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PREDICTION OF FAULT TREND IN A LNG PLANT USING WAVELET TRANSFORM AND ARIMA MODEL

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ABSTRACT: Operation of LNG (Liquefied Natural Gas) plants requires an effective maintenance strategy. To this end, the long-term and short-term trend of faults, such as mechanical and electrical troubles, should be identified so as to take proactive approach for ensuring the smooth and productive operation. However, it is not an easy task to predict the fault trend in LNG plants. Many variables and unexpected conditions make it quite difficult for the facility manager to be well prepared for future faulty conditions. This paper presents a model to predict the fault trend in a LNG plant. ARIMA (Auto-Regressive Integrated Moving Average) model is combined with Wavelet Transform to enhance the prediction capability of the proposed model. Test results show the potential of the proposed model for the preventive maintenance strategy.

Keywords: MODWT, WAVELETS, ARIMA, PLANTS FAULT

1. INTRODUCTION

The maintenance activities in LNG plants are divided into two parts: regular and irregular maintenance works. The former is the preventive maintenance approach where the maintenance activities are performed on a regular basis, even without a hint of certain component failing. The purpose of the preventive maintenance is mainly improving the status of the machines and preventing the machines breakdown. The latter is the unscheduled maintenance where the repairing activity is performed when the failures actually occur. This type of maintenance usually has to be finished as soon as possible, because the plants may not operate properly during the maintenance work.

It is necessary to predict when the unscheduled maintenance is needed in order to minimize the downtime of LNG plants. To this end, the long-term and short-term trend of fault in LNG plants has to be carefully understood and analyzed. This paper presents a method to predict the future fault trend in a LNG plant. The method is based on maximal overlap wavelet transform and ARIMA analysis. A case study is also presented to show the validity of the proposed model.

2. RESEARCH BACKGROUND

2.1 Wavelet Transform

The wavelet transform is similar to the Fourier transform in the sense that both methods could extract frequency domain information from time domain information. The most interesting dissimilarity between these two kinds of transforms is that the basis functions for the wavelet transform are localized in space or time unlike Fourier transform. The Wavelet transform divide time series data to each different frequency domain. The characteristics of the Wavelet transform are determined by the basis wavelet filters such as Haar, Daubechies, and Symlets. Continuous Wavelet Transform (CWT) means that each frequency value and transition value are used continuously, whereas Discrete Wavelet Transform (DWT) are effectively used when CWT is considered to generate too many data. Discrete wavelet transform supply a useful tools for analyzing, decomposing, de-noising and compressing (Karim and Adeli, 2002).

In this research, Maximal Overlap discrete wavelet transform (MODWT) is used. Maximal Overlap Discrete wavelet transform (MODWT) is a kind of un-decimated discrete wavelet transform. MODWT have five important characteristics that are different from other DWT; First, MODWT needs much more calculation than DWT. Second, the decomposed signals are circularly shifted according to the corresponding amount of shift in the original signal, 3) the decomposed signals are associated with zero phase filters, 4) ANOVA(analysis of variance) is possible based on wavelet and scaling coefficients, 5)

MODWT has the invariant power spectrum of coefficients (Percival and Walden, 2000).

2.2 ARIMA models

The acronym ARIMA stands for "Auto-Regressive Integrated Moving Average." ARIMA models are widely used to forecast the short-term time series. This model is used to analyze the time series data in statistical ways. This model is based on the methodology developed by statisticians George Box and Gwilym Jenkins. In this model, the order of the auto-regressive term and moving average term can be identified by autocorrelation and partial autocorrelation plots. The order of differentiation term can be identified by sequence plot to turn series data to stationary signal. Lags of the time series appearing in the forecasting equation are called "auto-regressive" terms, lags of the forecast errors are called "moving average" terms, and the time series which needs to be differenced to be made stationary is said to be the "integrated" version of a stationary series. Xie et al. (2005) and Conejo et al. (2005) combined the discrete wavelet transformation and ARIMA to forecast short-term traffic volume and electricity prices. They reported that discrete wavelet transform and ARIMA models are better than the usage of ARIMA from the original data. Jiang et al. (2004) used wavelet transform function and autocorrelation function to detect the traffic flow pattern analysis.

3. Prediction of the fault trend

3.1 Data acquisition

Fig.1 shows the number of faults on a monthly basis between Jan 2000 and March 2008 in a LNG plant. This shows that in winter there are more machinery operations and breakdowns since more heating demand exist in winter time. From 2006, almost all construction was finished. The vertical axis of Fig. 1 shows the number of trouble - degree of performance and safety in the LNG plant.

