DYNAMIC VOLTAGE RESTORER FOR POWER QUALITY ENHANCEMENT USING DSP CONTROLLER

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Abstract: The increasing reliance on sensitive electronic equipment in modern power systems has heightened the importance of maintaining a high-quality power supply. Voltage sags, interruptions, and other disturbances can adversely affect the performance and reliability of critical loads. This research proposes a Dynamic Voltage Restorer (DVR) system designed for power quality enhancement, employing a Digital Signal Processor (DSP) controller for precise and efficient voltage restoration.

The DVR acts as a real-time compensator that dynamically injects compensating voltage to mitigate short-term voltage variations, ensuring a consistent and reliable power supply to sensitive loads. The integration of a DSP controller enhances the system's performance by allowing for rapid and adaptive response to voltage disturbances. The DSP controller processes real-time data from voltage sensors and employs advanced control algorithms to generate compensating signals swiftly and accurately.

Key components of the proposed system include voltage sensors for monitoring the power supply, a DSP controller for signal processing and control implementation, and a power electronic converter for injecting compensating voltage into the system. The integration of DSP technology promises to offer a robust and adaptive solution for dynamic voltage restoration, thereby addressing the challenges associated with modern power systems.

Keywords: Voltage Sag, Voltage Swell, Dynamic Voltage Restorer (DVR), Digital Signal Processor (DSP), Voltage Enhancement.

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1. INTRODUCTION

In power distribution networks, the power quality disturbances are made by the voltage sags, swells, and harmonics. A Dynamic Voltage Restorer is a specialized device used to rectify Voltage Sag, Swell and Harmonics. These disturbances can occur due to various reasons such as short circuits, faults, or sudden changes in load. Voltage sags, swells and harmonics can have detrimental effects on sensitive electronic equipment and can lead to the malfunctions, data loss, or even damage.

A Dynamic Voltage Restorer primary function is to dynamically inject the voltage into the power system to maintain a steady and constant voltage at the load side while compensating for transient voltage changes. The device continuously monitors input voltage and detects a deviation beyond a certain threshold, rapidly injects the necessary compensating voltage to restore the voltage at the load within acceptable limits. The DVR operates on a principle of real-time correction, providing rapid response to voltage variations.

To protect the loads from these problems with power reliability, the dynamic voltage restorer (DVR) senses and corrects voltage sag in the AC power source. The injection transformer, an IGBT converter, and DC power sources are linked in series with the power line and the sensitive load to form the DVR. Batteries, flywheels, supercapacitors, and superconducting magnetic storage units are examples of DC power sources that can be employed. A failure in one of the distribution feeder lines may cause a sag, swell, or harmonics in the input AC power line voltage to spread across the power network.

2.Literature Survey

In this paper a brief literature review is done on DVR and its control strategies. By selecting any one of them we provide solution to various power quality problems like voltage harmonics, voltage sag/swell compensation.

This includes journal work of Hongchuan Li , Bin Li, Zhongge Luo, Hang Li, Yu Zhao, TingWang, Yanfei Sun on the title “Power Supply Reliability Enhancement for Low-Voltage Distribution Area With Power Quality Improvement Function” from IEEE Journal Dec 2022

3.FUNCTIONAL MODULES

3.1 Description

The Dynamic Voltage Restorer (DVR) system with a Digital Signal Processor (DSP) controller is a cutting-edge solution designed to enhance power quality in electrical systems. It operates by actively monitoring the incoming voltage, identifying disturbances, and injecting compensating voltage to mitigate any deviations. The integration of a DSP controller adds a layer of intelligence, enabling real-time analysis and adaptive responses to a variety of power quality issues.

3.2 Real-time Disturbance Detection

The DVR system, equipped with advanced voltage sensors and a DSP controller, ensures the real-time monitoring and instant detection of voltage disturbances, such as sags and interruptions.

3.3 Adaptive Compensation

The DSP controller utilizes intelligent algorithms to analyze the nature and severity of voltage disruptions, allowing the system to adapt its compensating response accordingly.

