CHAPTER 3

DEVELOPMENT OF THE ENERGY MANAGEMENT SOLUTION

3.1 Preamble

This chapter describes the development process of the proposed energy management solution. The functionalities and shortfalls of the energy management systems, investigated in Section 2.7, are incorporated in the development process in order to obtain a comprehensive solution. The solution specifications and design are presented in this chapter.

3.2 Requirements for a comprehensive solution

3.2.1 Input requirements

Compressed-air system information

Information is required to define the physical attributes of the individual compressors as well as the compressed-air system as a whole. A description of the required input parameters is given in Table 3-1.

Table 3-1: Compressed-air system parameters

Location	Parameters
Individual compressors	Capacity [m^3/h] Power rating of the compressor motor [MW] Manufacturer
Compressor system (all compressors)	Number of compressors Location of compressors
Air network (piping)	Air network layout (surface) Location of measurement equipment and valves relative to the compressors

These inputs purely describe the compressed-air system, and its components, in order to assist the operator of the Energy Management System (EMS). This information will only be revised if compressed-air system changes are made.

Real-time inputs

Real-time inputs are either received from the compressed-air system or a human operator. Inputs from the air system include statuses; measurements; and control permissions, and are described in Table 3-2.

Table 3-2: Real-time inputs

Input types	Inputs	Units/modes
Statuses	Running	True / False
	Loaded	True / False
	Available	True / False
	Inlet throttle-valve position	0% to 100%
	Blow-off valve position	0% to 100%
Measurements (instantaneous)	Delivery mass flow	kg/s
	Delivery pressure	kPa
	Electrical power consumption	kW
Control permissions	Start	True / False
	Stop	True / False
	Load	True / False
	Unload	True / False
	Pressure set-point	True / False

The operator can manually initiate control operations for individual compressors. These operations are described in Table 3-3.

Table 3-3: Real-time user input

Inputs	Description
Start	Translated to control output
Stop	Translated to control output
Load	Translated to control output
Unload	Translated to control output
Pressure set-point changes	Translated to control output
Lockout	Disable automatic compressor control
Automatic control enabled/disabled	Disable/enable automatic compressor control

An operator can use these real-time inputs to disable automatic control, which will allow for full manual control of all compressors. Automatic control of individual compressors can be disabled by locking out the compressor. The purpose of compressor lockouts is described in Section 3.3.2.

Control constraints

Control constraints must be defined to ensure safe compressor energy management. These constraints are system specific and will differ from one air system to another. Typical constraints are described in Table 3-4.

Table 3-4: Control constraints

Constraints	Description
Compressor priorities	According to capacity, efficiency, total running hours, time left before regular maintenance, etc.
Pressure set-point schedules	Schedules based on the demand of different types of production days
Pressure set-point control range	Minimum and maximum control limits relative to the pressure set-point
Minimum and maximum number of compressors running	Determined by user preference
Start, stop, load and unload delays	Ensure sufficient time for the air system to stabilise after control changes are made (start/stop/load/unload)

The choice of each constraint provides a trade-off between optimal energy management and safe compressor operation. Conservative safety margins on control constraints will ensure uninterrupted production with moderate energy management capability. Less conservative system control margins will increase the energy saving capability of EMS. This however comes with an increased possibility of production losses due to the tighter control limits.

3.2.2 Required outputs

The outputs required from EMS are compressor control and pressure set-point schedules. These schedules are implemented with control instruction. Control instructions are used to start up, shut down, load or unload compressors according to the calculated compressor schedule. Running compressors are controlled according to the pressure set-point schedule.

Compressor energy consumption can be reduced through dynamic compressor capacity control and scheduling. EMS is required to provide the means necessary to achieve sustainable compressor energy management.

3.3 Energy management philosophy

3.3.1 Individual compressor capacity control

The energy management philosophy includes individual compressor capacity control and compressor scheduling. Compressor output is varied according to predefined pressure set-point schedules.

These schedules are based on the historic demand of each specific compressed-air system. Different set-point schedules are defined for weekdays, production Saturdays, non-production Saturdays and Sundays or public holidays. A day-type calendar is used to define day types for several months ahead of the present date. The correct pressure set-point is calculated according to the current date and time.

3.3.2 Compressor scheduling

Compressor priorities

Compressor priorities are used to determine the sequence in which compressors must be started up or shut down. The compressor with the lowest priority is shut down first, whereas the compressor with the highest priority is started up first. The compressors are prioritised by an operator as part of the control constraint inputs, and can be reconfigured at any time. The priorities are dependent on the compressed-air system and operator preference. Compressors can be prioritised according to capacity, efficiency, total running hours, time left before regular maintenance, etc.

Start, stop, load and unload delays

Time delays play a very important role in the energy management control strategy. If a compressor is scheduled to be shut down, the compressor is first unloaded. After an operator-defined time delay, the compressor will be stopped if the real-time system inputs stabilise, indicating that the compressor is not required to maintain the system pressure. This time delay is dependent on the characteristics of the compressor system and may range from 10 to 20 minutes.

This delay allows the energy management system additional time to reassess the real-time inputs for any changes which may indicate that the compressor should not be shut down. Time delays ensure that instantaneous faulty real-time input does not cause incorrect compressor control. Time delays can be added for stopping, starting and loading as well.

Additional time delays are added to prevent a specific compressor from being stopped-and-started again before a certain minimum time has elapsed. A typical time interval of 20 to 30 minutes is chosen for this delay, to reduce unnecessary compressor cycling and mechanical wear.

Pressure-control range

The compressor delivery pressure has to be kept within the pressure control range. This control range has a minimum and maximum limit, which is defined at a certain offset below and above the pressure set-point respectively. An indication of whether the pressure set-point is not maintained accurately is when the delivery pressure exceeds the minimum or maximum control limit. A visual illustration of the pressure control range is shown in Figure 3-1.

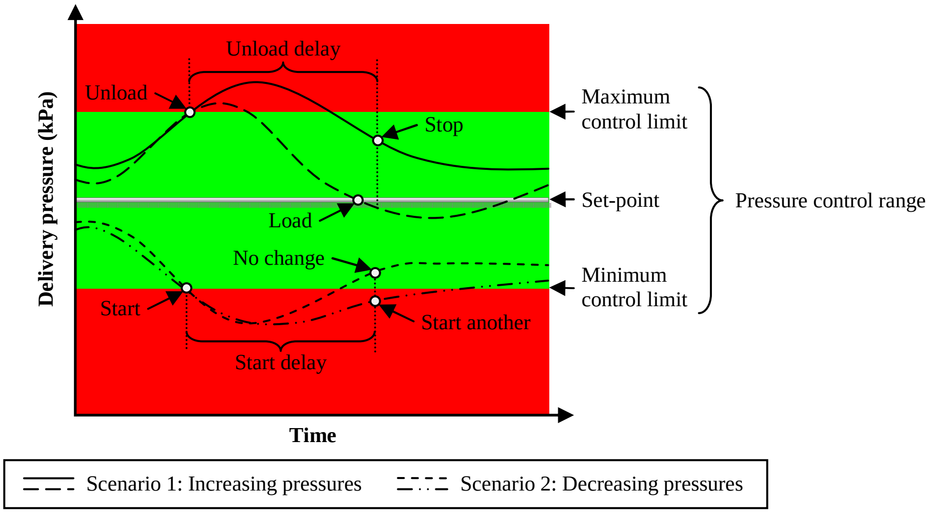


Figure 3-1: Compressor control strategy

If the pressure reaches the maximum control limit, the compressor with the highest priority is unloaded and the unload delay is activated. Control changes are only made in the delay period if the pressure decreases to below the pressure set-point. In this case, the unloaded compressor is loaded again. If however the delay expires without the pressure reaching the set-point value, the air system is stable and the unloaded compressor is shut down.

