

Design and Simulation of DVR Used For Voltage Sag Mitigation at Distribution Side

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Abstract: The Dynamic voltage restorer is custom power device which is utilized to mitigate the voltage at load terminals. Power quality is one of major concerns in the present era. It has become important, especially, with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply. Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure of end user equipments. One of the major problems deal at here is the power sag. To solve this problem, custom power devices are used. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. DVR injects required voltage in series with supply voltage through injection transformer for correcting voltage amplitude, phase and harmonic component into line. This paper presents development, simulation and analysis of a Dynamic Voltage Restorer (DVR) using MATLAB/ SIMULINK. To enhance the voltage sag restoration capability of the DVR, this paper deals with the development of a control structure using a Discrete PWM pulse generator. This paper discussed abc to dq0 based new control algorithm to generate the pulse. Results obtained shows that the developed DVR has good capability to starch the voltage level during voltage sag conditions.

Keywords: Voltage sag, power quality improvement, dynamic voltage restorer, pulse width modulation, MATLAB/SIMULINK.

I. INTRODUCTION

In modern industrial devices most of devices are based on electronic devices such as programmable logic controllers and electronic drives. The power electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics in the entire problems associated with voltage dips is considered as one of the most severe disturbances to the industrial equipment The problem of poor power quality like voltage sag for sensitive loads can be better dealt or solved by power electronics based Dynamic Voltage Restorer. With the application of DVR, the power system can be operated without voltage sag and the power supply by flexibly changing the distribution configuration after the occurrence of a fault. The DVR is a series conditioner based on a pulse width modulated (PWM) voltage source inverter (VSI), which could generate or absorb real or reactive power independently. The condition of Voltage sags caused faults is, influenced in case of sensitive loads. The DVR injects the individual voltages to restore and maintained sensitive loads to its nominal value. The combination of the custom power devices DVR with PI controller for the power quality improvement in the distribution system is describe here for operation of DVR to improve the power quality in distribution system. A new control strategy has been developed for achieving maximum benefits by eliminating or mitigating voltage sag / swell and power quality problem when abnormal condition occur in the distribution system, for this purpose the dynamic voltage restorer is proposed to improve the power quality and to reduce the sag and swell problem in the system.

II. SYSTEM DISCRIPTION

Dynamic Voltage Restorer is one of custom power device specially used to maintain the load voltage constant in the distribution system. DVR has two operating modes. In normal operation mode it is in standby mode in which voltage injection by DVR is zero. The primary function of DVR is to compensate voltage sags and swells but it can also perform the tasks such as harmonic compensation, reduction of transient in voltage and fault current limitation. The main parts of DVR are injection transformer, harmonic filter, a voltage source

converter, energy storage device and control & protection system [3-4]. As soon as control circuit detects the any voltage disturbance, reference voltage is generated for required magnitude, duration and phase and is injected through injection transformer. This mode of DVR is known as injecting mode [1]. This injection should satisfy the equation (1)[2]

$$V_L = V_S + V_{inj} \tag{1}$$

Where V_S is the source voltage, V_{inj} is the injected voltage by DVR and V_L is the load voltage. Fig.1 shows the basic configuration and operation of DVR which consist of an injection transformer, Voltage Source Converter (VSC), harmonic filter, storage device and control system.

A. Injection Transformer:

Injection transformer is used to connect the DVR to the distribution network via High Voltage winding and injects the compensating voltage generated by VSC after the detection of any disturbance in supply voltage by control circuit. Another main task of injection transformer is that it will limit the coupling of noise and isolate VSC and control circuit from the system [5].

