A

Project work II

Report on

IDENTIFICATION OF POWER QUALITY DISTURBANCES – A SIGNAL PROCESSING APPROACH

Submitted to

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY, ANANTHAPURAMU

In Partial Fulfilment of the Requirements for the Award of the Degree of

BACHELOR OF TECHNOLOGY

In

ELECTRICAL AND ELECTRONICS ENGINEERING

Submitted by

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Under the Guidance of

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MADANAPALLE INSTITUTE OF TECHNOLOGY AND SCIENCE (UGC-AUTONOMOUS)

(Affiliated to JNTUA, Ananthapuramu, Approved by AICTE, New Delhi)

AN ISO9001:2008 Certified Institution

P. B. No: 14, Angallu, Madanapalle – 517325,

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

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ORIGINALITY CERTIFICATE

This is to certify that the project report titled **“IDENTIFCATION OF POWER QUALITY DISTURBANCES – A SIGNAL PROCESSING APPROACH” Submitted by SHAIK MAHAMMAD YASEEN (19691A0244), S. D. MOHAMMED VASEEM (19691A0252), S. MD. YOUSUF (19691A0251), S. KARIM BASHA (19691A0238)** has been evaluated using Ouriginal software for originally check. The similarity index is found to be 7% which is verified and approved for submission.

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DECLARATION

We hereby declare that the results embodied in this project "**Identification of Power Quality Disturbances – A Signal Processing Approach**" by us under the guidance of**Mr. N.Ramesh**, Associate Professor, Dept. of EEE in partial fulfilment of the award of **Bachelor of Technology** in **Electrical & Electronics Engineering** from **Jawaharlal Nehru Technological University**, **Ananthapuramu** and we have not submitted the same to any other University/Institute for award of any other degree.

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ABSTRACT

The detection and classification of Power Quality Disturbances (PQD) are crucial for the timely identification and mitigation of power issues. Poor power quality can have significant consequences for sensitive electrical devices, making it challenging for consumers to quantify the cost of equipment failure. Recognizing and mitigating PQD is essential to ensure the delivery of clean and reliable power to consumers. This project addresses the need for effective detection and classification methods for PQD. MATLAB R2022b was used to simulate PQDs, providing a controlled environment for testing and validation. Experimental validation was conducted on a test bench equipped with a step-down transformer, allowing for real-time assessment of the proposed methodologies. The project also explores various methods for detecting and classifying power quality disturbance signals, with a specific focus on pure sine wave analysis. Techniques such as Fast Fourier Transform and continuous wavelet transform were employed, enabling the classification of a wide range of disturbances, including voltage sag, voltage swell, transients, and interruptions. The simulation study showcased the effectiveness of Fast Fourier Transform in extracting frequency information, while wavelet techniques contributed valuable insights into power quality disturbance and its detection.

CHAPTER-1

INTRODUCTION

Nowadays, the emphasis is on improving the quality of electrical power and delivering it to the distribution end without Power Quality Disturbances (PQD), which have developed into a significant worry in an electric system. Recent technological advancements in solid-state devices, the spread of renewable energy sources, and non-linear loads have all increased the significance of PQ, “the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment”.Power quality disturbances refer to variations in the voltage, current, or frequency of an electrical power supply that can result in performance or operational problems for electrical equipment.

PQD issues disrupt electrical and electronic equipment, which is often discovered using instrumentation methods. These PQD have a significant negative impact on expensive equipment like computers, production line control systems, etc. PQD issues include voltage sag and swells, different interruptions, noise, harmonics, transients, voltage fluctuation, and flickering. In general, the methods for identifying PQDs rely on the graphical analysis of voltage and current waveforms in the time and frequency domain.

Power Quality (PQ) associated issues are one of the most concern Problem in an electrical system. The wide spread use of the electronic equipment, such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. Due to their non-linearity, all these loads cause disturbances in the voltage waveform.

Power quality disturbances can have a significant impact on the performance and reliability of electrical equipment, which can result in production downtime, equipment damage, and increased maintenance costs.These PQD have a significant negative impact on expensive equipment like computers, production line control systems, etc. Therefore, it is important to detect and identify power quality disturbances to minimize their impact and prevent potential damage.

The various techniques used to detect the power quality disturbances are voltage and current monitoring, waveform analysis, spectrum analysis and power quality meters. However, detecting power quality disturbances is critical for ensuring the reliable and efficient operation of electrical systems, and can help to minimize the impact of disturbances on equipment and processes. In this project the Waveform analysis technique is used to identify the power quality disturbances in a real time signal by using signal processing approach in MATLAB.

Fault Detection is essential to describe for accuracy operation of fault mitigation devices. There are various methods to identifying power quality problems. The method to detect power quality discuss in this paper is Fast Fourier Transform. The FFT plays important roles in analysis, design and implementation of discrete signal processing. FFT algorithms are based on fundamental of discrete fourier computation. An FFT computes the DFT and produces exactly the same result as evaluating the DFT definition directly; the most important difference is that an FFT is much faster [3].Likewise refined frequency techniques have been created. For instance, Wavelet transform (WT), stockwell transform (S-transform), and Hilbert Huang transform (HHT). S-transform is a variable window hybrid of STFT and WT. When the PQ disturbance occurs, WT can precisely identify a single event under non-stationary conditions. WT is capable of handling some acceptable levels of noise and has an appropriate frequency, focusing characteristics, and resolution. Different methods should be taken into consideration when setting up the WT. The Continuous Wavelet Transform (CWT) examines how a signal changes over time as various scaling factors are applied [4]. In this paper the real time and simulated PQ signal have been generate and the signal processing techniques like Fast Fourier Transform (FFT) and Continuous Wavelet Transform (CWT) have been applied for the identification of the power quality disturbances.

CHAPTER-2

LITERATURE SURVEY

N Ramesh, S Deepa, P VanajaRanjan, 2020, "The Mystery Curve: A Signal Processing Based Power Quality Disturbance Detection" This paper [1]gives detail information about various power quality disturbances in electrical system. Importance of quality of power to be delivered to customers and gives idea that power quality disturbances can be identified by using signal processing approach. The paper also suggests the idea of acquiring real time power quality disturbances.

IEEE Std. 1100-(1992), "IEEE recommended practice for powering & grounding sensitive electromag. equipments" This article [2] gives the clear definition of power quality. The quality of electrical power and deliver it to the distribution end and utility, without Power Quality Disturbances (PQD), has become a major concern in an electric system. On account of quick extension of solid-state gadgets, dispersion of renewable energy sources and non-linear loads, the centrality of PQ has been expanded.

G Devadasu, M Sushama, 2016, "Identification of Voltage Quality problems under Different types of Sag/Swell Faults with Fast Fourier Transform Analysis" The simulation study of Fast Fourier Transform has been presented in this paper[3] for extracting voltage component of source voltage under fault conditions. The function of FFT in Matlab is a powerful tool for doing that even with noisy signals. The identification process is very accurate by using FFT.

Abdullah, Muhammad Umar Khan, Waqas Ali, 2020, "A signal analysis approach towards detection and classification of power quality disturbances"This[4] article presents a novel and unique approach for detection and classification of different PQD classes. Multi-class Support Vector Machine was presented for automatic classification of PQDs.callsifies the vaious power quality disturbances in electrical system.

M, Arrabal-campos, G, Montoya, j, Martinez-lao, 2018, "Simulation of Power Quality Disturbances through the Wavelet Transform"This paper presents a graphical user interface for simulating Power Quality disturbances of synthetic and real signals using some time-frequency transformations. This application, implemented in MATLAB, is useful for monitoring power signals since it applies advanced transformations

S Poornima, k Ravindra, 2016, "Comparison of CWT & DWT based Algorithms in combination with ANN for Protection of Power Transformer" in this paper An attempt is made to compare two advanced protection algorithms that have been developed to discriminate the magnetizing Inrush current from the internal fault current of the power transformer. The proposed algorithm/scheme consists of a processing unit based on Wavelet Transform (WT) in combination with Artificial Neural Networks (ANN).

CHAPTER-3

Types of Power Quality Events in Electrical Systems

3.1. Sag:

A Sag is a decrease in the RMS voltage between 0.1 pu and 0.9 pu for a duration from 0.5 cycles to 1 min.

Sag disturbance equation and its Parameter	
Equation	$A(1 - \alpha(\mu(t - t1) - \mu(t - t2)))\sin(\omega t)$
Parameter	$0.1 < \alpha < 0.9$, $T \le t2 - t1 \le 9T$

Table 3.1 Sag disturbance equation and its Parameter

Voltage Sag Waveform:

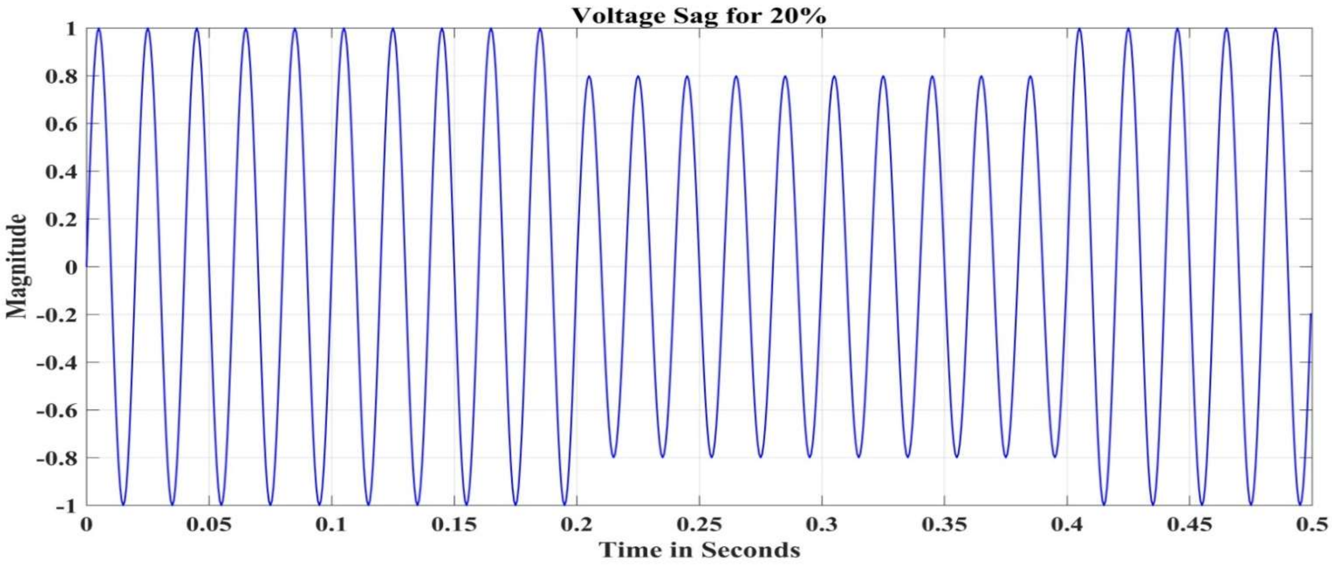


Figure 3.1 Voltage sag signal

The equation provided represents a sag disturbance in an electrical power system. The parameters and their descriptions are as follows:

Equation: $A (1 - \alpha (\mu (t - t1) - \mu (t - t2))) \sin(\omega t)$

- A: Amplitude of the sag disturbance. It determines the depth or severity of the sag.
- α: Depth factor or severity factor. It represents the proportion of the sag depth compared to the amplitude A. It must be within the range $0.1 < \alpha < 0.9$.
- μ: Unit step function. It changes its value from 0 to 1 at $t = t1$ and from 1 to 0 at $t = t2$.
- t1: Starting time of the sag disturbance. It represents when the sag begins.
- t2: Ending time of the sag disturbance. It represents when the sag ends.
- ω: Angular frequency. It determines the frequency of the sinusoidal component of the sag disturbance.
- Parameter condition: $0.1 < \alpha < 0.9$, $T \le t2 - t1 \le 9T$

- α must be within the range 0.1 < α < 0.9. This ensures that the depth factor is neither too small nor too large.
- The time duration of the sag disturbance, t2 - t1, must be greater than or equal to the period of the sinusoidal component T, and it should not exceed 9 times the period T.

These parameters and the equation describe a sag disturbance, which is a temporary drop in voltage magnitude typically caused by faults or disturbances in the power system. The equation represents how the voltage magnitude varies during the sag period.

Causes:

Faults on the transmission or distribution network (frequently on parallel feeders).

Faults in consumer's installation.

Connection of heavy loads and start-up of large motors.

Consequences:

Malfunction of microprocessor-based controlsystems (such as PCs, PLCs, ASDs, etc.) that may lead to a process stoppage. Tripping of contactors andelectromechanical relays. Disconnection and loss of efficiency in electric rotating machines.

3.2. Swell

A swell is an increase in RMS voltage above 1.1 pu.For a duration from 0.5 cycles to 1 min.typicalmagnitudes are between 1.1 pu and 1.2 pu. The magnitude is also described by its remaining voltage and,therefore, will always be greater than 1.0 pu.

Swell disturbance equation and its Parameter	
Equation	$A(1 + \alpha(\mu(t - t1) - \mu(t - t2)))\sin(\omega t)$
Parameter	$0.1 < \alpha < 0.9$, $T \leq t2 - t1 \leq 9T$

Table 3.2Swell disturbance equation and its Parameter

Voltage Swell Waveform:

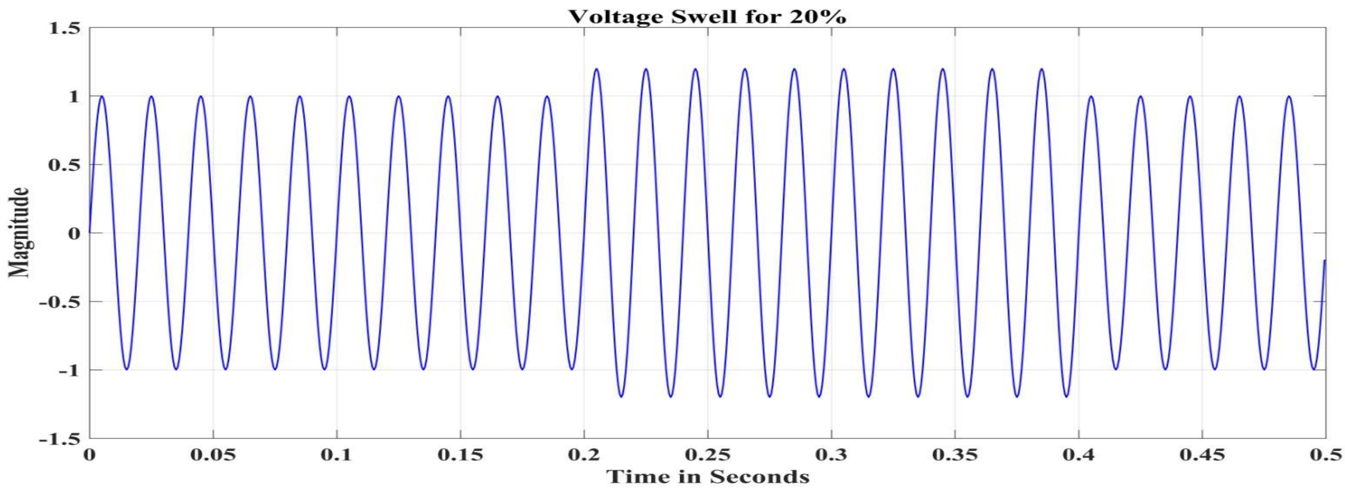


Figure 3.2 Voltage swell signal

The equation provided represents a swell disturbance in an electrical power system. The parameters and their descriptions are as follows:

Equation: $A(1 + \alpha(\mu(t - t1) - \mu(t - t2)))\sin(\omega t)$

- A: Amplitude of the swell disturbance. It determines the magnitude of the voltage increase during the swell event.
- α: Magnitude factor. It represents the proportion of the voltage increase compared to the amplitude A. It must be within the range $0.1 < \alpha < 0.9$.
- μ: Unit step function. It changes its value from 0 to 1 at $t = t1$ and from 1 to 0 at $t = t2$.
- t1: Starting time of the swell disturbance. It represents when the swell begins.
- t2: Ending time of the swell disturbance. It represents when the swell ends.
- ω: Angular frequency. It determines the frequency of the sinusoidal component of the swell disturbance.

  Parameter condition: $0.1 < \alpha < 0.9$, $T \leq t2 - t1 \leq 9T$
- α must be within the range $0.1 < \alpha < 0.9$. This ensures that the magnitude factor is neither too small nor too large.
- The time duration of the swell disturbance, $t2 - t1$, must be greater than or equal to the period of the sinusoidal component T, and it should not exceed 9 times the period T.

These parameters and the equation describe a swell disturbance, which is a temporary increase in voltage magnitude typically caused by factors such as capacitor switching or load disconnection. The equation represents how the voltage magnitude varies during the swell period.

Causes:

Start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers (mainlyduring off-peak hours).

Consequences:

loss of Data, flickering of lighting and screens, stoppage or damage of sensitive equipment, ifthe voltage values are too high.

3.3. Interruption

An interruption occurs when the supply voltage or load current decreases to less than 0.1 PU for a period of timethat does not exceed 1 min. Interruptions can be the result of power system failures, equipment failures and control malfunction. Interruptions are measured by their duration, since the voltage's magnitude is always less than 10% of the nominal value.

Interruption disturbance equation and its Parameter	
Equation	$A(1 - \alpha(\mu(t - t1) - \mu(t - t2))) \sin(\omega t)$
Parameter	$0.1 < \alpha < 0.9, T \leq t2 - t1 \leq 9T$

Table 3.3. Interruption disturbance equation and its Parameter

Interruption Waveform:

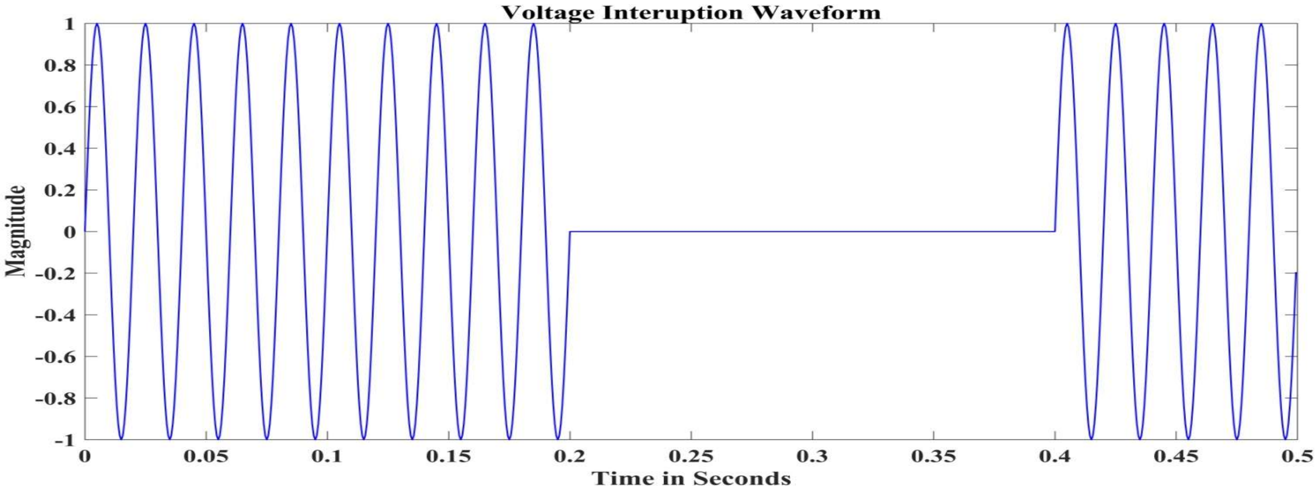


Figure 3.3 Voltage interruption signal

The equation provided represents an interruption disturbance in an electrical power system. The parameters and their descriptions are as follows:

Equation: $A(1 - \alpha(\mu(t - t1) - \mu(t - t2)))\sin(\omega t)$

- A: Amplitude of the interruption disturbance. It determines the magnitude of the voltage drop during the interruption event.
- α: Depth factor or severity factor. It represents the proportion of the voltage drop compared to the amplitude A. It must be within the range $0.1 < \alpha < 0.9$.
- μ: Unit step function. It changes its value from 0 to 1 at $t = t1$ and from 1 to 0 at $t = t2$.
- t1: Starting time of the interruption disturbance. It represents when the interruption begins.
- t2: Ending time of the interruption disturbance. It represents when the interruption ends.
- ω: Angular frequency. It determines the frequency of the sinusoidal component of the interruption disturbance.
- Parameter condition: $0.1 < \alpha < 0.9, T \leq t2 - t1 \leq 9T$
- α must be within the range $0.1 < \alpha < 0.9$. This ensures that the depth factor is neither too small nor too large.