If the pressure decreases from the pressure set-point to the minimum control limit, an additional compressor is started up and the start-up delay is initiated. If the delay expires — with the pressure below the minimum control limit — another compressor is started up and the start-up delay is reinitiated. If the pressure has however increased to above the minimum control limit, the system is stable and no control changes are made.

Compressor lockout

It may be necessary to manually specify a compressor as unavailable for control. This is typical during normal compressor maintenance. A compressor may also be locked out by the operator when abnormal measurements — such as excessive vibration or high temperatures — do not initiate an automatic compressor trip. A compressor lockout is a control override on a specific compressor.

3.4 A typical mine compressed-air system

A stand-alone compressor system, as defined in Section 2.2, is used as the model for a typical mine compressed-air system. The characteristics of this model are based on the existing compressed-air systems at several South African mines. The air-system model consists of multiple compressors in a compressor house, connected to a compressed-air system, which supplies compressed air to a single mining shaft.

Most mines have a centralised control room. The control room is situated a significant distance, typically greater than one kilometre, from the compressor house. This model compressed-air system contains sufficient information for the development of EMS. The solution development is based on this model and can be scaled to a compressed-air ring, as defined in Section 2.2.

The steps required to enable remote compressor control from the centralised control room are:

- Installing measurement equipment
- Installing control instrumentation on individual compressors
- Establishing local control of all the compressors
- Establishing remote control of all the compressors

The hardware specifications in the next section are structured according to these steps.

3.5 Hardware specifications

3.5.1 Measurement equipment

An overview of measurement equipment required for compressor control was given in Section 2.6. This equipment is installed on the compressor, compressor motor, lubrication system and air network. The equipment primarily measures electrical energy consumption of the motor, as well as airflow and air pressure of the compressor. In addition, vibration and temperature transmitters are installed. Instrumentation required on the compressor motor is listed in Table 3-5.

Table 3-5: Compressor motor instrumentation

Instrument	Unit
Ampere meter	A
Volt meter	V
Power factor meter	-
Temperature transmitter and probe	ºC
Vibration transmitters	mm/s

Measurements on the compressor are accomplished using the instrumentation listed in Table 3-6.

Table 3-6: Compressor instrumentation

Instrument	Unit
Differential pressure transmitter	kPa
Air mass-flow transmitter	kg/s
Temperature transmitter and probe	ºC
Vibration transmitters	mm/s
Axial displacement transmitters	mm

The diagram in Figure 3-2 shows the extent of typical compressor instrumentation, with the locations of individual measurement instrumentation clearly indicated. This diagram shows the instrumentation of the compressor, compressor motor and the lubrication system.

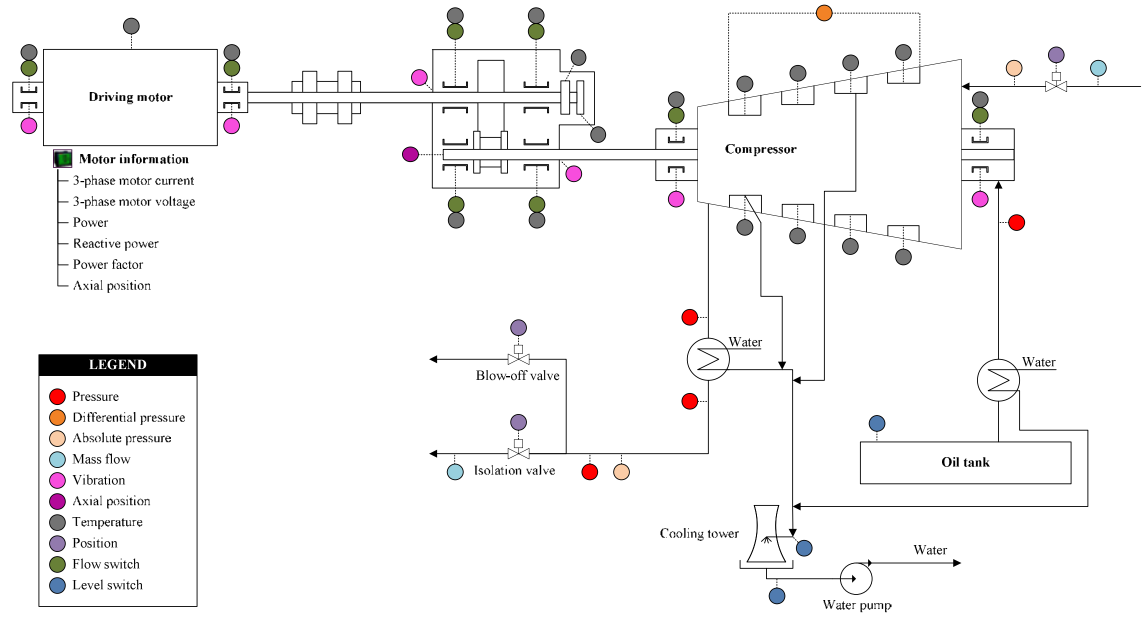


Figure 3-2: Typical compressor measurement instrumentation

Historic measurements from pressure transmitters at strategic points in the compressed-air network are used to calculate pressure set-point schedules. After implementation of EMS, these transmitters provide feedback of the system response to variations in compressor capacity and scheduling.

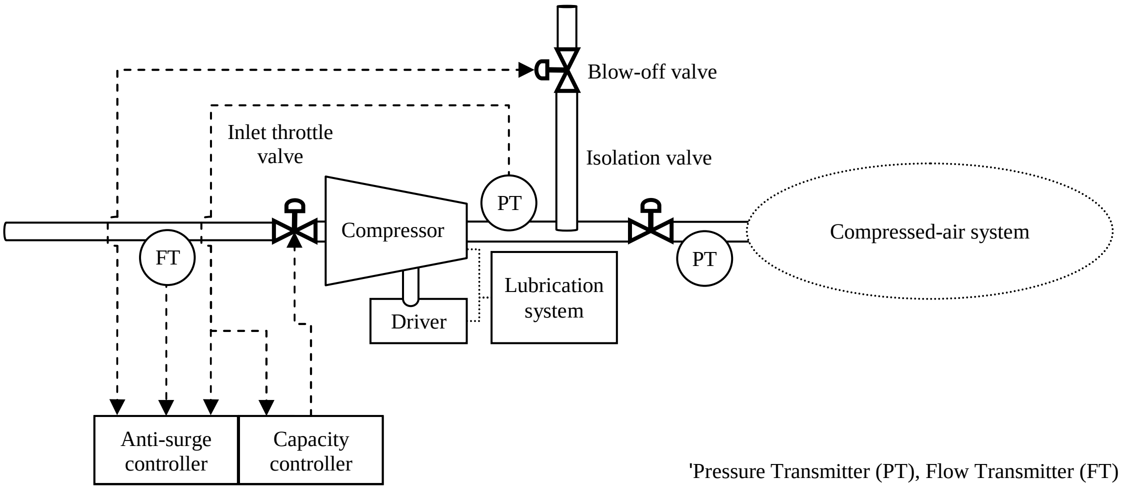
3.5.2 Control instrumentation

The requirements for compressor automation include control of the compressor motor, lubrication system and various control valves, as mentioned in Section 2.5.4. The instrumentation required to achieve complete compressor automation is described in Table 3-7.

