SBM PROJECT

Similarity Based Modelling:

The marine sector is under significant pressure to optimize operations and reduce operational costs. This is leading to the development and implementation of remote monitoring, asset support and predictive analytics solutions. There are new sets of technologies that are starting to impact the sector, potentially providing key benefits. This approach is leading to centralized **Condition Based Monitoring** enabling us to make more informed decisions based on data and helping improve a fleet's operational efficiency.

Condition Based Monitoring (CBM):

The aim of Condition Based Maintenance (CBM) is to perform maintenance when there is evidence of need, as an alternative approach to planned routine maintenance. Planned maintenance has benefits, but it also has problems. It can be implemented in such a conservative manner that parts are replaced long before they reach their end of useful life, or alternatively unexpected early life failures can be missed.

There are broadly two types of diagnostic approach to CBM:

- Knowledge based
- Data Driven

Knowledge based:

The knowledge-based approach relies on knowing how the system can fail, then designing the CBM system to look for explicit predefined symptoms.

- Using threshold to monitor each features(tag) to give alarm and trip if it reaches particular threshold, currently followed in vessels to detect failures (Statistical method- Figure 7.3.A Single sensor analysis)

Data driven:

The data-driven approach does not require deep knowledge of how a fault occurs and develops, but instead relies on training a model using historical data. When the model finds an anomaly in behavior, the equipment expert can then be notified to investigate the problem.

There are many different modelling and diagnostic techniques, here Similarity Based Modelling is set to monitor early detection. **Similarity Based Modelling (SBM)** is a non-parametric method of system modelling, in which no assumption is made about how the equipment should operate. It is totally data driven, looking for patterns in the data that deviate from what is learned to be normal.

- Normalizing the features(tags) based on **MOVING AVERAGE** to monitor the deviation(Figure 7.3.A Model based analysis)

Following figure shows the early detection of deviation

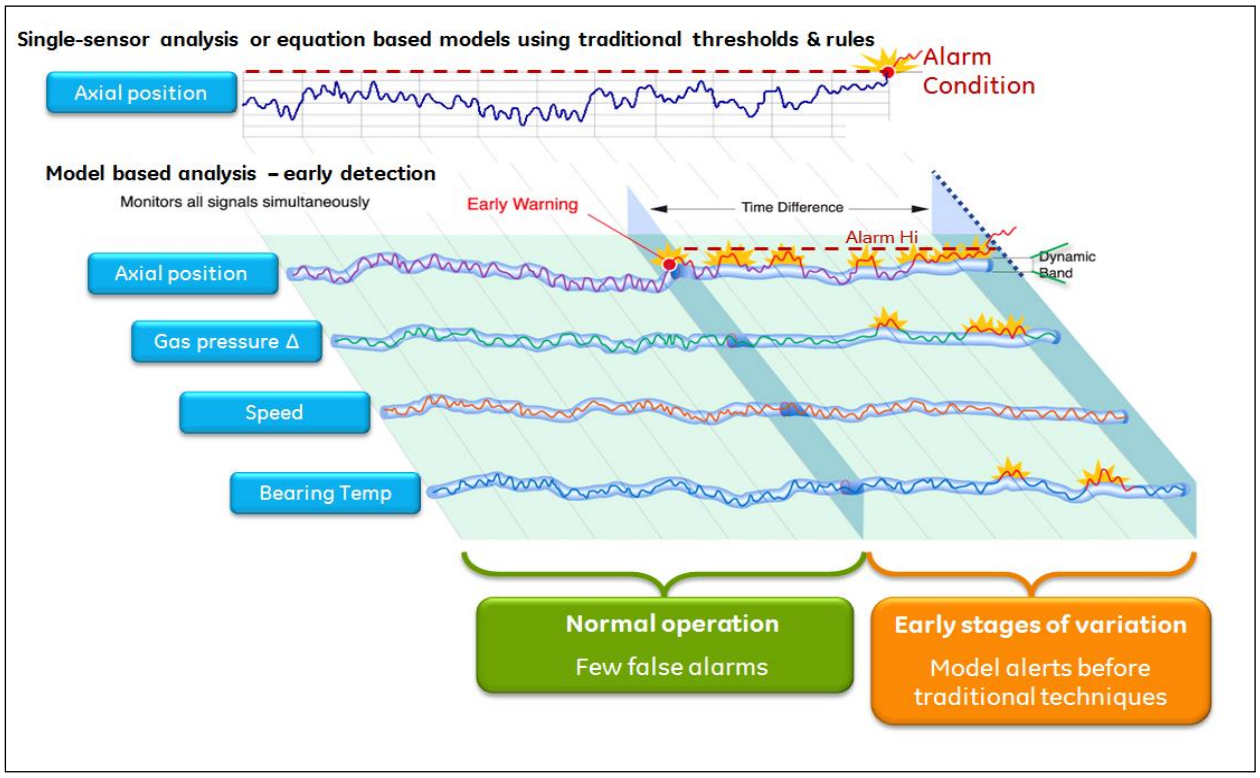


Figure1: Illustration of early detection using model based analysis (SBM)[1]

SBM model is based on taking the available parameters of an asset and partitioning them into sub-sets that have physical meaning to the engineering. Using a sample of collected data, a set of normal operating conditions is defined that can be used to reconstruct normal operational behavior in real time. In use the analytic computation can be done and abnormal behavior can then be identified.

