ISSN: 2454-9940

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

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www.ijasem.org

INTERNATIONAL JOURNAL OF APPLIED SCIENCE ENGINEERING AND MANAGEMENT

ISSN2454-9940
www.ijsem.org
Vol 13, Issuse.3 Aug 2019

ENHANCING POWER QUALITY WITH THREE-LEVEL INVERTERS IN DYNAMIC VOLTAGE RESTORERS

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ABSTRACT: Customer pollution is the most important element influencing distribution network power quality (PQ). The sensitive loads must be safeguarded from swells, sags, source voltage imbalances, and so on. The answer is a dynamic voltage restorer (DVR). Dynamic voltage restorers are series-connected compensators. When the voltage varies, a DVR must power the load. Multiple DVR inverters improve the harmonic performance of the system. Synchronous reference frame control is used for DVR control. The design and simulations of a three-level inverter-based DVR are described in this work. In MATLAB, simulate and analyze a three-level and two-level inverter DVR. The results reveal that a three-level inverter raises load voltage THD while injecting a series voltage keeps the reference value constant.

Keywords*:* PQ-Power Quality, DVR-Dynamic Voltage Restorer, THD-Total Harmonic Distortion, PWM-pulse width modulated.

1.INTRODUCTION

EN 50160 defines voltage sag as a sudden drop in supply voltage below 90% of the specified voltage. Voltage sag may lower power quality when more electronics are interrupted. Unexpected power outages in textile or paper mills can cause adjustable speed drive (ASD) speed variations and product damage. A transitory voltage sag lowers dc-link voltage, causing overcurrent or undervoltage trips. Continuous process firms lose money and income because to ASD equipment tripping.UPSs protect loads from power outages. However, the UPS cannot handle excessive power. Therefore, a device that supports the load without changing the supply is needed. Serially connecting DVRs achieves the purpose. Figure 1 shows a power-electronic DVR that can grow to correct voltage swell and maintain load voltage during supply voltage sag.Remove voltage sag with Dynamic Voltage Restorers. Dynamic Voltage Restorers are series compensators. Powering the load during electricity drops requires a DVR. A DC-side shunt converter helps DVRs offer long-term active power. At a fundamental frequency, the DVR provides voltage amplitude and phase power to each phase.

Literature discusses DVR. Duke Power's Electric Power Research Institute installed Westinghouse's first DVR in 1996.

2.LITERATURE SURVEY

Dynamics voltage restorers (DVRs) are power electronic converter-based series compensators that protect critical loads from supply-side disturbances other than power loss. Restorer AC output terminals create or absorb actual and reactive power separately. This device uses solid-state power electronic switches and PWM inverters. Distribution feeder voltages are paralleled with three-phase alternating current output voltages. Varying the injected voltages' amplitude and phase angle controls actual and

ISSN2454-9940
www.ijsem.org
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reactive power exchange between the device and the distribution system. The restorer's DC input terminal connects to an energy source or large energy storage device. The restorer creates distribution system reactive power without AC passive reactive components. The restorative input DC terminal powers the output AC terminals from an external energy source or storage device.

To compensate for defective voltages, DVR injects three single-phase AC voltages in series with three-phase incoming network voltages during a drop. Adjust the amplitude and phase of all three injected voltage phases. An inverter using a DC voltage source generates active and reactive electricity. The DVR enters standby mode when grid power drops below 50% or rises over 90%. A DVR provides load voltage when the grid voltage is 50% to 90% of its maximum. Zero series voltage is injected when the DVR is controlled (top or lower three switches on) or bypassed. If the load current exceeds a threshold, the bypass switch closes to protect the DVR at low voltage (LV), usually via a two-level voltage source converter (VSC) and coupling voltage transformer. In medium voltage (MV) and high power applications, two-level switches must block high voltages. However, a high-turns transformer increases DVR losses and converter side current. DVR integration in MV apps is best with an MVSC. This approach cuts conversion and current losses. Sharing the DC bus lets DVR and shunt compensator talk.

