PLANT SYSTEMS INTEGRATION USING THE SAMI MODEL TO ACHIEVE ASSET EFFECTIVENESS IN MODERN PLANTS

by

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DECLARATION

This thesis is the result of my own independent work, except where otherwise stated. Other sources are acknowledged by giving explicit references. A bibliography is appended.

Signed ...Gaubert...

Date 1 October 2008

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DEDICATION

This work is dedicated to my wife Liana. Her belief in my abilities is constant and has helped me to persevere when doubts arose. Her love, encouragement, and support are the key success factors in my life.

To my two daughters, Mignon and Amóre, who in so many ways inspired and motivated me, even when they didn't realize it. With such a loving family believing in me, how could I fail to accomplish my dream?

ABSTRACT

In recent years, industrial plant maintenance has changed dramatically. These changes are due to a considerable increase in the number and variety of physical plant assets, increased design complexity, new maintenance techniques and changing perspectives regarding on how to perform maintenance effectively. Managers at modern process plants are becoming increasingly aware of the extent to which equipment failure affects safety and the environment.

Process plant personnel are limited in their ability to accurately and consistently evaluate the health of plant assets. Due to poor record keeping, maintenance staff often has little defence against aging equipment and asset failures. As a result companies have undertaken to implement planned equipment maintenance schedules and install new technology to allow for efficient tracking and analysing of equipment health across the board.

The introduction of an integrated asset management solution is presented in this thesis. The integrated asset management solution will assist maintenance staff to cost-effectively predict the probability of asset failure prior to the occurrence of any actual plant incidents. The integrated solution documented in this thesis will be implemented at the Sasol Solvents site to enhance plant availability, maximum up time for all plant assets and plant safety.

Strategic Asset Management Inc. (SAMI) uses the Operational Reliability Maturity Continuum model to improve profitability, efficiency and equipment reliability. The SAMI empirical model employs various stages to address improved performance and asset management and was used as a guideline to develop an integrated solution to optimise plant performance and profits.

The integrated asset management solution, documented in this thesis, was developed with the intended function of bringing information from diverse plant based systems and field

equipment to the maintenance personnel in an understandable interface so that the information can be used to improve the reliability and availability of all plant assets.

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GLOSSARY OF TERMS AND SYMBOLS

ACE	Application Control Environment
AM	AssetManager
AMS	Asset Management System (Emerson)
APC	Advance Process Control
DCS	Distributed Control System
DD	Device Descriptor Files
ESD	Emergency Shutdown System
EBI	Enterprise Buildings Integrator
FDM	Field Device Manager
FF	Foundation Field Bus
FSC	Fail Safe Control (Honeywell)
HCF	HART Communication Foundation
HART	Highway Addressable Remote Transducer
OLE	Object Link Embedded
OPC	OLE for Process Control
PHD	Plant Historian Database
PID	Proportional, integral and derivative control
RCM	Reliability Centered Maintenance
RDI	Real-time Data Interface
RCFA	Root Cause Failure Analysis
RMPCT	Robust Multivariable Predictive Control Technology
RTDC	Real Time Data Collector
SAMI	Strategic Asset Management Inc.
SIL	Safety Integrity Level
SCADA	Supervisory Control and Data Acquisition

CHAPTER 1 INTRODUCTION AND PURPOSE OF THE STUDY

1.1 Introduction

In recent years, industrial plant maintenance has changed dramatically and these changes are due to a great increase in the number, variety and complexity of physical assets which must be maintained. Plant maintenance has been influenced significantly by innovations in plant instrumentation, computer and mechanical equipment as well as complex designs, new maintenance techniques and changing views on how to effectively conduct plant maintenance (Moubray 2003:1-2).

The process of plant maintenance has changed as a result of these changing expectations. This may be ascribed to a rapidly increasing awareness of the extent to which equipment failure affects safety and the environment. This increased awareness is also influenced by the relationship between maintenance, product quality and environmental issues. Industry is additionally under pressure to achieve higher plant availability and to maintain constant operating costs (Moubray 2003:2-3).

Process plant employees are limited in their ability to accurately and consistently monitor the health condition of various types of plant assets. Maintenance staff in large industrial plants is constrained by multiple databases and weak record keeping, and subsequently have little defence against aging equipment and asset failures (Honeywell 2003). Plant staff may devote up to 50 percent of their time reacting to asset failure issues (ARC White Paper 2003); sometimes very serious. Companies are beginning to implement planned equipment maintenance schedules; meaning installing new technology to allow for efficient tracking and analysing of equipment health across the board. The introduction of integrated asset monitoring solutions can enable maintenance staff to cost-effectively predict the potential of asset failure prior to occurrence of any actual plant incidents (ARC White Paper 2003:2).

A question that frequently arises in the operation of a plant include: Is the right **amount** of maintenance being conducted or is the right **type** of maintenance being conducted. These questions can be difficult to answer. Numerous preventative maintenance programs have been developed in recent the years (SAMI 2002) for a variety of reasons. At present there is not a single program in existence that is capable of taking care of all plant assets on its own. Stand alone systems that are currently available make it very difficult to be used in these maintenance programs (Joubert 2005) because they need dedicated attention and additional resources to operate and maintain.

The question therefore arises with regard to what aspects make it so difficult to conduct proper preventative or predictive maintenance on various plant assets?

Elements of preventative maintenance are well known (Mobley 1990). Certain tasks must be performed at a certain frequency and need to be scheduled and performed by qualified artisans or operators. Problems typically arise when an attempt is made to implement some sort of prevention in a reactive environment. A reactive environment often requires that unanticipated work must be performed and effective planning is required so that spare parts and equipment are readily available. One of the main concerns is the identification of the correct tasks and the appropriate frequencies at which these tasks must be performed.

Reliability Centred Maintenance (RCM) is often the tool of choice for plants sufficiently advanced to understand that preventative tasks must be aimed at correcting specific defects or failure causes (Moubray 2003:1-2). Insufficient resources unfortunately often result in the failure to correct specific defects and failures. In addition, the use of RCM techniques on every item of equipment is extremely time consuming.

This thesis documents an interpretative study undertaken to gain insight into the potential implementation of integrating different plant control and asset management systems into a single system. This would enable plant managers to effectively determine problems with regard to plant assets and subsequently establish a maintenance strategy that can maximise plant uptime.

This chapter provides an introduction to the concept of plant maintenance and presents an overview of the research that was conducted. The problem statements are presented in this chapter, the limitations of the study are discussed and the boundaries of the research are defined. The value of the research in terms of its contribution to industry is motivated. An overview of the chapters that follow is also presented in this chapter.

1.2 Objective of the study

1.2.1 Background

Prominent companies such as Sasol, Shell, Trans Alta, Union Camp, Mobil Oil Corporation, British Petroleum, Columbian Chemicals, Iron Ore Company of Canada and Montel have selected the Strategic Asset Management Inc (hereafter referred to as the SAMI model), for predictive plant maintenance. The SAMI model aims to improve production equipment health, employ the creativity of plant personnel in order to produce an improved skilled workforce, higher equipment utilization, lower maintenance costs and improved profits (SAMI 2002).

The Strategic Asset Management Inc. (SAMI) Company uses the Operational Reliability Maturity Continuum model (Figure 1) to assist the improvement of profitability, efficiency and equipment reliability for industrial organizations. The widespread use of the SAMI model by leading companies, as mentioned above, may be ascribed to the improved reliability that results from application of the SAMI model. Reliability may be used as a measure of a system's performance. If a system performs at 100 percent reliability, then the system functions at optimal levels that produce maximum outputs.

Should a system perform at any level lower than maximum reliability, the system may be considered to be inefficient and perform under optimal capacity.

The objective of plant maintenance is to assure the likelihood (probability) that equipment is capable to perform a certain function when required (SAMI 2002). Reactive maintenance can only minimise or reduce the impact of an equipment failure.

A reduction in the frequency of a failure mode leads to an increase in the probability of performing the intended task or function. Although all of the properties of components may be understood, there will remain uncertainty with regard to the timing of a given failure mode. The goal of plant maintenance is therefore to manage the probability of the performance of the intended function of the equipment (SAMI 2002).

As the assured availability of a plant approaches 100 percent, cost for maintenance escalates exponentially. The following question therefore arises:
"What is the appropriate type and amount of maintenance necessary to assure a specific level of performance for a specific asset?"

1.2.2 The SAMI model

The SAMI empirical model describes five different stages of mastery that form the foundation of improved performance and asset management (SAMI 2002). Once a proper maintenance process has been implemented, the plant's performance is likely to improve over time as proactive maintenance approaches are adopted in a staged and measured environment. The above-mentioned stages are represented in the SAMI Asset Healthcare Triangle as shown in Figure 1 below.

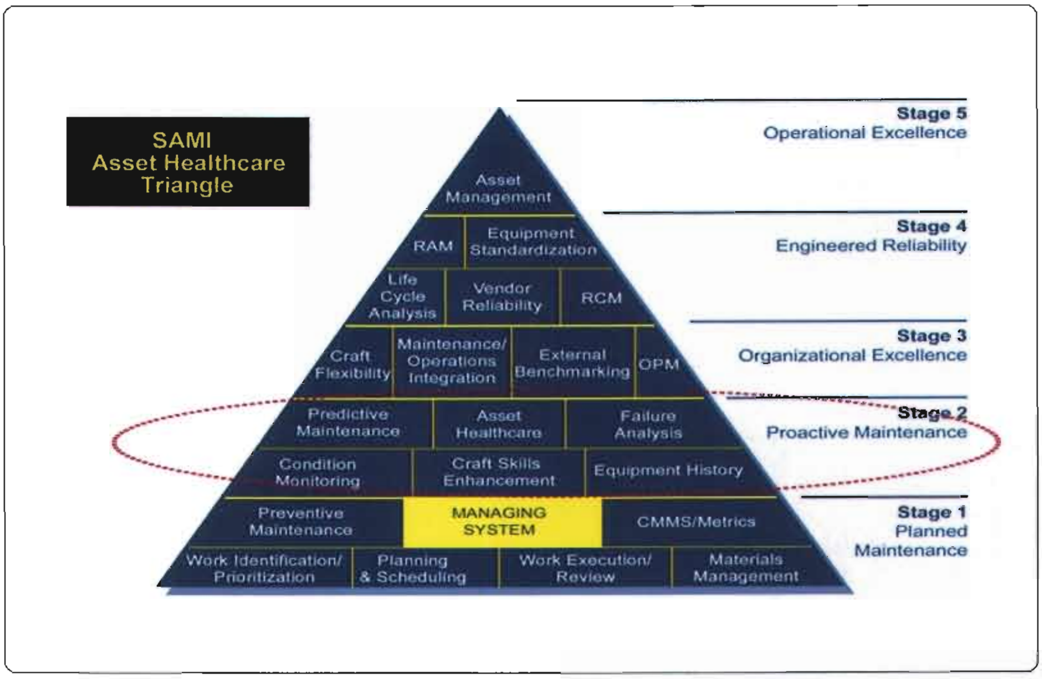

Figure 1: Operational reliability maturity continuum model

The stages of the SAMI model are summarised below:

Stage 1: Planned Maintenance. Focus is on planning and scheduling, work identification and prioritization, work execution, and moving towards preventative maintenance. This is managed by a management system such as SAP. This level represents reactive and preventative maintenance (SAMI 2002).

Stage 2: Proactive Maintenance. The proactive maintenance stage builds on the success of stage 1 (planned maintenance). RCM techniques are used to redesign the preventative and predictive maintenance systems to begin the reduction of failure events. Failure analysis and equipment history are used to eliminate failure modes (SAMI 2002).

Stage 3: Organizational Excellence. The organisational excellence stage explores resources outside maintenance and engineering to improve reliability. The focus is on human resources (operators and maintenance staff) who are involved in the maintenance process (SAMI 2002).

Stage 4: Engineered Reliability. The focus of the engineered reliability phase is on proactive elimination of failure modes and maintenance prevention. The impact of equipment failures is minimized and resources are used to identify equipment problems and to maintain proper health conditions of equipment (SAMI 2002).

Stage 5: Operational Excellence. The fifth stage of the SAMI Model is highly dependent on the reliability of equipment. A holistic approach is followed for asset management which integrates the cycle of annual business planning with equipment conditions in order to meet business requirements. The critical nature of equipment for all systems is evaluated, the correct current condition of equipment is monitored, and a zero-based maintenance strategy is developed for each component in the plant (SAMI 2002).

The second stage of the SAMI model, namely proactive maintenance will be considered in this study, in particular the development and implementation of an integrated solution to link all the blocks in the stage. Each of blocks can be viewed as problem areas that must be solved to allow for proper proactive maintenance. The blocks are briefly discussed below to clarify understanding of the asset healthcare model and the particular problems that are associated with pro-active maintenance (SAMI 2002).

- **Failure Analysis** – Data obtained from the symptoms of equipment failure must be used to establish and pre-empt the causes of failures. Analysis of the failure is must be undertaken be means of Root Cause Analysis (RCA) and Failure Modes and Effects Analysis (FMEA). Failure analysis may be considered from a hypothetical perspective by means of historical data regarding failure modes. In Stage 2, established failure modes are considered. A modified Failure Modes and Effects Analysis must be followed.
- A modified FMEA analysis allows maintenance staff to determine trends in terms of groups of related failures on equipment and consider multiple causes (Blaney 2006).

- **Asset Healthcare** – The asset effectiveness solution must provide for assets to maintain good health from a holistic perspective. Maintenance personnel can effectively target and manage plant assets that have the greatest impact on business success. The system must help personnel to become effective and efficient, optimizing operation and reducing costs (Honeywell 2004:1).

- **Equipment History** - The data pertaining to the previous performance of equipment and failure history must be obtained in order to guide the analysis and support proactive maintenance. In a SAP environment, the asset database must include failure catalogue information and work order histories including causes and functional locations. Data regarding the assets obtained from the database will allow cost and causal information to be pinpointed to related symptoms.

- **Failure Analysis** - The equipment that performs the worst is usually associated with varied factors regarding material, design, training, documentation, process, and material problems that add up to a unstable plant environment that is unable to cope with equipment faults (Blaney 2006). The information leading to a failure must be recorded so that the re-occurrence of symptoms preceding failure can be identified and acted upon in order to prevent equipment failure. The solution that is proposed in this thesis allows plant personnel to identify and act upon data obtained from field devices in order to maximise plant production and minimise loss through failure.

- **Skills Enhancement** – Training of maintenance personnel to understand the data obtained from field devices remains essential. Due to the open architecture of the solution, implementation of an integrated software interface must be accompanied by appropriate training so that maintenance personnel can competently interpret and react to data obtained from advanced field equipment. Modern plants contain diverse assets, from a wide variety of manufacturers that use industry standard communication protocols such as the Foundation Field bus, HART, Profibus and OLE for process control (OPC) (Honeywell 2004:1).

As the Asset Strategies get more sophisticated, maintenance personnel need to obtain additional training to make use of technological advances and diverse software platforms. Human resources that are equipped to cope with effective pro-active plant maintenance are required (Joubert 2005). Lack of training and experience in maintenance personnel can result in plant failures that could have been avoided.

The effect of poor training is evident in the case of the Secunda Refining Plant. Despite a month of clear vibration analysis output that predicted impending bearing failure, the production and maintenance leaders failed to read the data correctly and the subsequent plant failure and fire resulted in considerable losses. According to Blaney (2006), despite a sound asset management strategy, personnel at the specific plant did not know how to read and use the data obtained from the field devices and therefore did not react to information that predicted the failure. Employees were unable to read and understand the vibration reports on a pump; subsequently the equipment caught fire resulting in tremendous loss. Blaney (2006) ascribes the losses due to human error as a result of insufficient training.

- **Predictive Maintenance** - Maintenance plans and tools that use data other than measured time or running time to predict the condition of equipment and drive a maintenance schedule for it. Predictive tasks entail checking whether equipment is about to fail or has started failing. Predicting when failure is likely to occur is the aspect of maintenance that is considered to be proactive (Moubry 2003:7).

1.3 Problem statement

The problem statement is contained in the following question:

How can the various **blocks** in the second stage of the SAMI model be effectively used to develop an integrated solution to interface with diverse system platforms so that a proactive maintenance strategy in context of the Sasol Solvents environment is achieved?

1.4 Aim of the study

The aim of this study is to develop software interfaces connected to the different systems such as a plant distribution control systems (DCS), emergency shutdown systems (ESD), a loop management system, hardware management system, network management system and asset management systems and integrating them into a single system solution where all the plant assets status information can be monitored and viewed. The solution with its various plant control and asset management systems has not been developed or implemented previously referencing to the SAMI model.

The developed integration solution will enable maintenance managers to manage plant assets within proactive maintenance strategies to ensure maximum plant uptime and availability. The needs are defined for every block in the second stage of the SAMI model.

The objective of this research project was to develop a failure analysis model based on the newly developed symptoms and fault model that can be used for all plant assets. The model will be used to configure the symptoms and faults of all plant assets using the developed software interface. The single software interface makes use of configuration tools so that diverse interfaces can communicate to a central software interface called the **AlertManager** within the Honeywell based **AssetMax** software application.

- One of the specific goals of this research was to develop software interfaces to communicate with different plant control systems and field devices and to retrieve diagnostic information from these systems so that the status and availability of all plant assets can be monitored. In order to achieve the above-mentioned research objective, this thesis documents the development and configuration of an integrated solution capable of storing and retrieving information pertaining to diverse plant assets and using history information about failures in Root Cause Failure Analysis (RCFA) processes.

- To develop and configure an interface to access maintenance procedures, user manuals, data sheets and relevant process information to enhance the technical skills of the maintenance and process personnel.

- To use the results from the developed interfaces in maintenance strategies to ensure maximum asset availability and plant uptime.

1.5 Research methodology

1.5.1 Literature study

A comprehensive literature study was conducted with specific focus on asset management systems at various plants, nationally and abroad, the different vendors supplying these systems and the way they use these systems in proactive maintenance strategies. The study was conducted by consulting the internet, journals and internal documentation from several hardware and software suppliers.

1.5.2 Action research

Action research methodologies were used to facilitate the process of design and implementation of the different interfaces. This thesis documents the testing of these interfaces. The diagnostic information reports are interpreted and feedback is provided in order to change problem areas within the different interfaces.

1.5.3 Interface development

- Failure analysis model for all plant assets using the symptoms and fault model and the configuration of the models.
- Retrieval of diagnostic information from plant control systems and field devices to monitor their status and availability.
- To develop and configure an interface Management Information System to retrieve history from the different configured plant assets and using the data in Root Cause Failure Analysis (RCFA) processes and to determine the effectiveness of the maintenance strategies being used.
- To develop and configure an interface to have access to maintenance procedures, user manuals, data sheets and relevant process information to enhance the technical skills of the maintenance personnel.
- To use the results from the mentioned interfaces and use them in different type of maintenance strategies to ensure maximum asset availability and plant uptime.

1.5.4 Global developed integrated solution

The global developed integrated solution will be discussed in the thesis. This will include the described interfaces interfaced into one solution (AlertManager) where all the plant assets status information will be monitored and viewed. Sources used for the research include books referring to reliability centered maintenance, asset management and control systems. Articles looked at smart field equipment, asset management strategies and asset management solutions implemented. Research and conference papers were used for reference to smart field equipment used in asset management systems and the internet to look at the action research methodologies and field equipment being used in modern plants.

1.6 Contribution of the study

1.6.1 Integrated plant systems solution

This thesis presents an integrated plant systems solution and the research, development and implementation of the suggested integration between the different plant-based systems. The integrated system bridges the knowledge gap between plant operations and maintenance staff. The block diagram depicts how information can be relayed from plant systems to the maintenance personnel. The maintenance staff can utilize the information to improve the reliability and availability of plant assets (Honeywell, 2004).

The integration of the different plant systems that are used in the specific Sasol production plants is shown in Figure 2. The AlertManager interface (presented in the main red block) that is part of the Asset Manager Software (Honeywell 2004) will be used as the main asset management interface to view the information from the different interfaced systems to assist in the maintenance process as discussed in the SAMI model.

The reason for using the specific asset management software from Honeywell was a decision made by Sasol Technology management.