For each parameter an estimate is derived for what the present value should be, based on the data used to train the model and the conditions of the current observation. Performing single sensor analysis using thresholds and rules as in a conventional alarm system, many signals are cross-compared to look for deviation in performance.

To attain this goal, modeling has been done in Water Injection Package of FPSO Brasil which was decommisioned. The downtime(requisition maintenance) happened in this particular equipement is considered, few cases were selected, examined and presented.

For time series analysis, continuous values are considered for detecting outliers in the pattern. The raw data contains 229 features with both continuous and binary values with a time stamp.

The features corresponds to different equipmets are grouped into three subsets:

- Gas Turbine(Gas generator and Power turbine)

- Gas Path(Air intake and Exhaust)
- Pump & Gear box

GAS TURBINE:

The Gas turbine subset consist of tags that record continuous timeseries data from sensors of Gas generator and power turbine.

The recorded sensor values are catogorical, such as UD10X1, UD10Y1, UD11X1, UD11Y1, ZD10T1, ZD10T2 as vibration signals, TC21, TC22, TC23, TC24 as temperature signals, PT8 as pressure, GGSpeed and PTSpeed represents speed, FFDEM represents the fuel demand(Power).

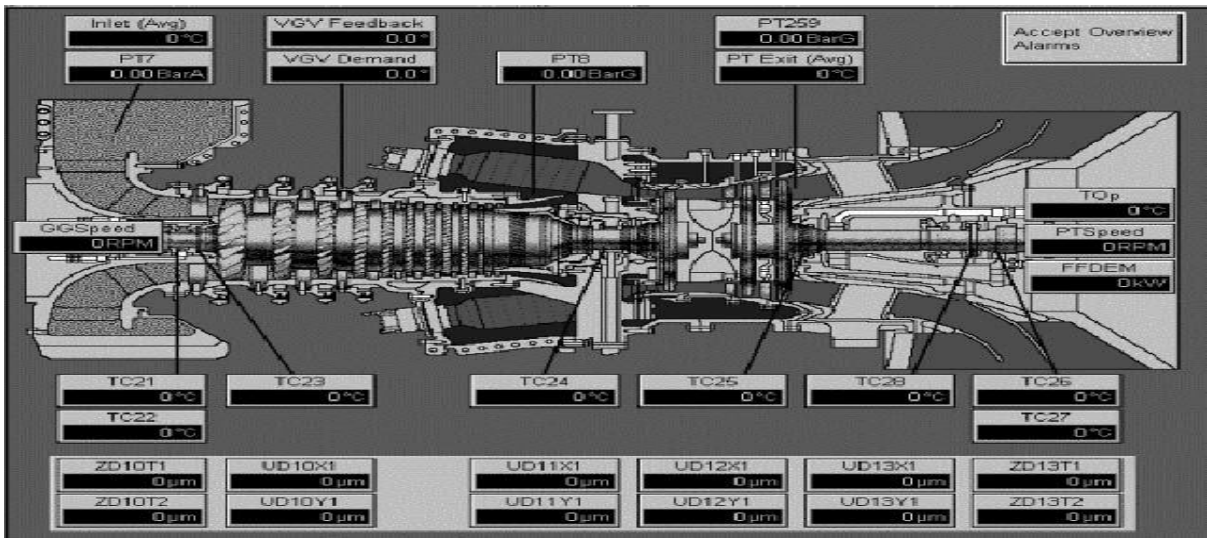


Figure2: Gas Turbine with Tag's[4]

GAS PATH:

The Gas path subset consist of tags that record continuous timeseries data from sensors of Air intake and exit of Gas turbine.

The recorded sensor values are catogorical, such as TC1, TC2, TC3, TC4,etc as temperature signals, PT7 as pressure signal and PCB bands.