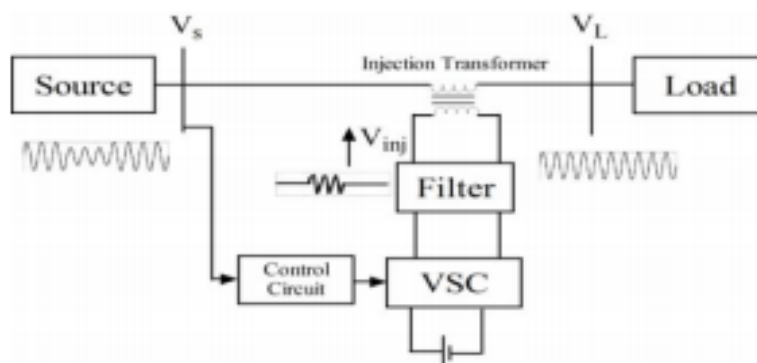


Figure 1 Structure of DVR.

B. Voltage Source Converter (VSC):

VSC is a power electronic device consists of storage device and switching devices used to generate the compensating sinusoidal voltage of required magnitude, duration, in phase as that of system and instantaneously. In DVR voltage source converter provides the missing voltage during voltage sag [2].

C. Harmonic Filter:

Output of VSC contains large content of harmonics. Harmonic filter is used to keep this harmonic content in Permissible limit [7].

D. Storage Device:

It is basically used to supply the necessary energy to VSC to generate the compensating voltage [2], [7].

E. Control Circuit:

Control circuit continuously monitors the supply voltage. The function of control system is to detect the disturbance in the supply voltage, compare it with the set reference value and then generate the switching pulses to the VSC to generate the DVR output voltages which will compensate the voltage sag/swell [2], [7].

III. DESIGN OF DVR

The aim of the control scheme is to maintain constant voltage magnitude at the sensitive load under voltage disturbance condition. The proposed control scheme based on comparison of actual supply voltage and desired load voltage. The error is determined dynamically based on difference between desired and measured value. In the control scheme the actual voltage is measured and also the desired voltage. These voltages are converted in dq0 with the Parks transformation [2].

$$V_d = 2/3*[V_a*\sin(\omega t) + V_b*\sin(\omega t - 2\pi/3) + V_c*\sin(\omega t + 2\pi/3)]$$

$$V_q = 2/3*[V_a*\cos(\omega t) + V_b*\cos(\omega t - 2\pi/3) + V_c*\cos(\omega t + 2\pi/3)]$$

$$V_0 = 1/3*[V_a + V_b + V_c]$$

And according Inverse Parks Transformation

$$V_a = [V_d*\cos(\omega t) + V_q*\sin(\omega t) + V_0]$$

$$V_b = [V_d*\cos(\omega t - 2\pi/3) + V_q*\sin(\omega t - 2\pi/3) + V_0]$$

$$V_c = [V_d*\cos(\omega t + 2\pi/3) + V_q*\sin(\omega t + 2\pi/3) + V_0]$$

In normal and synchronous conditions, the voltage is a constant, d-voltage is one pu and q-voltage unit is zero pu, but in normal circumstances can be a change. The d-voltage and q-voltage with the interest that needed for best performance is compared then the d and q error is generated.

These error components are converted into abc component using dq0 to abc transformation. Phase Locked Loop (PLL) is used to generate unit sinusoidal wave in phase with main voltage. This abc components are given to generate three phase Pulses using Pulse Width Modulation (PWM) technique. Proposed control technique block is shown in Fig 2

