Faculty of Electrical Engineering

VOLTAGE VARIATION SIGNALS SOURCE IDENTIFICATION SYSTEM BY TIME-FREQUENCY ANALYSIS TECHNIQUE

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Master of Science in Electrical Engineering

2019

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**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science
in Electrical Engineering**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled "Voltage Variation Signals Source Identification System by Time-Frequency Analysis Technique" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	....
Name	:	....
Date	:	....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Electrical Engineering.

Signature	:	....
Supervisor Name	:	Assoc. Prof. Ts. Mohd. Rahimi Bin Yusoff
Date	:	....

DEDICATION

Specially dedicated to

My beloved family,

To my respectful supervisor, co-supervisor and friends

Thank you for all the encourgement and support

ABSTRACT

The quality of power supplies has become one of the issues concern of power supply utilities and users these days. Power quality (PQ) can bring severe problems such as processing interruption within the industries, malfunction and downtime of the equipment and impact in economic losses. Voltage variation signals are the common events in power systems that will affect the equipment or load within the premise. Thus, the source identification of the voltage variation is needed to reduce the impacts caused by the variation. This research presented the analysis and detection of voltage variation signals with time-frequency distributions (TFDs) which included spectrogram, Gabor transform and S-Transform. The voltage variation signals were generated in MATLAB/Simulink according to IEEE Standard 1159-2009. Parameters of the signals were calculated from the time-frequency representations (TFRs) and used for detection of the signals. The detection of the voltage variation signals were performed by k-Nearest Neighbors (kNN), Support Vector Machine (SVM) and rule-based classifiers in which both kNN and SVM gave 100% successful signals detection while rule-based gave successful detection above 97%. Based on the analysis, the best TFD was distinguished by comparing the performance analysis of the TFDs in terms of accuracy, memory size used and computational complexity of the signal analysis. Result showed that S-Transform was the best TFD to be used to analyze voltage variation signals among the three TFDs. In the source identification analysis, voltage variation signals from upstream, downstream and both uptream and downstream were simulated and analyzed by phase TFR. The phase angle of voltage and current variation signals calculated were similar to the input angle with precision above 0.95. The average impedance TFR phase power of the signals were calculated from the phase TFR of each variation signal at each problem source. The classification accuracy of source identification was performed by kNN, SVM and rule-based classifiers. SVM showed the best performance of 94.22% overall classification accuracy followed by kNN of 93.56% while rule-based showed the worst performance among the three classifiers with overall classification accuracy of 83.44%.

ABSTRAK

Kualiti bekalan kuasa telah menjadi salah satu isu kebimbangan bekalan utiliti dan pengguna bekalan pada masa kini. Kualiti Kuasa (KK) boleh membawa masalah yang teruk seperti gangguan pemprosesan dalam industri, kerosakan dan tidak fungsi peralatan dan kesan dalam kerugian ekonomi. Isyarat variasi voltan adalah kejadian biasa dalam sistem kuasa yang akan menjejaskan peralatan atau beban di dalam premis. Oleh itu, pencarian sumber variasi voltan diperlukan untuk mengurangkan kesan yang disebabkan oleh variasi. Kajian ini membentangkan analisis isyarat variasi voltan dengan taburan kekerapan masa (TKM) yang merangkumi spectrogram, Gabor transform dan S-Transform. Isyarat variasi voltan dihasilkan dalam MATLAB / Simulink mengikut IEEE Standard 1159-2009. Parameter isyarat dikira dari perwakilan frekuensi masa (PFM) dan digunakan untuk pengesanan isyarat. Pengesanan isyarat variasi voltan dilakukan oleh K-Nearest Neighbors (kNN), Mesin Vektor Sokongan (SVM) dan pengelas berasaskan peraturan di mana kedua-dua kNN dan SVM memberikan pengesanan isyarat sebanyak 100% manakala kaedah berasaskan peraturan memberikan pengesanan sebanyak 97 %. Berdasarkan analisis, TKM terbaik dibezakan dengan membandingkan analisis prestasi TKM dari segi ketepatan, saiz memori yang digunakan dan kerumitan komputasi analisis isyarat. Keputusan menunjukkan bahawa S-Transform adalah TKM terbaik yang digunakan untuk menganalisis isyarat variasi voltan antara ketiga-tiga TKM. Untuk analisis pengenalan sumber, isyarat variasi voltan dari hulu, hiliran dan kedua-dua hulu dan hiliran telah disimulasi dan dianalisis oleh fasa PFM. Sudut fasa voltan dan arus elektrik variasi dikira adalah sama dengan sudut input dengan ketepatan lebih daripada 0.95. Kuasa fasa impedans PFM purata isyarat dikira dari fasa PFM setiap isyarat variasi pada setiap sumber masalah. Ketepatan pengkelasan pengenalan sumber dilakukan oleh kNN, SVM dan pengelas berasaskan peraturan. SVM menunjukkan prestasi terbaik dengan 94.22% ketepatan klasifikasi keseluruhan diikuti oleh kNN dengan 93.56% manakala berasaskan peraturan menunjukkan prestasi terburuk di kalangan tiga pengelasan dengan ketepatan kelas keseluruhan sebanyak 83.44%.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my greatest gratitude to my respected supervisor, YBhg. Associate Prof. Ts. Mohd Rahimi bin Yusoff and my co-supervisor, Associate Prof. Ir. Dr. Abdul Rahim bin Abdullah for their humble guidance, encouragement, patient, enthusiasm, invaluable support and motivation throughout the whole completion of this project. This project would not have succeeded without their continuous support and precious time.