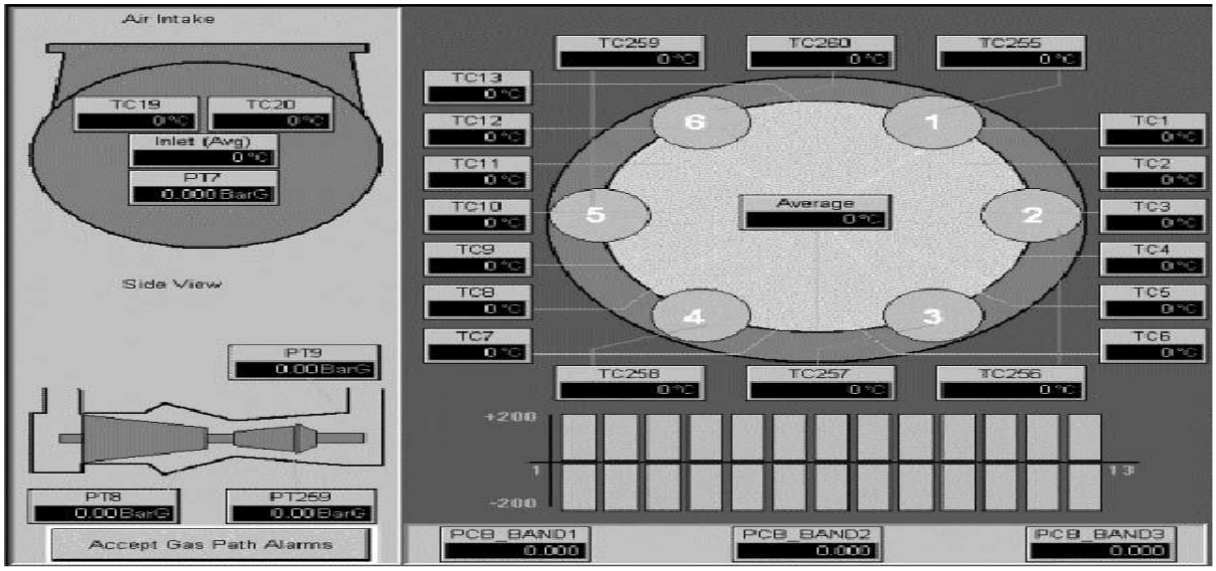


Figure3: Gas Path (Air intake and Exit)[4]

Pump & Gear Box:

The Pump & Gear Box subset consist of tags that record continuous timeseries data from sensors of pump and Gear box of water injection package.

For Pump the recorded sensor values are catogorical, such as UD51X1, UD152Y1, UD52X1, UD52Y1, ZD20T1, ZD20T2 as vibration signals, RTD190, RTD191, RTD188, RTD209, RTD210 as temperature signals.

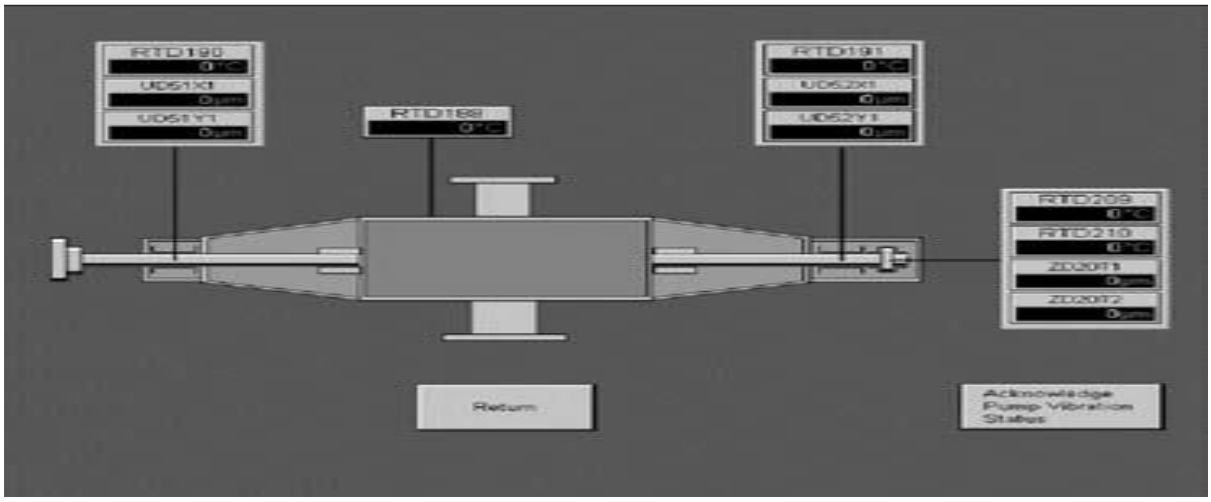


Figure4: Pump[4]

For Gear Box the recorded sensor values are catogorical, such as UD16X1, UD16Y1, UD17X1, UD17Y1, ZD24T1, ZD24T2 as vibration signals, RTD209, RTD210, RTD214 as temperature signals

