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POWER QUALITY IMPROVEMENT USING DISTRIBUTION STATIC COMPENSATOR OPERATING IN VOLTAGE CONTROL MODE

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Abstract:-In this project, a new algorithm to generate reference voltage for a distribution static compensator (dstatcom) operating in voltage-control mode. The proposed scheme exhibits several advantages compared to traditional voltage-controlled dstatcom where the reference voltage is arbitrarily taken as 1.0 p.u. The proposed scheme ensures that unity power factor (upf) is achieved at the load terminal during nominal operation, which is not possible in the traditional method. Also, the compensator injects lower currents and, therefore, reduces losses in the feeder and voltage-source inverter. Further, a saving in the rating of dstatcom is achieved which increases its capacity to mitigate voltage sag. Nearly upf is maintained, while regulating voltage at the load terminal, during load change. The state-space model of dstatcom is incorporated with the deadbeat predictive controller for fast load voltage regulation during voltage disturbances.

With these features, this scheme allows dstatcom to tackle power-quality issues by providing power factor correction, harmonic elimination, load balancing, and voltage regulation based on the load requirement.

INTRODUCTION

Power quality is becoming important due to proliferation of nonlinear loads, such as rectifier equipment, adjustable speed drives, domestic appliances and arc furnaces. These nonlinear loads draw non-sinusoidal currents from ac mains and cause a type of current and voltage distortion called as 'harmonics'. These harmonics causes various problems in power systems and in consumer products such as equipment overheating, capacitor blowing, motor vibration, transformer over heating excessive neutral currents and low power factor.

Power quality problems are common in most of commercial, industrial and utility networks. Natural phenomena, such as lightning are the most frequent cause of power quality problems. Switching phenomena result in oscillatory transients in the electrical supply.

For all these reasons, from the consumer point of view, power quality issues will become an increasingly important factor to consider in order satisfying good productivity. To address the needs of energy consumers trying to improve productivity through the reduction of power quality related process stoppages and energy suppliers trying to maximize operating profits while keeping customers satisfied with supply quality, innovative technology provides the key to cost-effective power quality enhancements solutions. However, with the various power quality solutions available, the obvious question for a consumer or utility facing a particular power quality problem is which equipment provides the better solution.

Power quality, like quality in other goods and services, is difficult to quantify. There is no single accepted definition of quality power. There are standards for voltage and other technical criteria that may be measured, but the ultimate measure of power quality is determined by the performance and productivity of end-user equipment. If the electric power is inadequate for those needs, then the "quality" is lacking.

Hence power quality is ultimately a consumer-driven issue, and the end user's point of reference the power quality is defined as "Any power problem manifested in voltage, current or frequency deviations that results in failure or misoperation of customer equipment".

The Power system network is designed to operate at a sinusoidal voltage of a given frequency (typically 50 or 60Hz) and magnitude. Any recordable variation in the waveform magnitude, frequency, or purity is a potential power quality problem. In practical power system, there is always a close relationship between voltage and current. Even if the generators supply a pure sine-wave voltage, the current passing through the impedance of the system can cause a variety of disturbances to the voltage. For example,

Therefore, while it is the voltage with which we are ultimately concerned, we must also address phenomena in the current to understand the basis of many power quality problems.

LITERATURE SURVEY

A distribution system suffers from current as well as voltage-related power-quality (PQ) problems, which include poor power factor, distorted source current, and voltage disturbances. A DSTATCOM, connected at the point of common coupling (PCC), has been utilized to mitigate both types of PQ problems . When operating in current control mode (CCM), it injects reactive and harmonic components of load currents to make source currents balanced, sinusoidal, and in phase with the PCC voltages. In voltage-control mode (VCM), the DSTATCOM regulates PCC voltage at a reference value to protect critical loads from voltage disturbances, such as sag, swell, and unbalances. However, the advantages of CCM and VCM cannot be achieved simultaneously with one active filter device, since two modes are independent of each other.

Hence, it is not necessary to regulate the PCC voltage at 1.0 p.u. While maintaining 1.0-p.u. voltage, DSTATCOM compensates for the voltage drop in feeder. For this, the compensator has to supply additional reactive currents which increase the source currents. This increases losses in the voltage-source inverter (VSI) and feeder. Another important aspect is the rating of the VSI. Due to increased current injection, the VSI is de-rated in steady-state condition. Consequently, its capability to mitigate deep voltage sag decreases. Also, UPF cannot be achieved when the PCC voltage is 1 p.u. In the literature, so far, the operation of DSTATCOM is not reported where the advantages of both modes are achieved based on load requirements while overcoming their demerits.