- The time duration of the interruption disturbance, t2 - t1, must be greater than or equal to the period of the sinusoidal component T, and it should not exceed 9 times the period T.

These parameters and the equation describe an interruption disturbance, which is a temporary drop in voltage magnitude typically caused by factors such as faults or equipment failure. The equation represents how the voltage magnitude varies during the interruption period.

Causes:

Circuit breaker tripping

Control malfunctions

Failure of equipment's

3.4. Transient

A transient is a sudden unidirectional or bidirectional change in voltage which mainly occurs due to switching of power correction capacitors or transformers. According its direction it is divide into impulsive or oscillatory transients.

Transient disturbance equation and its Parameter	
Equation	$y(t) = \sin(\omega t) + \alpha^{-(t-t1)/T} \sin\omega n(t - t_1)$
Parameter	$0.1 < \alpha < 0.8$, $0.5T \le t2 - t1 \le 3T$, $8ms \le T \le 40ms$

Table 3.4. Transient disturbance equation and its Parameter

Transient Waveform:

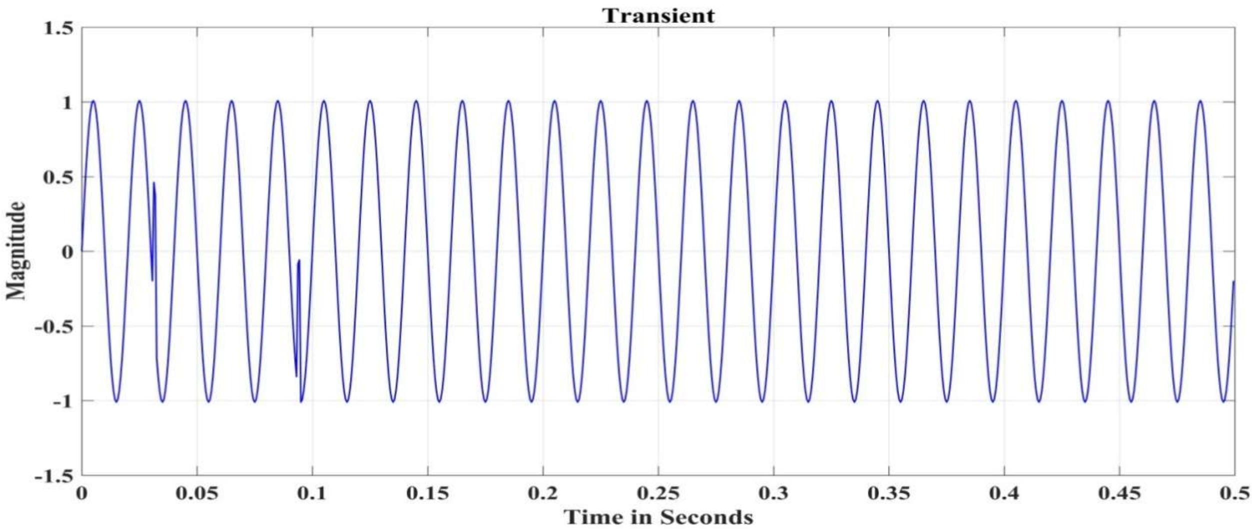


Figure 3.4 Transient signal

The equation you provided represents a transient disturbance in an electrical power system. The parameters and their descriptions are as follows:

Equation: $y(t) = \sin(\omega t) + \alpha$^-(t - t_1)/T * sin(ωn(t - t_1))

- y(t): Represents the voltage disturbance waveform.

- ω: Angular frequency. It determines the frequency of the sinusoidal component.
- t: Time variable.
- α: Attenuation factor. It must be within the range $0.1 < \alpha < 0.8$.
- t_1: Starting time of the transient disturbance. It indicates when the disturbance begins.
- T: Period of the sinusoidal component.
- ωn: Angular frequency of the transient component. It determines the frequency of the transient disturbance.
- Parameter conditions:
- $0.1 < \alpha < 0.8$: This range ensures that the attenuation factor is within a suitable range.
- $0.5T \leq t_2 - t_1 \leq 3T$: The duration of the transient disturbance should be within this range, where t_2 is the ending time of the disturbance.
- $8 \text{ ms} \leq T \leq 40 \text{ ms}$: The period of the sinusoidal component should fall within this range to represent the desired frequency characteristics.

The transient disturbance equation combines a sinusoidal component with a transient component that decays over time. It represents the temporary disturbance in the voltage waveform caused by various factors such as switching operations, lightning, or load changes.

Causes:

Heavy-duty motor starting
Lightning.
Power capacitor energization.
Cable switching.

CHAPTER-4

SIGNAL PROCESSING TECHNIQUES

In this project our aim is to identify the power quality events, we have used various signal processing techniques to identify the power quality events. The signal processing techniques identify the power quality events and locates in frequency domain or time domain.

The signal processing techniques used are:

1. Fast Fourier Transform
2. Wavelet Transform.

4.1. Fast Fourier Transform:

Fast Fourier Transform is a method that presents the frequency content for the entire time range of a signal. In a Fourier Transform, a signal is considered as sum ofthesinusoidal wave with different frequencies that exist from minus infinite to plus infinite.

The expression for calculating the fast Fourier transform is: $x[k] = \sum_{n=0}^{N-1} x[n]e^{\frac{-j2\pi kn}{N}}$

The Fast Fourier Transform (FFT) is a mathematical algorithm used to convert a signal from the time domain to the frequency domain. It is a widely used tool for analysing signals and is used in a wide range of fields, including audio processing, telecommunications, and image processing.

The basic idea behind the FFT is to break down a signal into its component frequencies. This is done by analysing the signal over a specific time interval and looking at how its amplitude changes over time. The signal is then divided into a number of smaller sections, each of which is analysed separately. These sections are called "frames" or "windows."

X(k) = Σ_{n=0}^{N-1} x(n) * e^(-i * 2π * k * n / N)   (1)

Where:

X(k) represents the frequency component at index k in the frequency spectrum.

Σ_{n=0}^{N-1} represents the sum of values from 0 to N-1, where N is the length of the input signal.

x(n) represents the amplitude of the input signal at index n.

e^(-i * 2π * k * n / N) represents a complex exponential function with a frequency of k/N. This function is used to weight each input value based on its position in the signal.

The FFT algorithm performs this calculation for each frequency component in the spectrum, from 0 to N-1. The resulting frequency spectrum shows the strength of each frequency component in the input signal.

Once the signal is divided into windows, the FFT is applied to each window individually. The FFT algorithm computes the frequency spectrum of the window, which gives a measure of the strength of each frequency component present in the window. This is done by performing a series of mathematical operations on the data in the window.

The output of the FFT is a graph of frequency versus magnitude, which is called a frequency spectrum or power spectrum. The x-axis represents frequency, and the y-axis represents the magnitude of each frequency component. The FFT can provide important information about the frequency content of a signal, such as which frequencies are present and how strong they are.

Thus, the FFT is used to analyze a wide range of signals, including audio signals, images, and biomedical signals. For example, the FFT can be used to analyze the frequency content of an audio signal to determine which notes are being played or to identify noise in the signal. It can also be used to analyze the frequency content of an image to identify specific features or patterns. In biomedical research, the FFT can be used to analyse the frequency content of physiological signals such as electroencephalogram (EEG) and electrocardiogram (ECG) signals to detect abnormalities or identify specific features.

4.2. Wavelet Transform:

wavelet transform which is a powerful and useful tool in signal processing technique that have been used in many applications such as signal processing, image compression and pattern recognition [3]. Fourier transform is also used for signal analysis and processing. But this traditional method possess some drawbacks for that it is not applicable for non-stationary signals. Wavelet transform is used for analyse different power quality events. The power quality events like pure sine voltage, voltage sag, voltage swell, transients and interruptions can be obtained using wavelet transform. Fourier transform is also used for denoising but limited to stationary signals. For continuous analysis of non-stationary signals wavelet transform is used. The presence of noise can be detected by wavelet methods and analyse the noisy signal. The noisy signal can be denoised by using wavelet transform.

Wavelet analysis is defined as the analysisofthe signal with the short duration finite energy function (mother Wavelet).Wavelet analysis allows the use of long time intervals where more precise low-frequency information is required, and short regions where high frequency information is looked for. Wavelet algorithms process data at different scales or resolutions.

4.2.1. Continuous Wavelet Transform(CWT):

Continuous wavelet transform (CWT) is defined as the sum over all time of the signal multiplied by scaled, shifted versions of the wavelet function.The continuous wavelet transform shows output in both the frequency domain and the Time domain, so that we can easily identify the time period and frequency of the signal.

Expression for calculating the continuous Wavelet transform is: $\mathrm{T(a,b)} = \frac{1}{\sqrt{a}}\int_{-\infty}^{\infty} x(t)\psi * \frac{(t-b)}{a} dt$

Continuous Wavelet Transform (CWT) is a mathematical tool used for signal analysis that provides time-frequency representation of signals. It is particularly useful for analysing non-stationary signals, such as transients. The CWT is computed by changing the scale of the analysis window and shifting the window in time, multiplying the signal with the mother wavelet, and integrating over all times.

The CWT uses a wavelet function, called the mother wavelet, which is dilated and shifted to analyse the signal at different scales and times. The CWT provides a continuous time-frequency analysis, which means that it provides a high-resolution representation of the signal in both time and frequency domains. The CWT is more computationally expensive than the Discrete Wavelet Transform (DWT), but it provides a higher resolution time-frequency analysis. The formula for Continuous Wavelet Transform:

$$CWT(a,b) = (1/\sqrt{|a|}) \int h(t)\ \Psi^* [(t-b)/a]\ dt \qquad (2)$$

Where h(t) is the input signal, Ψ(t) is the mother wavelet, a and b are dilation and translation parameters, respectively, and * denotes the complex conjugate.

The CWT is a mathematical tool used to analyse various types of signals, including audio, images, and biomedical signals. It provides a time-frequency representation of the signal that shows the strength of the signal at different scales and shifts. The CWT is particularly useful for analysing non-stationary signals, such as transient signals, and provides a high-resolution representation of the signal in both time and frequency domains.

By selecting an appropriate mother wavelet and adjusting the dilation and translation parameters, the CWT can be used to analyse signals with different characteristics and properties. For example, the CWT can be used to detect and analyse transient events in audio signals, identify features in biomedical signals, and extract texture and edge information from images.

In summary, the FFT and CWT are two powerful mathematical tools used for signal analysis that provide important information about the frequency content and time-frequency representation of a signal, respectively. While the FFT is more commonly used for stationary signals, the CWT is particularly useful for analysing non-stationary signals and providing a high-resolution time-frequency analysis.

CHAPTER-5

SIMULATION RESULTS

In this project, four Power Quality Disturbance (PQD) signals have been simulated using MATLAB. PQD signals are sag, swell, interruption and transient. The proposed signal processing algorithms like Fast Fourier Transform (FFT), Continuous Wavelet Transform (CWT) methods are to arrive distinct pattern for each PQD and are obtained in both 2D and 3D views for their detection. Detailed simulation results along with discussion are provided in the following subsections.

5.1. Pure Voltage Signal:

Fig. 5.1(a) displays the pure sinusoidal voltage signal generated for 0.5 sec. The proposed FFT, periodogram, CWT and DWT is obtained by the complex-valued analytic signal output of the input signal.

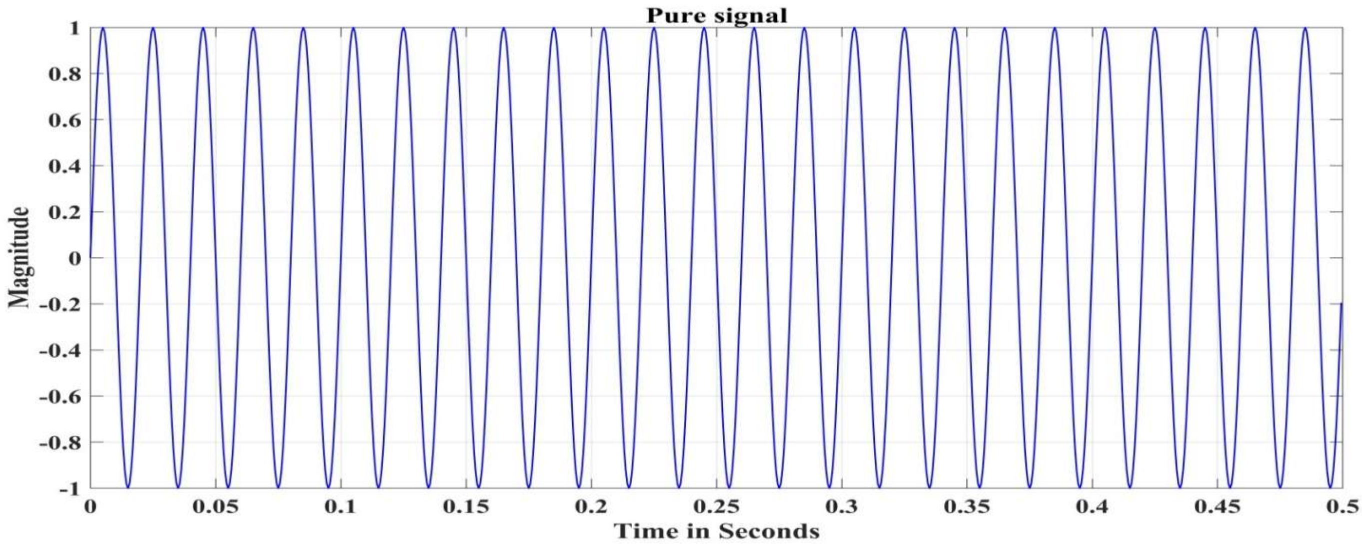


Figure 5.1(a) pure voltage signal

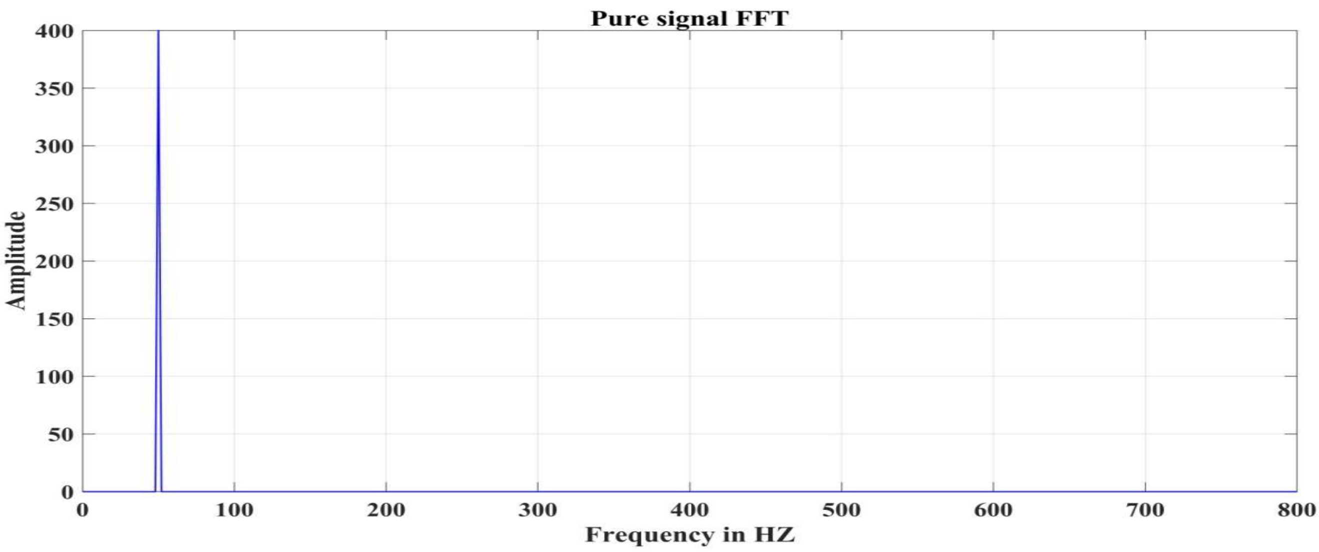


Figure 5.1(b) FFT of pure voltage signal

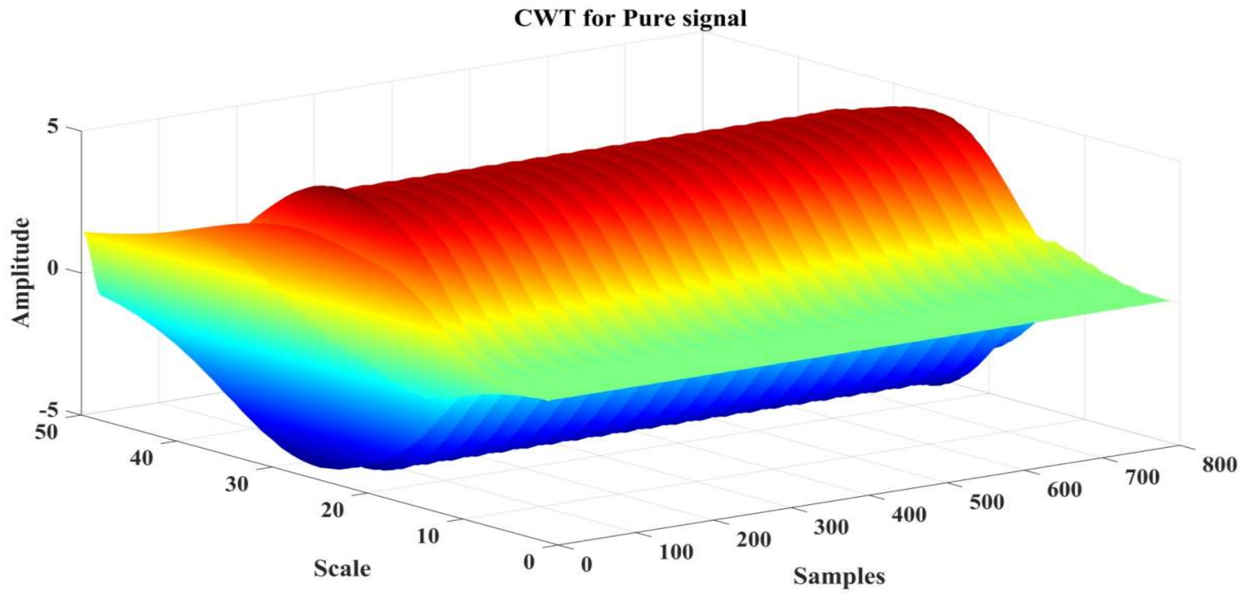


Figure 5.1(C) CWT of pure voltage signal

The FFT and CWT for the pure voltage signal are delineated in Fig. 5.1(b) and Fig. 5.1(c). It is seen from the Figures that, absence of PQD in the signal results in no disturbances observed from the above figures.

5.2. Voltage sag signal:

Fig. 5.2(a) shows voltage signal generated for 0.5 sec with 30% sag is simulated from 0.2 sec to 0.4 sec. The proposed FFT and DWT is obtained by the complex-valued analytic signal output of the input signal.