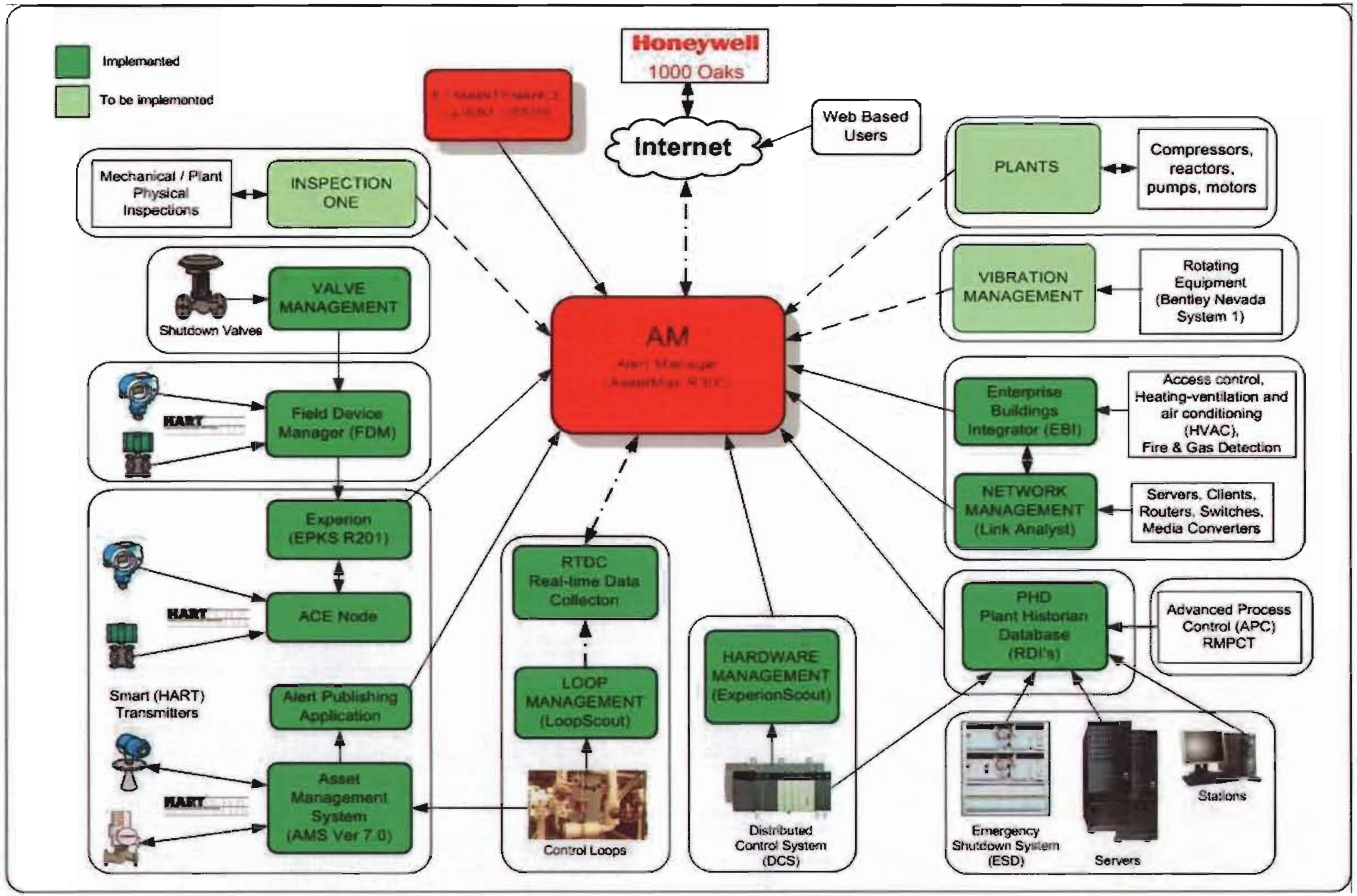

Figure 2: Block diagram of the different integrated plant systems

The HART-based intelligent field device monitoring systems (Joubert 2005) such as Emerson's AMS 6.2 (Emerson 2005a) and Field Device Manager (FDM) applications (on the left of the diagram) will be interfaced to the AlertManager (Honeywell 2006a). The control loop management system used to optimize loop performance, the distributed control system (DCS) and DCS hardware, the Fail Safe Control (FSC) system that is used as the Emergency Shutdown System (ESD) and ESD hardware will all be interfaced to the AlertManager (Joubert 2006).

The network management system (on the right of the diagram) which monitors the network and network components will be interfaced to the main AlertManager interface. The Enterprise Buildings Integrator (EBI) system that monitors the plant emergency evacuation system (PEAP) and components will also be interfaced to the main AlertManager interface. The Uniformance Plant Historian Database (PHD) will allow the different software interfaces to link to the AlertManager, all contributing to getting the data from the hardware devices that don't have normal software interfacing capabilities (Joubert 2005).

1.6.2 Contributions of this research project

- A total integrated solution is developed and implemented to assist maintenance personnel to move from a reactive (run-to-failure) maintenance strategy to a proactive maintenance strategy.
- Integration techniques used in this context may assist other companies by means of the introduction of new technology in their current plant asset management systems.
- The new system will save costs by preventing plant failure using the asset optimization solution.
- Improved valve management can be conducted by using valve signatures in a predictive maintenance strategy.
- The asset effective solution (implemented at the Sasol Chemical plant in Sasolburg) was submitted to the HART Communication Foundation and was

awarded the 2005 HART Plant of the Year award. Fifty five companies participated in the international competition (Hogan 2005).

- Two international and three national papers were generated as a direct result (consequence) of the work.
- The publishing of three articles in an accredited journal (submitted) also resulted from the work.
- The publishing of more articles in international journals.

1.7 Limitations

The vibration management system, namely the Bentley Nevada System 1, the mechanical plant inspections system "Inspection One" which is used for mechanical centric-based assets as well as the process monitoring system referred to as "plants" in figure 2 are planned for future integration and are not addressed in this research.

1.8 Term clarification

Active Asset	An asset is considered to be in an "Active" state when either a symptom or fault is present (i.e., the state is anything other than "Normal")
Asset	Any subject entry into the Alert Manager. (i.e., Compressor, Pump, Control Valve, etc.)
Asset Folders	Information folders within the Asset Folder module used to gather data from specific plant assets, which the user needs for problem analysis and action
CMMS	Computerized Maintenance Management System
Evaluation Activity	An activity used to obtain the current status of a symptom that is important to the isolation of a possible fault
Fault	The malfunctioning of an asset. A fault may be associated with one or more symptoms

Fault Close Out	A fault is closed out when the operator determines that the fault has been repaired
Fault Elimination	When a fault is eliminated, it is no longer a candidate fault. This can be determined automatically by the absence of a required symptom or by operator knowledge
Normal Asset	An asset that is functioning properly (i.e., no symptoms or faults present)
Notification Activity	An activity (such as paging or email) that notifies personnel when a given symptom or fault is present, or absent
PID	Proportional, integral and derivative control
SCADA	SCADA refers to a system that collects data from various sensors at a factory, plant or in other remote locations and then sends this data to a central computer which then manages and controls the data
SIL	Safety integrity level refers to the impact it has on process equipment, human life and environmental hazards
SOAP	Simple Object Access Protocol
Symptom	Observable characteristics of an asset that may result in the malfunctioning (fault) of that asset. Relationships may be created within the Diagnostic Builder to trigger the recognition of faults
Symptom Details Activity	An activity that provides additional information about a given symptom
XML	Extensible Markup Language

1.9 Chapter layout

The research and conclusions of this study are discussed and summarised in the following chapters:

Chapter 1: Introduction and purpose of the study
Chapter 2: Literature Study
Chapter 3: Research Methodology and Design
Chapter 4: Failure Analysis
Chapter 5: Asset Healthcare
Chapter 6: Equipment History
Chapter 7: Skills Enhancement
Chapter 8: Predictive Maintenance
Chapter 9: Conclusions and recommendations

CHAPTER 2 LITERATURE STUDY

2.1 Introduction

This chapter presents the literature study pertaining to the different systems that are currently used at the three chemical plants in the Sasol Solvents environment. The functionality and the typical software interfaces that are available in these systems intended to facilitate the "open platform" device integration technology will be discussed in the literature review.

The network diagram shown in figure 3 provides a graphic representation of the integrated solution to be discussed. Every network level is discussed and the method used to handle information by the different control systems and other systems on the network. The network design was redesigned to facilitate the incorporation of "open platform technology" from various equipment and control systems suppliers (Raghavendra 2007:1).

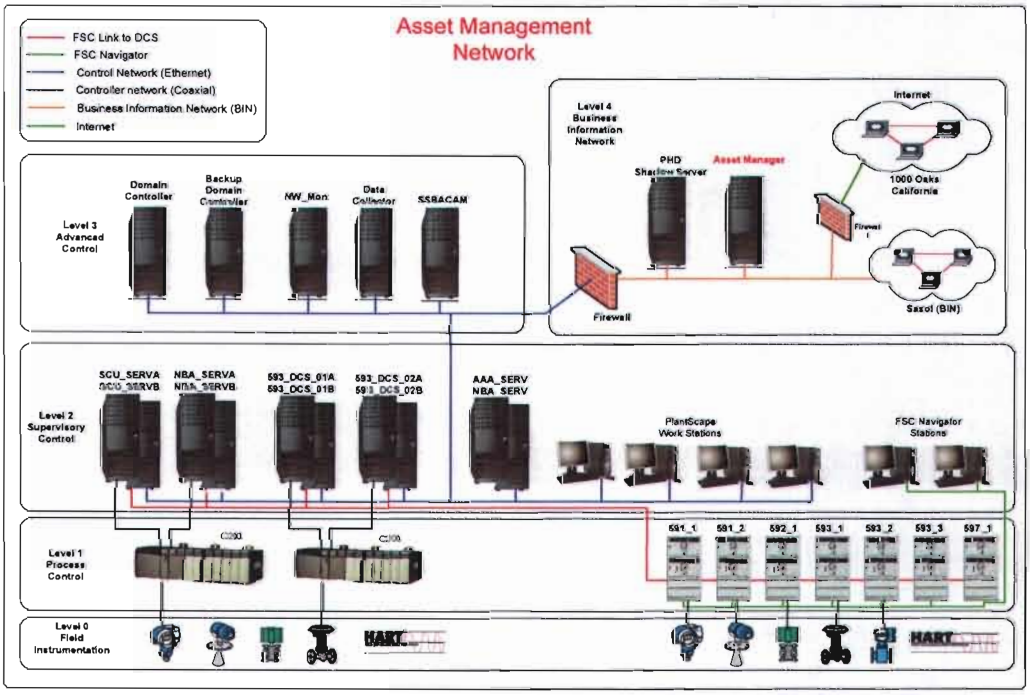

Figure 3: Asset management network layout

Figure 3, provides a detailed overview of the Asset Management Network used for the integrated solution to optimise plant performance.

2.2 Level 0 – Field Instrumentation

The field instrumentation level addresses the actual field equipment on the plant. The different instrumentation is connected by means of wiring to junction boxes where the cabling is terminated and connected back to the field terminal assemblies and interface cards situated in equipment rack in the different equipment rooms.

2.2.1 HART-enabled field devices

Level 0 depicts the field devices that are connected to the process controllers (C200) in level 1. These field devices include 4-20mA devices that are generally used to measure a particular variable on plant equipment. The variables that are measured include flow readings, pressure levels, equipment temperatures and gas flow or emissions. The smart positioner, also known as actuators form part of another type of field devices that are used to control the valves that open and close as required by the process.

According to Pratt (2004:2) a Smart Field Device is a microprocessor-based process transmitter or actuator that supports two-way communications with a host, digitizes the transducer signals, and digitally corrects its process variable values to improve system performance. Pratt (2004:2) continues to state that many field devices contain sophisticated signal processing algorithms to perform the measurements or control action required. The value of a smart field device is perceived by Pratt to be a product of the quality of the data provided by the field device.

HART-enabled field devices are one of the new technologies being implemented on plants that use the 4-20mA signal and digital communication signal simultaneously on the same wires. Typical benefits using these smart type of device includes the following:

- digital process variables with standardised engineering unit codes and status;
- device status from field device in order to allow continuous monitoring of system integrity; and
- extensive calibration support and detailed diagnostic information.

Many manufacturers supply HART-enabled devices with Device Descriptor files (DD) that allow access to advanced diagnostic information pertaining to these devices. All HART-enabled devices are certified and managed by the HART Communication Foundation (HCF) (Helson 2005:1).

2.3 Level 1 – Process Control

The process control level depicted as level 1, is the level where the actual control takes place. The equipment in this layer is controllers or CPU's, I/O cards, special I/O cards, isolators, field terminal assemblies (FTA), multiplexer's networks used for HART devices (see 2.7.1).

2.3.1 C200 Controllers

The C200 Controllers are connected to field devices by means of Input and Output (I/O) cards. A HART-enabled field device such as a pressure transmitter is connected as an input to an analog input card; a control valve is then connected to an analog output card as an output. The input and output control is maintained by the controller according to control philosophies and certain algorithms. In addition other types of I/O cards such as digital input and output cards, Foundation Field bus cards, Profibus DP cards, serial interface cards, HART cards and special temperature cards are used with the controllers (Honeywell 2002).

In the Honeywell's PlantScape control system the C200 controller is used with the Chassis Series I/O cards meaning they are all on the same back plane with a common power supply. Information from the C200 controller is fed back to the PlantScape servers via the control-bus network. This network consists of an interface card (PCIC) located in the server that connects directly to the C200 controllers with coax cable and special network software (Honeywell 2004).

2.3.2 Fail Safe Control Systems (FSC)

Honeywell's FSC (fail safe control) systems are other types of controllers at level 1 that form part of the emergency shutdown system (ESD). This system is responsible for shutting down a plant in a predetermined manner to ensure that an abnormal situation does not develop (Honeywell 2004).

The various different field devices are also connected to the central parts (CPU's) via specialised I/O cards that are usually IS (intrinsically safe). An IS certified I/O card guarantees that the field device will not cause a spark in an explosive environment. The FSC is a redundant system with double central parts, double I/O Cards and power supplies.

The FSC is managed from a PC running FSC Navigator software that allows users to view the status of the system and the logics that are responsible for controlling the critical loops on the plant and is indicated by the green line in figure 3 (Honeywell 2005). Four plants in the Sasol Solvents site make use of seven FSC redundant systems namely 591_1, 591_2, 592_1, 593_1, 593_2, 593_3 and 597_1.

The FSC systems are all interfaced to the Distributed Control System (DCS) using serial communications or Modbus (serial bus) to enable the different type of serial signal transfer between the systems as part of the shutdown systems (depicted by the red line in figure 3).

2.4 Level 2 – Supervisory Control

The supervisory control level is the second level and represents a higher level of control on a plant. At level 2 the different software on the diverse software platforms interfaces with one another. The supervisory control level provides an interface for the diverse software of various devices on plant equipment to relate to one another. The software interface at this level manages data from the controllers and field devices and produces viewable data for operators and technical personnel to interpret and act upon (Honeywell 2004).

2.4.1 Distributed Control System (DCS)

The distributed control system (DCS) that is used on the Solvents site is manufactured by Honeywell and is called the PlantScape R500.1 (Honeywell 2003). The DCS consists of a redundancy server pair that runs the PlantScape software.
The PlantScape software system consists of various applications that are used to configure and setup the control philosophies, alarm and loop management within the DCS. The Control Builder application is used to build the control logics, configure and monitor every control loop on the plant.

The control philosophy is usually built into the PlantScape control logics that control the plant. The QuickBuilder application addresses the SCADA points and provides an interface to third party hardware and software such as the FSC or any other vendor system or equipment (Honeywell 2006a).

The HMI Web Builder application is the interface that builds the operator graphics in the DCS. Information from the QuickBuilder and Control Builder are linked via software interfaces to various tags on the operator's display to produce a live representation of all plant operations and can indicate the status of a specific item of equipment or process (Honeywell 2006a).

Alarm management is embedded into the PlantScape software so that alerts and alarms can be defined, configured and prioritised for certain plant areas so that alarms can be triggered when a certain event (or probable event) occurs. The alarm management system can be interfaced to specialised alarm management software that is not discussed in this thesis. Technicians also make use of loop management that enables users to manage control loops by tuning or adjusting their parameters for optimized control.

Trends are a DCS system tool that monitors a device tag such as 593_TI_1001 which is a temperature indication monitored over a certain period of time. The trend identified by the tool is represented as a graph of the equipment item's performance over time. The output of the configured trend is very useful for personnel to monitor a process condition, a possible indication of a process upset or trip condition (Honeywell 2006b).

Different interfaces such as the OPC Alarm and Event interface are embedded into the DCS software (Honeywell 2006a). This interface is used by different OPC clients that access the DCS database for data such as tag information and t relevant data associated with the specific tag for a certain period of time. This interface is typically used by the Uniformance Plant Historian Database interface that retrieves the onboard history data from the PlantScape servers to build a database of event history and performance.

System diagnostics that indicate the condition of the PlantScape server software and interfaces are also embedded in the software. Only the main features of the DCS are discussed. There are many more features that are not relevant to this discussion. Four pairs of PlantScape servers are used to control the plants on the Sasol Solvents site (Honeywell 2004).

2.4.2 Uniformance Plant Historian Database

Honeywell's Uniformance Process Historian Database (PHD) is a data historian that is designed to collect and store data for future retrieval (Honeywell 2005). Data is collected by means of real-time data interfaces (RDI) and stored in virtual tags.

Figure 4 depicts the Plant Historian Database (PHD) and indicates the links to the data buffers that collect data from the various different DCS systems. The dual data buffers are connected to two sets of DCS servers, retrieving data from the DCS onboard historian database, thereby providing redundancy. Data from the onboard historian database is saved on the buffers and thereafter forwarded to the PHD shadow server (Honeywell 2006a). .

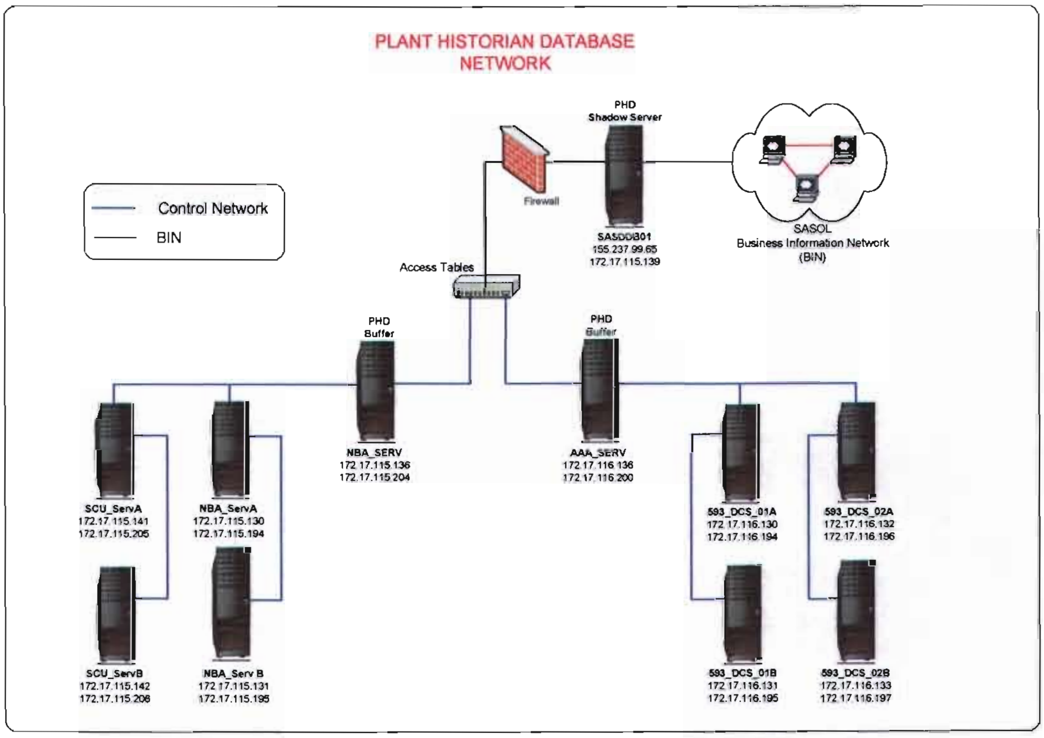

Figure 4: Plant Historian Database Network layout

The Uniformance database software runs on the shadow server where PHD clients can access the required history data. If the link between the buffers and the shadow server breaks, the buffers will continue to collect data. Once the link is restored, the store and forward feature will immediately transfer data that is new to the shadow server.

