Optimising compressor control strategies for maximum energy savings

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Research into the energy consumption of South African industry revealed that compressed air makes up 9% of the industry’s total maximum demand. Methods in use for generating compressed air in the mining industry have created the potential to decrease energy consumption by improving on compressor control strategies. The savings generated by optimising compressed air delivery will have a substantial impact on energy efficiency.

South Africa is presently experiencing an energy supply crisis. The energy supplier Eskom has determined that the mining industry must reduced their power consumption by at least 10% or risk being heavily penalised. It is therefore of paramount importance that all the energy intensive systems in the mining industry be optimised, resulting in sustainable energy savings without affecting the production of the mine.

Compressor energy consumption in the mining industry

According to Eskom’s figures compressed air makes up 9% of the industry’s maximum demand [1]. One of the major energy resources in the South African industry is compressed air.

Air compressors are one of the main electricity consumers found on a typical mining site. The total energy consumption can therefore be greatly improved by optimising the compressor systems. Analysis of the five year life cycle of a new compressed air system indicates that energy consumption makes up 80% of total costs [2]. Reducing the energy consumption of a compressor will therefore greatly impact the overall costs of the system.

The stable operational region of a compressor is illustrated by the compressor performance map shown in Fig. 3 [3]. By optimising the control of the inlet guide vane angles and the opening of the blow-off valve the compressor can be operated to deliver the optimum amount of air to the system, resulting in substantial energy savings, with minimal input costs.

Reducing system pressure

Presently the common control strategy of a typical compressor system has the sole purpose of providing sufficient flow of compressed air to sustain maximum production. The manual control of the compressors is set up to keep the pressure of the system at a predetermined level. However manual operation of the system results in all the compressors constantly running at a specified set point. Fig. 4 indicates the baseline system pressure of a mine before the control upgrade was implemented. The pressure baseline was created using the average weekday pressure of the system over a predetermined time period.

The system had an operational set point of 600 kPa. The graph illustrates that the system maintained this set point for the entire day except for the morning period between 07h00 and 10h00. This is the same time that the drilling operations of the mine commence. During the drilling period the demand for compressed air is at its highest for the day. Due to the high level of air consumption the compressor system is not able to maintain the set pressure. This results in the system pressure eventually dropping to 560 kPa. The drop in pressure indicates a problem in the system. The installed compressors are unable to satisfy the maximum demand of the system. Possible solutions are to increase the amount of air that can be delivered by adding extra generation capacity or to lower the system demand. Analysis of the data leads to the conclusion that the system pressure is too high. The system will still function effectively at 560 kPa as illustrated by the data gathered. Mining operations may be able to function at an even lower system pressure. Lowering the pressure will result in an improvement of the overall energy efficiency. In order to safely and effectively facilitate a lower system pressure the complete compressed air generating system will have to be optimally monitored and controlled.

A generally accepted estimation is that a compressor’s energy efficiency can be increased by 1% for every two psig (+14 kPa) that the set point can be lowered [4]. As an added benefit air losses through various leaks in the system will also be reduced when the system operates at a lower pressure. Fig. 5 illustrates estimated air losses through leaks in the system. The graphs, shown by Fig. 5 were generated from data released by the US DOE in 2004 [5].

By automating the compressor operation, a system was created that will start and stop the compressors according to specific pressure set points. A new
minimum air system pressure had to be determined. The system pressure would be dependant on the minimum pressure needed to operate equipment at a mining site. The pressure set point would also have to take system losses into account. Fig. 6 illustrates the loss of system pressure from the supply to the end users [6].

Investigations conducted into the constraints of the system resulted in the realisation that the safe operational pressure of the system can be as low as 480 kPa. The new air pressure profile is illustrated in Fig. 7.

Because accumulators cannot be used to store compressed air in the system all the excess air produced is released into the atmosphere through the compressor blow-off valve. This results in large energy losses. Existing control strategies attempt to limit the amount of air being wasted by stopping some of the compressors. Certain scenarios will cause this control method to start and stop compressors multiple times per day. The stresses experienced by a compressor during repetitive start-up and shut-down phases will increase the amount of wear and tear on the machine, resulting in increased breakdowns and higher maintenance costs.

**Improving existing control**

To improve on the existing control philosophy a simulation model was created to test various other possibilities and concepts. The simulation model was developed by investigating present control strategies. The model can be adjusted to incorporate specific constraints of a particular mine such as working pressure, number and capacity of the compressors and system layout. By utilising the simulation model an optimised control philosophy can be developed. The following control philosophy was simulated to supply the mine with a given amount of compressed air at a lowered pressure.

The compressed air demand of the mine is shown in Fig. 8.

**Results**

The improved control strategies were implemented on several compressor systems. The compressors at mining site A were upgraded to better facilitate the new control. An optimised control strategy was developed and implemented. Fig. 11 illustrates a typical 24 h profile.
of the individual compressors’ power consumption and shows how the power consumption of a compressor can be lowered without increasing the wear and tear on the compressor and without the risk of the system responding too slowly to sudden changes in air demand.

The graph of Fig. 12 illustrates the electrical profile of the compressed air system of a mine before and after the implementation of the optimised control philosophy.

The implementation of this concept has realised a saving of 1251 MW during Eskom’s evening peak demand window. This saving was generated on a baseline of 7224 MW and shows an improvement of 17.3% in energy consumption during the evening peak period. The savings at this mine is an estimated R2 750 000 per annum.

The system at site B was also optimised to improve control; an added system of underground actuated valves was added. The added benefit of the underground valves was that the valves would help to sustain underground pressure during the Eskom peak, thereby increasing the amount of cutback the compressors can perform. Fig. 13 shows the pressure profile of an average production day.

Fig. 13 shows how the system pressure was lowered during certain times of the day. The morning period was before drilling started to take place, and the demand for air was low due to shift changes. The second dip in air pressure was during the Eskom peak period. The pressure was lowered to reduce compressor energy consumption; the added underground valves sustained the systems pressure during the two peak demand hours. The result of the optimised control strategy is illustrated in Fig. 14.

The lowered pressure supply set point combined with the optimised delivery of air resulted in the mine shutting down a compressor permanently. Fig. 14 illustrates the average profile for a normal production day. The data used for the profile was taken over the period of one month. During this month the saving for the project was an average of 7978 MW during the Eskom evening peak. This corresponds to a 45.96% saving during the evening peak (18:00 – 20:00).

The overall energy efficiency combined with the peak clipping resulted in a saving of 4130.8 MWh for the month. This saving resulted in R441 237 saved for the month. These savings are only due to a reduction in power consumption, added savings are reduced wear and tear on equipment, resulting in lower maintenance costs over the long term as well as improved air delivery.

Conclusion

The mining industry is under pressure to reduce energy consumption. The mine’s compressed air systems are major energy consumers that have significant scope for improvement with minimal input costs. By investigating the unique setup of each individual site the compressor system can be modelled and simulated to determine the optimal use of the resources available.

By optimising the control strategy of the compressed air system the mine will be able to generate energy savings without the requirement for any physical changes to the system. Savings can also be realised without the requirement of any significant financial outlay. A further benefit will be the reduced wear and tear on the machinery which will result in lower maintenance costs as well as increased dependability.

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References


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