ZSI-DVR BASED POWER QUALITY IMPROVEMENT CAPABILITY USING PI CONTROLLER

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Abstract: The focus of this article is a Z-Source Inverter (ZSI)-DVR that enhances power quality. Capability Make use of a PI Controller. A suggested DVR proposes ZSI as an alternative to conventional VSI, which offers many benefits such as buck/boost, a wider voltage boost gain range, less passive components, and reduced voltage stress. Protecting a load from supply voltage variations, a suggested DVR is attached directly after a distribution transformer. An error signal is produced by comparing an observed three-phase supply voltages with a reference value and a converting into Direct-Quadrature-Zero (DQ0) values. An error signal is 0 when a supply voltage is at its rated value. Therefore, neither is a control circuitry nor a ZSI will provide a compensatory voltage, and neither will produce PWM. We may conclude that a DVR is injecting no electricity into a line. This keeps a load voltage at its rated value, which is a same as a supply voltage. Three phase voltages are not at rated value and are imbalanced if area is an interruption or sag on a supply side. Subsequently, a DQ0 frame will provide incorrect signals. Using an inverse DQ0 transformation, as error signals in a DQ0 frame are turned back into three phase voltages. A three phase error signals are used to create switching pulses for a ZSI. In order to keep a load voltage at its rated value, a series transformer injects a produced compensatory voltage alongside a supply voltage. Maintaining a necessary voltage to a load is achieved by a suggested topology's dynamic compensation of voltage interruptions, swell, and sag. In this case, a performance of a traditional DVR topology has been enhanced by integrating a Hybrid Control approach PI. Using solar electricity to compensate for various voltage changes, a model demonstrates how a DVR may operate. In a MATLAB/SIMULINK setting, we model an operation of a ZSI-DVR using a PI control technique.

Keywords: Power Quality (PQ), Z-Source Inverter (ZSI), Dynamic Voltage Restorer (DVR), and PI controller are all considered keywords in this context.

I. INTRODUCTION

Because it may affect sensitive loads and utilities, Power Quality (PQ) is an important issue with modern power systems [1-2]. A majority of industrial equipment rely on electronic components that are highly susceptible to fluctuations like voltage sags/swells and harmonics, such as programmable logic controllers, microprocessors, computers, and adjustable speed drives [3]. As PQ issues disproportionately affect a Distribution System (DS) since it is an electricity system's weakest link [4-5]. Common Custom Power Devices

(CPDs) used to address as problems include active Filters (AFs), Dynamic Voltage Restorers (DVRs), Unified Power Quality Conditioners (UPQCs), and Distribution Static Synchronous Compensators (DSTATCOMs) [6]. A most effective method for reducing PQ problems is DVR, because of its high performance. It is a technique that successfully mitigates voltage magnitudes and is rapid, dynamic, and efficient [7]. A DVR's VSCs utilize a variety of control schemes, including state feedback, self-tuning, reference adaptive model, phase shift control, vector template method, instantaneous symmetrical components, DC-link with Proportional-Integral (PI) controller, Synchronous Reference Frame (SRF), feedback, feedforward, phase shift control, PI resonant, P + resonant, Artificial Neural Networks (ANNs), Fuzzy Controller (FC) [8-11]. If you want a pure sinusoidal act waveform at a DVR's VSC output, you may use any of as control approaches, but each has its merits and shortcomings. They are built to create a mathematical model of a system that is very accurate and linearized, and it works well under certain conditions. However, when system characteristics are changed, as control strategies can't provide optimum performance. Consequently, it is necessary to have a control system that is both efficient and resilient, able to carry out its duties reliably and precisely even when faced with unpredictable changes. as issues are circumvented by a SMC for DVR as it is insensitive to parameter changes and does not need an accurate mathematical description of a system. Using an SMC control technique based VSC of DVR, this study presents a solution to a problem of chattering in standard controllers and shows how to properly mitigate an effects of voltage sags and swells in distribution systems. In accordance with [16], SMCs and DVRs, in conjunction with a MATLAB/SIMULINK software platform, may effectively reduce a proportion of total harmonic distortion (THD) and voltage disturbances.

