CHAPTER 3

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"Leaders are made, they are not born. They are made by hard effort, which is the price all of us must pay to achieve any goal that is worthwhile." – Vince Lombardi

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[9] Photo taken by Johan Bredenkamp at a South African gold mine.

3 RECONFIGURING MINING COMPRESSED AIR NETWORKS FOR COST SAVINGS

3.1 Introduction

The information gathered in Chapter 2 will be used to develop a strategy to reconfigure mining compressed air networks for cost savings. The strategy will focus on evaluating existing networks and determining the relevant constraints. Following this, the process of collecting and evaluating data is discussed. Finally methods to evaluate potential solutions and their cost benefits are presented.

3.2 Network analysis and constraints

3.2.1 Overview

Implementing energy savings strategies on mining compressed air networks entails a clear and thorough understanding of the network being analysed. Therefore, it is important to obtain sufficient information of the entire system and not just selected sections thereof. This will enable the development of a cost effective energy saving strategy that will not negatively influence production and safety constraints of the mine.

A compressed air network can be divided into three sections, namely: supply side, demand side and air reticulation network. As discussed in Chapter 1, energy savings strategies can be implemented on each section. This study focuses on reconfiguring the air reticulation network, but it is still important to analyse the supply and demand sides as the three sections influence each other.

Figure 25 is a simplified schematic layout of a typical compressed air network. The layout serves as a reference example in this chapter to identify the three sections and how they relate to one another. Typical aspects of the network and its incorporation into the energy savings approach will be discussed.

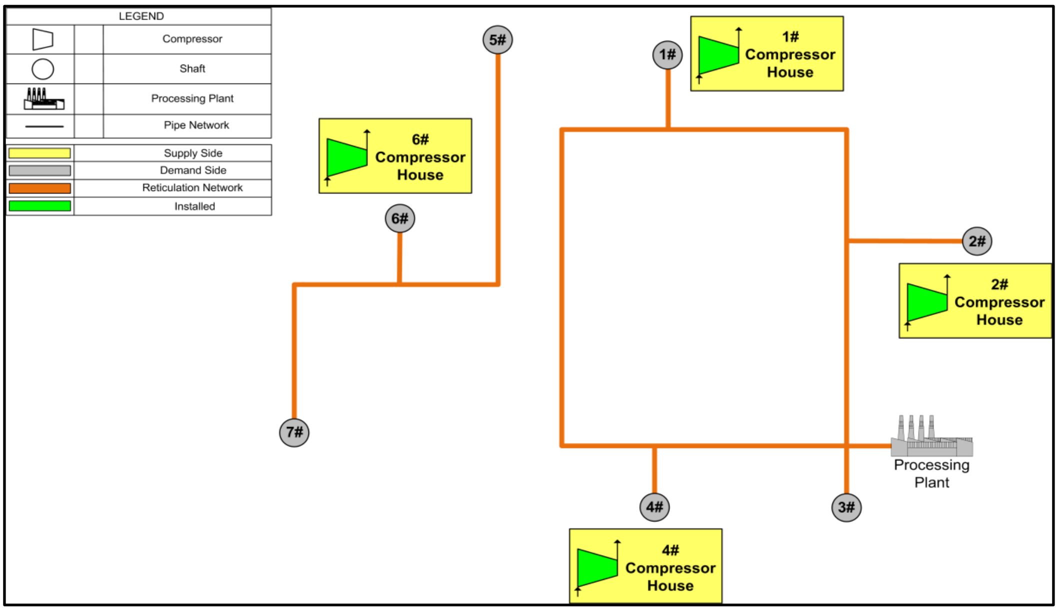


Figure 25: Three different sections identified in a compressed air network

3.2.2 Supply side

The compressors in a compressed air network are the focus point when investigating the supply side of a system and they form a major part of the reconfiguration process. Energy savings resulting from reconfiguration initiatives are measured on the compressors. The following information must be retrieved from relevant mine personnel:

- number of compressors;
- installed capacities of the compressors;
- location of the compressors in the network;
- usage of the compressors; and
- automation and capacity control on the compressors.

This information can be used to determine which compressors should be incorporated in the proposed reconfiguration strategy.

3.2.3 Demand side

The consumers on the demand side usually include processing plants and mining shafts. These consumers have specific compressed air requirements, which vary with each consumer [25], [26]. It is important to determine these requirements as the reconfiguration of the network depends on the requirements of the different consumers. The following information should be obtained:

- number of processing plants and shafts in the compressed air network;
- number of operational processing plants and shafts;

- compressed air requirements of the processing plants and shafts; and
- leaks and any additional compressed air consumers connected to the network.

This study only focuses on reconfiguring the surface air reticulation network. The detailed underground compressed air consumers will therefore not be incorporated in the design strategy. The total surface compressed air requirements of each shaft and processing plant will be obtained and analysed. The total flow consumed by each shaft and processing plant, measured on surface, will be sufficient to determine each consumer's requirements.

3.2.4 Air reticulation network

A compressed air reticulation network can be very complicated. It is not unusual for mines to have networks extending over several kilometres. Intricate networks are often very difficult to analyse and investigate. Investigation processes may be influenced by several factors. Pipe bends, pipe locations, pipe lengths and varying pipe diameters are all factors that could complicate the investigation process. The following information should be obtained:

- basic layout and overview of the reticulation system;
- total span of the reticulation system;
- pipe sizes and materials; and
- state of the reticulation system.

