ISA Delhi Section

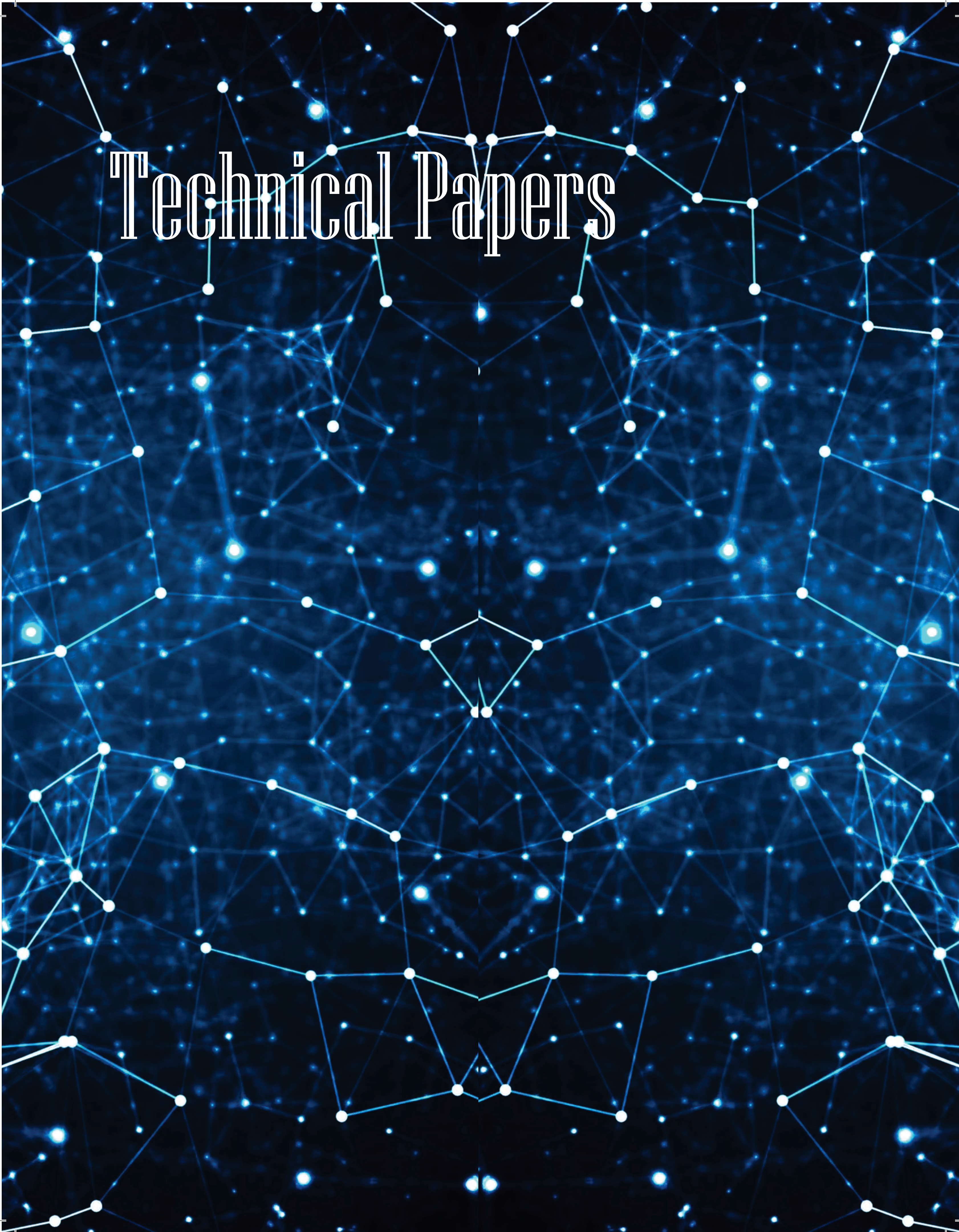
Petroleum & Power Automation Meet 2019
Program Details
Date-3rd & 4th May-2019
Hotel Taj Palace, New Delhi

DAY-1		03-May-2019 (Friday)		Pg no.
Inauguration Session		Time		
Registration		08:30 AM	09:30 AM	
Arrival of Guests of Honours	IOCL, NTPC, GAIL, EIL, IGL,	09:30 AM		
Welcome of Dignitaries		09:45 AM		
Lamp Lighting		09:50 AM		
Welcome address by ISA-D President		09:55 AM		
Address by Guest of Honours		10:00 AM		
Release of Souvenir		10:30 AM		
Honours & Awards Ceremony		10:40 AM		
Vote of Thanks by Convener		11:00 AM		
Inauguration of Exhibition		11:15 AM		
Networking Tea Break		11:30 AM	12:00 PM	
		12:00 PM	**01:00PM**	
CEO CONCLAVE :- "Leveraging Industry 4.0 for Industrial Process Control and Automation:- The Way Forward"				
Session-1	**Moderator : Mr. Alok Shrivastava**			
1. EMERSON	Mr. Anil Bhatia			
2. ABB	Mr. Madhav Vemuri			
3. SIEMENS	Mr. Umesh Sathe			
4. SCHNEIDER	Mr. Rajat Kishore			
5. DELOITTE	Mr. Gaurav Angira			
Networking Lunch Break		01:00 PM	02:00 PM	
Session-2		**02:00 PM**	**03:30 PM**	
1. Modular Automation		WAGO	Mr. Ulrich H. Hempen	109

2. Update on Digital Technologies for the Risk Based Inspection Program	GE	Mr. Kapil Bhardwaj	23
3. Digitalization and benefits	P&F	Mr. Arasu Thanigai	
4. Totally Integrated Automation and Totally Integrated Power for the Bioethanol Industry	SIEMENS	Mr. Hemant Jain	
Smart Quiz with Special Prizes			
Networking Tea Break	**03:30 PM**	**04:00 PM**	
Session-3	**04:00 PM**	**04:45 PM**	
1. Tunable Diode Laser based Analysers	E&H	Mr. Jiwan Jain	41
2. Advance Blending Solutions – Towards Better Refinery Margins	ABB	Mr. Ajay Patil	137
3. SPD MCR Technology available and its importance in Process Industry- Paper cum live demo	PHOENIX	Mr. Jens Willmann	85
Workshop & Hands on			
Session-4	**04:45 PM**	**05:30 PM**	
W1.	AMETEK	Mr. Jochen Geiger Mr. James Cross Mr. Anantha K	
a) Combustion Control as a Safety aspect for Process Heater and Power Plants			
b) Continuous Temperature Measurement and Furnace Optimization for Reformers and Process Heaters			
Smart Quiz with Special Prizes			
Free Time To Visit The Stalls	05:30 PM	07:00 PM	
Networking Dinner	07:00 PM	10:00 PM	
Day-2	**04-May-2019 (Saturday)**		
Session-5	**09:30 AM**	**11:00 AM**	
1. Innovative Non Contact Non Nucleonic Elemental and Moisture Analyser for Coal	EIP	Dr. Abhishek Goyal	45
2. Bridge HSE gaps with Wireless toxic gas monitoring	EMERSON	Mr. Tan ShingYenn	133
3. Leveraging Iot In Mission Critical Industrial Control Systems	NTPC	Mr. Prem Prakash Rai	77
4. Demystifying API 670,Safety & Cyber Security	MEGITT	Mr. Vivek K Tyagi	71
Smart Quiz with Special Prizes			
Networking Tea Break	**11:00 AM**	**11:45 AM**	

Session-6		11:45 AM	01:30 PM	
1.	Latest Innovations in Video wall technology and trends from DLP rear projection to Seamless Fine pitch LED video wall	PYROTECH	Mr. Kuldeep Singh Rathore	93
2.	Test & Calibration- Key to Safety & Efficiency	FLUKE	Mr. Satyajit Nath	
3.	Emerging Needs and Requirements of Industrial Automation: Do We Raise An Alarm – Always?!	McDERMOTT	Mr. Indranath Chatterjee Mr. Atanu Chakravarty Mr. Tanmoy Majumder	65
4.	Mercury Monitoring at Stack	THERMOFISHER	Mr. Anant Ghadigaonkar	101
	Smart Quiz with Special Prizes			
Networking Lunch Break		**01:30 PM**	**02:30 PM**	
Session-7		**02:30 PM**	**03:45 PM**	
1	Better and faster control on Flares in Refineries and Petrochemical Plants	AMETEK	Mr. Jochen Geiger Mr. James Cross	
2	Smart contract - A trusted system for empowering Process Industries	EIL	Mr. Arupjyoti Saikia	125
3	Dynamic simulation analysis for efficient control of Centrifugal Gas Compressors to ensure safe and reliable operation of LNG plants	BECHTEL	Mr. V V V Prakash	3
4	Next Gen Automation in Refineries – Fast Forward Control	UOP	Mr. Castro Baskaran Mr. Animesh Das Mr. Priyanka Karan	
	Workshop & Hands on			
Session-8		**03:45 PM**	**04:30 PM**	
W2		PHOENIX	Mr. Manuel Ungermann	
1	SIL 3 relays in ESD Application & live Workshop where in physically Relays will be powered and demonstrating of Error LED Indication of SIL 3 contacts and its importance along with Safe Coupling Relays with Force guided contact for Process Industry			
	Smart Quiz with Special Prizes			
	Felicitations Ceremony	04:30PM	05:15 PM	
Networking Tea Break and END of the PPAM 2019		05:15 PM	06:00 PM	

Technical Papers



ICSSDESIGN WITH REMOTE I/O SYSTEM

S Thiruvari, Satya Prakash Jain Bechtel India Pvt.Ltd, Gurgaon

ABSTRACT

In this paper,advantages ofRIO in Oil &Gas/Petrochemical industry are discussed.

KEYWORDS

BPCS, SIS, FGS,RIO,ICSS, CAPEX and CTO.

INTRODUCTION

In Oil & Gas production facility, all the daily activities are being carefully monitored and controlled to guarantee smooth production and to ensure environmental and personnel safety. Heart of the Control building is the Integrated Control and Safety System (ICSS), which regulates the production process by means of the Basis Process Control System (BPCS), SafetyInstrumented System (SIS) and Fire and Gas detection System (FGS). Traditionally for ICSS, conventional IO system (i.e. field instruments withjunction boxes, multipair home run cables,marshalling cabinet at control building) is used. In this paper advantages of RIO concept over traditional I/O concept are discussed.

TRADITIONAL I/O SYSTEM

Traditionally, automation engineer needed to know the required number and type of I/O points before designing hardware and building cabinets. Each type of I/O needed a certain type of I/O card. Each I/O card had to be tied to its respective controller.

The approach for connecting field signals to process controllers follows a common formula: the field signal wiring is first brought to local junction boxes, which are then consolidated into more centralized junction boxes, which are then grouped into multi-core cables.These multi-core cables are then brought into ICSS marshalling cabinets.

With the conventional design of I/O system, accommodating late changes including addition, deletion or change in the I/O types affect the project schedule due to the delay in finalization of marshalling panels with additional risks of complex cross wiring, cost escalation and engineering rework.

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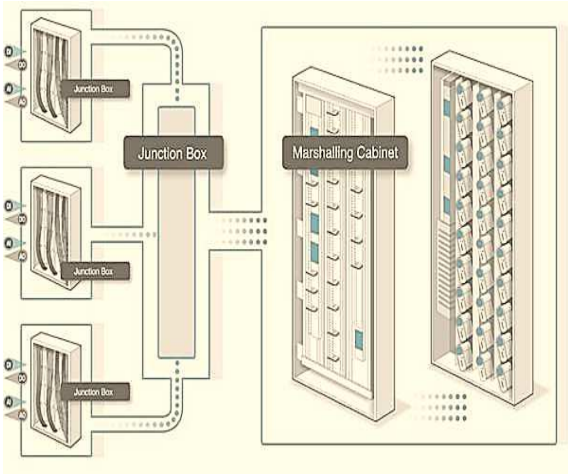
Figure 1-Conventional I/O system



REMOTE I/O SYSTEM

RIO will enable reduction of CAPEX (installation & commissioning efforts, cabling, footprint etc.).Moving I/O modules out into the field and closer to process instruments can eliminate the need for multi-core cables and marshalling cabinets and simplifying the field-to-control room architecture. Followings are benefits in using the RIO:

Since field signals can be landed directly on I/O terminals, the need for marshalling is eliminated. This has many benefits, including reductions in material costs, such as cabinets, conduits, home run cables, cable trays, and supports. It also reducesproject labor costscommissioning costs, documentation costs and maintenance easier.

The overall system footprint in the control building is reduced because the I/O is located directly at the process. The only cable runs to the control building are I/O communication cables.

RIO system in fast-track projects are easier to accommodate as the RIO system can be tested and shipped prior to completion of field designs.

Reduction in home run cables – Multiple home run cables are replaced with two redundant fiber optic communication cables and power cables. This provides redundancy for signals from the field that were previously simplex signals. Savings include a reduction in copper wire, cable trays and labor for installing cables. Wiring manufacturers produce a dual-purpose wire (Composite cable) that includes the fiber optic and power cables in one wiring package, which simplifies the installation process. By using the RIO system, we can reduce 40% wiring cost.

Figure 2-Minimize Expensive Wiring

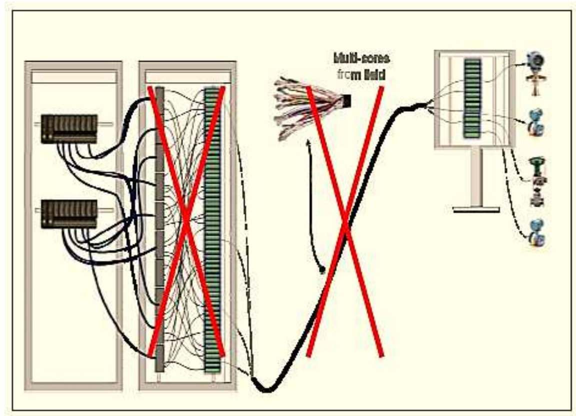
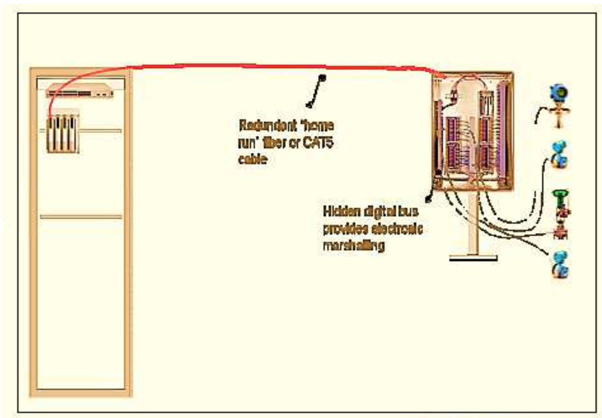


Figure 3-Maximize Inexpensive Fiber



Any signal type can be connected to any channel without the need for additional hardware or interfacing modules. Cabinets can be standardized, since any standard field signal can be connected to any I/O channel. Configure to order cabinets (CTO) in the RIOare ready to be connected to the field I/O's. The RIO eliminates the need for any internal cross wiring and I/O rationalization. "No Rules for I/O assignment". Allow fast changes for following.

- Addition of I/O's
- Move I/O's (Change controller)
- I/O type (DI to AI)

Commissioning times are reduced since the system is tested during FAT all the way to the junction box. Errors in wiring on the home run cables are removed since the home run cables are non-existent.

Engineering effort -The SPI database is greatly simplified due to a removal of all marshalling terminals between the field junction boxes and the control building. This will eliminate the loop diagrams.

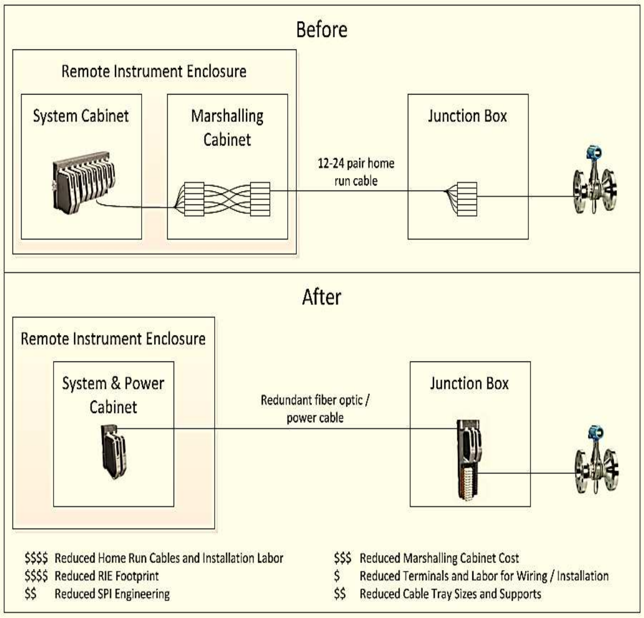
MTBF – No Single point failure in the RIO.

MTTR – Mean time to repair is less for RIO compare to Conventional I/O concept.

RIO boxes are available with 32,48,64,96, 128 Channels etc. in the market from various ICSS vendors.

RIO are available with Hazardous area classification Class I, Division 2, Group A, B, C, D in the market.

Figure -4



PROJECT EXECUTION:

REMOTEI/OBOX DESIGN

RIO box design can be done at the earlier stage of projectas RIO quantity can be decided based on I/O count, not on I/O type distribution.

REDUCE THE IMPACT OF LATE CHANGES TO WIRING

Late changes inevitably happen. Wiring changes can significantly add time to the schedule during FAT, commissioning or startup. The RIO solution can mitigate the risk associated with these changes by simplifying the amount of work that must take place for wiring changes. Traditional control systems are based on multi-channel I/O cards for a typeof I/O (digital, analog, thermocouple, etc.). If a wire is connected to the wrong I/O terminals in a traditional system, the I/O must be re-wired to land on the correct I/O card and terminals, and subsequent changes in the software must take place to program the I/O.

RIO approach can accept any signal type (analog, digital, input, or output), late arriving changes in the instrumentation package can be accommodated throughsoftware configuration or replacing the only characterizing module in the field.So, they can behandled in hours rather than days.

ADDITION OF NEWLY ADDED I/O's

Adding room for spare devices is much simpler. Since every I/O channel can beconfigured as any point type through software configuration or replacing the characterization module, it is simple to adapt to late wiring changes. Instead of allocating I/O modules of each point type, which may or may not be used, configurable I/O modules are available for multiple point types.

REDUCTION IN LOOP CHECK AND COMMISSIONING TIMES

There is no need to go out and verify that the device is connected to the correct I/O point as this is automatically verified by the system. Calibration checks and loop verification can be greatly reduced due to the remote advanced features of the system.

SAVINGS

Afurther analysis, when compared to traditional wired analogue infrastructure the cost saving due to RIO system is shown in below figure.

Activities	% Savings
Installation Material	12%
Cable Trays	20%
Engineering, Procurement	45%
Cable Routing	75%
IO design	45%
Late change Impact	50-100%

CONCLUSIONS

For plants where instrument locations are highly distributed, RIO can be a very cost-effective for ICSS design.

ACRONYMS

ICSSIntegrated Control and Safety System
BPCSBasic Process Control System
SIS Safety Instrumented System
FGS Fire and Gas System
CAPEX Capital expenditures
RIO Remote Input output
CTO Configure to Order

REFERENCES

Pictures used in this paper are taken from Honeywell and Emerson RIO system Cutsheet

BIOGRAPHIES

Mr.S Thiruvari was born in Tenkasi, Tamil Nadu, India in the year 1981. He graduatedin Electronicsandcommunication engineeringfromUniversity of madras, India.He joined Control systems, Bechtel in December 2012. At present he is working as Senior Control System Engineer -II.

Mr. Satya Prakash Jain was born in Kota, Rajasthan, India in the year 1971. He graduated in Electronics andcommunication engineeringfromUniversity of Rajasthan, India.He joined Control systems, Bechtel in March 2005. At present he is working as Engineering Group Supervisor.

APPLICATION OF AUTOMATION USING ANALYTICAL RESULTS OF ON-LINE POLYMER ANALYZERS IN PETROCHEMICAL PLANT TO IMPROVE PLANT EFFICIENCY

Gangaram Pramanik, Sunil Bhandari, Subhro Sengupta
Bechtel India Private Limited, Gurgaon

ABSTRACT

Application of Online Analyzers in Petrochemical Industries plays a major role to enhance productivity by reducing off-spec product generation through Feed Analysis, Reactor Composition Control and finally Mechanical and Chemical Properties analysis of Polymer pellets after Extrusion. Intent of this Paper is to emphasize on Application of On-line Polymer Analyzer as initiator for automation to maximize plant throughput and to minimize overall Production cost. The usage of online polymer analyser ensures smooth operation as well as quality of the final product. The implementation of advance control demonstrates the results of dynamic analysis at various stage of production and taking necessary preventive action to maximize profitability.

The Polymer analyser technologies which are developed and applied to the following areas after extrusion either at laboratory or On-line:

1. Measurement of Melt Flow Index to control Co-polymer and Hydrogen ratio.
2. Monitoring Polymer Quality for Mechanical Properties
3. Continuous Monitoring and control of film purity using Optical Property
4. Pellet Analyser to detect contamination as well as size and shape distribution

Traditionally all the above analysis performs at Laboratory and Operator takes corrective action based on result through manual Intervention for Controlling additives leading to huge time-lag. However, using those result as input for adjustment of additivation within recipe Improves Response Time and thereby reduces Off-Spec Production and ultimately Improves Plant Efficiency.

KEYWORDS

Polymer Plant, Polymer Resin Quality, Melt Flow Index, Online Polymer Analysis, Plant Performance Optimization, Utilization of Advance Automation

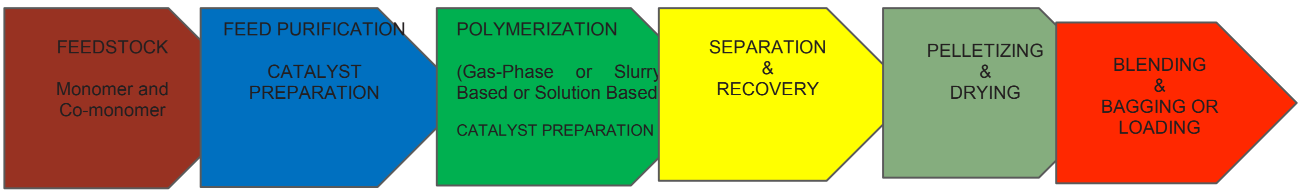
INTRODUCTION

Polypropylene (PP) and polyethylene (PE) are genericname belongs to the group ofpolyolefins, that are derived from agroup of base chemicals known asolefins. Polyolefins are made of joining together small molecules(monomers) to form long-chainmolecules (polymers) with thousandsof individual links using avariety of catalystssuggested by technology provider.The base monomer for PP is propylene and PE is ethylene, those are in gaseous state at room temperature,but when linked together aspolymers, it forms tough, flexibleplastic materials with a large varietyof Industrial as well as domestic applications. Thelinking process is referred as polymerization.