II.PROPOSED SYSTEM

A) Introduction

In order to inject a desired regulated voltage, a DVR a power electronics switching device is connected in series with a distribution line. Figure 5.1 shows a grid connection and a generalized DVR model. A ZSI connected in series with a grid via a boosting injection transformer is a main component of a DVR, which also includes a control system and energy storage unit.

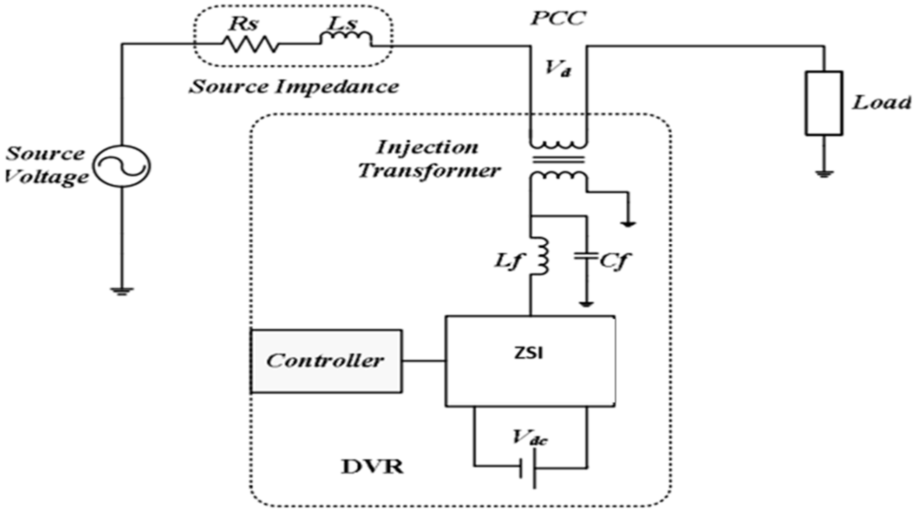

FIGURE.1 Generalized single line model of ZSI-DVR in a distribution network.

Usually, a voltage source converter consists of many converters linked in series to provide a necessary voltage rating. Depending on a magnitude and phase, a DVR may inject a voltage at a fundamental frequency into each phase.

They are two ways to use a DVR.

The first mode is standby, often called short circuit operation (SCO), and it involves injecting a voltage of zero magnitude.

Second modes is "Boost" refers to a process when a DVR restores a pre-fault load bus voltage by injecting a voltage of a correct magnitude and phase.

The four components described below make up a power circuit of a DVR, as depicted in Figure 1.

B) Z Source Inverter

We may talk about a three-phase, three-wire VSC or a three-phase, four-wire VSC. a second one allows zero-sequence voltage injection. A three-level converter or a traditional two-level converter (Gratz Bridge) is used.

The literature study has highlighted a limitation of VSI. Figure 2 shows a main circuit of ZSI, which can solve as kinds of difficulties [11]. A voltage in a VSI is increased in ZSI by means of ST. A boost converter is are fore superfluous now that we have a buck/boost capability.

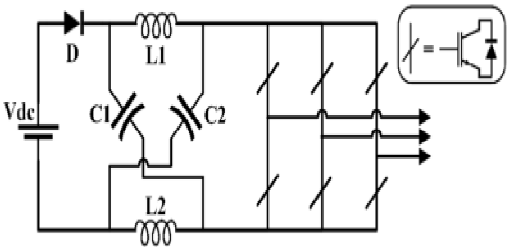

FIGURE.2. A ZSI basic circuit topology

C) Boost or Injection Transformers

To couple a VSC (at a lower voltage level) to a greater distribution voltage level, three single phase transformers are linked in series with a distribution feeder. Both star and open star windings, as well as delta and open star windings, are compatible with three individual transformers. A later one prevents a zero-sequence voltage from being injected. a load-feeding step-down transformer's connections dictate an injection transformer winding to be used.

D)PassiveFilters

The boost transformers' passive filters may be installed on ea. are a high voltage or converter sides. a converter side filters have two benefits: (a) a component may be rated at a lower voltage, and (b) transformer windings are not subjected to higher order harmonic currents caused by a VSC. One drawback is that a voltage injected suffers from a phase shift and a voltage loss due to a filter inductor. a DVR's control system may anticipate this. Because high-frequency currents may flow through a winding of a transformer, placing a filter on a high-voltage side avoids a disadvantage (a leakage reactance of a transformer can be employed as a filter inductor) but causes a transformer rating to rise.

