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Harmonic Analysis to Utilize a Smart Grid Monitoring System

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***Abstract*-- Power efficiency Monitoring has evolved from a way of investigating consumer grievances to an important part of measurements of power system performance. In addition to special purpose power quality sensors, data on power quality is obtained from several other system control instruments. The effect is an immense amount of calculation data that is continually accumulated and must be analyzed to determine if the data will draw meaningful conclusions. In the 10-250 kHz range, which is primarily due to the generation of electronic power interfaces, higher-frequency components, also referred to as high-frequency harmonics, are now being important. A major difficulty lies in developing methods of analysis and reporting that simplify the data to a form that is easily understood and clearly describes challenges but does not omit important details, given the vast amount of harmonic data that can be obtained by grid instrumentation. This study examines a range of groundbreaking analysis and reporting methods that can be used to reduce vast volumes of harmonic data for individual harmonic orders down to a small number of indices or graphical representations that can be used to describe harmonic activity both at an individual site and at multiple sites via an electricity network. For mitigation methods, the techniques presented may be used to rank site efficiency.**

***Keywords*-- Power quality, Grid Monitoring, Harmonic data, Power efficiency, Electricity network.**

I. INTRODUCTION

The majority of problems with power efficiency can be described by current and voltage measurements. Since Power Qaulity (PQ) disturbances are comparatively rare and the intervals at which they occur are unplanned, it is often important to track or monitor continuously across a sustained period. PQ tracking has been commonly used to measure system-wide efficiency in addition to characterizing PQ concerns (benchmarking). A utility may identify unusual characteristics (can be an indication of equipment or device issues) by understanding the usual power quality performance of a system and can provide customers information to help them match their vital equipment characteristics with realistic power quality characteristics.

As the time scales of PQ disturbances vary significantly, power management systems should ideally have the capacity to record incidents ranging from DC to a few megahertz frequencies.

Although the majority of PQ events have frequency content below 5 kHz, many commercial power quality monitoring instruments have sampling speeds of 256 samples per cycle. The effect on consumer equipment of low power efficiency (PQ) has been well reported [1-2]. Electrical energy providers typically have a statutory obligation to ensure that the consistency of the service to particular consumers stays within the scope of technical requirements and national standards. The roll-out of the new grid system [3] has made much of this monitoring technology usable. Voltage distortion rather than distortion of the present waveform tends to be the parameter of choice with regard to waveform distortion. Instead of determining the total PQ status of a power delivery network, current distortion is useful for source detection and mitigation design for particular locations. In certain cases, in order would include a theoretical explanation of the harmonic output at a monitored site, the analysis of data obtained from monitoring operations requires the measurement of the voltage gross harmonic distortion (VTHD) (VTHD). There are two main drawbacks to this approach, however. First, if a site has poor VTHD performance (i.e. the overall VTHD is well below the defined by appropriate parameters or operational requirements), the VTHD does not give an indication of the specific harmonic order(s) causing a problem. Second, a VTHD value below a fixed limit does not necessarily ensure that all harmonic orders are well below their corresponding thresholds.

II. VARIOUS CHALLENGES IN ANALYSIS OF ELECTRIC POWER QUALITY

Many problems with power quality (PQ) arise from the incompatibility between both the energy transmission grid and the applications it supports in the electrical environment. There are indeed PQ problems that arise from negative interactions between some of the machinery as well as the chain of supply. For example, it is understood that nonlinear weights make consonant streams that can empower the reserve system into resonation [11].

2.1 Offline and Online Power Quality Monitoring

As utilities and modern customers have expanded their observing projects for power quality, the parts of information the board, examination, and translation have been the most basic errands in the general checking exertion for power quality. The move from a customary information assortment framework to a completely incorporated shrewd examination framework in the utilization of force quality administration frameworks would altogether improve the significance of force quality checking, as proposed in [14]. There are two floods of information examination of force productivity, that is, disconnected and online investigations.

