DEVELOPMENT OF THE TECHNICAL OPERATING STRATEGY AT AL TAWEELAH ALUMINA REFINERY: APPLICATION OF INDUSTRY 4.0.

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ABSTRACT

Al Taweelah alumina refinery is a 2.0 Mt greenfield facility situated in the UAE between Abu Dhabi and Dubai. The refinery is being developed by Emirates Global Aluminium (EGA). Being a greenfield project has given the refinery team the unique opportunity to create a holistic technical operating system from infancy, in order to achieve business objectives. This system is focused on the main business drivers and cascades to associated process and maintenance strategies and procedures. One of the most modern Process Information Management Systems (PIMS) has been selected and customised to visualise the technical operating system; to monitor key performance indicators, indicate deviations, and guide the user to problems and appropriate mitigations. ATA has applied the latest of the Industry 4.0 elements in these first significant steps towards the 'smart refinery'. This paper describes the philosophy behind this development and how it is applied.

1. INTRODUCTION

Al Taweelah alumina refinery is the first alumina refinery to be built in the UAE with an expected annual production of 2 Mt/year of smelter grade alumina. The refinery is part of Emirates Global Aluminium (EGA), one of the world's largest 'premium aluminium' producers. The refinery, which is set to produce its first alumina in the first half of 2019, is applying Industry 4.0[1] elements to its technical operation strategy.

Originating in Germany the term Industry 4.0 is the industry manufacturing mindset that utilises digitalisation of industry and intelligent manufacturing. It describes the smart factory in which smart digital devices are utilised to network and to communicate with raw materials, intermediates, finished goods, equipment, machines, people, etc. It is characterised by flexibility, and the efficient and integrated use of people, process, technology and organisation. Industry 4.0 is no longer a "future trend" – it has become more and more part of day-to-day business operations with a drive to excel and dominate the market. Companies are combining advanced automation, sensors and actuators, cloud computing, data analytics and intelligent algorithms. Through application of key Industry 4.0 elements, EGA Refinery is striving to create the first significant steps towards 'smart refinery' operations management. This paper will mainly focus on the digitalisation and the intelligent visualisation aspect of Industry 4.0.

2. APPROACH AND DISCUSSION

2.1 Technical Operating Philosophy

The Al Taweelah alumina refinery Technical Operating Philosophy[2] was devised to support the core business vision, values, and principles of EGA. This philosophy delivers the application of knowledge, skills, tools and techniques to define, visualise, measure, control, report and improve the process, in order to meet refinery requirements and support profitability.

The refinery business drivers define the macro strategy of the Refinery and are set behind three main drivers which are Production, Quality and Cost/Consumption (Refer Figure 1). Environment, Health and Safety (EHS) is a non-negotiable

requirement within this framework. The implementation follows seven steps:

1) Development of driver trees for the entire Bayer Process
2) Identification of plant KPI's linked to the business drivers (level 1 KPI)
3) Identification of process KPI's (level 2 KPI)
4) Development of strategies and executable procedures for the process KPI's
5) Development of appropriate impacting factors and control levers (level 3), success criteria for the controls and appropriate troubleshooting
6) Development of a suitable information management system and a visualisation platform for the information to be centralised and appropriately displayed and used
7) Integration into the EGA system, with routine checks, reviews and continuous improvements.

Traditional examples of plant KPI's include flow, yield and availability for production; raw materials and total energy for consumption; while for quality they are the parameters defined in the specification. For each individual plant KPI a proper strategy and procedure was developed (Figure 1).

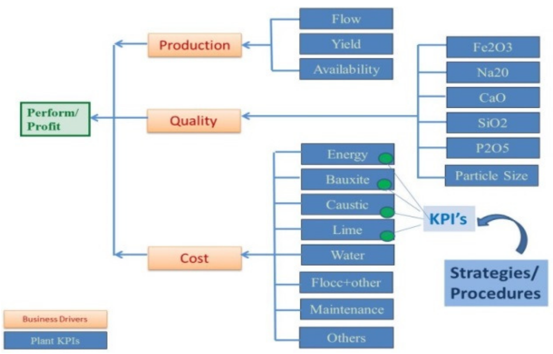

Figure 1: ATA's Business Drivers and Plant KPIs

2.2 Developing the Al Taweelah alumina refinery Technical Operating Strategy

In a conventional Bayer Process Circuit, from bauxite to alumina there are several facilities. One way to describe the productivity of each facility is according to the equation:

Production = Flow * Yield * Availability

Traditionally yield refers to precipitation yield, defined as how many grams per litre of equivalent alumina is precipitated in the circuit. However, specifically for a given facility, it can also be efficiency or a quality parameter; for example, particle size in the grinding facility or solids in pregnant liquor in security filtration. For 18 individual facilities, this consideration was adopted to facilitate elaboration of KPI's, in addition to a consideration of raw materials consumption, alumina quality and precipitation yield.