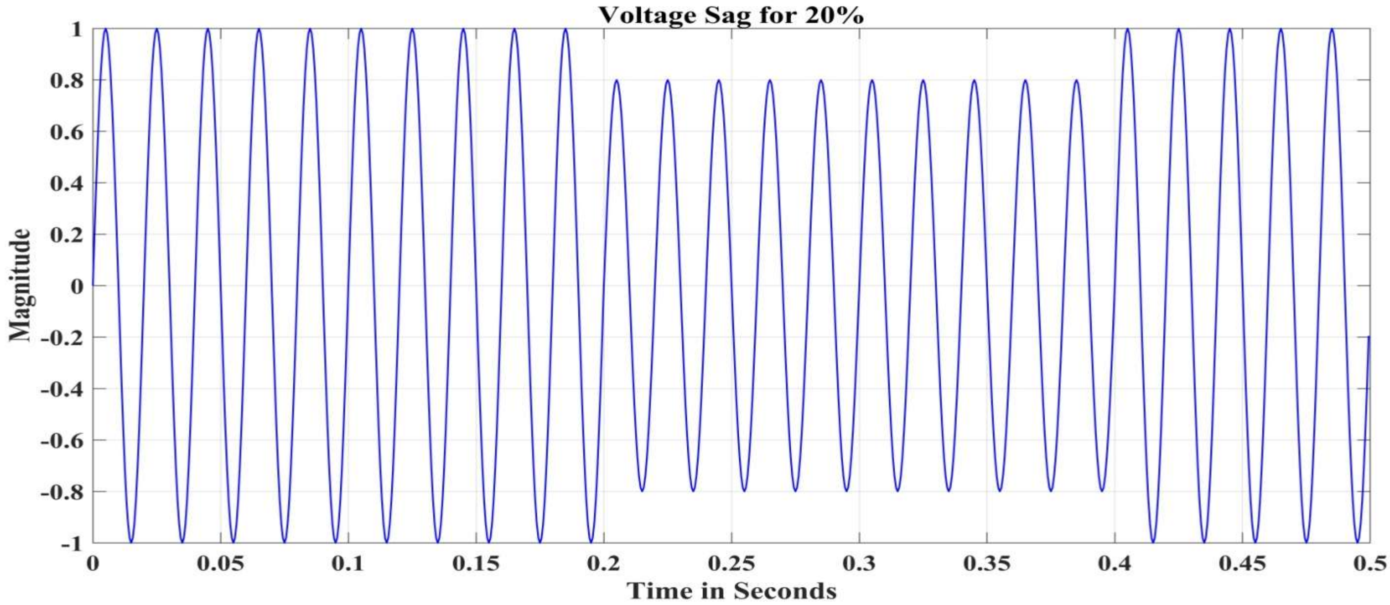


Figure 5.2(a) Voltage signal with 20% sag

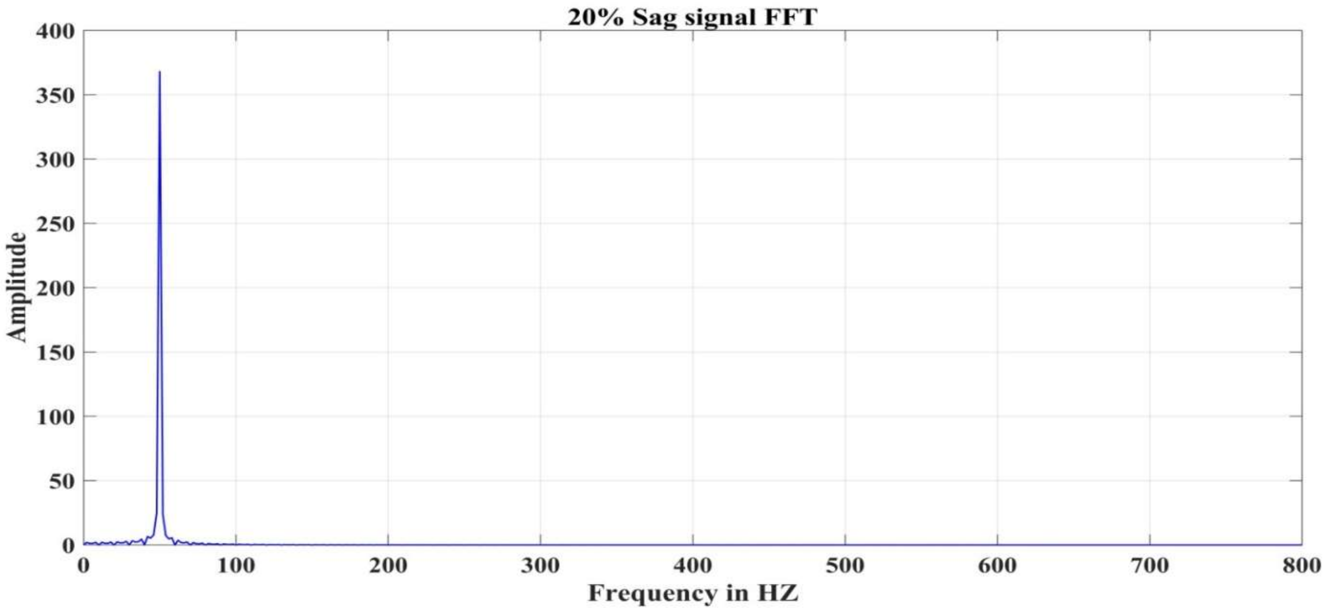


Figure 5.2(b) FFT of voltage sag signal

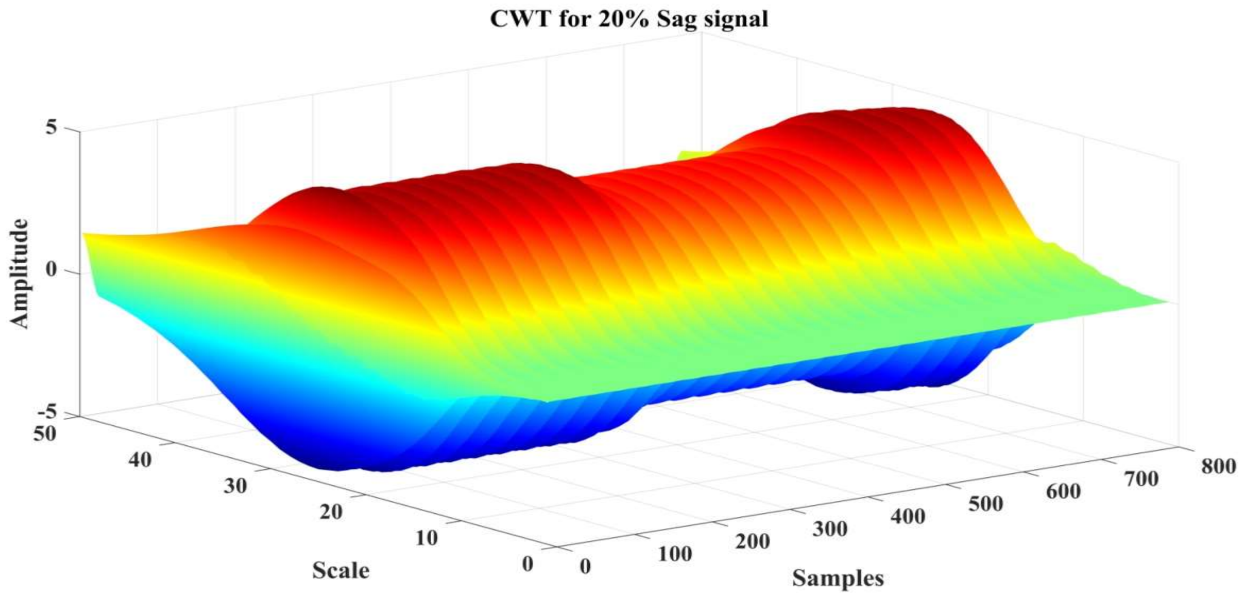
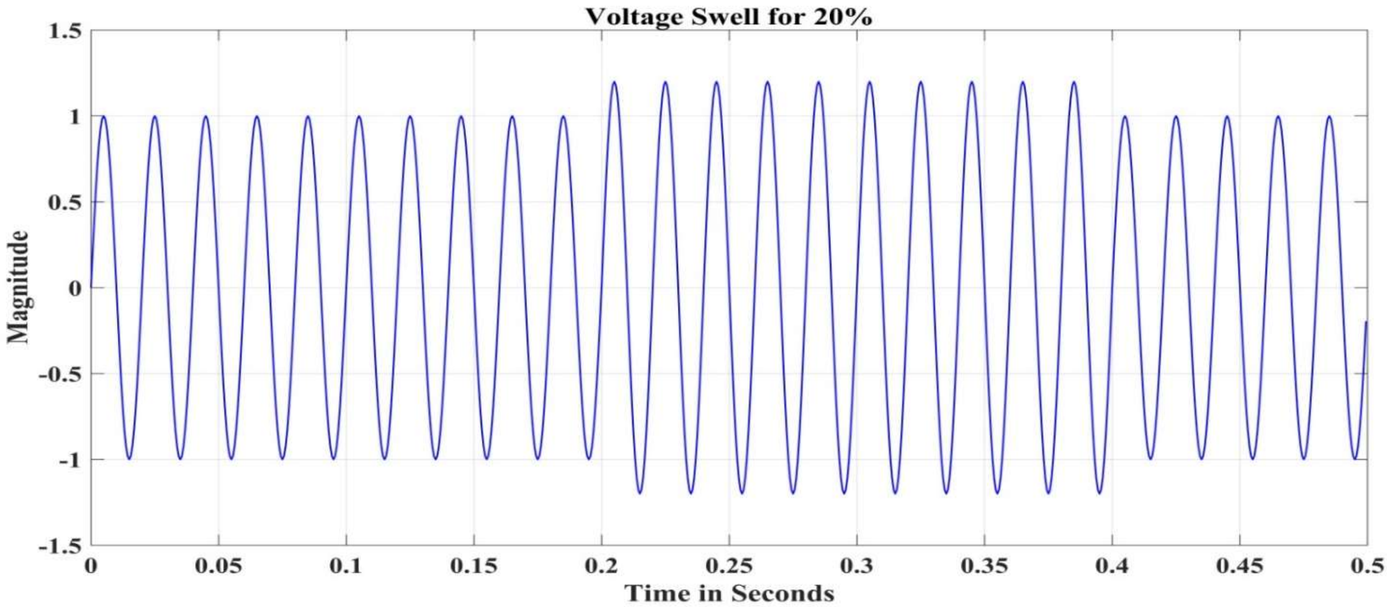


Figure 5.2(c) CWTof voltage sag signal

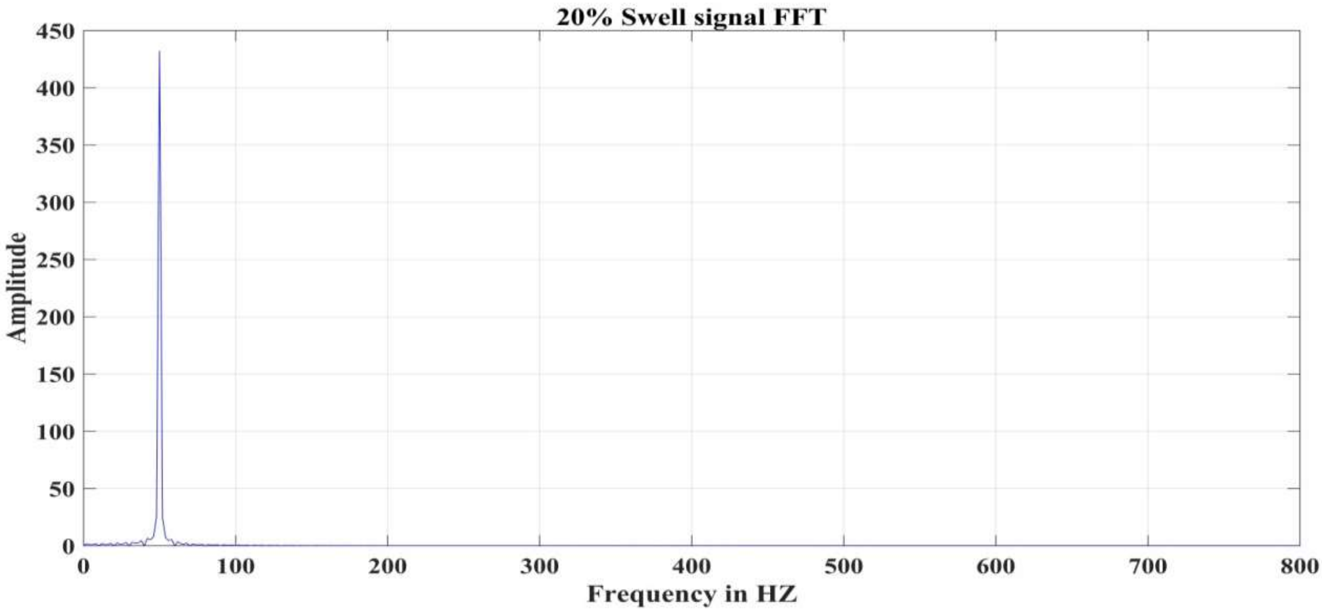
The FFT andCWT for the sag voltage signal are delineated in Fig. 5.2(b) and Fig. 5.2(c). It is seen from the Figures that, the sag disturbance is clearly observed from above techniques. In FFT the magnitude of the spike at 50Hz frequency have been decreased as compared to pure signal and we can observe a dip in the CWT which represents sag.

5.3. Voltage Swell signal:

Fig. 5.3(a) shows voltage signal generated for 0.5 sec with 30% swell is simulated from 0.2 sec to 0.4 sec. The proposed FFT and CWT is obtained by the complex-valued analytic signal output of the input signal.



5.3(a) Voltage signal with 20% swell



5.3(b) FFT Voltage signal with 20% swell

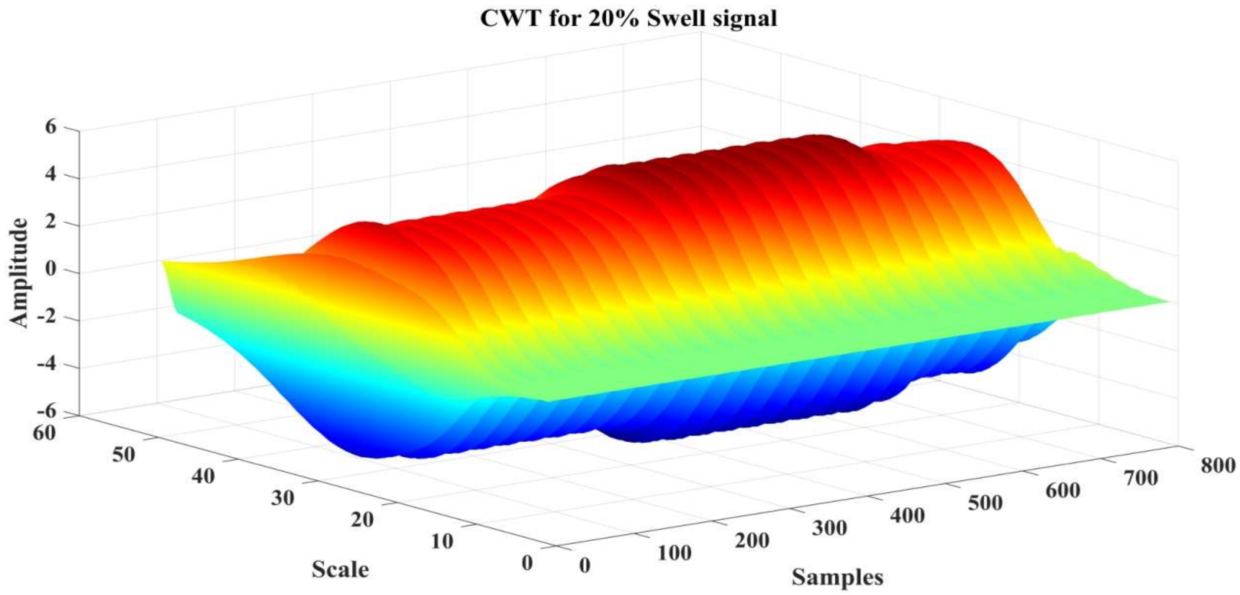


Figure 5.3(c) CWT of voltage swell signal

The FFT and CWT for the swell voltage signal are delineated in Fig. 5.3(b) and Fig. 5.3(c). It is seen from the Figures that, the swell disturbance is clearly observed from above techniques. In FFT the magnitude of the spike at 50Hz frequency have been increased as compared to pure signal and we can observe the uphill in the CWT which represents swell**.**

5.4. Voltage Interruption signal:

Fig. 5.4(a) shows the voltage signal generated for 0.5 sec and a voltage interrupt (instantaneous type) is simulated from 0.2 to 0.4 sec. The proposed FFT and CWT is obtained by the complex-valued analytic signal output of the input signal.

