Realizing the Full Value of Industrial Internet and Data Analytics in LNG Facilities

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Presentation Overview

- Introduction to Industrial Internet (IIoT)
- Key Application Areas in LNG Operations
  - Process monitoring, Predictive maintenance, Process optimization
- Leveraging Existing Assets
- Benefits of EPC Phase Implementation
- Case Study in Data Analytics
  - LNG plant amine system monitoring
Introduction to Industrial Internet/Data Analytics

- **Digital Transformation Enabled by**
  - Cloud computing
  - Decreasing cost of sensors, storage, bandwidth
  - Big data analytics and Sensor technology

- **Integration of**
  - Physical plant and Digital information
  - IT (ERP/CRM etc.) and OT (DCS/PLC etc.)

- **Cybersecurity**
  - IT and OT security challenges
Industrial Internet Domains/Solutions
- Includes new ways of using existing technology
- OEM, Automation provides and others

Sensors
- Wireless sensors/Intelligent sensors
- Vibration Monitoring
- Virtual sensors

Big Data Analytics
- Ability to deal with large datasets
- Higher resolution/Storage
- Better analytics – Machine learning
Applications of Industrial Internet

Applications Related to LNG Facility Operation

- Predictive Maintenance
- Process Optimization
- Anomaly/Fault Detection
- Exploratory/Statistical Analysis

Data Analytics

Value

Complexity
LNG Process/Equipment Monitoring

- Tracking Key Performance Indicators (KPI) for LNG
  - Efficiency, Production, Yield, Quality
- Condition and Performance Monitoring of Equipments
- Process Control Monitoring
  - Ensure loops are in auto and working

- Abnormal Situation management/Anomaly or Fault Detection
  - Enhancement of safety
  - Reduce plant downtime
  - Early detection of anomalies – Operator intervention
    » Fault diagnosis important
LNG Process/Equipment Monitoring - 2

- Approaches to Fault/Anomaly Detection

- Numerous Application Areas in LNG
  - Amine system and dehydrators
  - Heavies/Scrub Columns
  - Plate and Frame and Other Exchangers
Asset Management - Predictive Maintenance

- Continuous Monitoring and Prediction of Equipment Conditions
  - 82% random failure pattern

- Benefits Compared to Reactive/Preventive Maintenance (ARC)
  - Reduction in maintenance cost (50%)
  - Reduction in unexpected failures (50%)
  - Increase in MTBF (30%)
  - Increase in availability (30%)
Asset Management - Predictive Maintenance - 2

Failure – Latent Error and Enabling condition
- Methodologies for Predicting Failure
  - Engineered algorithms
  - Supervised learning for prognostics
    » Models for Remaining Useful Life (RUL)
    » Model for probability of failure in time
  - Unsupervised learning techniques
    » Limited failure history

- Application Areas in LNG includes
  - Turbomachinery
  - Heat exchangers/Valves etc.
LNG Plant Optimization

- LNG Process Optimization Current Status
  - Advanced Process Control (APC)
  - Supervisory Systems

- Real Time Optimization (RTO) not Common

- Opportunities from Industrial Internet
  - Supervisory optimization (Less frequent)
  - Smaller units/equipments that are currently ignored
  - Enterprise-wide optimization (Multiple facilities)
Typical Application Areas in LNG

- Maximizing Plant Efficiency
  - Optimum Process Conditions – MR compositions, Other operating parameters
  - Operating point for compressors to enhance efficiency
  - Optimal load distribution between compressors

- 5-15% power reduction reported in studies
  - 12.9% (Wang et al., 2012)
  - 4.5% (Alabdulkarem et al., 2011)

- Energy Optimization for Utilities
Existing Assets for Data Analytics

- Process Knowledge Key to Successful Applications
  - Selecting right variables
  - Selecting right objectives for optimization

- Digital Plant Information
  - Digital repository of plant information
  - EPC project data for greenfield facilities

- Existing Control Infrastructure
  - Working with DCS/PLC systems
  - Starting with supervisory levels and gradual move to base layer
LNG Simulation Models and Digital Twins

Existing Assets
- Steady State/Dynamic Models
- Operator Training Simulator
- Computational Fluid Dynamics Models

Applications
- Selection of Variables/Causality
- Model Based Optimization
- Boosting Data Models

Digital Twins for LNG Plants

IIoT

Process Model/OTS

3D Models

Digital Data

Equipment Model
EPC Phase Implementation of IIoT

- **Benefits of Early Implementation**
  - Preparing sensors/IT infrastructure
  - Configuring models based on process/project information
  - Testing during startup and commissioning

- **Avoiding Retrofits after Commissioning**
Case Study – Anomaly Detection

- Monitoring of Amine System in LNG Plant
  - Amine system performance important – CO₂ removal

- Anomaly Detection Method used
  - Identify abnormal operation considering group of variables
  - Statistical approach using data

- Operating Data from Plant after Startup
  - About 320 tags for amine system
  - Seven months of operation

- Performed in Offline Mode
Anomaly Detection – System Set-up

- Big Data Analytics Framework/Tools
  - Splunk - Machine data database and indexer
  - Prelert – Anomaly detection tool
  - Neo4j – Graphical database

- Design Data from Smartplant Instrumentation
  - Captures relationships among tags, equipment
  - Enables setup of monitoring system with minimal effort
Anomaly Detection - Methodology

- Predictive Model Consists of Statistical Probability Distribution
  - Bayesian distribution modeling
  - Fit is determined by unsupervised machine learning
  - Distributions have different shapes (Not just bell curves)
  - Distributions used to determine what is unexpected (anomalies)

- Anomaly Score – Normalized Probability Score
  - Score measures level of unusualness
  - Output has no false positives or negatives
Anomaly Detection – Approaches

Three Different Approaches

- All amine tags used to calculate anomaly scores (unit-wide)
- Individual equipment tags to calculate separate anomaly scores
  – Clustering based on Smartplant Instrumentation
- Individual groups to calculate separate anomaly scores
  – Obtained from process understanding
Case Study – Scenario 1

Increase in CO₂ to >100ppm Caused by Amine Regenerator Operation

- Reflux failure leading to increase in regen column pressure
Case Study – Scenario 2

Increase in CO2 to >100ppm Caused by Increase in Feed Gas CO₂ Concentration

- Column differential pressure increases

Feed Gas CO₂

Anomaly Score - Absorber
Column Diff. Pressure
CO₂ Composition

Anomaly Score (see legend for units)
Case Study – Root Cause Analysis

- Ability to Quickly Evaluate the Root Cause
  - Equipment contribution to anomaly score
  - Further drill down to particular tag

![Graph showing anomaly score and influences by field]
Thank You

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Questions