The use of simulations to identify operational improvements on mining compressed air systems

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It all starts here ™

Abstract

Title:	The use of simulations to identify operational improvements on mining compressed air systems
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Degree:	Masters in Electrical and Electronic Engineering

As operational costs of deep level mines increases and gold ore grades decrease, profitability in the gold mining sector is becoming difficult. Electricity tariff increases have contributed a rise in cost to operate a mine. Compressed air systems utilise a large portion of a mine's total energy. It has been shown that many deep level mine compressed air networks have large inefficiencies and often can not meet performance set-points. Therefore improving the efficiency could result in a reduction of operational costs by reducing the energy required to produce compressed air. Additionally an improvement in service delivery could be achieved.

Previous studies have shown the usefulness of simulations to develop improvements for large mining systems. J. Marais developed a simplified "vessel" model of a mining compressed air system. CJR Kriel created a simulation using KY pipe software to validate intervention proposals. AJM van Tonder developed an innovative component model to simulate dynamic compressor selection (DCS).

A simulation methodology was developed to achieve the study objects. Firstly an investigation into the compressed air system is performed. Next a model is developed in software to accurately recreate the system outputs. Finally an proposed method of improvement is simulated, analysed and quantified in terms of improvements in energy savings and service delivery.

Two case studies were evaluated. For each case study a variety of methods of improvements were simulated. In case study by reducing air used by refuge bays in simulation, a reduction of 1 MW E.E. would be achieved with addition to an improvement of 18 kPa to system pressure.

The study showed that simulation is a important tool for identification improvements in large compressed air systems. The value of simulation is the ability to accurately predict outcomes of interventions without doing costly tests on an actual system.

Keywords: Mining, Energy, Compressed air, modelling, Simulation, operational improvements

Contents

Abbreviations

THS Thermal-hydrolic simulation.

Nomenclature

kPa kilopascal.

MW MegaWatt.

T Tonne.

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CHAPTER 1

Introduction and background

"*Your ideas are like diamonds. Without the refining process they are just rock. But cutting away impurities, they become priceless.*" - Paul Kearly

1.1 Preamble

1.2 Background on deep level mining

1.2.1 Mining profitability

Various technical, economic, social and operational challenges are posing a risk to the profitability of the South African mining sector. One of the challenges the sector faces is a rise in the cost of operation[1].

A considerable factor that is contributing the the rise of operational costs in South African gold mines has been the increase in electricity costs. As shown in figure 1.1 the general cost of electricity has increased at a rate greater than inflation since 2008 [2].

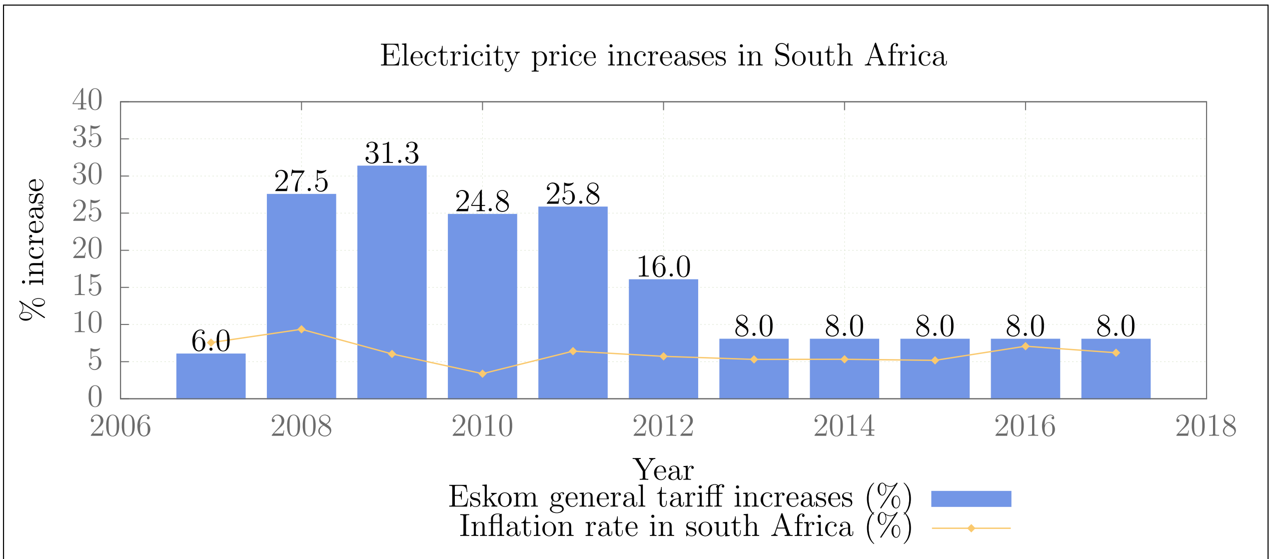

Figure 1.1: Electricity price increases between 2007 and 2017 [2, 3].