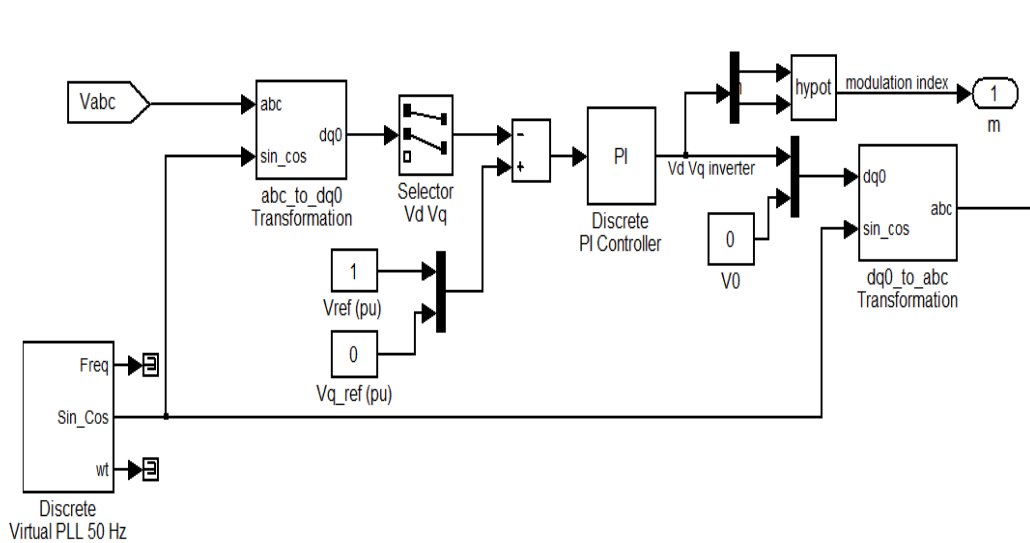


Figure 2 Schematic diagrams of control block

IV. CONTROL ALGORITHM

The basic functions of a controller in a DVR are the detection of voltage sag/swell events in the system; computation of the correcting voltage, generation of trigger pulses to the sinusoidal PWM based DC-AC inverter, correction of any anomalies in the series voltage injection and termination of the trigger pulses when the event has passed. The controller may also be used to shift the DC-AC inverter into rectifier mode to charge the capacitors in the DC energy link in the absence of voltage sags/swells. The dqo transformation or Park's transformation [4-5] is used to control of DVR. The dqo method gives the sag depth and phase shift information with start and end times. The quantities are expressed as the instantaneous space vectors. Firstly convert the voltage from abc reference frame to d-q-o reference. For simplicity zero

phase sequence components is ignored. Fig.3 illustrates a flow chart of the feed forward dqo transformation for voltage sags/swells detection. The detection is carried out in each of the three phases.