3.4 Precise Voltage Restoration

The system's ability to inject compensating voltage with precision ensures that sensitive electronic equipment receives a stable and reliable power supply, preventing potential damage or operational issues.

3.5 Harmonic Mitigation

Using advanced control strategies facilitated by the DSP, the DVR system can effectively mitigate harmonic distortions in the power supply, contributing to improved overall power quality.

3.6 Advantages

- Minimized Downtime
- Versatility and Adaptability
- Optimized Efficiency
- Comprehensive Power Quality Improvement:

3.7 Components:

- Three-phase Source:

  The three-phase source represents the initial power supply in the simulation. It typically provides balanced voltages and currents across three phases, simulating the input from a utility or generator.

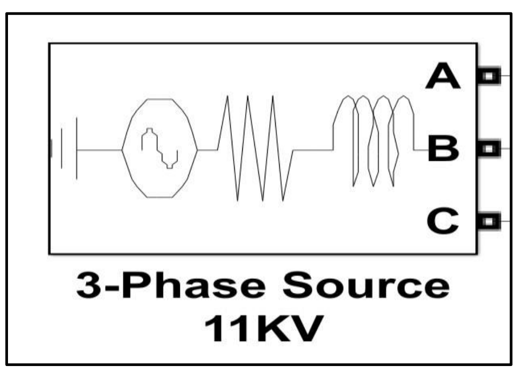


Figure 1 – 3 Phase source

- 11kV/0.4kV Transformer:

The 11kV/0.4kV transformer is a key element for voltage transformation. It steps down the incoming 11kV voltage to a lower 0.4kV level, suitable for distribution to the load. Transformers are essential in power systems for adjusting voltage levels.

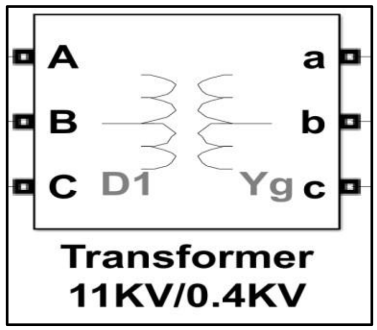


Figure 2 - 11kV/0.4kV Transformer

- Three-phase Series Injection Transformer:

The Three-phase series injection transformer is used for injecting compensating voltage into the power system. It can be employed to regulate voltage levels, correct power factor, or mitigate disturbances. In this context, it acts as a dynamic compensator, injecting signals to counteract undesirable voltage fluctuations.

- DSP Controller

The DSP controller is a digital signal processor that plays a crucial role in the simulation. It processes real-time data from sensors, analyzes power quality, and determines appropriate control signals. In this context, it likely controls the operation of the series injection transformer for dynamic voltage compensation.

- Three-phase Load

  The three-phase load represents the electrical demand on the system. It includes various types of loads such as resistive, inductive, or capacitive elements. The load absorbs power from the system, and its characteristics influence the overall performance of the power distribution.

4.POWER SYSTEM DISTURBANCES

Power quality is a measure of source of electrical power that meets the energy supply needs of the connected load. If the load does not experience any operational problem, then by this measure, power quality is equal.

The term power quality broadly refers to maintaining a near sinusoidal power distribution bus voltage of a rated magnitude and frequency. When power quality becomes poor, it affects almost all consumers. There are important terms in power quality, they are

4.1 Short duration voltage variations

A short duration voltage variation is any variation in the supply voltage that lasts less than one minute. Voltage swells, sags, and interruptions are further classifications for short-duration variations.

