FURTHER APPLICATION OF THE GENERIC GROSS ERROR DETECTION AND DATA RECONCILIATION SYSTEM FOR ALUMINA REFINERY DIGESTION PROCESS

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ABSTRACT

Further to the successful application of the model-based generic gross error detection (GED) and data reconciliation system to the alumina evaporation process, reported in the last AQW conference (Lee *et al*, 2012), this paper presents the extension of the system for the Bayer digestion process. The system, implemented at a number of Alcoa-operated refineries, has been demonstrated to be able to not only detect field instrument errors and provide reconciled process and laboratory readings to site engineers, but also to provide soft sensors for unmeasured key parameters. The reconciled readings of the field instruments such as bauxite slurry, liquor flow meters, heater temperature meters and blow off ratio are available to the plant area engineers and instrument maintenance staff via customised manufacturing execution system (MES) visualisation on a regular schedule. Examples provided in this paper demonstrate the capability of the GED system to address process and instrument issues within the building.

1. INTRODUCTION

The main objectives of the Bayer digestion process are to extract the available alumina from the bauxite by dissolving it in a hot caustic soda solution following removal of desilication product (DSP) at the lowest possible energy costs (Hudson, 1982). Detailed, the knowledge in the process has been translated into first principle-based models for simulation of the Bayer digestion process as reported in the literature (see e.g. Sidrak, 2001).

The Process and Equipment modelling group within Alcoa's Technology Delivery Group maintains a library of Bayer refinery unit operation models and process models of each refinery. Development of these models extends back to the mid 1980s (Langa *et. al.,* 1986; Bahri *et. al.,* 2005; Lee *et al.*, 2007). The wealth of experience and knowledge in developing and using these offline, fundamental-based models to support process improvements, plant design and optimization decisions, coupled with the need to improve energy efficiency, and the success with the Evaporation GED trial at Alcoa's Jamalco Alumina Refinery (Lee *et al*, 2012) provided motivation for further application of the GED system to the digestion process in this work.

2. PROJECT OBJECTIVES

The intent of the project was to determine if GED could be applied to the alumina digestion process and to assess the benefits. Another successful implementation would provide further evidence to support a broader application of data reconciliation techniques within Alcoa's alumina refining system. Specific objectives for the pilot application are: 1. Improve digestion energy efficiency; 2. Better process performance monitoring through regular/scheduled execution of the online model and 3. Improved process and instrument troubleshooting through dedicated MES visualisation for digestion process GED

3. SYSTEM DEVELOPMENT

3.1 Infrastructure

The Alcoa QUASAR[1] infrastructure (Darnbrough, 2008) already existed prior to the project. As a result, connections between the centralised data historian and the geographically distributed site data historians already existed and were supported. The Alcoa GED system leverages this infrastructure through the provision of a single

[1] Quality Automation Solutions in Alumina Refining

connection from the GED modelling server to the centralised data historian. Further information about the GED architecture employed in this work is described by Lee *et al.* (2012).

3.1 Implementation process

The project involved execution of a standard 4-stage implementation process involving conceptual design, detailed design, implementation, commissioning and handover (Love, 2013). The process ensures all activities such as the user requirement specification (URS) document, functional design specifications, process models and MES visualisation required for each of the phases of the project are delivered and signed off.

3.2 Model development

During the conceptual design, a model of the digestion process, which uses the Alcoa Technology Delivery Group's best understanding of the Bayer process chemistry (Bahri *et al*., 2005) was developed and validated based on a review of the documents supplied by the customer, discussions with site engineers as well as a review of process historical data. One of the most time consuming aspects of the modelling work was the investigation of the heater configurations on the plant. Logic was developed and included into the model such that it accounts for heaters which are in or out of circuit at any given point in time. For instrument gross error detection and data reconciliation, the generic GED block described by Lee and Love (2009) was also included into the model.

3.3 Fault injection testing

Fault injection testing is one of the GED deployment activities for factory acceptance testing (FAT) of the models during the detailed design phase of the project. As its name implies, faults of a specified size are injected into the models to determine if the model can reliably flag a gross error for the instruments at precisions required by the customers in the URS document. Numerically, the precision of the instrument is defined as one standard error (or 1 sigma). The predetermined value of the standard error is then used to compute the relative size of the error of a reconciled reading and reported as a value termed EPS. EPS quantifies the instrument error and is defined as the bias between the measured and reconciled value over standard error of the measurement.

A fault is injected into one of the plant or laboratory tags within a base data set and the model run to produce a set of EPS values. This is repeated automatically for all subsequent tags such that a matrix of EPS values is generated. Figure 1 shows an example of the EPS matrix of the FAT on the digestion process model. Since the fault injection and model runs were performed sequentially, the tag names for vertical and horizontal elements of the matrix appears identical.

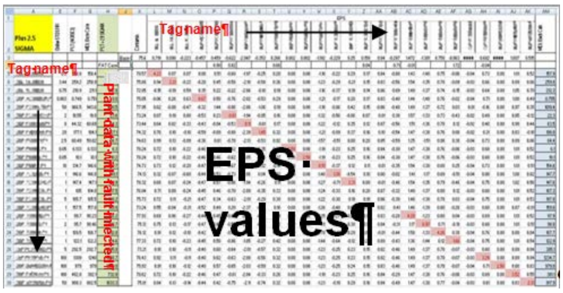

Figure 1. FAT testing results

The diagonal values of the EPS values in the red cells are relatively larger than the non-coloured cells indicating that the model was able to detect gross errors for most of the instruments or process variables. It should be pointed out that because of error smearing, the base EPS value used as the criterion for gross error detection was detuned. Because of the ease with which the FAT testing method works, it provides a means to rapidly tune the standard error of each instrument or laboratory tag within the model such that the user requirements are met.

3.4 Model Deployment and post design verification

During the implementation stage, a "run time" version of the verified 'on-demand' model is placed 'on-line' and scheduled to run automatically. The online models are monitored via an email alerting system to allow responsible parties to diagnose and take plausible actions should model failure persist for a defined period of time.

As part of the commissioning stage, post design verification of the GED application was carried out collaboratively between the plant personnel and the development team. This included field checks when an instrument error was flagged or the GED system

indicated a potential problem for instruments with significant impact on the digestion production. The results of these checks were used to consider further model refinements. Field checks were commonly performed for temperature instruments using a thermal imaging gun. The electromagnetic flow meter (EMF) checks were done by removing the meter from the line during a routine maintenance shut down and conducting testing on Alcoa's NATA certified electromagnetic flow meter test facility.

4. RESULTS AND DISCUSSION

In this section, we discuss the key outcomes of the project using examples of the MES visualisation screens developed. This is one of the key deliverables for the project. In addition, we discuss a case study on the digestion contact heater temperature meter to illustrate how the GED model can benefit the plant.

4.1 MES Visualisation

Figure 2 shows a section of the "Daily Troubleshooting" screen that allows for regular monitoring of the process by the process engineer. This screen allows the engineer to focus on process troubleshooting and provides the required information to facilitate communication with the electrical and instrument (E&I) staff or plant operators should there be any instrument errors flagged on a shorter term basis. The data displayed on the screen is expected to change once an hour if the GED calculation is successful.

The numbers in pink and those filled with yellow are model calculated and measurements with gross errors respectively. Where no instruments exist, the model provides soft sensor capability such as the live steam condensate flow and flash tank pressures. The process engineer may also perform real-time tracking of the building's financial performance based on reconciled data made available on the same screen. The process allows the engineer to determine the "top three" instruments via a Pareto analysis of the gross errors and to communicate issues to the E&I staff.

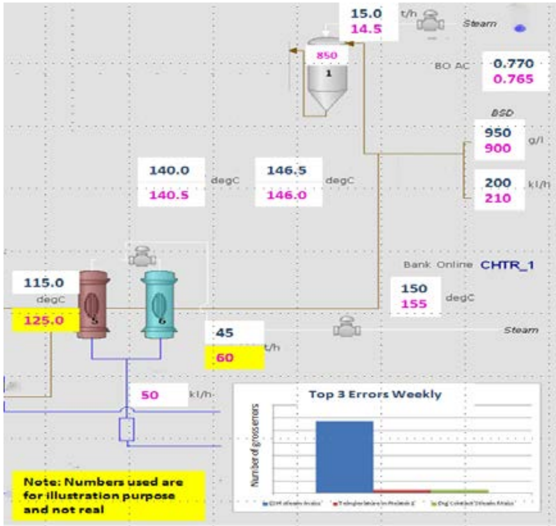

Figure 2. Digestion GED MES visualisation

Figure 3 shows a section of the weekly GED summary targeted at not only the process engineer but also plant managers. The summary provides an overall view of the health of the instruments and the digestion process. Weekly metrics of the building performance based on reconciled data such as gross alumina production, bauxite cost ($/t) and energy efficiency (GJ/t) are prominently displayed. Trends of important process variables such as digestion and live steam exit temperatures and production as well as a Pareto of top 3 instruments are also shown to allow rapid troubleshooting.

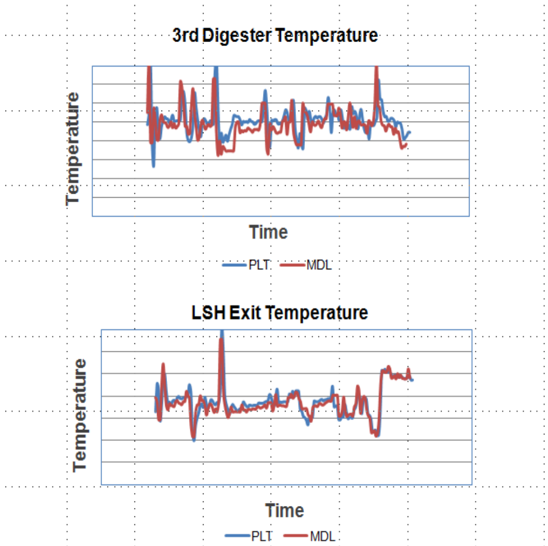

Figure 3 Weekly GED summary

If it is necessary for the process engineer to perform further analysis, individual charts (not shown in this paper) for each unit showing the trends of the individual measured and reconciled key variables and EPS values are available for troubleshooting.

4.2 Unit E Digestion contact heater temperature

Contact heater temperature is typically employed as part of the digestion temperature control. This can then be used to determine the digestion extraction and impact on production. This is therefore regarded as an important measurement.

Figure 4 shows an image from a field verification using an infra red (IR) measurement of the existing contact heater temperature meter (or sensor). The IR reading was then compared with the model and the sensor readings which were taken prior to the field investigation. Table 1 compares the results of the temperature biases between the sensor, IR reading and the model. Bias between the IR gun and model reading is relatively smaller compared to the bias between the IR gun and the temperature sensor suggesting that the GED reconciled temperature is more accurate. This also means that the sensor had grossly over-stated the contact heater temperature. The process engineer was notified and a work order was submitted for E&I staff to fix the problem. Inspection by E&I staff confirmed a calibration fault with the instrument, which was then rectified.

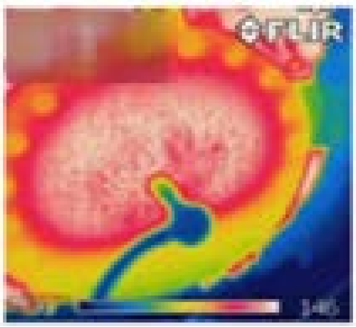

Figure 4. Monitoring and site verification

Table 1. Results of temperature bias

BIAS type	Temperature bias, deg C
Sensor – IR reading	4.4
IR reading - model	1.3
Sensor - model	5.7

Figure 5 shows the trends of the contact heater temperature for the problematic digestion bank. It clearly shows the gap between the measured and GED numbers during the problem period and the minimal gap after the instrument was fixed.

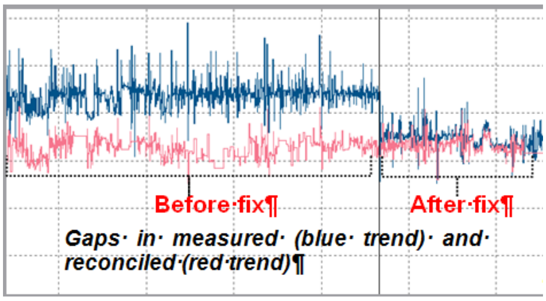

Figure 5. Digestion GED MES visualisation

Figure 6 shows the Unit E bias plot of the contact heater temperature compared to other banks. It clearly shows the problem instrument in Unit E stood out from the rest of the digestion banks within the refinery. It is also noticeable from the plot that the bias peaked at around 4.5 deg C but dropped sharply to below 1 deg C after the instrument was re-calibrated by E&I staff.

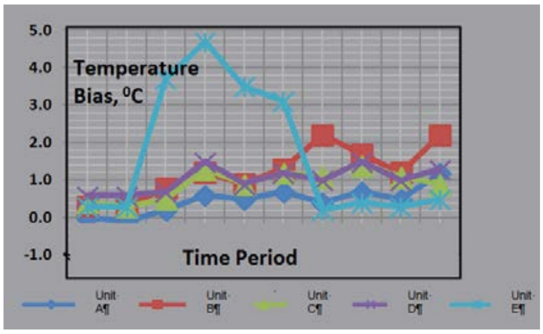

Figure 6. Bias plot of the digestion contact heater

5. CONCLUSION

An online digestion GED system, based on a rigorous process model, has been successfully piloted for the Alcoa refining system. Customised MES visualisation has helped in monitoring and detecting problem instruments more rapidly. The system has ultimately enabled resolution of instruments and process issues as demonstrated in the digestion contact heater temperature case study. It is expected that the weekly GED summary report available via the MES visualisation will enable process engineers and plant managers to monitor the building performance and, if necessary, to take timely actions to bring the building performance closer to its optimal conditions.

The GED application has proven capable of detecting temperature discrepancies within the required tolerance for the third digester temperature and for the contact heater temperature readings. The capability of GED to reveal discrepancies in flow, density and laboratory readings is the subject of an ongoing verification effort

6. REFERENCES

Bahri, P., Beckham, K. Brown, G., Fillery, E., Langa, J. Lee, M. Nooraii, A., Olszewski, Z., Riley, G., White, D. (2005) A generic system of plant impurity balance models: further improvements. Proc. 7th International Alumina Quality Workshop, AQW Inc., 63-68.

Darnbrough, J. (2008), Best practice for Alcoa, [Online], Australian Mining. Available from: <http://www.miningaustralia.com.au/news/best-practice-for-alcoa > [27 August 2014].

Hudson, L. K., 1983. Alumina Production, USA.

Langa, J. M.; Russell, T. G.; O'Neil, G. A.; Snyder, J. G.;Gacka, P.; Shah, V. B.; Stephenson, J. L. (1986) Aspen Modeling of the Bayer Process. Proc. Technical Sessions of the 11th TMS Annual Meeting, New Orleans, LA, 169-178

Lee, M., Love, R., Brown, G., Chatfield, R., Fletcher, S. and Asquith, J. (2012) Online gross error detection system applied to an alumina refinery evaporation process Proc. 8th AQW workshop, 176-177

Lee, M. and Love, R. (2009) Sao Luis evaporation GED and data reconciliation Alumina IPS project report, September 2009 (*Confidential*)

Lee, M, Tindall, G. and Elms, C. (2007) On the pseudo-dynamic modelling of an alumina refinery residue lake system. Proc. CHEMECA 2007, Melbourne, (2) 1652-1656

Love, R. (2013), Project management process for Alcoa TDG Process Modelling GED projects (*Confidential*).

Sidrak, Y.L. (2001), Dynamic simulation and control of the Bayer Process: A Review. Ind. Eng. Chem. Res. 40, 1146–1155.