Table 3-7: Control instrumentation

Instrumentation type	Instrument	Description
Controller	Capacity controller	Controls compressor capacity
	Anti-surge controller	Prevents compressor surge
Actuated valves	Inlet throttle valve	Allows capacity controller to vary the capacity of the compressor
	Blow-off valve	Controlled by anti-surge controller
	Isolation valve	Used to unload compressor
Measurement	Flow switch	Prevents compressor operation with insufficient oil flow
	Pressure switch	Prevents compressor operation with insufficient oil pressure

At most mines, the valves in Table 3-7 are already installed and only require electric actuators to enable automated control. A schematic of the compressor control system is shown in Figure 3-3.



'Pressure Transmitter (PT), Flow Transmitter (FT)

Figure 3-3: Instrumentation diagram for a typical compressor

The capacity controller receives a measurement of the total pressure downstream of the compressor and adjusts the inlet throttle valve in order to maintain a predefined pressure set-point. By changing the pressure set-point on the controller, the capacity of the compressor can be varied. The function of this controller is in line with the discussion in Section 2.5.1.

The anti-surge controller retains surge curves and other compressor performance information. This controller receives measurements from the flow and pressure transmitter. These real-time measurements are used in conjunction with compressor performance information in order to achieve surge avoidance as discussed in Section 2.5.3. This controller overrides the capacity controller in order to avoid compressor damage due to surge. The blow-off valve is opened to avoid surge. If the operating point moves to the right of the surge control line, control will be returned to the capacity controller.

On the lubrication system, heating elements; oil pumps; water pumps and cooling fans are controlled in conjunction with flow and pressure switches. This ensures that oil is continuously supplied to the correct areas for lubrication on the compressor and the motor. Insufficient lubrication oil pressure will cause a compressor trip to avoid damage. The compressor motor is only started up if lubrication system measurements indicate completion of the prelubrication cycle.

3.5.3 Local compressor control

The metering and control instrumentation is connected to a local PLC. The PLC incorporates analogue and digital inputs and outputs (I/O) to control the operation of all the components of the compressor system, which include:

- Oil heaters
- Oil and water pumps
- Water pumps
- Cooling fans
- The compressor motor
- Control valves

The PLC transmits the desired pressure set-point to the capacity controller. Adjustment of the compressor characteristic information, such as surge curve, on the anti-surge controller is done via the PLC. An instrumented compressor can be fully controlled by the PLC to which its instrumentation is connected. When all the compressors have been instrumented, the PLC is the central point from which all compressors can be controlled locally.

3.5.4 Remote compressor control

A SCADA system is installed in the control room. This system is connected to the PLC via Ethernet; fibre; wireless connection; or a combination of these technologies. The SCADA system offers a user-friendly interface to the PLC and has an extended database capable of logging real-time data from the

PLC. The SCADA system has full control over the PLC. Remote control of all the compressors is accomplished through the SCADA system.

A remote server, running the EMS software, is connected to the SCADA system via a local Ethernet network. This software acts as an Object Linking and Embedding for Process Control (OPC) client and establishes a connection to the OPC Server, running on the SCADA computer. The OPC server has software I/O referred to as tags. These tags give the software remote control of the PLC via the SCADA system.

This concludes the discussion of the required hardware infrastructure that enables remote compressor control, and forms the basis on which the EMS software is developed.

3.6 Software development

3.6.1 Overview

The energy management software is developed to run on a server machine as discussed in the previous section. The EMS software is developed in the 32-bit Microsoft Windows® environment and is implemented on Microsoft Windows Server 2008®. The Borland Delphi Integrated Development Environment® (IDE) is used to facilitate the software code implementation.

3.6.2 Functional flow

Conceptual design

The desired software functionality is broadly defined in the high-level functional flow diagram shown in Figure 3-4. Function Block 3-4.1 represents the process of calculating the applicable pressure set-points from the user-defined set-point schedules. This forms the first part of the energy management algorithm. An additional part of the algorithm is represented by Function Block 3-4.2 where the compressor schedule is calculated. In Function Block 3-4.3 visual feedback is given to the user to confirm the calculated set-points and compressor schedule.

If automatic control is disabled, the set-points and schedule can be used as a guideline for manual compressor energy management. However, if automatic control is enabled, the selected pressure set-points are implemented on the individual compressors. This is represented by Function Block 3-4.4. Function Block 3-4.5 represents the implementation of the compressor schedule. This is accomplished by sending commands to start, stop, load or unload compressors according to the schedule.

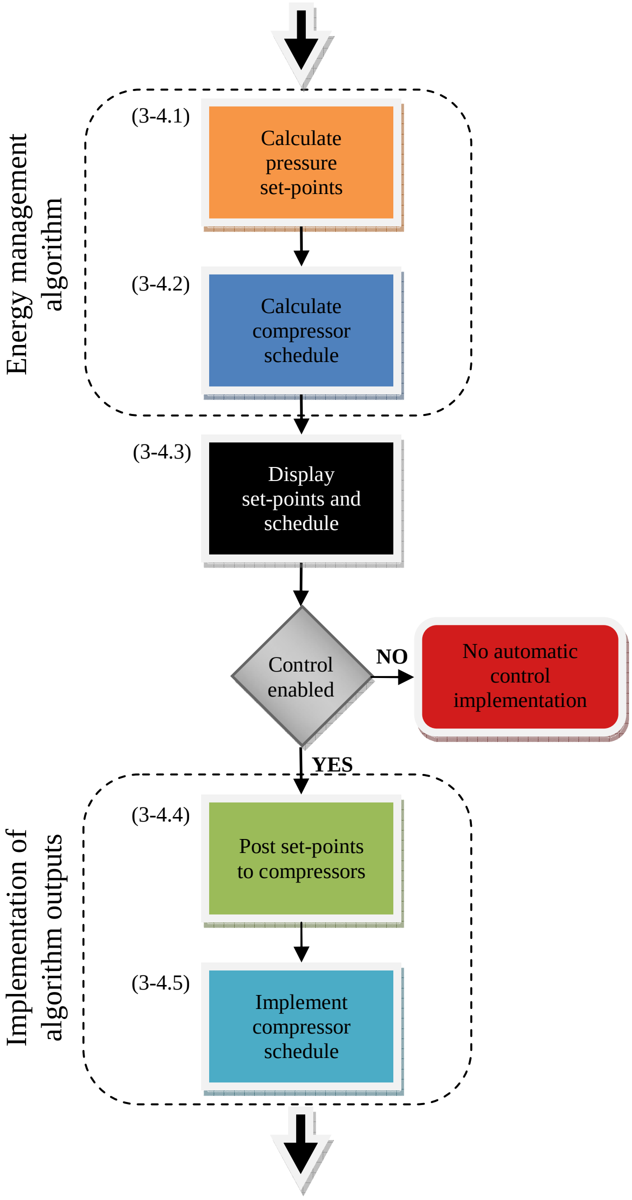


Figure 3-4: Functional flow diagram

Energy management algorithm

The energy management philosophy is the core component of the EMS software. The algorithm derived (using this philosophy) calculates the correct compressor pressure set-points and calculates the optimal compressor schedule while observing the control constraints. Function Blocks 3-4.1 and 3-4.2 in Figure 3-4, together form the complete energy management algorithm. Pressure set-point calculation in Function Block 3-4.1 is described in more detail by the flow diagram in Figure 3-5.