Figure 4 above depicts the Plant Historian Database Layout. In order to be able to retrieve the historic data from the DCS, different interfaces must run on the PHD shadow server. These interfaces are called real-time data interfaces (RDI) that are configured to retrieve certain tag data (history) from the DCS in a predefined manner and format. These RDI's can also be configured to retrieve data from other data sources such as third party vendors and suppliers of software.

Performance monitoring RDI's are developed as an integral part of the asset management solution presented in this thesis. Real-time data interfaces (RDI's) allow diverse interfaces to access data from Microsoft Windows operating systems and other data sources used in the asset management software. Performance monitoring is discussed in Chapter 4.

2.4.3 PlantScape Stations

PlantScape work stations are used by operators to control plant equipment in a typical chemical or manufacturing process. PlantScape client software, including all plant graphics is installed on the PlantScape stations. The graphics allow the operators to manipulate the various screens on these graphs, build trends, and monitor process alarms.

The graphics allow personnel to react to critical alarms that may indicate possible abnormal situations within the plant. In addition, the PlantScape stations allow staff to view different sections of a plant if the appropriate graphics are built into the software of the station.

The user is able to manipulate set points, outputs on valves and typically starting and stopping of motors by activating certain points on the graphics. Additional functionality is available to the operator or user.

Workstations are connected to the PlantScape servers by means of an Ethernet network going through SISCO switches. These connections and availability of work stations are monitored by the PlantScape software on the server. The PlantScape software allows the user to determine which stations are connected and to establish which operator has logged onto a particular station.

2.5 Level 3 – Advanced Control

Advanced control is performed at the third level by means of domain controllers; shuttle servers connected to the Internet (up- and down-loading data), real-time data collectors used with loop management and alarm management systems as well as the network monitoring server.

2.5.1 Domain controller and backup domain controller

Gibson (2005:1) states that Microsoft Windows Server 2003 has the ability to be a domain controller (DC). A domain controller can store user names and passwords on a central computer and will allow "friendly" names within the local area network (LAN).

A domain controller (DC) can also provide a platform for host headers to be used within the servers IIS (Internet Information Services) configuration. In the Solvents environment, the domain controller is used to authenticate users between the four different PlantScape for Distributed Server Architecture (DSA). The alarms from one DCS can be viewed or moved by the domain controller. The Backup Domain Controller (BDC) is a backup server for the main domain controller which is also referred to a Primary Domain Controller or PDC. The BDC is installed in order to ensure full redundancy on the control network.

2.5.2 NW_Mon Server

Link Analyst software is used on the NW_Mon Server to monitor network assets such as servers, work stations, switches and building network adapters. The NW_Mon Server software is used to detect network abnormalities, device and routing errors, log response times as well as monitor degradation severity through spot trends that may indicate an impending failure on configured network assets (Network Instruments 2006:1). The software allows for a graphic representation of various assets in a particular area or plant.

2.5.3 Real Time Data Collector (RTDC)

The real time data collector (RTDC) is a server that is used to run the LoopScout software that assists control engineers to detect problems in regulatory control loops at any location in the plant. Any proportional, integral and derivative (PID) controller can be analyzed, regardless of the hardware platform. The afore mentioned is provided that data can be collected from the Set Point (SP), Process Variable (PV), and Out Put (OP) at a frequency sufficient to capture 40 to 60 samples within the closed loop settling time of the controller.

The Real Time Data Collector software collects time series data from the controller and stores the data to a text file. This text file is automatically compressed and encrypted in preparation for uploading to the LoopScout web site. The software also collects the controller configuration information for a more detailed analysis, and compresses this data to the ScoutExpress file.

The Real Time Data Collector for OPC allows data collection from any system supported by an OPC server. The OPC data collector creates a ScoutExpress file for upload to the LoopScout web site (Honeywell 2001:7). The network connections depicted in Figure 5, overleaf indicate the loop management network layout and incorporate the RTDC and upload server.

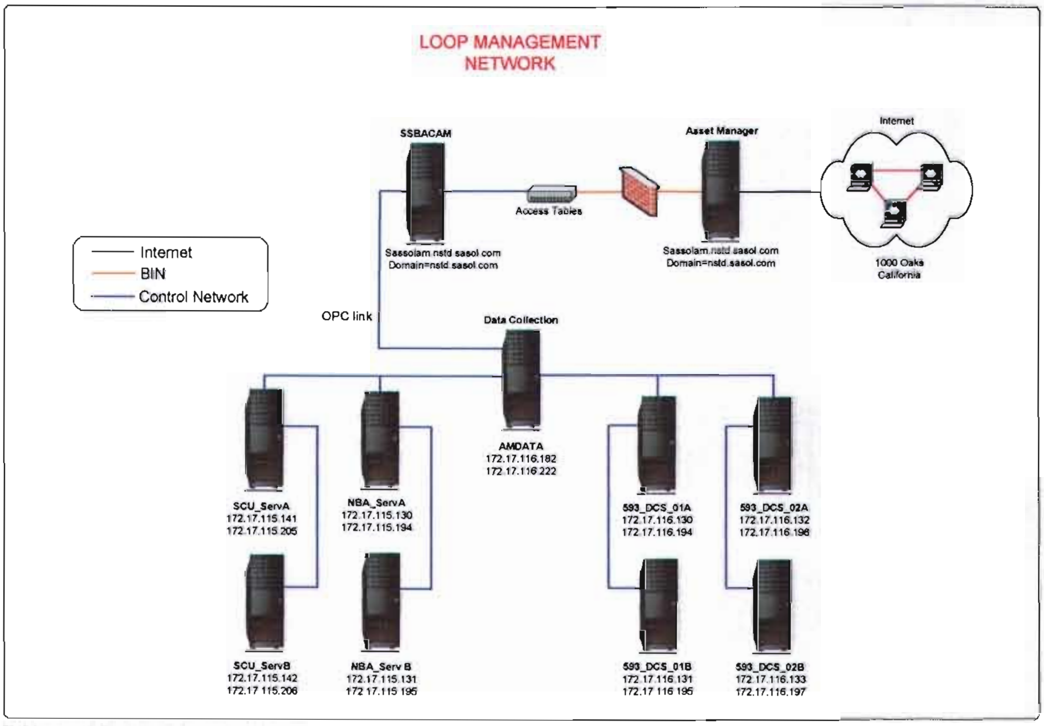

Figure 5: Loop management network layout

2.5.4 Upload Server (SSBACAM)

ScoutExpress (SE) Port is a simple application that moves files that were collected by the RTDC. SE runs as a service and requires one instance of a ScoutExpress Port running on each machine for files to be transferred from one machine to the other.

SE communication is a low level TCP/IP connection over one TCP/IP port. Files are transferred from the upload directory on the sending machine to the download directory on the receiving machine.

Events can play a very important role in the analysis of a controller or analysis of control systems in general. Events often characterize external events that are not

necessarily obvious by looking at the real time data. The Event Data Collector (EDC) is an important part of the analysis chain. EDC is usually scheduled to run once per day in order to collect the event data from the system.
The data is compressed, encrypted and stored in a ScoutExpress file. The ScoutExpress file will be stored to a specified folder – usually the SE Port upload or Shuttle upload folder so the data can be sent for analysis to Honeywell in 1000 Oaks, USA. (Honeywell 2001:2). The layout of the loop management network layout is indicated in Figure 5.

2.6 Level 4 – Business Information Network

Sasol's Business Information Network (BIN) is available for users to access mail, the Internet and view information between various plant information systems. Depending on firewall and access table protection, rights assigned by the systems administrator, users can access the Shadow PHD server situated on the control network from the Business Information Network (BIN) network.

2.6.1 Uniformance PHD Shadow Server

Uniformance Desktop client software is installed on the user's personal computer that resides on the business information network. Users can access the historical data, process trends or import data into Microsoft Excel spreadsheets by means of add-in application such as the PHD_Addin.

The Uniformance Process Trend is another application that allows users to use historical data to configure and setup trend information for monitoring certain process conditions and process trends (Honeywell 2004). Configuration and application of trends are used in the asset management software; this aspect is discussed in Chapter 7.

2.6.2 Asset Manager Server

The Asset Manager R300 software is installed on the Asset Manager Server and by using the different applications within the package, various assets and interfaces can be managed. The Asset Manager R300 is based on expert process and accident/failure knowledge of the Abnormal Situation Management (ASM) Consortium.

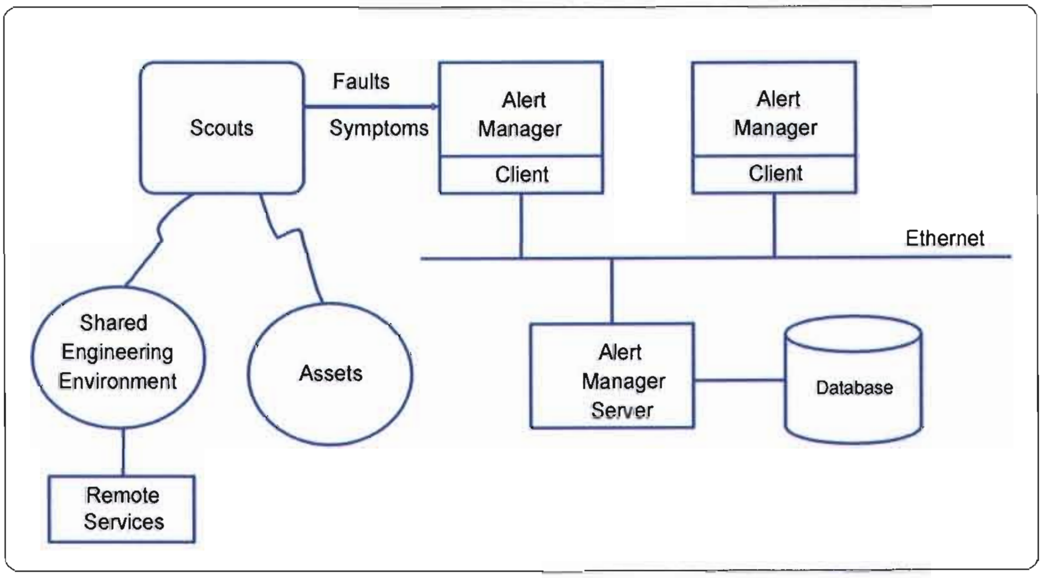

Figure 6: Asset Manager System architecture

Figure 6 depicts the Asset Managers System architecture used in the system. Assets are interfaced through the different scouts and symptoms and faults are passed on to the AlertManager clients. The AlertManager clients can then connect to the AlertManager server and store the data in the database.

Within the Sasol Solvents environment, client-server connections are established by means of an Ethernet network and relayed to the control network that uses virtual LAN's to ensure network security.

The following applications are embedded in the Asset Manager package:

- AlertManager Server and Client
- DataScout Server and Client
- Experion Scout
- Experion Tree Builder
- Loop Scout
- Tree Builder

2.6.2.1 AlertManager

AlertManager is a suite of Honeywell applications (Honeywell 2004) designed to monitor and track the health of various assets (instruments, pumps, valves, compressors, heat exchangers). AlertManager assists decision making in terms of planning for support and/or maintenance.

AlertManager automates decision support for the identification and repair of equipment problems by analyzing and organizing data into symptoms and faults. AlertManager has the capability to transform thousands of data points collected from plant systems, historians, sensor networks, and other plant databases into symptom-based fault isolation.

An important feature of AlertManager is that it provides directed troubleshooting and gathers the associated relevant data to analyse the problem.

2.6.2.2 ExperionScout

Alarm & Event notifications are sent from an OPC Event Server to an OPC Client when specified alarm and event conditions occur. The Alarm & Event (A & E) Configurator provides a manner to filter incoming alarm and event notifications in order to manage the amount of information received by the user.

The A & E Configurator allows you to receive notifications for specified alarms and events which are of particular concern for the plant operation.

Figure 7 depicts the A&E Configurator that is used to setup the various OPC servers that are linked to the Experion Scout. A service called AEClient monitors Experion for symptoms and reports these symptoms to Alert Manager which must be running on the Asset Manager server. The example below (Figure 7) shows a setup for the NBA DCS server that uses the HWHsc.OPCServer interface on NBA_SERVA to connect to the Alert Manager's OPC server.

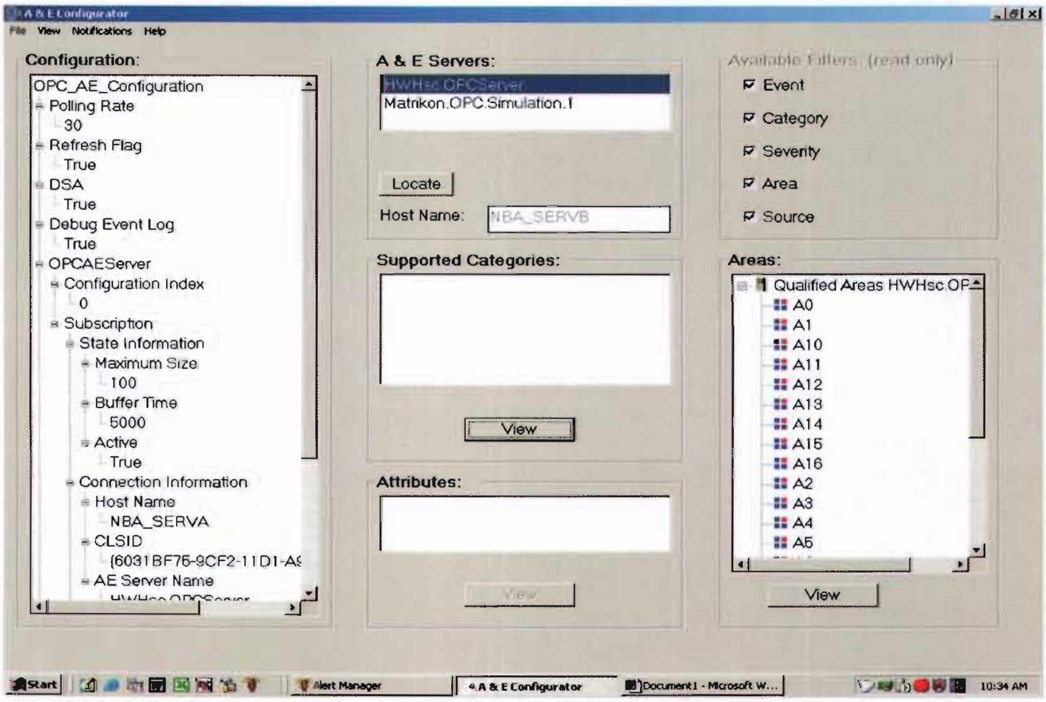

Figure 7: Alarm and Events Configurator configuration of OPC Server

2.6.2.3 APCScout

The Profitcontroller or Robust Multivariable Process Control technology controller (RMPCT) is used as the Advanced Process Control (APC) engine for advanced control of complex plants sections where implementation is possible. This software is used to improve throughput and control continuous process variables that have incipient disturbances. The Profitcontroller is interfaced to PHD (see 2.4.1) by means of the APCScout using an OPC interface. The different inputs and multivariable variables from process are monitored with the APCScout (Honeywell 2004).

2.6.2.4 DataScout

The DataScout (shown in Figure 8 overleaf) allows the user to retrieve, test, and create Alert Manager Symptoms based on OLE for Process Control (OPC) data (see 2.8). The DataScout application enables the configuration of symptoms based on data obtained from an OPC server, perform data checks, and report associated symptoms to the Alert Manager. Figure 8 shows the DataScout Process Symptom setup screen where the symptoms are built and configured for each of the different plant assets.

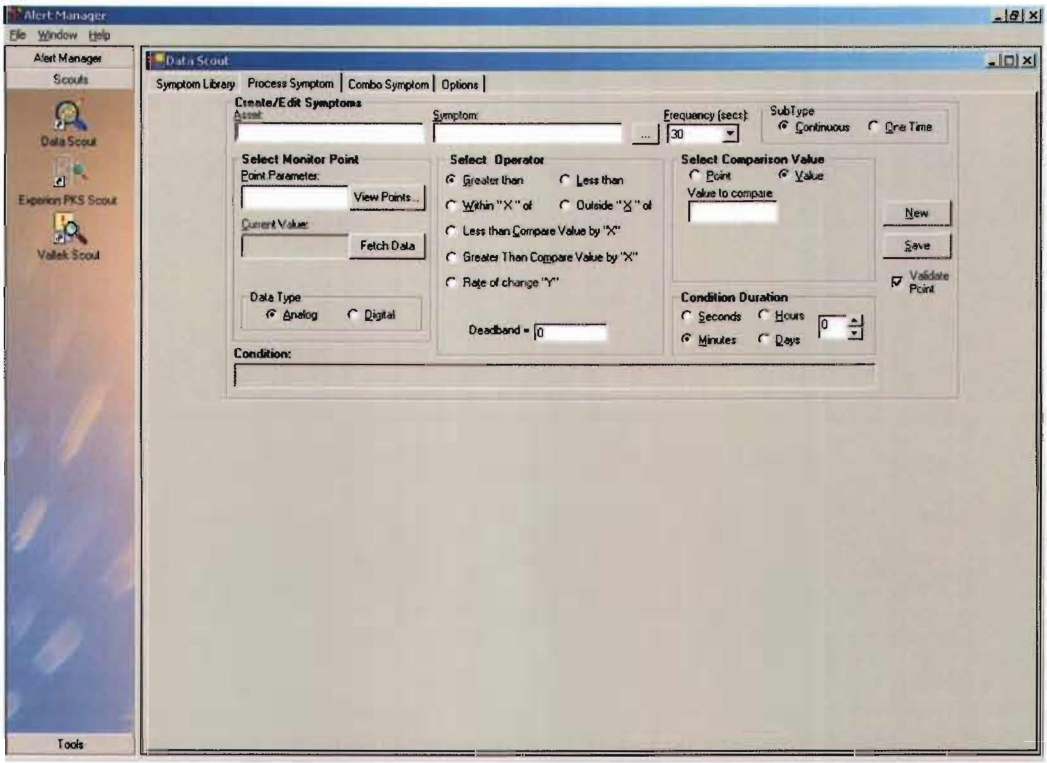

Figure 8: DataScout interface

2.6.2.5 AssetBuilder

The AssetBuilder (presented in Figure 9 above) allows the user to define the asset structure within the AlertManager The AssetBuilder is a component of the AssetManager system that enables users to configure asset types, assets, diagnosis types, and hierarchy views. AssetBuilder is also used to define unique asset properties such as priorities, plant areas, type of equipment e.g. pressure transmitter, description of the equipment, maintenance e-mail recipient and any additional properties that may need to be configured.

