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A Review on Methods to Find Harmonic Sources in IEEE Buses

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ABSTRACT

This Paper Gives A Comprehensive Evaluation Of Approaches For Suppressing Harmonics In Ieee Buses By Detecting Harmonics In The Buses Using Various Methodologies, Accounting For A Variety Of Uncertainties, And Then Determining The Right Source Of Harmonics. Matlab Software To Determine And Test Both The Problem And The Solution Utilizing Various Methods. Increased Use Of Nonlinear Loads Causes Sag And Swell Due To Multiple Times Switching, Which Has An Impact On Power Quality (Pq) And Raises The Demand For Power Quality Enhancement. Various Forms Of Irregularities Are Connected With Power System Signals, Resulting In Harmonics Of Various Frequencies [26] Therefore, There Is A Pressing Demand For Approaches Right Now That Can Influence The Present Era's Collective Harmonic Impact On Various Modern Loads [25].

Keywords-- Harmonics, Harmonic Sources, Point of Common Coupling

I. INTRODUCTION

When it comes to power quality, the most difficult part is figuring out where harmonics originate from and then finding out how to suppress them. Because switch mode power supply was rarely employed previously, there were few harmonic sources and minimal need to be concerned about power quality. However, as the usage of advanced equipment grows, so does the use of switch-mode power supply, and hence harmonics, necessitating improvements in power quality as well as precision in locating harmonic sources. Several procedures, including as the critical impedance method, the least-squares method, the voltage magnitude comparison method, the vector projection method etc. are used to determine the source of the harmonic and reduce it at the point of common coupling.

As a result, this paper presents a review of harmonic reduction strategies in order to enhance power quality and obtain a more sinusoidal and smooth waveform in output.

II. REASONS TO FIND METHODS TO REDUCE THE HARMONIC MAGNITUDE

The existence of non-linear loads can generate a variety of problems, ranging from increased line loss to the irradiation of disturbances on communication lines, numerous approaches to analyze the behavior of power systems under nonsinusoidal situations have been proposed [23] This paper demonstrates methods for reduction of harmonic magnitude in interconnected networks based on simultaneous measurement of maximum voltage and current harmonic contribution. This approach is based on lowering the amplitude of the signal [1].

The harmonic sources can be found by different methods, such as:

1. Power direction method
2. Method to determine customer and utility harmonic contributions at PCC
3. Voltage magnitude comparison method
4. Critical impedance technique
5. Bayesian method to harmonic state and source identification
6. Independent component analysis model
7. JADE algorithm
8. Steady state harmonic stability analysis
9. Vector draft method
10. Harmonic estimation using non-linear optimization method
11. Identification of harmonic using HARMFIND computer programme
12. Multiple linear regression method
13. Finding harmomic location using apparent power approach
14. Particle swarm optimization approach
15. Harmonic search using robust independent component analysis
16. State estimation using a kalman filter approach
17. Neural network-based identification of harmonic sources by process of hypothesis testing
18. Controlled voltage disturbance method

2.1 Power Direction Method

This method [2] introduces power- direction

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approach that has been extensively utilized to locate harmonic sources in a power system.

There have been a number of disagreements between utility companies and their customers about who is responsible for what. The approach has been used to resolve harmonic distortions. The distortion of sinusoidal voltage and current waveforms is the disturbing factor for power system harmonics. A distorted waveform can cause electrical circuits to malfunction even with little harmonic power. As a result, defining the contribution of each harmonic source based on current and/or voltage characteristics is critical. To measure the contributions of harmonic sources, this work presents superposition-based current and voltage indices.

The relative phase angle between the two harmonic sources has a significant impact on the active power direction. It makes no difference to the size of the sources. The method of (active) power direction has been extensively applied, as a technique for finding harmonic sources that are practical. This research has demonstrated that the technique is ineffective, so that new harmonic source detection technologies must be developed.

2.2 Method to Determine Customer and Utility Harmonic Contributions at PCC

At the point of common coupling, this approach [3] is used to extract the harmonic contributions of consumers and utilities. Limit violations are induced by either harmonic source changes or harmonic impedance changes that may be quantified using this approach, which can be used by both customers and utilities. The equivalent circuit is used for harmonic analysis.