3.2.5 System constraints

Preamble

The system constraints play a crucial role in determining the successful development of a reconfiguration strategy. The strategy must comply with all the system constraints to avoid negatively influencing mining operations and protocol. The following sections discuss the crucial constraints that need to be considered.

Minimum and maximum compressed air requirements

The minimum and maximum compressed air requirements of the network must be determined. This gives the ESCO a boundary within which to develop a reconfiguration strategy without negatively influencing the mine's production and operations. Figure 26 presents an example of the minimum and maximum pressures a reconfiguration solution should be designed for. According to Figure 26, the minimum and maximum pressure margins compensate for both the minimum pressure of 300 kPa and the maximum pressure of 500 kPa in the network.

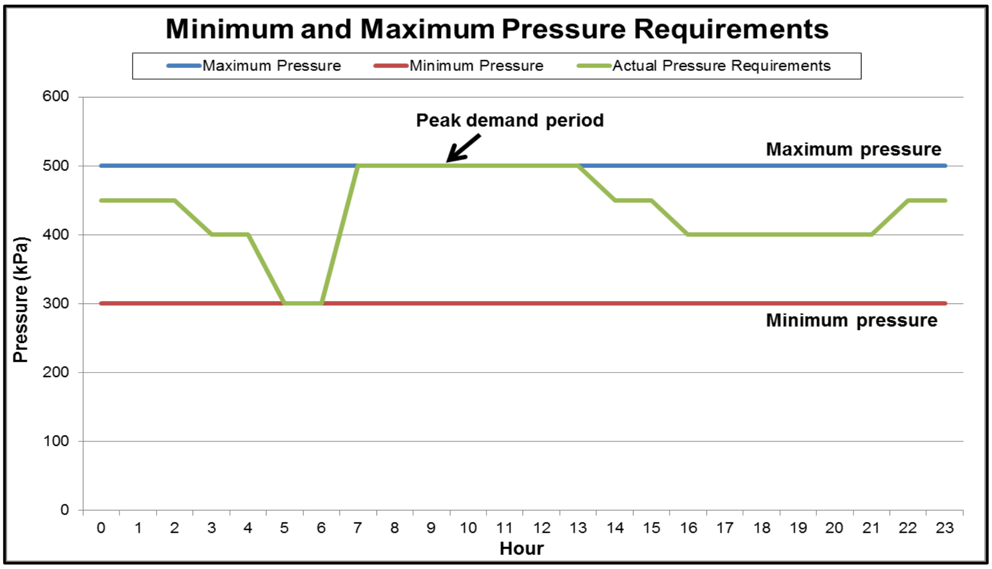


Figure 26: Minimum and maximum pressure requirements of a compressed air network

The minimum and maximum compressed airflow requirements can also be determined if the exact number and consumption trends of all the end-users are known. It is, however, difficult to keep track of all the pneumatic equipment being used as mines usually divide into small intricate sections on underground mining levels. If the specific mine being analysed do keep track of all the different end-users, it would be useful to determine the required airflows during certain periods of the day. Figure 27 presents an example of the minimum and maximum flows a reconfiguration solution should be designed for.

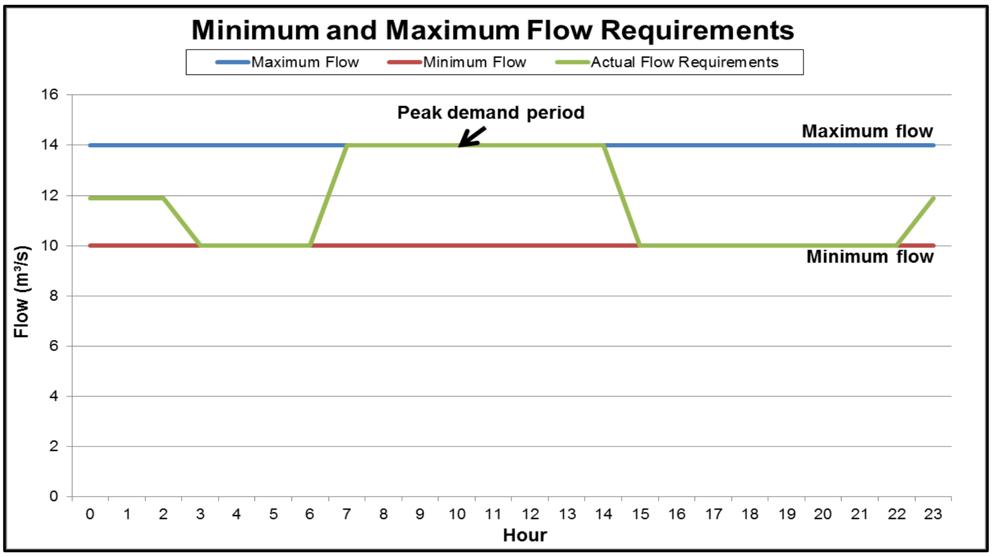


Figure 27: Minimum and maximum airflow requirements of a compressed air network

Future developments

Relevant mine personnel must be consulted to determine the mine’s plans for any future developments and changes to mining operations. New developments and changed operations on certain shafts and processing plants may influence the reconfiguration design parameters directly. The changes may influence compressed air consumption, which in turn affects compressor power consumption. The same applies to the decommissioning of shafts and processing plants within the network.

Reconfiguring a mining compressed air network is a permanent change in the physical air reticulation network of the mine. If the solution is not designed to accommodate future changes, it may become obsolete when the changes do occur.

The following section focuses on data collection and data processing.

