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Research Article

ACTIVE CONTROL FOR POWER QUALITY IMPROVEMENT IN DISTRIBUTION SYSTEM

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A R T I C L E I N F O

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A B S T R A C T

As we aware that electrical energy is now became a part of our life as the dependency on the electrical energy has been increased greatly. Everybody is using electrical energy in their day- to-day life, which needs to think about the quality and continuity aspects of electrical energy. The quality of power supplied is affected by variation in the supply and the presence of nonlinear loads. In this project, we are discussing about power quality problems- voltage variation, harmonics & purpose of methods to overcome these problems. There are many methods to overcome these problems. Among them the use of FACT devices is an efficient one. This project presents an overview of the FACT devices like- DVR, DSTATCOM. And also the control strategies to control these devices are presented in this project. The proposed control strategies are simulated in MATLAB SIMULINK environment and the results are presented.

INTRODUCTION

Change is unavoidable as world progresses. This progress shows advancement in every aspects of life. Even we cannot spare power system. The advancement makes available more sophisticated & dedicated electronic equipment's. Ultimately it demands more precise and accurate power supply. The customer uses Power Quality (PQ) as keyword for power utilities. If PQ is not good then it will affects profitability which definitely is a driving force in the industry [10]. Although electrical transmission and distribution systems have reached a very high level of reliability, disturbances cannot be totally avoided. Any disturbances to voltage & current waveform can cause problems related with the operation of electrical and electronic devices.

Today most ofpower electronic based equipment is used in industrial and domestic purpose. This equipment has significant impact on PQ. They have many negative impacts such as additional losses in overhead and underground cables, transformers and rotating electric machines, problem in the operation of the protection systems, error of measuring instruments and malfunction of low efficiency of customer sensitive loadsUltimately users need constant sine wave shape, constant frequency and symmetrical voltage with a constant Root Mean Square (RMS) value to continue the production. This increasing interest to improve efficiency and eliminate variations in the industry has resulted in more complex instruments sensitive to PQ problems such as voltage sag, voltage swell, and interruption, harmonic.

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Even if consider customers side or load side, the consumers that are connected to the same bus that supplies a large motor load may have to face a severe voltage sags or dips in their supply. Thus it affected by voltage sags and outages. Voltage sags is much more serious and can cause a large amount of damage. In some extreme cases, they may have to tolerate with blackouts. This is unacceptable to most customers. There are also very sensitive / critical loads such as hospitals (life support, operation theatre and patient database system), processing plants (semiconductor, food, rayon and fabrics), air traffic control, financial institutions and many other data processing and service providers that require clean and uninterrupted power. In several processes such as semiconductor manufacturing or food processing plants, the products can be destroyed by voltage sag of very short duration. Such customers are very wary of such voltage sags since each such interruption cost them a substantial amount of money. Thus in this changed scenario in which the customers increasingly demand quality power, the term PQ attains increased significance.

Power Quality

Definition

There is an organization which called as Institute of Electrical and Electronic Engineers (IEEE) that specifies global standards. According to IEEE, standard Power Quality (PQ) is defined as "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment".

The focus of this survey is on the use of FACTS devices to resolve PQ problems [21].

Voltage Variation

Faults on the transmission or distribution network (most of the times on parallel feeders), Faults in consumer's installation, Connection of heavy loads and start-up of large motors are main cause for voltage variation. These voltage variations are directly related to real and reactive power variations. Voltage Sag/ Dips/ Swell, Short Interruptions and Long duration voltage variation are common voltage variation issues.

Harmonics

Harmonics are created due to electric machines working above the knee of the magnetization curve (magnetic saturation), arc furnaces, welding machines, rectifiers, and DC brush motors. Also modern sources: all non-linear loads, such as power electronics equipment including ASDs, switched mode power supplies, data processing equipment, high efficiency lighting cause harmonics. The harmonic content in a voltage or current should be under the limit at source. The filtering by rapid switching largely reduces the lower order harmonic current, but the remaining current will have higher order frequency content which can be easily filtered-out.