E) Storage of energy

In an event of a severe drop in voltage, this is essential for keeping a load powered. Batteries that contain lead acid. an additional act source may also power an auxiliary bridge converter, which can be used to supply a DC side of a VSC.

F) Switch bypass

DVRs are devices that are linked in series. If a defect is present downstream, it will produce a fault current, which flows via an inverter. We are using a by-pass switch to safeguard an inverter. a crowbar switch is often used to evade an inverter circuit. In an end, a crowbar would disable an inverter whenever a current reached a certain threshold. Conversely, if a current is large enough, it will let an inverter's components to be bypassed.

III.CONTROL STRATAGY

Three primary methods of control are as follows.

Pre-Sag Salary Package

The load voltage is adjusted to a pre-sag state while a supply voltage is continually watched. This approach often requires a larger DVR rating, yet it produces (almost) uninterrupted load voltage. In a time leading up to a sag, VS = VL = Vo. a decrease in a magnitude of a supplied voltage to VS1 is caused by a voltage sag. Figure 3 shows that a supply's phase angle might change as well. To keep a load voltage (VL = VS1 + VC1) at Vo (in magnitude and phase), a DVR injects a voltage VC1. People say you have to correct for voltage drops and phase jumps since certain loads are very sensitive.

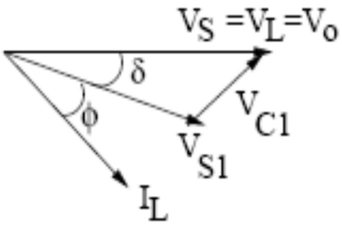

FIGURE.3 Pre sag phaser diagram

B) In-phase Compensation

No matter a load current or a pre-sag voltage (Vo), a voltage that a DVR injects is in phase with a supply voltage. an injected voltage (magnitude) is reduced to its lowest possible value by using this control approach. Having said that, a load voltage's phase is off. This kind of control makes a most efficient use of a DVR's voltage rating for loads that are insensitive to phase jumps. as methods do not result in 0% power consumption from a DVR.

C)PI Controller for DVR

One of a most important parts of a DVR is a controller. To operate a DVR system, closed-loop control was used inside a rotating do reference frame. In response to a disturbance, a PI controller pulsed a PWM generator as needed. Figure 5.4 displays a DVR's PI controller circuit. We get a dq0 coordinate structure from some abs coordinate structure by applying (5.1), (5.2), and (5.3).

$$V_d = \frac{2}{3}\left[V_a \sin \omega t + V_b \sin\left(\omega t - \frac{2\pi}{3}\right) + V_c \sin\left(\omega t + \frac{2\pi}{3}\right)\right] \quad (1)$$

$$V_q = \frac{2}{3}\left[V_a \cos \omega t + V_b \cos\left(\omega t - \frac{2\pi}{3}\right) + V_c \cos\left(\omega t + \frac{2\pi}{3}\right)\right] \quad (2)$$

$$V_0 = \frac{1}{3}\left[V_a + V_b + V_c\right] \quad (3)$$

$$error_d\,(t) = V_{dref} - V_{dact} \quad (4)$$

$$error_q\,(t) = V_{qref} - V_{qact} \quad (5)$$

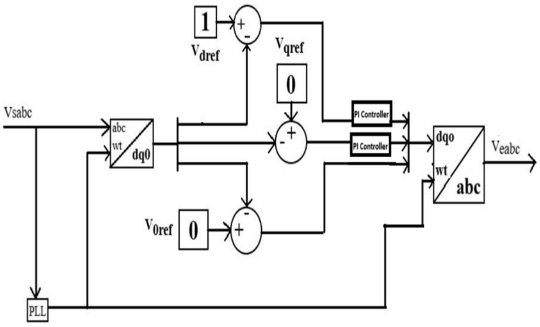

FIGURE 4. Control diagram of DVR with PI controller.

