REDUCED RATED DVR WITH A BATTERY ENERGY STORAGE SYSTEM BY ARTIFICIAL NEURAL NETWORKS

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Abstract*:* In this paper, totally different voltage injection schemes for dynamic voltage restorers (DVRs) square measure analyzed with specific concentrate on a replacement technique accustomed minimize the rating of the voltage supply device (VSC) employed in DVR. a replacement management technique is planned to regulate the capacitor-supported DVR. The management of a DVR is incontestable with a reduced-rating VSC. The reference load voltage is calculable victimization the unit vectors. The synchronous frame of reference theory is employed for the conversion of voltages from rotating vectors to the stationary frame. The compensation of the voltage sag, swell, and harmonics is incontestable employing a reduced-rating DVR with Artificial neural network.

Index Terms— Dynamic voltage restorer (DVR), power quality, unit vector, voltage harmonics, voltage sag, voltage swell, Artificial neural network.

I.INTRODUCTION

Power Quality problems in the present-day distribution systems are addressed in the literature [1]–[6] due to the increased use of sensitive and critical equipment pieces such as communication network, process industries, and precise manufacturing processes. Power quality problems such as transients, sags, swells, and other distortions to the sinusoidal waveform of the supply voltage affect the performance of these equipment pieces. Technologies such as custom power devices are emerged to provide protection against power quality problems [2]. Custom power devices are mainly of three categories such as series-connected compensators known as dynamic voltage restorers (DVRs), shunt-connected compensators such as distribution static compensators, and a combination of series and shunt-connected compensators known as unified power quality conditioner [2]–[6]. The DVR can regulate the load voltage from the problems such as sag, swell, and harmonics in the supply voltages. Hence, it can protect the critical consumer loads from tripping and consequent losses [2]. The custom power devices are developed and installed at consumer point to meet the power quality standards such as IEEE-519 [7].Voltage sags in an electrical grid are not always possible to avoid because of the finite clearing time of the faults that cause the voltage sags and the propagation of sags from the transmission and distribution systems to the low-voltage loads. Voltage sags are the common reasons for interruption in production plants and for end-user equipment malfunctions in general. In particular, tripping of equipment in a production line can cause production interruption and significant costs due to loss of production. One solution to this problem is to make the equipment itself more tolerant to sags, either by intelligent control or by storing “ride-through” energy in the equipment. An alternative solution, instead of modifying each component in a plant to be tolerant against voltage sags, is to install a plant wide uninterruptible power supply system for longer power interruptions or a DVR on the incoming supply to mitigate voltage sags for shorter periods [8]–[23]. DVRs can eliminate most of the sags and minimize the risk of load tripping for very deep sags, but their main drawbacks are their standby losses, the equipment cost, and also the protection scheme required for downstream short circuits. Many solutions and their problems using DVRs are reported, such as the voltages in a three-phase system are balanced [8] and an energy-optimized control of DVR is discussed in [10].Industrial examples of DVRs are given in [11], and different control methods are analyzed for different types of voltage sags in [12]–[18]. A comparison of different topologies and control methods is presented for a DVR in [19]. The design of a capacitor-supported DVR that protects sag, swell, distortion, or unbalance in the supply voltages is discussed in [17]. The performance of a DVR with the high-frequency-link transformer is discussed in [24]. In this paper, the control and performance of a DVR are demonstrated with a reduced-rating voltage source converter (VSC). The synchronous reference frame (SRF) theory is used for the control of the DVR with Artificial neural network.

II.OPERATION OF DVR

The schematic of a DVR-connected system is shown in Fig. 1(a). The voltage V_{inj} is inserted such that the load voltage V_{load} is constant in magnitude and is undistorted, although the supply voltage Vs is not constant in magnitude or is distorted. Fig. 1(b) shows the phasor diagram of different voltage

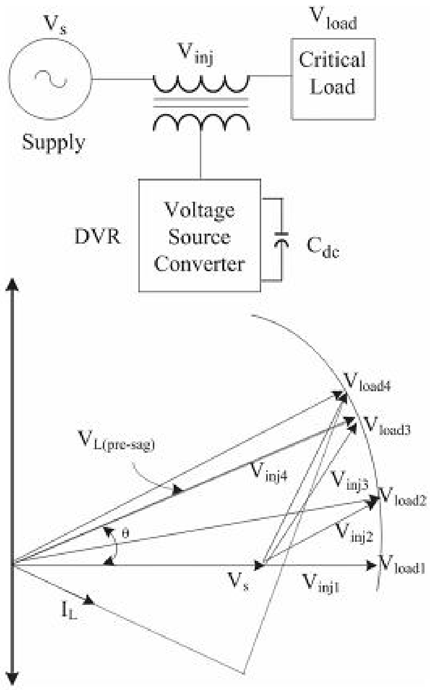

Fig.1. (a) Basic circuit of DVR. (b) Phasor diagram of the DVR voltage injection schemes.

