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ENHANCING ELECTRICAL POWER QUALITY WITH ADVANCED POWER ELECTRONICS

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ABSTRACT: Over the past few years, advancements in power electronics have mostly been driven by improvements in power semiconductor devices. The development has significantly impacted converter technology and its potential applications. Electrical power system networks have undergone numerous changes as a result of power electronics technology. These include the movement, distribution, and usage of AC power, as well as producing levels and HVDC transmission systems (such static AVRs). This paper tests the functionality of a DVR, a private power processor, using MATLAB/SIMULINK. The basis of the DVR is power electronics. Its purpose is to enhance end consumers' power quality and quantity in distribution networks. Moreover, the claim that DVR successfully enhances the quality of power flow on the distribution side is supported by simulation results displayed for a range of model parameter values.

KEY WORDS: Active Harmonic Filters, Multilevel Converters, Power Factor Correction, Voltage Regulation, Grid Synchronization

1. INTRODUCTION

In deregulated power systems, power distribution companies place a high priority on deploying power electronics technology to guarantee energy supply to its clients. The term "electrical power quality" typically describes characteristics such as a constant power factor, balanced phases, a sinusoidal waveform free of constant harmonics, continuous operation, a steady voltage level devoid of abrupt variations, and the capacity to manage and bounce back from issues. In any electrical grid, the transformers, generators, control devices, and input devices are the most crucial components. Proper assembly of these components allows for the production of power in areas where it will cause the least amount of damage and in sufficient quantities to meet demand. At a cost that benefits the company, it is delivered to the shipping hub.

Computer power controllers are being developed by experts to ensure that generators operate efficiently in the new market. Power electronics controllers, advanced power studies, and current FACTS versions all heavily rely on the voltage source converter (VSC). HVDC light, STATCOM, and UPFC are three brand-new high-voltage technologies that will be available soon. At the low voltage distribution level, the active filters, the VSC, and the D-STATCOM (distribution STATCOM) all cooperate and depend on one another. It is now far more likely than it was five years ago that a defective power supply will harm a larger variety of applications. Certain consumers, such as large corporations, are extremely vulnerable to variations in the quality of their energy; even brief blackouts can seriously impair their financial situation. The massive changes that are currently taking place in the distribution industry are the result of numerous factors, including continuous efforts to relax regulations and grant unfettered access to the market.

The utilization of distribution systems that power electronics-based controllers is a significant technological advancement. Each person can obtain high-quality energy rapidly with such a system. The team is considering building specialized power systems to reduce power outages and enhance power quality. One device that can be used for anything is Custom Power. It functions similarly to FACTS', but with less power consumption. While FACTS and customized power initiations have a technological foundation, their scientific and commercial objectives differ.

For those who need to control electricity at the point of distribution and own generators, individualized power controllers are designed. FACTS system processors, on the other hand, are designed for usage at the communication level.

Ensuring dependable and high-quality power transmission is the primary objective of bespoke power. Actually, there are many advantages to this technology, including improved voltage balancing, harmonic suppression, and control.

D-STATCOM and DVR are the two most well-known bespoke power controllers and tools. Reactive power management, voltage control, and active filtering are all possible when two D-STATCOM devices are connected in parallel. Signal distortion and other disturbances can be substantially reduced on one or more nearby sensitive loads by using an electrical device called a Dynamic Voltage Restorer (DVR). In bespoke power usage, PWM switching is utilized to adjust the D-STATCOM instead of the conventional frequency switching methods used in FACTS. PWM utilizes relatively little power, which makes it popular in certain power applications. Power electronics and DVRs required a great deal of theoretical research for this project. The conventional DVR model was studied using MATLAB and SIMULINK. It is evident from simulation experiments with various parameter values that the model is ideal for application in a power distribution system.

2. REVIEW OF LITERATURE

Hirofumi Akagi (2005) "Active Harmonic Filters: Hirofumi Akagi wrote this book, "Active Harmonic Filters: Recent Advances and Industrial Applications," in 2005. Akagi (2005) conducts a comprehensive analysis of active harmonic filters with an emphasis on their manufacturing, regulation, and industrial applications. This article emphasizes the value of active filters in reducing harmonic distortion and improving power quality.

Mittal, Bhim Singh, and Alka Adya (2009) published a paper titled "Improved Power Quality AC-DC Converters for Diverse Applications." This 2009 article discusses how advancements in AC-DC converter technology have improved power quality. It investigates the effects of various architectures and control strategies on power quality.