EXISTING SYSTEM

This thesis considers the operation of DSTATCOM in VCM and proposes a control algorithm to obtain the reference load terminal voltage. This algorithm provides the combined advantages of CCM and VCM. The UPF operation at the PCC is achieved at nominal load, whereas fast voltage regulation is provided during voltage disturbances. Also, the reactive and harmonic component of load current is supplied by the compensator at any time of operation. The deadbeat predictive controller is used to generate switching pulses. The control strategy is tested with a three-phase four-wire distribution system. The effectiveness of the proposed algorithm is validated through detailed simulation results

PROPOSED SYSTEM

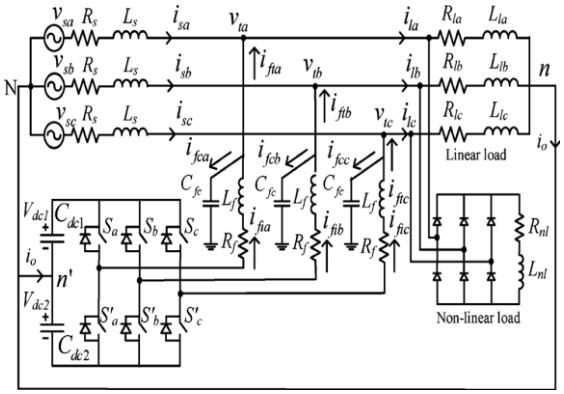


Fig.1: Circuit diagram of the DSTATCOM-compensated distribution system

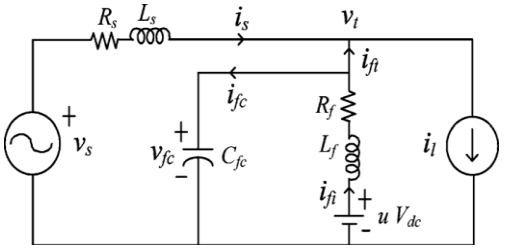


Fig.2: Single-phase equivalent circuit of DSTATCOM

The control scheme is implemented using MATLAB/SIMULINK software. Simulation parameters are given in Table 1

Circuit diagram of a DSTATCOM-compensated distribution system is shown in Fig. 1. It uses a three-phase, four-wire, two-level, neutral-point-clamped VSI. This structure allows independent control to each leg of the VSI Fig. 5.2 shows the single-phase equivalent representation of Fig. 5.1. Variable 'u' is a switching function, and can be either +1 or -1 depending upon switching state. Filter inductance and resistance are L_f and R_f, respectively. Shunt capacitor C_{fc} eliminates high-switching frequency components.

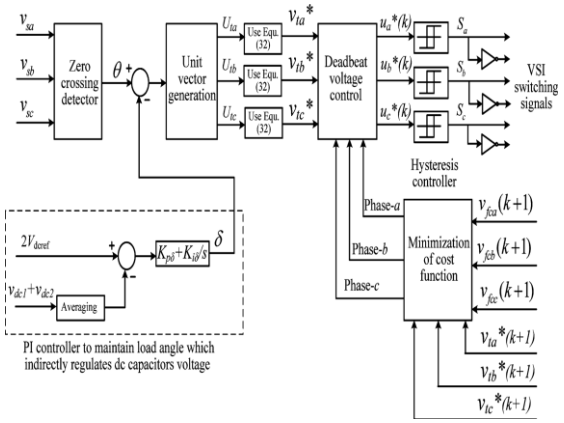


Fig.3: Overall block diagram of the controller to control DSTATCOM in a distribution system