3.2 Wavelet transform

Original signal is analyzed with LA (Least Asymmetric) wavelets called 'symlets' (Percival and walden 2000) with the filter length of 8. Fig. 2 shows the decomposed signals by MODWT. The decomposed signals are influenced by circularity in the start and ending parts. To minimize the effect of any abrupt change in the boundaries, the original signal is extended by reflection extension. Two graphs (left and right) in Fig. 2 are almost identical to each other except for the beginning and ending times.

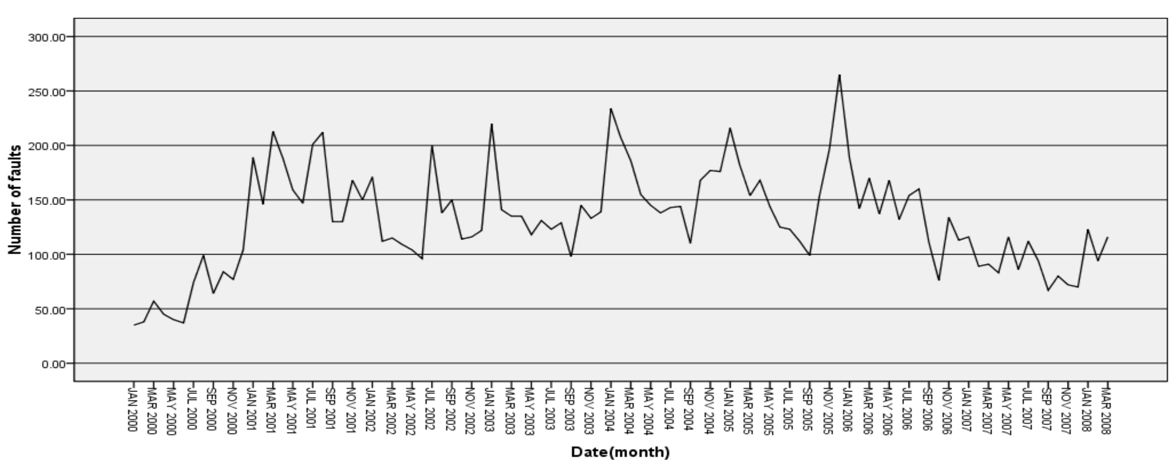

Fig. 1 Original fault in LNG plant

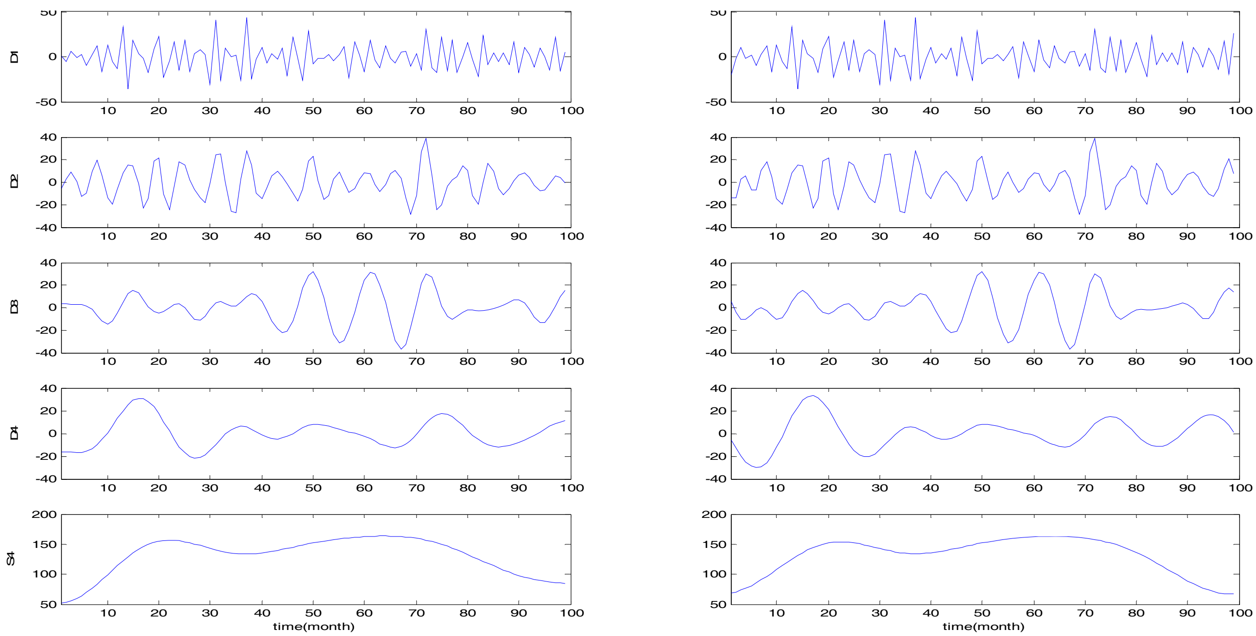

Fig. 2 Multi resolution analysis with MODWT (left: reflection extension; right: periodic extension)

