Indonesian Journal of Electrical Engineering and Computer Science
Vol. 9, No. 3, March 2018, pp. 690~695
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v9.i3.pp 690-695

Harmonic Load Diagnostic Techniques and Methodologies: A Review

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Article Info

Article history:

Received Jun 9, 2016
Revised Nov 20, 2016
Accepted Dec 11, 2016

Keywords:

Diagnostic
Harmonic
Harmonic load
Power systems

ABSTRACT

This paper will review on the existing techniques and methodologies of harmonic load diagnostic system. The increasingly amount of harmonic producing load used in power system are the main contribution in quantifying each harmonic disturbance effects of the multiple harmonic producing loads and it became very important. Literature proposes two different techniques and methods on the harmonic source identification under the soft computing technique classification. The advantages and disadvantages of harmonic load identification techniques and methods are discussed in this paper. In the proposed method, the issue on the harmonic contribution is determine and transformed to a data correlation analysis. Several techniques to identify the sources of harmonic signals in electric power systems are described and reviewed based on previous paper. Comparative studies of the methods are also done to evaluate the performance of each technique. However, without sufficient information in this inconsistent environment on the property of the power system, accurate harmonic producing load diagnosis methods are important and further investigations in this regard assumes great implication.

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1. INTRODUCTION

Power quality disturbances are becoming major issues to all electricity consumers with the rapid growth of electrical equipment used in our technologies [1]. These disturbances can affect a lot of sensitive loads that are connected to the power system which lead to hardware failure and malfunction [2]. The monitoring of the power quality signals are still using the conventional techniques that are based on visual of voltage and current waveforms [3]. The diagnosis of these disturbances are very difficult and it require engineer's expertise and knowledge in many electrical areas [4]. Some waveform distortions that usually affect the power quality signal are harmonic and interharmonic distortions [5]. Identification of harmonic load has been increasingly important due to the increase level of harmonic distortion present in power systems. The identification and classification of harmonic loads based on power system measurements undeniably a difficult task [6]. The frequently changing nature of harmonic and the uncertainty associated with the harmonic characterization of even commonly used loads, make the use of conventional methods outdated [7], [8]. Reducing and controlling such harmonics have been a major concern of power engineers for many years. Researches predict that harmonic levels in power system are going to increase in the future [9] considering the convenience brought to everyday life by the use of these nonlinear loads. Harmonics are here to stay regardless of the ill effects associated with the presence of harmonics are well documented in the literature. The increased in the non-linear load uses may distorting the steady state of the current waveforms and ac voltage. It is in return becomes a potential problem to the regular performance of power system. This threat may result in both current and voltage to appear as a non-sinusoidal waveform at a given location. The harmonic distortion issue is becoming more important in power system [10]. It is usually not possible to separate the contributions or to identify the source of the harmonic distortion by just looking at the waveforms.

The increasingly amount of harmonic producing load uses in the power system nowadays are making the harmonic producing load diagnostic issue become more complex. It is very important to develop techniques and methods to measure the harmonic disturbance of all the harmonic producing load in power quality management particularly when there is a harmonic disturbance in power system. Measuring each harmonic impacts of the several harmonic producing loads is becoming more important especially right after the paper proposing the "reward and punishment program" [11]. Widespread use of harmonic producing loads are making the harmonics disturbance become an essential part of the power quality networks [12]. Various regulations like the IEC 61000 and IEEE Std.519-1992 [13] restrict the power utilities to operate properly within the certain limits of distortion.

Ahmad et.al [14] reviewed several of the existing systems, methods and techniques that are used to monitor power quality. The paper is mainly focus on the power quality monitoring systems which are composed of various tools, communication links, software etc. that work together as one coherent system. They are developing an understanding about the power quality management in the area of power industry. Power quality meter placement techniques that were presented and the basic idea of each method or system are discussed in order to have an understanding about its importance and role. The comparisons of the techniques is made in terms of their merits and demerits.

