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Compensation of Voltages Sag and Swell using Dynamic Voltage Restorer

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ABSTRACT

Power quality is an essential concern in the modern power system that affect customers and utility. Integration of renewable energy source in smart grid system by power electronics devices may rise power quality problems like current harmonics, voltage harmonics, voltage sag and swell. Voltages sag and swell is one of the major power quality problems which mainly can be caused by short circuit fault and overloaded condition. DVR is an effective modern constant power device which is used for restoring the voltage and modifies voltage sag by injecting voltage in series. Park's transformation is used to convert the voltage from rotating vectors to the stationary frame. In phase by properly inserting a compensation techniques for a voltage through DVR. Simulations are performed on MATLAB/SIMULINK platform to analyze the DVR performance.

KEYWORDS: *Dynamic voltage restorer, FACTS, sag, swell, In-phase compensation, SRF theory.*

I. INTRODUCTION

Numerous arrangements have been proposed to conquer power quality issues in the force business that among them custom power gadgets, for example, dynamic voltage restorer (DVR), circulation static simultaneous compensator, and bound together power quality conditioners have a viable part in force quality improvement in the electrical conveyance systems. [1-3] DVR is a powerful gadget which is utilized for re-establishing voltage and alters voltage hang by infusing voltage in arrangement. .Voltage list is one of intensity quality issues which mostly can be brought about by cut off and over-burdens in the framework. Compensation techniques of In-phase and Pre-sag is [8] study in DVR for the superior result in conventional [3]. DVR on the distribution feeder is employed to guard the load from the fault thanks to voltage sag and swell, that's mounted serial with the load and battery energy storage system (BESS) is connected [2]. DVR injects a small amount voltage is injected in series with the transmission lines for normal condition and also delivers or absorbed the active or reactive power from DC link [4].Improving power quality using a grasshopper optimization algorithm (GOA) based DVR [6]. For the PI controller is used in control block for restoring the power quality restraint [5]. Voltage sag compensation in distribution system by employing an integrated power quality controller by injecting reactive power simultaneously is presented in [7].A power quality problems that are caused by the non-standard voltage or current or frequency. The problems which are faced due to low power quality are voltage sag, swell, interruptions harmonics and transients. These are creates disturbances in the system and thus it is required to resolve the problems for the lossless and efficient working of the system. The process with mitigates such problems is known as compensation (12. Various compensation devices are being used now days. Harmonics are generally refer to distortions in the voltage and current waveforms(11-12). These distortions are caused by the overlapping of the standard wave at 50 HZ with waves at other frequencies.

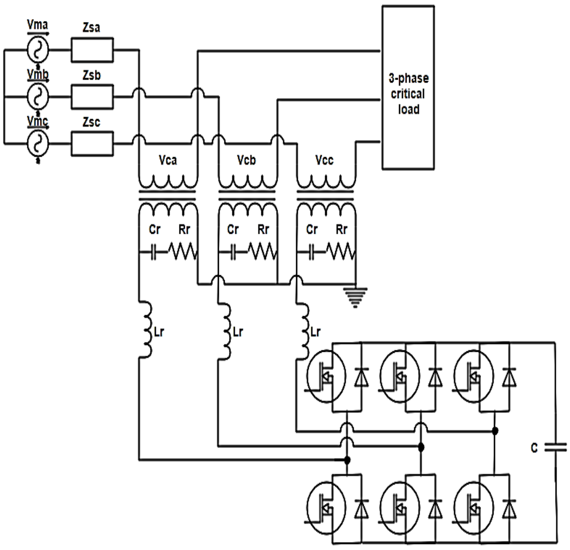

Fig. a. power circuit diagram of DVR

STRUCTURE OF PAPER

The paper is organized as follows: In Section 1, the introduction of the paper is provided along with the structure of paper and description. In Section 2 we discuss construction and working principle of DVR. In Section 3 we have the complete information about control of DVR. Section 4 shares information about the simulation and outputand FFT analysis. Section 5 tells us about the parameters for simulation. Section 6 tells us about the conclution the paper with references.