Frede Blaabjerg, Zhe Chen, and S. B. Kjaer's research "Power Electronics as Efficient Interface in Dispersed Power Generation Systems" was released in 2004. In his research, Blaabjerg examines the function of power electronics in distributed power production systems, paying particular attention to control and grid synchronization concerns. The paper examines how power electronics enhance the power quality for renewable energy-using devices.

José Matas, Juan C. Vasquez, Josep M. Guerrero, Miguel, and others were among the authors of the publication "Hierarchical Control of Droop-Controlled AC and DC Microgrids—A General Approach Toward Standardization". Guerrero wrote a piece regarding the technology and management of microgrids in 2011. The paper's primary focus is on the impact of hierarchical control techniques on power quality.

The book "Power Quality in Power Systems and Electrical Machines," authored by Ewald F. Fuchs and Muhammad A. S. Masoum, was released in 2008. This 2008 paper investigates power quality issues that impact electrical devices and power systems. It demonstrates the significance of power circuits in solving these issues.

The book, written in 2010 by Sanjeet Dwivedi and Jean-Marie Kauffmann, discussed doubly fed induction generators and how to increase power output by utilizing more complex controls. In 2010, Dwivedi conducted research on the effects of various control strategies on doubly fed induction generators (DFIGs), which generate electricity using wind energy.

In 2014, they published a paper titled "High Performance Control of AC Drives Using MATLAB/Simulink Models."

Abu-Rub (2014) published a paper discussing the applications of power electronics in renewable energy, business, and transportation. The primary focus of the paper is energy quality improvement.

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Authors Ahmed S. Abu-Siada and Vassilios G. Agelidis wrote "Recent Developments in Multilevel Converters for Industrial Applications" in 2013. The 2013 paper by Agelidis investigates the impact of multilayer converter replacement on factory power quality. It focuses on various control techniques and topologies.

published in Maharashtra in 2000 and was written by A. Ghosh, K. R. Rajagopal, and Mahesh K. Mishra. "Design and Analysis of Active Power Filters for Power Quality Improvement"

Mishra (2000) focused primarily on the design and testing of active power filters. It evaluates how well various control strategies address power quality issues.

They published a paper titled "Power Quality and Electromagnetic Compatibility in Smart Grid" in 2014.1. Zare (2014) examines the issues of electromagnetic compatibility and power quality in smart grids, emphasizing the potential role of power electronics in resolving these issues.

3. POWER SWITCHING DEVICES

Three categories are distinguished by the amount of degrees latitude that each type of power switching device offers:

The diode is a useful example of an infinite switch. The power circuit can be used to determine if a device is on or off.

In a semi-controlled switch, a gate signal activates the thyristor or silicon-controlled rectifier. Once the device is switched on, it cannot be turned off; the power circuit regulates this.

In the past 20 years, scientists and engineers have created an enormous number of power devices that can manipulate electricity in extremely complex ways. BJTs and MOSFETs are the two most popular kind of transistors. The insulated gate bipolar transistor (IGBT) and the gate turn-off thyristor (GTO) are two novel forms of hybrid electronics.

THYRISTOR:

Fast and low-loss transistors are known as metal-Another name for the Silicon Controlled Rectifier (SCR) is a thyristor. It is a power semiconductor device with three conductors and four layers. The electrodes A, K, and G, which are matched to them, represent the anode, cathode, and gate. The device can monitor three separate links because of its four layers. A two-transistor model, for instance, might make the device's operation easier to comprehend. When an IG pulse is not applied to the gate, positive anode current in a perfect thyristor encounters no resistance. Subsequently, the thyristor transitions into its conducting state, distinguished by an extremely low resistance. Until the current level of the anode reaches zero, the state won't change. The gate pulse (IG) is absent, therefore the thyristor returns to its initial condition. Against an extremely high resistance, current is currently moving from the anode to the cathode. When a thyristor is activated, even though the gate pulse current (IG) is one, the anode current is greater than zero. Thyristors vary from other kinds of fully controlled semiconductors because of this.

