ASIA TURBOMACHINERY & PUMP SYMPOSIUM

**PETRONAS ROTATING EQUIPMENT ANALYTICS (PROTEAN): DISTRUPTING AND CHALLENGING THE STATUS QUO OF DIGITAL REMOTE MONITORING SOLUTIONS**

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**ABSTRACT**

In this paper, the author will describe how PETRONAS Carigali Sdn Bhd started to embark on their journey in developing their own in-house digital solution for rotating equipment remote monitoring system for the supercritical turbomachinery equipment for offshore platforms. Instead of the traditional way of relying heavily on Original Equipment Manufacturer's (OEM) remote monitoring solutions, the status quo has been challenged and resulted in astronomical replication from the pilot project of two (2) units to currently covering 200 units within four years of PROTEAN operationalization. PROTEAN was also recognized by the industry by winning the Institute of Engineering and Technology (IET) Malaysia Industry Excellence Gold Award 2019 due to its contribution towards the advancement of science, engineering & technology impacting human, environment, social needs, and economy in Malaysia.

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## INTRODUCTION: PROTEAN CASE FOR CHANGE

Traditionally, rotating equipment remote monitoring system is being done by a third party solution or the Original Equipment Manufacturer (OEM) as part of their offered services to their clients. Hefty capital expenditure is a necessity in order to install new hardware and software coming from the service providers. In addition, end users are required to pay monthly subscriptions for the monitoring services which is a part of operational expenditure. All of this changed when the world oil price went down back circa 2014-2015 where oil hit below USD40 per barrel. The event prompted some oil and gas operators to change the way they operate, including to look for cheaper alternatives instead of relying on subscription fees to service providers. Upon further study, PETRONAS Rotating Equipment Analytics (PROTEAN) was born when the management challenged the team to reduce the overall operating expenditure.

In coming up with PROTEAN, turbomachinery was identified as one of the most important equipment in oil and gas facilities as described by Harris et. al, (2013). As described by Campos et al., (2013) and Carnero (2002), the pumping and compression systems for oil and gas facilities require high level of equipment availability. Therefore, every effort to reduce the faults that can lead into equipment trip and system shutdown must be minimized as low as possible or even eliminated. Thus, major effort in implementing remote monitoring system for compression and pumping system is technically justified to reduce risk, increasing equipment availability and to prevent loss of production for each particular oil and gas facility.

The Upstream Center of Excellence (COE) realized the critical needs of innovative monitoring & analysis to address operational and maintenance challenges of the turbomachinery equipment. The identified major issues were monitoring of turbomachinery health; recognising equipment failure patterns; reducing unplanned repair costs; ensuring uninterrupted production and avoiding unscheduled downtimes.

With hundreds of turbomachinery equipment in operation, OEM and third party solutions would have meant considerable financial commitment for PETRONAS in the long run. Therefore, Upstream COE in collaboration with Group Technical Data (GTD) decided to embark on its digital journey by developing an in-house monitoring and analysis tool using Plant Information (PI System/PI Vision), which was capable of identifying anomaly in trends, highlight potential incipient failures and identify opportunities for reliability improvement of our turbomachinery equipment. GTD, having its strength on understanding technical data from various technical applications, provided in-depth insights on data trend as well as accountability for data quality from various sources, was the right partner for this initiative.

The main objectives of PROTEAN to be deployed are as follows:

- To monitor the assets from a central location, partnering software solutions with predictive capabilities with analytics experts trained to convert small anomalies in industrial data into actionable early warnings of potential failure.
- To ensure that expensive equipment deployed in disparate locations which is challenging to reach and have difficult operating conditions are able to establish top-flight monitoring and diagnostics systems and can continue without interruption.
- To provide tools that project trend analysis which is extremely valuable as an early warning indicator of potential problems and issues.
- To identify anomalous trends, highlight potential incipient failures and identify opportunities for reliability improvement.

In principal, it utilizes Plant Information (PI) system. PROTEAN is capable to select, store and manage real-time data from rotating equipment using the following tools:

- **PI Asset Framework (AF)** to build standard equipment templates for rotating equipment modelling regardless of their manufacturer. From AF, data is analysed, subsequently the users will be alerted for potential threat to the machine.
- **PI Vision to** intuitively present information through a simple yet effective visual of self-configuring analytic trends, graphs, data values, gauges of the rotating equipment.
- **PI Processbook** to graphically create a library of displays to show every facet of the operations from overall regional rotating units to individual equipment displays.

PROTEAN provides Descriptive and Diagnostic analytics with minimum assistance of human intervention as a one-stop digital solution center for rotating equipment. PROTEAN's capability covers management of diagnostic, simple check mechanism and detailed equipment display. It can generate automatic email notification, report digital alarm changes, display high-low limits on analog values and use simple abstraction to detect anomalies. In addition, it can also be expanded to monitor centrifugal compressor and centrifugal pump performance which is covered under the more advanced version called PROTEAN+.

According to Santos et al, (2015), data from sensors were stored, processed and analysed in order to identify the following:-

1. Correlation between parameters that best explain the event
2. Patterns of behaviour (symptom) related to the major occurrence
3. If there were variables that should be included in the monitoring set
4. What more can be considered in the correlation of the variables with their failure modes or critical components

As defined by Davies and Greenough (2000), collected data can be categorized into two groups i.e. Condition monitoring; parameters that are related to the machine health such as pressure, temperature, vibration, oil analysis etc. another is Event; data that explains the event that happened to the machines, including the triggering point and what action has been taken at site. As stated by Campos et al, (2015), main objectives to perform monitoring of critical equipment is to increase safety, availability and operational efficiency. Apart from that, it was also identified that these are the benefits of implementing remote monitoring system:-

- Reduce the requirement to have subject material experts on board to troubleshoot and diagnose a technical problem related to rotating equipment
- Reduce unplanned shutdown, trippage and unplanned maintenance of the rotating equipment
- Contribute towards the reduction of operational and maintenance cost
- Improvise interaction and collaboration among technical disciplines, operation and maintenance team
- Better maintenance planning

According to Marco Piantanida et al (2013), a reputable oil and gas company began the introduction of the Predictive Monitoring software in September 2011, with the aim of progressively moving from a Preventive to a Condition-based maintenance process. Predictive Monitoring tools provide the capability of performing the early detection (several weeks/months ahead of failure) of malfunctions / degradation of performance of the equipment. The anticipation of the detection allows to timely plan the corresponding maintenance activity, without the risk of incurring a production loss due to the failure of the equipment. Similar approach has been undertaken by PETRONAS in order to obtain similar benefits, as well as to adapt to the current digitalization effort aligned with Industrial Revolution 4.0.

Referring to a survey conducted by Heng et al (2009), the existing methods for predicting rotating equipment failures can be divided as follows:-

1. Traditional reliability approach – event based prediction
2. Prognostic approach – condition based prediction
3. Integrated approach – prediction based on event and condition data

## PROTEAN FUNCTIONS AND DISPLAY

- ❑ PI System Explorer is the Asset Framework (AF) user interface which enables users to explore information about the equipment and processes.

- ❑ PI ProcessBook is a graphics software that enables users to create interactive, dynamic displays and trends presenting real-time PI data

- ❑ PI Vision is a web browser-based application that enables users to easily retrieve, monitor, and analyse process engineering information.

- ❑ PI Vision allows users to:
  - Search for and visualise time-series or other PI System data.
  - Save displays for easy retrieval and further analysis.
  - Reuse displays for multiple assets.
  - View PI ProcessBook displays.
  - Share displays with other members of a group or anyone with access to PI Vision

- ❑ PI Vision is supported by most modern browsers on a wide variety of computers, including tablets and phones running iOS or Android operating systems.