4.2 Voltage Sag

A fundamental frequency drop in the supply voltage over a brief period is called a voltage sag. The voltage sag lasts anything from five cycles to a minute. Large motors or heavy loads being started can also create voltage sags, although system breakdowns are usually the reason. Efficiency declines in electric rotating machinery

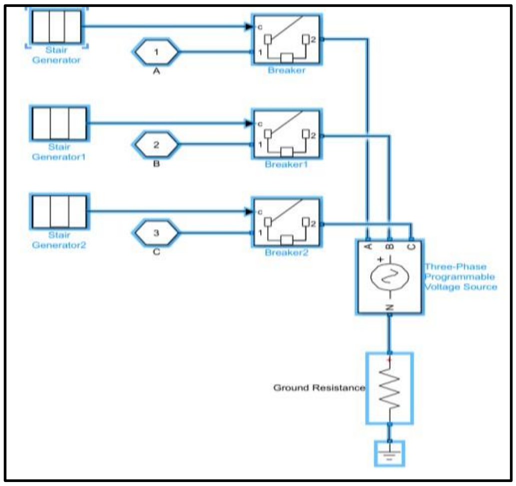


Figure 3 - Voltage Sag and Voltage Swell Circuit

4.3 Voltage Swell

A brief increase in the fundamental frequency voltage is referred to as a voltage swell. IEEE 1159 defines it as the rise in the RMS voltage level to 110%–180% of nominal, for a maximum of one minute of cycles at the power frequency. Typically, it is brought on by fault situations, turning off large loads, and energizing capacitor banks.

5. Methodology

Dynamic Voltage Restorer (DVR) using a Digital Signal Processor (DSP) controller typically consists of the following components:

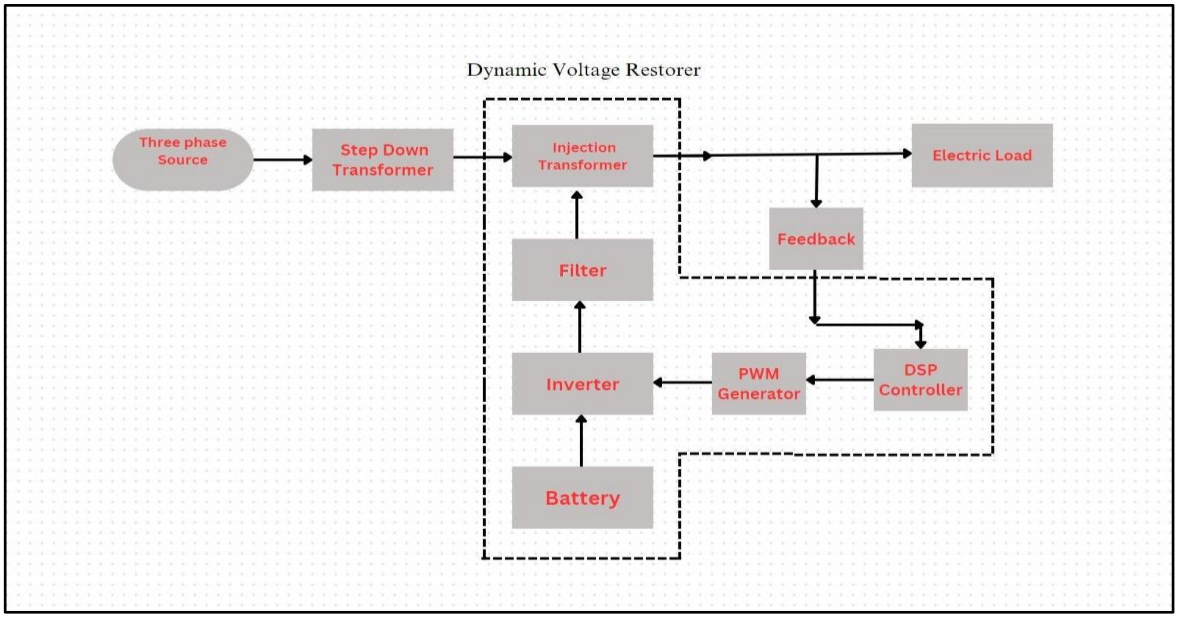


Figure 4 - Block Diagram of proposed system

5.1 Working Principle

The working principle of a DVR with a DSP controller involves the following steps:

- Voltage Monitoring

  The voltage sensor continuously monitors the incoming voltage from the power grid.

- DSP Signal Processing

  The DSP controller analyzes the voltage signal in real-time, employing advanced signal processing algorithms to identify and characterize voltage sags or interruptions.

