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FUZZY LOGIC CONTROLLED DVR USING COMPENSATION OF VOLTAGE WITH SAG AND SWELL

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ABSTRACT:

Dynamic Voltage Restorers (DVR) are presently winding up more settled in industry to lessen the effect of voltage droops to touchy burdens. Be that as it may, DVR's invest the vast majority of their energy in Standby mode, since voltage lists happen rarely and subsequently their usage is low. On a basic level, it would be worthwhile if the arrangement associated inverter of a DVR could likewise be utilized to make up for any unfaltering state stack voltage sounds, since this would build the Power Quality. The voltage infusion plans for dynamic voltage restorer are dissected by utilizing fluffy rationale controller absolutely with BESS and self upheld DVR for relieving the Power quality (PQ) issues, for example, homeless people, droops, swells, and different contortions to the sinusoidal waveform of the supply voltage influence the execution of these hardware pieces. The execution of a DVR with BESS works so appraising of VSC can be diminished. The synchronous edge of reference hypothesis is utilized for the transformation of voltages from turning vectors to the stationary edge, where unit vectors are gotten by 0 using PLL.

Index Terms— Dynamic voltage restorer (DVR), power quality, unit vector, voltage harmonics, voltage sag, PLL, voltage swells.

INTRODUCTION

VOLTAGE sags are the marvels of sudden voltage drops going on for a brief length, which are caused essentially by lightning in control in appropriation or transmission framework. The measure of profundity in voltage droops more often than not goes from 10% to50%, and its span is under 0.2 s. Voltage droops may cause the breakdown of voltage-touchy loads in industrial facilities, structures, and healing centers. Because of the utilization of touchy and basic hardware pieces, for example, delicate and basic gear pieces, for example, correspondence organize, process enterprises, control quality issues are arised in the present-day dissemination frameworks which are tended to in the writing [1]– [6] . Power quality issues, for example, homeless people, lists, swells, and different bends to the sinusoidal waveform influence the execution of the gear Technologies, for example, custom power gadgets are developed to give security against control quality issues [2]. Custom power gadgets are for the most part of three classifications, for example, arrangement associated compensators known as unique voltage restorers (DVRs), shunt-associated compensators, for example,

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circulation static compensators, and a mix of arrangement and shunt-associated compensators known as brought together power quality conditioner [2]– [6]. The utilization of a dynamic voltage restorer (DVR), or a voltage hang compensator, is a standout amongst the best answers for "reestablishing" the nature of voltage at its heap side terminals when the nature of voltage at its source-side terminals is bothered The DVR can direct the heap voltage from the issues, for example, droop, swell, and music in the supply voltages. Subsequently, it can shield the basic buyer loads from stumbling and ensuing misfortunes [2]. The custom power gadgets are created and introduced at purchaser point to meet the power quality norms, for example, IEEE-519 [7].Voltage hangs in an electrical matrix are not generally conceivable to stay away from in light of the limited clearing time of the deficiencies that reason the voltage droops and the spread of lists from the transmission and appropriation frameworks to the low-voltage loads. Voltage lists are the normal purposes behind interference underway plants and for end-client hardware glitches by and large. Specifically, stumbling of gear in a generation line can cause creation interference and critical expenses because of loss of creation. One answer for this issue is to make the hardware itself more tolerant to droops, either by smart control or by putting away "ride-through" vitality in the gear. An option arrangement, rather than altering eachcomponent in a plant to be tolerant against voltage lists, is to introduce a plant wide uninterruptible power supply framework for longer power interferences or a DVR on the approaching supply to moderate voltage droops for shorter periods [8]– [22]. Common DVR arrangement associated topology, with a fleeting vitality stockpiling ability, (for example, a capacitor bank or batteries) to ride through a voltage hang. The vitality stockpiling framework is ordinarily energized utilizing a little unidirectional power supply. Consequently should DVR's can't supply critical enduring state genuine power and furthermore can retain no consistent state genuine power back through the arrangement association. In this way, any unfaltering state consonant voltage pay system that is actualized must guarantee that the enduring state genuine power move through the DVR is kept near zero. DVRs can dispose of a large portion of the lists and limit the danger of load stumbling for profound hangs, however their fundamental downsides are their standby misfortunes, the hardware cost, and furthermore the assurance conspire required for downstream shortcircuits. Numerous arrangements and their issues utilizing DVRs are accounted for, for example, the voltages in a three stage framework are adjusted [8] and a vitality streamlined control of DVR is talked about in [10].Industrial cases of DVRs are given in [11], and distinctive control strategies are broke down for various sorts of voltage lists in [12]– [18]. An examination of various topologies and control strategies is introduced for a DVR in [19]. The outline of a capacitor-bolstered DVR that secures sag,swell, twisting, or unbalance in the supply voltages is talked about in [17]. The execution of a DVR with the high-recurrence connect transformer is talked about in [22]. In this paper, the control and execution of a DVR are shown with a lessened rating voltage source converter (VSC). The synchronous reference outline (SRF) hypothesis is utilized for the control of the DVR with fluffy logic controller.

