

Chapter 2: Challenges and limitations leading to the development of a dynamic compressor selector

2.1 Introduction

Chapter 1 gives a brief background to the mine's compressed air network, present compressor control and DSM strategies. A problem formulation was set.

In this chapter, challenges arising from each component of the compressed air network are discussed. These challenges will be divided into present compressor control limitations, shaft compressed air challenges and challenges with the supply lines of the compressed air network. A user requirement is developed accordingly.

2.2 Compressor control limitations

The operational limitations of the existing compressor master controller prevent the compressors from being controlled dynamically. One of these limitations is that the controller cannot anticipate and react timeously to dynamic changes on the compressed air network caused by varying shaft demand. This is because shaft pressure schedules are not incorporated into the compressor master controller's control philosophy.

Consider, for example, a sudden disturbance in air pressure at a shaft of the compressed air network. The speed of transmission of a disturbance in the compressed air network will travel at the speed of sound [14]. Assuming a temperature of 316 K in the pipeline, the speed of sound would be approximately 356 m/s. This speed is relative to the fluid flow, and the actual speed of propagation from the shaft to the compressor house is the speed of sound minus the fluid speed. Assuming a speed of 25 m/s, the actual speed of propagation would be 331 m/s. For a pipe with a length of 5 km, this pressure drop would take approximately 15 seconds to reach the compressor house. During this time, the pressure at the

user end may have changed again. If, for example, a pressure reduction is recorded, the compressor master controller will start an additional compressor from the fixed priority list. Similarly, the effect of the additional compressor will not be sensed immediately and this compressor may have to be shut down again, depending on the user end pressure.

A challenge that arises from not being able to anticipate changes in the demand or responding appropriately is compressor cycling. This is the term used when a compressor is started unnecessarily and has to be stopped again shortly afterwards [15, p. 36], [16]. Figure 13 on the following page shows an example of compressor cycling.

If the compressed air network pressure drops below the pressure set point, the compressor master controller will start an additional compressor. A control room operator updates the compressor priorities on a weekly basis. This means that the compressor priorities are fixed until there is an intervention from the control room operator.

Small pressure variations can be relatively easily countered by suitable inlet guide vane control. Figure 14 shows an example of the effects of present guide vane control. Three VK50 compressors are shown that have been controlled to cut back on the guide vane opening to approximately 55 %.

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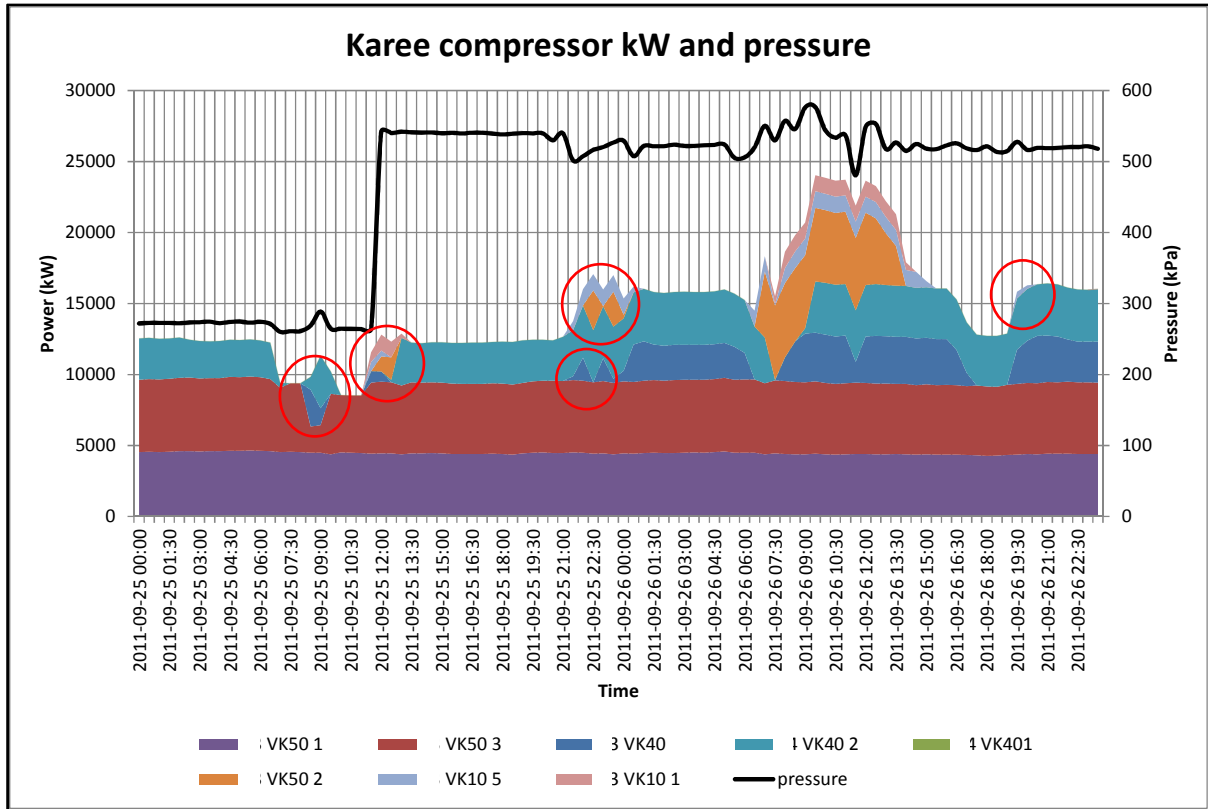