3.3 Data processing and network operation

3.3.1 Overview

This phase may commence once the three sections (supply side, demand side and air reticulation network) of the compressed air network have been defined and analysed. During this phase, it is necessary to identify all the measuring points for possible data collection. The data is then collected from these points for processing and evaluating. Analysing the data will reveal the compressed air consumption/generation trends of each section in the network.

3.3.2 Identifying data-measuring points

Figure 28 illustrates data-measuring points, and the absence thereof, in a compressed air network. Flow and pressure points (FPP) refer to the compressed airflow and pressure measuring points combined. Power-measuring points (PP) represent the compressor power-measuring points. No-measuring points (NP) refer to all the points where no data is being measured or logged on the local SCADA system.

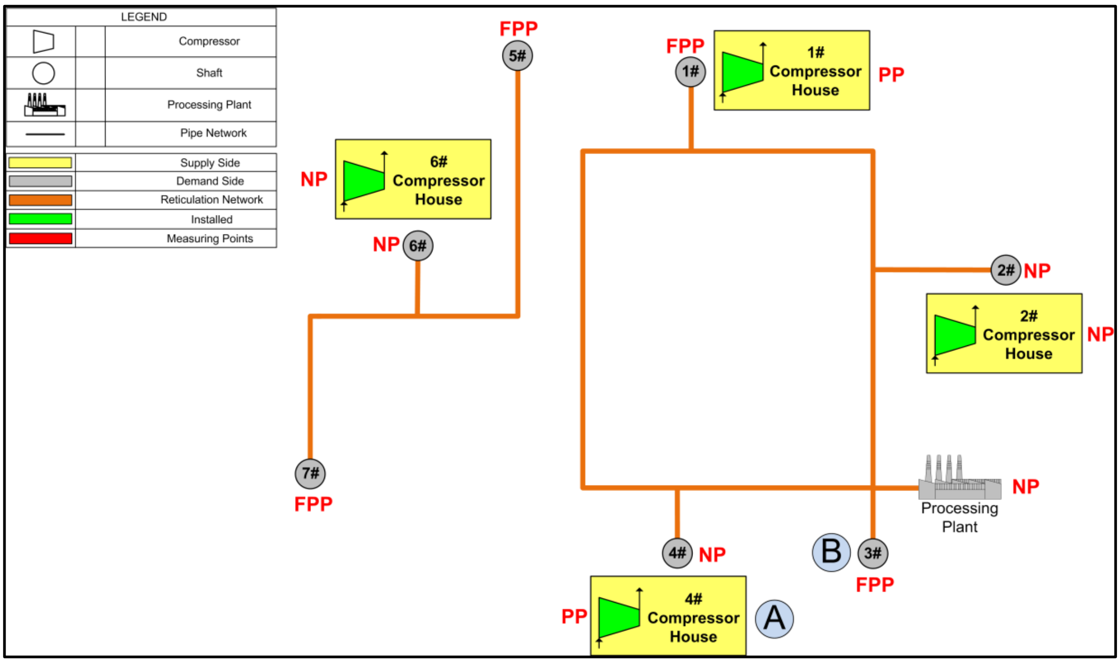


Figure 28: Illustration of identified data-measuring points in a compressed air network

It is very important to identify data-measuring points for possible data collection. The network in Figure 28 cannot be reconfigured prior to the determination of the compressed air requirements of the NPs. For example, the NP at 4# may be a very high compressed air consumer. The production at 4# may be negatively influenced if the reconfiguration strategy entails the relocation of a compressor from point A to B.

The importance of measuring points in a compressed air network is evident as they contribute to the development of an effective reconfiguration strategy. The strategy must be applied to the network for cost savings and not influence mining operations negatively.

3.3.3 Data collection

Most South African mines make use of a SCADA system. The software is used to monitor the mine’s instruments, control certain components, display trends and store data from selected data points. It is important to ensure that the required points are logged on the SCADA system. Relevant mine personnel can be consulted to obtain a copy of the logged data. The data is very useful in determining the compressed air requirements and compressor power consumption of the network. Figure 29 is an illustration of a typical SCADA system used at a South African mine.