OPERATION OF DVR

The schematic of a DVR-connected system is shown in Fig. 1(a). The voltage V□□□ is inserted such that the load voltage V□□□□ 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 injection schemes of the DVR.

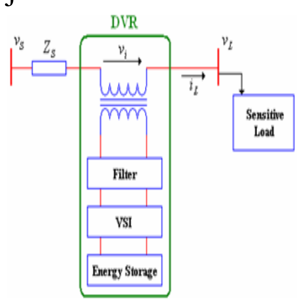

Fig.1.(a) Schematic configuration of DVR.(b) Phasor diagram of the DVR voltage injection schemes.

V(pre−sag) is a voltage over the basic load before the voltage droop condition. Amid the voltage droop, the voltage is lessened to Vs with a stage slack edge of θ. Presently, the DVR infuses a voltage with the end goal that the heap voltage greatness is kept up at the pre-droop condition. Agreeing t the stage edge of the heap voltage, the infusion of voltages can be acknowledged in four ways [19].V□□□□ speaks to the voltage infused in-stage with the supply voltage. With the infusion of V□□□, the heap voltage extent stays same however it drives Vs by a little point. In V□□□□, the heap voltage holds an indistinguishable stage from that of the pre-list condition which might be an ideal edge considering the vitality source [10].V□□□□ is where the infused voltage is in quadrature with the current, and this case is reasonable for a capacitor-upheld DVR as this infusion includes no dynamic power [17]. Be that as it may, a base conceivable rating of the converter is accomplished byVinj1 The DVR is worked in this plan with a battery vitality stockpiling framework (BESS) Fig. 2 demonstrates a schematic of fundamental rule of DVR associated with reestablish the voltage of a basic load. A three-stage supply is associated with a basic and delicate load through at three-stage arrangement infusion transformer. The voltage infused by the DVR in stage An is to such an extent that the heap voltage is of appraised greatness and undistorted. A three-stage DVR is associated with the line to infuse a voltage in arrangement utilizing thee single stage transformers. Fig. 2. Fundamental rule of DVR

CONTROL OF DVR

The remuneration for voltage droops utilizing a DVR can be performed by infusing or retaining the receptive power or the genuine power [17]. It is said over that the DVR can be intended to providereactive or both dynamic and responsive forces pay. A DVR with both dynamic and responsive power pay is however favored since it can moderate both a plunge in voltage size and in addition a bounce in stage edge dissimilar to that with just receptive power remuneration as phasor outline is appeared

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in Fig 3(a) When the infused voltage is in quadrature with the current at the crucial recurrence, the pay is made by infusing receptive power and the DVR is with a self-upheld dc transport as appeared in Fig 3(b). Nonetheless, if the infused voltage is in stage with the current, DVR injects real power.