In addition to rising electricity cost, gold ore grades in South African mines have fallen substantially over the last few decades[4]. As ore grades decline, the energy utilised per unit of metal increases exponentially [5]. Therefore mines require significantly more energy per unit of metal produced. This combination of tariff increases and increased energy usage per unit have lead to significant rises in mining operation costs.

1.2.2 Mining systems and energy

`Discus mining electrical energy users.`

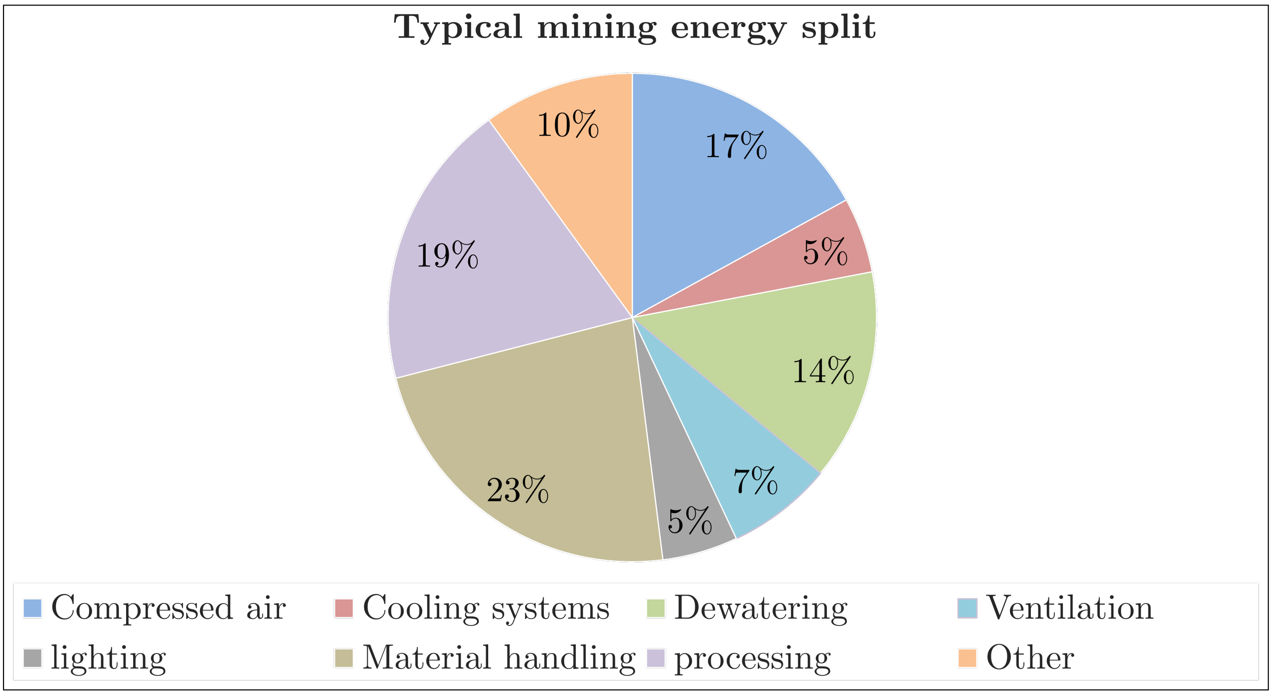

Figure 1.2: The energy split for the south african mining industry [6].

1.2.3 Need to improve service delivery and efficiency

`Discuss how improvements in service delivery and efficiency will reduce operation costs therefore increase profitability.`

1.3 Mining compressed air

Due to their reliability, versatilely and ease of use, the South African mining industry has installed extensive compressed air networks. These systems can have compressors with capacities of up to 15 MW [7].