This section provides system architecture, templates and analytics design for the PROTEAN PI Asset Framework (AF) as illustrated in Figure 1 and Figure 2 illustrates the workflow of the PROTEAN System.

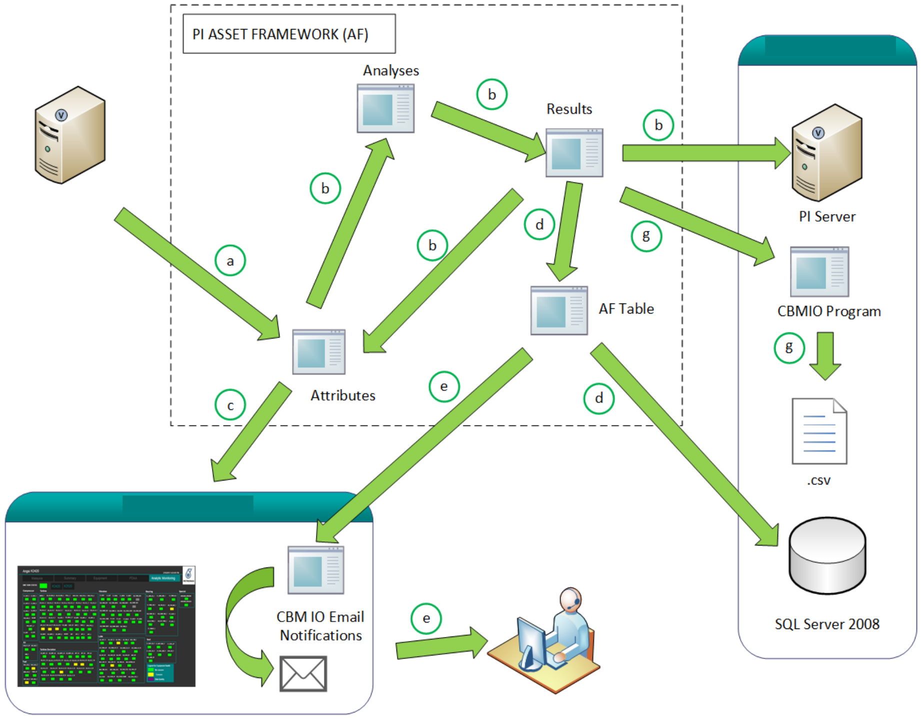



**Figure 1: PROTEAN PI Asset Framework**

a. Data from PROTEAN Server will be read by PI AF which stores the value in the operating value attribute.
b. From the value in the operating value attribute in each of the AF elements, AF analyses will run and calculate the related calculations and store the results in the predefined attributes in AF.
c. Normal attributes will later be displayed in the PI Vision graphics accordingly.
d. However, in case of alerts whether it is SHUTDOWN, UPPER or LOWER, the results will be stored in the related AF table based on the alert category.
e. PROTEAN Monitoring program that periodically checks for the table will send the email to the saved AF contacts. In the event of a TRIP or SHUTDOWN, a notification email will automatically be sent out once on the equipment speed tags. For criticality 1, it will check and send email for each alert tag in 10 minutes while for criticality 2 and 3, the program will check and send email for every 6 hours. However, this email alert will only occur once per day for each tag.
f. During the TRIP or SHUTDOWN event, the PROTEAN program will read from ShutdownMasterStatus attributes. If the value is on alert, the program will automatically retrieve the PI tags from PROTEAN Server and dump the data 5 minutes before the event and 2 minutes after the event in a .csv file.

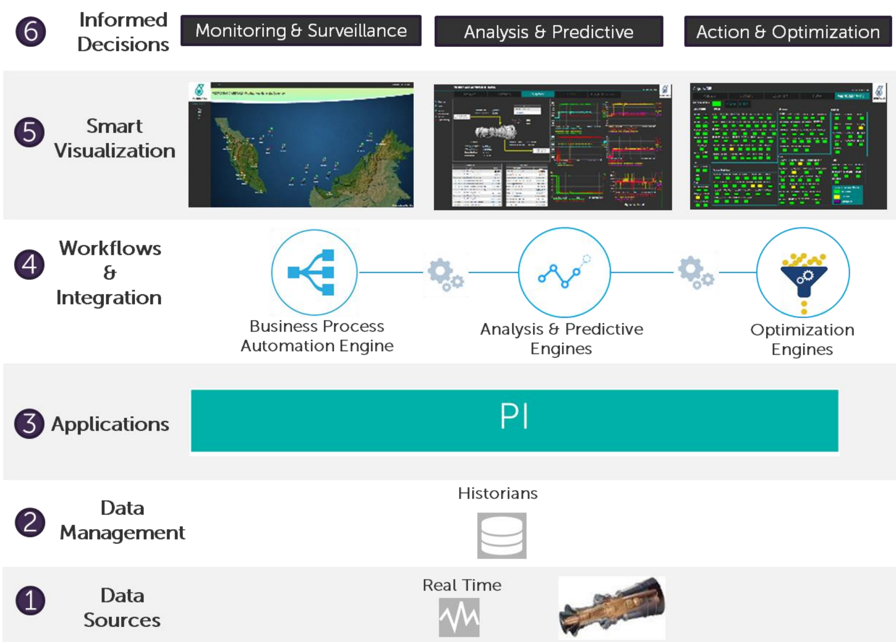


**Figure 2: PROTEAN System Workflow**

## PROTEAN DEVELOPMENT

For each rotating equipment developed under PROTEAN, it starts with the Data Point Identification, where each critical data point will be broken down into three levels of criticality. It must be stressed that this system is purely monitoring and has no executive function on the units being monitored and as such the break down on criticality will only affect the remote monitoring and diagnostic alerts and notification issuance.

Criticality 1 is defined as any data point which relates to a monitoring of high level control system, major system monitoring or a safety critical data point as defined by the OEM. This critical group would also include data points where a sudden increase or decrease of the value is predicted to occur.

These includes but not limited to:-

- Speed (NGP/NPT/N1/N2/NComp)
- Vibration
- Turbine Control Combustion Temperatures (TRIT/T5/Top)
- Fuel actuators
- VIGV Command/Position
- Suction Pressure and Temperature
- Discharge Pressure and Temperature
- Process Flow
- Anti-Surge Valve
- Generator Power
- Generator Voltage
- Generator Frequency
- Generator Amps
- Seal system Flow

Criticality 2 is defined as any data point from systems which support the major equipment and have no direct control function or a data point which monitors external influences not directly related to the equipment being monitored. This critical group would also include data points where a sudden increase or decrease of the value is not predicted to occur.

These includes but are not limited to: -

- Lube oil Temperature and Pressure
- Generator Winding Temperatures
- Any filter ΔP
- Gas Monitoring
- Turbine Compressor Pressure (P1/P2/P3) and Temperatures (T1/T3/T7)
- Fuel System Pressure and Temperature
- Bearing temperatures

Criticality 3 is defined as any data point which is used for information or has no control function of the unit being monitored. These includes but are not limited to:-

- Unit internal PLC performance calculations
- Discrete inputs
- Duplicate data points
- Data of systems not active during normal running. (Start/Rundown Tanks)

Once the criticality has been defined, the next important step is to categorize each data point based on International Standard (2016) ISO 14224 Petroleum, petrochemical and natural gas industries- Collection and exchange of reliability and maintenance data for equipment. The boundary definitions are as shown in Figure 3 and Figure 4.

