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POWER ELECTRONICS TECHNOLOGY FOR POWER QUALITY IMPROVEMENT IN MODREN POWER SYSTEMS

[#1]**MR.RAMBABU THOMMANDRU,** *Assistant Professor, Department of EEE,*
[#2]**MR.V.SATYAVARDHAN RAO,** *Assistant Professor, Department of EEE,*
[#3]**MR.DARIPALLI NAGA,** *Assistant Professor, Department of EEE,*
Sai Spurthi Institute Of Technology(Autonomous), Sathupally, Khammam, Telangana

ABSTRACT: Recent breakthroughs in power semiconductor devices have fueled recent advances in power electronics. These innovations have had a direct impact on the advancement of power electronics converter technology and its diverse uses. Power electronics includes a wide range of effects on electrical power system networks, including usage, generating levels, distribution, and transmission of alternating current (AC), as well as HVDC transmission systems (e.g. static automated voltage regulation). The goal of this research is to assess the performance of the Dynamic Voltage Restorer (DVR), a power electronics-based Custom Power Controller, within the distribution network. The goal is to increase electricity quality and availability to end users. For simulation and analysis, the inquiry makes use of MATLAB/SIMULINK. The results of simulation tests are also shown, demonstrating how different parameter settings affect the model. These findings show that the Distributed Voltage Regulator (DVR) is helpful in improving the quality of power distribution.

Keywords: *Dynamic voltage restorer, automatic voltage regulator, flexible alternating current transmission system, high voltage direct current transmission, voltage source converter, static synchronous compensator, unified power flow controller, and voltage source inverter are all abbreviations for similar devices.*

1. INTRODUCTION

Power distribution companies have added power electronics controllers to deregulated power networks to assure consistent supply. Consumers define electrical power quality as a sinusoidal waveform without constant harmonics, balanced phases, a constant voltage magnitude without fluctuations or abrupt variations, a constant frequency, a constant power factor, uninterrupted service, and fault tolerance. Transformers, generators, transmission lines, charges, safety devices, and control equipment make up an electrical power system. When all components operate together, power may be generated in locations that minimize negative effects and meet demand. Shipments arrive at the cargo hub at reasonable prices.

Experts are inventing electronic power controllers to ensure generator reliability in a growing market. Recent FACTS versions and power research controllers use more voltage source converters (VSCs). High-voltage transmission systems include UPFC, HVDC light, and STATCOM. Since it is the core of the distribution voltage regulator (DVR), active filters, and distribution STATCOM, the VSC is vital for many low voltage distribution applications. Over the past

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decade, the number of software programs that can cause problems owing to capacity has increased dramatically. Some large industrial users are quite sensitive to even little electrical quality changes. Any disruption, big or small, can hurt finances. Deregulation and free access electrical markets are contributing to the distribution sector's current instability.

The distribution systems industry has advanced with power electronics controllers. This delivers high-quality electricity to specific users most efficiently. The company is considering customized power solutions to increase power quality and prevent outages. Custom power is a commonly used standard technology like FACTS but runs at lower voltage. FACTS and customized power initiations share technology but have different economic purposes.

Specialized power controllers are made for delicate loads and independent generators. Where an organization's electrical distribution system connects, they are installed. FACTS system controllers are designed for transmission implementation.

Customized electricity aims to improve power transfer reliability and quality. Enhanced voltage balance, harmonic cancellation, and voltage management are benefits of this technology.

D-STATCOM and DVR are the most popular Custom Power Controllers/equipment. Parallel D-STATCOM devices regulate reactive power, active filtering, and voltage. Dynamic voltage restorers (DVRs) effectively attenuate waveform distortion and disturbances on neighboring sensitive loads. In custom power applications, pulse width modulation (PWM) switching manages the Distribution Static Synchronous Compensator (D-STATCOM) instead of fundamental frequency switching in Flexible AC Transmission Systems (FACTS). Specialized power applications use pulse-width modulation (PWM) because to its low power usage. The current study provides theoretical insights on many power electronics and DVR topics. This MATLAB/SIMULINK study analyzed a traditional DVR model. With different parameter values, the model was more suitable for power distribution.