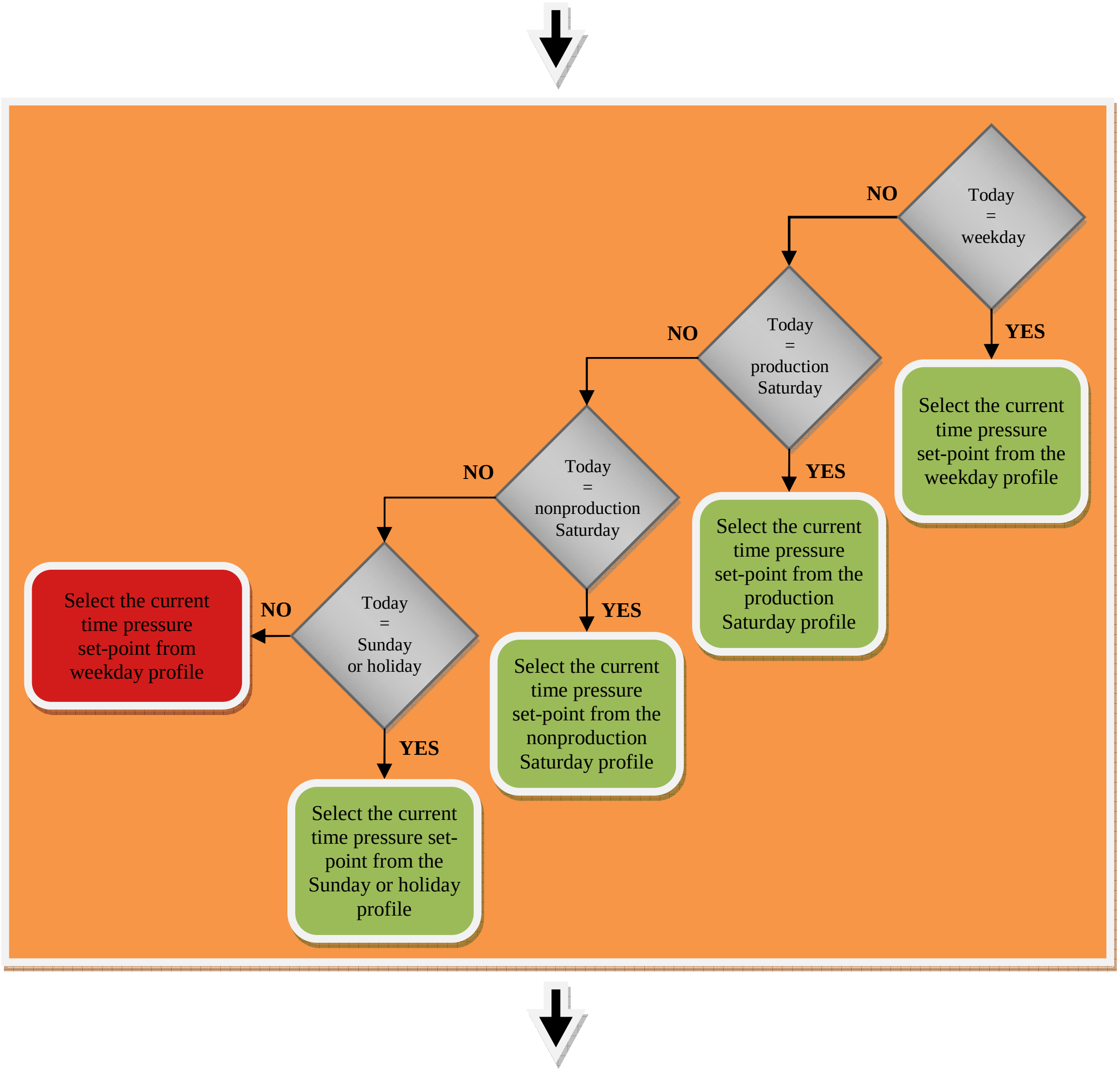


Figure 3-5: Pressure set-point calculation

The current day type is obtained from the user-defined calendar of day types described in Section 3.2.1. The day type determines which set-point schedule is used to actively calculate the pressure set-point. Compressor scheduling in Function Block 3-4.2 (as per Figure 3-4) is described in more detail by the flow diagram in Figure 3-6.

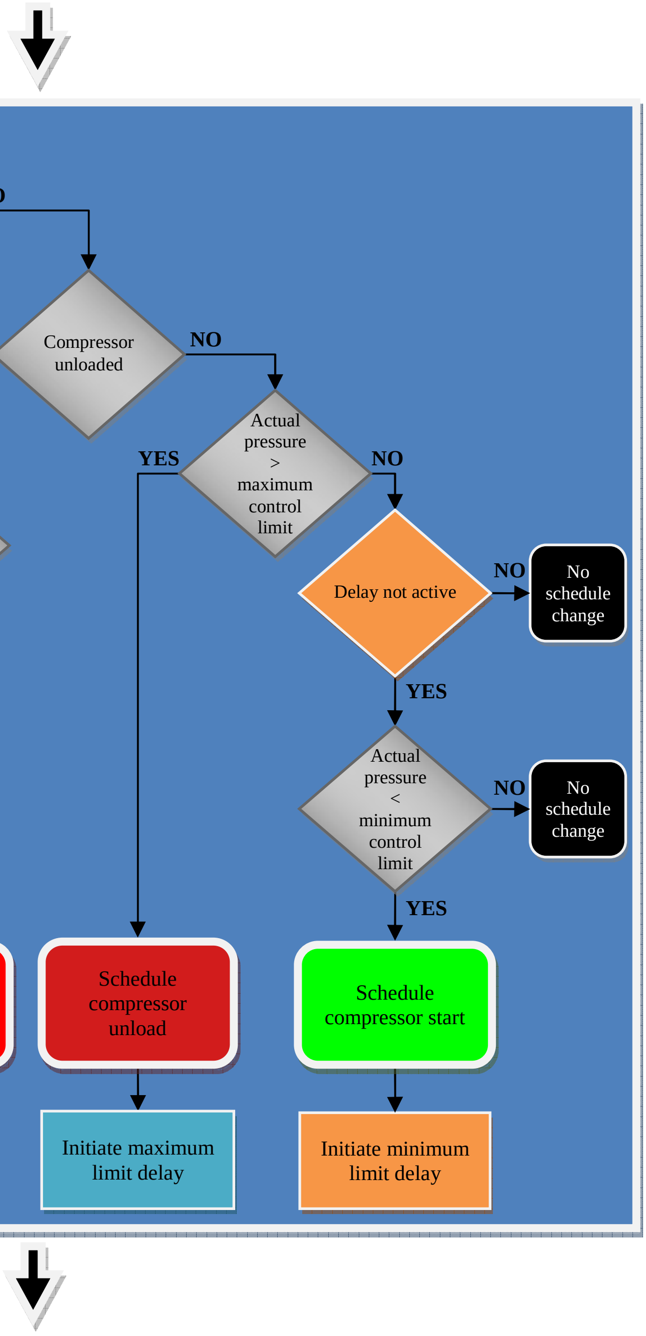


Figure 3-6: Compressor control schedule calculation

The compressor schedule is calculated in order to determine whether a compressor should be started up, or can be unloaded in anticipation of a possible shutdown. Function blocks in Figure 3-5 and Figure 3-6 encapsulate the energy management algorithm.

