An Implementation of Improved Voltage Stability VSC based D-Statcom with PV based Harmonics System

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***Abstract*—I**mproved power quality is the driving force for today's modern industry. Consumer awareness regarding reliable power supply has increased enormously in the last decade. This has led to an additional bump to the development of small distributed generation (DG). Small isolated DG sets have the proficiency to feed local loads and thus leads to improvement in the reliability of power with low capital investment. These systems are also acquisition increased importance in isolated areas where transmission using overhead conductors or cables is unrealistic or prohibitive due to high cost and other circumstances. Small generation systems in rural areas, islands, hilly terrains, marine plants, aircraft, etc. can be efficiently utilizing even in developing countries. However, these DG sets could have to be de-rated if the induction motor loads are instantaneously started. One useful choice is to use DSTATCOM in a shunt structure with the central system so that the full capacity of producing sets is efficiently utilized. DSTATCOM consists of a voltage source converter (VSC), and it internally produces the required capacitive and inductive reactive power. Its control is high-speed and has the ability to provide acceptable reactive power compensation to the system to which it is connected.

Before DSTATCOM, Thyristor based systems were proposed for reactive power compensation and were used for voltage flicker reduction due to arc furnace loads. However, due to the disadvantages of passive devices such as fixed compensation, large size, the opportunity of resonance, etc., the usage of new compensators such as DSTATCOM is growing to solve these power quality problems. The method of DSTATCOM for solving power quality problems due to voltage fall/dip, flickers, swell, etc., has been suggested. The purpose of DSTATCOM is to provide efficient voltage regulation at the point of standard coupling (PCC) and thus prevent significant voltage dips.

Keywords—Harmonic losses, DSTATCOM, Photovoltaic renewal energy source.

I. Introduction

A distribution system is an interface among bulk power and custom powers, which maintains a balance between two for the maintenance of continuous healthy operation of our system. The control of the distribution system usually means a system that is capable of enhancing the overall system efficiency by considering features like loss reduction and power quality control. In recent years, some of the distribution side equipment such as transformers, capacitor banks, synchronous machines, static volt-ampere reactive compensators (SVCs) and other compensating FACTS devices including DSTATCOM is applied for such controls. However, there are various challenges faced by the system with respect to smart-grid de-centralizing function which affects the power system, such as voltage and reactive power compensation (now known as Volt-VAR optimization), power factor correction (PF), distribution system automation (DSA), phase current balancing, low loss transformers (for efficiency improvement), small loss transformers and some energy storage facilities (at the consumer side).

For understanding power quality issues, we classify losses of distribution lines and transformers into resistive and reactive components. Among these losses, resistive losses cannot be avoided at any cost, while reactive power losses which arise from capacitive and inductive circuit properties (should cancel each other) can be avoided. But the increase in demand for reactive power at the load side increases the amount of current flowing through lines being responsible for energy losses. Distribution sides transformers often work at higher efficiency, almost 97% result negligible core losses are produced. However, total losses of transmission and distribution system together constitute 9% of the total losses from generation to the consumer's end. Another effect of significant current waveform distortion is caused because the utility supply has a finite impedance. The distorted current produces a voltage distortion due to the simple V=IR effect. This type of voltage distortion can, in turn, seriously affect other products powered from the same utility outlet. Various academic groups in the world are presently doing research into the control of DSTATCOM to remove power quality problems. In particular, with the evolution of the current wave of smart grid, many multinational electricity companies are taking an interest in DSTATCOM technologies with the hope of integrating such with the smart grid.

Objective:

The objective of this project work is to study the DSTATCOM and to improve the power quality so that it maintains Voltage magnitude close to nominal value by compensating the required amount of current to the distribution system from the storage element through DSTATCOM. The compensation resulting from the operation of the DSTATCOM is to be investigated.

II. Methodology

MATLAB model is designed for the distribution system. The figure shows the MATLAB model for the distribution system. In this system, the three-phase ideal source is supplying power to a nonlinear load. The non-linear load is indicated by a three-phase diode rectifier module connected to resistor-inductor (R-L) load. The DSTATCOM is an IGBT based three-phase voltage source converter. This converter is controlled to supply needed reactive power and harmonic current into the system. To interface DSTATCOM to the distribution system, filter inductors are used. These inductors are used to limit circulating current flowing in the system.

To control the amount of power flow from DSTATCOM is designed in simulation.

