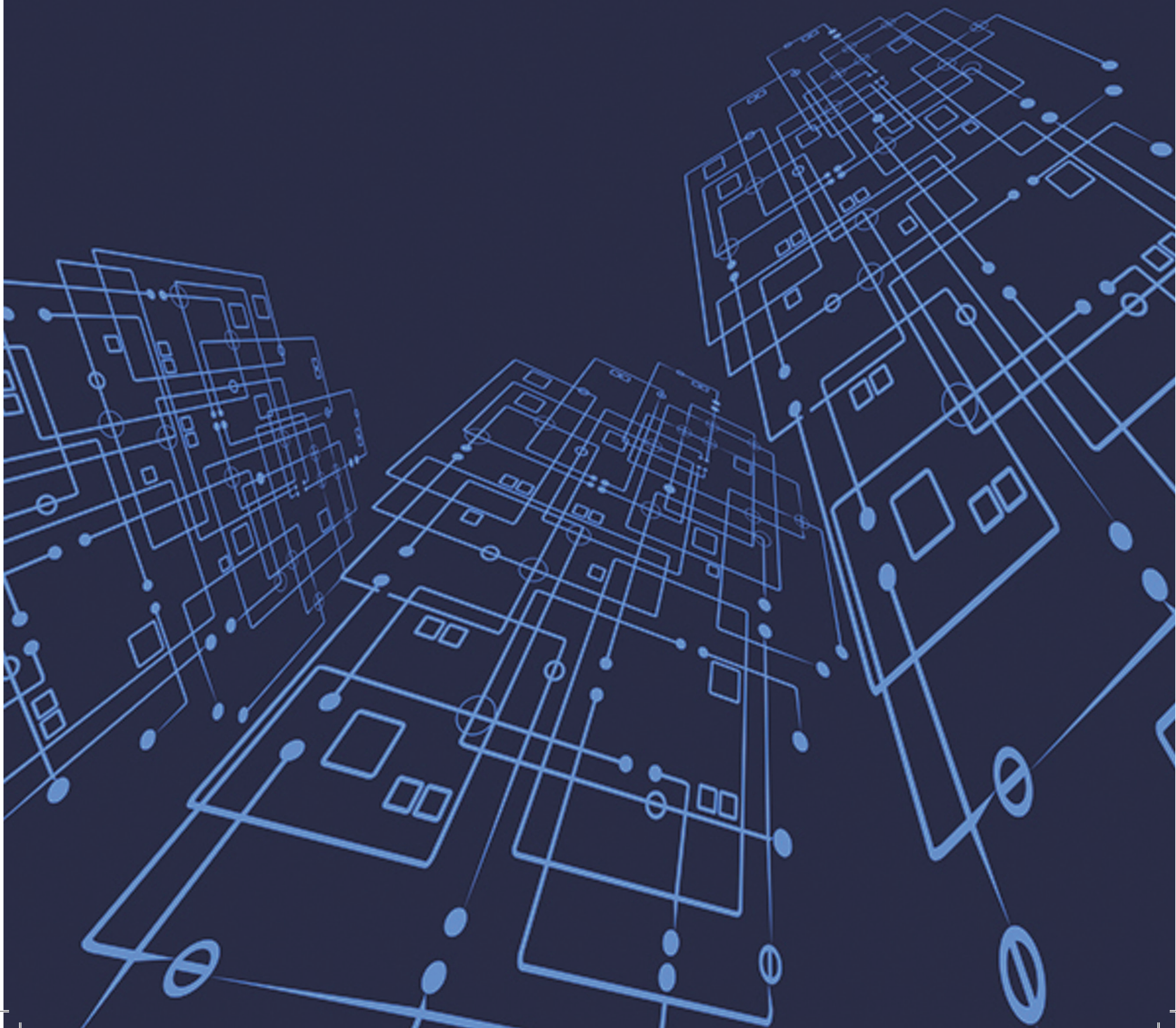
Technical Papers



Fast and Accurate Analysis of Process Streams Using the Process Mass Spectrometer for Economic Benefits and Regulatory Compliance

Jian Wei, PhD and Zbigniew Krieger, PhD
Extrel CMS, LLC
Pittsburgh, PA, USA

Oscar Everitt, Retired Senior Technologist, Dow Chemicals,
Plaquemine, LA

Abstract

For decades chemical commodity manufacturers have been applying optimization tools to increase their profits. With recent developments in energy prices on the international markets, it has become even more imperative for plant managers to look for possibilities of improving profitability. Industrial mass spectrometers have been used for control of the production processes for at least 40 years. Their speed of analysis and analytical accuracy/repeatability make it possible to tighten process parameters, which leads to improvements in profitability. As reported by the users, the investment in a process mass spectrometer system pays for itself on average in just a few months. There are several chemical processes, such as ammonia, methanol or ethylene oxide, which adapted mass spectrometry as a primary analytical tool for optimization. Most recently, energy content in some of the low quality sources, like in refinery spent gases, is high enough to render them as valuable process streams, worth of purification and return to the process. This paper highlights economic advantages of using fast and accurate mass spectrometer analyzer for optimization of several processes in chemical production plant.

Introduction

There are several chemical production processes which utilize high speed reactions occurring in large scale reactors. The dynamics of such an apparatus is measured in seconds. High throughput reactors pass through products worth of millions of dollars every day. An improvement in yield by just a fraction of a percent allows for the increase of production by several thousands of dollars per day. The processes, which are slow by nature (e.g. distillation) and feeds do not change rapidly, can be monitored by slow analyzers. The processes, which require fast analysis, are such, where the composition of the feed is changing fast enough to affect the reactor performance if not corrected on time. During past 40 years mass spectrometers found such applications and now are the default analyzer of choice. These applications include: Ethylene Cracker, Ethylene Oxide, Ammonia, Methanol, Polyethylene, Polypropylene and others.

Another group of applications, where fast analysis is required, is ambient air monitoring. Here, however, the driving force is not return of investment. It is the need for compliance in the state and local health and environmental regulations.

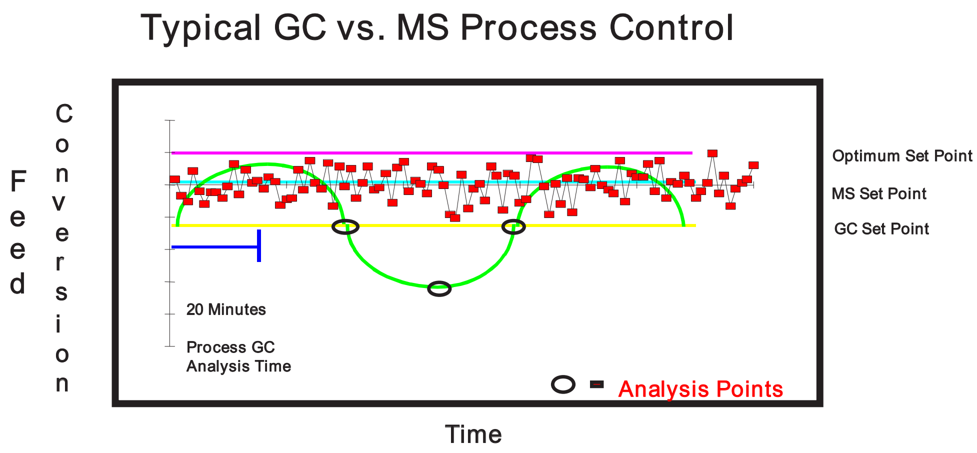


Figure 1. GC vs. MS process control.

In this article, a couple of typical fast chemical processes are reviewed from the point of view of return of investment and regulatory compliance by using fast and flexible multi-compound analysis offered by the process mass spectrometer.

The Benefits on Ethylene Cracker

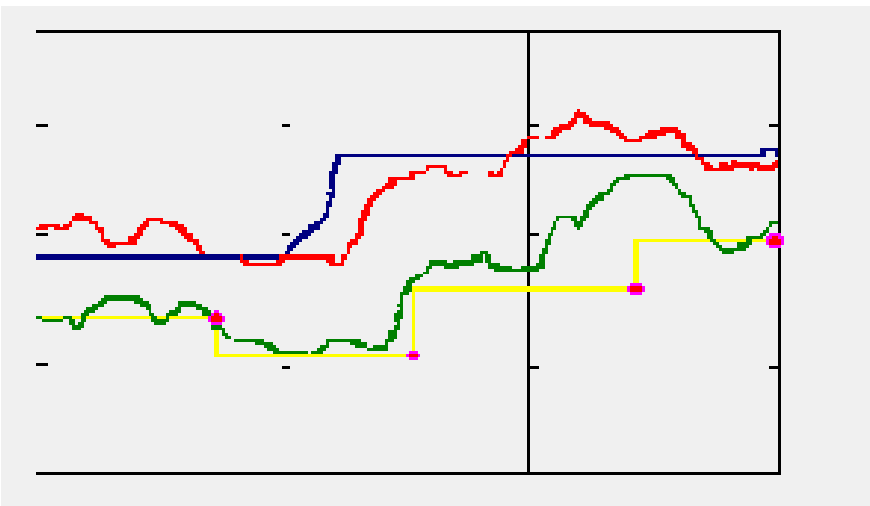


Figure 2. Typical response of the Ethylene Cracker from MS and GC.

Fig. 2 shows the response of an Ethylene Cracker on the change of furnace temperature during the GC vs. MS study at one of the major ethylene producer plants. The furnace established new performance level in less than three minutes. The blue profile reflects the temperature set point while the red profile is the actual exit coil temperature measurement. The green profile represents the furnace conversion measured by the Extrel process mass spectrometer. The yellow profile represents the furnace conversion measured by the gas chromatograph.

As a rule, an analysis update should be about 5 to 10 times faster than the dynamics of the process. As it can be seen, the GC analysis update does not keep up with the dynamics of the reactor.

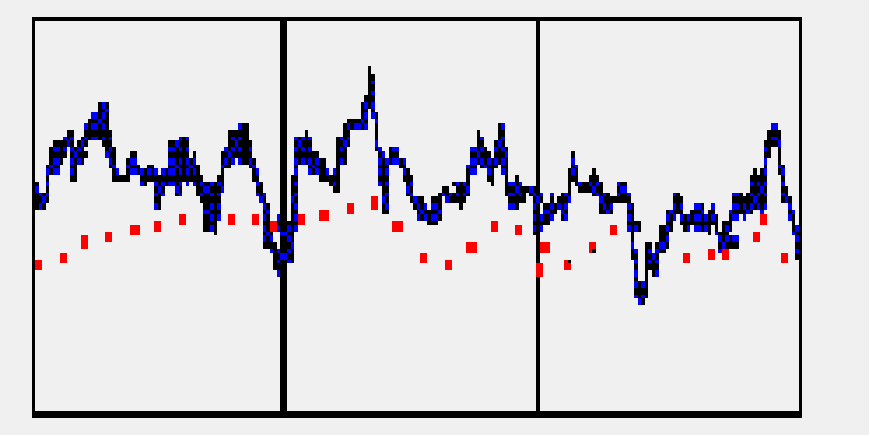


Figure 3. Ethylene cracker on the GC-based control.

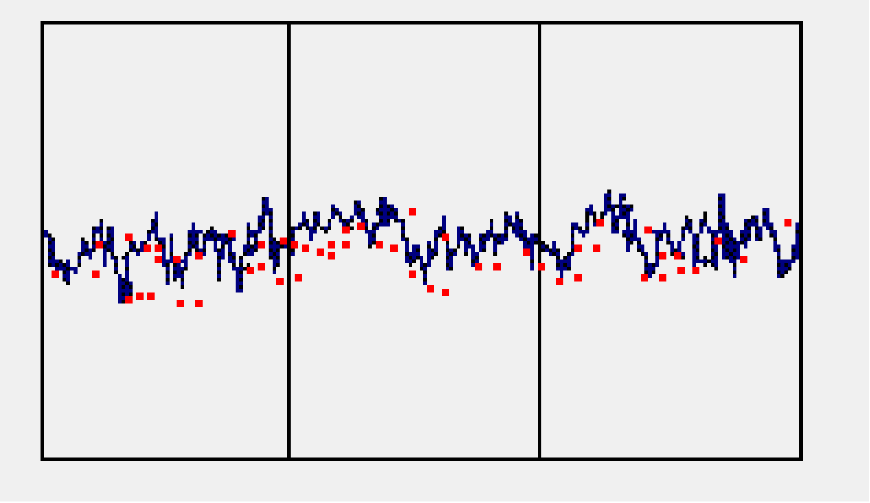


Figure 4. Ethylene cracker on the mass spectrometer-based control.

Figures 3 and 4 show the process variability of the ethylene cracker when the control was based on GC or mass spectrometer analysis data. Red dots are GC analysis results, blue profile is the MS analysis. It can be easily seen that fast mass spectrometer analysis results in reduced process variability. During this study, it has been documented that by the use of the process mass spectrometers, the ethylene conversion could be moved by 2% closer to the optimum point and ethylene production increased by at least 5 %. In this setup, the cracker contained 12 furnaces. If the gas chromatographs were applied, to obtain the analysis results of three minutes, one GC would have to be used for each furnace, or 12 GCs per cracker. Traditionally, one GC is used on 4 to 6 furnaces, with an update time between 10 and 20 minutes. One mass spectrometer provides complete analysis of all 12 furnaces in less than two minutes.

For an average ethylene plant production size of 500,000 t/y, a 5% increase in production equals to about $60,000 per day. If we assume just 10 % profit margin, the return of investment of $150,000 for the mass spectrometry system is achieved in just 25 days.

The benefits on ammonia plant

Ammonia producers have proved that a very fast and automatic process control will lead to better production efficiency. Basic ammonia production stages require unique control techniques. These techniques will work optimally when fast analysis results are available, thus enabling the control computer to respond to the process changes accordingly to the process dynamics. Faster response allows for smaller process swings and tighter control on the target parameter.

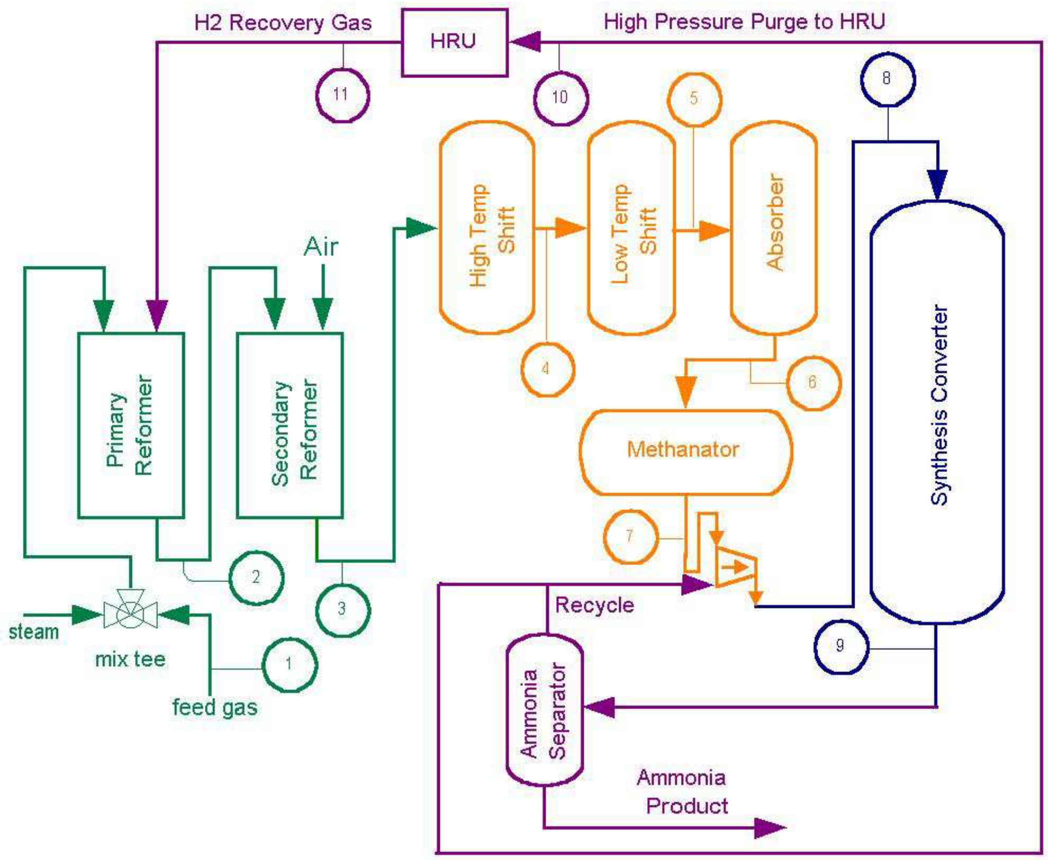


Figure 5. Ammonia plant layout.

In comparison to ethylene crackers, ammonia plant is more complex. The plant is modular, each of the modules being a separate center of control and optimization. However, the performance of one sector affects the other. For example, the analysis of hydrogen to nitrogen ratio in the Methanator exit stream affects the rate of air compression and injection to the Secondary Reformer.

The control parameters for the plant are:

Steam to carbon ratio in the Primary Reformer
Methane slippage in Secondary Reformer
Hydrogen to nitrogen ratio in the Methanator exit
Hydrogen to nitrogen ratio in the Converter inlet
Purge gas composition

All the above parameters influence plant performance. Plant control objectives are:

Maximize ammonia production
Minimize energy consumption
Minimize waste by controlling Purge Gas
Extend equipment life by running steady operation

- Steam to carbon ratio in the Primary Reformer

Here the mass spectrometer allows for optimization of energy consumption and also allows for smoother operation of compressors. This leads to energy savings and prolonged lifetime of equipment. One of the Extrel mass spectrometer users indicated, that the introduction of the mass spectrometer together with the process control software resulted in the energy savings of 0.6 GJ per ton of ammonia.

- Methane slippage in the Secondary Reformer

The concentration of methane out of the secondary Reformer should be approximately 0.3 % vol. This level assures optimum conversion of feed gas to the syntheses gas, e.g. a mixture of hydrogen and nitrogen. The repeatability of methane measurement determines the quality and efficiency of the reformers operation. The mass spectrometer's repeatability of methane analysis is as good as +/- 20 PPM vol.

- Hydrogen to nitrogen ratio out of the Methanator

The material balance relies heavily on the quality of the hydrogen to nitrogen ratio. The stoichiometric ratio of three to one is required. Any slight deviation from this number results in a loss of material. The mass spectrometer will provide the analysis results of the ratio of 3 with +/- 0.01 repeatability. One of the users reported: in his 1,350 and 1,650 t/day plants, transition from a gas chromatograph to a mass spectrometer based control resulted in 8 t/day per plant increase of ammonia production. An introduction of computer control of the process gave another 4 t/day of increased production.

- Purge gas recovery

The inert gases (argon, helium, and methane) circulate in the synthesis loop and their concentration increases in time. Periodical venting of the recycle stream is needed to keep inert gases at low level. Significant amounts of process gas are lost here. The application of fast results from the mass spectrometer allows optimizing the purge process. One of the users told us that optimization of purge gas recovery unit resulted in savings of $100,000 to $120,000 per year.

- Ammonia converter loop control

Monitoring of hydrogen to nitrogen ratio combined with precise analysis of all other compounds in the sample allows for energy optimization of the ammonia converter. This analysis provides full composition of converter inlet, outlet and recycle streams. The speed of analysis offers the opportunity to save large amounts of money in terms of lowering energy use per ton of ammonia or maximizing ammonia output while keeping energy consumption under control.

Another user told us that the use of mass spectrometer as opposed to gas chromatograph reduced process variation from +/- 25 t/d to 1 to 2 t/day on the day-to-day basis. Overall savings of using the mass spectrometer combined with the Optimizer program resulted in the savings of $330,000 per year.

These savings are attributed to lower energy consumption, better process gas inventory, smoother operation and prolonged equipment and catalyst life.

Benefits on ethylene oxide

Ethylene oxide is produced in the reaction between ethylene and oxygen over a catalyst. The reaction is exothermic and the heat must be removed efficiently. The Ethylene Oxide yield increases with temperature. Therefore, to maximize production, the catalyst activity is maintained at such a level to maximize EO production but not to reach the dangerous condition of catalyst bed overheating. A continuous injection of a chlorinated hydrocarbon, like 1,2-dichloroethane, as an inhibitor allows controlling catalyst activity. In order to maximize production of EO, a very fast analysis of the inlet and outlet streams is necessary. The results are used to calculate several process parameters, like oxygen and carbon balances, ethylene conversion, and efficiency. These parameters need to be maintained at a very narrow range. Fast and precise analyses of reactor inlet and outlet are used by the control system in fully automated operation of the series of reactors. At the same time the analysis of chlorinated hydrocarbons in the inlet stream allows for control of the chloride injection rate to keep the catalyst efficiency at maximum but safe level. A typical analysis involves up to eight compounds at % level and a minimum of three chlorinated hydrocarbons at low PPM level. All these analyses are performed by the Extrel MAX300-IG Quadrupole Process Mass Spectrometer in a matter of seconds. A typical analysis time is 400 milliseconds per compound and a total analysis cycle, including sample switching time is less than 10 seconds per stream. The analysis of one inlet stream, three reactor outlet streams and CO2 absorption column overhead is typically accomplished in less than one minute. Extrel is a leader in Ethylene Oxide reactor control applications with numerous installations delivered to the clients worldwide since over 20 years.

