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by

UGASCINY ARUMUGAM

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MONITORING HARMONICS IN UTP DISTRIBUTION NETWORK USING VIRTUAL HARMONIC ANALYSER AND FORECASTER (V-HAF) SYSTEM

by

UGASCINY ARUMUGAM

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DECLARATION OF THESIS

Title of thesis | MONITORING HARMONICS IN UTP DISTRIBUTION NETWORK USING VIRTUAL HARMONIC ANALYSER AND FORECASTER (V-HAF) SYSTEM

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To My Family

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ABSTRACT

In power distribution system across the world, the need to maintain its power quality remains crucial. As technology takes over various aspects of life, the amount of non-linear equipment has been increasing, forming distortion in the distribution network. This is mainly due to the harmonics current injected by non-linear loads into the distribution line, which then pollutes the power quality and poses risks and losses. In Universiti Teknologi PETRONAS's (UTP's) distribution network, similar issues being faced. Hence, this study aims to propose and demonstrate an intelligent system that not only enable harmonic monitoring in UTP, but also reduces instrument cost at data gathering phase. This thesis proposed implementation of Virtual Harmonic Analyser and Forecaster (V-HAF) system to monitor harmonic fluctuation in UTP distribution network. The proposed V-HAF system compromises two different intelligent tool, which are estimation (Tool#1) and time-series prediction (Tool#2) tools in order to serve the objective. Techniques for both tools proposed based on literature study done in respective fields. For the estimation tool, feed-forward neural network with Levenberg-Marquardt back-propagation training technique was proposed and tested against the common Gradient Descent training method. These estimated data samples were further utilized to produce future harmonics data or time-series prediction using a Radial Basis Function (RBF) network. The techniques suggested were successfully tested on UTP distribution network and justified. A quick comparison was also carried out at the end of this study between the proposed V-HAF system and a conventional time-series prediction system, to justify on the system's accuracy based on error at time-series prediction. Simulation results are presented to test the hypothesis. The results are compared to the actual data gathered from Fluke 1750 Power Analyser and presented accordingly. Therefore, the proposed system exhibits a reliable tool to replace the current practise in UTP distribution network that rely on Fluke 1750 power analyser for data logging, which is not only expensive but requires sufficient experience/ability to operate the instrument. The implementation of

this system in UTP also expects to achieve a lower maintenance cost due to damages in electrical instruments due to harmonic imbalances.

ABSTRAK

Kepentingan mengekalkan kualiti kuasa elektrik kini menjadi suatu keperluan mutlak dalam sistem agihan tenaga di seluruh dunia. Memandangkan teknologi gian mengambil alih pelbagai aspek dalam kehidupan seharian manusia, jumlah penggunaan peralatan bukan linear semakin meningkat, membentuk penyelewengan dalam rangkaian pembahagian tenaga elektrik. Hal ini berlaku disebabkan oleh arus harmonic yang disuntik ke dalam system agihan kuasa oleh beban bukan linear yang seterusnye mencemarkan kualiti elektrik dan menimbulkan risiko serta kerugian. Dalam rangkaian pengedaran elektrik di Universiti Teknologi PETRONAS (UTP), isu yang sama sedang dihadapi. Oleh itu, kajian ini bertujuan untuk mencadangkan dan menunjukkan sistem yang pintar yang tidak hanya membolehkan pemantauan harmonik di UTP, tetapi juga mengurangkan kos instrumen pada fasa pengumpulan maklumat. Tesis ini mencadangkan pelaksanaan system Virtual Harmonic Analyser and Forecaster (V- HAF) untuk memantau kejadian harmonik dalam rangkaian pengedaran UTP. Cadangan sistem V- HAF kompromi dua alat pintar yang berbeza, yang merupakan alat anggaran (Tool #1) dan alat ramalan siri masa (Tool#2) untuk mencapai misi/objektif. Teknik untuk kedua-dua alat yang dicadangkan dibuat berdasarkan kajian kesusasteraan yang dilakukan dalam bidang masing-masing. Untuk alat anggaran , rangkaian neural ‘feed-forward’ dengan teknik latihan ‘Levenberg – Marquardt’ telah dicadangkan dan diuji serta dibandingkan dengan kaedah latihan ‘Gradient Descent’. Sampel data anggaran yang dikumpul dari teknik anggaran itu kemudian terus digunakan untuk menghasilkan data harmonik masa depan atau ramalan siri masa menggunakan teknik pintar ‘Radial Basis Function’ (RBF). Teknik-teknik yang dicadangkan telah berjaya diuji pada rangkaian pengedaran UTP dan dibuktikan kewajarannye. Satu perbandingan cepat juga telah dijalankan pada akhir kajian ini antara cadangan sistem V- HAF dan system ramalan masa -siri konvensional, untuk menguji ketepatan sistem melalui perbandingan antara kesilapan pada kedua-dua ramalan. Keputusan simulasi dibentangkan untuk menguji

hipotesis. Keputusan dibandingkan dengan data sebenar yang diperolehi daripada ‘Fluke 1750 Power Analyser’ dan dibentangkan secara teratur. Oleh itu, sistem yang dicadangkan mempamerkan alat yang boleh dipercayai untuk menggantikan amalan semasa dalam rangkaian pengedaran UTP yang bergantung pada ‘Fluke 1750 Power Analyser’ untuk data, yang bukan sahaja mahal tetapi memerlukan pengalaman serta keupayaan untuk mengendalikan instrumen tersebut. Pelaksanaan sistem ini di UTP juga menjangkakan penurunan pada kos penyelenggaraan disebabkan oleh kerosakan instrumen elektrik yang disebabkan oleh ketidakseimbangan harmonik.

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LIST OF ABBREVIATIONS

ADALINE	Artificial Intelligence
AI	Artificial Intelligence
ANN	Artificial Neural Network
APF	Active Power Filter
EMTDC	Electro-Magnetic Transient for DC
EMTP	ElectroMagnetic Transient Program
EPRI	Electric Power Research Institute
FFT	Fast Fourier Transform
GD	Gradient Descent
GDC	Gas District Cooling
GPS	Global Positioning System
GTS	Group Technology Solutions
HSE	Harmonic State Estimation
IEEE	Institute of Electrical and Electronics Engineering
MAE	Mean Absolute Error
NER	Neutral Earth Resistor
PSCAD	Power System Computer Aided Design
PSO	Particle Swarm Optimization
PQ	Power Quality
PQSE	Power Quality State Estimation
RBF	Radial Basis Function

RMS	Root Mean Square
SE	State Estimation
SWT	Stationary Wavelet Transform
TNB	Tenaga Nasional Berhad
THD	Total Harmonic Distortion
UTP	Universiti Teknologi PETRONAS
WLS	Weighted Least Squares

LIST OF SYMBOLS

t	Time
%	Percentage
$V_{h(max)}$	Maximum harmonics voltage
V_{h7}	7^{th}-order harmonics voltage
Hz	Frequency measure in Hertz
φ	Activation function
$\hat{\theta}_j$	Observation value
θ_j	Real vector
$\emptyset_k$	Basis function of network
w_k	Weight vector between hidden and output layers
n	Number of neurons
f_i	Predicted value
y_i	Real value
r	Correlation coefficient