# **Study on Identification of Harmonic Contributions Between Utility and Customer**

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Abstract— Harmonic contributions can be decreased in Power System Transmission and Distribution by planning the voltage harmonic levels in the acceptable limits so that Harmonic pollution can be limited to some extent. In this research paper, These harmonic contributions are evaluated and measured at Point of Common Coupling (PCC) by using Harmonic Power Direction Method and Critical Impedance method. The locations of harmonic sources in the power system can be identified by using Harmonic Power Direction Method. Determination of both utility and customer harmonic contributions at point of common coupling is somewhat difficult task and that depends on connected loads, background of the loads and power system configuration. In this research paper, we tries to explain Harmonic Power Direction Method and Critical Impedance methods which can solve this problem and identifies the sharing responsibilities of harmonic contributions between utility and customer

Keywords-component; Point of common coupling, Harmonic power, Harmonic source detection, Power quality.

### I INTRODUCTION

In last few decades there must be a abnormal increase of the loads and in equal proportionate there is an increase of harmonic distortion levels due to non linear loads such as power electronic devices, saturable reactors which absorb non sinusoidal currents. Dominant harmonic sources can be identified and measured by using both upstream and downstream from the section of metering, such that load and utility are responsible for harmonic contributions. In the presence of unbalanced supply conditions, the voltage and current are much more effected because of negative sequence components, and harmonic source detection is very difficult. Dr.K.Ramesh Reddy HOD & Dean of PG Studies, G.Narayanamma Institute of Technology and Science, Hyderabad, A.P.

This difficulty is mainly due to overlapping effects of unbalance and nonlinearity. The Harmonic Power Direction method is the most common method for the identification and evaluation of harmonic sources. In this method, the direction harmonic power due to harmonic sources can be checked. At the measurement point, by considering the power direction we can estimate the dominant harmonic source or which have to greater harmonic contributions. The importance of this power direction method is explained in [1],[2]. T his method is so effective and has been used as tool in industries for many years. In the literature, to find out the dominant harmonic sources different methods have been proposed which includes: both distributed ( multipoint) and single point[3]. The distributed methods gives exact information about the harmonics source state in power system, but practical implementation is so hard because of the requirement of expensive and complex measurement instrumentation.

In Critical Impedance method, first of all utility generated harmonic reactive power is calculated first, then their equivalent impedance or admittance that consumes the reactive power is then calculated. This impedance is termed as Critical Impedance. By comparing the combined impedances of utility and customer with that of Critical Impedance dominant harmonic sources can be estimated.

Harmonic distortion above certain limit causes more expenditure has to be spent by customers and electric power companies. These excessive expenses are mainly due to the result of malfunctioning and frequency maintenance of equipment due to Harmonic distortion. The electric power companies are required to take necessary action to keep the harmonic distortion levels defined by standards, i.e. ,IEEE Standard 519-1992[4], and IEC6100-3-2[5].

# $P = R(V_{PCC} I_{PCC} *)$

Deregulated electric utility environment encourages the competition between generation, transmission and distribution companies to ensure a low market price and to enhance the stability and reliability of the system. Because of security, market operations and privacy, the data like system network parameters, actual generation and connected load data cannot be shared by other electric companies. So under these type of situations, actual information may not be get from the network to identify the harmonic distortion levels. Generally measurements of harmonic level are costly and sophisticated than ordinary measurements [6].

In this research paper, single point measurement is adopted which is taken at point of common coupling by considering a single phase simple system to explain the strength of Harmonic Power Flow method[7] and Critical Impedance method[8], and a simulation is done using MATLAB and results are presented here by considering the sample of utility and customer parameters.

#### II. PRINCIPLE OF THE PROPOSED METHOD

A .Power Flow Method:

To determine whether utility or customer is the dominant contributor to harmonic current if harmonic pollution is mainly concerned with current harmonics which are measured at point of common coupling, for this utility and customer sides are represented by their Norton's Equivalents as shown in Fig.1.