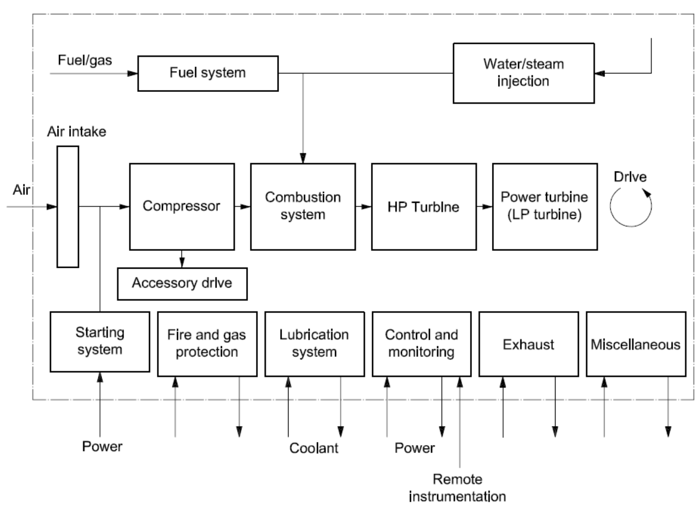



**Figure 3: ISO 14224 Boundary Definition for Gas Turbines**

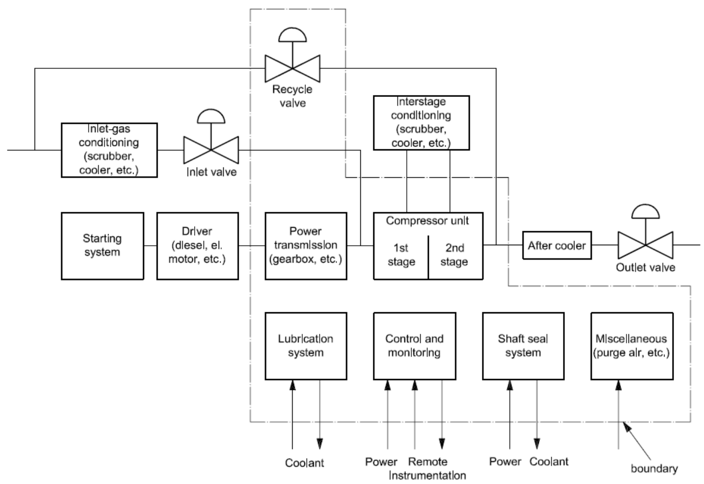



**Figure 4: ISO 14224 Boundary Definition for Compressors**

Once the boundary definition has been defined according to its subunit, each data point has to be assigned to each specific equipment subunit as defined in ISO 14224 (2016). By having such standardization, this enables the team to come out with high level data analysis especially on statistical analysis on numbers of alerts generated.

PROTEAN Development team has to go through the same exercise every time a new equipment is being replicated for PROTEAN. Figure 5 indicates a sample of results for one equipment train.

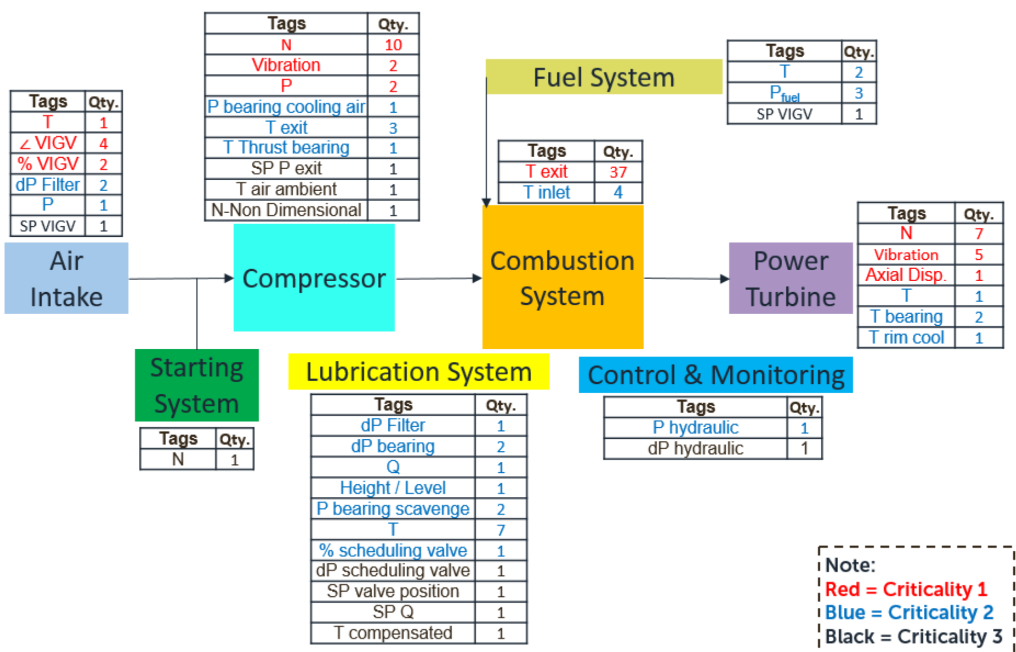



**Figure 5: Sample of Results After Categorization based on ISO 14224 (2016)**

The final step would be to perform the PROTEAN limit setting based on available historical data. Nevertheless, the main challenge would be the data clean up, where some of the data points might have been giving bad data for a certain period of time. Currently the process of data cleaning is done manually, however as part of enhancement, the intention is to automate the process in near future utilizing on-shelf tools available in the market. The limit setting would be much easier for data points which has been provided with OEM limits. Bear in mind that not all data point parameters comes with OEM limits, therefore the team needs to utilize their engineering experience to determine what would be the normal operating region, which would usually be based on historical data. Once the unit starts to operate, then the adjustments or tuning of the limit setting will be done manually to reduce the numbers of false flag email generated by the system.

The development team will utilize the PI System Explorer which builds the Asset Framework to become the user interface that can be displayed via PI Vision later. Figure 6 represents the snapshot of how the PI AF page looks like. All the data points will be exported back into PI AF, and the associated algorithm to detect anomalies will be built inside the PI AF structure itself.