Implementation of algorithm outputs

The pressure set-points calculated according to the diagram in Figure 3-5, are transmitted to the compressor controllers via the SCADA and PLC. The compressor controller ensures that the compressor capacities are adjusted accordingly. Subsequently, the calculated compressor control schedule — calculated according to Figure 3-6 — is implemented as shown in Figure 3-7.

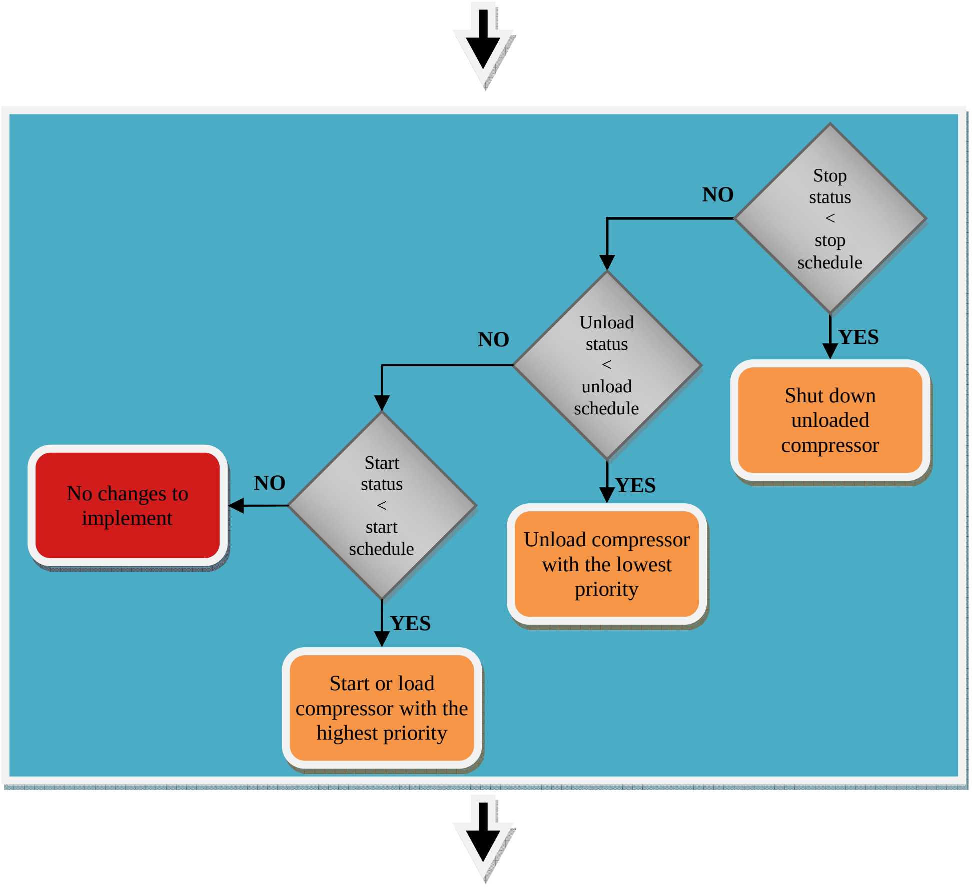


Figure 3-7: Compressor schedule implementation

All compressors available for control are classified according to the statuses: *stopped, unloaded* or *loaded*. The compressor control schedule is also structured in the same way. The status is systematically compared to the schedule. An identical status and schedule requires no control changes. Differences in the status and schedule require different control outputs as shown in Figure 3-7. This is done to determine whether compressors have to be unloaded to be stopped, or if additional compressors have to be started up or loaded. The compressor priorities are used to determine which specific compressor should be started, loaded, unloaded or stopped if the status differs from the schedule.

3.6.3 Architecture and functionality

The software has an Object Oriented Design (OOD) consisting of several software modules with common functionality. The software architecture, shown in Figure 3-8, is a simplified diagram which clearly shows the main software modules and their interaction with each other. The Unified Modelling Language (UML) diagram, found in Appendix B, gives more detail of the software design.

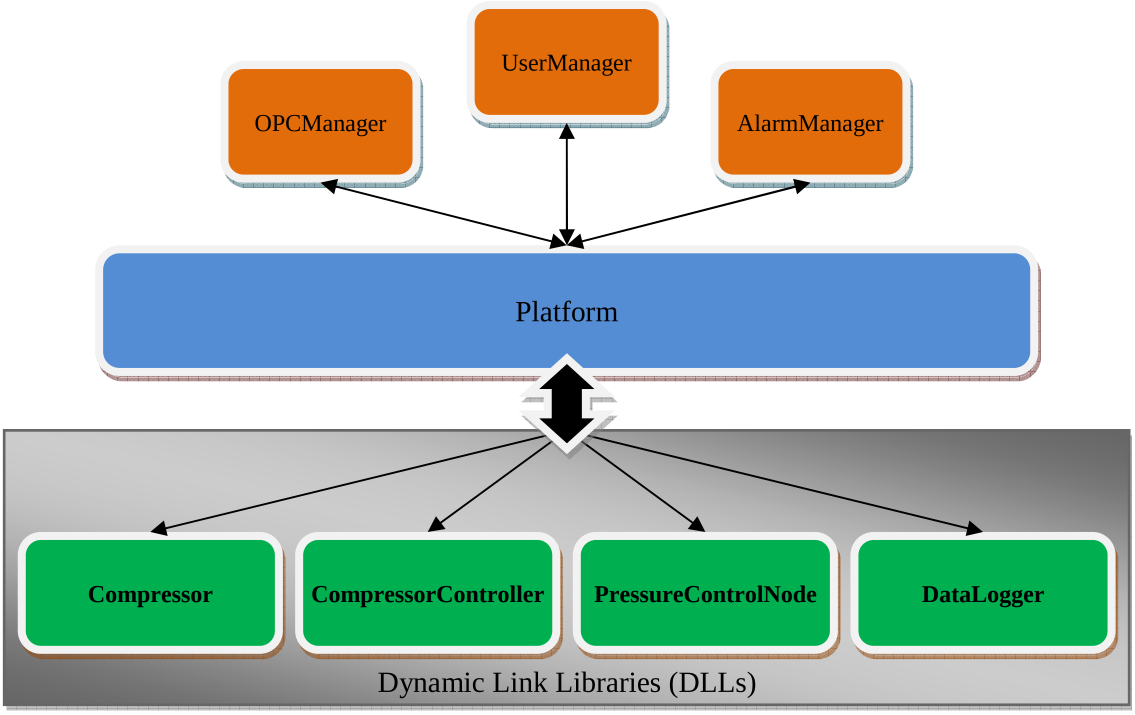


Figure 3-8: Software architecture

The main modules from which the software platform is constructed are: *OPCManager*, *UserManager* and the *AlarmManager*. Instances of the *Compressor*, *CompressorController*, *PressureControlNode* and the *DataLogger* modules are created from DLLs, and are referred to as *software objects*. Multiple software objects can be instantiated for each of these DLLs. For example, multiple compressor objects can be instantiated in order to model a real compressor system, consisting of several operational compressors.