Power Switching Devices:

Controllability divides power switching devices into three categories.

Diodes are uncontrolled switches. Active or inactive gadgets depend on their electrical circuits.

Semi-controlled switches activate thyristors or SCRs with gate signals. After activation, the operator loses control and the power circuit deactivates it.

Power semiconductor technology has improved during the previous two decades, allowing engineers to perform several control functions. Many applications use bipolar junction transistors (BJTs) and metal oxide semiconductor field effect transistors (MOSFETs). Recent hybrid devices include the gate turn-off thyristor (GTO) and insulated gate bipolar transistor (IGBT).

Power Mosfet:

A silicon controlled rectifier (SCR) or thyristor is a four-layer, three-electrode power semiconductor. The A, K, and G electrodes indicate the anode, cathode, and gate electrodes. Three connections are conceivable using the device's four-layer construction. The device's functioning

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properties can be modeled with two transistors. When a thyristor gate receives no IG pulse, positive anode current resistance approaches infinite. The thyristor then conducts, lowering its resistance. This state will last until the anode current approaches zero. When the gate pulse IG is absent, the thyristor returns to its initial state of current flowing from anode to cathode against high resistance. Anode current does not approach zero when a thyristor is triggered, regardless of gate pulse current (IG). Thyristors differ from other completely controlled semiconductors in this way.

Insulated-Gate Bipolar Transistor (Igbt):

MOSFETs function well at high speeds and low switching losses. This method works better for low-power applications. Many electrical devices use switch-mode power supply (SMPS) and low-voltage, variable-speed motor drives. MHz frequency ranges are suitable for low-power converters. The fastest switching power semiconductor is activated and deactivated by a gate-controlled electric field. Bipolar junction transistors (BJTs) require current discharge to activate. This component responds much slower than MOSFETs. Despite power handling limitations, MOSFETs are frequently used in consumer products, making their composition and working principles important. The device is controlled by a voltage signal above the gate (G)-source (S) threshold.

Gate Turn-Off Thyristor (Gto):

Thyristors are high-power semiconductor devices such as the gate turn-off thyristor (GTO). Unlike traditional thyristors, Gate Turn-Off thyristors (GTOs) are completely programmable switches. A third terminal controls the gate's opening and shutting. A silicon-controlled rectifier, or SCR, is a switch that can be turned on and off selectively. This is not possible with a standard thyristor. A gate signal with either positive or negative polarity can be used to activate and deactivate the GTO. A positive current discharge to the gate and cathode terminals activates the gadget. A potential difference will arise between these two components as a result of the creation of a PN junction between the gate and cathode. However, it is thought that the GTO (Gate Turn-Off) device's turn-on behavior is less dependable than that of an SCR (Silicon-Controlled Rectifier), thus a moderate positive gate current must be maintained even after turn-on to improve the GTO device's reliability. When a negative voltage is discharged between the gate and cathode terminals, the gadget is disabled. Forward current is lowered when the Gate Turn-Off Thyristor (GTO) enters the blocking state. This is performed by rerouting 30% to 20% of the forward current to generate a cathode-gate voltage. Because of the GTO thyristor's extended turn-off period, there is a noticeable delay after the forward current decreases. The lag, also known as tail time, allows the device's leftover current to run until complete discharge is achieved. As a result, the maximum switching frequency is around 1 kilohertz. A Silicon Controlled Rectifier (SCR) has ten times the off duration of a Gate Turn-Off Thyristor (GTO). GTO has a substantially higher switching frequency than SCR.

