MF Based Arc Signal detection for SWG linked Wastewater Treatment Plant

Eunyoung Ko[1], Jaesang Cha[2, *], Juyoung Lee[2],
Jintae Kim[3], Jaekwon Shin[3], Jawan Gu[3], Myongchul Shin[1]

[1]*Dept. of Information & Commun. Eng. Sungkyunkwan Univ., Suwon, Korea*
[2]*Dept. of Media Eng., Seoul National Univ. of Science and Tech., Seoul, Korea*
[3]*R&D center of Fivetek Co,. ltd, Sungnam, Korea*

** Corresponding Author: chajs@seoultech.ac.kr*

Abstract

This paper dealt with a detection of electric Arc signal by using Matched Filter in wastewater treatment plant of SWG(Smart Water Grid). We proposed one of solutions to prevent fires due to arc signals happened frequently in SWG linked wastewater treatment plant. As an arc signal detection solution in wastewater treatment plant of SWG, we proposed MF(matched filter) based arc signal detection algorithms and certified its availability by various simulation results.

Keywords: *Wastewater Treatment Plant, Arc, Matched Filter, Smart Water Grid*

1. Introduction

The National Emergency Management Agency said there were 255,552 fires in Korea until June 2011. According to the causes of the fires, 8,001 fires were by actuators and 4,905 of them were by electric Arc. It showed that most of fires were caused by electric Arc, so we badly need prevention against it. During the first half of 2011, 154 people were killed and 835 people were wounded by fires. Also, the cost of the fire damage were estimated at about 138,800 million and 30,700million of them were caused by electrical factors[1]. One the other hand, a strong fire at wastewater treatment plant was happened in July 20, 2011 at Manhattan of New York, USA. Thousands of people were evacuated from a packed Harlem park after sewage plant fire at a North River wastewater treatment plant in Manhattan of New York[2].

As mentioned above, fire accidents frequently happened at wastewater treatment plant related with SWG causes huge economic losses including the losses of both life and property. Therefore, fire factors have to be identified before electrical fire occur and the method to detect them beforehand is required. For this reason, we need to study an algorithm that can be prevented electrical fires. However, this system doesn't study yet.

Generally, there are a lot of fire accidents due to arc signals from the power wire of various facilities including wastewater treatment plant or home network environments. Thus, developing efficient fire arc detection method at wastewater treatment plant or home network facilities is important thing to prevent fire accident beforehand. Therefore, several time detection methods are proposed to detect arc signals. conventional methods used virtual value of amplitude of arc signals using Zero Crossing Point amplitude data sample or radio frequency component related to

harmonic wave component[3][4]. Conventional arc detection methods, however, have malfunction happened frequently because they are difficult to distinguish clearly normal condition and Arc signal by incorrect detection algorithms. Thus, new efficient arc detection method is required for correct arc detection having improved detection schemes. Accordingly, this paper suggests MF based arc signal detection algorithms for the method to increase the reliability and efficiency. Thus, the characteristic of proposed system is better than existing system.

In this paper is organized Chapter 2 describes MF based Arc Signal detection algorithm for SWG linked Wastewater Treatment Plant, and Chapter 3 describes Experimental and the simulations results, and Section 4 concludes the end.