injection schemes of the DVR. V_L(pre−sag) is a voltage across the critical load prior to the voltage sag condition. During the voltage sag, the voltage is reduced to Vs with a phase lag angle of θ. Now, the DVR injects a voltage such that the load voltage magnitude is maintained at the pre-sag condition. According t the phase angle of the load voltage, the injection of voltages can be realized in four ways [19].V_{inj1} represents the voltage injected in-phase with the supply voltage. With the injection of V_{inj2}, the load voltage magnitude remains same but it lead Vs by a small angle

In V_{inj3}, the load voltage retains the same phase as that of the pre-sag condition which may be an optimum angle considering the energy source [10].V_{inj4} is the condition where the injected voltage is in quadrature with the current, and this case is suitable for a capacitor-supported DVR as this injection involves no active power [17]. However, a minimum possible rating of the converter is achieved byVinj1 The DVR is operated in this scheme with a battery energy storage system (BESS) Fig. 2 shows a schematic of a three-phase DVR connected t restore the voltage of a three-phase critical load. A three-phase supply is connected to a critical and sensitive load through at three-phase series injection transformer. The equivalent voltage of the supply of phase A u_{MA} is connected to the point of common coupling (PCC) V_{SA} through short-circuit impedance Z_{sa}. The voltage injected by the DVR in phase A V_{ca} is such that the load voltage v_{la} is of rated magnitude and undistorted. A three-phase DVR is connected to the line to inject a voltage in series using three single-phase transformers Tr. L_r and C_r represent the filter components used to filter the ripples in the injected voltage. A three-leg VSC with insulated-gate bipolar transistors (IGBTs) is used as a DVR, and a BESS is connected to its dc bus.

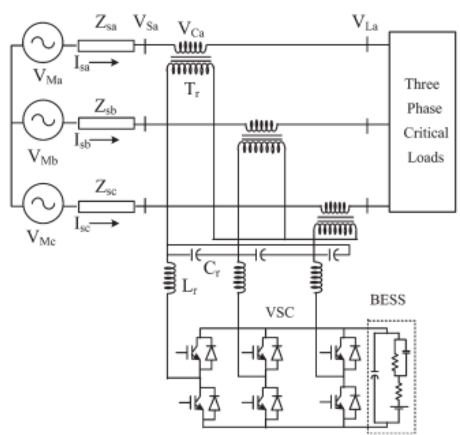

Fig.2. Schematic of the DVR-connected system.

III.CONTROL OF DVR

The compensation for voltage sags using a DVR can be performed by injecting or absorbing the reactive power or the real power [17]. When the injected voltage is in quadrature with the current at the fundamental frequency, the compensation is made by injecting reactive power and the DVR is with a self-supported dc bus. However, if the injected voltage is in phase with the current, DVR injects real power, and hence, a battery is required at the dc bus of the VSC. The control technique adopted should consider the limitations such as the voltage injection capability (converter and transformer rating) and optimization of the size of energy storage.

A. Control of DVR With BESS for Voltage Sag, Swell, and Harmonics Compensation

Fig. 3 shows a control block of the DVR in which the SRF theory is used for reference signal estimation. The voltages at the PCC v_S and at the load terminal v_L are sensed for deriving the IGBTs' gate signals. The reference load voltage V_L^* is extracted using the derived unit vector [23]. 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 ($\sin\theta$, $\cos\theta$) derived using a phase-locked loop as

