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A METHODOLOGY FOR POWER QUALITY IMPROVEMENT USING DSTATCOM

MS. SNEHAL V.BIJWE[1], MRS. Y. D. SHAHAKAR[2]

1. Electrical Engineering Department, M. E. Scholar, Sant Gadge Baba Amravati University.
2. Electrical Engineering Department, Faculty of Electrical Engineering, Sant Gadge Baba Amravati University

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Abstract: The quality of power in electric distribution system is deteriorated due to development in the field of power electronic equipment, the intensive use of static converters, and the use of number of domestic electronic-based applications. The nonlinear loads generate current harmonics and can cause voltage drops on the supply network impedance resulting in unbalanced conditions. These effects are worse in the case where the loads change randomly. The Conventional method like passive filter for elimination of current harmonic pollution can eliminate only a particular frequency range and hence ineffective. This paper presents a three phase distribution static compensator (DSTATCOM) using a back propagation (BP) control algorithm for the reduction of the power quality issues such as harmonic elimination, load balancing and reactive power compensation for power factor correction, and zero voltage regulation under nonlinear loads. A BP-based control algorithm is implemented for the extraction of the fundamental weighted value of active and reactive power components of load currents which are required for the estimation of reference source currents. A DSTATCOM is designed, and its performance is studied under various operating conditions.

Keywords: Back propagation (BP) control algorithm, active and reactive power, power quality problem, weights.

Corresponding Author: MS. SNEHAL V.BIJWE

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INTRODUCTION

In any electric distribution system improved power quality is the primary requirement. It has many advantages such as maximum utilization of electrical equipments, enhanced loading capability, zero voltage regulation, etc. The quality of available supply power has a direct economic impact on industrial and domestic sectors which affects the growth of any nation. The sources of poor power quality can be divided depending on consumer loads and subsystem of a distribution system. These consumer loads can be classified as linear, nonlinear, or mixed type of loads.

In electronic based systems the power quality issue is more serious. The level of harmonics and reactive power demand are popular parameters that specify the degree of distortion and reactive power demand at a particular bus of the utility. One of the most common problem that is reported in low and medium-level distribution systems is the harmonic resonance. It is due to capacitors which are used for power factor correction and source impedance. Power converter-based custom power devices (CPDs) are useful for the reduction of power quality problems such as PFC, harmonic compensation, voltage sag/swell compensation, resonance due to distortion, and voltage flicker reduction within specified international standards. These custom power devices include the distribution static compensator (DSTATCOM), dynamic voltage restorer (DVR), and unified power quality conditioner (UPQC) in different configurations. Depending upon the control algorithm used for the reference current estimation and gating pulse generation scheme the performance of these custom power devices is based.

Distributed Static Compensator (D-Statcom)

A D-statcom (Distributed static compensator) as shown in figure1 is a parallel voltage controller, consists of a filter, Voltage source converter, a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The voltage source converter 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 through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-statcom output voltages allows effective control of active and reactive power exchanges between the D-statcom and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. The VSC connected in shunt with the ac system provides three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;

2. Correction of power factor; and

3. Eliminating of current harmonics

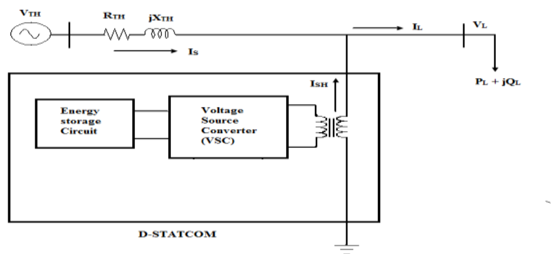

Fig-1: Principle of operation of D-statcom system

METHODOLOGY

As shown in figure 2 a voltage source converter (VSC)-based DSTATCOM is connected to a three phase ac mains. The tuned values of interfacing inductors (Lf) are connected at the ac output of the VSC in order to reduce ripple in compensating currents. A three phase series combination of capacitor (Cf) and a resistor (Rf) represents the shunt passive ripple filter which is connected at a point of common coupling (PCC) for reducing the high frequency switching noise of the VSC. The required compensating currents to cancel the reactive power components and harmonics of the load currents DSTATCOM currents (iCabc) are injected as so that loading due to reactive power component/ harmonics is reduced on the distribution system.