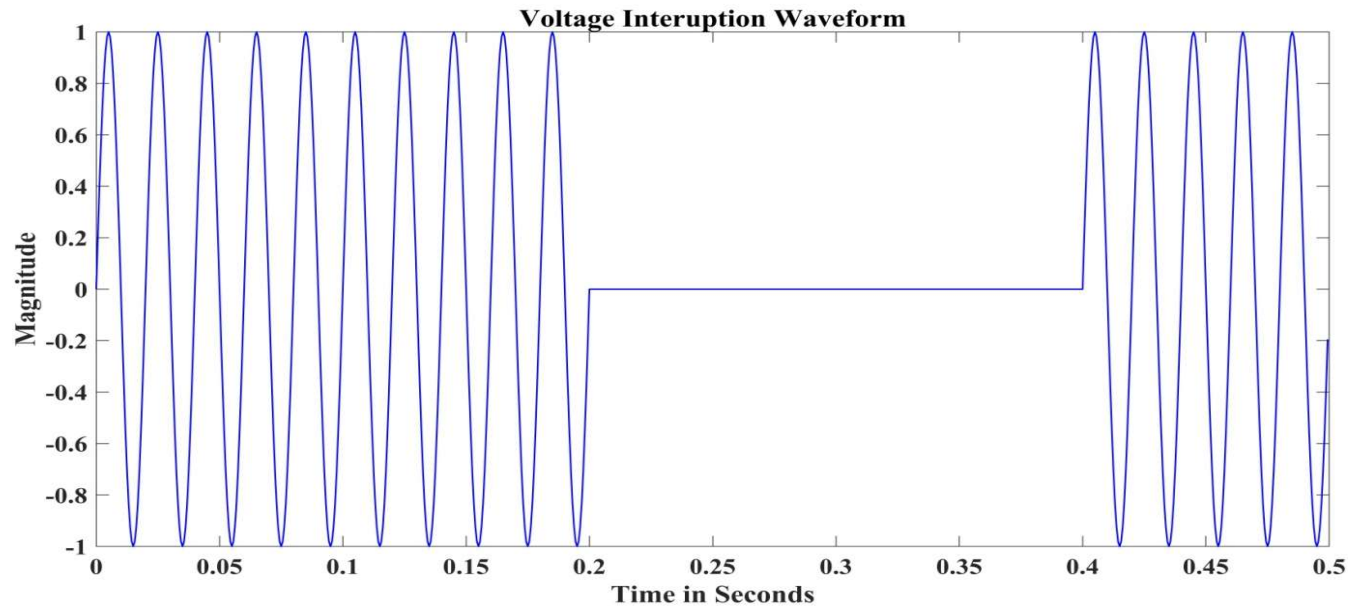


Figure 5.4(a) Voltage interruption signal

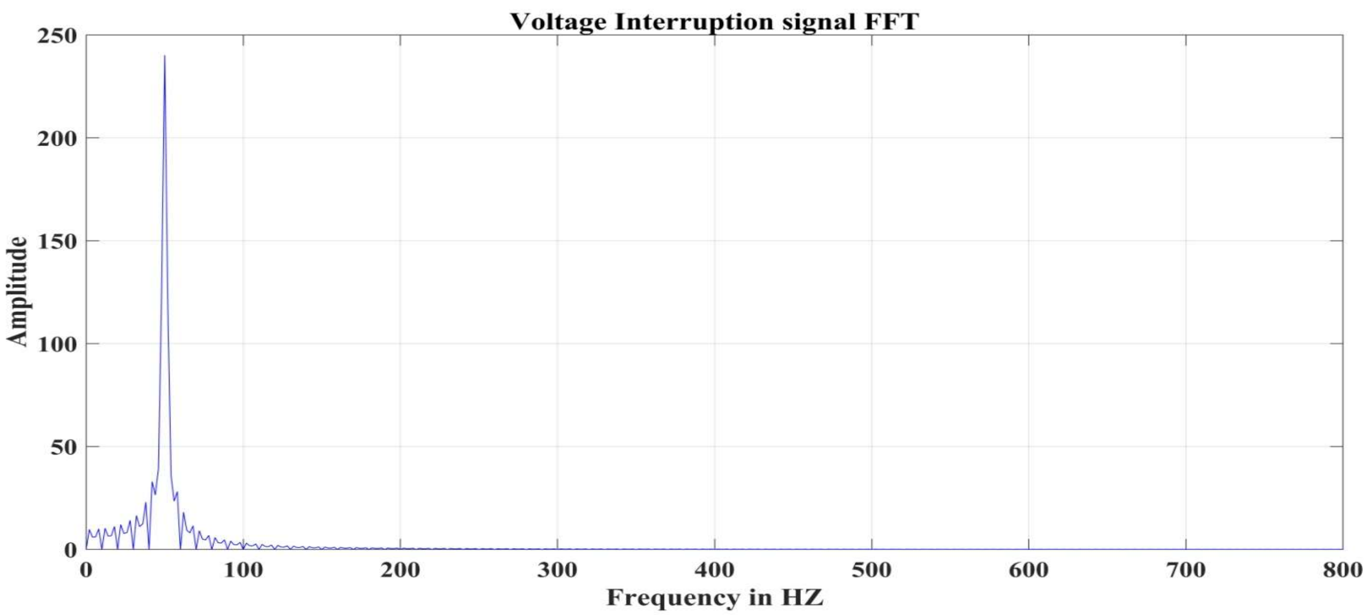


Figure 5.4(b) FFT of voltage interruption signal

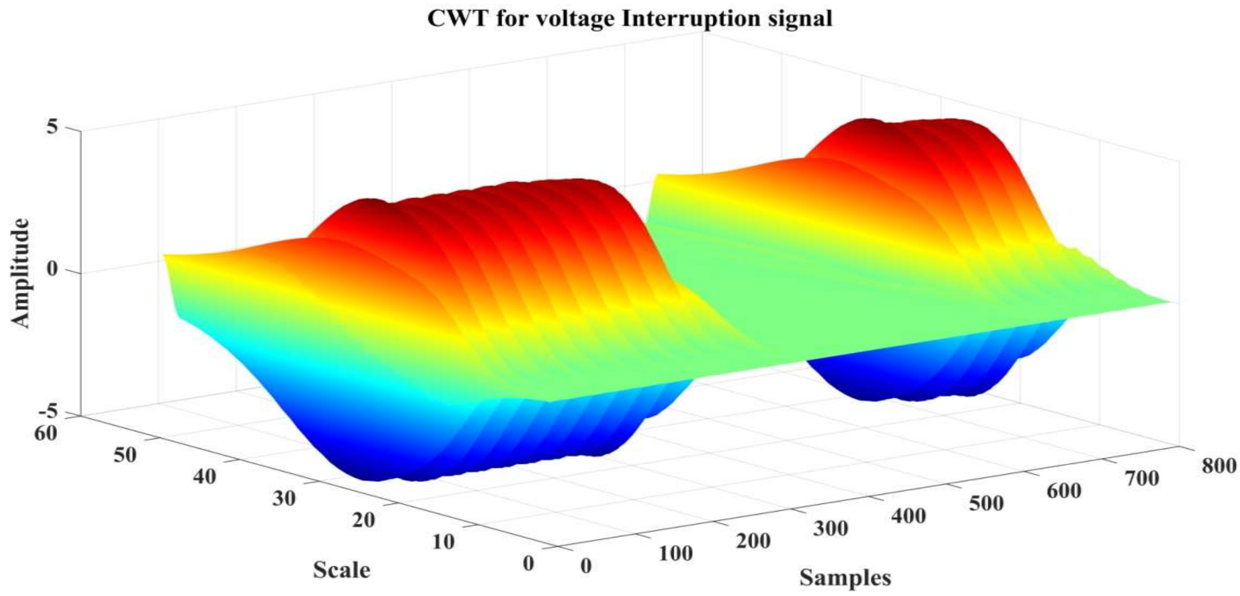


Figure 5.4(c) CWT of voltage interruption signal

The FFT and CWT for the voltage signal with interruption are delineated in Fig. 5.4(b) and Fig. 5.4(c). It is seen from the Figures that, the interruption disturbance is clearly observed from above techniques. In FFT the magnitude of the spike at 50Hz frequency have been decreased as compared to pure signal as well as sag signal and we can observe the flat in middle of the signal in CWT which represents interruption.

5.5. Transient signal:

A transient voltage is defined as, “a transient can be a unidirectional impulse of either polarity or a damped oscillatory wave with the first peak occurring in either polarity”. Repeatable transients are caused by operation of motors, switching reactive power devices, etc. Fig. 5.5(a) depicts the signal generated for 0.5 sec and a transient is simulated twice.

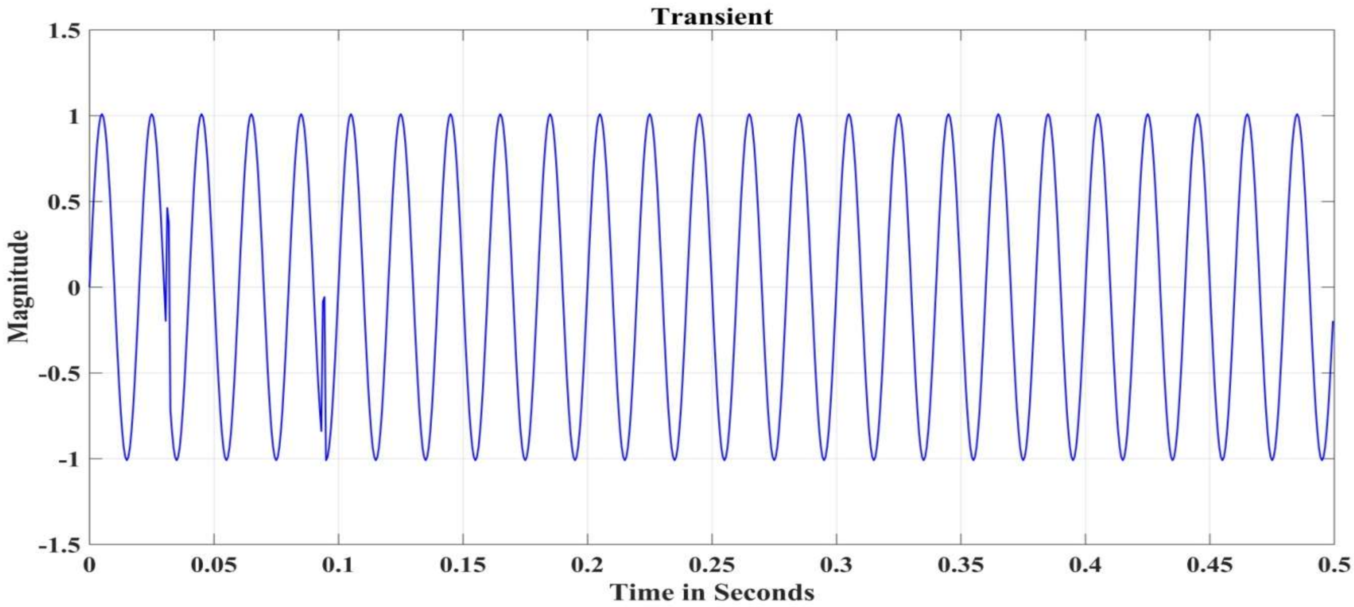


Figure 5.5(a) Voltage transient signal

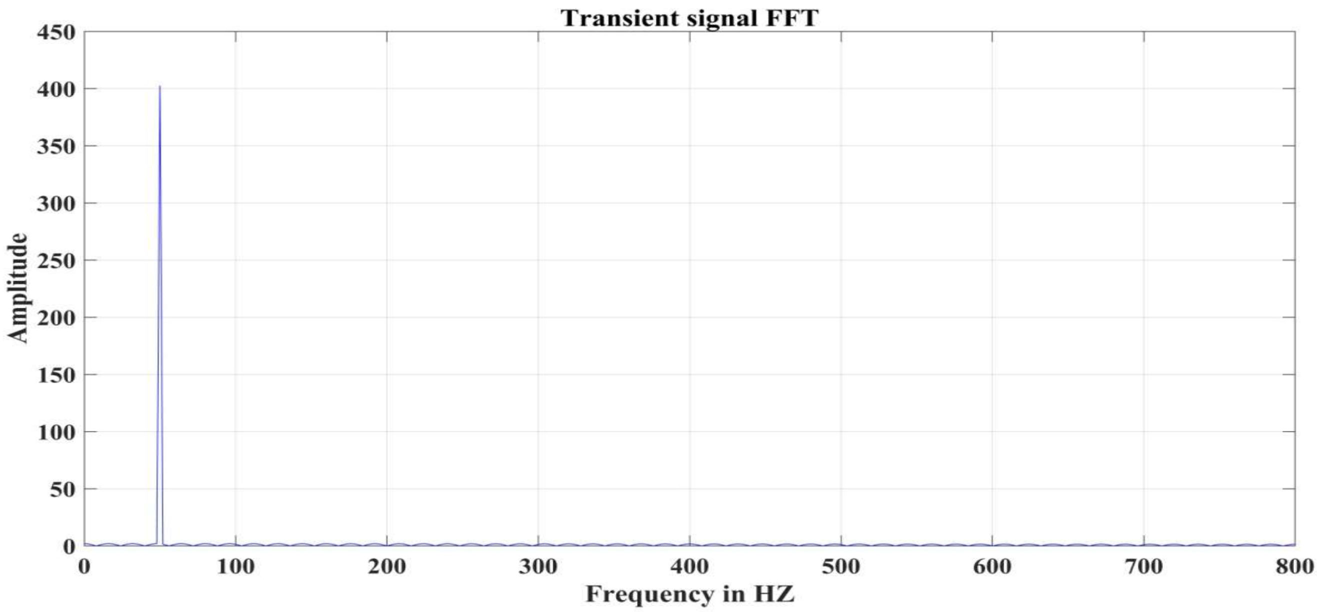


Figure 5.5(b) FFT of voltage Transient signal

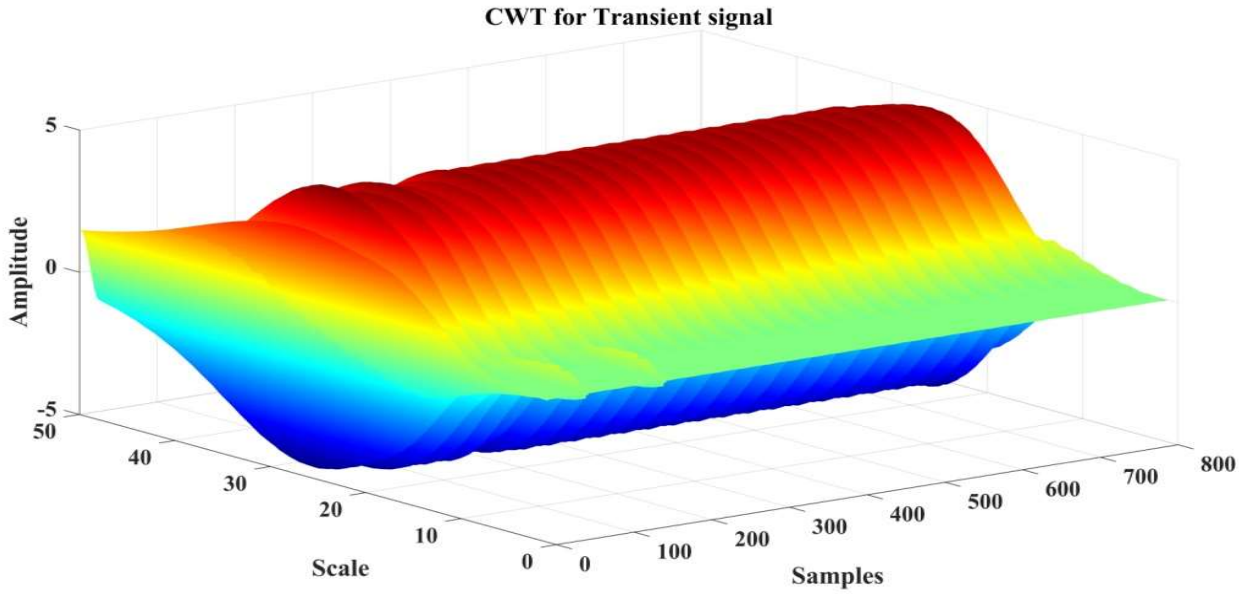


Figure 5.5(c) CWT of Transient voltage signal

The FFT and CWT for the Transient are delineated in Fig. 5.5(b) and Fig. 5.5(c). It is seen from the Figures that, the Transient disturbance is clearly observed from above techniques. In FFT the very small spikes along the signal is observed and we can observe the two uneven spikes in the signal in CWT which represents transient

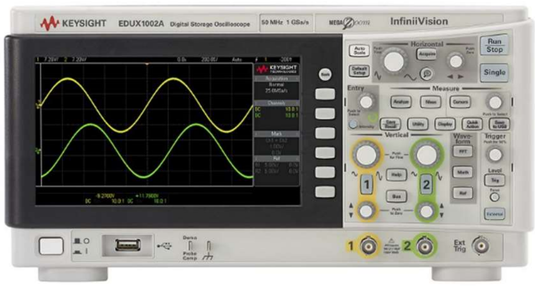
CHAPTER – 6

HARDWARE COMPONENTS

6.1. KeysightEDUX1002A Oscilloscope:

Keysight’sInfiniiVision 1000 X-Series oscilloscopes are engineered to give you quality, industry-proven technology at unbelievably low prices. Now it’s easy to get professional measurements and accessible expertise at your fingertips. Don’t settle for less – and test to impress.

- 50 to 100 MHz – See more signal detail with 50,000 wfms/sec update rate
- Have confidence in your measurements with Keysight-custom technology that leverages more than 60 years of oscilloscope expertise
- Test quickly and easily with a simple, intuitive user interface and built-in help and training signals
- Get professional-level functionality with industry-leading software analysis and 6-in-1instrument integration



6.1.2. Features of EDUX10002A:

Superior measurements: The EDUX10002A incorporates Keysight's MegaZoom IV custom ASIC technology, enabling it to deliver up to 50,000 waveforms per second. This high speed provides enhanced visibility of glitches and anomalies that may be overlooked by other oscilloscopes in its class.

Automatic measurements: With the EDUX10002A, accessing and analyzing signal parameters is effortless. The oscilloscope offers easy access to 24 typical oscilloscope measurements, allowing users to quickly analyze signals and make informed decisions. Real-time display of up to four individual measurements with continuous updates on the screen facilitates efficient signal analysis.

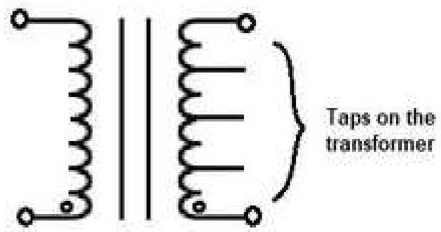
USB save: Documentation and data management are simplified with the oscilloscope's USB save feature. Users can easily save screenshots, binary data, oscilloscope setups, reference waveforms, and mask files to the internal memory or an external USB storage device. This enables quick retrieval and convenient sharing of data for reporting and analysis purposes.

Connectivity compatibility: The EDUX10002A is equipped with built-in USB host and USB device ports, ensuring seamless PC connectivity. Users can leverage the power of BenchVue Software, specifically the BV0004B BenchVue Oscilloscope app, to control and visualize the oscilloscope and perform multiple measurements simultaneously. The software also streamlines automation of test sequences and allows for easy export of measurement data to popular software tools such as Excel, Word, and MATLAB.

5. **Simplified testing with BenchVue software:** The inclusion of BenchVue software further enhances the testing experience. Users can efficiently control and visualize the EDUX10002A oscilloscope, create automated test sequences, and export measurement data with ease. This software streamlines workflows and improves overall testing efficiency.

6.2. Multi turn transformer:

Multiple Winding Transformers are a type of transformer that features one primary winding and two or more secondary windings. They offer the advantage of having additional windings on either the primary or secondary side. These transformers operate on the same principle as ordinary transformers, with calculations for primary and secondary voltages, currents, and turns ratios performed in the same manner. The key difference lies in paying attention to the voltage polarities of each coil winding and using the dot convention to mark the positive or negative polarity of the winding when connecting them together.



In this project, a single-phase step-down transformer with an input of 230V and a frequency of 50 Hz has been utilized. The transformer provides multiple outputs tapped at 3V, 6V, 12V, 15V, and 18V. It has a current rating of 3A, making it suitable for generating various power quality disturbances.

6.3. Voltage Probe:

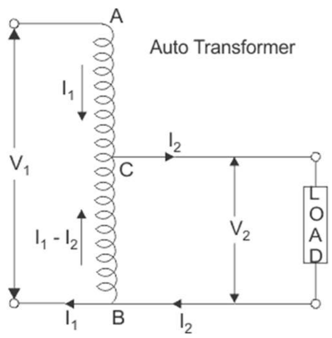
In this project, a voltage probe with a 10:1 ratio is utilized to represent the voltage signal on the oscilloscope. An oscilloscope probe is an essential tool that enables the measurement and display of waveform voltages at different terminals or wires. It is designed with a fine needle point that allows for precise probing without the risk of shorting out to other pins, wires, or grounded surfaces.

Oscilloscope probes are often equipped with various accessories to cater to specific situations. For example, a commonly used accessory is the hook tip, which securely clips onto the wire or terminal of interest and remains in place during measurements.The 10:1 designation of the probe indicates that it attenuates the signal by a factor of 10. This means that when a 10-volt signal is measured, it will appear as 100 volts at the input of the oscilloscope.

6.4. Auto transformer:

An autotransformer is an electrical transformer that features a single winding. The term "auto" in autotransformer refers to the single coil acting alone, derived from the Greek word meaning "self." It does not imply any automatic mechanism. While an autotransformer resembles a two-winding transformer, it differs in how the primary and secondary windings are interconnected.

In an autotransformer, a single winding serves as both the primary and secondary winding, unlike a two-winding transformer that employs separate windings for each purpose. The circuit diagram below illustrates the configuration of an autotransformer.



The winding labeled AB, which consists of N1 turns, functions as the primary winding. This winding is tapped at point 'C', and the portion BC serves as the secondary winding.To implement this project, an autotransformer is utilized with an input voltage of 230 volts on the primary side. The output voltage is variable, ranging from 0 to 240 volts, allowing for adjustable power supply.

CHAPTER-7
TEST BENCH SETUP

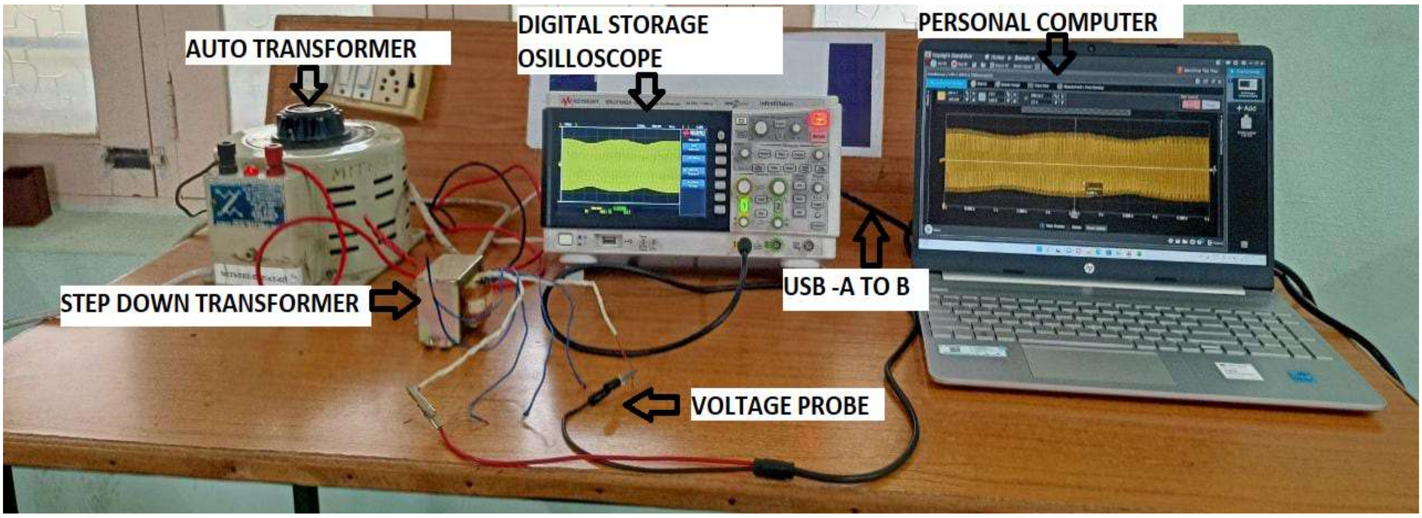


Figure 7.1 Test Bench Setup

In the process of acquiring real-time signals, the initial step involved obtaining the signal directly from the power supply. This signal was then subjected to an autotransformer operating at 230V and 50 Hz, followed by connection to a step-down transformer to reduce the voltage level. To investigate the effects of power quality disturbances, deliberate variations were introduced into the system by short-circuiting specific components. The setup incorporated tapping and autotransformer capabilities, allowing precise control and adjustment of the voltage output from the main power supply. By connecting a signal source to the transformer outputs, various waveforms were generated, inducing power quality disturbances of interest.