Each Polymer technologyproduces unique combinations ofpolymer characteristics.Polyolefinsare the world'smostly produced and fastestgrowing polymer family becausemodern polyolefins cost less toproduce and process than otherplastics or conventional materials. Polyolefins are available in manyvarieties. They range from rigidmaterials, which are used for carparts, to soft materials such asflexible fibres. Some are as clearas glass; others are completelyopaque. Some, such as microwavefood containers, have highheat resistance while others melteasily.All polymer plants require process analytical Instruments to collect reliable andaccurate information for process monitoring, control,product quality, plant safety andenvironmental compliance.

Basic steps of Gas-Phase based Polymerization may be represented as below:

The below steps may vary depending on selection Polymer Technology



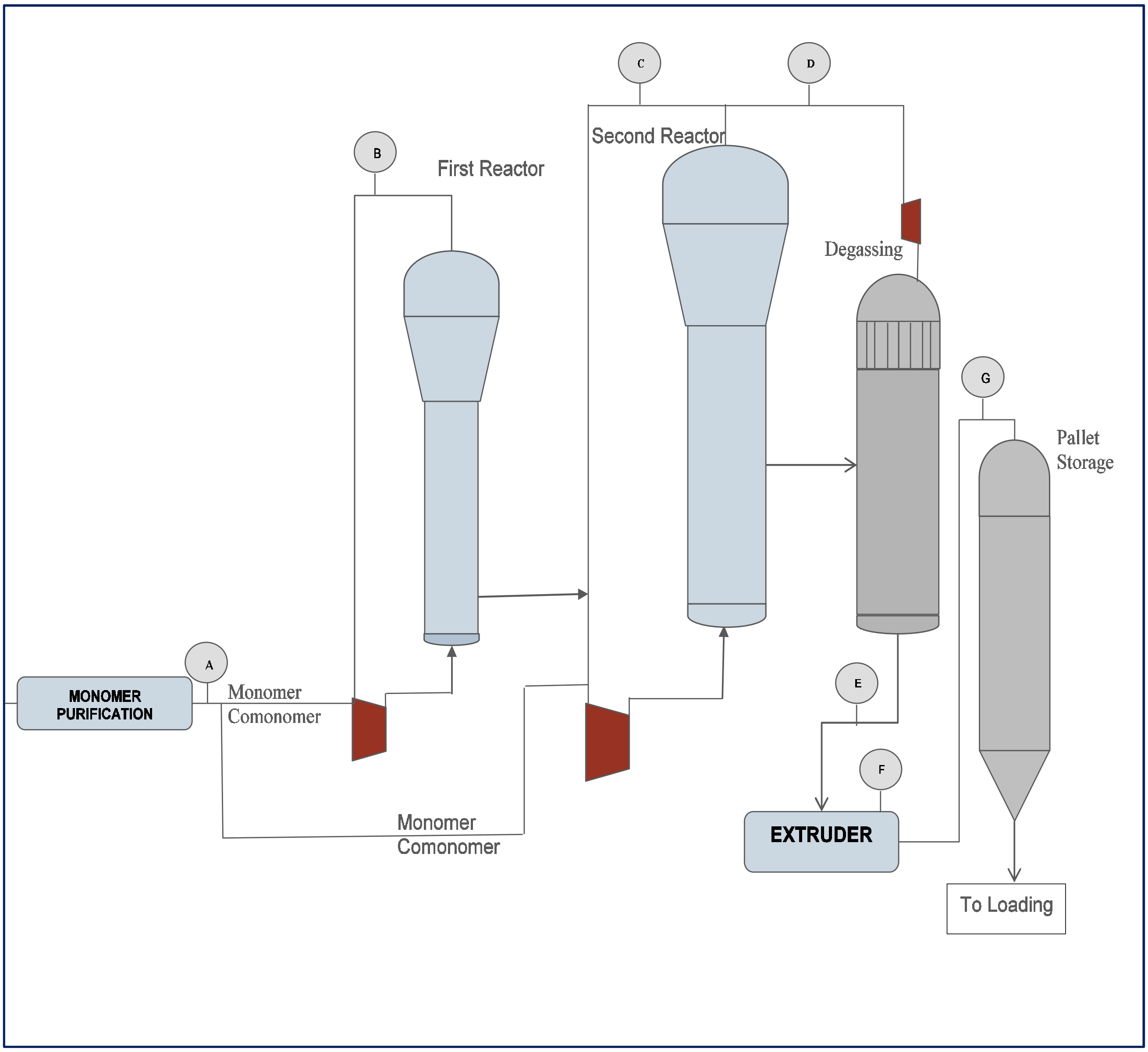
TYPICAL APPLICATION OF ANALYZERS AT DIFFERENT STAGE OF POLYMERIZATION PROCESS

Process analytical devices are most critical and indispensablepart of any polymer plant because it provides the controlsystem and the operator with key datafrom the process to monitor and control the product quality. Based on Technology and Licensor they may vary however the typical applications can be categorized in to major groups.

1. Feed Analysis of Monomer and Co-monomer
2. Reactor Composition Monitoring and Control
3. Emission levels in compliance with local regulations

5. Finally Pellet Quality Monitoring and Control

Typical Sampling points of a Gas-Phase Polymer Plant.



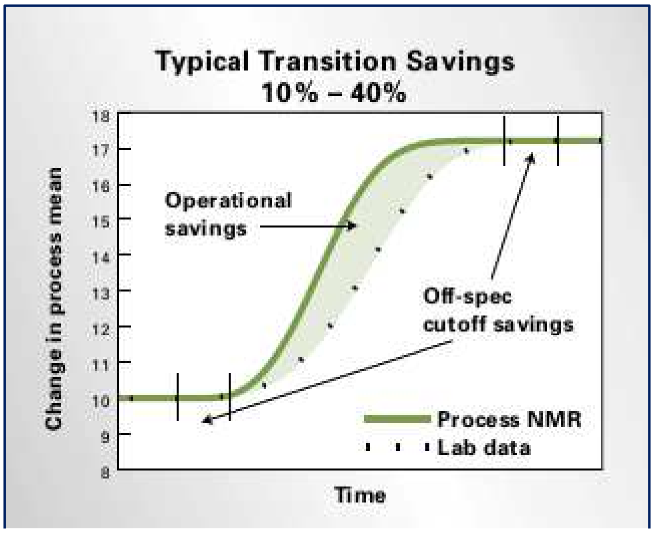
4. Measurement of Melt Flow Index

TYPICAL SAMPLING POINTS

Sampling Point	Sample Steam	Component	Purpose
A	Monomer and Co-Monomer Feed	Moisture, SOx, NOx, COx	Performance Monitoring of Dying Unit
B	Recirculation of 1st Reactor	Methane, Ethane, Propane, Ethylene, Propylene, Butene/Hexene, Hydrogen	Reactor Composition Monitoring and Control
C	Recirculation of 2nd Reactor	Methane, Ethane, Propane, Ethylene, Propylene, Butene/Hexene, Hydrogen	Reactor Composition Monitoring and Control
D	Recycle Gas	Methane, Ethane, Propane, Ethylene, Propylene, Butene/Hexene, Hydrogen	To Monitor and Control off gas flow from Polymerization unit
E	Polymer Powder	Hydrocarbon and Oxygen	Residual Hydrocarbon and Oxygen for safety
F	Molten Polymer	Melt Flow Index	To Monitor Melt Flow Index for various grade
G	Polymer Pellet	Pellet Quality	To Monitor and Control Pellet Shape, Size and Optical Property

AUTOMATED ADDITIVATION THROUGH ONLINE POLYMER ANALYZER

Polymer properties can be categorized as Mechanical, Chemical, Optical and Physical.However, Mechanical and Chemical Properties are specified by Technology providers based on various grades of product and are monitored and controlled through Composition analysis using Chromatograph during polymerization process. Optical property controlled through additivation per recipe is recommended by Licensor and as per Laboratory Result. Physical Property of Polymer pellets is monitored and controlled manually based on visual inspection and Laboratory result leading to massive off-spec generation due to huge time lag. Application of On-line Polymer Analyzer may be used as initiator for automation to minimize overall Production cost. The usage of online polymer analyser ensures smooth operation as well as quality of the final product. The implementation of advance control required rigorous transient analysis with the objective of controllability and stability.

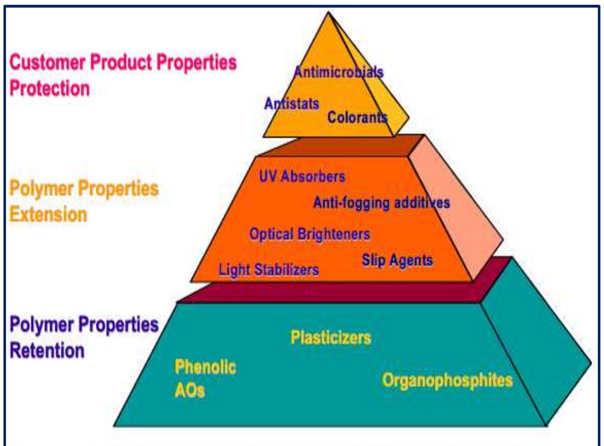


Source: LexMar Global Inc.

TYPICAL APPLICATION OF SOLID AND LIQUID ADDITIVES

Additives are used in the process of pelleting PE or PP resins to retain and enhance polymer properties for long term stability.

The major additives are typically used to protect, enhance and retain polymer properties are as shown:



Additives can provide additional properties or effects beyond stabilization.

1. Calcium Stearate/ Zink Stearate are generally use to make acid radical free and act as acid scavenger
2. Tin Oxide / Hostarinare normally use as UV protector
3. Irgafos / Irganox are act as Anti-oxidant to improve and control Yellow index
4. Amaid/ Finawax are use to control Optical property and to improve clarity

The above additives are some example and the typical names the actual selection of additives and their quantities in % or ppm based on different grade of final product decided by Technology provider.

MEASUREMENT OF PELLET QUALITY

The following critical Analyzers are used to monitor and control of Physical and Optical properties of polymer pellets after extrusion process is over.

Melt Flow Index Analyzer

Melt flow Rate from process extruder measured with separate Sensor unit and Panel Mounted Processing unit to compute and Communicate Melt Flow Index (MFI).

Online MFI Analyzer provides information to operator on how the polymerization process is happening in Reactorand to take necessary preventive action. Earlier this was built with two stepper motor arrangement however due to plugging issue and frequent failure of stepper motor manufacture has developed with a bypass arrangement with an additional stepper motor which provides reliable and accurate result to operator. Analysis results & instrument failure signals of the two analyzers shall be transmitted to DCS via a serial link using RS485 MODBUS protocol or Profibus. Analysis results shall also be transferred in analog 4-20mA to DCS.

Polymer Quality Analyzer

The Nuclear Magnetic Resonance (NMR) Pellet analyzer automatically measures multiple physical properties of polymer like Tacticity, Flex modulus, Crystallinity, Melt Index etc. This proven technology is available as non-destructive analyses of powders, pellets or slurries and provides results directly communicated to the plant Distributed Control System (DCS). High performance data analysis provides reliable measurement of process parameters for Advanced Process Control (APC). It is a complete solution designed for harsh industrial conditions, and includes sample extraction, sample handling, data analysis, software control and plant interface.

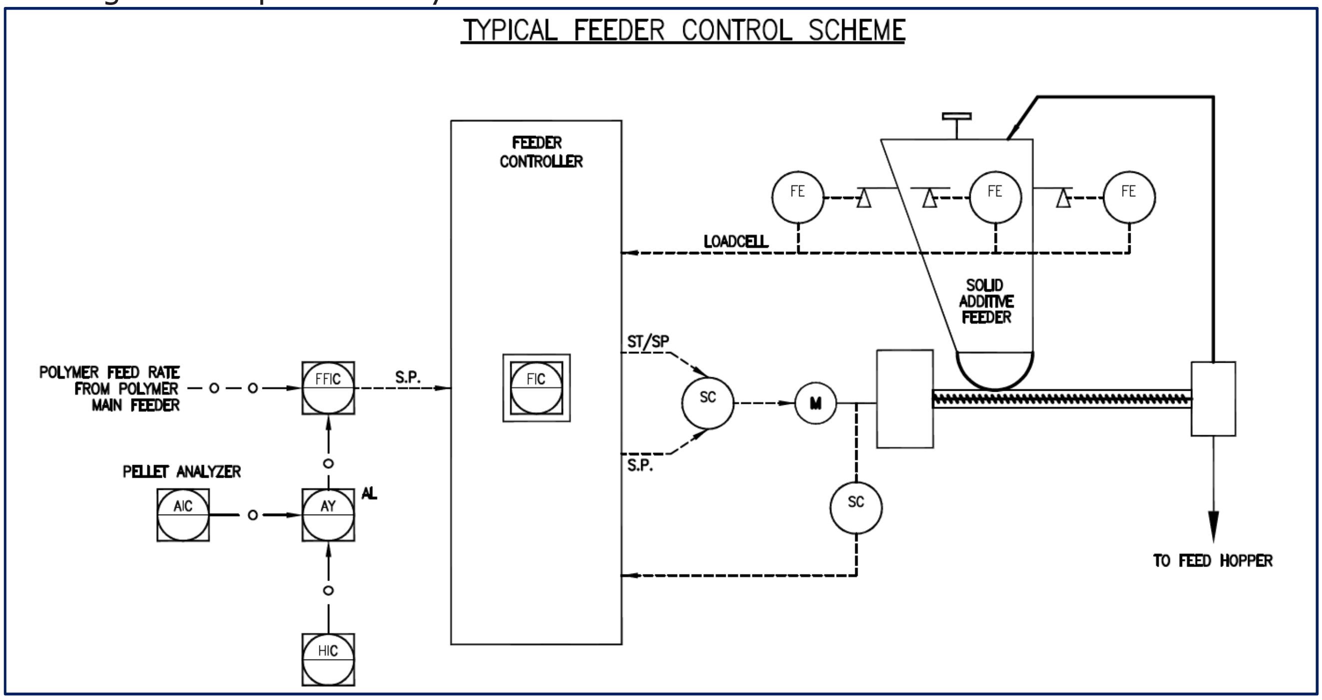
Pellet Analyzer

Online Polymer Pellet Analyzer System used for detection of contamination as well as size and shape distribution of granules. It is a combination of Optical CameraSystemsoperate differently. The first one inspects transparent and opaque granules for inhomogeneities, enclosed defects and color aberrations. It uses a colour camera torecognize and differentiate between colour changes.

The second one is called Pellet Shape and Size Detector, counts and measures size and shape of the pellets. It also detects twins, triples, spikes and dog-bones as well as pellets with fines and tails. The system can also indicate dust and tails proportion. Analysis results can betransmitted to DCS via a serial link using RS485 MODBUS protocol or Profibus or 4-20mA to DCS.

AUTOMATED ADDITIVE CONTROL

Automated Additive feed control is achieved through solid additive feeders used in Polymer industries. To further advancement for implementing Advance Process Control (APC) by utilizing online pellet analyzer which can be cascaded with recipe control within the allowable tolerance provided by Licensor for a particular grade of product. A typical Advance Process Control scheme can be achieved through an Algorithm considering input from Pellet Analyzer reading as well as the set point recommended by Technology Provider. The algorithm must be developed in consultation with Licensor. A typical control scheme can be represented as shown below:



DOCUMENTATION

Documentation is an essential part of any automation system and required to performinstallation,commissioning, operation and maintenance Control system. The documentation needs to align with Owners preference, Licensor’s agreement and finally both device manufacturer and Control system provider Recommendation. Therefore, it is very important to have upgrades severaltimes during planning and implementation of proposed scheme in plant. The document should contain "know-how" of the systemfor easy operation and maintenance of the Plant.Documentation provide evidence that control system development cycle has followed Specified engineering processand final product conforms to requirement set forth.

CONCLUSION

This paper is outlined the idea to capitalize the installed high value Measurement and Control Devices. However, there may have adequate means and ways will emerge over a period to establish the performance of the proposed Advance Process Control scheme at plant level in a wider fashion.

ACKNOWLEDGEMENTS

Relevant information on polymer technology, application of additives as well as various product futures written here used from internet available in public domain.

BIOGRAPHIES

Gangaram Pramanik wasgraduated in Instrumentation and Electronic Engineering fromJadavpur University. He joined Haldia Petrochemical Limited in 2000. At presenthe is working as Senior Engineer and associated with design, engineering andprocurement of Instrumentation and Control Systemsat Bechtel India Private Limited. He has hands-on experience on various Polymer Technology.

Sunil Bhandari is a Senior Control Systems Supervising Engineer working in Bechtel since 1995. He has more than 30 years of rich experience in Instrumentation & Controls related to Oil & Gas, Refineries and Petrochemicals. He worked in various national and international projects.

Subhro Sengupta is a Certified Automation Professional (CAP) from ISA working as Assistant Chief Engineer — Control Systems in Bechtel. He has more than 34 years of experience in Instrumentation & Controls related to Oil & Gas, Refineries and Petrochemicals in various national and international projects.

DYNAMIC SIMULATION ANALYSIS FOR EFFICIENT CONTROL OF CENTRIFUGAL GAS COMPRESSORS

V VV Prakash, Anjaneyulu Kalluri
Bechtel India Private Limited, Gurgaon

ABSTRACT

We are witnessing an increasing demand for Natural Gas as a proven, reliable and safe energy source due to growing concerns over global warming and environmental problems worldwide. As the Natural Gas provides significantly lower amount of environmental impact than Oil or Coal, the demand for Liquefied Natural Gas (LNG) plants is receiving much attention, which in turn increasing the demand for Process Gas Compressors used in the plants. Typically, Liquefied Natural Gas (LNG) plants comprise of severaltypes of Gas Compressors like Feed Gas, Regeneration Gas, Fuel Gas (with Gas Turbine), Main Refrigerant Gas and Boil Off Gas etc., which are the major contributors of the plant capital investment and operational costs. The sustained performance of the Gas Compressors with an efficient anti-surge control systemis very critical to boost and maintain the plant operability. The dynamic simulation or modelling strategy in the Compressor Control facilitates design optimization, minimize disturbances associated with surge which in turn attribute to a safe and reliable operation of LNG plants with enriched productivity.

KEYWORDS

Centrifugal Gas Compressor, Anti-Surge Control, Dynamic Model or Simulation, Valve Characteristics, Validation of Dynamic Simulation

INTRODUCTION

A typical Centrifugal Gas Compressor consists of several components like a Suction drum, a Compressor, a Driver, an Intercooler, an Anti-Surge control valve and an Anti-Surge control System.The Gas Compressors are highly prone to an undesired event called Surge phenomenon, which is evolved in the form of the backward flow of the gas from the discharge of the Compressor to the suction.

As the surge will damage the internal components of the Compressor, reduce the Compressor life time and

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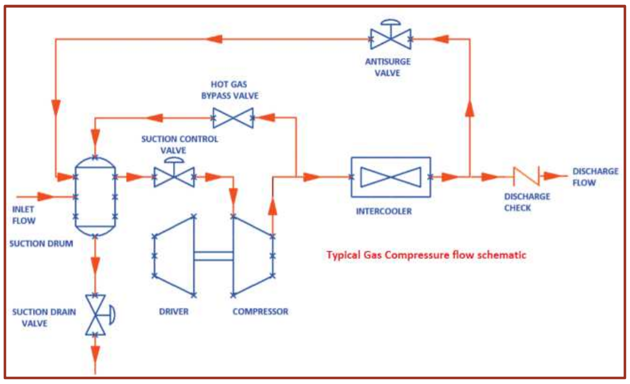
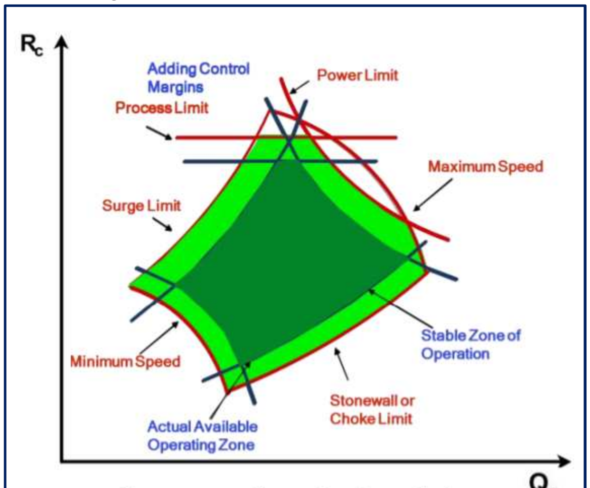
the impact will be further extended to the internals of upstream equipment; hence it is very important to prevent the surge occurrence. The Anti-Surge control systems are designed to safely operate Compressor trains by preventing the Compressors from surging, but also handle pressure and flow transitions seen during start-up, load transfer, shutdown and power interruption.

The Anti-Surge control systems, Anti-Surge control valve and Plant DCS are integrated to prevent damage to the Compressors, Control valve, upstream equipment and the Plant. The conventional methodology of preventing surge includes installing a Hot Gas Bypass valve (HGBV) and Anti-Surge Valve (ASV) in the recycle line of the Compressor.



The operating zone of a Compressor is a region constrained on almost all sides by additional boundaries that are to be controlled or at least must be taken in to design. The operation of the Dynamic Compressor can well be represented in the Compressor map, on which the Volumetric flow Q_s is plotted on X-axis and Compression ratio R_c on Y-axis.



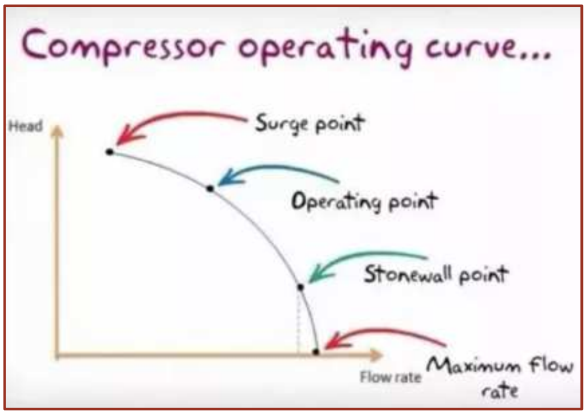
Compressor Operating Boundaries

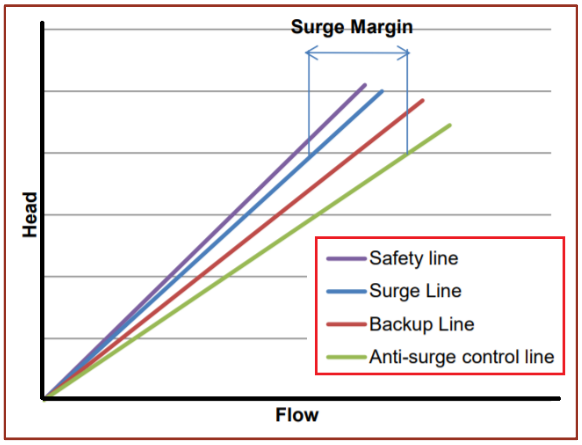
ANTI-SURGE CONTROL

The main goal of the Anti-Surge Control is to prevent the Compressor from Surging. This is done by modulating the recycle Anti-Surge valvethat allows the flow back to the inlet. It will open if the flow is too close the surge flow and thereby increase the flow through Compressor and prevent surge.