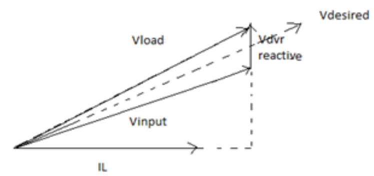

Fig.3 (a).Phasor diagram for reactive power

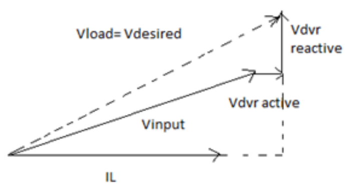

Fig.3 (b).Phasor diagram for active and reactive power compensation

A. Control of DVR with BESS for Voltage Sag, Swell, and

Harmonics Compensation Fig. 4 shows a control block of the DVR in which the SRF theory is used for reference signal estimation. The voltages at the PCC v and at the load terminal v are sensed for deriving the IGBTs' gate signals. The reference load voltage V ∗ is extracted using the derived unit vector [21]. Load voltages (V , V , V) are converted to the rotating reference frame using abc−dqo conversion using Park's transformation with unit vectors (sinθ,cos θ) derived using a phase-locked loop as Similarly, reference load voltages (V , V , V) and voltages at the PCC v are also converted to the rotating reference frame. Then, the DVR voltages are obtained in the rotating reference frame as

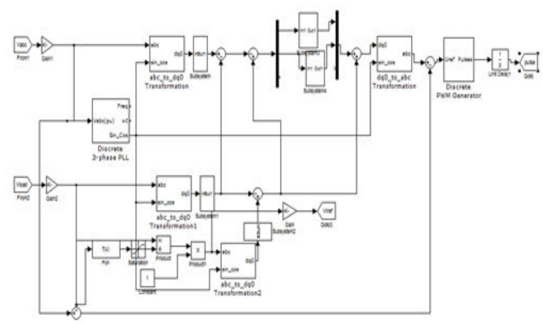

Fig. 4. Control block of the DVR that uses the SRF method of control.

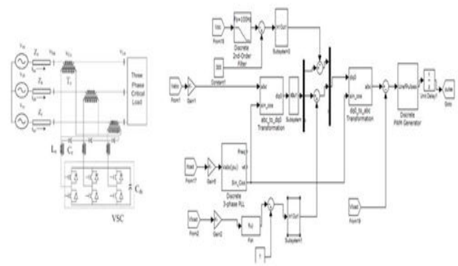

Fig.5. (a) Schematic of the self-supported DVR. (b) Control block of the DVR that uses the SRF method of control

The reference DVR voltages are obtained in the rotating reference frame as 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 actual DVR voltages(vdvra,vdvrb,vdvrc) are used ina 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. 5(a) shows a schematic of a capacitor-supported DVR connected to three-phase critical loads, and

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Fig. 5(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□ = v□□ + v□□□+v□□□ (7)

v□ = v□□□ + v□□□ (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

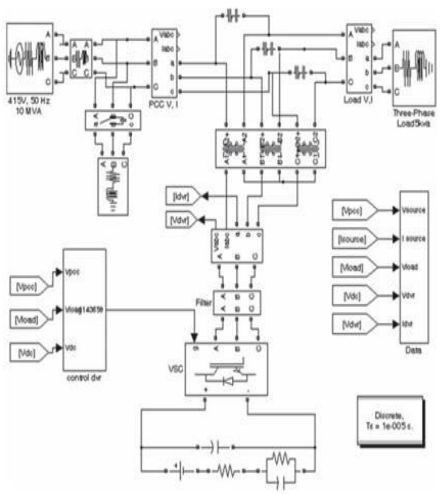

Fig. 6. MATLAB-based model of the BESSsupported DVR-connected system.