To capture and analyze the resulting signals, a bench view oscilloscope connected to a computer was employed. The oscilloscope software was configured with a timebase of 5 seconds, aligning with the voltage range of the autotransformer, ensuring accurate measurements. This configuration facilitated the acquisition of real-time signals comprising 2000 samples, which were subsequently saved in Excel or CSV format for comprehensive analysis and manipulation. To extract further insights from the acquired data, advanced analysis techniques such as the Fast Fourier Transform (FFT) and Continuous Wavelet Transform (CWT) were applied. The FFT analysis provided an examination of the signal's frequency content, enabling the identification of harmonics and frequency components present. This spectral analysis facilitated an understanding of the signal's characteristics and the detection of any abnormalities or distortions.

In addition, the CWT analysis offered a time-frequency representation of the signals, enabling an investigation of frequency variations over time. This technique proved valuable in identifying transient events and associated frequency components, thereby enhancing the understanding of signal behavior. By employing these advanced analysis techniques, the aim was to extract valuable information from the acquired data, gain deeper insights into power quality disturbances, and assess their impact on the real-time signals. This comprehensive analysis approach contributed to an improved understanding of the observed phenomena and provided valuable insights for future research and the development of mitigation strategies.

CHAPTER- 8

HARDWARE RESULTS

A test bed was created to experimentally validate the role of power signal identification in detecting power quality disturbances (PQD). The experiment was conducted on a 230V, 50 Hz, single-phase step-down transformer with outputs tapped at 3V, 6V, 12V, 15V, and 18V, with a current rating of 3A. The acquired signals were captured using a 10:1 voltage probe, which was connected to Edux1002A. The signals were acquired at a sampling frequency of 2kHz and visualized in real-time on a laptop screen using Keysight Technologies Software tool.

To analyze the PQD, the procured signals were processed using two techniques: Fast Fourier Transform and Continuous Wavelet Transform based Signal Processing. These techniques were implemented using MATLAB R2023b and adhered to the IEEE Std. 1159-1995 standard for power quality analysis.

The Fast Fourier Transform was used to convert the time-domain signals into the frequency-domain, allowing for the identification of the frequency components present in the signal. The output of the FFT was a graph of frequency versus magnitude, which is called a frequency spectrum or power spectrum. By analyzing the power spectrum, it was possible to identify the presence of PQD and determine their frequency and magnitude.

The Continuous Wavelet Transform was used to analyze the PQD events in the time-frequency domain. This technique allowed for the identification of the exact time and frequency location of the PQD events, providing more detailed information about their characteristics.

Overall, the experimental setup and data processing techniques used in this study provided an effective means of detecting and analyzing PQD in power systems. The results obtained from this study can be used to improve power quality monitoring and maintenance in the future, ultimately leading to more reliable and efficient power systems.

8.1. Normalvoltage signal:

Fig. 8.1(a) and Fig. 8.1(b) show snapshot and power signal output from the secondary of a transformer for the duration of 5sec withrms of 18 volts. The proposed FFT and CWT is obtained by the complex-valued analytic signal output of the input signal.

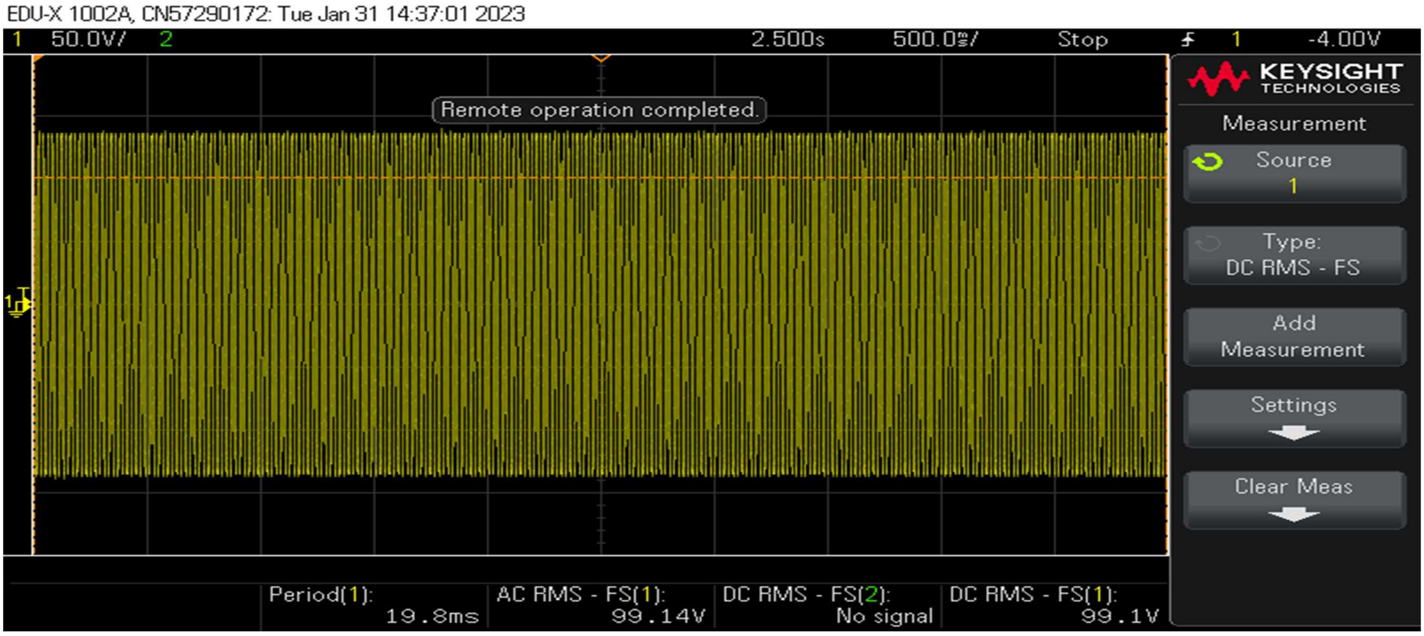


Figure 8.1(a) Normal voltage – Snapshot

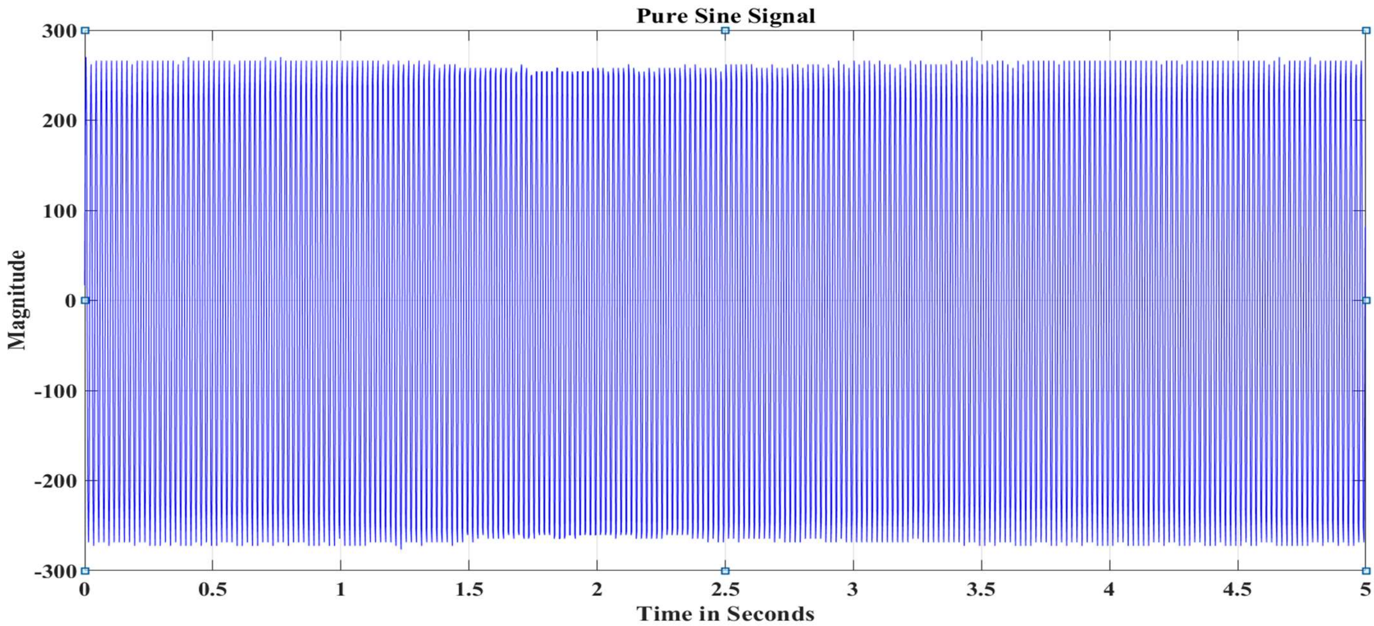


Figure 8.1(b) Normal voltage – signal

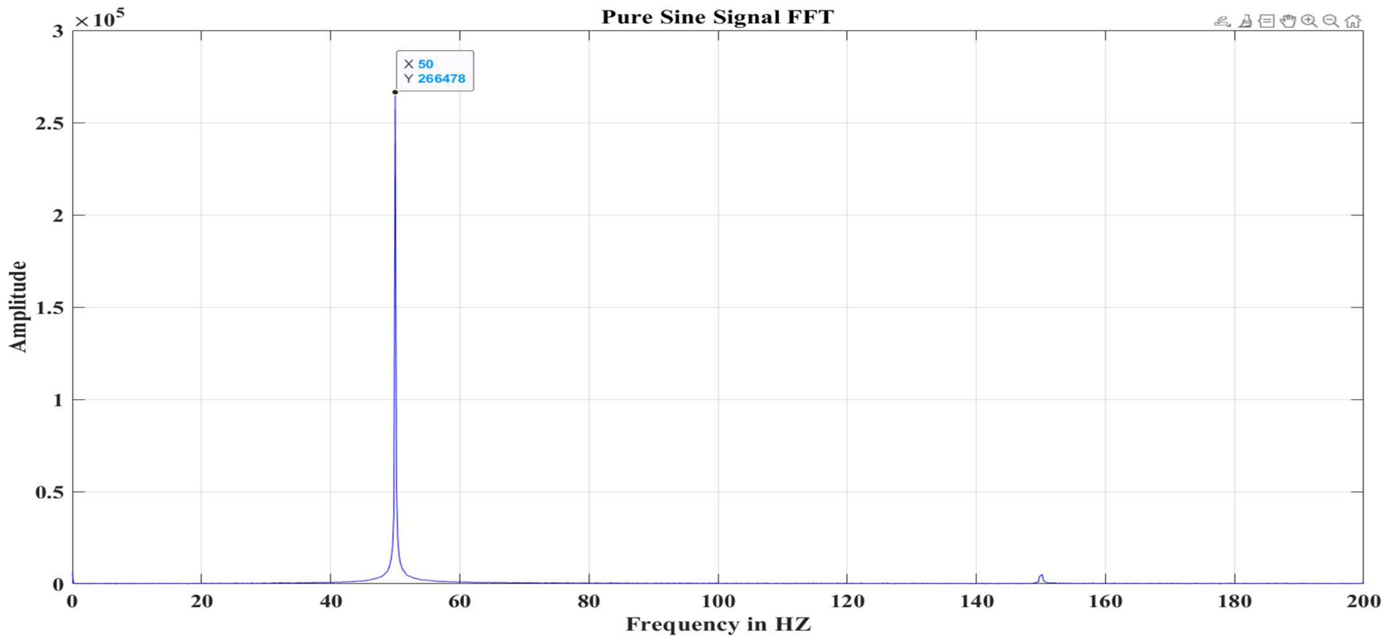


Figure 8.1(c) FFT of Normal voltage signal

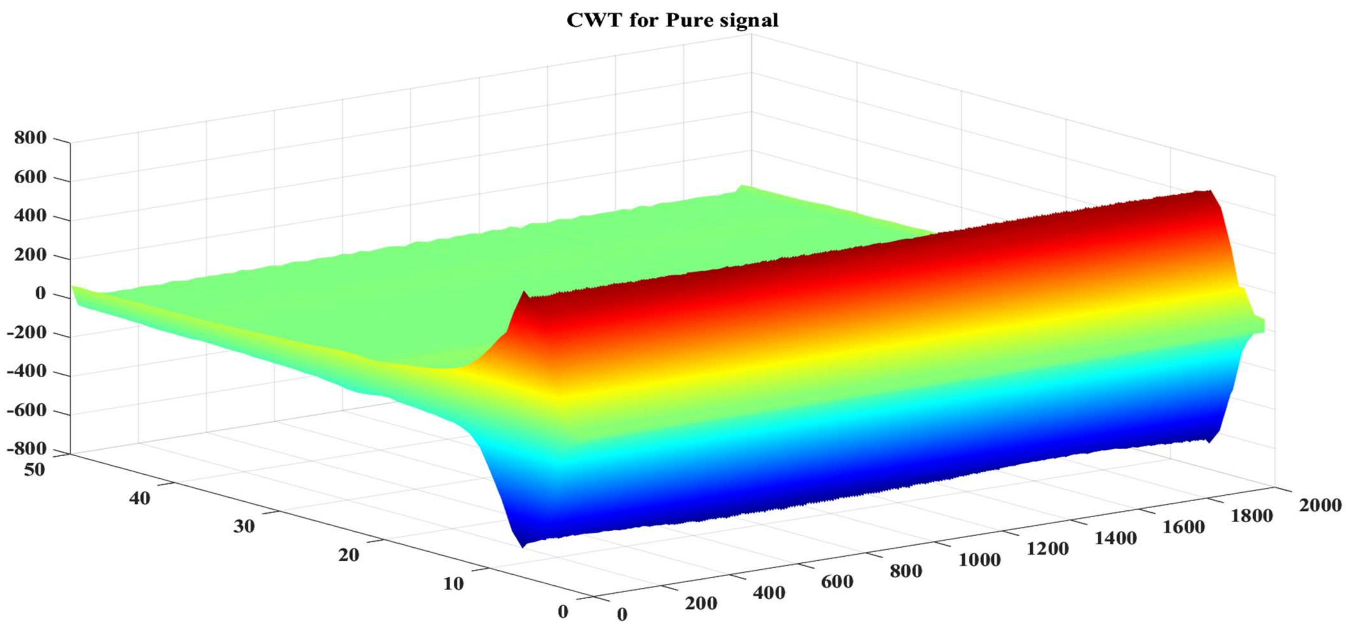


Figure 8.1(d) CWT of Normal voltage signal – 3D view

The FFT and CWT for the pure voltage signal are delineated in Fig. 8.1(c) and Fig. 8.1(d). It is seen from the Figures that, absence of PQD in the signal results in no disturbances observed from the above figures. The real-time pure voltage signal analyzed through FFT and CWT provides valuable insights into the frequency and time-frequency characteristics of the signal, aiding in the identification of any potential power quality disturbances.

8.2. Voltage Sag

Fig. 8.2(a) and Fig. 8.2(b) show snapshot and voltage signal output from the secondary of a transformer for a duration of 5 seconds, with a root-mean-square (rms) value of 18 volts, and 20% sag is observed during 1.9 to 3.3 sec.The complex-valued analytic signal output of the input signal is used to obtain the proposed FFT and CWT, as shown in Fig. 8.2(c) and Fig. 8.2(d), respectively.

