

An integrated approach to optimise energy
consumption of mine compressed air systems

J.H. MARAIS

12609900

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Promoter: Prof. M. Kleingeld

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ABSTRACT

Title: An integrated approach to optimise energy consumption of mine compressed air systems

Author: Johannes Hendry Marais

Promoter: Prof. M Kleingeld

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The demand for electricity in South Africa has grown faster than the increase in generation capacity. However, it is expensive and time consuming to commission new power stations. Another approach is to reduce electricity demand through the implementation of energy efficiency projects. This alternative is usually less expensive.

Compressed air on South African mines is a large electricity consumer with a reputation of wastage. This allows significant potential for electrical and financial savings. A typical mine compressed air system consists of multiple compressors at various locations, surface connection networks, underground distribution systems, thousands of users and leaks.

The size, complexity and age of these systems provide a major challenge for electricity saving efforts. Simulating such an intricate system is difficult as it is nearly impossible to accurately gather all the required system parameters.

Some initiatives focused on subsections of mine compressed air systems. This is not the best approach as changes to one subsection may adversely affect other systems. A new approach to simplify mine compressed air systems was developed to identify saving opportunities and to assess the true impact of saving efforts. This new approach enables easier system analysis than complex simulation models. Techniques to gather critical system information are also provided.

A new implementation procedure was also developed to integrate different energy saving strategies for maximum savings. An electrical power saving of 109 MW was achieved through the implementation of the integrated approach on twenty-two mine compressed air systems.

The savings is equivalent to a reduction of 0.96 TWh per annum that relates to a saving of 0.4% of South Africa's total electricity consumption. Average compressor power consumption was reduced by 30%. The power consumption reduction relates to an estimated annual electricity cost saving of R315 million. A saving of 0.96 TWh per annum is equivalent to a carbon dioxide emission reduction of 0.98 million tonne.

The implementation of the integrated approach could be applied to other industrial compressed air systems. A reduction in electricity consumption of 30% on all industrial compressed air systems has the potential to reduce global electricity demand by 267 TWh per annum. That is more than the total amount of electricity consumed in South Africa.

Keywords:

Mine compressed air, energy efficiency, integrated approach, saving approximation, demand side management.

SAMEVATTING

Titel:	‘n Geïntegreerde benadering om die energieverbruik van myndrukluugsstelsels te optimaliseer
Outeur:	Johannes Hendry Marais
Promotor:	Prof. M Kleingeld
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In Suid-Afrika het die aanvraag na elektrisiteit vinniger toegeneem as die opwekkingskapasiteit. Dit is egter baie tydrowend en duur om nuwe kragstasies te bou en in gebruik te neem. ‘n Alternatiewe benadering is om die aanvraag na elektrisiteit te verminder met behulp van elektrisiteitsbesparingsprojekte. Hierdie alternatiewe benadering is goedkoper as die bou van nuwe kragstasies.

Drukluugsstelsels by Suid-Afrikaanse myne is hoë energieverbruikers met ‘n geskiedenis van verliese. Dit laat ‘n wesenlike potensiaal vir elektrisiteits- en finansiële besparings. ‘n Tipiese myn se drukluugsstelsel bestaan uit ‘n kombinasie van verskillende kompressors by ‘n verskeidenheid van plekke, bogrondse pypnetwerke, ondergrondse verspreidingsnetwerke en duisende verbruikers.

Die grootte, kompleksiteit en ouderdom van hierdie drukluugsstelsels verskaf ‘n groot uitdaging om elektrisiteit te bespaar. Die simulاسie van so ‘n ingewikkelde drukluugsstelsel is moeilik aangesien dit bykans onmoontlik is om al die nodige stelselparameters te bekom.

Meeste energiebesparingsprojekte op myndrukluugsstelsels het op die onderafdelings van die drukluugsstelsels gefokus. Dit is egter nie die beste benadering nie aangesien veranderinge aan een onderafdeling ander stelsels kan beïnvloed. ‘n Nuwe benadering, gemik op die vereenvoudiging van myndrukluugsstelsels, is ontwikkel om die impak van tipiese energiebesparingsprojekte te ontleed. Hierdie nuwe benadering om stelsels te analiseer is heelwat makliker as die gebruik van ingewikkelde simulasiemodelle. Prosedures word ook verskaf om die nodige data in te vorder sodat die impak van beoogde projekte ondersoek kan word.