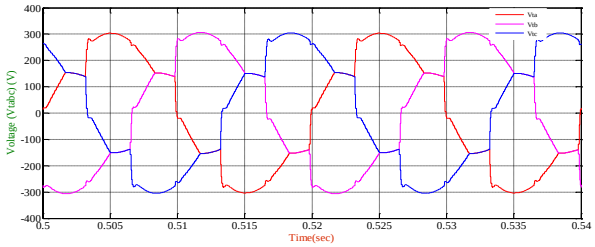
Table 1: Simulation Parameters

S. No.	System quantities	Values
1.	Source Voltage	400 V rms line-line, 50Hz
2.	Feeder impedance	Z_s= 1+j3.14Ω
3.	Linear load	Z_{la} = 30+j62.8Ω Z_{lb} = 40+j78.5Ω Z_{lc} = 50+j50.24Ω
4.	Non-linear load	An R-L load of 50+j62.8Ω
5.	VSI Parameters	V_{dc} = 650 V, C_{dc} = 2600 μF, R_f=1Ω, L_f=22Mh C_{fc} =5μF, I_{rated} = 30A
6.	PI gains	$k_{p\delta} = 8.5e^{-7}$, $k_{i\delta} = 1.8e^{-6}$
7.	Hysteresis Band (h)	1V

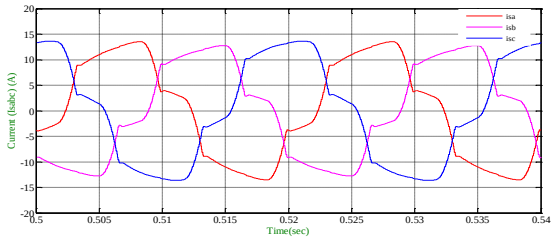
First, discrete modeling of the system is presented to obtain a discrete voltage control law, and it is shown that the PCC voltage can be regulated to the desired value with properly chosen parameters of the VSI. Then, a procedure to design VSI parameters is presented. A proportional-integral (PI) controller is used to regulate the dc capacitor voltage at a reference value. Based on instantaneous symmetrical component theory and complex Fourier transform, a reference voltage magnitude generation scheme is proposed that provides the advantages of CCM at nominal load. The overall controller block diagram is shown in Fig.3.

SIMULATION RESULT ANALYSIS

Terminal voltages and source currents before compensation are plotted in Fig. 4. Distorted and unbalanced source currents flowing through the feeder make terminal voltages unbalanced and distorted. Three conditions, namely, nominal operation, operation during sag, and operation during load change are compared between the traditional and proposed method. In the traditionalmethod, the reference voltage is 1.0 p.u.



(a)



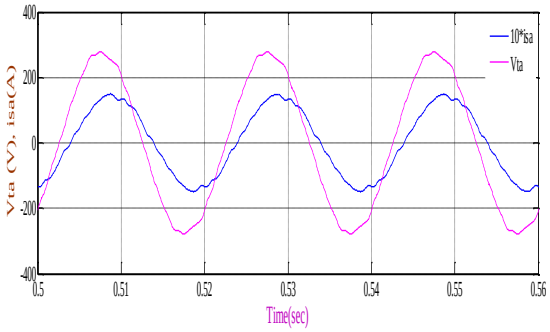
(b)

Fig. 4: Before compensation. (a) Terminal voltages. (b) Source currents

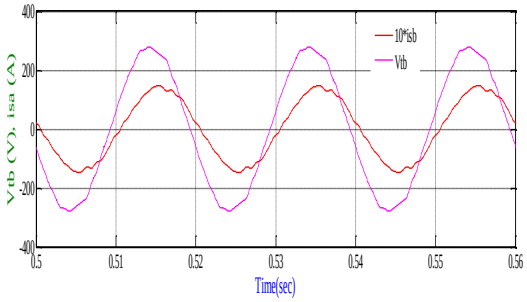
Nominal Operation

Initially, the traditional method is considered. Fig. 5 (a)–(c) shows the regulated terminal voltages and corresponding source currents in phases a, b and c respectively. These waveforms are balanced and sinusoidal. However, source currents lead respective terminal voltages which show that the compensator supplies reactive current to the source to overcome feeder drop, in addition to

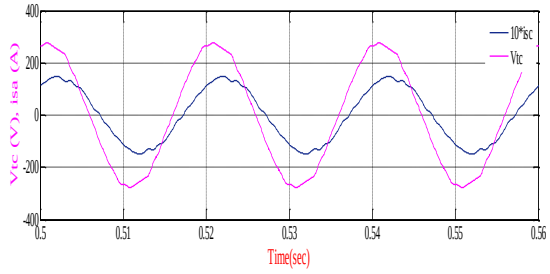
supplying load reactive and harmonic currents. Fig. 6(a) shows the dc bus voltage regulated at a nominal voltage of 1300 V. Fig. 6(b) shows the load angle settled around 8.5^0. Using the proposed method, terminal voltages and source currents in phases, and are shown in Fig.7 (a)–(c), respectively. It can be seen that the respective terminal voltages and source currents are in phase with each other, in addition to being balanced and sinusoidal. Therefore, UPF is achieved at the load terminal.



(a) Phase- a



(b) Phase-b



(c) Phase-c

Fig. 5: Terminal voltages and source currents using the traditional method

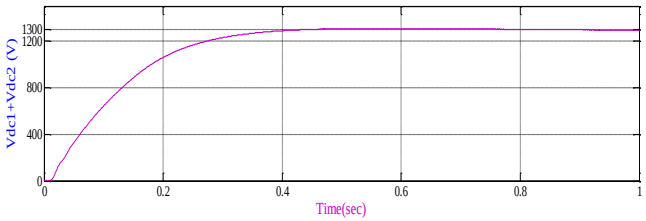
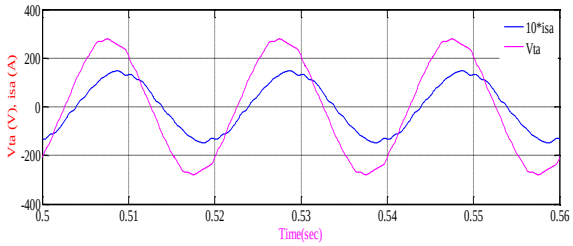
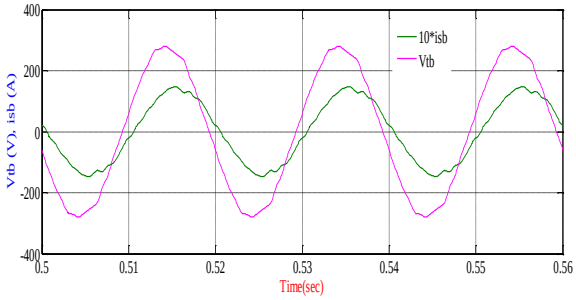


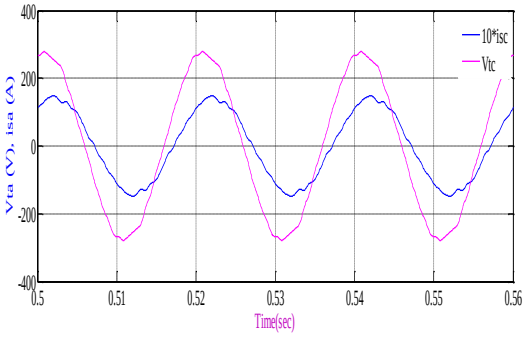
Fig. 6: Voltage at the dc bus



(a) Phase- a



(b) Phase- b

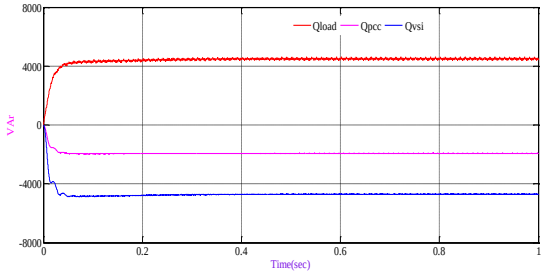


(c) Phase- c

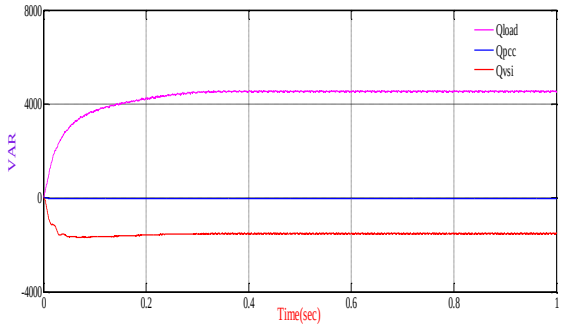
Fig. 7: Terminal voltages and source currents using the proposed method.

For the considered system, waveforms of load reactive power (Q_{load}), compensator reactive power (Q_{VSI}), and reactive power at the PCC (Q_{PCC}) in the traditional and proposed methods are given in Fig.8 (a) and (b), respectively. In the traditional method, the compensator

needs to overcome voltage drop across the feeder by supplying reactive power into the source. As shown in Fig. 5.8(a), reactive power that is supplied by the compensator and has a value of 4.7kVAr is significantly more than the load reactive power demand of 2.8kVAr. This additional reactive power of 1.9kVAr goes into the source. This confirms that significant reactive current flows along the feeder in the traditional method. However, in the proposed method, UPF is achieved at the PCC by maintaining suitable voltage magnitude. Thus, the reactive power supplied by the compensator is the same as that of the load reactive power demand. Consequently, reactive power exchanged by the source at the PCC is zero. These waveforms are given in Fig. 8(b).