II. CONSTRUCTION AND WORKING PRICIPLE OF DVR

(i) CONSTRUCTION

There are two parts of the DVR: one is the power circuit, and the other is the control circuit. The control signal consists of magnitude, phase shift, the frequency that are complex parameters of it, and injected by the DVR systemFig.(a), where the DVR consists of essentially a series connectedinjection transformer, a Voltage Source Inverter (VSI), inverter outputfilter and an energy storage device connected to the dc-link.Fig(a)The power system upstream to DVR is represented by an equivalentvoltage source and source impedance. The disturbances correction ability of the restorer depends on the maximumvoltage injection capability of the device.The power circuit consists of energy storage unit, voltage source inverter, filter and injection transformer Fig(a). In the power circuit, the switches are used to generate a voltage-dependent on control signals. Additionally, this section will describe thefundamental structure of the DVR by the power circuit.Fig(a), shows the detailed schematic diagram of a capacitor-supported DVR connected to threephasecritical loads. In a capacitor-supported is Dynamic voltage restorer, the power absorbed/supplied is zero under steadystatecondition and the voltage injected by the DVR is in quadrature with the feeder current.

(ii) OPERATION

DVR is woks as a method of an injecting transformer means a voltage control fig(c), is done by arrangement to the bus voltage a forced commuted converter. To overcome the of voltage drops is did not efficiently mitigate by the DVR fig(a), when there is no issue like voltage sag under conditions.DVR will produce a required voltage control for a high frequency in distribution system, a need phase angel ensure that load is perfectly maintained.

Capacitor is discharge the stored energy DVR can absorb and generate a reactive power injection, the sag detection time and power electronic device shorten the time response of DVR fig (a). Compared to conventional method of voltage correlation, like tap changing transformers response time of a DVR is less than 26millisec.

a. Energy storage unit

During voltage sags, the storage unit provides the specified real power as its primary function. The compensating capability of DVR fig(a), is defined by the active power produced the device of energy storage. The devices of the high response time of charging and discharging are being used a lead batteries. The rate of discharge determines the internal space of available for the storage of energy, and this discharging rate is based on a chemical reaction (2),(3).

b.Voltage source inverter

Pulse-Width Modulated VSI (PWMVSI), storage unit creates DC voltage. A VSI is the conversion of voltage from DC-AC voltage. at the time of sag, a step-up voltage injection transformer is increase magnitude of voltage. So, a minimum voltage value with VSI is enoughfig (a).

c. Voltage injection of transformer

The use of low passive Filters in this method in which the PWM inverted pulse waveform converted into a sinusoidal waveform. In VSI for the achievement of this conversion, it is compulsory to remove high-value harmonic components while DC-AC transformation, and it will also change the compensated output voltage. A passive filter is an essential source in voltage inverter. If we put the filters on the inverter side, it can overcome maximum value harmonics from passing through the voltage transformer fig (a). So, the stress on the injection transformer is also decreased by it. When the filter is placed in the inverter side and causes phase shift and voltage drop in inverted,that is the disadvantage of the filter. Thus, by putting the filter on the load side, this problem can be solved. The secondary side of the transformer permits the high valued harmonics currents because the transformer with high values is necessary.

(iii) IN-PHASE COMPENSATION

The in-phase compensation method is used for the active loads. Compensation is needed for voltage magnitude not for compensating phase angel. Compensation and support of DVR which means of storage (11) devices fig (c), it is used when both the real and reactive powers are needed. Minimization of voltage amplitude in this method where DVR fig (b) is to compensate the load voltage with minimum voltage injection (10-11). voltage compensation in phase to post sag value of PCC voltage. Hence by this method injected voltage magnitude can be minimized. Butsome of the cases, phase changes occur with voltage sag,[8] in this method producesa distortions to the voltage load leading to transients and circulating currents fig (b). For sensitive load, in phase compensation is beneficial as it compared to other compensation tripping of the load. Realize this compensation strategy, the phase locked loop (PLL) is synchronized to the grid voltage itself, and not be locked to the pre-sag grid voltage during the compensation.