V.SIMULATION RESULTS

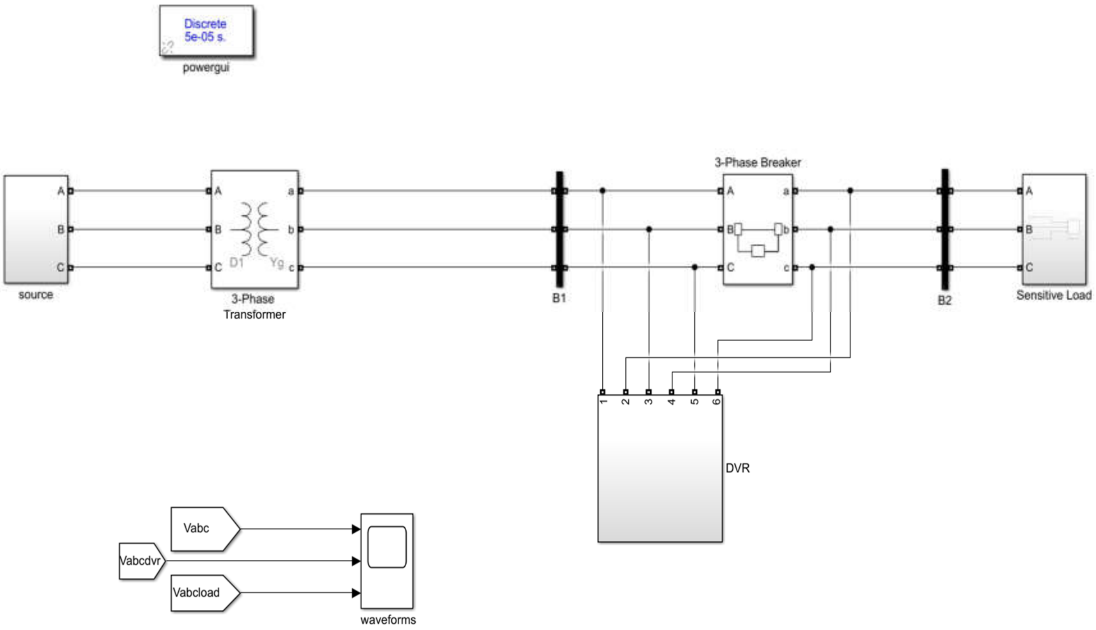

FIGURE 5: MATLAB/SIMULINK Circuit diagram of a system

A) EXISTING RESULTS

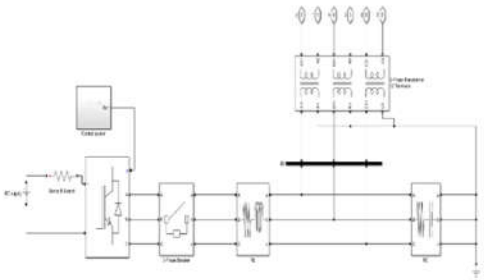

FIGURE 6: DVR System with VSI

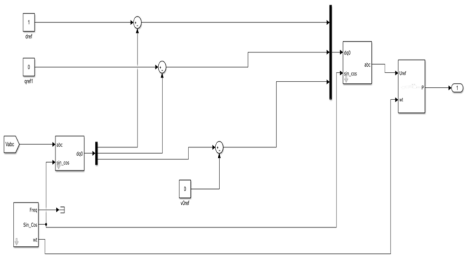

Fig .7 Control system

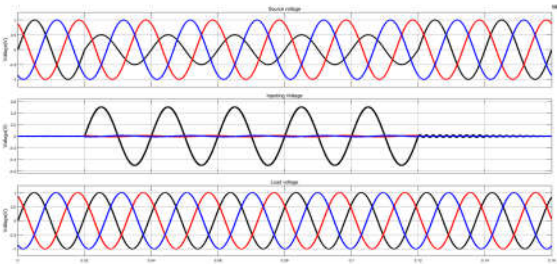

FIGURE 8. Single phase voltage sag mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In above fig-8 A voltage sag occurs when this value drops below 1.0 p.u. (per unit), typically between 0.1 to 0.9 p.u. The VSI-DVR injects a compensating voltage (in p.u.) in series with the source to restore the load voltage. With effective DVR operation, the load voltage is maintained close to 1.0 p.u..