DVR and the output is considered as a voltage vcap for meeting its losses is the error between the reference v□□ ∗ and sensed dc voltages v□□ at the nth sampling instant. K□□And K□□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□ ∗ =v□□□ − v□□□ (10) The amplitude of load terminal voltage V□ is controlled to its reference voltage V□ ∗ using another PI controller. The output of the PI controller is considered as the reactive component of voltage V□□ for voltage regulation of the load terminal voltage. The amplitude of load voltage V□ at the PCC is calculated from the ac voltage Then, a PI controller is used to regulate this to a reference value as denotes the error between the reference V□ ∗ and actual V(n) load terminal voltage amplitudes at the n□□ sampling instant. K□□ and K□□ are the proportional and the integral gains of the dc bus voltage PI controller. The reference load quadrature axis voltage is expressed as follows:

in the abc frame are obtained from a reverse Park's transformation as in (6). The error between sensed load voltages (v□□, v□□, v□□) and reference load voltages is used over a controller to generate gating pulse to the VSC of the DVR.

PLL IMPLEMENTATION

VSCs such as PWM rectifiers and gridparallel inverters for integration of renewable energy and energy storage devices typically rely on digital signal processing for realization of their current control and grid synchronization functions. The blockdiagram of PLL is shown in Fig.7 (a) .Other forms of power-electronics based equipment such as DVR and active power filters commonly include such control functions among many other power regulation functions. Three-phase power converter current control is usually performed in a dq-coordinate system because of its ability to eliminate steady-state tracking errors. Transformation of the converter currents in the abc-coordinate system into a rotating reference frame requires making the transformation angle available to the current controller

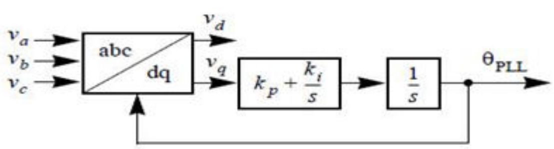

Fig.7 (a).Block diagram of PLL

Among the several grid synchronization methods, many of the advanced strategies rely on the fundamental concept of a synchronous reference frame PLL. The output of the PLL is typically regarded as the synchronization angle. However, this represents a challenge if analog signal transmission of the PLL angle is to be realized by conventional operational amplifier circuitry. The problem in any practical implementation of the PLL is that it requires resetting of the detected angle every 2□ radians, which makes it impossible to transmit the detected angle through band-limited analog channels without causing distortion at the sharp angle reset instants.

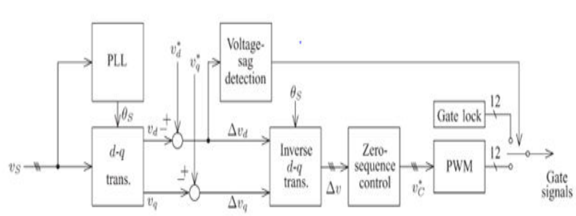

Fig 7(b) Sag detection

FUZZY LOGIC CONTROLLER

In FLC, basic control action is determined by a set of linguistic rules. These rules are determined by the system. Since the numerical variables are converted into linguistic variables, mathematical modeling of the system is not required in FC. The FLC comprises of three parts: fuzzification, interference engine and defuzzification. The FC is characterized as i. seven fuzzy sets for each input and output. ii. Triangular membership functions for simplicity. iii. Fuzzification using continuous universe of discourse. iv. Implication using Mamdani's, 'min' operator. v. Defuzzification using the height method.

Fuzzification:

Membership function values are assigned to the linguistic variables, using seven fuzzy subsets: NB (Negative Big), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium), and PB (Positive Big). Partition of fuzzy subsets and the shape of membership CE(k) E(k) function adapt the shape up to appropriate system. The value of input error and change in error are normalized by an input scaling factor In this system the input scaling factor has been designed such that input values are between -1 and +1. The triangular shape of the membership function of this arrangement presumes that for any particular E(k) input there is only one dominant fuzzy subset. The input error for the FLC is given as

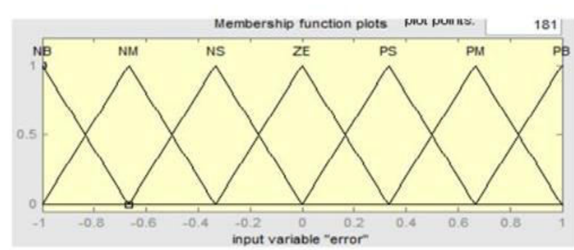

Fig .8(a).Membership functions

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Inference Method:

Several composition methods such as Max–Min and Max-Dot have been proposed in the literature. In this paper Min method is used. The output membership function of each rule is given by the minimum operator and maximum operator. Table 1 shows rule base of the FLC.