POWER MOSFET:

Fast and low-loss transistors are known as metal-oxide semiconductor field-effect transistors, or MOSFETs. It operates best in low-power settings; high-power settings are too strong for it. Numerous electrical items use low voltage adjustable speed motor controllers and switch-mode power supply (SMPS). For low-power computers, processing speeds in the megahertz (MHz) range are not difficult to achieve. This device has the shortest switching power of any semiconductor because a gate controls the electric field that initiates and ends its action. A bipolar junction transistor (BJT) cannot function until an electrical current is discharged. The response time of this device is nearly double that of MOSFETs. Despite the fact that MOSFETs are limited to controlling tiny power levels, it is crucial to comprehend their operation and construction because they are found in a wide variety of contemporary market goods. Between the source (S) and the gate (G), a voltage signal is transmitted that is greater than the cutoff voltage of the device. The controller now has control over this.

INSULATED GATE BIPOLAR TRANSISTOR (IGBT):

Three-terminal power semiconductor devices, or

IGBTs, are well-known for their quick switching speeds and effective performance. This type of switch is commonly seen in many modern household equipment. Switching amplifiers are used in radios, refrigerators, air conditioners, and variable speed motor drives in addition to electric cars. These amplifiers' fast switching nature allows them to use methods like pulse width modulation and low-pass filtering to create complex waveforms. The isolated-gate field-effect transistor (IGFET) serves as the device's control input, while the bipolar power transistor (BPT) acts as the switch. It combines the simple gate-drive capabilities of MOSFETs with the significant current capacity and low saturation voltage of bipolar transistors. IGBTs are used in traction motor control, switched-mode power supplies, and induction heating at medium to high voltages. Large IGBT modules often contain several parallel devices, each with an own set of differentiating features. These include resistance to voltages as high as 6,000 volts and currents in the hundreds of amps.

GATE TURN-OFF THYRISTOR (GTO):

The gate turn-off thyristor is one of the high-power semiconductor devices known as thyristors. GTOs are completely programmable switches, as opposed to traditional thyristors. The gate, which makes up the third terminal, controls how the components are activated and deactivated. Traditional thyristors cannot be selectively toggled on and off; however, fully programmable switches called Silicon-Controlled Rectifiers (SCRs) can. A gate signal with either positive or negative polarity can be used to activate or deactivate the GTO. A pulse of "positive current" is applied to the gate and cathode terminals of the device in order to activate it.

A potential difference happens when the cathode and gate create a PN junction. To improve reliability, a modest positive gate current must be kept flowing even after the GTO turn-on since GTO (thyristor) turn-on is less dependable than SCR (thyristor) turn-on. A "negative voltage" is discharged between the cathode and gate terminals when the gadget is deactivated. In the "blocking" state, the cathode-gate voltage is generated by diverting 30–20% of the forward current and deactivating the GTO.

After the forward current stops, there is a discernible delay time due to the GTO thyristor's lengthy turn-off period. The tail time, sometimes called the lag, ensures that leftover current will flow through the device continuously until the entire charge is released. As a result, the maximum toggling frequency is roughly 1 kilohertz. A Gate Turn-Off Thyristor (GTO) has an off duration of one-hundredth of that of a Silicon Controlled Rectifier (SCR). SCR has significantly lower switching frequencies than GTO.

4. ADVANCEMENT IN POWER SWITCHING DEVICES

Semiconducting diamond, gallium arsenide, and silicon carbide (SiC) are a few materials that can be used to improve semiconductor performance. The first group of gadgets has the greatest promise. These new power semiconductor materials provide a wide range of advantages, including better thermal and electrical conductivity, increased carrier mobility, and an expanding band gap. These previously described characteristics bestow onto this innovative grouping of power transfer networks numerous advantages. This device's benefits include high power management, high frequency performance, minimal voltage loss during conduction, and high junction temperature functioning.

The operating temperature of these devices is 600 degrees Celsius. Using this approach, semiconductors similar to those described in the previous section can be fabricated. Matrix converters are a significant improvement since they eliminate the requirement for a DC-link step when converting AC to AC. For the converter to function, components that can control the direction of current flow must be developed. Happy discoveries are coming in plenty as a consequence of continuous research efforts. However, there is very little chance that a commercial product will be made available in the next twenty years.

Semiconductor devices have come a long way in the last 20 years, and more innovation and improvement are bound to come. This bodes well for the future of electrical and electronic systems. In later developments, completely controlled semiconductors will be able to function without snubbers even when they are subjected to extremely high currents, voltages, and rates of variation. These semiconductors will find new and extended uses in industries such as high-voltage industrial motor circuits and electricity transmission and distribution. Because of its unique qualities, the thyristor will continue to be used as the only component in some designs. However, its importance may decrease when new gadgets are developed and GTO and IGBT technologies progress.