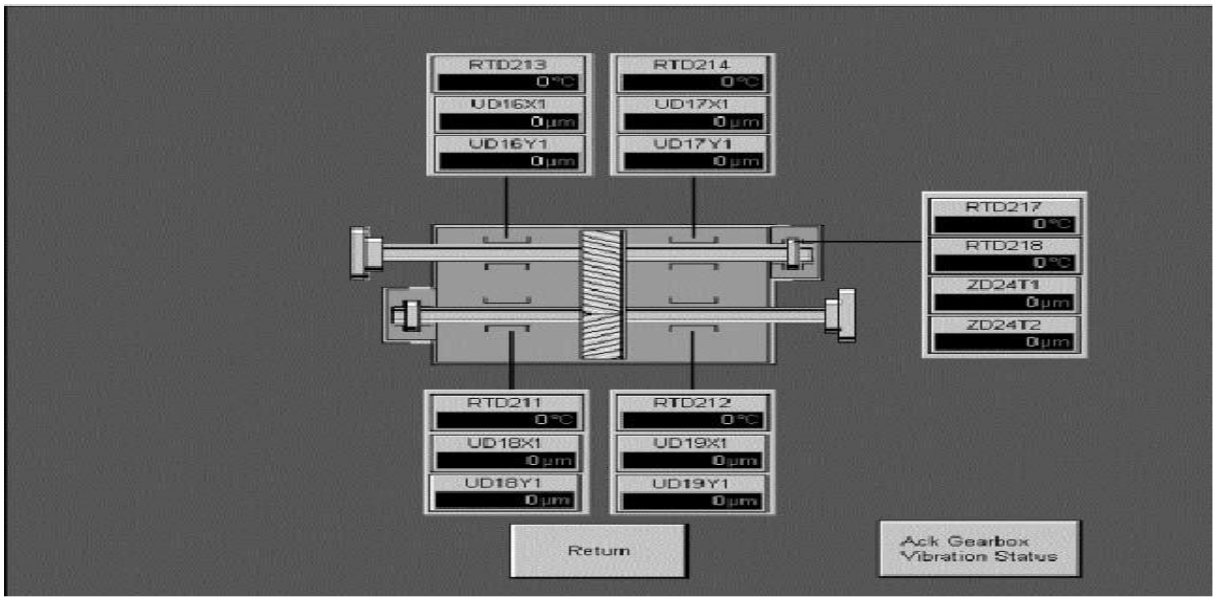
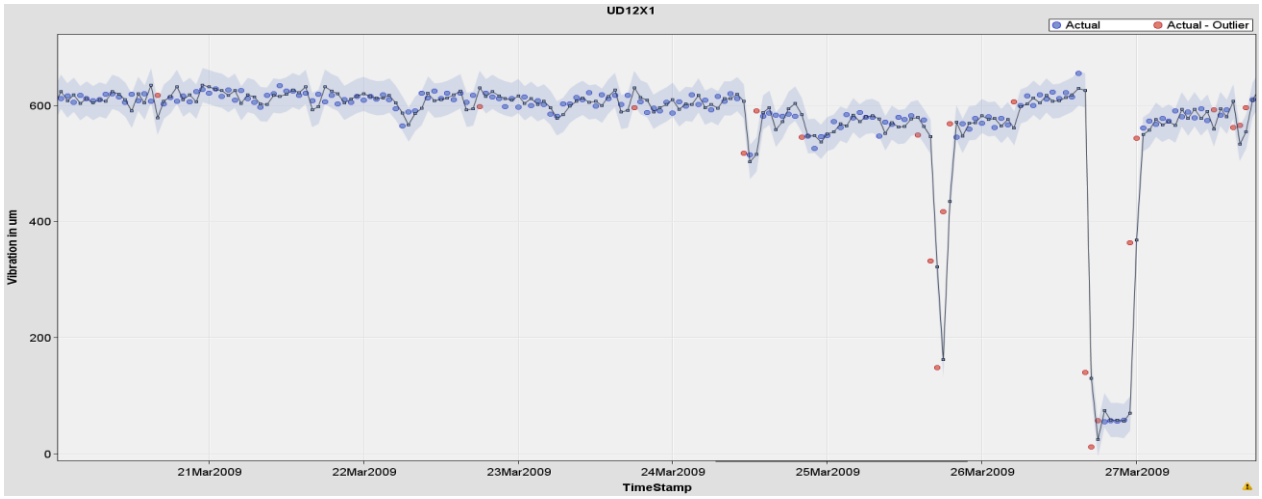


Figure5: Gear Box[4]

OUTLIER DETECTION:

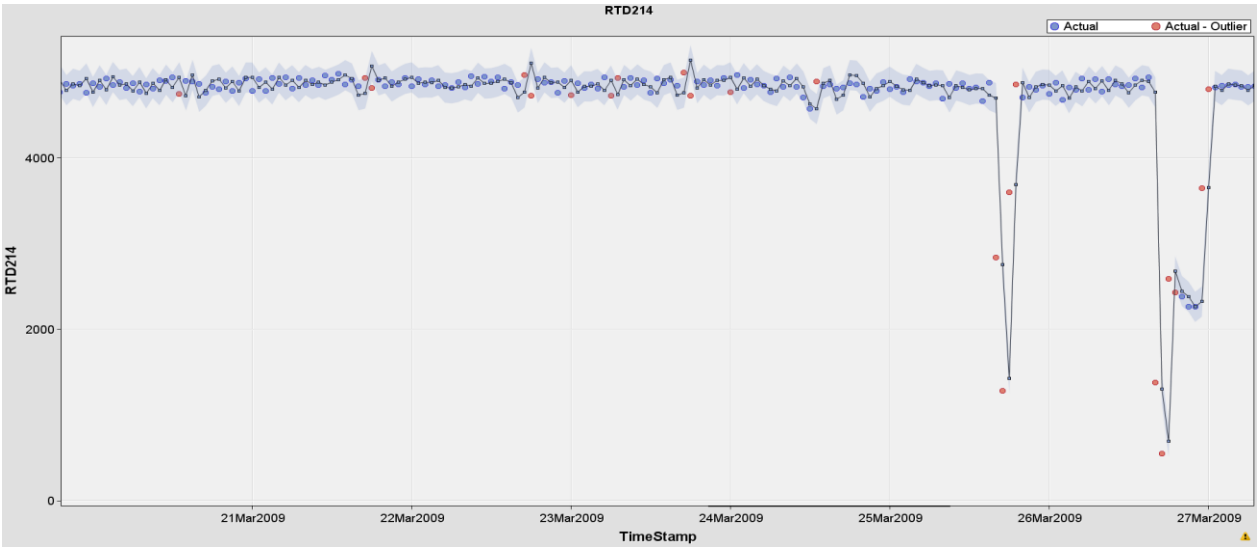
In **Data mining**, anomaly detection (also outlier detection) is the identification of items, events or observations which do not conform to an expected pattern or other items in a dataset. A confidence band is set for each parameters so that the real time values which is out of the confidence band is flagged as outliers.

In the below graph, the red dots denotes the outliers that are out of the confidence band and the blue dots corresponds to real values in the confidence band. The blue line in the center is the moving average or rolling mean that defines the confidence band. Here vibration value is taken as an example- UD12X1



Graph1 : Outliers detection in UD12X1

The above graph shows the outliers in vibration, yet another example to show the outliers in temperature values. The below graph shows the outliers in a temperature variable(RTD214).



Graph2 : Outliers detection in RTD214

The outliers found in every variable of a subset is plotted together in scatter plots to acknowledge that there is difference in many variables and not one. So that the particular equipment with deviation which leads to downtime is know and deployment can be considered. At times, even senor failure can be know thru this **SBM** approach.

The SBM approach is used for the modelling the Water injection package dataset and few cases are explained with early detection of outliers before a downtime.

Note: The features corresponding to Air intake will be always high which shows outliers every time, it is set as the reference features for conditions like the machine is working or not. The features are Average Inlet, TC 19 and TC20.

CASE: Vibration (16 Jun 2010 to 27 Jun 2010)

In this case using Similarity Based Modelling we can efficiently predict the variation in vibration and temperature signals. The outliers were detected from 03rd June 2010, in daily report it was recorded from 16th June to 27th June and in work order the requisition maintenance was completed on 28th June. So, the failure happened was for 12 days which can be detected 14 days in advance if SBM approach was followed.