As the surge can damage the Compressor, it is important that the anti-surge controller response is fast and accurate. To achieve this requirement, a more advanced controller than the normal PID is used. The set point of the controller is set to have a defined distance to the surge line of the Compressor called the surge margin. The surge margin is calculated continuously during the operation of the Compressor.

The occurrence of the surgecan be observed onthe Compressor curve which isplotted between flow rate and suction head.





Surgingcan be observed if the flow falls below setpoint andthe Compressor operating point on the curve crossesthe surge line. As the occurrence of surge and itsimpact on the Gas Compressors and the upstreamequipment in various plants is continuingfor a longer period of time, the Compressor control mechanism adapts dynamic simulation method to facilitate stabilization of the Compressor operation by compensating the disturbances and avoid surge phenomenon.

DYNAMIC SIMULATION OF COMPRESSOR CONTROL

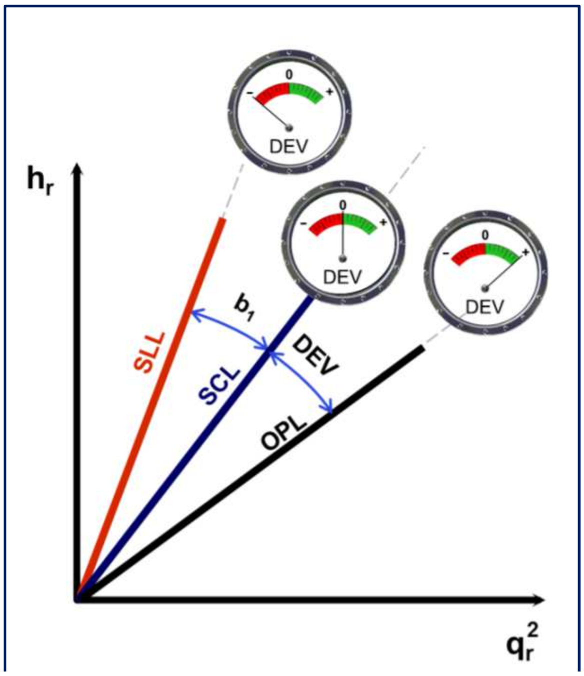
An innovative automation approach has been successfully evolved in developing dynamic simulation of the plant, with various scenarios, which are based on all the possible and variety issues of a gas compression system like changes in the suction pressure, flow and changes in the gas composition.

The accuracy of the base model is first validated in steady state against plant operating conditions. The dynamic data like axial stage inlet guide valve (IGV) closing speed, control and actuator delay, valve stroke time, and other dynamics were based on the available data from the plant.This innovation processhas little complexity in effectively collaborating the efforts with all the stake holders like Compressor vendor, ASV and HGBV Suppliers, Detail design engineering team and Dynamic simulation group in gathering the data like final piping isometrics, equipment volumes from S3D model, purchase data of ASV and HGBV, as-tested compressor performance curves and data, but the results deriving from the simulation are leading to positive solutions in overcoming the surge phenomenon.

The main objective of the dynamic study is to improve the efficiency of anti-surge control strategy in mitigating the associated risk. The key aspect in this objective is selecting "right" characteristics of the Anti-Surge valve, which has an influential contribution in overcoming Surge.

SELECTING THE ANTI-SURGE VALVE CHARACTERISTICS

The Anti-Surge valve provides adequate anti-surge protection during the worst possible surge-inducing upset in any operating regime within the operating envelope of the Compressor.



The distance between the Surge Control Line (SCL) and Surge Limit Line (SLL) is mainly a function of the Anti-Surge control system response time, Anti-Surge control valve characteristics, and the control algorithm used.

The selection of vital characteristics of Anti-Surge Valve include

- Sizing the valve for 1.8 to 2.2 times the Cv required for Surge conditions
- Anti-Surge valve must not be oversized such that when fully open, it drives the Compressor in to Choke region or it introduces Controllability issues
- Full stroking time to open, under positioner control, of less than 2 seconds with less than 0.4 seconds of time delay without significant overshoot and closing time, and under positioner control of no more than 8-10 seconds
- Linear (preferred) or equal percentage valve characteristic
- Positioning accuracy of 1 percent or better and use of single solenoid valve to de-energize to trip.
- Design modifications in the ASV pneumatic circuit (without compromising the reliability of the ASV actuator) will avoid doing any software modifications in the standard Compressor PLC program.
- Changes in the piping design and modifying the ASV to ramp

behavior to avoid impact on the upstream equipment due to excessive reverse flow in the event of surge.

The anti-surge valve must stroke quickly and precisely in response to complex command signal profiles generated by an anti-surge controller.

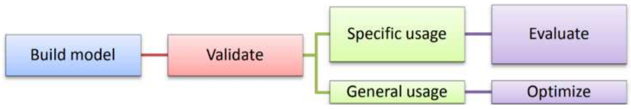
The anti-surge valve actuation system typically includes

- ❖ A digital positioner that provides for both slow and fast command signals of the anti-surge controller
- ❖ Devices (e.g. volume boosters for pneumatic actuators)that amplify action of the moving fluid of the actuator in both opening and closing directions
- ❖ A quick-dump device (e.g. solenoid valve) that permits the quick opening of the anti-surge valve in response to an ESD (emergency shutdown) signal that may be generated outside of the anti-surge controller.

VALIDATION OF DYNAMIC SIMULATION RESULTS

To use a dynamic model of a real system to draw accurate conclusions, it is essential to validate the model.The validation is done by examining the real system and comparing its behavior with the model.

All the different operating scenarios of Compressor like steady state, shutdown and start-up are included in the analysis. During the validation process, the simulation results will help to resolve many of the Compressor operational issues and allow refining the Compressor control to provide better protection of the Compressor against the disturbances.



As depicted in the above picture, the model is validated by simulating specific operating conditions and comparing results from the plant. The model is then remade to simulate and evaluate the design of a proposed modification.Based on the results, the activities of process tuning and optimization using dynamic models shall be exercised.

CONCLUSION

The dynamic simulation analysis provides identification and elimination of design issues pertaining to the operation of the Compressor which in turn benefits the reliable operation of the plant in the entire life cycle.

The analysis will highlight the potential design issues, recommended modifications can be tested and verified in the model prior to implementation. The analysis has enhanced the precision, capability and credibility to develop realistic and reliable solutions for the actual plant system.

BIOGRAPHY

VVV Prakash, was born in Andhra Pradesh, India in the year 1971. He is currently working in in Bechtel India Pvt. Ltd, Gurgaon as Engineering Group Supervisor in Control Systems Engineering. He has been working on OG&C, Power and Mining & Metal Projects for the last 25 years. He was ISA Delhi member since 2008 and submittedTechnical paper on "Green House Gas Emissions monitoring" in ISA conference on Power Automation Technology event POWAT-2012.

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Update on Digital Technologies for the Risk Based Inspection Program

Kapil Bhardwaj
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Abstract:
Historically the Risk Based Inspection methodology has been divided between the so called ***quantitative*** approaches based on API RP 581 *Risk-Based Inspection Technology*and the many other methods which are classified as ***semi-qualitative*** and comply only with API RP 580*Risk-Based Inspection*. The upstream and downstream sectors of the oil and gas industry are the typical adopters of a quantitative API RP 581 approach while the petrochemical and chemical industries have been adopting simplified, semi-qualitative API RP 580 based solutions. The current selection practice is to identify the most suitable approach to the business and basically capture the benefits, but also live with the disadvantages of the chosen method.

A quantitative method is characterized as being comprehensive and detailed, but has the disadvantage of requiring a big amount of data and being time consuming, which drives a long implementation time and is challenging to manage in a large equipment base. On the other hand, a semi-qualitative method requires less data and time to implement, but may result in a less-than-adequate inspection strategy for the most critical equipment.

Given the benefits of both methods, the ideal situation is to have both available, supported by a selection process to define which assets which are better suited to be manage by each methodology. The criteria for selecting which method to use can be also risk based however with fewer rigors, characterized by a quick screening, utilizing a company-defined asset criticality risk matrix. The assets which are high critical are the ones selected for a quantitative (based on API RP 581) method track, and the assets which are moderate to low risk take the semi-qualitative track (based on API RP 580).

Regardless of the method chosen, the output of the risk based inspection analysis is conceptually the same. The analysis will produce a detailed inspection plan to be executed in the field and a monitoring strategy based on the API RP 584 *Integrity Operating Windows* defined as the critical process parameters which can eventually influence the probability of failure of the asset.

Keywords: risk-based inspection, API RP 580, API RP 581, API RP 584, integrity operating windows, risk matrix, risk-prioritized inspection, risk-informed inspection.

How to Benefit from the Many Approaches to Risk-Based Inspection Analysis

Introduction

As companies operate in today's competitive environment, owner operators are continuously working to improve process safety and environmental stewardship while accomplishing their business objectives of operating in a cost effective manner. While pursuing these objectives, one of the methodologies that has gained widespread acceptance is risk-based inspection (RBI).

Risk-based inspection drives the usage of inspection resources in a more efficient and effective way, helping companies make decisions about inspection planning with a higher degree of confidence while ensuring compliance.

The American Petroleum Institute (API) Recommended Practice 580 standard outlines the essential elements of an RBI program specifically as it pertains to secondary failures or failures associated with loss of containment and use of inspection activities to manage the risk associated with these type of failures. API RP 581 provides quantitative risk-based inspection (RBI) methods that support the minimum guidelines presented by API RP 580.

API RP 580 proposes the application of risk based inspection methods in the hydrocarbon and chemical process industries.

It is axiomatic in the industry that an increase in the degree and frequency of inspections of fixed equipment is going to reduce the overall risk of a plant. The practice demonstrates that this is true, until a certain boundary is reached. In specific circumstances, increasing the degree or frequency of inspections can actually increase the risk, causing additional deterioration (e.g. moisture ingress in equipment with polyphonic acid; inspection damage to protective coatings or glass-lined vessels).

Risk based inspection is a method which includes analyzing a potential increase on the probability of failure by evaluating different combinations of inspection methods and intervals in an optimized manner, targeting to achieve the lowest practical residual risk.

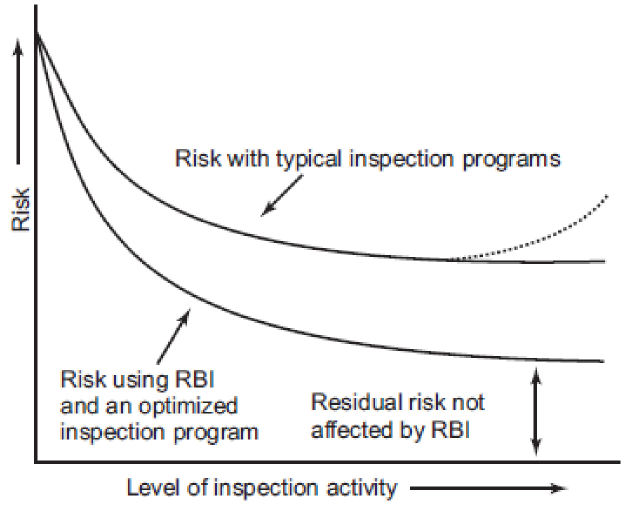


Figure 1 – Residual risk expectation by having a RBI program in place. (Source: API RP 580)

The hydrocarbon and chemical process industries globally have reached a maturity level where the adoption of a RBI program is mostly accepted by stakeholders and the expectations around its benefits is fairly understood. Despite being a common practice in many plants, the RBI method differs based on specific needs of each business, technical requirements, engineering philosophy, etc. In order to be flexible and sensitive to the different requirements and needs of the industry, APIRP 580 provides what is called the “Continuum of RBI approaches”, including many different methods as an APIRP 580 compliant RBI, differentiating them on the extremes of qualitative and quantitative methods, and accepting many other different shapes and forms in between, which characterizes the many semi-qualitative methods developed over the years.

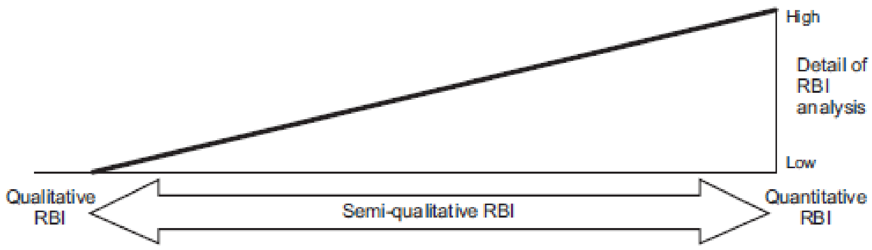


Figure 2 - Continuum of RBI approaches. (Source: API RP 580)

The qualitative approach is characterized by the use of engineering judgement, subject matter expertise and experience to broadly categorize probability and consequence of failure, where the quantitative approach is model-based: numerical values are calculated and more discreet inputdata used.

The RBI process, shown in the simplified block diagram in Figure 3, identifies the essential elements of inspection planning based on risk analysis. This diagram is applicable to Figure 2 regardless of which RBI approach is applied, i.e. each of the essential elements shown in Figure 3 are necessary for a complete RBI program regardless of approach (qualitative, semi-quantitative, or quantitative).

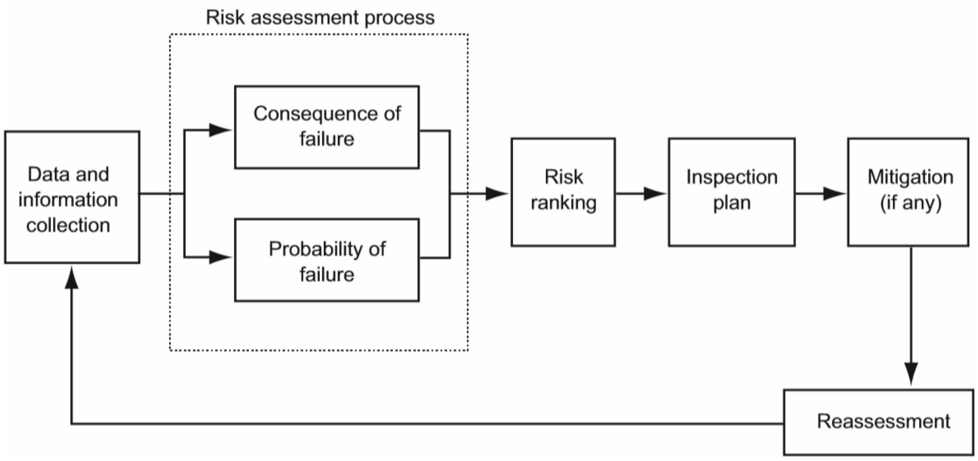


Figure 3 – Risk Based Inspection planning process. (Source: API RP 580)

From APIRP 580*Risk-Based Inspection*, *3rd Edition, 2016*: "In practice, an RBI study typically uses aspects of qualitative, quantitative, and semi-quantitative approaches. TheseRBI approaches are not considered as competing but rather as complementary. For example, a high level qualitativeapproach could be used at a unit level to select the unit within a facility that provides the highest risk for furtheranalysis. Systems and equipment within the unit then may be screened using a qualitative approach with a morequantitative approach used for the higher risk items. Another example could be to use a qualitative consequenceanalysis combined with a semi-quantitative probability analysis."

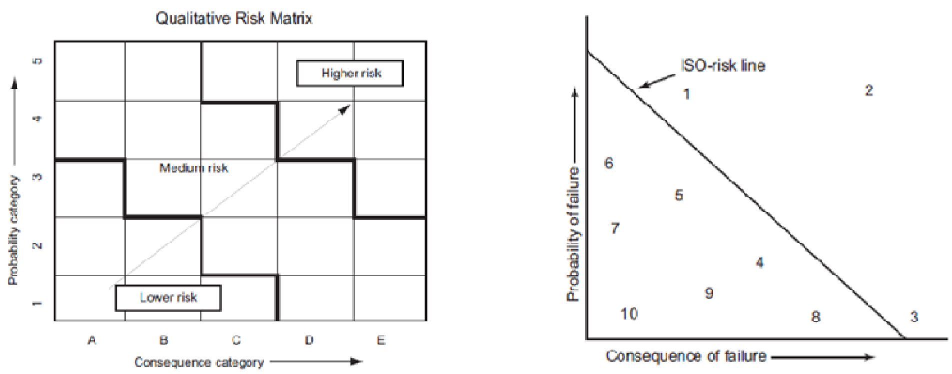


Figure 4 – Outputs of qualitative and quantitative methods respectively. (Source: API RP 580)

Both APIRP 580 and APIRP 581 are aligned with the concepts of ISO31000:2009 *Risk Managementas* they provide details necessary for identifying, analyzing, evaluating, treating, monitoring and communicating risk, specifically related to damage mechanisms which can potentially cause loss of containment in fixed equipment. The purpose of risk management is to prevent, reduce, or control future impacts of unfavorable events as opposed to reacting to unwanted events after they have already occurred.

Both API RP 580 and API RP 581 provide as output a risk mitigation plan in the form of an inspection strategy. The inspection strategy is considered effective if the process conditions utilized during the RBI analysis are maintained inside certain boundaries called integrity operating windows (IOW). Operating outside the integrity operating window can trigger risk reassessment in order to define a new inspection strategy to mitigate the reassessed risk. Therefore any RBI approach should be complemented by a comprehensive monitoring of integrity operating windows.

Qualitative RBI vs Quantitative RBI

Adopting RBI is a business choice. API RP 580 is a recommended practice which is trending as a common practice across the globe. Many benchmark exercises are regularly associating the practice of RBI to top performance companies and this eases the management decision for its adoption.

Once a company chooses to adopt RBI, the next step is to decide which method to apply, and here resides the most challenging part. RBI is a complex risk management method because it includes handling large amounts of information, data collection from many different sources, performing simple and complex calculations, managing the results in an organized manner, and executing the actions defined by the method and accepted by the RBI analyst.

In order to have a reference method, APIRP 581 was created to have the quantitative procedures to establish an inspection program using risk-based methods for pressurized fixed equipment including pressure vessels, piping, tankage, pressure relief devices, and heat-exchange tube bundles. The industry then recognized APIRP 581 as the standard reference for the RBI quantitative method.

APIRP 581 has been applied successfully in many plants across the globe,however, some disadvantages have been pointed out:

- The amount of data needed is not always available and not always easy to collect;
- The APIRP 581 analyst role requires a highly specialized professional;
- The implementation is typically time-consuming and the results can take a long time to be realized;
- In some cases there is a perception that a less quantitative approach would bring similar results, particularly for the lower risk equipment.

Broader qualitative or semi-qualitative approaches such as defined in API RP 580 are expected to be less accurate in most cases. However, for the mid- to lower-risk equipment, they provide the needed set of actions which are required, with the advantage of quicker time-to-results and requiring less specialized RBI analysts.

Despite the fact that APIRP 580 encompasses the continuum of RBI approaches, which theoretically brings a lot of flexibility to the user, the actual adoption of different methods within the same plant is very limited as a typical RBI approach selection is made based on the methodology provider (3rd party) and the RBI software supplied. The user of the RBI approach eventually is obliged to apply a single method from a 3rdparty and have limited influence to configure the method for its specific needs. Flexible solutions, providing quantitative and semi-qualitative RBI methods can address these asset owner needs.

However, with this flexibility comes great responsibility. But, it should be noted, as highlighted by API RP 580, Section 5.3.6:

“When performing risk analysis across different equipment, a single site or multiple sites, the user is cautioned about comparing specific results unless the same or very similar RBI methodologies and assumptions were applied. The user is also cautioned against drawing conclusions about different results when different methodologies are used to evaluate the same piece of equipment.”

And also in API RP 580 Section 5.3.1:

“The chosen approach may be selected at the beginning of the analysis process and carried through to completion, or the approach may be changed (i.e. the analysis may become more or less quantitative) as the analysis progresses. However, consistency of approach will be vital to comparing results from one assessment to the next.”

The need for selecting a method from a 3rd party is common as most successful RBI adoptions are associated with the use of software which handles the data, calculations and management of actions. The development of in-house software tools to address specific RBI requirements is a practice coming to its obsolescence.

Given the constant optimization requirements of the hydrocarbon and chemical industries, it is fundamental to address the appropriate level of inspection requirements associated with a rapid return on investment and delivery of the results. The following workflow intends make sense of the continuum of RBI approaches and address this issue:

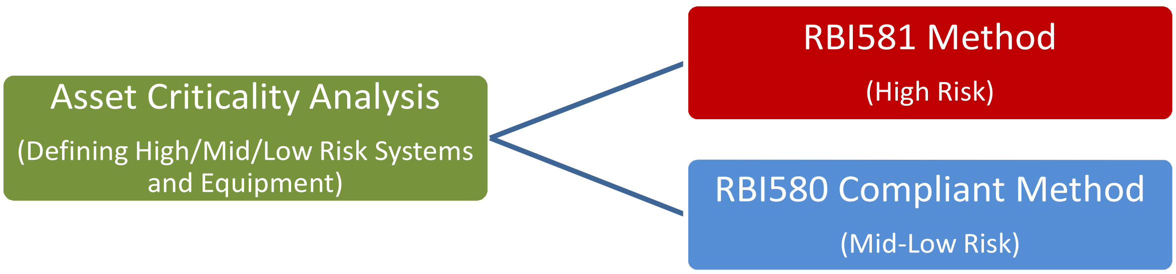


Figure 5 – Proposed workflow of multiple RBI methods being applied concurrently.

A fully qualitative approach has the advantage of being quick to apply to a sizable amount of equipmentby employing the experience of the operators in order to identify the higher risk equipment in a relatively accurate manner. This approach is highly recommended to be the done initially. The expected output is a grouping of equipment by risk ranges providing prioritization packages for further analysis.

This approach requires data inputs based on descriptive information using engineering judgment, subject matterexpertise, and experience as the basis for the analysis of probability and consequence of failure. Inputs are often given in data ranges instead of discrete values. Results are typically given in qualitative terms such as high, medium, and low, althoughnumerical values may also be associated with these categories. The value of this type of analysis is that it enablescompletion of a risk assessment in the absence of detailed quantitative data. The accuracy of results from aqualitative analysis is dependent on the background and expertise of the risk analysts and team members.