2. MF based Arc Signal Detection Algorithm for SWG Linked Wastewater Treatment Plant

2.1. MF Based Arc Signal Detection Algorithm

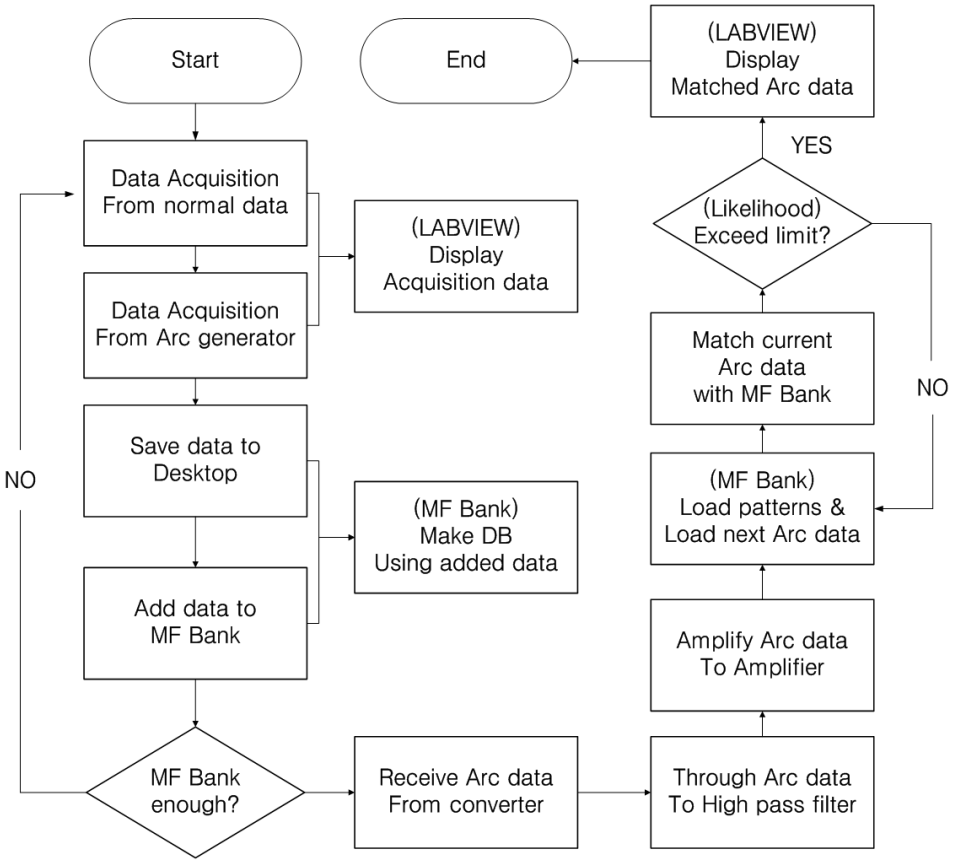


Fig 1. Algorithm of Arc Signal Detection using MF Bank

MF based Arc signal detection algorithm is shown above in fig 1. First, both normal signal data and arc data signal generated from arc generator are acquired. Acquired signals are actual AC waveform and they are displayed in Labview SW. Then, these data are saved in Desktop and added the MF Bank database until the MF Bank is enough. Second step is arc detection process using MF Bank. Every Arc data are received from converter and through

the high pass filter. Next, these data are amplified by using amplifier and all arc pattern signals are loaded from MF Bank. And every arc data are compared continuously with loaded arc pattern signals. Likelihood concludes the matched result to mapping block. If this result exceed definite limit, Labview SW display matched arc data. If not, next arc data is compared with loaded arc pattern signals until the result exceed definite limit.

2.2. Base Theory of Matched Filter

In the system model of the arc detection algorithms based MF, transmitter has the arc signal codes M ($2^m = M$) which differ each them. In this point, m is the number of data bit mapped with binary data.

One of arc signal codes is mapped with each current data. Receiver calculates auto-correlation value of all arc signal code. And then it restores the original signal having the largest correlation value through mapping the arc signal.

The code error rate (P_{ec}) of MF system in AWGN is as follow.

$$P_{ec} = 1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp\left(-\frac{u^2}{2}\right) \left\{1 - \Phi^u\left(u + \sqrt{\frac{2mE_b}{N_0}}\right)\right\}^{M-1} du \quad (1)$$

In this formula, $\Phi^u(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} \exp\left(-\frac{Z^2}{2}\right) dZ$ shows the cumulative distribution function of normal distribution. Eb/No is the ratio of the signal power and noise power density. If this system has the environment of the rayleigh fading, Code error rate of MF system code is presented by formula (1) and probability density function of the rayleigh fading.

$$P_{ecf} = \frac{1}{\gamma_0} \int_0^{\infty} \exp\left(-\frac{\gamma}{\gamma_0}\right) \times \left[1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp\left(-\frac{u^2}{2}\right) \left\{1 - \Phi^u\left(u + \sqrt{2\gamma}\right)\right\}^{M-1} du\right] d\gamma \quad (2)$$

In this formula, γ is Eb/No of the each time, $\gamma_0 (= \gamma)$ is the average of the time(γ).