Defuzzification:

As a plant usually requires a nonfuzzy value of control, a defuzzification stage is needed. To compute the output of the FLC, „height" method is used and the FLC output modifies the control output. Further, the output of FLC controls the switch in the inverter. In UPQC, the active power, reactive power, terminal voltage of the line and capacitor voltage are required to be maintained. In order to control these parameters, they are sensed and compared with the reference values. To achieve this, the membership functions of FC are: error, change in error and output. The set of FC rules are derived from u=-[αE + (1-α)*C] Where α is self-adjustable factor which can regulate the whole operation. E is the error of the system, C is the change in error and u is the control variable. A large value of error E indicates that given system is not in the balanced state. If the system is unbalanced, the controller should enlarge its control variables to balance the system as early as possible. One the other hand, small value of the error E indicates that the system is near to balanced state. Overshoot plays an important role in the system stability. Less overshoot is required for system stability and in restrainingoscillations. During the process, it is assumed that neither the UPQC absorbs active power nor it supplies active power during normal conditions. So the active power flowing through the UPQC is assumed to be constant. The set of FC rules is made using Fig.8 (b) is given in Table 1.

MODELING AND SIMULATION

The DVR-connected system consisting of a three phase supply, three-phase critical loads, and the series injection transformers shown in Fig. 5(A) is modeled in MATLAB/Simulink environment along with a sim power system toolbox and is shown in Fig. 6. 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

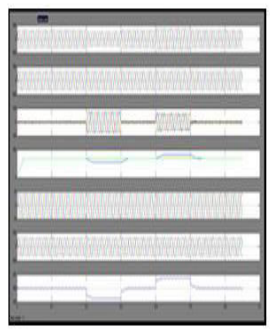

Fig. 9. (a) Dynamic performance of DVR with BESS during voltage sag and swell applied to critical load.

The control algorithm for the DVR shown in Fig. 4 is modeled in MATLAB. The reference DVR voltages are derived from sensed PCC voltages (v□□, v□□, v□□) and load voltages (v□□, v□□, v□□). 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.5 is modeled and simulated in MATLAB, and the performances of the systems are compared in three conditions of the DVR.

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PERFORMANCE OF THE DVR SYSTEM

The performance of the DVR is demonstrated for different supply voltage disturbances such as voltage sag and swell. At 0.2 s, a sag in supply voltage is created for five cycles, and at0.4 s, a swell in the supply voltages is created for five cycles. It is observed that the load voltage is regulated to constant amplitude under both sag and swell conditions.Fig.9 (a) shows the in-phase injection of voltage by the DVR. The compensation of harmonics in the supply voltages is demonstrated in Fig.9(b) and 9(c). At 0.2 s, the supply voltage is distorted and continued for five cycles. The load voltage is maintained sinusoidal by injecting proper compensation voltage by the DVR