Multiple-layer inverters are used in DVRs. A three-phase DVR is recommended by this study, and the Transformer Coupled H-Bridge Converter Applied To DVR, Multilevel Inverter With Adjustable Dc-Link Voltage, Cascade Asymmetric Multilevel Converter (CAMC), Dynamic Voltage Restorer Based On Flying Capacitor Multilevel Inverter, and Cascaded Multilevel Inverter DVR are all cost-effective. It performed like a two-level, inverter-equipped DVR.

3.PROPOSED DVR TOPOLOGY

Fig. shows the proposed DVR construction in block diagram form. 1. The suggested DVR has a clamped inverter, LC filter, battery energy storage system, injection transformer, and control circuit.

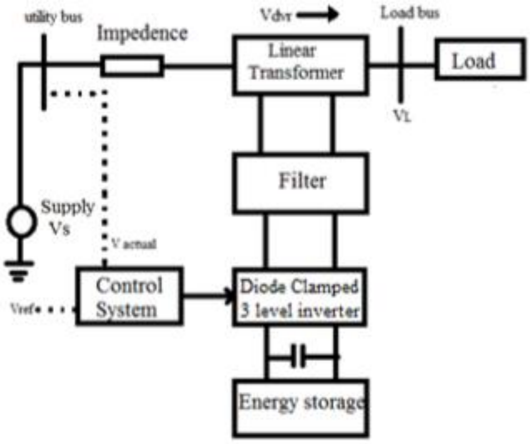

Fig 1. Configuration advice for DVR

DVRs convert DC to AC via a voltage source inverter. DVRs employ two-level PWM Voltage Source Inverters. Inverter contains three diodes. Fig. shows a Diode Clamped Three Level Inverter circuit. 2. Each leg has four clamping diodes and switches. Vdc/2 is the inverter's input DC voltage for all voltage sources. Midpoint grounding. DVR power circuits use step-up voltage injection transformers to raise voltage during sag. Low-voltage inverters work well.

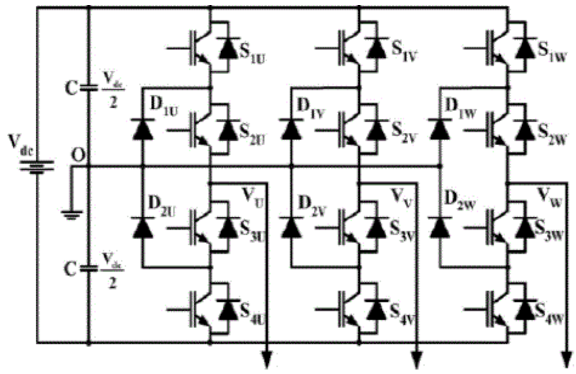

Fig 2. Three phase three level diode clamped inverter

Three-level diode clamped inverters use two diodes and two switches. Each switch pair receives the mid-point voltage from diodes in complementary mode. C1 and C2, two DC capacitor series connections, split the DC bus voltage into three levels. Clamping diodes D1u

ISSN2454-9940
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and D2u reduces switching device voltage stress to Vdc. If the DC link voltage is Vdc and the mid-point is synchronized at half, each capacitor has a voltage of Vdc/2. Three-level diode clamped inverters apply the stair case voltage to the output voltage connected to the DC link capacitor voltage rate in three switching states. Two switches are constantly on in a three-level inverter, four in a five-level, etc. Table 1 lists three-level inverter switching states.

Table 1 One leg of the three-level diode clamped inverter is switched.

Switching state	Q1	Q2	Q3	Q4
+Vdc	1	1	0	0
0	0	1	1	0
-Vdc	0	0	1	1

Injection transformers in series with distribution feeders supply voltages to the distribution system. The injection transformer has a primary series connection to the distribution line and a secondary connection to the DVR power circuit. A three-phase transformer or three single-phase transformers may now power three-phase DVRs.

Three-level PWM inverted pulse waveforms are converted to sinusoidal waveforms by passive low pass filters. The voltage source inverter must convert DC to AC to remove higher order harmonic components that affect corrected output voltage. These crucial filters can be mounted on injection transformer load or inverter sides. Filters on the inverter side prevent higher-order harmonics from reaching the voltage transformer. Thus, the injection transformer is less stressed. A little filter is needed for the suggested DVR, unlike dual-level ones. This lowers DVR prices.