Secondly, I would like to drop my sincere appreciation to thank Dr. Nik Syahrim bin Nik Anwar and Ts. Muhamad Faizal bin Yaakub, all my friends, and others who have provided assistance at various occasions. Their views and supports are useful indeed. Moreover, I would to thanks the advance digital signal processing (ADSP) laboratory, which provides continuous support to this research. This research was supported by Ministry of Higher Education Malaysia under the grant PJP/2017/FKE/H14/S01544.

My appreciation also goes to my parents and family for being so tolerant and supporting. I am thankful for their guidance, encouragement, advice and emotional support that they had given to me for prepare this project. I have learnt a lot, not just theoretically but also practically for the entire project.

Last but not least, I would like to express my heartiest appreciation to those who directly and indirectly in helping all the way through this research. The knowledge and guidance that I acquired from them are priceless and useful. Thank you to all the parties above, without their helps I can never go through this mission.

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LIST OF ABBREVIATIONS

AC	-	Alternating Current
ANN	-	Artificial Neural Network
Atan	-	Arc Tangent
CR	-	Computation Ratio
DC	-	Direct Current
DCI	-	Downstream Current Interruption
DCSG	-	Downstream Current Sag
DCSL	-	Downstream Current Swell
DFT	-	Discrete Fourier Transform
DVSG	-	Downstream Voltage Sag
DVSL	-	Downstream Voltage Swell
DVI	-	Downstream Voltage Interruption
FT	-	Fourier Transform
FFT	-	Fast Fourier Transform
FF	-	Fundamental Frequency
FN	-	False Negative
Hz	-	Frequency unit, Hertz
I	-	Current
IEC	-	International Electrotechnical Commission

IEEE	-	Institute of Electrical and Electronics Engineers
Imag	-	Imaginary
KNN	-	*K*-Nearest Neighbor
MAPE	-	Mean Absolute Percentage Error
MRA	-	Multi Resolution Analysis
MS	-	Malaysian Standard
OSWS	-	One Sample Window Shift
PQ	-	Power Quality
p.u	-	Per-unit System
R	-	Resistant
RMS	-	Root Mean Square
ST	-	Stockwell Transform
STD	-	Standard
STFT	-	Short Time Fourier Transform
SVM	-	Support Vector Machine
TFD	-	Time-Frequency Distribution
TFDs	-	Time-Frequency Distributions
TFR	-	Time-Frequency Representation
TFRs	-	Time-Frequency Representations
THD	-	Total Harmonic Distortion
TP	-	True Positive
TWD	-	Total Waveform Distortion
UCI	-	Upstream Current Interruption
UCSG	-	Upstream Current Sag

UCSL	-	Upstream Current Swell
UDCI	-	Upstream and Downstream Current Interruption
UDCSG	-	Upstream and Downstream Current Sag
UDCSL	-	Upstream and Downstream Current Swell
UDVI	-	Upstream and Downstream Voltage Interruption
UDVSG	-	Upstream and Downstream Voltage Sag
UDVSL	-	Upstream and Downstream Voltage Swell
UVI	-	Upstream Voltage Interruption
UVSG	-	Upstream Voltage Sag
UVSL	-	Upstream Voltage Swell
UTeM	-	Universiti Teknikal Malaysia Melaka
V	-	Voltage
WT	-	Wavelet Transform
Z	-	Impedance

LIST OF SYMBOLS

$a(n)$	-	Actual value
A_m	-	Signal magnitude
d_{st}	-	Euclidean distance
f	-	Frequency
f_o	-	Fundamental frequency
f_{hi}	-	High frequency
fl_o	-	Low frequency
f_s	-	Sampling frequency
$i(t)$	-	Input current
m	-	Signal sequence component
$m(n)$	-	Measured value
N	-	Length of the input signal
Ns	-	Number of sample shift
N_w	-	Number of window length
$STFT_x(t,f)$	-	Short time fourier transform
$S_x(t,f)$	-	TFR of signal
t	-	Time
$T_{d,int}$	-	Duration of interruption
$T_{d,sag}$	-	Duration of sag

$T_{d,\ swell}$ - Duration of swell

$THD(t)$ - Instantaneous total harmonic distortion

$TWD(t)$ - Instantaneous total waveform distortion

$v(t)$ - Input voltage

$V_{h,\ rms}(t)$ - Instantaneous RMS harmonic voltage

$V_{rms}(t)$ - Instantaneous RMS voltage

$V_{1rms}(t)$ - Instantaneous RMS fundamental voltage

$w(t)$ - Window function

$x(t)$ - Input signal interested

$\pi(t)$ - Function of the signal

% - Percentage

σ - Gaussian window sigma parameter

γ - Kernel parameter

LIST OF PUBLICATIONS

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