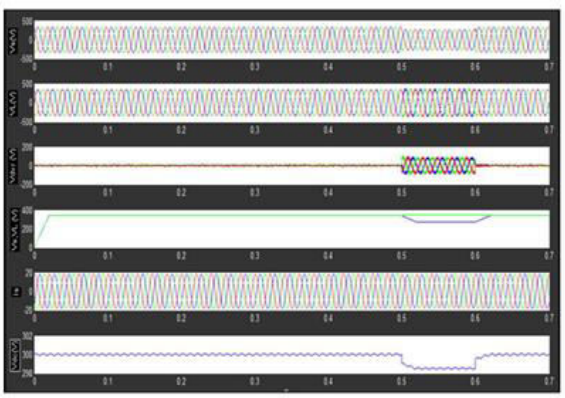

Fig. 9(b) Dynamic performance of self supported DVR for voltage sag compensation

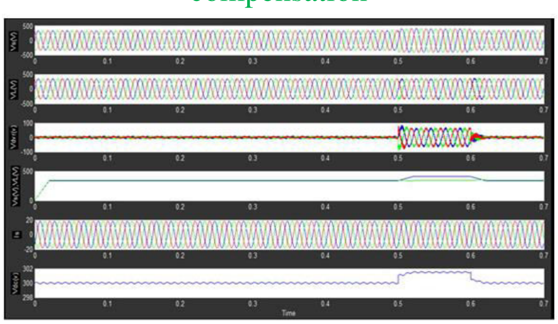

Fig.9(c). Dynamic performance of self supported DVR for voltage swell compensation

The total harmonics distortions (THDs) of the voltage at the PCC, supply current, and load voltage are shown in Figs. 9–11, respectively. It is observed that the load voltage THD is reduced to a level of 0.51% from the PCC voltage of 6.41%. The magnitudes of the voltage injected by the DVR for mitigating the same kinds of sag in the supply with different angles of injection are observed. Theinjected voltage, series current, and kilo volt ampere ratings of the DVR for the four injection schemes are given in Table I. In Scheme-1 in Table I, the in-phase injected voltage is Vinj1 in the phasor diagram in Fig. 1. In Scheme-2, a DVR voltage is injection at a small angle30□, and in Scheme-3, the DVR voltage is injected at an angle 45 . The injection of voltage in quadrature with the line

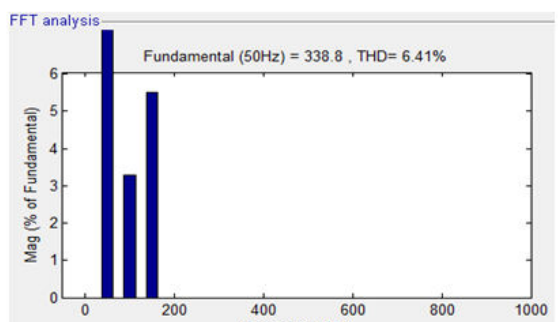

Fig.10 (a) THD values at source without controller.

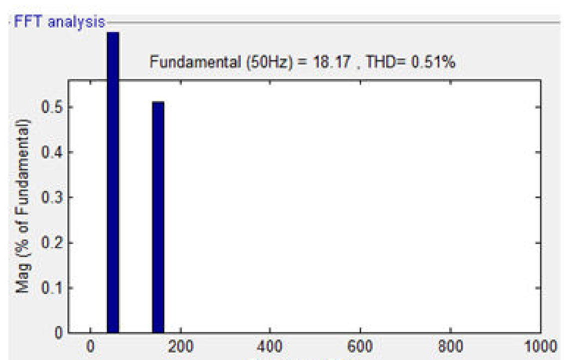

Fig.10 (b) THD values with Fuzzy controller.

Current is in Scheme-4. The required rating of compensation of the same using Scheme-1 is much less than that of Scheme-4.The performance of the self-supported DVR (Scheme-4) for compensation of voltage sag is shown in Fig. 9(b) and that of a voltage swell is shown in Fig. 9(c). It is observed that the injected voltage is in quadrature with the supply current, and hence, a capacitor can support the dc bus of the DVR. However, the injected voltage is higher compared with an in phase injected voltage (Scheme1).

CONCLUSION

This paper has discussed the control, design, and performance of a DVR and design considerations for the proposed scheme have been with particular focus 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 fuzzy logic controller. The THD values were further reduced from 6.41% to 0.51% which could be achieved by Fuzzy controller. 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. 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.

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