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

Similarly, reference load voltages (V_{LA}, V_{LB}, V_{LC}) and voltages at the PCC v_S are also converted to the rotating reference frame. Then, the DVR voltages are obtained in the rotating reference frame as

$$v_{Dd} = v_{Sd} - v_{Ld} \quad (2)$$

$$v_{Dq} = v_{Sq} - v_{Lq} \quad (3)$$

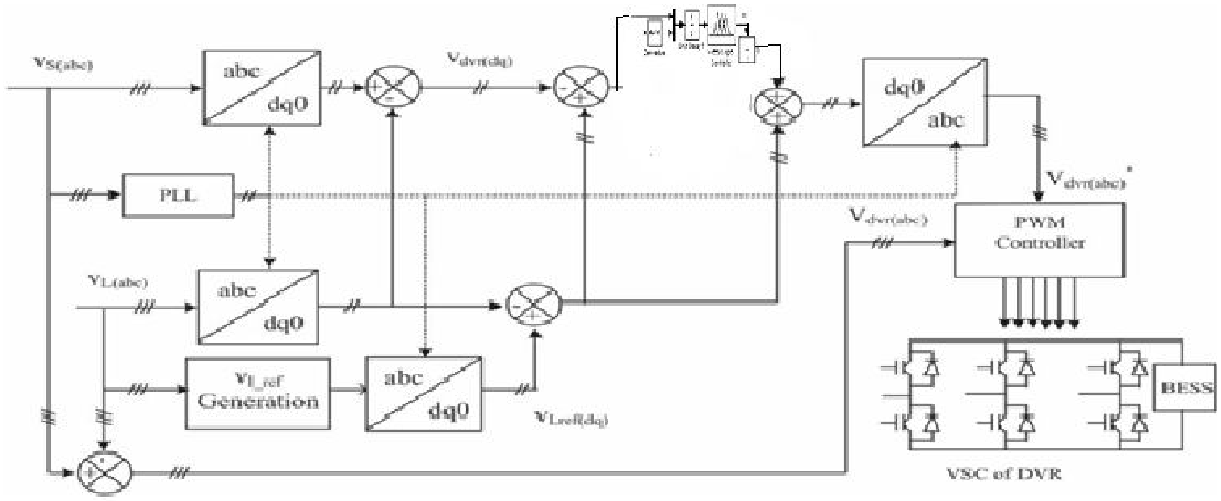

Fig.3. Control block of the DVR that uses the SRF method of control.

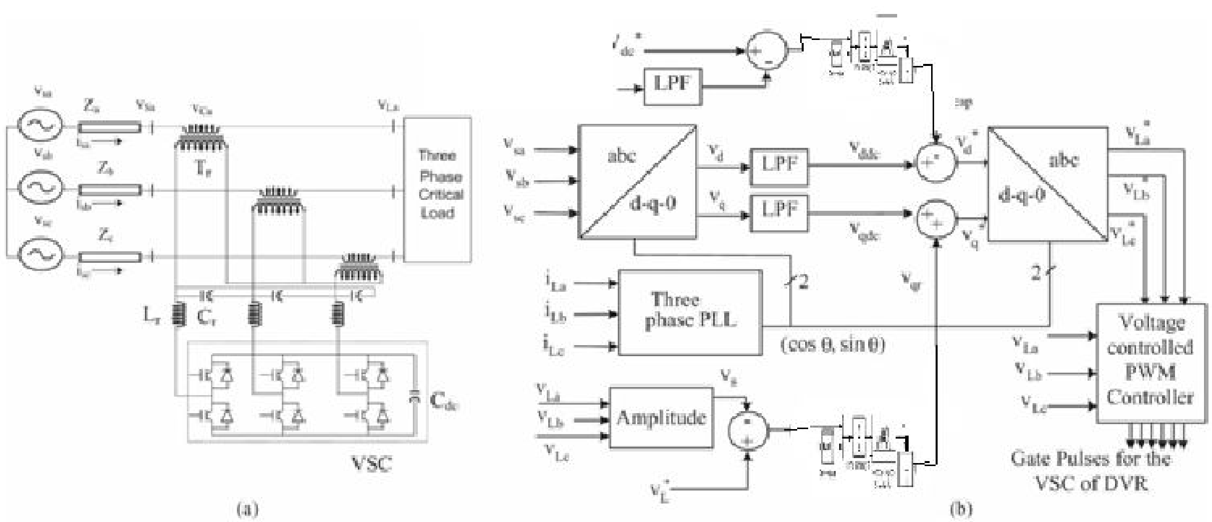

Fig.4. (a) Schematic of the self-supported DVR. (b) Control block of the DVR that uses the SRF method of control