When code error rate (P_{ec}) and original data (m bit) is restored, the relation among bit error rate P_{eb} is as follow.

$$P_{eb} = \frac{2^{m-1}}{2^m - 1} P_{ec} \quad (3)$$

3. Experimental and Simulation Results

3.1. Schematization of Experiment

Fig 2. shows the diagram of arc generator getting arc surveyed data for the series arc signal experiment. In accordance with UL1699, the experiment were consisted with normal generator and arc generator[5][6].

Also, the high performance oscilloscope was used to measure signals and measuring equipment for electric current measurement was consisted by P5205 probe.

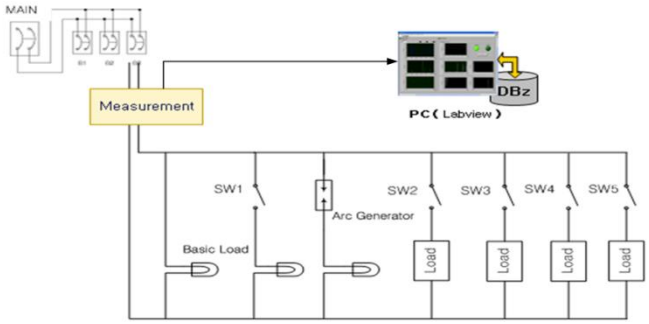


Fig 2. Diagram of Arc Devices

3.2. Program for Experiment Analysis

Labview was used to calculate detailed value to check whether arc is real or not by experimental data divided into 1/10,000 second.

Fig 3. shows the block diagram through Labview and Fig 4. shows detailed programming of it.

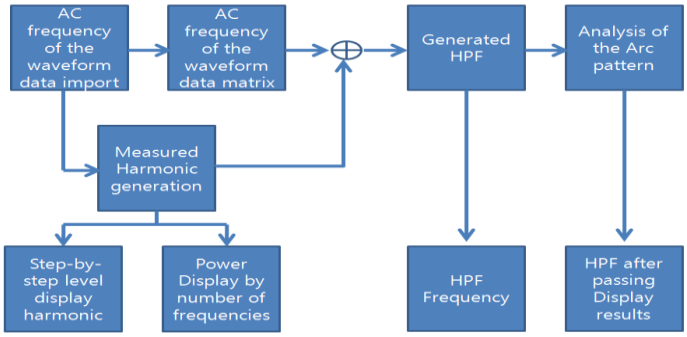


Fig 3. The Block Diagram through Labview

The modeling of arc patterns were made by changing the higher harmonic into each level through the HPF based on measured data from Labview's block diagram.

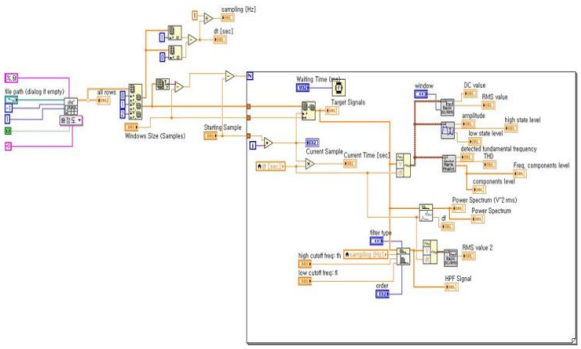


Fig 4. Labview GUI Program

3.3 Suggesting MF BANK Applied Algorithms

Similar data was analyzed to treat the measured value through Labview GUI as data bank for arc pattern modeling.

Fig 5. shows the results of comparison between normal signal and arc pattern by analyzing the characteristics correlations using Matched Filter BANK.