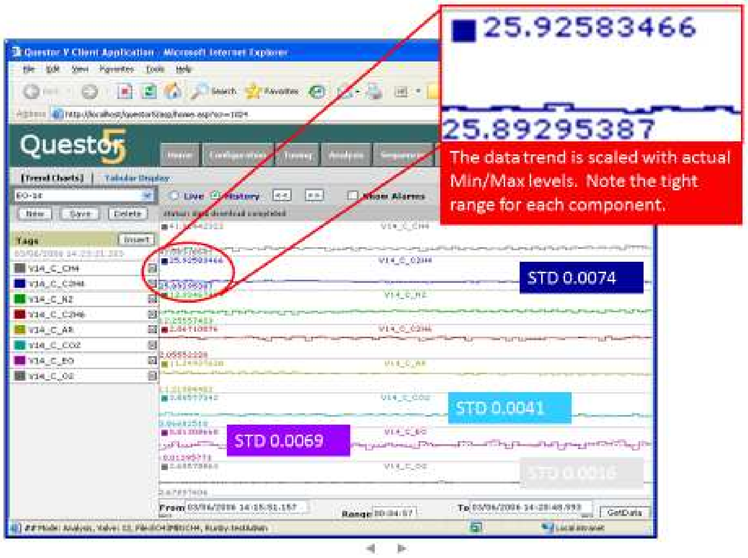


Figure 6. Reactor inlet process trending data

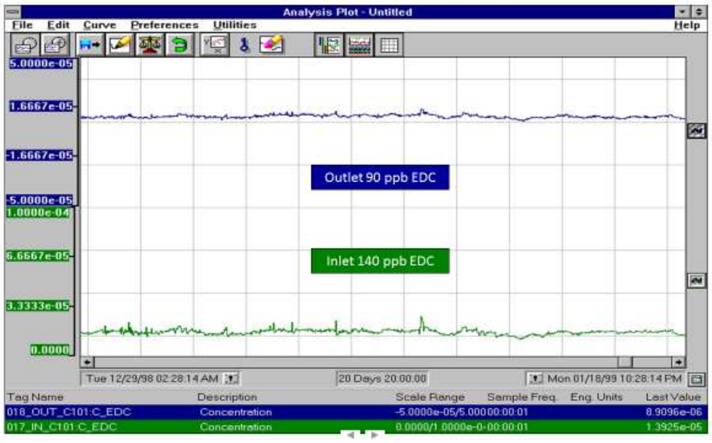


Figure 7. Analysis of chlorides (EDC) at reactor inlet and outlet over a 20 day period

Regulatory compliance in flare gas monitoring

With the increased awareness of the health effects some chemicals can cause to humans and animal world, there is an ever increasing need for an analysis of the atmosphere around a chemical plant. Vinyl Chloride plants, BTX plants, Ethylene plants are rapidly installing fence line monitoring systems in order to comply with government regulations as well to protect their own workers and neighbors. The spectrum of compounds measured is very wide, depending on what is produced on site. VCM plants need to monitor Vinyl Chloride, 1,2-Dichloroethane and other chlorinated hydrocarbons. BTX plants need to monitor Benzene, Toluene, Xylenes and other chemicals. The compounds like acrylonitrile, Propylene Oxide, Styrene, Chlorine, Phosgene, HCL are only a small example of tens of other chemicals being monitored. Extrel quadrupole process mass spectrometer, due to its excellent low detection limit of 10 PPB and below, became an analyzer of choice in the industry worldwide. With the analysis cycle less than 10 seconds per sample, Extrel process mass spectrometer is capable of analyzing 80 sample points in 15 minutes, which became an expected standard in the industry. To achieve this cycle time with other technologies, quite a number of analyzers would have to be used, making the project uneconomical. Extrel has over 70 ambient air installations worldwide with some units in operation for over 15 years.

MAX300-AIR Low Detection Limit (LDL) Examples

Compound	Standard LDL	Membrane Inlet LDL
Benzene	10 ppb	**10 ppt**
Pyrrole	10 ppb	**10 ppt**
VCM	20 ppb	**2 ppb**

Figure 8: Detection limit for MAX300-AIR

Regulatory compliance in flare gas monitoring

According to new requirements in the General Provisions, flares used as Air Pollution Control Devices (APCD) are expected to achieve 98% Hazardous Air Pollutant (HAP) destruction efficiencies. These updated requirements include monitoring of the pilot flame, visible emissions, flare tip velocity, net heating values, and dilution parameters, as well as maintaining a Flare Management Plan and a ContinuousParameter MonitoringSystemPlan. The Net Heating Value of the gas in the Combustion Zone (NHVcz) is of particular importance as it has a direct impact on combustion efficiency. As a result, the RSR update mandates a NHVcz ≥ 270 Btu/scf, based on a 15 minute block average, when regulated material is sent to the flare for at least 15 minutes. For flares actively receiving perimeter assist air, NHV_{dil} must be greater than or equal to 22 Btu/ft2, when regulated material is sent to the flare. To meet this requirement, continuous direct measurements of refinery vent gas must be made. High variability, sulfur content, and corrosivity can make these samples difficult for many analytical techniques.

The MAX300-RTG, real-time gas analyzer, is currently used at many US refineries for NSPS Subpart Ja sulfur monitoring. The analyzer measures the full, speciated composition of the flare gas and delivers continuous updates of NHV, H2S, and Total Sulfur several times per minute (Fig. 1). Rapid updates of NHV are critical for compliance because the refinery must be able to both monitor and control the gases at the flare tip within the regulated 15 minute block. The additional information provided by full speciation can be used at RSR sites for Ja sulfur compliance, validating or replacing existing sulfur analyzers, as well as for operational control and accurate root cause analysis.

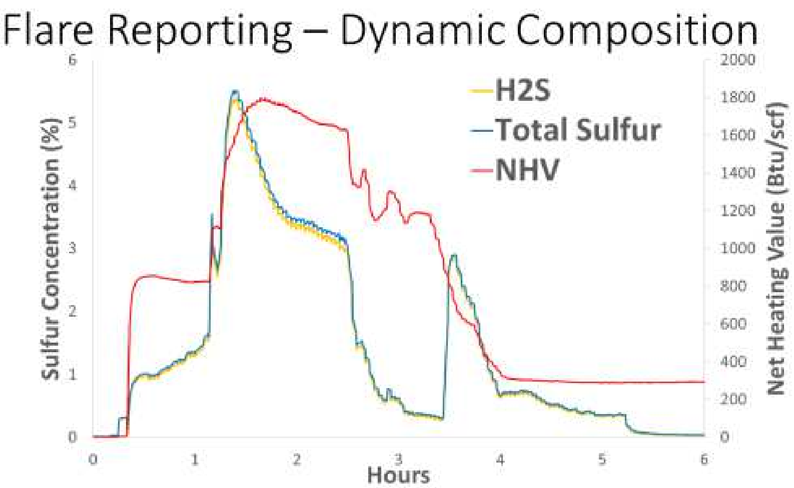


Figure 9. Net Heating Value and Sulfur in refinery flare gas reported by the MAX300-RTG. These data were recorded during a high-sulfur event and calculated from a fully speciated analysis consisting of 31 individual components. Total composition analysis time is <20 seconds.

The MAX300-RTG measures the total composition of flare gas and is currently employed at refineries across the US reporting NHVvg, H2S and Total Sulfur for compliance with Refinery Sector Rule (RSR) regulations, 40 CFR 60 and 63. To meet the most recent updates to RSR, a vent gas monitor must be able to measure NHVvg in a highly dynamic sample stream that may contain high-level H2S and, in some cases, HF acid. Many calorimeters do not perform well under these sample extremes and, without a speciated hydrogen measurement, they will require the integration of a separate, external hydrogen analyzer. The MAX300-RTG always measures speciated hydrogen, ensuring that NHVvg is reported accurately using the 1212 Btu/scf value specified in the regulation.

In addition to monitoring, refineries will need to control the gas composition at the flare tip. When regulated material is vented, NHVcz can change rapidly but must be kept above 270 Btu/scf for each 15 minute block, according to the rule. Slow analytical techniques will not update fast enough for reliable control, increasing the risk of violation and wasting supplemental gas and steam. The MAX300-RTG has the speed necessary to update the NHVcv parameter several times per minute, giving the refinery real-time information for effective flare control.

The additional information provided by the MAX300-RTG's speciated, total composition analysis is available for use by refinery operations or, in the event of a reportable noncompliance, to help make root cause analysis easy and accurate. Sites with existing flare gas sulfur analyzers can use the H2S and Total Sulfur values from the mass spectrometer as a backup, or replacement, for those systems. For Ja compliance monitoring, the linearity of the MAX300-RTG ensures accuracy from <1 ppm to 100%, prompting EPA approval of low-sulfur validations that significantly increase the safety, and reduce the cost, of flare gas compliance.

Other applications

Other applications, which fall in the same category from the return of investment point of view are polyethylene, polypropylene, methanol, propane dehydrogenator. They all benefit from fast analysis, resulting in more production, lower energy consumption and increased profit.

Cost of ownership

Analyzer	Cost of Ownership	Typical number of streams	Cost per stream	Typical number of compounds	Cost per compound	Cost per stream per compound
Mass Spectrometer	16,545	8	2,068	6	2,758	345
FTIR	20,481	1	20,481	6	3,414	3,414

Filter Infra-red	**15,246**	**1**	**15,246**	**3**	**5,082**	**5,082**
GC-Intermediate difficulty-FID	**20,892**	**3**	**20,892**	**5**	**4,178**	**1,393**
GC-Low difficulty-TC	**12,666**	**3**	**12,666**	**3**	**4,222**	**1,407**

Figure 10. Comparison of cost of ownership.

Figure 10 shows the comparison in cost of ownership based on 15 years life of the instrument. The cost contains all items, like initial purchase cost, sampling system, commissioning, training, utilities, tech support and de-commissioning. The information is based on 1995 Dollars. While the mass spectrometer is a fast and flexible analyzer, it can analyze several streams and several compounds in each stream. This way, the cost of ownership per stream and per analyzed compound is greatly lower than of any other type of analyzer.

It is a wide spread opinion in process analytical world that mass spectrometers are expensive and difficult to use. This opinion, however, is not shared by those, who actually use the mass spectrometers for their routine analyses. During over 30 years presence in process mass spectrometry business, Extrel developed seven generations of analyzers, each one improved from the use and maintenance point of view. The replacement of a consumable part is reduced to a plug-in function. The downtime associated with a repair or routine maintenance is reduced to just a few hours.

So, what is the mass spectrometer?

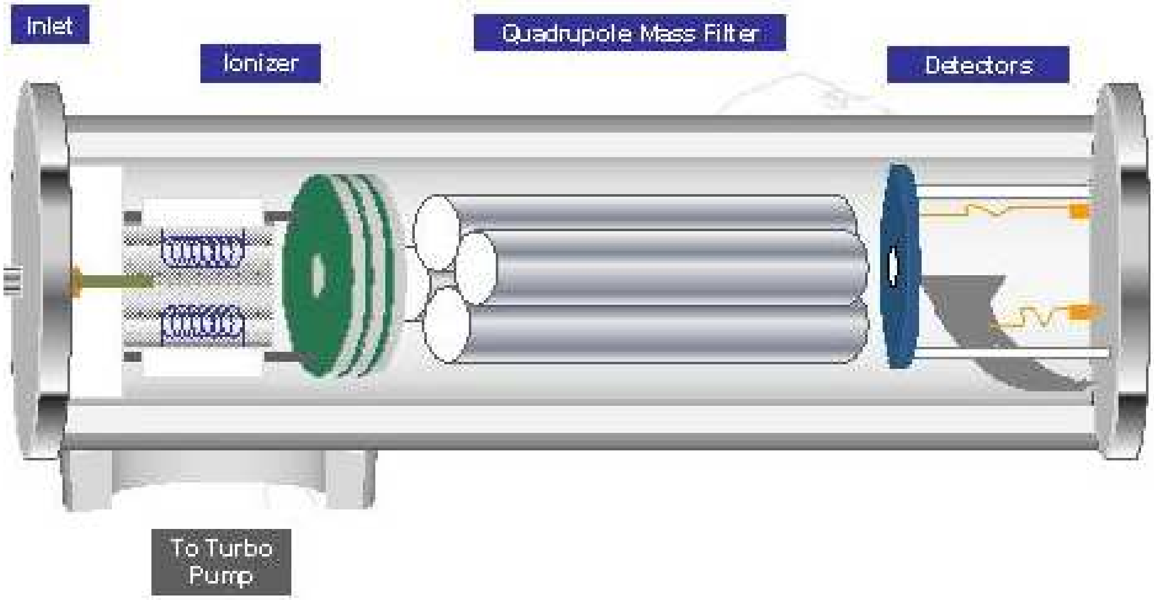


Figure 11. Quadrupole mass spectrometer components.

Mass spectrometry is an analytical technique, where the gas mixture of compounds is being analyzed with the use of separation principle of the mass filter. To accomplish the analysis, molecules of compounds are ionized to produce unique ions for each compound. These ions then pass along the rods of a quadrupole mass filter, where they are separated and sent to the detector, each at a time. This way, a representative signal for each compound can be amplified and digitized with the use of a specific ion detector, called Faraday Cup. After ion intensities are acquired, incorporation of the calibration table leads to the resulting full stream composition. See Fig. 11.

Ion Source

Ions are introduced to the mass spectrometer via a capillary leak, which simply serves as a flow restrictor. Molecules of sample enter an ionization chamber, where they are ionized by a beam of electrons at control energy.

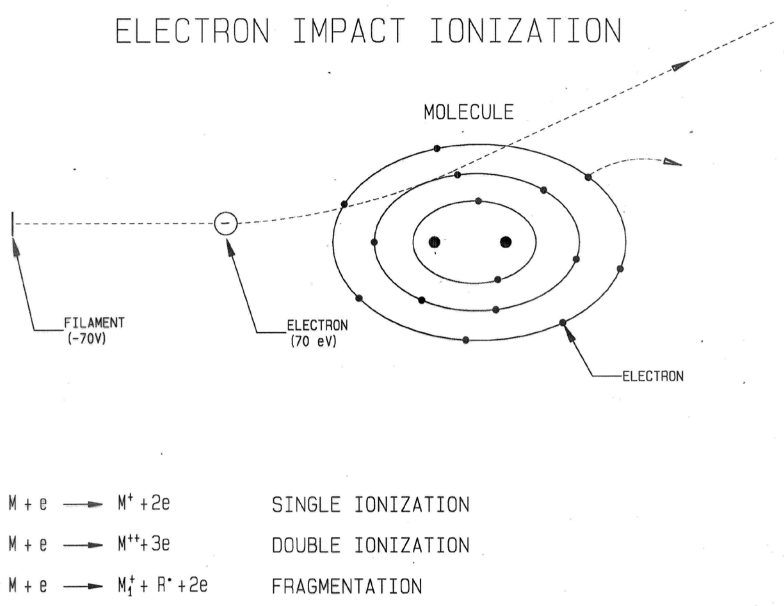
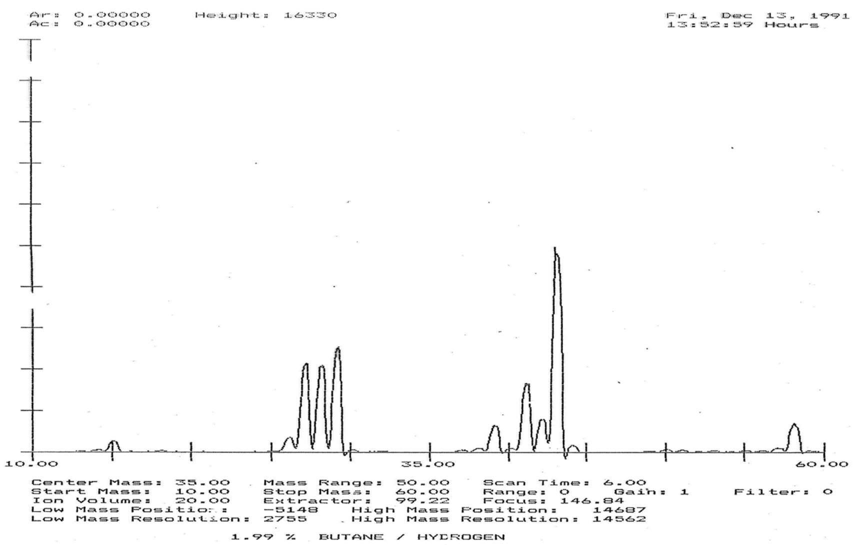


Figure 12. Electron Impact ionization.

Ionization of molecules of one chemical results in several different ions. They form a fragmentation pattern, characteristic for each compound. By comparing these patterns, called mass spectrum, a mass spectrometrist can recognize the original chemical.



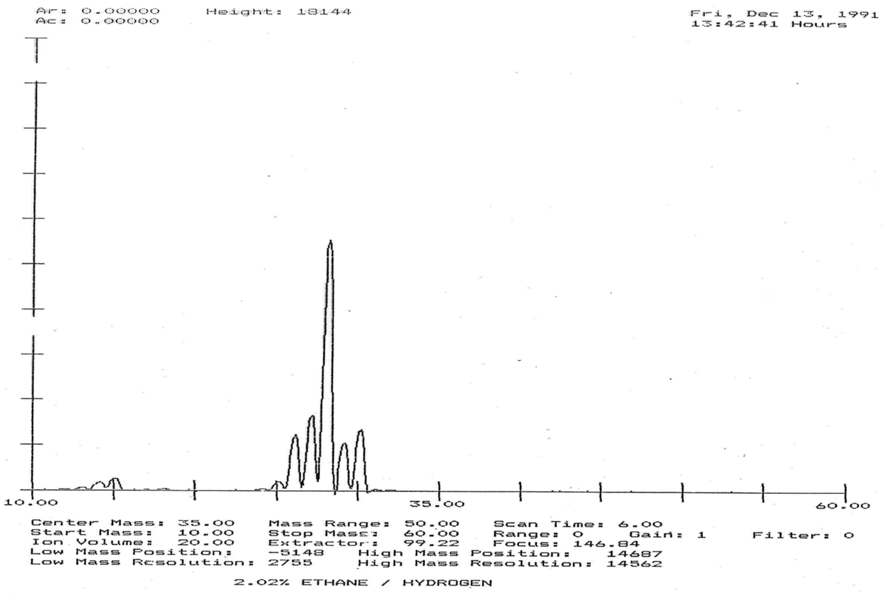


Figure 13. Mass spectra of n-butane and ethane.

After ions are formed, they are extracted from the ion source and sent to the quadrupole mass filter.

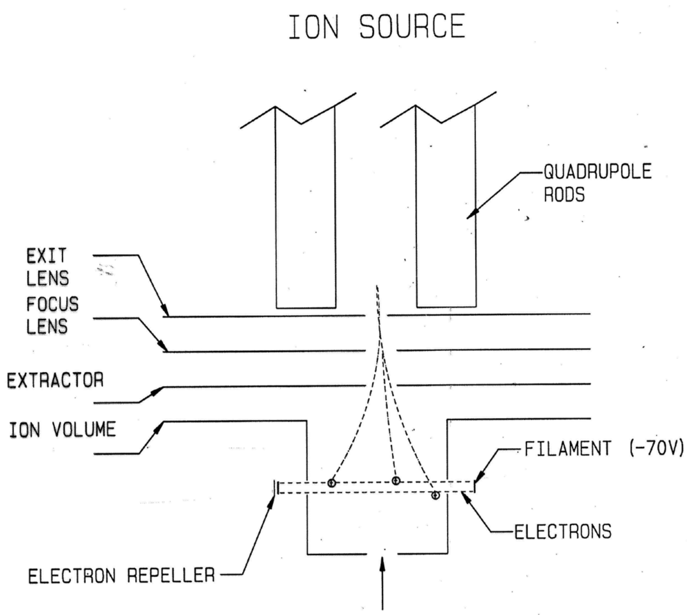


Figure 14. Extraction of ions.

Quadrupole mass filter.

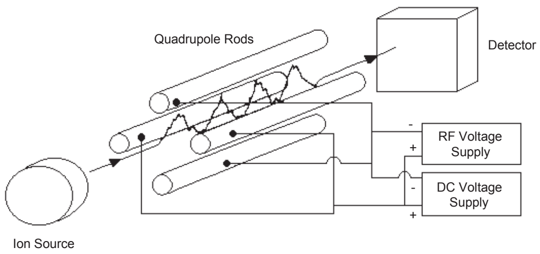


Figure 15. Separation of ions by the quadrupole mass filter.

Four rods of the quadrupole mass filter are supplied with the combination of DC and RF voltages of high frequency and amplitude. The ion, which travel in the space between rods, are subjected to the electrostatic forces with changing polarity. As a result, they vibrate in the direction perpendicular to the rods. Different mass-to-charge ratio ions respond differently to the electrostatic forces. Some ions will have so called "unstable" trajectory and will be rejected (separated out) by the filter. Some ions will have "stable" trajectory and will pass the along the rods without collision and eventually enter the ion detector. By adjusting the amplitude of the RF and DC voltages, the mass spectrometer can send a desired mass-to-charge ration ion beam to the detector and measure its intensity.
The current from the detector is proportional to the ion beam intensity and, in turn, proportional to the concentration of a given compound in the mixture.

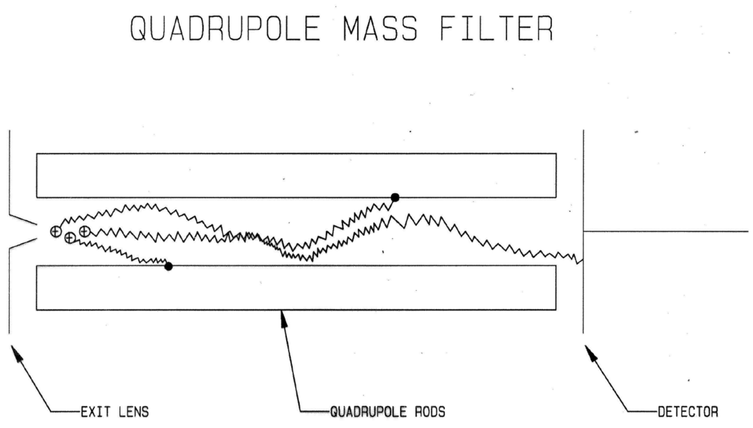


Figure 16. Mechanism of ion separation.

Conclusion.

The entire ionization, separation and detection process takes only about 400 milliseconds per compound. Thus the total analysis time of a multi-compound mixture is as low as a few seconds. Such a short analysis time makes mass spectrometry a very useful tool for multi-compound and multi-stream applications, where the speed of analysis is essential for the quality control of the chemical process. It can typically replace more than three process gas chromatographs and, especially on multi-stream applications, several different analytical technologies. Therefore it is always less expensive from initial investment point view. Additionally, the cost of ownership over 10 to 15 years life is lower than other analyzers due to lower cost of utilities, which offsets the higher initial investment cost.

Jian Wei, Ph.D.

Jian Wei is currently Asia Sales Manager for Extrel CMS LLC.He received his BS degree from University of Science and Technology of China in 1981 in Chemistry and his Ph.D. from the University of Maryland in 1992 in Physical Chemistry.

After graduation he has worked for a number of laboratory and process analytical instrument companies holding senior position in application, product development, and salesmanagement. He has presented at numerous technical meets globally, and is the author of many research papers and technical publications.

His experience spans from catalyst and surface characterization, and mass spectrometry in scientific research to process applications of mass spectrometer systems.