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The reference DVR voltages are obtained in the rotating reference frame as

$$v^*_{Dd} = v^*_{Sd} - v_{Ld} \qquad (4)$$

$$v^*_{Dq} = v^*_{Sq} - v_{Lq} \qquad (5)$$

The error between the reference and actual DVR voltages in the rotating reference frame is regulated using two proportional–integral (PI) controllers. Reference DVR voltages in the abc frame are obtained from a reverse Park's transformation taking v^*_{Dd} from (4), v^*_{Dq} from (5), v^*_{D0} as zero as

$$\begin{bmatrix} v^*_{dvra} \\ v^*_{dvrb} \\ v^*_{dvrc} \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & 1 \end{bmatrix} \begin{bmatrix} v^*_{Dq} \\ v^*_{Dd} \\ v^*_{D0} \end{bmatrix} \qquad (6)$$

Reference DVR voltages ($v^*_{dvra}, v^*_{dvrb}, v^*_{dvrc}$) and actual DVR voltages(vdvra,vdvrb,vdvrc) are used in a pulse width modulated (PWM) controller to generate gating pulses to a VSC of the DVR. The PWM controller is operated with a switching frequency of 10 kHz.

B. Control of Self-Supported DVR for Voltage Sag, Swell, and Harmonics Compensation

Fig. 4(a) shows a schematic of a capacitor-supported DVR connected to three-phase critical loads, and Fig. 4(b) shows a control block of the DVR in which the SRF theory is used for the control of self-supported DVR. Voltages at the PCC vS are converted to the rotating reference frame using abc−dqo conversion using Park's transformation. The harmonics and the oscillatory components of the voltage are eliminated using low pass filters (LPFs). The components of voltages in thed- and q-axes as

$$v_d = v_{dc} + v_{ddc} + v_{dac} \qquad (7)$$

$$v_q = v_{qdc} + v_{qac} \qquad (8)$$

The compensating strategy for compensation of voltage quality problems considers that the load terminal voltage should be of rated magnitude and undistorted. In order to maintain the dc bus voltage of the self-supported capacitor, a PI controller is used at the dc bus voltage of the

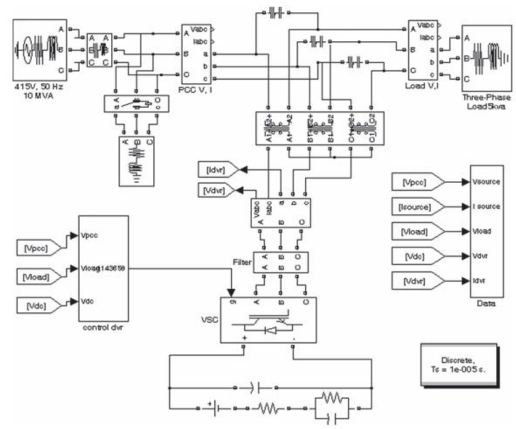


Fig. 5. MATLAB-based model of the BESS-supported DVR-connected system.

DVR and the output is considered as a voltage vcap for meeting its losses

$$v_{cap(n)} = v_{cap(n-1)} + K_{p1}\left(v_{de(n)} - v_{de(n-1)}\right) + K_{i1} v_{de(n)} \qquad (9)$$

Where $v_{de(n)} = v^*_{dc} - v_{dc}(n)$ is the error between the reference v^*_{dc} and sensed dc voltages v_{dc} at the nth sampling instant. K_{p1} and K_{i1} are the proportional and the integral gains of the dc bus voltage PI controller. The referenced-axis load voltage is therefore expressed as follows:

$$v^*_d = v_{ddc} - v_{cap} \qquad (10)$$

The amplitude of load terminal voltage V_L is controlled to its reference voltage V^*_L using another PI controller. The output of the PI controller is considered as the reactive component of voltage V_{qr} for voltage regulation of the load terminal voltage. The amplitude of load voltage V_L at the PCC is calculated from the ac voltages (V_{LA}, V_{LB}, V_{LC}) as

$$V_L = (2/3)^{1/2}\left(v^2_{La} + v^2_{Lb} + v^2_{Lc}\right)^{1/2} \qquad (11)$$

Then, a PI controller is used to regulate this to a reference value as

$$v_{qr(n)} = v_{qr(n-1)} + K_{p2}\left(v_{te(n)} - v_{te(n-1)}\right) + K_{i2} v_{tc(n)} \qquad (12)$$

Where $v_{te(n)} = V^*_L - V_L(n)$ denotes the error between the reference V^*_L and actual $V_L(n)$ load terminal voltage amplitudes at the n^{th} sampling instant. K_{p2} and K_{i2} are the proportional and the integral gains of the dc bus voltage PI controller. The reference load quadrature axis voltage is expressed as follows:

$$v_q^* = v_{qdc} + v_{qr} \quad (13)$$

Reference load voltages(v_{La}^*,v_{Lb}^*,v_{Lc}^*) in the abc frame are obtained from a reverse Park's transformation as in (6). The error between sensed load voltages(v_{La}, v_{Lb}, v_{Lc}) and reference load voltages is used over a controller to generate gating pulse to the VSC of the DVR.