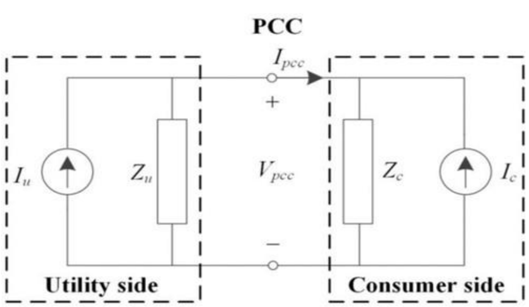

Figure 1: Equivalent circuit for harmonic analysis[3]

The technology allows for the creation of fair and consistent harmonic distortion control charging systems. The approach is capable of accurately determining responsibilities. Limit violations caused by harmonic source changes or harmonic impedance are the responsibility of a utility and its customer. The technology may be used with existing digital revenue meters. The approach has been found to be effective in evaluations. The results are also consistent with past research. This is an approach that is technically sound and also customers and utilities both are fairly treated.

2.3 Voltage Magnitude Comparison Method

The suggested approach [4] is known as the "voltage magnitude comparison method" because it compares the observed harmonic voltage at the PCC with the estimated voltage in the Thevenin equivalent circuit, either at the utility side or at the customer side. The major harmonic source is the estimated voltage magnitude that is larger than the observed voltage at the PCC. The PSCAD/EMTDC application is used to conduct many case studies and a series of simulated system switching tests.

This study proposes a new approach for determining the harmonic source based on the magnitude of the voltage at the PCC and the magnitude of the voltage at the utility or customer side. Simulation results have proved the suggested method's correctness. The suggested method's key advantage is its simplicity, as voltage and current measurements at a single point are sufficient to detect the location of harmonic sources.

2.4 Critical Impedance Technique

The "critical impedance technique" [5] (CIM) is presented as a new way for detecting harmonic sources in distribution systems. Using Thevenin equivalent circuit, the concept of CIM is to compare two magnitudes of harmonic voltage sources and pick the greater one as the dominant harmonic source. Through voltage and current measurements at the point of common coupling, a crucial impedance is established to "detect" the equivalent harmonic voltage source. When the value of equivalent harmonic impedance is known then results can be calculated using CIM with the superposition method (SPM) but When the equivalent harmonic impedance is unknown the CIM can give out the range of the harmonic impedance to find the main harmonic source.

The CIM is right in the actual world, according to real-world testing. It is easy, and implementable in real-world situations. As a result, the CIM may be utilized as a way for finding harmonics in distribution systems.

2.5 Bayesian Method to Harmonic State and Source Identification

Independent component analysis (ICA) is a statistical model in which observable data is represented as a linear mixture of dependent latent variables [20]. To achieve a thorough observation of the electric quantities in distribution systems, too many measuring equipments should be employed. As a result, model-based state estimation approaches are used to take advantage of the limited real-time observations available from the locations and any other available information to estimate the desired quantities.

A Bayesian method [6] to harmonic state and source identification in an electric distribution system is described in this study. The main purpose is to give the network management information on the presence of

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harmonic-producing loads, as well as an indicator o how reliable that information is. This system, which is based on the IEEE 13 bus radial distribution test feeder, is recommended as a standard for harmonic propagation analysis in unstable networks.

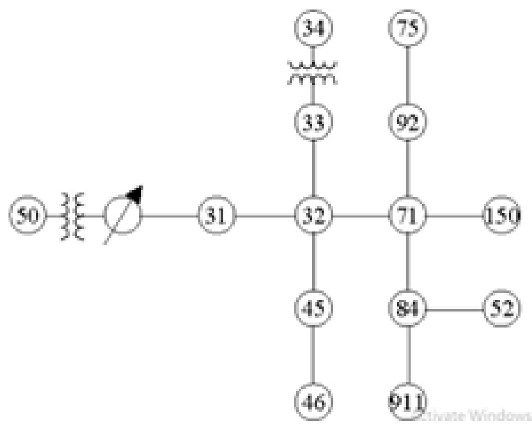

Figure 2: IEEE 13 bus test system[27]

2.6 Independent Component Analysis Model

For harmonic source identification and estimation, the study of use of independent component analysis (ICA) [7] is a statistical signal processing approach. If the harmonic currents are statistically independent, ICA can estimate them with only a few harmonic voltage measurements and no prior knowledge of the system admittances or topology. Simulation models in the modified IEEE 30-bus test system are used to demonstrate the findings. Because the number of measures is minimal and measurements may be collected away from the sources, the suggested approach looks prospective for use in a decentralized network. This approach may also be expanded to discover the smallest set of data for the harmonic meter placement problem, lowering measurement costs and improving estimation accuracy.

The ICA limitation was defined as the search for a linear transformation that minimizes the mutual information of the resultant components, which is a type of redundancy reduction. This is approximately equal to finding directions with the highest negentropy, which can also be thought of as projection pursuit directions [17].

In simulations, [21] overlearning of the ICA technique was not a concern because the smallest sample size was large enough when compared to the dimension of sources. In this flow chart the process for identifying harmonic loads is described.

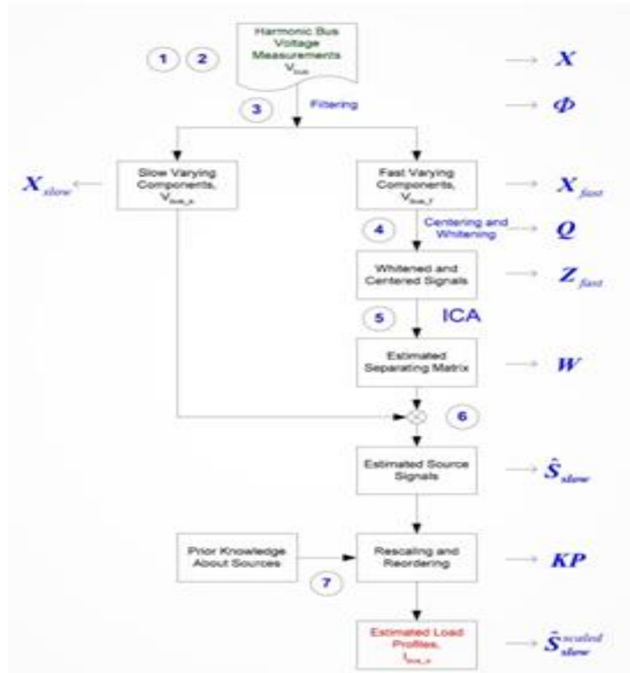

Figure 3: ICA flow chart[7]

Even with the tiny sample sizes used in this article, the suggested technique can estimate harmonic sources with a limited error range and a short number of observations.

2.7 JADE Algorithm

JADE algorithm [8] is used to piecewise estimate harmonic sources. The calculated mixing matrices are ordered and scaled using the overlap segment approach. In the conventional IEEE 14- bus system, voltage measurements are taken at three buses. The topology of the network has changed and been identified. It is evaluated what influence segment length has on the estimate process. The estimate algorithm's performance is measured using absolute square error (ASE). The simulation results were seen for various segment lengths and network alterations.

This paper's harmonic estimation approach for piecewise models is beneficial for detecting power system harmonics from time-varying network changes. To rank and scale estimated harmonic sources in successive segments, we use the idea of segment overlap. Segment length has an effect. It was discovered that segment length has an impact on harmonic source estimate. As the projected segment length approaches the segment with network change, the ASE values fall. As a consequence, the power system network's changeover point is discovered.

2.8 Steady State Harmonic Stability Analysis using IEEE 14 Bus

In this method [9] the steady state harmonic

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stability of an IEEE 14 bus method was tested for a generator bus fault. It was accomplished through the use of a passivity-based impedance model in a recursive method based on Gauss- Seidal. The load angle and the power have also changed and been determined in both normal and fault conditions during the state of the generator bus.

The voltages for both normal and fault conditions have been determined and calculation of power system stability is critical for determining the feasible zone of operation of a system in the event of various failures in the linked network. The presence of a symmetrical short circuit fault at the generator bus of an integrated grid system changes the location of the operating point for harmonic stability analysis and fault bus assessment, as shown in this analysis.

2.9 Vector Draft Method

The concern of power quality has become important in modern power networks because of the increased burden, (PQ) is becoming increasingly necessary. Which is very susceptible to current disruptions This is primarily due to the fact that non sinusoidal current is drawn by increasing the usage of non-linear power electronic equipment, causing current distortion [10]. Consequently, there is a growing need to track PQ in order to determine its effectiveness.

PQ disturbances may be identified by their nature, cause, and position, enabling for rectification measures that must be done As a result, harmonic is among the most popular disturbances in power quality. The formulation of a power quality plan requires a source. A new single-point measuring approach is presented in this work.

Based on a vector draft approach [10], this work provides a new single-point measuring method for estimating the harmonic source. A measurement are taken at the original locations. The process of common coupling (PCC) with harmonic distortion is carried out by PSCAD's simulation and data are examined with the help of a spectrogram in MATLAB.

Waveforms of voltage and current are adjusted with fundamental magnitude. To estimate the perpendicular point between the vectors, the normalised voltage and current are shown on the vector draught. The border between downstream and upstream is the center point of the normalised voltage. The location of the perpendicular point that falls on the precise region can be used to detect the harmonic source.

A comparison of the actual and power direction results was carried out. Finally, the proposed approach is more accurate and comparable to the real result than the power direction method.

2.10 Harmonic Estimation using Non- Linear Optimization Method

There are a variety of dispersed harmonic sources, like distributed generation (DG) with inverter interface, Identifying the origin of a problem has become more difficult as a result of new systems.

Harmonic voltages or currents are voltages or currents that are measured at a particular location. The purpose of this work [11] is to present a novel approach for estimating harmonics.

The difficulties are discussed and definitions are offered. Then, relevant materials are discovered in the literature, with an emphasis on the most recent approach (i.e. linear method) and the suggested method's details.

Lastly, using CYME and MATLAB software, the linear and nonlinear approaches are simulated and assessed using an example 27.6 kV distribution feeder with two big PV generators. The results reveal that while the linear technique may be correct in some cases, the nonlinear method is substantially more accurate in a wider variety of cases.

2.11 Identification of Harmonic using HARMFIND Computer Programme

It uses HARMFIND, a reverse harmonic power flow study programme, that has been developed to study the flow of harmonics in a given space as from point of view of the radial distribution system. The harmonic sources are identified, It [12] performs this by treating each system bus as a harmonic source one at a time and then estimates bus voltages and injected or absorbed power according to the sources of harmonic power or current direction, in this way the harmonics are identified, and the results are obtained.

2.12 Multiple Linear Regression Method

The topic of quantifying the harmonic impact of numerous known harmonic producing loads on a specific area of a power network is investigated in this research. To overcome the problem, a multiple linear regression (MLR) analysis- based approach [13] is provided. This method eliminates one of the key drawbacks of correlation-based methods: the difficulty in identifying reliable data sets as the number of possible loads increases. As a result of overcoming this constraint, the suggested approach may be utilized to analyze harmonic effects using all collected data. Simulation and a field case study were used to validate the suggested strategy. A sensitivity analysis is also carried out to resolve some practical concerns. This multiple linear regression(MLR) analysis flow chart is used to estimate harmonic impact of individual loads. The findings reveal that the suggested approach is a reliable tool for calculating the individual harmonic influence of a number of different large harmonic-producing loads.

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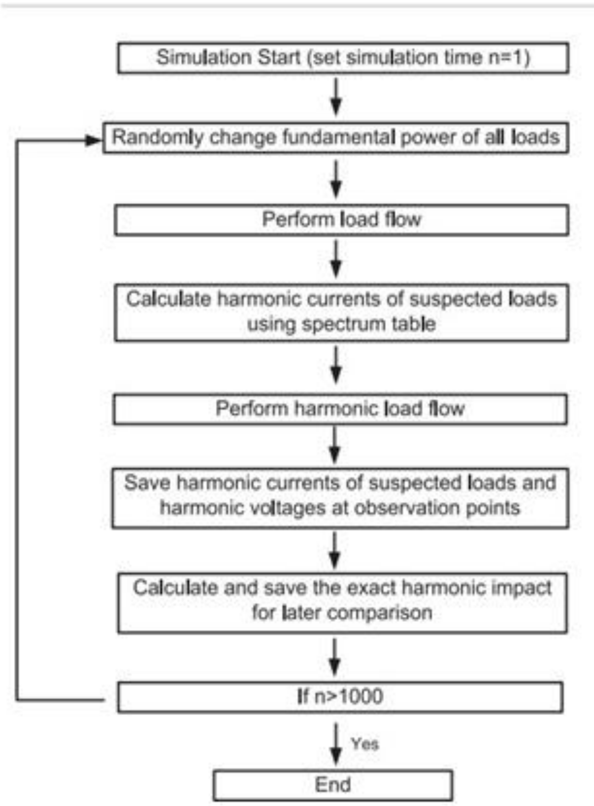

Figure 4: Flow chart of multiple linear regression method[13]

2.13 Finding Harmonic Location using Apparent Power Approach

The research [14] provided a novel approach of detecting the major harmonic source at the point of common coupling based on the harmonic apparent power established by the IEEE 1459-2010 power standard (PCC). The operator and customer harmonic voltage and current effects are determined using the reference impedance approach. The harmonic apparent power created by the effective action of the equivalent harmonic source on the system side and the user side was defined by directly comparing the size of the two to establish the position of the primary harmonic source, which was then coupled with the IEEE 1459-2010 standard. The harmonic impact of utility and customer at the PCC point can be calculated using the reference impedance approach suggested. The approach can account for the effect of impedance fluctuation on contribution decomposition. The principle is as follows: set a utility reference impedance and a customer reference impedance, make the difference between the real and reference impedance equivalent as an extra added harmonic source, and the new equivalent harmonic source is the actual harmonic source plus additional harmonic source. Figure depicts the specific procedure. Where Zu and Zc are the utility and customer's harmonic impedances, Zur and Zcr are the utility and customer's reference impedances, and Vpcc and Ipcc are the voltage and current of the PCC point, respectively.

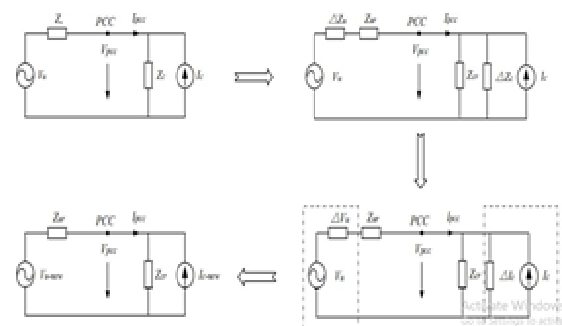

Figure 5: Reference impedance method[14]

The approach suggested in this research is easy to use and can be applicable to metering equipments, which would be crucial in engineering.

2.14 Particle Swarm Optimization Approach

An independent system operator tasked with providing fair and appropriate transmission services in an open-market system has a challenging problem in dynamic security-constrained network dispatch. A new approach based on recursive stability-constrained optimal power flow is demonstrated in this paper. With regard to normal conditions and contingencies, the particle swarm optimization approach [15] is used to optimise societal welfare while taking into account static and dynamic functional operating limits, as well as dynamic loading margin needs. A new approach for finding the sensitive loading direction associated with a dynamic loading margin is presented since the pattern of load rise is difficult to anticipate. To demonstrate and test the suggested approach, an IEEE 14-bus test system with both supply and demand bids is employed. Figure depicts a single-line layout of the IEEE 14-bus test system. Comprises of five synchronous machines with IEEE exciters, two of which are reactive power support synchronous compensators. The system has 11 loads totaling 259 MW and 81.3 Mvar.

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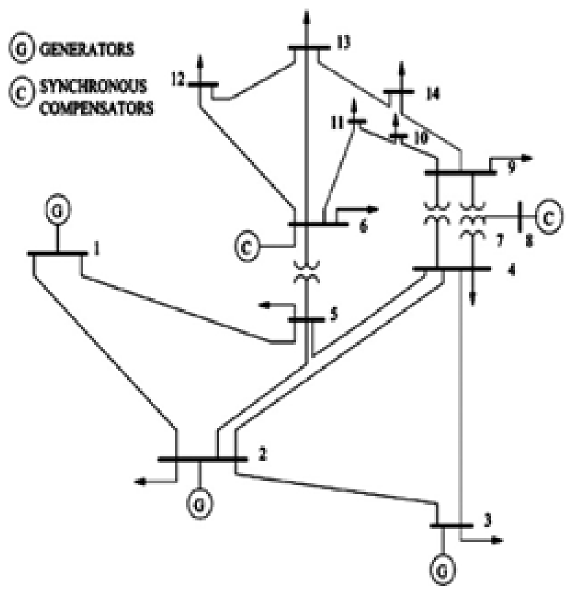

Figure 6: Single-line diagram of the IEEE 14- bus system.[15]

2.15 Harmonic Search using Robust Independent Component Analysis

A new approach for measuring utility harmonic impedance based on robust independent component analysis (RICA) and bootstrap check is proposed in this paper. For smaller data records, the RICA technique, which uses precise line search to find the best step size in each iteration and performs better. Simultaneously, a bootstrap check methodology is offered to eliminate the single solutions of these types of independent component analysis techniques [16]. The dispersion degree of the estimations of the bootstrap samples, which is defined by the coefficient of variation, is used to accomplish this verification approach.

Based on computer simulation and field testing, it is demonstrated that combining the RICA approach with the bootstrap check technique effectively reduces the negative impact of background harmonic variation and unique solutions on impedance evaluation, resulting in acceptable measurement results.

2.16 State Estimation Using a Kalman Filter approach

The Kalman filter is a recursive, on-line optimum estimator for a system that is represented by state variables [17]. The Kalman filter's main goal is to estimate state variables as accurately as possible from noisy observations by minimising the square of the anticipated error between the actual and predicted values. The Kalman filter was created by combining knowledge of the starting state, dynamic models of systems, and it is necessary to have a measurement model, For the linearizations the extended Kalman filter employs the filter estimated trajectory. At each iteration, the extended Kalman filter's computational processes are identical to those of the linear Kalman filter. The figure shows flow chart of kalman filter approach.

2.17 State Estimation Using a Kalman Filter approach

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The findings of this work are extremely useful in determining the system harmonic distortion over time (load daily cycle). The findings will also be useful in developing filters to reduce harmonics in the power system and improving the system load power factor.

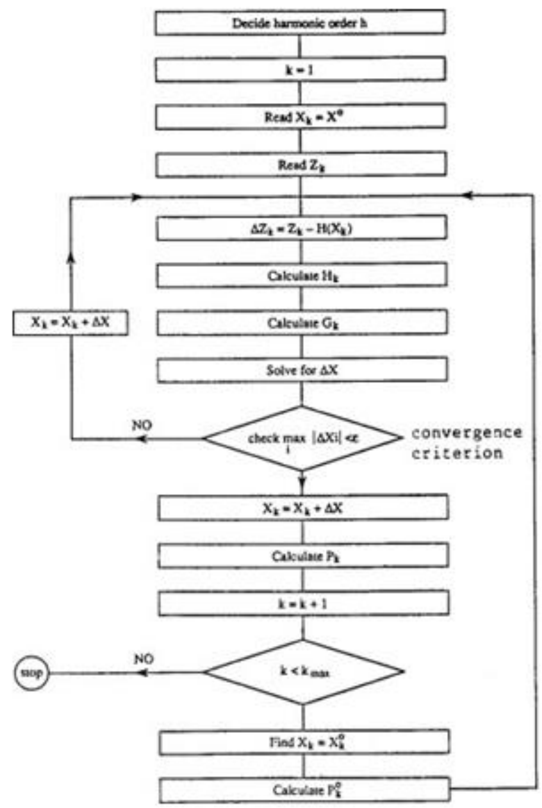

Figure 7: Flow chart of kalman filter approach[17]

2.17 Neural Network-Based Identification of Harmonic Sources by Process of Hypothesis Testing

In power systems with nonlinear loads and few

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permanent harmonic measurement devices, a structured neural network with several parallel two-layer feedforward nets may be trained to determine the amplitude of harmonic sources [18].

After then, the neural estimates may be limited to correspond to whatever direct harmonic measurements are available, which improves their accuracy. The overall rms errors for the limited estimates are always fewer than the errors for the neural estimates alone, according to a simulation test on a ten bus example system. The restricted neural network technique may then be employed in a hypothesis testing procedure to determine the source of new harmonic currents and their magnitudes.

A weighted rms error function is utilised to detect unknown harmonic injections and to identify the injecting bus. If the unknown harmonic source can be seen from the metering locations, hypothesis testing can be used to discover it. Closely connected neighbouring buses that are electrically distant from the metering locations, on the other hand, are hard to determine.

2.18 Controlled Voltage Disturbance Method

A power converter is used to inject a voltage transient into the supply system [19]. Because the approach makes use of controlled power electronic components, it may be employed as a stand-alone piece of portable measuring equipment or integrated into the operations of an active shunt filter for better harmonic control. The impedance is calculated by correlating the voltage and current transients recorded. The measuring approach is very accurate and effective, as demonstrated by simulations and experimental findings.

It works by injecting an appropriate transient voltage into the system, measuring the current transient that results, and then processing both with the MATLAB embedded transfer function estimation (TFE). With the simulation data, a good harmonic impedance evaluation is obtained, and actual analysis shows that this method performs well for a variety of simple network topologies.

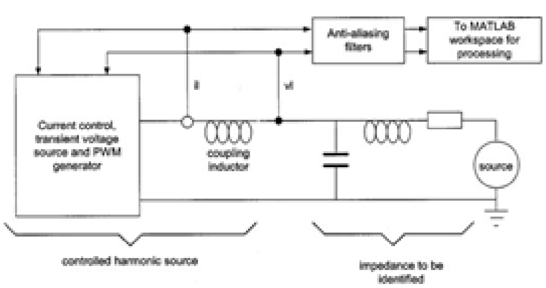

Figure 8: Simplified scheme of the overall system simulation[19]

Using an experimental facility based on a three phase active shunt filter, the approach was evaluated on four distinct passive circuits. In the presence of PWM waveforms, measurement noise, limited resolution (A/D converters), general noise due to power system harmonics, and switching noise present in a real experimental power electronic research lab, the impedance estimates believe with the anticipated impedances, indicating that the method is effective. The transient injection and TFE implementation offer a fair estimate of the impedance back to the supply for each test, as can be observed.

The 50 Hz source and other network harmonics can introduce errors into the impedance calculation, so a "steady state" data set can be used to decrease them. This works well sometimes with simulation, but in reality, these source harmonics can shift from period to period and cannot be corrected precisely. Several aspects of Power Quality Control may benefit from the estimating technique. To begin with, when employed as a stand alone piece of equipment, it will be feasible to create mesh equivalent networks of unknown power and distribution systems, which can subsequently be utilised for load flow studies, protection, or harmonic penetration prediction (as well as reliable passive filter design). The approach may also be included into an active shunt filter's control algorithm to offer on-line impedance estimates for control optimization, as well as a mechanism for reference current computation that does not need instrumentation outside of the active shunt filter. The approach may also be employed in embedded generating systems, where on-line impedance estimate can be used for load flow management and transient stability tracking.

III. CONCLUSION

The review gives introduction about various proposed methods present to find harmonic sources by utilizing different approaches and control methods, this is due to the increasing concern about power quality issues by utility customers, these days there is significant increase in use of power switching devices for controlling purpose because of its fast and accurate performance in controlling the equipments used in power systems as well as by utility customers, these methods use current and voltage from multiple locations in grid and then detect the source of harmonics in grid sites through the use of various approaches as discussed above.

These methods use Matlab and Digsilent software in a specific harmonic frequency to get improved outcome in non linear power systems IEEE model bus system, and they use coding and Simulink models in the process to correctly identify harmonic sources that contain the majority of the proportion of harmonics, However, its primary disadvantage is its calculation time, which necessitates the development of more accurate techniques. Future study should focus on developing more practical

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methods for solving non linear complicated optimization problems, as well as reducing computing time to obtain results.

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