- Detection of Voltage Anomalies:

  Based on the analysis, the DSP controller determines if the incoming voltage deviates from the nominal value and identifies the severity and duration of the disturbance.

- Compensating Voltage Generation:

  Upon detection of a voltage anomaly, the DSP controller calculates the compensating voltage required to restore the system to its nominal state.

- Energy Storage Utilization:

  The compensating voltage is generated using the energy stored in the energy storage system (e.g., capacitors or batteries).

- Inverter Operation:

  The compensating voltage is then converted to the appropriate form (e.g., AC) using an inverter.

- Injection into Power System:

  The compensating voltage is injected into the power distribution system through the switching devices, correcting the voltage sag or interruption.

- Feedback and Continuous Adjustment:

  The feedback loop ensures continuous monitoring of the power system, allowing the DSP controller to make real-time adjustments to the compensating voltage as needed.

6 SIMULATIONS AND RESULTS

The simulations, conducted in MATLAB/Simulink, aim to validate the DSP algorithms' effectiveness in mitigating voltage sags. Various test scenarios are explored, evaluating the DVR's response time and accuracy in real-world conditions. The comparison framework includes conventional DVR systems, with criteria such as efficiency and precision. These simulations play a crucial role in affirming the DSP controller's functionality, contributing insights into the system's behavior and potential advancements in power quality solutions.