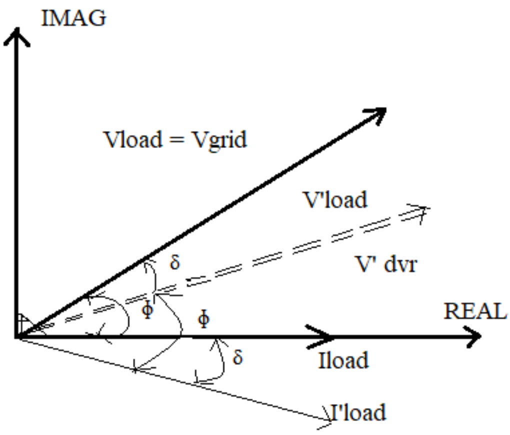

Fig .b. In-phase compensation

$S_{DVR} = \sum_{K=a,b,c}[V'_{DVR} \cdot I_{Load}]$.....(1)

v'_{DVR} is the rms of DVR injected voltage in phase K where, $V_{D'}V_R$, k is the rms of DVR injected voltage in phase k and *load* is rms of l □oad current. The exchanged active power between the DVR and power grid is as follows:

$P_{DVR} = P_{Load} - P_{grid}$ --------------- (2)

$= [[3.V_{L.}I_{L.}COS(\emptyset)]$

$\sum_{K=a,b,c}\left[V'_{grid} . k . I_{Load}\cos(\emptyset)\right]]$----(3)

$v'_{DVR} = \sqrt{2} . [v_{Load} - v'_{grid}]$--------- (4)

In phase compensation technique minimise the voltage injected by the DVR. It also minimizing the energy storage device it support both real and reactive power for the compensation.

III. CONTROL OF DVR

The control algorithm of the DVR in which the SRF theory is used for the control of aself-supported DVR. The voltages at PCC (V_s) are converted to the rotating reference frame using theabc–dq0 conversion using the Park's transformation fig (c). The harmonics and the oscillatory components ofthe voltages are eliminated using low-pass filters (LPFs).

(i) Park transformation

Converts the time-domain components 3phase in an abc reference frame to direct, quadrature, and zero components in a rotating reference frame fig (c). The active and reactive powers with the system in abc reference frame by implementing an invariant version.

Zero component is equal to zero in balanced system. It is mathematical transformation used to simplify the analysis related to three-phase circuit. This techniques can be applied to reduce the three AC quantities of two DC quantities. It make the calculation and simulation is become simple.

It the supply voltage equ(5) and reference voltage are transformed from abc coordinates to dq0 coordinates with the help of adc_to_dq0 transformation block.[9]
The dq0 signal of both supply voltage and reference voltage split using de-mux block. The direct qudrature(d) and the (q) value of the supply signal. The resultant d and q is then sent to the dq0_to_abc transformation block equ(5) with the help of mux block is shown in fig(c).

$$\begin{bmatrix} V_{Ld} \\ V_{Lq} \\ V_{L0} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \sin\theta & \sin\left(\theta-\frac{2\pi}{3}\right) & \sin\left(\theta+\frac{2\pi}{3}\right) \\ \cos\theta & \cos\left(\theta-\frac{2\pi}{3}\right) & \cos\left(\theta+\frac{2\pi}{3}\right) \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix}\begin{bmatrix} V_{La} \\ V_{Lb} \\ V_{Lc} \end{bmatrix} \quad \text{---(5)}$$

The dq0_to_abc transformationblock convert the resultant dq0 coordinates to abc coordinates output of the block fig (c) is then sent to the VSC with harmonic filter unit fig (a).
Discrete three phase PLL block generates an output signal whose phase is related to the phase of the input signal.The output from the PLL block is sent to the abc_to_dq0 transformation and dq0_to_abc transformation block. This helps to generate the signal for pulse generator in phase with the system voltage.Load voltages (V_{La},V_{Lb},V_{Lc}) are converted to the rotating reference frame using abc-dqo conversion using Park's transformation with unit vectors(sinθ, cosθ) and are derived using a phase locked loop as, Similarly, reference load voltages and voltages at (VL_b,$VL_{C,}$PCC VS are also converted to the rotating reference frame.
Then, the DVR voltages are obtained in the rotating reference frame as, we obtain reference DVR voltages in the abc frame from a [10] reverse Park's transformation as follows.The harmonics in the voltage are eliminated using the low pass filters, The components of voltages in the d-axis and q-axis respectively are The voltages at the PCC (VS) are converted to the rotating reference frame using Park's transformation (abc-dqo conversion).