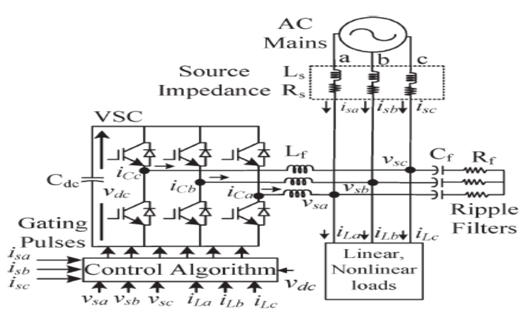

Fig-2: Schematic diagram of VSC-based DSTATCOM.

The BP training algorithm is implemented for the estimation of reference source currents through the weighted value of load active power and reactive power current components. In this algorithm, for the extraction of reference source currents (isa*, isb*, and isc*) the phase

PCC voltages (vsa, vsb, and vsc), source currents (isa, isb, and isc), load currents (iLa, iLb, and iLc) and dc bus voltage (vdc) are required. The detail application of this technique is as explained as follows

Estimation Of Weighted Value Of Average Fundamental Load Active And Reactive Power Components

In this estimation, the input layer for three phases (a, b, and c) is expressed as

ILap=wo+iLauap+iLbubp+iLcucp (1)

ILbp=wo+iLbubp+iLcucp+iLauap (2)

ILcp=wo+iLcucp+iLauap+iLbubp (3)

The amplitude of sensed PCC voltages is estimated as

$$v_t = \sqrt{\frac{2\left(v_{sa}^2 + v_{sb}^2 + v_{sc}^2\right)}{3}}. \quad (4)$$

The in-phase unit templates of PCC voltages (uap, ubp, and ucp) are estimated as

$$u_{ap} = \frac{v_{sa}}{v_t}, \quad u_{bp} = \frac{v_{sb}}{v_t}, \quad u_{cp} = \frac{v_{sc}}{v_t}. \quad (5)$$

The output signals (Zap, Zbp, and Zcp) of the feedforward section are expressed as

Zap =f(ILap) = 1/(1 + e−ILap) (6)

Zbp =f(ILbp) = 1/(1 + e−ILbp) (7)

Zcp =f(ILcp) = 1/(1 + e−ILcp). (8)

The three phase outputs of this layer (Iap1, Ibp1, and Icp1) before the activation function are expressed as

Iap1=wo1+wapZap+wbpZbp+wcpZcp (9)

Ibp1=wo1+wbpZbp+wcpZcp+wapZap (10)

Icp1=wo1+wcpZcp+wapZap+wbpZbp (11)

The updated weight of phase "a" active power current components of load current "wap" at the nth sampling instant is expressed as

wap(n)=wp(n)+μ{wp(n)−wap1(n)}f'(Iap1)zap(n) (12)

Similarly, for phase "b" and phase "c," the updated active power current components of the load current are expressed as

wbp(n)=wp(n)+μ{wp(n)−wbp1(n)}f'(Ibp1) zbp(n) (13)

wcp(n)=wp(n)+μ{wp(n)−wcp1(n)}f'(Icp1) zcp(n). (14)

The estimation of the fundamental active components in terms of three phase weights wap1, wbp1, and wcp1 as

wap1=f(Iap1)=1/(1+e−Iap1) (15)

wbp1=f(Ibp1)=1/(1+e−Ibp1) (16)

wcp1=f(Icp1)=1/(1+e−Icp1) (17)

The average weighted amplitude of the fundamental active power components (wp) is estimated as

Wp=(wap1+wbp1+wcp1)/3. (18)

Similarly, the average weight of the amplitudes of the fundamental reactive power current components (wq) is estimated as Wq=(waq1+wbq1+wcq1)/3. (19)

Amplitude Of Active Power Current Components Of Reference Source Currents

An error in the dc bus voltage at the nth sampling instant is expressed as

vde(n)=v*dc(n)−vdc(n) (20)

At the nth sampling instant, the output of the PI controller is as follows:

wdp(n)=wdp(n−1)+kpd {vde(n) − vde(n−1)}+kid vde(n) (21)

The amplitude of the active power current components of the reference source current (wspt) is estimated as

wspt=wdp+ wLpA. (22)

Similarlly for the reactive power current component, the weighted output of the ac bus PI controller wqq at the nth sampling instant is expressed as

wqq(n) = wqq(n−1)+kpt {vte(n) − vte(n−1)}+kit vte(n) (23)

The amplitude of the reactive power current components of the reference source current (wsqt) is calculated as

wsqt=wqq−wLqA. (24)