IV.ARTIFICIAL NEURAL NETWORKS (ANN)

Neural-networks is one of those words that is getting fashionable in the new era of technology. Most people have heard of them, but very few actually know what they are. This essay is designed to introduce you to all the basics of neural networks — their function, generic structure, terminology, types and uses.

The term 'neural network' is in fact a biological term, and what we refer to as neural networks should really be called Artificial Neural Networks (ANNs). I will use the two terms interchangeable throughout the essay, though. A real neural network is a collection of neurons, the tiny cells our brains are comprised of. A network can consist of a few to a few billion neurons connected in an array of different methods. ANNs attempt to model these biological structures both in architecture and operation. There is a small problem: we don't quite know how biological NNs work! Therefore, the architecture of neural networks changes greatly from type to type. Neural networks are models of biological neural structures. The starting point for most neural networks is a model neuron, as in Figure 6. This neuron consists of multiple inputs and a single output. Each input is modified by a weight, which multiplies with the input value.

The neuron will combine these weighted inputs and, with reference to a threshold value and activation function, use these to determine its output. This behavior follows closely our understanding of how real neurons work.

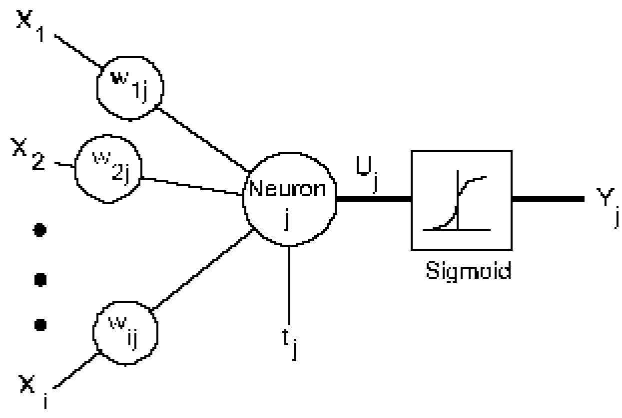


Fig.6. A Model Neuron

While there is a fair understanding of how an individual neuron works, there is still a great deal of research and mostly conjecture regarding the way neurons organize themselves and the mechanisms used by arrays of neurons to adapt their behavior to external stimuli. There are a large number of experimental neural network structures currently in use reflecting this state of continuing research.

In our case, we will only describe the structure, mathematics and behavior of that structure known as the back propagation network. This is the most prevalent and generalized neural network currently in use.

To build a back propagation network, proceed in the following fashion. First, take a number of neurons and array them to form a layer. A layer has all its inputs connected to either a preceding layer or the inputs from the external world, but not both within the same layer.

A layer has all its outputs connected to either a succeeding layer or the outputs to the external world, but not both within the same layer.

Next, multiple layers are then arrayed one succeeding the other so that there is an input layer, multiple intermediate layers and finally an output layer, as in Figure 3. Intermediate layers, that is those that have no inputs or outputs to the external world, are called >hidden layers.

Back propagation neural networks are usually fully connected. This means that each neuron is connected to every output from the preceding layer or one input from the external world if the neuron is in the first layer and, correspondingly, each neuron has its output connected to every neuron in the succeeding layer.

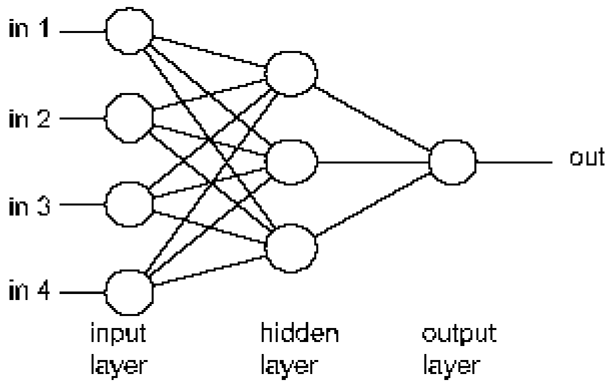


Fig.7. Back propagation Network

Generally, the input layer is considered a distributor of the signals from the external world. Hidden layers are considered to be categorizers or feature detectors of such signals.

$$Y_j = F_{th}(U_j + t_j)$$

The output layer is considered a collector of the features detected and producer of the response. While this view of the neural network may be helpful in conceptualizing the functions of the layers, you should not take this model too literally as the functions described may not be so specific or localized.