5. POWER ELECTRONIC CONVERTER

Solid-state DC-AC power electronic converters fall into two main categories: those made to accept voltage and those made to accept current.

An apparatus that converts a voltage source—usually a capacitor—into alternating current (AC) is known as a voltage-source converter (VSC) or voltage-source inverter (VSI). Positive and negative currents can both be supported by the voltage source. Electricity can be transmitted using either direct current or alternating current by simply changing the direction of the current.

Current sources, usually in the form of inductors coupled in series with voltage sources, are directly connected to the DC bus and supply input to current source converters (CSCs) or current-source inverters. It is possible to apply both positive and negative voltages across the DC circuit simultaneously. Bidirectional current is possible between the DC and AC terminals by flipping the polarity of the voltage.

Typical uses of phase-controlled thyristor-based converters are limited to current sources. Both types of modern semiconductor-based converters are achievable. Value-source converters are used in applications that need reactive power adjustment when fully regulated power semiconductors are used. Thyristor-controlled converters are still used in high-power direct current (HVDC) systems that follow tradition.

APPLICATIONS OF VOLTAGE SOURCE CONVERTER:

Power electronics components called voltage-source converters can generate sinusoidal voltages with any desired phase, amplitude, and frequency. Voltage source converters are used not only in variable-speed devices but also in the regulation of voltage fluctuations. The VSC is used to correct the situation when there is a difference between the nominal and actual voltages. It does this by either adding the "deficient voltage" or completely replacing the voltage. The converter is usually powered by a direct current (DC) voltage source or an energy storage device. The desired output voltage is then produced by modifying the converter's solid-state circuitry. The VSC is often used to remedy harmonic distortions, blinking, and voltage variations.

VSC IN SERIES VOLTAGE CONTROLLER (DVR):

by connecting the protected load in series with the series voltage controller. Usually, a coupling transformer is used to make the connection. With the use of a power electronics system, a direct connection can be made nevertheless. The voltage provided by the DVR is added to the grid voltage to get the load bus bar voltage. The energy storage module provides the active power, and the converter produces the reactive power. Requirements for compensation may influence which energy storage methods are used. Sometimes the length and size of voltage drops can make it more difficult for the DVR to fix them.

VSC IN SHUNT VOLTAGE CONTROLLER (D-STATCOM):

A two-level Voltage Source Converter (VSC), a coupling transformer, and a direct current (dc) energy storage device coupled in parallel make up a D-STATCOM. The Voltage Source Converter (VSC) is a part that changes the voltage across the storage device into three-phase alternating current. The coupling transformer's reactance keeps the voltages and the alternating current system in sync. By adjusting the amplitude and phase of the D-STATCOM's output voltages, the active and reactive power transfer between the AC system and the device can be controlled. This device in its current design has the ability to both produce and reversibly absorb active and reactive power.

6. DYNAMIC VOLTAGE RESTORER SYSTEM

As an individualized Custom Power controller, the DVR system protects sensitive or critical loads from transient voltage variations and guarantees outstanding dynamic performance. Figure 1 shows the injection transformer, VSC, and energy storage unit of the DVR.

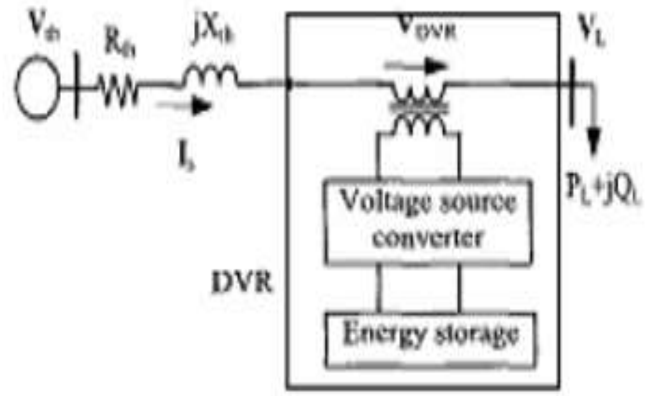

Figure 1: Schematic Diagram of DVR

The primary distribution feeder of the power company is connected to the DVR. This controller can help you with a number of power quality and reliability issues, including power factor optimization, power interruptions, voltage fluctuations, voltage asymmetry, and harmonic distortion. The DVR initiates a series of three-phase alternating current voltages that are timed to match the voltages of the AC system's distribution feeders. By modifying the amplitude and phase angle of the injected voltages, active and reactive power transmission between the DVR and the alternating current system may be controlled. Limitations on the admission and outflow of electricity (which are negative and positive, respectively) limit the size of these exchanges.

MAIN COMPONENTS OF DVR:

The four primary parts of a DVR system are a battery pack, a voltage source converter circuit, a series injection transformer, and a filter device. The section that follows has more information.

ENERGY STORAGE SYSTEM:

Depending on the topology in place, the Dynamic The Dynamic Voltage Restorer (DVR) can pull power from the grid or an auxiliary source with energy storage to regulate the load voltage during a drop, depending on the architecture in use. To enhance performance, an extra supply technique is applied when the DVR receives a poor quality grid signal. In this design, the voltage across the DC link could be either constant or variable. Under the alternate setup, the DVR is connected to the resilient grid and draws power from supply-side or demand-side residual voltage. By continuously supplying a consistent load voltage, a load-side connected design produces a stable DC link voltage. A load-side-attached converter arrangement will be used in the investigation.

VSC CIRCUIT:

The DVR may receive output voltages of various magnitudes by utilizing the voltage source conversion circuit. Semiconductors are used in insulator circuits to limit power. A continuous, low-impedance DC voltage is fed into the VSC. The discharge current has no effect on the output voltage. There is very little difference in the VSC output voltage when a capacitor is included. Attempts to limit current flow are hindered by the capacitor's existence. Three-phase pulse width modulation, or PWM, is the most common type of VSC inverter at the time of this analysis. The inverter changes the output voltage waveform to adjust the voltage.

FILTER SYSTEM:

Filtering is used to remove harmonics from a VSC's output voltage. The two most common filtering algorithms are line-side and inverter-side filtering. The inverter side filter is located on the low voltage side, close to the harmonic source, and it blocks harmonic currents from entering the series injection transformers. Phase and voltage changes in the inverter's primary output component could so occur. Because the line sides are close together and the voltage is high, a higher rated transformer is required. This setup has no bearing on the filter's worries about phase shift and voltage drop. Filter capacitors improve inverter ratings in both filtration stages. By closely relating the filter capacitor's value to the inverter's rated rating, harmonics are less likely to be present. The current paper uses an inverter-side filtering approach.

SERIES INJECTION TRANSFORMERS:

The voltage of the system is raised by using three single-phase injection transformers. Achieving maximum reliability and efficiency requires accurate determination of the electrical parameters controlling the series injection transformer. Transformers need to have the following qualities in order to be used with the DVR: turn ratio, MVA rating, short-circuit impedance values, primary winding voltage and current ratings, and turn ratio.

OPERATING MODES OF DVR:

The DVR operates in three different modes: injection, standby (also known as decline during constant state), and protection.

PROTECTION MODE:

Minimal risk of DVR damage is presented by significant inrush currents and a transient circuit on the load side. Bypass switches create an electrical current path around the DVR to isolate it from the rest of the system.

STANDBY MODE:

When in standby mode, the default steady state setting, the DVR can either short circuit or introduce a small amount of voltage to make up for voltage drops caused by transformer reactance and loss. DVRs are often used in short-circuit mode since low voltage decreases in steady-state settings do not affect load requirements when the distribution circuit is resilient.

INJECTION MODE:

The DVR switches to injection mode when it senses a voltage loss. Three different single-phase alternating current voltages are connected in series to achieve compensation, ensuring that each voltage has the proper waveform, phase, and magnitude.

7. SIMULATION RESULTS AND DISCUSSIONS

Figure 2 shows a Matlab/Simulink model of the DVR that is used to evaluate various model parameter combinations. The VSI subsystem of the model was used to connect a three-phase VSI, a dc voltage source, and the necessary control circuits in order to build the energy storage system. Voltage waveforms under different situations are examined using three instruments. Three, two, and one. While Scope2 looks at the patterns of voltage injection on the secondary surfaces of series injection transformers, Scope1 is used to monitor the voltage distribution at the sensitive load. To sum up, voltage patterns are examined using Scope3 when there are fault conditions present. One way to create a model of the VSI for the DVR system is to simulate IGBT and GTO switches.

