DETECTION AND CLASSIFICATION OF MULTIPLE POWER QUALITY DISTURBANCES: A REVIEW

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INTRODUCTION

- The discovery of electricity began around four centuries ago. Known as “Power System”.
- The power system is growing up parallel to the development of a country and manufacturing of electrical machines.
- Accordance with economic competition for products in terms of continuity of supply, voltage quality and commercial services, electrical machines became smaller in size and more efficient.
- power quality disturbances affecting the electricity supply and becomes a concern for electrical users.
- This is in accordance with the increasing development of electrical equipment, which will affect the quality of energy supply.
- An accurate detection of PQ disturbance is necessary for precise classification and further mitigation process.
- Originally, the waveform of power is a perfect sinusoidal which operates at 50Hz rated frequency, with rated voltage (0.4kV, 11kV, 22kV, 33kV, 132kV, 275kV, and 500kV).
- Multiple disturbanceS - two or more disturbances can occur simultaneously and they could also take place together with or without noisy environment.

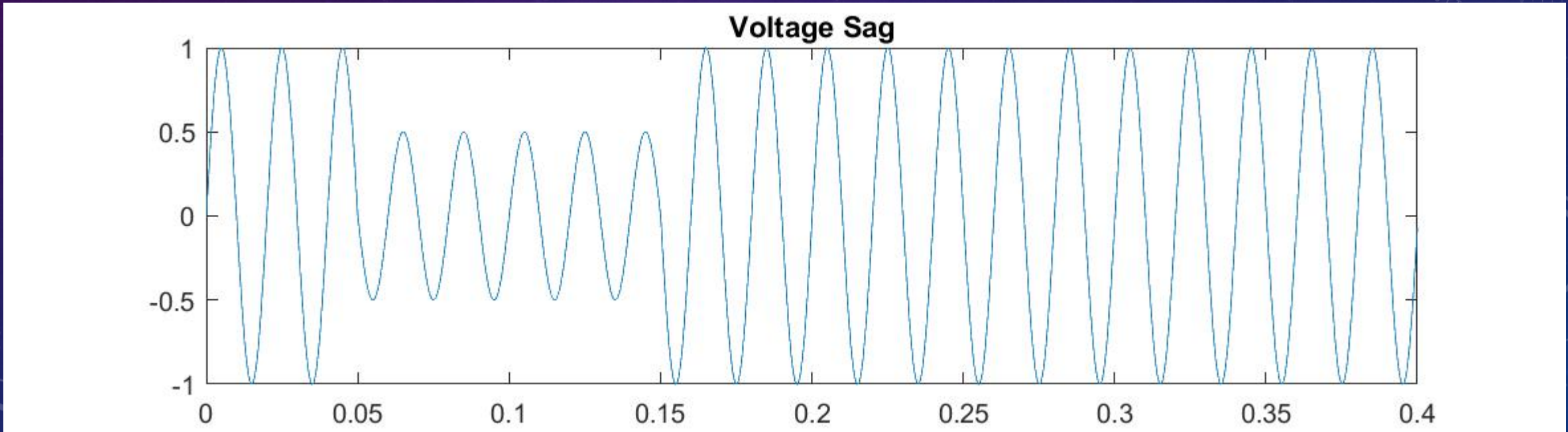
DISTURBANCE IN POWER QUALITY

- The voltage waveforms may reduce, increase, fluctuate, or distort due to controllable or uncontrollable circumstances.
- This will affect the system such as blinking lamp, unintended trip, and reverse rotation of motors.
- multiple disturbances may appear simultaneously and most are superposition

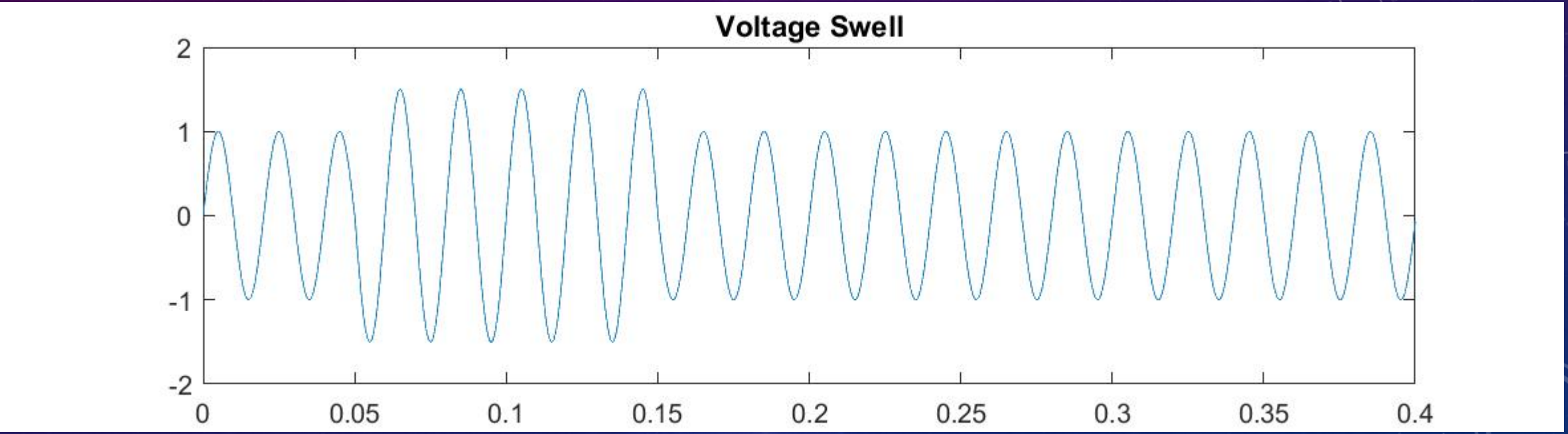
SINGLE DISTURBANCE

The single disturbance is an occurrence where only one pq disturbance is taking place at the specific time. examples of single pq disturbance are discussed according to IEEE STANDARD 1159

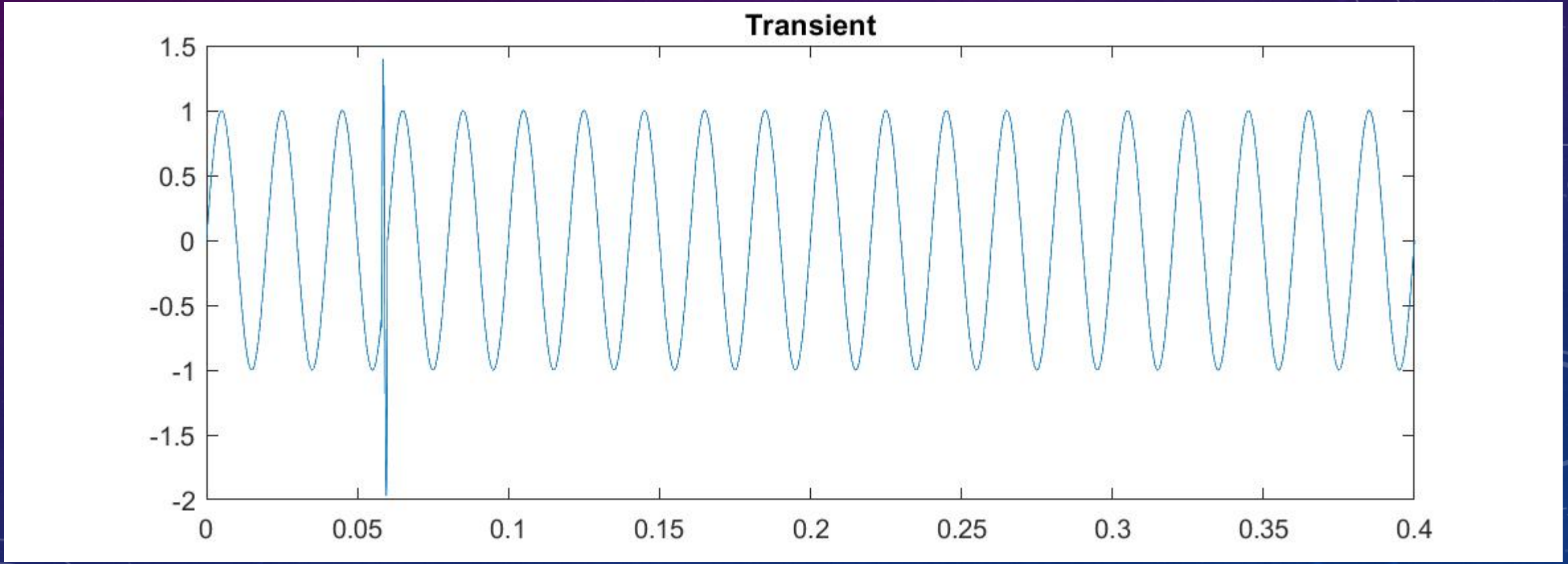
1) **Voltage sag** - Root Means Square (RMS) reduction due to the reduction of the AC line voltage of 10% to 90% of the nominal line-voltage at certain power frequencies in the duration of half of a cycle to 1 minute



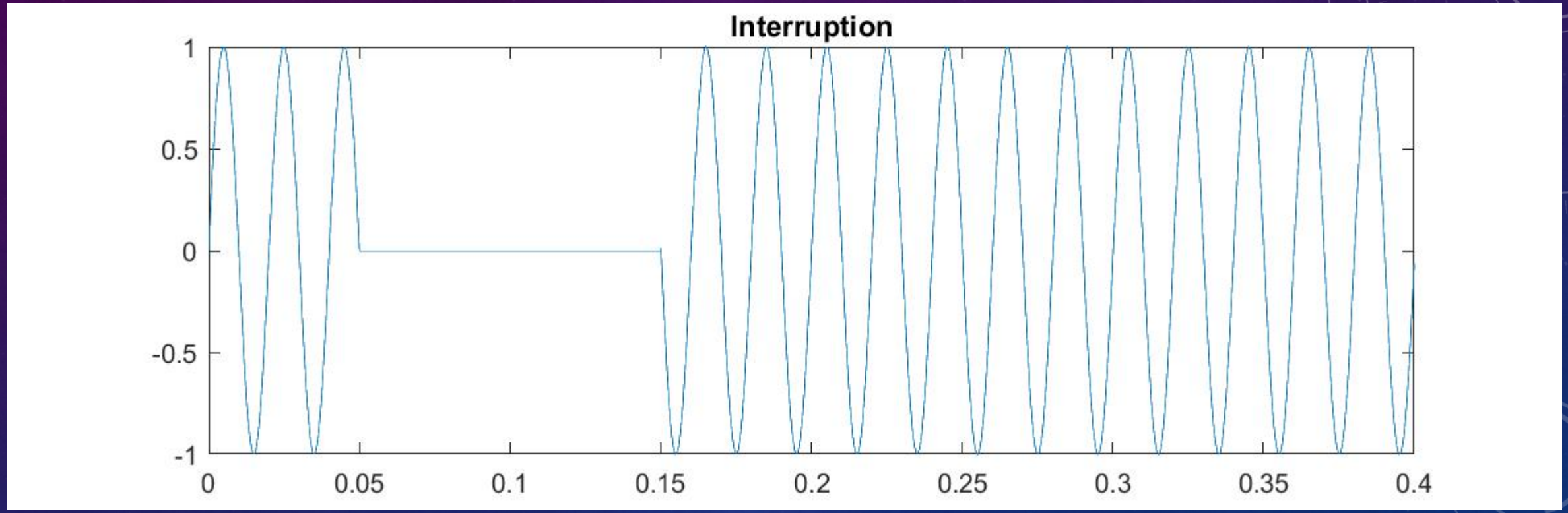
2) **Voltage swell** - increase in RMS caused by AC line voltage increment of 110% to 180% of the nominal line-voltage at a certain power frequency in the duration of half cycle to 1 minute.



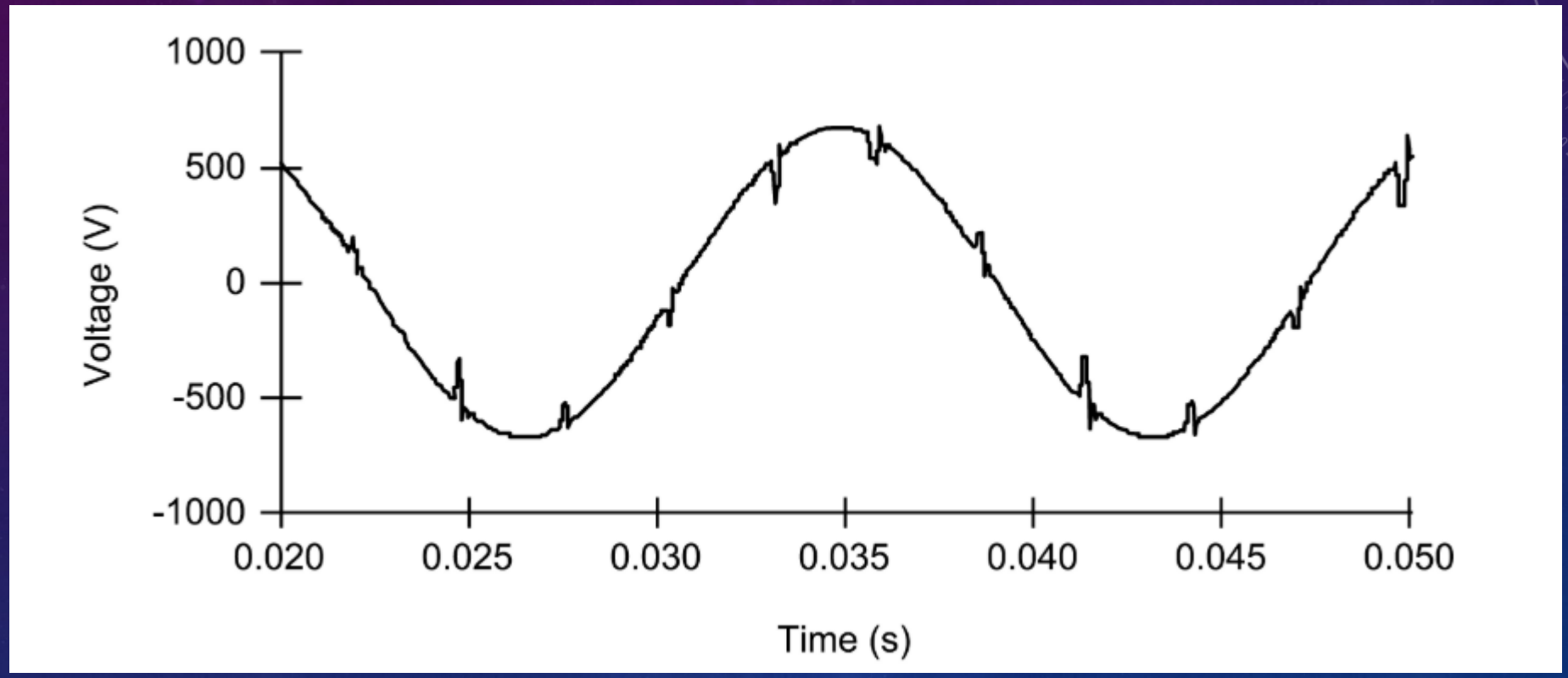
3) **Transient** - short-duration events in which, the characteristics are predominantly determined by resistance, inductance, and capacitance of the power system network at a given point. The primary characteristic defining transient is the peak amplitude, the rise time, the fall time, and the frequency of oscillation.



4) **Interuption -** is a reduction in line-voltage or current of less than 10% percent of the nominal in the duration of half cycle to 1 minute.

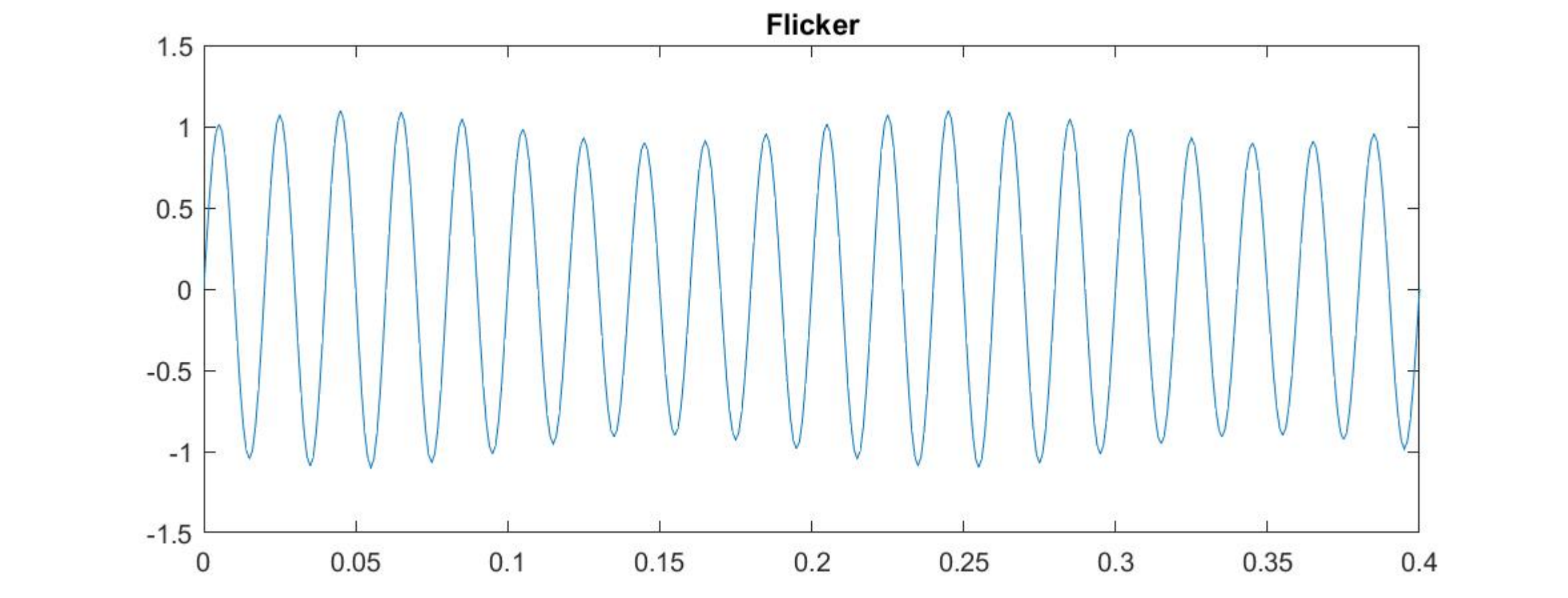


5) **Notch -** A steady state phenomenon is known as notch. Notch is a periodic supply of voltage caused by power electronic devices such as converters, rectifiers, or universal bridges. This happens due to current commutation from one phase to another.

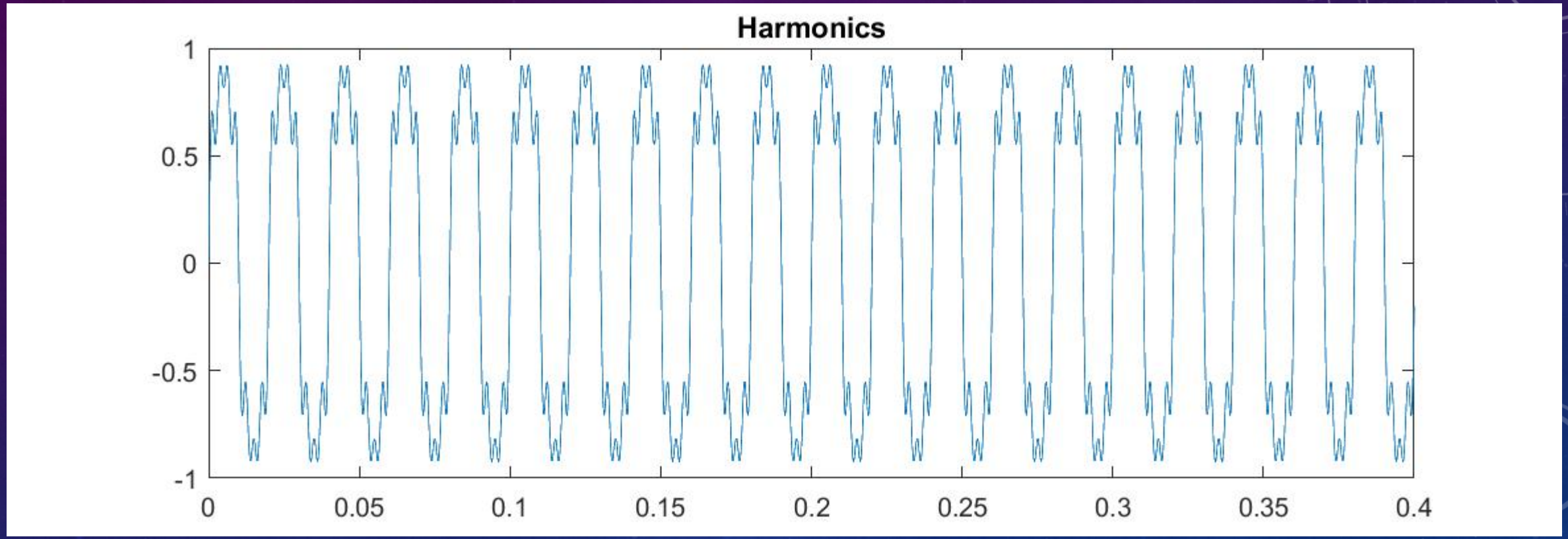


Picture from: IEEE Power and Energy Society, *EEE Std 1159™-2019: Recommended Practice for Monitoring Electric Power Quality*, vol. 2019. 2019.

6) **Flicker -** The variation of sufficient input voltage in a duration to allow visual observation of a change in electric light source intensity defines flicker. Quantitatively, flicker may manifest as there are changes in voltage over the nominal.

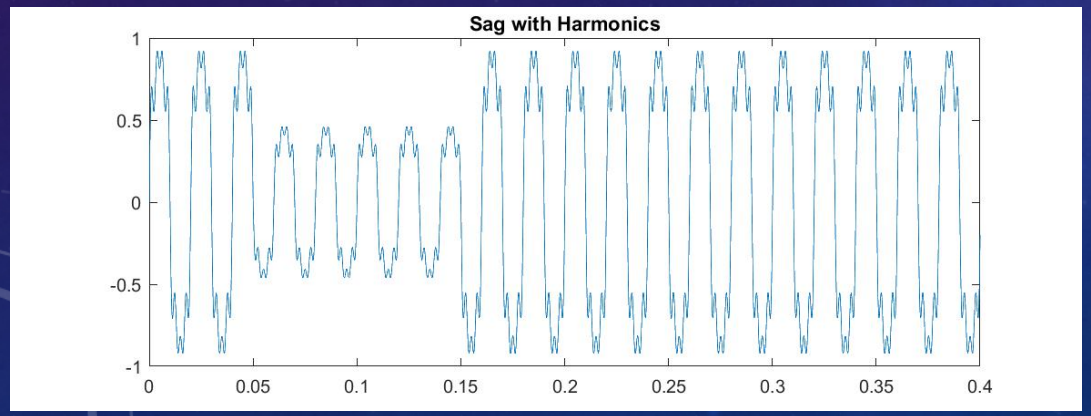


7) **Harmonics -** is a condition where a component's frequency in multiplication of the fundamental frequency at certain peak points



MULTIPLE DISTURBANCES

- Multiple disturbance is a combination of two or more disturbances (with or without noise) occurring simultaneously at the same point.
- e.g. Sag with Oscillatory Transient, Oscillatory transient with Swell, Sag with Notching with Oscillatory Transient, Harmonics with Notch with Swell, and Notch with Oscillatory Transient with Sag with Harmonic.
- With multiple possible combinations of PQ disturbance and a close characteristic of each other, multiple disturbances become more complex in detection stage



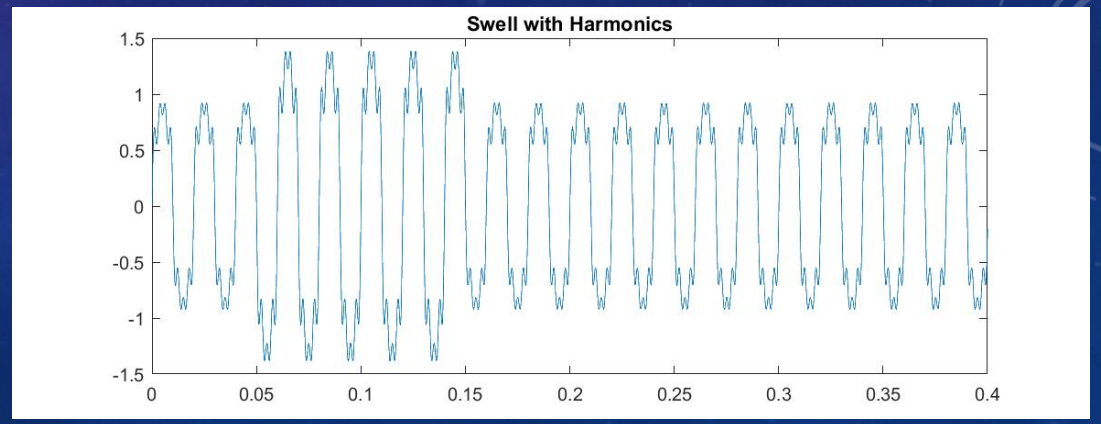
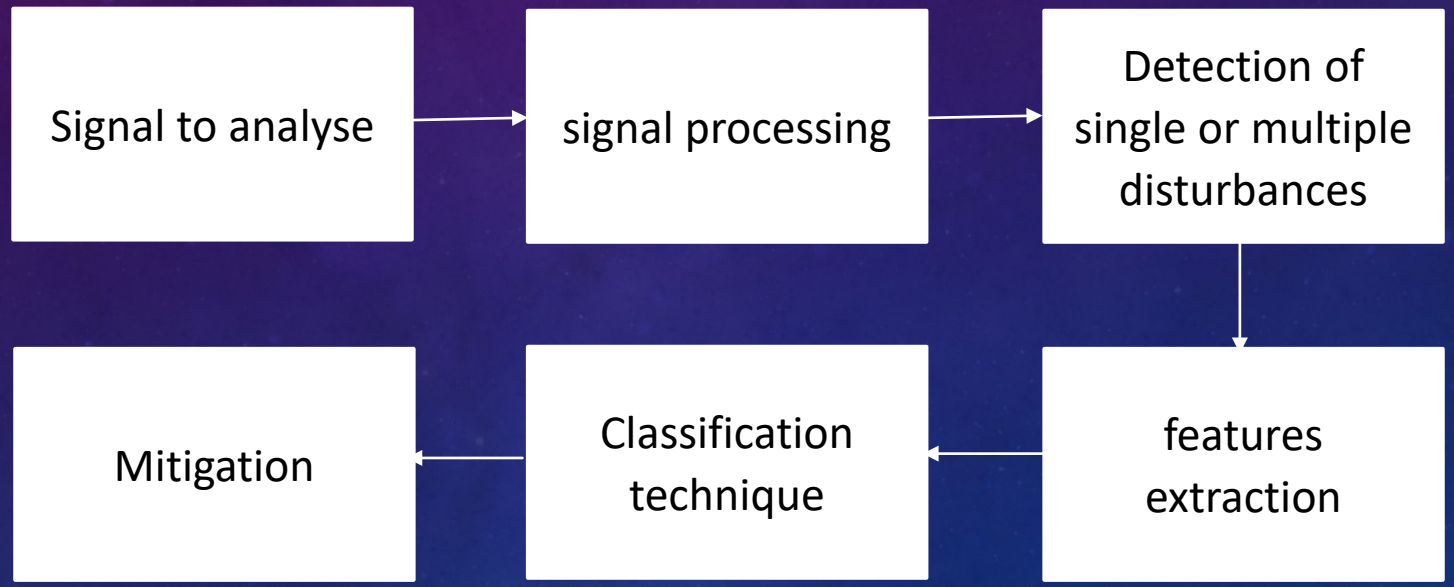


FIGURE 1: BLOCK DIAGRAM OF STEPS FOR DETECTION AND CLASSIFICATION PQ DISTURBANCES



SIGNAL PROCESSING AND CLASSIFICATION ALGORITHM FOR MULTIPLE DISTURBANCES

There are two steps to be taken before the types of disturbance can be identified

1. Signal processing or features extraction
2. The classification method

TABLE 1: ADVANTAGES AND DISADVANTAGES OF METHODOLOGIES

Method	Advantages	Disadvantages	References
FT	- Usually used in the analysis of stationary signals.	- Not perform well for monitoring PQ signals which are mostly nonstationary signals due to the reliance of resolution on the window size. - Not suitable to get amplitude and frequency due to leakage.	[13][22][27][31] [26]
STFT	-Time frequency information related to disturbance waveforms.	- Transient signals cannot be adequately described with this transform due to a fixed window size. - Cannot track the signal dynamics properly.	[31][13][22]
FFT	- Can classify large volumes of PQ problems.	- Spectral leakage and loss of time information. - Not suitable to get amplitude and frequency due to leakage.	[8][26]

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WT	- Advantage of analysing singularity and non-stationary signals.	- Complicated computation and significantly degraded in real practice in noisy environments. - Exist many drawbacks such as huge calculation complexity and excessive dependence to power quality signals.	[31][13][22][27][35] [17][19]
Svm	- Convex optimization problem. - Better performance when processing high dimensional data.	- Difficult to apply these approaches in real-time monitoring. - Sometimes fails to apply in multiclass problems.	[5]
ELM	- The parameter must properly adjust is the number of hidden nodes only. - Suitable in applications which request fast prediction and response capability.	- Uses randomly determined input weights and biases, and thus a higher number of hidden neurons may be require to achieve the desired accuracy, which inevitably increases the model size and the test time.	[36]
HHT	- Able to provide the user with the amplitudes and frequencies. - Designed for non-stationary signals when time is important. - Assimilates advantages of wavelet transform's multi resolution, and overcome the difficulties of choosing wavelet basis.	- End effects and a mode-mixing problem. - Has no supporting mathematical theory. - Noise sensitive.	[22]

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ST	- Has the advantages of FT and WT. - Can analyze the signals amplitude of every frequency component.	- Suffers from mode mixing problem. - Exist many drawbacks such as huge calculation complexity and excessive dependence to power quality signals.	[8] [19]
NN	- Does not impose any restrictions on the input variables. - Ability to learn and model non-linear and complex relationship.	- Training time is too long.	[38]
Decision Tree	- Can fragmented the training data with maximum possible distinction. - Low bias and high variance.	- The rules establishment is complex.	[38][5]

TABLE 2: COMBINATION OF SIGNAL PROCESSING AND CLASSIFICATION ALGORITHM.

No.	Signal processing	Classification method	advantages	references
1.	ADALINE	Feedforward Neural Network (FFNN)	They study up to six simultaneous disturbances. The use of NNs allows obtaining good results in noisy environments due to the high immunity to noise of an NN. The methodology can be easily expanded for three-phase power systems.	[17]
1.	S-transform	a rule-based decision tree and ANN.	Features extracted from contours of the S-matrix are effectively used for the automatic classification of the PQ disturbances. The ANN and rule-based decision tree, is an effective and intelligent technique for the PQ monitoring instruments.	[8]
1.	S-transform	multi-resolution analysis (MRA)	The proposed approach using S-transform can effectively be applied to detect various operational events and assess the power quality in a hybrid power system with RE penetration.	[36]
1.	Variational Mode Decomposition	Decision Tree	The potential ability of VMD technique to accurately estimate amplitudes, frequencies and phases of the fundamental, harmonic and in-terharmonic, and flicker components under mixture of other non-sinusoidal PQ disturbances, in both noise-free and noisy scenarios. The VMD with decision-tree based algorithm is an effective and efficient method for detection and classification of single and mixed PQ disturbances under noise-free and noisy environments.	[18]

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1.	Time Frequency Analysis (MWT)	Decision Tree	The feature-extraction algorithm can acquire the target statistics of different PQ disturbances using TF analysis. the proposed method requires only four feature statistics, and the computational cost is relatively small, and it also has implications for conquering the challenges faced in modern smart grids.	[37]
1.	Histogram of Oriented Gradients	Support Vector Machine	It is more effective than other techniques because of less pro- cessing time since this technique can be applied to multiple events occurring at same time. All the events have been generated synthetically as per IEEE standards so the results obtained are highly reliable.	[30]
1.	Variational Mode Decomposition (VMD) and Fischer liear discriminant analysis (FDA)	Reduced Kernel Extreme Learning Machine (RKELM)	It is vastly used in different classification problems with different data types. Computationally RKELM is much efficient, and has a faster response, with lowest training time, for almost all the multiclass power system disturbances. It has been found that polynomial RKELM is giving the best results than other kernel functions.	[14]
1.	Fast S-Transform (FST)	Extreme Learning Machine (ELM)	The statistical based features of the FST amplitude matrix remain more observable and logical.	[38]
1.	Variational Mode Decomposition (VMD	Random discriminative projection extreme learning machine for multi-label learning (RDPEML)	The RDPEML could achieve better classification performance compared with several state-of-the- art multi-label algorithms, but with far lower computational costs (training time).	[32]
1.	Tunable-Q wavelet transform (TQWT)	Multiclass support vector machines (MSVM)	Excellent decomposition, less number of features and computationally efficient.	[3]

CONCLUSION

- The main objective of this paper is to provide a comprehensive understanding on papers cited, focusing on the methodologies on features selection and classification methods
- ST and SVM are the combination of technique chosen for next study.
- ST will give a good result in extracting data.
- SVM will classify the disturbances.
- Comparisons with other techniques are taken into account.
- For future venture, the development of new or at least modified methodologies is needed in improving robustness in features extraction and better performance of PQ disturbances classifier within two cycle

END OF SLIDE….THANKYOU ☺