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PI Controller Based Power Quality Improvement In Distribution System

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Abstract

Recent times due to the increased usage of loads, maintaining the power factor and harmonic standards are the major challenging task for control engineer. This paper presents the power quality enhancement in power distribution system both linear and nonlinear with the help of shunt active power filter (D-STATCOM) and series active power filter (DVR) using PI controller. The proposed method mitigates current and voltage related power quality problems with dc link voltage. The total harmonic distortion value is reduced from 8.05 percent to 0.44 percent using MATLAB software.

Keywords: Power quality, D-STATCOM, DVR, Voltage source inverter, Linear and non-linear load.

1. Introduction

STATCOM and DVR is custom power device, which mitigates voltage and current-related PQ issues in the power distribution systems. The widespread use of Power Electronics based equipment has produced a significant impact on quality of electric power supply. One modern and very promising solution that deals with both load current and supply voltage imperfections is the STATCOM and DVR. The proposed topology enables to have a reduced dclink voltage without compromising its compensation capability. The average switching frequency of the switches in the VSI also reduces; consequently the switching losses in the inverters reduce. The compensating group includes distribution static compensator (DSTATCOM) to compensate for load reactive power and current harmonics, dynamic voltage restorer (DVR) for voltage support.

Ghosh, A. and Joshi, A.[1] deals with the generated reference signal is used to produce gate switching signals of the inverter. The main modulation techniques used in DVR are space vector Pulse width modulation, dead beat control, Pulse width modulation control and hysteresis control. The hysteresis control has rapid controllability, simple execution and uneven switching frequency. Pulse width modulation control has a great force on its transient performance and superior operating frequency capacity. Pulse width modulation method is broadly used for gate signal generation in custom power applications.

The deadbeat controller has very quick transient response. Jindal, K. and Joshi, A. [2] describe the Combined operation of many types of filter can achieve greater advantages for some applications. The combinations are both parallel and series active filters, combined operation of series active and parallel passive filters, combined operation of parallel active and passive filters. Seven-level Active power Filter configuration also examined in.Han, B., Baek, S. and Jang, G. [3] presents the standby mode operation using Bypass switches, the insertion transformer works as a secondary shorted current transformer and delivering utility power directly to the load. During standby mode operation of Dynamic Voltage Restorer, two upper IGBTs in each phase of the inverter remain turned off while the two lower IGBTs remain turned on. Zhili, T. and Shanxu, D. [4] deals with the DVR can act as a series active filter, isolating the source from harmonics generated by loads. It is used to compensating the voltage sag/swell, voltage unbalance and voltage harmonics presented at the point of common coupling.Zhili, T and Dongjiao, Z [5] this converter has both regenerated energy generation and active power filtering capabilities. An inductance for output filtering of VSI is used to eliminate the harmonic at different frequencies. The different combination of L and C filters to attenuate the switching ripple currents.Sano, K.; Takasaki, M [8] deals with a Cascaded Multilevel Converter which has multiple dc voltage values (multi voltage cascade converter) for a 6.6-kV transformer less distribution static synchronous compensator (D-STATCOM). A control method is proposed to realize dc voltage regulation of series connected three cells in the STATCOM operation, making it possible to remove dc sources from all H-bridge cells. The simplified configuration without the dc sources makes the STATCOM small and lightweight.

Tang Ping; Yin Xianggen; Zhang Zhe. [9] analyzed that Distributed Static Compensator is an important member in Distributed Flexible AC Transmission Systems. The resonance phenomenon in traditional LC output filter is pointed out. Then, two modified topologies (LCR and LCCR topologies) are proposed to solve this problem. M. Moradlou and H. Karshenas. [10] Deals the compensator has to supply additional reactive currents which increase the source currents. Due to increased current injection, the VSI is de-rated in steady-state condition. Consequently, its capability to mitigate deep voltage sag decreases.A. Khoshkbar Sadigh; K. M. Smedley. [11] deals with different methods of voltage compensation in the distribution systems using DVR.Firouz Badrkhani Ajaei,Shahrokh Farhangi, and Reza Iravani. [12] in this paper deals the analysis of fault current interrupted in the Dynamic Voltage Restorer. Handan Kumar;Mahesh K. Mishra .[13] Madhavasarma et al designed a pi controller for spherical tank non linear process.[14].In this paper, a control algorithm has been proposed for the generation of reference load voltage for a voltage-controlled DSTATCOM.In this work, the performance of D-STATCOM

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and DVR control strategies are evaluated by using conventional PI controller and simulations results are compared.