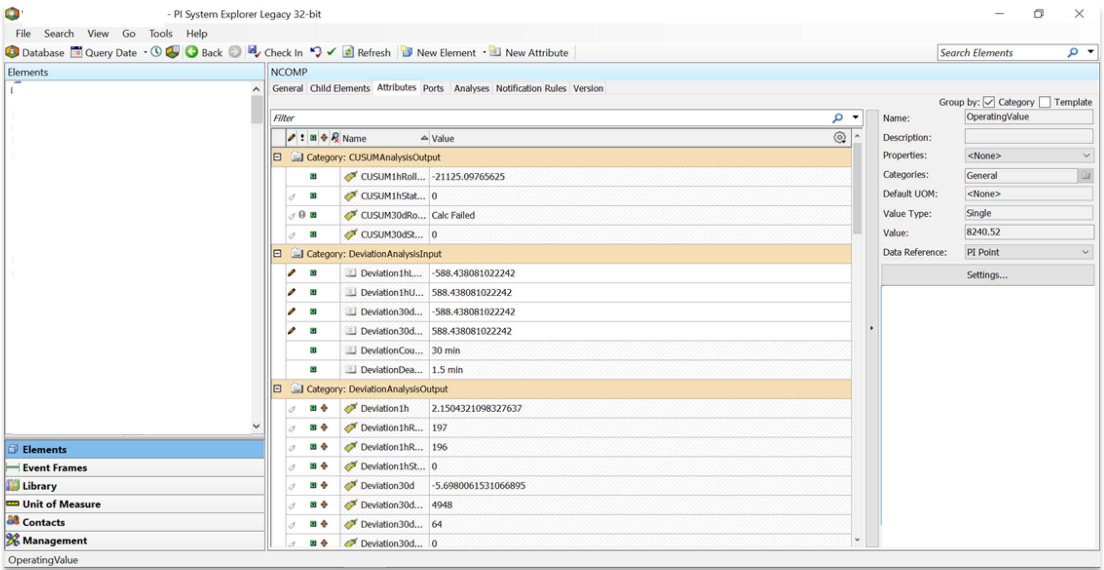



**Figure 6: PI System Explorer Asset Framework (AF)**

The complexity of PI system in PROTEAN is that it is dealing with large amounts of data. This is up to 10,549 PI Tags or data points of 126 rotating equipment as of September 2019. The equipment encompasses 79 gas turbines, 29 generators, 35 highly critical pumps and 59 centrifugal compressors. PROTEAN covers 35 PETRONAS assets with 6 regions in Malaysia and 3 international regions. In Malaysia, it monitors 107 units of rotating equipment from Peninsular Malaysia Asset (PMA), Sarawak Gas (SKG), Sarawak Oil (SKO) and Sabah Assets (SBA). Besides that, PROTEAN's coverage has also expanded to Malaysia Liquefied Natural Gas (MLNG) onshore facility and even on the world's first floating facility, PETRONAS Floating Liquefied Natural Gas (PFLNG). For international coverage, PROTEAN remote-monitors 19 rotating equipment units from Middle East, Central Asia and Southeast Asia. There will be more expansion and replication plans for the upcoming 2020 to cover more units, especially for International Assets.

One of the biggest advantages of PROTEAN is that the algorithm would be able to be used for all types of gas turbines, compressors and pumps regardless of the OEMs. Now, PROTEAN has become one of PETRONAS' icons in digitalization and Industrial Revolution (IR) 4.0. It has received more than 50 visitors from various parties including host government, oil and gas operators, service providers and multinational companies.

For the end users located at the assets, they can only view PROTEAN via the PI Vision and will not have the access to PI AF. All the modification can only be done via PI AF, therefore the PI AF usage is only restricted with the PROTEAN Development Team located at the central office and not accessible by the assets. This is to avoid unnecessary and uncontrolled changes being made. Only authorized personnel are allowed to make necessary changes on the limits, settings and to update the system. According to Marco Piantanida et al (2013); in some cases it is necessary to review data at higher sampling intervals, in order to perform deeper diagnostic analysis or to understand phenomena that develop much quicker than the sampling rate used by a predictive monitoring tool. The PI historian provides a number of powerful graphical tools to analyze sensor data at the lowest resolution level, therefore allowing the engineers to complement the predictive diagnostics with a more detailed analysis of the issues.

PROTEAN PI Vision pages are shown in Figure 7.

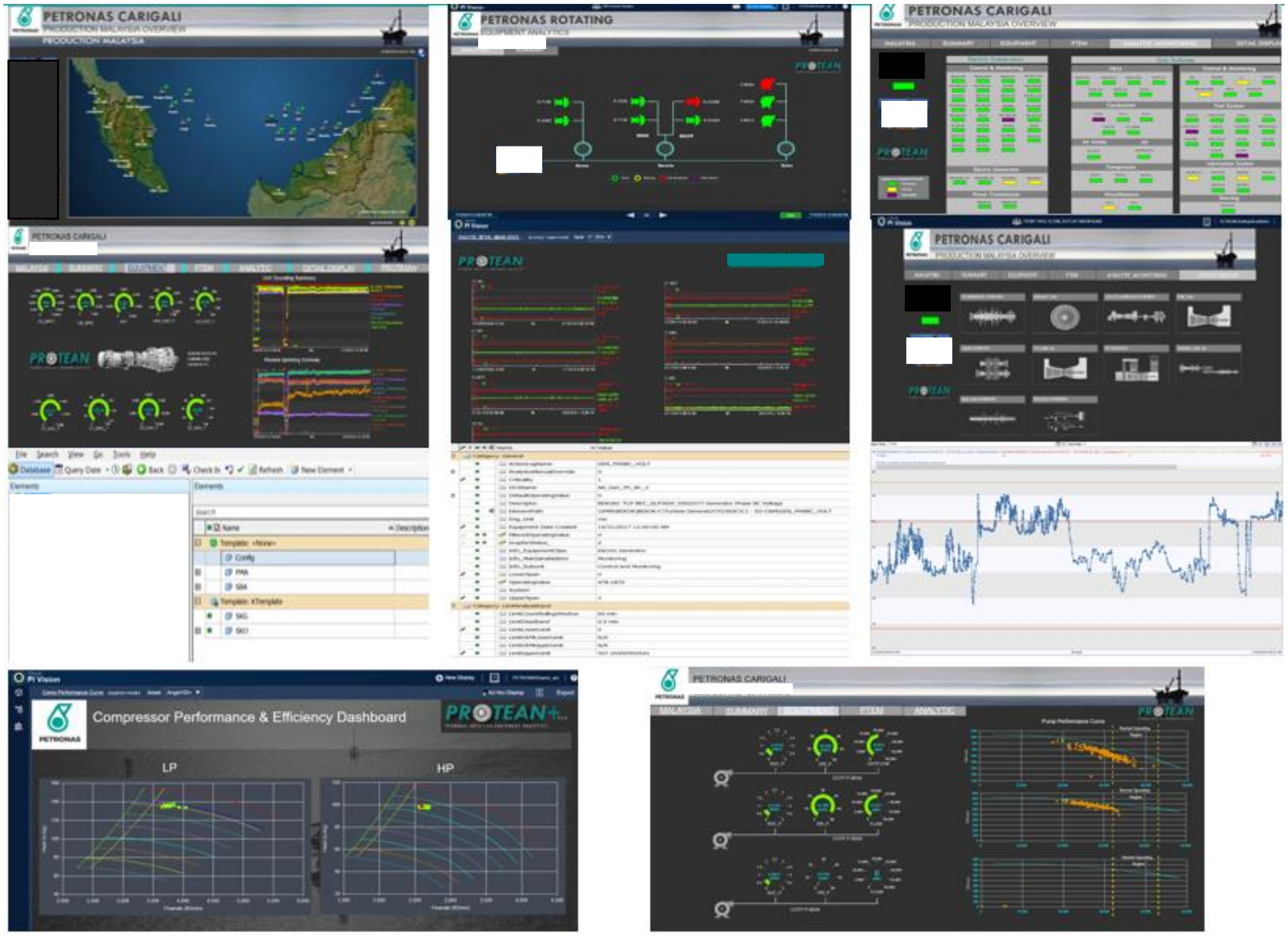



**Figure 7: PROTEAN PI Vision Pages**


**Figure 8: PROTEAN Control Centre at PETRONAS Digital Collaboration Centre**

## ANALYZING DATA: TURN IT INTO INSIGHTS AND VALUE CREATION

There were many success cases throughout the implementation of PROTEAN. From data analysis to report generation, PROTEAN was able to give data insights and create value to the users. The team put their effort in identifying the possible failure modes and mechanisms when an alert is triggered by the system. From detailed analysis, the action required will be informed to the users who will also be warned on the possible consequences if no action is taken at site (Figure 9). Figure 10 shows the sample of PROTEAN Alert generated and sent to the end users for further action.