Although the qualitative approach is less precise than more quantitative approaches, it is effective in screening outunits and equipment with low risk; being less precise does not always mean at the qualitative method is lessaccurate. However, qualitative assessments generally are not as repeatable as quantitative assessments. Thequalitative approach may be used for any aspect of inspection plan development; however, the conservatismgenerally associated with the more qualitative approach should be considered when making final mitigation andinspection plan decisions.

As the qualitative approach may not be the best to define the inspection strategy, the intent of the workflow presented in the Figure 4 is to utilize the qualitative approach only as an initial step of the RBI program providing the quick screening which will direct packages of equipment to a quantitative or semi-qualitative approach.

The probability and consequence categories are evaluated without calculations, only by having the result selected based on qualitative guidelines.

Examples of probability and consequence of failure categories in a qualitative approach (API RP 580):

Table 1 – Example of probability of failure levels

Possible Qualitative Ranking	Annual Failure Probability or Frequency
Remote	<0.00001
Very Low	0.00001 to 0.0001
Low	0.0001 to 0.001
Moderate	0.001 to 0.01

High	0.01 to 0.1
Very High	>0.1

Table 2 – Example of economic consequence of failure levels

Category	Description	Economic Loss Range
I	Catastrophic	>$100,000,000
II	Major	>$10,000,000 <$100,000,000
III	Serious	>$1,000,000 <$10,000,000
IV	Significant	>$100,000 <$1,000,000
V	Minor	>$10,000 <$100,000
VI	Insignificant	<$10,000

Table 3 – Example of safety, health and environmental consequence of failure levels

Category	Description	Safety, Health, and Environmental Categories
I	Catastrophic	Large number of fatalities and/or major long-term environmental impact
II	Major	A few fatalities, and/or major short-term environmental impact
III	Serious	Serious injuries and/or significant environmental impact
IV	Significant	Minor injuries and/or short-term environmental impact
V	Minor	First-aid injuries only and/or minimal environmental impact
VI	Insignificant	No significant consequence

The result of each individual analysis can be visualized on a risk matrix which is defined based on the many probability and consequence categories, and each combination between them defines a specific position on the risk matrix, grouping the equipment into low, medium and high risk ranges.

The probability and consequence categories of a qualitative analysis provide as a typical result around 20% of the analyzed equipment into the high risk regions, as the remaining 80% belong to the medium/low risk regions. This depends directly on the quality of the risk matrix on representing the risks of the business being analyzed. The definition of the risk matrix is a key success factor for the qualitative approach.

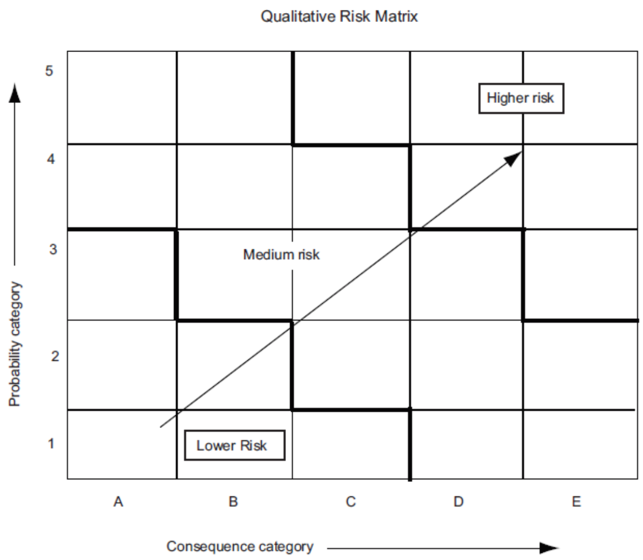


Figure 6 – Example risk matrix using probability and consequence categories to display risk rankings (Source: API RP 580)

The qualitative approach,as described on the figure 6, becomes only the initial step of the analysis, providing the prioritization and directing the respective equipment (high risk) to anAPI RP 581 analysis and the remaining to an API RP 580 analysis.

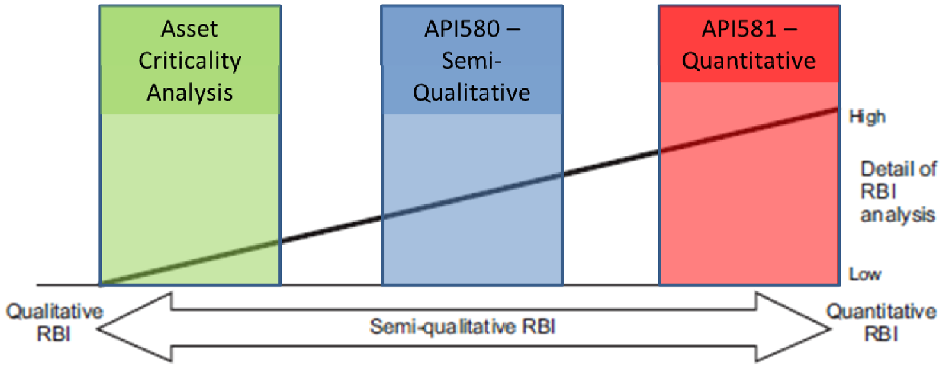


Figure 7 – Applying the continuum of RBI approaches in the same RBI program.

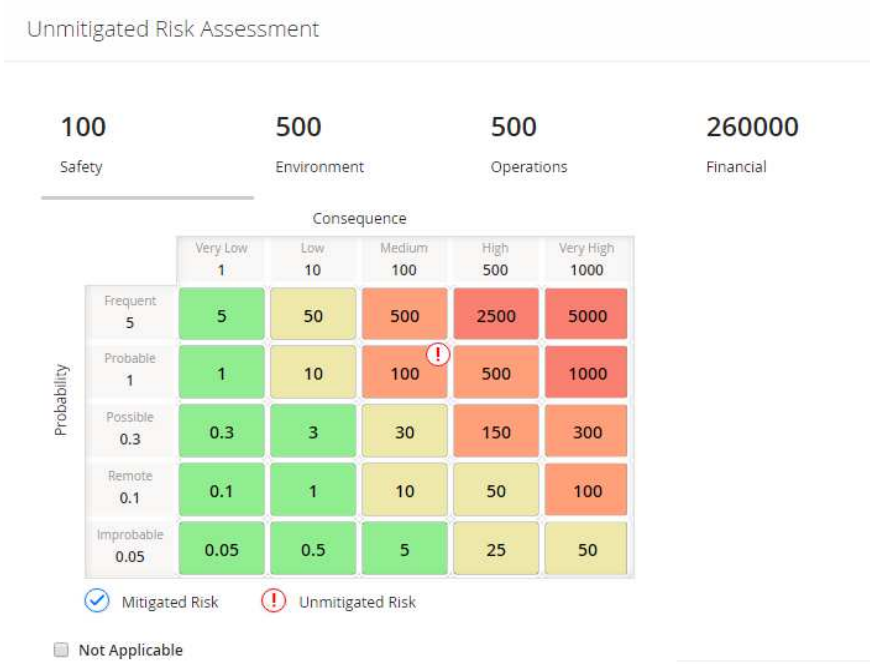


Figure 8 – Qualitative risk matrix utilized to define the asset criticality.

Despite the fact that historically RBI programs are based on a single RBI approach, it seems logical that all approaches can be combined giving the end user a valuable combination, maximizing the advantages of each individual approach.
High risk equipment, which typically account for less than 20% of the total, are recommended to go through a more comprehensive exercise involving a more detailed data collection and analytical effort, which is expected to provide a more detailed risk mitigation strategy. Medium to low risk equipment, which typically account for more than 80% of the total, can be further analyzed by a semi-qualitative approach, which benefits from the available data and simplified analysis requirements.

Quantitative programs are model-based approaches where numerical values are calculated and more discreet inputdata used. The advantages of a quantitative approach are:

- Calculates, with some precision, when the risk acceptance limit is reached or exceeded;
- Discrimination between equipment risk allowing prioritization of mitigation;
- Trending and monitoring risk exposure over time as well as other metrics;
- Benchmarking of reliability management such as probability of failure trending and comparisons.

Quantitative methods are more systematic, consistent, and documented, and they are easier to update withinspection results than qualitative approaches. A quantitative approach generally uses a software program tocalculate risk and develop inspection program recommendations. The models are initially data-intensive, but use ofmodels removes repetitive, detailed work from the traditional inspection planning process.

Quantitative RBI outlines a methodology for prioritizing equipment risk in a risk matrix or ISO-risk plot in addition tocalculating discrete risk values for prioritization from higher to lower risk. Probability of failure and consequence of failure are combined to produce anestimate of risk for equipment. Equipment items are ranked based on risk with probability of failure, consequence of failure, and risk calculated andreported separately to aid identification of major contributors to risk, or risk drivers.

Figure 9 – Expected output from quantitative or semi-qualitative RBI analysis, where the specific risk result is given for the equipment sub-component (e.g. reactor cylindrical shell)

Semi-quantitative is a term that describes any approach that has aspects derived from both the qualitative andquantitative approaches. It is geared to obtain the major benefits of the previous two approaches (e.g. speed of thequalitative and rigor of the quantitative). Typically, most of the data used in a quantitative approach is needed for thisapproach, but in less detail. The models may not be as rigorous as those used for the quantitative approach. The resultsare usually given in consequence and probability categories or as risk numbers, but numerical values may beassociated with each category to permit the calculation of risk and the application of appropriate risk acceptance criteria.

Having access to all qualitative, semi-qualitative and quantitative approaches is valuable to the asset owner as it is possible to maximize the advantages of each approach based on a pre-defined selection criteria. This becomes the full realization of the continuum of approaches as defined by API RP 580.

Integrity Operating Windows (IOWs)

A relevant aspect where technology can add value to the RBI program is the monitoring of integrity operating windows.

Operating within integrity boundaries is fundamental to the validity of the RBI study as well as good operating practice. It is vital to establish and monitor key process parameters that may affect equipment integrity to determine whether operations are maintained within boundaries.

From API RP 584, IOW monitoring is defined as a vital component of integrity management (material degradation control), assisting in the inspection planning process, including risk based inspection.

IOWs should be established for process parameters (both physical and chemical) that could impact equipmentintegrity if not properly controlled. Examples of the process parameters include temperatures, pressures, fluidvelocities, pH, flow rates, chemical or water injection rates, levels of corrosive constituents, chemical composition, etc.Key process parameters for IOWs should be identified and implemented, upper and lower limits established, asneeded, and deviations from these limits should be brought to the attention of inspection/engineering personnel.Particular attention to monitoring IOWs should also be provided during start-ups, shutdowns, and significant processupsets.

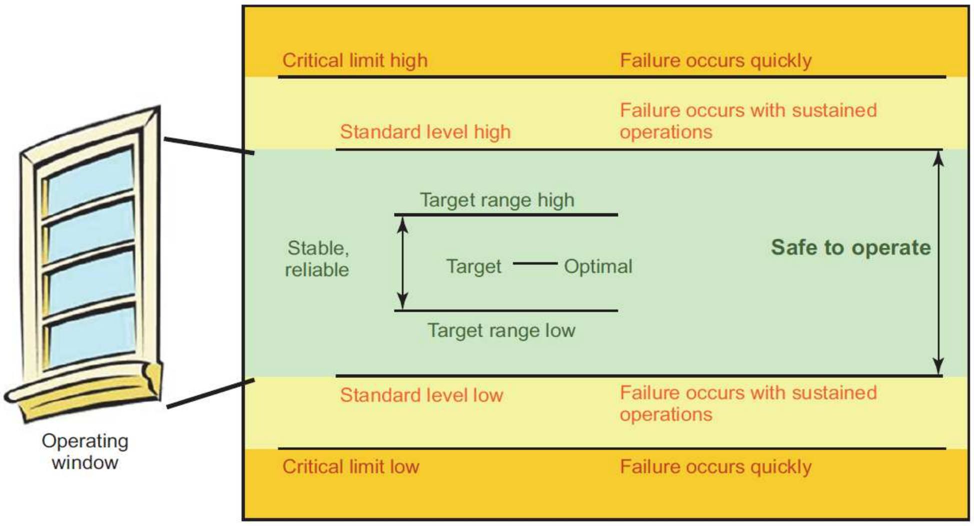


Figure 10 – Integrity operating window definition (Source: API RP 584)

A technology platform can be utilized not only to provide the RBI solutions for the risk assessment and inspection strategy definition, but also to be the place holder for the IOW definition and the data collection using automatic interfaces with process historians or manual data entry by operators via data loggers (e.g. industrial tablets).

Monitoring IOWs and having the capability to manage excursions provides great value to the RBI program. The changes in the process condition, if not captured accordingly, can invalidate RBI strategies at a minimum, or in a worst case scenario, accelerate a degradation mechanism without the awareness of the asset owners.

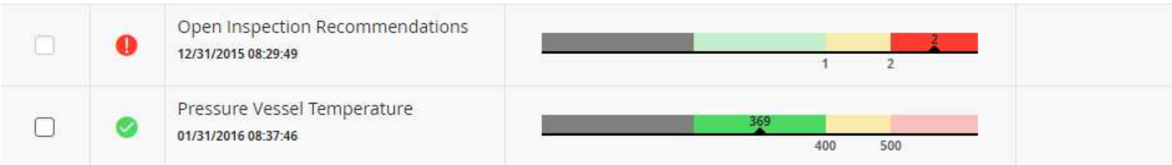


Figure 11 – Integrity operating window monitoring showing current status.

IOWs are not the only important variables to be monitored and can be combined with other indicators of the health of the equipment for a comprehensive view (e.g. # of open inspection recommendations).

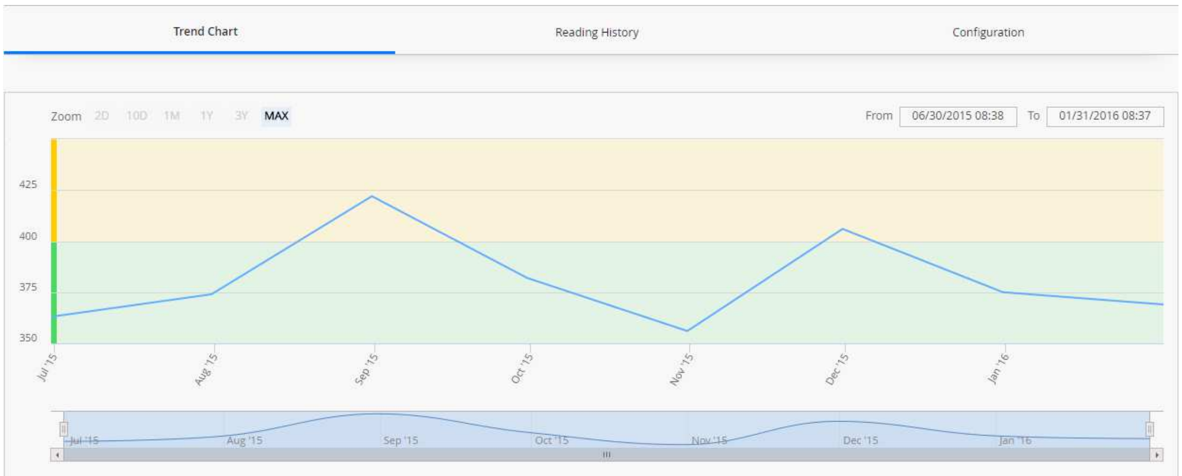


Figure 12 – Integrity operating window monitoring showing temperature trend.

The use of a robust database for continuous monitoring of IOWs provides also the ability to store readings related to specific dates and times. This is particularly important when dealing with time dependent potential degradation mechanisms like creep, where not only the excursion in temperature matters, but also the duration of the excursion.

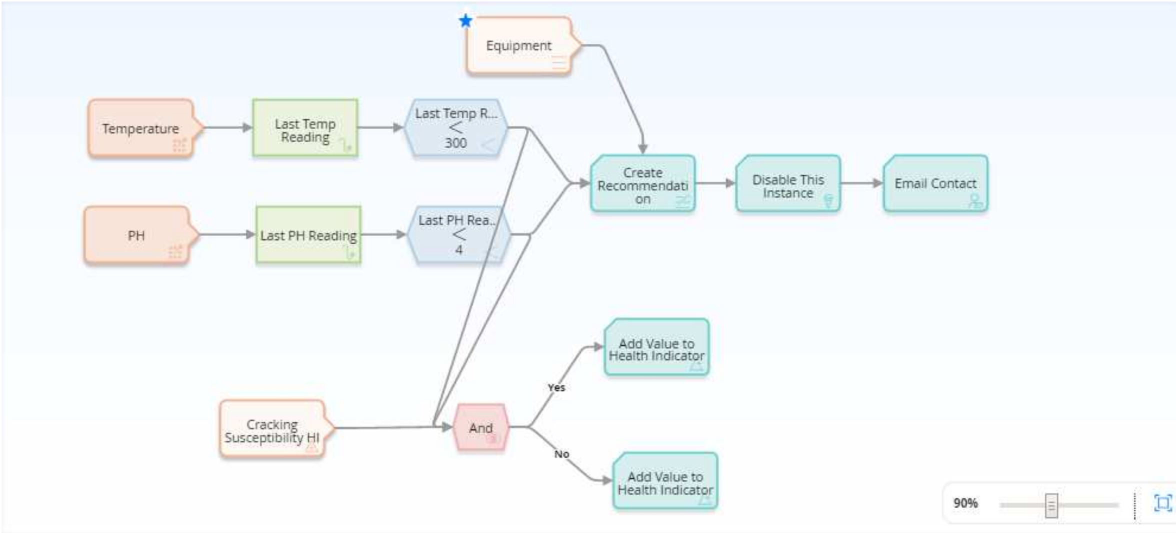


Figure 13 – Policy automating warning based on wet H_2S potential degradation mechanism.

Asset owners often have multiple equipment to manage, which increases the complexity for a more individualized attention for specific equipment. This is still somehow complex even if only high risk items are taken into consideration. Technology can also support automated monitoring of individuals IOWs and the relationship among them (thorough engineering equations), where the logic is pre-defined and once the given conditions are met, the automated alert will call for a follow up action.

Benefits of a Certified Provider

Among many available methods and supporting software solutions available, it is very important for asset owners to have additional assurances that the method is designed according the recommended practices. A third party certification process, although not mandatory, represents an additional level of compliance other than proven-in-use methods and software.

Certificate / Certificat
Zertifikat / 合格証
MER 1101026 C001
exida hereby confirms that the:
RBI Fixed Equipment Criticality Engine
Mericium, Inc.
Roanoke, VA - USA

Has been assessed per the relevant requirements of:
API 580, ed. 1
and meets the relevant rsk-based inspection requirements.

Additionally, the product development process was assessed as compliant to SIL 1 requirements, per IEC 61508, Part 3.

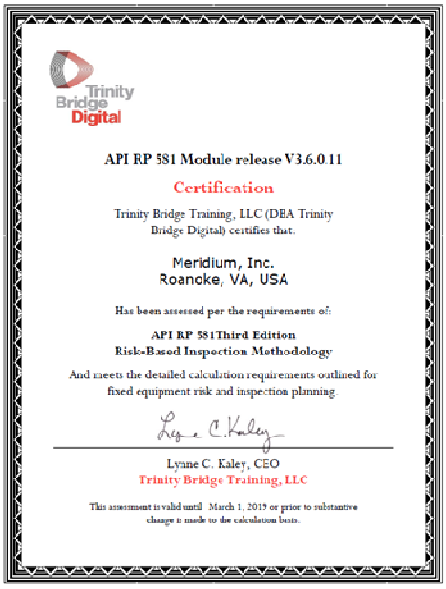
Application Restrictions:
The user of the RBI software must be knowledgeable in the area of Risk Based Inspection as described in the RBI user manual that accompanies the product.

MER1101-026 R001 V2R0
Assessment Report

This assessment is valid until September 1, 2016
Revision 2.0 August 26, 2015

Evaluating Assessor
Certifying Assessor

Page 1 of 1



API RP 581 Module release V3.6.0.11
Certification
Trinity Bridge Training, LLC (DBA Trinity Bridge Digital) certifies that:
Meridium, Inc.
Roanoke, VA, USA
Has been assessed per the requirements of:
API RP 581 Third Edition
Risk-Based Inspection Methodology
And meets the detailed calculation requirements outlined for fixed equipment risk and inspection planning.

Lynne C. Kaley, CEO
Trinity Bridge Training, LLC

This assessment is valid until March 1, 2019 or prior to substantive change is made to the calculation basis.

Figure 14 – API RP 580 and API RP 581 third party certifications

Conclusion

By improving the mechanical integrity and availability of industrial equipment, asset intensive companies can achieve and maintain increased uptime and asset availability resulting in greater profitability and reduced risk as a means to achieving operational excellence. Supported by tools and methodologies based on API RP 580, 581 and 584 standards, integrated asset maintenance and inspection programs can help companies gain comprehensive visibility over critical degradation mechanisms on their high risk assets and act as insurance policies that help guarantee efficient, safe and reliable operations while processing on-spec products without fear of mechanical failure or production disruption.

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Trace Moisture analysis in Refinery/Petrochem industries.

Natural Gas and Petrochemical industries are the keystone of world economy. It is critically important that they reduce unnecessary costs and pollution. The entire petrochemical and natural gas industry will benefit from accurate, dependable, low maintenance and cost-effective online gas analyzers for process monitoring and control purposes. An ideal gas analyzer would allow for on-site, accurate, continuous monitoring with unattended operation in hostile environment having wide temperature fluctuations and high humidity over extended periods of time.

Traditional approaches for monitoring trace level H2O are all based on analysers which use either electrochemical probes (Phosphorus Pentaoxide probes) or Aluminium Oxide based capacitance type probes or more recently Quartz Crystal Microbalance (QCM, vibrating quartz crystal) type analysers. One common characteristic of these technologies is that the sensor is always in contact with the sample. Trace hydrocarbons and other impurities (methanol, glycols, amines and oils) which may be present in the stream can easily contaminate the sensor probes, resulting in drift and possible loss of sensor response. More over these probes require intensive maintenance such as periodic recalibration or replacement of the sensor heads, resulting in high maintenance costs.

Case Study:

To verify the performance of these analysers one of a large refinery requested us to carry out an evaluation of the technology under their plant conditions. They were facing challenges in the measurement of trace Moisture in their H2 recycle stream. Among the challenges were: a) slower response time of the existing analyser, b) expensive, repeated sensor failure and c) need to require frequent calibrations leading to more field trips than required. A TDL based moisture analyser was chosen for the purpose. It (SS 2100i-2) was installed in parallel to the existing Moisture analyser. TDL analyser was fed from the sample tapped at the inlet of the existing analyser so that both analysers could receive the same sample for comparison purposes. The study period agreed was three months.