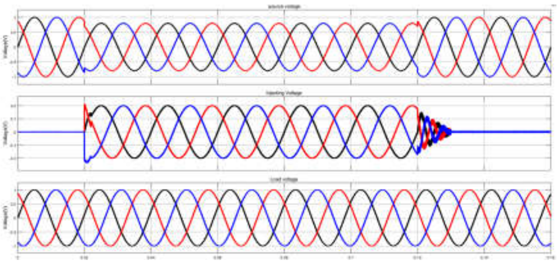

FIGURE 9. Balanced voltage sag mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In the above fig-9 A balanced sag occurs in all phases drop equally below 1.0 p.u. The VSI-DVR injects equal compensating voltages in all phases. And Restored to around 1.0 p.u. across all phases.

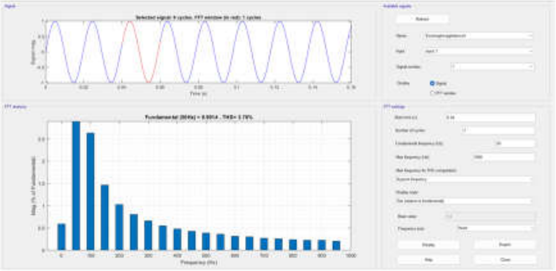

Fig 10. THD% load voltage under Balanced sag

In fig-10 The Total Harmonic Distortion (THD%) of load voltage under balanced sag indicates the level of distortion in the voltage waveform due to the sag and compensation process. During a balanced voltage sag, if the DVR compensates effectively with clean sinusoidal voltage, the THD% remains low.

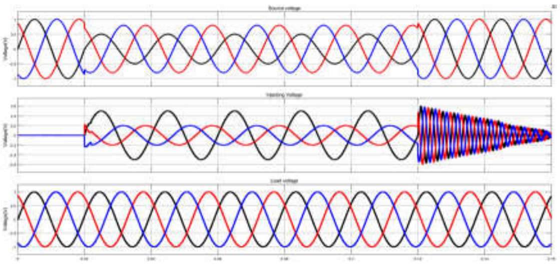

FIGURE 11. Unbalanced voltage sag mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-11 A unbalanced voltage sag mitigation, the source voltage in per unit (p.u.) drops unevenly across the phases, causing imbalance in the supply. The VSI-DVR detects the sag and injects phase-specific compensating voltages in p.u. to correct each affected phase individually. This targeted compensation helps restore the load voltage in each phase close to 1.0 p.u.

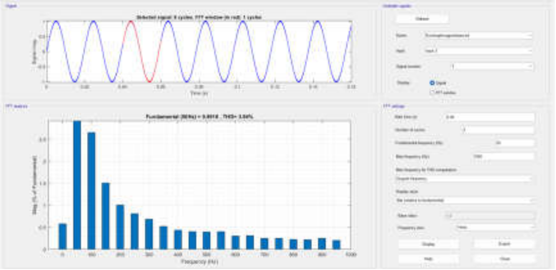

Fig 12. THD% load voltage under Unbalanced voltage sag.

In fig-12 Under unbalanced voltage sag, THD% in load voltage may increase due to uneven phase compensation. Poor compensation can introduce more harmonics. Low THD% ensures better power quality.

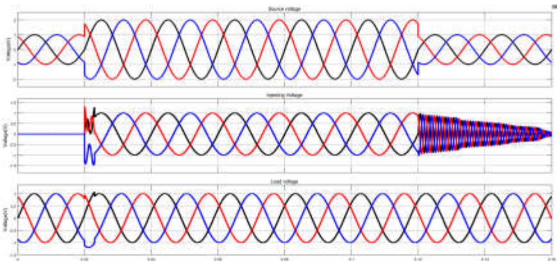

FIGURE .13 Balanced voltage swell mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-13 The balanced voltage swell mitigation, the source voltage in per unit (p.u.) rises equally in all phases above 1.0 p.u. A VSI-DVR manages this by generating a compensating voltage in p.u. with opposite polarity to reduce the excess voltage. The injected voltage cancels out the swell, maintaining the load voltage close to 1.0 p.u. across all phases.