Consequences of the Issues

Power system and its equipments are badly affected by this PQ issues like breakdown of information technology equipment or may be stoppage of all equipment, circuit breakers trip without being overloaded, automated systems stop for no apparent reason, electronic systems work in one location but not in another location.

Dynamic Voltage Regulator (DVR)

DVR Model

The operation of DVR is based on the fundamental principle that a voltage waveform is injected through an injection transformer that is the difference between pre-sag and sag voltage. This is often made possible by the supply of required real/active power from an energy storage device together with reactive power. The turn's ratio of injection transformer and ratings of the energy storage device can put limitations on the maximum injection capability of DVR.The basic components of DVR are represented in fig. 1[6].

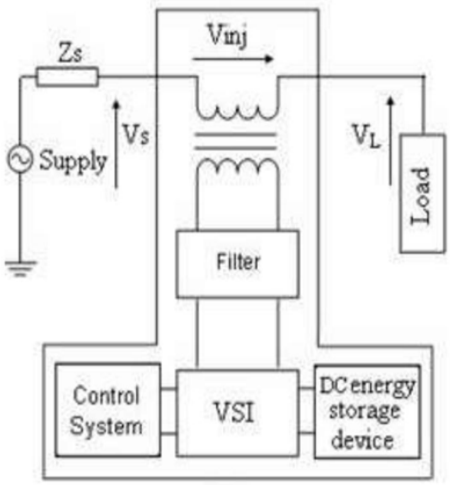


Figure1 Basic DVR topology

Selection of Reference Signal

To compare voltage existing level there should be some reference voltage which has constant magnitude. So considered separate three phase source of constant magnitude.

Compensating Signal Generation

To generate compensating signal, need to use control algorithm. There are many algorithms but we used DQ transformation. The dqo technique provides the magnitude of sag and details of phase shift with their starting and finishing times. The quantities are expressed as the instantaneous space vectors. The voltage is converted from a-b-c reference frame to d-q-o reference. We have a tendency to ignore zero sequence parts for simplicity. The management is enforced by comparing a set reference voltage and also the measured load phase voltage (Va, V_b, V_c).

Generate Gating Signal (SPWM)

The error signal formed by the above comparison is used as a control signal that generates a commutation sequence pattern for the power switches of the VSI using sinusoidal Pulse width Modulation technique (SPWM); voltages are controlled by modulation. The PLL (Phase Locked Loop) circuit is employed for the generation of a unit sinusoidal wave in phase with mains supply voltage.

The block diagram of the control system used is shown in Fig. 2 [2]. The control system of a DVR plays an important role, with the requirements of fast response in the face of voltage sags and variations in the connected load. This paper uses a close loop control for the DVR system using PLL. The PLL is to synchronize the DVR with the power system by generating a reference voltage to be compared with the actual one.

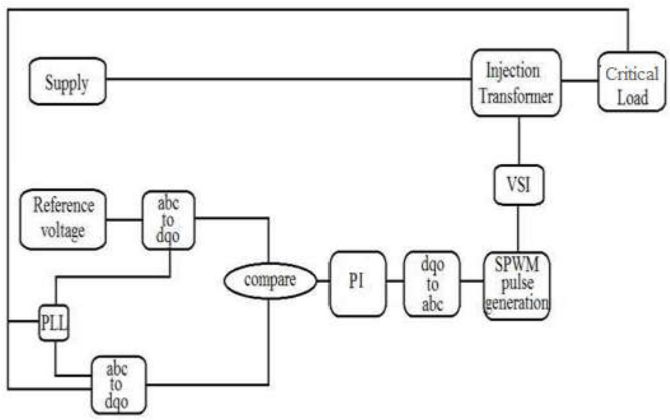


Figure 2 Control of SPWM switching pulses

DSTATCOM Model

The DSTATCOM has been reported to improve the power quality in power systems. DSTATCOM can be implemented to mitigate harmonics as a shunt compensator for the Non-linear load. It is a Battery Energy Storage System (BESS) connected to a DC link capacitor which itself connected to a Voltage Source Converter (VSC).