Flywheels, lead acid batteries, SMES, and supercapacitors store energy. Power delivery during voltage drops is energy storage's main role. DVR compensating capacity depends on energy storage device active power. Lead batteries are most common because they charge and discharge quickly. Therefore, this architecture uses a lead acid battery.

4.DVR CONTROL

As load voltage varies, the DVR injects voltage. Voltage sag must be identified. Supply voltage peak, d-, and q-axis voltages are measured. Each phase undergoes a band pass filter, phase-locked loop, Fourier, wavelet, and numerical matrix sag detection.

Visit to learn these strategies. This study measures supply voltage's d- and q-axis components to detect voltage sags.

Figure. In Figure 3, a DVR control block calculates reference signals using SRF theory. Measure the load terminal (vL) and PCC (vS) voltages to determine VSC gate signals. VL* is calculated using the unit vector [8]. Park's transformation rotates load voltages (VLa, VLb, and VLc) while a PLL generates unit vectors.

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

PCC (VS) and reference load voltages (VLa*,VLb*,VLc*) are converted by the revolving reference frame. DVR voltages are measured in the rotating reference frame.

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

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

Rotating reference frame produces reference DVR voltages.

$$V_{Dd}{}^{*} = V_{Sd}{}^{*} - V_{Ld} \quad (4)$$

$$V_{Dq}{}^{*} = V_{Sq}{}^{*} - V_{Lq} \quad (5)$$

In the rotating reference frame, two PI controllers control the DVR voltage difference. VDd*, VDq*, and VD0* are the ABC frame's reference DVR voltages after reverse Park's translation.

$$\begin{bmatrix} V_{dvra}{}^{*} \\ V_{dvrb}{}^{*} \\ V_{dvrc}{}^{*} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos\left(\theta - \frac{2\pi}{3}\right) & \sin\left(\theta - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\theta + \frac{2\pi}{3}\right) & \sin\left(\theta + \frac{2\pi}{3}\right) & 1 \end{bmatrix} \begin{bmatrix} V_{Laref} \\ V_{Lbref} \\ V_{Lcref} \end{bmatrix} (6)$$

Reference and real DVR voltages provide the PWM controller's reference signal for gating pulses to a DVR VSC. Three-level PWM signals

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are formed by comparing the reference voltage with two repeated sequences. Switches 1, 2, and 4 produce a three-level output voltage. Comparing two triangular carrier waves to the DVR reference voltage generates switching signals. The figure shows how inverter switches receive PWM signals. 3.

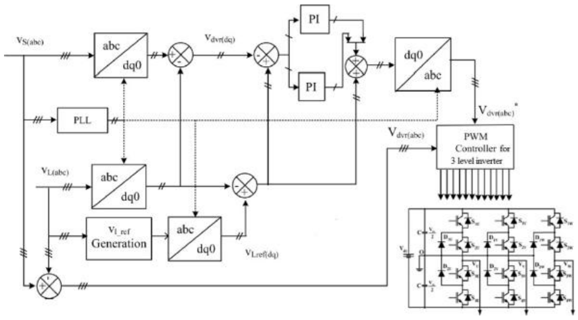

Fig 3. SRF diode with three levels is utilized in clamped inverter-based DVR control block.

5.RESULT AND DISCUSSION

Using Matlab for simulations. Two-level and three-level diode clamped inverter-based DVRs are simulated and examined

DVR with Three Level Diode Clamped inverter

The Simulink diagram is in Figure 4.

Programmable voltage sources produce sag.