(i) Records of uniform force productivity (e.g., day by day reports, month to month reports, measurable execution reports, leader rundowns, client PQ outlines).
(ii) Transient investigation, including numerical examination of maximal voltage, transient recurrence and transient length. Such examinations can uncover exchanging issues with gear, for example, capacitor banks.
(iii) Association of the level of force quality or use of assets with significant boundaries (e.g., voltage list execution as opposed to lightning streak thickness).
(iv) Energetic usage survey.
(v) Defensive framework activity investigation.
(vi) The output of machinery as a result of power quality levels (equipment sensitivity reports).

Data measurement of online power output requires data interpretation as it is collected. The findings of the study are available for quick dissemination immediately. The complexity of the online test program architecture criteria is typically greater than that of offline. In offline research, most characteristics are available.

2.2 Online Power Quality Monitoring

Data measurement of online power output requires data interpretation as it is collected. The findings of the study are available for quick dissemination immediately. The complexity of the online test program architecture criteria is typically greater than that of offline. In an online environment, the bulk of features available in offline research applications will also be made available. One of the key benefits of online data analysis is that it can offer quick transmission of messages and inform consumers of particular events of interest. On getting the updates, consumers may then take prompt action.

The origin of a fault on a delivery circuit is an exceptional example of an online analysis. In order to extract and analyze voltage and current waveforms, signal processing methods will be used. The measurement would show the location of the fault and this data would be disseminated to the line crew quickly [8].

III. PROBLEM STATEMENT & METHODOLOGY

For several years, harmonic distortion has occurred in electric power systems. However, electric utilities have increasingly established more tools for tracking and assessing the nature and impact of system and consumer interface distortions. This increased sensitivity is the product of concerns that in many electric power systems, harmonic distortion levels can increase [21-22]. There are two aspects that significantly add to this issue. In order to maximize the efficiency of current delivery grid infrastructures, the first is the expanded usage of utility and commercial capacitors. The second problem is the growing scale and application of nonlinear instruments, which, for distribution systems, produce the bulk of harmonic distortions. Due to the additional energy efficiencies and versatility they provide, the proportion of electric power that passes through electronic power devices is rising. With respect to harmonics, electronic power devices present a two-fold challenge. Not only do they produce harmonics, but they are often usually more sensitive than more common power system instruments to the resulting distortion. Therefore, with the volume of distorting technologies being used, consumer perceptions of the quality of service offered improve.

A stronger focus is placed on the level of service offered to clients as a result of these and other quality issues. In order to assess the typical level of service quality delivered, a large number of utilities have started implementing robust service quality control systems throughout their delivery systems. Utilities must greatly quantify the raw calculated data, whether they determine the overall system service output or the specific quality of customer service. Using sustained outage indexes such as SAIFI and CAIDI, utilities have measured service efficiency in the past. However, with the growing number of power electronic devices and other sensitive end-use devices, indexes that measure more nuanced areas of service efficiency such as harmonic distortion are required.

3.1 Sampling Techniques

Many electric utilities employ power quality control tools that report periodic measurements in order to determine harmonic distortion.

For each of the three phases and the neutral, power quality engineers configure these instruments to capture a sample of voltage and current. At daily time intervals, the monitors report (for example, every thirty minutes). The measurements usually consist of a continuous cycle. Thousands of calculations that need to be effectively summarized can be reported by power efficiency monitors. The waveforms reported include data on many characteristics of the steady state, including harmonic distortion, phase unbalance, power factor, form factor, and crest factor. The study of these waveforms for harmonic content will be the subject of this article. By using Fourier analysis, harmonic distortion can be studied due to its periodic existence. A Swift Fourier Transform is the computational process of measuring the magnitude and phase angle for each harmonic of a waveform (FFT). A mapping of time domain information to the frequency domain is the FFT. It shows the graphical output of an FFT in which the simple voltage variable, VI, has normalized the harmonic components. It is important to use indexes to summarize the multiple single-cycle calculations. A simple distortion analysis determines one unique useful index while the basic frequency variable normalizes the total voltage harmonic information. This value is called the voltage's complete harmonic distortion (THD).