His current focus is on business development and global distribution for Extrel Mass Spectrometer. For the past 52 years Extrel has providedquadrupole mass spectrometer components, flanged probes systems, laboratory QC/QA and Process systems for the research and industrial markets globally. He can contacted jian.wei@extrel.com, mobile: +1-412-215-3674

Brijesh Singh Chowdhary

Brijesh Singh Chowdhary is co-founder & co-owner of “Spectrum Automation & Controls”, a specialty analytical company. He received his BE degree from Thapar University in 1990 in Electronics Instrumentation & Controls &MBA in Financial Management from Indira Gandhi National Open University. He has rich experience inonline process analytical systems, with specialisation in process gas chromatography &calorimetry. He has participated in several technical meets on the subject. His interests include business development, operations management, technical collaborations, project execution and guidance todesign engineering. Besides Mass Spectrometer Systems, his company deals in System Integration, Gas Analyser Systems (Process analysers, CEMS, Purity gas analysis), Dew Point Meters, Moisture analysers, Wobbe Index analysers, BTU Gas Chromatographs, Optical Flare Gas Flowmeters, ConaxSealing Glands &Special Temp measurement products (bearing temp sensorsfor turbines etc.). The company provides complete solutions including supply of analytical equipment, sample handling systems, start-ups, after sales support, training, AMCs, upgrades, retrofits etc.

He can contacted at bs.chowdhary@spectrum-automation.com , mobile: 98688-43828

Mukesh Arora

Mukesh Arora is co-founder & co-owner of “Spectrum Automation & Controls”, a specialty analytical company. He received his BE degree from Thapar University in 1992 in Electronics Instrumentation & Controls & post graduation in Financial Management from Indira Gandhi National Open University. He has rich experience inonline process analytical systems, with specialisation in process mass spectrometry(& Ammonia process control as the main application). He has participated in several technical meets on the subject. His interests include business development, operations management, technical collaborations, project execution and guidance todesign engineering. Besides Mass Spectrometer Systems, his company deals in System Integration, Gas Analyser Systems (Process analysers, CEMS, Purity gas analysis), Dew Point Meters, Moisture analysers, Wobbe Index analysers, BTU Gas Chromatographs, Optical Flare Gas Flowmeters, ConaxSealing Glands &Special Temp measurement products (bearing temp sensorsfor turbines etc.). The company provides complete solutions including supply of analytical equipment, sample handling systems, start-ups, after sales support, training, AMCs, upgrades, retrofits etc.

He can contacted at mukesh.arora@spectrum-automation.com , mobile: 98714-27476

CENTRALIZED SCADA SYSTEM FOR COMPLETE UTILITY MONITORING OF PLANT

Sachin Bhavsar, Himanshu Desai
SSM InfoTech Solutions Pvt. Ltd., Surat

ABSTRACT

Centralized monitoring systems can increases visibility of all current utilities of your plant and you can achieve best possible lowest cost. Monitoring is in your integrated control room itself for Power, Gas, Steam and Water distribution. We can optimize the cost of Natural Gas, can optimize power credit from wind mills and can be future ready for power trading. In this paper centralized SCADA with utility solution is discussed which is implemented at GSFC Ltd – Vadodara by SSM InfoTech.

INTRODUCTION

Central SCADA system should provide the reliable monitoring of live data of steam, power, NG and water utilities over the whole enterprise level to various stack holders with secure access to data through web, reports and email functionality.

System should provide the mean to centralized required data and provide the insight in usage of various utilities and balance of parameters.

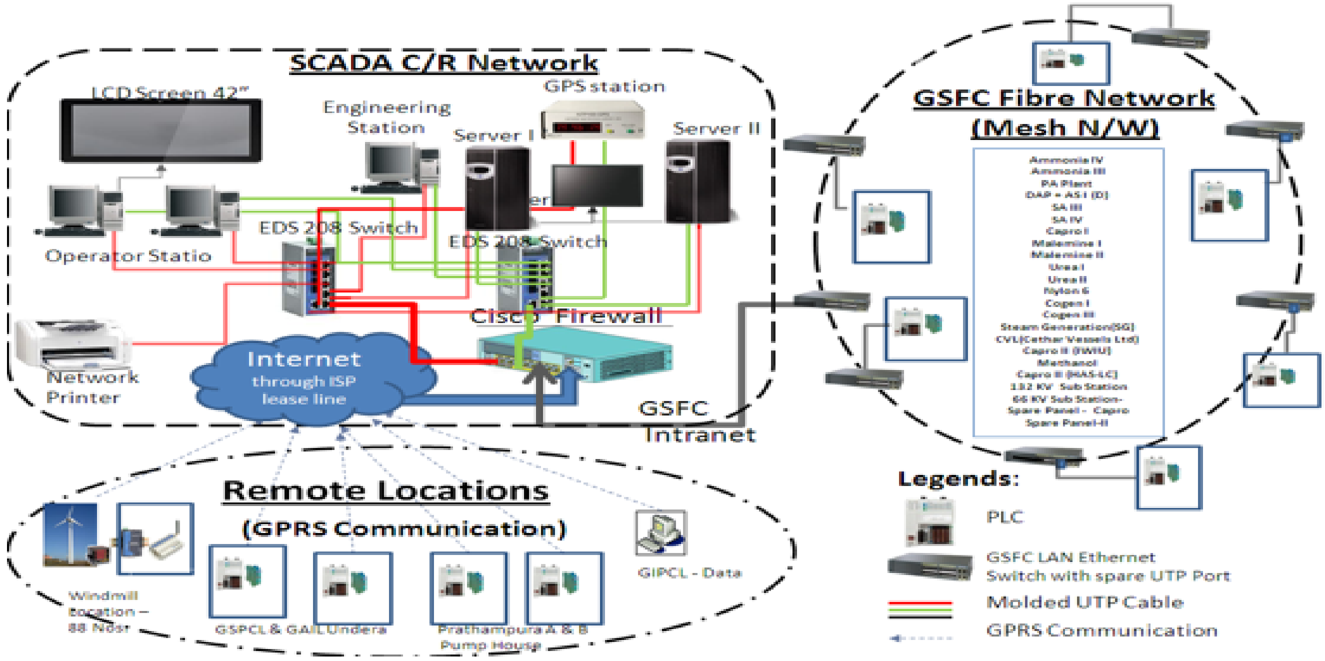
TYPICAL ARCHITECTURE OF CENTRALIZED UTILITY MONITORING SYSTEM

We proposed to install X-Force Plant Information Management System to achieve the required functionality. It will provide seamless data display and other required features. This system have features like trending of all utility parameters and live screen layouts.

It has been proposed to install two servers in redundant configuration at central control room with one operator station with big 42” screen monitor and one engineering station. Existing EMS system will be directly integrated with central SCADA servers to provide better reliability and features
Windmills will be integrated with the system using GPRS communication. Each wind mill have secure make Energy Meter with communication port available. We propose to install a converter which convert data from RS485 and provides it to GPRS modem.

GPRS modem connects with GSFC network through real IP base high speed internet at data logger system. All plant parameters provided as 4-20 mA signals will be connected to PLC. PLC will provide better accuracy in integration and can store the data in case of main server is disconnected due to any reason.

Distributed with the permission of authors by ISA-D [2018]
Presented at [ISA-D: Petroleum & Power Automation Meet-2018]; http://www.isadelhi.org



Power Systems: For meeting power requirement, Windmill generation is first utilized. (Which needs to be monitored as well).

Electrical department have installed energy management system (EMS) for on-line monitoring of actual power consumption at main sub-station. Moreover, monitoring of status of 12 nos. 66 & 132 KV Line circuit breakers (ON / OFF & Trip indications) is required in the proposed control room. System should integrate existing energy meters connected with existing EMS system.

Total 72 Energy meters are required to communicate. This includes captive power generation, MGVCL incomers and consumption inside the plant area. Energy generation monitoring of 88 windmills located at different sites and maintained by Suzlon.

Steam Flow: Total steam generation of @ 180 MTPH in the complex through Co-generation and WHBs in process plants is utilized in different plants/locations in the complex.

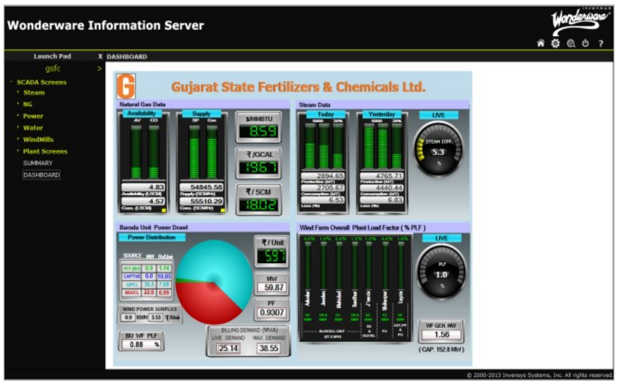
Any change in the consumption pattern shall be noticed at SCADA control room for corrective measures / avoiding loss of energy / proper accounting of the steam energy.

Monitoring and history of various steam flow meters. 4-20 mA signal will be provided for instantaneous flow.

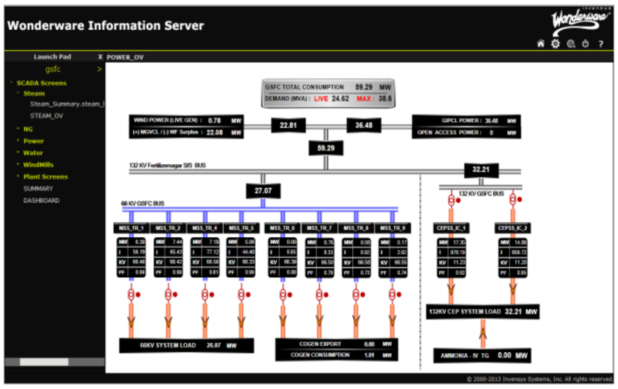
Natural Gas Flow: GAIL natural gas (HP- 40k & LP- 4K) receipt is through two NG Lines and RIL gas is received through GSPL line at 40K pressure.

The natural gas is utilized at about 10-12 different locations in the complex. We can monitor and histories of various NG flows parameters. Temperature compensated 4-20 mA signal will be provided for instantaneous flow reading from DCS.

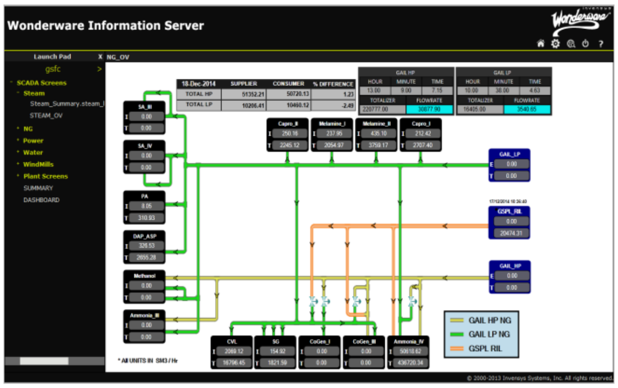
It is required to integrate and generate total consumption with best possible accuracy.



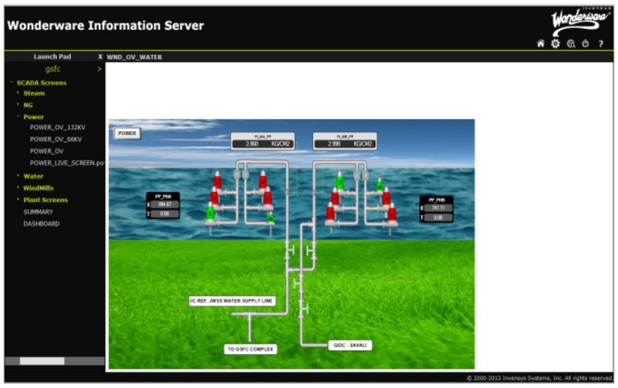
Centralized Dashboards - Wonderware



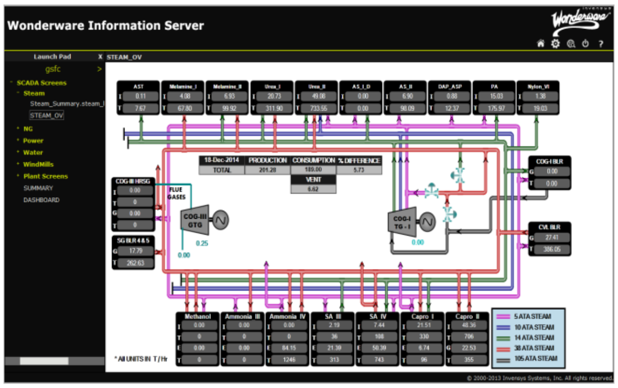
Dashboard – Power Overview



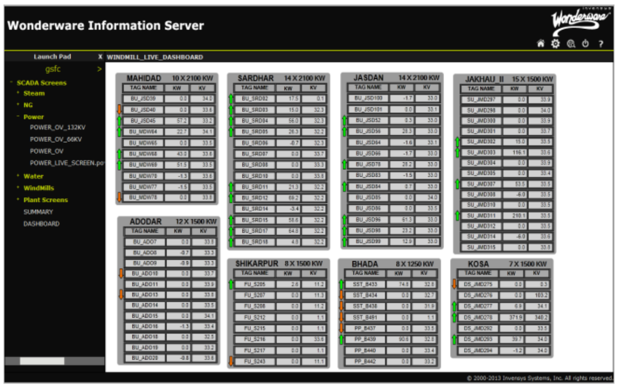
Dashboard - Natural Gas Overview



Dashboard – Water Overview



Dashboard – Steam Overview



Dashboard – Wind Mills Overview

Dashboard Advantages:
Decision making will be on a Real Time basis so process failures can be identified and addressed more proactively/promptly.

It helps to achieve Plant Economics with controlled energy balance on a Macro Level/ Cross functional parameters.

Benefit of Enterprise level monitoring systems:
Inter plant operations are enhanced due to Centralized Monitoring with Greater Speed, Accuracy, Efficiency and Reliability.

It helps to keep track of Contractual obligations and penalty (Overdraw & Under draw) by monitoring the Supply and demand.

ENERGY EFFICIENCY IMPROVEMENTS VIA COMBUSTION CONTROL FOR FIRED HEATERS

Ng Inn Hoe, Bryan
Emerson Automation Solutions, Singapore

ABSTRACT

The Fired Heaters are devices used for high-temperature heating eg. used in boiler applications to produce steam, to provide heat for chemical reactions such as ethylene cracking, and as the heat source for fractionation or distillation columns. In this paper, challenges associated with safe, efficient, and regulatory compliant of fired heater operation are discussed. In addition, the details on control scheme options and a net present value study to evaluate various methods of fuel gas control for natural draft fired heaters are also provided.

KEYWORDS

Fired Heater, O2, API, Energy, Efficiency, Flue Gas, Gas Composition, Variability, Mass Flow, Coriolis, Specific Gravity Meter, Smart Meter Verification, Control Method, NPV.

CHALLENGES

The biggest challenge for fired heater operations is to keep them safe and at the same time, energy efficient and environmentally friendly/compliant.

The best and most common measure of combustion efficiency is monitoring the percent O2 in the flue gas. High levels of O2 in the flue gas assures an added margin of safe furnace operation, but has negative implications for thermal efficiency and environmental compliance. High levels of flue gas O2 have other implications.

High levels of O2 in the flue gas can lead to increased emissions, and permitting issues. Depending on the burner type, an increase of 2% O2 could cause an increase of 25% - 30% in NOx emissions (see Figure 1, published in API RP 535). "Excess air" (oxygen) is added to assure more thorough combustion. For every molecule of oxygen added, almost 4 molecules of Nitrogen are along for the ride. The large amount of Nitrogen is responsible for the lowering of thermal efficiency and increase in NOx emissions.

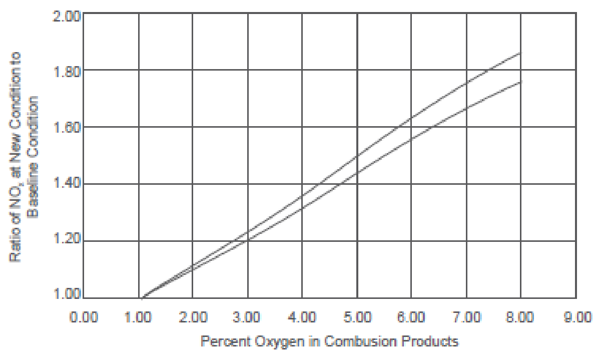


Figure 1: Percent O_2 in flue gas. Note that an increase 2% O_2 could cause an increase of 25%-30% in NO_x emissions

Running high levels of O2 in the flue gas also results in decreased energy efficiency, through heating excess air. Conversely, enabling small reductions — even only 1% — of excess O2 in the flue gas of fired heaters at an average-sized refinery or petrochemical plant can result in operational savings exceeding $1M/year. On the other hand, operating with too low a level of O2 in the flue gas creates the risk of sub-stoichiometric (insufficient oxygen) combustion, possibly tripping the heater, or in the extreme case, causing damage to the heater. Sub-stoichiometric conditions can result when the composition of the fuel feeding the combustion suddenly changes to a richer fuel that is higher in heating value, requiring more oxygen. If this could be anticipated (ie, feed-forward control), much of this challenge could be eliminated. Reducing variability of the O2 in the flue gas is the primary means of being able to lower the target O2 setpoint and achieve the desired balance for safe, efficient, and environmentally friendly operation.

In the traditional approach, the process outlet temperature controller and/or the %O2 trim controller give feedback to the flow controller. These are lagging indicators. A cascade control loop is implemented using either pressure or volumetric flow of the fuel gas. This method of control can lead to problematic operation when there are rapid changes in the fuel composition.

The Solution

The root cause of heating value variability, leading to variability in %O2 in the flue gas, is the fact that the gross heating value of fuel gas and natural gas changes during operation since the components can change. The table below, which is published in API RP 538, Industrial Fired Boilers for General Refinery and Petrochemical Service, shows the gross heating values, on a mass basis vs. a volumetric basis, for components normally found in fuel gas and natural gas. The table also shows the percent change from methane (CH4) for all the components.

The table shows that the heating value correlates much more closely to mass flow than volumetric flow. By controlling the set point of fuel gas on a mass flow basis you can more closely control the energy feeding the combustion, and thus the air (oxygen) required. Hydrogen (H2) is the exception to the relatively consistent energy value. On a mass basis, it has twice the energy content of methane. However, H2 is so light compared to the hydrocarbons that it doesn't impact the overall heating value of the gas significantly on an energy/mass basis furthering the case for mass flow measurement.

Compound		Mass Flow Basis			Volumne Flow Basis		
		BTU/lb	KJ/kg	%?from CH_4	BTU/scf	KJ/Nm³	%?from CH_4
Methane	CH_4	23.887	55.561	—	1012	37.706	—
Ethane	C_2H_6	22.323	51.923	-7%	1772	66.023	75%
Propane	C_3H_8	21.669	50.402	-9%	2522	93.967	149%
I-Butane	C_4H_{10}	21.186	49.279	-11%	3251	121.129	221%
n-Butane	C_4H_{10}	21.313	49.574	-11%	3270	121.837	223%
I-Pentane	C_5H_{12}	21.064	48.995	-12%	4012	149.483	297%
n-Pentane	C_5H_{12}	21.105	49.090	-12%	4020	149.781	297%
(n)Hexane+	C_6H_{14}	20.804	48.390	-13%	4733	176.347	368%
Hydrogen	H_2	51.900	120.719	117%	273	10.172	-73%

A simple flow schematic for a natural draft fired heater, using Coriolis for the flow control, is shown in Figure 2.

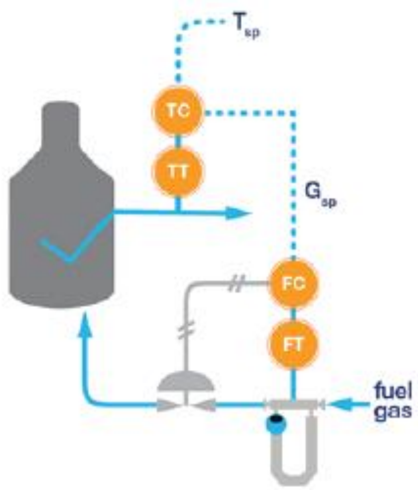


Figure 2. Flow schematic for a natural draft fired heater, using Coriolis for the flow control.

Variability in inerts (non-combustibles) is the one condition that this control scheme cannot compensate for. Because they have a high molecular weight, but have no heating value, an analyzer for non-combustibles should be added to the control scheme. Another option for enhancing this control scheme is to add a specific gravity analyzer on the fuel or natural gas. The relationship between the specific gravity of natural gas and its energy content is well established by AGA-5 in the following equation.

Heating Value (BTU/SCF) = 1150.1 (S.G) + 143.77 – (%CO2 x 25.38) – (%N2 x 16.639)

For fuel gas (RFG), the energy content cannot be defined in a general sense, but data can be collected for each site to establish and validate the relationship between the RFG and the specific gravity of the gas. Combining the mass flow measurement from the Coriolis meter with the energy content of the gas allows you to control the energy for combustion and the heat release at the burner.

Operational Benefits

There are regulatory compliance benefits, in addition to the safety and efficiency benefits, to improving combustion control using Coriolis with Specific Gravity Meters with proper design and configuration on the fuel. The fuel that is consumed in combustion operations has to be reported to governing environmental regulatory agencies. The meters controlling that process have requirements for accuracy and calibration or verification frequency.

The necessity to calibrate sensors, transmitters or pull orifice plates or other primary elements to verify measurement accuracy is eliminated with Coriolis meter that has Smart Meter verification (SMV) technology. Most regulatory agencies and governing bodies recognize recommended practice to verify accuracy. Simply running SMV while the meters are fully functional during normal operations meets the requirement.

To sum up, the benefits of the Coriolis with Specific Gravity Meters solution for combustion control include:

- Improved fuel-to-air ratio control with changing composition
- Reduced O2 in the flue gas (reduced excess air fed to the combustion process)
- Reduced probability of insufficient air and heater trips
- Ability to select a %O2 setpoint acceptable from a safety, efficiency and environmental perspective
- More accurate and reliable emissions reporting
- Operational cost savings

Economic Benefit Study

A study was performed by members of an API RP556 subcommittee to evaluate various methods of fuel gas control for natural draft fired heaters. The objective was to calculate the net present value (NPV) for each of the following control methods:

- Pressure control
- Pressure corrected flow control
- Temperature, Pressure corrected flow control
- Uncorrected flow control
- Temperature, Pressure, Molecular Weight
- corrected flow control
- Mass flow control
- Mass flow with specific gravity analysis
- BTU control (assumed to be theoretical)

The study looked at the impact of changing fuel gas compositions on the indicated flow and the heat release to the burners under each control scheme.

The goal of the fuel control scheme is to be able to control the potential heat release to the burners. Whatever control method is used, the control valve responds to the actions from the controller to keep the process at its setpoint. For example, if the fired heater uses pressure control, regardless of upstream pressure, temperature, or composition of the fuel gas, the pressure controller will control the pressure. However, the amount of fuel and the potential heat release that it brings with it can change considerably with changing composition and changes to flowing temperature.