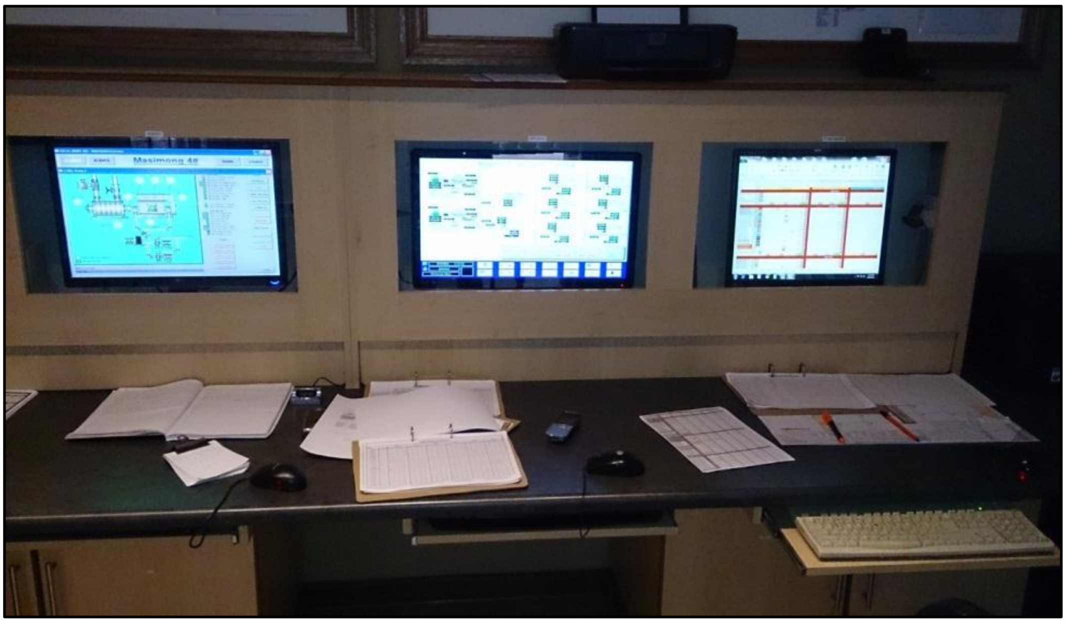
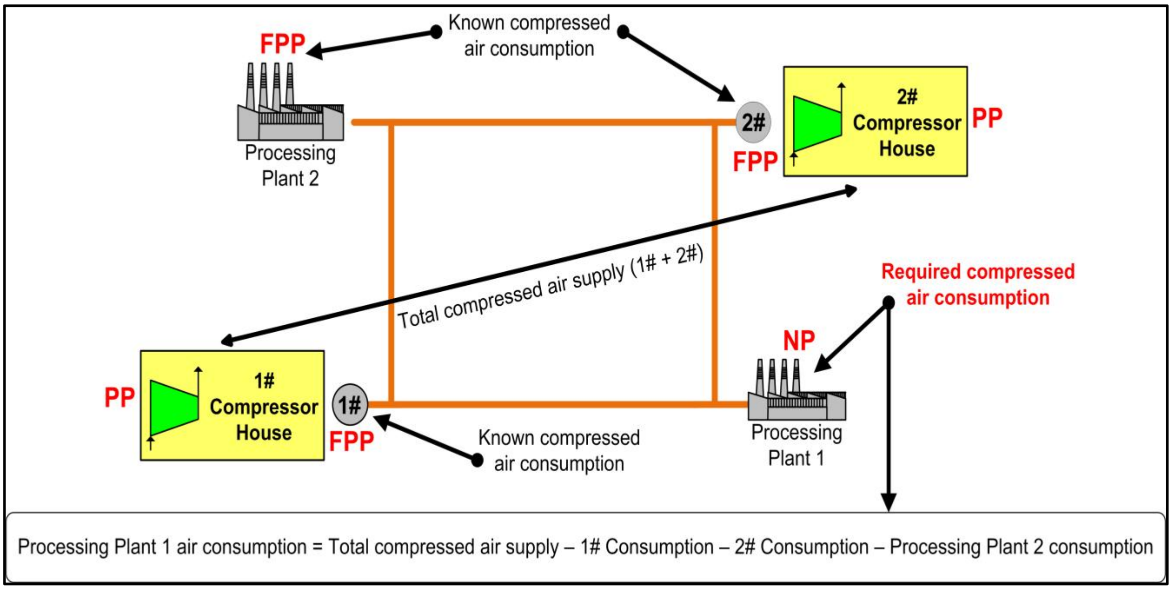


Figure 29: Typical SCADA system used on a South African mine[10]

Compressed air and compressor power data may not be available on the mine's SCADA system. Outdated equipment, faulty instrumentation and communication failures of operating equipment may restrict the SCADA from logging any data. Referring to Figure 28, data may also be required from certain points where there are NPs. An alternative approach would then be required to obtain the data. Flow balancing is a very simple approach to determine the compressed air requirements. Figure 30 is a simplified illustration to explain the concept.



Processing Plant 1 air consumption = Total compressed air supply – 1# Consumption – 2# Consumption – Processing Plant 2 consumption

Figure 30: Simplified illustration explaining the flow-balancing concept

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[10] Photo taken by Johan Bredenkamp at a South African mine.

According to Figure 30 the compressed air consumption of Processing Plant 1 is required. The flow consumption of Processing Plant 2 and the two shafts are known. The total compressed air supply capacities of the compressors at the two shafts are also known. The required consumption of Processing Plant 1 is calculated by subtracting the flow consumption of 1#, 2# and Processing Plant 2 from the total compressed air supply. The following must be considered when using this method:

- The measured values used to do the calculations must be very accurate. If any suspicion arises that the data may be faulty, additional steps need to be taken to verify the accuracy of the data.
- The compressed air network must contain as few leaks as possible.

Another method to collect data from the NPs is to use portable power monitors, flow meters and pressure loggers. The equipment can be expensive and it should be the last resort to obtain the required data. The flow-balancing method can be used to determine most of the unknown compressed air consumption trends. The remaining consumption trends can be determined by strategically using portable measuring equipment. Figure 31, Figure 32 and Figure 33 are examples of portable measuring equipment.

Figure 31: Portable power monitor[11]

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[11] Photo taken by Johan Bredenkamp.

Figure 32: Portable flow meter[12]

Figure 33: Portable pressure logger[13]

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[12] Photo taken by Johan Bredenkamp.
[13] Photo taken by Johan Bredenkamp.

3.3.4 Data evaluation

Preamble

Evaluation of data may commence once all the data has been successfully measured for the same periods. The data also need to be evaluated for accuracy and consistency. The following can be done if any suspicion arises that the data may be faulty:

- Use additional calibrated measuring equipment to measure data from the suspicious points. Compare the measured data with the data collected from mine personnel. Thus, suspicious data can be verified.
- Compare the total measured flows throughout the network with the compressor’s flow output. However, the losses in the network have to be considered when using this method.

Once the data has been verified flow, pressure and power profiles are developed with data collected over extended periods. Using larger data samples minimises the impact of outliers. Profiles developed give an indication of the general operation and requirements of the compressed air network.

The developed flow and pressure profiles are compared to the compressed air requirements of the end-users obtained in Section 3.2. The comparison will assist in identifying compressed air wastage, as well as potential shortfalls in the network. The power profiles give an indication of the power saving potential on the compressors due to the potential reconfiguration of the network. The profiles are discussed in detail in the following sections.

Flow profiles

Flow profiles are developed for each individual consumer in the network. Figure 34 represents typical examples of flow profiles developed for a compressed air network. It is evident from the graph that different consumers within the same network may have different air consumption trends.

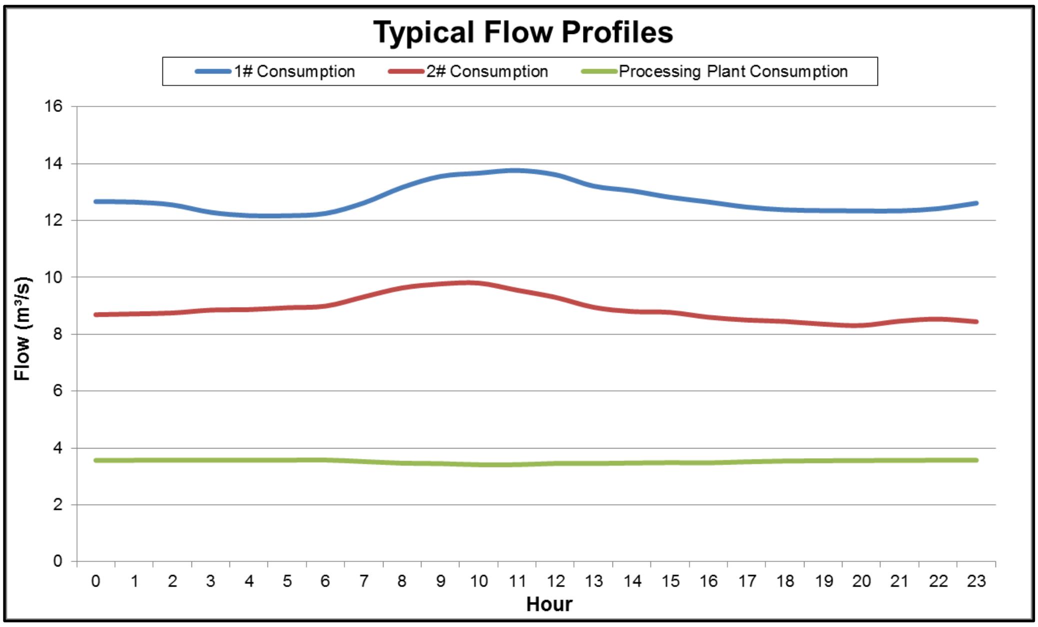

Figure 34: Typical flow profiles developed for a compressed air network

Figure 35 is an example of a flow profile constructed against the original flow requirement trend, developed in Section 3.2.5. According to this figure, a shortfall of compressed airflow occurs between 07:00 and 14:00. A major amount of air is wasted in the afternoons and in the early mornings. The shortfall occurrence may be due to insufficient supply capacity or inefficient distribution of compressed air. The wastage may be attributed to illegal mining activities, compressed air leaks or ineffective configuration of the reticulation network.

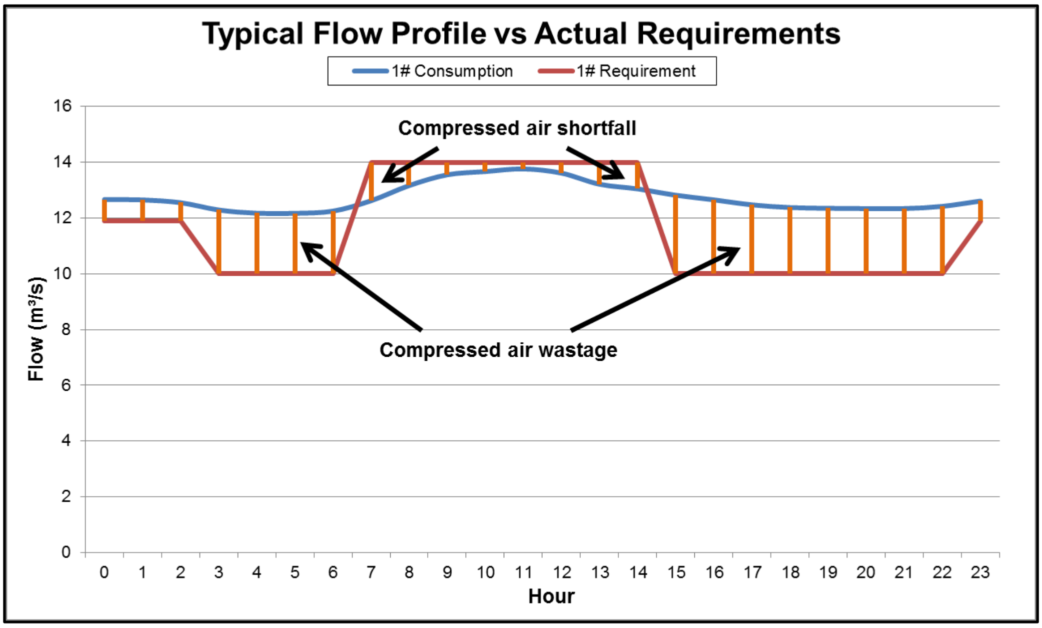

Figure 35: Identifying compressed air shortfall and wastage by developing flow profiles

Pressure profiles

Pressure profiles are developed for each consumer in the compressed air network. The profiles will assist in revealing an oversupply or lack of sufficient air pressure in the network. Figure 36 is an example of typical network pressure profiles.