$$\begin{bmatrix} V_{La} \\ V_{Lb} \\ V_{Lc} \end{bmatrix} = \begin{bmatrix} \sin\theta & \sin\left(\theta-\frac{2\pi}{3}\right) & 1 \\ \sin\left(\theta-\frac{2\pi}{3}\right) & \cos\left(\theta-\frac{2\pi}{3}\right) & 1 \\ \sin\left(\theta+\frac{2\pi}{3}\right) & \cos\left(\theta+\frac{2\pi}{3}\right) & 1 \end{bmatrix}\begin{bmatrix} V_{Dd} \\ V_{Dq} \\ V_{D0} \end{bmatrix} \quad \text{--(6)}$$

The control algorithm of the DVR in which the SRF theory is used for the control of aself-supported DVR. The voltages at PCC (V_s) are converted to the rotating reference frame using theabc–dq0 conversion using the Park's transformation. The harmonics and the oscillatory components ofthe voltages are eliminated using low-pass filters (LPFs). The components of voltages in d- and q-axes are

$$V_d = V_{dDC} + V_{dAC} \text{--------(7)}$$
$$V_q = V_{qDC} + V_{qAC} \text{--------(8)}$$

Thecompensating of a strategy for compensation of voltage quality problems considers that the loadterminal voltage should be of rated magnitude and undistorted in nature.In order to maintain the DC bus voltage of the self-supported capacitor, a PI controller is used at the DCbus voltage of the DVR and the output is considered as the voltage loss (V_{cap}) for meeting its losses:

$$V_{cap\,(n)} = V_{cap\,(n-1)} + K_{p1}(V_{de\,(n)} - V_{de\,(n-1)}) + K_{p1}V_{de\,(n)} \text{----(9)}$$

Where,

$$V_{de\,(n)} = V*_{dc\,(n)} - V_{dc\,(n)} \text{----------------(10)}$$

Where, $V_{de\,(n)}$= $V*_{DC}$- V_{DC} is the error between the reference DC voltage (V*DC)

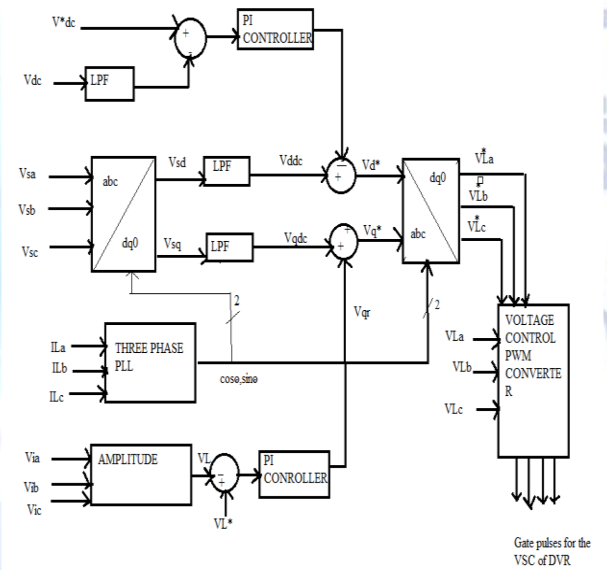

Fig.c. control block of the DVR uses SRF method

And sensed DC voltage(VDC) at the nth sampling instant. Kp1 and Ki1 are the proportional and the integral gains of the DC busvoltage PI controller.Therefore, the reference d-axis load voltage is shown in fig (b),. The voltages at PCC (V_s) and the load terminal voltages (V_L) aresensed to derive the IGBT gate signals.
The reference load voltages ($V*_a$, $V*_b$, $V*_c$) are extracted using thederived unit vectors.The amplitude of the load voltage (V_L) at PCC is calculated as,

$$V_L = [\,(2/3)^{1/2}\,(V_{La}^2 + V_{Lb}^2 + V_{Lc}^2)]\text{\^{}}1/2 \text{----(11)}$$

$$V_d = V_{dDC} - V_{cap} \text{---(12)}$$

The amplitude of the load terminal voltage (V_L) is controlled to its reference voltage ($V*_L$) using anotherPI controller.