The DSTATCOM is shunt connected and in this paper uses a Hysteresis current control method to inject a current in the system to counter the harmonics created by the non-linear load. The basic DSTATCOM model is shown in Fig.3 [28].

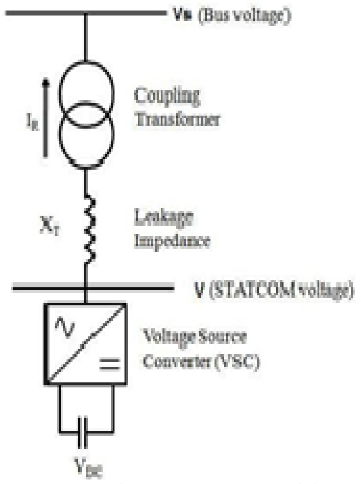


Figure 3 Basic DSTATCOM Model

Reference current generation

To get a reference current to use in the DSTATCOM control, we need a topology for grid coordination. This paper uses these formulas to synchronize the reference currents to the grid voltage of the infinite bus, which is a bus with theoretical voltage of 1 per unit (p.u.) with infinite stability. If we take the phase RMS voltages (V_{sa},$V_{sb,}$$V_{sc}$) and is expressed, as sample template V_{sm}, sampled peak voltage, as in equation(1).

$$V_{sm} = \left\{\frac{2}{3}(V_{sa}^2 + V_{sb}^2 + V_{sc}^2)\right\}^{\frac{1}{2}} \quad \text{....... (1)}$$

Then the unit vectors are generated from the source are shown inequation (2).

$$\mu_{sa} = \frac{V_{Sa}}{V_{sm}},\ \mu_{sb} = \frac{V_{Sb}}{V_{sm}},\ \mu_{sc} = \frac{V_{Sc}}{V_{sm}} \quad \text{.......(2)}$$

Then the reference currents will be as inequation (3):

$$i_{Sa}^* = I.\mu_{Sa},\ i_{Sb}^* = I.\mu_{Sb},\ i_{Sc}^* = I.\mu_{Sc} \quad \text{.........(3)}$$

This creates a fixed sinusoidal reference current synchronized with the grid without using a Phase Locked Loop (PLL).

Hysteresis (also called Bang-Bang)

The actual currents are detected subtracted from the reference current and obtain current error. This error is compared by a relay that gives an ON OFF signal for the IGBT switching if the error is higher or lower than a previously set band.

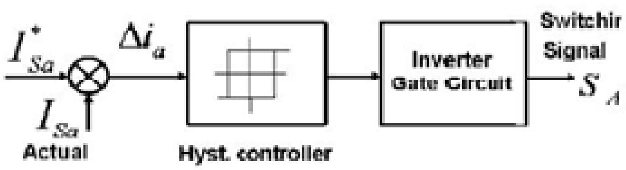
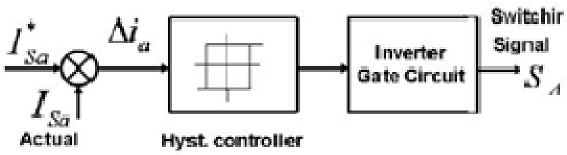


Figure 4 Generation of switching signals

For phase A we have the following switching logic

- if $Is_a - Is_a^* < -hb$, then we need to inject a current and Sa =1
- if $Is_a - Is_a^* > hb$, then we need to absorb current then Sa=0

Phase B and phase C work in the same way; **'hb'** is the hysteresis band. The wider the hysteresis band is the larger the error, the smaller the hysteresis band the smaller the error but this means the need for very fast switching and higher rating devices [14].