The *OPCManager* establishes an OPC connection to the SCADA system. This object is an OPC client and uses OPC tags for reading data from, and writing data to, the SCADA system. The *Platform* uses the *OPCManager* to facilitate communication from the DLLs to the SCADA system, which in turn communicates control instructions to the PLCs.

The *AlarmManager* has access to data available on the SCADA system via the *OPCManager*. In addition to this data, the *AlarmManager* also has access to the data held by the instantiated DLL objects via the software platform. This data is used to continually evaluate user-defined alarm conditions. Whenever a condition is breached, an alarm is displayed onscreen. The *AlarmManager* allows for additional Short Message Service (SMS), electronic mail (e-mail) and audible alarms.

The *UserManager* is used to create user accounts with different privilege levels. These accounts are password protected and allow privileges for administrators, supervisors, operators and viewers. Table 3-8 shows the functionality available to individual privilege levels.

Table 3-8: Functionality available to the respective privilege levels

Functionality	Privilege level			
	Administrator	**Supervisor**	**Operator**	**Viewer**
View construction area	●	●	●	●
Initiate real-time inputs	●	●	●	
Enabling and disabling automatic control mode	●	●	●	
Change control constraints	●	●		
Edit system layout and components	●			

Pressure set-point schedules for the different production days are held by the *PressureControlNode*. The pressure set-point schedule holds the desired pressure values for each hour of the day. Multiple control nodes can be used to store the pressure set-point schedules for different locations on the compressed-air system, hence the name *PressureControlNode*.

The *CompressorController* receives data from the selected *PressureControlNode* object or objects, which is used to calculate the pressure set-point according to which the *Compressor* objects are controlled. All the control constraints are defined in the *CompressorController*. The energy management algorithm is executed by the *CompressorController* based on the control constraints and real-time inputs from the *Compressor* objects.

All the data held by the *CompressorController*, *PressureControlNode* and the *Compressor* objects are logged in a Comma Separated Value (CSV) file. This data is allocated as shown in Table 3-9.

Table 3-9: Compressor data logging

DLL object	Data description
Compressor	Delivery air pressure
	Air mass flow
	Power consumption
	Control permission
	Inlet valve positions
	Running status
	Loaded status
PressureControlNode	Current pressure set-point
CompressorController	Control enabled
	Control schedule
	Compressor statuses

The time and date is included with each log entry. The data described in Table 3-9 is logged with an interval of two minutes.

3.6.4 Graphical user interface (GUI)

Platform

The *Platform* forms the basis of the EMS software and contains the code that handles the GUI and the interaction between all the other software objects. Figure 3-9 shows the user interface of the *Platform*, with no items added to the interactive construction area.

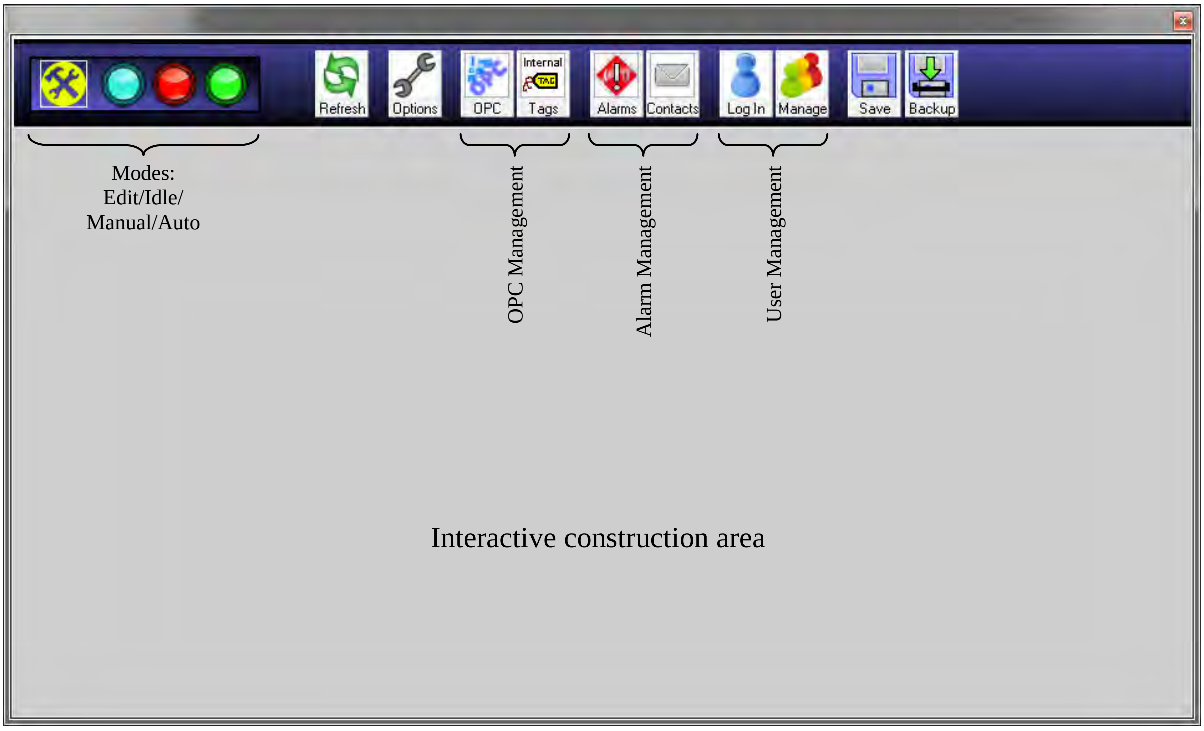


Figure 3-9: Basic software platform GUI

The *Platform* has four modes of operation. The privileges of these modes are described in Table 3-10.