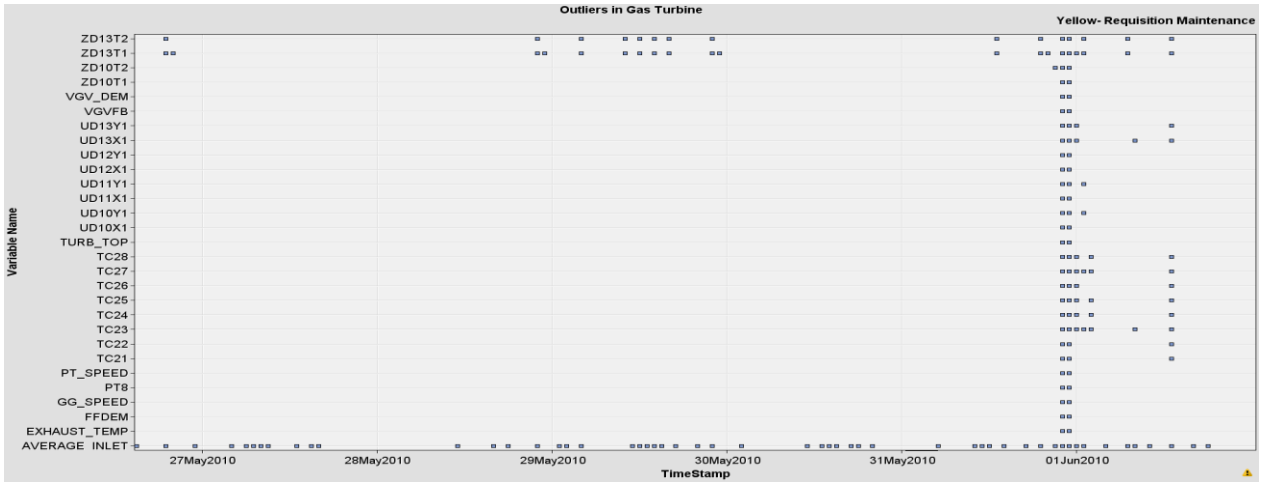
Work Order : Requisition Maintenance

- Equipment Name- Water Injection Pump Turbine
- High vibration on W.I Turbine starter
- Job completed by the vendor. Assisted him. Ch.Pierre

Daily report: Down

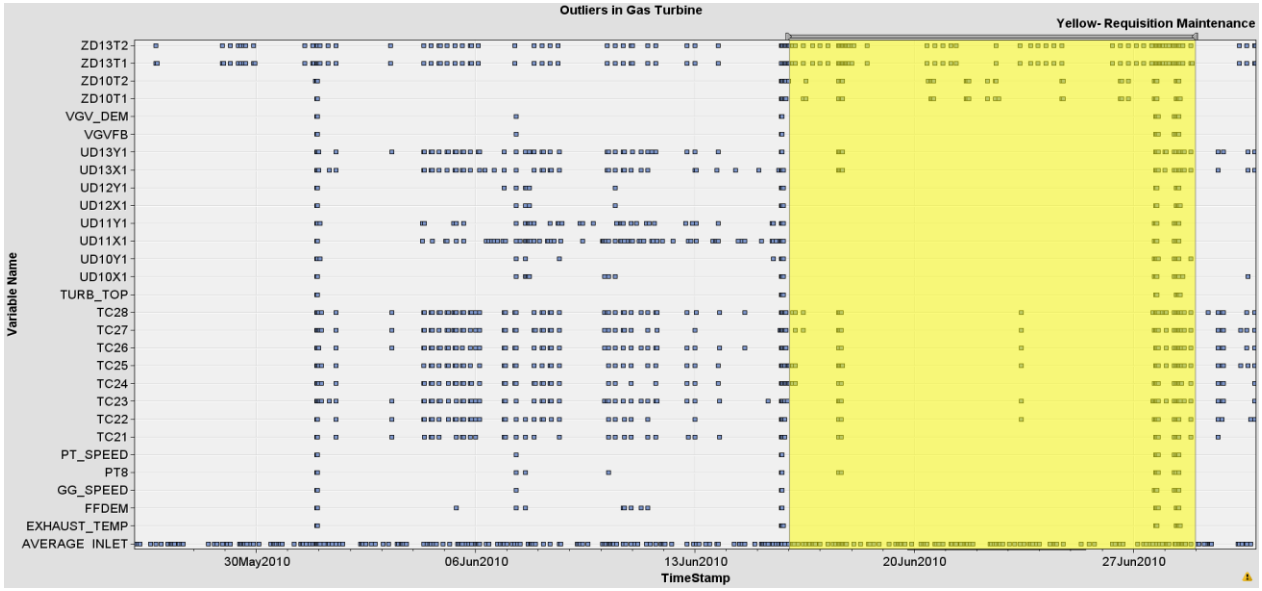
- On 16 June - Turbine tripped on high vibration. Start motor coupling, sliding tracks damaged investigation ongoing.

The below graph shows the normal working condition of Gas turbine, where ZD13T2 and ZD13T1 started deviating initally but nill deviation with other features. Average inlet will show deviation always as it's a reference inlet line.