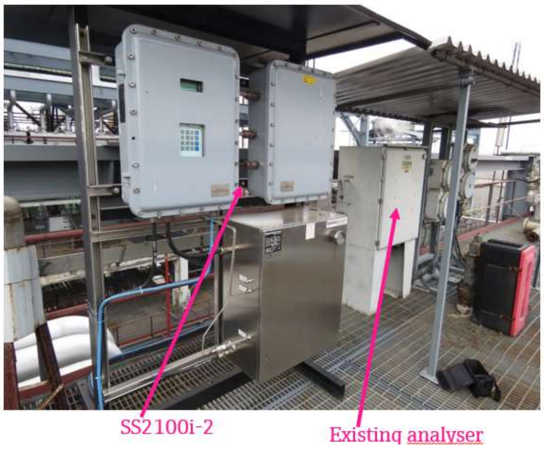

Fig: 1. TDL analyser and the existing analysers as installed at site.

From the commencement of the trial, TDL analyser, due its fast response, picked up the minor variations in H2O concentrations compared to the existing analyser. Solid line representing the TDL analyser (SS 2100i-2) , while the dotted line represents existing analyser readings.

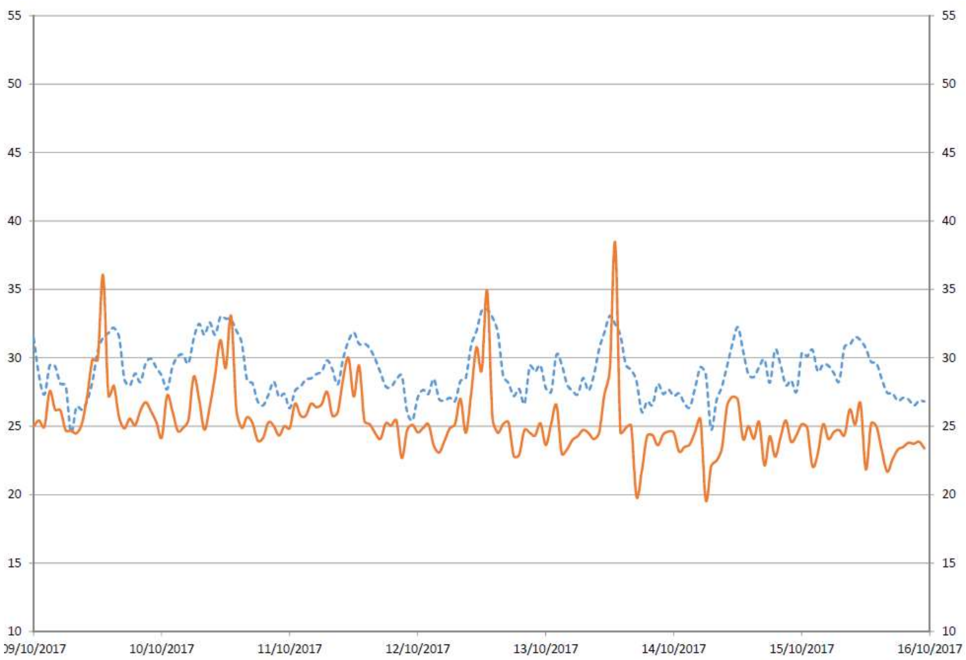

Fig: 2. Comparison of TDL and Existing analyser readings over one-week period.

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In one specific instance after a major process interruption our analyser picked up the upset almost instantaneously , whereas the existing analyser could pick up that event almost an hour later.

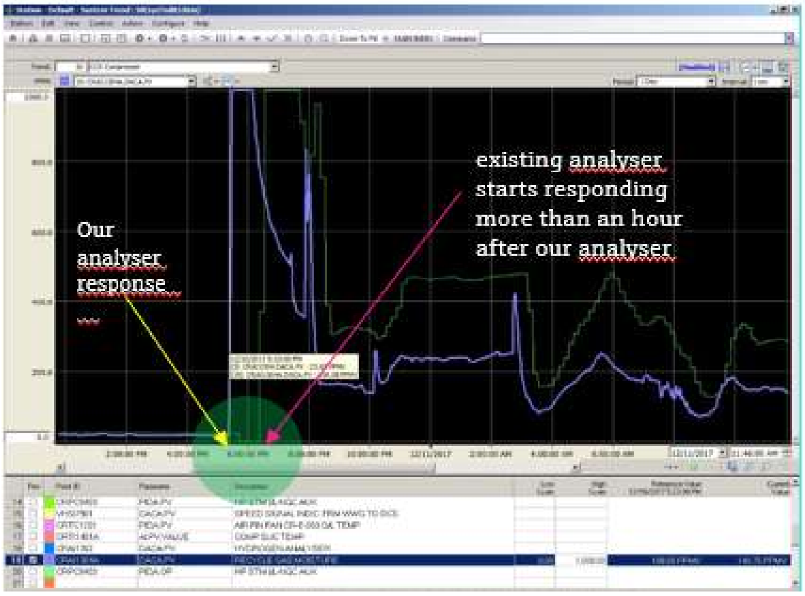

Fig: 3. TDL analyser picking up a moisture breakthrough event almost an hour earlier than the existing analyser.

At the end of the agreed period the analyser (SS2100i-2) was taken back with a client satisfied with the performance of the technology and the product itself.

Technology:

Tunable Diode-Laser Absorption Spectroscopy (TDLAS) based trace moisture analyzers, utilize Wavelength Modulation Spectroscopy with 2nd harmonic detection (WMS-2f) to enhance the detection sensitivity.
The basic principle of a TDL analyzer starts with Beer-Lambert’s Law. Laser light is injected into an optical cell with a current modulation on laser. See figure 4.

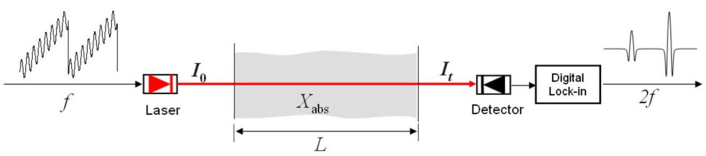

Fig.: 4. Operating principle of TDL analyser.

A modulated laser beam passes through gas with absorption factor X_{abs} and laser interaction length, L. The current to the laser is modulated at frequency f and a demodulated 2f signal is used to reduce noise and improve the sensitivity. The transmitted optical power, I_t will be smaller than the initial power, I_0 if the target molecule (e.g. H2O) is present in the cell.

Advantages:

WMS-2f TDLAS based analysers offer significant opportunities and advantages for on line measurement of trace moisture due to their high sensitivity, high spectral resolution, fast response time, robustness, and non-intrusive character.

Summary:

While WMS-2f TDLAS describes a technology and a class of analyzers, the technology can be applied in various ways. The key to any WMS-2f TDLAS based technology is operating the laser at the analyte absorbing wavelength and isolating that 2f signal in such a way to measure extremely low levels of analyte, in this case moisture (H2O).

Courtesy – Various SpectraSensors Inc. publications .

Contact: jiwan.jain@endress.com

(Jiwan Jain is graduate in Electrical Engineering and has over 25 years of experience in process Gas analysis. Currently he handles the Gas Analysis portfolio at Endress+Hauser India Pvt ltd.)

NON-CONTACT, NON-NUCLEONIC ONLINE COAL ELEMENTAL AND MOISTURE ANALYSER

By

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KEYWORDS

Coal fired power plant, Steel Plants, Conveyor Belt, Mining Industry, Coal Moisture Measurement, bulk solids, Instrumentation, Microwave, IR Type

ABSTRACT

Indian coal inherently contain low inherent moisture (IM) (5.5-9.5 % with an average of around 7.5 %) and moisture addition is through the surface moisture (SM) due to sources external to the coal. Presence of surface moisture (SM) is a major liability to the power generating process and it's and control needs to be understood on a broader national perspective. Great importance must be given during the transportation, handling, transfer and storage of coal to ensure that its heating value is preserved and there is no deterioration on account of SM addition en-route to the power plant or in the coal yard storage prior to its entry into the furnace of the boilers. It is the SM which affects the power plant operations. While there have been many technologies in the past like the Conductance, Capacitance, Laboratory and IR, however, none of them have stood the test of time due to the offline nature of measurement or being affected by dust in the environment or capturing only the surface of the material and not the entire depth of the material. The Indutech Microwave Moisture Analyser measuring depths of material up to 600mm has solved the problem with an accuracy of moisture measurement up to 0.1% error only. The very nature of the sensor and the advanced software analysis with a patented high resolution detector and algorithm. The PM 2450 and 2500 are truly industry revolutionizing solutions for the Coal Fired Power Plants to increase the efficiency of the Boiler.

Another painstaking area for our Coal fired power plants is the measurement of the Elemental nature of the Coal which not only provides us significant information on the Calorific Value of Coal but also determining the other properties of Coal which influence the purchase price for Coal. The conventional solution for Elemental Coal Analysis were based on the Nucleonic Isotope based because of which the universal acceptance was limited even though the device has shown its presence for more than a decade. The new XRF, non-nucleonic solution by Indutech for Elemental Analysis has changed the perception for the customers who can now employ an Elemental Analysis of Coal and other minerals. The Indutech OXEA XRF Elemental Analyser utilizes the energy-dispersive method of X-ray fluorescence using high resolution detectors and thus allows product-specific matrix compensation as well as the use of fundamental parameters.

With the above 2 solutions, we are here to offer an increase in efficiency of the Power Plant thus contributing towards the growth of Indian Power and Mineral Industry with more Return on Investment by measuring accurately the properties of it essential commodity that is Coal and other minerals.

Introduction

Indutech started in 1997 to develop an online analyzer based on energy dispersive XRF technology. Initially the main objective was to determine the sulphur content of coal. The patented technology allows an online XRF elemental analysis with bulky coal accurate with a particle size up to a quarter inch. This allows the calculation of the ash content from the elemental composition of the ash. In combination with a moisture meter, the calorific value can be determined.

Since that time the technology was continuously improved. This results in the following features:

- excellent energy resolution and spectra quality.
- excellent limit of detectivity and accuracy even for low elements such as magnesium, aluminium and silica.
- matrix compensation gives an excellent long-time stability of the calibration
- the Partial Least Square (PLS) regression method makes the calibration simple
- a new XRF-based method for the ash determination improves accuracy and long-term stability.

Determination of the volatile matter content Offline tests

The voestalpine Stahl GmbH contacted Indutech with the question, if in addition to the short proximate analysis also the volatiles can be determined to introduce these parameters in the thermal control of the coking ovens. Intensive investigations in Indutech´s laboratories showed, that the information taken by XRF measurements is sufficient to develop a model for describing the volatiles. These tests were carried out at over 100 samples. Six types of 'as received coal' were investigated, coming from Czech Republic and Poland.

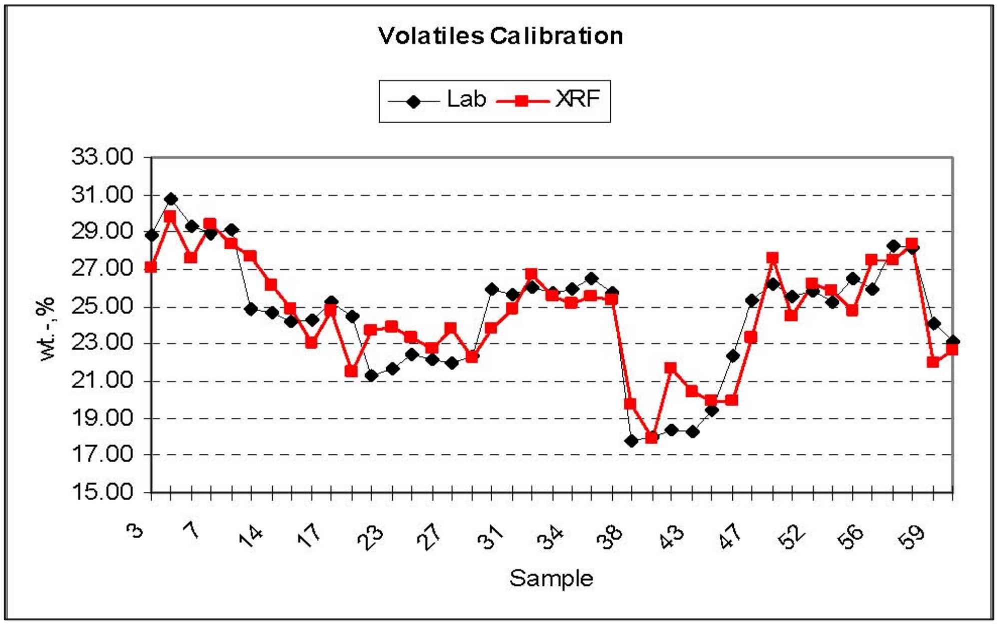

Fig. 1: Volatiles of the received coal

All types are calibrated with one calibration curve. The accuracy for the volatiles is 1.5 wt.-% at one sigma. Of course, with separate calibration curves the result can be improved remarkably.

The second group of samples were the blended samples. This is the blend, which voestalpine wants to measure. In this case the standard deviation is 0.25 wt.-%, which is absolutely sufficient to control the gas fuel requirement of the coking process.

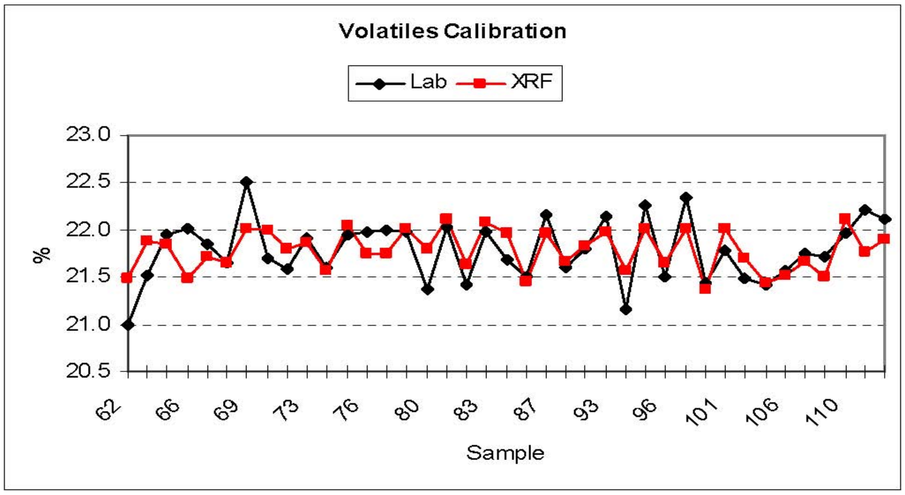

Fig. 2: Volatiles of the blended coal

Online installation and results

Based on these results an OXEA® Online X-ray Elemental Analyzer was ordered in 2003. The analyzer was installed on a sled at the belt transporting the blended coal from the blending facility to the coal towers. The load is 300 t/h, time of operation: 18 h/day, the belt speed is 2.3 m/s. The maximum particle size is less than 10 mm. OXEA® is installed on a sled, which slides upon the material. The sled can swing in arms, which are hinged at the sled as well as at the support frame. This allows the sled to slide always on the material independent of the load, as shown in Fig. 3.

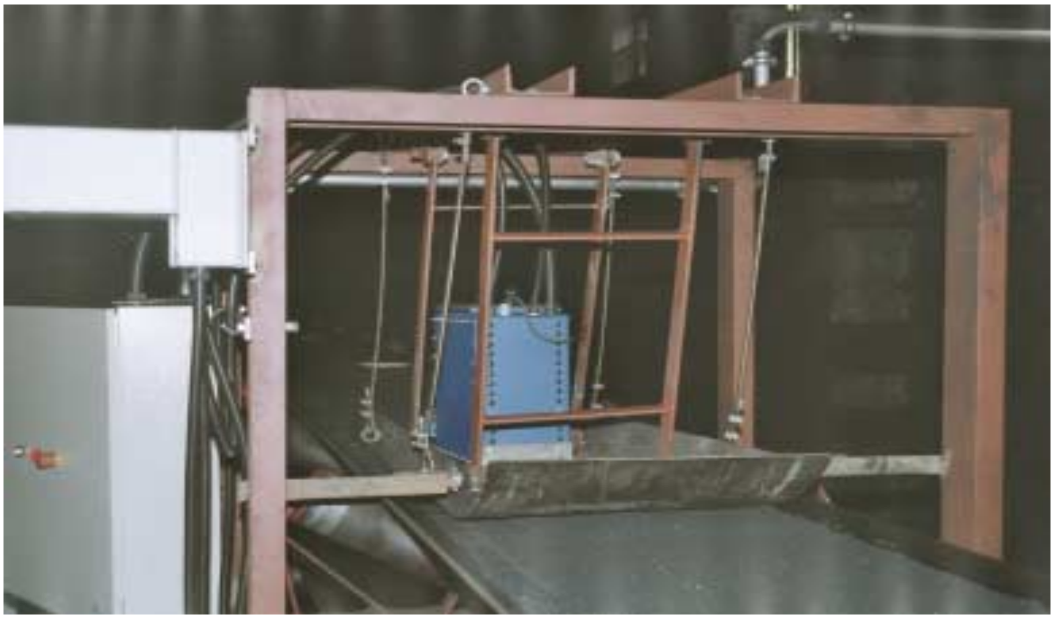

Fig. 3: OXEA® installed on a sled at a main belt of the voestalpine coking plant.

Of course, conditioning of the material stream is required to enable a smooth sliding of the sled. This is done in 3 steps: At first a fixed plough removes the piles on the belt. Then two hinged plates smooth the surface. Figure 4 shows such a hinged plate.

Fig. 4: Hinged plate to smooth the surface

If the belt is empty, the sled is hanging above the belt, so the sled will never touch and damage the belt. Fig. 4 shows the sled with the analyzer in empty state.

Fig. 5: Sled on empty belt

The presence of material is detected by a proximity switch, which also controls the electronic shutter, by which the X-ray tube is switched. The lifetime of the X-ray tube is hereby not reduced.

The figures 6-9 show the online results for ash, volatiles, bulk density and sulphur.

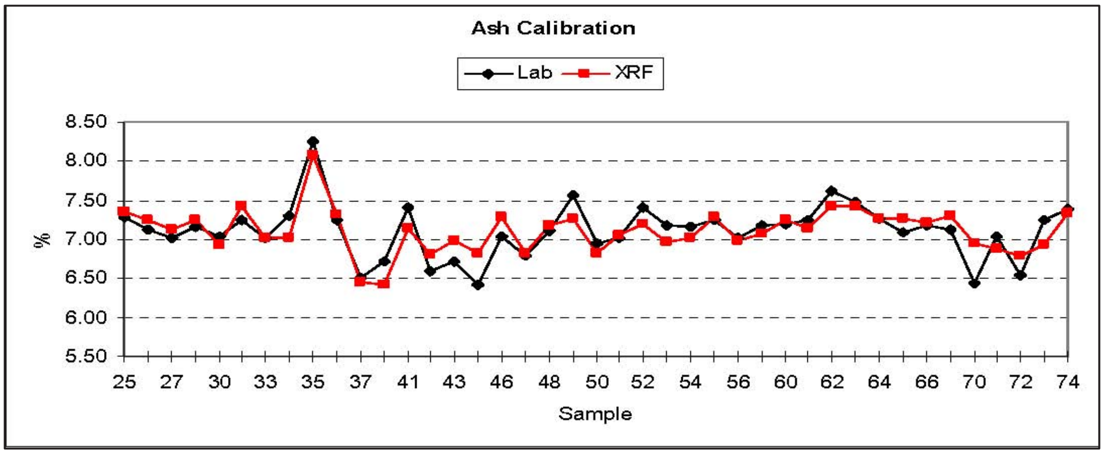

Fig. 6: Online measured ash content

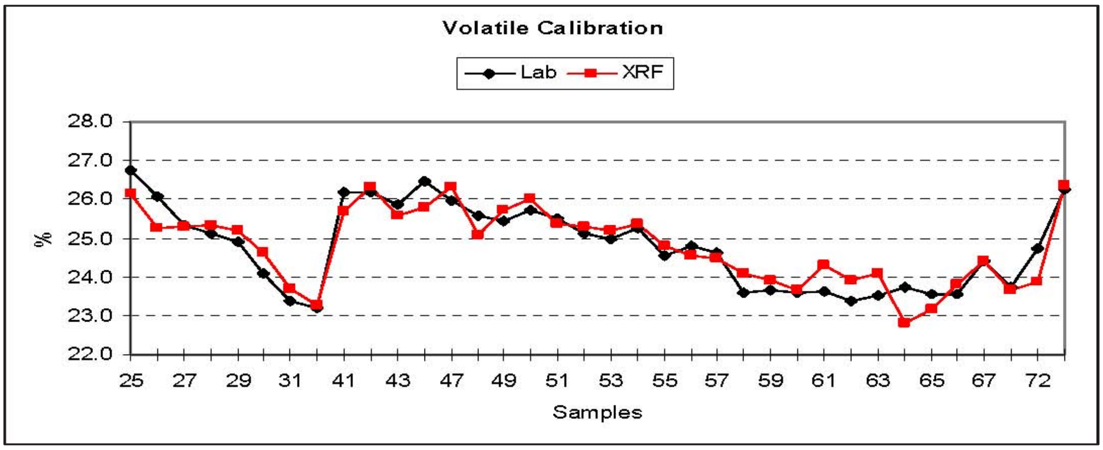

Fig. 7: Online measured volatiles

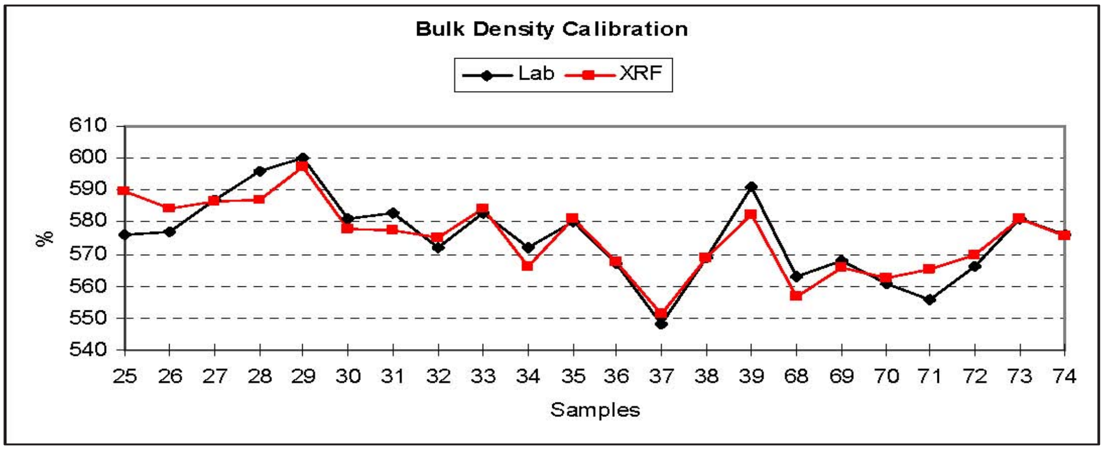

Fig. 8: Online measured bulk density

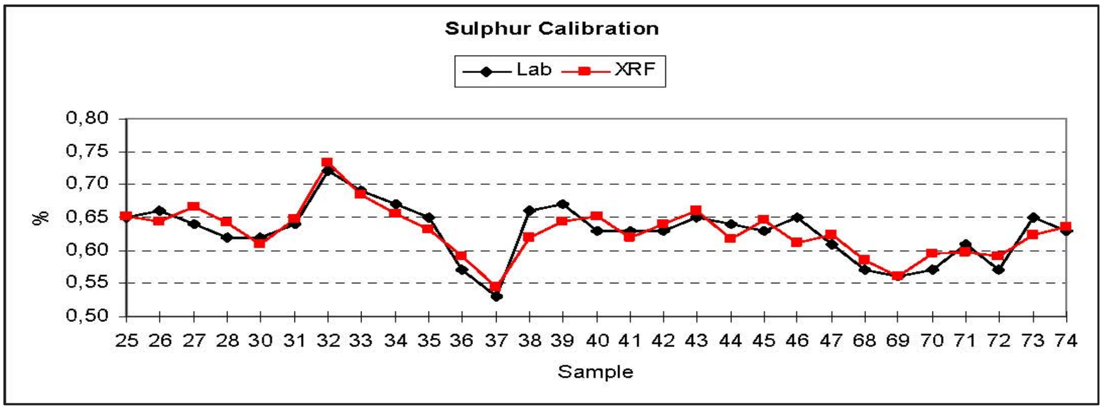

Fig. 9: Online measured sulphur content

Table 1 shows the achieved accuracies of the online calibration for the most important parameters.