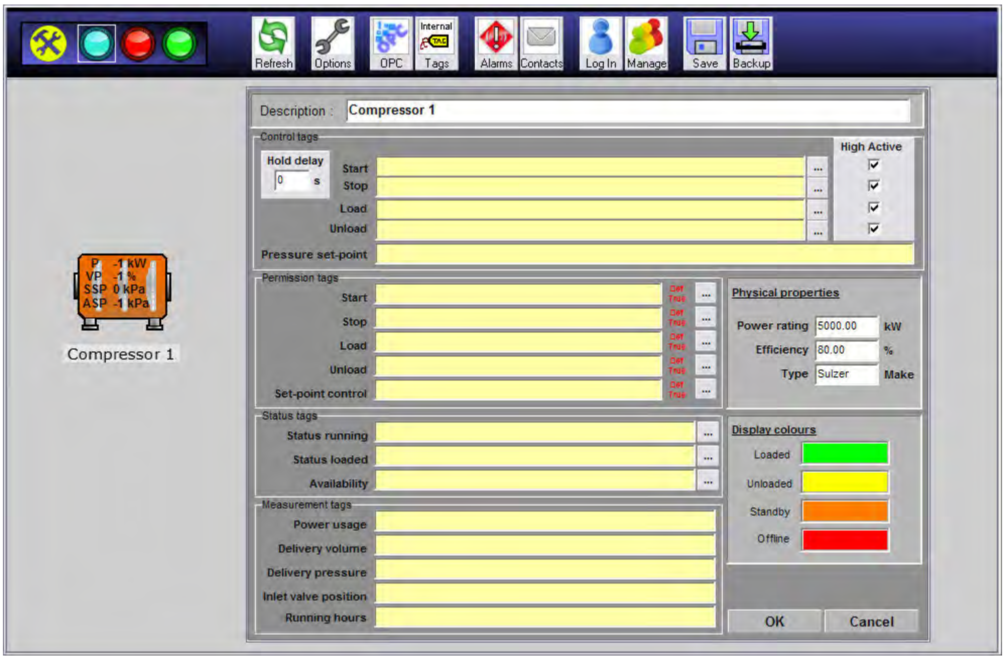
Table 3-10: EMS modes of operation

Functionality	Mode of operation			
	Edit	Idle	Manual	Auto
Edit system layout	●			
View real-time system measurements		●	●	●
Execution of control algorithm			●	●
Implementation of control algorithm outputs				●

The software has an interactive GUI which allows the user to visually construct the schematic of the compressed-air system. When a DLL module is added to the construction area, a new instance of that specific DLL is created, represented by a distinct icon in the construction area. This instance models a compressor, compressor controller, pressure control node or data logger, holding all the parameters of the individual object. All these objects are accessible through the *Platform*. These icons can be readily moved from one position to another.

Compressor

The *Compressor* icon in Figure 3-10 displays the delivery pressure, inlet valve position, scheduled pressure set-point and the actual pressure set-point.



Description : Compressor 1

Hold delay 0 s

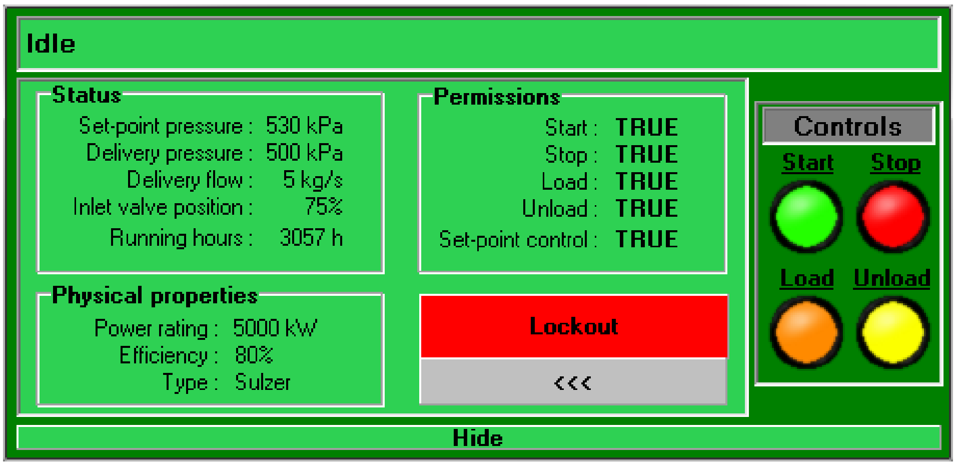
Power rating 5000.00 kW

Efficiency 80.00 %

Type Sulzer Make

Figure 3-10: Compressor Options window

The Compressor Options window is displayed in Figure 3-10. The inputs are either monitoring tags, control tags or both. An additional Compressor Control window is shown in Figure 3-11.



Idle

Status

Set-point pressure : 530 kPa
Delivery pressure : 500 kPa
Delivery flow : 5 kg/s
Inlet valve position : 75%
Running hours : 3057 h

Permissions

Start : TRUE
Stop : TRUE
Load : TRUE
Unload : TRUE
Set-point control : TRUE

Physical properties

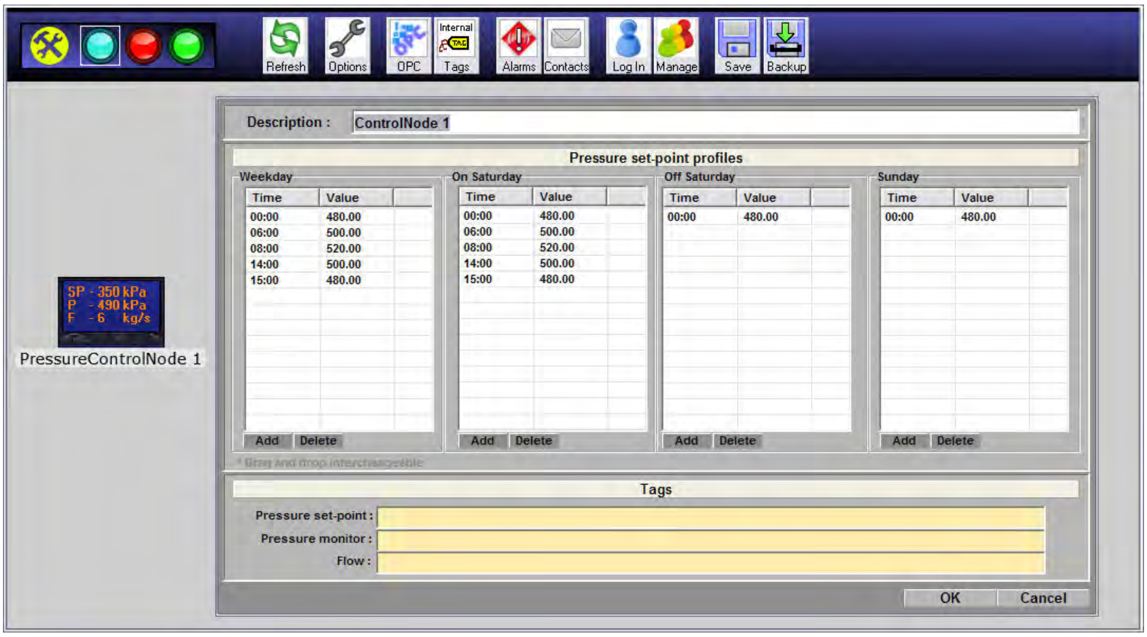
Power rating : 5000 kW
Efficiency : 80%
Type : Sulzer

Figure 3-11: Compressor Control window

This window allows the user to manually start, stop, load or unload a compressor. The specific compressor can also be locked out, to disable all control of the compressor as discussed in Section 3.3.2. Additional data for the specific compressor is displayed in the status panel of the Control window.

PressureControlNode

The *PressureControlNode* icon in Figure 3-12 displays the scheduled pressure set-point, the actual pressure, and the flow at the point in the air network for which the *PressureControlNode* calculates the desired pressure set-point.