The output of PI controller is considered as the reactive component of voltage (V_{qr}) forvoltage regulation of load terminal voltage. The amplitude of the load voltage (V_L) at PCC is calculatedfrom the AC voltages (V_{La},V_{Lb},V_{Lc}).The voltages at PCC (V_s) and the load terminal voltages (V_L) aresensed to derive the IGBT gate signals.The voltages at PCC (V_s) and the load terminal voltages (V_L) aresensed to derive the IGBT gatesignals.The voltages at PCC (V_s) and the load terminal voltages (V_L) aresensed to derive the IGBT gate signals.

IV. SIMULATION AND OUTPUT

Fig (d), the performance of various topologies of three-phase DVR is simulated using MATLAB software using Sim-power Systems (SPS) toolboxes. However, because of space limitation and to give just basic understanding a capacitor-supported DVR are considered for the compensation of sag, swell, harmonics, and an unbalance in the terminal voltage for various injection schemes using SRF theory control algorithm.DVR is simulated using MATLAB fig (d), software using Sim-Power Systems (SPS) toolboxes. However, because of space limitation and to give justbasic understanding a capacitor-supported DVR are considered for the compensation of sag, swell, harmonics, and an unbalance in the terminal voltage for various injection schemes using SRF theory control algorithm.

Case 1: Compensation of voltage sag using DVR

The performance of SRF-controlled capacitor-supported DVR for different supply disturbances is tested under various operating conditions. A balanced voltage sag of amplitude 0.75pu occurs 0.2 to 0.5. The waveform of disorted voltage, injected voltage (V_{inj}) and compensated voltage (V_{LOAD}) is shown in case 1 fig (e). The load voltage (V_L) is regulated at rated value, which shows the satisfactory performance of the DVR.

The sourcecurrent (I_s), the amplitude of the load terminal voltage (V_L), the amplitude of the supply voltage (V_S), andthe DC bus voltage (V_{DC}) are also shown in Figure (e) and (f), The DC bus voltage is regulated at the reference value, although small fluctuations occur during transients.