Figure 13: Compressor cycling (circled in red)

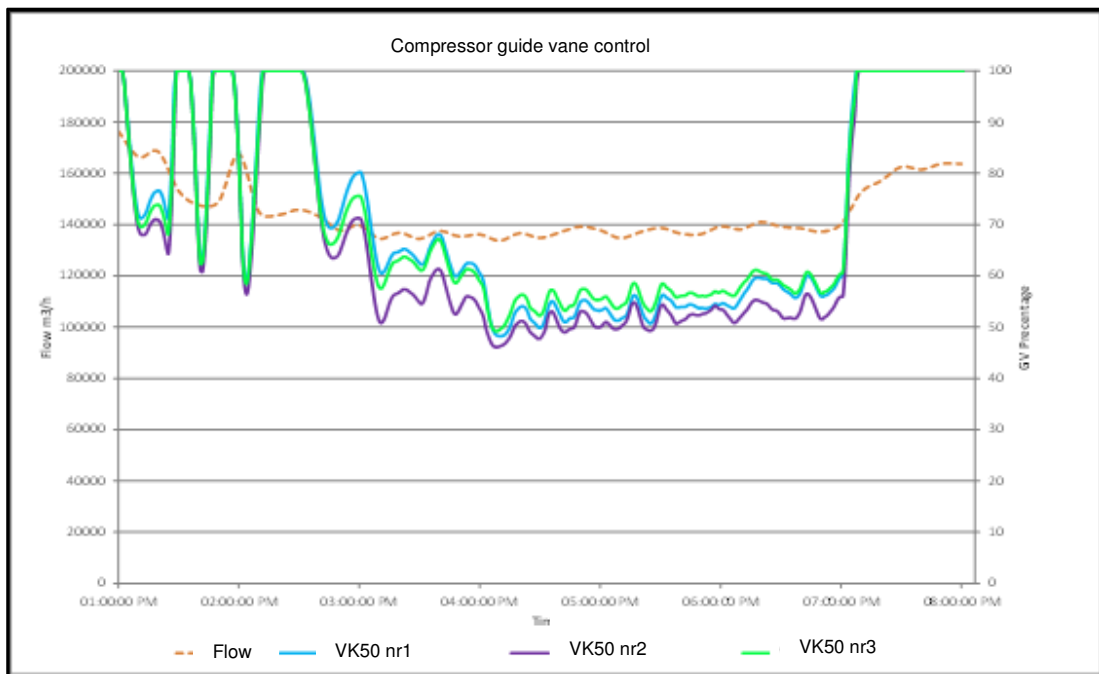


Figure 14: Multiple compressors controlling pressure

The efficiency of all three these compressors is reduced. The system would be more efficient if only one compressor were to adjust the system pressure, instead of all three, as is the case in this instance.

2.3 Shaft compressed air challenges

The shafts on the compressed air network are located at various and very often long distances from the compressor houses. One particular shaft is 5.2 km from the nearest compressor house. This often leads to an inaccurate and ineffective supply of compressed air to the end users and can cause pneumatic, operational and production problems. Increasing the pressure set point of the compressed air network may not necessarily solve the problem for all users. However, an increased pressure set point will result in increased electrical energy costs.