System in Study

Proposed System

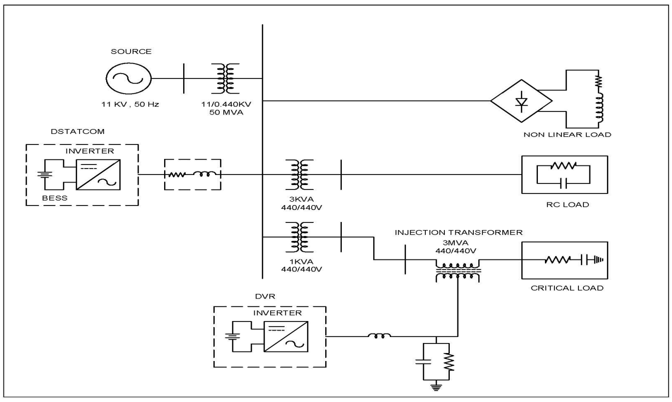


Figure 5 Proposed System in Study

To study purpose of my project, I used simple distribution system which is consist of source 11KV which is step down to 440 V through step down transformer and connected to PCC. Studying at the PCC will give an idea of the system behaviour at any other Bus, so I have to study our system at the PCC. Fig 5 represents view of proposed system where I have connected different loads.

I want to tackle PQ issues like voltage sag, swell and current harmonics so I use DVR and DSTATCOM as active filters to mitigate voltage sag, swell and current harmonics respectively. DVR cancel the effect of voltage sags & swells by injecting a voltage into the system and DSTATCOM mitigates the harmonics by injecting a current into the system.

For simulation, three systems are considered.

1. Uncompensated system
2. Voltage compensated system with DVR
3. Current harmonics mitigation system with DSTATCOM

Also three types of load are considered.

1. Resistive load for voltage sag
2. Capacitive load for voltage swell
3. Nonlinear load for Current harmonics

Here Fig 6 shows the proposed system model in MATLAB /SIMULINK.

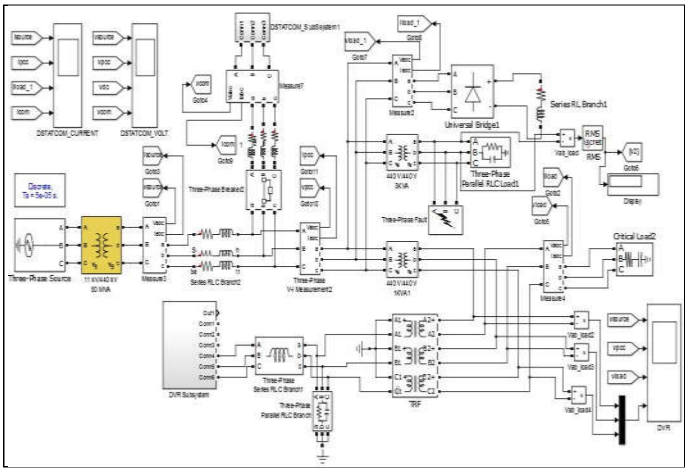


Figure 6 MATLAB / SIMULINK modelled System

In Fig. 7 the system shows proposed control scheme of DVR model in MATLAB / SIMULINK which is compose of DC batteries with an inverter connected to an injection transformer and with the relative control.

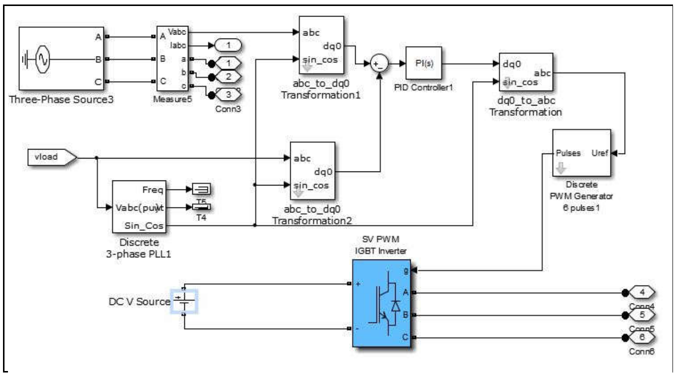


Figure 7 Control scheme of DVR model in MATLAB /SIMULINK

Fig. 8 shows proposed control scheme of DSTATCOM model in MATLAB / SIMULINK which is compose of DC batteries with an inverter which is get firing pulse through the hysteresis current controller.