6.1 Schematic Diagram of Proposed System

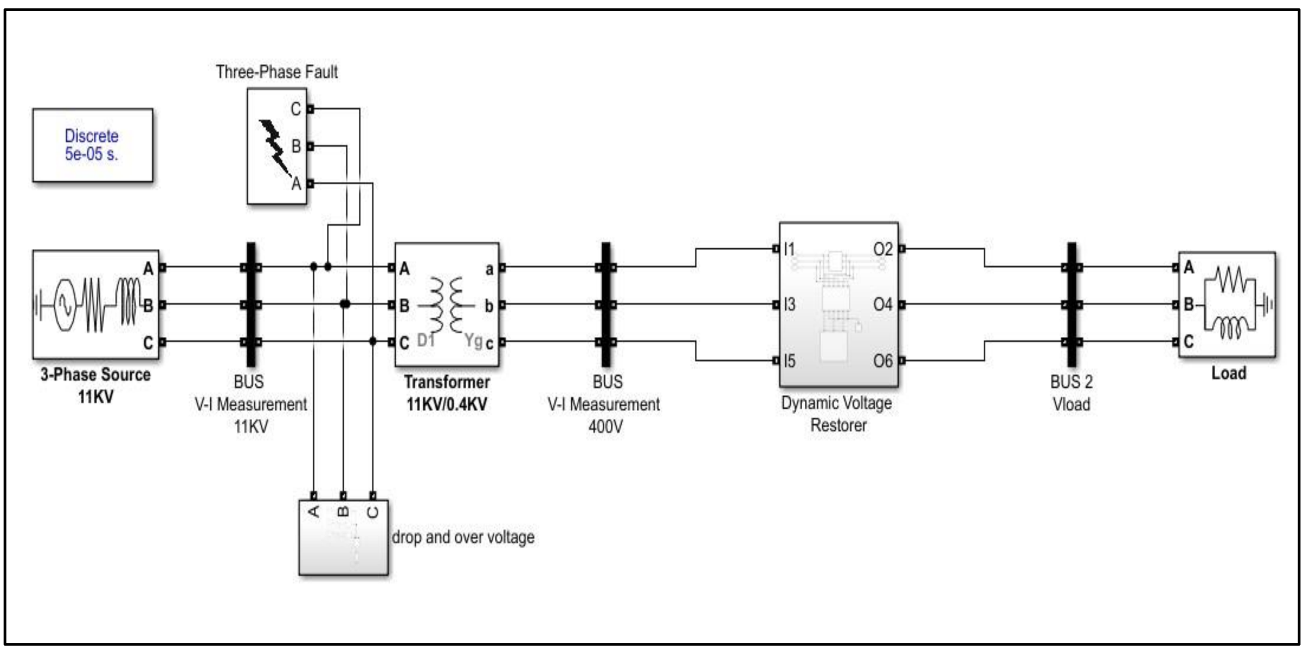


Figure 5 - Simulation of DVR System

6.2 Dynamic Voltage Restorer

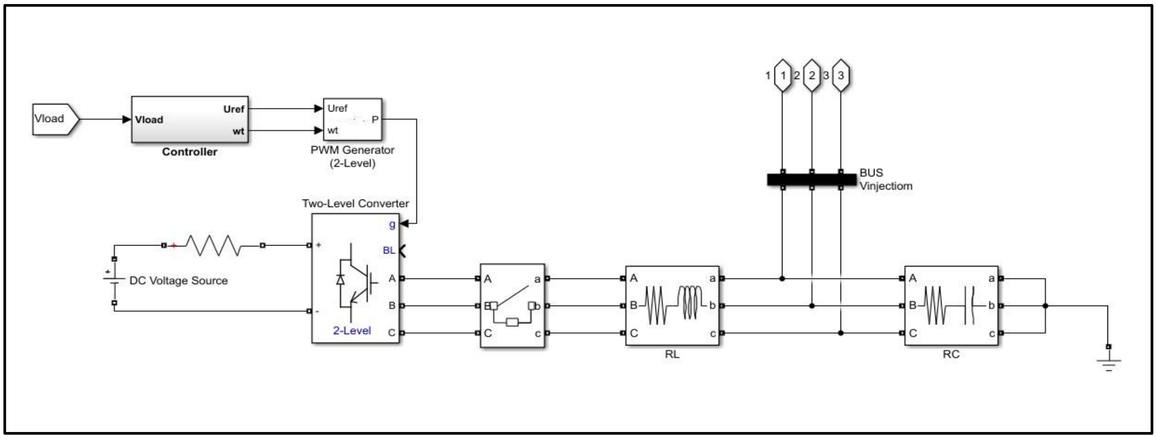
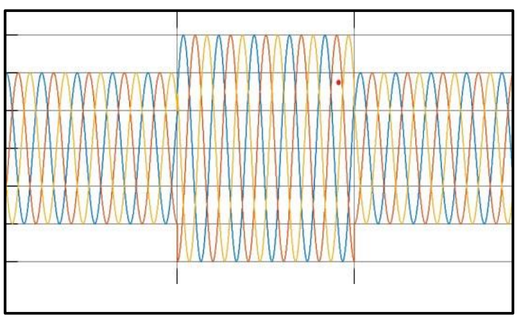


Figure 6 - DVR with DSP Controller

6.3 Voltage Sag, Swell and Harmonics Input



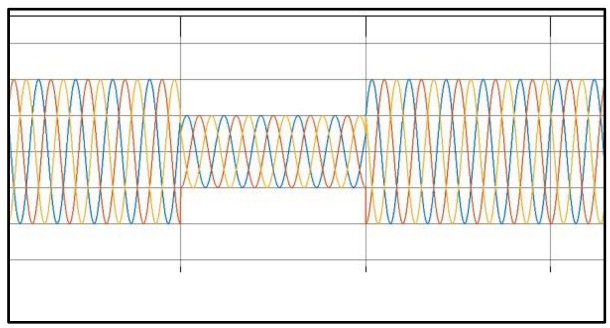
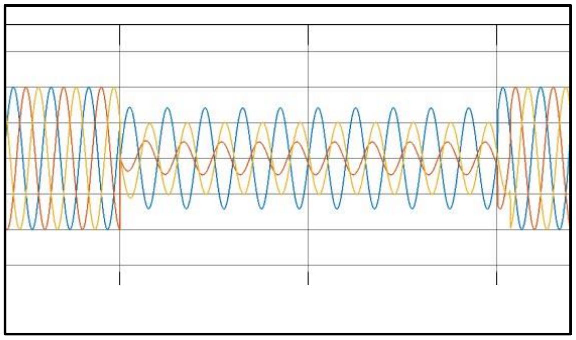


Figure 7 - Voltage Swell **Figure 8 - Voltage Sag**

Fig 7 represents a **Voltage Swell** which is an increase in the RMS voltage above the nominal voltage or a sliding reference voltage. The increase lasts from half a cycle to several seconds.