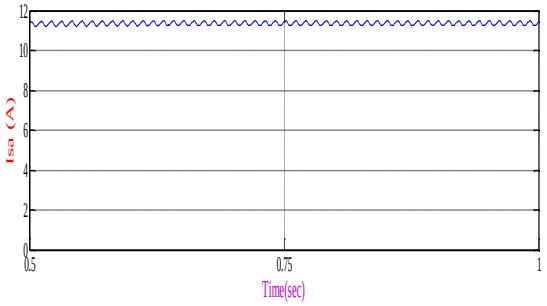
(a) Traditional method



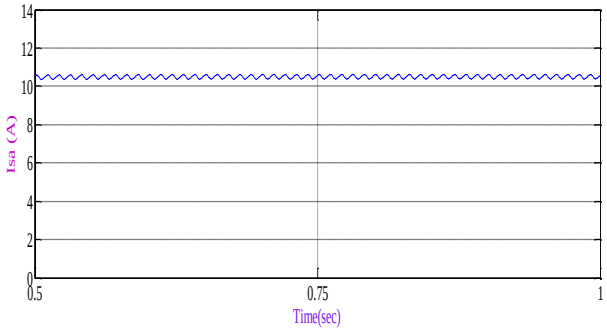
(b) Proposed method

Fig. 8: Load reactive power (Q_{load}), Compensator reactive power (Q_{VSI}), and reactive power at PCC (Q_{PCC})

Fig. 9(a) and (b) shows the source rms currents in phase for the traditional and proposed methods, respectively. The source current has decreased from 11.35 to 10.5 A in the proposed method. Consequently, it reduces the ohmic losses in the feeder. Fig. 10(a) and (b) shows the compensator rms currents in phase- for the traditional and proposed methods, respectively. The current has decreased from 8.4 to 5.2 A in the proposed method.

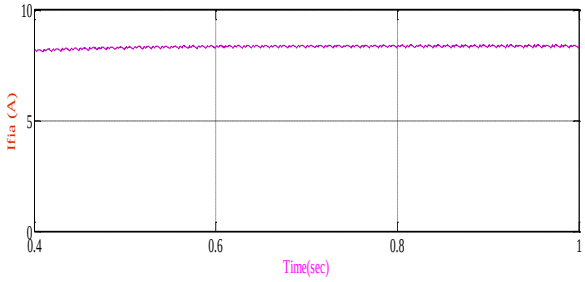


(a) Traditional method

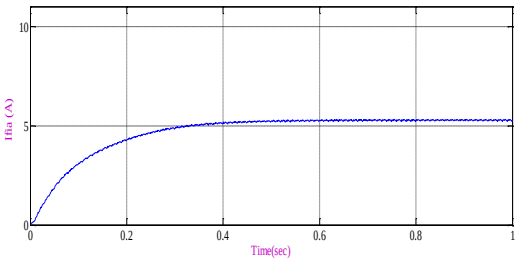


(b) Proposed method

Fig. 9: Phase-a' source rms currents



(a) Traditional method



(b) Proposed method

Fig. 10: Phase-a' compensator rms currents

In the traditional method, DSTATCOM maintains a load terminal voltage at 1.0p.u. For this, it needs to

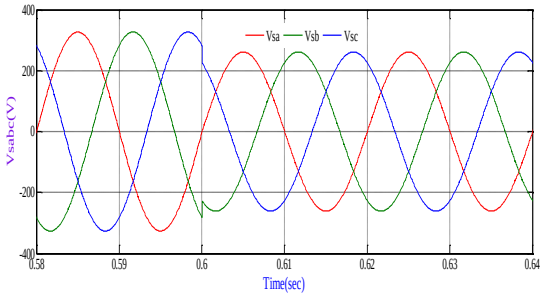
compensate for the entire feeder drop. Hence, at the steady state, the compensator supplies reactive power to the source to overcome this drop. However, in the proposed scheme, the compensator does not compensate for the feeder drop in the steady-state condition. Hence, a lesser rating of VSI is utilized in the steady state. This savings in rating is utilized to mitigate deep sag, and DSTATCOM capacity to mitigate deep sag increases.