3.2 Characterization of 3-Phase Harmonic Voltage Measurements

From a single process, multiple delivery system loads are supported. The harmonic content of each primary phase voltage varies as a consequence. As is always valid during testing at the point-of-common-coupling between the utility and a particular consumer, the difference in phase harmonic material may be important. The challenge of characterizing such harmonic data is how the harmonic distortion of a three-phase calculation that has different degrees of distortion at each point can be interpreted.

For the characterization of three stage harmonic measurements, there are two potential approaches. The first technique is to consider the distortion levels to be independent quantities at each point. The problem with this approach is that it is theoretically three times too big to count how much distortion levels surpass a specified level. The second way of characterizing harmonic three-phase calculations is to average the degree of distortion in the three phases. As a consequence, a single distortion level leads to the propagation of harmonic distortion samples through each three-phase steady-state calculation. It is likely that the importance of elevated levels of distortion in a single phase would be diminished by the other two stages, which could have lower levels of distortion.

Nonetheless, for the estimation of the harmonic distortion indices presented, we designate this form of combining the individual phase distortion levels.

3.3 Novel Harmonic Indices for Individual Sites

This examination joins an assortment of imaginative methodologies that can be utilized to limit enormous amounts of symphonious information to a set number of lists or graphical portrayals for singular consonant orders that can be utilized to clarify consonant movement at an individual site just as at a few locales in a power organization. The tools provided will classify low performing sites and thereby provide a way of rating site success that can be used to identify sites that need further investigation. To decide whether specific loads or other variables are present, it is also possible to identify sites and examine site clustering.

Which may be the case with data generated by advanced metering infrastructure, where data is to be analyzed from a very large number of locations, a particular location would generally not be of apprehension unless there is unequal activity at the situate; i.e. limits are surpassed or an unusual harmonic range is present. Indices are used to classify places of concern, and can be used to easily identify and rate sites that need further investigation in terms of disruption intensity.

3.4 Harmonic Compliance Index

The Harmonic Compliance Index (HCI) is intended to show that singular symphonious orders have been followed at an area with important cutoff points. As referenced in Section I, THD has recently been utilized as a proportion of similarity with restrictions because of absence of information or different devices. It is possible, however, to have a THD value that is far below the limit of THD but also has individual harmonic orders that surpass individual limits of harmonic order. The HCI solves this shortfall by including an immediate indicator of if, and if so, to what degree, any harmonic order at a site is above the cap. The HCI is calculated using (1);

$$HCI = \max\left(\frac{H_{THD}}{H_{THD\ \text{limit}}}, \frac{H_2}{H_{2\ \text{limit}}}, \frac{H_3}{H_{3\ \text{limit}}}, \dots \frac{H_n}{H_{n\ \text{limit}}}\right) \times 100\%,$$

Where:

HTHD limit addresses the most extreme permissible THD,
HTHD addresses the THD of the sign under scrutiny,
Hn addresses the greatness of symphonious n and
Hn limit addresses the suitable furthest reaches of symphonious n (variable for various consistence prerequisites).

On the off chance that all symphonious orders at a site are underneath their particular cutoff points as indicated by principles or working measures while considering the use of (X), the HCI worth would be under 100%. For this situation, before any symphonious request hits its cutoff, the record likewise shows the edge accessible. The HCI will be more prominent than 100 if each consonant request is over its cutoff and it will mean how far over the breaking point the most minimal performing symphonious request is. In order to decide the sites which need attention, the HCI can be used to rank sites. Figure gives a preview of the HCI's graphical representation, demonstrating how to use it to rate pages.