	Correlation	Std. Deviation
Ash	0,826	0,192 wt.-%
Volatiles	0,950	0,475 wt.-%
Bulk density	0,899	5,424 kg/m³
Sulphur	0,866	0,019 wt.-%

Table 1: Results of the online calibration

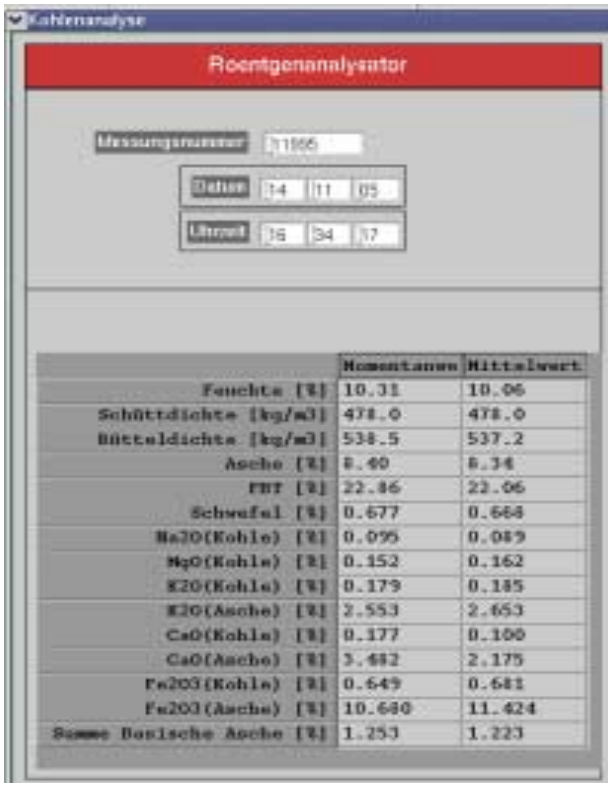

Fig. 10: Numerical display in the control room with all readings given by OXEA®

After the calibration the analyzer was observed by the R&D group of voestalpine. The OXEA® worked absolutely stable. During this final test period the signals of the analyzer were transferred to the PLC of the coking plant and visualized in the control room. The figures Fig. 10 and Fig. 11 show the alphanumerical and graphical visualization in the control room.

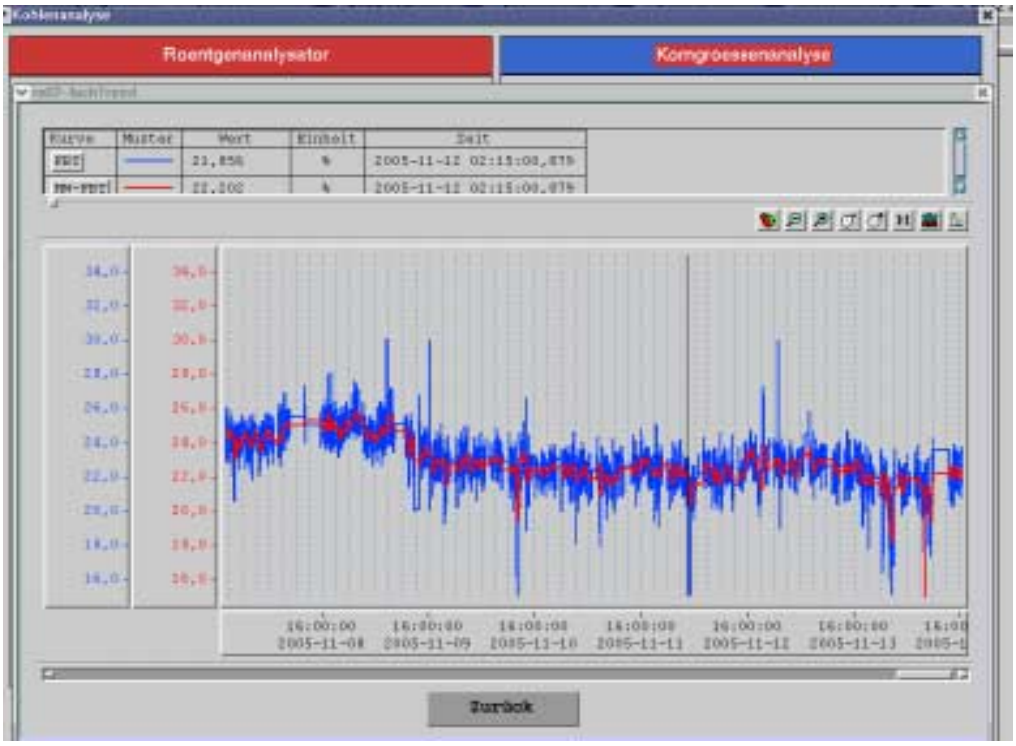

Fig. 11: Trendplot of the volatiles

After a successful online test of the analyzer, the volatiles were switched in a closed loop to control the gas fuel consumption of the coking oven. This test showed that the model for the volatiles works very stable. Adapting the model is only necessary if the received coal types are changed. The analyzer is now running since 5 years without noteworthy problems. The service personal of the coking plant maintains the analyzer. In the last 4 years Indutech was only called twice for service. This shows the high availability of the analyzer.

Importance of online quality control for the coking plant

Before the installation of OXEA® the analysis of ash, sulphur, volatiles and bulk density **was** only available on a daily basis. Fluctuations of individual parameters in the course of a day could not be registered. The elemental composition of the ash was determined once a month only. – The online moisture measurement was already installed.

With OXEA® the volatiles can be determined continuously. The desired final temperature of the coke can be achieved with a low standard deviation, because the required gas fuel can be calculated more exactly. Hereby the consumption of energy is reduces remarkably and the investment for the OXEA® is amortized within a short time. Furthermore, impurities such as ore can be recognized and a reaction is possible to avoid the production of low quality coke.

Long-term Experience

The analyzer now operates for more than 4 years. The stability of the calibration was observed during this period continuously on the basis of the daily samples and was found to be stable over this period, i.e. a recalibration was not necessary. Even after the exchange of a type of coal it was not necessary, to recalibrate the system.

However, recently the recipe of the blending was completely changed. The number of types of coal was increased. Therefore, a new calibration was started in August 2008. The samples were taken and the model for the volatiles will be adapted to the new types of coal once the laboratory results are available. This opportunity was also used to upgrade the system in hard- and software.

Further developments

In 2004 Indutech developed a specific geometry with a helium flush. Hereby the limit of detection and the accuracy of low elements Na, Mg, Al and Si are improved. The helium flush causes, that the height of the Si- peak is twice, the height of the Al peak is three times over. This method was developed within a project to determine low Silicon concentrations in magnesite ore. In the meantime this method is successfully used in different coal applications.

Another coking plant has installed OXEA® to analyze the received coal. In addition to the parameters measured at voestalpine this customer wants to distinguish between the coals of different origin. For this application Indutech developed a fingerprint method, which compares the actual spectrum with spectra of the used types of coal. Of course, impurities are also detected. This analyzer was installed in February 2008. The analyzer is installed at the main belt on a sled too. The maximal particle size is 50 mm and the load variation on the belt is dramatic. In spite of these much stronger installation conditions the analyzer works fine. This shows: the precondition, that the particle size should be less than 10 mm is too restrictive. Specific results about this application will be reported later.

Furthermore, Indutech developed a complete new generation of XRF analyzers. This allows to use the XRF technology for a coal with a particle size of up to about 100 mm.

After the success with the coal analyzer Indutech has also installed several OXEA® for non-coal applications. These applications will be discussed in another paper.

Summary

In this paper it is reported about an online XRF analyzer, which is designed to measure the ash- and sulphur content, the volatiles and the bulk density in a coal blend for coke production. In addition to these parameters, the elemental composition of the material is measured to detect impurities by ore. The analyzer was installed in 2003/ 2004 and is now running for 4 years of continuous use without major problems and an availability over 95%. The model for the volatiles works stable. A recalibration is necessary only if the types of coal are changed. The achieved accuracy allows the use of the readings of the analyzer in a closed loop to calculate the gas fuel consumption for the coking

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STPA – Case Study for Application to Process Industry

Amit K Aglave, Debopam Chaudhuri

Fluor Daniel India Pvt. Ltd.

ABSTRACT

One of the important activities carried in the lifecycle of the Safety Instrumented System (SIS) is hazard identification. Proper hazard identification can be considered as the foundation for the development of the SIS design. Thereby, it's important that all hazards are properly identified before proceeding with the succeeding safety lifecycle activities.

Hazard and Operability Study (HAZOP) study is a structured study for identification of hazards. The process of conducting HAZOP is matured process and being applied for around five decades in the process industry. The success of HAZOP however relies on the premise that the plant design is mature and sufficient design information of the plant is available. HAZOP process involves simplifying the complex process into simpler sections termed as nodes. The individual nodes are studied for identification of potential hazards and operability problems.

STPA (System Theoretic Process Analysis) is tool based on the concepts of STAMP (System-Theoretic Accident Model and Processing). STPA is relatively new hazard analysis technique based on an extended model of accident causation and being tried for applicability in various industries like defense, automobiles, aviation etc. apart from the process industry. STPA analyzes the potential cause of accidents during design development with aim to eliminated or control hazards.

The HAZOP studies considers deviations in process or component failures as cause for what may go wrong and result into accident. Whereas in STPA, it is assumed that accident may also be caused due to unsafe interactions of the system components, none of which have failed.

It is claimed that STPA can:

- Identify more accident causal scenarios than HAZOP apart from identifying all the accident causal scenarios which HAZOP can.
- Be applied in early concept analysis when the design is not mature for identifying safety requirements and constraints. These identified requirement and constraints can then be used for designing system architecture and avoidance of costly rework in contrast to HAZOP recommendations which are based on mature design.

The intent of this case study is to apply concepts of STPA on a process unit and then compare it with the HAZOP findings which are performed by separate team. Based on the findings, the applicability and effectiveness of STPA concepts to process industry will be established.

KEYWORDS

Functional Safety, HAZOP, Safety Lifecycle, STAMP, STPA, Safety Instrumented System.

INTRODUCTION

The Functional Safety Standards IEC61508 and IEC61511 are widely adopted in process industry for achieving the Functional Safety. These standards provide the framework for achieving functional safety by considering the entire life-cycle of the safety instrumented system (SIS). Typical SIS safety life-cycle phases and functional safety assessment stages are illustrated in Figure-7 of IEC61511-1 [1].

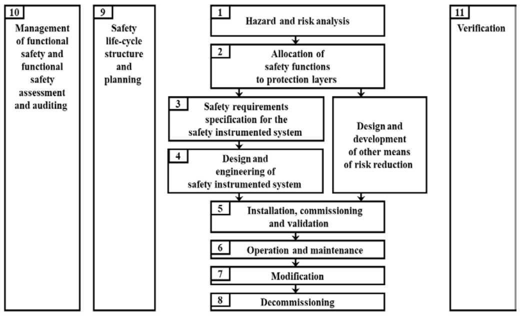

Figure 1. SIS safety life-cycle phases and FSA stages

Hazard identification is one of the most important activities carried out in the SIS safety lifecycle. Proper hazard identification and analysis of its risk lays the foundation of safeguarding strategy implemented in the SIS and non-SIS protection layers.

The common method for a structured study for the first phase of the hazard and risk analysis is Hazard and Operability Study (HAZOP) study. The concepts of HAZOP are well evolved and applied for over five decades.

This premise of mature design availability of HAZOP means if there are findings in HAZOP which require change in design, the design is often costly. Further, it will directly impact the schedule of the project. The project cycles are aggressive compared to around two decades back and schedule delays directly impacts the return of investment period.

It thereby becomes prudent to question that is the HAZOP being performed at the right time and whether it is addressing all the scenarios?

As STAMP concepts can be applied in early phase of the project and the preliminary results of the STAMP in other industries are promising, the paper intents to understand the concepts of STAMP and apply it to a part of process. The results of findings from STAMP are compared to HAZOP findings to ascertain further use.

HAZOP

HAZOP is commonly applied method for a structured study for the identification of hazard in process under consideration. The basic premise for HAZOP considers plant design is mature enough and sufficient design information on the plant operation is available. HAZOP process involves breaking down of complex process into simpler sections which are termed as nodes. These individual nodes are then studied by a multi-disciplinary team for identifying the potential hazards and operability problems.

The paper does not cover the details of what HAZOP is due to its common understanding in the industry.

STAMP [2]

STAMP (System-Theoretic Accident Model and Processes) is the new accident causality model based on systems theory. It expands the traditional model of causality beyond a chain of directly-related failure events or component failures to include more complex processes and unsafe interactions among system components.

In STAMP, safety is treated as a dynamic control problem rather than a failure prevention problem. No causes are omitted from the STAMP model, but more are included and the emphasis changes from preventing failures to enforcing constraints on system behavior.

The approach in application of STAMP considers the following main concept:

- Works top-down rather than bottom up and hence can be applied to very complex systems
- Includes software, humans, organizations, safety culture, etc. as causal factors in accidents and other types of losses without having to treat them differently or separately.

STAMP is a model or set of assumptions about how accidents occur. STAMP is an alternative to the chain-of-failure-events (or dominos or Swiss cheese model) that underlies the traditional safety analysis techniques such as Fault Tree Analysis, Event Tree Analysis, HAZOP and FMECA (Failure Mode, Effects and Criticality Analysis).

The two most widely used STAMP-based tools today are STPA (System Theoretic Process Analysis) and CAST (Causal Analysis based on Systems Theory).

STPA is a proactive analysis method that analyzes the potential cause of accidents during development so that hazards can be eliminated or controlled.

CAST is a retroactive analysis method that examines an accident/incident that has occurred and identifies the causal factors that were involved.

This paper applies the STPA concepts to the process under study.

STPA [2]

The concepts of STPA (System-Theoretic Process Analysis) are drawn from Systems Theory which was developed in era post second world war to address the complex systems which were being developed as the technology advanced. STPA is a relatively new hazard analysis technique based on an extended model of accident causation. STPA assumes that in addition to component failures, accidents can also be caused by unsafe interactions of system components, none of which may have failed.

It is claimed that STPA has several advantages over traditional hazard and risk analysis techniques. These are:

- STPA can be applied for analysis of very complex systems. Many unknown hazards which were found during operation phase only, can be identified early in the development process. This helps to either eliminate or mitigate these hazards in a cost effective manner with little or no impact to the schedule.
- STPA can be started in early concept phase when documents such as P&IDs, control narrative and cause and effect charts are not fully developed. Further, the findings of STPA assist in identifying safety requirements and constraints and are used in development of control narrative and cause and effect charts. As the design progressed and more details are available, STPA can be applied to refine more detailed design decisions. Documentation developed in each step provides traceability of the system requirements and design.
- STPA includes software and human operators in the analysis, ensuring that the hazard analysis includes all potential causal factors in losses.

Traditional vs. STPA Approach

Traditional method like HAZOP involves analysis of the complex unit for identifying the hazards and operability problems. The analysis is performed by breaking down the part of a process unit based on the equipment or set of equipment which work together and termed as node. The nodes are then individually studied for the risk it poses using guide words. The results of individual nodes are not combined together to assess the risk for the unit as whole.

Layers of protection analysis (LOPA) rely on the fact that it is chain of event which leads to an accident scenario resulting in and undesired consequence.

The STPA approach:

- Considers system as a whole instead of breaking down into components.
- Addresses emergent properties, i.e. behaviour of system as details about interaction between components emerge during system development.
- The emergent properties of the system are controlled by addition of a controller.
- The controller interacts with the system by providing control action and draws feedback for knowing the behaviour of the system post control action is applied.
- The controller enforces constraints on the behaviour of the system which are basically the safety requirements of the system.

STPA Methodology

STPA can be carried out in four steps:

1. Define Purpose of Analysis.
2. Model the Control Structure.
3. Identify the Unsafe Control Action.
4. Identify Loss Scenarios.

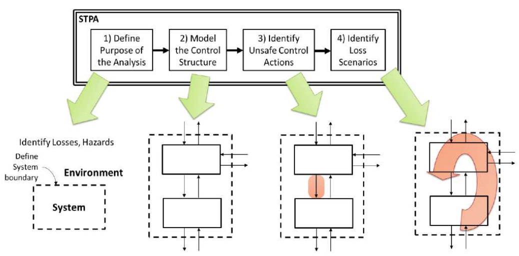

Figure 2. Overview of the basic STPA method [2]

1. *Define Purpose of Analysis.*
   The 'define purpose of the analysis' aims to identify:
   - The losses to be prevented

2. Goals of STPA, i.e. prevent loss to health and safety, environment, asset loss, production loss etc. The system and the system boundary.

3. Model the Control Structure.
   This step involves building the model of the system under study and termed as control structure. The control structure establishes functional relationships and interactions of the system components by modelling the system. Feedback control loops are added. The control structure can start at a very high level and can be expanded over time as more details are available.

4. *Identify the Unsafe Control Action.*
   In this step, control actions in the control structure are analyzed to determine how they could lead to the losses. The analysis of the unsafe control actions provides functional requirements and constraints to be enforces on the system.

5. *Identify Loss Scenarios.*
   The final step is to identify the reasons what may lead to unsafe control. This is done by creating scenarios that find out:
   i. What may cause unsafe control actions and if it leads to loss.
   ii. How the control actions execution can go wrong and lead to a loss.

These scenarios then may be used to develop / refine requirements similar to safety requirement specifications.

The details of each of the above steps are explained with the case study in the following sections. The concepts of STPA are applied on a part of process unit and findings are compared with results of the HAZOP results already performed in an actual project executed at Fluor for undisclosed client.

Case Study

Process Description

The system 'Sulphur Tanks' is used to store liquid Sulphur product from the upstream Sulphur Recovery Units. The system consists of 4 tanks each capable of holding liquid Sulphur equivalent to 3.5 days Sulphur production rate.

The Sulphur Tanks are open to atmosphere, as each has atmospheric vents for allowing atmospheric air into the tank. A positive sweep of air inside the tank is maintained by a set of ejectors which allow air to be sucked in from the vent ports, thus preventing the possible formation of an H2S rich atmosphere inside the tank, which if allowed may lead to fire hazards. One of the two ejectors needs to be in operation for this. The ejector then transfers the swept gas out of the system.

The normal H2S content in the liquid Sulphur is less than 10 ppmw, but under certain abnormal conditions, the H2S content may raise in range of 100 to 150 ppmw, due to upstream upsets. During this condition, both the ejectors need to be in operation to allow faster rate of sweeping as more H2S is evolved from the liquid Sulphur. This operation allows the Sulphur to meet the specifications of having only 10 ppmw of H2S in it.

To maintain Sulphur in its liquid form, the tank is having steam coils inside as well as along the walls and the roof. This steam allows the Sulphur to maintain the most optimum temperature of 140-150°C. The condensate generated from these steam coils moves out of the system.

The liquid Sulphur from the tanks is finally pumped out of the system to the downstream pelletizer unit. For this two pumps are provided, one normally operating and one as installed spare.

The four Sulphur tanks are considered to operate as the following:

- One tank is receiving feed from upstream unit.
- One tank is pumping out product to downstream unit
- One tank remains in holding mode, full with liquid Sulphur
- One tank is either available for maintenance or remains in holding mode.

In brief the system contains:

- Four number of liquid Sulphur storage tanks (one is operating spare)
- 2x100% liquid Sulphur transfer pumps
- 2 X 100% tank vent ejectors for each of the Sulphur tanks, total 8 ejectors

The figure 3 shows the simplified sketch of the system with all the major equipment, which will be used in the STPA Analysis.

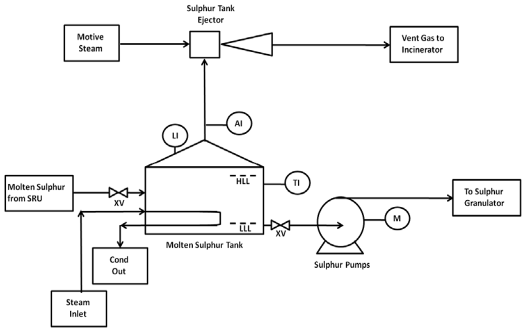

Figure 3. Simplified sketch of the Sulphur tank

Performing STPA

For understanding the methodology of performing STPA, it is recommended to refer the STPA handbook [2].

1. *Define the Purpose of the Analysis: Case Study Application*

   For the case study, the results of the first step are listed below.

