VOLTAGE STABILITY USING STATCOM UNDER UNBALANCED VOLTAGE SAGS

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Abstract – Static synchronous compensators have been broadly employed for the provision of electrical network services, which include voltage regulation, network balance, and stability improvement. Several studies of such compensators have also been conducted to improve the ac network operation during unbalanced voltage sags.This project presents a complete control scheme intended for synchronous compensators operating under these these abnormal network conditions. In particular, this control scheme introduces two contributions: a novel reactive current reference generator has as a main feature the capacity to supply the required reactive current even when the voltage drops in amplitude during the voltage sag.Thus,a safe system operation is easily guaranteed by fixing the limit required current to the maximum rated current .The voltage control loop is able to implement several control strategies by setting two voltage set points. The two theroretical contributions of this project have been validated by experimental results. Certainly ,the topic of voltage support is open for further research , and the control scheme proposed in this project can be viewed as an interesting configuration to device other control strategies in future works.

Keywords: *Emerging Technology, Skills, Competencies, Libraries, faculty members pharmacy Colleges, Analysis, Knowledge.*

1.INTRODUCTION

Distributed renewable energy sources with low rated power traditionally use reactive power control to govern directly the power factor of the installation. As the generation capacity rises, voltage control is the preferred choice since the ability of these high power sources to influence the terminal voltage increases in this case. The evolution of grid codes for wind power plants clearly illustrates this idea. Most of the previous and current grid codes consider wind power plants as marginal energy sources and specify reactive power (current) injection requirements. Some grid codes that require voltage control have recently emerged as the penetration of wind power is growing significantly. In these codes, the voltage regulation is linked with the reactive power injection normally by means of $V - Q$ curves. In a future scenario, where the penetration of the distributed power plants will be high enough to replace some conventional power generators, the voltage regulation should be carried out by positioning the terminal voltage at a predefined level. This operation will overcome the traditional steady-state error observed in the droop $V - Q$ voltage control.

The capacity of reactive power compensation by renewable energy sources is limited. These sources, interfaced by power inverters, are mainly conceived to export all available active power; thus, the power rating of the inverters is easily achieved. In addition to energy sources, constant power loads can also supply reactive power to the electrical network. Interfaced by active rectifiers, these widely used loads absorb constant active power from the ac network. However, they can exchange only a small amount of reactive power according to the power rating of the active rectifier.

The objective of this paper is to propose a reactive power control scheme for STATCOMs that is able to support the ac network voltage under unbalanced voltage sags. As a first contribution, this paper introduces a new reactive current reference generator, which employs a current set point instead of the usual reactive power set point. The generator has as main feature the capacity to supply the required reactive current even when the voltage drops in amplitude during the voltage sag. Thus, a safe operation is easily obtained by an appropriate design of the current set point. In addition, the control algorithm of the current generator is simple, given that the online calculation of the maximum reactive power delivered to the ac network is not required. As a second contribution, this paper presents a flexible voltage support control loop with two voltage set points. By setting the values of these set points, different control strategies for voltage support can be devised. In this paper, three strategies are proposed, and their advantages and limitations are discussed in detail. The first strategy sets the set points as in normal network operation. The performance of this strategy during the voltage sag is good enough if the current limit is not reached. Otherwise, the control saturates, and the system operation is clearly deteriorated. As an alternative, two control strategies are thus introduced to cope with this saturation problem.

2. POWER QUALITY:

The static synchronous compensator (STATCOM) has been well accepted as a power system controller for improving voltage regulation and reactive compensation. There are several compelling reasons to consider a multilevel converter topology for the STATCOM. Here well-known reasons include the following:

1. Lower harmonic injection into the power system
2. Decreased stress on the electronic components due to decreased voltages and
3. Lower switching losses.

Various multilevel converters also readily lend themselves to a variety of PWM strategies to improve efficiency and control. An eleven-level cascaded multilevel STATCOM uses several full bridges in series to synthesize staircase waveforms. Because every full bridge can have three output voltages with different switching combinations, the number of output voltage levels is $2n + 1$ where n is the number of full bridges in every phase. The converter cells are identical and therefore modular. As higher level converters are used for high output rating power applications, a large number of power switching devices, will be used. Each of these devices is a potential failure point. Therefore, it is important to design a sophisticated control to produce a fault-tolerant STATCOM. A faulty power cell in a cascaded H-Bridge STATCOM can potentially cause switch modules to explode leading to the fault conditions such as a short circuit or an overvoltage on the power system resulting in an expensive down time. Subsequently, it is crucial to identify the existence and location of the fault for it to be removed. Several fault detection methods have been proposed over the last few years. Resistor sensing, current transformation and *VCE* sensing are some of the more common approaches. For example, a method based on the output current behavior is used to identify IGBT short circuits. The primary drawback with the proposed approach is that the fault detection time depends on the time constant of the load.

In this paper, the method we propose requires only that the output dc link voltage of each phase be measured. This measurement is typically accomplished anyway for control purposes. If a fault is detected, the module in which the fault occurred is then isolated and removed from service. This approach is consistent with the modular design of cascaded converters in which the cells are designed to be interchangeable and rapidly removed and replaced. Until the module is replaced, the multilevel STATCOM continues to operate with slightly decreased, but still acceptable, performance.

In summary, this approach offers the following advantages:

1. No additional sensing requirements;
2. Additional hardware is limited to two by-pass switches per module;
3. Consistent with the modular approach of cascaded multilevel converters and
4. The dynamic performance and THD of the STATCOM is not significantly impacted.

3.0 VOLTAGE SAG:

Voltage sags and momentary power interruptions are probably the most important PQ problem affecting industrial and large commercial customers. These events are usually associated with a fault at some location in the supplying power system. Interruptions occur when the fault is on the circuit supplying the customer. But voltage sags occur even if the faults happen to be far away from the customer's site. Voltage sags lasting only 4-5 cycles can cause a wide range of sensitive customer equipment to drop out. To industrial customers, voltage sag and a momentary interruption are equivalent if both shut their process down.

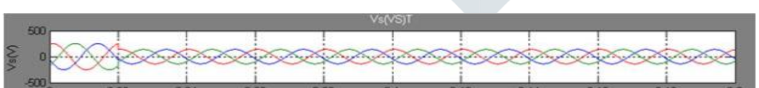


Fig 2.1 A typical example of three phase voltage sag

3.1 VOLTAGE-SAG ANALYSIS:

3.1.1. Load Flow:

A load flow representing the existing or modified system is required with an accurate zero- sequence representation. The machine reactance Xd" or Xd' is also required. The reactance used is dependent upon the post fault time frame of interest. The machine and zero-sequence reactance are not required to calculate the voltage sag magnitude.

3.1.2. Voltage Sag Calculation:

Sliding faults which include line-line, line to ground, line to line- to ground and three phases are applied to all the lines in the load flow. Each line is divided into equal sections and each section is faulted.

3.1.3. Voltage Sag Occurrence Calculation:

Based upon the utilities reliability data (the number of times each line section will experience a fault) and the results of load flow and voltage sag calculations, the number of voltage sags at the customer site due to remote faults can be calculated. Depending upon the equipment connection, the voltage sag occurrence rate may be calculated in terms of either phase or line voltages dependent upon the load connection. For some facilities, both line and phase voltages may be required. The data thus obtained from load flow, Voltage sag calculation, and voltage sag occurrence calculation can be sorted and tabulated by sag magnitude, fault type, location of fault and nominal system voltage at the fault location.

4. FACTS:

Flexible AC Transmission Systems, called FACTS, got in the recent years a well-known term for higher controllability in power systems by means of power electronic devices. Several FACTS-devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice.

In most of the applications the controllability is used to avoid cost intensive or landscape requiring extensions of power systems, for instance like upgrades or additions of substations and power lines. FACTS-devices provide a better adaptation to varying operational conditions and improve the usage of existing installations. The basic applications of FACTS-devices are:

1. Power flow control,
2. Increase of transmission capability,
3. Voltage control,
4. Reactive power compensation,
5. Stability improvement,
6. Power quality improvement,
7. Power conditioning,
8. Flicker mitigation,
9. Interconnection of renewable and distributed generation and storages.

The influence of FACTS-devices is achieved through switched or controlled shunt compensation, series compensation or phase shift control. The devices work electrically as fast current, voltage or impedance controllers. The power electronic allows very short reaction times down to far below one second.

10.

4.1 STATIC SYNCHRONOUS COMPENSATOR (STATCOM):

The STATCOM is a solid-state-based power converter version of the SVC. Operating as a shunt-connected SVC, its capacitive or inductive output currents can be controlled independently from its terminal AC bus voltage. Because of the fast-switching characteristic of power converters, STATCOM provides much faster response as compared to the SVC. In addition, in the event of a rapid change in system voltage, the capacitor voltage does not change instantaneously; therefore, STATCOM effectively reacts for the desired responses. For example, if the system voltage drops for any reason, there is a tendency for STATCOM to inject capacitive power to support the dipped voltages.

STATCOM is capable of high dynamic performance and its compensation does not depend on the common coupling voltage. Therefore, STATCOM is very effective during the power system disturbances.Moreover, much research confirms several advantages of STATCOM.

These advantages compared to other shunt compensators include:

- Size, weight, and cost reduction
- Equality of lagging and leading output
- Precise and continuous reactive power control with fast response

4.1 SYSTEM DESCRIPTION:

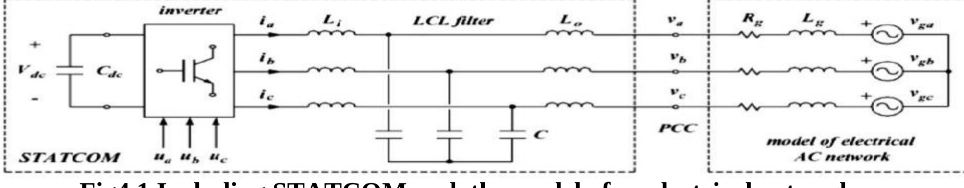


Fig4.1 Including STATCOM and the model of ac electrical network

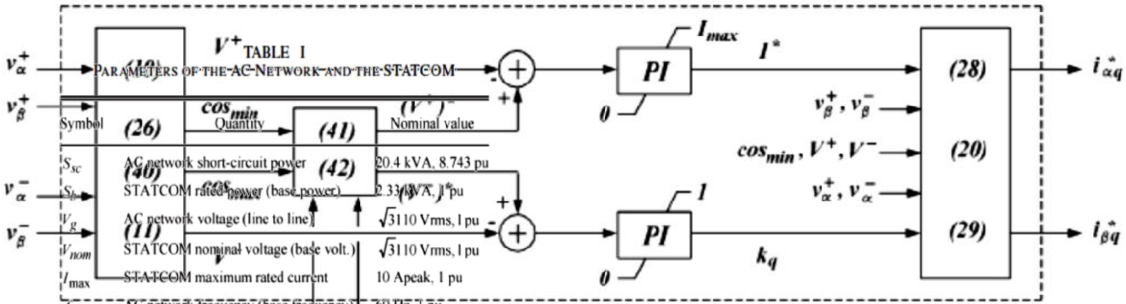


Fig 4.2 Diagram of the proposed reactive current reference generator with voltage support auxiliary service