The aim of the study was to evaluate rapid changes in the fuel gas header conditions, conditions where the coil outlet temperature controller cannot adjust the fuel quickly enough to avoid an unstable condition in the heater. The study also assumed that the air flow control is manually operated, and the outside operator cannot adjust the air flow quickly enough, so a large step change in the %O2 may occur.

The study has two main parts. The first was evaluating how each control method would perform under changing temperature, pressure, and composition, and how that would impact the %O2 in the flue gas. The second part of the study used the data from the first part to perform an NPV calculation for each control method. For the first part of the study, a Monte Carlo simulation (1,000 simulations per control type) was performed first to calculate a steady state condition, and then to evaluate an after step change condition. For each of the 1,000 simulations, a steady state condition was calculated using the following sequence:

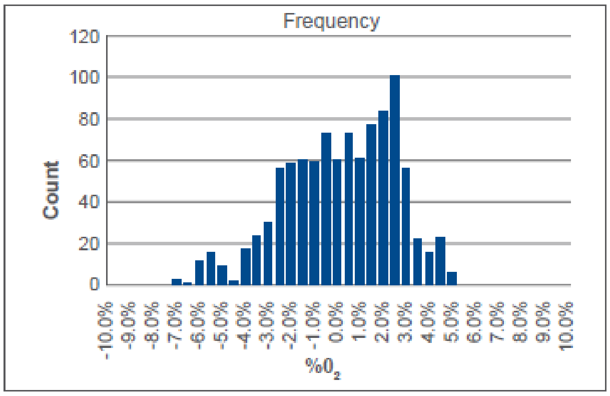
1. Fix the fuel gas pressure at the burner tip
2. Randomly select fuel gas composition case
3. Run burner tip calculation to find the fuel gas mass flow
4. Assume fuel gas temperature and pressure are normally distributed
5. Calculate the reported fuel gas volumetric flow rate
6. Assume a normal distribution in the %O2 about a fixed target, and calculate the air flow rate

Next, a Monte Carlo simulation sequence was performed to calculate an after step change condition and determine the resulting deviation in the %O2 in the flue gas. The simulation steps were:

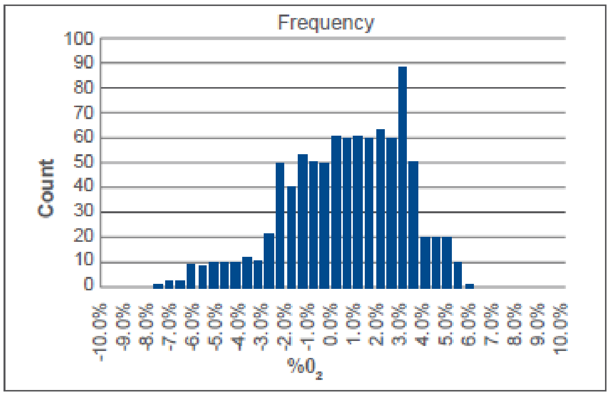
1. Randomly select new fuel gas composition
2. Calculate the fuel flow rate by equalizing one of the steady state conditions (depending on the control type being simulated, i.e. burner pressure, reported volumetric flow, etc.)
3. Using the steady state air flow rate, calculate the %O2 in the flue gas
4. Compare the calculated %O2 with the %O2

from steady state to evaluate the deviation

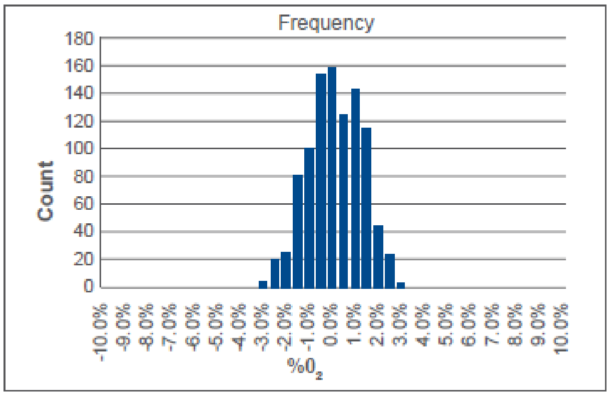
From a histogram of the results for each method of control, the target %O2 was chosen, and used in the second part of the study to calculate the NPV of each control method. The histograms below show example results from several methods of control.



Pressure Control



Volume Flow Control (Orifice dP)



Mass Flow Control

NPV calculation for the study was performed using a decision tree (see Figure 3). This approach to evaluating the NPV associates a cost with the consequence of each action being evaluated. In this case, the costs associated with running in that mode are evaluated.

One of the most important costs to evaluate is the firing cost, which depends upon the heater to be evaluated. For the specific absorbed duty of the heater chosen, the firing cost is calculated for the target O2 from the histogram results, subtracting the firing cost at 0%O2. A cost for the firing rate can then be plugged into the decision tree.

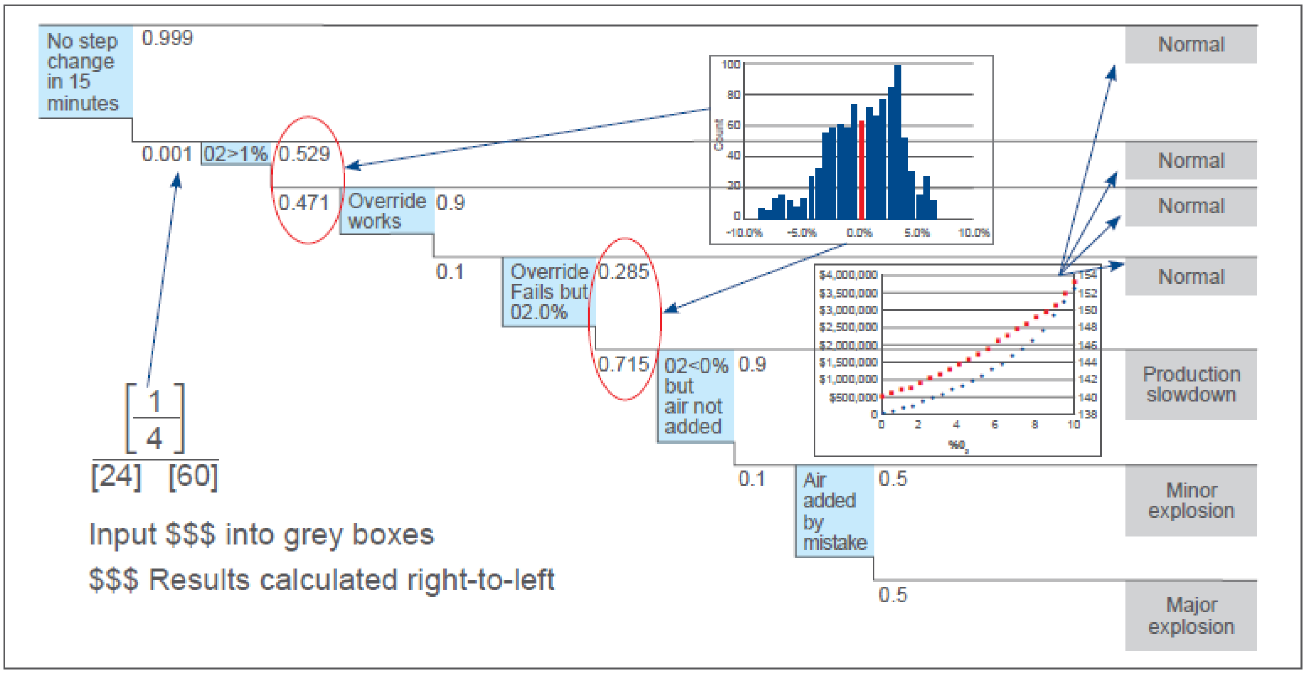
Costs were also assigned to the following events:
a) Safe shutdown
b) Minor explosion
c) Major explosion

Although the chances of having to shut down the heater are rare, and the chances of having a major or minor explosion even rarer still, it is a cost that can be evaluated by multiplying the cost by a very low probability of it occuring.

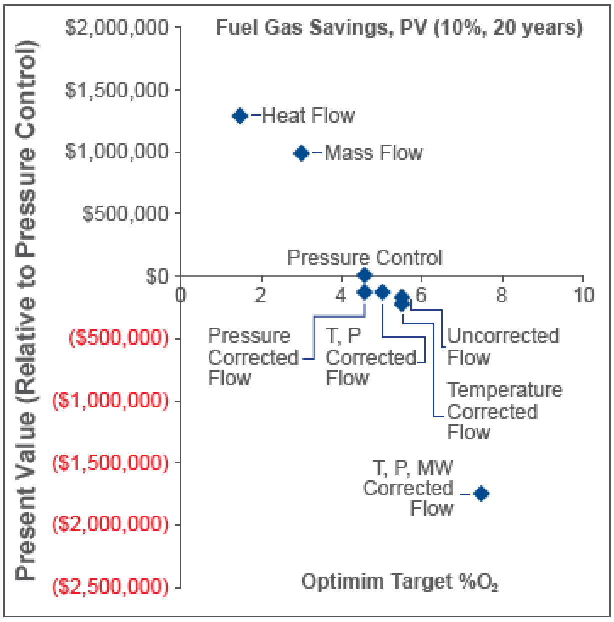
The decision tree is then populated with the following information:

a) Cost data
b) Probability of a fuel gas step change in a 15-minute period
c) A target %O2
d) Monte Carlo simulation results for a specific
e) control type
f) Probability of mitigation steps not working

An example decision tree is shown below. It is important to note that all the information that populates the decision tree can be changed based on experience with the heater under evaluation.



The results of the decision tree for a specific heater evaluated by the API group gave the following results for the various methods of control, seen in the chart below:



The NPV calculation uses a time period of 20 years, with a discount factor of 10%.

Conclusion

The fired heater study showed highly interesting results, and gave compelling reason for an evaluation to be performed for operators of natural draft fired heaters. The study found that controlling the fuel gas using Coriolis mass flow meters with Specific Gravity Meters (with proper design and configuration) had a NPV of approximately $1,000,000, whereas temperature, pressure, or molecular weight corrected volumetric flow showed no benefit over pressure control. The only method of control that had a higher NPV was actual energy flow, but this was assumed to be a theoretical method of control because the response time for most composition analyzers is too slow for control purposes with rapidly changing composition.

The study results were based on data from a specific crude charge heater. Using data from an operator's specific furnace will give the confidence to make decisions about whether to invest in and implement a different method of control for their furnace.

ACRONYMS

API	American Petroleum Institute
RP	Recommended Practice
BTU	British Thermal Unit
SCF	Standard Cubic Foot
S.G	Specific Gravity
RFG	Refinery Fuel Gas
SMV	Smart Meter Verification
NPV	Net Present Value

REFERENCES

AN-00335 : Mass-Based Fuel Measurement with MicroMotion Coriolis Flowmeters Boosts Combustion Control

ACKNOWLEDGEMENTS

Relevant standards, codes and guides of API RP556 (Instrumentation, Control, and Protective Systems for Gas Fired Heaters), API RP535 (Burners for Fired Heaters in General Refinery Services) and API RP583 (Recommended Practice Industrial Fired Boilers for General Refinery and Petrochemical Service) have been used.

BIOGRAPHIES

Bryan Ng has over 12 years of Instrumentation and Control Automation experience mainly in Refining, Petrochemical and Terminal industry. He has joined Emerson in 2012 and is currently the Refining Industry Leader in Asia Pacific for Emerson Flow Group. In this role, he works extensively with oil majors on Operation Certainty programs and solutions in striving towards Top-Quartile Performance achievement. Bryan hold a B.H. degree in Industrial Engineering, MPA (Master in Professional Accounting) and MBA (Master in Business Administration).

Julie Valentine first joined Micro Motion in 1993, and worked as the Refining Industry Marketing Manager for Micro Motion. She has total 25 years with Emerson and is currently the Refining Industry Director for Emerson Flow Group responsible for all of Emerson's flow technologies. Julie is a graduate of the Colorado School of Mines in Golden, Colorado with a B.S. degree in Chemical and Petroleum Refining Engineering. Before joining Emerson, she worked for UOP, primarily in the technical services group, where she was involved in the commissioning, start-up and troubleshooting of UOP process units around the world. Julie is a member of several working committees for the instrumentation and control group of API's Refining and Equipment Standards Program.

"Intelligent Instrument Maintenance and Inventory Management Systems"

Pramod Gupta, Project Controls, Fluor Daniel India Pvt. Ltd.
Anand Srivastava, Project Management, Fluor Daniel India Pvt. Ltd.
Sheikh R. Manihar Ahmed, Control Systems, Fluor Daniel India Pvt. Ltd.

With reducing profitability, Oil & Gas companies are continuously seeking new opportunities to make existing process more efficient by reducing the costs incurred in a life cycle of a plant/ Unit. Greater efficiency often calls for more plant instrumentation and spare management system, but unavailability of instrument spare during planned and unplanned maintenance can significantly add to plant operating expenditure.

Continuous and timely availability of instrument spares is a key to elimination of production losses due to:

- Unplanned Shutdown.
- Breakdown Maintenance.
- Opportunity Maintenance.
- Preventative Maintenance.
- Predictive Maintenance.

Moreover utilizing intelligent spare management systems can also help in reduction in direct and indirectcost associated with instruments spare management i.e. service cost of various procedural, Space for spare's storage, optimization of time,

This paper discuss about:

1. Classification and Optimization of Instrument spares.
2. Automated ordering of spares based on ROL (Re-order Levels), ROQ (Re-order Quantity), SOP (Standard Operating Procedure) and SMP (Standard maintenance practices).
3. Advanced trigger of required spares and auto notification for ordering process depending on preventative and planned shutdown maintenance.
4. How we can use advanced diagnostic and prognostic feature of field Instruments to trigger procurement of spares.

This paper also examines intelligent instruments spare management system, its impact and potential benefits, the technologies that underpin or support it, and its typical role in the smart Industries.

Author's Profile

Pramod Gupta is working in Project Controls at Fluor Daniel India Pvt. Ltd, Gurgaon. He is having an industry experience of 23 years in Project Planning, Scheduling, Monitoring & Controls, Project Execution and project management of Oil and gas based, Fertilizer plant, Upstream, Refinery & Petrochemical industries. His earlier stint was with Larsen & Toubro Ltd, Essar oil Ltd, Chambal Fertilizers & Chemicals Ltd and Modi Alkalies & Chemicals Ltd and involved extensively in various project execution at site, Plant Maintenance and Inventory management.

Anand Srivastava is working in Project Management at Fluor Daniel India Pvt. Ltd., Gurgaon, India. He has 15 years of professional experience in Project Management, FEED, Detail Engineering & Design, Procurement, Field Engineering, Proposal Development and Construction for Oil & Gas, Petrochemical and Chemical Projects. His earlier stint was with Indian Oil & Gas major as a Lead Instrumentation Manager. The present is with EPC Giant Delivering Integrated Engineering, Procurement, Fabrication, Construction, Maintenance and Project Management Solutions to clients globally.

Deloitte.

THE DIGITAL POWER PLANT: THE POWER PLANT OF FUTURE

By Rajesh Ivaturi and Himadri Singha

Deloitte India

1 ABSTRACT

The digital revolution is coming to power industry. Emerging digital technologies have tremendous potential to contribute to growth in the sector and help deliver exceptional shareholder and customer value. However, the maturity of the digital initiatives in the industry is varied and is still in a nascent stage. In the sector, various new themes are emerging such as- rapid penetration of renewables, emergence of storage solutions and distributed generation, flexible operation of thermal power stations etc. These themes require new capabilities and are triggering for innovation in operating model and new regulatory frameworks. To thrive amid these challenges, the generation utility of the future will consist of a digital system. By leveraging the building blocks of digitalization, such as Industrial Internet of Things (IIOT), service platforms, smart devices, cloud and advanced analytics, exponential technologies (robotics, block-chain etc), generation utilities have the opportunity to increase the asset life cycle of infrastructure, streamline enterprise work processes, optimize cost and efficiency and enhance workforce productivity.

2 BACKGROUND

Digital is transforming companies across diverse sectors, societies and lives. Thanks to the connected era of devices, human-machine interface, intelligent systems and products. The same is true for the power sector as well, which was traditionally asset focused and utility driven. Emerging digital technologies will transform power sector across value chain- generation, transmission and distribution.

Policy does play a significant role, but given the uncertainties around the timelines for these changes, future ready power generating companies will have to be prepared to undergo a paradigm shift, potentially revamping their operating models completely to effectively ride these changes.

3 KEY CHANGES AND DISRUPTIONS INDIAN ELECTRICITY SECTOR IS EXPERIENCING

Indian electricity sector is experiencing groundswell of changes and disruptions. Some of the visible trends are:

3.1 Penetration of Renewable Energy (RE) is rapid

Rapid decline in RE tariffs is reinforcing the fact that the country should focus more and more towards RE power addition. Solar levelized tariff has reached to Rs. 2.44/kWh[1], which is lower than tariff of many coal based power stations. Additionally, Government of India's clean energy push (target of 175 GW RE by 2022) is a major driver of RE penetration.

3.2 Falling PLF of thermal power station

India is projected to become energy surplus in FY 2018. In fact, as per Draft National Electricity Plan, with the current demand growth, if all the committed plants are constructed as planned, then there will be no need of additional capacity till 2022. Due to falling use of existing coal plants, plant load factor of thermal stations in India have fallen to 60%[2]. With slower than expected demand growth and increased generation from non-conventional sources, thermal PLF can fall below 50% by 2025.

With lower than expected capacity utilization and RE induced volatility, significant quantum of coal based generation capacity are expected to experience cyclic load operation in future. Already, few plants of NTPC, located in the high RE zone, are experiencing cyclic operation; however, this phenomenon will be more conspicuous after 2020. With significant influx of power from solar modules during daytime and going out of those modules during evening, specific coal based plants may require to start and stop multiple times during a day.

3.3 Power exchange trades are increasing

Increasingly, with states becoming power surplus along with stranded coal fired power capacity of ~25 GW[3] in the country, the prices in the power exchange have plummeted leading to increase in share of power exchange in short term trades. With more maturity in the trading market, many smart consumers are likely to shift from

---

[1] *https://economictimes.indiatimes.com/industry/energy/power/solar-power-tariff-drops-to-historic-low-at-rs-2-44-per-unit/articleshow/58649942.cms*

[2] *Executive summary report: CEA*

[3] *India's Power Plants stranded as 50 million homes left in the dark, The Economic Times, 09th Jun 2017*

traditional long term PPA to short-term power procurement from exchanges. This may reduce 'assured regulated return' of many generation utilities.

3.4 Emergence of Energy Storage, Distributed Energy Resources (DER) and Electric Vehicles (EVs)

The steep fall in prices of lithium ion batteries has made rooftop solar clubbed with battery storage increasingly cheaper, transforming them as serious competitors to utilities. The battery price has fallen by more than 70% since 2010 and is expected to fall below $100/kWh as early as 2020[4]. From ancillary services to Electric Vehicle, storage solution will play a key role to enable a smart and reliable power eco-system. In addition, Government of India's push to encourage adoption and manufacturing of EVs in the country is likely to play a role in boosting EV sales. By 2020, 6-7 Million EVs[5] are estimated to be on road. With the advent of roof top solar and other distributed energy sources, consumers would produce their own power, thus reducing their dependence on power utilities. Ancillary services such as time of use tariff, demand response etc., will become further relevant and imperative.

3.5 Stringent regulatory compliance

Evolving regulatory environment has led to significant changes in the market structure. Stringent emission norm, tightening of tariff revision and ask for stringent technical and commercial requirements are likely to pose commercial challenges for the utilities. In addition, the institutionalization of the impending separation of content and carriage would instil unprecedented competition in the Indian power sector. Consumers would have the option to get supply from the retailer of their choice, inducing utilities to innovate to differentiate.

3.6 Digital innovation- Information becomes a key asset

The world is expected to have ~20 Billion[6] connected devices by 2020 and India is projected to have 1.9 billion[7] Internet of Things (IoT) units in 2020. Leveraging big data analytics and other advance optimization tools can enable Power and Utilities companies for data driven decision-making. While emerging digital technologies and rise in connected devices will disrupt distribution industries in a big way, there will be significant impact in the generation industry also. Exponential technologies like Robotics and Blockchain are becoming easily accessible and affordable. These new revolutionary technologies are emerging with unprecedented speed and have the potential of changing the way the world works. However, it is needed to develop new digital talent and culture to address these new challenges.

A close observation shows that all these trends and disruptions are inevitably likely to change the operating model of generation utilities globally. Therefore, it is imperative for the utilities to start transforming themselves digitally.

4 CHALLENGES FACED BY GENERATION UTILITIES OF INDIA

With the change in the regulatory landscape, increased competition and rapid penetration of renewable energy, thermal power stations are likely to face challenges in three key areas:

- Asset Management
- Enterprise Management
- People Effectiveness

Some of the emerging challenges, as per assessment of various thermal power stations in India, are as following:

[4] *Lithium-ion Battery Costs: Squeezed Margins and New Business Models, Bloomberg New Energy Finance*

[5] *National Electric Mobility Mission Plan 2020, Department of Heavy Industry, GoI*

[6] *Leading the IoT - Gartner Insights on How to Lead in a Connected World, Gartner*

[7] *The Internet of Things: Revolution in the making, Deloitte - NASSCOM, November 2017*

Deloitte.

Themes	Challenge areas
Asset Management	▪ **Asset performance management** - reduction in 'Asset Useful Life' due to frequent start/stop, cyclic load; increase in outage hours ▪ **Maintenance optimization** ▪ **High spare cost** - large number of emergency procurement ▪ **Efficiency loss** due to partial load ▪ **Technical minimum** – stable operation at low load ▪ **Coal quality monitoring** ▪ **Visualization** - Comprehensive monitoring of asset parameters ▪ **Asset security** - damage, theft and sabotage
Enterprise management	▪ **Business processes and KPI alignment** ▪ **Decision making** – better forecasting and quick decision making ▪ **Process agility** – time delay in information flow ▪ **Cyber security** - threat of Data and System security breach ▪ **Stakeholder management** - effective supplier management, mapping and risk analysis
People Effectiveness	▪ **Workforce productivity** – workforce mobility, pace of decision making ▪ **Employee engagement & collaboration** - various groups working in silos causing ineffective communication ▪ **Knowledge management** - loss of institutional knowledge due to employee retirement and attrition ▪ **Safety management** - accidents, fatalities and unauthorized access to places

Figure 1: Key challenge areas in power generation utilities

5 DIGITALIZATION OF POWER GENERATION UTILITIES

The disruptive changes of digital transformation are currently sweeping through the Power industry. Increased use of renewables, resiliency issues and sustainability concerns are just a few of the drivers behind the industry's need to transform - and digitalization is the single biggest enabler of that change.