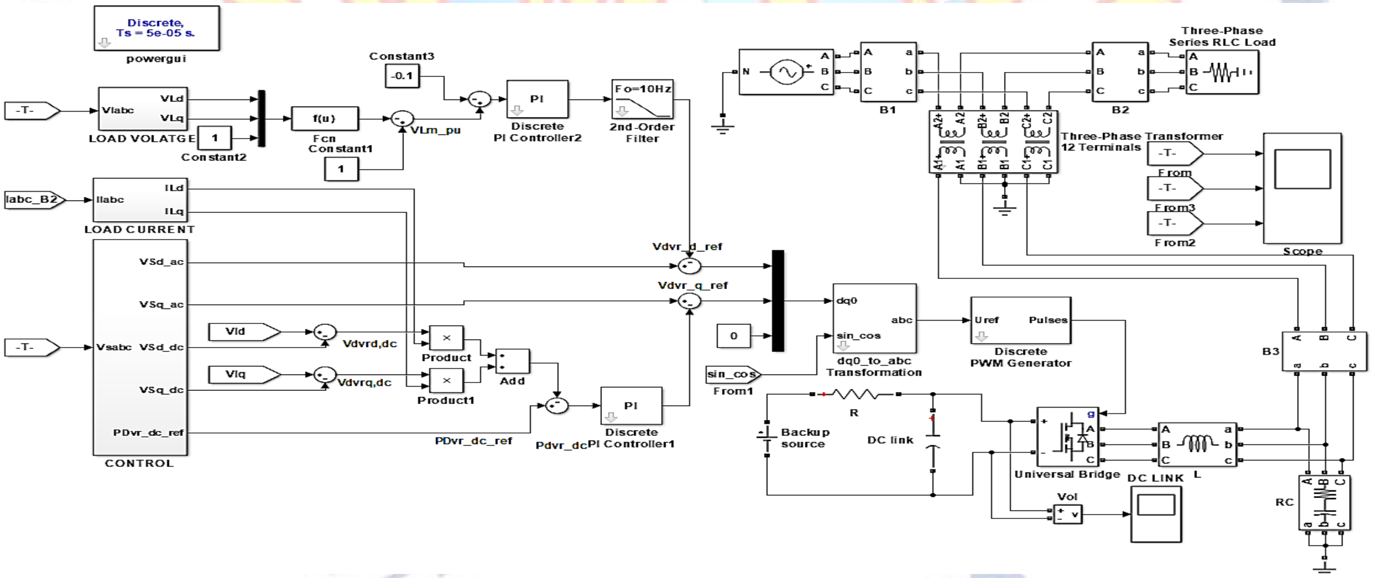

Fig d. Simulation diagram capacitor supported DVR

Case 2: Compensation of voltage swell using DVR

A balanced voltage swell of amplitude 0.75pu occurs from t = 0.25 to 0.3;.The waveform of disorted voltage , injected voltage (V_{inj}) and compensated voltage (V_{LOAD}) is shown in case 2 fig(f).The harmonics compensation in supply voltage is tested and depicted in Figure (e). The voltage atPCC is disturbed by switching on and off a load in parallel at PCC.

FFT Analysis

The voltage terminal at PCC is distressed through the switching on a resistive load V_L is succeed with sinusoidal with low harmonics , is balanced and get a constant magnitude due to the inserting of voltage with help of the DVR. The total harmonic Distortion (THD) for case 1 and case 2 are shown in fig(g),. The THD of sag voltage and swell voltage is shown below in fig (g), the THD is 4.66% and 4.92%.

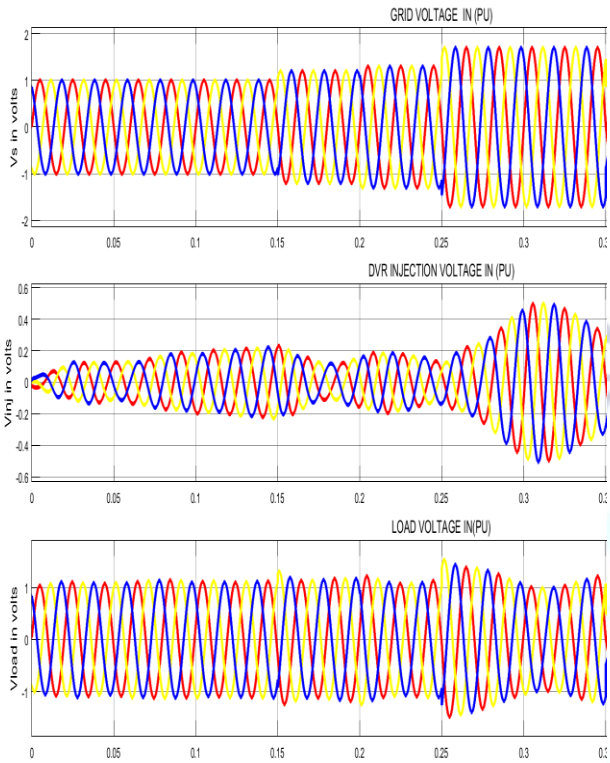

Fig.(e). Compensation of voltage sag (a) Grid voltage (b) injected voltage (c)load voltage

The load terminal voltage (V_L) isundistorted and constant in magnitude due to the injection of harmonic voltage (V_C) by the DVR.