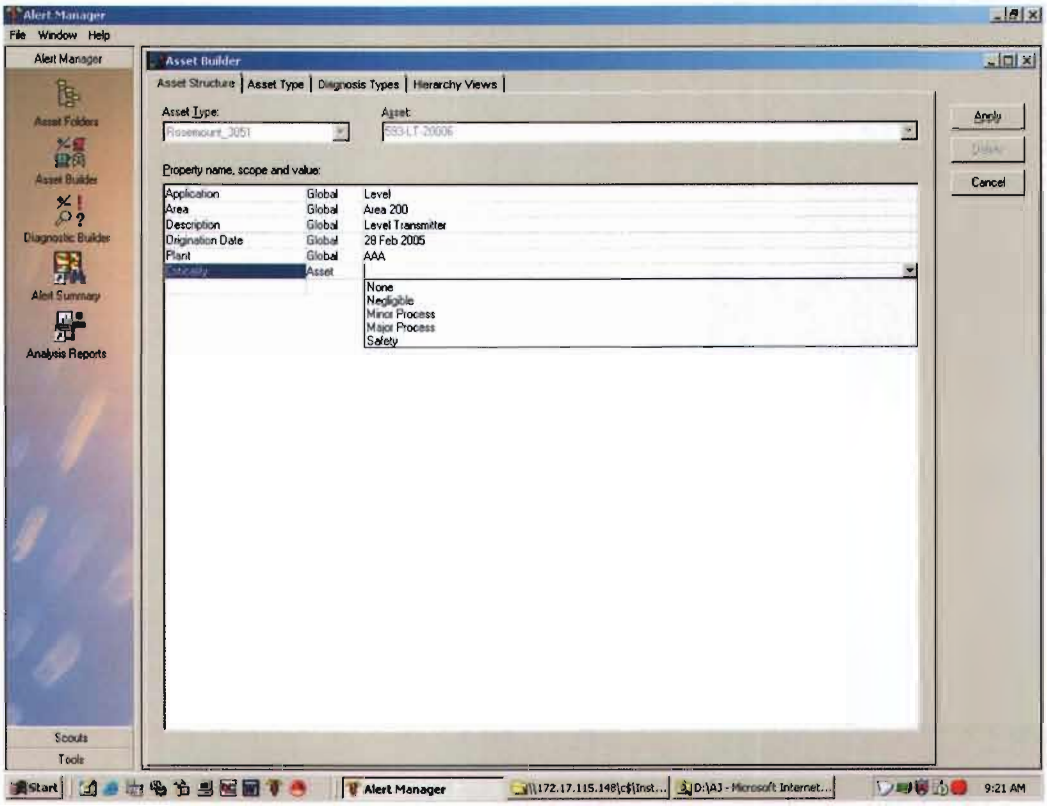

Figure 9: Asset Builder

2.6.2.6 Diagnostic Builder

The Diagnostic Builder (shown in figure 10) is the component of the Asset Manager application that is used to define the fault models (Honeywell 2004). This application is used to build the different assets that are not imported via the OPC clients. In order to create an asset fault model, the following information must be configured:

- Faults, Repair Procedures, Fault Notifications
- Symptoms, Symptom Evaluations, Symptom Details, Symptom Notifications
- Fault Trees

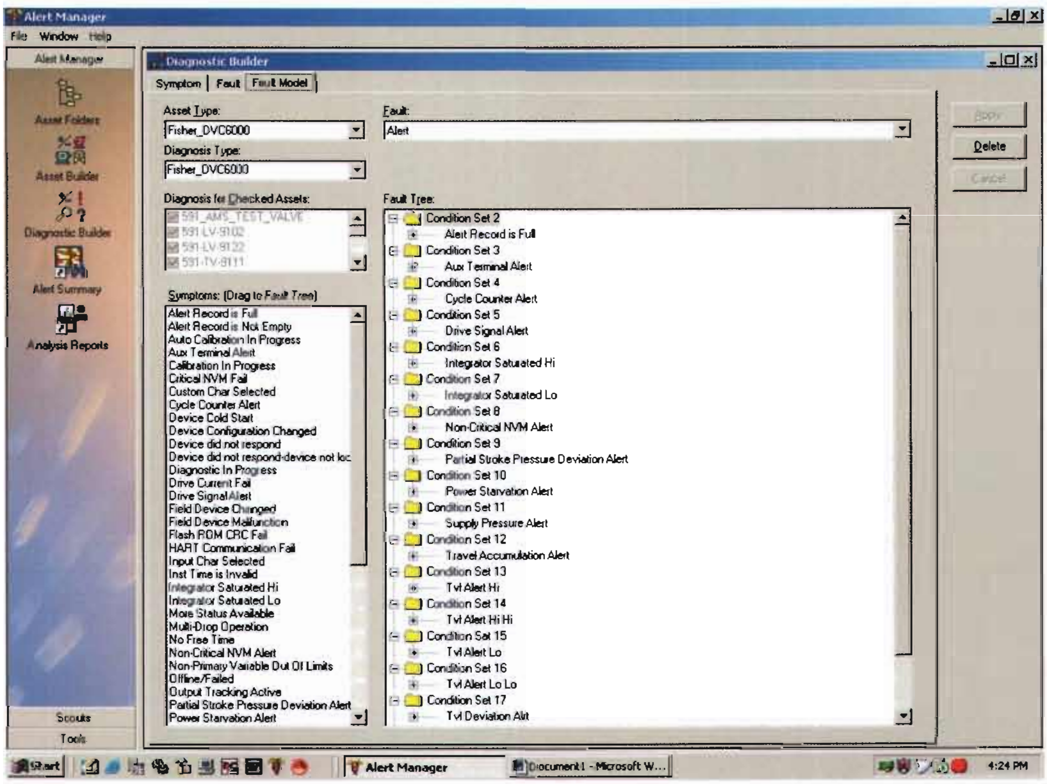

Figure 10: Diagnostic Builder

Symptom configuration pertains to the development and implementation of evaluation activities, symptom details, and symptom notifications. A symptom evaluation activity defines how the symptom is generated (i.e. by Asset Manager, DataScout or by another symptom reporting mechanisms). Symptom generation may be external (e.g. pushing symptoms manually for testing purposes) or automatic, and may be determined by the status of evaluation condition (Honeywell 2002).

2.6.2.7 TreeBuilder

TreeBuilder is an interface that connects to the PlantScape DCS database, extracts the DCS hardware configurations and builds the corresponding assets in the AlertManager infrastructure. The TreeBuilder allows the user to import a bulk configuration setup of the different symptoms and faults model using an Excel spreadsheet. All the DCS assets are built using the TreeBuilder.

2.7 AMS Device Manager

Asset Management System (AMS) Device Manager is an application that is used to commission and configure field instruments and valves, monitor status and alerts from the hart enabled field devices. AMS Device Manager enables maintenance staff to do troubleshooting from a workstation by reviewing current and historical events. In addition, the AMS Device Manager manages calibrations and documents these activities (Emerson 2006:9).

AMS is used at the plants in the Sasol Solvents environment to manage field instruments by performing calibrations and requesting replacement when needed. The diagnostic information is monitored within the AlertMonitor application.

2.7.1 Multiplexer networks

The AMS systems are connected to a multiplexer network that is depicted in Figures 11 and 12. Figure 11 indicates the connection from the field devices to the field terminal assemblies (FTA) where the normal 4-20mA control signals are taken to the DCS via a system connector. The HART information is stripped from the FTA and fed to the master multiplexer.

The RS485 signal from this multiplexer is taken to a media converter that converts the RS485 signal to a RS232 signal. The converted RS232 signal is then connected to the ASM PC's serial port (Joubert 2005). Figure 12 shows the master-slave connections that are used to extend the number of field devices that can be connected to the multiplexer network.

In the Sasol Solvents environment the multiplexer networks use a maximum of 15 slaves to a master multiplexer connection to access field instrumentation and valves.

The configuration of the Automated Multiplexer System (AMS) is shown in Figure 13. The different multiplexer networks and the connected instruments are indicated. The different systems such as the AAA FSC and the AAA DCS connections are connected to their respective multiplexer networks by means of the system's own serial port. If the multiplexer is expanded, the configured devices are shown (Joubert 2005).

Figure 11, below depicts a multiplexer network layout, and depicts an expansion of the multiplexer network is shown overleaf in Figure 12, indicating the master and slave configuration.

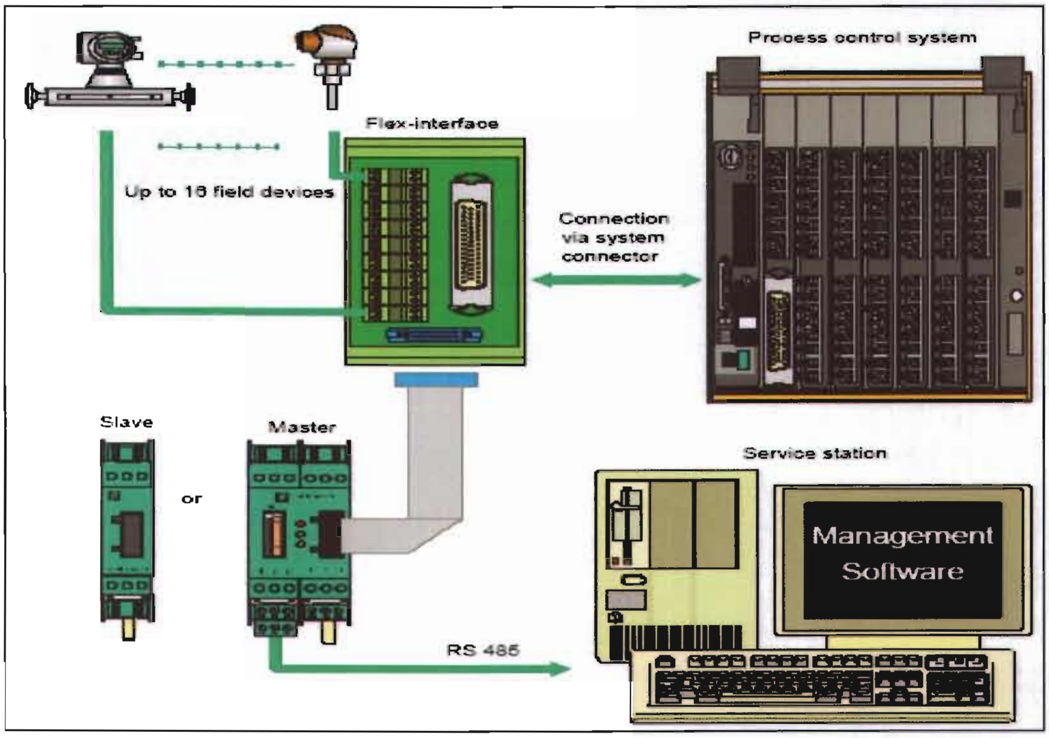

Figure 11: Multiplexer network

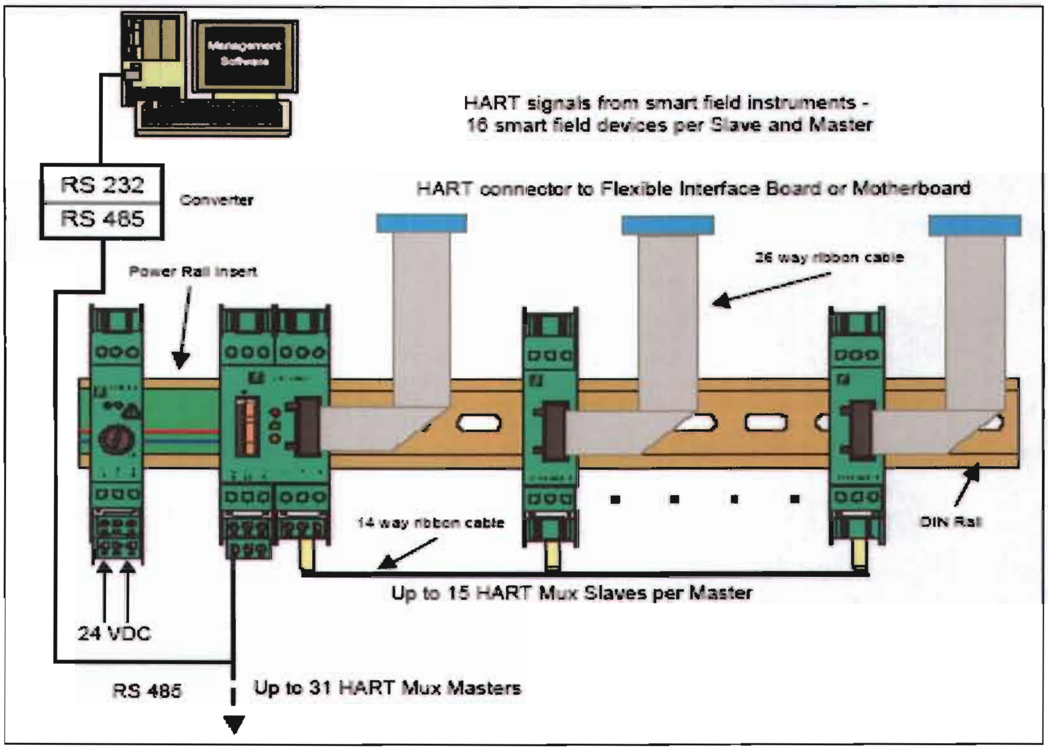

Figure 12: Multiplexer network with master and slave configuration

An expanded view of the Muliplexer Network as configured in AMS is shown in Figure 13 below.

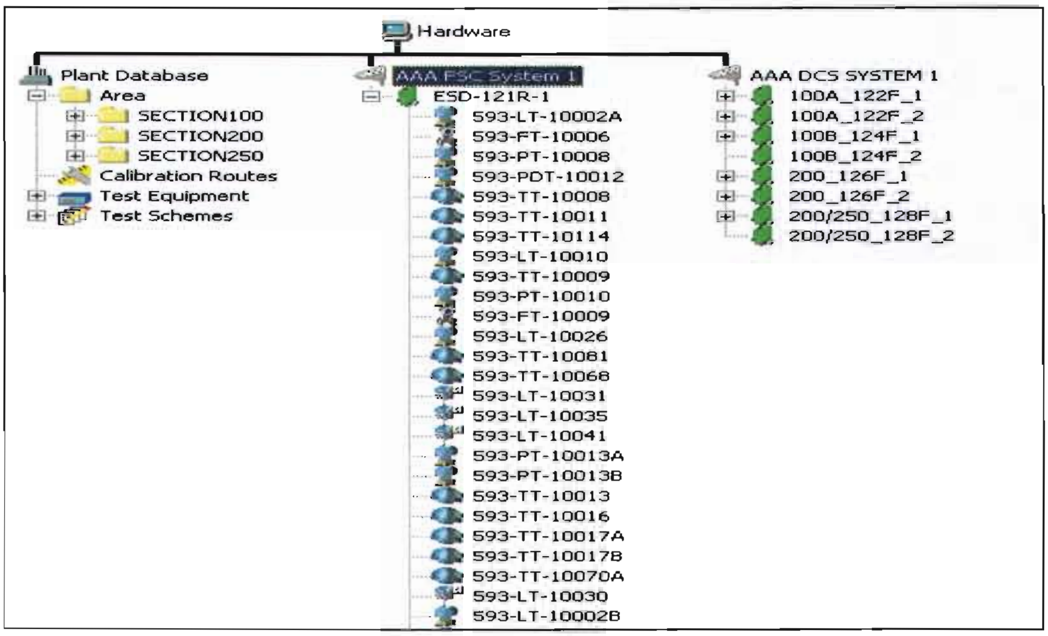

Figure 13: Expanded view of the multiplexers and field devices

2.7.2 AlertMonitor

The diagnostic information obtained from the HART-enabled field devices (see 2.2.1) is monitored by the AlertMonitor by observing the basic seven bits of the diagnostic information received from the HART-enabled field devices. When a fault bit is activated it is shown in the AlertMonitor display. AlertMonitor indicates the device tag. 593_PT_1234 that has an alert for a device malfunction is indicated. The diagnostic alerts generated by AlertMonitor indicate the status of the configured field devices for specific plant areas.

2.7.3 AMS ValveLink® SNAP-ON application

AMS ValveLink® SNAP-ON application allow easy access to valve diagnostics and provides the ability to work with HART or Foundation field bus FIELDVUE® digital valve positioners. The AMS ValveLink® SNAP-ON application provides a user friendly Windows based environment for diagnosing operating characteristics of the Fisher DVC5000 and DVC6000 series digital valve positioners.

Valve signature information (refer to appendix B) can be obtained from digital valve positioner's that indicate typical problems such as air leakage, valve assembly friction and dead band, instrument air quality, loose connections, supply pressure restrictions and valve assembly calibration (Emerson 2006:6).

2.8 OPC Server

OPC (OLE for Process Control) is a standard established by the OPC Foundation task force to allow applications to access process data from the plant floor in a consistent manner. Vendors of process devices provide OPC servers (see 2.6.2.2) whose communications interfaces comply with the specifications laid out by the task force (the OPC Standard). Client software that complies with the OPC Standard can communicate with any of the abovementioned servers regardless of hardware releases or upgrades (OPC Foundation 1997).

2.9 Field Device Manager

Field Device Manager (FDM) provides plant instrumentation technicians and maintenance personnel with an optimized environment to remotely manage smart field instrumentation and valves. The Field Device Manager allows for complete command and control of HART-enabled field devices throughout the plant and helps improve overall asset effectiveness (Honeywell 2006a).

The FDM is a stand alone configuration tool for HART-enabled devices that allows configurations to be managed, monitored and changed for a large number of HART devices. This software is based on the HART Communication Foundation SDC 265 standard HART host and device descriptor product (Helson 2005:1). The software is fully integrated with the Experion™ Process Knowledge Systems (PKS). It can be interfaced with other systems such as FSC, PlantScape R500.1 and other third party DCS systems (Honeywell 2006b).

2.10 Experion™ PKS R201

The Experion™ PKS R201 DCS server software provides the ability to communicate with HART devices by removing barriers such as scan rate limitations. The HART solution is used to automatically populate all the configured HART data through I/O cards into the C200 process controller (see 2.3.1) and thereafter to the standard detailed operator displays (Honeywell 2006a).

2.11 Enterprise Building Integrator

The Enterprise Building Indicator (EBI) is an integrated software package that manages access control, heating ventilation and air conditioning (HVAC) and plant emergency action plan (PEAP). The Enterprise Building Integrator system consists of fire, gas and CO sensors, sirens, light probes and shut off systems. Figure 14 depicts the EBI system architecture at the Sasol Solvents site.

Tema servers and building network adapters (BNA) are connected to an Ethernet network while the different controllers (XL500), the I/O modules and Tema Readers are connected via a LON Network (Temaline 2000).

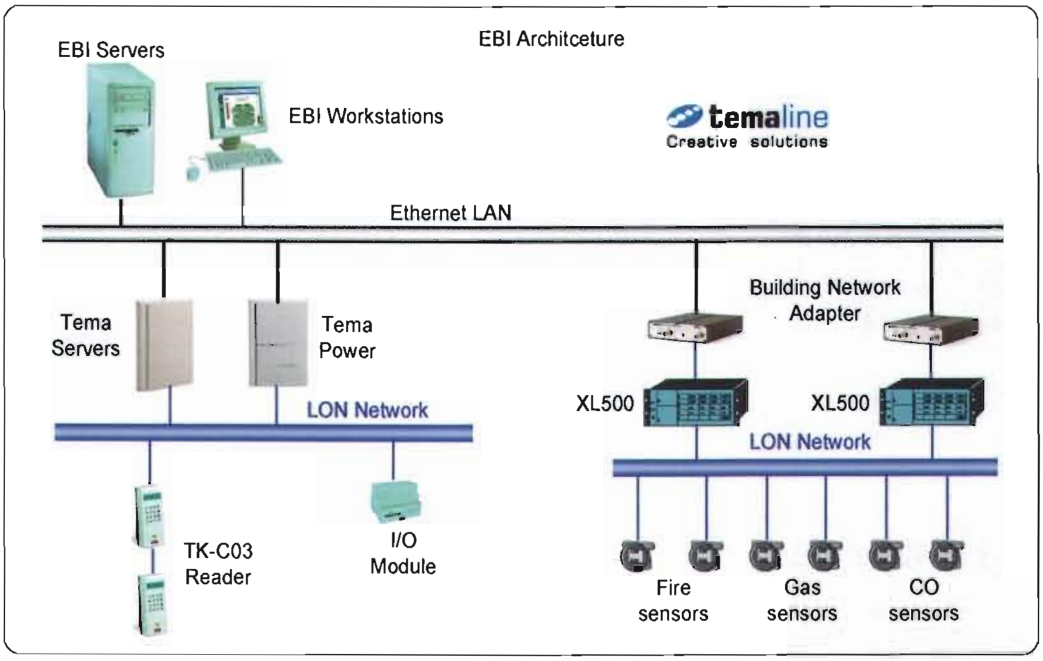

Figure 14: EBI System

2.12 FieldCare™

Shut off valves such as the smart Metso VG800 (Metso Automation Inc 2003) are installed on the plant and managed by the FieldCare software. FieldCare manage these valves by doing partial stroking without influencing plant conditions.

Partial stroking indicates that approximately 10 percent of the valve is opened and thereafter closed. Partial Stroking is required to ensure that the valves can be shut off in an emergency. Diagnostic information is also available from these smart valves. The FieldCare system is a stand alone system and requires that a technician must go to an equipment room which may be a substantial distance from the control room in order to access this information.