3.3 ARIMA analysis

In this study, ARIMA analysis is applied to each decomposed signal on different resolutions and the resultant signals are added to produce the refined signal. Differencing values are selected based on ACF (Autocorrelation function) and PACF (Partial autocorrelation function) to find the stationary signal. Fig. 3 shows ACF and PACF of the D1 level signal. The graphs in Fig. 3 are analyzed to assume the adequate order of AR (Autoregressive), Differencing and MA (Moving Average) for each signal. An ARIMA model is developed using the time series data between Jan. 2000 and Mar. 2008. Then the model is used to forecast the time series data from Apr. 2008 to Nov. 2008.

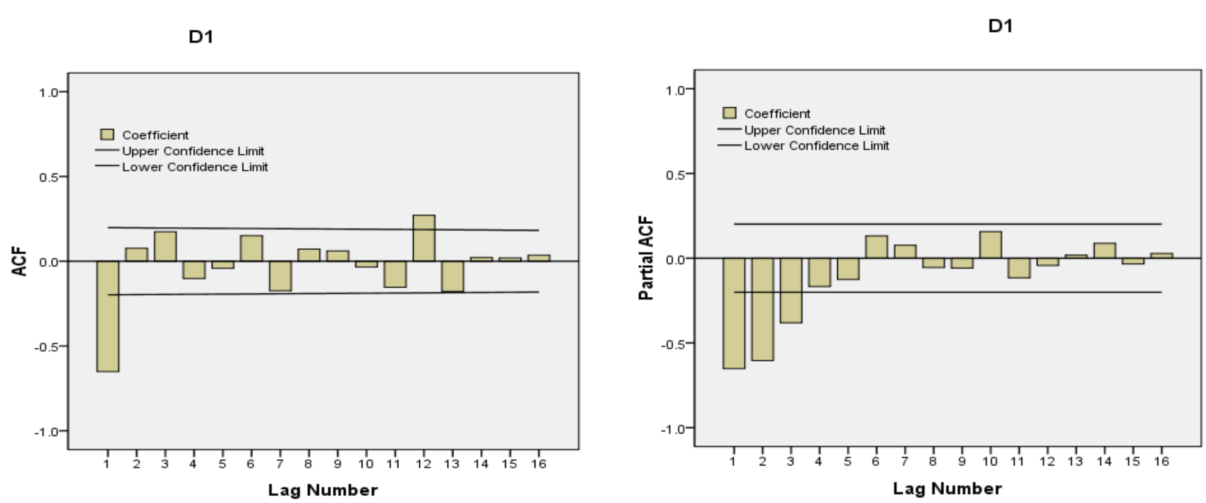

Fig. 3 ACF and PACF of D1 level of periodic extension signal

3.4 ARIMA analysis

Figs. 4 and 5 show the results of the fault trend analysis. Fig. 4 is the result with periodic extension signal. The original signal is well estimated by the ARIMA model except for the forecast period due to the effect of circularity. Fig. 5 is the analysis result with the reflection extension. The original signal is well represented by the ARIMA model and even the forecast period is better estimated. Fig.6 is the forecast error of the analysis result with periodic and reflection extension signal for 8 months. Fig.6 shows that the result analysis from reflection extension signal is better.