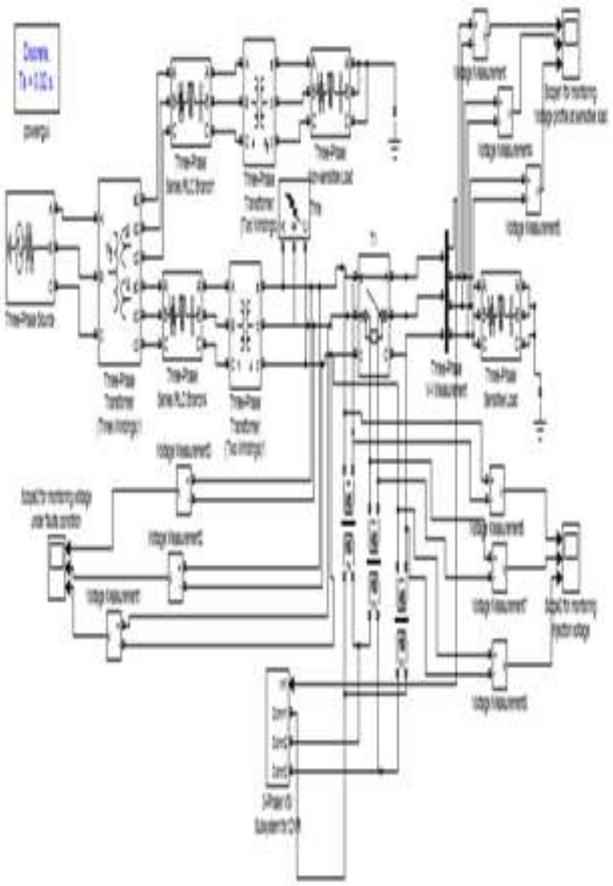

Figure 2: Simulink model of the DVR

RESULTS OF SIMULATION RUNS WITH IGBT SWITCHES:

Figure 3 (a) shows the output voltage waveforms for a line-to-ground fault occurrence.

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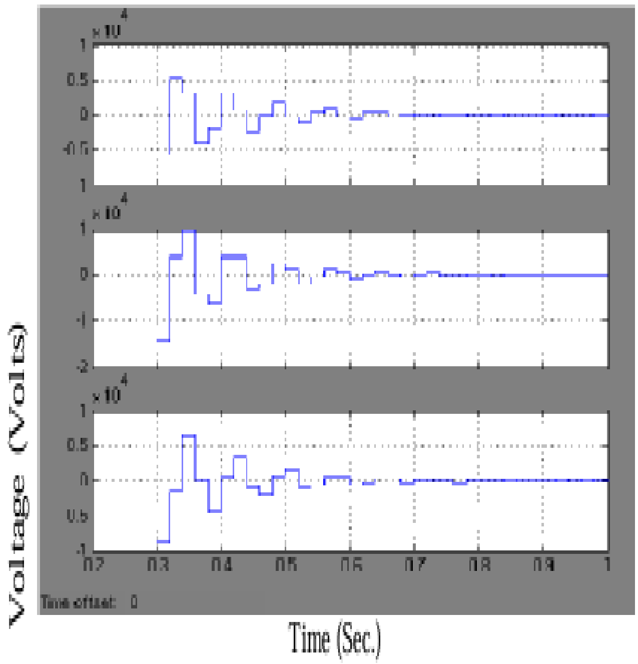


Figure 3: (a) Fault voltage waveforms

As shown in Figure 3(b), the DVR system integrates the proper three-phase voltages to offset the reduction in output voltage.