With this picture of how a neural network is constructed, we can now proceed to describe the operation of the network in a meaningful fashion

V.SIMULATION RESULTS

The DVR-connected system consisting of a three-phase supply, three-phase critical loads, and the series injection transformers shown in Fig. 2 is modeled in MATLAB/Simulink environment alongwith a sim power system toolbox and is shown in Fig. 5. An equivalent load considered is a 10-kVA 0.8-pf lag linear load. The parameters of the considered system for the simulation study are given in the Appendix

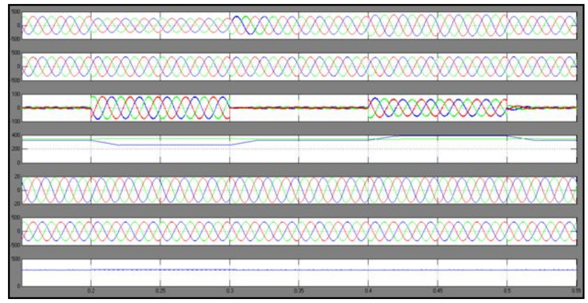


Fig.8. Dynamic performance of DVR with in-phase injection during voltage sag and swell applied to critical load using ANN.

The control algorithm for the DVR shown in Fig. 3 is also modeled in MATLAB. The reference DVR voltages are derived from sensed PCC voltages (v_{sa}, v_{sb}, v_{sc}) and load voltages (v_{La}, v_{Lb}, v_{Lc}). A PWM controller is used over the reference and sensed DVR voltages to generate the gating signals for the IGBTs of the VSC of the DVR. The capacitor-supported DVR shown in Fig. 4 is also modeled and simulated in MATLAB, and the performances of the systems are compared in three conditions of the DVR.

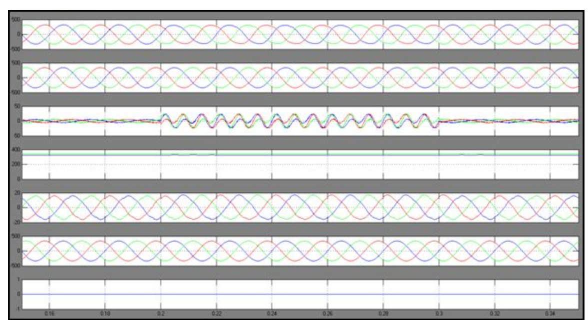


Fig.9.Dynamic performance of DVR during harmonics in supply voltage applied to critical load using ANN.

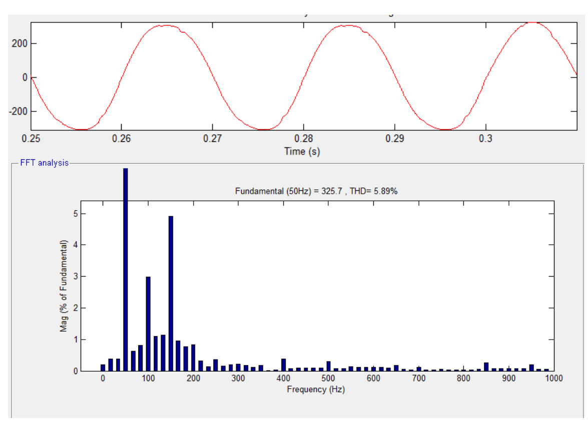


Fig.10. PCC voltage and harmonic spectrum during the disturbance using ANN.