2.13 Virtualisation

Virtualisation is a new technology that makes it possible to run multiple operating systems and multiple applications on uniform powerful x86 computers simultaneously, increasing the utilization and flexibility of hardware (Green 2005).

VMware software makes use of virtual machines that are used to test the different platform and software packages. VMware's approach to virtualisation is to inserts a thin layer of software directly onto the computers hardware or onto a host operating system. This software layer creates virtual machines and contains a virtual machine monitor that allocates hardware resources dynamically and transparently. Vmware includes video adapters, network and hard disk adapters. In addition, Vmware provides pass-through drivers for USB, serial and parallel devices (Green 2005).
VMware offers a robust virtualisation platform that can scale across hundreds of interconnected physical computers and storage devices to form an entire virtual infrastructure (Green 2005).

These VMware virtual machines will be used to design develop, install, implement and test the different interfaces to produce the integrated asset management solution for the Sasol Solvents plants.

2.14 Conclusion

This chapter explored various plant control and asset management systems that are installed on the Sasol Solvents site. Most of the systems discussed in this chapter are stand alone systems. It is argued that an integrated solution would assist technicians, process and maintenance staff to manage all plant assets in a cost effective and efficient manner.

Implementation of an integrated solution can make it possible for a maintenance team to move from reactive (run-to failure) maintenance to predictive and eventually proactive maintenance that will ensure maximum plant up-time and 100 percent plant availability. In the chapter that follows, the research design and methodology employed in this research project are discussed.

CHAPTER 3 RESEARCH METHODOLOGY AND DESIGN

3.1 Introduction

An overview of the research methodology employed in this project is presented in this chapter. The research design is described as action research in the first part of this chapter and the action research cycle is presented graphically. The scope of the project is outlined in terms of three cycles: technical discussions with personnel, interviews with technology vendors and design and implementation of a time line review. Assessment and prioritisation of asset maintenance tasks are integral to optimise plant performance. The action research cycle presented in this chapter allows for the use of the research cycle process in order to solve the stated problems so that an integrated solution for predictive maintenance can be realised.

3.2 Action research methodology

Action research is defined by Lewin as comparative research on the conditions and effects of various forms of social action and research leading to social action that uses "a spiral of steps", each of which is composed of a circle of planning, action and fact-finding about the result of the action" (Lewin 1946).

Coghnan and Brannick (2001) define action research as a form of applied social research that differs from other types of research in terms of the proximity of the researcher's involvement in the action process.

This thesis presents a strategic research project that was developed with the intention of addressing plant maintenance concerns at the Sasol Solvents plants. Terreblanche and Derheim (1999) states that strategic research generates knowledge about specific needs and problems with a view to eventually solving or reducing the problem through further development and evaluation.

Research in practice involves collecting new information known as primary data from physical sources. According to Babbie and Mouton (2001:100) sufficient access to primary data of a technical nature is essential. As an employee at the Sasol Solvents Plant the researcher had sufficient access to data obtained from field devices which may be considered a physical source of data. The research design used quantitative data obtained from the field devices and also made use of qualitative techniques to investigate the research problem stated in the first chapter of this thesis.

According to Taylor (1993:58) the use of multiple appropriate data gathering techniques improves the predictive validity of the research. Validity of the research findings are influenced by aspects such accuracy and consistency of measurement (Taylor 1993:58). Due to the complexity of human nature (Van den Berg 1993): absolute consistency of results will probably never be achieved.

The value of data obtained from qualitative techniques such as personal interviews and surveys should however not be underestimated. According to Prinsloo (1993) personal interviews and surveys are diagnostic techniques that make it possible for the researcher to pinpoint sources of anger, frustration or unhappiness. Plant maintenance is reliant on personnel to cope with a very large range of devices and incompatible platforms. In order to develop a solution that effectively could improve plant performance the qualitative techniques were essential to obtain information from maintenance personnel.

Babbie and Mouton (2001:105) distinguishes between field research and the use of secondary or historical data. In this research project active data collection methods are used to obtain information from field devices. This data is then stored in a historical database which is used to identify trends and prevent the failure of equipment by means of pro-active maintenance. Mouton emphasizes the importance of meticulous documentation if the data is intended to be used in the future for secondary research.

Action research is not only research that describes how humans and organizations behave in the outside world but also a change mechanism that helps human and organizations reflect on and change their own systems (Reason & Bradbury 2001).

The outcome of this research will impact the way asset management solutions and assets utilization in modern plants will be planned, developed, prioritized, and implemented. The findings of this research show that the selection of technology and the development of a single software interface have a beneficial impact on work processes, task and expertise optimization and performance measurement at modern plants such as Sasol Secunda.

The management planning at plants such as the Sasol Solvents Site is greatly enhanced by means of improved information provided in a manner that appropriately trained personnel can take advantage of. Due to improved information receipt and processing times of data obtained from a single software interface that plant personnel can read and interpret based on data obtained from field devices based on diverse operating platforms.

By means of the Action Research Model, this thesis shows that continuous improvement is one of the driving forces to obtain maximum value from an asset management system. Figure 15 shows a graphic representation of the action research model that is used to implement the global asset management solution in the Sasol Solvents plants.

Throughout the entire action research process the SAMI model (see 1.2.2) was used in conjunction with the action research model as the basis for the design and implementation of the integrated solution. The different blocks in stage 2 are used to ensure that they are addressed and incorporated into the integrated solution.

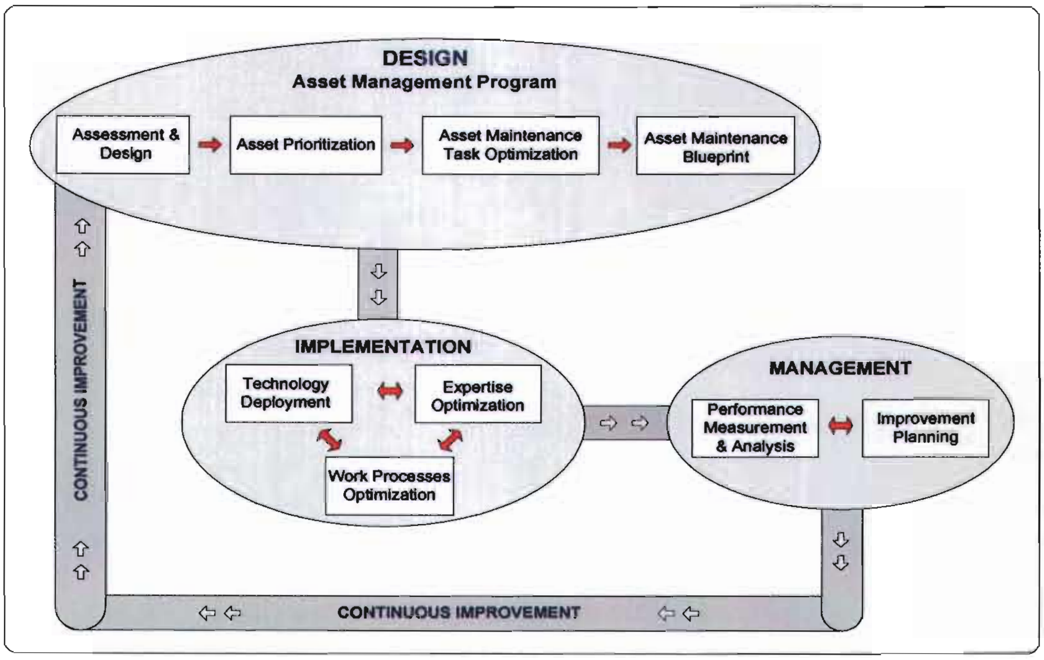

Figure 15: Action research cycle

3.3 Scope of work

The information required for the asset management solution was obtained by discussions with the Electrical/Instrumentation (E/I) maintenance manager, maintenance technicians, process managers and engineers as well as reliability engineers to determine what the requirements for such a system would be.

Based on Norton and Horsman (1999:6) research philosophy an assessment of:

- the problems associated with asset management at the three plant, based on installed technology;
- and the desired outcome of an integrated solution are done.

Based on the above assessment it was possible to build and strengthen the connection between research and practice with a view to improve practice, building the required knowledge and extending or shifting the perspectives of users of the various systems.

Three cycles, presented below, were followed to assess and design the proposed solution:

- Cycle 1: Technical discussions with process, maintenance and reliability staff and preliminary system layout and design.
- Cycle 2: Interviews with technology vendors to determine integration capabilities of the different systems on site.
- Cycle 3: Design and implementation time line review.

3.4 Cycle 1: Technical discussions with process, maintenance and reliability staff

3.4.1 Assessment and design

The first cycle of technical discussions with process, maintenance and reliability staff indicated that emphasis should be given to the way the solution should be implemented. The plant information would be structured based on the physical plant assets and systems. The typical structure of the plant assets was discussed and it was decided that the structure shown in Figure 15 should be followed.

The discussion with personnel was also aimed at verification of the assets tags that were used in the design and how the data would be managed. Data management between the different interfaces, control systems, asset management systems and third party vendors is an important aspect of the integrated solution that was developed.

Based on the assessment and application design indicated in Figure 16, the integration design was planned, implemented and finally executed in the live plant during a shutdown period of one month.

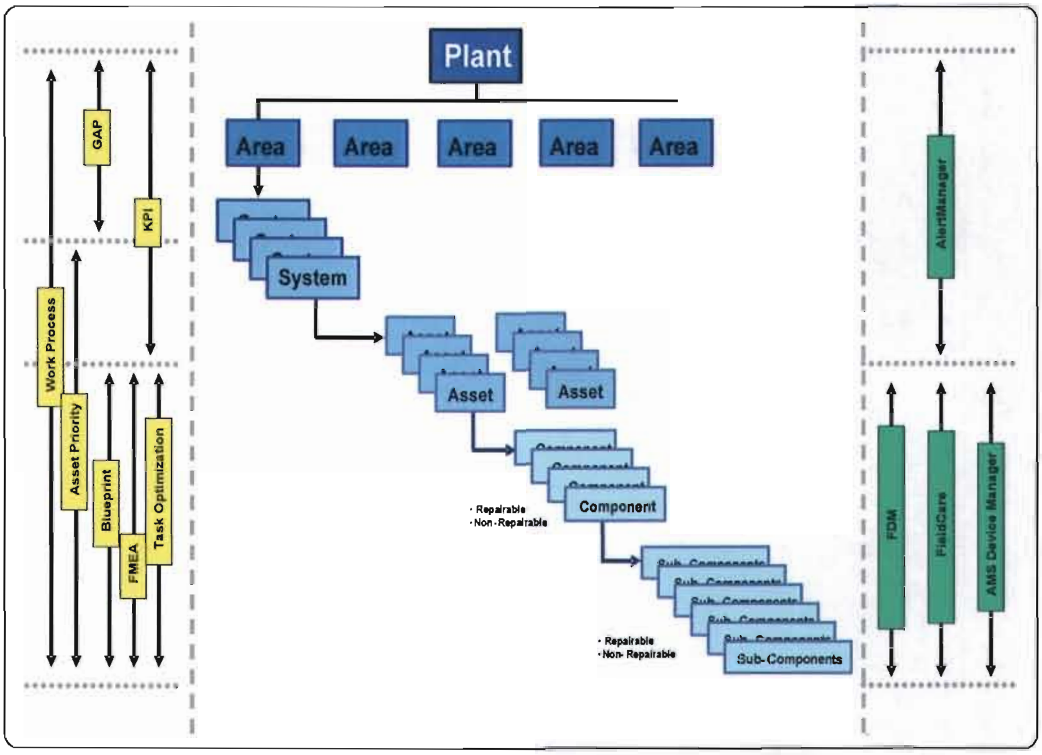

Figure 16: Assessment and application design

3.4.2 Asset Prioritization

There was a need to consider division of the operational units at the different plant systems and to bench mark them to the specific Sasol business requirements. The business criteria applied that were applied are presented below:

- Safety
- Regulatory compliance
- Product quality
- Process throughput
- Operational costs

These criteria were taken into consideration in the calculation of priorities. The weighted average was derived from these criteria and used to determine the operational criticality ranking. The asset failure probability factor was determined and finally the maintenance priority index was calculated. These values were used in the design phase for the integrated asset management solution.

3.4.3 Asset maintenance task optimisation

Various consultations were conducted to obtain an understanding of key performance indicators (KPI), work flow execution, the prioritization concepts used and implementing a possible asset maintenance matrix referencing all plant assets and their impact on process.

3.4.4 Asset maintenance blueprint

The maintenance blueprint was discussed in terms of a typical cause and effect diagram where the different assets are priority validated and mapped into its functional requirements. All particulars pertaining to the assets are complied in the blueprint to ensure that all required details were available for configuration and implementation. The blueprint then formed the basis for the design of the integrated solution.

3.4.5 Technology deployment

The technology installed was considered in terms of how these systems could be integrated and into the main integration solution. As discussed in Chapter 2, a large variety of systems are installed and this requires a complex and involved solution.

3.4.6 Expertise optimisation

The level of expertise of the maintenance staff was evaluated and the need for skills development was considered to ensure that once the integrated solution was installed, it could be used effectively and correctly by the different parties.

3.4.7 Work process optimisation

The existing work flow processes were reviewed and the "execution" work flow process evaluated to ensure compliance to best maintenance practises. Suggestions were made to adapt the work process where needed. The focus was to move away from the traditional way of doing maintenance to a totally new approach (Emerson 2005a).

3.4.8 Performance measurement and analysis

This action could not be conducted because the process was still in the design phase and no final decision had been reached regarding how the total integrated solution should be implemented and interfaced. No analysis was made.

3.4.9 Improvement planning

Planning was discussed and the final proposal was submitted to determine the impact on planning. After going through the processes in cycle 1 it was seen that the processes needed to go through another cycle to solve more system related issues. After this session, a three month period was set aside to resolve certain system related issues that had not been clarified by process and maintenance staff.

3.5 Cycle 2: Interviews with technology vendors to determine integration capabilities of the different systems on the Solvents site

3.5.1 Assessment and design

The outcome from the first cycle identified certain concerns:

- Implementation of the integrated solution was possible but licensing of OPC connections was a problem had to be resolved with the system vendors.
- The interfaces should have been tested on the systems but due to the environment being an active production plant, it was impossible to test the interfaces on a live process – if the interfaces caused a system crash, the cost implication would be phenomenal. It was necessary to find a solution for testing.
- The technical skills of maintenance personnel were not up to standard for using the new technology and solutions.
- Change management was a major concern, since management was not buying into the proposed integrated solution and there was resistance to use the new technology solution by maintenance and reliability staff.

Most of the vendors that were involved with the different systems were prepared to consider possible license issues to resolve integration problems. In essence all the vendors were able to assist with open licenses to get involved in the planned integration and solution. This was an opportunity for vendors to learn from the exercise and to adapt their software and platforms to be more open and accessible to third party integration (see 2.1).

The design was reviewed looking at system architecture and all the components. This information was compiled into a preliminary functional design specification (FDS) document. This was submitted to all parties for review. The FDS was discussed again, after four weeks of review.

3.5.2 Asset Prioritization

Although certain changes were suggested after review of the FDS, there was general consensus that that the design should remain according to the priorities decided in cycle 1.

3.5.3 Asset maintenance task optimisation

With the proposed preliminary design (FDS) the maintenance tasks were evaluated in terms of the integration that would take place. Certain changes were suggested which would be effected after implementation of the solution.

3.5.4 Asset maintenance blueprint

The asset maintenance blueprint was re-evaluated and certain changes were implemented in order to incorporate the systems that had originally not been part of the integration planning. These systems were the Metso's FieldCare system managing the shut-off valves and the Field Device Manager. These systems are the only two systems that could be used to interface to each other, retrieving the required diagnostics information from the shut-off valves. The blue print document (refer to appendix C) was updated with these changes.

3.5.5 Technology deployment

The decision regarding what technologies would be used was made by management. No additional software would be purchased to facilitate the integration. Installed systems were to be used and integrated into the proposed solution. It was necessary to keep integration costs to a minimum.

3.5.6 Expertise optimisation

Training programmes were initiated which also formed part of the change management that needed to be implemented. Device and system specific training was given over a period of two years to ensure that the solution and integrated systems could by optimally utilized.

3.5.7 Work process optimisation

The work process that normally followed at Sasol was adapted to facilitate the new approach to conduct maintenance smarter and more effectively. A mind shift was required to start thinking about predictive maintenance strategies. The importance of change management was stressed because a new way was needed for all maintenance actions.

3.5.8 Performance measurement and analysis

The proposed solution was implemented on virtual machines (see 2.13) to facilitate integration between the different systems. By means of the virtual machines it was possible to do some sort of performance measurements. The analysis that was conducted on the different systems proved to be satisfactory to facilitate the final implementation in the live plant environment.

3.5.9 Improvement planning

At this stage the planning personnel had become involved in the process and made suggestions were made regarding how SAP could be used to generate work orders for defects detected by the proposed asset management solution and systems within the solution.

All parties were aligned regarding the proposed integrated solution and the only outstanding issue was the time line and when the system would be implemented into the live plant environment.

3.6 Cycle 3: Design and implementation time line review

3.6.1 Assessment and design

The final design was on the table with the virtual machines activated and running the different software packages and indicating the different interfaces. The final implementation time line was finalized and it was decided to implement the integrated solution in two phases. The two phases were divided as follows:

- The asset management solutions were in the first phase because this would have the least impact on field devices and asset management systems such as the AMS, ValveLink, FieldCare, FDM and AlertManager. The plants could still operate without these systems.
- The second phase was the RDI (see 2.4.2) implementation in PHD, the FSC (see 2.3.2) and the PlantScape (see 2.4.1) interfaces. LoopScout (see 2.5.3), network management (see 2.5.2) and the EBI system (see 2.5.11) would be the final systems to be integrated.

3.6.2 Asset Prioritization

No changes were made to the existing priority lists and it would be implemented as designed. The prioritization for the assets was to be conducted in AlertManager as the assets were built and configured.

3.6.3 Asset maintenance task optimisation

Asset maintenance task optimisation had already been done in the previous cycle. However, this remains a continuous improvement process as systems are better understood and more experience is gained from one integrated asset management solution.

3.6.4 Asset maintenance blueprint

The asset maintenance blueprint remained the same as had been decided in the previous cycle.

3.6.5 Technology deployment

The only change in terms of technology deployment was to incorporate the Experion™ PKS R201 software (see 2.10) as a test to establish the functionality and integration of the FDM server (See 2.9). This was implemented as a parallel connection to the existing PlantScape configuration in order for Honeywell SA to test certain functionality of the software in terms of HART integration into their new DCS embedded HART capabilities. Honeywell SA supplied the Experion™ PKS R201 server with the required software.

3.6.6 Expertise optimisation

Training was continued on a weekly basis and formed part of the change management process that was implemented to ensure that maintenance staff were competent to work with the final integrated solution. This training also formed part of career development of maintenance staff and they were evaluated on the different competencies required to work with these systems. An important component of this project was to provide training that would emphasise the effectiveness and advantages involved with using the integrated solution.

3.6.7 Work process optimisation

The work process was changed in a minor way but maintenance procedures were developed and incorporated into the asset management solution. This was necessary to assist in the skills enhancement of maintenance staff. The manner that the defects were managed was also adapted to the SAMI maintenance model (see 1.2.2). SAP was also modified to adapt to the SAMI approach to maintenance. This was a different process that would only be changed after implementation of the integrated solution.

3.6.8 Performance measurement and analysis

Some of the software packages were unable to run with the multiplexer network (see 2.7.1). Hart simulation software was used to simulate the symptoms and faults retrieved from the field devices (see 2.2.1). This was fairly successful but still needed to be tested in the live environment to determine the impact of the scanning times of the multiplexers and field terminal assemblies (FTA) (see 2.7.1).

3.6.9 Improvement planning

Due to the faster detection of faults from the integrated asset management solution, it would be possible to conduct more planned maintenance moving away from reactive maintenance to more predictive maintenance. Improvement of planning in order to optimise plant production was the primary purpose of the design and implementation of an integrated asset management solution.

3.7 Conclusion

This chapter has presented the action research process and research cycle that was followed. The selection of an action research design was motivated and the methodology employed was discussed. The identified problems were reviewed using the research cycle process to determine certain outputs that would be used to solve these problems. Implementation of the results obtained from the action research steps (see 3.3.1) will be discussed in the chapters that follow.