Supriya and Nambiar [12] on the other hand reviewed the harmonic identification techniques in their paper. Single point methods and multipoint methods are proposed as the two main techniques of harmonic source identification in their paper. They provide a detailed survey of these methods along with their advantages and disadvantages. Based on their review, they concluded that harmonic state estimation using the multipoint methods are better suited for harmonic source identification. However, without sufficient information on the topology of the power system, correct harmonic source identification methods are essential and investigations in this regard assumes great significance.

Identification of harmonic load source in complex power networks assumes great significance for determining these committers of harmonics. Eventually, to effectively detect the harmonic mitigation means so that the entire power system is not polluted. No researchers has found any standard on defining the method of identifying the dominant harmonic disturbance [15]. When the location of the dominant harmonic sources is unknown to the utilities, several technical problems will come up. These problems may include the malfunctioning of the instruments, reduction in the life of the electrical equipment and other few creating operational problems in the identification methods of power network. Accurate techniques for harmonic source identification are essential under such circumstances. Figure 1 shows the block diagram of the existing techniques and methods on the identification of harmonic load.

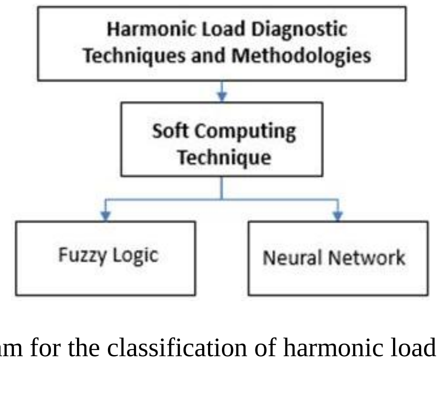

Figure 1. Block diagram for the classification of harmonic load identification methods

2. DISCUSSION OF METHODS

2.1. Neural Networks

An adaptive perception approach in neural networks have been actively tested, used and applied successfully for harmonic estimation in a power system. The advantages of applying artificial neural networks are their ability to recognize non-linear functions, adaptation to different environments and high noise tolerance. These networks have to be trained properly for accurate identification of harmonic sources.

This method of load identification helps in non-intrusive harmonic source detection without human intervention. To make initial estimates of harmonic sources in a power system with nonlinear loads, neural networks are able to be use and relatively few permanent harmonic measuring instruments. The estimates can then be used with the state estimation to find additional unknown sources.

In [16], to make initial estimates of harmonic sources in a power system with nonlinear loads, neural networks are applied. For further improves the measurements, the initial estimates are then used as pseudomeasurements for harmonic state estimation. By using a simulation tests, it shows that the trained neural networks are able to produce acceptable estimates for varying harmonic sources. In addition, the state estimator will generally pull these estimates closer to the correct values. Eventually, the process can be successfully monitored and identified the "suspected" harmonic source that had not previously been measured. However, the neural networks must "learn" to associate the available power network data patterns with patterns of harmonic source behavior. To learn this behavior, system operating data and data are obtained from temporary harmonic source monitors at known sources. Then, the neural networks will estimate the harmonic sources based on experience in the same way an experienced operator infers pseudo measurements from available data for conventional state estimation.

Srinivasan [17] proposes a neural networks based approach for non-intrusive harmonic source identification. The application of neural networks based models on nonintrusive signature identification without human intervention in investigated in this paper. Neural networks are trained to extract important features from the input current waveform in this approach to uniquely identify various types of loads using their distinct harmonic signatures. Therefore, the non-invasive load diagnostic will be important in future power-quality monitoring and enhancement systems. The function and classification approximation capabilities of artificial neural networks have been used in power-quality studies, fault, and harmonics source classification [18]–[22]. Meanwhile, the support vector machine model has shown a high potential in power harmonics related pattern recognition [23], [24]. One the major benefits that are derived from the parallel structure of artificial neural networks is their ability to adapt to different environments, their high noise tolerance and ability to recognize non-linear functions. The diagnosis of harmonic producing loads by using the application of artificial neural networks has been verified before with great success. The useful aspects of such an application are discussed by Varadan and Makram in [25]. In the paper, it shows the success in the implementation even though the choice of architecture, the topology and the selection of features of the neural networks are speculative decisions based on engineering judgement. The known back-propagation technique and a supervised learning procedure is used and adopted in the network training. However, to examine the neural networks, the pre-processing raw data is needed from the power system before being input to the networks.