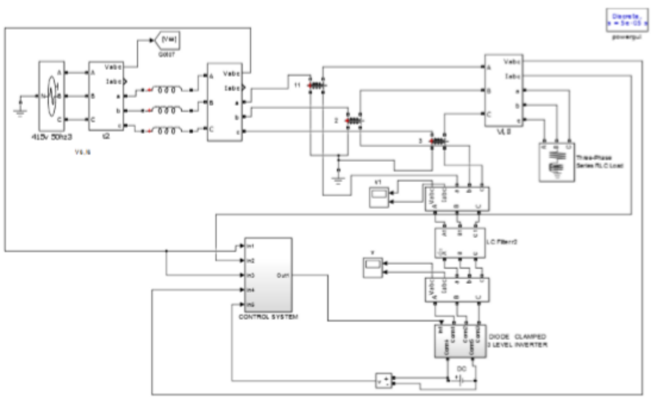

Fig.4 Three-Level Simulink Inverter Diagram for Diode-Clamped DVR

The input voltage is 230Vrms. A DVR should inject 115 V rms to compensate for 50% supply voltage sag. Uses a 200 V battery. In-phase injection is used. Clamping inverters use three-level diode IGBT switches. Three alternating current voltages are injected in series to maintain load voltage during sag. A 1:1 turn-ratio linear transformer injects DVR voltage. A 10 KVA rms transformer at 240 volts powers a 1000-watt active and 400-watt reactive load.

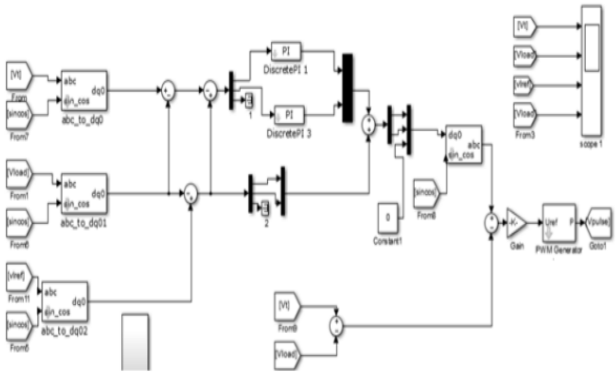

Fig 5. Matlab DVR controller

50% DVR sag is tested. The supply voltage with a 50% sag from 0.2 to 0.3 instantaneous values is displayed in Figure 6(a).

Figure 6(c) shows the DVR reference voltage, (b) the load reference voltage. Adjusted load reference voltage is 230 V rms. Figure 7(a) shows three-level DVR inverter voltage injection. A DVR with an LC filter injects real voltage in Figure 7(b). After modification, Figure 7(c) shows load voltage and Figure 7(d) load current. Filtering the converter output voltage reduces harmonics. As shown, the DVR injects sag-proportional voltage to maintain 0.2–0.3 load voltage.

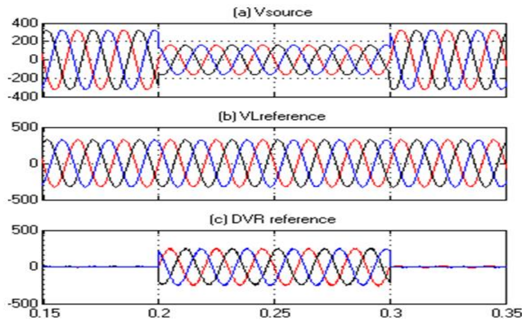

Fig .6 DVR reference voltage (c), source voltage, and load reference voltage

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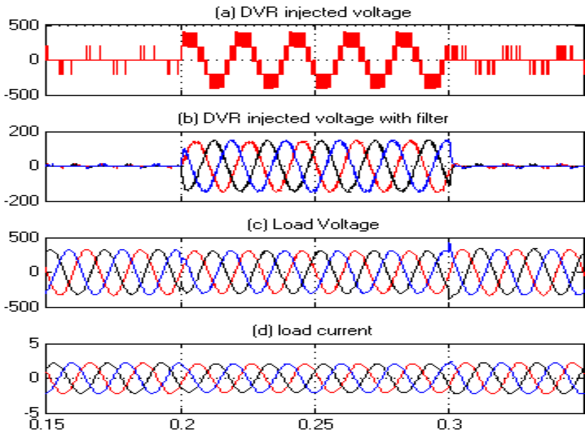

Fig.7 (DVR injects voltage (b), filtered voltage (c), load voltage (d), and load current.