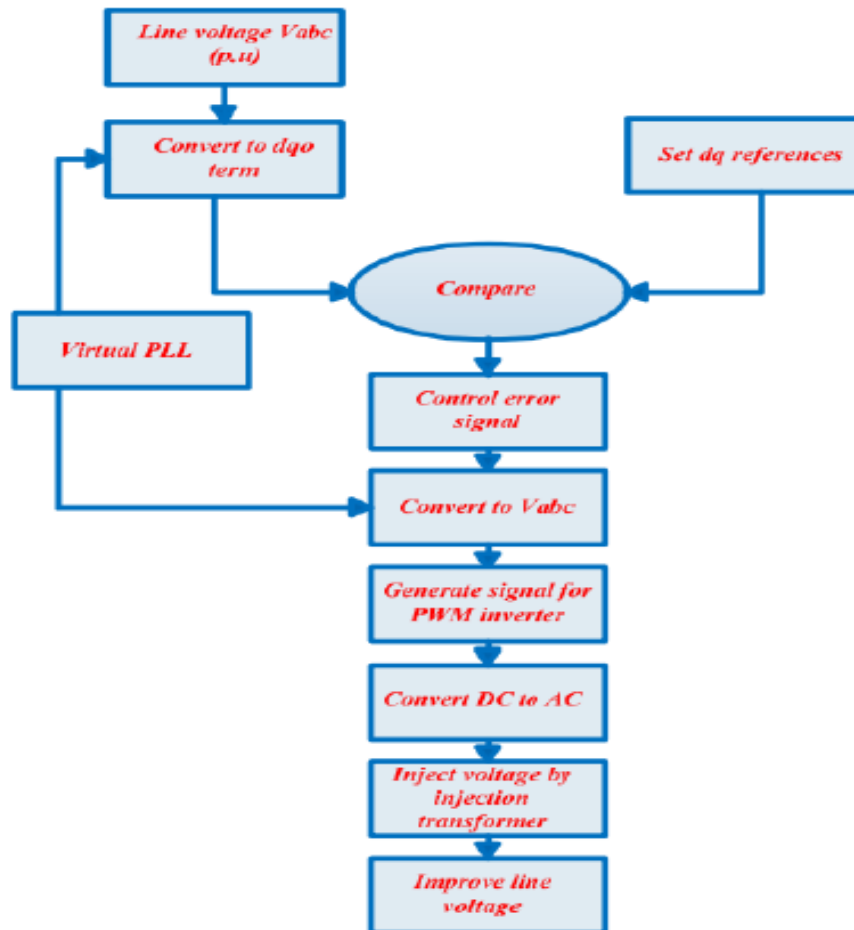


Figure 3 Flow chart of method

The control scheme for the proposed system is based on the comparison of a voltage reference and the measured terminal voltage (V_a , V_b , V_c). The voltage sags is detected when the supply drops below 90% of the reference value whereas voltage swells is detected when supply voltage increases up to 25% of the reference value. The error signal is used as a modulation signal that allows generating a commutation pattern for the power switches (IGBT's) constituting the voltage source converter. The commutation pattern is generated by means of the sinusoidal pulse width modulation technique (SPWM); voltages are controlled through the modulation. The block diagram of the phase locked loop (PLL) is illustrated in Fig 3. The PLL circuit generates a unit sinusoidal wave in phase with mains voltage. Parks transformation convert three phase system a, b, c to dqo stationary frame. In this transformation, phase A is aligned to the d axis that is in quadrature with the q-axis.

V. MATLAB MODELING AND SIMULATION

A. MATLAB Model of Uncompensated System:

A Distribution system is modeled and simulated using the MATLAB. The model is shown in Figure-5. The three-phase source of 220 KV is connected to step down transformer (220 kv/11kv) and secondary of transformer (11kv) is connected to pi section of length 21 km and a three phase load is connected through a load bus.

A fault is applied at the distribution line and then analyzes system through scope showing voltage magnitude in per unit system.

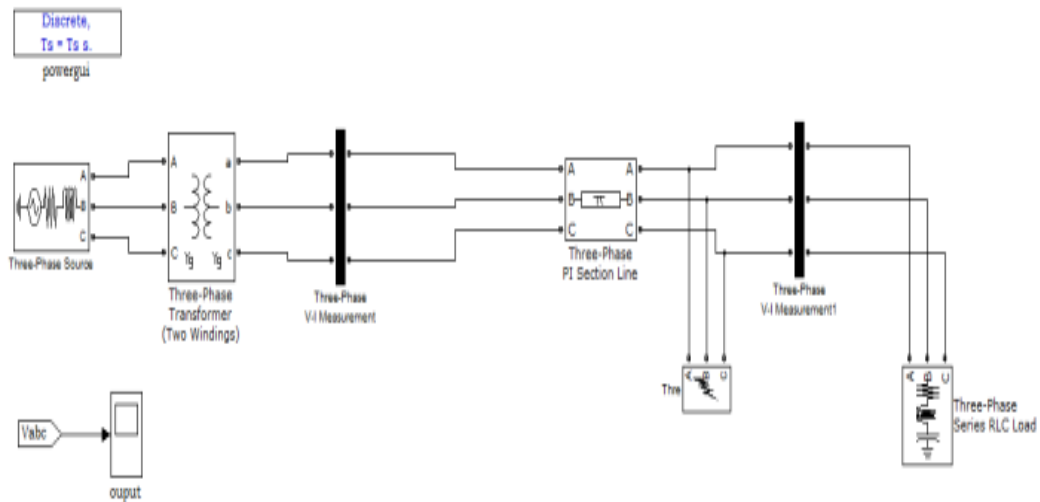


Figure 4 MATLAB model of uncompensated system

B. MATLAB Model of DVR:

The DVR is modeled and simulated using the MATLAB and its Simulink and Sim Power System toolboxes. The MATLAB model of the DVR connected system [8] is shown in Figure-5. DVR consists of a PWM inverter circuit and a DC Voltage source connected at the DC Link of VSI. The IGBT based PWM VSI is modeled using Universal Bridge Block from Power Electronics subset of Power System Block-set.

