HARMONIC SOURCE IDENTIFICATION IN POWER DISTRIBUTION SYSTEM AND METER PLACEMENT USING NETWORK IMPEDANCE APPROACH

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DEDICATION

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ABSTRACT

The growing use of non-linear loads in the electrical systems has made harmonics a serious problem. Harmonic disturbance leads to degradation of power quality by deforming the current or voltage waveforms, thus, necessitating the effective techniques for harmonics detection. The purpose of this study is to propose a method for a single harmonic source identification in power distribution system by implementing a network impedance technique, and optimize the meters allocation by optimum meter placement algorithm (OMPA). The main advantage of this technique is that it results in enhanced accuracy with minimum vulnerability towards deviations in the measurements. Moreover, it minimizes the number of nodes for meter allocations, thereby resulting in economic advantages. To validate the results and effectiveness of the proposed methodology, a standard IEEE 13-Bus industrial network is designed using ETAP software and the algorithm is developed in MATLAB software. The validation of proposed algorithm OMPA is done by comparing its results with Monte Carlo (MC) technique. The results show that without any deviation in the network impedances, OMPA gives 89% accuracy as compared to 75% accuracy of MC. For the deviation value $\partial = 1^{-13}$ in the harmonic impedances, the overall accuracy of OMPA stays at 75%, while that of MC drops down to 56%. The developed algorithm OMPA is not only better in performance in harmonics identification with minimum number of meters, but also shows more resistance to the variations in the harmonic impedances as compared to MC algorithm.

ABSTRAK

Penggunaan beban tidak linear dalam sistem elektrik yang semakin meningkat menjadikan harmonik menjadi masalah yang serius. Gangguan harmonik membawa kepada penurunan kualiti daya dengan mengubah bentuk gelombang arus atau voltan. Oleh itu, ia memerlukan teknik yang berkesan untuk pengesanan harmonik. Tujuan kajian ini adalah untuk mencadangkan kaedah bagi mengenal pastis umber harmonik tunggal di dalam system pengagihan kuasa dengan menerapkan teknik impedans rangkaian dan mengoptimumkan peruntukan meter dengan algoritma penempatan meter optimum (OMPA). Kelebihan utama teknik ini adalah, ia dapat meningkatkan ketepatan dengan kerentanan minimum terhadap perbezaan dalam pengukuran. Selain itu, ia meminimumkan bilangan nod untuk meter sehingga menghasilkan kelebihan ekonomi. Bagi mengesahkan hasil dan keberkesanan metodologu yang dicadangkan, rangkaian perindustrian IEEE 13-Bus standard direka meggunakan perisian ETAP dan algoritma dikembangkan menggunakan perisian MATLAB. Pengesahan algoritma OMPA yang dicadangkan dilakukan dengan membandingkan hasilnya dengan teknik Monte Carlo (MC). Hasilnya menunjukkan bahawa tanpa penyimpangan dalam impedans rangkaian, OMPA memberikan ketepatan 89% berbanding ketepatan MC, 75%. Untuk nilai penyimpangan $\partial=1^{-13}$ dalam impedans harmonik, ketepatan keseluruhan OMPA kekal pada 75% sementara nilai MC turun sehingga 56%. Algoritma OMPA yang dikembangkan bukan sahaja berprestasi lebih baik dalam pengenalpastian harmonik dengan bilangan meter minimum, tetapi juga menunjukkan lebih banyak ketahanan terhadap variasi dalam impedans harmonik berbanding dengan algoritma MC.