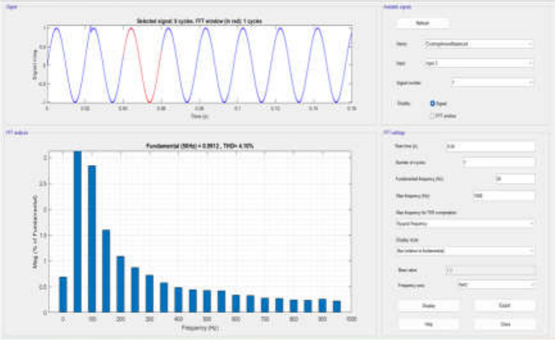

Fig.14 THD% load voltage under Balanced voltage swell.

In fig-14 The THD% of load voltage under balanced voltage swell indicates the level of harmonic distortion during overvoltage conditions. If the DVR compensates effectively with clean sinusoidal voltage, the THD% remains low.

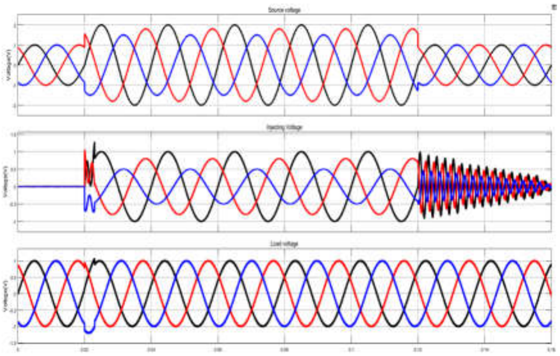

FIGURE.15 Unbalanced voltage swell mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-15 In unbalanced voltage swell mitigation, the source voltage in per unit (p.u.) rises unevenly across the phases, causing voltage imbalance. The VSI-DVR detects this and injects phase-specific compensating voltages with opposite polarity to reduce the overvoltage in each affected phase. The compensating voltage in p.u. is adjusted individually for each phase to restore balance.

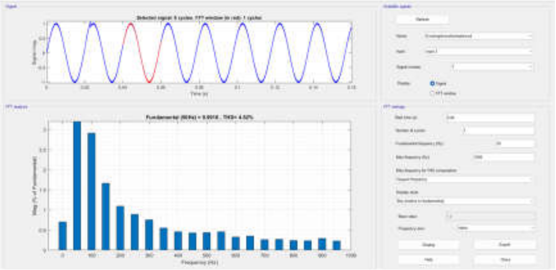

Fig.16 THD% load voltage under Unbalanced voltage swell.

In fig-16 The THD% of load voltage under unbalanced voltage swell reflects the harmonic distortion caused by unequal overvoltages in different phases.

B) EXTENSION RESULTS

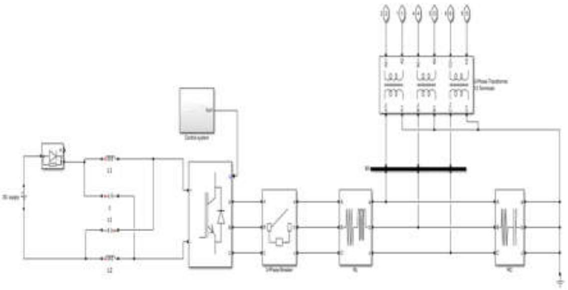

Fig.17 DVR System with ZSI

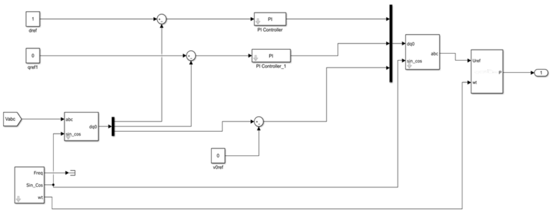

Fig.18 Control system

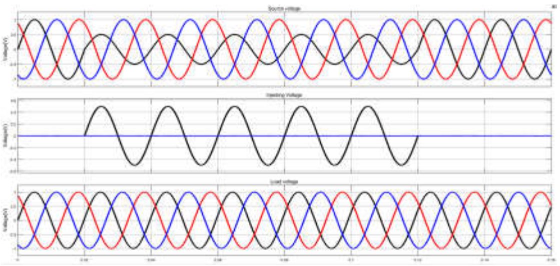

FIGURE .19 Single phase voltage sag mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-19 The single-phase voltage sag mitigation, the source voltage in per unit (p.u.) drops below 1.0 in one phase due to a disturbance. A ZSI-DVR detects this sag and injects a compensating voltage in p.u. in series with the affected phase. The ZSI - DVR gives near to pure sinewave compared to VSI-DVR.