A standard way to visualise and model the plant KPI's is to develop a Value Driver Tree (VDT) and subsequently conduct a sensitivity analysis (VDTs). Figure 2 presents an example of the VDT for Digestion. The Driver Tree gives the opportunity to simply identify and visualise the main KPI's, lagging and leading indicators and enables impacts to be quantified as it uses simplified calculations.

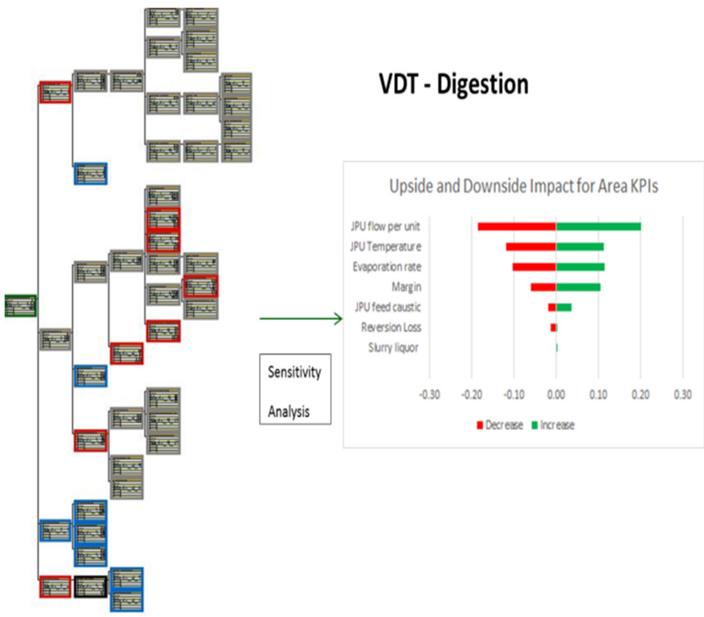

Figure 2: Example of VDT and sensitivity analysis for Digestion in ATA refinery.

VDTs were developed for each plant KPI to identify all process KPIs and control levers that are relevant for the facility or for the Process KPI. A quantitative sensitivity analysis for each of these control levers or

impacting factors was carried out to characterise their criticality.

The next step of this development was to map all strategies, procedures and levers/factors for each process KPI. Figure 3 is an example of a Heat Interchange facility, with an illustrative map of all relevant KPIs for this facility, Process Management Strategy documents (PMS), Process Management Procedures (PMPs) and the Control Levers required to support the business driver. Note that there is a strategy for the technical aspects of the facility that addresses the flow performance and efficiency and an asset management strategy for the maintenance tactics and cleaning schedule.

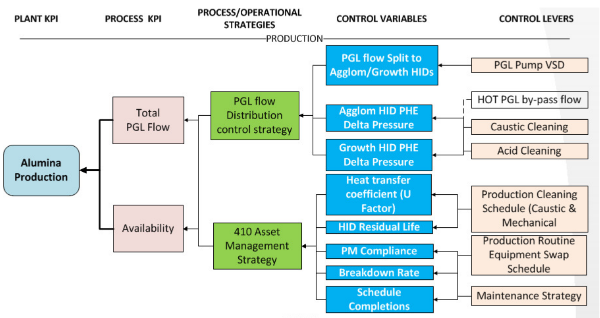

Figure 3: Example of Driver Tree for Heat Interchange Facility

The strategy documents cover business sensitivities and define the overarching philosophy to achieve the objectives. Procedures support the Strategies by defining the targets and limits of operation. The Procedure provides clear guidelines listing how to execute the strategy and governs the process controls and its variables and establishes limits of operation of the variables and justification of those limits for the Central Control Room (CCR) operation.

The Technical Operating strategy, which links the execution level to the business drivers, forms the foundation of the Process Information Management System (PIMS).

2.3 Development of Process Information Management System (PIMS)- Industry 4.0

An important step to monitor daily production performance that is linked to the Technical Operating Strategy is to define an appropriate Process Management and Information System (PIMS). This system visualises and reconciles all levels of information and solutions into one single web based platform and hence, enables the user to understand quicker where the opportunity to improve or to close a gap lies and therefore enables a better process decision. The importance to operational performance of well-presented and timely information in a form that is easily assimilated is highlighted in the recent paper by Clancy[3]. Ultimately it will create more value for the business by means of:

- Increasing Safety, Reliability, Quality and Operational efficiency
- Maintaining and improving sustainable and high quality production and maintenance
- Reducing Operations costs and production losses
- Driving Operational Excellence and Best Practices by continuous improvement

The underlying philosophy that has guided the EGA refinery team through the design of the visualisation and dashboard system are the following:

- Enhancing collaboration and communication by providing the same view of the business for all users at any given time. This approach is intended to eliminate the practice of maintaining individual calculation and trending tools on local drives, and to create a single source of truth
- Visualisation of the relevant elements of the business drivers to quickly identify performance gaps and improvement opportunities
- Improving decision making by centralising data and providing real time analysis tools
- Role specific dashboards supported by contextual navigation
- Ability to re-visualise data in other chart formats
- Enabling the viewing, analysis and interaction with data on any device – from PCs to smartphones, tablets.

To achieve the objectives described above the Al Taweelah alumina refinery team have developed and incorporated a series of interrelated software solutions.

(1) Dashboards, including traditional process graphics and trends,

(2) KPI Management,
(3) Production Loss,
(4) Capability analysis,
(5) Equipment Performance (OEE),
(6) Residual Life,
(7) Inventory Management and Metallurgical Accounting,
(8) Reporting System,
(9) Work Execution

One of the differentiators of the Al Taweelah alumina refinery PIMS solution to traditional monitoring systems is the use of Smart Dashboards, where the use of Business Intelligence[4] (BI) tools are embedded into the PIMS portal (Figure 4). They provide interactive visual data analysis. These dashboards empower the user by providing not only data, but insights and also provide the flexibility to interrogate the data with minimum effort.

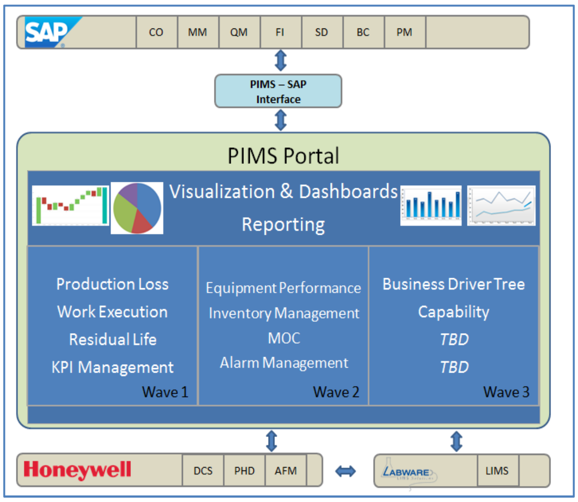

Figure 4 – Process Information Management System architecture overview

Figures 5, 6 and 7 illustrate some of the applications and visualisation of this system.

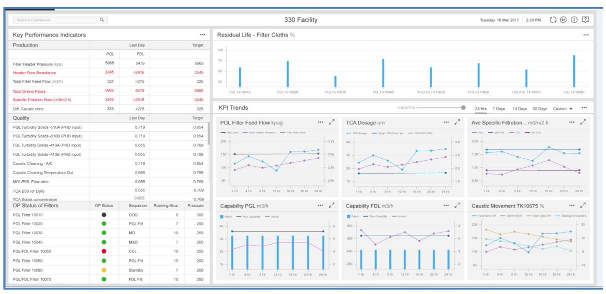

Figure 5 – Example Dashboard

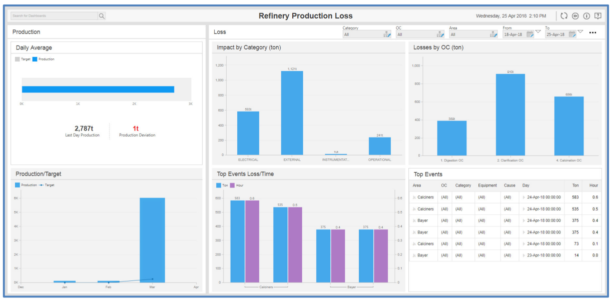

Figure 6 – Example of Production Loss application

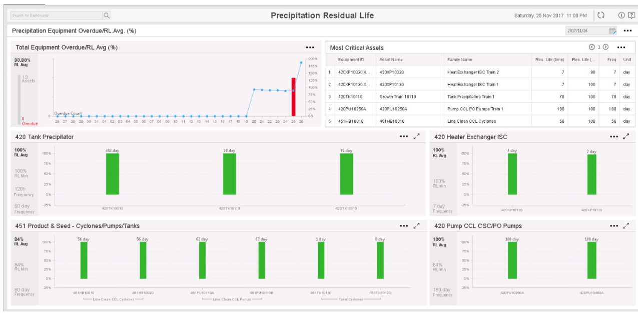

Figure 7 – Example of Residual Life application

This approach has achieved a tight integration between the Operation Technology (OT) with Information Technology (IT) that integrates the Distributed Control System (DCS), SCADA, Operator Training Simulator (OTS), Advanced Process Control (APC) and Operator support systems such as alarm management, Maintenance support for Condition Monitoring (non-destructive testing) and the Laboratory Information Management System (LIMS).

2.4 Al Taweelah alumina refinery Industry 4.0 strategy

One of the great advantages of this approach was that the Al Taweelah alumina refinery had few constraints due to existing systems or corporate requirements on process control. Al Taweelah alumina refinery management endorsement of the development of a completely new system provided the unique opportunity to design a system from scratch tailored to the specific needs of the refinery by incorporating a holistic approach.

Furthermore, the use of “data analytics” as one of the enablers to excel and

continuously keep focus on a broader range of human-factors while investing in digital technologies on sensors, algorithms and analytics has added benefits.

Even though the refinery is not operating yet, the use of an OTS as a digital twin[5], that incorporates the thermodynamic process models and the one-to-one mirror image of the DCS, has helped to identify gaps in the design and hence, avoided potential issues in the control logic during commissioning and start up, that would have hampered or even delayed the ramp up of the refinery. The OTS has demonstrated its value as an excellent test environment for different scenarios not only to better prepare the control room operators but also as a mitigation tool for ramp up risks.

To best utilise the assets and provide values to the business, Al Taweelah alumina refinery mapped the business objectives into practical operational use cases. "Use Cases" focused on defining the business need to adapt to Industry 4.0 vision and how it is expected to translate into beneficial outcomes for Al Taweelah alumina refinery. Some of these "Use Cases" are detailed in Table 1.

Some technical applications that have historically been challenging, such as production loss reconciliation and residual life tracking, are tailored and thus easier to use, since they are fully integrated in the portal and interactive with the user. These applications will significantly reduce the amount of time process engineers spend on these tasks and provide early alerts for deviations as required.

The Capability application will assess each facility of the refinery on its theoretical production potential and hence, will provide early indication of when a facility is deteriorating in its performance, since the focus is often only on the facility-bottleneck. This application will facilitate the assessment process, since it is also integrated in the overall solution and will therefore save the engineers time.

Below are just a few examples of use cases to illustrate the approach the team have taken to utilise the potential of modern, digital analytics.

Table 1: Industry 4.0 levers applicable to Al Taweelah alumina refinery

Industry 4.0 value drivers as applicable for ATA	What to do - Use cases
Inbound and outbound material movement optimization	Use case 1: Provide visualization and analytics for Bauxite Residue Management Use case 2: Provide visualization and analytics for material movement outside refinery operating limits
Transform Operator Training Simulator (OTS) into a Multi-Purpose Dynamic Simulator (MPDS) thereby improving overall effectiveness of engineering via digital simulation	Use case 1: Design and test entire refinery operations through "digital refinery" concepts using Operator Training Simulator (OTS). Use case 2: Share operational and process knowledge to test current DCS design and come up with improved plant operational requirements Use case 3: Use Operator Training Simulator technology to build DCS engineering changes, test and simulate to maximize effectiveness and reducing deployment times of engineering changes to the production facility
Strengthening customer integration and channels	Use case 1: Provide near real-time lab analytical information to DCS operators by integrating LIMS results into DCS graphics with sample time and validity information. Use case 2: Integrate Substation Control and Monitoring System (SCMS) i.e. HV, MV and LV status and energy consumption into the DCS and PIMS to provide complete energy performance information to all stakeholders
Managing and reconciling raw materials	Use case 1: Implement "metallurgical accounting" work process and automating inventory management Use case 2: Reconciling electrical energy consumption across the refinery for good management of energy costs
Maximizing asset utilization and minimizing downtime	Use case 1: Provide visualisation of "Residual Life" of the refinery Use case 2: Provide analytics of "Production Loss events" Use case 3: Performance monitoring of critical process equipment like JPUs, GEHO pumps,…
Production asset intelligence	Use case 1: Use proactive sensing using inferential models
Creating a digital link between operations and information technology	Use case 1: Establish a "one stop shop" for all plant information and knowledge in our MES solution named "Process Information Management System (PIMS)"

Predicting changes and responding in real time	Use case 1: Establish a highly automated "Distributed Control System (DCS)" and enhance plant operations using "Advanced Process Control (APC)"
Driving direct and indirect labor efficiency	Use case 1: Implement "work planning and execution" to oversee resource allocation and capacity

2.5 Roadmap and execution journey

Traditionally process industries lagged in the adoption of technology when compared to other industries like banking, transportation, retail, healthcare etc[6]. Process industry leadership was sceptical of technology impact in plant operations. Some industry leaders have developed digital models of the entire production process ("digital factories") while the rest have achieved very little of the potential value that can be captured.

The authors believe that harnessing the capabilities brought forward by technology that supports Industry 4.0, will enable the creation of significant value and differentiate a business from its peers and market players. EGA refinery's attempt to leverage on these opportunities is demonstrated in Table 2, which describes some showcase implementation of Industry 4.0 in Al Taweelah alumina refinery.

Table 2: Industry 4.0 implementation to the Al Taweelah alumina refinery

Timeline: Prior to 1st Alumina production (tactical) focus
Business objectives to be realised : 1. Implement smart process control through use of DCS 2. Train plant operations staff using Operator Training Simulator. This is our version of "digital factory" 3. Initial Advanced Process Control (APC) applications 4. Pilot deployment of operator assistance systems like Alarm Management systems 5. Establish foundation level historian and MES infrastructure supporting "business intelligence" visualisation and dashboards. 6. Implement "productivity improvement" MES applications like Residual Life, Production Loss, etc… 7. Implement "labour efficiency" MES application like Work Planning and Execution 8. Improve overall effectiveness of engineering via digital simulation 9. Establish pilot Instrument Asset Management System 10. Establish "base level" industrial cyber-security
Timeline: First 2 years after 1st alumina (strategic)
Business objectives to be realised : 1. Implement wireless mobile instrumentation with geospatial location detection 2. Additional APC applications 3. Extend Alarm Management system to all areas of the refinery. 4. Implement "state based" dynamic alarming and enforcement 5. Implement raw material management MES applications like "metallurgical accounting", automating inventory management along with reconciling electrical energy consumption 6. Implement "Production Asset Intelligence" MES applications 7. Implement refinery capability determination and "what if" operational insight applications 8. Implement an automated process shutdown monitoring and safety integrity validation application focused on "Process Safety" 9. Implement business driver visualisation leading to quantifying monetary gains and losses
Timeline: 2+ years after 1st Alumina (strategic)
Business objectives to be realised : Extend APC applications for machine-learning capabilities

2.6 General considerations during the PIMS design

The refinery team has taken additional considerations into account, which are discussed in further detail below.

Invest in internal functional/business translation resources: These resources are able to translate the business needs into practical application requirements and execute them. They need to have a combination of organisational, industry and functional knowledge.

Invest in state of art visualisation: The refinery's ability to distil complex data and bring these data to life through visualisation. This is a key to success as the operational staff require information to be presented in a digestible manner so that they can take necessary actions/decisions.

Active focus on business insights and innovative ideas has originated from human ingenuity and creativity – data and analytics can support and enhance them. The value of data depends on its ultimate use. Value is tied to how and by whom data will be used. Data management consists of[7]:

i. Data collection
ii. Data aggregation
iii. Data analysis

Value is magnified if data analysis is coupled with business insights. It is important to remember that while analytics provides tools for decision making, it does not replace sound judgment. Building digital trust should be a top priority.

Success in the journey does not come with just investing in the right technology, but with long term change programs like setting the organisation up for the right culture. Without limiting the vision on current constraints, move the focus beyond technical details and consider what impact new applications can have on the value chain to the business and customers. It is important to take time to evaluate the maturity level in all areas of Industry 4.0 so that understanding increases as to where the business stands, what strengths and weaknesses it has, where it can build on strengths and which systems/processes may need to be integrated into future solutions.

Encourage and embrace external partnerships with industry research groups, educational institutions, and change leaders in the industry- rewards.

6. CONCLUSION

The authors have described the philosophy behind the development of the Refinery Technical Operating strategy. Central to the success of this endeavour is to start from the technical drivers of the refinery. The authors have also demonstrated through the Technical Operating Strategy and the integrated solution portal from the PIMS that Al Taweelah alumina refinery will make a significant step towards the "Smart Refinery". The Al Taweelah alumina refinery has applied elements of the Industry 4.0 generation and the guiding principles established are well aligned with key industry 4.0 levers. For those who have experienced the commissioning of a Greenfield refinery would know that this is a very challenging journey and any system that can facilitate this process is well received.

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