Operation during Sag

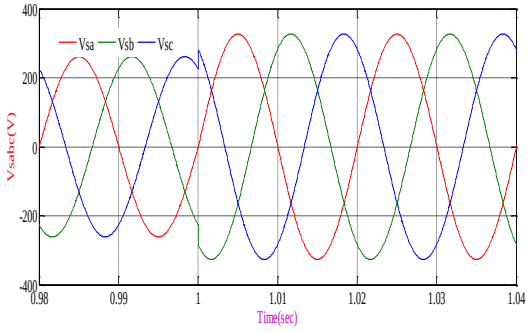
To create sag, source voltage is lowered by 20% from its nominal value at 0.6 s as shown in Fig. 11(a). Sag is removed at 1.0 s as shown in Fig. 11(b). Since voltage regulation capability does not depend upon reference voltage, it is not shown separately for the traditional method. Fig. 11(c) and (d) shows terminal voltages regulated at their reference value.

The controller provides a fast voltage regulation at the load terminal. Fig. 11(e) shows the total dc bus voltage. During the transient period, capacitors supply real power to maintain load power which results in discharging of capacitors.

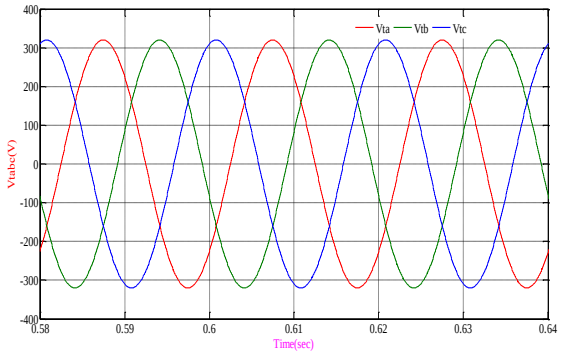
If the rating of VSI is limited to mitigate 20% sag, then this savings in rating can be used to mitigate additional sag.



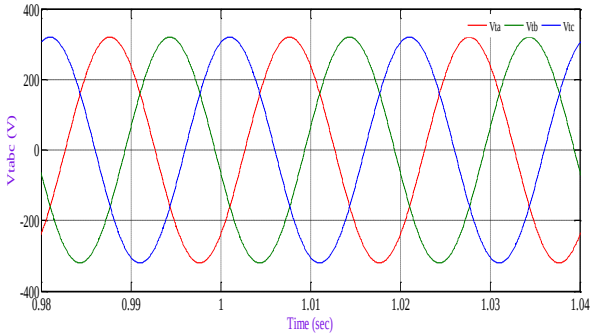
(a) Source voltages during normal to sag



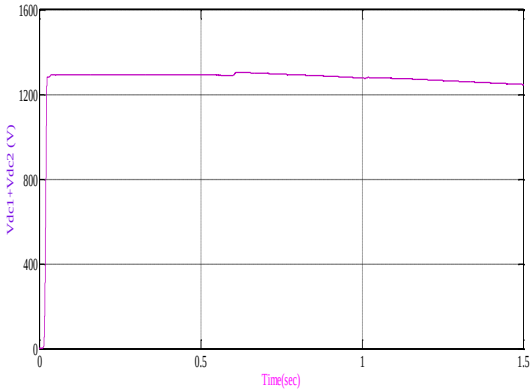
(b) Source voltages during sag to normal



(c) Terminal voltages during normal to sag



(d) Terminal voltages during sag to normal

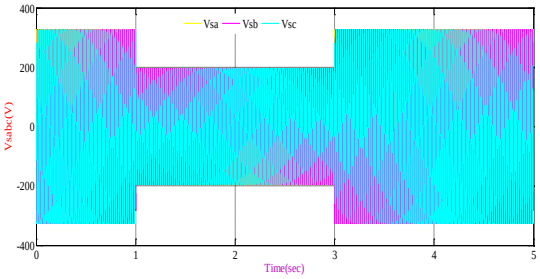


(e) Voltage at the dc bus

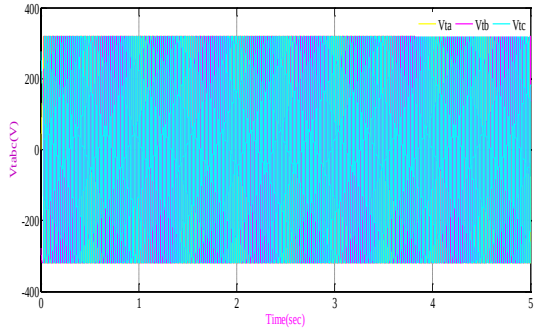
Fig. 11: Various waveforms during sag operation