Description : ControlNode 1

Pressure set-point profiles

Weekday

Time	Value
00:00	480.00
06:00	500.00
08:00	520.00
14:00	500.00
15:00	480.00

On Saturday

Time	Value
00:00	480.00
06:00	500.00
08:00	520.00
14:00	500.00
15:00	480.00

Off Saturday

Time	Value
00:00	480.00

Sunday

Time	Value
00:00	480.00

* Drag and drop interchangeable

Tags

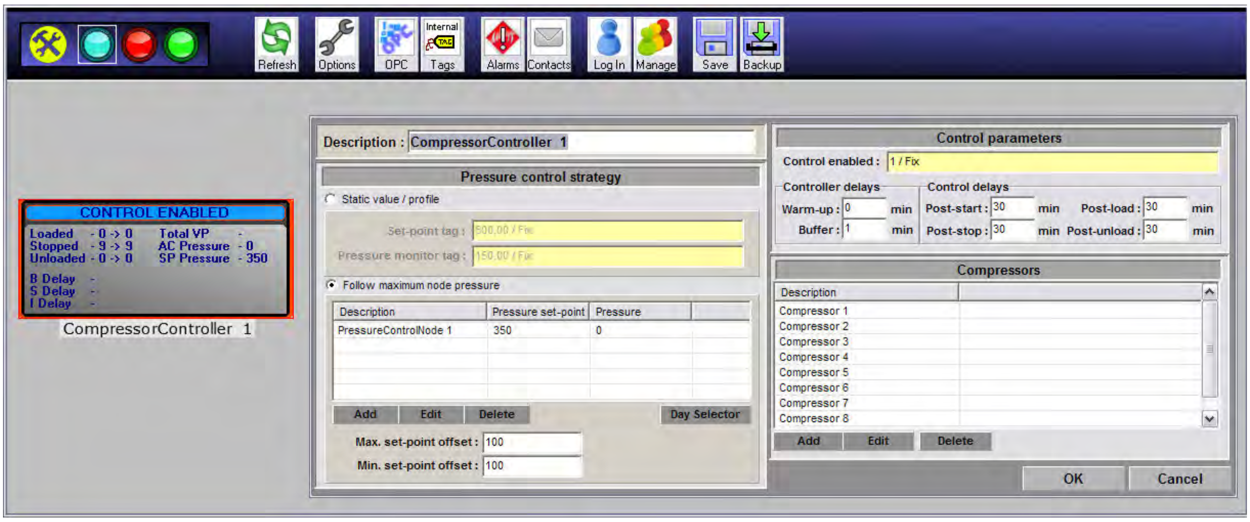
Pressure set-point :
Pressure monitor :
Flow :

Figure 3-12: PressureControlNode Options window

The *PressureControlNode* is not capable of control, and thus does not have an additional control window.

CompressorController

The *CompressorController* icon in Figure 3-13 displays the compressor statuses and the compressor schedules for stopped, unloaded and loaded compressors. Active time delays are also displayed on this icon.



CONTROL ENABLED
Loaded - 0 -> 0 Total VP -
Stopped - 9 -> 9 AC Pressure - 0
Unloaded - 0 -> 0 SP Pressure - 350
B Delay -
S Delay -
I Delay -
CompressorController 1

Description : CompressorController 1

Set-point tag : 500,00 / Fix
Pressure monitor tag : 150,00 / Fix

Description	Pressure set-point	Pressure
PressureControlNode 1	350	0

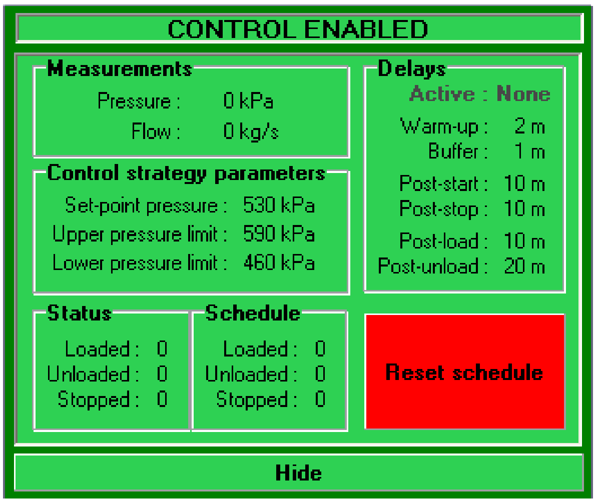
Max. set-point offset : 100
Min. set-point offset : 100

Control enabled : 1 / Fix
Warm-up : 0 min
Buffer : 1 min
Post-start : 30 min
Post-stop : 30 min
Post-load : 30 min
Post-unload : 30 min

Description
Compressor 1
Compressor 2
Compressor 3
Compressor 4
Compressor 5
Compressor 6
Compressor 7
Compressor 8

Figure 3-13: CompressorController Options window

Compressors and *PressureControlNodes* are added to the *CompressorController* via the Options window in Figure 3-13. The *Compressors* can either be controlled according to a fixed pressure set-point or according to the maximum pressure set-point obtained from the *PressureControlNodes*. A pressure set-point control range and control delays are defined using this window. All the mentioned inputs are displayed in the *CompressorController* View window shown in Figure 3-14.



CONTROL ENABLED

Measurements
Pressure : 0 kPa
Flow : 0 kg/s

Control strategy parameters
Set-point pressure : 530 kPa
Upper pressure limit : 590 kPa
Lower pressure limit : 460 kPa

Delays
Active : None
Warm-up : 2 m
Buffer : 1 m
Post-start : 10 m
Post-stop : 10 m
Post-load : 10 m
Post-unload : 20 m

Status
Loaded : 0
Unloaded : 0
Stopped : 0

Schedule
Loaded : 0
Unloaded : 0
Stopped : 0

Figure 3-14: CompressorController View window

This window displays the control constraints and measured compressor system data. The control schedule is also displayed in this window.

DataLogger

The *DataLogger* logs all the *Compressor, PressureControlNode* and *CompressorController* data available through SCADA tags, in addition to the control constraints, instructions and schedules.

3.7 System reliability and sustainability

The mine compressed-air system facilitates production and therefore is a critical energy source. Interruptions in air supply might have negative financial implications and must be avoided at all cost.

The EMS software runs on a server machine. A system crash or hardware failure is therefore a possible threat to reliable compressor control. The SCADA machine is typically a personal computer and poses the same vulnerability to system crashes or hardware failure. This problem is addressed by watchdog counters published by the EMS software as well as the SCADA system. If the counter value fails to change over a predetermined time interval, the connection is compromised and the PLC will divert to safety default pressure set-point values. This precaution is sufficient because most of the mines have operators monitoring the compressor system 24 hours of the day.

The EMS software has a complete log of all occurrences such as operation mode, tasks, events, errors, logged-on users, etc. at the date and time of the occurrence. This log can be used for diagnostic purposes in the event of incorrect compressor control. Predefined alarm conditions can be set up for critical system changes. Notifications are immediately sent, via e-mail or SMS, to notify the responsible parties of a breached alarm condition.

3.8 Summary

An energy management philosophy was developed. Various input and output requirements are identified to ensure that all aspects of the energy management philosophy can be written as a software control algorithm.

The typical application environment is investigated to identify the hardware required to make local and remote compressor control possible. Hardware consists of a SCADA system, PLCs, measuring instrumentation, control equipment and electronic communication devices. Development of the EMS software is documented together with the interaction between the software and hardware.

EMS thus consists of computer software (capable of remote compressor control) and the hardware which makes this control possible. Incorporating the control algorithm in the software development enables the software to produce the required outputs to make compressor energy management possible.