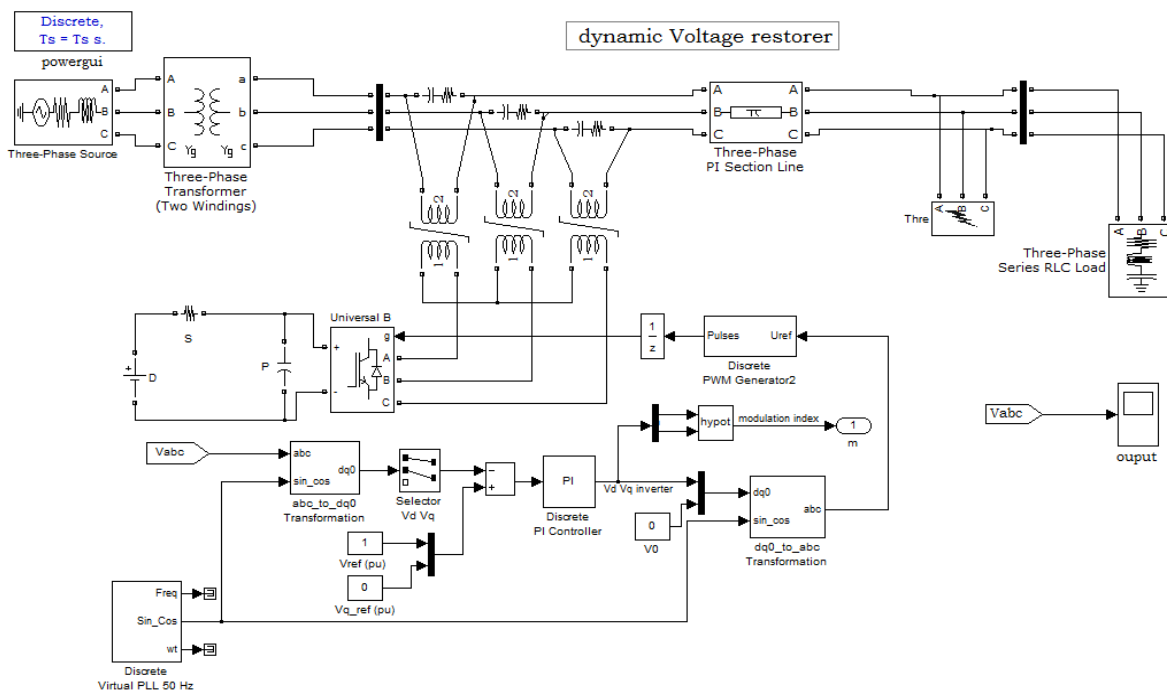


Figure 5 MATLAB model of DVR connected system

VI. RESULT AND DISCUSSION

A. Simulation Result of Uncompensated System during fault:

In simulation of uncompensated system when a three-phase short-circuit fault is applied at point A, during the period 200 ms. The voltage sag at the load point is almost 80% with respect to the reference voltage.

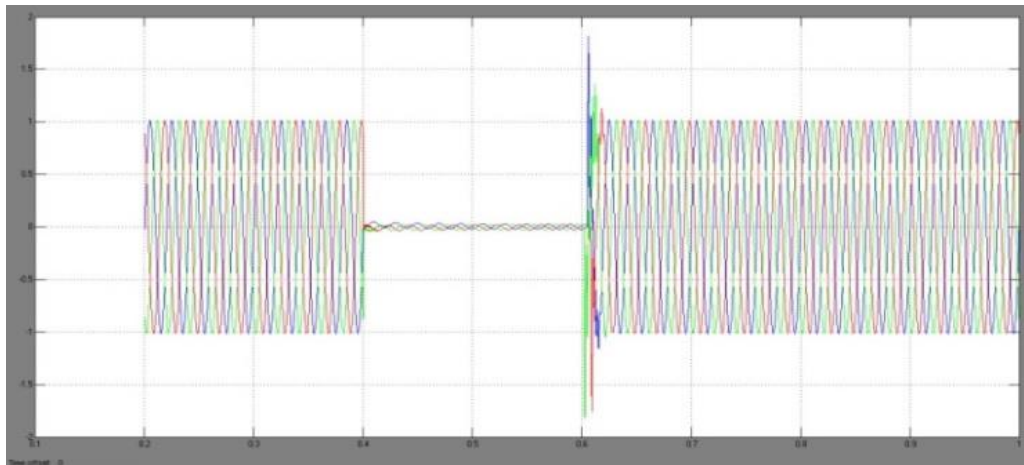


Figure: 6 Source Voltage waveform during Fault with Uncompensated system

B. Simulation Result of DVR during Fault:

Now simulate system with using DVR at point A where three-phase short-circuit fault has been applied. The voltage sag at the load point is now becomes almost 90% with respect to the reference voltage. Using the facilities available in MATLAB the DVR is simulated to be in operation only for the duration of the fault.

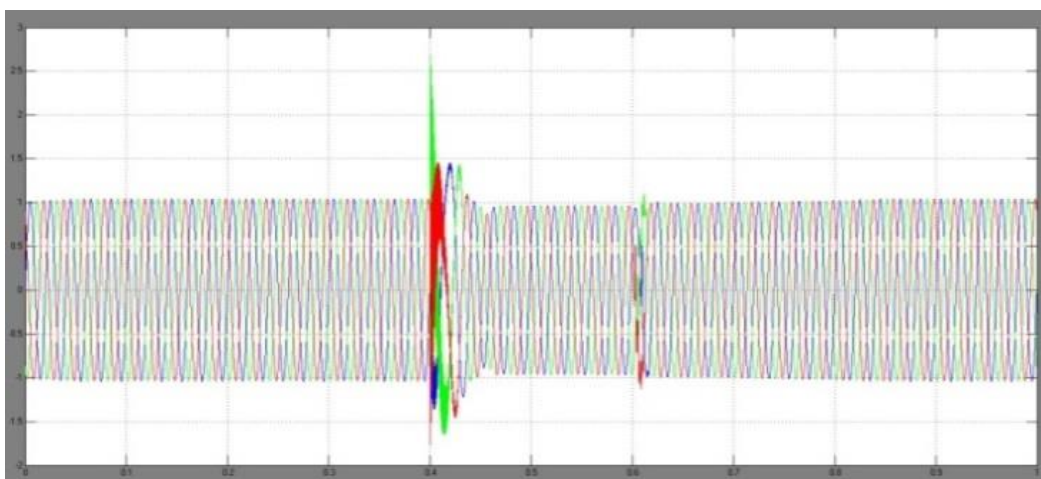


Figure: 7 Source Voltage waveform before Fault mitigation without DVR

• Voltage Improvement:

The load side voltage (in p.u.) during a fault condition of DVR is presented in this table. From this table we can see that DVR deliver good compensation.

Voltage Magnitude(p.u.)	DVR
Before compensation	0.2 p.u.
After compensation	0.9 p.u.
improved voltage	0.7 p.u.

• THD Analysis:

Total harmonic distortion is an important criterion for power quality improvement. For the basis of presented harmonics in a power line THD is being calculated. This table created by the help of MATLAB FFT Analysis Result. During a fault condition THD of load side voltage presented in this table. From this presented table we can see that DVR

is much better than DSTATCOM because the harmonics which is generated in the distribution line eliminated by the help of DVR system and the load voltage is approximately sinusoidal.