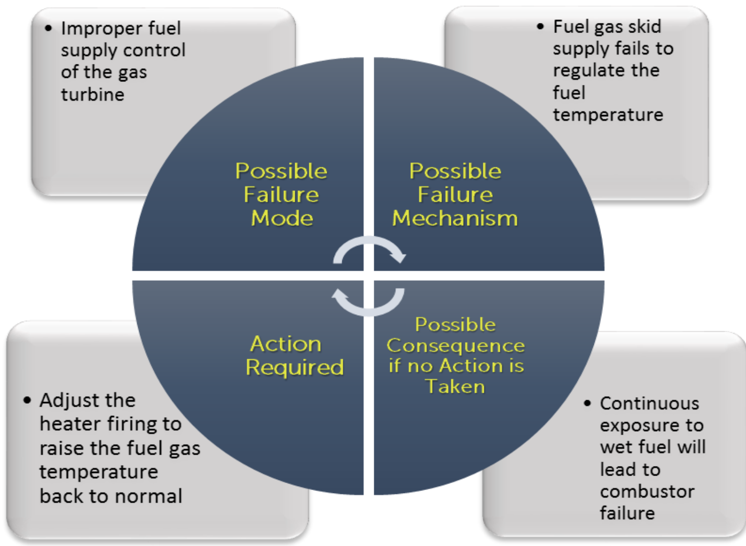
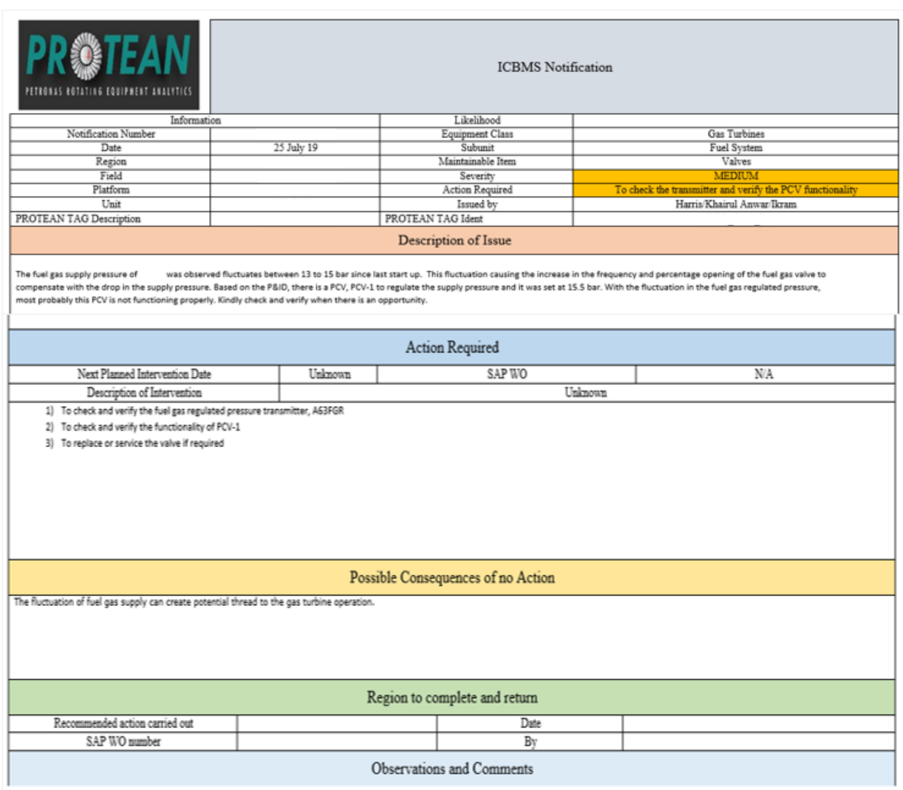



**Figure 9: PROTEAN Alert Notification Workflow**



PROTEAN
PETRONAS ROTATING EQUIPMENT ANALYTICS

ICBMS Notification

| Information | | Likelihood | |
|---|---|---|---|
| Notification Number | | Equipment Class | Gas Turbines |
| Date | 25 July 19 | Subunit | Fuel System |
| Region | | Maintainable Item | Valves |
| Field | | Severity | MEDIUM |
| Platform | | Action Required | To check the transmitter and verify the PCV functionality |
| Unit | | Issued by | Harris/Khairul Anwar/Ikram |
| PROTEAN TAG Description | | PROTEAN TAG Ident | |

Description of Issue

The fuel gas supply pressure of was observed fluctuates between 13 to 15 bar since last start up. This fluctuation causing the increase in the frequency and percentage opening of the fuel gas valve to compensate with the drop in the supply pressure. Based on the P&ID, there is a PCV, PCV-1 to regulate the supply pressure and it was set at 15.5 bar. With the fluctuation in the fuel gas regulated pressure, most probably this PCV is not functioning properly. Kindly check and verify when there is an opportunity.

Action Required

| Next Planned Intervention Date | Unknown | SAP WO | N/A |
|---|---|---|---|
| Description of Intervention | Unknown | | |

1) To check and verify the fuel gas regulated pressure transmitter, A63FGR
2) To check and verify the functionality of PCV-1
3) To replace or service the valve if required

Possible Consequences of no Action

The fluctuation of fuel gas supply can create potential thread to the gas turbine operation.

Region to complete and return

| Recommended action carried out | | Date | |
|---|---|---|---|
| SAP WO number | | By | |

Observations and Comments

**Figure 10: Sample of PROTEAN Alert**

In this paper, three case studies are presented as follows:

**Case Study 1: Instrument Air Pressure Dropped at Platform A**

The instrument air pressure for Platform A was observed to be on a decreasing trend (Figure 9). Normal running pressure is at 820 kPag to 810 kPag but has dropped to around 750 kPag on a decreasing trend (Figure 10). OEM alarm for the instrument pressure is at 550 kPag for TC and 585 kPag for TG.