However, the supply of compressed air is a highly energy demanding and costly process [8]. The energy used for compressed air production contributes to between 9% and 20% of the total mining energy consumption [6, 9].

Large compressed air systems are likely inefficient. Internationally, the expected energy savings potential of a large compressed air network is 15% [10]. Marais [11] showed that energy savings of up to 30% and 40% can be obtained from some systems.

1.3.1 Compressed air in operation

Operation schedule

On a typical mine, various operations will take place at different times of the day. Depending on the activity taking place, many mines will control the pressure to meet the requirements [12, 7]. Figure 1.3 shows the schedule and pressure requirement on a typical deep level mine. As shown in the figure, the pressure requirement changes depending on the activity taking place.

Drilling

A study by Bester *et al.* showed that between 2002 and 2013 compressed air and energy consumption per tonne of ore produced had steadily increased as shown in figure 1.4. The increase in consumption is a result of a reduction in air pressure at the mining stopes. Measurements indicated that the pressure was as low as 300 kPa. This would have an

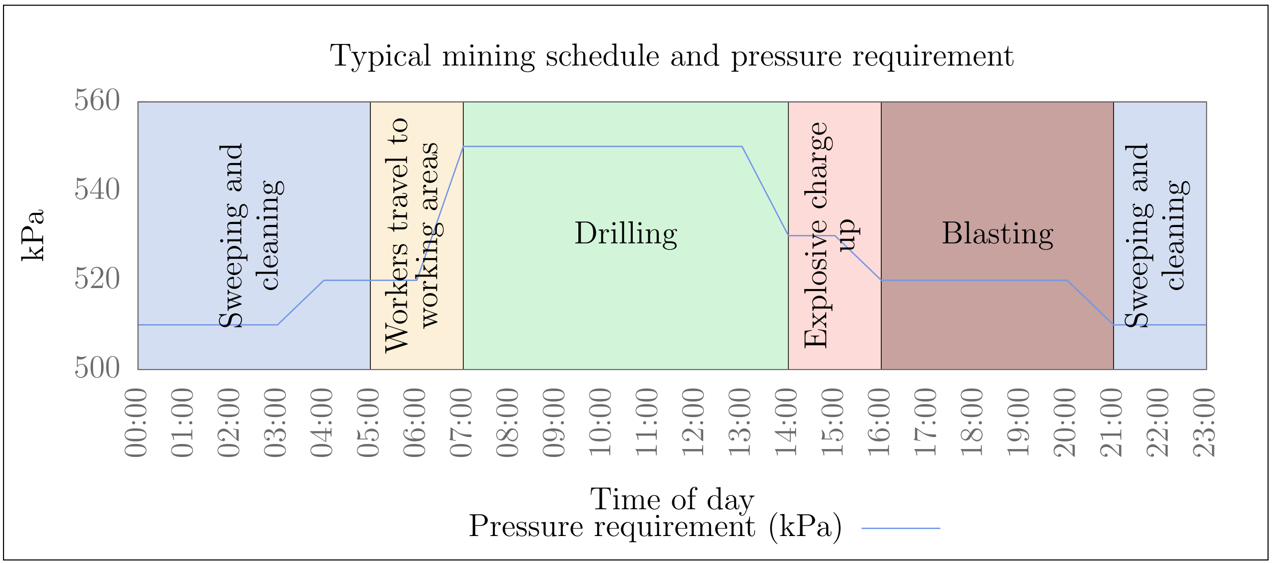

Figure 1.3: The typical operation schedule of a deep level mine [12].

effect the efficiency of the rock drills. Before 2002 pressure was maintained above 500 kPa at the stopes. The study showed that as pressure decreased, rock drilling efficiency also decreased.[13]