Figure shows load voltage harmonic spectrum. 8. The THD is 3.57%, which is normal. A three-level inverter improved DVR harmonics.

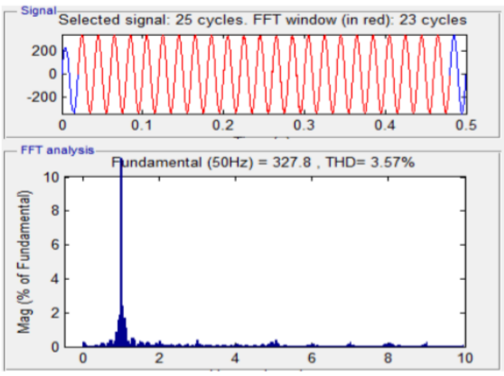

Fig. 8 applied voltage harmonic range

DVR with Two Level inverter

Simulate the performance of a two-level inverter and three-level diode clamped DVR. Simulation findings are used to compare the two DVRs' harmonic performance and test the DVR for 50% sag. Figure 9(b) shows the load reference voltage from 0.2 to 0.3, while Figure 9(a) shows the supply voltage with a 50% sag. Adjustment requires 230 V rms load reference voltage. Fig. shows DVR reference voltage. Figure 10(a) shows LC-filtered DVR injected voltage. 10(b). Injecting the needed voltage in series with the sag maintains load voltage and eliminates converter output voltage harmonics.

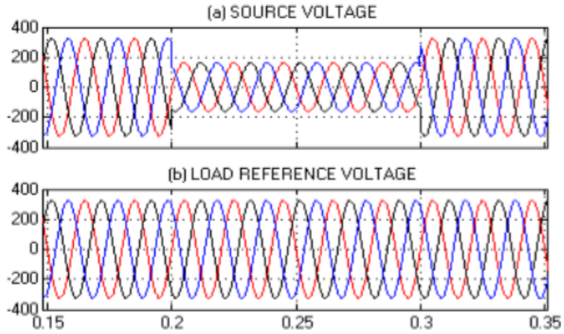

Fig 9. Voltage supply (Vs), voltage load

Figure shows changed load voltage. 11(a). DVRs restore power supply voltage. The modified load current is illustrated in Fig.11(b). Figure 12 shows switching PWM pulses.

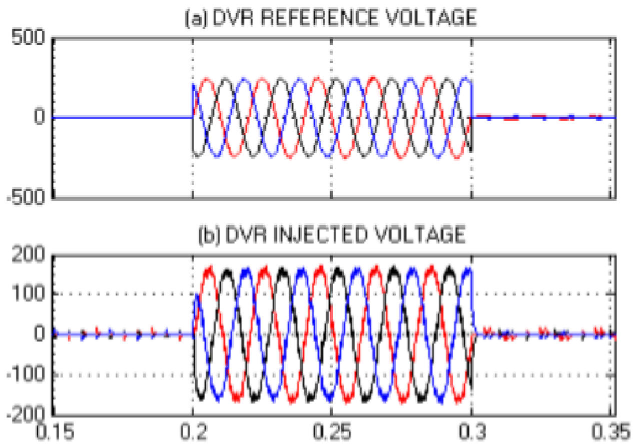

Fig 10 (The compensator's reference voltage (V) and DVR-injected voltage

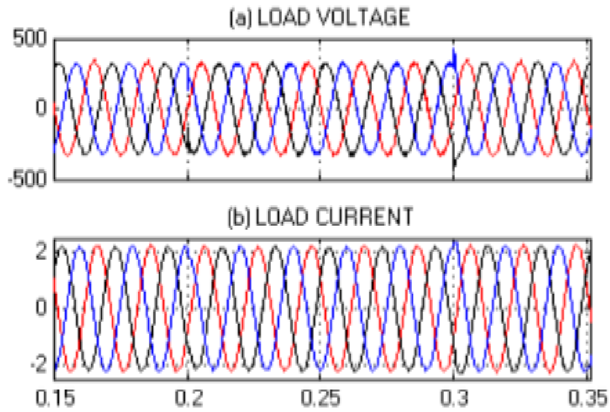

Fig 11. (a) load voltage (VL), (b) load current

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Fig 12. Switching inverter signals