Big Data Analytics, Internet of Things (IOT), Robotics, Augmented Reality, Blockchain, Mobility solutions, Smart devices etc. are few elements that constitute the digital ecosystem through which utilities can deliver better operational efficiencies, enhanced organization agility and effective enterprise management.

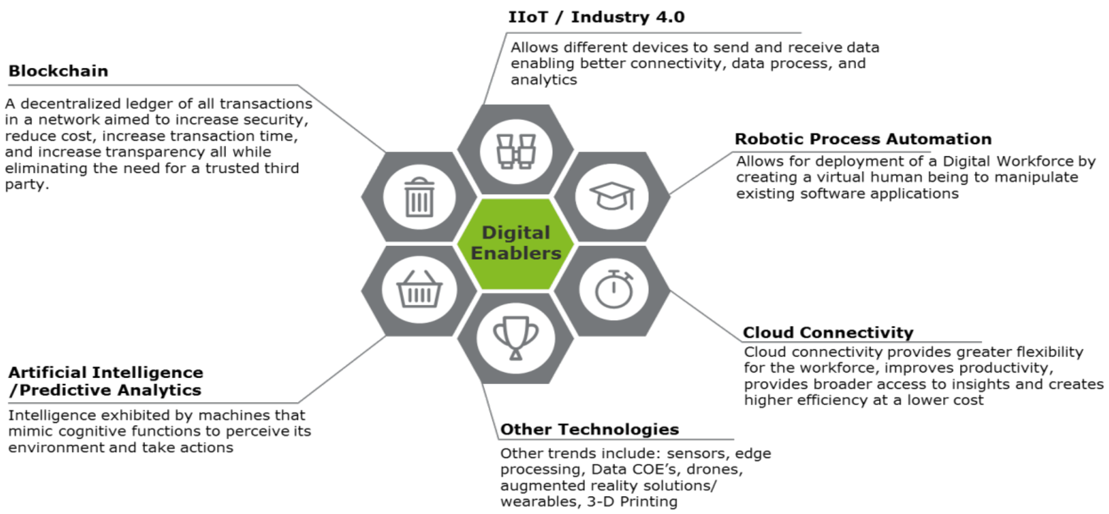


Figure 2: Key technologies driving change in the industry

Digital interventions is well capable of addressing some of the existing business challenges of generation utilities and transform them into smart utilities. From data driven decision making to uptime management to maintenance optimization to workforce productivity enhancement, digital technologies have a role to play.

5.1 Digital Asset Management

5.1.1 Reliability enhancement

Present day utilities are struggling to run in a reliable and sustainable manner. In future, this problem will be more threatening due to increase in cyclic operation, frequent start and stop of units and partial load (sub-optimal) operation of plant equipment. By leveraging IOT technology i.e. inter-connected assets, large pool of data can be captured, processed and analyzed. Further, the captured data can be used as input to predictive analytics platform to predict failure, enhance availability and optimize maintenance schedule. Operational recommendations can be generated in real time by using data captured from connected devices, plant equipment and sensors, and applying algorithms to this data. Plant managers can immediately identify actions that decrease production costs, and can predict and prevent unplanned downtime. Engineers can be more productive by making better-informed decisions; this can eventually lead to a smaller, more skilled workforce.

Duke Energy[8] has saved significant amount towards O&M cost by leveraging IOT and analytics. A $10 Mn catastrophic failure drove the initiation of IOT enabled predictive maintenance program at Duke Energy's power plants. This has saved $31.5 Mn in repair costs during first 3 years of operation. Duke Energy has used predictive tool developed by Schneider Electric.

FinGrid, Finland[9] employed a centralized asset management solution, big data analytics and spatial analytics platform to enable predictive maintenance, save costs and boost reliability. FinGrid achieved instant issue identification and faster fault analysis, at the same time enabling smarter investment decisions

5.1.2 Remote monitoring and control

Asset life cycle management encompasses the technology solutions that enable real-time remote control for extending the life cycle or operating efficiency of assets. Many utilities worldwide are deploying technologies such as smart sensors on generation and distribution assets. This will help collect and transmit data to a central platform so that remote monitoring is possible to enhance operational efficiency. Remote monitoring will help improving visibility of the assets and monitoring of asset health.

A prominent Indian IPP[10] is developing an IOT enabled reliability enhancement and component health monitoring solution for its long distance conveyor. The solution will include use of acoustic sensor, temperature sensor, vibration sensor, belt condition monitoring and fire detection system

5.1.3 Operation optimization

Thermal power stations are majorly base load stations with little fluctuation of load. Except any emergency condition, thermal plants do not ramp-up and ramp down frequently. With the impact of renewables in to the electricity mix, flexible operation of thermal stations, volatile fuel prices, and the emergence of competitive markets, today's power generation fleet is expected to run differently than it was originally designed. Many plants will have cyclic operation, which in turn will impact overall efficiency and performance. Therefore, it has become imperative to ensure:

- the plant runs at its true capacity
- operations flexibility without sacrificing efficiency
- stable operation at 'technical minimum'
- performance slippages are identified and optimized

Use of various types of customized software suit, modelling solutions and advanced process control software can address some of the operating challenges.

- **Advance control system** enables frequent ramp-up and ramp down, stable operation at low load and combustion optimization
- **Optimization software** compares plant performance with historical values, identifies performance slippages in equipment. The software, along with predictive analytics, constantly samples data from historian and analyzes the data the data to detect, diagnose, and prioritize impending problems.
- **Modeling tool** will carry out thermodynamic modelling of plant systems, which builds accurate models and scenarios to understand the physics behind any loss of performance

---

[8] *Source: https://industrial-iot.com/*

[9] *http://www.ibm.com/press/us/en/pressrelease/49144.wss*

[10] *Source: Deloitte Internal*

RWE Power, Germany[11] has installed a comprehensive process optimization solution to reduce its minimum load to less than 40% of the nominal output increasing the flexibility of the thermal plant. With the flexibility gained, the units contribute substantially to the new requirements on the energy market.

5.1.4 Augmented Reality assisted maintenance

Current training programs are heavily dependent on repetitive classroom or field training and most assisted maintenance involves documented work instructions. Optimal use of Virtual Reality and Augmented Reality can potentially help utilities to impart quality knowledge to field force, help maintenance technicians with relevant information and guided work instruction and ensure safety and collaboration.

Smart Glasses / Smart Helmets provide support to field staffs and technicians by extending live guidance during repair and maintenance procedures. These devices are designed to integrate to DCSs, PLCs, SCADAs, Histograms, CMMSs and ERPs, making information previously constrained to the control room available right on the glass/helmet, wherever the worker goes.

Duke Energy is working with EPRI[12] to investigate and pilot the use of smart glasses in electric utility operations. The team tested three use cases using four different technologies: Google Glass, Golden-I by Kopin, Vuzix MX100 platform by XOEye Technologies and Atheer Air. The team found having live video and audio was more helpful than a phone call for field personnel who needed assistance.

5.1.5 Robot and Drone assisted inspection

Currently, most of the inspection work is done manually. Use of drones and robotics is very limited. But, there have been major advances in capability of physical technology. Technological advances and reduced costs of surveillance drone technology will be allowing use of these technologies for inspection of linear and hard to reach assets.

Automated drone inspection solution uses cognitive visual recognition, analytics, and weather data from cloud computing platform to schedule and perform inspections. Drones are suitable for transmission line, high and confined areas, solar stations, coal stockyard etc. Similarly, different type of 'Smart Robot' technologies are available, which are used for inspection purpose. Climbing robots are capable of inspecting waterall, chimney etc.; on-ground robots can potentially inspect solar modules, status of vegetation etc. in any solar project site

Enel, Italy uses Boiler Climbing Robots[13] to simultaneously measure thickness of boiler tubes and clean off the dust and debris from the tube surface to help reduce boiler tube leakages and improve plant reliability in a cost-effective and safe way. Climbing robots will also conduct various types of **NDT**. Robots will be equipped with camera and probes. Potential benefits of adopting this kind of technologies are optimized time for inspection, minimal requirement of scaffolding and reduction in human intervention in hard-to-reach and hazardous areas.

5.1.6 Digital Twin

A Digital Twin is a digital replica of an actual asset being constructed or in operation. A digital twin provides a digital 3D status report that allows management to "look around the platform", and understand the status of each component from design, components build, to assembly. Information is fed into a dashboard that tracks real time actuals at the part and component level and compares outputs against historical performance. Digital twin provides insight into opportunities for process and design improvements.

5.2 Digital interventions to enhance Enterprise effectiveness

5.2.1 Customized dashboard and business intelligence tool

A well-designed governance system is pivotal to an enterprise functioning. It includes customized dashboard, business intelligence tools and robust reporting and MIS. All these together improve visualization and governance by capturing all relevant data, ensuring smart information flow to the right people at the right time in an actionable format

5.2.2 Business optimization through smart scheduling

Robust mathematical models backed up by Artificial Intelligence based algorithm can potentially help generation utilities to schedule daily power generation most optimally. Input to these models are historical

---

[11] *https://www.energy.siemens.com/hq/pool/hq/automation/automation-control-pg/sppa-p3000/Steam_Power_Plants/FR_SPPA-P3000-Neurath_EN.pdf*

[12] *Source: http://www.tdworld.com/asset-management-service/duke-augments-reality*

[13] *Source: www.enel.com*

demand data, weather data, physical parameters of the network etc. Optimum scheduling has potential to reduce cost of generation and optimize overall field-force productivity

5.2.3 Digital work-process – Paperless organization

For any organization, it's often desirable to simplify information flow, enhance agility and optimize workforce productivity. A journey towards 'paperless organization' can potentially help to achieve some of those. It involves a set of defined processes, strategies and tools that allow a business to effectively obtain, organize, store and deliver critical information to its employees and other stakeholders.

5.2.4 Robotic Process Automation (RPA)

Present day enterprises carry out all back-office repetitive work manually, which in most of the cases are error prone and inefficient. Business processes and workflows are not very often optimized. However, future enterprises are expected to operate in a different way. They will automate these repetitive tasks and eliminate redundancies by leveraging robotic process automation (RPA) which enables to gain operational efficiency and speed and delivers fast return.

RPA is a type of software that mimics the activity of a human being in carrying out a task within a process. It will do repetitive stuff more quickly, accurately, and tirelessly than humans, freeing them to do other tasks requiring human strengths such as emotional intelligence, reasoning, judgment, and interaction with the customer.

5.2.5 Block-chain enabled transaction

Block-chain, one of the latest technologies, is already changing financial service sector and ready to enter the energy sector also. Blockchain enables direct processing and recording of transactions between parties, without the need to have an intermediary, such as a power supplier. Each party in a blockchain has access to the complete history and database, and no single party controls the data. Block-chain technology is altering the way parties do transactions, shifting away from centralized and toward a decentralized system. This technology is new and yet to gain full-fledged maturity in the power industry. Block-chain has potential to disrupt areas like power trading, peer-to-peer transaction such as payment for Distributed Generators, EV charging payment etc.

Enel and E.On[14], two largest utilities of Europe recently traded energy through a new market place called Enerchain using blockchain technology. This obviates the need of a central broker thereby reducing the cost of power procurement.

5.2.6 Enterprise security

As the power system becomes hyper-connected, importance of overall enterprise security can not be ignored. Future assets, data and information, network and confidential information need to be extremely secured and shielded against any kind of external attack. This requires deployment of robust security protocols, operations technology (OT) security and smart surveillance system.

In 2015, more than 1.5 million homes in Ukraine were left without power when a hacker group attacked the Ukrainian Power grid with BlackEnergy malware[15]. A major **North American power generator[16]** wanted to protect its operations from such malwares and established a robust set of cyber security protocols. The solution enabled intrusion detection and prevention thus securing its OT environment from exposure to security breaches

5.3 Digital interventions to enhance People effectiveness

5.3.1 Digital workforce

The focus of this digital initiative is to use digital technology to improve field workers' performance and productivity by empowering them with data and tools to drive operational efficiencies. Electronic work packages can transform the end to-end work cycle, from the planners and schedulers to maintenance engineers to those responsible for data entry and reporting.

Today's workforce is yet to be disrupted by the digital business landscape. Considering the trend of future of work, it still lacks agility, pace of decision-making, productivity and competence to leverage tools and new technologies. The future of workforce will be very different from what it is now. As digital transforms the business landscape, the successful organizations of the future will likely be those that can move faster, adapt

[14] *https://www.jsonline.com/story/money/energy/2017/10/16/blockchain-technology-contributing-big-digital-disruption-energy-sector/761383001/*

[15] *https://www.welivesecurity.com/2016/01/04/blackenergy-trojan-strikes-again-attacks-ukrainian-electric-power-industry/*

[16] *https://www.ge.com/digital/sites/default/files/Discover-the-Power-of-Digital-Customer-Stories.pdf*

more quickly, learn more rapidly, and embrace dynamic career demands. A fusion of new algorithms, automation, machine learning and digital platforms will radically change the future workforce.

Smart hand-held devices and mobile applications have tremendous potential to increases the agility of processes and enhance workers' safety. Smart devices transfer information efficiently, reduce manual paper work, allow increased effectiveness in the field, bring agility to workflow management, enhance collaboration and ensure safety. Devices also integrate with various enterprise systems to coordinate effort in real time.

Smart devices include tablets, Smart phone, Smart glass etc. These devices can intervene with various areas of generation value chain, such as:

Communication and reporting

- Smart devices act as unified platform with simple and interactive interfaces
- Faster communication between field forces and control room decreases idle time and enhances productivity. Faster information flow is ensured as the device is connected with all relevant enterprise system and network – ERP, DCS etc.
- Paper work is reduced through extensive use of digital checklist, work instruction, videos
- Digital log-sheet, digital reporting of inspection, health-checks etc. increase process accuracy

Maintenance management

- Tablet / Smartphone based maintenance ticketing, commencement of work, status update and closure etc. increase productivity of crew
- Immediate reporting helps in proactive asset maintenance

Outage management

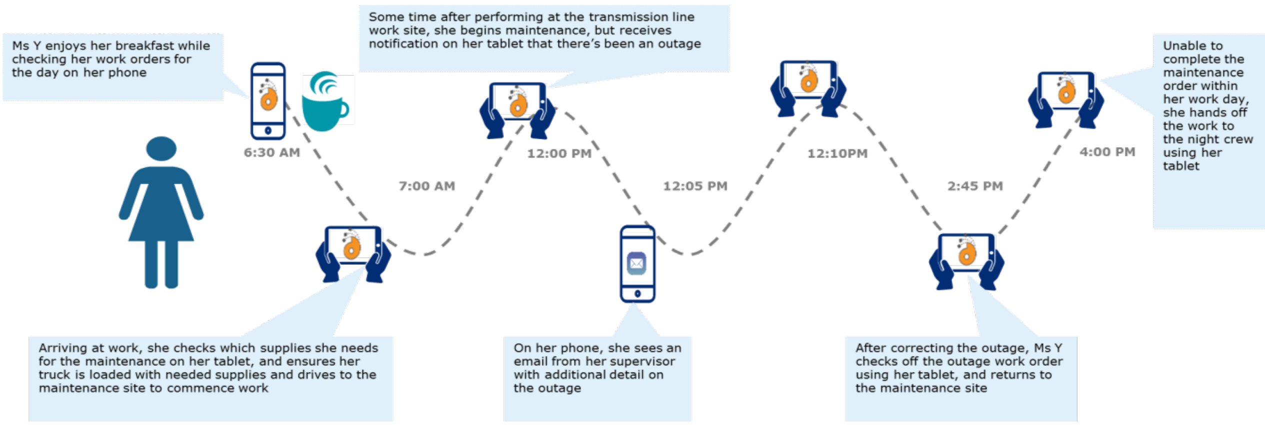
- Outage reporting and response become faster. Smart devices provide quick and relevant information to frontline workers

Safety management

- Better communication, collaboration and situational awareness help in managing workplace safety more effectively. For example, immediate reporting of unsafe working condition becomes possible just by uploading a picture through tablet or smartphone.
- Probability of human error reduces with better communication
- Field force movement can be tracked through sensor enablement

Exelon Corporation, USA implemented a mobile technology solution[17] for enhancing workforce productivity and efficiencies in nuclear plant operations and maintenance. Key features were:

- Apple iPads distributed to plant maintenance crews
- Utilizing mobile technology in place of the legacy paper-based packages, the crew have the ability to use real-time information and apply advanced analytics to improve reliability and maintenance effectiveness



[17] *Source: https://www.cioreview.com/*

Figure 3: Illustration of Workforce Mobility – Day in the Life of Field Worker at a Utility

5.3.2 Digital health & safety management

Digital technologies can contribute to manage workplace safety and workforce health condition more effectively than it's managed currently. For example, advanced wearable technologies can be effective to enhance safety of workforce in the field and hazardous areas. Wearable technology allows real time monitoring of the environment as well as interfaces with which to communicate with field workers. Google glass and other optical sensors allow engineers to access information whilst keeping their hands free. Health sensors are becoming more effective and can interface into apps to improve health and safety and monitor the health of workers in the field.

Figure 4: Illustration of Vital parameters monitoring

Deployment of remote surveillance system is another focus area that will ensure better workplace safety by identifying unauthorized access, hazardous element and any visual anomaly. For example, Smart Camera and RFID nodes help in detecting unauthorized access, leakage of oil, any temperature anomaly etc. and initiates necessary alarm with picture of the unsafe place.

Schlumberger, USA[18] realized that that the average worker has very little information available while he/she is engaged in a task in a remote location. Maintenance workers were using traditional maintenance methods (referencing user manuals, calling for assistance using mobile phones/communication devices) which could lead to unsafe working conditions. It was difficult to integrate timely Subject Matter Expert assistance on complex maintenance issues.

The company collaborated with technology specialist Wearable Intelligence to create a special version of Google Glass that can be used on an oil and gas site. As part of a pilot, the company used 30 units in the field to provide real-time information to workers. The information included live gauge readings, inspection and safety checklists, inventory checks, and systematic procedure videos. Voice commands were the main command inputs used in this solution, freeing up the workers' hands to continue on the task. It also enabled hands-free maintenance and SME assistance.

5.3.3 Knowledge management, interactive platforms, training & capability development

Knowledge management, interactive platforms and training infrastructure contribute to the enhanced employee engagement and productivity.

A robust knowledge management system facilitates capture and retrieval of data easier to avoid any loss of institutional knowledge as the existing workforce approaches retirement.

Interactive tools and software, surveys and feedback mechanisms facilitates in measuring and enhancing employee engagement.

Well-designed training programs enable workforce to take training on various cross-functional areas by facilitating e-learning training modules. Additionally, emerging technologies like Augmented Reality – Virtual Reality (ARVR) are very effective in training field staffs. By enabling trainees to access digitized practical equipment operation experience, virtual reality strips away the costs and the natural risk factors associated with first time practical experience training.

[18] *Source: "Google Glass – The Smart Wearable Intelligence". The OGM. 09/17/15, Deloitte Research*

Deloitte.

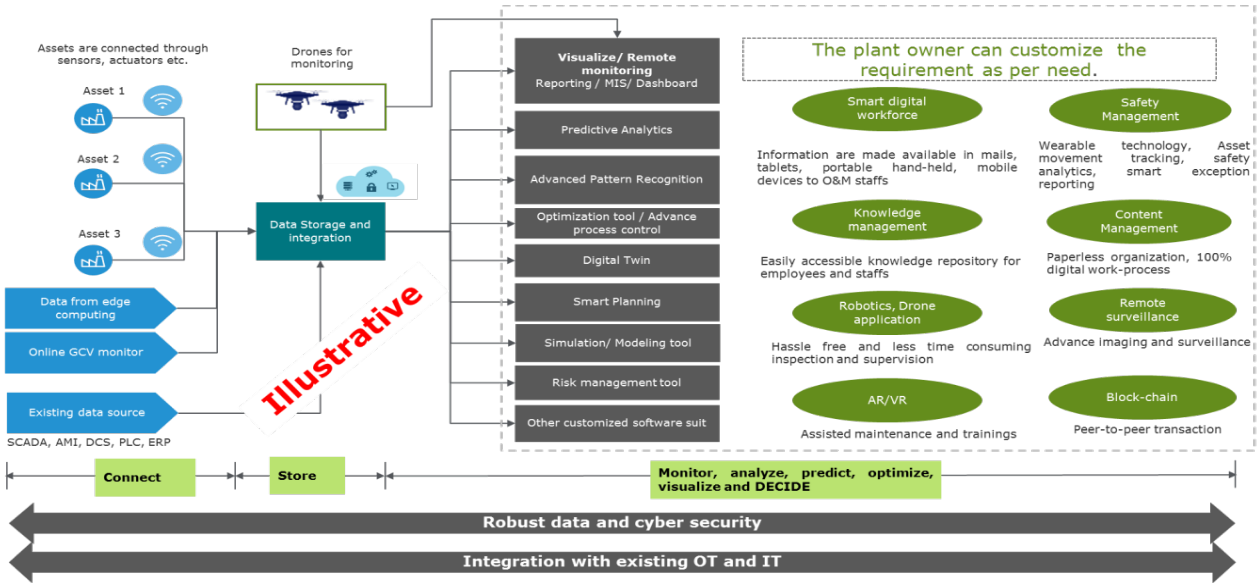


Figure 5: Illustration of a 'Digital Power Plant'

6 HOW CAN ONE TRANSFORM THEIR BUSINESS MODELS INTO DIGITAL UTILITY OF TOMORROW – THE NEXT STEP?

The fourth Industrial revolution or Industry 4.0 is here, which is about leveraging the data generated by an industry and digital technologies to transform every aspect of the industry's value chain. While the Indian Generation utilities are largely data ready (with DCS, historians etc.), Transmission & Distribution utilities are in the process of becoming data ready through investments in technologies like GIS, smart metering, OMS etc., Power sector is an ideal candidate for taking a leap ahead to undergo digital transformation. The success of generation utilities would hinge on their ability to transform their operating models and processes. Digital utilities of the future need to have systems which are seamlessly integrated but loosely coupled making them responsive to the dynamic trends and business challenges of the future. Becoming a digital utility is neither an instantaneous job nor something that can be achieved in a few steps. Rather, it is a continuous process of making a series of business transformations aimed at digitization. To become a digital utility of the future, it would be important to identify innovative business models that help in leveraging the digital ecosystem in creating value to the enterprise and all the other key stakeholders in the value chain. Success will come from breaking the complexity into a sequence of manageable chunks and creating a robust implementation plan. Efficient program management, effective change management, and risk management also go a long way in enabling utilities transform to digital. Perhaps the most important aspect however, for any firm in this journey, would be to develop a digital mind-set which would change the organizational culture to become a true utility of the future.