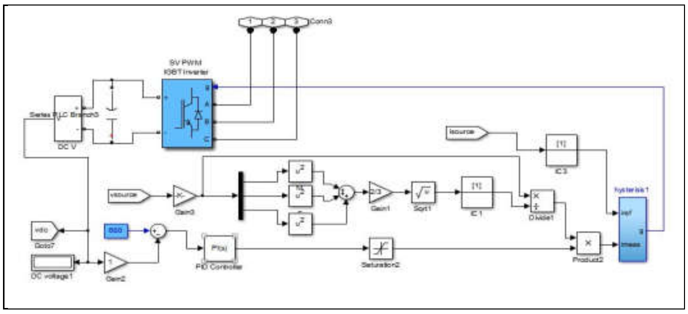


Figure 8 Control scheme of D-STATCOM model in MATLAB /SIMULINK

SIMULATION AND RESULTS

Uncompensated System with Voltage Sag

Voltage sag is initiated in the system by connecting an extra resistive load for certain periodof time in above proposed system. Here the extra load is connected to the system for duration 0.4 to 0.6 secwhich causes voltage sag at PCC and Critical load. Fig 9 present simulations for output before the incorporation of DVR at

1. Source
2. PCC
3. Critical load

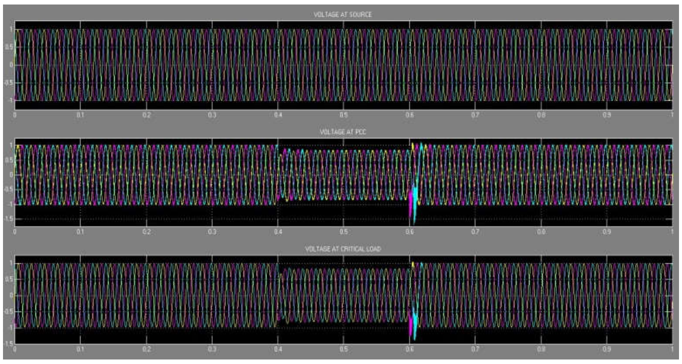


Figure 9 Simulation of Uncompensated System with Voltage Sag (a) Voltage at Source (b) Voltage at PCC (c) Voltage at Critical Load

DVR Compensated System for Voltage Sag

To compensate voltage sag at critical load, we connect DVR in series with system. Here DVR is engaged to the system for duration 0.4s to 0.6s. During this time period the voltage across critical load got compensate against voltage drops at PCC is as shown in Fig. 10. This fig. is presentation for simulation output after the incorporation of DVR and voltages at

1. Source
2. PCC
3. Critical load

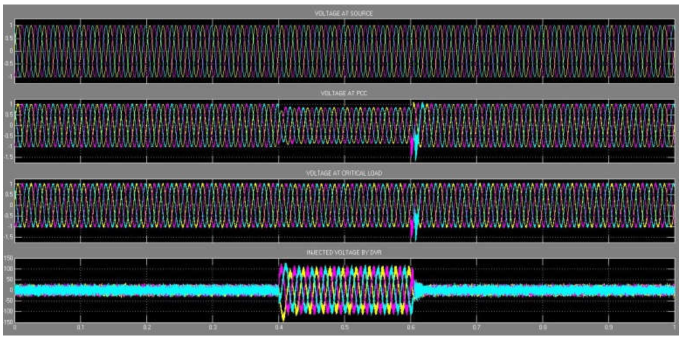


Figure 10 Simulation of Compensated system with DVR (a) Voltage at Source (b) Voltage at PCC (c) voltage at Critical load (d) Voltage injected by DVR

Uncompensated System with Voltage Swell

Voltage swell is initiated in the system by connecting an extra capacitive load for certain period of time in above proposed system. Here the extra load is connected to the system for duration 0.4 to 0.6sec which cause voltage swell at PCC and Critical load. Fig 11 present simulation output before the incorporation of DVR at

1. Source
2. PCC
3. Critical load

Here the voltages are taken in per unit values.