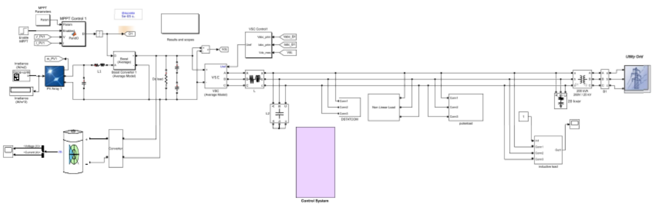


Figure 1: Simulation model for DSTATCOM for harmonic voltage reduction in hybrid grid

Solar Photovoltaic Array

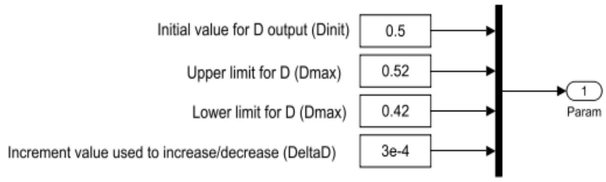
A photovoltaic array (PV system) is an interconnection of modules, which in turn is made up of multiple PV cells in series or parallel. The power generated by a single module is not sufficient to meet the requirements of industrial applications, so modules are attached to form array to supply the load. In an array, the connection of the modules is identical to that of cells in a module. The modules in a PV array are usually primarily connected in series to reach the desired voltages; the individual modules are then connected in parallel to concede the system to produce more current.
Solar Cells/ arrays have unique characteristics that cannot be imitated by any of the electrical sources. For evaluating the transient and steady-state performance of the converter, it was necessary to develop the Electromagnetic Model of the Solar arrays, which could represent the solar cell characteristics as best as possible. The solar array has two distinct regions of operation. Before the Maximum PowerPoint, it acts as a voltage source, and after the MPPT, it acts as a current source. This model has given excellent performance for various operating conditions.
We use MPPT control for MPPT measurement in this system. We use the P&O method for the MPPT measurement of solar power. The MPPT method considers to automatically find the current IMPP or voltage VMPP at which a PV array should work to obtain the maximum output power PMPP under a delivered temperature and irradiance. Most of the MPPT methods respond to variations in both irradiance and temperature, but some are precisely more useful if the temperature is approximately constant. Most MPPT methods would automatically react to differences in the array due to aging, though some are open-loop and would require periodic fine-tuning. In our context, the module will typically be combined with a power converter that can differ the current expanding from the PV array to the load.

The PV cell parameters

Module type: sun power SPR-305-WHT
Number of cells per module- 96
Number of series connected module per string-9
Number of parallel strings-40
Specifications of considered PV system under STC:
Voc = 64.2 V, Isc = 5.96 A, Vmp = 54.7 V, Imp = 5.58 A
Module parameters for one module
Rp =993.51 Ω, Tsat =1.1753 e-8°C, Iph = 5.9602 A
Qd= 1.3 J/S

Perturb and Observe Algorithm

The most commonly used MPPT algorithm is the P&O method. This algorithm uses a simple feedback preparation and little measured parameters. In this method, the module voltage is periodically given a perturbation and the conforming output power is compared with that at the preceding perturbing cycle [17]. In this algorithm, an insignificant perturbation is introduced to the system. This perturbation reasons the power of the solar module numerous. If the power increases due to the perturbation, then the perturbation is continued in the same direction. After the peak power is achieved, the potential at the MPP is zero and the next instant reductions and hence after that, the perturbation reverses.



The conventional boost converter has only one equivalent inductor and only one equivalent output capacitor. This makes the input current time-varying and full of ripples. The theory of the boost converter is well documented, and [3] & [4] are some references to the same. The proposed design is multi inductor design with a firing circuit controlled by a phase-shifting algorithm in such a way that the converter input current is held constant corresponding to the maximum power point of the solar array. The phase-shifting algorithm can be used in conjunction with any MPPT. [5] –[7] highlight some of the references which discuss the MPPT algorithms.