ADVANCEMENTS IN 19” RACK BASED - VIBRATION MONITORING SYSTEM

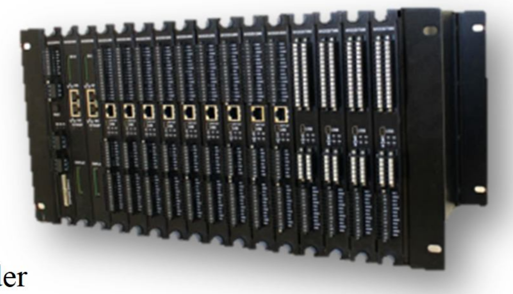
ABSTRACT

Vibration & Condition monitoring systems as per API670, standards have been in use in Industry for many decades. However, despite digitization and processing capabilities of the processors increasing many fold in past 15 years, there has not been as significant development in the Condition monitoring field and data acquisition. How this Ice age in Condition Monitoring field has ended is described in this paper in brief.

INTRODUCTION

Although the global condition-monitoring equipment market is a mature, yet evolving industry, faced with multiple industry challenges such as

- Lack of customer awareness and openness
- An aging workforce of experienced professionals
- Well-established incumbents dominating
- Limited New Global entrants, or New Products



There has been a very limited advancement of products and technology in this industry Since a Global Leader upgraded its last VMS system from partly digital to a fully microprocessor-based system, which was way back in 1995. For about more than 15 years since then either there has not been any enhancement of product in terms of capabilities and technology. Most of the suppliers have systems that compete with this global leader, but all that has been more of a copy of features and design to a large extent. This has changed with the inception of the new technology product SETPOINT.

TYPICAL MARKET BEHAVIOR

There always has been growing emphasis on improving plant productivity and efficiency, and to meet this requirement, trend toward online condition monitoring and understanding causes for machine failure through diagnostics and predictive maintenance strategies has ever since its inception has been gaining prominence. Today even minute deviation from the healthy operating condition of a machine to beginning of deterioration, needs to be detected and worked upon to keep machines in running condition for longer than ever before.

Further the need to have the capability in the system to enable remote diagnostics has till date remained a distant dream. The capability to log into the customer network to acquire the data raises security issues and nore secure firewalls and antivirus programs, restrict further the transmission of such active plots and lynamic data over internet. The plots and figures required for analysis and diagnostics are dynamic plots .nd require high bandwidth of internet which in India till date has been a challenge specially if the plants .re in remote location, which more often than not are due to availability of raw material and resources being ıigh in such remote locations.

)espite ever growing and dire need of advancements in technology, Condition-Monitoring :quipment customers have historically tended to be cautious and risk-averse, unwilling to :xperiment with new and latest technologies

NEED FOR DEVELOPMENT OF NEW SYSTEM

The system that were designed in 1995, were truly good and capable for performing the functionality that hey promised in 90's, however since there was no concept of cloud computing and BIG DATA in the 90's, ***he systems designed then are clearly not capable of handling the challenges of today***. Since there had ›een no development in the condition monitoring equipment for more than 10 years, this period of no levelopment also known as ICE AGE (Where all developments have been frozen) in condition nonitoring field, was contrary to the **'Moore's Law'.**

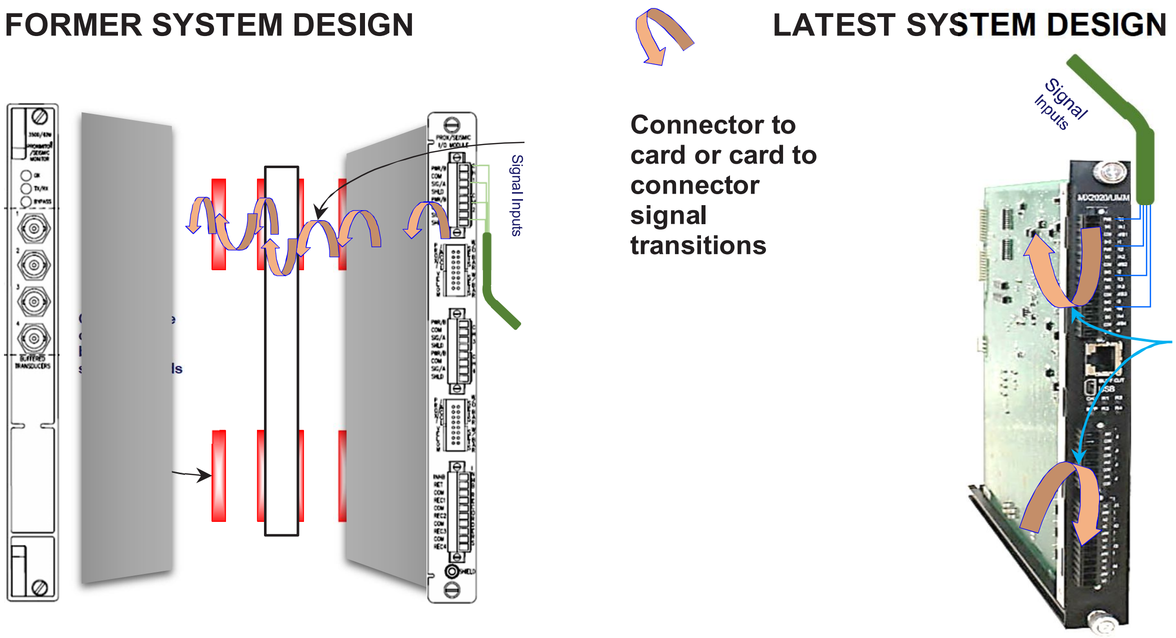
Aoore's law refers to an observation made by Intel co-founder Gordon Moore in 1965. He noticed that the ıumber of transistors per square inch on integrated circuits had doubled every year since their invention. Aoore's law predicts that this trend will continue into the foreseeable future. Although the pace has slowed, he number of transistors per square inch has since doubled approximately every 18 months. This is used ıs the current definition of Moore's law.

Considering the above fact, the deep urge for development of a new system united the team of highly :xperienced individuals to build and lead what would become the **NEW PRODUCT LINE**. Their :xperience was extensive; in fact, they belonged to the same leading manufacturer of technology, that had lesigned the world's largest installed base of machinery protection systems. The only change was that it vas no longer under the same brand name, as the brand till then had been acquired by another Global Giant.

'urther with API committee designing new standards under API 670 -fifth edition, it was also a challenge o comply to the latest requirements of the standards. Further going beyond API compliance, the major :oncentration was to provide a system to the market that is truly user friendly, meets and supersedes :ustomer expectations, and eliminates the shortcomings that existed in the products available in the market. The system was initiated on a drawing board and soon the STATE OF THE ART Product was presented to he world.

ADDITIONAL CAPABILITIES OF THE NEW PRODUCT

Dozens of innovations have been embedded in this new system, including a self-containe **TRULY** "universal" monitoring module (UMM) that can be configured for any Vibration or Turb Supervisory and reciprocating machine parameter measurements, with simple intuitive and eas to use excel like configuration software. This single truly Universal module type, is suitable fo all available vibration sensor, making the addition of new measurements no more difficult tha loading a new app on your smartphone. Besides maintaining the standard industry features, suc as 4 channel monitor cards with latest 24 bit A/D Converters and on board microprocessors enabl freely configurable analog and relay outputs with logic programming for any channel. Since th sensor termination and signal processing takes place on a single card, without the need for rea input / Output cards, signal transitions for generating 1 alarm from 1 signal have reduce significantly, making system more reliable as all functionality, including relays remains inheren on a single card.

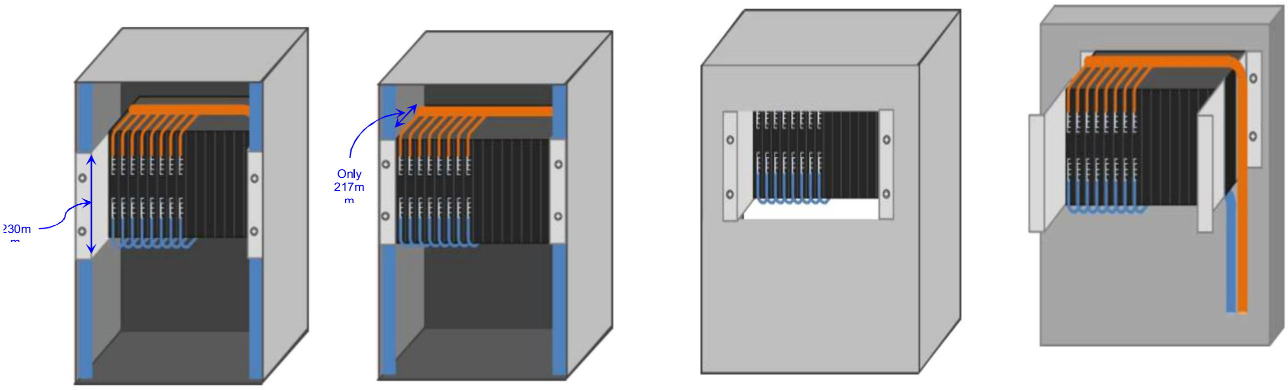


This reduced module size enables higher channel density (56 vibration Channels) in standard 19 rack size, but also enhanced the capability of the processing module (Moore's Law in play provides features like configuration and display of 1x & 2x or Nx in addition to the overall value being monitored by the card, and this functionality on the rack display itself, without any Conditio Monitoring software requirement, thereby providing the first level of analysis on the rack itself.

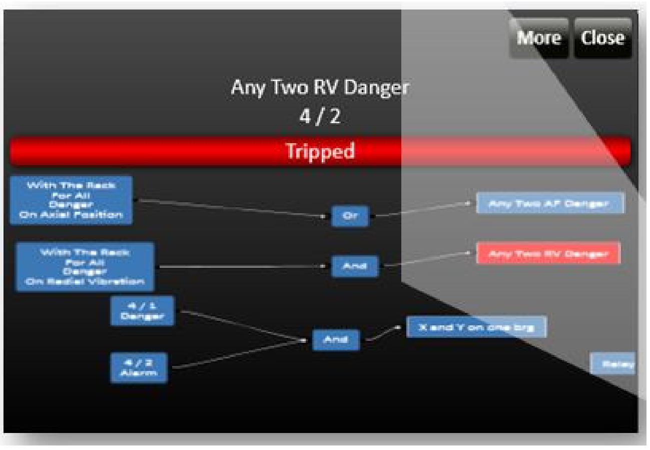
The extension of Moore's law is that computers, machines that run on computers, and computing power all become smaller and faster with time, as transistors on integrated circuits become more efficient. The faster microchips process signals, the more efficient a computer becomes. Costs of these higher-powered computers eventually came down as well, usually about 30 percent per year. This we today witness in mobile phones, I-pads and laptops in everyday market

The SETPOINT system’s design allows the same rack to be used in panel cutout, 19” EIA, or bulkhead mounting configurations by simply employing different rack brackets. The chassis, backplane, and all modules remain the same., saving precious control room space.

19” EIA Mounting Styles — Recessed — Flush — Panel Cutout Mounting Style — Bulkhead Mounting Style



The Color touch panel display, provides from distance clear picture of all the channels on a single screen, with channels in alerts & Danger flashing in yellow and red colors respectively. Further in case of alerts / relay activation, the operator can on the monitor itself view the logic diagram, which with older systems is a challenge and requires experts to identify the same, or a DCS programmer to dig out the information.

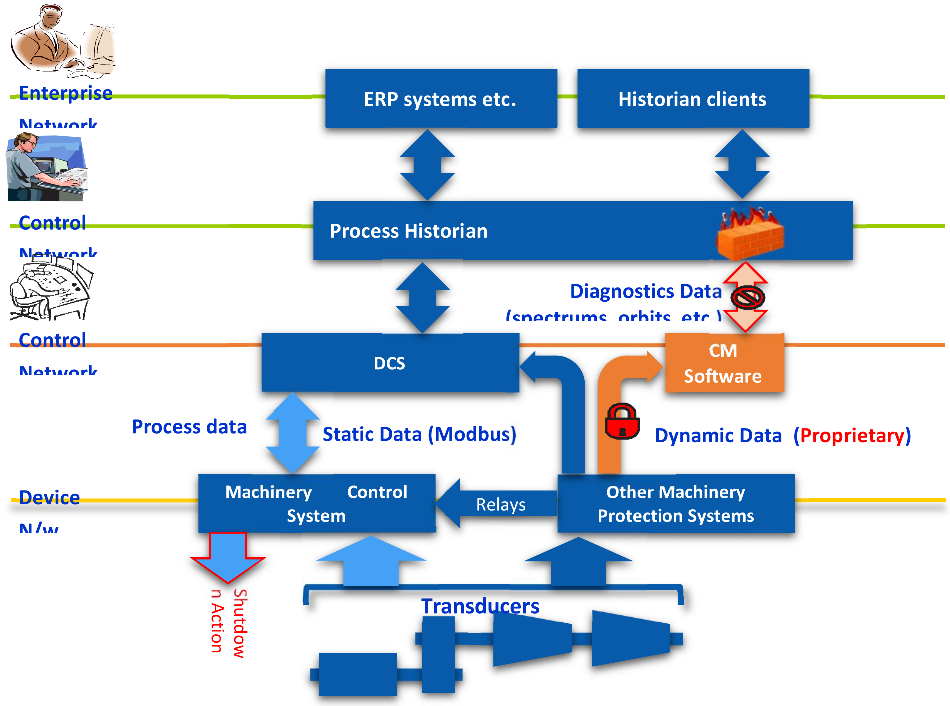


By 2011, this team further expanded its capabilities by embarking on the addition of condition monitoring software to its portfolio. Rather than building a stand-alone software infrastructure – as is used by every other provider in this space unique out of box idea was implanted by entering into a partnership with OSI soft, - maker of the PI System® software. Together, they showed that high-bandwidth, sub-millisecond vibration waveform data could be streamed directly into a PI database – something that had been routinely dismissed by the vibration industry as “impractical” or even “impossible.”

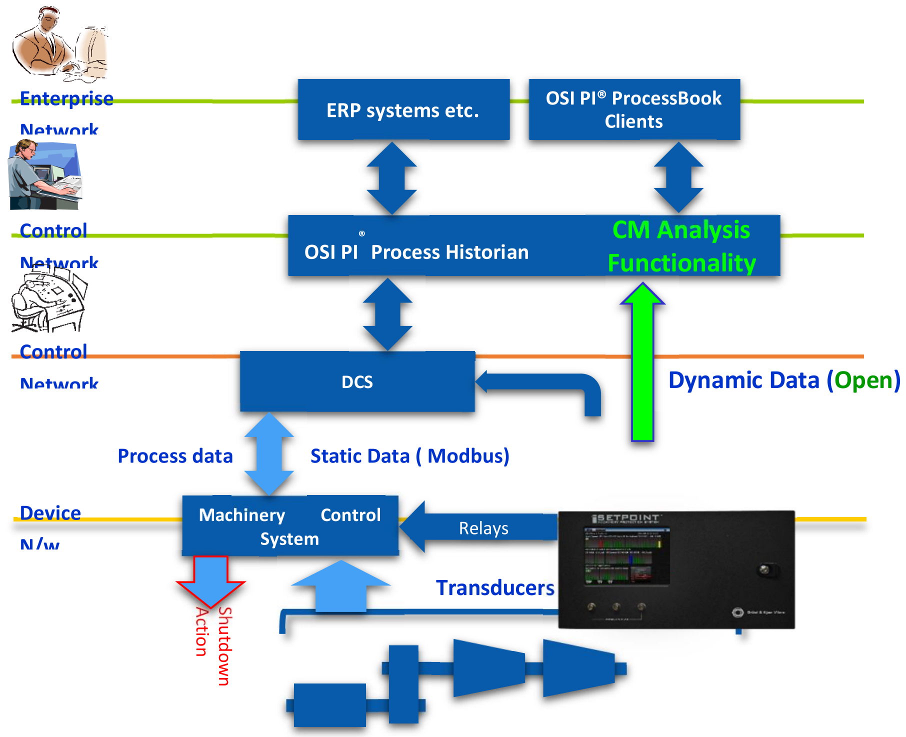
And certainly, something unheard of in this industry is OPEN ARCHITECTURE of the CMS software that has been asked for by industry, but it’s implementation has till date been a question to large extent.

Presented at [Petroleum and Power Automation Meet 2018]: http://www.isadelhi.org

On-line Condition Monitoring Software data acquisition: Proprietary vs. Open



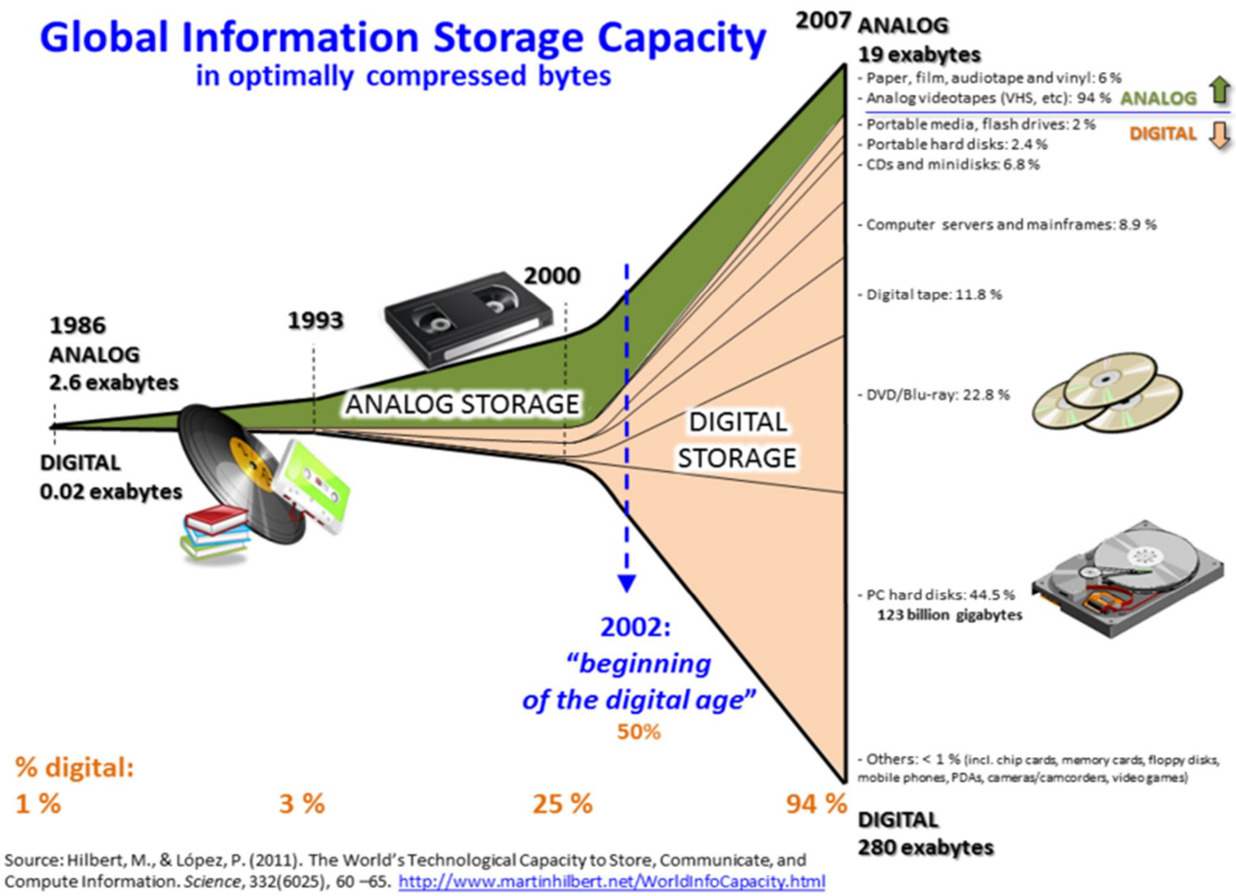
OLD / EXISTING SYSTEM ARCHITECTURE OF THE CONDITION MONITORING SOFTWARE



NEW SYSTEM ARCHITECTURE OF THE CONDITION MONITORING SOFTWARE

Further during that time the performance capabilities of the PI System continued along its Moore's Law trajectory, doubling in speed and making high-speed, online vibration data collection completely practical. With Data being taken to historian, its availability across the plant and over internet to remote locations has been made easily possible & feasible.

Primary reason behind NEW PRODUCTs strategic partnership with OSIsoft was the elimination of redundant computing, network, and software infrastructure, using the existing PI System to do more for its customers. Another reason was growing need of making quick and informed decisions on the condition of an asset requires real-time analysis of large volumes of data, also known as **Big Data**.

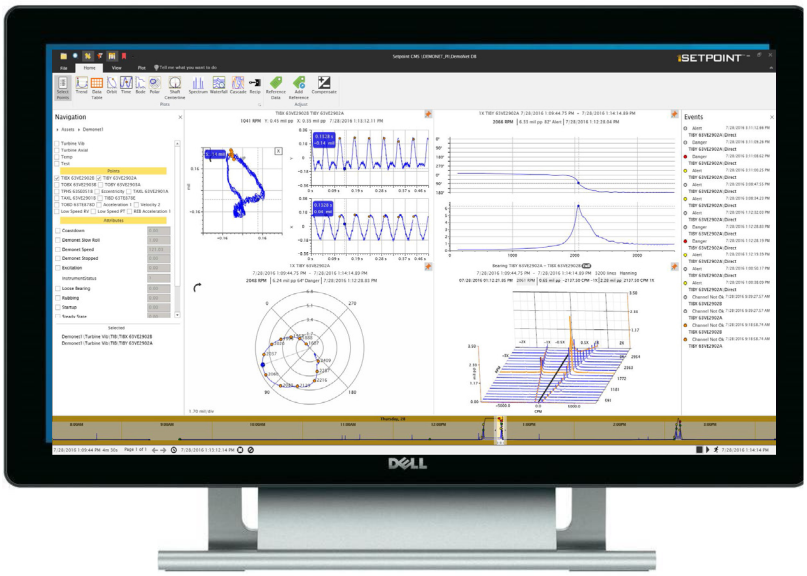


Based on an IDC report prediction, the global data volume has grown exponentially from 4.4 zettabytes to 24 zettabytes between 2013 to 2017, by 2025, IDC predicts there will be 163 zettabytes of data. This is where old instruments and data processing technologies have not been able to cope up, as Big data is data sets that are so voluminous and complex that traditional data processing application software are inadequate to deal with them. Big data challenges include capturing, storage, analysis, search, sharing, transfer, Visualization and updating of data. There are five dimensions to big data known as Volume, Variety, Velocity and the recently added Veracity and Value.