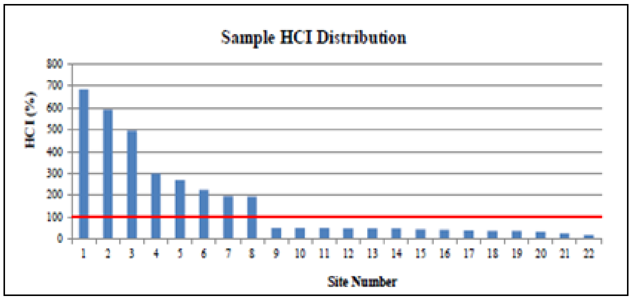


Figure: HCI Sample Distribution

3.5 Methods to Describe Harmonic Spectrum

Although the HCI will show if any provided singular symphonious request is over the important site limit, it does exclude any detail regarding the exact consonant order(s) over the breaking point and whether the symphonious reach is atypical. There are three new models acquainted with clarify the state of a consonant continuum. A type of normal is given by the principal boundary, featuring where the consonant orders are focused. This boundary is alluded to hereinafter as the Harmonic Average, hav. The other two boundaries give a thought of where the consonant range's significant lower and upper limits exist. Such parameters are hereinafter referred to respectively as hlow and strong. It is possible to determine places that have a harmonic range very different from what would be considered common by the help of such markers. The conventional dominant harmonic orders are low orders, precisely, 3rd and 5th, in an LV network, for example. If the spectrum shape was found to concentrate on using the above process, say the 15th harmonic, this would suggest a location that is not working as anticipated. It is obvious that not the same degree of insight is given by the traditional THD measurement.

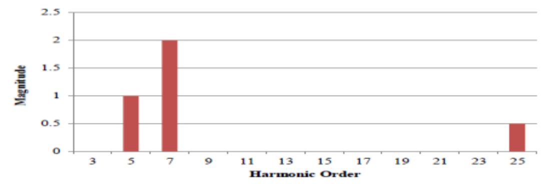
1) Calculation of Average Harmonic: The motivation behind the Average Harmonic count is to produce a sign of the convergence of a large portion of the symphonious range. This should be possible in the primary example by the condition found in (2):

$$h_{av} = \frac{\sum h_i H_i}{\sum H_i}, \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

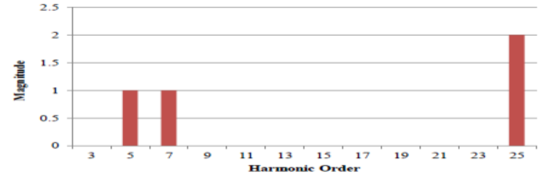
Where:
h_{av} is the Average Harmonic
h_i is the harmonic order for the i^{th} harmonic and
Hi is the magnitude of the i^{th} harmonic.

Think about two occasions, A and B, as demonstrated in Figure, for instance. 2. From Figure and all relating consonant continuum figures), the vertical hub mirrors an extent of the symphonious abundance corresponding to the principal.

$$h_{av} = \frac{(5 \times 1) + (7 \times 2) + (25 \times 0.5)}{1 + 2 + 0.5} = 9$$



(a) Case A



(b) Case B

Figure: Sample Harmonic Spectrums - Cases A and B

Hav = 15:5 for Case B. A property of the Average Harmonic idea yielded (2) is that few segments of low greatness can have an impact as significant as one segment of high extent. It is conceivable to stress the enormous parts of extent by supplanting Hi in (2) with,

H_i^n where n is 2 or larger. This substitution results in (3).

$$h_{av}(n) = \frac{\sum h_i H_i^n}{\sum H_i^n} \qquad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The impact of different estimations of n on hav for the two model cases appeared in figure is exhibited in Table I.

TABLE I
***hav* for various values of n**

n	Case A	Case B
1	9	15.5
2	7.5	18.7
3	7.0	21.2
5	7.0	23.9
10	7.0	25.0

The observer will see that with n = 10, just the biggest estimation of H decides hav. As the effect of a specific symphonious on gear is corresponding to the square of the size [11], it is suggested that an estimation of 2 be chosen. This will decrease the weight that little consonant extents provide for the outcome.

2) Lower and Upper Boundaries (h$_{low}$ *and h*$_{high}$*) - Preliminary:*

(a) Lower limit: the lower limit (hlow) is a portrayal of as per the pattern in which where the range has all the earmarks of being applicable at the lower recurrence end. These necessities the low frequencies of the continuum to be pushed in (3). In the principal case, by estimating each word with 1/hey, this should be possible by duplicating the details of the numerator and denominator by 1/hey, as found in (4).