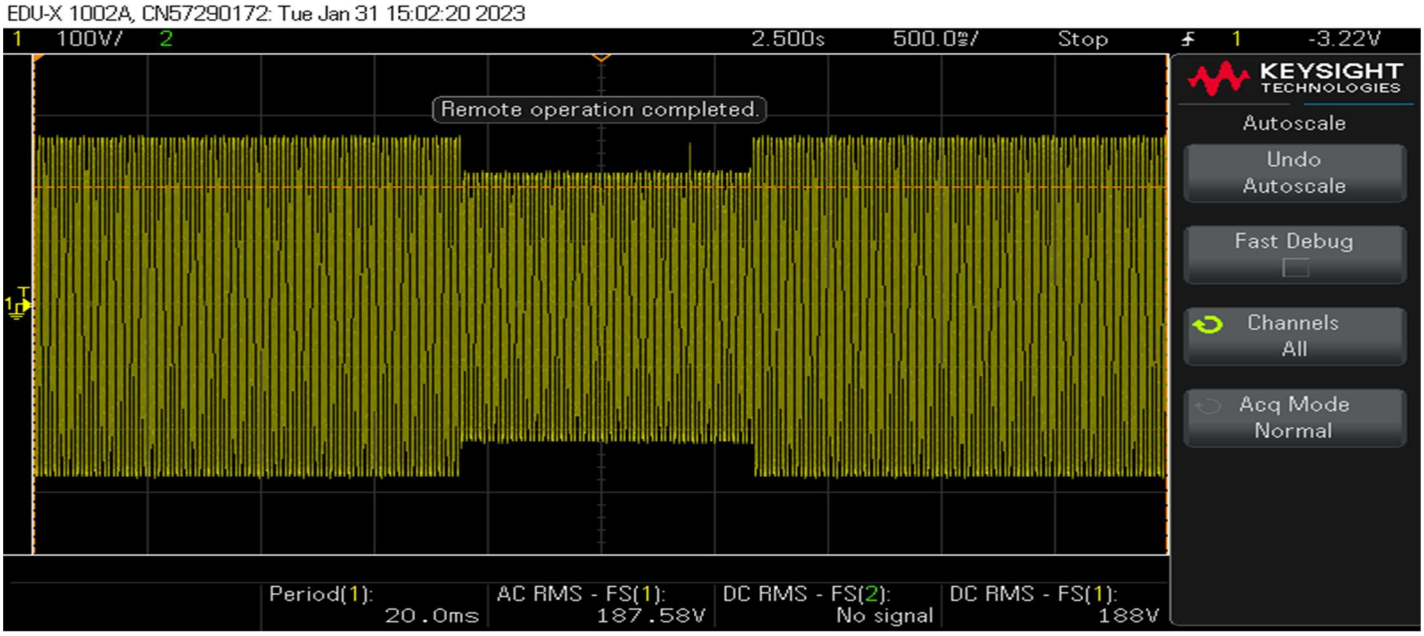


Figure 8.2(a) Voltage with sag – Snapshot

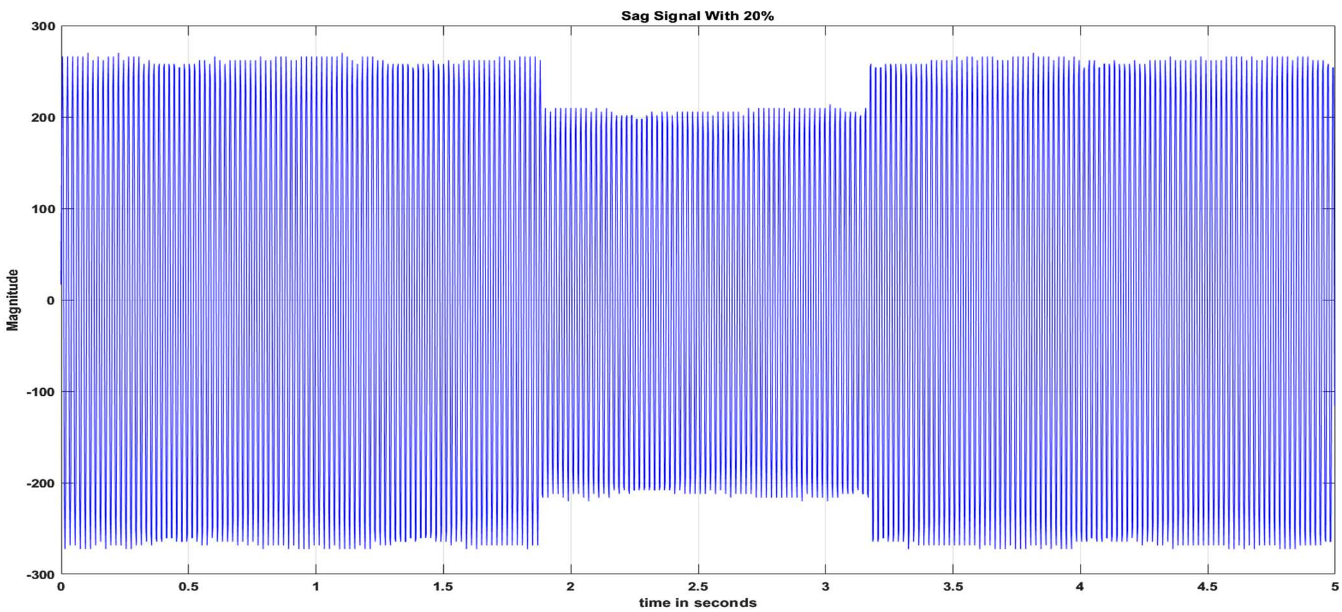


Figure 8.2(b) Voltage with sag signal

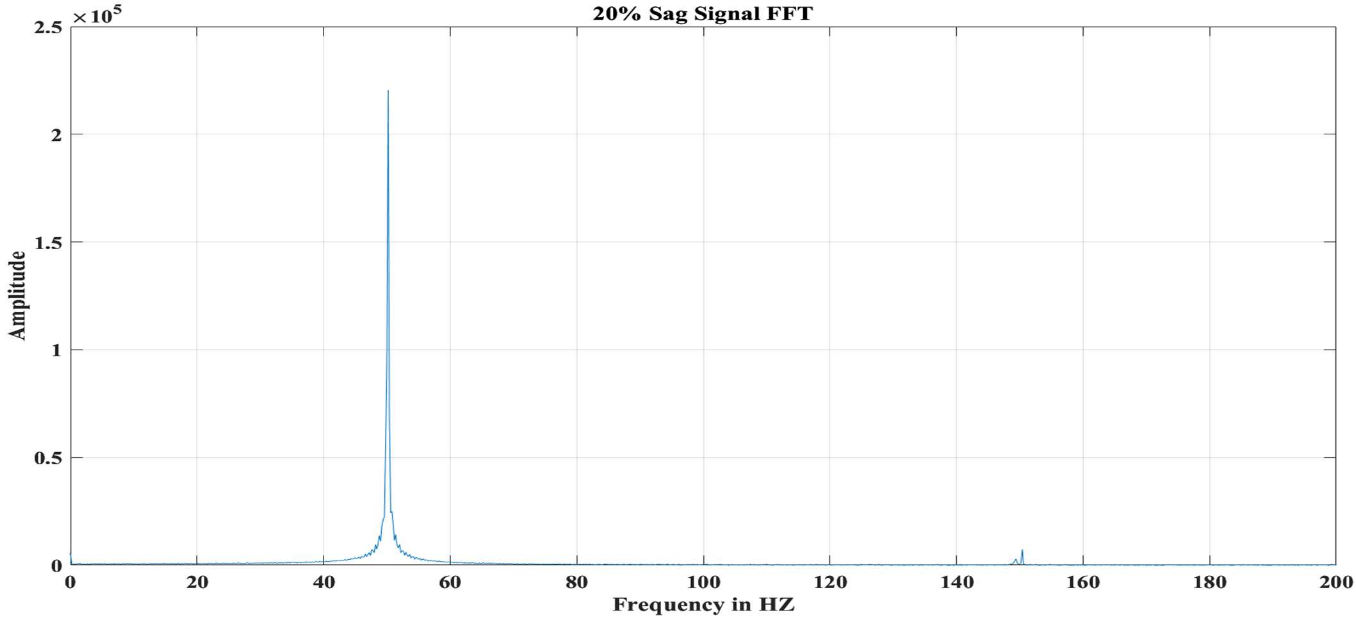


Figure 8.2(c) FFT of voltage sag signal

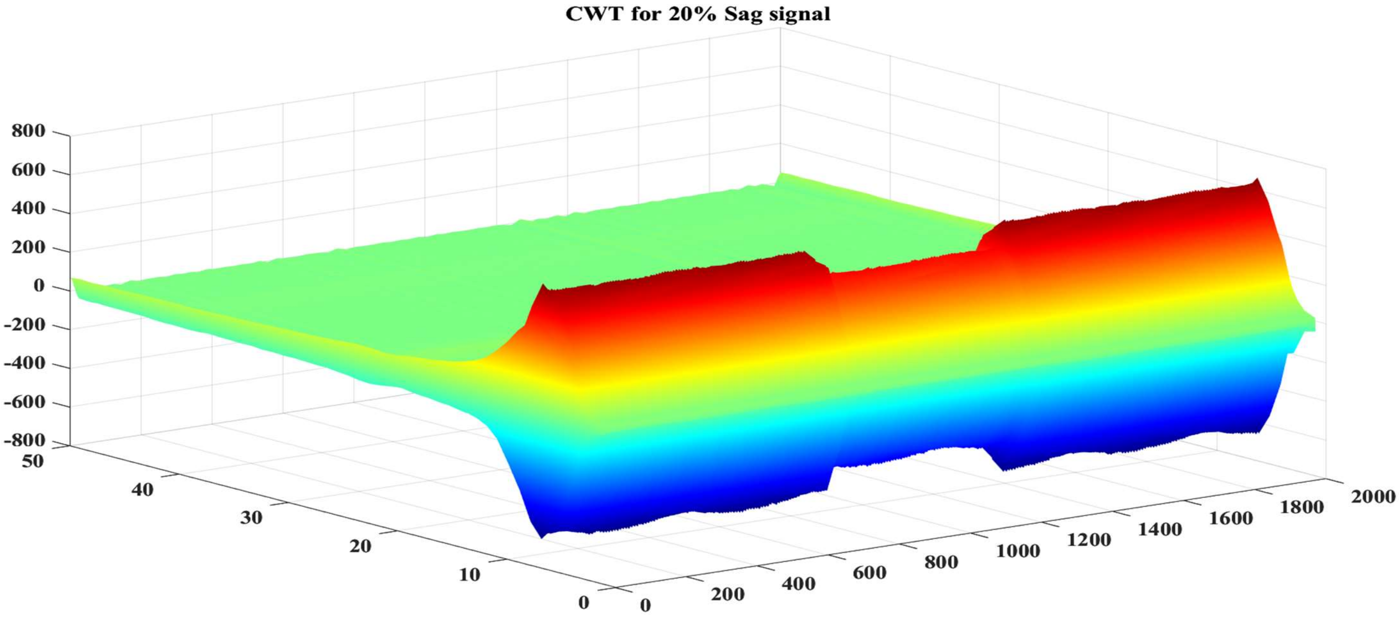


Figure 8.2(d) FFT of voltage sag signal

The voltage sag disturbance is clearly visible in the FFT, where the magnitude of the spike at the fundamental frequency (50 Hz) is reduced as compared to the pure signal, indicating a reduction in the signal strength. Additionally, a dip in the CWT is observed at the time when the voltage sag occurs, highlighting the time-frequency characteristics of the signal.

Real-time analysis of voltage signals using FFT and CWT can provide valuable insights into power quality disturbances, aiding in the early detection and diagnosis of potential issues.

8.3. Voltage Swell

Fig. 8.3(a) and Fig. 8.3(b) display the snapshot and voltage signal output from the secondary of a transformer for a duration of 5 seconds, with a root-mean-square (rms) value of 14 volts and a voltage swell of 20% at 2.1 seconds. The complex-valued analytic signal output of the input signal is utilized to obtain the proposed FFT and CWT, as shown in Fig. 8.3(c) and Fig. 8.3(d), respectively.

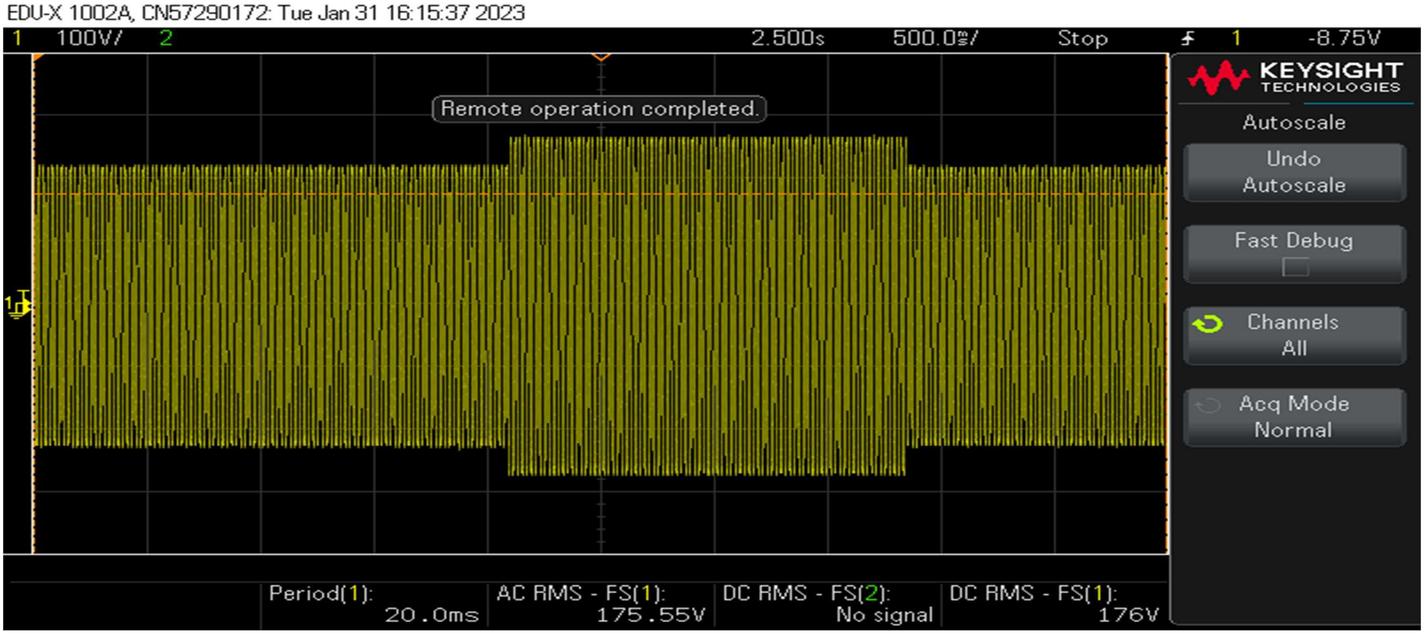


Figure 8.3(a) Voltage with swell – Snapshot

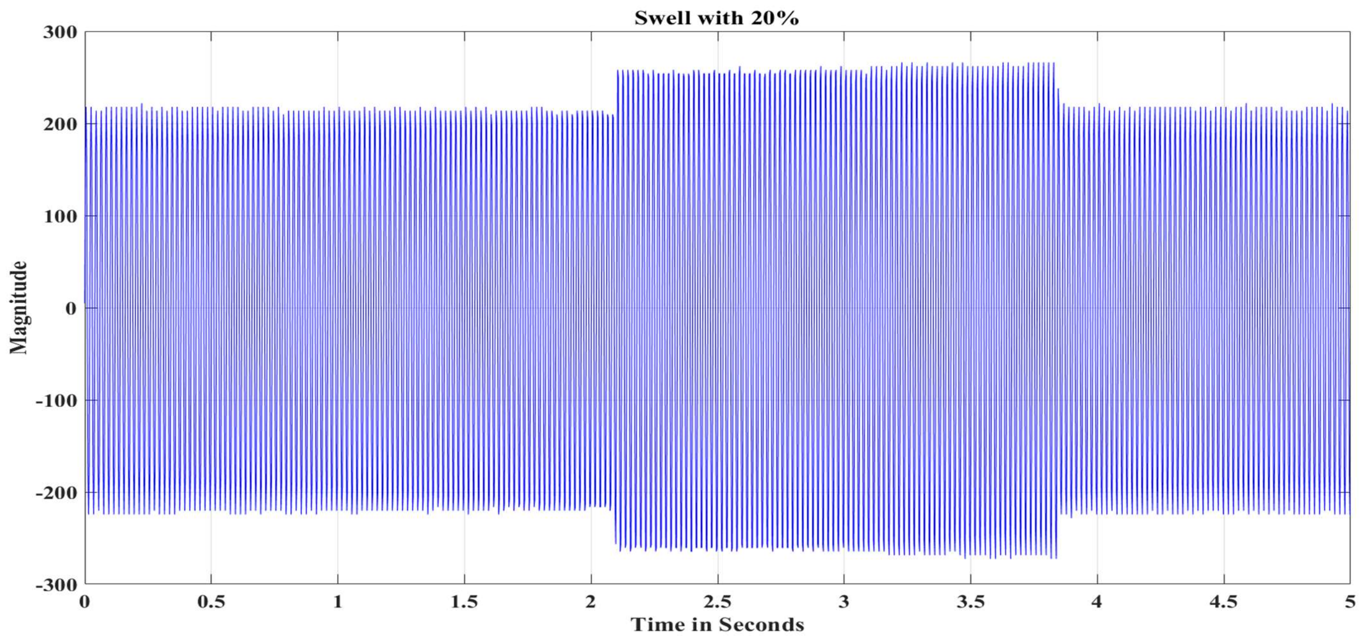


Figure 8.3(b) Voltage with swell signal

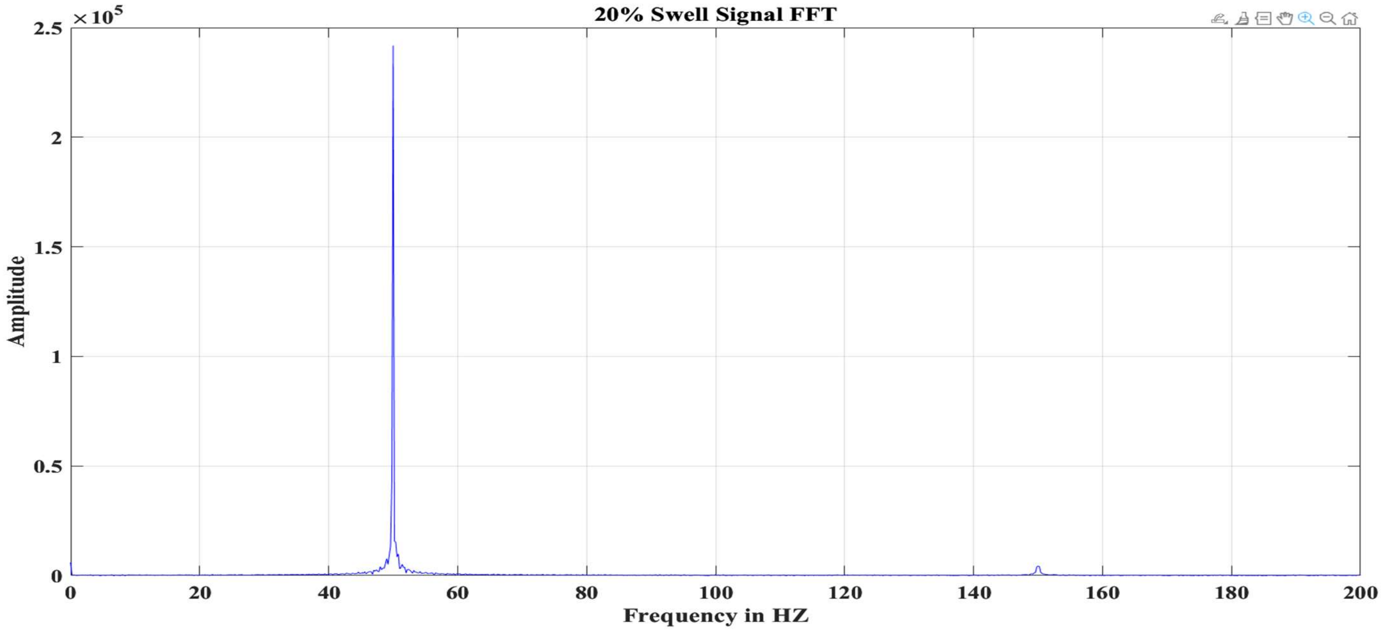


Figure 8.3(c) FFT of voltage swell signal

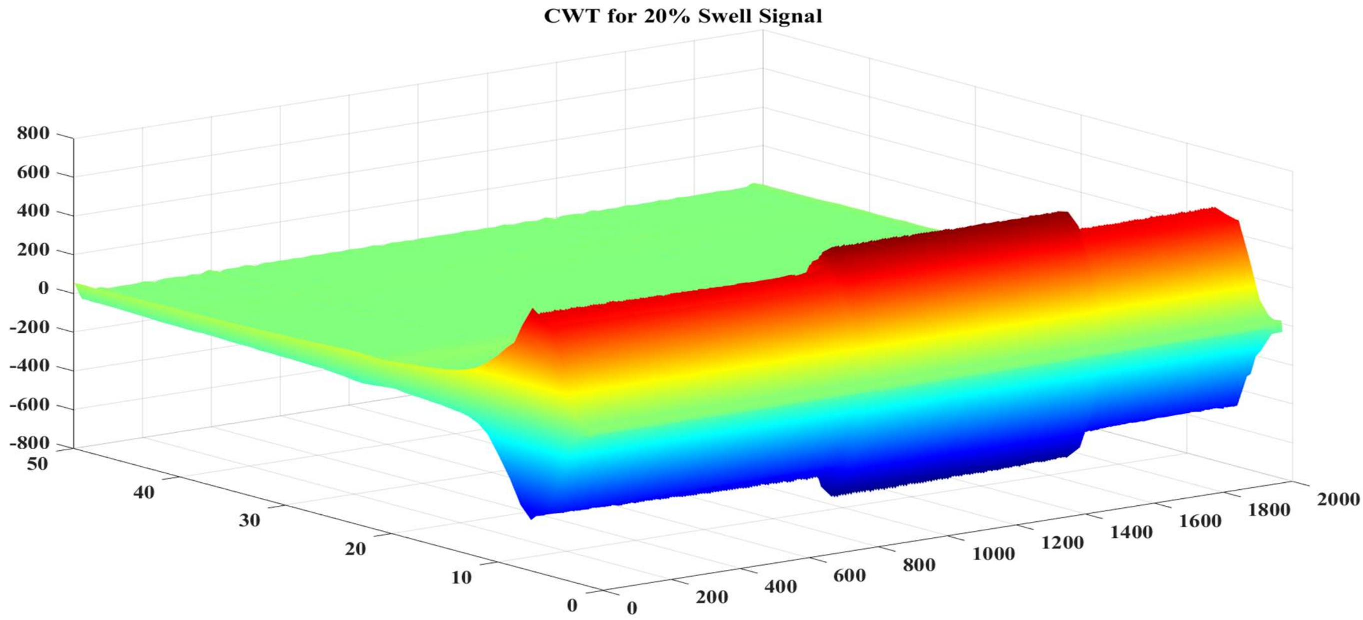


Figure 8.3(d) CWT of voltage swell signal

The voltage swell disturbance is evident in the FFT, where the magnitude of the spike at the fundamental frequency (50 Hz) is increased compared to the pure signal, indicating an increase in signal strength. A uphill in the CWT is observed at the time when the voltage swell occurs, highlighting the time-frequency characteristics of the signal.