2. Control Strategy

The shunt and series active filter compensation performance depends on the turning on and turning off of semiconductor switches. In this paper two control techniques were used namely, PI and Hysteresis controller. In hysteresis controller the reference current is compared with the actual current that is injected by the compensation circuit. It is based on a feedback loop, with two level comparators. It is used to generate gate pulses for VSI switches .When the limit is violated hysteresis controller supplies triggering pulses for appropriate switches for both series and shunt active filter. VSI are supplied from a dc link capacitor. Controllers are used to regulate the capacitor voltage constant, and for achieving load compensation or harmonic current compensation. Over a long period, PI controller has been used effectively to control the operation as shown in figure1. For achieving power quality, controllers give firing pulses to turn on the switches at proper intervals of time. Switches are turned on to energize the capacitor, when the capacitor voltage falls below a particular value and load compensation and voltage regulation has achieved at all periods of time. In figure 2. ABC co-ordinates are converted into dq co-ordinates using Synchronous reference frame theory. The output is fed to low pass filter. The reference current is fed to hysteresis current controller and it is compared. The dq co-ordinates again converted into ABC. The hysteresis controller generates gate pulse for DVR and compares the reference current and voltage injected by series active filter.

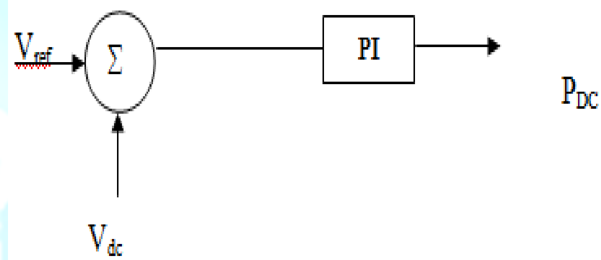


Figure .1.Basic PI Controller

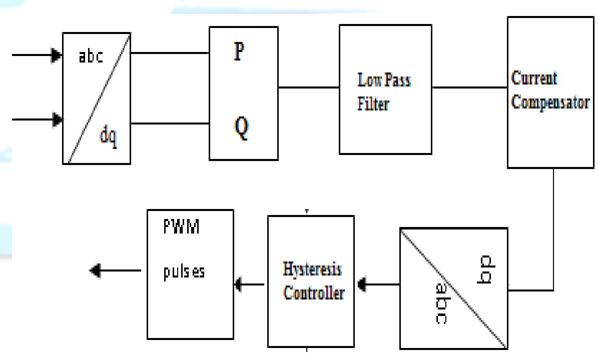


Figure .2.Basic Hysteresis Controller

Switches are turned on to energize the capacitor, when the capacitor voltage falls below a particular value and load compensation and voltage regulation has achieved at all periods of time. The controller is used to generate a 3 phase reference current by comparing it with load current. DVR injects voltage through series transformer when a voltage drop occurs. Source and load voltages are sensed and compared so as to obtain a reference voltage for the phases a, b and c.

3. Simulation Analysis

3.1 DVR & DSTATCOM with PI &Hysteresis Controller

UPQC is a complex power electronics device, which leads to improved and it is very difficult without computer simulations. The overall design process can be shortened through the use of computer simulations, since it is usually easier to study the influence of a parameter and the system behavior in simulation. This section presents the MATLAB simulation and demonstrates the effectiveness of the proposed control strategy for the active filter for harmonic current filtering, reactive power compensation, and load current balancing. All the compensators are implemented using blocks to observe the performance of Shunt filter for current compensation and Series filter for voltage correction PI and Hysteresis controller used separately.