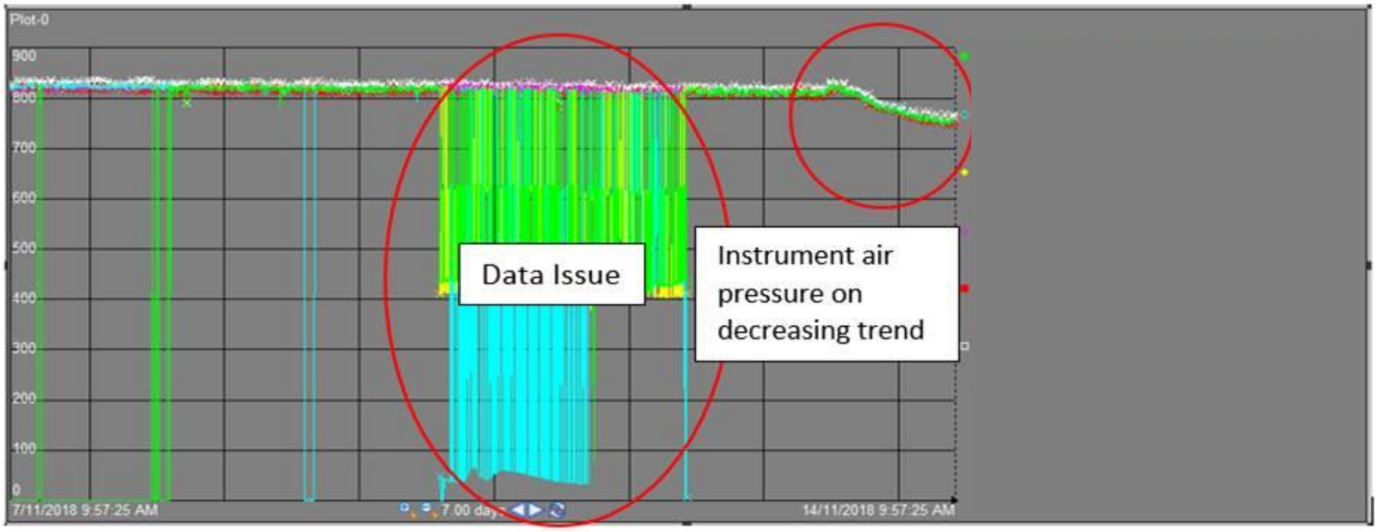



**Figure 11: Instrument Air Pressure for Platform B on Decreasing Trend**

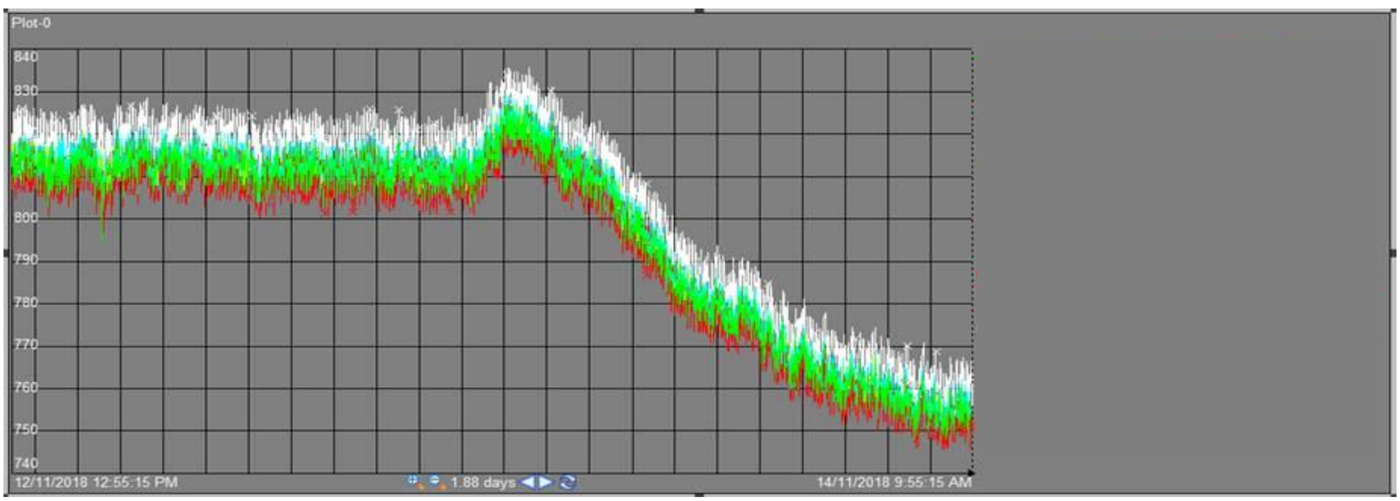



**Figure 12: Instrument Air Pressure Dropped to about 750 kPa**

It was observed that pre-filter of the instrument air dryer was very dirty and contaminated with foreign materials. The instrument was found with desiccant carried over from the instrument air dryer. Black carbon liquid has been found at the carbon filter. UPD was successfully avoided because contamination of the instrument air dryer pre-filter was identified and cleaned before it tripped the unit. This avoidance helped the asset owner to contain approximately RM3.42 mil loss while allowing enough time for operators to restore the instrument air pressure to normal pressure of 840 kPag (Figure 11).

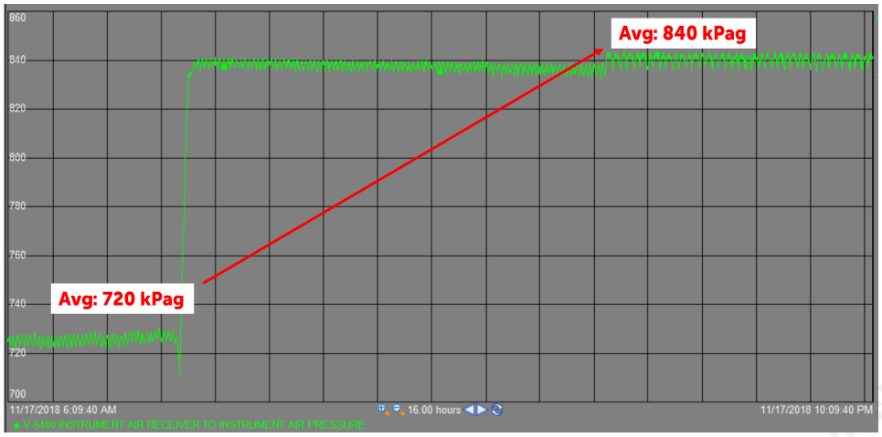



**Figure 13: Instrument Air Pressure was Back to Normal Operating Pressure**

**Case Study 2: Gas Generator Lube Oil Level Dropped at Platform B**

There was abnormal trend of gas generator lube oil level detected on Equipment X at Platform B on 27th May 2019. It was observed that the lube oil was topped up but it showed a rapid drop from the normal lube oil consumption since the last top up. Investigation had been carried out to check if there was any external oil leakage. The current actions are:

- To carry out investigation on the rapid lube oil level drop.
- To rectify and top-up the lube oil.

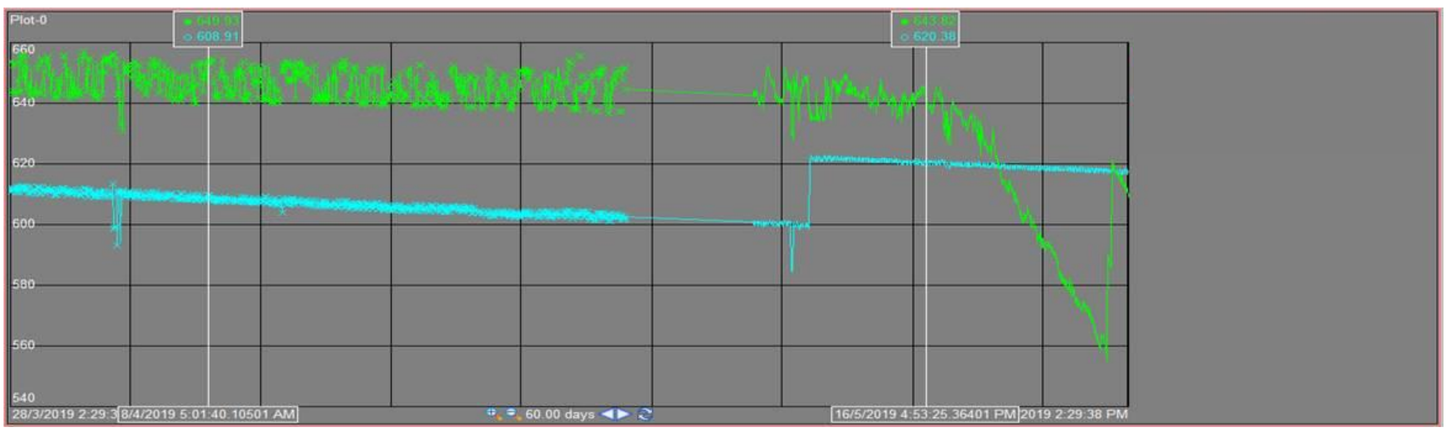



**Figure: Abnormal trend of Gas Generator Lube Oil level on unit K2520**

**Case Study 3: Early Detection of Elevated Compressor Vibration Levels at Platform B**

From Jan till Mar 2018, Compressor Y at Platform B had been operating above rated capacity to cater for higher gas export demand. Due to that, the compressor was required to run at higher speed which in turn elevated compressor vibration levels (Figure 12). With increasing trend of the vibration levels, the compressor was expected to operate beyond Safe Operating Limit (SOL) if no intervention took place. Troubleshooting revealed that the compressor load sharing control was also an issue. PROTEAN team thus sent an alert notification to the operators. Action was immediately taken by operators who performed advanced vibration analysis and troubleshooting. Compressor load sharing control issue was also rectified. Early detection of anomalies and timely intervention had prevented equipment from bearing premature failure which could have caused 3 days of production deferment, major equipment repair and OEM manpower cost.