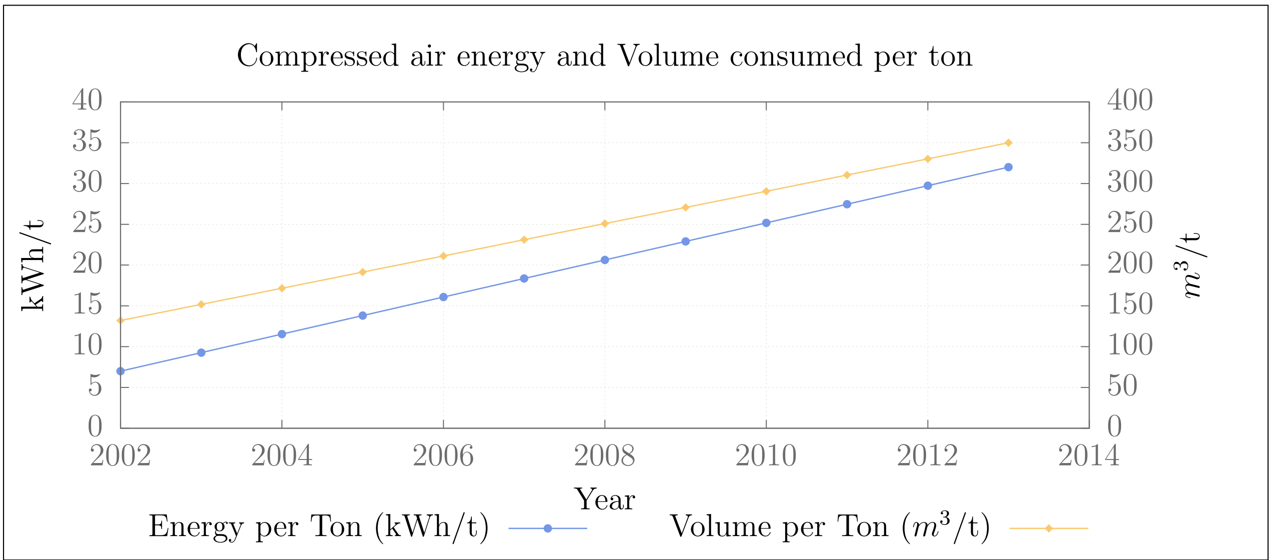

Figure 1.4: The compressed air energy and flow per T of ore produced, adopted from Bester *et al.* [13].

1.3.2 Characteristic inefficiencies

`Discuss typical ineficiencies in large compressed air systems: leaks, Filters, Compressors, valves, piping changes`

1.3.3 Instrumentation and measurements

`Instrumentation and monitoring systems on compressed air networks: Sensors -> PLC -> SCADA`

1.3.4 Inefficiency identification methods

`Methods currently used by industry to identify and estimate losses due to an ineffici`

1.4 Simulations in industry

Continuous improvements in computing hardware has led to major advancement in software technology. Consequently the use of computational simulation has become an increasingly valuable tool for many industries.[14]

In *Handbook of simulation: principles, methodology, advances, applications, and practice*, the advantages of the use of simulation in industry are discussed as follows [15]:

- The ability to test new policies, operating procedures and methods without causing a disruption to the actual system.
- The means to identify problems in complex systems by gathering insight in the interactions within the system.
- The facility to compress or expand time to investigate phenomena thoroughly.
- The capability to determine the limits and constraints within a system.
- The potential to build consensus with regard to proposed designs or modifications.

1.4.1 Thermal-hydraulic simulation

Thermal-hydrolic simulation (THS) is the modelling and computational analysis of Thermal-hydraulic systems.

Simulation toolbox

`STB background.`

1.5 Problem statement and objectives

`Identification of research problem and formulation of objectives should be unambiguous and intelligible`

1.5.1 Problem statement

1.5.2 Research objectives

1.6 Dissertation overview

`Describe (in approximately one sentence each) the contents of each of the dissertation chapters. No results here.`

CHAPTER 2

Literature study

"*Your ideas are like diamonds. Without the refining process they are just rock. But cutting away impurities, they become priceless.*" - Paul Kearly

2.1 Preamble

2.2 Methods to identify operational improvements

Johan Marais benchmarking method. Test of bib.

2.2.1 Summary

2.3 Review of compressed air energy interventions

2.3.1 Summary

2.4 Use of simulation to identify improvements in mining systems

2.4.1 Summary

2.5 Conclusion

CHAPTER 3

Developing a simulation methodology

"*Your ideas are like diamonds. Without the refining process they are just rock. But cutting away impurities, they become priceless.*" - Paul Kearly

3.1 Preamble

3.2 Investigation

3.2.1 Layouts, Data from SCADA Instrumentation, etc.

3.2.2 Manual measurements, audits and approximations

3.2.3 Mining schedule philosophies - (drilling, blasting shifts, etc.)

3.2.4 Summary

3.3 Model development and verification

3.3.1 Compressed air component models

3.3.2 Simulation inputs

3.3.3 Verification of model

3.3.4 Summary

3.4 Implementation of method

CHAPTER 4

Results and validation

"*Your ideas are like diamonds. Without the refining process they are just rock. But cutting away impurities, they become priceless.*" - Paul Kearly

4.1 Preamble

4.2 Case study: Mine A (Kusasalethu)

4.2.1 Background

4.2.2 Scenario 1. Refuge bay simulation

tested scenario where all excessive leaking valves are removed. refuge bays savings 1MW E.E.

4.2.3 Scenario 2. Closing off levels/stopes

4.2.4 Scenario 3. Periodic simulation

4.2.5 Summary

4.3 Case study: Mine B (Beatrix 123)

4.3.1 Background

4.3.2 Compressor set points

4.3.3 Control valves set points

4.3.4 Summary

4.4 Validation of results

4.5 Conclusion

CHAPTER 5

Conclusion

"*Your ideas are like diamonds. Without the refining process they are just rock. But cutting away impurities, they become priceless.*" - Paul Kearly

5.1 Conclusion

5.2 Limits of this study

5.3 Recommendations for future studies

Bibliography

[1] P. Neingo and T. Tholana, "Trends in productivity in the south african gold mining industry," *Journal of the Southern African Institute of Mining and Metallurgy*, vol. 116, no. 3, pp. 283–290, 2016.

[2] Eskom, "Revenue application - multi year price determination 2013/14 to 2017/18 (mypd3)," [Online] http://www.eskom.co.za/CustomerCare/MYPD3/Documents/NersaReasonsforDecision.pdf, 2013, [Accessed 22 March 2017].

[3] inflation.eu, "Historic inflation south africa - cpi inflation," [Online] http://www.inflation.eu/inflation-rates/south-africa/historic-inflation/cpi-inflation-south-africa.aspx, 2017, [Accessed 25 March 2017].

[4] G. M. Mudd, "Global trends in gold mining: Towards quantifying environmental and resource sustainability," *Resources Policy*, vol. 32, no. 1, pp. 42–56, 2007.

[5] J. Müller and H. Frimmel, "Numerical analysis of historic gold production cycles and implications for future sub-cycles," *The Open Geology Journal*, vol. 4, no. 1, pp. 29–34, 2010.

[6] Eskom Demand Side Management Department, "The energy efficiency series - towards an energy efficient mining sector," [Online] http://www.eskom.co.za/sites/idm/Documents/121040ESKD_Mining_Brochure_paths.pdf, February 2010, [Accessed 19 March 2017].

[7] J. Marais, "An integrated approach to optimise energy consumption of mine compressed air systems," Ph.D. thesis, North-West University, 2012.

[8] L. Padachi *et al.*, "Energy efficiency through the integration of compressed air supply control with air network demand control," in *Proceedings of the Sixth Conference on the Industrial and Commercial Use of Energy*. Citeseer, 2009, pp. 77–80.

[9] J. Du Plessis and R. Pelzer, "Development of an intelligent control system for mine compressor systems," in *Industrial and Commercial Use of Energy (ICUE), 2011 Proceedings of the 8th Conference on the.* IEEE, 2011, pp. 59–63.

[10] J. Neale and P. Kamp, "Compressed air system best practice programmes: What needs to change to secure long-term energy savings for new zealand?" *Energy Policy*, vol. 37, no. 9, pp. 3400–3408, 2009.

[11] Marais *et al.*, "Simplification of mine compressed air systems," in *Industrial and Commercial Use of Energy Conference (ICUE), 2013 Proceedings of the 10th.* IEEE, 2013, pp. 1–8.

[12] C. Kriel, "Modernising underground compressed air dsm projects to reduce operating costs," Masters dissertation, North-West University, 2014.

[13] Bester *et al.*, "The effect of compressed air pressure on mining production and energy demand," in *Industrial and Commercial Use of Energy Conference (ICUE), 2013 Proceedings of the 10th.* IEEE, 2013, pp. 1–4.

[14] Kocsis *et al.*, "The integration of mine simulation and ventilation simulation to develop a 'life cycle' mine ventilation system," *Application of Computers and Operations Research in the Minerals Industries, South African Institute of Mining and Metallurgy*, pp. 223–230, 2003.

[15] J. Banks, *Handbook of simulation: principles, methodology, advances, applications, and practice.* John Wiley & Sons, 1998.

APPENDIX A

Something

APPENDIX B

Something else