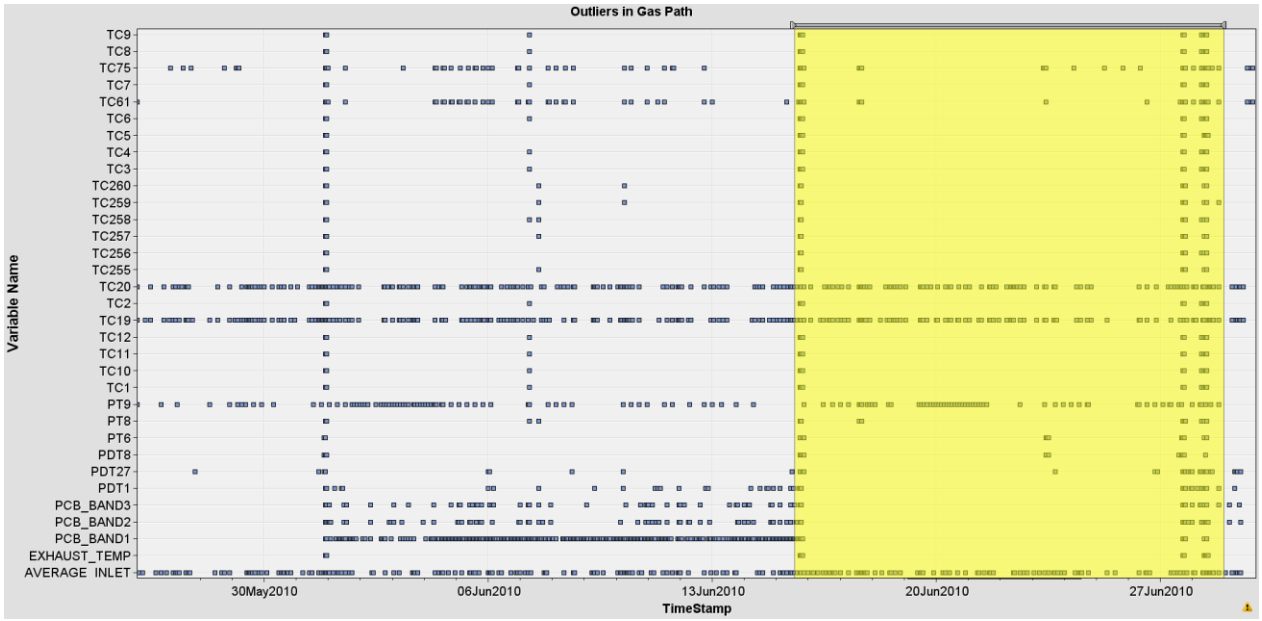
Graph 3

It was clear that, the high vibration is produced in the Power turbine side as ZD13T2, ZD13T1, UD13Y1, UD13X1, UD11Y1, UD11X1 and the temperature features show constant devation from normal moving average which leads to continuous outliers. Here it was seen 14 days in advance that the outlier detection was found well before a downtime.



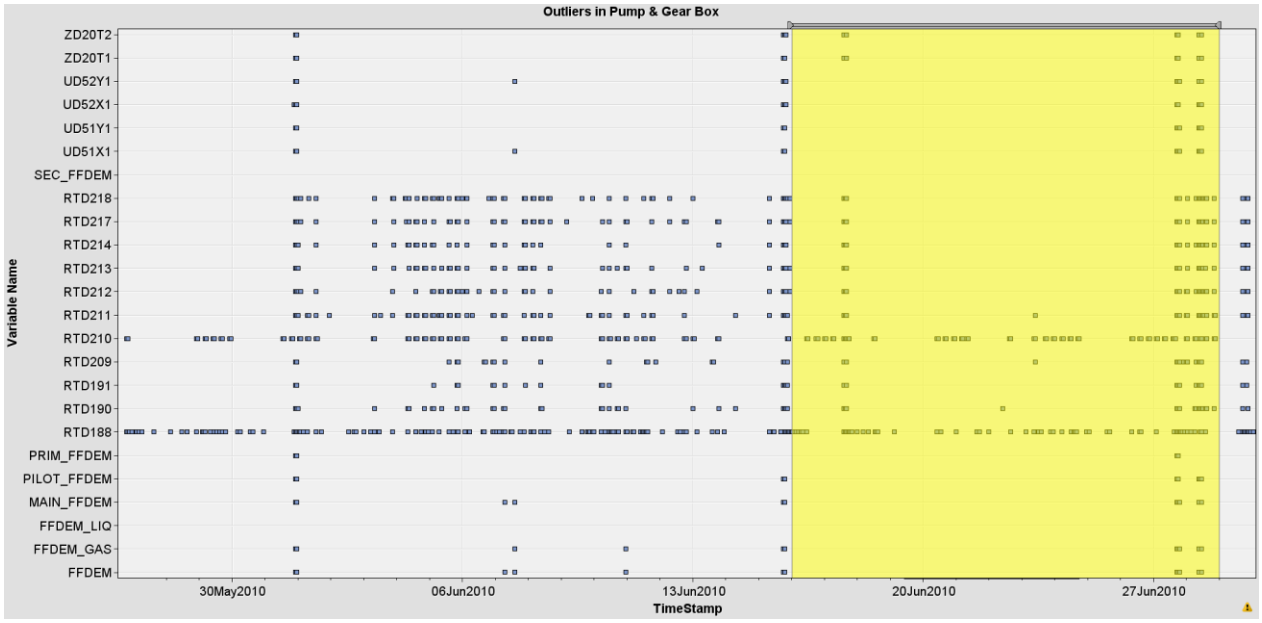
Graph 4

The below graph shows the outliers found in some feauters which is an impact of vibration increase.



