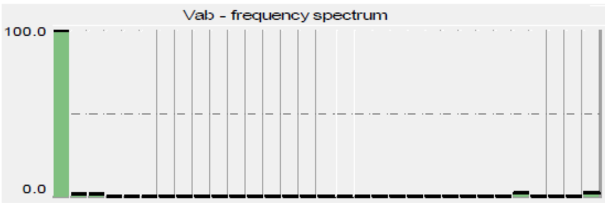
Vab Line Voltage at PCC without FD-STATCOM



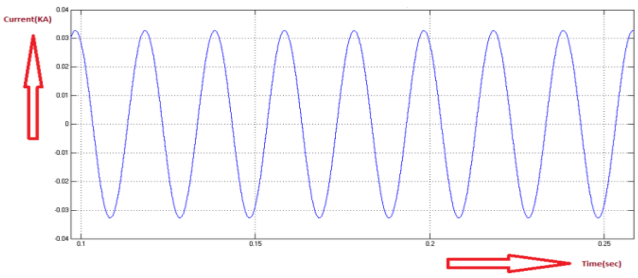
Compensated RMS Voltage



Mitigated Line Voltage Vab at the Load Point

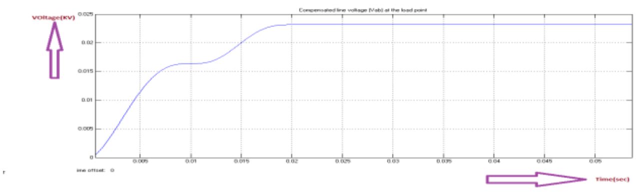


Frequency spectrum for Vab during mitigation of DLG fault

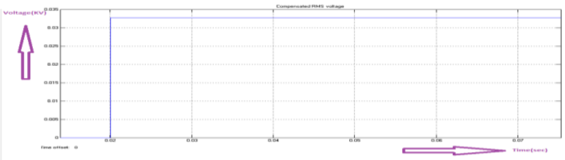


Compensated line Current (KA) at the load point

Simulation Results under islanding condition:



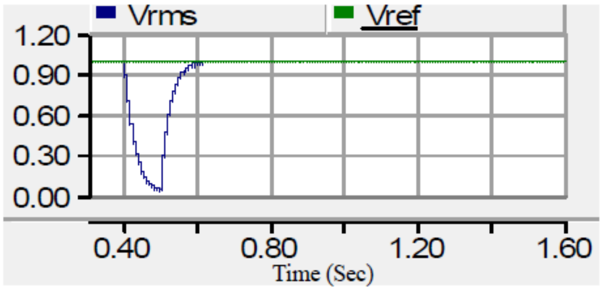
RMS voltage without using D-STATCOM



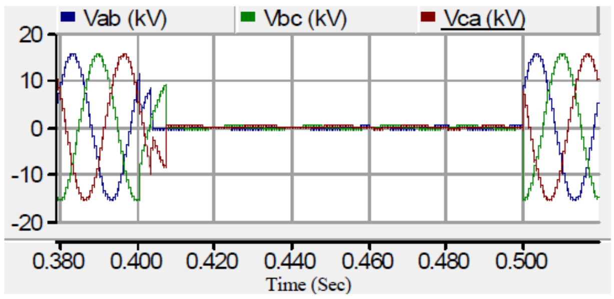
Compensated RMS Voltage by using D-STATCOM

Simulation results under islanded operating condition:

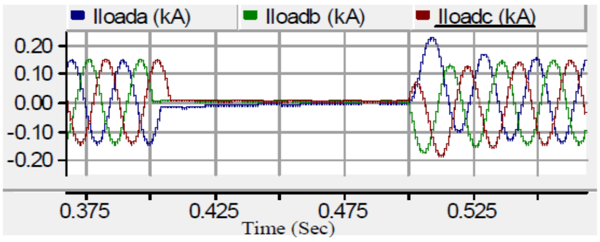
The RMS voltage, line voltages and load currents (versus kA) at the PCC, respectively, for the case when the system operates without FD-STATCOM and under islanded operating condition



V_{RMS} at PCC without FD-STATCOM under islanding condition

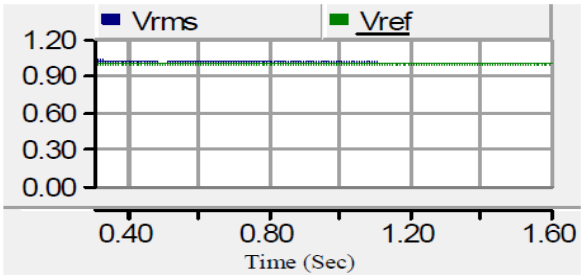


Line Voltages at PCC without FD-STATCOM

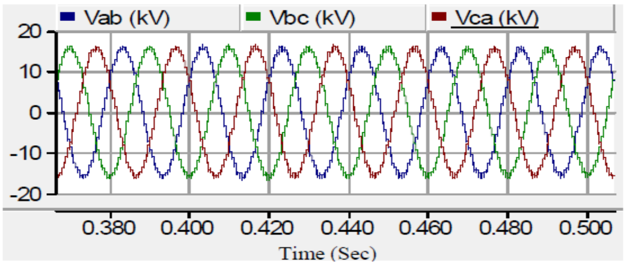


Load Currents without FD-STATCOM in islanding condition

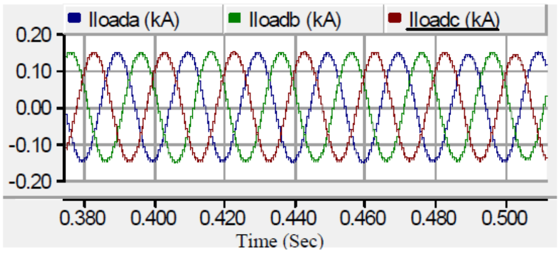
The mitigated RMS voltage, line voltages at the load point and compensated load currents, respectively, using the proposed method. It is observed that the RMS load voltage is very close to the reference value, i.e., 1pu and FD-STATCOM is able to supply power to sensitive loads, correctly. The Vab frequency spectrums during mitigation of voltage sag caused by islanding condition.



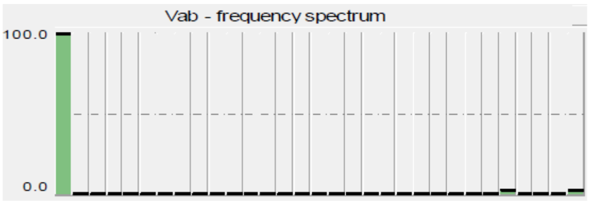
Compensated RMS voltage



Compensated line voltages at the load point



The mitigated load currents (in KA)



Frequency spectrum for Vab under islanding operating condition

VI. CONCLUSION AND FUTURE WORK

In System design document I have identified the different type of modules in my project, and illustrated different type of circuit diagrams for the modules to describe about the Statcom devices. A flexible D-STATCOM is proposed that could both mitigate unbalanced faults and operate as a DG, when it supplies power to sensitive loads while the main utility source is disconnected. As a result, D-STATCOM operates same as a FDG and consequently, it is called FD-STATCOM. In addition, this project has proposed a new control method for mitigating the voltage sags, caused by unbalanced faults and islanding condition, at the PCC. The proposed method is based on integrating FD-STATCOM and SCESS. This proposed control scheme was tested under a wide range of operating and it was observed that the proposed method is very robust in every case. In addition, the regulated VRMS voltage showed a reasonably smooth profile. It was observed that the load voltage is very close to the reference value, i.e., 1pu and the voltage sags are completely minimized.

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