CHAPTER 4 RESEARCH OUTCOMES - FAILURE ANALYSIS

The purpose of this chapter is to indicate the outcomes of the action research processes that were followed in Chapter 3. The design processes that were employed are presented in this chapter. The outcomes of the action research included the creation of plant assets in the interface and the configuration of symptoms and faults according to the symptoms and fault model. In addition this chapter will discuss the establishment of a relationship between symptoms and particular faults in order to create a fault tree for each configured asset.

Failure analysis is indicated in stage two of the SAMI model as highlighted in the blue block in Figure 17 below.

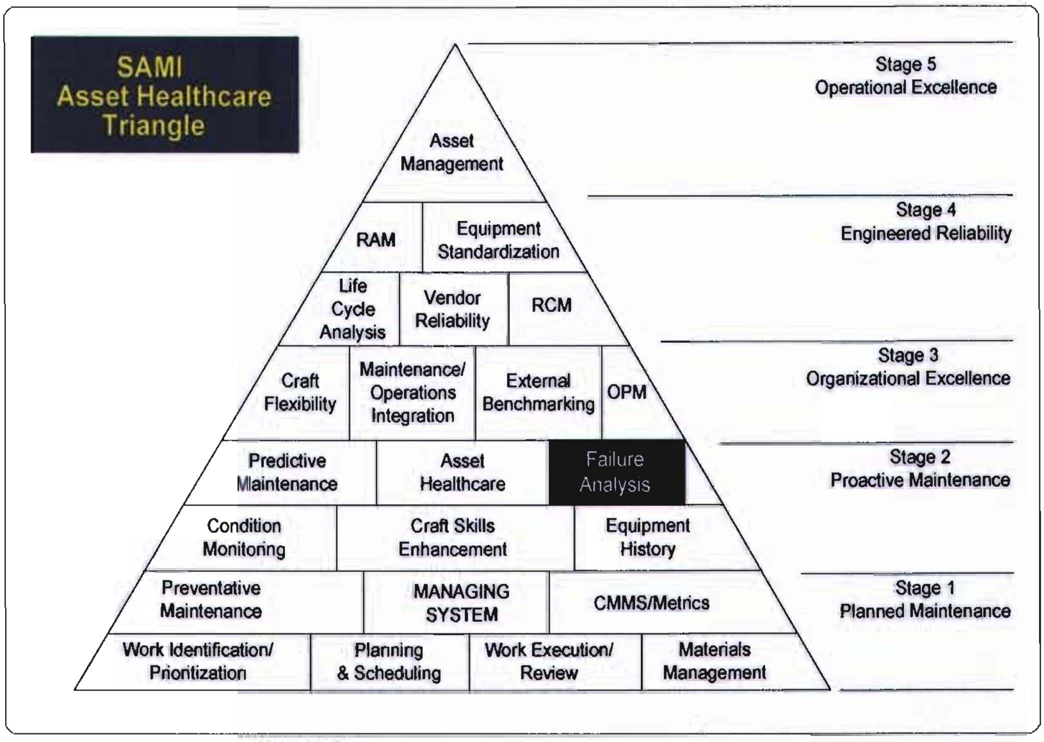

Figure 17: Failure Analysis

The focus of failure analysis in this thesis is on the various symptoms and fault model that has been developed and used in the configuration for all the different assets implemented in the proposed integrated asset management solution. The different symptoms and faults for the non-intelligent equipment (Joubert 2005) will be discussed.

4.1 Building plant assets in Asset Manager

An important aspect of the Action Research Process discussed in Chapter 3 includes the creation of an asset maintenance blueprint to form a benchmark (or point of departure for creating the different plant assets in the Asset Manager R300 (see 2.6.2).

The asset maintenance blueprint contains all the required information regarding plant assets so that the Asset Manager can be correctly configured. It is intended that a total of 4140 assets can be created and configured, based on the information contained in the blueprint.

Figure 18 shows the steps that are followed to build the plant assets within the Asset Manager interface, the symptoms and fault models and all the DCS hardware. The first step is building the assets using the Asset Builder application (see 2.6.2.5). Once all the assets have been created (or built) the symptoms and fault model is used to configure the symptoms and faults for every configured asset. Symptoms and faults are configured using the Diagnostic Builder (see 2.6.2.6) application.

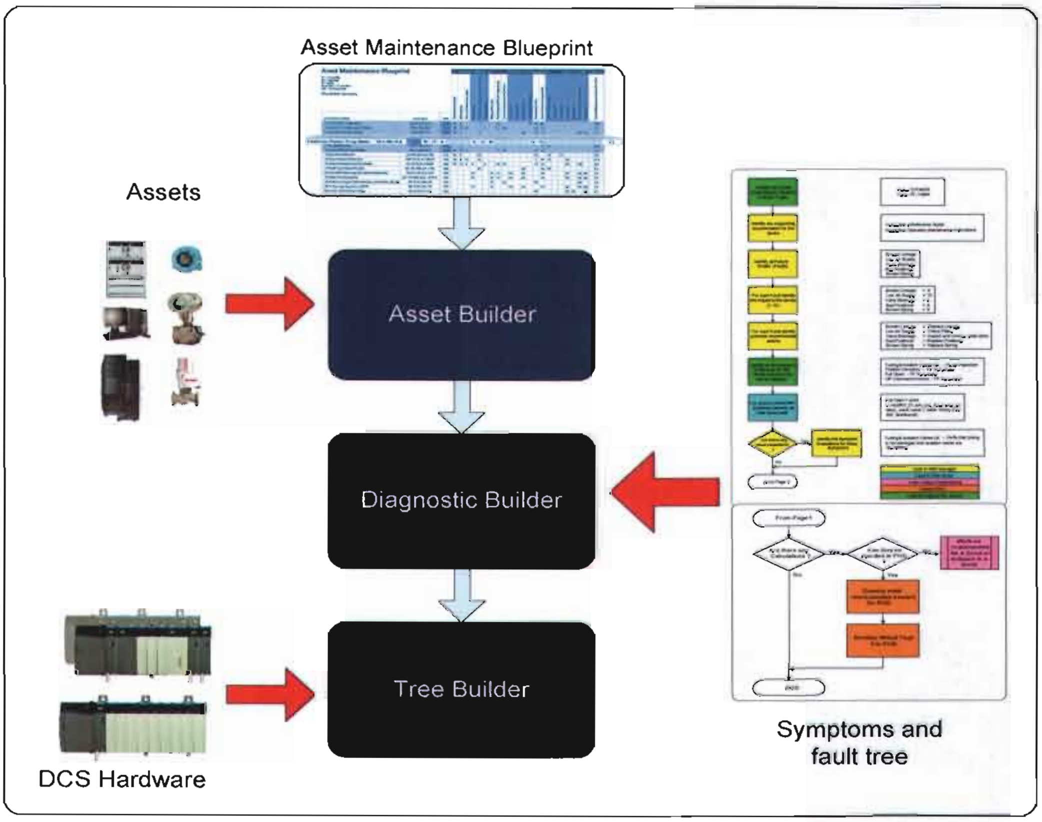

Figure 18: Steps to build assets

All DCS (Distributed Control System) assets are built using the TreeBuilder (see 2.6.2.7) and written into the Asset Managers infrastructure. PlantScape Hardware assets also include the PlantScape Servers (PSc_Server) and PlantScape Operator Stations (PSc_Station) as well as the Network Infrastructure (Network Asset).

The computer hardware is monitored via Plant Historian Database (PHD) that receives the data from a Performance Monitor real time data interface (RDI). This means that any information that is available from the Microsoft Windows Performance Monitor can be logged in PHD. In addition this information will be used to establish symptoms such as low available disk space, thread counts, CPU processes and available memory.

The symptom and fault model that is used to configure the required information for each of the plant assets in Alert Manager is discussed below in terms of the Fault Model Flow diagram.

4.2 Fault Model Flow Diagram

The fault model flow diagram (Figure 19a and 19b) was developed to determine the specific symptoms and faults associated with the various HART-enabled field devices and plant control systems. The example of a Fisher DVC 6000 valve is used to describe the fault model. This model is also used to formulate the processes for RCFA and FMEA (see 1.2.2) used for failure analysis.

The colour scheme at the bottom right of figure 19a refers to the different systems that are used to configure the symptoms and faults. Configuration information of the symptoms and fault tree will be displayed in the AlertManager. The DataScout is configured with the required parameters in order to determine the impact of the identified symptoms on HART-enabled field devices as well as non-HART assets. In addition the DataScout can be configured to determine any combination of these symptoms that may generate a fault condition.

Figure 19a, shows how symptoms are identified and how these symptoms are linked to a particular device. The parameters for the valve that will be used as symptoms for possible failure or malfunctions are indicated on the right hand side of figure 19a, shown below.

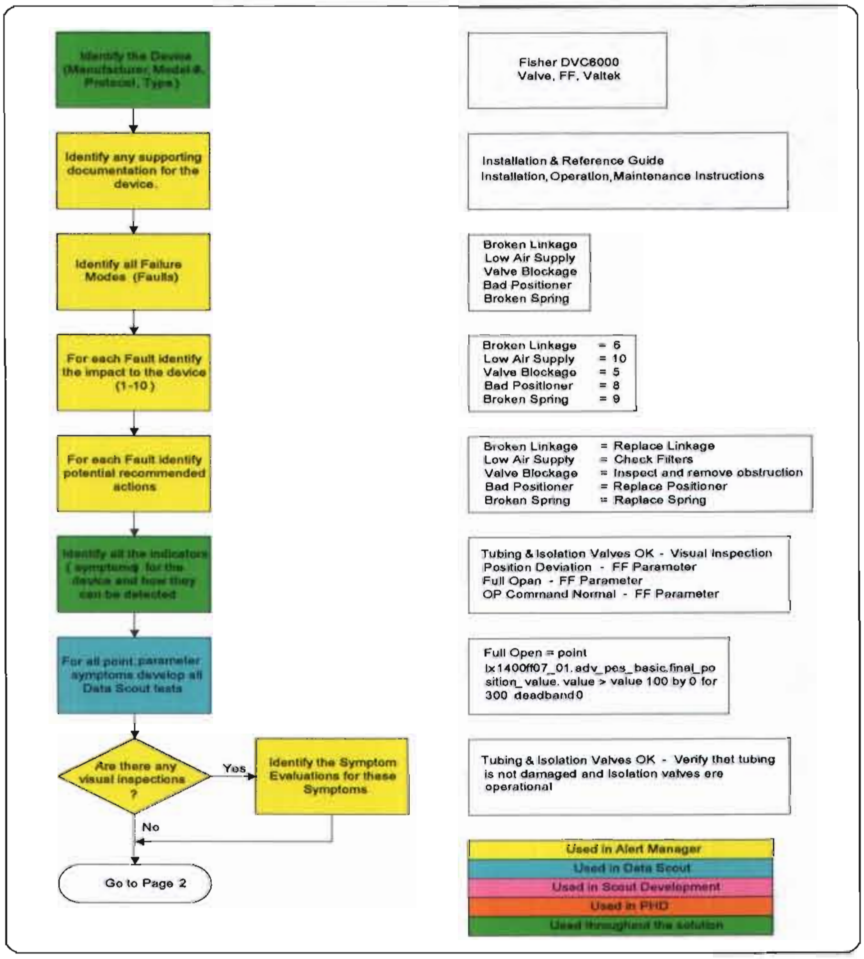

Figure 19a: Typical fault model for a Fisher DVC 6000 valve – part 1

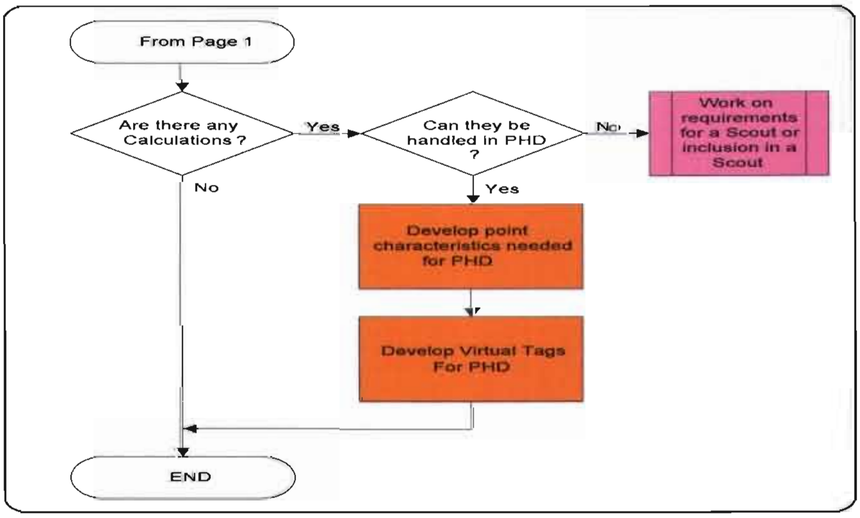

Figure 19b: Typical fault model for a Fisher DVC 6000 valve - part 2

The yellow blocks in Figure 19a are configured in the AlertManager and the brown tags shown in Figure 19b are configured in PHD (Plant Historian Database).

The light blue block (figure 19a) is used in the configuration of the DataScout where the parameters are configured for the different symptoms criteria. Figure 19b shows the various parameters required to configure and enable the DataScout in order to activate symptoms and faults in the AlertManager.

Symptoms are separately developed for non intelligent equipment such as the FSC system or retrieved from the device descriptor (DD) files from intelligent equipment such as HART-enabled devices as described in 2.2.1.

4.3 Symptom Configuration for a System Tag

According to the blueprint layout that was discussed in the preceding chapter, the symptoms for particular non-intelligent system assets are predefined as indicated in the symptoms tables. The DataScout interface shown in Figure 20 is used to build and configure the process symptoms for a particular asset.

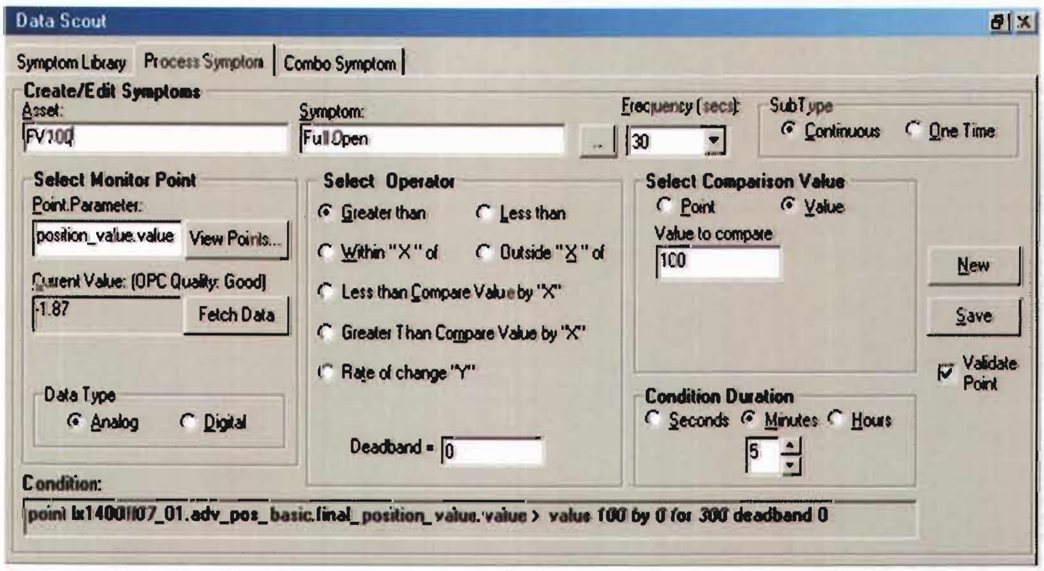

Figure 20: DataScout Process Symptom configuration

The asset that was created in Asset Builder is shown in the asset block. The point.parameter block indicates the virtual tag built into the real-time performance RDI on PHD. It is possible to verify the data through the OPC interface to PHD. When a value is returned it means that the OPC interface (see 2.8) has retrieved the correct data from the historian database. In the data type block a selection is made between analog or digital input. If analog is selected it refers to equipment that has an ON, OFF condition. The digital data type is used when interfacing to the different DCS and FSC systems.

Different operators are used to configure the symptom conditions in addition to condition duration in order to establish the length of time that the symptom condition must be active for a fault condition to be activated.

The sample frequency is specified to determine the sampling of the point parameters and when needed the point condition is compared to a value. This determined by the type of system and symptom. The condition information can be viewed at the bottom of Figure 20. The point is compared to a certain value for certain duration within a certain dead band; should these parameters be exceeded then an alert will be generated by the DataScout into the AlertManager infrastructure (Honeywell 2006a).

The dead band is used to desensitise the triggering of alerts within a certain range around the mean. The symptom parameters for all devices and systems were verified and included in the blueprint design in order to ensure that a valid alert is generated when these device symptoms are activated in the field devices. This process is followed for all assets that are used on the three Sasol Solvents Plants.

4.4 Process Historian Database (PHD)

The majority of the data that is required to make decisions regarding whether a symptom is present or absent resides in PHD. The PHD forms the benchmark according to which all DataScout evaluations will be made. Figure 21 indicates the various RDI's running on PHD and collecting data from the different interfaced systems.

Figure 21: Real-time data interface on the PHD shadow server

4.5 DataScout

DataScout is a tool that connects to any OPC data source to retrieve data. DataScout uses a set of preconfigured rules to determine whether a symptom is present and then reports the result to AlertManager. DataScout connects without difficulty to the PHD OPC Server for data retrieval. The AlertManager client software installed on the PHD server will connect to the AlertManager server via the client software (Honeywell 2006a) to retrieve the required data.

For systems that do not have onboard diagnostic information, the DataScout is used to generate and configure the symptoms and faults. An asset is generated and the different symptoms and faults are manually created for the asset.

Point parameters are created as a virtual tag in PHD. This data is accessible from the DataScout through the different OPC connections (OPC Foundation 1997) to the different DCS, ESD or other plant control equipment, OPC servers and client connections.

4.6 DataScout Activation of Plant Control Systems Assets

The highlighted blocks in Figure 22 indicate the systems that are affected by the DataScout interface. The DataScout is used to activate the symptoms and fault models for the systems that are shown as not having onboard diagnostic information. HART and Foundation Fieldbus (FF) enabled field devices (see 2.2.1) do have onboard diagnostic information available.

The systems referred to in Figure 22 are the PlantScape DCS (see 2.4.1) that will be managed by the ExperionScout (see 2.6.2.2) interface, populating the AlertManager should the hardware devices on the control-net network fail. The fail safe control (FSC) system (see 2.3.2.), the PlantScape DCS servers and PlantScape stations are interfaced to PHD (see 2.4.2) via the custom written performance monitoring real time data interfaces (RDI).

Non-PlantScape servers and stations form part of the control network that is activated using the DataScout interface. Loop management consists of the control loops on the DCS that are configured and interface to the AlertManager by means of the LoopScout software and interfaces (see 2.5.3).