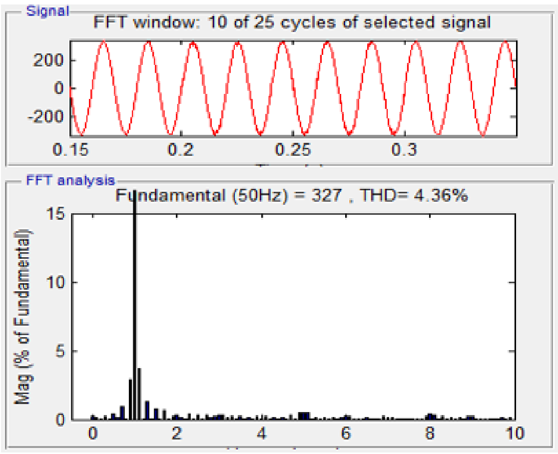

Figure shows load voltage harmonic spectrum. THD is acceptable at 4.36%. The figure has no higher-order harmonics. THD for 3-level inverters is 3.57%. Increasing inverter level improves THD. Thus, a three-level Diode Clamped inverter-based DVR has a much smaller filter than a two-level DVR. Thus, the three-tier DVR is affordable.

Fig.13 applied voltage harmonic range

Simulations contain a 30% voltage sag. The statistics below show DVR function at 30% sag. Figure. 14(a) indicates 0.2-0.3 seconds of 30% supply voltage sag. Figures 14(b) and 14(c) illustrate the load and DVR reference voltages. To maintain load voltage, Fig. shows DVR injected voltage. 15(a). Figure shows changed load voltage. 15(b). Injecting voltage in series maintains load voltage. See Figure 15(c) for current load.

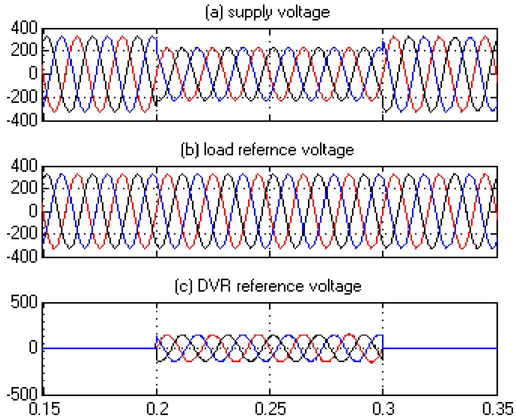

Fig 14 Allow 30% voltage drop. B) Set load reference voltage. DVR voltage reference

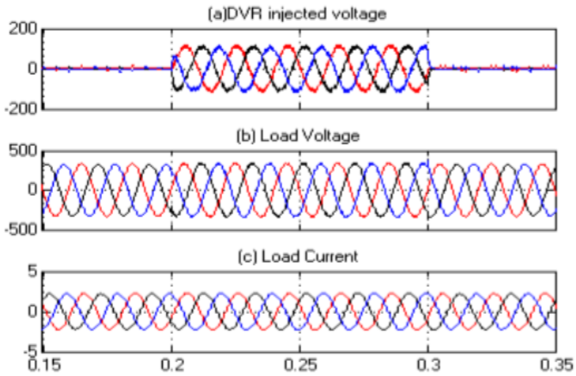

Fig .15 DVR-injected voltage. Correction of load current and voltage

6.CONCLUSION

Three-inverter DVRs improve harmonic performance, switching losses, and voltage blocking. The Diode Clamped multilayer inverter-based DVR features fewer components and more sag compensation than earlier systems. This article covers Diode Clamped multilayer inverter-based DVR operation and control. SRF controls the DVR, and SPWM generates the inverter switching pulse. Matlab Simulink simulates and analyzes two- and three-level DVRs. Two-level inverter-based DVRs have 4.36% load voltage THD and three-level DVRs 3.57%. Thus, the multilevel inverter-based DVR surpasses the two-level DVR in harmonic performance. Three-stage inverters shrink filters. Thus, DVRs cost less.

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