Fig.1. Norton equivalent circuit for harmonic source detection

In this figure, IU and IC are the utility and customer harmonic currents and ZU and ZC utility and customer harmonic impedances. At PCC, we have to measure voltage and current to determine which side causes the harmonic distortion. After calculating the voltage and current the harmonic power index can be calculated as, In this figure,  $I_U$  and  $I_C$  are the utility and customer harmonic currents and  $Z_U$  and  $Z_C$  utility and customer harmonic impedances. At PCC, we have to measure voltage and current to determine which side causes the harmonic distortion. After calculating the voltage and current the harmonic power index can be calculated as,

$$P = R(V_{PCC} I_{PCC} *)$$

The Norton's approach [9] is more commonly used method for the identification and evaluation of dominant harmonic sources. The direction of harmonic power can be monitored by using this method at PCC, and by measuring the harmonic voltage Vh and harmonic current ih and their respective phase angles  $\theta_{vh}$  and  $\theta_{ih}$ . The active power can be calculated as,

$$P = VhIhcos(\theta vh - \theta ih) --- (1)$$

In this approach, if measured active power is positive, then harmonic distortion is on utility side, and if active power is negative, then harmonic distortion is on customer side. By using Fig 2 and the information available at PCC, we can evaluate dominant harmonic sources by using direction of power.



Fig.2. Harmonic source contributions

From the above Fig.2.,

$$\begin{array}{rcl} I_U &=& V_{PCC} / & Z_U \; + \; I_{PCC} \\ I_C &=& V_{PCC} / & Z_C \; - \; I_{PCC} \end{array}$$

According to the principle of superposition and by using Fig.3, customer and utility IPCC can be determined.

$$\begin{split} I_{U-PCC} &= Z_U / [Z_U + Z_C] * I_U & --- & (2.1) \\ I_{C-PCC} &= Z_C / [Z_U + Z_C] * I_C & --- & (2.2) \end{split}$$



# Fig.3. Decomposition of IPCC of the hth harmonic into two components

From the above Fig.3,

$$I_{PCC} = I_{U-PCC} + (-I_{C-PCC})$$
 --- (3)

A similar index can be defined in terms of Voltage distortion point of view. The voltage distortion contribution at each harmonic source can be evaluated as,

$$V_{U-PCC} = Z_U Z_C / [Z_U + Z_C] * I_U --- (4.1)$$

$$V_{C-PCC} = Z_U Z_C / [Z_U + Z_C] * I_C$$
 ---- (4.2)

Again, similar to that of the current phasors, the phasors of  $V_{U-PCC}$  and  $V_{C-PCC}$  have to be projected onto the axis for scalar harmonic contribution indices.

$$V_{PCC} = V_{U-PCC} + V_{C-PCC}$$
 --- (4.3)



Fig.4 a practical case that can cause large phase angle between utility and customer.

### B. Critical Impedance method:

Harmonic contributions of customer and utility can also be determined by using Critical Impedance method. This method can be explained by using the same model as shown in Fig.1. As analyzed in [10], Critical Impedance method is theoretically equal to power direction method for calculating the utility side voltage( $I_UZ_U$ ) and customer side voltage( $I_CZ_C$ ). If  $I_CZ_C$  is greater than  $I_UZ_U$ , then customer side will have more harmonic contributions at PCC. By keeping in mind of above, Fig.1 of Nortons equivalent can be converted into Thevenin's Equivalent circuit as shown in Fig.5



Fig.5. Thevenin equivalent circuit

Then the total impedance of the network will become the sum of utility and customer side impedances.

$$E_U = |I_U Z_U|$$
 and  $E_C = |I_C Z_C|$  --- (5.2)