Graph 5

The below graph shows the outliers found in some feauters of Gear box which is an impact of vibration increase.



Graph 6

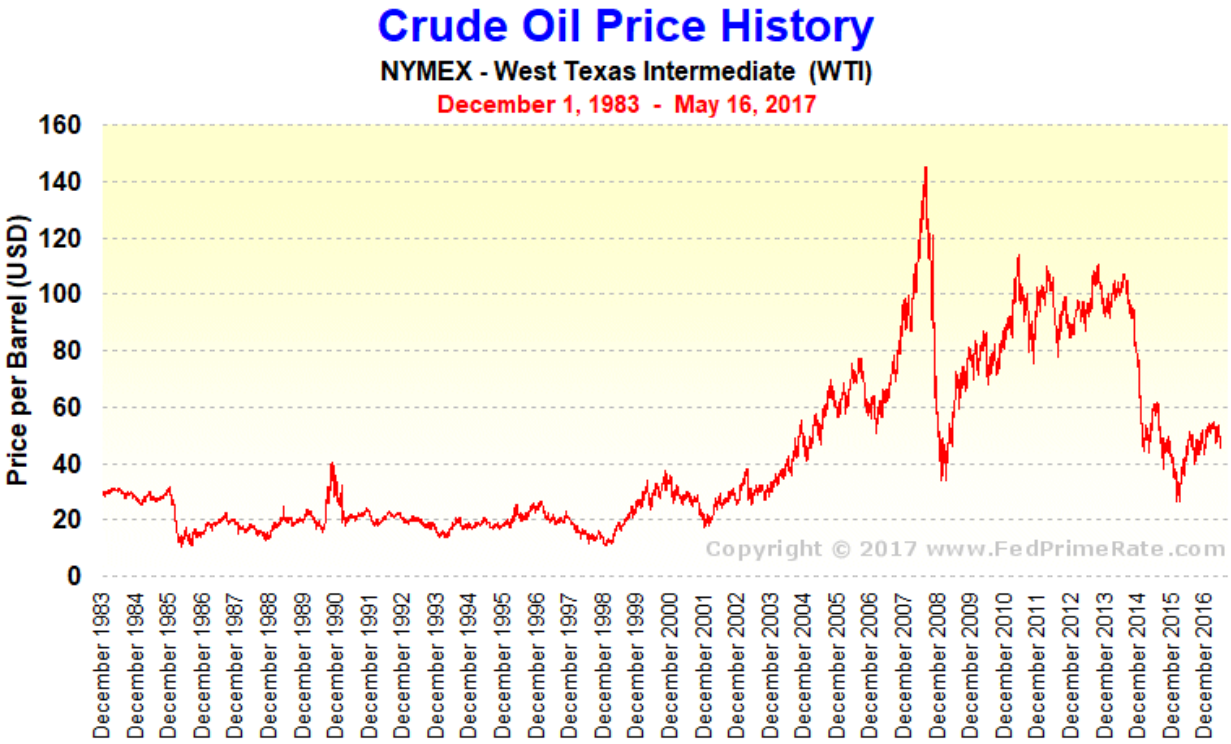
Conclusion:

Using **Simularity Based Modeling** early detection of machines failure can be detected. In this report the failure caused by Vibration was detected well in advance using SBM Method. Likewise 15 cases where detected during my tensure.

Appendix:

General info about crude oil rate in the past:

Crude oil rate in June 2010- 77.18 to 78.86 dollars for case 1



Link: http://www.fedprimerate.com/crude-oil-price-history.htm

Reference :

1. S J Cort ' Moving from planned to condition based maintenance', GE Power Conversion
2. LH Lehman, M Saeed, GB Moody, and RG Mark- 'Similarity-Based Searching in Multi-Parameter Time Series Databases', Harvard-MIT Division of Health Sciences and Technology, Cambridge, MA, USA
3. Yihua Chen, Eric K. Garcia, Maya R. Gupta- 'Similarity-based Classification: Concepts and Algorithms', Journal of Machine Learning Research- Department of Electrical Engineering, University of Washington, Seattle, WA 98195, USA
4. Opeators & control procedure, Water injection Package- FPSO Brasil, SBM Documentaion