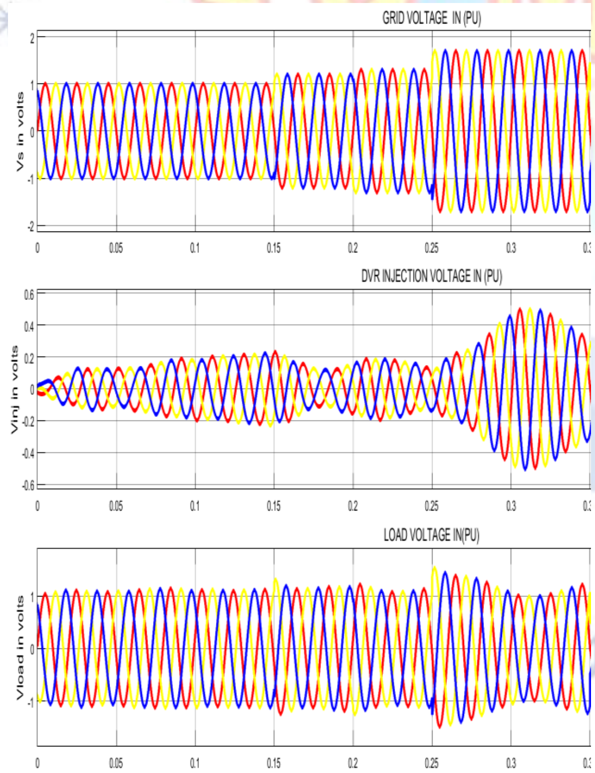

Fig.f. Compensation of voltage swell (a)supply voltage (b)injected voltage (c)load voltage

The loadterminal voltage (V_L) has a THD of 4.66% for FFT analysis of 25 cycles with frequency of 50Hz.

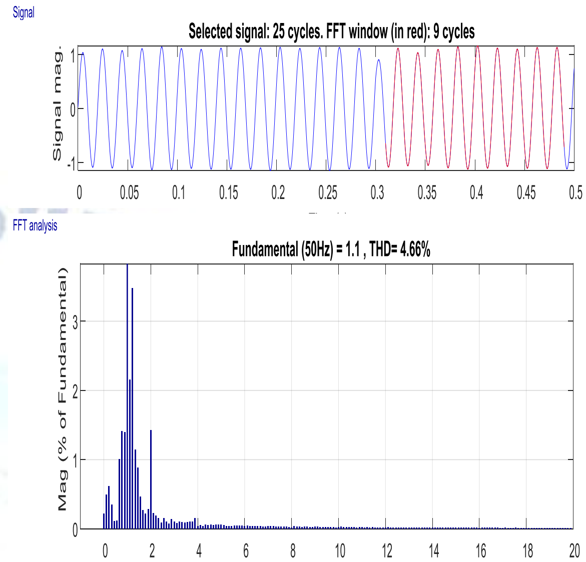

Fig.g(a) total harmonic distortion swell

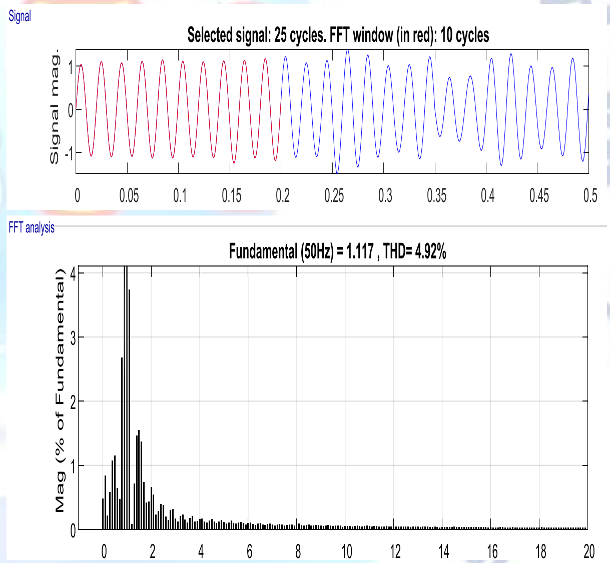

Fig.g(b)Total harmonic distortion sag

V. PARAMETERS FOR SIMULATION

Parameter Name	Value
Line Impedance	Ls 1mH,Rs 1ohm
Load	5KVA,415V,pf:0.9lag
Ripple Filter	Cr 1μF,Lr 3.1Mh,Rr 1ohm
DC bus capacitance	Cdc 2000μF
AC line voltage	VV_{l-l}-L 440V,50Hz
PWM switching frequency	6Hz
Transformer	10KVA,150V/300V

VI. CONCLUSION

In this these, the synchronous frame theory based control scheme is proposed. The performance of DVR has been verified through simulation using MATLAB. The reference voltage for the DVR has been attained indirectly by take out the reference terminal voltage. Three phase harmonic filter is used in this simlink DVR model that reduces the harmonics generated by VSI. DVR performance in mitigation numerous power quality complication such as voltage dip, unbalanced conditions and voltage swell, and has been observed and balanced voltage at the load terminal.

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