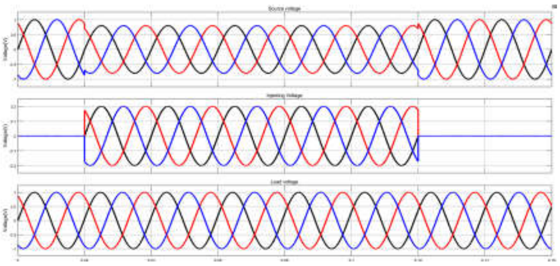

FIGURE .20 Balanced voltage sag mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-20 The balanced voltage sag mitigation, the source voltage in per unit (p.u.) drops equally across all three phases, typically falling below 1.0 p.u. A ZSI-DVR detects the sag and injects equal compensating voltages in each phase to restore the voltage which gets near to sinewave.

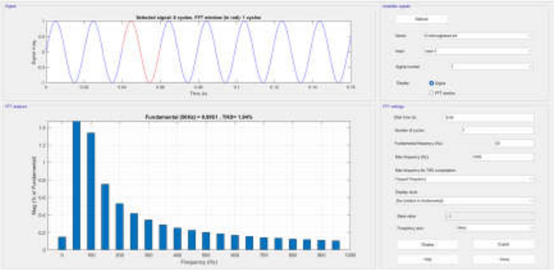

Fig .21 THD% load voltage under Balanced sag

In fig-21 The Total Harmonic Distortion (THD%) of load voltage under balanced sag refers to the distortion level in the voltage waveform when all three-phase voltages drop equally in magnitude.

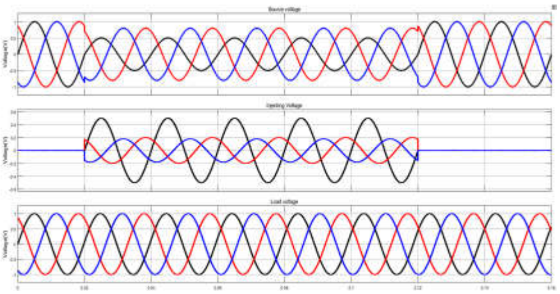

FIGURE .22 Unbalanced voltage sag mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-22 The Unbalanced voltage sag mitigation involves the source voltage in per unit may drop unevenly across phases. A ZSI-DVR compensates by injecting the missing voltage in each affected phase. The compensating voltage generated by the DVR in per unit helps correct the imbalance near to sinusoidal voltage.

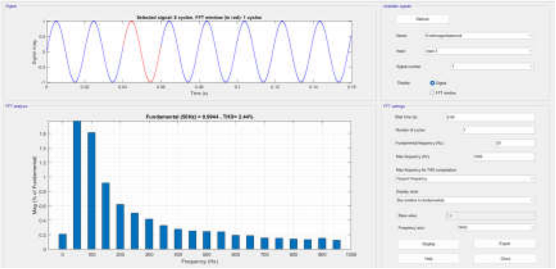

Fig .23 THD% load voltage under Unbalanced voltage sag

In fig-23 During an unbalanced voltage sag, the THD% of the load voltage can increase due to asymmetrical voltage drops across the phases. This imbalance can cause waveform distortion, especially when supplying sensitive or nonlinear loads.