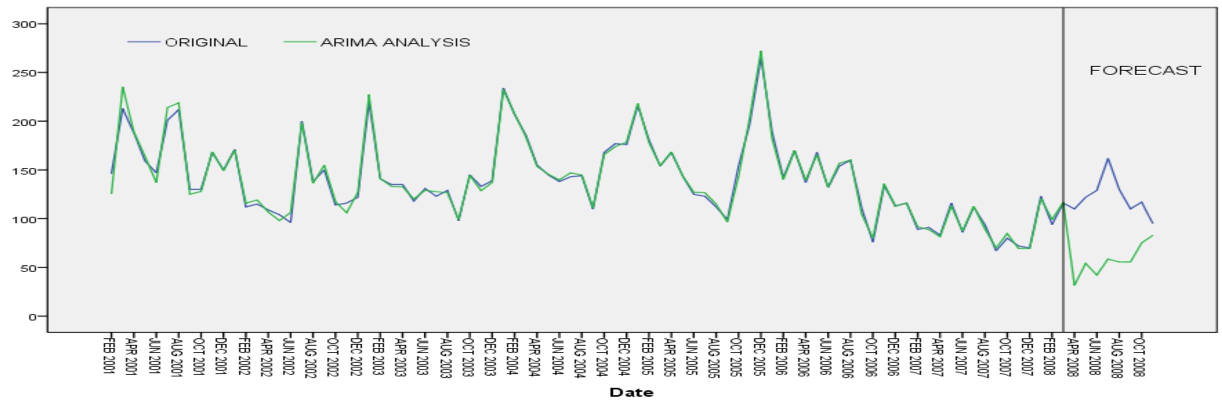

Fig. 4 Result of periodic extended signal

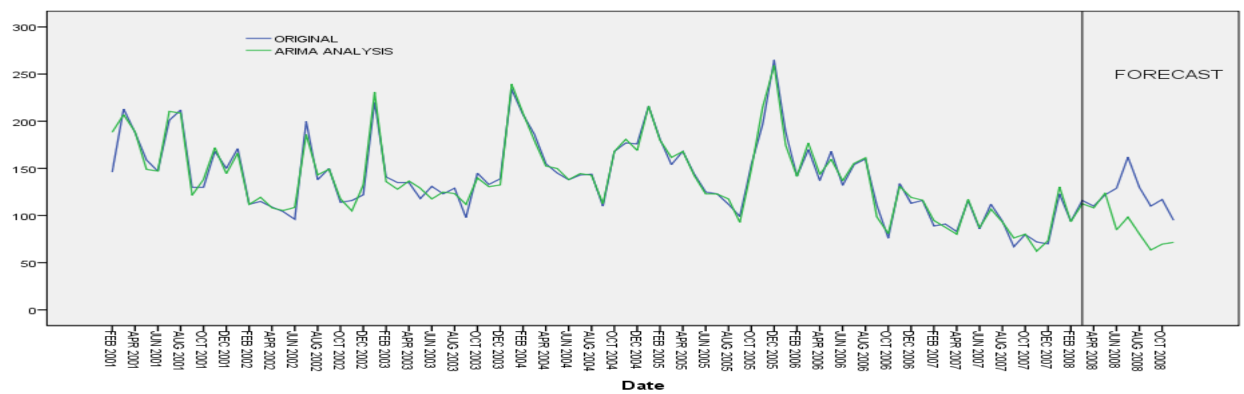

Fig. 5 Result of refection extended signal

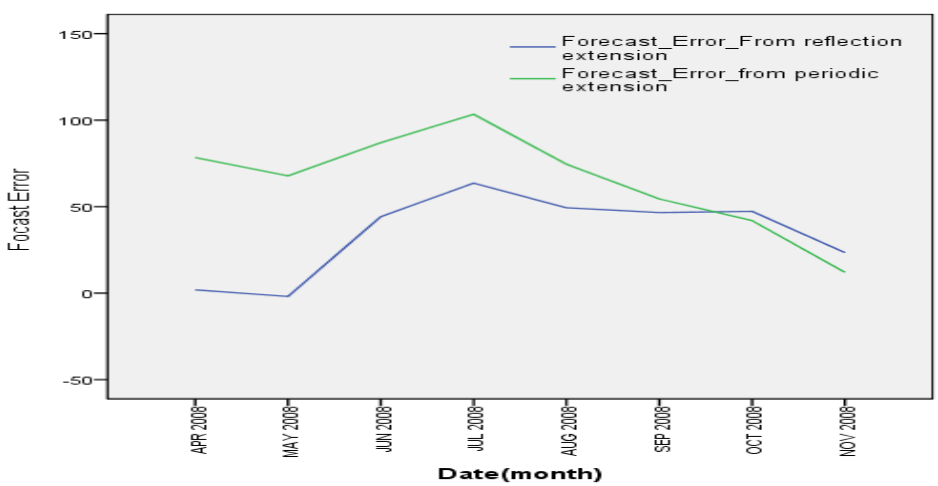

Fig. 6 Forecast Error

4. CONCLUSIONS

This paper presented a model to predict the fault trend in LNG Plants. The model adopted MODWT and ARIMA with the reflection extension approach. A real plant operation case of approximately 9 years was used to test the proposed model. In particular, the MODWT showed the strength that the signal to be decomposed with wavelet transform does not have to be the number expressed by 2^n. The proposed model was able to accurately represent the original signal and show the potential to predict the future fault trend.

ACKNOWLEDGEMENT

This work was supported by a Grant (07UrbanRenessanceB03) from High-Tech Urban Development Program funded by the Korean Ministry of Land, Transport, and Maritime Affairs.

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