Die nuwe implementeringsprosedure is ontwikkel om verskillende energiebesparingstrategieë te integreer vir maksimum besparings. 'n Elektrisiteitsbesparing van 109 MW is bereik deur die implementering van die geïntegreerde benadering op twee-en-twintig myn-drukflugstelsels. Die besparing is ekwivalent aan 'n jaarlikse energiebesparing van 0.96 TWh wat ongeveer 0.4% van die totale elektrisiteitsverbruik van Suid-Afrika is.

Die projekte het gelei tot 'n gemiddelde besparing van 30%. Die gemiddelde jaarlikse elektrisiteitskostebesparing as gevolg van hierdie projekte is R315 miljoen. 'n Besparing van 0.96 TWh lei verder tot 'n beraamde verlaging van 0.98 miljoen ton koolsuurgas uitlatings.

Die geïntegreerde benadering kan verder uitgebrei word na ander industriële drukflugstelsels. 'n Besparing van 30% op alle drukflugstelsels in die wêreldwye industriële sektor sal lei tot 'n 1% verlaging in wêreldwye elektrisiteitsverbruik. Dit sal lei tot 'n jaarlikse besparing van 267 TWh wat meer is as die totale elektrisiteitsverbruik van Suid-Afrika.

Sleutelwoorde:

Mynlugdrukstelsels, energie besparing, geïntegreerde benadering, benaderde besparings, bestuur elektrisiteit aanvraag.

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NOMENCLATURE

A	Minimum cross-sectional area (m^2)
$C_{\text{discharge}}$	Discharge coefficient
D	Diameter
η_{comp}	Compressor efficiency
η_{motor}	Efficiency of the electrical motor
$F_{\text{flow_pressure_leak}}$	Mass flow to line pressure and leak ratio ($\text{kg/kPa}\cdot\text{s}\cdot\text{m}^2$)
$F_{\text{power_pressure}}$	Power to line pressure ratio (kW/kPa)
GWh	Gigawatt hour (1 000 MWh)
k	Specific heat ratio
kg	Kilogram
KJ	Kilojoule
kPa	Kilopascal (1 000 Pa)
kW	Kilowatt (1 000 W)
kWh	Kilowatt hour (1 000 Wh)
l	Litre
m	Meter
m^2	Square meter
m^3/s	Cubic meter per second
m^3/m	Cubic meter per minute
m^3/h	Cubic meter per hour
\dot{m}_{air}	Compressed air mass flow rate (kg/s)
MI	Megalitre (1 000 000 l)
Mt	Megatonne (1 000 000 t)
MW	Megawatt (1 000 kW)
MWh	Megawatt hour (1 000 kWh)
n	Polytropic compression exponent
p_2	Compressor discharge pressure (absolute pressure) (kPa)

p_1	Compressor inlet pressure (kPa)
Pa	Pascal
$P_{\text{electrical}}$	Electrical power (kW)
P_{line}	Line pressure (kPa)
R	South African Rand (ZAR)
R	Gas constant (0.2870 kJ/kg.K)
s	Second
t	Tonne
T_{inlet}	Inlet temperature (Kelvin)
T_{line}	Line temperature (Kelvin)
TWh	Terawatt hour (1000 GW)
W	Watt
Wh	Watt hour
$w_{\text{comp, in}}$	Energy required to compress a unit mass of air (kJ/kg)

ABBREVIATIONS

CALDS	Compressed Air Leakage Documentation System
CDM	Clean Development Mechanism
CER	Certified Emissions Reductions
DoE	Department of Energy
DSM	Demand Side Management
ECS	Energy Conservation Scheme
EEDSM	Energy Efficiency and Demand Side Management
ESCO	Energy Service Company
IP	Intellectual Property
M&V	Measurement and Verification
NERSA	National Energy Regulator of South Africa
OAN	Optimisation of Air Networks
OEM	Original Equipment Manufacturer
OSIMS	On Site Information Management System
PLC	Programmable Logic Controllers
REMS	Real-time Energy Management System
SCADA	Supervisory Control and Data Acquisition
UNFCCC	United Nations Framework Convention on Climate Change
VSD	Variable Speed Drives