Fig 8 represents a **Voltage Sag** which is a short-duration reduction in the voltage of an electric power distribution system.

X axis → Time (Sec)
Y axis → Voltage (Volt)



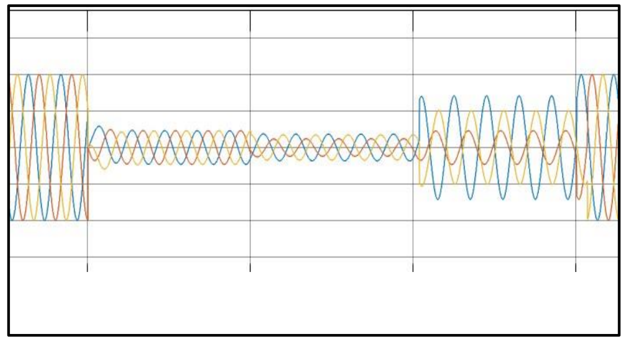


Figure 9 - Three Phase Fault **Figure 10 - Harmonics**

Fig 9 represents a **Three-phase bolted fault** that describes the condition where the three conductors are physically held together with zero impedance between them.

Fig 10 represents **Harmonics** that occur when non-linear loads draw current from the power supply, they generate harmonic currents that create a distorted waveform that can cause problems in the power system.

X axis → Time (Sec)
Y axis → Voltage (Volt)

6.4 Voltage Sag, Swell and Harmonics Output

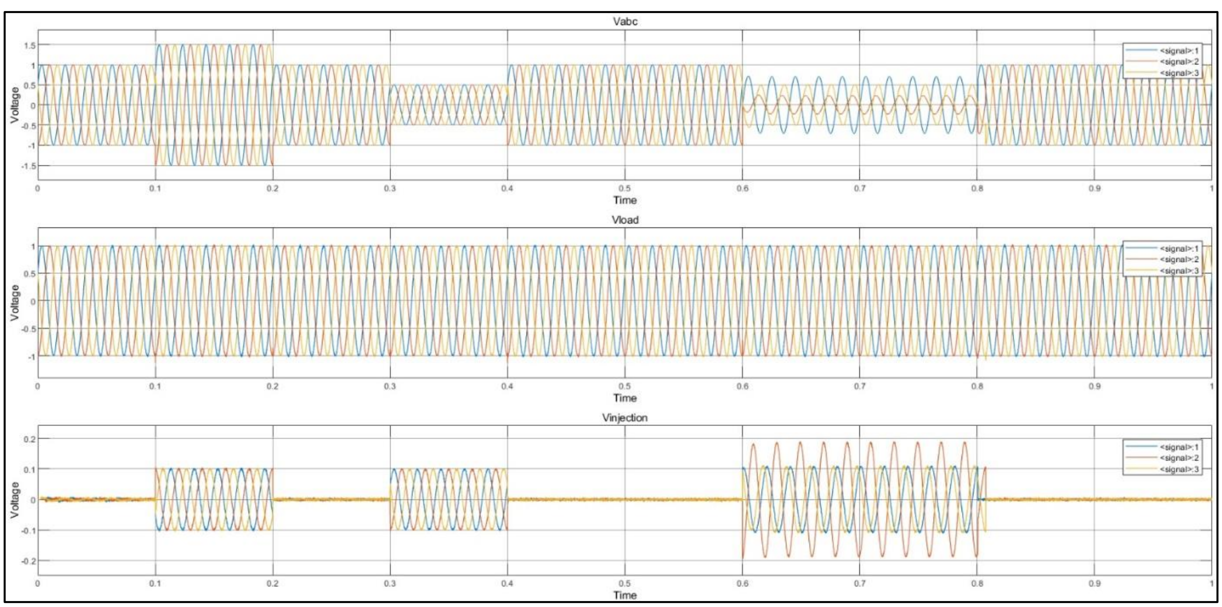


Figure 11 - Voltage Sag, Swell Output

Fig 11 - represents a scenario when **Voltage Sag and Swell** occurred in a system and compensation voltage is injected to rectify the error