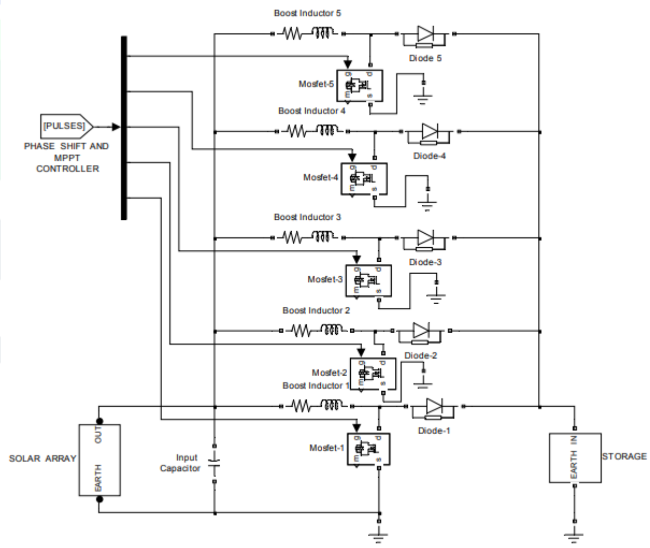


Figure 2: DC-DC Boost conveter Simulink model

Battery Storage Unit

A typical PV solar farm is basically inactive during nighttime and the bidirectional inverter used to deliver the PV DC power as three-phase AC power to the grid remains unutilized as well. The point at which the solar farm is connected to the grid is called the point of common coupling (PCC). In Figure, vS and iS represents the voltage and current at the secondary of the distribution transformer; vPCC and vL denote voltages at PCC and load terminal, respectively, and iPV is the current delivered by the PV solar panels. AC current is drawn/delivered by the solar farm inverter and the DC current flowing through the storage battery are represented by iSF and iBatt, respectively.

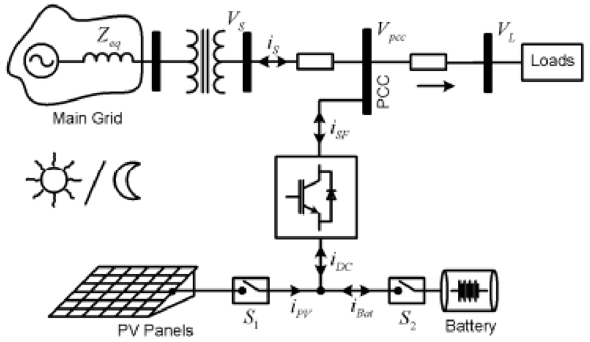


Figure 3: Battery management unit in Solar Grid

Voltage Source Regulation for Load side

The structure of detailed two-level VSC is depicted in Figure

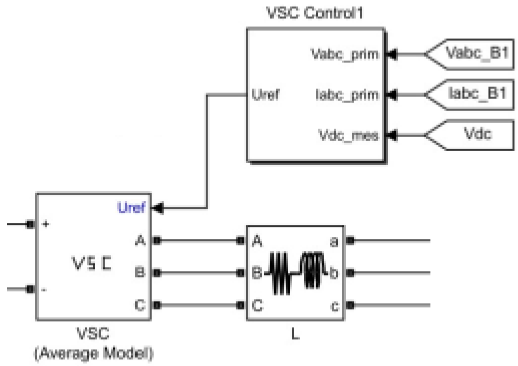


Figure 4: Structure of detailed two-level VSC

Where Us is the voltage of the AC system connected to the VSC. Uc is AC side voltage of the VSC.isa,isb, isc and ica, icb, icc refer to the three-phase current components correspond to us and uc respectively. udc, idc, idrefer to the DC voltage and current of the VSC respectively. C is the DC side capacitor of the VSC. The structure of equivalent average-value model of two-level VSC is depicted in Figure.

Configuration of Hybrid Microgrid

The HRES structure with proposed methodology is depicted in Fig. 1. The presented HRES is identified as three groups and they are connected to DC bus commonly. The first group consists of the renewable energy sources, solar PV system, which provides power to the DC bus when there is solar resources available. The second group encompasses the energy storage systems, battery, UC and FC, which offers the durable electrical energy as well as the fast dynamic power regulation. Finally, the VSI delivers the active and the reactive power to the AC load-connected, using the DC bus power. The model of renewable energy sources, energy storage devices and proposed energy management system are described in the following subsections.

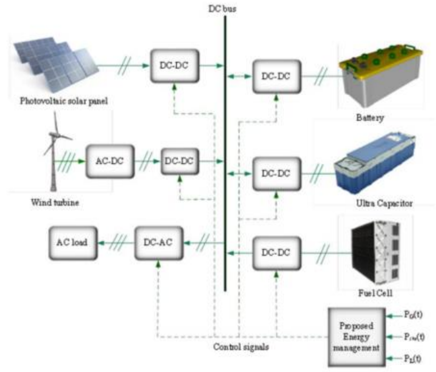


Figure 5: Structure of the HRES with proposed methodology

Different Load Section in Grid

We apply various load in distribution network and control the power balance via DSTATCOM in the system. Here we can see the simulation design for various load.