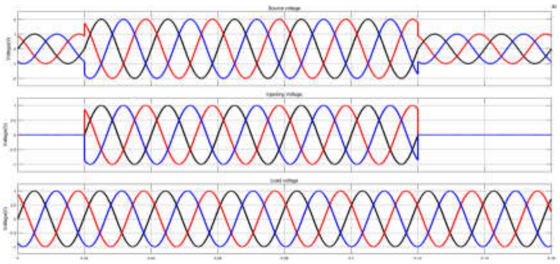

FIGURE .24 Balanced voltage swell mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-24 A Balanced voltage swell mitigation is aimed at reducing the excessive voltage equally present in all three phases. During such a condition, the source voltage in per unit rises uniformly above the nominal value. A ZSI-DVR generates a compensating voltage in per unit to counteract the swell by injecting an opposite polarity voltage.

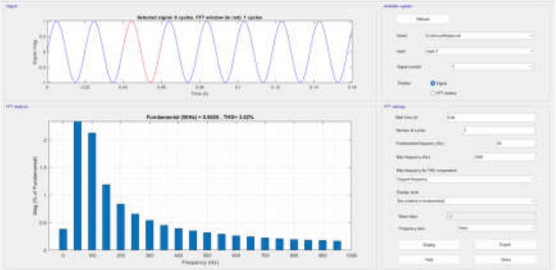

Fig 25 THD% load voltage under Balanced voltage swell

In fig-25 During a balanced voltage swell, the THD% of the load voltage generally remains unaffected if the swell is purely a uniform increase in voltage magnitude without waveform distortion.

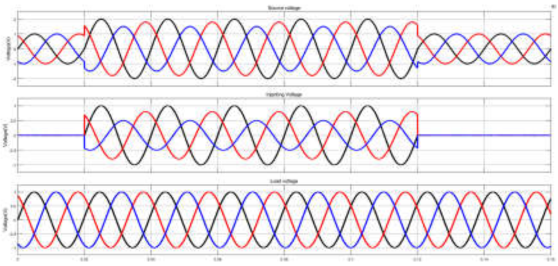

FIGURE .26 Unbalanced voltage swell mitigation (a)Source Voltage in Per Unit (b) Compensating voltage generated by a DVR in Per Unit (c) Load voltage in Per Unit.

In fig-26 Unbalanced voltage swell mitigation focuses on correcting excessive and unequal voltage rises in the three phases. A ZSI-DVR generates a compensating voltage in per unit with opposite polarity to reduce the overvoltage in each affected phase nearly to sinusoidal compared to VSI-DVR.

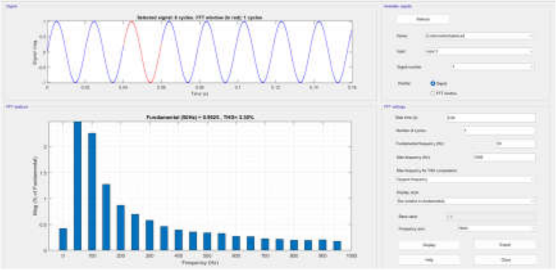

Fig .27 THD% load voltage under Unbalanced voltage swell

In fig-27 During an unbalanced voltage swell, the THD% of the load voltage can increase due to unequal voltage rises across the phases. This imbalance can distort the voltage waveform and introduce harmonic components.

COMPARISION TABLE

	EXISTING SYSTEM (VSI-DVR)	EXTENSION SYSTEM (ZSI-DVR)
Load voltage (THD%) under Balanced sag	3.70%	1.94%
Load voltage (THD%) under Unbalanced sag	3.94%	2.44%
Load voltage (THD%) under Balanced swell	4.10%	3.02%
Load voltage (THD%) under Unbalanced swell	4.52%	3.30%

CONCLUSION

A dynamic voltage restorer (DVR) has been an effective and practical tool for improving power quality, and it has been recommended as a most notable technology for this purpose. By modelling a control circuit and power system with a sensitive load, a simulation of a ZSI-DVR with a power circuit is conducted using a MATLAB/Simulink platform. Under sag, swell, and fault situations, a DVR is tested with a test system. Compared to a traditional VSI-DVR, a suggested ZSI-DVR with PI based control method successfully corrected a distorted load voltage and kept a voltage profile stable and smooth with little harmonic content. If area is an issue with a voltage supply, a DVR may fix it by injecting an appropriate voltage component, which keeps a load voltage normal and stable within an ideal range. Prospects for a future of this study for an implementation of control strategies based on optimization techniques similar to soft computing for a purpose of improving power quality are encouraging.

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