Real-time analysis of voltage signals using FFT and CWT can provide valuable insights into power quality disturbances, aiding in the early detection and diagnosis of potential issues.

8.4.Voltage Interruption:

Fig. 8.4(a) and Fig. 8.4(b) show a snapshot and voltage signal output from the secondary of a transformer for a duration of 1 second, with a root-mean-square (rms) value of 18 volts. An interruption was created in the signal, causing a drop in voltage from 18 volts to 0 volts during the period of 2 to 3 seconds. The complex-valued analytic signal output of the input signal is used to obtain the proposed FFT and CWT, as shown in Fig. 8.4(c) and Fig. 8.4(d), respectively.

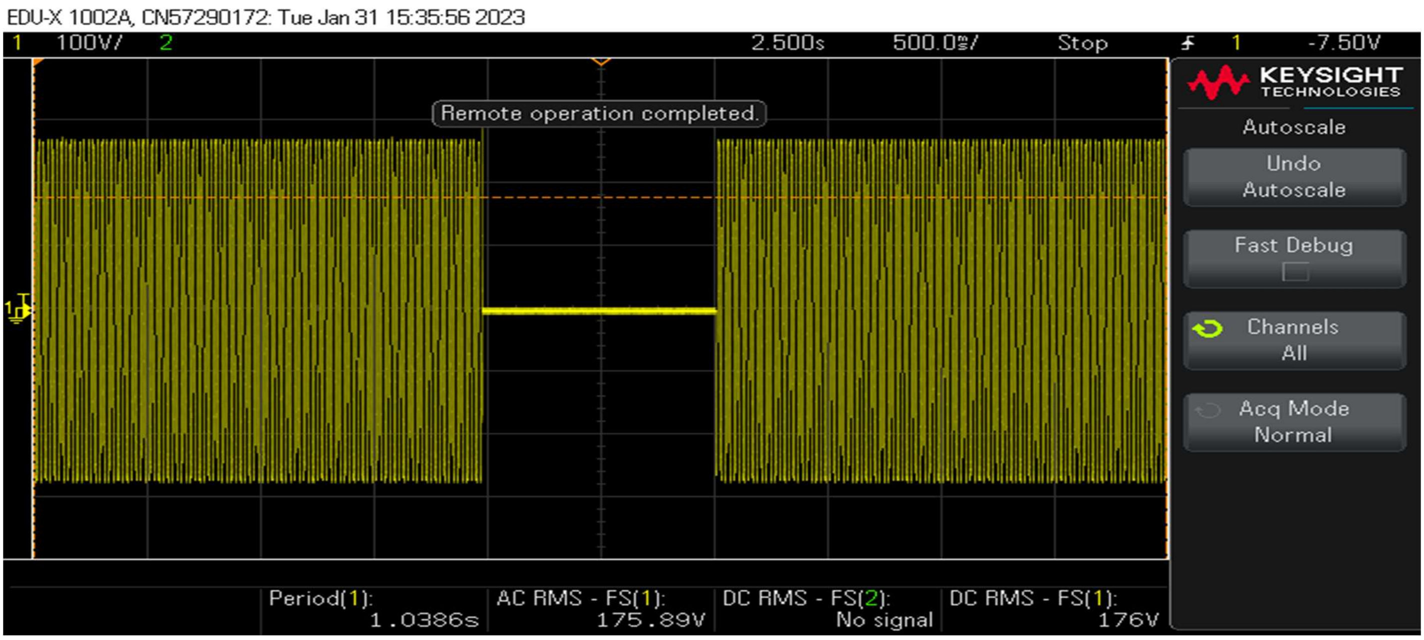


Figure 8.4(a) Voltage with interruption – Snapshot

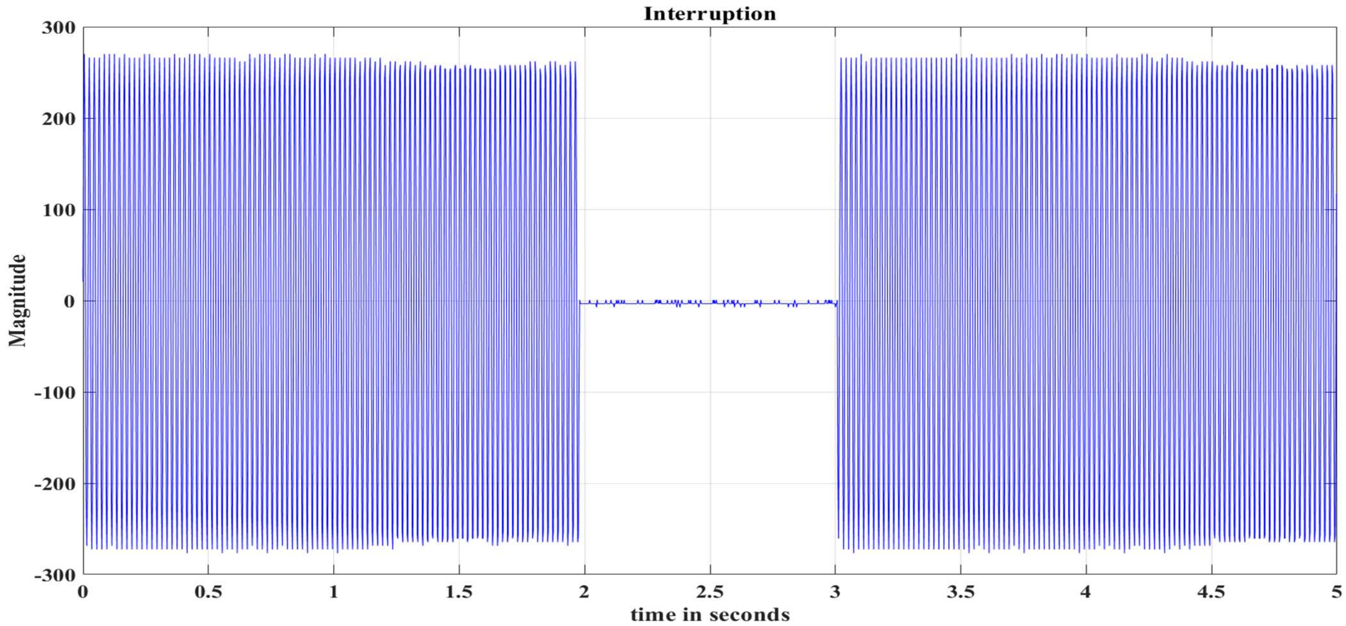


Figure 8.4(b) Voltage with interruption signal

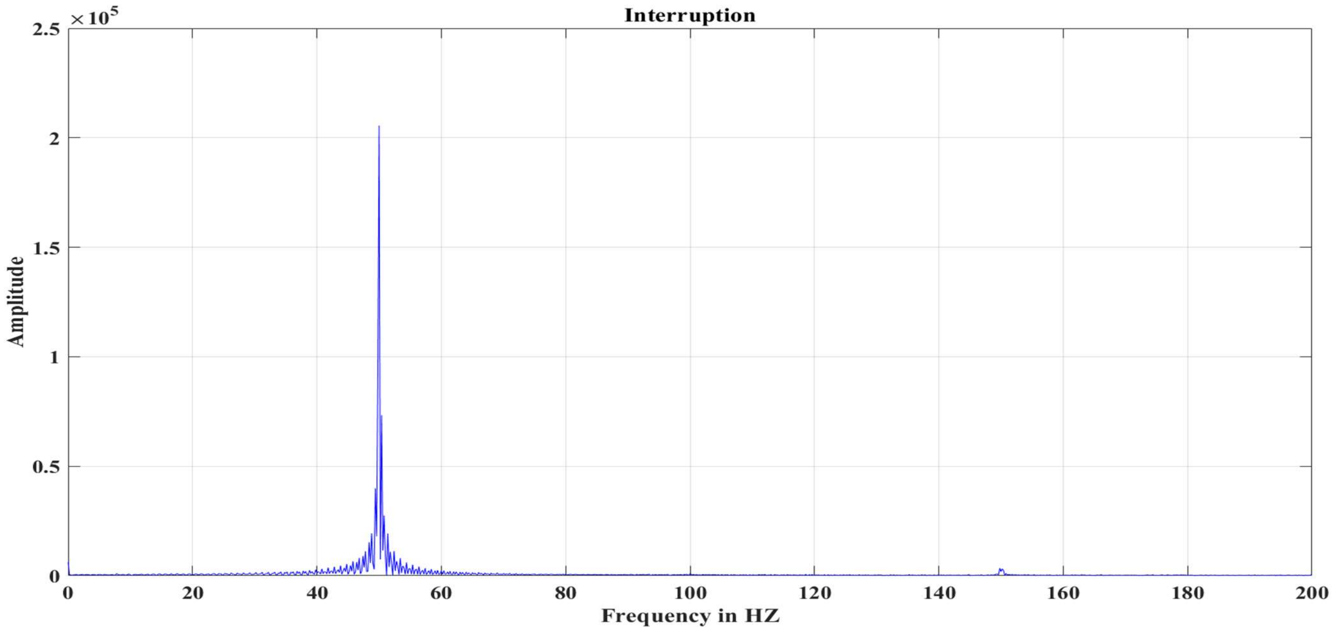


Figure 8.4(c) FFT of voltage with interruption

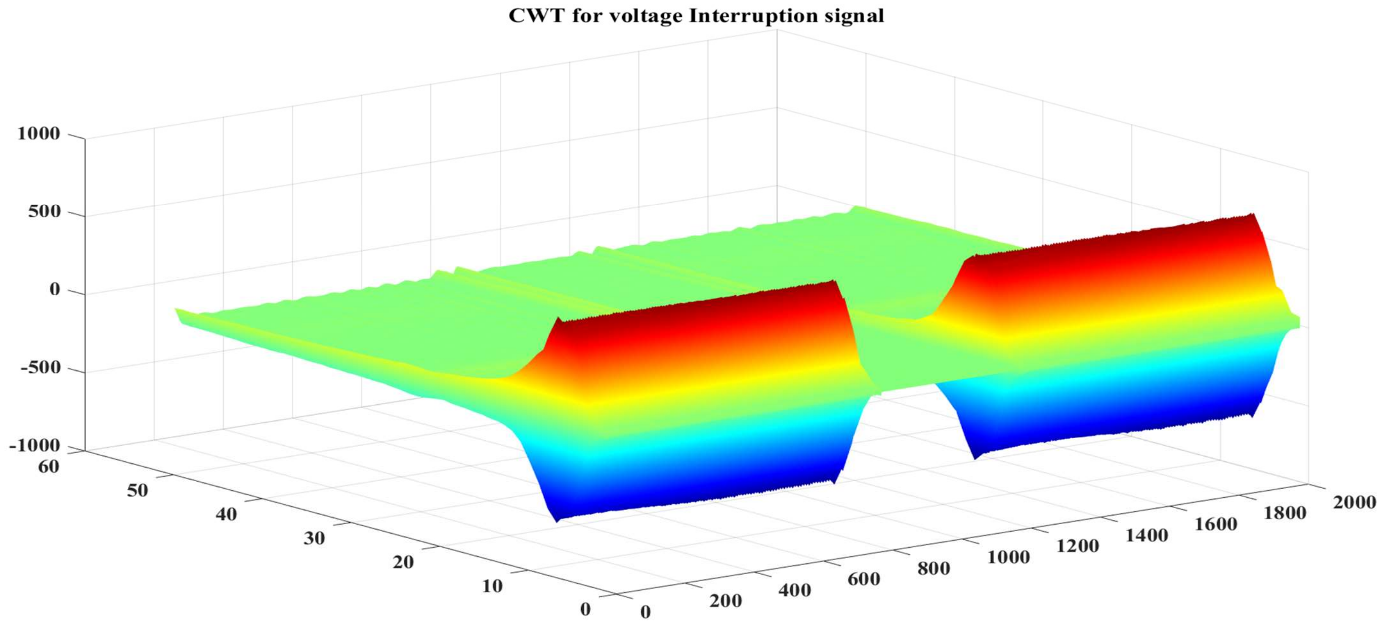


Figure 8.4(d) CWT of voltage with interruption

The interruption disturbance is clearly visible in both the FFT and CWT. In the FFT, the magnitude of the spike at the fundamental frequency (50 Hz) is completely diminished during the period of the interruption, indicating a complete loss of signal strength. Additionally, in the CWT, a complete absence of signal power is observed during the period of the interruption.

Real-time analysis of voltage signals using FFT and CWT can provide valuable insights into power quality disturbances, aiding in the early detection and diagnosis of potential issues. Interruptions in voltage signals can lead to significant problems in power systems, and the ability to detect and diagnose them early can help prevent or mitigate their effects.

8.5.Voltage Transient

Fig. 10(a) and Fig. 10(b) illustrate a snapshot and voltage signal captured in the presence of sampling noise for a duration of 5 seconds, with a root-mean-square (rms) value of 18 volts. In this case, a transient occurs at 0.8 seconds by deliberately shorting a few turns of the secondary of a transformer. The complex-valued analytic signal output of the input signal is used to obtain the proposed FFT and CWT, as shown in Fig. 10(c) and Fig. 10(d), respectively. Sampling noise can introduce unwanted artifacts into voltage signals, making it challenging to detect and diagnose power quality disturbances. However, real-time analysis of voltage signals using FFT and CWT can provide valuable insights into the frequency and time-frequency characteristics of the signal, even in the presence of noise.