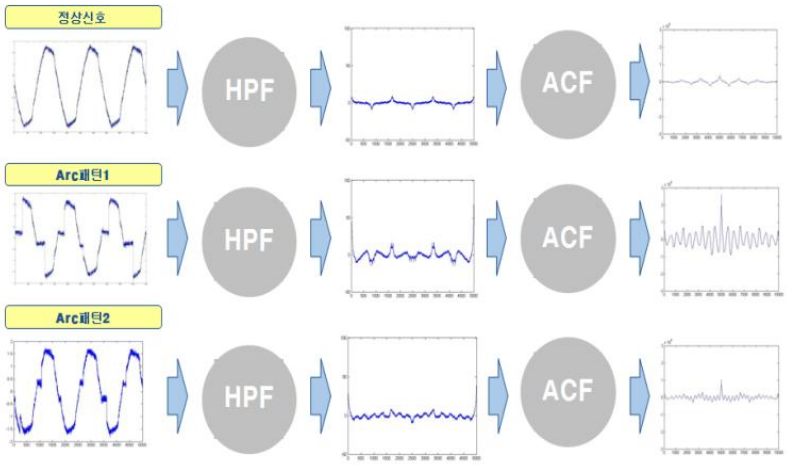
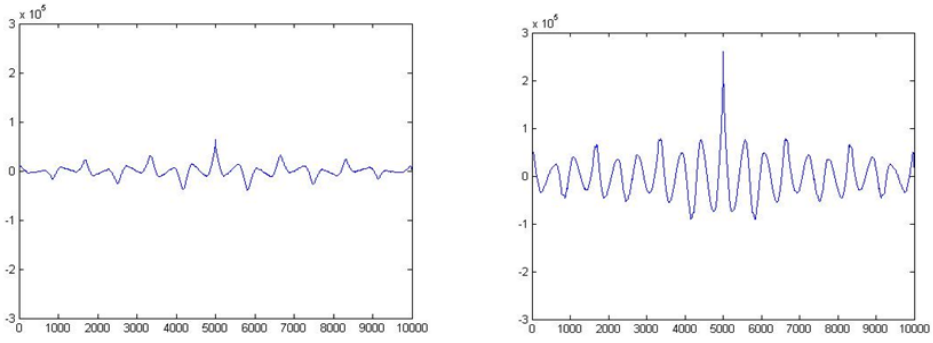


Fig 5. The Characteristics Correlations using Matched Filter BANK

In Fig 6, through these characteristics correlations, MF BANK was made and by the test result of it, the obvious distinction between normal signal and arc pattern was found from large peak value.



Normal signal Matched Filter BANK Arc pattern using Matched Filter BANK

Fig 6. Output using Matched Filter BANK

3.4 Analysis of the Performance in Proposed MF Bank System

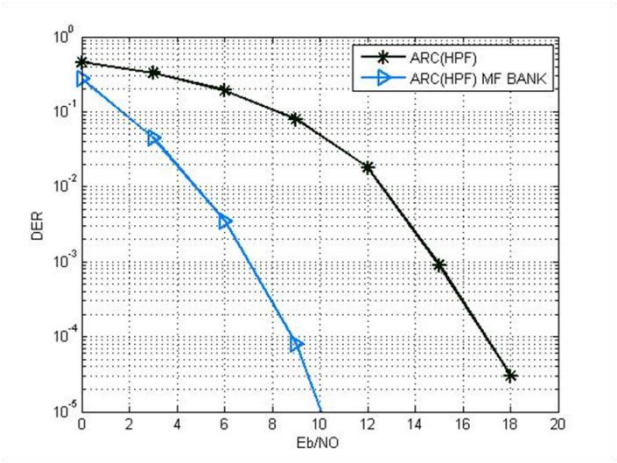


Fig 7. DER performance applied to MF Bank

As shown in Fig. 7, we confirmed that DER performance of arc data applied MF bank is closed to 10^{-3} at 7dB, point of Eb/No. And DER performance of existing arc data method is closed to 10^{-3} at 15dB, point of Eb/No. It demonstrated the efficiency better than existing Arc detection method through simulation result increased 8dB at 10^{-3}. In this experiment, we demonstrate the increase of the performance for the detection error rate.

4. Conclusion

This study presented MF based arc signal detection algorithms. It is possible to prevent fires due to arc signals happened frequently in SWG linked wastewater treatment plant. And we demonstrated the usefulness of proposed system by using the Labview to analyze the different of normal signal and arc signal. Also, we demonstrated the efficiency better than existing Arc detection method through simulation result increased 8dB at 10^{-3}. In future work, it needs to study of improving reliability of the decision for arc signal for SWG linked wastewater treatment plant.