Identify Losses:

- L-1: Loss of life or injury to people
- L-2: Loss of or damage to Equipment
- L-3: Loss of or damage to Environment
- L-4: Loss of asset / production

Identify System Level Hazards:

- H-1: Sulphur Tank sees abnormal liquid levels [L-1, L-2, L-3, L-4]
- H-2: Sulphur Tank experiences abnormal high pressures [L-1, L-2, L-3, L-4]
- H-3: Sulphur Tank releases H2S rich gas into atmosphere[L-1, L-3]
- H-4: Sulphur Tank sees abnormal temperatures [L-2, L-4]
- H-5: Sulphur Tank experiences fire inside [L-1, L-2, L-3, L-4]
- H-6: Sulphur Tank experiences loss of containment [L-1, L-2, L-3, L-4]
- H-7: Sulphur Pump fails to deliver Sulphur to downstream unit for pelletization [L-4]
- H-8: Tank change over fails [L-1, L-2, L-3, L-4]

Define System Level Constraints:

- SC-1: Sulphur Tank Level must be maintained with in HLL and LLL at all times [H-1]
- SC-2: If Level becomes abnormal, the abnormal level must be detected and measures taken to avoid overflow or total emptying out by tank changeover.[H-1]
- SC-3: Sulphur Tank pressures shall be always within the allowable limits.[H-2]
- SC-4: If pressure fluctuates, measures to be taken to maintain pressure.[H-2]
- SC-5: H2S relief into atmosphere must be avoided at all times [H-3]
- SC-6: Sulphur Tank temperature must be maintained within normal limits at all times[H-4]
- SC-7: If temperature becomes abnormal, the abnormal temperature must be detected and measures taken to avoid high or low temperature in tank. [H-4]
- SC-8: Fire inside tank must be avoided at all times. [H-5]
- SC-9: In case of fire, proper arrangements must be made for detecting and quenching fire. [H-5]
- SC-10: Sulphur must be contained at all times.[H-6]
- SC-11: Sulphur needs to be delivered at all times to downstream unit for pelletization. [H-7]
- SC-12: In case of loss of flow, adequate arrangements to be made for detecting and alternate means to be made. [H-7]
- SC-13: Tank changeover must be completed in defined time and failures alarmed. [H-8]
- SC-14: Output for valve operation should be active for sufficient time. [H-8]

Refining the System-Level Hazards:

To keep the case study simple, this step is not performed in the present case study.

2. *Modelling the Control Structure: Case Study Application*

   The following section highlights how a control structure has been prepared for one of the identified hazards in the system (H-1). Similar brainstorming can also be done for all other identified hazards.

The high level control structure is prepared in an abstract manner based on the hazards that have been already identified before further details are added. For this the main two controllers are considered, one is the Plant Operator (the human interface which allows monitoring of the System), and the Controllers (the DCS logics defined to maintain normal operation in the System).

The basic control structure for Hazard H-1 is represented in the below figure 4:

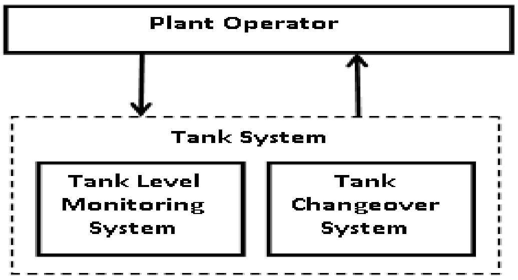

Figure 4. Basic Control Structure for Hazard H-1

Defining the Responsibilities and Feedback:

The responsibilities defined are a refinement of the safety or the system level constraints already assigned against each of the identified hazards.

For H-1, the system level constraints are defined above as SC-1 and SC-2. Based on the above, the following responsibilities are assigned:

Tank Level Monitoring System:

- R-1: The tank level is being measured by level transmitters to monitor the level at all conditions. [SC-1, SC-2]

Tank Changeover System:

- R-2: The tank changeover procedure has to be initiated once the level in the tank becomes abnormal. [SC-2]
- R-3: Identify the tank to be lined up and align the valves

At this point, the Feedback is derived from the control actions and the responsibilities to ascertain that the controller needs to take an action. The feedbacks for the above responsibilities are highlighted below:

- F-1: The DCS indication of the tank level is available along with sounding high and low level alarms [R-1, R-2]
- F-2: The XVs in the tank inlet and outlet lines have limit switches to ensure that the valves have fully opened or closed [R-2, R-3]

a) Refining the Control Structure:

Based on the defined responsibilities and feedbacks, the control structure may be refined as indicated in figure 5.

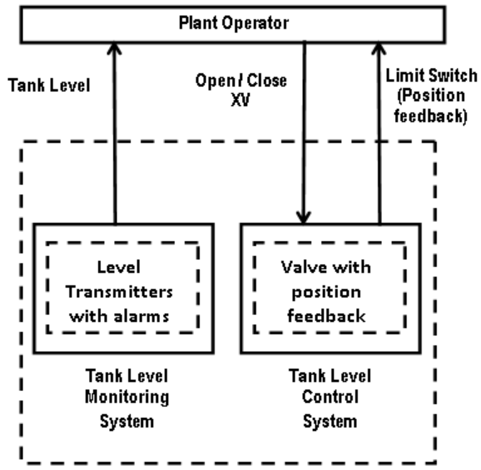

Figure 5. Refined control structure

3. *Identify Unsafe Control Actions: Case Study Application*

The table 1 simplifies and lists the probable unsafe control actions that may arise for the control structure that has been defined above for the case study. The table 1 below is limited to unsafe control actions related to the Hazard H-1.

Control Action	Not providing causes hazard	Providing causes hazard	Too early, too late, out of order	Stopped too soon, applied too long
Tank Level Monitoring System	UCA -1: Tank level malfunction remains undetected[H-1]	NA	UCA-3: Incorrect level measured and hence the hazard remains undetected [H-1]	NA
Tank Changeover System (valves)	UCA-2: Tank level can be monitored but cannot be controlled by closure of inlet valves[H-1]	UCA-4: Improper line up of valves.[H-1]	UCA-5: Limit switches malfunction leading to failure of the tank change over system [H-1]	UCA-6: Valve close command withdrawn before actual closure of valve OR valve stuck [H-1]

Table 1. Unsafe controller actions for case study

The next step is to assign each of these unsafe control actions a constraint. This will specify the controller behavior to prevent the unsafe control action and the following table 2 is generated.

Unsafe Control Hazard	Controller Constraints
UCA -1: Tank level malfunction remains undetected [H-1]	C-1: Tank Level Indication and alarms must be provided
UCA-2: Tank level can be monitored but cannot be controlled by closure of inlet valves[H-1]	C-2: A proper tank changeover system must be defined for Operators to follow
UCA-3: Incorrect level measured and hence the hazard remains undetected [H-1]	C-3: The level transmitters provided in the tank must be redundant and preferably of diverse technology
UCA-4: Improper line up of valves [H-1]	C-4: Proper training must be provided to Operators
UCA-5: Limit switches malfunction leading to failure of the tank changeover system [H-1]	C-5: C-5: The HMI (Human machin interface) should provide alarm for failure of the line up
UCA-6: Valve close command withdrawn before actual closure of valve OR valve stuck	C-6: Valve closure command to be withdrawn based on limit switch for close feedback AND alarm to be provided if valve does not closes in specified time

Table 2. Controller constraints for case study

4. *Identify Loss Scenarios: Case Study Application*

Loss scenarios are identified for the already identified unsafe control actions. The analysis of the unsafe control actions and controller constraints provides a guidance to identify the loss scenarios:

Unsafe Control Hazard	Controller Constraints	Loss scenarios
UCA -1: Tank level malfunction remains undetected [H-1]	C-1: Tank Level Indication and alarms must be provided	If the tank level indications are not provided [UCA-1],the tank may experience abnormal levels [H-1]
UCA-2: Tank level can be monitored but cannot be controlled by closure of inlet valves[H-1]	C-2: A proper tank changeover system must be defined for Operators to follow	If the tank changeover procedure is not available, the tank may experience abnormal levels [H-1]
UCA-3: Incorrect level measured and hence the hazard remains undetected. [H-1]	C-3: The level transmitters provided in the tank must be redundant	In case the level measurement devices fail, the tank may experience abnormal levels [H-1]
UCA-4: Improper line up of valves. [H-1]	C-4: Proper training must be provided to Operators	In case the operators are not trained with the correct tank change over procedure, the tank may experience abnormal levels [H-1]
UCA-5: Limit switches malfunction leading to failure of the tank changeover system [H-1]	C-5: The HMI (Human machin interface) should provide alarm for failure of the line up	In case there is malfunction of the limit switches, the line up of the tanks can not be ascertained, provision to stop the flow from should be provided [H-1]
UCA-6: Valve close command withdrawn before actual closure of valve OR valve stuck	C-6: Valve closure command to be withdrawn based on limit switch for close feedback AND alarm to be provided if valve does not closes in specified time	In case there is malfunction of the XVs and there are no manual valves available over and above the XVs already provided, the tank may experience abnormal levels [H-1]

Table 3. Loss scenarios for the case study

The table 3 provides the hazard analysis of the system in a way which is equivalent and comparable to the HAZOP table with its hazard identification, mitigation methods and the recommendations.

Finding from HAZOP for the case study

The below provides the findings of the HAZOP which were performed by a team of professionals from participating organizations of owner and contractor. The team was a multi-disciplinary team from Process, HSE and Control systems.

The hazards identified, the safeguards ascertained and the recommendations for the entire process unit is pretty exhaustive, and when they are limited to the conditions of level in the Sulphur tank, the following are the two recommendations made for this Unit.

A recommendation was made for allowing for proper Operator Training for the overall tank changeover system.

In a separate maintainability study, it was recommended to have manual valves for confirming isolation, in case of XV malfunctioning to avoid liquid overfill in the Sulphur Tank.

Safeguards related to the availability of redundant level transmitters, and the availability of level alarms had also been accounted for in the main HAZOP.

Comparison of HAZOP and STPA for the case study

Approach of study:

HAZOP was conducted on a well-developed P&ID of the Unit, while STPA has been performed on a much more simplified flow diagram of the process unit.

Findings of the study:

The findings for both the studies are strikingly similar and STPA was able to identify hazard scenarios identified in HAZOP.

The requirement of the manual valves has been identified in STPA. The same was not identified in HAZOP, though it was identified and implemented on a post HAZOP (HAZOP close out) maintainability review.

Conclusions

Though the case study was done on relatively simple process for ease of developing the understanding, the findings of the STPA are promising. The STPA was able to identify additional scenario in the relative simpler case study. This finding provides the confidence that the concepts of STPA can be applied further and pursued further.

Further work

The case study was performed on relatively simple process for which HAZOP was already performed. However, the STPA and HAZOP should be parallel performed for another example by two independent teams and results compared so that it can be established that STPA approach can be applied.

Once established, the next challenge is acceptance of this analysis by operating companies in the process industry. Further, the regulatory framework and reference international standards should include STPA as accepted methodology for identifying hazards. Until established firmly that STPA is a better approach, companies must be ready to invest in performing both STPA and HAZOP studies.

Further, the STPA should also be applied to SIS life-cycle phases other than HAZOP as the design gets mature. This will help to refine the functional requirements and constraints for the system.

Once the STPA is applied to a live project, the required estimate of effort hours, duration, stages at which iterations should be applied can be established.

ACRONYMS

HAZOP	Hazard and Operability Study
LOPA	Layers of Protection Analysis
STAMP	System-Theoretic Accident Model and Processing
STPA	System Theoretic Process Analysis
SIS	Safety Instrumented System
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SRS	Safety Requirements Specification

REFERENCES

[1] IEC, IEC 61511, Functional Safety of Instrumented Systems for the Process Industry Sector.

[2] STPA Handbook – Nancy G Leveson, John P Thomas.

[3] Fluor project execution for reference application

ACKNOWLEDGEMENTS

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where help in learning and understanding the concepts of the STAMP were shared.

BIOGRAPHY

Amit is an Instrumentation engineer with 22+ years of professional experience in process industry. He is working with Fluor Daniel India pvt. Ltd. for almost six years and previously worked with Honeywell India for around fourteen years. He has extensively worked on Safety System projects in different roles which involved activities like design and detailed engineering, HAZOP, SIL assignment and verification, Front End Engineering and Design (FEED), commissioning, project cost estimation and consultancy. Apart from India, he has worked on various projects across globe at locations like South Korea, Norway, UK, UAE, Netherlands, USA, Philippines and Australia.

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Debopam is a Process emical engineer with 17 years of professional experience in process industry. He is working with Fluor Daniel India pvt. Ltd. for past seven years. He has been involved in various design phases of the project such as feasibility study, FEED and EPC phase. He has experience in Oil and Gas upstream, Refineries and Petrochemical projects. He has also been extensively involved in safety studies such as HAZOP and SIL assessment for domestic and international projects.

Emerging Needs and Requirements of Industrial Automation: Do We Raise An Alarm – Always?!

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ABSTRACT

Alarm Systems are increasingly becoming an essential part for safe and efficient management of plant and machinery. It continues to be the primary focus for HSE engineers and an important aspect of Industrial Automation. This paper highlights the requirement and key design principles of an alarm system.

INTRODUCTION

The question often comes to our mind, as design engineers…How many alarms we should configure?How useful are the requirement of alarms in Industrial Automation? How to design an effective alarm system such that a plant is running safely to its optimal operation efficiency?

To answer these questions(or to raise more questions!) we need to understand what an alarm system is.

Alarms areinitiated when a process measurement crosses a defined setting and approaches an undesirable or potentially unsafe value. These are annunciated to the operator, indicating a situation requiring attention,

- By an audible sound
- Some form of visual indication, usually flashing
- Presentation of a message or some other identifier

Alarm systems form a core element of almost all modern operator interfaces to industrial plants including oil refineries, power stations, chemical plants and many others.

Alarms are a very important way of automatically monitoring the plantcondition and attracting the attention of the process plant operator to significantchanges that require assessment or action. An effective alarm system generates an alarm as soon as the process tends to move from normal operation to an upset condition.They also help the operator to maintain the plant within a safe operating envelope.

A good alarm systemsupports the operator to correct potentially dangerous situations before theEmergency Shutdown (ESD) system is forced to intervene, thereby improving plant availability. It also reduces the demand rate on the ESD system and, thus, increases plant safety.

Figures 1a and 1b distinguishes between an ineffective alarm system and an effective alarm system.

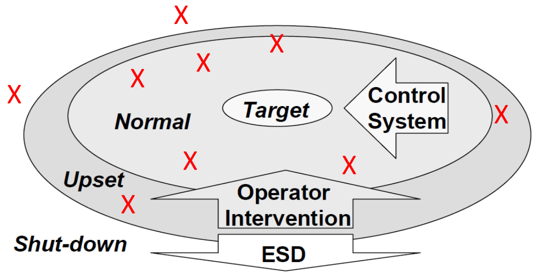

Fig 1a: Ineffective Alarm System

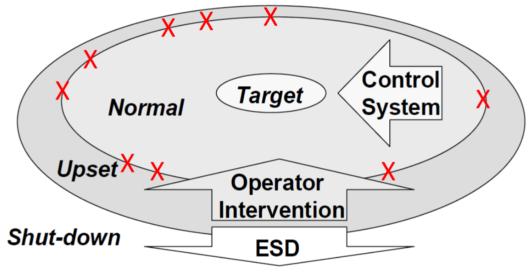

Fig 1b: Effective Alarm System

BACKGROUND

A brief peek into history and references from EEMUA 191, Edition 2, will reveal there are quite a few examples where ineffective alarm system has caused major accidents that have resulted in loss of life, loss to environment and loss of revenue.

The Texaco Incident, Milford Haven 1994, where there were 26 minor injuries and an estimated £48 million damage & major production loss.

The incident occurred as a consequence of flammable hydrocarbon liquid being continuously pumped into a process vessel that, due to a valve malfunction, had its outlet closed, and explosion occurred. The flare system was not designed to cope with this excursion from normal operation resulting in a failure in the outlet pipe. 20 tonnes of a mixture of hydrocarbon liquid and vapour were released, ignited and subsequently exploded. This caused a major hydrocarbon fire at the flare drum outlet and a number of secondary fires.

Operators did not have process overview to help diagnosis, and alarms were presented faster than they could be responded to. (87% of the 2040 alarms displayed as "high" priority, despite many being informative only!). Plant optimization was a total failure as well.

Next was the accident in **Esso Natural Gas Plant at Longford**, Victoria, Australia, where two workers were killed and eight injured. Gas supplies to the state of Victoria were severely affected for two weeks.

A pump supplying heated lean oil to heat exchanger (GP905) went offline. Investigators estimated that, due to the failure of the lean oil pump, parts of GP905 experienced temperatures as low as −48°C. Ice had formed on the unit, and it was decided to resume pumping heated lean oil in to thaw it. But the pump, pumped oil into the GP905 at 230 °C - the ΔT caused a brittle fracture in the exchanger. About 10 MT of HC vapour were immediately vented from the rupture. When it reached a set of heaters 170 meters away, it ignited causing a deflagration. The flame front burnt its way through the vapour cloud, without causing an explosion. When the flamefront reached the rupture in the heat exchanger, a fierce jet fire developed that lasted for two days.

The analysis revealed the operators were presented with 300-400 alarms daily, and up to 8500 in upset conditions. A plant cannot run on optimum design, if there are loads of alarms presented to the operator, who, for their convenience accepted number of alarms as 'normal'

Hence, there was a growing necessity to design an alarm system that alerts, informs and guides the operator making it focused and effective. A system that could make the plant safe and achieve optimal productions.

KEY DESIGN PRINCIPLES OF ALARM SYSTEM

The term 'Alarm System' refers to the complete system forgenerating and handling alarms (including field equipment, signal conditioning andtransmission), alarm processing and alarm display. It also includes hardware,software and supporting information.Alarm System are designed to direct the operator's attention towards plant conditions requiring timely assessment or action.Each Alarm should, Alert, Inform and Guide.

For an alarm system to be effective in supporting the operator, every alarmpresented to the operator should be a help rather than a hindrance. Theobjective should be to avoid the operator wasting time on deciding whether thealarm can be ignored and ensure that the operator does not adopt a mind framethat the alarms can be ignored!

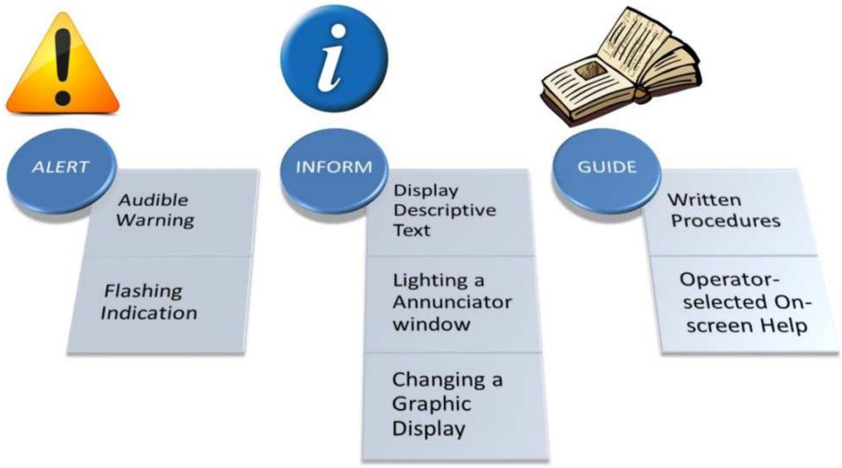

Fig 2: Key Design

Thus every alarm presented to the operator should be useful and relevant.One way of achieving this is to ensure thatevery alarm has a defined response.

Generally, this response should be an action (e.g. altering a control set point,changing over to a standby pump). Sometimes the response to the alarm will have to be conditional.For example, the operator might select a graphic display, check the plantcondition, and only in certain circumstances carry out any control action. In afew cases the defined response to an alarm will be purely mental. For example,in response to a ‘plant tripped’ or ‘start up sequence complete’ the operatormay need only to change the form of plant monitoring he is carryingout. There may not be any immediate control action required, but it is importantfor the operator to make this cognitive switch.

The key point is that every alarm (or combination of alarms) should have someresponse which should have been clearly defined.If a response cannot be defined, then the signal should not be an alarm!

Given that the operator is expected to respond to every alarm, it follows that in ausable alarm system:Adequate time should be allowed for the operator to carry out adefined response.

This implies that:

- The alarm should occur early enough to allow the operator to correct the fault and bring back the plant to safe conditions and deliver optimum output
- At the same time, it should not be too early that the operator tend to ignore
- The alarm rate should not exceed that which the operator is capable of handling

The Alarm System should be explicitly designed to take account of Human Limitations. In the The Texaco Incident, alarms were being presentedat an estimated rate of one every 2-3 seconds in the 5 hours leading up to theaccident. There were 275 alarms in the last 10.7 minutes before the explosion.

DESIGN OF INDIVIDUAL ALARMS

The following checklist addresses some of the issues that need to be resolved in the design of each alarm. This information should be recorded to provide a database for use during the lifetime of the plant

- What is the Purpose of the proposed alarm?
- What Response is the operator required to make to the alarm?
- What are the likely Consequences if the operator does not respond to the alarm?
- What Time is available for the operator to respond to the alarm?
- How likely is it that the operator response will be Effective?

LOGICAL PROCESSING OF ALARMS

During the design of the Alarm System the following different techniques can be used for processing signals from alarm sensors to generate more meaningful alarms for display to the operator.

- **GROUPING OF ALARMS**
  - A single grouped alarm may be used to display a number of different initiating events from a plant system. For example, a common alarm from a Nitrogen Generation Skid.

- **SUPPRESSION OF REDUNDANT ALARMS**
  - Eclipsing of several alarms on the same variable
  - Suppression of alarms from out of service plant
  - Suppression of alarms according to plant operating mode
  - Suppression of alarms following major events

- **INTELLIGENT FAULT DETECTION**
  - Intelligent fault detection is a term which covers a range of methods for logically processing alarms to reduce the amount of displayed information and increase its relevance.
    For example, in a complex system there may be several alarms that will be generated following a single fault. Some sophisticated processing systems are able to identify the root cause of a fault from the pattern of resulting alarms.
    However, this form of automatic alarm load shedding remains a research concept rather than a proven practical method.

- **AUTOMATIC ALARM LOAD SHEDDING**
  - There are fundamental limits on the amount of information that any human operator can assimilate and the number of actions the operator can perform.
    There is almost always a potential for the alarm load that the alarm system can generate to exceed that which the operator can handle. Automatic alarm load shedding concepts can offer help in these cases

- **HANDLING ALARMS FROM EQUIPMENT UNDER TEST**
  - It is quite common that numerous alarms may be generated from plant and equipment when it is undergoing maintenance or testing. Routine testing of automatic protection systems can be a particular problem. Logic can, in principle, be used to automatically suppress many of these non-critical alarms

CONCLUSION

Following bullet points are useful to engineers, who look to work on the design of an Alarm Systemfulfilling requirement of Industrial Automation,

- The Alarm System should be designed to support the user in his tasks
- A typical Alarm System should Alert, Inform and Guide
- Alarms should be logically processed so as to offer more meaningful alarms for display to the operator

Thus, we may conclude raising an alarm is always not appropriate, but raising an appropriate alarm is a requirement of Industrial Automation!

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EEMUA 191, Edition 2, Alarm Systems, A Guide to Design, Management andProcurement

AUTHOR BIOGRAPHY

Atanu Chakavarty

Atanu has 28 years of rich experience in Power, Fertilizer and Oil & Gas sector having executed various onshore, offshore, chemical and petrochemical projects.