$$h_{\text{low}}(n)' = \frac{\sum H_i^n}{\sum H_i^n / h_i} \qquad \text{………………(4)}$$

b) Upper limit: For the upper limit, by gauging each term in (3) with hello there, that is, increasing the numerator and denominator terms by howdy giving, it is essential to stress the higher recurrence segments of the range;

$$h_{\text{high}}(n)' = \frac{\sum h_i^2 H_i^n}{\sum h_i H_i^n} \qquad \text{…………………(5)}$$

From the preceding discussion, it would seem that a reasonable definition of bandwidth is;

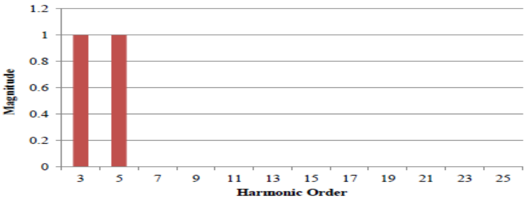
$$BW' = h_{\text{high}}(n)' - h_{\text{low}}(n)' \qquad \text{……(6)}$$

Applying these definitions to Cases A and B as shown in Fig. 2, gives the results in Table II.

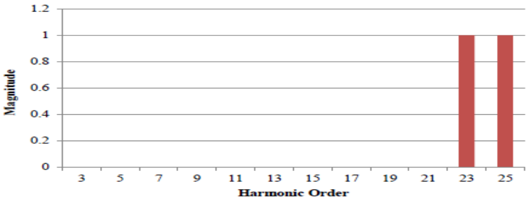
Table II
Preliminary Index Values For Cases A And B

	Case A	Case B
h_{av}	9	15.5
h'_{low}	6.9	9.5
h'_{high}	13.8	21.4
BW'	6.9	11.9

The qualities in table II will in general be level headed in any case. Regardless, if Cases C and D in figure are explored and for the two cases, identical data transfer capacities will be anticipated. Notwithstanding, as is appeared by the estimation esteems for the connected boundaries appeared in Table III, this isn't the situation.



(a) Case C



(b) Case D

Figure: Sample Harmonic Spectrums - Cases C and D

Table III
Testing Definitions Using Cases C And D

	Case C	Case D
h_{av}	4	24
h'_{low}	3.8	24.0
h'_{high}	4.3	24
BW'	0.5	0.08

Further dissecting the results in Table III, while the lower and maximum cutoff points sound reasonable, the transfer speeds are not same. In the accompanying area, the clarification for this can be seen by investigating the models given.

(c) Process conversation: accepting a continuum of music present at h1 and h2, every one of the greatness of the unit and utilizing n = 1. From (3);

$$h_{\text{av}}(n) = \frac{\sum h_i H_i^n}{\sum H_i^n} = \frac{h_1 + h_2}{2}$$

…..(7)

From(4)

$$h_{\text{low}}(n)' = \frac{\sum H_i^n}{\sum \frac{H_i^2}{h_i}} = \frac{2}{1/h_1 + 1/h_2} = \frac{2h_1h_2}{h_1 + h_2}$$

….(8)

From (5)

$$h_{\text{high}}(n)' = \frac{\sum h_i^2 H_i^n}{\sum h_i H_i^n} = \frac{h_1^2 + h_2^2}{h_1 + h_2}$$

…..(9)

This can be re-expressed as (10);

$$BW' = \frac{(h_1 - h_2)^2}{2h_{\text{av}}}$$

……..………………(10)

As seen in Table III, we see that the definition of BW' increases as the square of (h1- h2) and decreases with hav. Eqn (10) shows that a better definition of bandwidth is:

$$BW = \sqrt{2h_{\text{av}} BW'} = \sqrt{2h_{\text{av}}(h'_{\text{high}} - h'_{\text{low}})}$$

…….(11)

Further simplification of (11) leads to (12)

$$BW = \sqrt{2\left(\frac{\sum h_i^2 H_i}{\sum H_i} - \frac{\sum h_i H_i}{\sum \frac{H_i}{h_i}}\right)}$$

…….(12)

From (12), it is possible to determine the final values of h_{low} and h_{high} as follows:

$$h_{\text{low}} = h_{\text{av}} - BW/2$$

………………..(13)

$$h_{\text{high}} = h_{\text{av}} + BW/2$$

………………(14)

Table V
Testing Definations Using Cases A-D

	Case A	Case B	Case C	Case D
h_{av}	9	15.5	4	24
h_{low}	3.4	5.9	3	23
h_{high}	14.6	25.1	5	25
BW	11.2	19.2	2	2

3) Further Improvements: There was an assumption in the past treatment that hlow and high are evenly situated around the normal, yet there are a few spectra where this isn't the situation, like Case A in Fig. 2. The least estimated recurrence is 3.4, which is more modest than any consonant presence.

The issue is that it was assumed that the data transmission was comparably situated around the normal. A superior methodology is to accept that the data transfer capacity, BW, is situated so that the spectra over the normal are bound to the spectra beneath the proportion r, which ought to be determined as opposed to the default estimation of 0.5 as demonstrated in (13) and (13) (14). You will discover the articulation for r from the primer estimations of hhigh(n)' and hlow(n)'.

$$r = \frac{h_{\text{high}}(n)' - h_{\text{av}}}{h_{\text{av}} - h_{\text{low}}(n)'}$$

……………….(15)

Whence better values for h_{high} and h_{low} can be determined.

$$h_{\text{low}} = h_{\text{av}} - \frac{1}{r+1} BW$$

…..…….(16)

$$h_{\text{high}} = h_{\text{av}} + \frac{1}{r+1} BW$$

...……(17)

The change in the parameters for Case A are presented in Table V.

Table VI
Revised Definations of Upper & Lower Frequencies

	Case A Previous Definition	Case A Revised Definition
h_{av}	9	9
h_{low}	3.4	5.6
h_{high}	14.6	12.4
BW	11.2	11.2

3.6 Application of Methodology - Typical and Atypical Sites:

The fundamental point of this examination is to choose one of the few pages performs ineffectively or requires consideration somewhere else. This raises the issue; if the destinations are estimated by hlow and solid, How might lists be utilized to survey site effectiveness and give an approach to order atypical or consideration requiring locales? A method for recognizing ordinary and atypical locales is important to address this inquiry.

The technique taken is from the start to consider hlow and high independently. A histogram of the site esteems from most minimal to most noteworthy can be built on account of hlow. It is essential to order the least 5% and the best 5% of the web as atypical locales. This procedure would then be able to be duplicated to a serious level. Destinations would then be able to be partitioned into 4 structures:

Normal
Atypical h_{low} and typical h_{high}
Atypical h_{high} and typical h_{low}
Atypical h_{low} and atypical h_{high}

IV. RESULTS & DISCUSSION

4.1 Matlab Simulink Model

A graphical approach has been developed that effectively illustrates the distribution of harmonic magnitudes across all locations of a utility for each order. The system of graphical reporting requires showing the harmonic output of band locations. At every scene, the qualities for every band are focused on the 95% consonant norm and the cutoff points are standardized to such an extent that all symphonious orders can be shown on a similar scale (without standardization, some symphonious orders, for example, the fifth would have a greatness a lot bigger than others which would veil issues like inordinate high request, even music).

An example of this graphical strategy is found in Fig. 8. Noticing the third symphonious chart, 10% of the locales have third consonant levels that are higher than the suitable 95% possibility greatest. The chart additionally shows that consideration is given to the third, fifth, fifteenth and 21st sounds. A schematic representation of Fig. 8 has the benefit of explicitly showing the consonant orders of interest, the level of spots which may be higher than the breaking point for a provided symphonious request, and the conveyance of qualities for every symphonious request across the entire organization. This dissemination of qualities is significant in light of the fact that it tends to be utilized to show whether there are primary issues at all locales or whether there are consonant issues just at a predetermined number of anomaly destinations.

For the 3rd harmonic seen in Fig.8, for example, also the distribution of values appears to suggest that the 3rd harmonic has a significant number of places impacted.

Similarly, with more than 50 per cent of the positions exceeding the recommended value, the 21st harmonic has an equal range. These harmonic orders can require a solution which is network-wide. However, for the 5th harmonic, the compact distribution and the broad maximum value suggest that the source of the harmonic exceeding the prescribed value for this harmonic order is unique problems at comparatively few places. Any options will, however, be more regional.

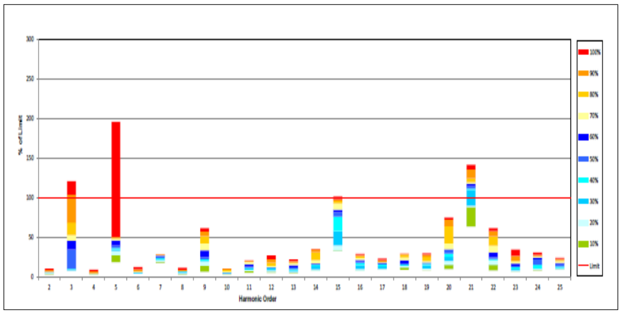


Figure: Example of a Graph for Network Reporting of Harmonics

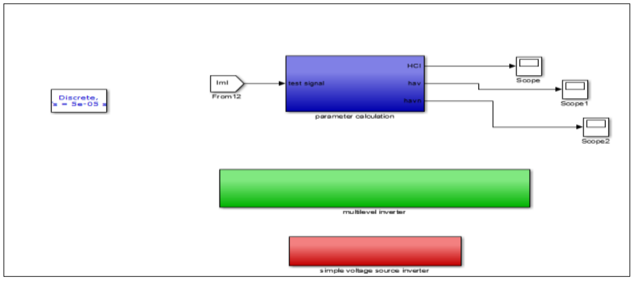


Figure: Matlab Simulink Setup for Harmonics Analysis

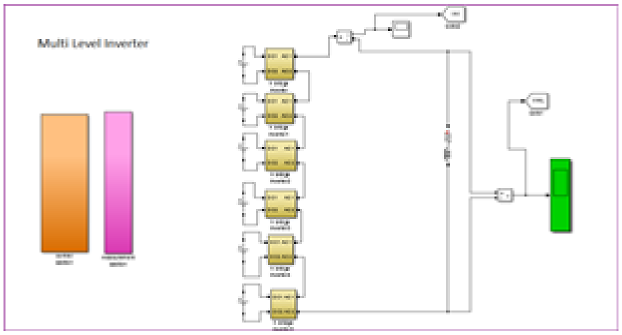


Figure: Simulink Model for Multi Level Inverter

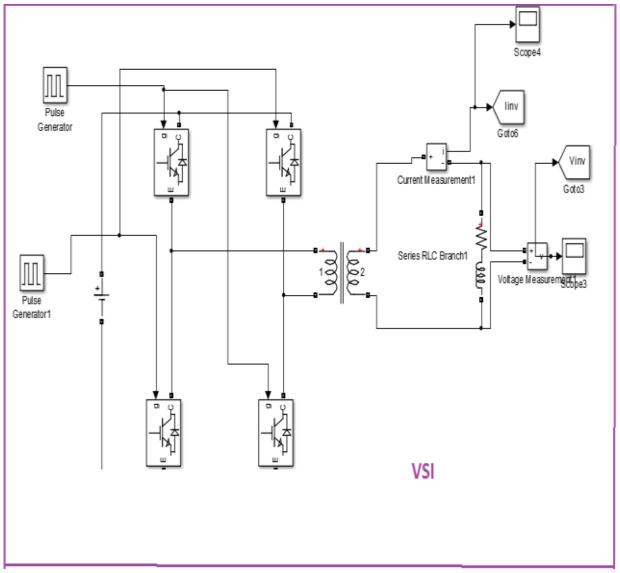


Figure: Simulink Model for VSI

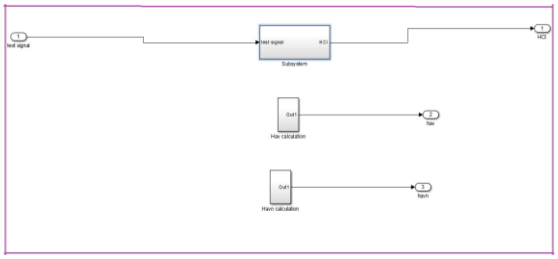


Figure: Parameter Calculations for Harmonics Analysis

Here hav and havn differ as the harmonics shifts in system. Fig. 5.6 displays the Simulink model setup for measurement of current in voltage source inverter in HCI, hav and havn while Fig. 5.7 displays the Simulink model configuration for measurement of current in voltage source inverter in HCI, hav and havn. It is obvious that as harmonics changes in system,values of hav and havn would also changes.

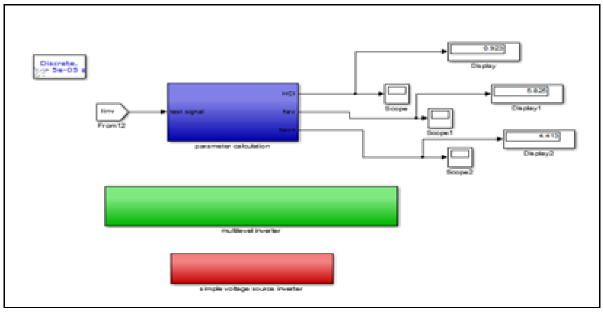


Figure: Simulink Model for calculation of voltage source inverter current (Iinv) for HCI, h_{av} and h_{avn}

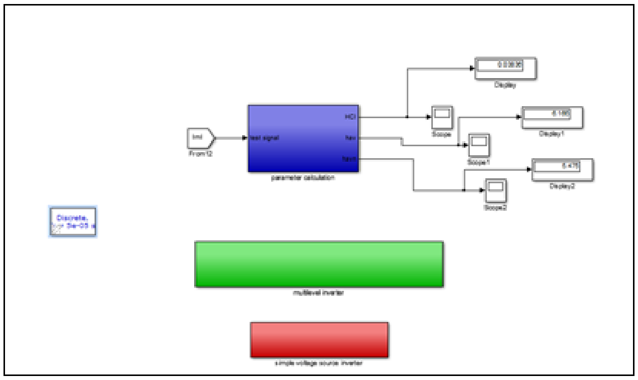


Figure: Simulink Model for calculation of multilevel inverter current (Iinv) for HCI, hav and havn

The consonant consistence record (HCI) is intended to demonstrate the consistence of individual symphonious orders at a site with significant cutoff points. Though to portray the state of a consonant range the boundary which gives a sort of normal, featuring where the symphonious orders are focused. This boundary is henceforth alluded to as the Average Harmonic, hav. A property of the definition for Average Harmonic given is that numerous low greatness segments will have as critical an effect as one huge size segment. The huge greatness segments can be underscored by supplanting havn. The impact of different estimations of n on hav is addressed by havn.

From above unmistakably music current through Harmonic Compliance Index (HCI) across VSI just as Multi level Inverter is less though the consonant current through hav and havn for both VSI and Multi level Inverter is enormous it is on the grounds that sounds are all around dispersed to figure estimations of hav and havn. Table No VII shows the aftereffects of sounds current and voltage boundary count.

Table VII
Harmonic Parameter Calculation

	HCI	hav	havn
I_{inv}	0.923	5.825	4.413
I_{ml}	0.08386	6.166	5.475
V_{inv}	0.9374	6.061	4.68
V_{ml}	0.125	7.338	7.075

V. CONCLUSION

This research implemented new harmonic-analysis and tracking methods that can be used to determine the performance of the harmonic site and network using data collected at a wide range of measuring points.

As a consequence of the vast number of measurement points, the volume of data produced means that traditional methods of calculating the level of harmonic distortion that exists in a network are no longer adequate and fail to produce a user-friendly visualization process. The techniques described in this paper address the issues correlated with the huge quantities of data and are capable of providing, even with a significant number of harmonic orders, a limited set of significant indices. Novel indices were presented to illustrate the shape of the harmonic continuum at a spot. Raw harmonic magnitudes are often used in this research. Related equations can be performed using normalized harmonic values (i.e. harmonic values separated by their respective limits) (i.e. harmonic values divided by their respective limits). Again, this is a field of future work which will theoretically prove to be more insightful than the methods explored in this work. Finally, in a compact way, a graphical method of network reporting of harmonics was implemented that shows precise detail of the harmonic output over many pages.

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