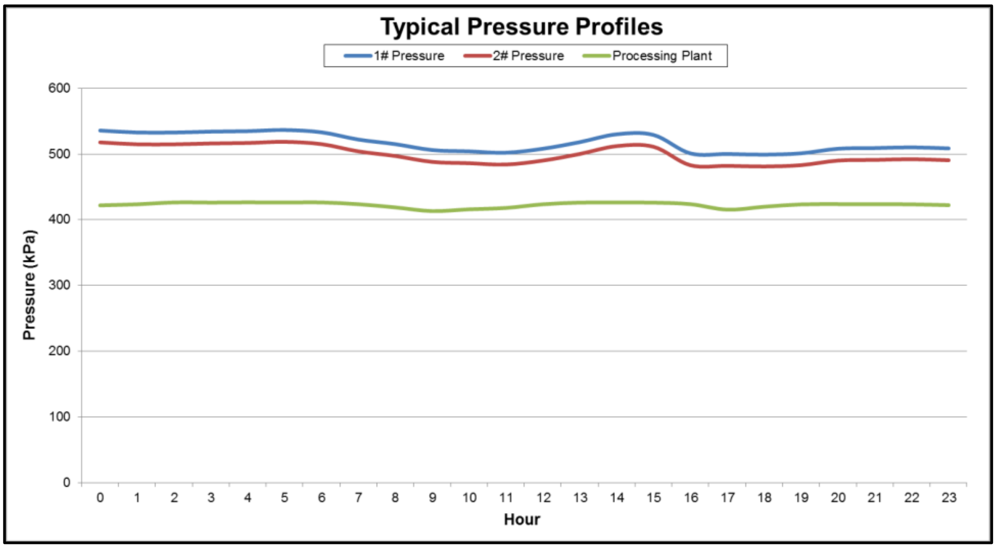

Figure 36: Typical pressure profiles developed for a compressed air network

Pressure differences may be the result of pressure drops due to pipe friction losses. Pressure profiles may be much higher than required. This scenario presents major reconfiguration opportunities as air is wasted through oversupplying the end-users. Figure 37 represents a typical pressure profile where the supply pressure is much higher than the actual requirements.

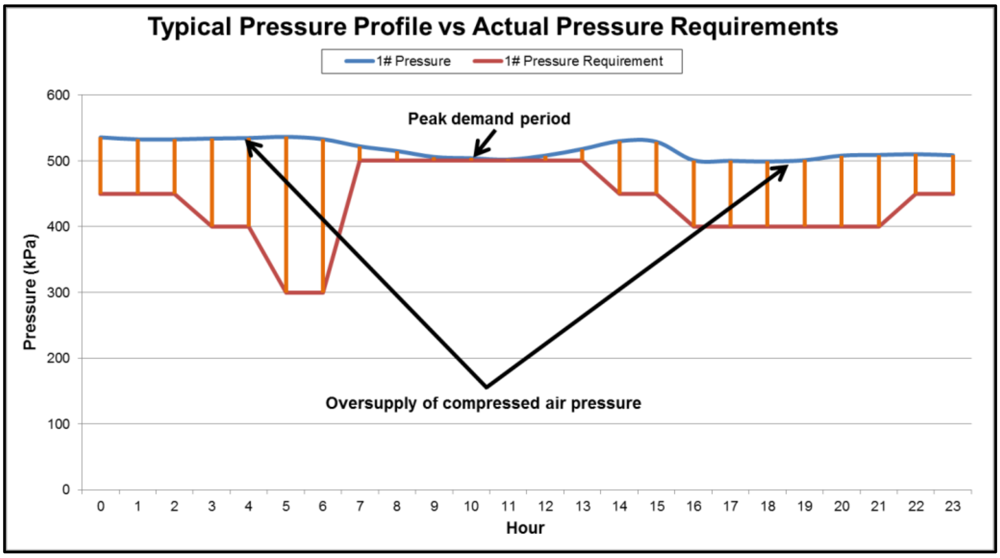

Figure 37: Pressure profile vs pressure requirements for a compressed air network

It is evident from Figure 37 that an oversupply of compressed air is delivered to this specific compressed air network. This presents major reconfiguration potential. However, it is very important to reconfigure the network in such a manner that it would still deliver adequate pressures during certain periods (peak demand).

Power profiles

A total compressor power profile is developed for all the compressors being used in the network. The profile is usually referred to as the compressor power baseline and developed prior to any reconfiguration proposals to the client. The power profile after reconfiguration of the network is compared to the compressor power baseline. One would therefore be able to determine the amount of power saved through the reconfiguration strategy. Figure 38 contains examples of typical weekday power baselines developed for large and smaller compressed air networks.