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2. ADVANCEMENTINPOWERS WITCHINGDEVICES

Several materials, including silicon carbide (SiC), semiconducting diamond, gallium arsenide, and others, can be used to increase the performance of semiconductors. The initial assembly of components has the most potential. Novel power semiconductor materials have numerous favorable qualities, such as a large band gap, improved carrier mobility, and excellent electrical and thermal conductivity. This innovative type of power transmission technologies benefits from a number of these qualities. The benefits of this product include higher power handling capacity, great high-frequency performance, reduced voltage loss during conduction, and the ability to function at elevated junction temperatures. These devices have an effective temperature range of up to 600 degrees Celsius. This technology has the ability to generate semiconductors that are comparable to those detailed in the preceding section. Matrix converters are an amazing advancement since they eliminate the requirement for a DC-link stage in the AC-to-AC conversion process. The converter necessitates the development of components capable of regulating bidirectional current flow. Several promising discoveries are being produced by current research activities. However, the chances of a commercial product becoming accessible within the next decade or so are slim. Significant breakthroughs in semiconductor devices have occurred during the last two decades, and this trend is expected to continue. This discovery has promising implications for the future of power electrical systems. Even in the presence of extremely high currents, voltages, and rates of change, completely controlled semiconductors will be able to operate without the use of snubbers in the future. This class of semiconductors is positioned to explore new and expanding applications in domains such as high voltage industrial motor circuits, power transmission, and distribution. The thyristor remains the single component in certain designs due to its unique features. However, due to continual developments in GTO and IGBT technology, as well as the introduction of new gadgets, it is probable that the aforementioned technology will become outdated.

3. POWER ELECTRONIC CONVERTER

Two types of solid-state DC-AC power electronic converters accept input voltage or current.

AC-producing capacitors are the input of a voltage source converter (VSC) or voltage-source inverter (VSI). The voltage source supports positive and negative currents. Reversing current can make electricity appear to be transmitted in both DC and AC directions.

Modern current-source inverters (CSI) or source converters (CSC) connect a current source (typically an inductor and a voltage source) directly to the DC bus for input. Positive and negative voltages can be applied to the DC bus. AC and DC current can be transferred bidirectionally between terminals due to the voltage polarity change.

Traditional applications limit phase-controlled thyristor converters to current sources. Both types of semiconductor

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converters are available. Voltage-based converters are utilized for reactive power adjustment in completely controlled power semiconductor applications. Traditional high-power HVDC systems use outdated thyristor-controlled converters.

Applications Of Voltage Source Converter:

Power electronics like the voltage-source converter may generate sinusoidal voltages with configurable amplitude, frequency, and phase. Variable-speed devices use voltage source converters to reduce voltage fluctuations. When desired and actual voltage levels diverge, the Voltage Source Converter (VSC) supplements the current voltage or provides insufficient voltage. A DC voltage source like an energy storage device powers the converter. Adjusting the converter's solid-state circuitry yields the desired output voltage. The VSC is mostly used for voltage fluctuation correction, harmonic distortion reduction, and flashing mitigation.

Vsc In Series Voltage Controller (Dvr):

The series voltage controller and protected load are connected. Connections usually employ a coupling transformer. However, power electronics establish a strong relationship. The load bus bar voltage is the grid voltage plus the Dynamic Voltage Restorer voltage. Energy storage handles active power, whereas the converter handles reactive power. Compensation criteria may affect energy storage technology selection. DVRs can't always resolve voltage drops due to their number and duration.

Vsc In Shunt Voltage Controller (D-Statcom):

A D-STATCOM has a two-level VSC, coupling transformer, and dc energy storage device. Parallel links connect these parts. A Voltage Source Converter (VSC) converts storage device voltage to three-phase alternating current. The coupling transformer's reactance syncs the voltages to the alternating current system. The D-STATCOM's output voltage phase and amplitude control active and reactive power exchange between the device and the AC system. This device can generate or absorb active and reactive power reversibly under certain conditions.

4. INTRODUCTIONTODYNAMICVOLTAGERESTORERSYSTEM

Specialized power controllers like the DVR system safeguard sensitive and crucial loads from voltage changes and give amazing dynamic performance. Figure 1 shows the injection transformer, VSC, and energy storage device as DVR system components.

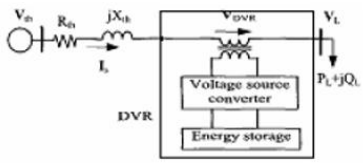

Figure1 The schematic below shows DVR components and connections.