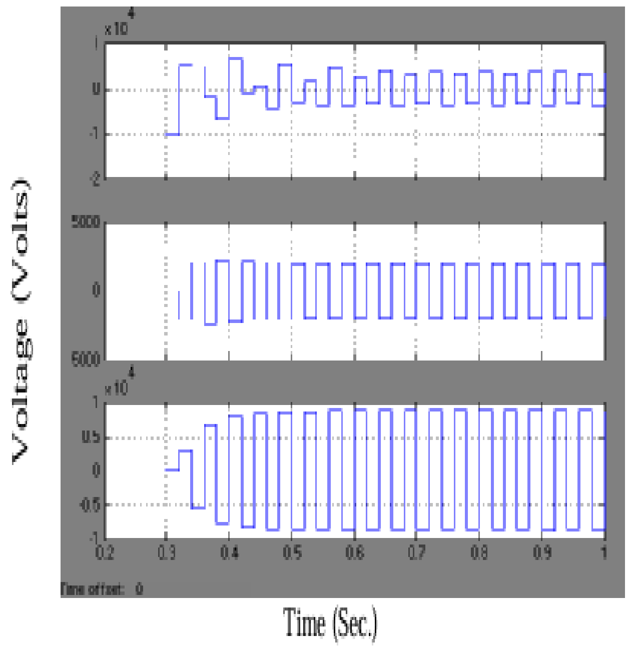
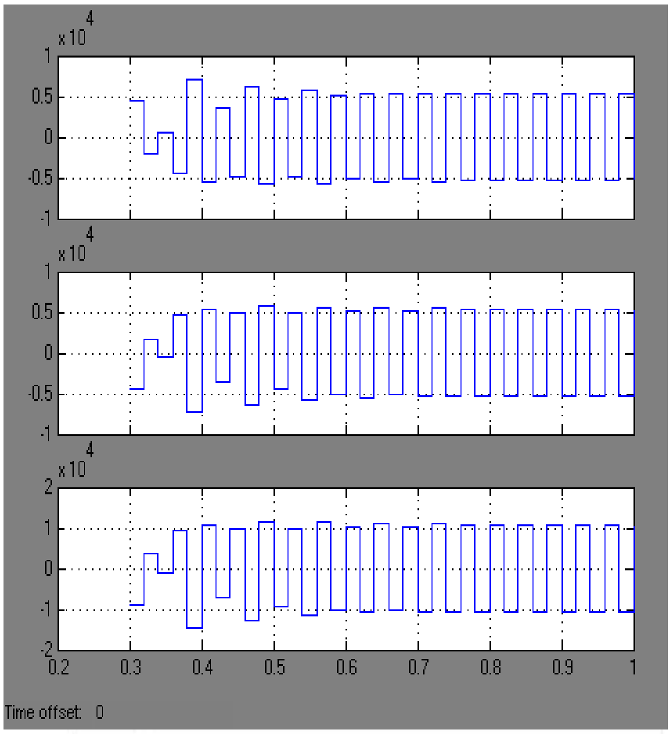


Figure 3: (b) Injected voltage waveforms

As shown in Figure 3(c), voltage injection into the DVR system corrects the output voltage waveforms over the whole load.



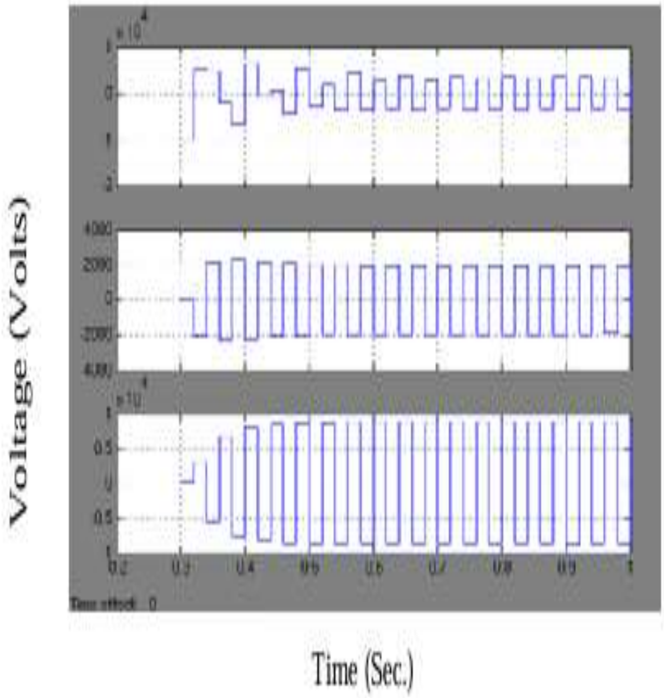


Figure 3: (c) Compensated output voltage waveforms

RESULTS OF SIMULATION RUNS WITH GTO SWITCHES:

(i) Sag/fault voltage waveforms generated by the The model displayed fault voltage waveforms exactly like those shown in Figure 3 (a) when GTO switches were added to the VSC circuit to mimic a single line to ground fault. Voltage waveforms are influenced by the DVR, as Figure

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4b shows.