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DEMYSTIFYING API670, SAFETY & CYBER SECURITY

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Abstract:-

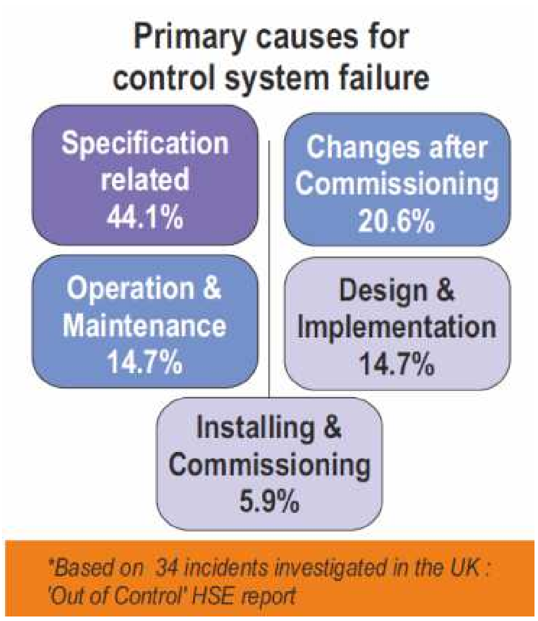
Operational safety within the process sector has always been a priority. As the process sector moved into the computer age, new issues arose as manufacturing plants converted to computer control to replace electrical, pneumatic, and electronic controls. The process sector developed a variety of tools to address these problems, but safety performance did not always meet expectations.

Standardisation of Machinery Protection system while complying with safety standard IEC 61511 and cyber security standard IEC 62443 can play a vital role in safe and secure operation of facility. This paper will touch critical aspects of API 670 Machinery Protection System Standard, IEC 61511 Safety standard and IEC 62443 Cyber security standards.

Introduction

A failed control system can cause significant plant downtime and is likely to be extremely costly; it can also create a hazardous situation when the system is controlling a critical process.

As per 'Out of Control' HSE report following are major causes for control system failure

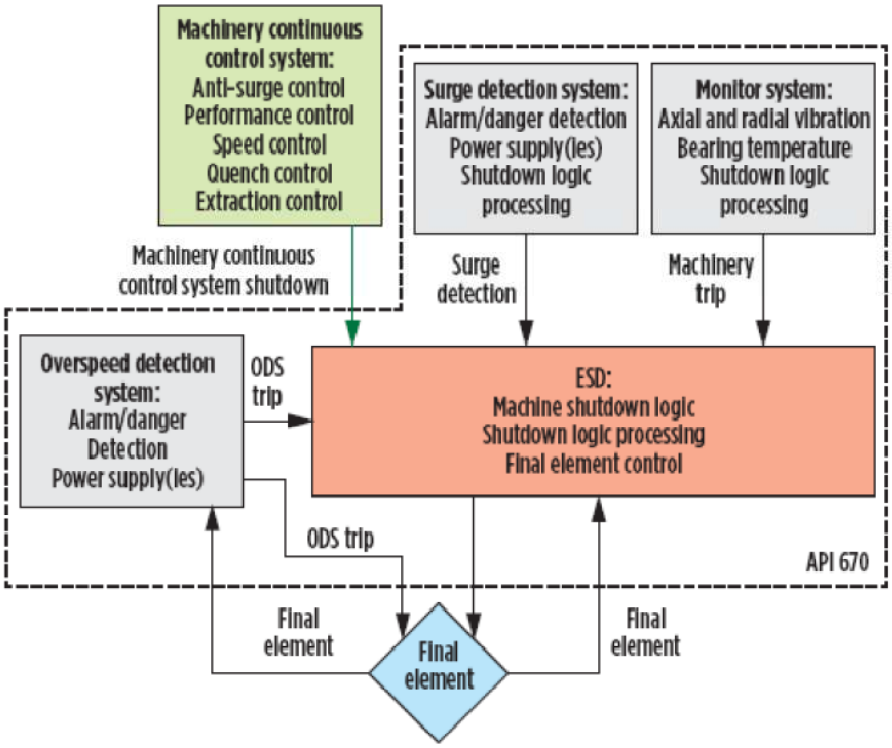


By following correct standards for Design & Specifications, project life cycle API 670, IEC61511 and IEC 62443 businesses can minimize the chances of system failure, which in turn increases productivity, minimizes costs and helps to maintain a valuable business reputation.

Applicable Standards: Few critical aspects implementation of which may help significantly are as follows:

API 670 (5th Edition) Machinery Protection Systems:

API's Standard 670 Machinery Protection Systems was created to stipulate the minimum requirements of a machinery protection system in a refinery application in an effort to improve safety, increase uptime and quality and reduce risk. A thorough understanding of the standard can facilitate proper MPS system for O&G applications.



Source: white paper on control and safety for turbo machinery by CCC

Distributed API670 architecture for the MPS

- The standard provides guideline about accuracy for sensors and monitoring cards (provided at Table-1 in the API760 standard).
- To support portable data acquisition and simultaneous online data analysis, the MPS shall have two buffered outputs per transducers (except temperature) on each monitoring card via front-panel bayonet nut connector (BNC) connectors (or similar) and rear panel connections
- The new annexure (N) to the standard of API 670 now recognizes that CMS (analysis system) is distinct and separate from machinery protection (monitoring) system. It is recommended that the system design should be such, that failure of CMS should not impact safety of the equipment or in other words implementation of CMS should not affect the MPS. Annexure-N also provided guidelines for the

processing capabilities of CMS hardware and the machine malfunction that the software should be capable of detecting.

IEC 61511-Functional safety - Safety instrumented systems for the process industry sector:

Functional Safety is part of the overall safety of a system or piece of equipment that depends on the system or equipment operating correctly in response to its inputs, including the safe management of likely operator errors, hardware failures and environmental changes. Functional Safety provides an opportunity to focus on specific risks and help prevent the consequences in a manner that process is driven to a safe state without human intervention. This strengthens the ability of the control system to deal with identified unacceptable risks with the desired level of reliability and integrity.

Safety instrumented systems have been used for many years to perform safety instrumented functions in the process industry. It is therefore essential that this instrumentation achieves certain minimum standards and performance levels. Key Concepts from IEC 61511 which should be taken in to consideration while dealing with safety systems are:

- SL selection should be based on extensive Hazard Identification and Layers of Protection Analysis.
- SIL should be applied to only those loops where risk cannot be reduced by other available layers. Adding more layers will increase buying and operating cost of equipment.
- Safety requirement specification is critical to meet safety standards of application. Owner/Consultant/suppliers should contribute to make it as per plant needs.
- There are technical and non technical requirements defined per SIL Level.
- SIL certification only will not ensure SIL compliance, It only provides assurance on System Capability (Quality) and Hardware Fault Tolerance (HFT/Voting) needed to meet SIL requirement.
- Consultant should always do SIL verification for SIF. Additionally Probability of Failure on demand (PFDavg) should be calculated based on end user practices (proof test interval, proof test coverage site safety index, Mission time, MTTR etc.) not on the basis of supplier recommendations. SIL Verification is most critical phase of implementation in safety life cycle.
- New edition puts emphasis on Functional safety management. End user should be briefed about right maintenance practice for safety systems and functional safety management aspects.

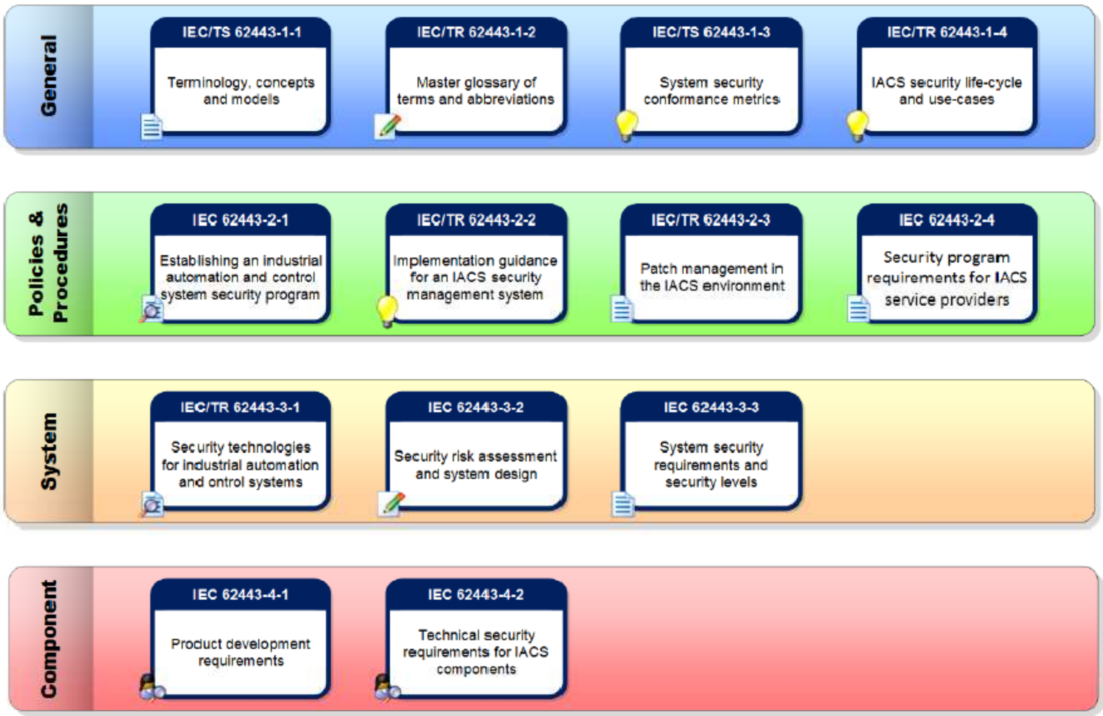
IEC 62443-Security for industrial automation and control systems:

An unprecedented number of security vulnerabilities have been exposed in automation and control products and owner/operators are demanding protection. There are well established strategies and techniques that automation professionals can employ to discover and mitigate security vulnerabilities and improve the inherent security of their products and systems. Much of this information is in a series of new international standards – IEC 62443. Learning and adopting these strategies will help companies stay ahead of potential vulnerabilities and reduce the likelihood of an incident.

The IEC 62443 series of standards and technical reports defines procedures for implementing electronically secure systems from many different industries including transportation, medical, robotics, and Industrial Automation and Control Systems (IACS). These strategies and techniques apply to end-users (i.e.

owner/operator), system integrators, security practitioners, and control systems manufacturers responsible for designing, manufacturing, integrating, or maintaining systems.

These standards are based on Operation Technology rather than information technology. Small description is as follows:



Source: ISA website

Key points worth noting are as follows:

- The risk analysis is an important precondition for Security Management relating to a plant or machine, aimed at identifying and assessing individual hazards and risks
- Measures and processes to prevent access by unauthorized persons to the surroundings of the plant
- Strict Network segmentation between plant and other areas. Follow zone and conduits philosophy as defined in standard.
- Reduce vulnerabilities by system hardening.
- Strong patch management system will ensure on time response against any threat.
- Strong access protection.
- Follow ICS cyber security life cycle.
- Old installation should be reviewed in accordance to IEC 62443 and strengthen cyber security measures.

Deconstructing peril

If observed closely all three standard works on minimizing risk for critical machines and installation. Following these standards helps you to minimize risk and improving operational efficiency. Associated frameworks consisting of standards, guidelines, and best practices to manage design, safety and cyber security related risk.

Also simplest way to reduce risk is to follow separation between safety and non safety system and cyber secure and non cyber secure zones.

Blending Standards

The 5th edition of the API Machinery Protection Standard API670 provides detailed guidelines on the implementation of the machinery protection systems (MPSs), taking into account IEC61508 and IEC61511. The IEC61508/IEC 61511 standard has added rigor to the risk assessment and considerations for selecting SISs. The standard's wide acceptance provides common ground for control equipment vendors and end users to select the right SIS for the application. The SIL analysis is greatly simplified through separation of the safety and control systems. Even without considering the IEC61508 standard, it has long been understood in the industry that, as far as safety is concerned, simplicity is synonymous with reliability. It is also crucial to understand that vulnerabilities in MPS system from cyber point of view can pose significant risk to people, environment and assets. Hence blending these three standards can provide robust framework for plant and its assets.

Conclusion

Earlier mentioned standards can provide significant advantages to end user e.g. safety, cyber security, reliability, interoperability and efficiency during operation of plant. It is combined responsibility of PMCs/EPC/End User and OEM to prepare a participatory mechanism where compliance to these standards can be evaluated considering practical aspects of operation in mind.

ACKNOWLEDGEMENTS

Relevant sections/standards, codes and guides of API (American Petroleum Institute) and IEC (International Electro technical Commission) have been used.

LEVERAGING IoT IN MISSION CRITICAL INDUSTRIAL CONTROL SYSTEMS

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ABSTRACT

All automation systems were designed in pre Internet of Things (IoT) revolution era where process industries opted for automation to help them in production and standardization of their process. Automation also provides safety for men and machine involved in the process industry in many cases. But it lacks interaction with the maintenance group or the management. Even in the latest power plants, the Control Systems (CS) are used for protection and control only. Due to the lack of interaction of CS with non-operation groups, its use is very limited. With the increasing use of automation, the industries served by CS have also increased. In mission-critical applications like power generation, early action on any fault by responsible team is utmost important to keep the process running. With the advent of IoT era and increased availability of IP connected devices and analytics; it's time to unleash the hidden power of control systems with IoT. In this paper, many IoT based features and future possibilities are discussed for taking maximum out of a CS. These features are implemented at IGSTPP and are helping in daily maintenance and reporting to the management. The capacity of CS at IGSTPP has been enhanced using advanced IoT techniques to enable it to report daily activities, health parameters & critical alarming conditions to maintenance groups automatically. These features have helped offload operation group from CS monitoring; reduce downtime due to CS in case of system component failure. It has helped in maintenance planning of CS components; reduce paper usage and other enhancements. Various challenges in implementing these changes are also discussed in the paper. The paper is concluded by Network layout, integration method adopted and security features implemented at the site.

KEYWORDS

Control System, IoT, Network Integration, DCS with IoT, Network Security, Thermal Power Plant, Targeted Information Communication.

INTRODUCTION

In pre-industrialization era, human or animal power was used for carrying out various works. With the advent of industrialization, various power intensive works were given to machines. This increased productivity by replacing the limited and environmentally subjective man or animal power with more reliable and powerful machines. Manpower was replaced with machine power to perform physical work. But the control of these machines was in the hands of humans. As time passed, control of these machines was given to other machines called control systems. With the control systems in place now the machines are controlled automatically without human intervention. Control systems helped in fast and reliable control of the machine. This has helped in increasing safety and repeatability in the system. The only job left with humans is to monitor the system and take corrective actions whenever required. As a part of continuous process improvement, the responsibility lies with the human to make machines more self-reliant and intelligent.

With the advent of IoT and expandable processing power and storage space, it's time to leverage the benefits of IoT to free man from the job of continuous monitoring the system. Now the systems can self diagnose and alert whenever required. Control systems can seek for human intervention with the help of IoT based solutions.

Increased availability of analytics can also help in diagnosing problems and predicting any future failures. This has the potential to assist man in the very intensive job of analysis of system failure.

MISSION CRITICAL CONTROL SYSTEMS

A power plant is a critical infrastructure of any country. As power plants are connected by grid, any disturbance can lead to widespread grid failure causing millions of people in dark, millions struck in transits, endangering many lives on life support systems and other risks. Failure of power plant's control system can also lead equipment worth millions at risk of damage. Hence the control system for a power plant is very critical.

Control systems work as brain and nervous system of a process industry where they gather real-time process data from sensors. Based on data and desired result, automatic actions are taken by the control system. The communication of a control system to the field equipment and operation groups is direct and almost real time. The communication to maintenance groups is limited by the desk operator's interpretation. With internet connectivity available to each and everyone today in mobile phones, there is a scope of improvement in the communication channel between the control system and maintenance groups/management.

CONTROL SYSTEMS AT IGSTPP

Indira Gandhi Super Thermal Power Project (IGSTPP), situated in district Jhajjar of Haryana, is a 3x500 MW fossil fuel based thermal power plant. Its control systems are provided by BHEL and Yokogawa. These control systems control different parts of the plant. The schematic connection diagram is shown in Figure 1.

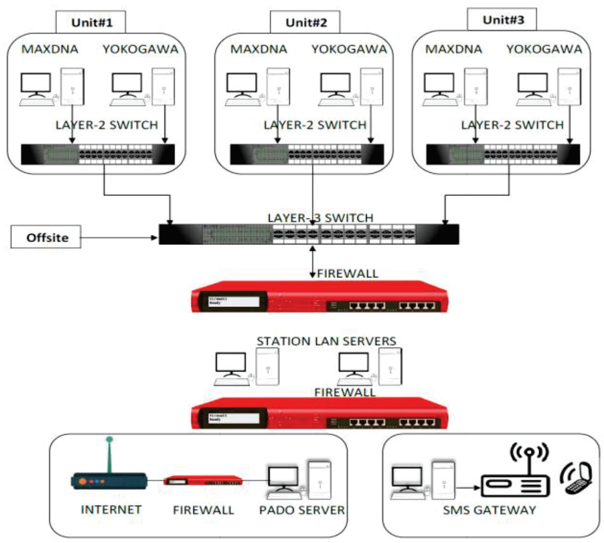


Figure 1

These control systems are connected via LAN switch. Data is exchanged between the control systems only for monitoring purpose. Any control related data is shared only via hardwired signals. This provides ease of showing data from one system to another. At the same time, it helps in avoiding any problems associated with the loss of communication between the control systems. Analog data is shared with robust 4-20 mA based signal, whereas digital data is shared only via contacts.

VARIOUS IOT BASED FEATURE IMPLEMENTED

The various features implemented in the control system are as follows:

ALARM/ALERT SYSTEM:

Various alarms are configured in the control system to be given to specific users. These users need not be in the plant control room. Alerts are provided in the mobile phones of the users. As long as users are in the coverage area alerts can be received and corrective actions can be initiated. These alarms are segmented to be provided to the different set of users based on their usage. Various types of messages configured are as follows:

1. **UNIT TRIP/SYNC:**
These messages are given to every user from top management to the bottom line as it is of everyone's concern. Messages for trip and synchronization of units are sent to users through GSM modems as well as through android based application. Since these events are critical, even when the user is not connected to data services, the message in the form of a text message is delivered. A message received in case of boiler tripping through GSM modem is shown in Figure 2. The message with detail reason for tripping shown in android app is shown in Figure 3. This helps the maintenance groups to know the reason for any boiler/turbine tripping without contacting the control room.

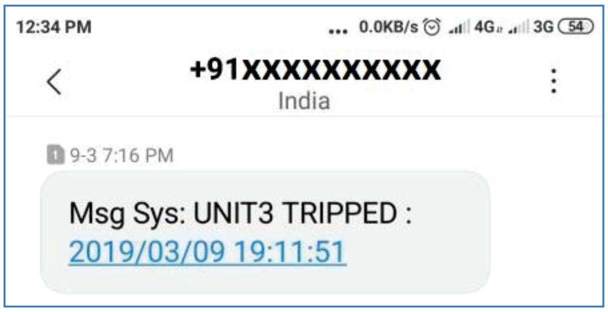


Figure 2

Figure 3

2. **MAJOR EQUIPMENT TRIPPINGS:**
Tripping of any major equipment may result in partial loading of unit and cause generation loss. This leads to heavy financial loss. Information regarding tripping of any major equipment is provided to all the users so as the restoration work can be started at the earliest. Messages similar to as shown in Figure 3 are sent for equipment trips also.

3. **CONTROL SYSTEM FAILURE ALARMS:**
Generation process stability is dependent on the reliability and availability of control and instrumentation systems. Mission Critical processes like power generation have dual redundant processor configuration with hot switching between processors. A single failure of a processor will not affect the process

immediately but if it is not attended timely, it may lead to a system outage. Process control rooms are usually monitored by operation engineers who are more concerned about generation optimization and maximization. Alarms like processor or network failure may go unacknowledged by them if they are not affecting the generation directly. In this scenario, it is utmost important to inform about the failure to the concerned department/targeted recipient so that the correction process is started at the earliest to avoid any system downtime. Instrumentation engineers continuously check for any error/outage of processor, network or critical sensor but due to the larger geographical distribution of different areas and different types of DCS in a single plant premise, it becomes time-consuming to visit each and every area to identify a fault.

To address this problem, the concept of group alarms is used at IGSTPP. Failures related control systems can be grouped under the following categories:

i) Controller redundancy failure

ii) Network redundancy failure

iii) Input / Output card failure

iv) Power Supply redundancy failure

Text message and android application based alarms have been configured to send instant alerts for any of the above condition to the concerned DCS groups. Any redundancy failure is immediately reported so that it can be restored at the earliest. Since the numbers of alarm points are significantly high, a grouping of similar alarms is done to provide alerts using the text message facility. Detail of the alarm condition is provided using the Android mobile application.

In Figure 4, a text message is shown for CPU card failure. The detail of failure is automatically captured and sent to the concerned group through email (Figure 5).

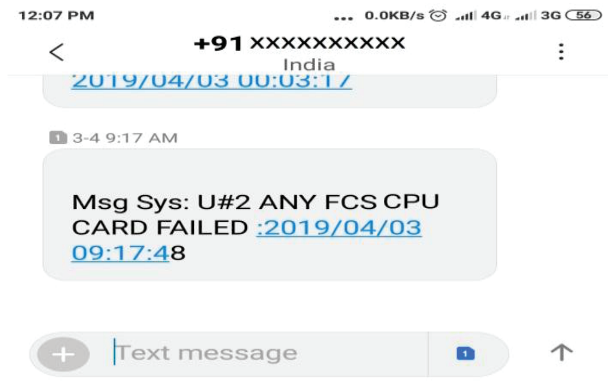
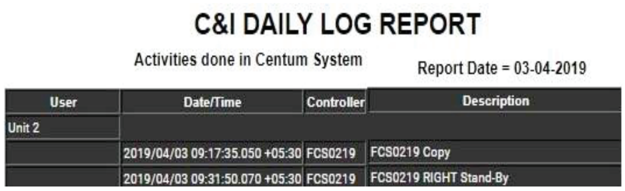


Figure 4



C&I DAILY LOG REPORT

Activities done in Centum System

Report Date = 03-04-2019

User	Date/Time	Controller	Description
Unit 2			
	2019/04/03 09:17:35.050 +05:30	FCS0219	FCS0219 Copy
	2019/04/03 09:31:50.070 +05:30	FCS0219	FCS0219 RIGHT Stand-By

Figure 5

A sample network failure based message on the Android app is shown in Figure 6. Clearly showing which network node has gone bad and which one has recovered from the failure.

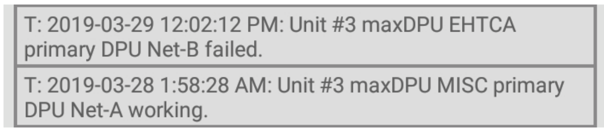


Figure 6

AUTO REPORTS:

Various daily reports are sent via email to different users for corrective actions if any. These reports contain various data captured by the control system. Various reports are as follows: