Application of STATCOM for Harmonic Mitigation and Power Factor Improvement Using Direct Current Control Technique

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***Abstract*—This paper focuses on the detailed analysis of STATCOM using direct current control method (DCC). This control is strongly recommended for harmonic elimination and reactive power control in the electric transmission system. In direct control method instantaneous value of system current is used for feedback control to achieve fast response. Compared to direct control method, indirect control method is simple but due to less response time and precise control, direct current control method is quite effective. An extensive digital simulation of the recommended STATCOM and its controller is carried out using MATLAB/SIMULINK software to study system performance and it is observed that using this control the overall power factor and Total Harmonic Distortion (THD) is improved.**

Keywords—Direct current control, Inverter, Non-Linear Load, Pulse Width Modulation

I. Introduction

Power quality is the main concern now a day due to recent development in the industrial load. To deal with the power quality issues there is an evolution of FACTS devices. STATCOM is one of central device among the various FACTS devices which are used to fulfill reactive power demand and harmonic mitigation [1-2] explains the basic operating principle of Static Synchronous Compensator (STATCOM).

There are number of control strategies introduced by researchers in order to detect the harmonic content and reactive power of the power system. [3] Investigates the direct current control method applied to distribution STATCOM. In general there are two methods, Direct current control method and indirect current control method for the operation of STATCOM which is discussed in [4]. Out of these two, direct current control method is fast and precise. Control system for PWM based STATCOM is explored in [5], where author explains the necessity of capacitor voltage control. Literature [6] deals with reactive power compensation and voltage stability using STATCOM. [7] discussed a collective system of active power filter and static var compensator to deal with power factor improvement, current harmonic and voltage stability issues.
To control active power filter revised Instantaneous reactive power theory is presented in [8] by Takeshi Furuhashi. This paper presents working of STATCOM and its controller which is based on estimation of direct current. As this control technique has major advantages over indirect one. The control method is verified by simulating the system using MATLAB/SIMULINK software.

II. Operating Principle of STATCOM

STATCOM is a device which absorbs or generates reactive power from the system to provide voltage support without using large reactor or capacitor bank. Fig. 1 shows equivalent circuit of STATCOM, where Vc is fundamental component, Vs is system voltage. The voltage of reactance is V_l and the impedance is $R+jX_l$.

a. When STATCOM voltage is greater than supply voltage it injects reactive power.

b. When STATCOM voltage is less than supply voltage it absorbs reactive power.

When both voltages are equal, there will be no interaction between STATCOM and the system.

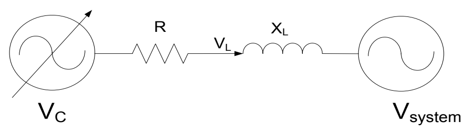

Fig.1. Equivalent circuit of STATCOM

Fig. 2 shows a single line diagram of STATCOM circuitry in which voltage source converter is coupled to power system through reactor. Here, VSC is fed by DC energy source. Voltage source converter used in STATCOM may be two-level or three-level type. Depending on the required output power and voltage, main function of VSC is to produce reactive power required for compensation. In normal condition VSC operate with fundamental frequency to minimize converter losses. Fig.3 shows the block diagram of controller based on direct current control. It is divided into two parts: first Estimation of instantaneous harmonic current and reactive power another one Generation of gate pulse for voltage source converter.

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For estimation of harmonic current and reactive power, initially Ia, Ib and Ic three phase load currents are transformed into stationery reference frame using abc-dq transformation (Park's transformation). Values of sine and cosine angle are obtained using virtual phase lock loop (PLL). In such a manner, ip (direct axis component) and iq (quadrature axis component) can be calculated. Here, only active channel ip is considered by terminating the reactive channel iq. Thereafter, ip is compare with the error signal obtained by the comparison of V_{dc} and V_{ref}. Furthermore, to obtain the fundamental component of active current signal dq axis components are converted back to abc coordinates

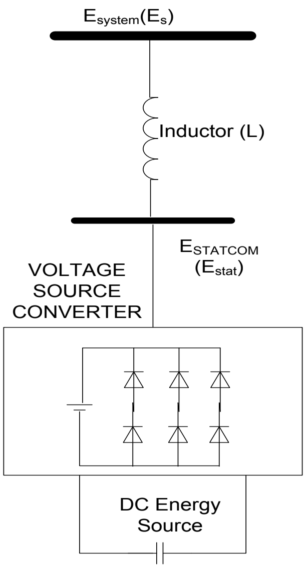


Fig.2. Power Circuit of STATCOM

III. DIRECT CURRENT CONTROL METHOD OF STATCOM

To obtain the gate pulses for VSC triangle wave comparison control method is used, in which the deviation between actual current value and reference current value is detected. This deviation is compared with the high frequency carrier signal to generate the triggering pulses for inverter which and accordingly inverter generates required current waveform. In this method, as shown in Fig.3, the deviated current signal is not directly compared with the triangular wave but the difference of compensation current and command current is fed to proportional integral to rectify the error and gate pulses for VSC are generated. Simultaneously, harmonic and reactive power compensation is carried out by using direct current control method with triangular carrier wave. In addition to this, to achieve better and precise compensation effect, DC side voltage constant must be constant.

The most important object in this control diagram is to tuning of PI controller. The correctness of result is totally depend upon the value of PI controller. PI controller outfits a controller with proportional and integral action. The value of kp and ki can be find out by using various technique. The transfer function of the PI controller for continuous system is defined as follows.

$$G_c(s) = K_p + \frac{K_i}{s} \quad (3.1)$$

The transfer function of the PI controller for discrete system is defined as follows.

$$G_c(z) = K_p + K_i T(\frac{z}{z-1}) \quad (3.2)$$

Where, Kp = the proportional gain constant Ki = the integral gain constant

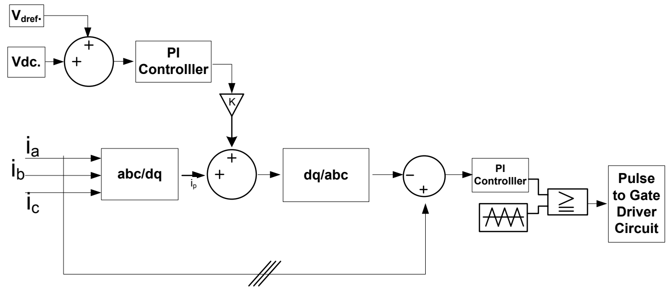


Fig.3. Control scheme of direct current control method for STATCOM

IV. SIMULATION RESULT

After Power system example is shown in Fig.4. Phase to phase voltage of 440V/50 Hz is considered on which STATCOM is installed. The model mainly consists of power circuitry, load module, detection unit and control unit.

Two types of loads are considered, nonlinear load (power electronics device) and inductive load. Reactive load come into picture after few cycles.

TABLE I. SYSTEM PARAMETERS

System Voltage	220V- line voltage, 50 Hz, Balanced/ Distorted
Non- Linear Load	Three phase uncontrolled rectifier with R = 15W , L = 100 mH
Interface Inductor	Rf = 5W , Lf = 3 mH
PI controller gains	Kp = 0.1 Ki = 0.005
DC link	Vdc1=Vdc2= 359V, Cdc1=Cdc2= 2000 µF Vdcref = 359V
Kp & Ki	0.5 & 0.0005

Considering the above mention parameter a system shown in Fig.4 is simulated using MATLAB/SIMULINK software. Initially the system is consider for linear load only and secondly linear and non linear load both are connected.

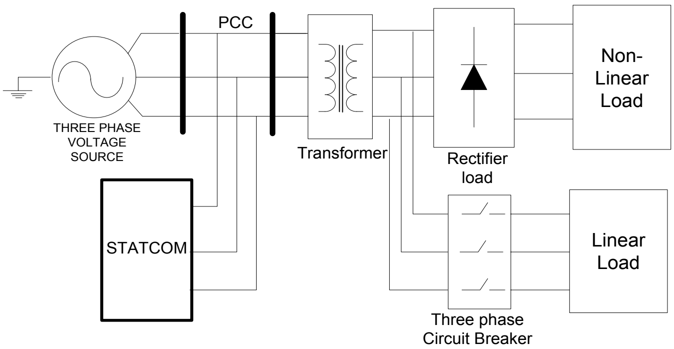
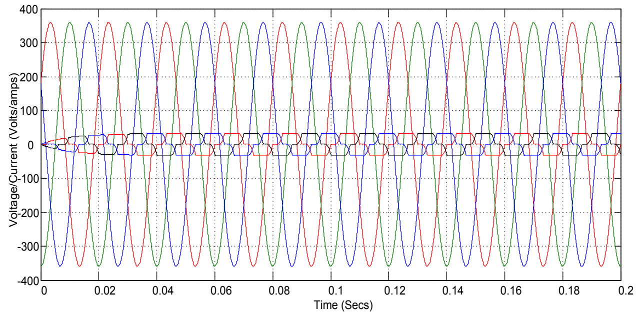


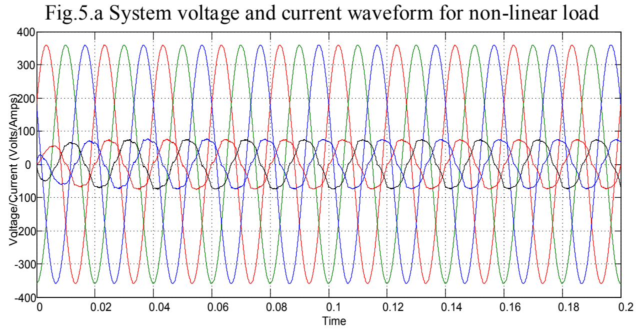
Fig.4. Schematic diagram of STATCOM connected power system with Linear and Non-Linear load

A. Non-Linear Load

As depicted in Fig.4 Usually there are two types of loads are connected to the electric power system. Here, non-linear load is considered initially. Fig.5 (A) shows the current and voltage waveform before compensation under non-linear load only. Rectifier load distorts systems source currents as shown in Fig.5 (A).



(Before Compensation)
Fig.5.a System voltage and current waveform for non-linear load

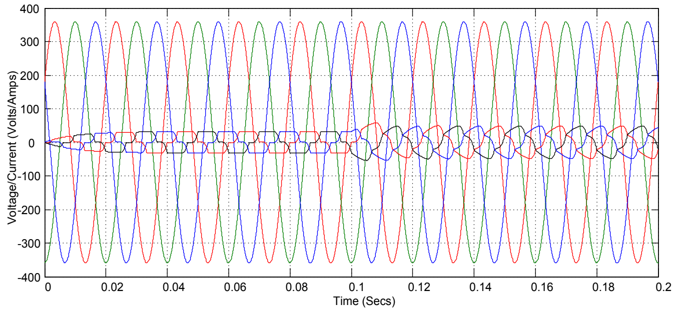


(After Compensation)
Fig.5.B System voltage and current waveform for non-linear load

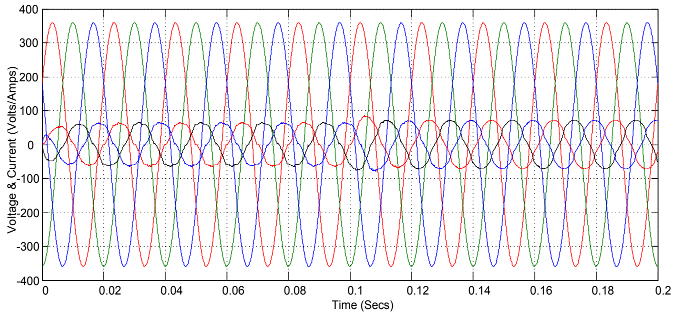
Current and voltage waveforms after compensation are shown in Fig.5 (B) under non-linear load condition. that the current waveforms approaches to sinusoidal which leads towards the improvement of power quality.

B. Linear & Non-Linear Load

Current and voltage waveforms before and after compensation are depicted in Fig.6 by considering both linear and non-linear loads. At the start of simulation, power electronic load is connected to the circuit. After 0.1 sec inductive load comes into picture. Before compensation current



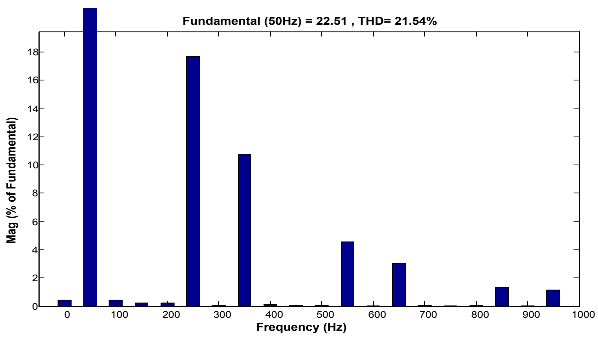
(Before Compensation)
Fig.6.a. System voltage and current waveform for linear and non linear load



(After Compensation)
Fig.6.b. System voltage and current waveform for linear and non linear load

waveforms are seem to be distorted. After compensation current waveforms approaches to sinusoidal.