Another contributing factor to shaft pressure problems is poor underground compressed air network maintenance. As much as 20 to 40% of the compressor output can be wasted due to system leaks of poorly maintained systems [17],[18]. Mining personnel are required to monitor, service and maintain the compressed air lines, but this is seldom done.

Rock drill operators have been known to cool themselves by making holes in the compressed air hose that is connected to the pneumatic rock drill. This practice not only increases compressed air leakage, but is obviously dangerous because the integrity of the compressed air pipe is compromised. The Mine Health and Safety Act of 1996 prohibits the use of compressed air if it endangers the health and safety of any person [19]. A more practical component that is often used for cooling and ventilation is venturi air blowers. These blowers are connected to the underground compressed air line [20].

High pressure compressed air is a very expensive way to cool and ventilate a work space [21]. It is difficult to monitor and control the cooling and ventilation practices.

These practices contribute to flow losses, which increase the energy requirements of the compressed air system.

2.4 Supply line challenges of the compressed air network

Although similar problems are often encountered on the underground compressed air networks, this study will be restricted to the surface compressed air network.

Surface compressed air supply lines are not only very long, but the pipe sections are often poorly joined and aligned. This is one of the contributing factors to pipe pressure losses. Figure 15 is a photograph of a section of the compressed air network taken at the site of this study.

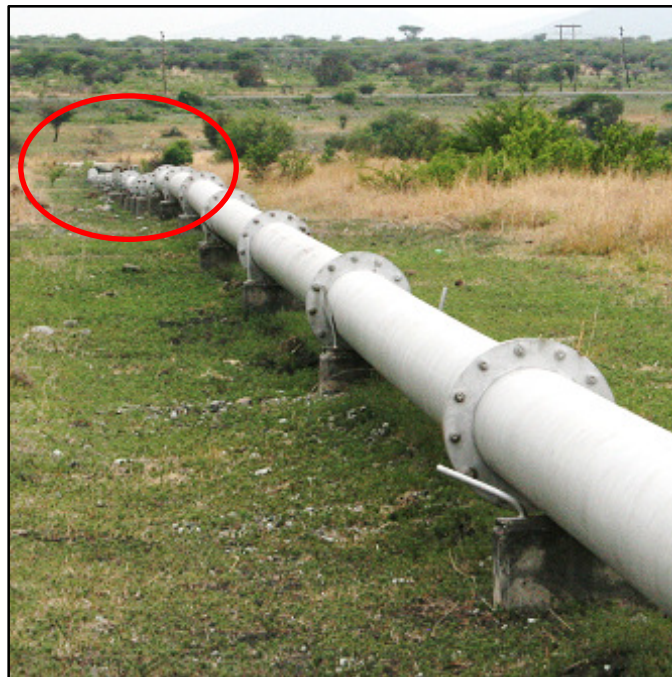


Figure 15: Discontinuities shown on a compressed air pipeline

2.5 Conclusion and user requirements for DCS

Long compressed air supply lines make accurate end user pressure requirements difficult to control. Various system requirements and component reaction to pressure changes exacerbate the accuracy and efficiency even further. Several concerns have to be addressed to improve the overall accurate compressed air supply and control.

When the compressor house registers a change in pressure, it would be beneficial to use shaft surface valve schedules to determine the proper action. If, for example, a pressure drop in the system is recorded, the normal procedure for the compressor master controller would be to start an additional compressor. If this happens and a shafts' surface control valve is scheduled to reduce pressure, the compressor might have been started unnecessarily. By using the shaft schedules, changes in compressed air consumption can be anticipated.

The fixed compressor priorities result in an unnecessary number of base load compressors operating during low flow requirements. This is because the primary priority selection is based on production periods when a larger amount of air is required. The opportunity may exist where a smaller capacity compressor can be used to deliver the required compressed air. This may be a more economical solution than using a large capacity compressor, operating at a reduced mass air flow. As mentioned in Chapter 1, cutting back on the guide vanes reduces the efficiency of the compressor.

The DCS has to reduce compressor and multiple compressor pressure control. The most efficient compressor combination needs to be scheduled by the DCS for varying system conditions. Energy costs can further be lowered by running the compressors at the optimal pressure set point to avoid unnecessary system losses.