Here reference is voltage source which of balanced one and customer side are controlled by  $\delta$ , which is the phase angle difference between two harmonic sources. By measuring the utility and harmonic side voltage magnitudes dominant harmonic sources can be identified. It is well known fact that active power flow can depend on bus voltage phase angles. while the magnitudes of bus voltages affect the flow of reactive power flow. The phase angle between the two sources are  $\delta$ . But  $\cos \delta$  is always less than unity. If  $X_U+X_C > 0$ , then utility side voltage is greater than customer side voltage, thereby the direction of Re-active power(Q) is from utility side to customer side, but this direction condition may not be sufficient one, because Re-active power still flows from utility side to customer side even though  $E_{\rm C}$  >  $E_U$  but  $EC\cos\delta < E_U$ . From above we can say,  $\delta$  plays a dominant role to find out the dominant harmonic sources.

Another important prerequisite condition is that for using the direction of reactive power as harmonic source indicator is  $X_U+X_C > 0$ , this condition only true at fundamental frequency and it fails at all high frequency conditions.

$$P=(E_{U}E_{C})/|Z|*\sin\delta ----(6.1)$$
  

$$Q = E_{U}I\sin\theta = (E_{U}/Z)(EC\cos\delta - E_{U}) ----(6.2)$$

If Q>0, then utility side voltage is smaller than customer side voltage and vice versa condition is applied. The new index called Critical Impedance(CI) defined in[8], which given by,

- $CI = 2(Q/I^2)$  ---- (7) If CI > 0, major harmonic contributor is customer, that is utility source absorbs more reactive power.
- If CI< 0, the following points are to be remembered,
  - a. If CI > Zmax, main harmonic contributor is utility.
  - b. If CI > Zmin, main harmonic contributor is
  - c. If CI is in between Zmin to Zmax, then no definite conclusion will get.

Now it is important to consider two cases,

**Case 1:** Suppose if the impedance is only capacitive, i.e., Z = -jX, this condition exists at customer side whenever there is a light load condition or reactive power Compensation exists.

> Then reactive power absorbed is given by,  $Q = E_U I sin\theta = (E_U/X)(E_C cos \delta - E_U)$

From above equation we can say utility delivers reactive power when  $E_C > E_U$ , so capacitive case is opposite to inductive case.

**Case 2**: Suppose if Z = R, the Re-active power (Q) is equal to Active power(P) and Re-active power(Q) is given by,

$$P = Q = E_U I sin\theta = (E_U/R)(E_C cos\delta - E_U)$$

Here in this case active power(P) component is the dominant harmonic source indicator instead of Re-active power(Q). but in practical Power System only resistive load between utility and customer rarely exists..

## **III SAMPLE TEST RESULTS**

The proposed method are verified in this section by using the fictitious circuit shown in Fig.2. The circuit parameters are,

Iu = 
$$1.0/_0$$
 p.u, Ic =  $3.0/_{\delta}$  p.u.,  
Zu =  $1.0+i8.0$ , Zc =  $5.0+i45$ ;

Let the phase angle ' $\delta$ ' of IC, which varies from 0° to 360°, and phase of utility side is set as reference and maintaining the phase angle is equal to 0°.

Below Fig.6 shows the correlation between current superposition indices at point of common coupling,



A. Maintaining the Integrity of the Specifications

### IV CONCLUSION

The voltage and current distortions of the power system is very much depends on Harmonics. Even if the calculated harmonic power is small, but there is much distortion in current and voltage waveforms can trigger the malfunction of electronic circuits.. So contributions of harmonics is very important to define, otherwise more expenditure has to spent by customers. The resultant voltage distortion at PCC is very much depends on the relative phase angles of the external harmonic voltage sources. The direction of reactive power, on the other hand, has a closer relationship to the source magnitudes.

If the circuit impedance is purely reactive, the direction of reactive power is actually a necessary condition indicating one source has larger magnitude than the other. The simulations carried out using a program written in MATLAB to indicate that without knowing the specific characteristics of the various distorting loads and the supply system, it is difficult to reach exact conclusion on the location of dominant harmonic sources, even though the distorting load is consider to be the dominant harmonic producing part of the system.

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