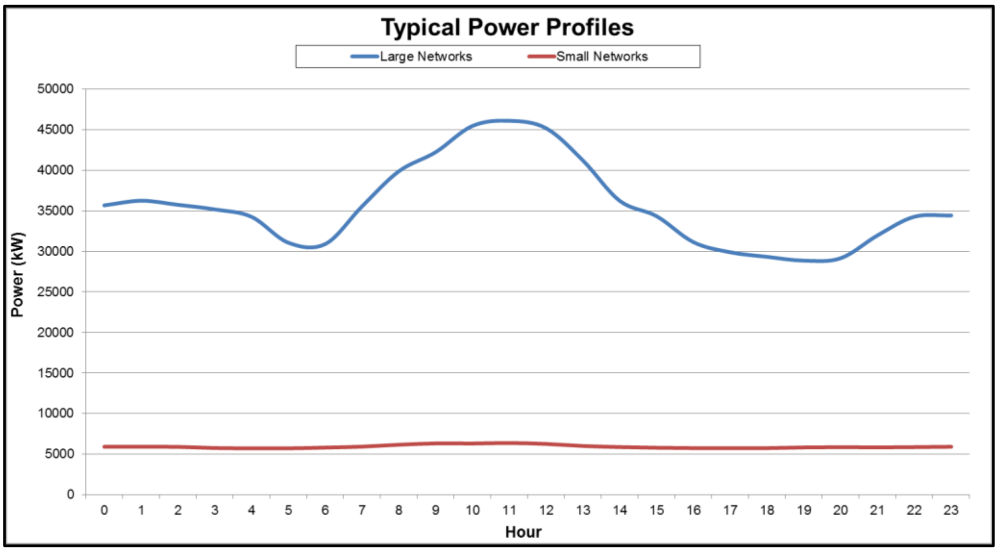

Figure 38: Weekday power profiles developed for compressed air networks (baselines)

3.4 Reconfiguration strategy development

3.4.1 Overview

The network’s operations and constraints are used to develop possible reconfiguration strategies. During this phase, possible solutions are identified and a theoretical analysis of each solution is developed. The theoretical analysis assists in determining the solution’s response in the compressed air network. Each solution’s savings potential is calculated and compared to the actual implementation costs and lifespan of the mine. The solution with the most suitable overall response to the network is chosen for implementation.

3.4.2 Possible solutions

The flow, pressure and power usage profiles have been developed. From these profiles one is able to identify possible solutions to minimise the compressed air and energy wastage in a network. Various solutions may be developed, whereas only one is chosen for implementation. Figure 39 illustrates examples of possible options to reconfigure a compressed air network for cost savings. The letters *A*, *B* and *C* represent the options.

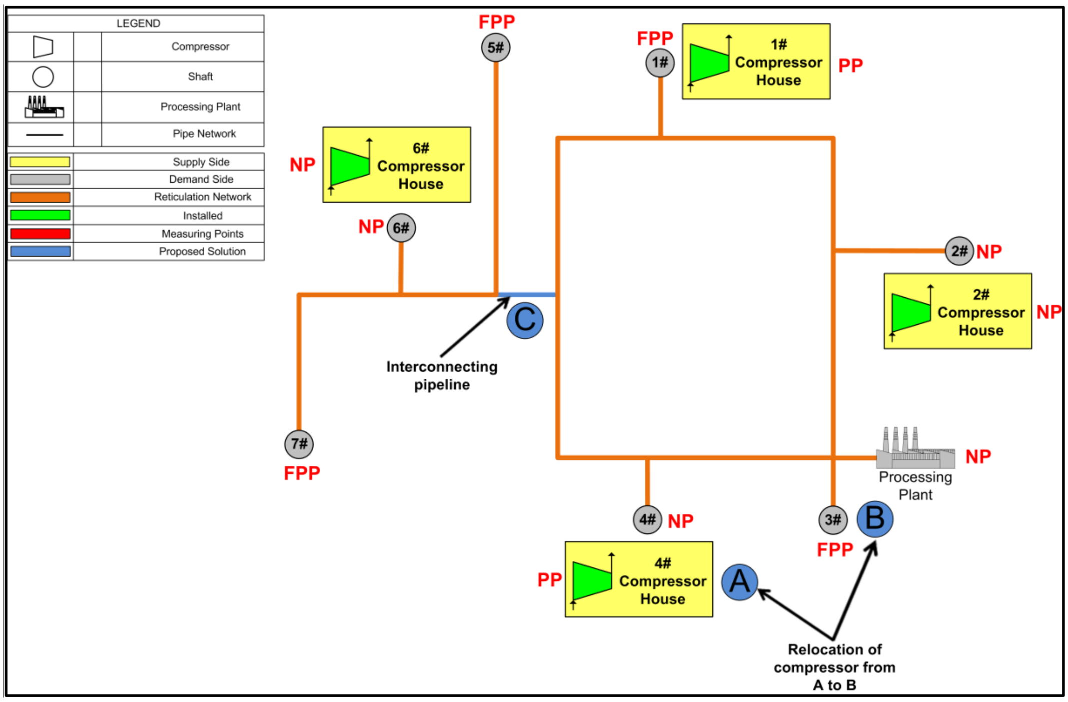

Figure 39: Possible reconfiguration strategies on a compressed air network

Solution A and B focuses on relocating a compressor from 4# to 3#. This is typically accomplished if 4# is an abandoned shaft and 3# have high compressed air requirements. To reduce pipe friction losses the connecting pipe section between the shafts can be removed after the relocation. Solution C presents the option to interconnect two sections of a compressed air network. Compressed air can then be exported from one section to another. The compressor at 6# can be stopped to achieve compressor power savings.