Acknowledgement

This subject is supported by Korea Ministry of Environment as “Global Top Project”(Project No.:GT-11-B-02-014-3)

References

[1] National Emergency Management Agency “fires statistics in Korea until June 2011”, 2011
[2] "Thousands Evacuated After Sewage Plant Fire at Riverbank State Park", July 20, 2011, http://www.dnainfo.com
[3] Jin kwon Hwang, “ A study on Analysis of Arc Current Wave forms for Detection of Prognostics of Electrical Fires” J. of Korean Institute of Fire Sci & Eng. Vol 23, No 1(2009)
[4] Sun-Bae Bang, Chong-Yeun Park, “ Analysis of Series Arc-Fault Signals Using Wavelet Transform” J. of Korea Electrical Eng. Vol 57, No3, pp 494~500, Mar, 2008

[5] Jong-Young Park, Doo-Hyun Kim, "Development of Monitoring Program for Analyzed Series Arc Pattern" The Korean Institute of Electrical Engineers, Spring Conference 2010

[6] George D. Gregory(1998), " The Arc-Fault Circuit Interrupter : An Emerging" IEEE Trans. on Industry Applications, Vol. 34, No.5, pp. 928~933

[7] Tammy Gammon, John Mattews, " Arcing-Fault Models for Low-Voltage Power System", IEEE, pp.119~126, 2000

Authors

Eunyoung Ko is Ph.D. candidate in Department of Information & Communication Engineering from Sungkyunkwan University, Korea. He has been a senior researcher of Institute for Information Technology Advancement from 2000. His research interests include design and implementation of wireless communication convergence, Smart Grid, Smart Water Grid and power system networks and applications.

Juyoung Lee received the B. Sc. Degrees in the computer science at Seokyeong University in Korea in 2011. He is currently studying as a master course in Department of Media Engineering at Seoul National University, Seoul, Korea.

His research interests include design and implementation of wireless communication convergence, Smart Grid, Smart Water Grid and power system networks and applications.

Myongchul Shin received the B.S. degree in electrical engineering from Sungkyunkwan University, Seoul, South Korea, in 1970 and the M.S. and ph. D. degrees from Yonsei University, Seoul, South Korea, in 1973 and 1978, respectively.

Present, He is a president of "The Korean Institute of Electrical Engineers(KIEE)" and Professor Electric and Computer Engineering at Sungkyunkwan university, since 1978. He has worked in many areas of computer applications in power systems. His research areas of interests are digital protection of electric power system, power system stability and power system control

Jaesang Cha received the B. Sc., M. Sc. Degrees from the School of Electricl Engineering, Sungkyunkwan University in Korea in 1991, 1997, and the Ph. D degree from the School of Electrical Engineering, Tohoku University in Japan in 2000, respectively. He was Member of Research Staff at the Electronics and Telecommunications Research Institute (ETRI), from 2002 to 2005. He is currently Professor at the School of Department of Media Engineering at Seoul National University, Seoul, Korea. His research interests include design and implementation of wireless home network, Smart Water Grid, multimedia communication systems for applications to spread-spectrum, digital broad casting transmission technology, ultrawideband (UWB), LED communication and LED-ID.

Jintae Kim received the B. S. and M. S., and Ph. D. degrees in electronic engineering at Kunkook University, Korea in 1991, 1993, and 1999 respectively. He is currently working as a professor in electrical and electronic engineering at Kunkook University. His current research interests are Instrumentation and Control for Smart Water Grid and communication applications.

Jaekwon Shin received the B. S. in electronic engineering at Dankook University, Korea in 1993. He is currently working as a director at R&D center of Fivetek Co,. Ltd. His current research interests are Instrumentation and Control for Smart Water Grid and communication applications.

Jawan Gu received the B. S. and M. S. degrees in computer engineering at Aju University, Korea in 1998, and 2000 respectively. He is currently working as a general manager at R&D center of Fivetek Co,. Ltd. His current research interests are computer system for communications and Smart Water Grid applications.