From Fig.7 (a) and (b), it is noticed that total current harmonic distortion in phase B, with and without compensation, get reduced to 6.96% from 21.54% and hence current quality is improved.



(Before Compensation)
Fig. 7a Phase B Current waveform Harmonic (FFT) analysis

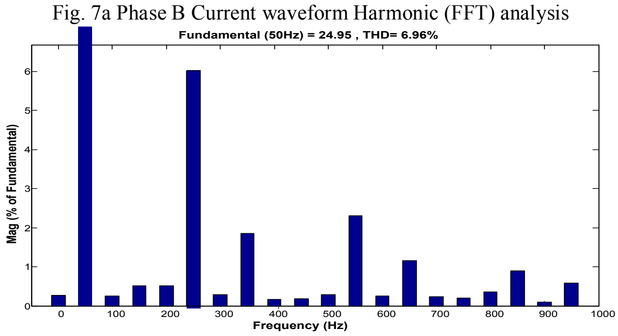
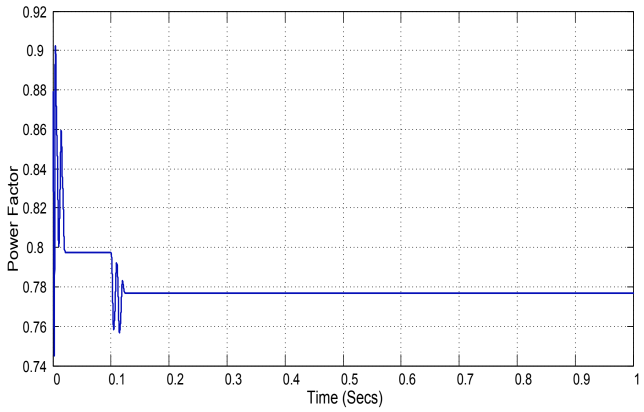


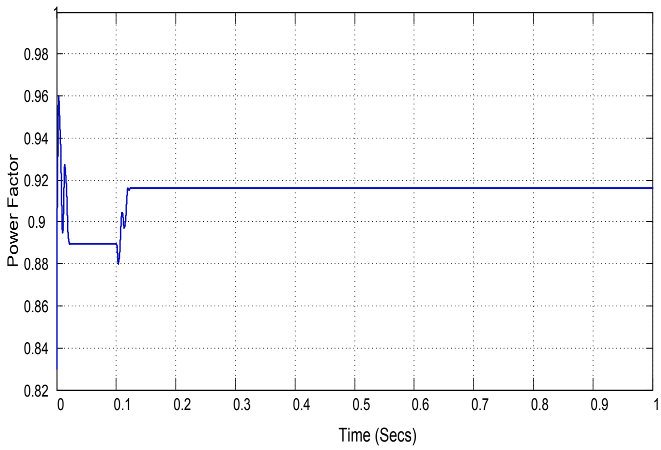
Fig. 7b Phase B Current waveform Harmonic (FFT) analysis

Also, fig.8 (a) and (b) shows that the power factor of considered system, before and after compensation, is improved from 0.77 to 0.916. This indicates the robustness of direct current control method. Hence, good reactive power compensation is achieved.



(Before Compensation)

Fig.8.a power factor of Phase B



(Before Compensation)

Fig.8.b Power Factor of Phase B

V. CONCLUSION

This paper mainly demonstrates the basic operating principle of STATCOM with direct current control scheme under linear and non-linear load conditions. It is observed that this method is complex in implementation as compared to indirect current control method but due to fast response and precise nature of direct current control method, STATCOM acts as a highly proficient device for power factor improvement and harmonic reduction.

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