The solutions displayed on Figure 39 are only used for illustration purposes and are not relevant to the profiles developed earlier in this chapter. The solutions should be carefully evaluated before commencing with implementation. Simulating the network with different solutions is an effective method for evaluating the available options. The following constraints need to be considered during the solution development.

Practical constraints

The location where proposed infrastructure is to be installed is a very important system constraint. Theft of electrical cabling, availability of electrical supply and distances to operational control rooms are all factors that play a crucial part in developing possible solutions. The availability of existing infrastructure and its specifications also have to be incorporated in the solution development process.

Cost constraints

The implementation cost of a possible solution plays a crucial part in the strategy selection process. Considering the remaining lifespan of a mine, the implementation cost should not exceed the solution’s financial potential through electrical energy savings.

3.4.3 Theoretical analysis and calculations

Once the possible solutions have been successfully identified, simulation models for each solution are developed by using appropriate software. As discussed, the simulation models are theoretical presentations of the solutions’ responses in a practical system. The simulation models of each solution are compared with one another. The comparison assists in determining each solution’s suitability for the specific application in the compressed air network.

The accuracy of the simulations must be verified. Simulation models do not compensate for losses such as leaks. Verification is achieved by manually solving the equations discussed in Chapter 2. The results are compared with each other in order to identify the discrepancies.

3.4.4 Savings potential

Prior to selecting the most suitable solution, it is necessary to calculate the electrical energy savings potential of each solution. The theoretical energy savings produced by each solution is calculated by comparing the solution’s proposed power profile against the baseline. It is necessary to calculate each solution’s energy savings potential. A solution may be the most suitable for its application in a compressed air network, but not necessarily have the required savings potential.

For the purposes of this study, cost saving is the main priority of reconfiguring a mining compressed air network. The cost savings can be divided into savings on electricity bills as well as savings on implementation costs and maintenance costs. Therefore, the energy savings potential of each solution must be compared to the implementation cost of the solution. The solution may be appropriate for selection if the amount saved on electricity bills justifies the implementation costs.

3.4.5 Solution selection

It is important to consider all the system constraints, simulation model results and electrical energy savings potential for each solution during the selection process. This will enable one to select the most appropriate solution for the specific application. The selected solution is presented to relevant mine personnel for approval. Once approved, the solution is implemented on the mine's compressed air network to generate the proposed cost savings. Figure 40 is a simplified illustration of a selection process to be followed.

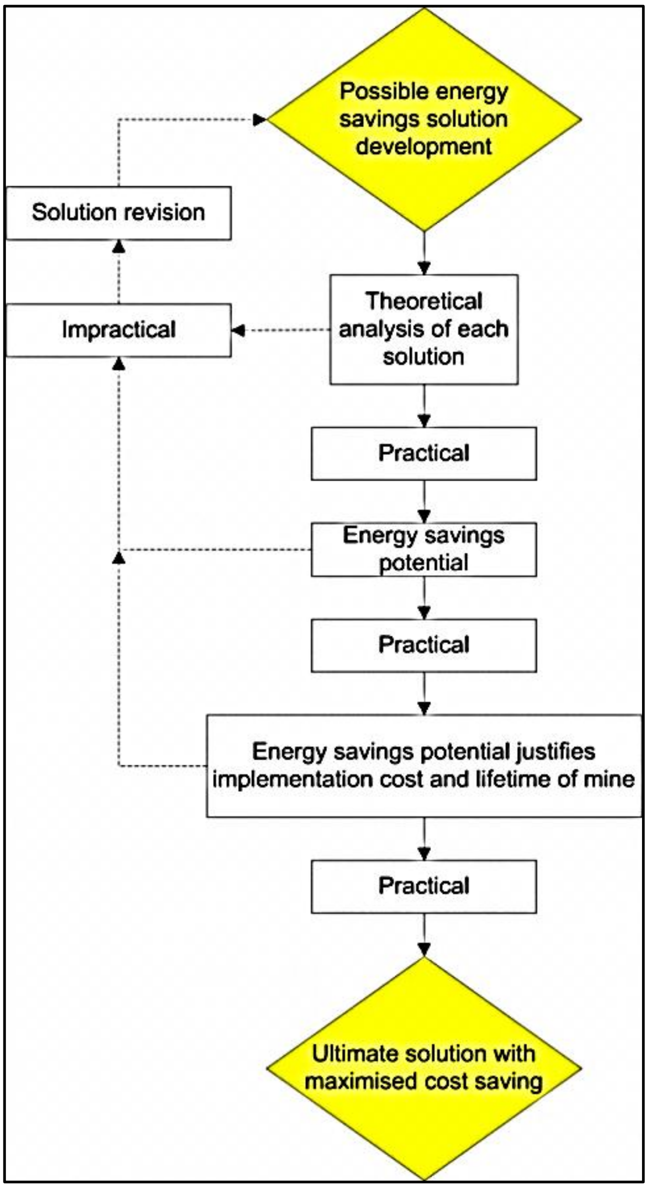

Figure 40: Solution selection strategy to reconfigure a mining compressed air network

3.5 Conclusion

This chapter devised a strategy to reconfigure mining compressed air networks for cost savings. The network analysis highlighted important components in a typical network. The process of identifying data-measuring points, collecting and evaluating data was discussed pertaining to practical implementation in the mining industry. Finally, all the relevant information was used to develop and select the most appropriate reconfiguration solution.

The strategy will be applied on two case studies in the following chapter. The case studies will assist in determining the reliability of the strategy's impact on a practical system.