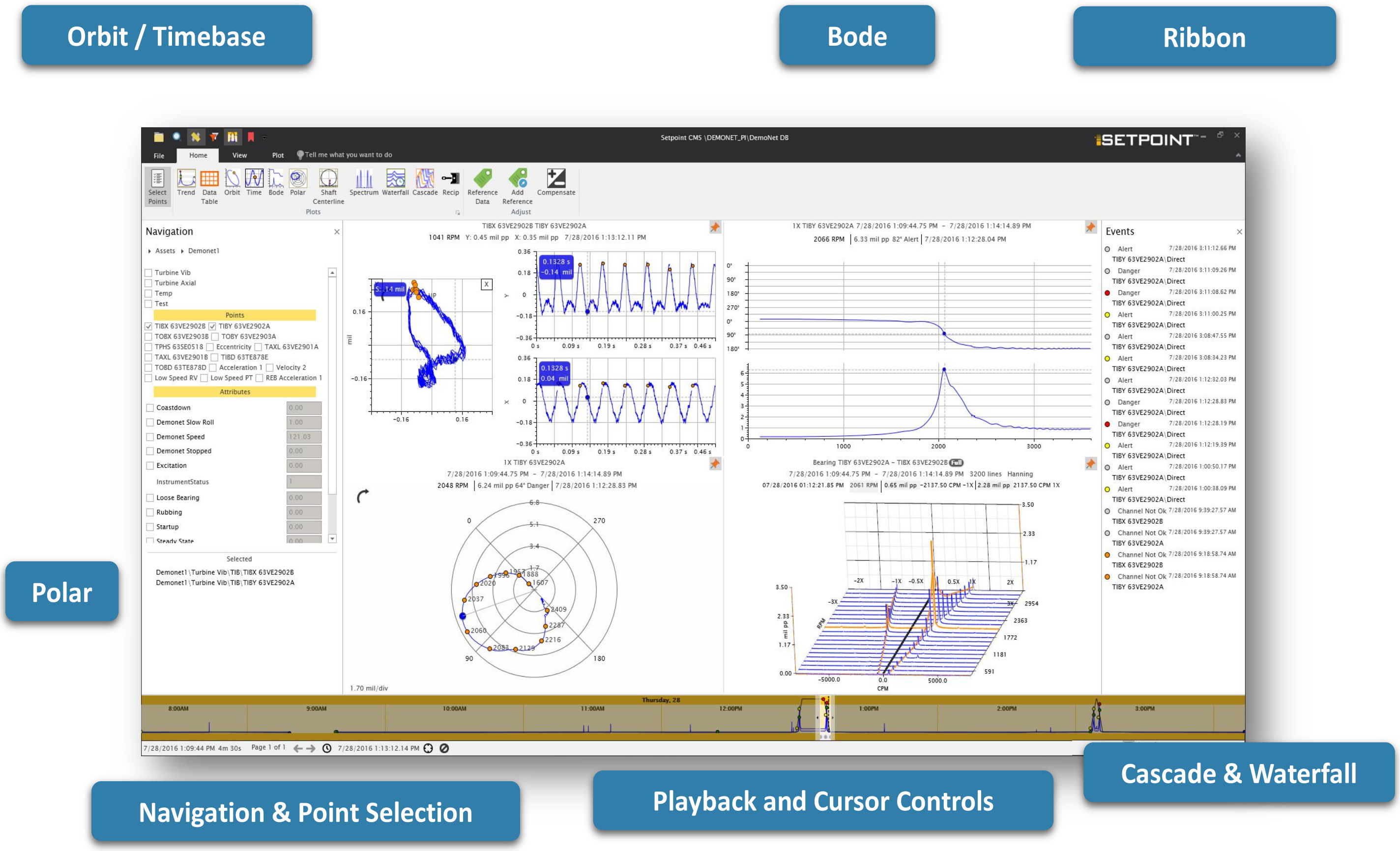
OSI soft is the foremost leader in Big Data, with the PI System being an integral part of the Big Data ecosystem, converting real-time data into actionable information in critical applications such as oil and gas, power generation, and process industries. Customers can use this data as part of their overall plant maintenance and reliability strategies to maximize machinery uptime and productivity.

In a market characterized by limited technology progress and development, The NEW PRODUCT’S bold and innovative approach to product development has produced several unique solutions, resolving the most critical challenges of its customers. Users have responded very positively to its efforts, despite the presence of market incumbents with its strong overall performance, The SETPOINT System has earned Frost & Sullivan’s 2014 Customer Value Leadership Award.

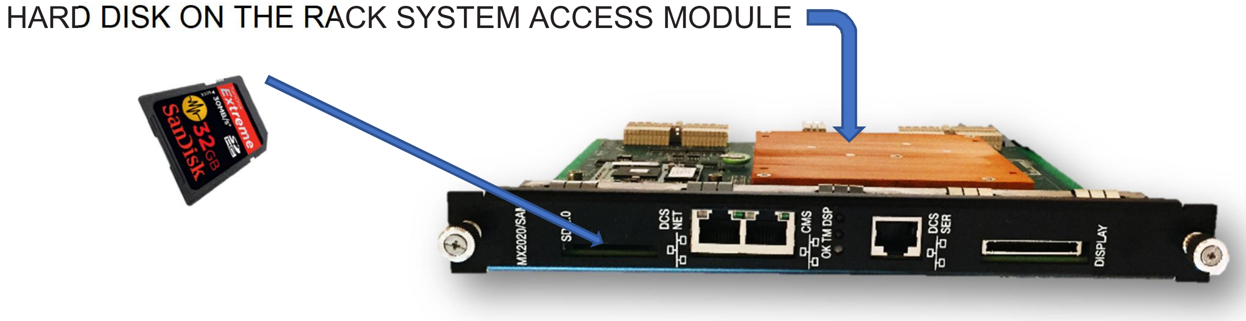
OSIsoft partner



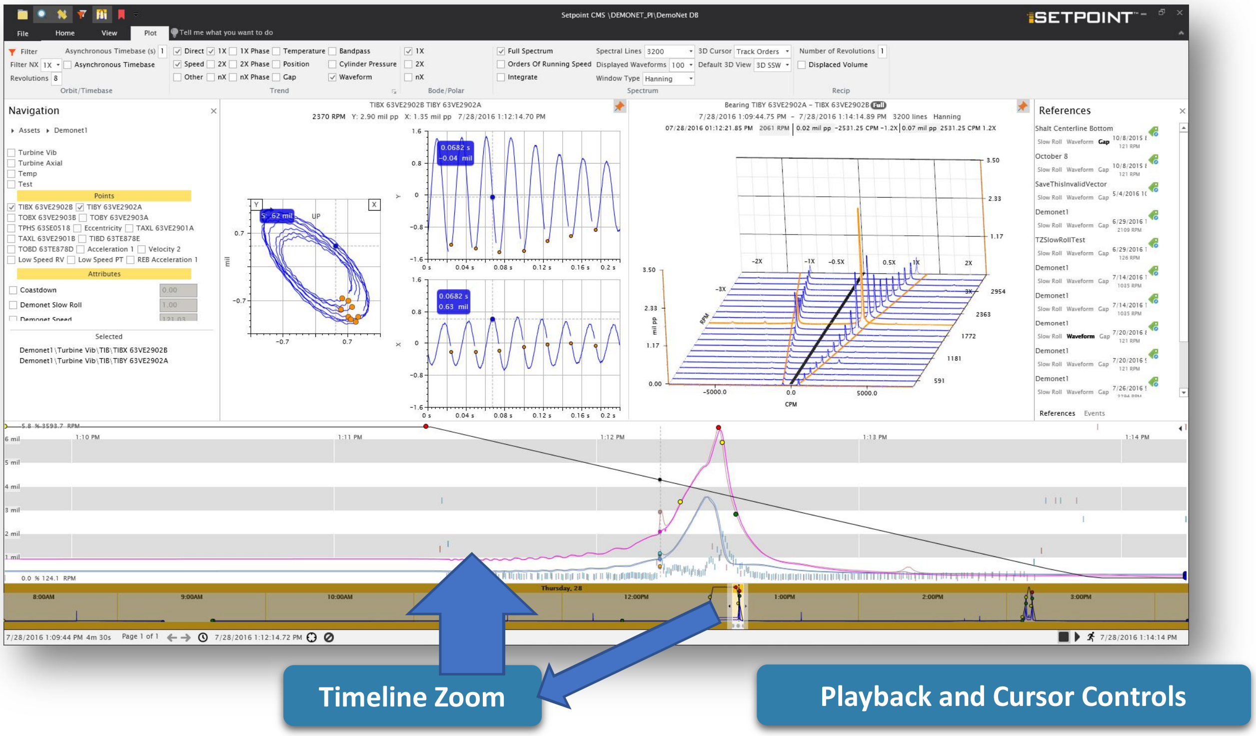
For users of OSI Pi historian, the most popular historian globally and undoubtedly the market leader, simplicity and ease of operation are the major advantages besides the reliability, integrity and security features. Riding on top of PI, as an application software the CMS software designed has capabilities to match the most stringent requirements of the customers and analysts. Observing various plots on the same screen for the same instance is crucial for fault detection and analysis and same with the CMS software is a child's play that can be obtained by simple drag and drop option. Multiple dynamic and transient plots can be clubbed on a single screen for analysis



Data storage, security and secure data transfer are major concerns for any plant, and in case of network failure data lost is not unknown. However, with features like Hard disk being installed on the rack, for data storage for months together, or just acquisition of data for few weeks on the standard SD slot are features that ensure required and useful data are never dependent on the networking and hence always secure.



Since the processors installed are much advanced, only intelligent data from the machine is acquired and stored, ensuring the redundant/useless data is not filling up the precious storage space, and hence a unique functionality and formula called i-Factor is configured in the rack to store only intelligent data, and ensures the most critical data, is available for the analyst to analyze and detect the fault. A unique capability to replay the data really enables the analyst to view the plots, as if any event that raised concern in the plant is happening at current time and place in front of the analyst.



Presented at [Petroleum and Power Automation Meet 2018]; http://www.isadelhi.org

These are only a few of the capabilities that have been highlighted in the above description, and the possibilities are innumerous with the new technology, if we are ready to embrace it.

Sanjeev Grover
DGM
Toshniwal Industries Pvt Ltd
09958899519
09116121975

Sanjeev Grover – has experience of 25 years in sales/ marketing/ installation & Commissioning of On Line Vibration Monitoring systems. E has experience with various leading industries in the VMS field such as SCHENCK, BENTLY, METRIX, BRUEL & KJAER Vibro, etc

OVERSPEED – TURBINE PROTECTION

ABSTRACT

Stringent safety norms and regulations have driven the process industries to invest on safety systems. Safety systems is in a growing stage which is primarily driven by oil and gas, chemicals and other process industries. It is witnessed that during the near period, safety system market will have a significant growth rate. Industries install safety systems not only as a preventive measure to avert accidents but see that as an opportunity for increasing profitability and productivity.

Turbine overspeed events lead to costly and dangerous catastrophic failures.This paper explores the opportunities for steam turbineoverspeed protection systems in line with the latest industry standards.

INTRODUCTION

The steam turbine users often face challenges withoverspeeding of the turbines.Equipmentisbecominglessreliabled uetorepairdifficulties and lack of rigid testing programs.

Theadventofdigital,industrialcontroltechnol ogyhasbroughtincreasingfocustoimprovingo verspeedsystems.

This paper reviews primary reasons for overspeed and reviews the latest requirements of API670 for the overspeed system.

Why Steam Turbines Overspeed?

Steam turbines can overspeed for the following reasons,

- The Steam deposits on the trip/throttle valve stem.
- Lubrication deposits in the trip/throttle valve elements.
- Mechanical failures of the overspeed bolt assembly
- Mechanical failures of the trip/throttle valveresulting from bent stems,damaged split couplings, etc.
- Lack of training for both operating and maintenance personnel (i.e. testing uncoupled turbines)
- Lack of a rigid testing program to detect problems early

Why Users care?

Users care about the turbine overspeed events so as to minimize the risk of loss of equipment, production revenues and life. Once the risks are minimized users can claim cost effective insurance premiums.

Concerns with ESD Systems

API 670 standard covers the minimum requirements for a machinery protection system (MPS) measuring radial shaft vibration, casing vibration, shaft axial position, shaft rotational speed, piston rod drop, phase reference,**overspeed**, surge detection, and critical machinery temperatures (such as bearing metal and motor windings). It covers requirements for hardware (transducer and monitor systems), installation, documentation, and testing.

Some of the concerns with the API 670 rewrite team were:

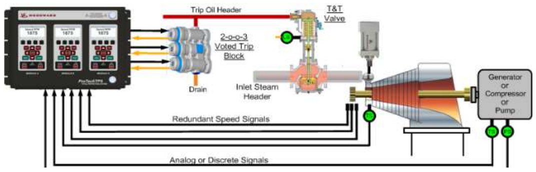
- Poor ESD designs
- Sticky/slow trip valves
- Sticky/slow solenoids
- Detecting problems too late
- Machine coverage

API 670 Definitions

3.1.104 Machinery protection system (MPS)

The system that senses, measures, monitors, and displays machine parameters indicative of its operating condition. When a parameter exceeds predefined limits, indicating an abnormal condition, the system will communicate the event to operators and/or a

shutdown system. The goal of the system is to mitigate damage to the machine. The system consists of the transducer system, signal cables, the monitor system, all necessary housings and mounting fixtures, and documentation



3.1.127 Overspeed detection system (ODS)

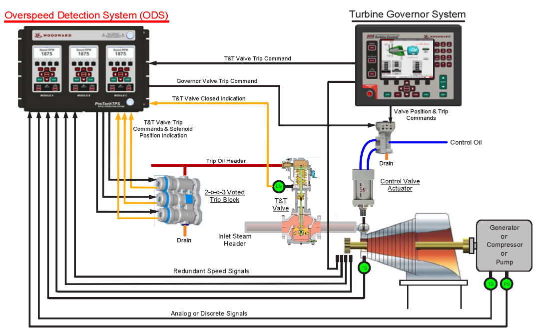
A system that consists of speed sensors, power supplies, output relays, signal processing, and alarm/shutdown/ integrity logic. Its function is to continuously measure shaft rotational speed and activate its output relays when an overspeed condition is detected.

3.1.128 Overspeed protection system (OPS)

An electronic ODS and all other components necessary to shut down the machine in the event of an overspeed condition. It may include (but is not limited to) items such as shutdown valves, solenoids, and interposing relays.

Only electronic ODS's are addressed in this standard. Mechanical ODS's are intentionally not addressed.

Basic ODS & OPS system



ODS – Responsibility

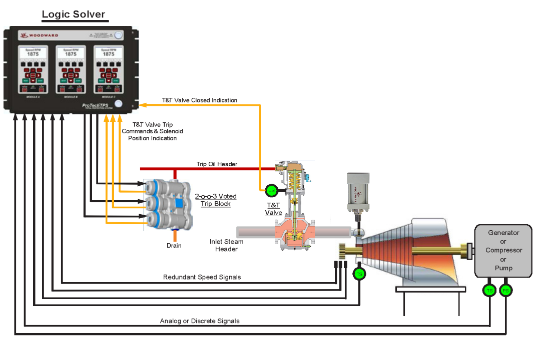
8 Electronic Overspeed Detection System

8.1.1 The vendor of the turbine or other prime mover that has the ability to overspeed shall have responsibility for providing the ODS.

8.1.2 The manufacturer of the monitoring system shall provide documentation affirming the system's compliance with and/or exceptions to all aspects of this standard except those that areconfiguration and/or installation related.

8.1.3 The entity(ies) responsible for installation and configuration of the system shall provide documentation affirming the system's compliance with and/or exceptions to all aspects of this standard that are configuration and/or installation related.

8.1.6 The party responsible for the MPS shall verify that the electronic overspeed protection system response time meets the required system response time to prevent the rotorspeed of all rotors in the train from exceeding their maximum rated rotor speed.



IEC 61508 Design Guidelines

7.4.2.3 Where an E/E/PE safety-related system is to implement both safety and non-safety functions, then all the hardware and software shall be treated as safety-related unless it can be shown that the implementation of the safety and non-safety functions is sufficiently independent (i.e. that the failure of any non-safety-related functions does not cause a dangerous failure of the safety-related functions).

7.4.2.4 The requirements for hardware and software shall be determined by the safety integrity level of the safety function having the highest safety integrity level unless it can be shown that the implementation of the safety functions of the different safety integrity levels is sufficiently independent.

ODS - Segregation

8.3 Segregation

8.3.1 The speed sensors used as inputs to the electronic ODS shall not be shared with any other system.

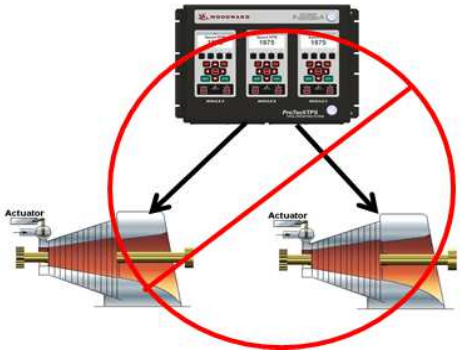
8.3.2 Electronic overspeed detection shall be separate and distinct from the speed control system, with exception of final control elements.

NOTE: The intent of this subsection is to ensure overspeed protection in the event of speed control system failure.

8.3.4 Combining the overspeed system with any other control, protection, or monitoring systems (except as allowed by 8.3.3) shall not be allowed. This restriction includes the monitoring systems of Section 7.

NOTE Combining the ODS with other systems may degrade the overall system response time, impact ease of serviceability/isolation, or otherwise interfere with overspeed integrity.

8.3.5 Each driving machine requiring overspeed detection shall have its own overspeed system. Combining multiple driving machines into a single ODS shall not be allowed.



ODS – Communication Interfaces

8.3.6 When digital or analog communication interfaces are provided, they shall not be used as part of the shutdown system. Failure of a communication link shall not compromise the ability of the overspeed system to carry out its protective functions.
NOTE: The intent of this subsection is to allow status and other data from the electronic ODS to be shared with process control, machine control, ESD, or other control and automation systems via digital or other interfaces, but without compromising the integrity of the overspeed shutdown function.

ODS – Number of Circuits & Logics

8.4.1.1 Overspeed detection shall use three independent measuring circuits and two-out-of-three voting logic for each shaft.
8.4.1.2 If specified, aero-derivative gas turbines may use two independent measuring circuits and one-out-of-two voting logic for each shaft.

NOTE 1: Electronic overspeed detection monitors and transducers are only two of the components in a complete overspeed protection system. This standard does not address these other components such as solenoids, interposing relays, shutdown valves, and so forth.

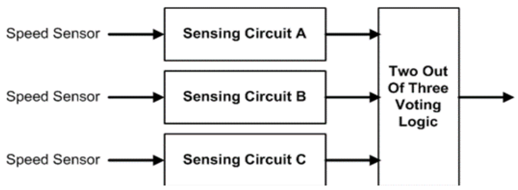
ODS – Inputs,Outputs & Configuration

8.4.3.1 The electronic ODS shall accept speed sensor inputs from either magnetic speed sensors (5.1.5) or proximity probes (5.1.1). Unless otherwise specified, the inputs shall be configured to the standard passive magnetic speed sensor of 5.1.5.2.

8.4.3.2 Each overspeed circuit shall accept inputs from a frequency generator for verifying the shutdown speed setting.

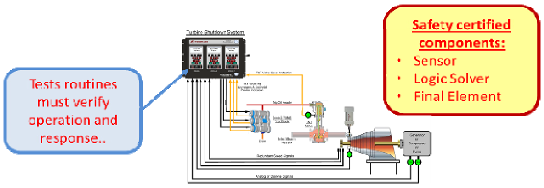
8.4.3.3 Each overspeed circuit shall provide an output for speed readout.

8.4.3.4 All settings incorporated in the overspeed circuits shall be field changeable and protected through controlled access.



8.4.3.6 If specified, the design of the electronic ODS shall conform to standards IEC 61508, IEC 61511, IEC 62061, or ISO 13849.

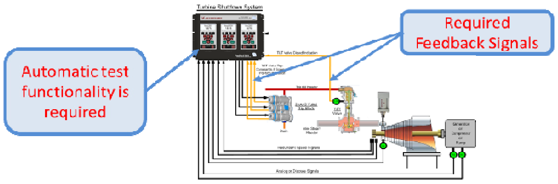
8.4.3.7 Online testing functions shall be provided. Activation or deactivation of these functions shall only be permitted through controlled access.



8.4.3.8 If specified, the electronic ODS shall include automatic overspeed testing functionality.

8.4.3.9 Automatic overspeed test functionality shall be determined by the responsible party, unless the system is an IEC 61508 or IEC 61511 certified system where it is dictated by the certification report.

8.4.3.10 Overspeed systems shall not have a system bypass.



ODS – Response Time & Verification

8.4.4.1 The system shall sense an overspeed event and change the state of its output relays within 40 ms or as determined in Annex O, whichever is more restrictive.

8.4.4.2 The maximum allowable rotor speed shall be determined as follows.

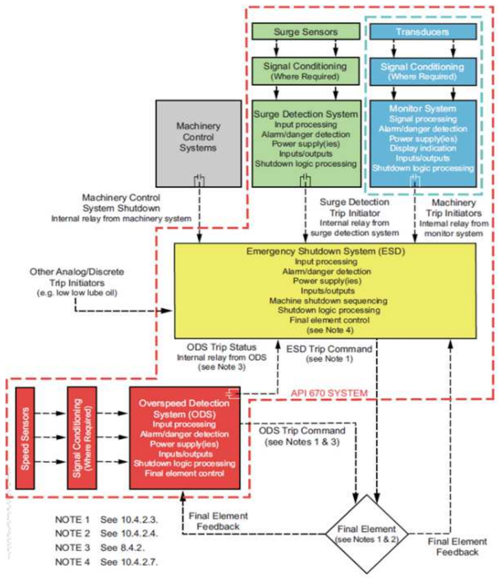
O.1 Steam Turbine Based Maximum Rotor Speed Calculations

This annex is used to calculate the maximum rotor speed of a typical non-reheat steam turbine during an overspeed shutdown event. However, it does not apply to gas turbines or steam turbines that incorporate reheat operations.

