IMPROVE RELIABILITY USING HOTELLING T² TECHNIQUE IN A LIQUEFIED NATURAL GAS PLANT

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Abstract - A method for improve the reliability in a gas liquefied plant using Hotelling T2 is showed in this paper. The stationery work in this manufacture facilities during a few moths in a year involve a heavy duty service of gas diesel engines and ammonia gas plant for processing the methane gas and extract the condensate fluid of it. Then, a predictive maintenance plan is necessary to prevent a possible malfunction or shut down of the plant and avoid an operational cost increased.
We are just sampling the signals from the plant when its working in optimal condition and then we will compare the next incoming data from the machinery versus the previous historical data set. An statistical process control algorithm Hotelling T2 based for monitoring the condition of gas engines and ammonia gas plant will be implemented.

Keywords - Gas Plant Process Control, Historical Data Set, Hotelling T2 method ,Predictive Maintenance.

I. INTRODUCTION
An in-control set of process data is a necessity in a multivariate control procedures. In this case a collection of 26 variables from the liquefied gas plant was recorded in order to establishment a predictive maintenance plan . The temperatures from natural gas spark engine motor, multiplier gear box and ammonia refrigeration gas plant pressures and temperatures was sampled 4 times each 1 hour.
Such a data set, often labeled historical, baseline, or reference, provides the basis for establishing the initial control limits and estimating any unknown parameters. However, the construction of a multivariate HDS is complicated and involves problem areas that not occur in a univariate situation (such as isolated diesel engine or general purpose machinery).
We development of the HDS is referred to as a Phase I operation. We are using it as a baseline to determine if new observations conform to its structure is termed a Phase II operation. The parameters estimates are used to construct a preliminary control procedures whose major porpoise is to purge the original data set of any observations that do not conform to the structure of the HDS. The nonconforming or atypical observations are label outliers. After the outliers are removed from the preliminary data set, new estimates of the parameters are obtained and the purging process is repeated . This is done as many times as necessary to obtain a homogeneous data set as defined by the control procedure. After all outliers are removed, the remaining data is referred to as the HDS.

II. MATERIAL AND METHODS
The variables analyzed were the follow: the 12 cylinder exhaust gas temperatures (left side and right side) from a spark gas engine, the six temperatures of multiplier gear-box lube oil; fit it between the engine and gas compressor and pressures a temperatures from the ammonia refrigeration plant. The rpm of the natural gas compressor was monitored also. It was taken 100 samples of them All devices are at the REPSOL GAS & OIL CO. facilities in Bermeo-Bizkaia-Spain and they are used for management the liquefied natural gas from the deep hole which it is stored to process plant for cleaning and condensating.
Firstly, we constructed the HDS using the guidelines showed in figure 1.
A correlation analysis and control X-bar, R Chart were used for detecting both correlations and outliers. HDS for the first 6 variables and 20 samples is showed in Table 1.
Considering to be this process a continuous steady-state process where the observation vector are independent and the parameters of the underlying normal distribution are unknown and must be estimated. We assume the process is being monitored by observing a array of 32 new samples of liquefied gas plant parameters $X' = (x_1, x_2, ...x_p)$,on variables at each time point. The T^2 Hotelling´s value associated with X is given by: $T^2=(X-\overline{X})'\times S'\times(X-\overline{X})$ where the common estimates *X* and *S* are obtained from the HDS. Here, the T^2 statistic follows the F distribution. For a α=0,05 given , the UCL is computed as:

$$UCL=\left(\frac{p\times(n+1)(n-1)}{n(n-p)}\right)_{F(\alpha,p,n-p),}$$

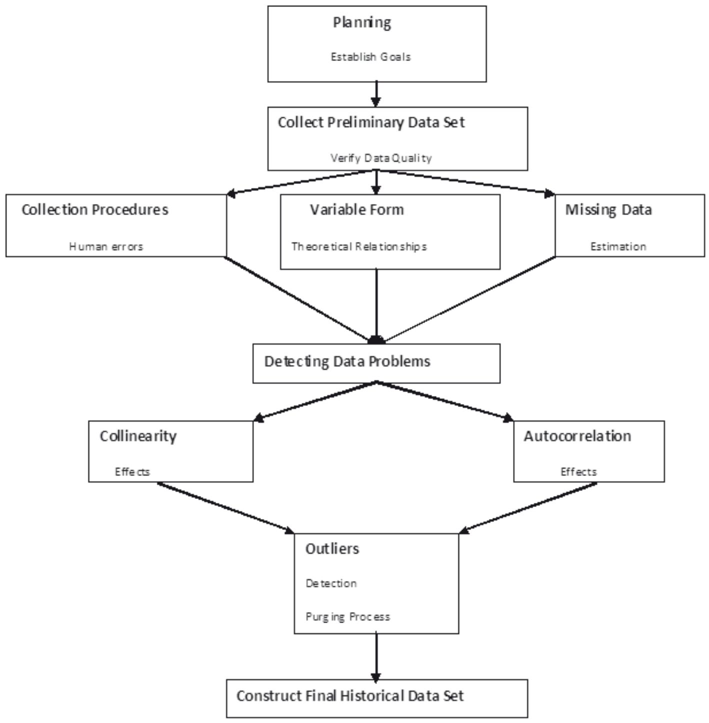

Fig. 1

Pos	TI-1964	TI-1966	TI-1968	TI-1970	TI-1972	TI-1974
0	ºC	ºC	ºC	ºC	ºC	ºC
1	559,22	552,6	541,76	528,34	514,39	485,86
2	557,26	552,8	541,76	527,96	514,39	485,48
3	559,98	554,56	541,55	528,54	514,78	487,41
4	560,95	554,15	542,31	529,51	514,98	489,35
5	559,6	553,77	541,55	528,75	514,78	485,86
6	557,46	553,01	541,35	527,58	513,63	484,31
7	557,08	552,8	541,17	527,58	514,39	488,38
8	558,25	553,39	540,59	528,16	514,6	484,69
9	556,11	554,56	541,17	528,75	514,6	486,45
10	557,84	553,59	541,76	527,58	514,6	488,38
11	559,39	553,39	542,31	528,54	514,78	487,21
12	554,94	553,59	541,17	528,54	514,98	486,06
13	553,01	552,42	541,35	528,34	514,39	481,96
14	557,46	553,39	541,76	527,96	515,19	485,65
15	553,97	552,8	541,93	528,54	514,6	487,21
16	559,22	553,39	543,11	528,93	514,78	485,48
17	559,8	554,15	541,93	528,34	512,08	487,21
18	557,84	553,39	542,52	528,54	512,08	484,31
19	559,39	553,59	542,31	527,58	513,43	487,41
20	559,98	553,59	543,11	528,93	515,95	488,58

Table 1

where n is the size of the HDS and $F(\alpha;p,n-p)$ is the α quantile of $F(\alpha;p,n-p)$.

III. CONCLUSION

Signal interpretation requires a procedure for isolating the contribution of each variable and/or a particular group of variables. As with univariate control, out of control situations can be attributed to individual variables being outside their allowable operational range

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A SOFTWARE FOR TIME SERIES ANALYSIS OF NORTEK INSTRUMENTS: TSA_NORTEK_V1

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Abstract - The software TSA_NORTEK_V1 has been created to carry out the processing of current meter data from NORTEK INSTRUMENTS: AWAC, AQUAPRO and AQUADOPP. The software offers a default data processing (spectral analysis, harmonic analysis, calculation of residual series) and an optional processing (axes rotation, choice of depth for the analysis, processing of vertical velocity component and filtering of time series). In addition, TSA_NORTEK_V1 produces harmonic constituents files to be used with the tidal prediction software TIDEX.

Keywords - software, processing data, time series analysis, AWAC, AQUAPRO, AQUADOPP.

I. INTRODUCTION

TSA_NORTEK_V1 software has been created by the Physical Oceanography Group of University of Cádiz in collaboration with the Instituto Hidrográfico de la Marina and INNOVA S.A. to carry out the processing of current meter data from NORTEK INSTRUMENTS: AWAC, AQUAPRO and AQUADOPP. TSA_NORTEK_V1 is written in Matlab language but it has been compiled to works independently of that.

The program begins asking some questions. First one, you should indicate which instrument data to process are from. Data can be derived from three different instruments: AQUADOPP (current meter), AQUAPRO o AWAC (current profilers). Later, you should indicate the mooring position and the header file name, to open and extract the more relevant information about the mooring and instrument configuration. This part of the program is common to any analysis you want to do, nevertheless, from here, the processing of AQUADOPP data varies slightly from the AQUAPRO and AWAC ones.

II. RUNNING TSA_NORTEK_V1 TO AQUAPRO AND AWAC DATA

The processing of AQUAPRO and AWAC data has the same features (both are current profilers) and, therefore, the software runs similarly in both cases. Once the header file is opened, the program shows the more important information related to the mooring and instrument configuration: mooring position, sample period, sample interval, cell size, blanking distance, mean mooring depth and cell depths. AQUAPRO and AWAC data are available along the whole water column at different depths and you can choose the desired depths for the data analysis. As an aid, the program displays two graphics. First one, illustrating the pressure (sea level) and velocity time series of the five surface cells.

The second one shows the time averaged current velocity profiles for the chosen period. Once the depths for the analysis are selected, the software carries out an optional and a default data processing

Optional data processing:

•Axes rotation to project the velocity data on the predominant direction.

•If several depths were chosen, you can decide between the data analysis for each depth or for the averaged depths.

•In many cases the value of the vertical velocity is not necessary for the study and then the analysis of this velocity component is optional.

•If you want, it is possible to obtain a filtered series of velocity and sea level data.

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Default data processing:

•Spectral analysis of original and/or residual series.

•Harmonic analysis of time series.

•Velocity and sea level tidal prediction for the mooring dates and computation of residual series.

•Creation of harmonic constituent files for tidal prediction software TIDEX.

The results from data analysis are saved in a set of files:

•A data processing information file.

•Harmonic analysis results for each depth (or averaged depths), each velocity component and sea level.

•Harmonic analysis results for each depth (or averaged depths), each velocity component and sea level compatible with TIDEX software.

•Residual series for each velocity component and sea level.

•Filtered data for each velocity component and sea level (only if filtered data option is chosen).

•Spectral analysis graphics for original and/or residual velocity and sea level data.

III. RUNNING TSA_NORTEK_V1 TO AQUADOPP DATA.

The recorded data by AQUADOPP, on the contrary that these obtained by current profilers (AQUAPRO or AWAC) are taken in only one depth, were instrument is placed. Therefore, the software varies slightly. The principal differences are three:

•Mooring information and depth choice. As there are not time series in different depths, it is not necessary to choose the desired depth to analyse.

•Sea level series analysis. Due to the fact that the instrument is moored at a certain depth suffering the displacement of the mooring line these measurements are frequently noisy an its analysis is not worthwhile.

•Output files. The number of result files is lesser by the cited reasons: Sea level analysis is not carried out and only one depth is processed.