Non-Linear Load

A load is considered non-linear if its impedance changes with the applied voltage. The changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage. These nonsinusoidal currents contain harmonic currents that interact with the impedance of the power distribution system to create voltage distortion that can affect both the distribution system equipment and the loads connected to it. Times have changed. Harmonic problems are now common in not only industrial applications but in commercial buildings as well.

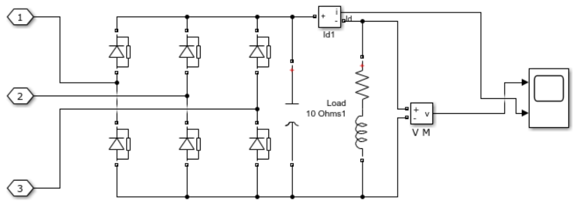


Figure 6: Non-Linear Load

Pulse Load

In this hybrid DC microgrid, rectifier, buck, boost and bidirectional converters are power electronic interfaces which are employed to be responsible for voltage conversion. Also some of these converters have to control the power injection to the grid and follow the determined reference signals by the EMS. The uncontrolled rectifiers type are used, hence Low pass filters are necessary to modify the rectifiers output voltage quality which are located between uncontrolled rectifiers and boost converters in this grid.

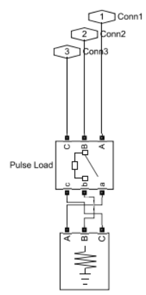


Figure 7: Pulse Power load in distribution network

Inductive Load

Inductive Loads, also called Lagging Loads or Inductive Load Banks or Inductive Reactive Loads or Power Factor Loads, are AC loads that are predominantly inductive in nature so that the alternating current lags behind the alternating voltage when the current flows into the load.

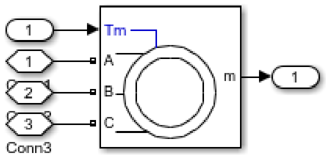


Figure 8: Inductive load in distribution network

III. DSTATCOM

The main function of DSTATCOM is to provide reactive power as demanded by the load. Therefore, with the help of DSTATCOM source currents are maintained at unity power factor and reactive power burden on the system gets reduced. Due to the compensation of the reactive power by DSTATCOM source has to supply only real power.

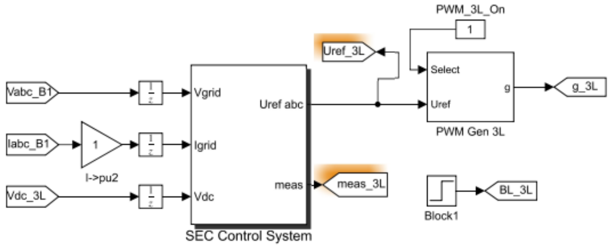
According to the IRP theory the instantaneous real and reactive powers are calculated by using these α-β co-ordinates. Load voltages where load is being connected and load currents are used to generate the reference source currents. The reference currents obtained are then fed to the hysteresis based PWM controller to obtain the pulses to be fed to the IGBT switches of the DSTATCOM.
Reference source currents are to be calculated to compensate only instantaneous reactive power theory and some part of active power drawn from source to compensate for switching losses of IGBT devices during operation of VSC.DC link Voltage controller play an vital role for maintaining constant dc link voltage. Sensed voltage of the dc link capacitor is compared with reference DC voltage and error is processed using PI controller. Output of PI controller is reference d axis component of current so it is added with active power instantaneous power for calculation of reference α-β component of source current from source instantaneous active and reactive power [3].

The performance of the DSTATCOM using IRP theory for power quality improvement in the distribution system is studied by observing waveforms of the different parameters of the system before compensation and after compensation.
A novel topology, supercapacitor supported VSC-DSTATCOM is used as a compensator to mitigate the power quality issues. Switching signals for IGBTs of VSC are generated by using instantaneous symmetrical component theory (ISCT) control technique.

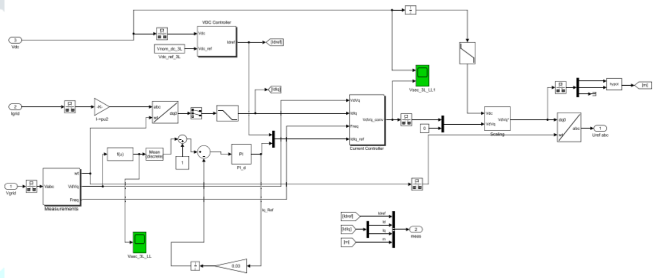
A. System Topology:-

This distribution system consists of a three phase supply and a three phase non-linear load. The proposed compensator is connected at the point of common coupling (PCC) through an interfacing impedance as shown in Fig.1. The compensator consists of an IGBT based VSC with a dc bus capacitor, a bidirectional chopper and a supercapacitor block. The supercapacitor block includes an internal series resistance (Rs) , parallel resistance (Rp) due to flow of leakage current and a supercapacitor as shown in Figurebelow.