TABLE I
PARAMETERS OF THE AC NETWORK AND THE STATCOM

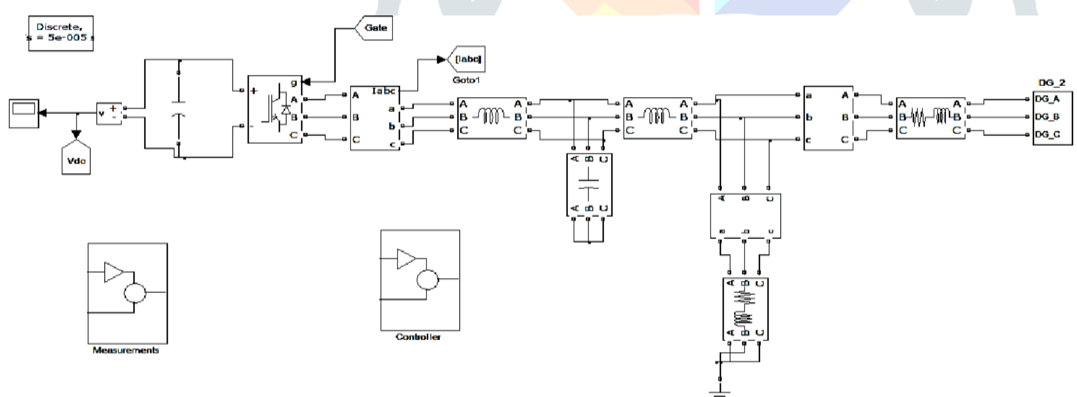
Symbol	Quantity	Nominal value
S_{sc}	AC network short-circuit power	20.4 kVA, 8.743 pu
S_b	STATCOM rated power (base power)	2.33 kVA, 1 pu
V_g	AC network voltage (line to line)	$\sqrt{3}$110 Vrms, 1 pu
V_{nom}	STATCOM nominal voltage (base volt.)	$\sqrt{3}$110 Vrms, 1 pu
I_{max}	STATCOM maximum rated current	10 Apeak, 1 pu
f	AC network frequency (base frequency)	60 Hz, 1 pu
R_g	grid impedance resistor	[illegible]mΩ, 0.008 pu
L_g	grid impedance inductor	4.7 mH, 0.114 pu
C_{dc}	DC-side capacitor	1.36 mF, 7.976 pu
L_i	LCL inverter side inductor	6.9 mH, 0.167 pu
C	LCL filter capacitor	680 nF, 0.004 pu
L_o	LCL grid side inductor	2.1 mH, 0.051 pu
f_s	switching and sampling frequencies	10 kHz, 166.66 pu

TABLE II
PARAMETERS OF THE PROPOSED CONTROL SCHEMES

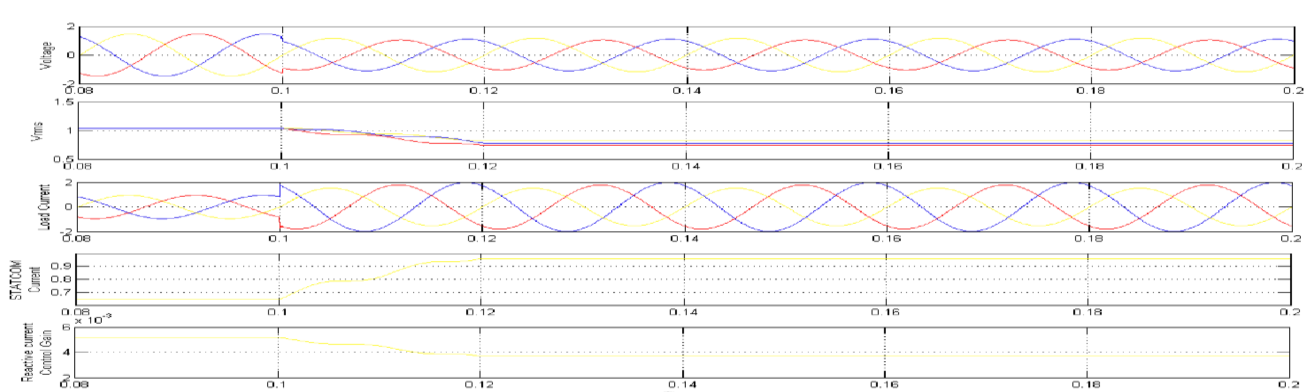
Symbol	Quantity	Nominal value
$k_{p,c}$	proportional gain of the current loop	30 V/A
$k_{m,c}$	resonant gain of the current loop	150 V/A
ξ_c	damping factor of the current loop	0.2
ξ_v	damping factor of the sequence detector	0.707
V_{dc}^*	DC-side voltage setpoint	350 V
$k_{p,V_{dc}}$	proportional gain of the V_{dc} voltage loop	0.3 V
$k_{i,V_{dc}}$	integral gain of the V_{dc} voltage loop	15 Vs
k_{p,V^+}	proportional gain of the V^+ voltage loop	0.2 A/V
k_{i,V^+}	integral gain of the V^+ voltage loop	20 A/(Vs)
k_{p,V^-}	proportional gain of the V^- voltage loop	0.01 $(V)^{-1}$
k_{i,V^-}	integral gain of the V^- voltage loop	2 $(Vs)^{-1}$
$k_{p,I}$	proportional gain of the CS3 strategy	0.04 $(A)^{-1}$