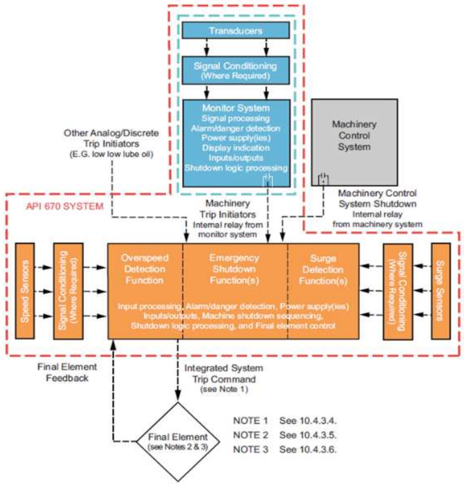
a) For steam turbines without reheat, the calculation methodology of Annex O shallbe used to determine the maximum allowable rotor speed. Worst case component delay times shall be used in Annex O calculations to verify that the system’s worst case response time is fast enough to safely shutdown the machine.

ODS – Architectures

If a distributed type approach is taken for the Machinery Protection system, where the ESD,ODS & SDS are separate then the control system is always separate.



If an integrated type approach is taken for the Machinery Protection system, where the ESD,ODS & SDS are combined then the control system is always separate.



CONCLUSIONS

Theintroductionstatedthat theSteam turbine overspeed events lead to costly and dangerous catastrophic failures.Digitaltechnologyoffersenhancedoverspeed protection systems which features not achievableinoldertechnologies.Steam turbine userslookingfornewopportunitiestopositionthemselvesagainstcurrentchallengesshouldconsiderupgradation to the latest Overspeed protection systems in line with the requirements stated in the latest industry standards.

REFERENCES

Understanding & Preventing Steam Turbine Overspeeds – William Nelson.
Business Wire - Frost & Sullivan's Electronics & Security Practice (2008).
API670

BIOGRAPHY

Sh. Harvinder Singh Kalsi was born in Lucknow, India in the year 1965. He graduated inElectronics engineering fromGulbarga University. He joined Woodward India Pvt Ltd in 1993. At present he is working as Regional Business Leader and is responsible for the Turbine business vertical which includes Sales, Engineering and Aftersales services.

MERCURY MONITORING IN THERMAL POWER PLANT

Anant Ghadigaonkar
Regional Sales Manager
ThermoFisher Scientific India Pvt. Limited, Mumbai

ABSTRACT

Thermo Scientific Mercury Freedom System is Uniquely simple through successfully adapting known measurement methods tomeet a complex application, the measurement of low levels of a transitory and reactive pollutant:

- Wet-basis Dilution Extractive method, widely used in the industry.
- Direct measurement using Cold Vapor Atomic Fluorescence, similar in concept to the SO2 Analyzer.
- Dry conversion of oxidized mercury in the probe, similar in principle to the NOx converter

KEYWORDS

Mercury, Hg, CVAF, Fluorescence, Elemental, Ionic, Dilution, Total, Speciate, Coal

INTRODUCTION

The Thermo Scientific Mercury Freedom System was Originally design to meet the requirement of the Clean Air Mercury Rule (CAMR). Several Hundred of Mercury Freedom System were Installed in Coal Fired Power Plants across the United States and Cement Plant and passing stringent Relative Accuracy Test Audits (RATAs) under varying plant conditions.

With respect to India, Ministry of Environment and Forest (MoEF) Notification and Climate Change Notification, New Delhi the 7th December 2015 (S.O. 3305 (E) – In exercise of the powers conferred by sections 6 and 25 of Environment (Protection) Act 1986 (29 of 1986), the need to select and install a Mercury Monitoring Solution / System is becoming increasingly important / Urgent.

BACKGROUND - EXPOSURE

- Mercury is a transition metal with 3 common states (Hg^0, Hg^{2+}, Hg^p).
- Elemental Mercury (Hg^0) – Dominant species in atmosphere, most pollution sources.
- Ionic or oxidized mercury (Hg^{2+}) – In air, reactive gaseous mercury (RGM), primarily HgCL2. Dominant species in rainfall, water, sediments, soil, and some pollution sources (notably incinerators).
- Particulate-bound mercury (Hg^p)
- Total Mercury (Hg^t) – The sum of $Hg^0 + Hg^{2+} = Hg^t$.
- Unit of measure - Micro-grams per cubic meter ($\mu g/m^3$).

- MDL: 1 ng/m³ ~ 0.1 ppt
- Inorganic mercury settles to the sediments of the water body where microbiological activity converts it to Methylmercury (MeHg).
- MeHg is easily passed up to animals at the top of the food chain (bioaccumulated).

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (NIOSH)

Exposure Limits

- Recommended Exposure Limits of Mercury vapor is 50 µg/m³ on a Time Weighted Average concentration for up to a 10-hour work day during a 40-hour workweek. Potential for dermal absorption; skin exposure should be prevented.
- The recommended ceiling value of 0.1 mg/m³ should not be exceeded at any time. OSHA ceiling value = 0.1 mg/m³.
- Immediately Dangerous to Life or Health (IDLH) =10 mg/m³ (as Hg).

MAIN APPLICATION FOR MERCURY MONITORING

POWER GENERATION

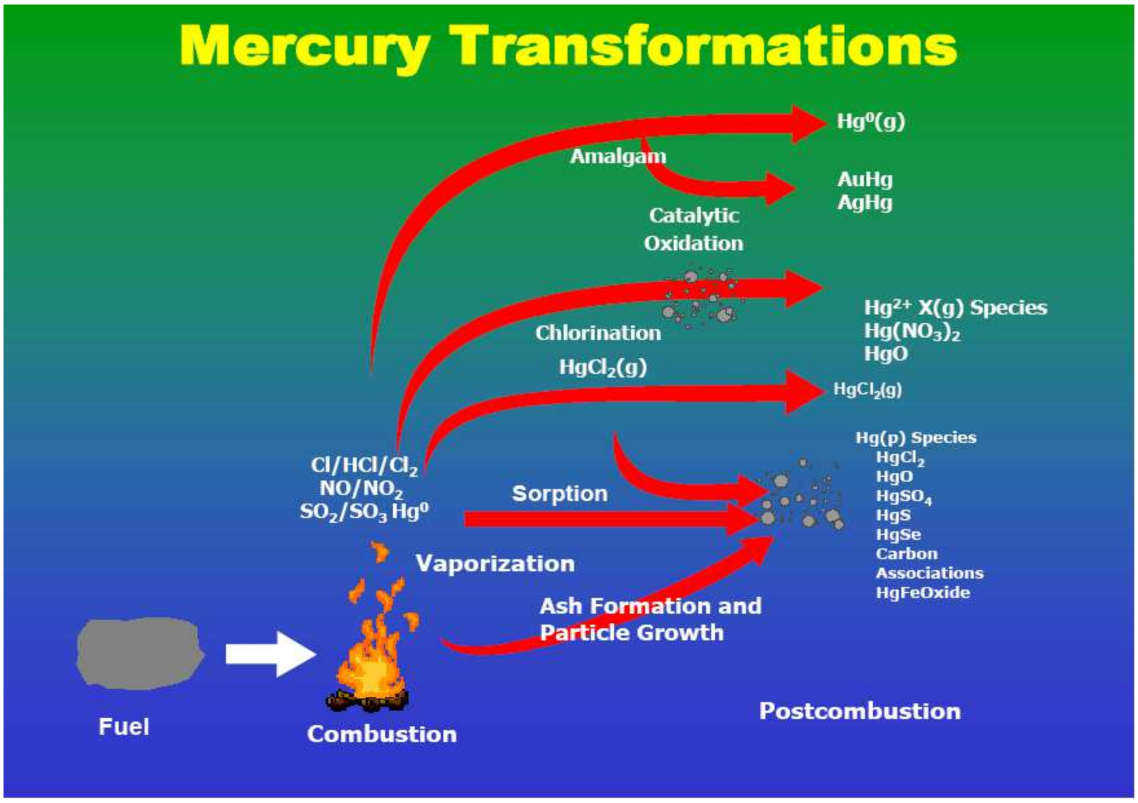
•Solid combustible (coal, wood, simple biomass)
•Liquid combustible (fuel, oil)
•Gaseous combustible (natural gas, biogas)

INCINERATION

•Domestic waste
•Special waste (sludge, hospital, industrial)
•Biomass (complex, mixture)

OTHER APPLICATIONS

•Cement, Glass, Fertilizer



THE THERMO SCIENTIFIC MERCURY FREEDOM SYSTEM

WORKING PRINCIPLE: COLD VAPOUR ATOMIC FLUORESCENCE (CVAF)

The ThermoScientific Mercury FreedomSystem is comprised of a Hg analyser (Model 80*i*), a Hg calibrator (Model 81*i*), a Hg probe controller (Model82*i*), and a Hg probe (Model 83*i*) along with additional peripheralcomponents, such as a zero air supply, umbilical, and instrument rack.

However, the Model 80*i* is also available as a stand-alone instrument.The Model 80*i* Analyzer is based on the principle that Hg atoms absorbultraviolet (UV) light at 253.7 nm, become excited, then decay back to theground energy state, emitting (fluorescing) UV light at the samewavelength. Specifically,
$Hg + h\nu(253.7nm) \rightarrow Hg^* \text{-}\rightarrow Hg + h\nu(253.7nm)$

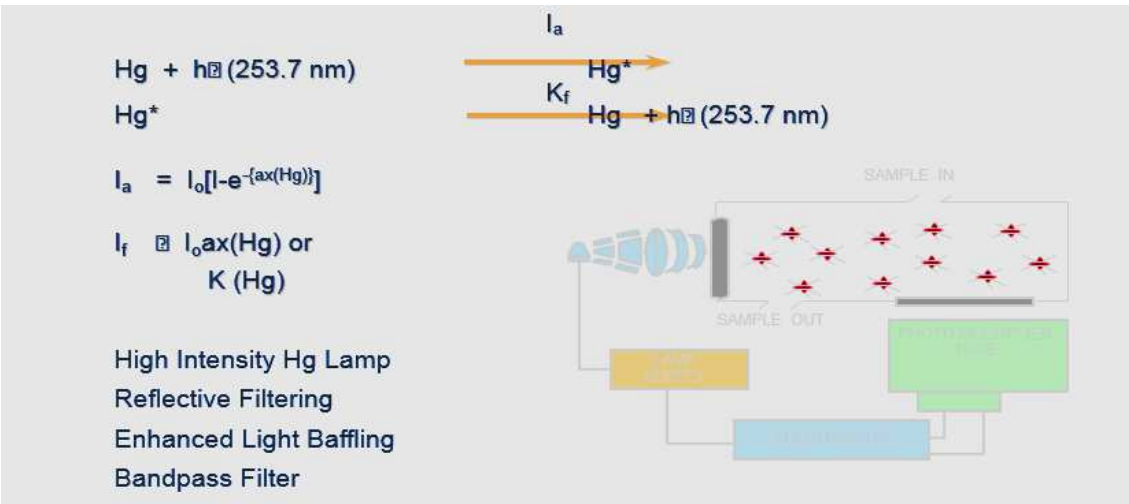
CONCEPT OF OPERATION – HG COLD VAPOR ATOMIC FLUORESCENCE

FEATURES OF MERCURY FREEDOM SYSTEM

- Direct Measurement and Continuous using CVAF
- No additional gases required
- Uses Diluted Sample
- Lower moisture, less reactive
- Capable of Speciation
- Measures bothHgT or Hg0
- Analyzer Detection Limit: ~1 ng/m3 (~0.1 ppt)
- No cross interference with SO2

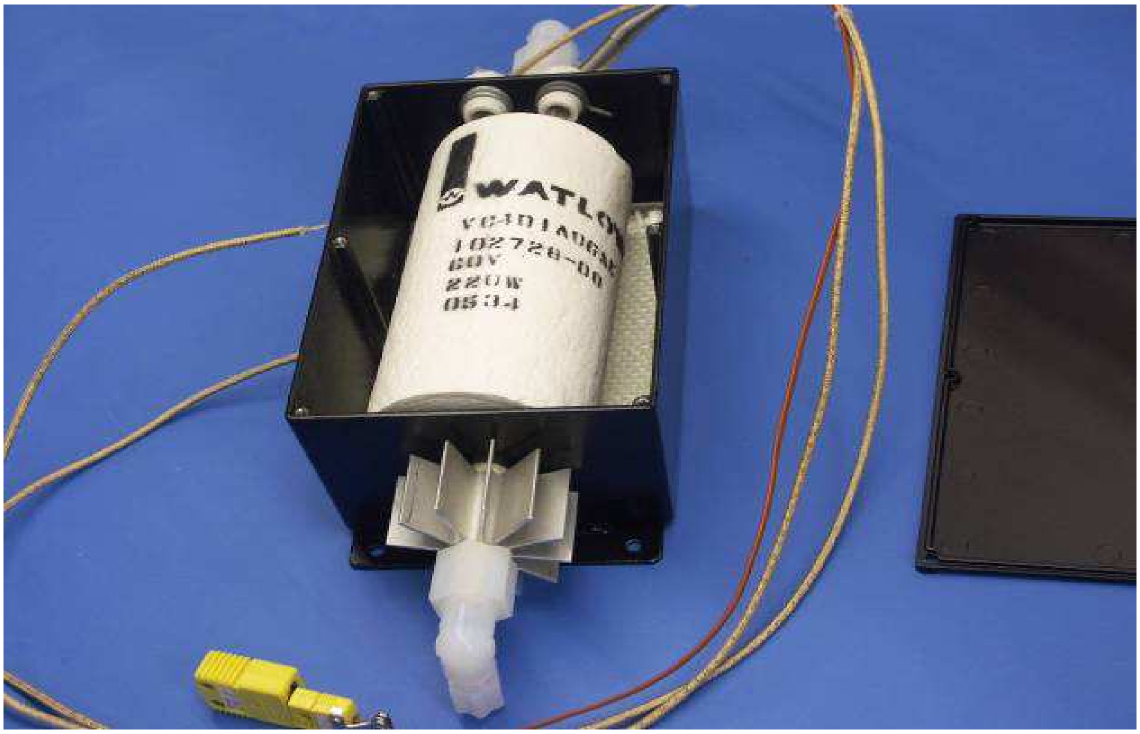
The Mercury Freedom System offers high measurement sensitivity, fast response times and robust operation in harsh environments through a simple design that closely resembles a traditional wet-basis dilution extractive CEMS. The system is capable of measuring elemental, ionic and total mercury in exhaust stacks through the use of Cold Vapor Atomic Fluorescence technology. This design also eliminates the need for an SO2 scrubber, commonly used with atomic absorptionsystems, or an expensive carrier gas (e.gArgon). The system provides true continuous measurement as opposed to batch collection by pre-concentration of mercury on a gold amalgamation trap

The Mercury Freedom System consists of a samplingprobe at the stack, a heated umbilical line for sampletransport, and a rack of instruments that include

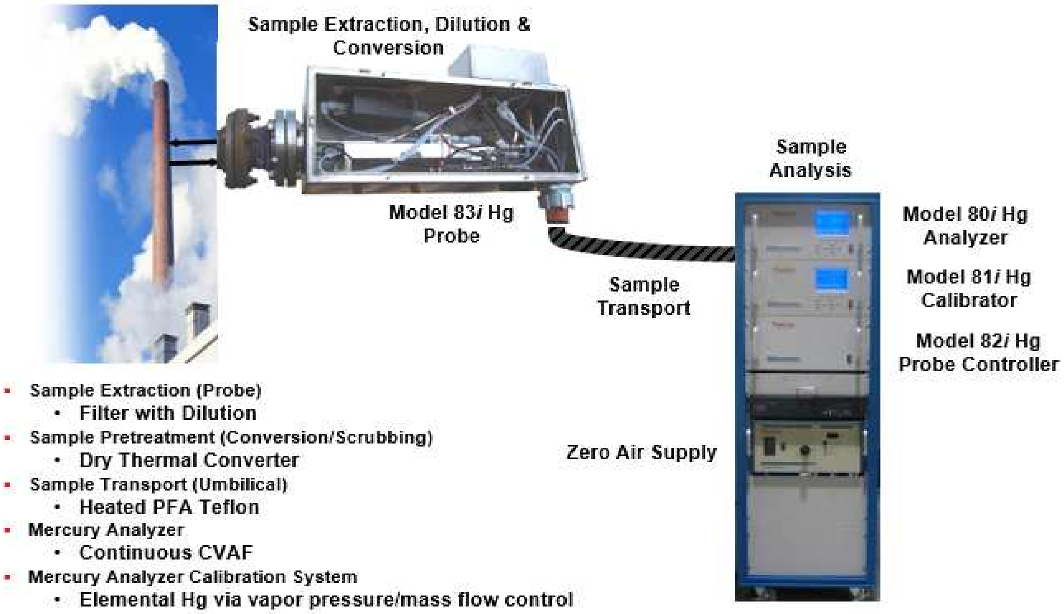


theanalyzer, calibrator and probecontroller. The rack, which is placed in an accessible temperature controlled location, also contains a zero-airgenerator and a sample pump. A working diagram of theMercury Freedom System is shown in Figure.The system extracts the sample using an inertial probe.The probe contains a fast loop with a glass-coated inertialfilter that prevents particulate clogging and requires lessfrequent maintenance. The sample is diluted withinstrument-generated zero air or nitrogen before it istransported to the Thermo Scientific Model 80i analyzer,which detects elemental mercury (Hg0), not oxidizedmercury (Hg2+). In order to detect all (total) mercury,oxidized mercury needs to be converted into elementalmercury.The probe splits the sample into two flow paths. One usesa dry converter to convert the oxidized mercury intoelemental mercury. This way, one of the sample tubescarries elemental mercury and the other tube carries totalmercury, which includes the converted oxidized mercury.Converting the oxidized mercury at the stack minimizesthe loss of mercury in the sample line, and consequentlyremoves the need for high temperature in the umbilicalline.The Model 80i analyser, Model 81i calibrator and Model 82iprobe controller allreside in the rack. The diluted sample from the probe istransported through the optical chamber, where is itsubjected to a high intensity UV light source. Mercury inthe sample is excited by 253.7 nm wavelength light, which causes it to fluoresce; the fluorescent intensity is directlyproportional to the amount of mercury in the sample. Thefluorescence is measured by a photomultiplier tube(PMT). Because only mercury is excited by the chosenwavelength, interference from other pollutants iseliminated.The Model 82i probe controller controls probe parameterssuch as pressure and temperature, and also controlsautomated blowback and secondary valve functions.

High Temperature Thermal Converter: Ionic Mercury to Elemental Mercury



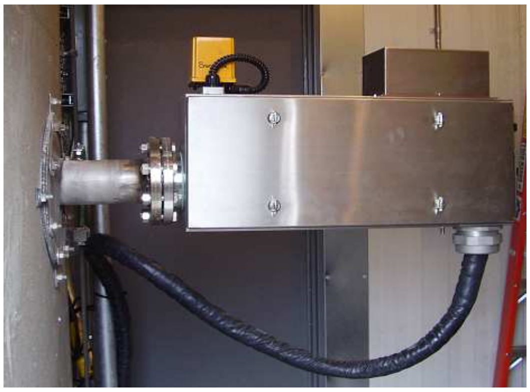
MERCURY CEMS OVERVIEW



When used with the Thermo Scientific Zero Air Supply,the Model 82i delivers clean dilution gas to both theModel 81i calibrator and the probe (Model 83i).The Model 81i calibrator generates mercury vapor used tocalibrate the Model 80i Analyzer and the CEMS. It uses a
Peltier Cooler and mass flow controllers to generateprecise amounts of elemental mercury. Mercury span gasis transported through the sample line to the probe. During a calibration cycle, the calibration gas floods theprobe and is drawn through the inertial filter back into
the analyzer for measurement.
The Model 80i analyzer displays Elemental Hg, Oxidized Hg, and Total Hg concentrations. The analyzer is totally self-contained, linear through all ranges and uses atomic fluorescence detection technology for fast response timeand high sensitivity. The Model 81i Mercury Calibrator generate a specific and consistent concentrationof mercury. The generated mercury concentration, as measured by the model 80i analyzer, is used to confirm thereliability of the model 81i calibrator output in accordance with U.S. EPA Interim Elemental Mercury Traceability Protocol requirements

At the stack

1. Mercury Extraction Probe (Model 83*i*)
   a. Eductor Extraction
   b. Inertial Separation Filter
   c. Dilution
   d. Dry Thermal Converter
   e. Oxidizer



Model 83*i* Probe Assembly installed at Stack

- Conversion at Stack of IONIC mercury to ELEMENTAL Mercury, Reduces re-oxidation of Hg especially in the presence of SO3 or other acid gases
- Stainless steel system housing meets NEMA 4X specifications.
- 4 inch Mounting Flange bolts to the Mantel special Flange.
- Extraction – EductorVenturi
- Filtration – Inertial Filter
- Dilution – 4 to 9 l/m : 250 ml/m
- Ionic Hg Conversion - Dry Chemical / Thermal Conversion (Hg (+2) -> Hg(0))
- Mercuric Chloride Generator $HgCl_2$
- A high velocity Sample is drawn from the Stack and across a Filter.
- The Dilution Module pulls a small volume of Stack gas through the Filter and an Orifice, and dilute the concentration with Conditioned Air.
- Small volumes of this "Diluted Sample" are drawn through an 250 mL/min critical orifice to mix with the dilution air or nitrogen.
- An Orifice and a Hg(2+) Hg(0) Converter (Total Channel)
- An Orifice (Elemental Channel)

PERIODIC QUALITY ASSURANCE REQUIREMENTS

For Hg CEMS:

- Daily calibrations---with elemental Hg or $HgCl_2$
- Weekly system integrity check (1 span point)
- Quarterly linearity check with elemental Hg or system integrity check with $HgCl_2$
- Annual RATA and bias test

SUPERIOR MEASUREMENT:

The Mercury Freedom System offers high sensitivity and a true real-time measurement:

- **High Sensitivity**: The specially designed CVAF bench operates under a superior vacuum thatallows the direct measurement of elemental mercury. The sample bench has high sensitivity
- **No interferences**: The CVAF method guards against interferences with acidic gases like SO2, anissue with Atomic Absorption Spectroscopy, because only mercury fluoresces at the chosen wavelength of light source, ~253.7 nm.
- **Real-time response**: Because the sample can be directly transported to the analyzer formeasurement, the Mercury Freedom System is able to generate a true continuous real-time response.

However, it must be recognized that the Mercury Freedom System requires more *support* than a generic CEMS. Our studies reveal that, by rule of thumb, that the Mercury Freedom System would require anywhere from 1.5 to 2 times the service resources needed for a conventional CEMS, a factor that is dependent on the application, familiarity with the system and regularity of service.