The bi-directional chopper decides the charging and discharging of a supercapacitor. The target of the supercapacitor is to maintain the voltage across the dc bus capacitor (Cdc).



(a)



(b)

Figure 9: (a) SEC control system (b) Simulation of internal SEC system

IV. RESULT AND DISCUSSION

Simulation activities of the proposed system are executed in MATLAB/Simulink to observe the performance of the system under various conditions such as without DSTATCOM, with DSTATCOM, and a supercapacitor supported DSTATCOM. These different cases are described independently as follows:

LOADS	ACTIVE POWER	REACTIVE POWER	%THD (V)	%THD (A)
Noload	4.5e+06	-1.6e+06	0.62	9.06
inductive	-5.6e+06	-1.7e+06	0.60	8.09
Inductive &pulse	-4.5e+06	-1.4e+06	0.48	9.22
Inductive, pulse& nonlinear	-4.6e+06	-1.4e+06	0.48	9.13

Table1: Variation of loading conditions with Three-phase fault

LOADS	ACTIVE POWER	REACTIVE POWER	%THD (V)	%THD (A)
Noload	-1.2e+06	4.3e+05	3.48	110.18
inductive	-1.1e+06	4.2e+05	0.89	141.10
Inductive &pulse	-1.2e+06	4.5e+05	2.23	158.76
Inductive, pulse& nonlinear	-1.2e+06	4.4e+05	0.92	167.65

Table 2: Variation of loading conditions with three-phase fault and D-STATCOM

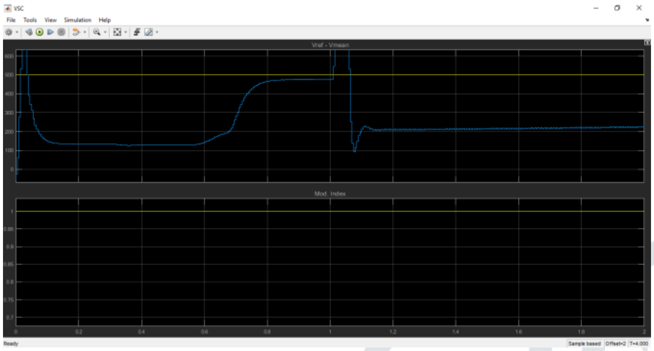


Figure 10: VSC Control Graph for Load Time

DSTATCOM has been modeled and simulated in MATLAB/Simulink environment. The operation of DSTATCOM has been investigated for non-linear load, pulse load and reactive load drive using distribution network transmission. The simulation shows the effectiveness of DSTATCOM in a distribution network. The simulation shows the performance of an inverter in compensating the reactive power when the supply voltage is not constant. The reactive current compensation is attained in no time during the increase and decrease in source voltage. The DSTATCOM responds well to the sudden change in the source voltage. The THD is also well below the IEEE standard, which reveals that the control algorithm performs well in eliminating the harmonics.

V. Conclusion

The design and control of a DSTATCOM have been carried out for a three-phase distribution system. A control algorithm based on correlation and cross-correlation function has been found suitable for generating the switching signals of DSTATCOM in a three-phase power system. In this project, algorithms are implemented for the operation of DSTATCOM to eliminate harmonics in source current due to non-linear load, pulse load, and reactive load. The MATLAB simulation model is designed for all power loads, and simulated results are analyzed. This system is implemented and compared for harmonic elimination, power factor correction and tracking capability to maintain DC bus voltage. With the effect of source distortion, these three algorithms are analyzed. The next step in the research is to consider Microgrid as a system. It is essential to know more about how the sources interact with each other. More specifically, their relationship to each other needs to be defined. If all goes as anticipated and the Microgrid system is developed, the control of the order will likely be embedded within the electronics. It is possible to use specialized controllers to get a more stable response and to use each power source more efficiently. This should undoubtedly be researched and considered once the power sources interaction and relationship with each other and the mains have been defined. Other aspects that could be developed further are the original sources within the Microgrid.

VI. Acknowledgment

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