The energy company's main distribution feeder connects to the DVR. This controller can handle voltage variations, asymmetry, harmonic distortion, power factor adjustment, and power interruptions. The DVR generates three-phase AC voltages that match the AC system's distribution feeder voltages. The AC system and DVR regulate the injected voltages' amplitude and phase angle to control active and reactive power transfer.

Energy exchanges are limited by positive and negative energy ingestion and output limitations.

Main Components Of Dvr:

DVR systems have four main components: the filter unit, voltage source converter circuit, battery cell, and series injection transformer. Later sections will elaborate on these themes.

Energy Storage System:

Depending on architecture, the Dynamic Voltage Restorer (DVR) can regulate load voltage during a decline by using grid power or an auxiliary supply with energy storage. When the DVR detects a bad electrical grid signal, the reserve supply strategy improves system performance. The current DC connection voltage may vary or remain constant. In the second configuration, the stable power grid powers the DVR from supply or demand side residual voltage. DC link voltage dependability in load-side linked architecture is ensured by constant load voltage delivery. Converter architecture with a load side connection will be employed in this study.

Vsc Circuit:

A voltage source converter circuit lets the dynamic voltage restorer (DVR) accept output voltages of varied magnitudes. Inverters use power-saving semiconductors. The VSC receives a low-impedance, continuous DC voltage. Discharge current does not impact output voltage. Capacitors have negligible effect on VSC output voltage. Capacitors make current limitation harder. Three-phase pulse width modulation (PWM)-based VSC inverters are employed in this work. Modifying the inverter's output voltage waveform regulates voltage.

Filter System:

Filtering reduces harmonics in a Voltage Source Converter (VSC) output voltage. Inverters use two main filtering algorithms: inverter-side and line-side. The low voltage inverter side filter is near the harmonic source. This device mainly prevents harmonic currents from entering series injection transformers. This can cause an inverter's primary output component to phase shift and drop voltage. Because the line and high voltage sides are close, a higher-rated transformer is needed. This filter has no effect on phase shift or voltage loss. Filter capacitors boost inverter ratings in both filtration methods. Higher-rated inverters have higher filter capacitor capacitance, which decreases harmonics. This study uses inverter-side filtering.

Series Injection Transformers:

Three independent single-phase injection transformers improve system voltage. To maximize efficiency and reliability, series injection transformer electrical qualities must be carefully chosen. The MVA rating, turn ratio, primary winding voltage and current ratings, and short-circuit impedance must be obtained to properly integrate the injection transformer into the DVR.

Operatingmodesofdvr:

DVRs operate in injection, inactive, and protection modes.

Protectionmode:

The DVR's protections prevent damage from strong inrush currents and load-side short circuits. Bypass valves remove the DVR from the system by rerouting electricity.

Standbymode:

In standby mode, the DVR can detect short

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circuits or apply a small amount of electricity to compensate for transformer losses and reactance. This is typical in steady-state. In steady-state settings, DVRs should be short-circuited because tiny voltage drops do not affect load needs if the distribution circuit is resilient.

Injectionmode:

DVRs enter injection mode when electrical potential drops. To compensate, three single-phase alternating current voltages with the right waveform, phase, and magnitude are injected in series.

5. SIMULATIONRESULTSAND DISCUSSIONS

Figure 2 shows a DVR Matlab/Simulink model that evaluates parameter combinations. Integrating a direct current (dc) voltage source, a three-phase voltage source inverter (VSI), and control circuits from the model's VSI subsystem created the energy storage system. Three oscilloscopes investigate voltage waveforms in three scenarios. First, then, final. Scope 1 monitors voltage distribution at the sensitive load, Scope 2 monitors voltage injection patterns on the secondary sides of series injection transformers, and Scope 3 investigates voltage injection patterns during fault conditions. Modeling the GTO and IGBT switches may enable a DVR system VSI model.