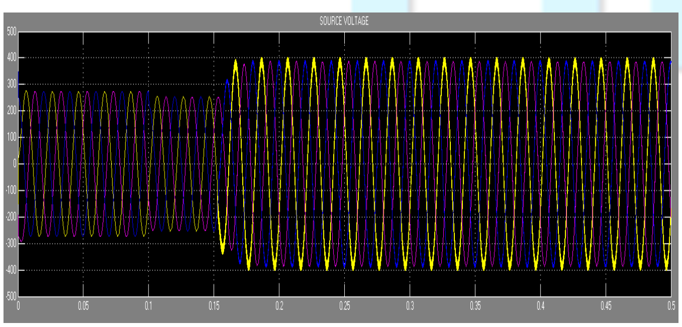


Figure.3. DVR Source Voltages

When DVR is in operation the voltage sag is mitigated completely and voltage of the sensitive load is maintained at 98%, as shown in Fig.3.The sag mitigation is performed with a smooth, stable, rapid DVR response and two transient undershoots are observed. The compensation capability of DVR depends on the capacity of the energy storage device. DVR can also added other features; those are line voltage harmonics compensation, reduction of transients in voltage and fault current limitations and then analyze the dynamic and steady-state performance of DVR.

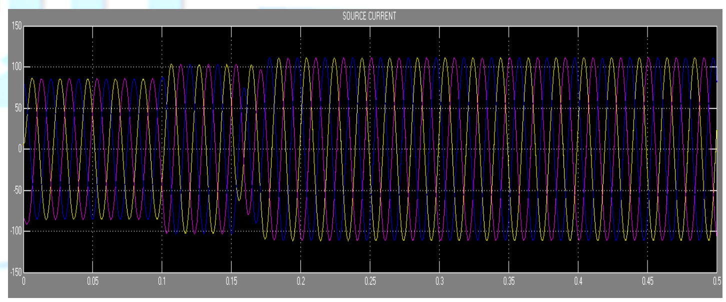


Figure.4. DVR Source Current

The source current shown in the Figure4. During 0.15 transition time breaker closed and DVR comes to picture and compensates voltage due to sag and reaches source voltage, then breaker gets turned off. The load current increases when there is voltage sag.

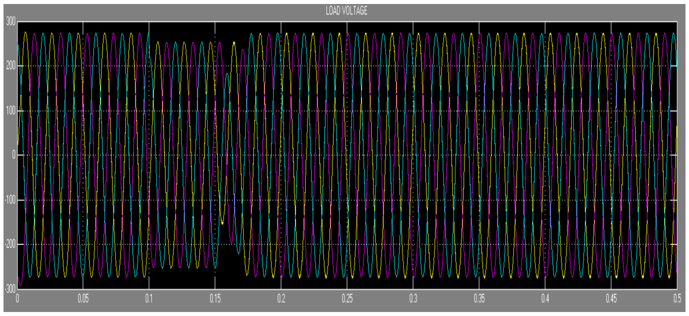


Figure.5. DVR Load Voltage

During t=0.1s load2 gets connected, there is a voltage drop. At t=0.15s DVR turned on and compensates voltage equal to source voltage as shown in figure.5.

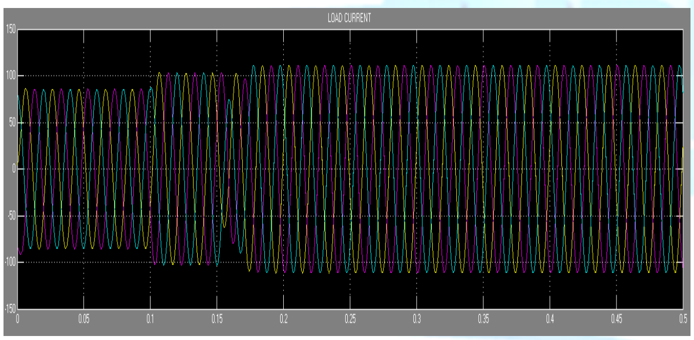


Figure .6. DVR Load Current

At t=0.15s DVR comes to a state and injects voltage due to sag and reaches the source voltage and corresponding load current as shown in figure.6.

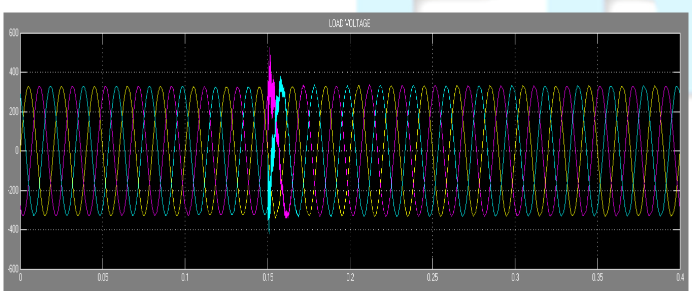


Figure.7. Wave form of Dstatcom Voltage Parameter

Here in figure 7 the total simulation time is 1sec. Load is always on entire range at t=0.1s, load 2 is on and there is a voltae sag. And t=0.15s DSTATCOM compensates voltage due to sag and reaches source voltage, then breaker gets turned off.

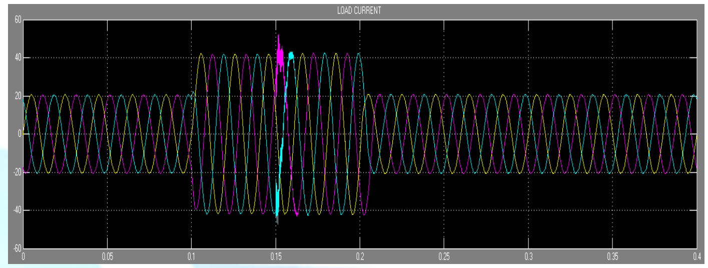


Figure .8. Wave form of Dstatcom Current Parameter

In figure .8. total simulation time is 1sec. Load is always on entire range at t=0.1s, load 2 is on and there is a voltae sag corresspondinly load current increases. And t=0.15s D-STATCOM compensates voltage due to sag and reaches source voltage, then breaker gets turned off. The load current maintain with the source voltage.Figure.9 (a) & (b).shows the real and reactive power source. In that the wave shapes harmonics are suppressed with source currents.

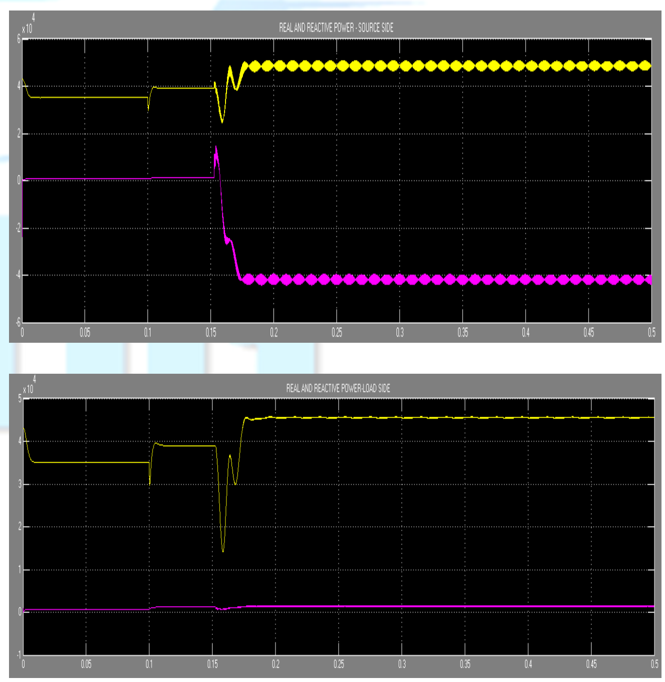


Figure .9 (a).Real and Reactive power source (DVR)

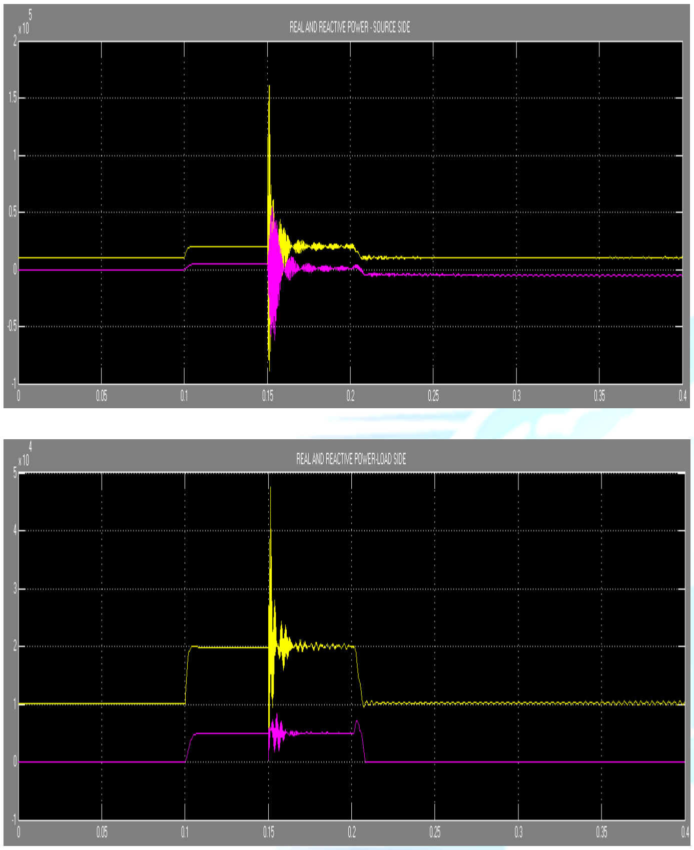
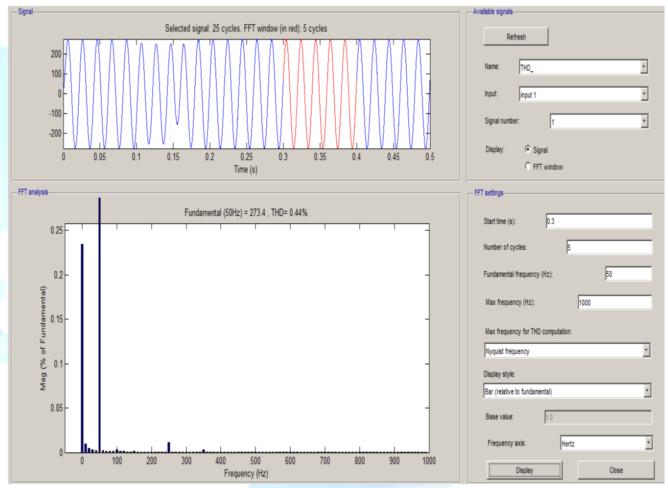


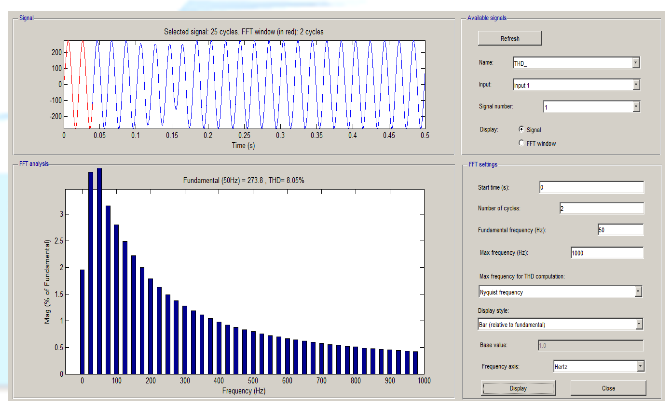
Figure .9(b).Real and Reactive power source(D-STATCOM)

Here Load-1 always on for entire time range. When t=0.1s the high inductive load will be turned on. So the reactive power consumption will be high at t=0.15sec. So the real power consumption from source would be reduced. At t=0.1 the DSTATCOM will enable and provide reactive power compensation. At t=0.15 reactive power consumption will be reduced from source side and real power consumption will be improved. Simulated results were showed good dc bus voltage regulation, reduced source harmonic currents, and improved power factor and stable operation.

3.2 FFT Analysis Using PI and Hysteresis :(DVR &DSTATCOM individually)



(a)FFT Analysis for DVR



(b)FFT Analysis for D-STATCOM

Figure .10.Total Harmonic Distortion (a) DVR (b) D-STATCOM

Figure.10.The total harmonic distortion, THD=8.05% for D-STATCOM with frequency of 50HZ using FFT analysis and the

THD reduced to 0.44% for DVR with frequency of 50Hz using FFT analysis. The THD values reduced due to the presence of DVR.

Table 1 Comparison Analysis of Filter Performance

FFT Analysis THD	DSTATCOM and DVR (With Pi &Hysteresis)
D-STATCOM	8.05%
DVR	0.44%

5. Conclusion

Power quality enhancement using shunt active filter and series active power filter was designed using PI controller. The total harmonic distortion value is reduced from 8.05 percent to 0.44 percent using MATLAB software.

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