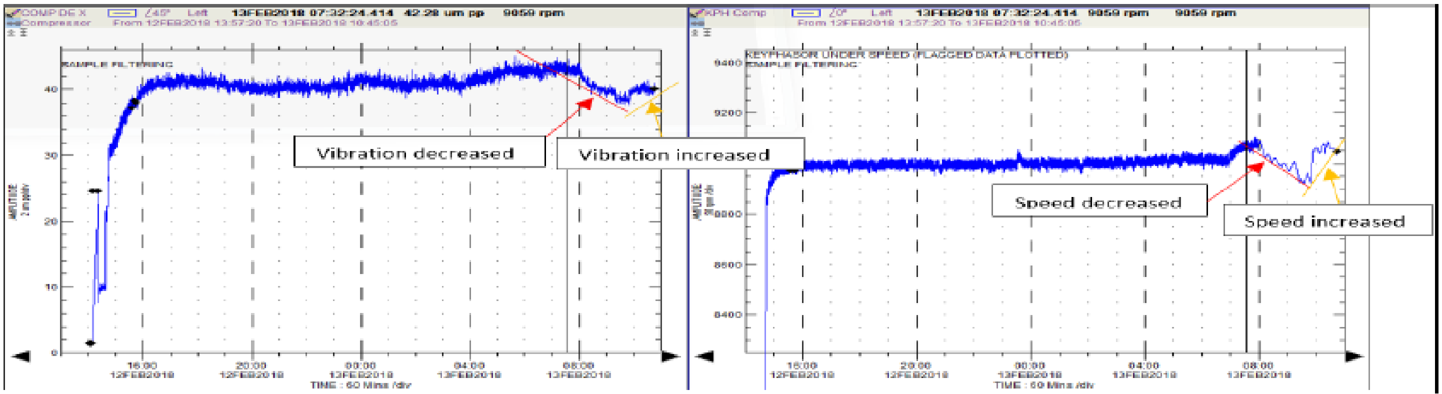



**Figure 14: Elevated Vibration Level**

By having quality data collected and more precise data trending, PROTEAN is able to prompt timely human intervention before the equipment built-in warning system is triggered. This not only prevents worse and catastrophic failures but also results in effective inspection and maintenance strategies. In other words, PROTEAN provides support for users or assets in PETRONAS regions in the aspects of production, cost avoidance and manpower. In terms of production, PROTEAN has improved the average equipment reliability to in between 96% and 99%. The contribution of rotating equipment to the planned and unplanned deferment is the least among other contributors and has been gradually decreasing with the existence of PROTEAN's solutions.

Besides that, PROTEAN promotes cost avoidance in the aspects of Unplanned Deferment (UPD) avoidance, major equipment maintenance avoidance and Field Service Representatives (FSR) call out avoidance which cost a significant amount of money every year. At the same time, PROTEAN benefits users as it provides manpower for monitoring of rotating equipment with its centralized support from PROTEAN control centre at PETRONAS Digital Collaboration Centre. The monitoring of equipment in PROTEAN equalizes the concept of roving team but in a remote manner besides gradually reducing PETRONAS' dependency on OEM for turbomachinery maintenance solutions.

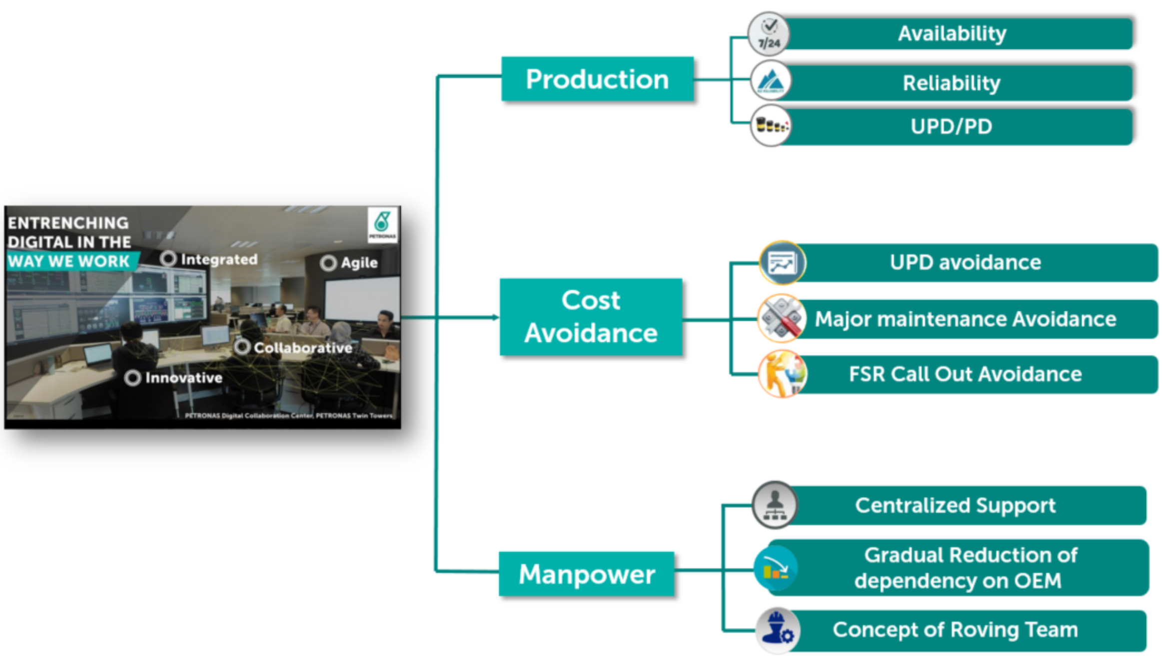



**Figure 15: Overall Value Creation of PROTEAN**

## WHAT IS NEXT: PROTEAN+

As a part of long-term development roadmap, PROTEAN is moving from descriptive towards prescriptive analytics through several PROTEAN+ projects. PROTEAN is developing event log via OSIsoft's PI system, centrifugal pump and centrifugal compressor performance algorithm. Apart from that, the functions that will be available under prescriptive analytics are equipment time to failure forecast and fault identification based on FMEA (Failure Mode and Effect Analysis). The equipment time to failure function is developed based on a hybrid of first principle and data science approach which will provide users a forecast of time remaining before the unit trip due to a particular anomaly detected. This function aims to assist and improve maintenance schedule and cost which is crucial in reducing unnecessary expenditures.

For the fault identification, it is developed based on in-house FMEA library. The FMEA library is a combination of internal expertise, experience and knowledge contributed by subject matter experts and users. It focuses on faults which are measurable and detectable by instruments on maintainable items which are categorized according to subunits of the equipment as described in ISO 14224 (2016). The possible failure modes and failure mechanisms will be auto-generated by Artificial Intelligence (AI) running on the FMEA library. The objective is to accelerate fault diagnosis and prescriptive analysis by identifying root causes with high possibility. Human intervention will only be required during the decision-making stages.

In summary, PROTEAN+ should be the advanced version of the basic PROTEAN. The application of PROTEAN+ would be based on asset tier and equipment criticality. There is no need to use PROTEAN+ for all equipment as it may not be economic to implement such advanced analytics on all rotating equipment. However, once the technology is matured enough and the overall implementation cost has been lowered down, there is a possibility of making PROTEAN+ as one of the basic features in PROTEAN itself.