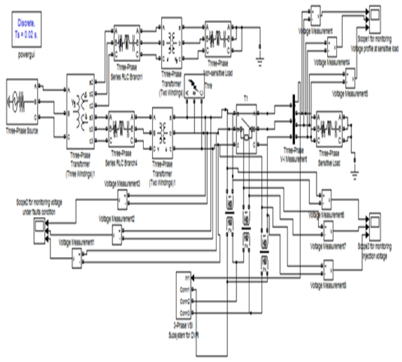

Figure2:DVR Simulink model

6. RESULTS OF SIMULATION RUNS WITH IGBT SWITCHES:

Line-to-ground fault output voltage waveforms are shown in Figure 3(a).

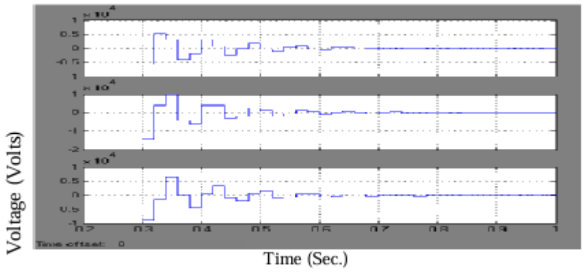

Figure3: A shows voltage fault waveforms.

Figure shows the DVR system introducing right 3-phase voltages to correct for load voltage loss.

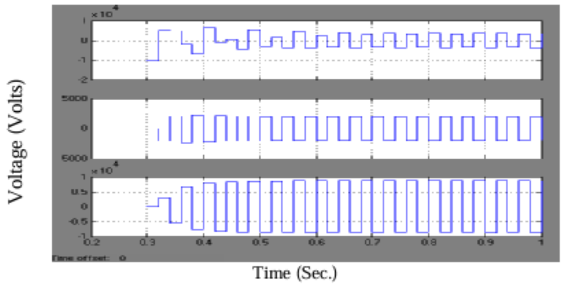

Figure3(b): Voltage waveform injection

Due to DVR system voltage injection, Figure shows compensated output voltage waveforms across the load.

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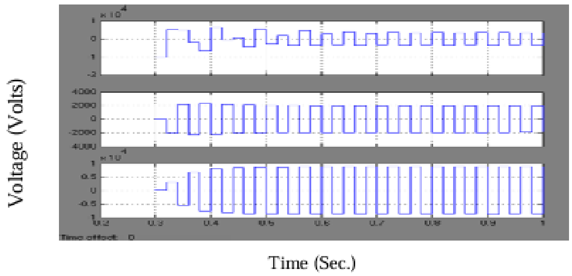
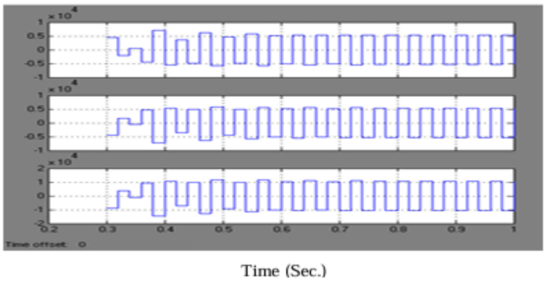


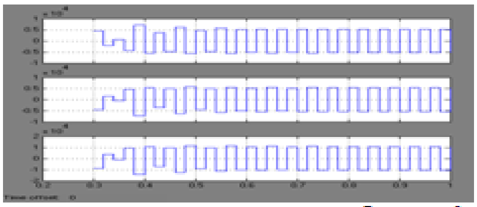
Figure3(c:)Output voltage compensation waveforms

(i) When GTO switches simulated a single VSC circuit line-to-ground failure, the model's sag/fault voltage waveforms matched Figure 3(a). The DVR affects voltage waveforms in Figure 4(b).



Voltage-injected waveforms

Figure 5(b) shows corrected output voltage waveforms for all three phases.


Output voltage compensation waveforms

7. CONCLUSION

The main objective of this research was to study power electronics-based power system controllers, particularly custom ones. DVR design is one example. The calculated output waveforms of the DVR model with IGBT and GTO switching devices in the VSI circuit are very comparable. Research demonstrates that energy users with sensitive loads are most upset when distribution voltage drops due to a failure. However, a well-designed DVR system may solve this issue.

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