To show the capability of DSTATCOM to mitigate deep sag for a longer time, the source voltage is decreased to 60% of the nominal value for t =1 to 3s duration as shown in Fig. 12(a). The terminal voltages, maintained at the reference value, are shown in Fig. 12(b). The voltage across the dc bus is shown in Fig. 12(c). During transients, this voltage deviates from its reference voltage. However, it is brought back to the reference value once steady state is reached. These waveforms confirm that the DSTATCOM has the

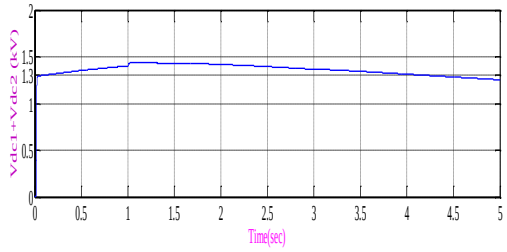
capability to mitigate deep sag independent of duration. However, it requires a high current rating of the VSI.



(a) Source voltages



(b) Terminal voltages

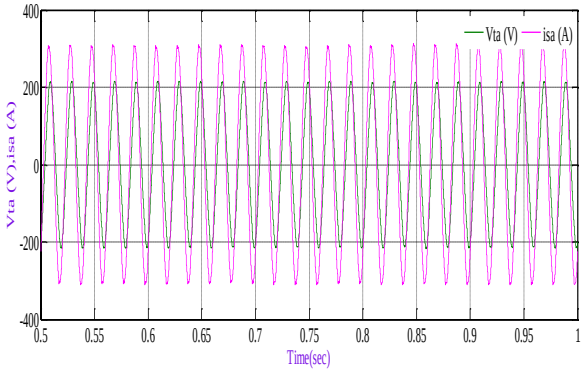


(c) Voltage at the dc bus

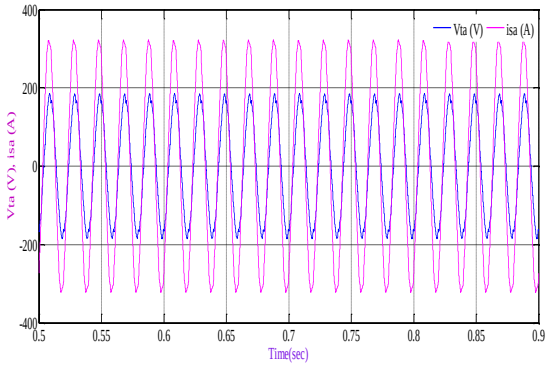
Fig. 12: Voltage waveforms during sag operation in the proposed method.

Operation during Load Change

To show the impact of load changes on system performance, load is increased to 140%of its nominal value. Under this condition, the traditional method gives less power factor as the compensator will supply more reactive current to maintain the reference voltage. The voltage and current waveforms, as shown in Fig. 13(a), confirm this. In proposed method, a load change will result in small deviation in terminal voltage from its reference voltage. Compensator just needs to supply extra reactive current to overcome this small extra feeder drop, hence, nearly UPF is maintained while regulating the terminal voltage at its reference voltage. It is evident from Fig. 13(b).



(a) Traditional method



(b) Proposed method

Fig. 13: Terminal voltage and source current in phase- during load change

CONCLUSIONS

In this thesis, a control algorithm has been proposed for the generation of reference load voltage for a voltage-controlled DSTATCOM. The performance of the proposed scheme is compared with the traditional voltage-controlled DSTATCOM. The proposed method provides the following advantages: 1) at nominal load, the compensator injects reactive and harmonic components of load currents, resulting in UPF; 2) nearly UPF is maintained for a load change; 3) fast voltage regulation has been achieved during voltage disturbances; and 4) losses in the VSI and feeder are reduced considerably, and have higher sag supporting capability with the same VSI rating compared to the traditional scheme. The simulation results show that the proposed scheme provides DSTATCOM, a capability to

improve several PQ problems (related to voltage and current).

FUTURESCOPE

The proposed method will also validate through any simulation software packages and it will possible to implement experimentally.

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