Ray and Subudhi [26] are mainly focuses on exploiting two computational intelligence techniques; artificial neural networks and evolutionary computation techniques in harmonics sources identification in power system. An accurate estimation of harmonics in distorted power system current or voltage signal is important to efficiently design filters for harmonics elimination. A new estimation algorithm for estimating harmonic contents in a power system signal contaminated with noise is presented in the paper. It is essential for designing filters for eliminating and reducing the effects of harmonics in a power system after the estimation of the harmonic content of the power system signal by using the proposed algorithm.

On the other hand, Janani and Himavathi [27] proposes the neural networks based approach for the identification of various harmonic sources present in an electrical installation. The harmonic source devices are identified in this method by using their distinct 'harmonic signatures' extracted from the input current waveform. With increase in the number of loads and their combinations, the complexity will be increase. Therefore, such automated non-intrusive harmonic load device identification may help in monitoring and enhancing power quality. Finally, the performance of a neural networks to a large extent depends upon the type of architecture used and their learning algorithm.

2.2. Fuzzy Logic

A fuzzy logic is a method to combine the natural events with the imprecision associated with the computational power of the computer to produce highly flexible, robust and intelligent reasoning systems. It consists of mathematical strength to the certain emulation of linguistic and attributes associated with human cognition. The theory of fuzzy logic is based upon the functions of persuasion and cognitive processes and the notion of relative graded membership. The utility of fuzzy sets lies in their ability to model uncertain or vague data which are so often encountered in real life.

Method based on fuzzy logic for harmonic source identification is presented by Banshwar and Chandel [28]. By using the fuzzy IF-THEN inference rules, harmonic sources are detected. Then, the outputs of the fuzzy rule bases are then de-fuzzified to recover crisp values to identify harmonic sources. By using the power quality analyzer, the harmonic signals and spectrums are obtained which act as an input in the proposed method. To identify the harmonics sources in power system, the technique utilizes the current as well as voltage spectra of loads. Various examples are done to demonstrate the potential of the proposed technique.

The application of fuzzy logic to power quality issue is also proposed by Nawi et.al [29]. It paper describes on how the sources of harmonics detected by using fuzzy sets and IF-THEN inferences rules. It is well known that the harmonics can create unwanted impacts on power systems and to eventually to the end-users. Manufactures, customer and electrical utilities have always been bothered by harmonic distortion problems in power system. By applying the application of Fast Fourier Transform, the harmonic signals and spectrum are determined. For these cases, a fuzzy inference system is experimentally implemented to show the general procedures of how to use this theory. In this approach, it appears that the fuzzy sets theory can play an important role in diagnosing power quality disturbances. Therefore, it can offer insights towards the satisfaction of the needs of customers, manufacturers and utilities.

The diagnosis of harmonic producing load is important in order to give a proper guidance for mitigation action. Therefore, the ability of fuzzy logic is applied as integrating system to identify various harmonic producing loads of those disturbance particularly of harmonic. It is done by adapting the fuzzy sets and IF-THEN inference rules. As far as the harmonics load identification is concerned, the technique developed by using the fuzzy logic method by studying the behavior and characteristic of the disturbance at the data produced a promising result.