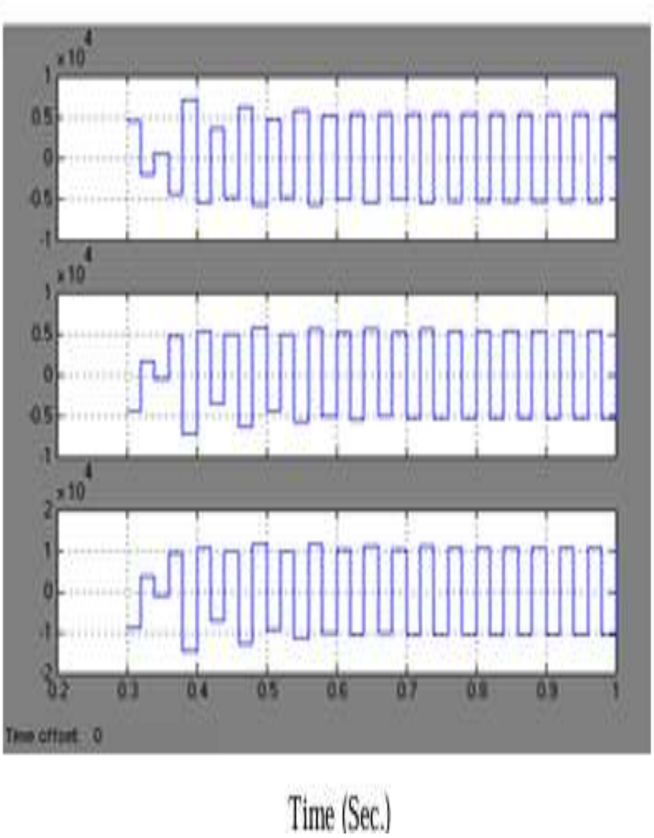

Figure 4: (a) Injected voltage waveforms

The compensated output voltage waveforms for all the 3 phases are depicted in figure 5 (b).

Figure 4: (b) Compensated output voltage waveforms

8. CONCLUSION

Since the goal of this paper was to understand how power system controllers using controllers based on power electronics operate, special attention was given to the construction of custom power controllers. The layout of a DVR can serve as an example. Using both IGBT and GTO switching devices in the VSI circuit results in almost identical output waveforms for the DVR model under paper in simulation. Furthermore, it has been noted that power users with sensitive loads experience the most upsetting voltage drop at the distribution level during fault conditions. Nonetheless, a well-thought-out DVR system can help to solve this problem.

REFERENCES

1. Bollen, M. H. (2000). Understanding Power Quality Problems: Voltage Sags and Interruptions. IEEE Press.
2. Ghosh, A., & Ledwich, G. (2002). Power Quality Enhancement Using Custom Power Devices. Kluwer Academic Publishers.
3. Rashid, M. H. (2014). Power Electronics: Circuits, Devices and Applications (4th ed.). Pearson.
4. Blaabjerg, F., & Ma, K. (2013). Future on Power Electronics for Wind Turbine Systems. IEEE Journal of Emerging and Selected Topics in Power Electronics, 1(3), 139-152.
5. Singh, B., Al-Haddad, K., & Chandra, A. (1999). A Review of Active Filters for Power Quality Improvement. IEEE Transactions on Industrial Electronics, 46(5), 960-971.
6. Hingorani, N. G., & Gyugyi, L. (2000). Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems. IEEE Press.
7. Zhang, L., Yin, X., Xu, X., & Li, Y. (2009). Review of Power Quality Problems and Solutions in the Smart Grid. Electric Power Components and Systems, 37(8), 941-951.
8. Peng, F. Z. (2001). Harmonic Sources and Filtering Approaches. IEEE Industry Applications Magazine, 7(4), 18-25.
9. Akagi, H., Watanabe, E. H., & Aredes, M. (2007). Instantaneous Power Theory and Applications to Power Conditioning. Wiley-IEEE Press.
10. Mohan, N., Undeland, T. M., & Robbins, W. P. (2002). Power Electronics: Converters, Applications, and Design (3rd ed.). Wiley.
11. Salmerón, P., & Litran, S. P. (2010). Improvement of the Electric Power Quality Using Series Active and Shunt Passive Filters. IEEE Transactions on Power Delivery, 25(2), 1058-1067.
12. Bollen, M. H. J., & Hassan, F. (2011). Integration of Distributed Generation in the Power System. Wiley-IEEE Press.
13. El-Hawary, M. E. (2008). Introduction to Electrical Power Systems. Wiley.
14. Singh, B., Chandra, A., & Al-Haddad, K. (2015). Power Quality: Problems and Mitigation Techniques. Wiley.
15. Mohan, N. (2011). First Course on Power Electronics and Drives. MNPERE.