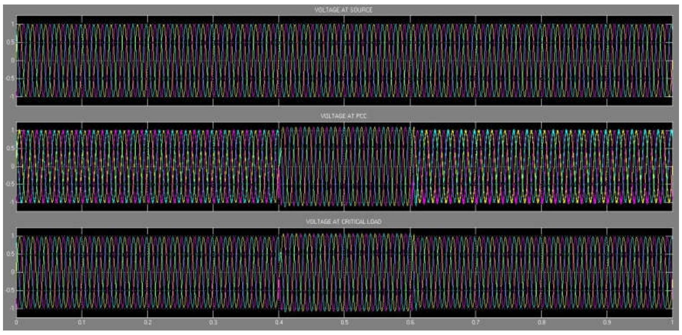


Figure 11 Simulation of Uncompensated System with Voltage Swell (a) Voltage at Source (b) Voltage at PCC (c) Voltage at Critical Load

DVR Compensated System with Voltage Swell

Voltage swell compensation is initiated by connecting DVR in series with system. Here DVR is engaged to the system for duration 0.4s to 0.6s. During this time period the voltage across critical load is got compensate against voltage swell atPCC as shown in Fig. 12. This fig.is presentation for simulation output after the incorporation of DVR and voltages at

1. Source
2. PCC
3. Critical load

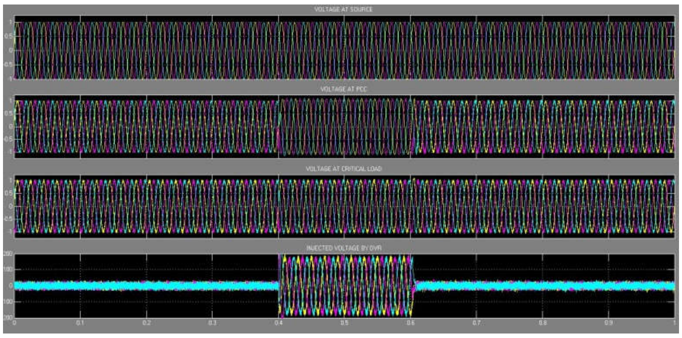


Figure 12 Simulation of Compensated System with DVR (a) Voltage at Source (b) Voltage at PCC (c) voltage at Critical load (d) Voltage injected by DVR

Uncompensated System with Nonlinear Load

Current harmonics initiated in the system by connecting an extra Nonlinear load for time (1 sec) in above proposed system. This Nonlinear extra load which is connected to the system causes current harmonics. Fig 13 present simulations for output before the incorporation of DSTATCOM at

1. Source
2. PCC
3. Non-linear load

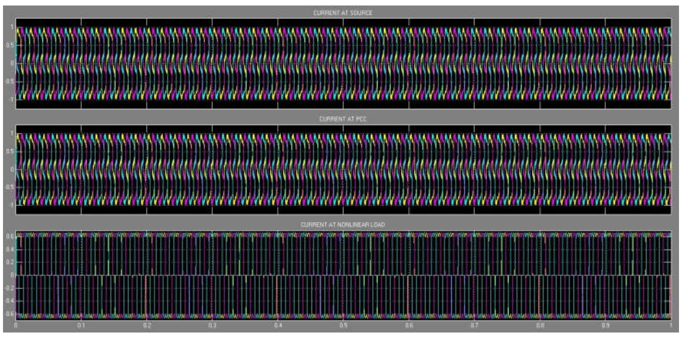


Figure 13 Simulation of Uncompensated System with Nonlinear Load (a) Current at Source (b) Current at PCC (C) Current at Nonlinear load

Also for the harmonic analysis, the FFT of source current before DSTATCOM have THD 26.12% is shown in fig 14.