3. COMPARATIVE STUDIES OF METHODS

Other than classifying the load diagnostic approach, it is important to compare individual techniques and different categories. Comparison of some of the methods used in harmonic load diagnosis has been attempted by several researchers. The most comprehensive and earliest comparisons was made by Willis and Northcote-Green [30]. They did the diagnosis method comparison tests on 14 loads. Meanwhile, Dash [31] also did the diagnosis comparison method on several neural networks and the fuzzy logic based methods. Liu [32] compared three other techniques neural networks, fuzzy logic and autoregressive models on the basis of the simulation study. It is concluded in the paper that the neural networks and fuzzy logic are much better compared to autoregressive models. To establish the superiority if their proposed diagnostic methods, many researches provide other limited comparative data over the limited number of previously published methods. Mbamalu and El- Hawary [33] has done the comparison of their autoregressive model with the Box-Jenkins method. Meanwhile, Willis [34] makes a comparison between their simulation method with two other simulation methods. The recent comparisons of the different load diagnosis methods are needed to provide a challenging opportunity for future research. With the wide variety of assumptions and objectives, the unlimited possibility of matching and mixing of different components of various methods is achievable. Based on the statistical robust method [35] the electric load diagnosis of different techniques are compared by using the short term load diagnostic. Other method like the diagnose the load in smart grid is discussed by Z. Aung [36] and identifying the load by considering the meteorology factors is expalained by Y.Jin [37].

The application of artificial neural networks method to the problem of harmonic load diagnosis has some practical issue and they are discussed in [25]. Based on the paper, it is shown that in the identification process, the magnitude and harmonic order of the injected harmonic current are the only two critical features. Furthermore, the feature space is not separated by simple linear boundaries from the need of a hidden layer in the implementation showed. The complex hyper-surfaces existence in the feature space that discriminate between the classes of loads justifies the use of artificial neural networks for this application. The choice of the final network in terms of its architecture and topology was examined on the basis of several factors, training time and correct classification being the main issues of the decision process. Table 1 illustrate the detailed numbers of the articles that used neural networks and fuzzy logic method.

Table 1. List of Literature for Harmonic Load Identification

Neural Network Method	Fuzzy Logic Method
[10,11,20,21]	[22,23]

1. Neural Networks: Neural networks is one of the most current effective classification methods. Its natural speed and versatility are the advantages of choosing neural network in the data classification. It can handle the non-linear and multi-variables data sets. Bitter et.al. [38], discussed critical cases in intrusions like spam, worm being resolved by neural networks. He reports that dataset characteristics, such as format, size and dimensionality are very critical in order to model a successful neural network. For harmonic device identification, the harmonic components of input current waveform are used as

sources of valuable information. However, the parameter of the phase angle of the currents can compromise the harmonic source identification as shown by [39].

2. Fuzzy logic: By applying the IF-THEN rules, fuzzy logic is a potential technique to cope with decision-making strategies. It can provide a linguistic representation and can solve the non-linear problems. Fuzzy logic classifiers are proposed by Liu et.al. [40], where fuzzy system employed to evaluate the potential threats. The results show that fuzzy system could decrease the false alarm rate and provide better evaluation of the potential threats.

4. CONCLUSION

A review of the harmonic load diagnosis techniques and methods are discussed and the possible direction of further research are analyzed in this paper. Based on this, two different methods under the soft computing techniques to determine the individual contributions of multiple harmonic loads are researched. Even though the techniques and methods for the diagnostics have been used, the algorithms used to determine the harmonic load of multiple harmonic sources remain to be verified due to its accuracy level. Therefore, the future step that need to be taken in this research is to develop a better theoretical support to the techniques and methods and getting a data processing method.

Different soft computing techniques namely; neural network and fuzzy logic have been used to harmonic load diagnostic. The advantages and disadvantages of these methods and techniques are presented and discussed. It can be concluded from the works reported so far that demand on the diagnostic techniques based on soft computing methods are gaining highly beneficial for their effective use. The research need to be replacing and shifting from the old methods and techniques with a newer and more accurate one. Thus, a further research on this issue using an advanced digital signal processing such as Time-Frequency Distribution (TFD) is needed due to achieve high accuracy and reliable result of harmonic load diagnosis.

ACKNOWLEDGEMENTS

This research is supported by Advanced Digital Signal Processing Laboratory (ADSP Lab). Special thanks also to the Faculty of Electrical Engineering and Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM), Center for Robotics and Industrial Automation (CeRIA) of UTeM, Ministry of Higher Education Malaysia (MOHE) and Ministry of Science, Technology and Innovation (MOSTI) for giving their cooperation and funding for this research with grant number 06-01-14-SF00119 L00025. Their support is gratefully acknowledged.

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