Estimation Of Reference Source Currents And Generation Of IGBT Gating Pulses

Three phase reference source active and reactive current components are estimated as

isap=wspt uap, isbp=wspt ubp, iscp = wspt ucp (25)

isaq=wsqtuaq, isbq=wsqt ubq, iscq = wsqt ucq. (26)

The addition of reference active and reactive current components is known as reference source currents, and these are given as

i*sa=isap+isaq,i*sb=isbp+isbq,i*sc=iscp+iscq. (27)

The sensed source currents (isa, isb, isc) and the reference source currents (i*sa, i*sb, i*sc) are compared, and current error signals are amplified through PI current regulators; their outputs are fed to a pulse width modulation (PWM) controller to generate the gating signals for insulated-gate bipolar transistors (IGBTs) S1 to S6 of the VSC used in a D-STATCOM.

SIMULATION RESULTS AND DISCUSSION

In this analysis, we have investigated the performance of D-statcom under the various sag conditions. Also, we have seen the nature of load voltage with D-statcom and without D-statcom during the disturbances. For the investigation of performance of D-statcom under various sag conditions, the system has been developed as shown in figures below. Simulation results are as shown below.

The Simulation Results Of Mitigation Of Voltage Sag Due To Three Phase To Ground Fault

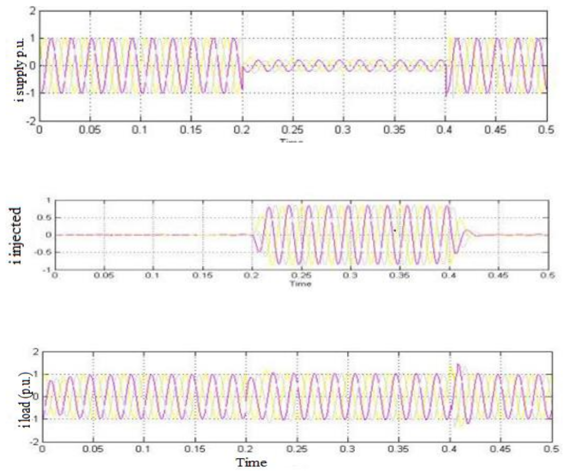

Fig-3: Simulation results for three- phase voltage sag

(a) Supply current (b) Injected current by DSTATCOM (c) Restored load current

The Simulation Results Of Mitigation Of Voltage Sag Due To Single Phase To Ground Fault

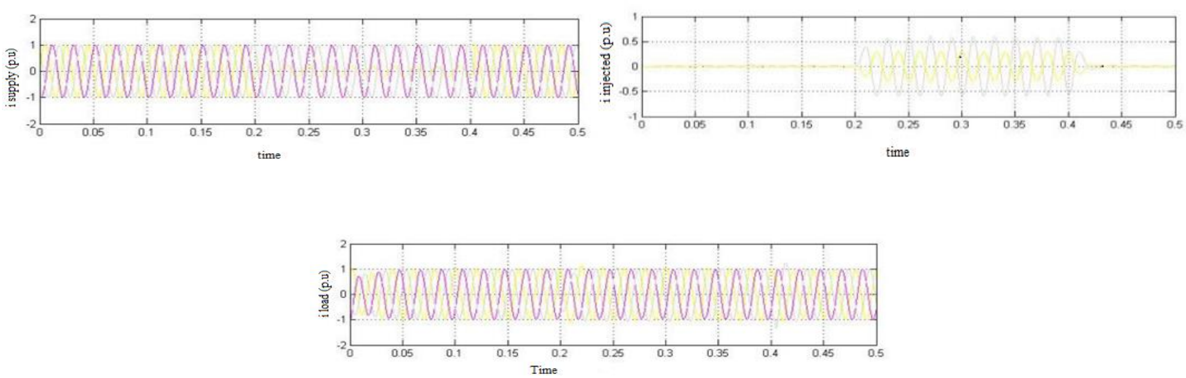

Fig-4: Simulation results for three- phase voltage sag

(a) Supply current (b) Injected current by DSTATCOM (c) Restored load current.

CONCLUSION

To maintain Power quality is an important technical issue for electrical researchers. This paper presents DSTATCOM as custom power device to mitigate power quality problems in distribution system. Voltage sag (0.8pu) due to single phase to ground fault, three phase to ground fault created using MATLAB Simulink. From the simulation and implementation results, it is concluded that DSTATCOM and its control algorithm have been found suitable for the compensation of nonlinear loads.

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