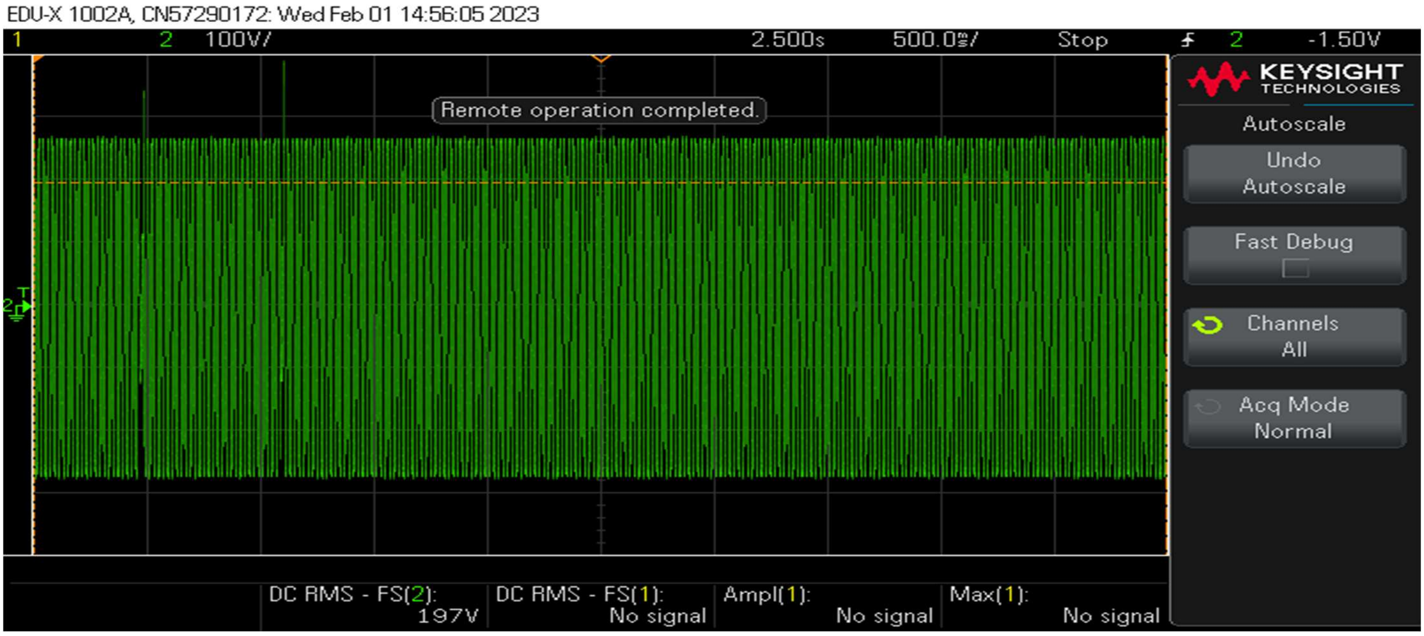


Figure 8.5(a) Voltage with transient – Snapshot

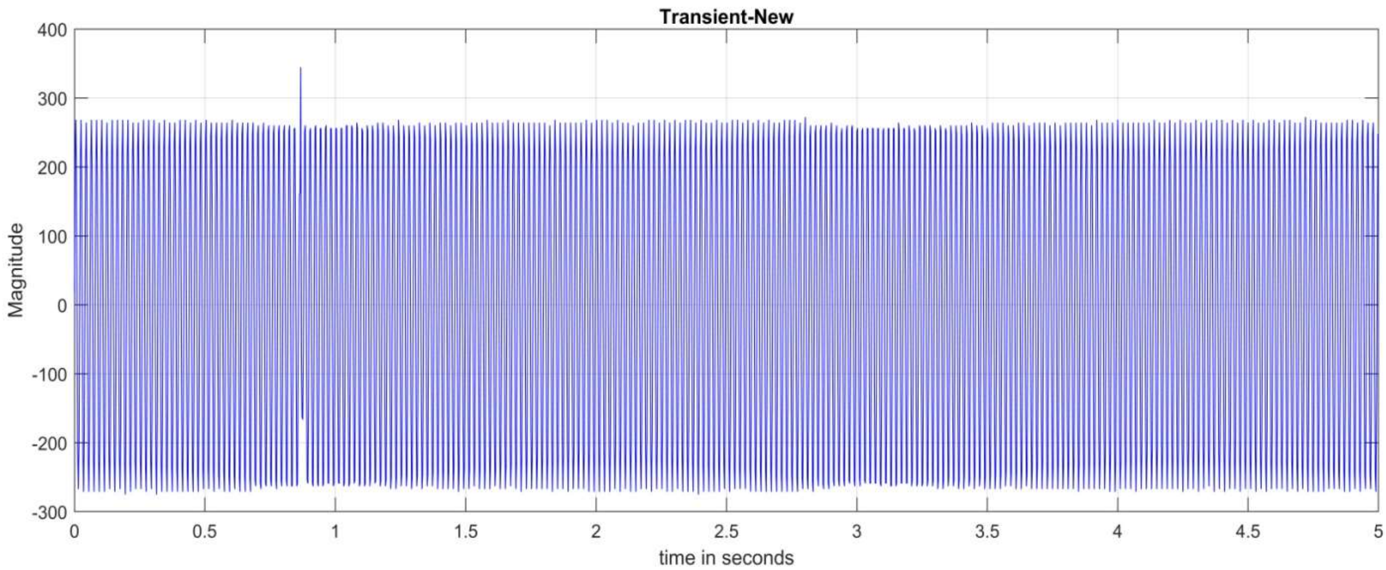


Figure 8.5(b) Voltage with Transient signal

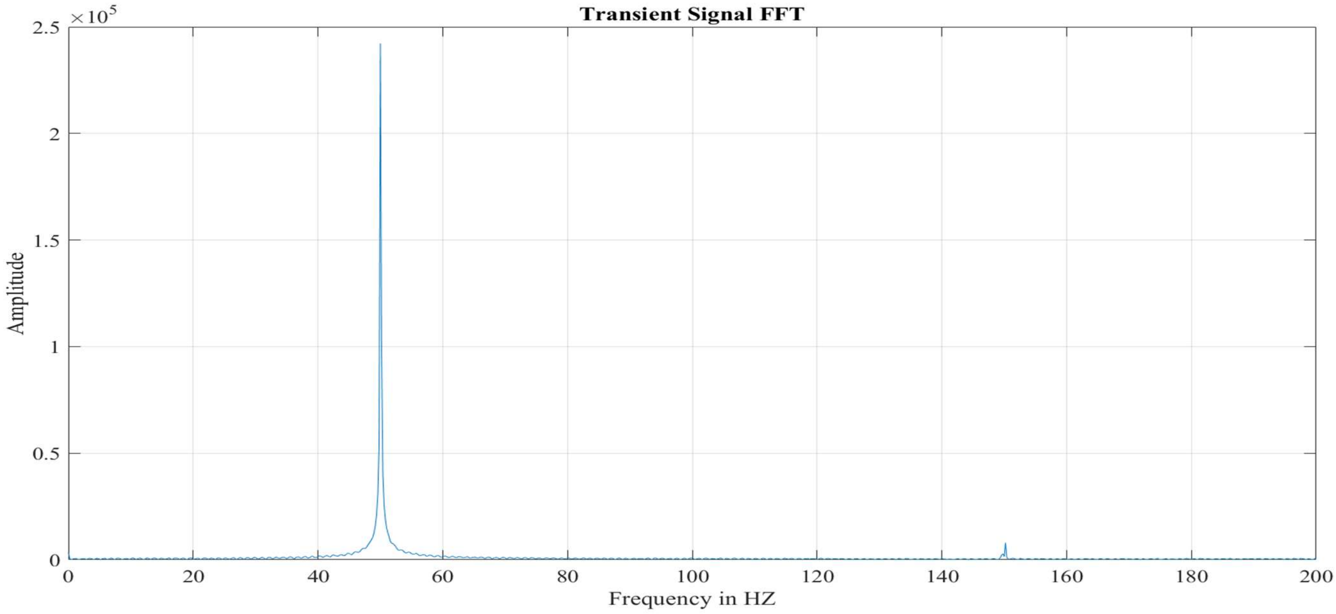


Figure 8.5(c) FFT of voltage with transient

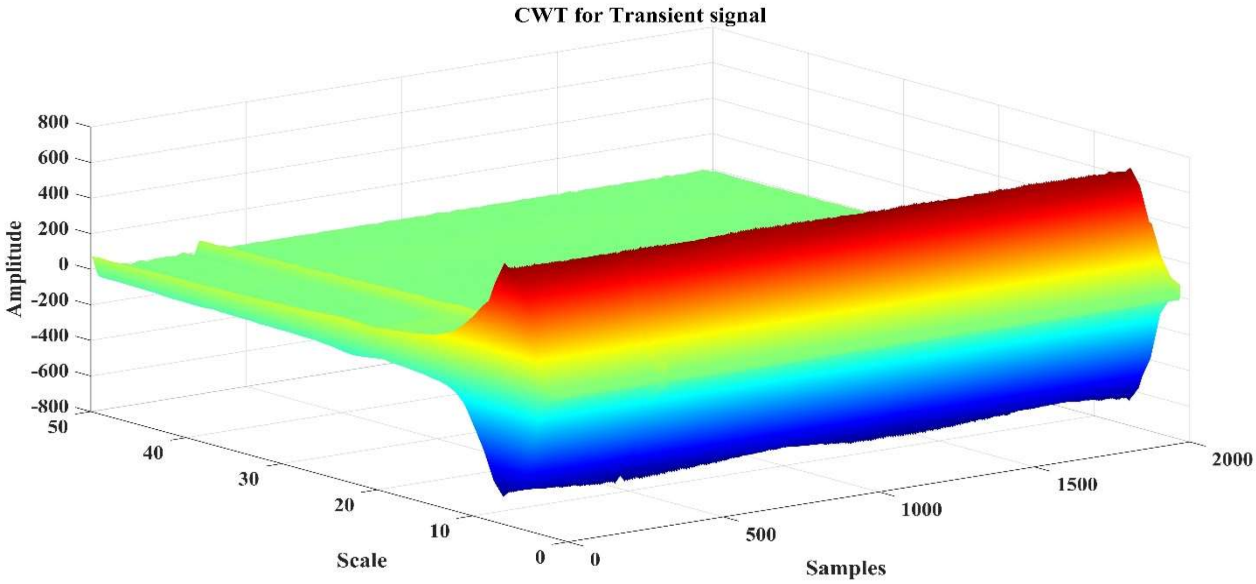


Figure 8.5(d) CWT of voltage with transient

The transient disturbance caused by the short circuit is visible in both the FFT and CWT. In the FFT, the magnitude of the spike at the fundamental frequency (50 Hz) is reduced, indicating a reduction in the signal strength during the transient. Additionally, a sharp peak is observed at the time of the transient in the CWT, highlighting the time-frequency characteristics of the signal.

It is essential to consider the impact of sampling noise on voltage signals when studying power quality disturbances. The use of advanced signal processing techniques, such as FFT and CWT, can provide valuable insights into the behavior of voltage signals, aiding in the early detection and diagnosis of potential issues.

8.6. Voltage Fluctuation

Fig. 8.6(a) and Fig. 8.6(b) display a snapshot and voltage signal, respectively, representing intentional fluctuations in the signal. The duration of the signal is 5 seconds, and the fluctuation is deliberately created using a variable auto transformer. The data is acquired while varying the root mean square (rms) voltage up to 18 volts.

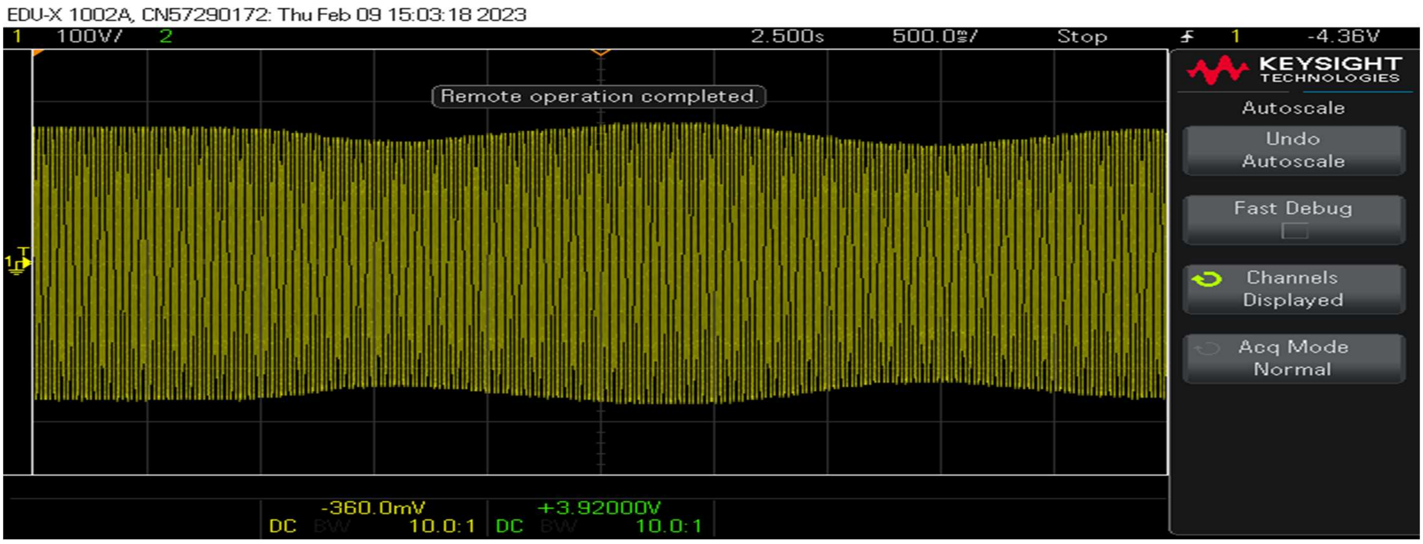


Figure 8.6(a) Voltage Fluctuation -Snapshot

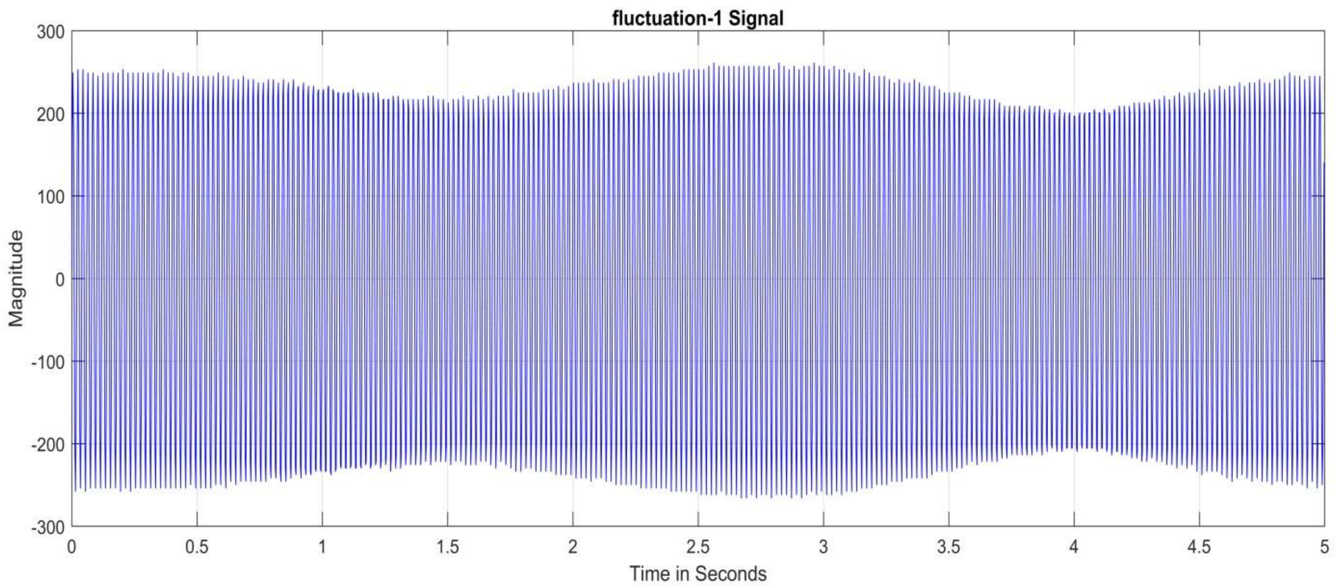


Figure 8.6(b) Voltage Fluctuation

The FFT and CWT analyses are applied to examine the signal and identify power quality disturbances related to voltage fluctuations. Upon analyzing the FFT results, it is observed that the magnitude of the signal at various frequencies deviates from the pure signal, indicating the presence of fluctuations. The amplitude changes in the FFT plot depict the variations in the signal strength across different frequencies.

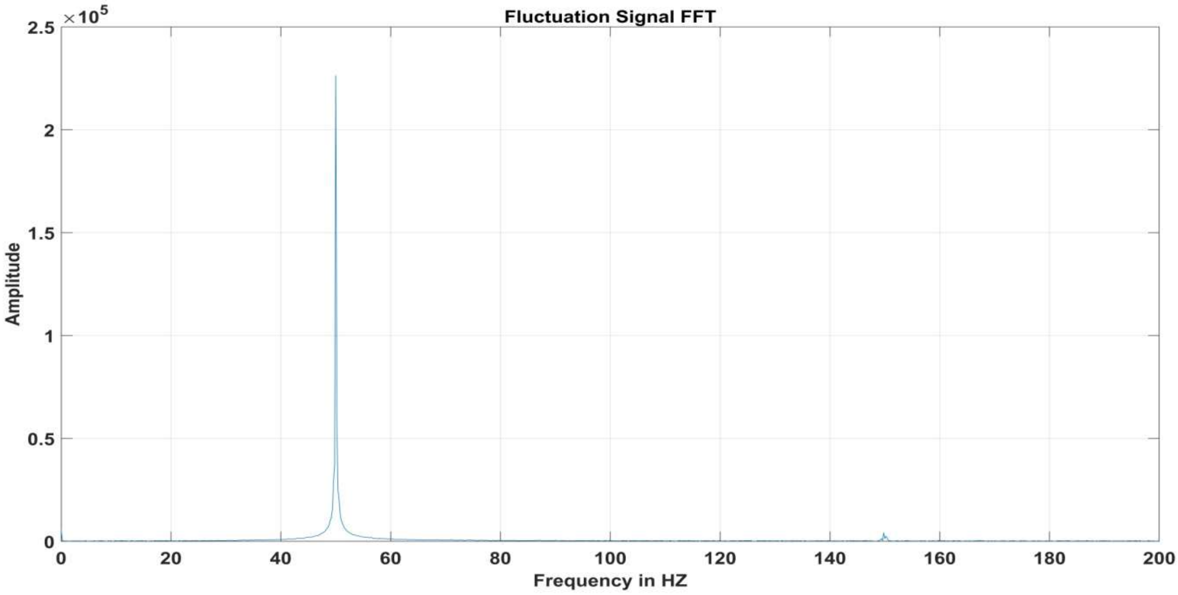


Figure 8.6(c) FFT of Voltage Fluctuation

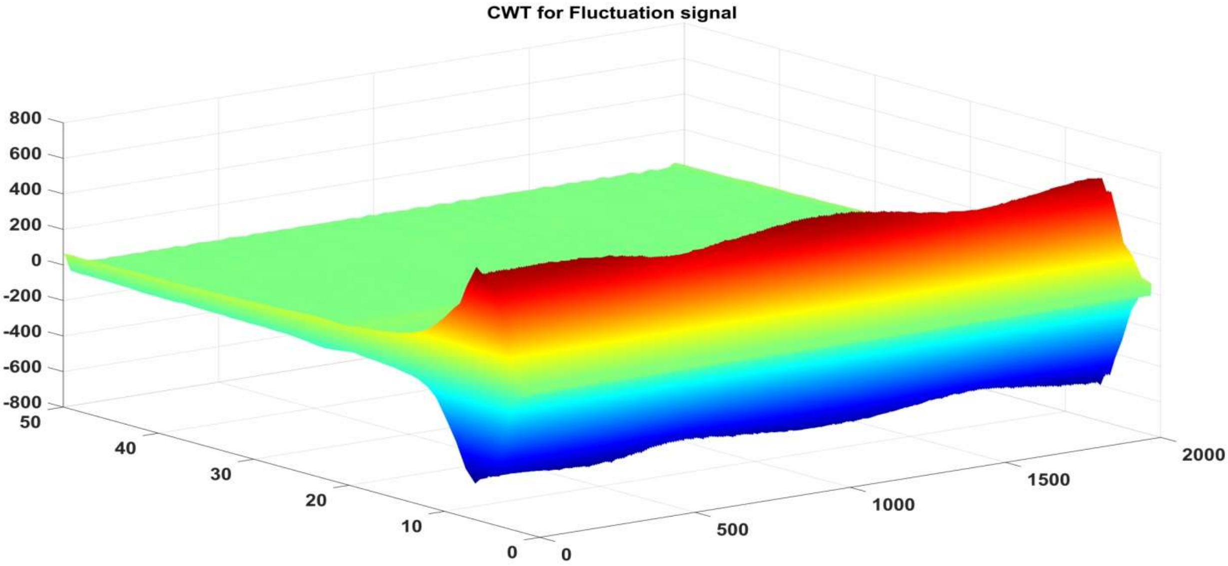


Figure 8.6(d) CWT of Voltage Fluctuation

The CWT analysis provides a comprehensive view of the time-frequency characteristics of the voltage signal during fluctuations. The 3D view of the CWT plot, depicted in Fig. 8.6(d), showcases the fluctuating nature of the signal over time. Real-time analysis using FFT and CWT techniques enables the detection and characterization of voltage fluctuations in power systems. This information is crucial for understanding the impact of fluctuations on system performance and identifying potential issues that may affect the stability and reliability of the electrical network.

CHAPTER-9

CONCLUSION

In conclusion, this project highlights the significance of power signal identification in detecting and analyzing power quality disturbances (PQD) in step-down transformers. By utilizing experimental test beds and employing signal processing techniques such as Fast Fourier Transform and Continuous Wavelet Transform, the study successfully identified the frequency, magnitude, and detailed characteristics of various PQD events in the time-frequency domain.

The findings emphasize the importance of power quality monitoring and maintenance in power systems. Implementing the techniques presented in this project empowers power system engineers to effectively identify and analyze PQD events, leading to enhanced reliability and efficiency of power systems.

Moreover, the project explores different methods for the detection and classification of power quality disturbance signals, specifically focusing on pure sine wave analysis. The employed techniques, including Fast Fourier Transform and continuous wavelet transform, exhibit the capability to classify a wide range of disturbances, such as voltage sag, voltage swell, transients, and interruptions. The simulation study demonstrates the effectiveness of Fast Fourier Transform in extracting frequency components of power system harmonics, while wavelet techniques provide valuable insights for power quality detection.

However, the project also identifies the need for further research to automate the detection and classification of PQDs, considering factors such as accuracy, computational time, and complexity. This suggests future opportunities for developing more sophisticated techniques that can enhance the accuracy and efficiency of power quality analysis.

In summary, this project establishes the importance of power signal identification in detecting and analyzing PQDs in step-down transformers. The employed techniques prove effective in capturing detailed information about the disturbances, enabling power system engineers to make informed decisions for improving the reliability and efficiency of power systems. The project also paves the way for future advancements in automated PQD detection and classification methods.

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MADANAPALLE INSTITUTE OF TECHNOLOGY & SCIENCE

An Autonomous Institution

(Approved by AICTE, New Delhi &Affiliated to JNTUA, Anantapuram)

Department of Electrical & Electronics Engineering

PROGRAMME OUTCOMES (POs)

At the end of the programme, graduate will be able to

PO	Statement
PO1:	**Engineering Knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialisation for the solution of complex engineering problems.
PO2:	**Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
PO3:	**Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.
PO4:	**Conduct investigations of complex problems:** Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions. .
PO5:	**Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations. .
PO6:	**The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
PO7:	**Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
PO 8:	**Ethics:** Apply ethical principles and commit to professional ethics and responsibilities an norm of the engineering practice.
PO 9:	**Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
PO 10:	**Communication:** Communicate effectively on complex engineering activities with the engineering community and with t h e society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
PO 11:	**Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary

	environments.
PO 12:	**Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.
	Program Specific Outcomes (PSOs)
PSO 1	Facilitate technical solutions for different power issues to maintain the stability and reliability of Power Systems.
PSO 2:	Control the various power electronics converters, electrical machines / drives used in industry.
PSO 3:	Understand various computational tools / methods for the design and analysis of various electrical systems.

18EEE702 – Project Work II

COs	Statement	POs												PSOs		
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
CO1	Prepare a detailed review of literature on topics within the discipline as well as other related disciplines, for identifying the problem.	**1**	**3**	**3**					**3**	**2**						**3**
CO2	Formulate the objectives and identify the requirements to meet the objectives.	**3**	**3**	**3**	**3**	**3**			**3**	**2**			**3**		**2**	**2**
CO3	Use advanced techniques/computer aided tools to carry out simulation studies or hardware experimentation to Analyze the problem and obtain results.		**2**	**3**	**3**	**3**	**2**						**3**		**2**	**2**
CO4	Communicate effectively the results of an engineering study both through a written report as well as an oral presentation using a PPT.							**2**			**2**	**3**	**2**			
CO5	Work within a team of one or more disciplines and exhibit leadership qualities.									**3**		**3**	**2**			

Contribution of Project work towards attainment of POs& PSOs

PO1: Engineering Knowledge: The project applies the knowledge of mathematics, science, engineering fundamentals, and engineering specialization in the analysis of power systems and power quality disturbances..	3
PO2: Problem Analysis: The project involves identifying and analyzing complex engineering problems related to power quality disturbances in electrical systems using literature review and research	3
PO5: Modern tool usage: The project utilizes MATLAB and BenchVue as modern engineering and IT tools for simulation studies and analysis of voltage signals.	2
PO8: Ethics: The project adheres to ethical principles and responsibilities relevant to professional engineering practice, such as ensuring the accuracy of project reports and avoiding plagiarism.	3
PO9: Individual and team work: The project is carried out within a team, demonstrating effective teamwork and leadership qualities	2
PO10: Communication: The project effectively communicates the results and findings through written reports and oral presentations using PowerPoint.	3
PO11: Project management and finance: The project demonstrates knowledge and understanding of engineering and management principles in managing the project's implementation.	3
PSO1: Facilitate technical solutions for different power issues to maintain the stability and reliability of Power Systems: The project contributes to addressing power quality disturbances, ensuring stable and reliable power systems.	3
PSO3: Understand various computational tools/methods for the analysis of various electrical systems: The project utilizes computational tools like MATLAB and Benchvue Software tool for the detection and analysis of power quality disturbances.	2

1 – Slightly; 2 – Moderately; 3 - Strongly

Project Guide

Mr. N. Ramesh,

Assisstant Professor,

Department of EEE.