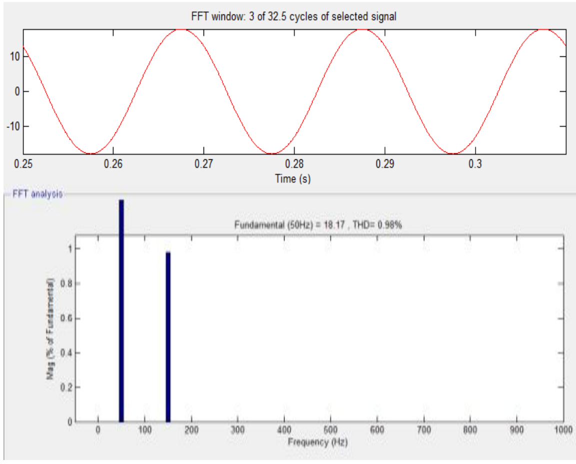
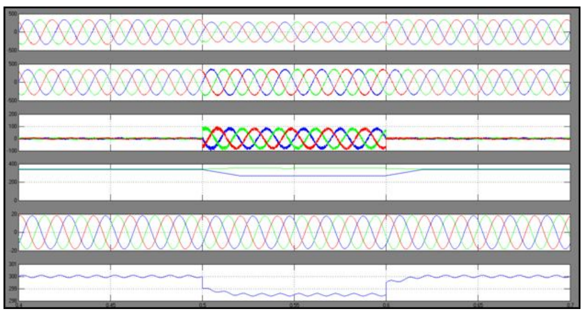
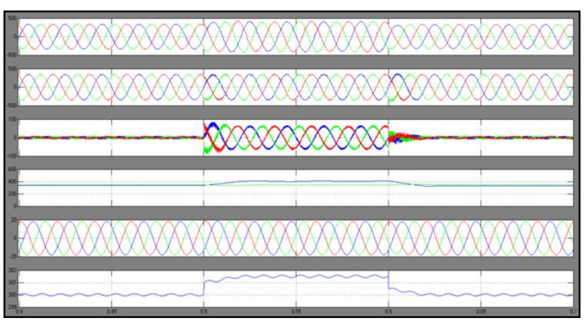


Fig.11. Supply current and harmonic spectrum during the disturbance using ANN.



(a)



(b)

Fig.12. Dynamic performance of the capacitor-supported DVR during (a) voltage sag and (b) voltage swell applied to critical load using ANN.

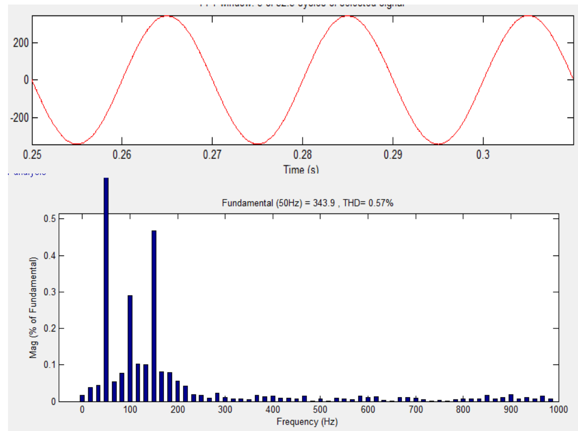


Fig.13. Load voltage and harmonic spectrum during the disturbance using ANN.

VI. CONCLUSION

The operation of a DVR has been incontestable with a brand new management technique victimization numerous voltage injection schemes. A comparison of the performance of the DVR with completely different schemes has been performed with a reduced-rating VSC, together with a capacitor-supported DVR with Artificial neural network. The reference load voltage has been calculable victimization the tactic of unit vectors, and also the management of DVR has been achieved, that minimizes the error of voltage injection. The SRF theory has been used for estimating the reference DVR voltages. it's complete that the voltage injection in-phase with the PCC voltage ends up in minimum rating of DVR however at the value of Associate in Nursing energy supply at its dc bus.

REFERENCES

[1] M. H. J. Bollen,Understanding Power Quality Problems—Voltage Sags and Interruptions. New York, NY, USA: IEEE Press, 2000.

[2] A. Ghosh and G. Ledwich, Power Quality Enhancement Using Custom Power Devices. London, U.K.: Kluwer, 2002. [3] M. H. J. Bollen and I. Gu, Signal Processing of Power Quality Disturbances. Hoboken, NJ, USA: Wiley-IEEE Press, 2006.

[4] R. C. Dugan, M. F. McGranaghan, and H. W. Beaty, Electric Power Systems Quality, 2nd ed. New York, NY, USA: McGraw-Hill, 2006.

[5] A. Moreno-Munoz, Power Quality: Mitigation Technologies in a Distributed Environment. London, U.K.: Springer-Verlag, 2007.

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