5.0 SIMULATION & RESULTS

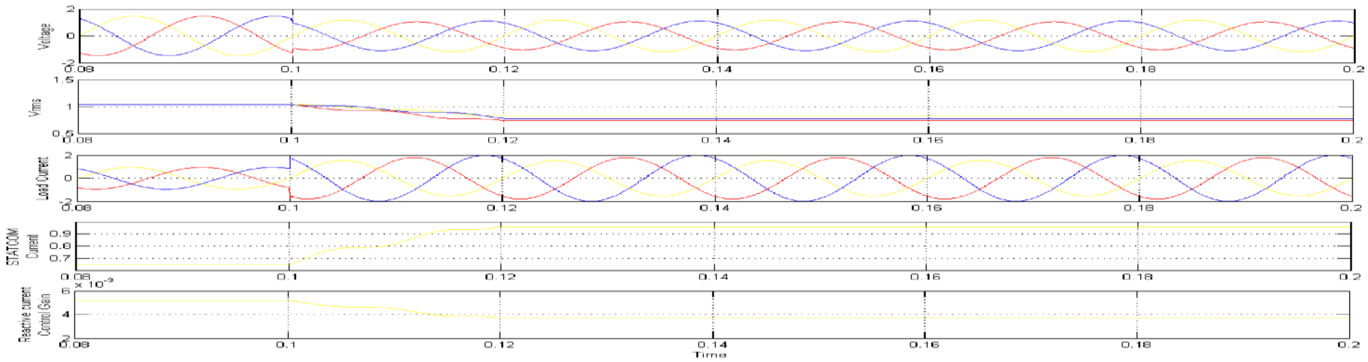
5.1 MODEL DIAGRAM:



5.2 SIMULATION RESULTS:



The above figure 5.2 shows the wave forms, from a time period of t=0.08sec to t=0.2 which is the initial stage for voltage sag effect due to unbalanced load conditions.



The above figure 5.2 shows the wave forms, from a time period of t=0.28sec to t=0.4 the above shown graphical results show the nature of our simulation.

CONCLUSION

A complete control scheme intended for STATCOMs operating under unbalanced voltage sags has been presented in this paper. The first contribution is a reactive current reference generator programmed with a current set point instead of the conventional reactive power set point. As an interesting feature, this generator guarantees a safe operation of the STATCOM by naturally limiting the amplitude of the current delivered to the ac network. The main advantage in comparison with previous reference generators is that the online calculation of the maximum reactive power is not required since the output limits in the proposed algorithm are constant values even in the presence of grid voltages with imbalances. The second contribution is a voltage control loop that makes possible the introduction of several voltage support control strategies by simply modifying two voltage set points. Three control strategies are proposed to verify the effectiveness of the control scheme under severe unbalanced voltage sags. The CS1 has good results in normal network conditions but has poor results during abnormal conditions with significant voltage imbalance. In fact, a STATCOM with higher power rating is required to supply the necessary reactive current to fulfill the requirements specified by the CS1. The voltage limits are not exceeded with a certain room for security. In comparison with existing voltage control loops based on a voltage-reactive power droop characteristic, the proposed control ensures an accurate voltage regulation to a predefined voltage set point provided that the STATCOM rated power and the impedance of the ac network are large enough. This feature will be particularly appreciated in a future scenario where the penetration of the distributed power plants will be high enough to replace some conventional power generators. Actually, the topic of voltage support control strategies is open for further research, and the synthesis of novel control strategies implemented with proposed voltage control scheme is left to future work.

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