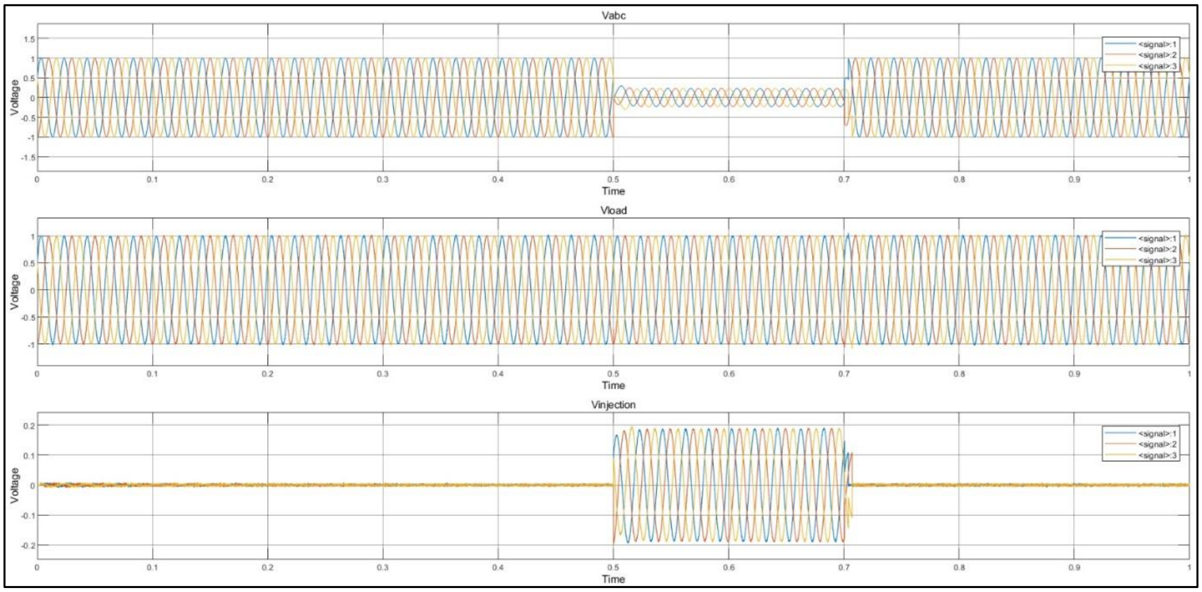


Figure 12 - Harmonics Output

Fig 12 - represents a scenario when **Harmonics** occurred in a system and compensation voltage is injected to rectify the error.

7. CONCLUSION

In conclusion, employing a Dynamic Voltage Restorer (DVR) with a Digital Signal Processor (DSP) controller proves to be a robust solution for enhancing power quality. The integration of DSP facilitates real-time monitoring and precise control, enabling swift and effective compensation for voltage sag and disturbances. This synergy between DVR and DSP technology contributes significantly to the overall reliability and stability of the power distribution system, ensuring a more resilient and efficient electrical infrastructure.

In terms of power quality enhancement, the DVR-DSP synergy is instrumental in mitigating voltage fluctuations, harmonics, and other disturbances that can degrade the overall quality of the electrical supply. By actively correcting these issues, the integrated system contributes significantly to maintaining a stable voltage profile within acceptable limits, meeting the stringent requirements of modern power-sensitive devices.

In conclusion, the combination of a Dynamic Voltage Restorer and a Digital Signal Processor controller offers a comprehensive and efficient solution for power quality enhancement. The real-time monitoring, adaptability, and precise control capabilities of the DSP contribute to a resilient and responsive system that safeguards critical equipment and ensures a reliable power supply. As technology continues to advance, the integration of DVRs with DSP controllers play a crucial role in shaping the future of power distribution systems, meeting the ever-growing demands for a stable and high-quality electrical infrastructure.

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