THD	DVR
Before Compensation	5.92
After Comensation	3.49

Table II THD analysis of uncompensated system:

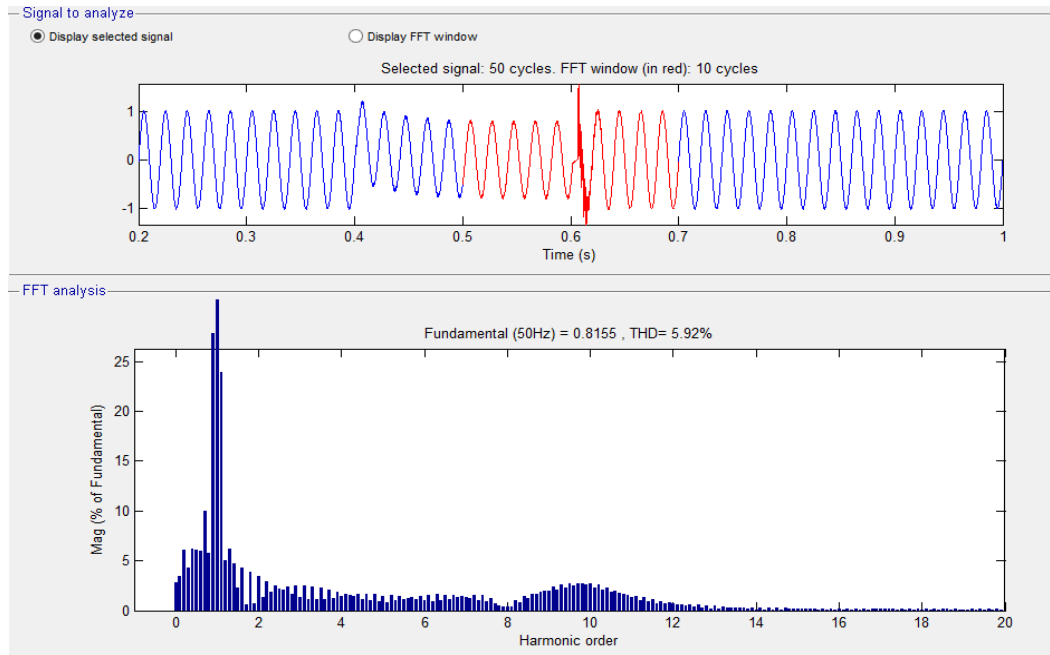


Figure 9 THD analysis of uncompensated system

THD analysis of DVR:

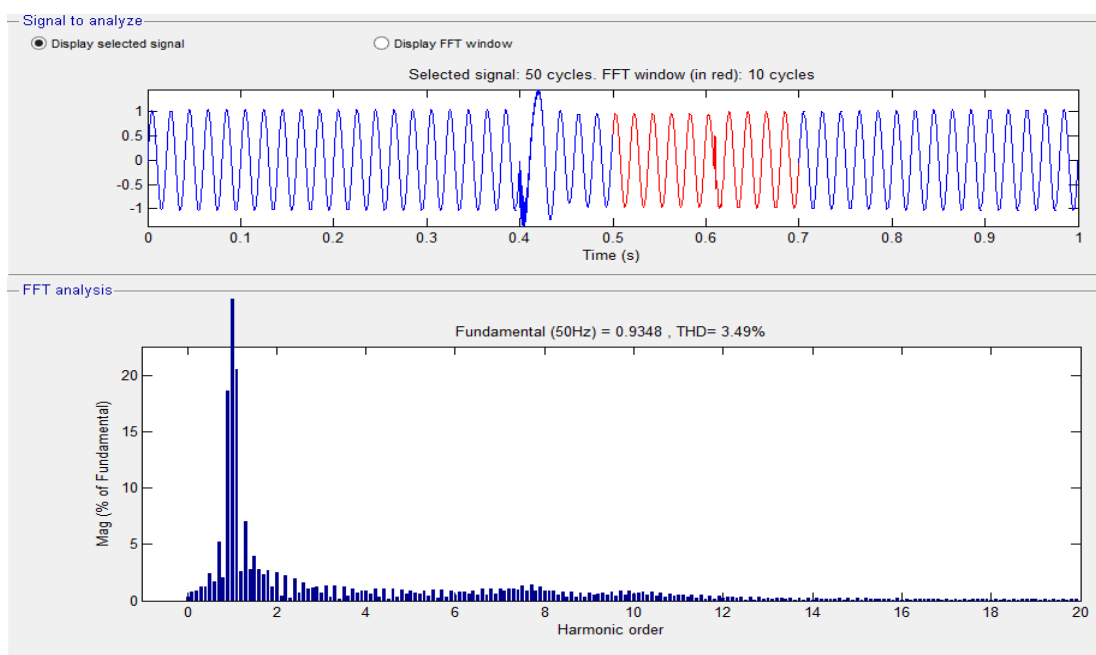


Figure 10 THD analysis of DVR

VII. CONCLUSION

This paper has presented the power quality problems such as voltage dips, swells and interruptions, and mitigation techniques of custom power electronic device DVR. The design and applications of DVR for voltage sags and interruptions, and comprehensive result is presented.

A new PWM-based control scheme has been implemented to control the electronic valves in the VSI used in the DVR. As opposed to fundamental frequency switching schemes already available in the MATLAB/SIMULINK, this PWM control scheme only requires voltage measurements. This characteristic makes it ideally suitable for low-voltage custom power applications. The simulations carried out showed that the DVR provides good voltage regulation capabilities. The simulation results presented shows good accuracy with results.

REFERENCES

- [1] Rakesh Kantaria and S.K.Joshi "A review on power quality problems and solutions" Power electronics National Conference November 2008. [4] Mitigation Of Voltage Sags/Swells Using Dynamic Voltage Restorer (DVR) Rosli Omarand and Nasrudin Abd Rahim VOL. 4, NO. 4, JUNE 2009 ISSN 1819-6608
- [2] S. Chen, G. Joos, L. Lopes, and W. Guo, "A nonlinear control method of dynamic voltage restorers," in 2002 IEEE 33rd Annual Power Electronics Specialists Conference, 2002, pp. 88- 93.
- [3] Rosli Omar And Nasrudin Abd Rahim " Modeling and Simulation for Voltage Sags/Swells Mitigation Using Dynamic Voltage Restorer (DVR)" 2008 Australasian Universities Power Engineering Conference (AUPEC'08).
- [4] Fawzi AL Jowder "Modeling and Simulation of Dynamic Voltage Restorer (DVR) Based on Hysteresis Voltage Control" The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON) Nov. 5-8, 2007, Taipei, Taiwan.
- [5] Chellali Benachaiba, Brahim Ferdi,"Voltage Quality Improvement Using DVR," Electric Power Quality and Utilization, Journal Vol. XIV, No.1, 2008.
- [6] Himdari Ghosh, Pradip Kumar Shah and Gautam Kumar Panda, "Design and Simulation of a Novel Self Supported Dynamic Voltage Restorer (DVR) for Power Quality Improvement," International Journal of Scientific and Engineering Research, Volume 3, Issue 6, June-2012.
- [7] K.N.V. Prasad, G.Ranjith Kumar, Y.S. Anil Kumar, G. Satyanarayana, "Realization of cascaded H-bridge 5-Level multilevel inverter as Dynamic Voltage Restorer," Computer Communication and Informatics (ICCCI), 2013 International Conference on , vol., no., pp.1,6, 4-6 Jan. 2013.
- [8] Mitigation Of Voltage Sags/Swells Using Dynamic Voltage Restorer (DVR) Rosli Omarand and Nasrudin Abd Rahim VOL. 4, NO. 4, JUNE 2009 ISSN 1819-6608.