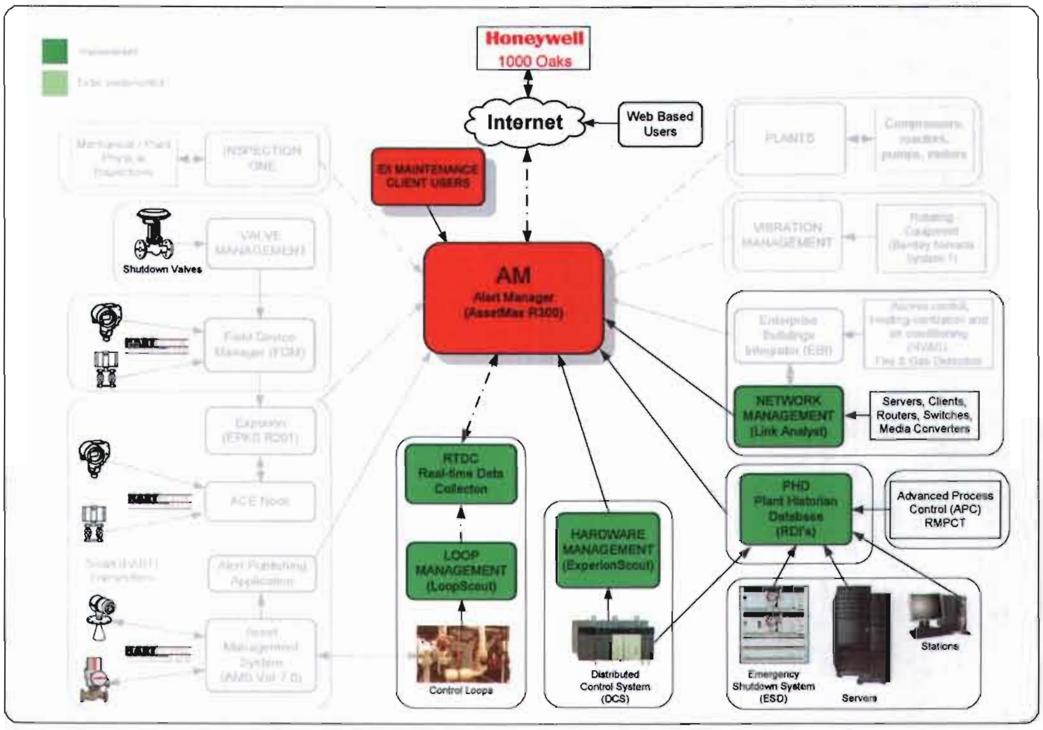

Figure 22: Block diagram indicating systems affected by the DataScout

4.7 Fault Tree Configuration for HART Based Device Tags

4.7.1 Device Descriptor (DD) Files

Use of the standard HART commands in HART-enabled field devices allows for greater functionality. These commands typically address on-line and diagnostic monitoring information. The HART, FF and PROFIBUS equipment are supplied with Device Descriptor (DD) files from the manufacturer that assist the user to identify device-specific features. These device specific features are typically used to access configuration properties and device-specific features (Pratt 2002:24).

According to Borst Automation (2006) the Device Descriptor Language (DDL) is a technology that has particular benefits for configuration and setup of device-specific features. DD files are optional for the HART protocol. All HART-enabled devices have a corresponding DD file registered with the HART Communication Foundation (HCF) (Helson 2005) that are used with the different field devices.

For a device such as the Fisher DVC6000 valve, the DD files are imported into the AlertManager where the configured device-specific symptoms are displayed and can be linked to the fault tree. The faults must be generated from the AlertManager application and then linked to the specific faults that are associated with specific filed devices. Figure 23 shows a "failure" fault being linked to the device specific symptoms that must be active before the fault will produce an alert. For the failure fault tree, ten symptoms were linked to produce the failure alert.

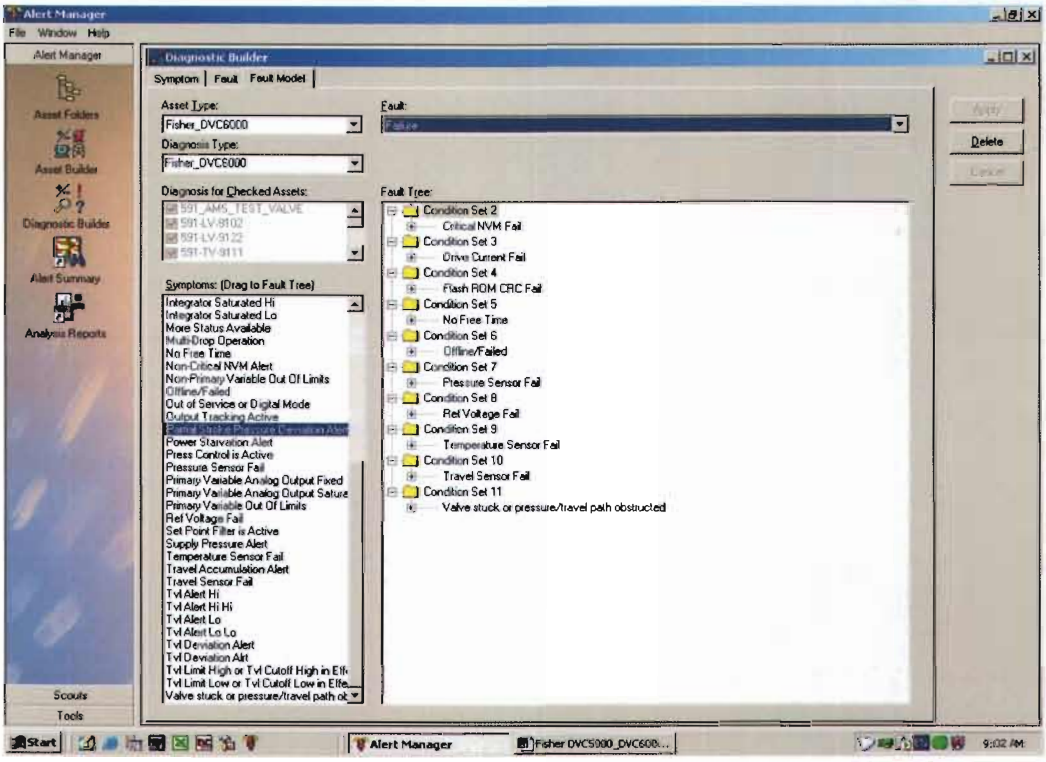

Figure 23: Diagnostic configuration to link symptoms to the fault tree model

The linking of symptoms is performed for all device related faults in order to ensure that the correct alerts are generated. Figure 24, overleaf, displays the configured symptoms from the imported DD files in the AlertManager for the specific

Fisher_DVC6000 valve. No active symptom is shown that can activate a fault condition for this specific valve. In addition Figure 24 shows that there are other multiple asset alerts active (shown in red – Fisher_DVC6000 Multiple Asset Alerts). This is from other valves that are part of the asset type group Fisher_DVC6000, (Joubert 2006:37).

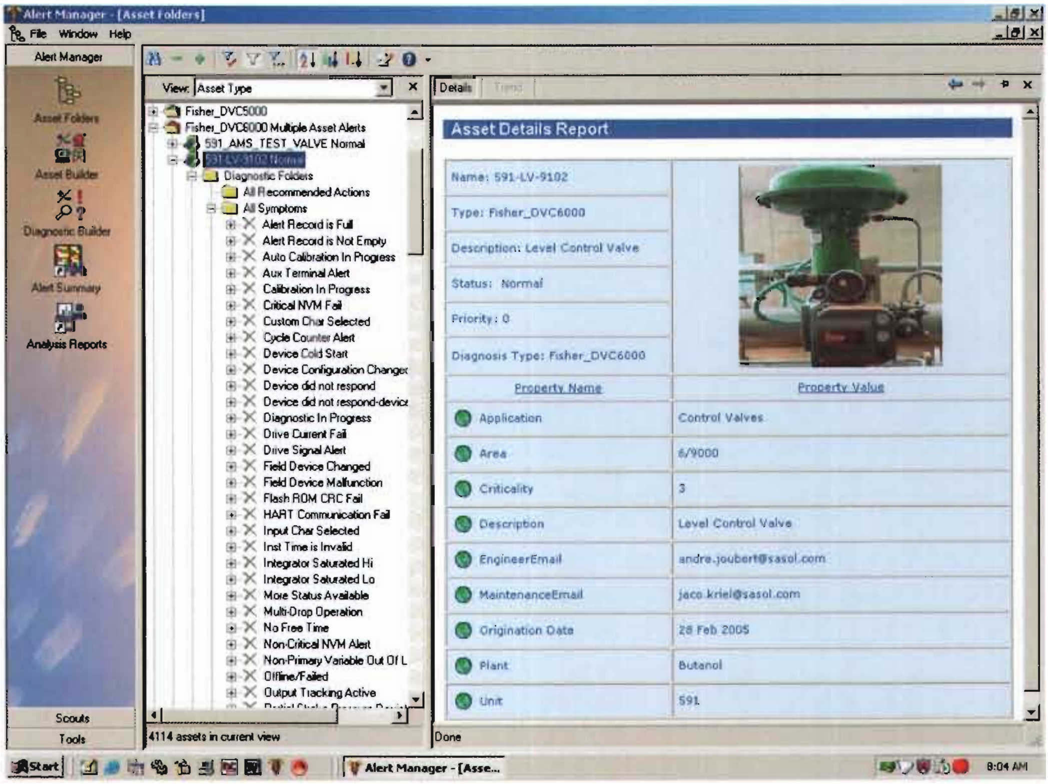

Figure 24: Fisher DVC6000 symptoms display in AlertManager

4.8 PlantScape Hardware

The PlantScape hardware that is configured includes the following:

- PSc_C200 Cntrl Processor module
- PSc_Chassis_Series-A_IO Module
- PSc_CNET Interface Module
- PSc_FF Interface Module
- PSc_FF Link

- PSc_Redundancy Module
- PSc_Serial_Interface Module
- PSc_Server
- PSc_Station
- Network Asset

4.8.1 PlantScape Symptoms

The symptoms for the DCS Hardware are created from events as reported in the PlantScape event log. These symptoms are created in AlertManager by the ExperionScout (see 2.6.2.2) as they become active on the DCS. The system administrator is required to apply the notification philosophy to these symptoms on the first occurrence. Subsequent symptoms will automatically generate the expected notifications.

In addition to the automatically created symptoms, several symptoms are available for the computer hardware associated with the PlantScape Servers and PlantScape Operator Stations. These symptoms are listed in Table 2.

4.8.2 PlantScape Faults

PlantScape symptoms related to DCS problems will have to be included into faults on an ongoing basis as these symptoms will only become available in AlertManager once they have become active in the event log. In addition to these faults the symptoms pertaining to the physical health of the server can be included in fault models as shown in Table 1. These specific faults were obtained from Microsoft operating system parameters used for hardware monitoring.

Table 1: PSc_Server and PSc_Station faults

Fault	Condition Set	Symptom
Resource problem	1	C-Drive % Free Space LOW
	2	D-Drive % Free Space LOW
	3	E-Drive % Free Space LOW
	4	Memory Available LOW
	5	Processor 1 Busy
	6	Processor 2 Busy
Computer Problem	1	Network Activity Absent
	2	Machine down
	3	Route traffic down

Table 2: PSc_Server and PSc_Station symptoms

Symptom	Driver	Description
C-Drive % Free Space LOW	DataScout to PHD	% Free Space < 15%
D-Drive % Free Space LOW	DataScout to PHD	% Free Space < 15%
E-Drive % Free Space LOW	DataScout to PHD	% Free Space < 15%
Memory Available LOW	DataScout to PHD	Memory Available < 128Mb for 6 hours
Processor 1 Busy	DataScout to PHD	Processor free time < 10% for 6 hours
Processor 2 Busy	DataScout to PHD	Processor free time < 10% for 6 hours
Network Activity Absent	DataScout to PHD	Network activity < x Bytes/sec for 6 hours
Machine down	LinkAnalyst	LinkAnalyst is unable to connect to specified machine.
Route traffic down	LinkAnalyst	LinkAnalyst is unable to connect to specified machine.

4.9 Experion Scout

Experion Scout connects to the PlantScape DCS Alarm and Events OPC Server and subscribes to certain events. The events associated with the DCS hardware are then reported to the AlertManager as symptoms.

4.10 FSC hardware

A set of performance and maintenance related points will be created on the DCS for each FSC that is connected by means of Ethernet network cables. These points will be stored in the PlantScape DCS database for use in displays, groups, trending, etc. This information will be collected and imported to the PHD tags and use DataScout to interrogate this information for Symptom/Fault generation.

4.10.1 Integration

It is necessary to create Supervisory Control and Data Acquisition (SCADA) points in QuickBuilder (located on the DCS server) for each FSC parameter used. Each of these SCADA points is then collected via the performance monitoring RDI on the PHD server. Table 3 provides a summary of the created parameters that will be collected and monitored.

Referring to table 3 and 5, the parameters are presented where:

- **Controller:** is the number of the controller connecting to the specific FSC as configured in PlantScape
- **XXX:** is an abbreviation for the plants 591, 592, 593 or 597
- **Y:** number of the FSC for the specific plant
- **Z:** which central part, A and B

Table 3: FSC Parameter Integration

Description	File	Record	Word (A)	Word (B)	Format	PHD Tag (example)
Number of external diagnostic messages	132	Controller Offset	555	556	Integer 2	591_FSC_1A_DM
Information Connection Status	132	Controller Offset	17	18	Integer 2	XXX_FSC_YZ_CS
Current Temperature	132	Controller Offset	577	578	Integer 2	XXX_FSC_YZ_CT
Temperature Alarm	132	Controller Offset	581	582	Integer 2	XXX_FSC_YZ_TA
Maximum Application Cycle Time	132	Controller Offset	541	542	Integer 2	XXX_FSC_YZ_ACT
Process Safety Time	132	Controller Offset	561	562	Integer 2	XXX_FSC_YZ_PST
Number of Forces	132	Controller Offset	553	554	Integer 2	XXX_FSC_YZ_NF
Force Status	132	Controller Offset	551	552	Integer 2	XXX_FSC_YZ_FS
Central Part Status	132	Controller Offset	549	550	Integer 2	597_FSC_1A_ CPS

4.10.2 Faults

The set of faults for this asset type that is configured is shown in Table 4. The condition set is the SCADA point reference built in QuickBuilder (see 2.4.1)

Table 4: FSC hardware faults

Fault	Condition Set	Symptom
FSC Force Fault	1	Forces Present (A)
	2	Forces Present (B)
	3	Force Override ENABLED (A)
		NOT Forces Present (A)
	4	Force Override ENABLED (B)
		NOT Forces Present (B)
General FSC Fault	1	Central Part Status Not RUN (A)
	2	Cycle Time Close To Process Safety (A)
	3	External Diagnostic Messages Present (A)
	4	Information Connection Status Not HEALTHY (A)
	5	Temperature Alarm (A)
	6	Central Part Status Not RUN (B)
	7	Cycle Time Close To Process Safety (B)
	8	External Diagnostic Messages Present (B)
	9	Information Connection Status Not HEALTHY (B)
	10	Temperature Alarm (B)

4.10.3 Symptoms

The set of symptoms for this asset type that is configured is shown in Table 5. The driver shows what interface is used.

Table 5: FSC hardware symptoms

Symptom	Driver	Description
Information Connection Status Not HEALTHY (A)	DataScout to PHD	591_FSC_1A_CS <> 1
External Diagnostic Messages Present (A)	DataScout to PHD	XXX_FSC_YZ_DM > 0
Temperature Alarm (A)	DataScout to PHD	XXX_FSC_YZ_TA < 1
Forces Present (A)	DataScout to PHD	XXX_FSC_YZ_NF > 0
Force Override ENABLED (A)	DataScout to PHD	XXX_FSC_YZ_FS > 0
Central Part Status Not RUN (A)	DataScout to PHD	3 > XXX_FSC_YZ_CPS > 2
Cycle Time Close To Process Safety (A)	DataScout to PHD	(XXX_FSC_YZ_PST - XXX_FSC_YZ_ACT) < 100mSec
Information Connection Status Not HEALTHY (B)	DataScout to PHD	XXX_FSC_YZ_CS <> 1
External Diagnostic Messages Present (B)	DataScout to PHD	XXX_FSC_YZ_DM > 0
Temperature Alarm (B)	DataScout to PHD	XXX_FSC_YZ_TA < 1
Forces Present (B)	DataScout to PHD	XXX_FSC_YZ_NF > 0
Force Override ENABLED (B)	DataScout to PHD	XXX_FSC_YZ_FS > 0
Central Part Status Not RUN (B)	DataScout to PHD	3 > XXX_FSC_YZ_CPS > 2
Cycle Time Close To Process Safety (B)	DataScout to PHD	(XXX_FSC_YZ_PST - XXX_FSC_YZ_ACT) < 100mSec

4.11 Network Assets

Network assets include non-PlantScape servers such as the RTDC, SSBACAM, PHD buffers and NW_Mon. Non-PlantScape work stations such as AMS, FieldCare and the network infrastructure necessary to ensure reliable operation of the DCS and supporting functions are included in the solution. Specific RDI's are developed and implemented on the PHD shadow server to collect data from the Microsoft Windows Performance Monitor interface used to collect several performance metrics from servers and work stations into PHD. These performance metrics are also monitored via DataScout.

LinkAnalyst (see 2.5.2) is used to monitor the health of several critical machines and switches on the process control domain. It has the capability to execute a program when an error is reported (present or returned to normal) for a specific asset. One of the methods of triggering symptoms in AlertManager is via a program called mksymptm.exe that is used in conjunction with command line arguments to generate symptoms in the AlertManager. Mksymptm.exe will be used to generate alerts for critical assets every time LinkAnalyst reports an alert. Refer to tables 6 and 7 for the symptoms and faults. For all the network assets these command line arguments are developed and interfaced to the different assets.

Table 6: Network Asset symptoms

Symptom	Driver	Description
Route traffic down	LinkAnalyst	LinkAnalyst is unable to connect to specified machine.

Table 7: Network Asset faults

Fault	Condition Set	Symptom
Network Problem	1	Route traffic down

4.12 Control loops

Control loops are monitored for maximum performance to ensure that the plant operates at maximum design capability. The LoopScout service (see 2.5.3) enables the user to collect data from the DCS and then upload the captured data by means of various software shuttles to a server at Honeywell in 1000 Oaks, USA. The data is analysed and a report is generated to indicate the condition of the sampled control loops.

4.12.1 Integration

The LoopScout software was installed on the Real Time Data Collector (RTDC) server and the data collectors were initialized to begin data collection from the different DCS systems as used in the Sasol Solvents environment (Figure 25). The results were downloaded every week and a web interface was designed to populate the AlertManager automatically. The AlertManager is able to identify and indicate poorly tuned loops and unacceptable performance parameters (Honeywell 2005).

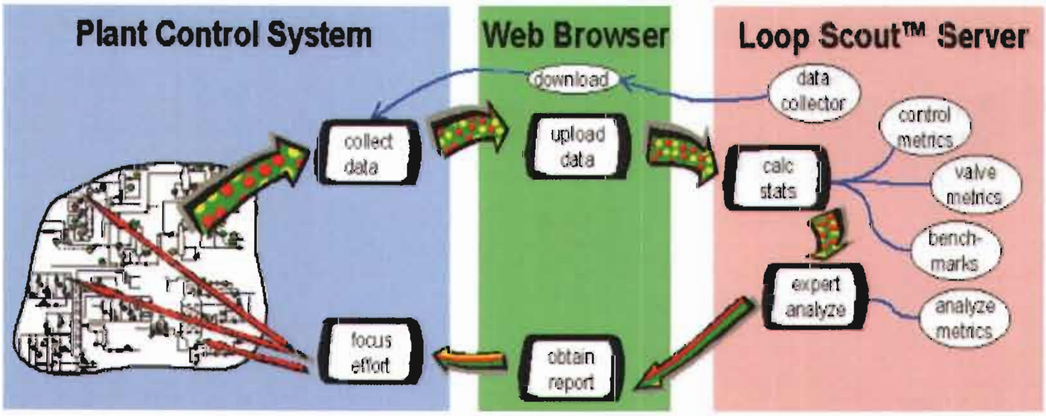

Figure 25: Block diagram of the LoopScout collection and reporting process

4.12.2 Symptoms

Table 8 shows the set of symptoms configured for this asset type. The driver is the LoopScout interface.

Table 8: Control loop symptoms

Symptom	Driver	Description
Inactive	LoopScout	Loop is inactive (values do not change)
Saturated	LoopScout	Control Loop is saturated (OP is at 0% or 100%).
Open Loop	LoopScout	Control Loop is in MAN.
Poor Performance	LoopScout	Loop performance is poor.
Fair Performance	LoopScout	Loop performance is fair.
Acceptable Performance	LoopScout	Loop performance is acceptable.

4.12.3 Faults

Table 9 shows the Conditions Sets that are configured as faults that for this asset type. Poor or fair performance is defined from the actual diagnostic info obtained from the loop information.

Table 9: Control loop faults

Fault	Condition Set	Symptom
Unacceptable Performance	1	Inactive
	2	Saturated
	3	Open Loop
	4	Poor Performance
	5	Fair Performance

4.13 DataScout configuration for FSC assets

By referring to the different symptoms specified in the tables above, the configured data can be observed from the DataScout for the FSC asset in Figure 26. The particulars of the specific symptom configuration are indicated in the DataScout configuration as shown in Figure 24. The configured symptoms and the fault tree for the FSC asset in the AlertManager display are shown in Figure 26.