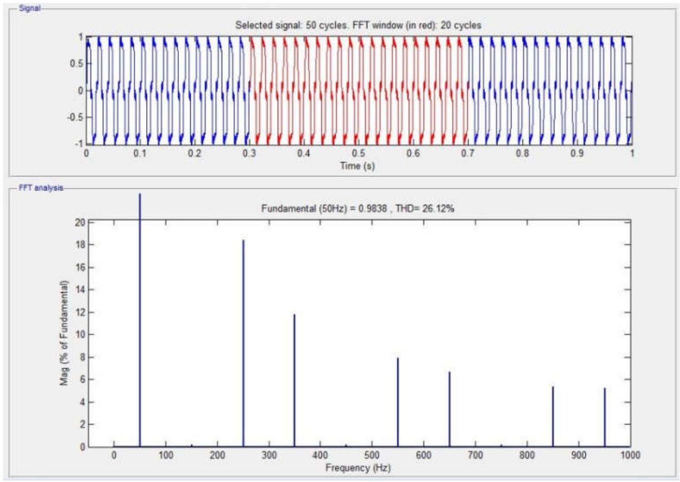


Figure 14 FFT of source current before DSTATCOM

DSTATCOM Compensated System for Nonlinear Load

Nonlinear load compensation is initiated by connecting DSTATCOM parallel to the system. Here DSTATCOM comes into picture as per requirement to the system.During this time period current harmonics at source is got compensate against harmonics at the nonlinear load shown in Fig. 15. This fig.is presentation for simulation output after the incorporation of DSTATCOMand currents at

1. Source
2. PCC
3. Nonlinear load

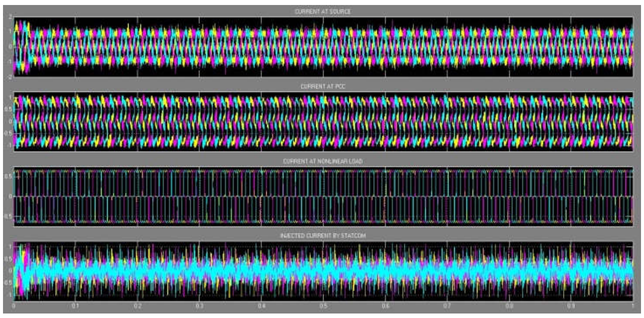


Figure 15 Simulation of Compensated System with DSTATCOM (a) Current at Source (b) Current at PCC (c) Current at Nonlinear load (d) Injected Current by DSTATCOM

Also for the harmonic analysis, the FFT of source current after DSTATCOM which have THD 13.79% is shown in fig 16.

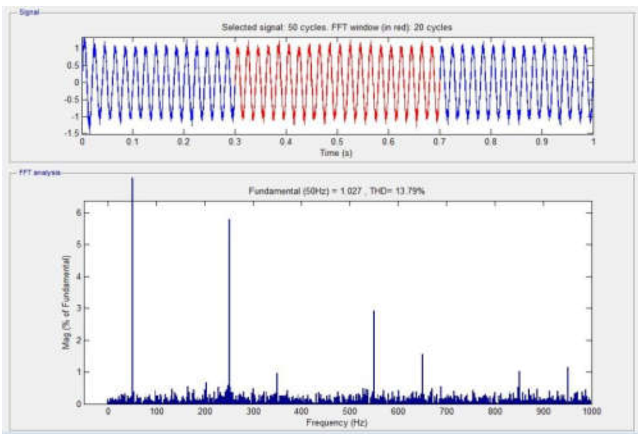


Figure 16 FFT of source current after DSTATCOM

CONCLUSION

An extensive review of compensating customer devices DVR & DSTATCOM have been presented to provide a clear perspective on various aspects of devices to the researchers, engineers and manufactures. Power system and its equipment is badly affected by PQ issues like harmonics & voltage sag/swell above the tolerance limits due to extensive use of non-linear loads and start of heavy loads. These PQ issues causes various affects i.e. nuisance tripping of breakers or stopping of automated systems, overheating of transformers and cables. The presented classification of configurations, topology and control strategies provide compensation solution to various power quality problem viz voltage sags/swells, voltage flicker, voltage regulation and harmonics.

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