## CHALLENGES, LESSON LEARNT AND BEST PRACTICES

According to Marco Piantanida et al (2013): The level of instrumentation of the equipment is often non-optimal. The Predictive Monitoring process should be able to work both on well instrumented equipment and on poorly instrumented ones. Therefore, mathematical methods based on First Principle models may not perform optimally due to the lack of key sensors to feed the model. Data driven methods, based on the observation of the behavior of the equipment during past operating conditions would be preferable.

The availability of historical data is often an issue. In many assets, data historians are either unavailable or limited to a few weeks of storage. In many cases, the implementation of the data historian is performed in correspondence with the beginning of the predictive monitoring project. Therefore, data driven methods which do not require a comprehensive set of historical data would be preferable.

The conditions at which the equipment is run are extremely variable, and they are heavily affected by the unpredictable composition of the oil and gas fluid from the wells. Therefore, data driven parametric methods based on training on observed behavior of equipment in normal operation conditions may not be able to perform as soon as the operating conditions change.

As part of the best practices, PETRONAS Rotating Equipment Analytic (PROTEAN) was recently crowned as the winner of the Institute of Engineering and Technology (IET) Malaysia Industry Excellence Gold Award 2019 for the category of ‘Large Local Company Energy’. The award was presented during the 9th IET Malaysia Network Prestige Lecture & Award Dinner (PLAD2019) held on 29 September 2019.

Upholding the spirit of ‘Shared Success’, winning the award would not be possible without the concerted efforts demonstrated by Upstream Centre of Excellence (CoE) and Group Technical Data (GTD).  This prestigious award recognises PROTEAN as one of the significant contributors to the advancement of science, engineering & technology impacting human, environment, social needs, and economy in Malaysia.

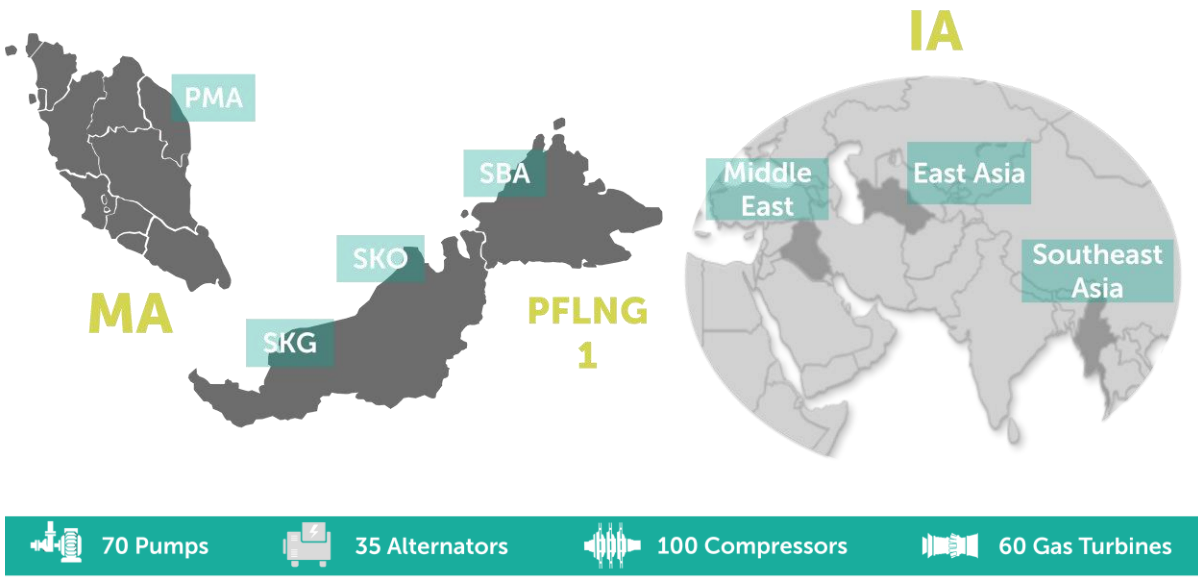



**Figure 16: PROTEAN's Coverage in Malaysia Assets (MA) and International Assets (IA)**

## CONCLUSION

PROTEAN was started in April 2017 by piloting 2 units of critical gas turbine driven compressors at Field A in Peninsular Malaysia Assets (PMA). In Nov 2018, PROTEAN has monitored up to 55 units of rotating equipment across PETRONAS operating regions in Malaysia. PROTEAN coverage has soared up more than double of the previous year, and as of end of 2020, the number has reached more than 250 of monitored equipment.

PROTEAN is a living proof that has been given the right time, budget and resources by PETRONAS to become an alternative for Original Equipment Manufacturer (OEM) remote monitoring solutions. It is able to generate insights based on data collected by PI system. Quality data collected in PROTEAN leads to more precise data trending which results in effective inspection and maintenance strategies. It ensures higher rotating equipment efficiency and thus reducing operating and maintenance costs. In addition, cyber security issues can be minimized since the data stays within the company's digital ecosystem. PROTEAN embraces digital journey to big data analytics which implies 'Data is the New Oil'. At the same time, PROTEAN enhances the development of local talents and potentials since its operations are fully carried out by Malaysian workforce.

Embracing our Statement of Purpose, PROTEAN has progressively strengthen its ability for being able to predict failures before it happens, provides insights based on data analytics as well as to drive the culture of data driven maintenance. With the presence of Industry 4.0, elements such as Artificial Intelligence will play a substantial role in taking PROTEAN to the next level, thus enabling PETRONAS to maximise its turbomachinery equipment performance.

## FIGURES

**REFERENCES**

Marco Piantanida, Eni, Federico Cristofori, Eni, Simone Fiorita, Eni, Cristina Bottani, Eni, Yanni Pappas, GE Intelligent Platforms, Nicolò Alessandro, Eni, Cosimo Piccione, Eni, (2013), Predictive Monitoring Of Critical Rotating Equipment In Val D'agri, Offshore Mediterranean Conference and Exhibition

Heng A., Zhang S. Tan A.C.C., Mathew J, 2009, Rotating Machinery Prognostic, state of the art , challenges and opportunities, Mechanical Systems and signal processing 23, 724- 739, Elsevier

Santos I.H.F., M. M. Machado., E.E. Russo., D.M. Manguinho.. et al. 2015, Big Data Analytics for Predictive Maintenance Modelling; Challenges and Opportunities, Offshore Technology Conference, OTC-26275-MS

C. Davies, R.M. Greenough, (2000), The use of information system in fault diagnosis, Proceedings of the 16th National Conference of Manufacturing Research, University of East London, UK.

Campos M. M., Teixeira A., Von Meien O., Neto S., (2013), Advanced Control System for Offshore Production Platform, Offshore Technology Conference

Campos M. M., Grizante R., Junior L. et al, (2015), Critical Equipment Monitoring in Production Platforms, Offshore Technology Conference, OTC-26246-MS

Carnero, 2002, Selection of Diagnostic Techniques and Instrumentation in a Predictive Maintenance, Decision Support System, 38, 539-555

Harris A. R. Sabri, Abdul Rahman A Rahim, Haris A Majid, 2013, Concepts of Turbomachinery Selection For Upstream Oil and Gas Facilities Project, 2nd International Conference on Mechanical, Automotive and Aerospace Engineering (ICMAAE) 2

International Standard (2016), ISO14224, Petroleum, petrochemical and natural gas industries – Collection and Exchange of Reliability and Maintenance Data for Equipment. Third Edition.

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