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LIST OF ABBREVIATIONS

MC	-	Monte Carlo
ETAP	-	Electrical Transient and Analysis Program
MATLAB	-	Matrix Laboratory
VFD	-	Variable Frequency Drives
SMPS	-	Switched Mode Power Supplies
VAR	-	Volt Ampere Reactive
FACTS	-	Flexible Alternating Current Transmission System
HVDC	-	High Voltage Direct Current
IT	-	Interference Potential of Harmonics
PWM	-	Pulse Width Modulation
XLPE	-	Cross-linked Polyethylene
THD	-	Total Harmonic Distortion
TNB	-	Tenaga Nasional Berhad
ICA	-	Independent Component Analysis
HSE	-	Harmonic State Estimation
ANN	-	Artificial Neural Network
PCC	-	Point of Common Coupling
PSO	-	Particle Swarm Optimization
OMPA	-	Optimum Meter Placement Algorithm

LIST OF SYMBOLS

δ	-	Voltage angle
Δ	-	Impedance ratio
∂	-	Impedance deviation random variable
Γ	-	Learning factor
ρ	-	Standard Deviation

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CHAPTER 1

INTRODUCTION

1.1 Background

The growing use of power electronic and other non-linear devices by the domestic, industrial and commercial consumers has led to a serious problem in the power quality, i.e. harmonics [1]. Usually harmonic related problems are not taken seriously as they do not show any instantaneous deteriorating effect, but in the long-run, the existence of harmonics can lead to certain serious problems such as waveform distortion, degradation of power quality, overheating of the electrical equipment, power losses and, in some cases, malfunctioning of the control systems [2, 3]. Recognition of origin of harmonics is, therefore, important for the regulation of energy quality in order to minimize the risks. Most of the techniques used to locate the harmonic sources require a large set of parameters such as voltage, real power (P), and reactive power (Q) at each harmonic frequency. The acquisition of these parameters require complex computation rendering the solution to be non-economical at large scale [4]. This work presents a simple, economical and comprehensive method for the identification of harmonic emitting sources by measuring the harmonic origin content in distribution system by using network impedance approach.

1.2 Problem Statement

Power system harmonics has gained a great deal of attention due to presence of non-linear loads in major portions of industrial plants, majorly because of power quality concerns emerged due to existence of harmonics in a power system. In a distribution system, the abundance of power electronic tools cause harmonic distortion which, if not addressed promptly and effectively, results in the serious operational issues in electrical systems [5]. A number of harmonics locating techniques are being utilized nowadays to identify and rectify harmonics related issues, but every method has certain requirements which either make them non-economical or complicated. The requirements of prior information about system parameters, history of load profiles, actual network impedance for each harmonic order, real and reactive power flows in the system for every harmonic frequency make these methods among the costly or complex solutions [6, 7]. Therefore, it is utmost important to develop method which ensures the harmonic source identification with enhanced accuracy along with the minimum cost. For this purpose, a network impedance based harmonic source algorithm is presented in this work.

1.3 Research Objective

The objectives of this research work are as follows:

i. To identify harmonic emitting source in a power system using network impedance method.
ii. To optimise the locations for meter placement in a distribution system to minimize the cost.
iii. To validate the developed algorithm on a standard IEEE 13-Bus test system and comparison with Monte Carlo (MC) technique.

1.4 Research Scope

The scope of this research work is illustrated below:

i. The harmonic source identification is done for single harmonic source in the distribution system.
ii. The simulation tool ETAP is used for modelling the system and MATLAB for the development and testing of the algorithms.
iii. The validation of the proposed algorithm is done by using IEEE 13-Bus industrial system as a test system.

1.5 Significance of the Study

The successful simulations and results of the proposed system will prove the effectiveness of using network impedance approach in determining the location of harmonic source in a power distribution system. The proposed algorithm not only shows improved efficiency in an economical way but also show its invulnerability against deviations in the measured network impedances.

1.6 Report Structure

In the subsequent sections, the theoretical and practical aspects of harmonic source identification method are discussed in details. The previous works about harmonic source identification is presented in Chapter 2. In Chapter 3, the proposed methodology for identification of harmonic injections in a distribution system is illustrated with the system design and modelling. Then the results along with the discussion are demonstrated in Chapter 4. Finally, the conclusion of the research work is presented in Chapter 5.

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