The AlertManager makes it possible to view the symptoms and faults in one single view. Maintenance staff can see the status of the different types of configured assets configured for the various plants, plant areas and types of equipment.

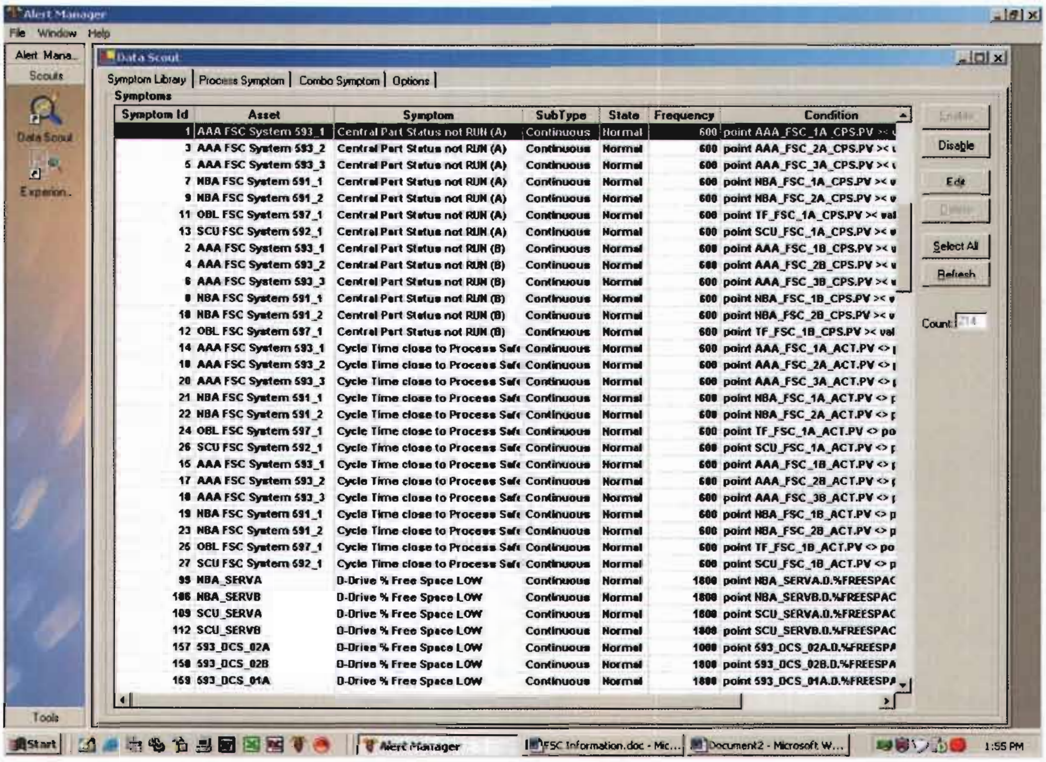

Figure 26: Configured symptoms for FSC assets

It is possible to obtain the history of failures per symptom and fault for every configured asset. This is discussed Chapter 6 which considers equipment history and how historic information is used in Root Cause Failure Analysis (RCFA) and maintenance processes.

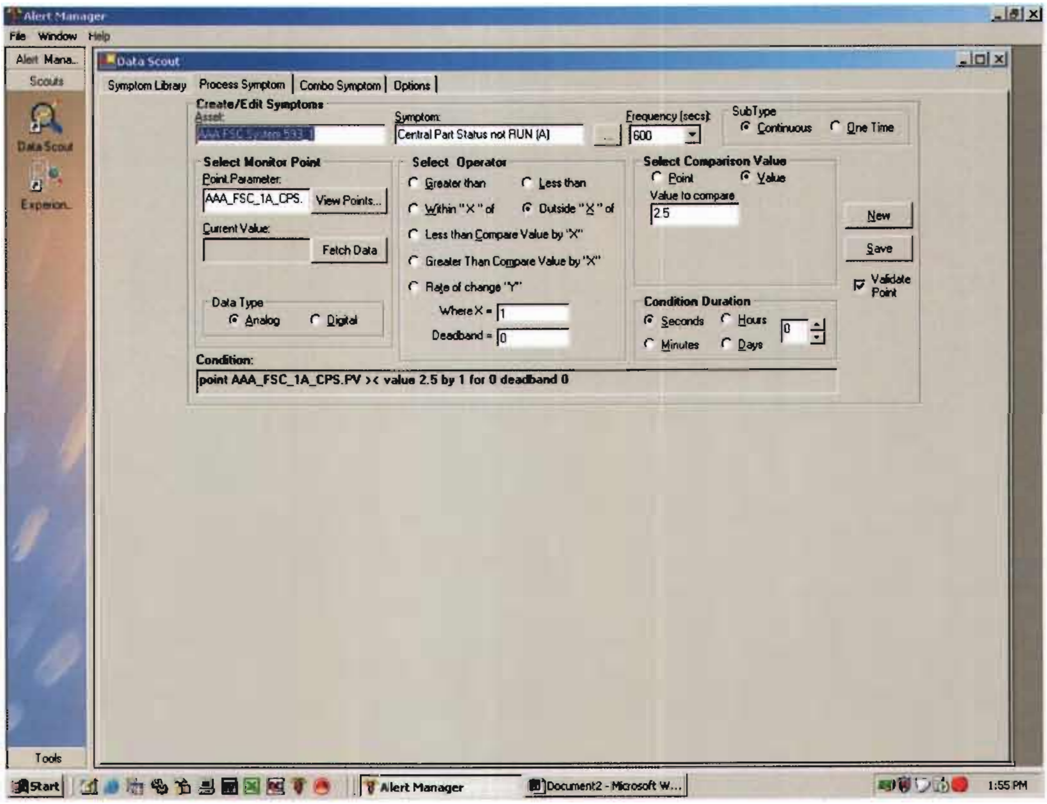

Figure 27: FSC process symptom configuration

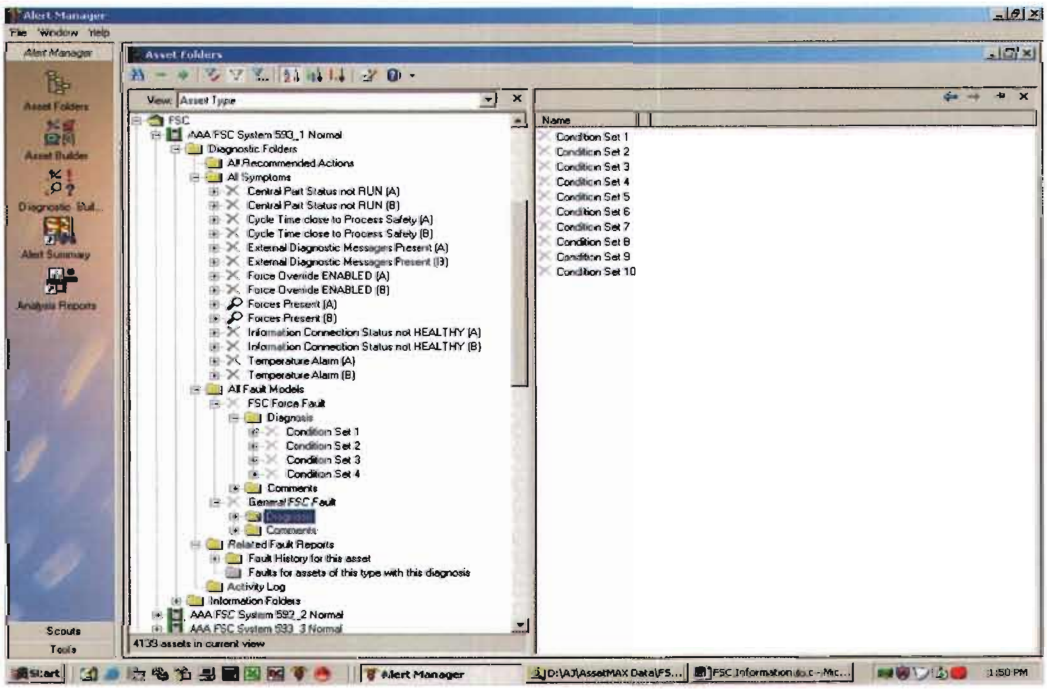

Figure 28: FSC asset view of symptoms and fault tree

4.14 Failure analysis from AlertManager

Failure analysis is an investigation of data obtained from the symptoms and faults of equipment failure in order to the causes of these failures. This information is obtained from the AlertManager and is used in root cause failure analysis (RCFA) and failure modes and effects analysis (FMEA).

Information from AlertManager is configured to address a particular need in the RCFA or FMEA. Reports are generated and in the Sasol Solvents environment, all the reports and views from AlertManager have a custom configuration.

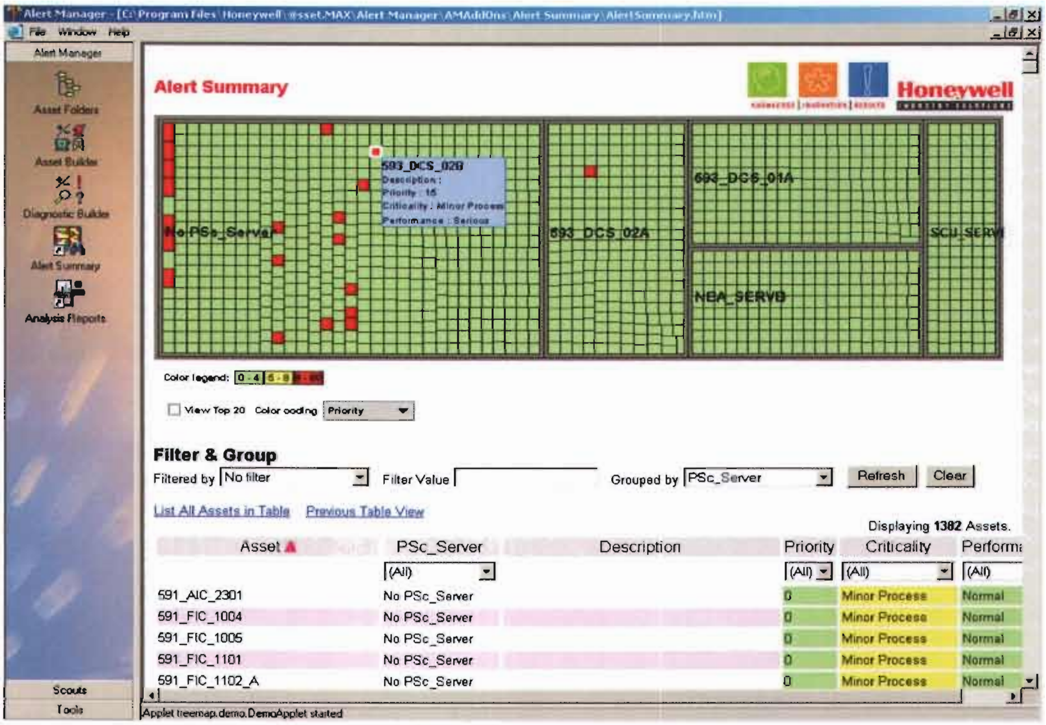

Figure 29: Alert summary of PlantScape assets

The reports were configured according to plant requirements specified in the blue print including specific equipment in particular plant areas, faults per area, faults per type of equipment and faults in a specific time period. Figure 29 indicates an alert summary of the different PlantScape hardware equipment. The server names are displayed and the red blocks indicate certain alerts. If the red block is activated as shown in figure 29, it will show the device in a fault condition. This particular summary will view what the status is of the system being monitored.

Another type of view is shown in figure 30. A specific asset is shown where the faults is generated and corrected. They would either be corrected by the system itself or by intervention of maintenance personnel. The report shows individual faults and a total of faults produced by an asset. This report is generated over a period of a month and this data is used in a RCFA process to determine why the station's resources were running low at certain periods of operation.

By using this type of failure analysis information, it is possible to adapt the maintenance strategies and maintenance procedures.

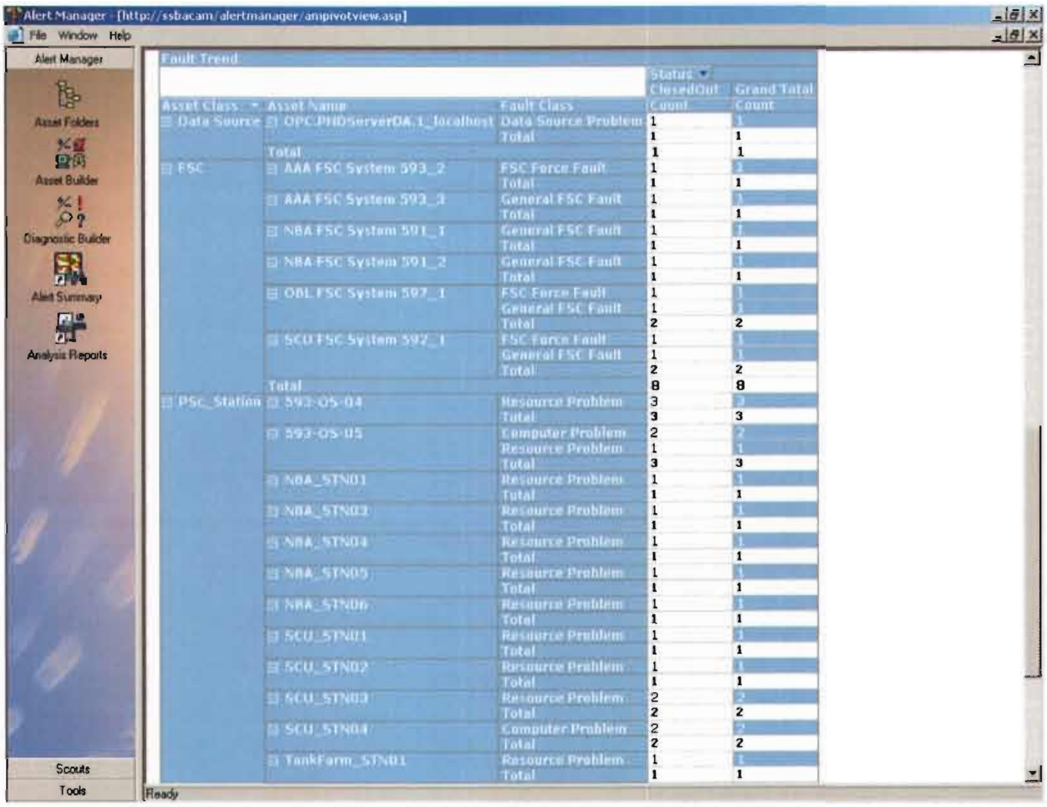

Figure 30: Fault trend report for specific assets

4.15 Root Cause Failure Analysis

Root cause failure analysis is the key to success in a good incident management process (Sasol 2005).

The business benefits of Root Cause Failure (Sasol 2005) are as follows:

- Reduces the re-occurrence of incidents and decreases production loss.
- Focuses on the problem and not on the people.
- Empowers people to solve plant related problems.
- Encourages team interaction between the different disciplines.
- Reduces time spent in circular discussion of the problem.

The personal benefits of Root Cause Failure Analysis (Sasol 2005) are presented below:

- No blame is put on an individual as the focus is on the problem.
- Offers the opportunity for maintenance personnel to give their inputs and make a difference in the maintenance process.
- Fosters creative thinking.
- Exposes employees to good plant maintenance practices..
- Interaction with team members from different disciplines with different levels of expertise.

Root cause failure analysis (RCFA) and failure modes and effects analysis (FMEA) are processes that address hypothetical as well as historical failure modes.

In Stage two, established failure modes are addressed and a modified FMEA approach must be followed to allow people to figure out bundles of related failures on equipment and dope out multiple causes (Blaney 2006). This will allow the production and maintenance personnel to investigate failures more effectively that could have an impact on the plants, people, equipment and the environment.

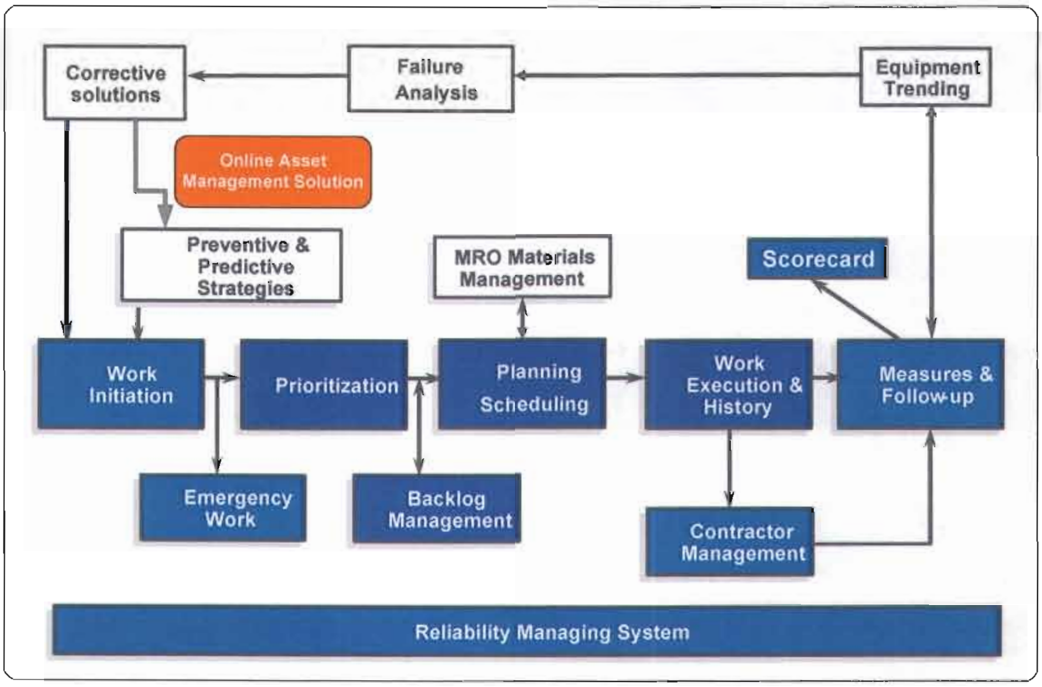

Figure 31: Basic work process for maintenance

Where does failure analysis fit into the bigger picture in the maintenance arena? In the Sasol Solvents environment it forms part of the basic work management process for maintenance as shown in figure 31. This process is followed to do maintenance and the RCFA (root cause failure analysis) and FMEA processes were developed to facilitate the investigation into equipment failure. The different views, reports and history from the AlertManager will be part of the complete process.

The outcomes from the failure analysis must be used to implement corrective actions and solutions as shown in figure 31. It is important to use the analysis data to be implemented in the specific maintenance strategies that will facilitate the work flow process to do the correct amount or type of maintenance (Joubert 2006:38-39).

4.16 Conclusion

This chapter has presented the symptom and fault models for the various types of assets used in the Sasol Solvents environment. The failure analysis processes were shown in the Sasol work process for maintenance. The different DataScout configurations were included to illustrate the setup and configurations that are configured for DCS, FSC and network systems. HART-enabled asset configuration was also discussed in terms of enabling the AlertManager to produce active alerts when equipment or systems are failing or have failed. In the next chapter the asset healthcare block from the SAMI model in stage 2 will be discussed.

CHAPTER 5 ASSET HEALTHCARE

Early detection and notification of potential problems opens a window of opportunity for repair or replacement of faulty equipment, eliminating unplanned downtime and reduces maintenance time and costs (Honeywell 2004:1). Asset healthcare is a concept whereby the status of a plant and all its assets are available to be viewed and managed by maintenance staff to achieve maximum plant availability (Honeywell 2004). A process-wide view must be provided, enabling maintenance personnel to target and more closely manage plant assets that have the greatest impact on business success. This chapter describes the asset healthcare block of stage two in the SAMI triangle shown in figure 32.

Using the open architecture of the solution, it is possible for users to connect to best-in-class assets from a wide variety of manufacturers using industry standard communication protocols like Foundation Field bus, HART, Profibus and OPC (Honeywell 2004:1). These interfaces and system interfacing will be discussed in this chapter.

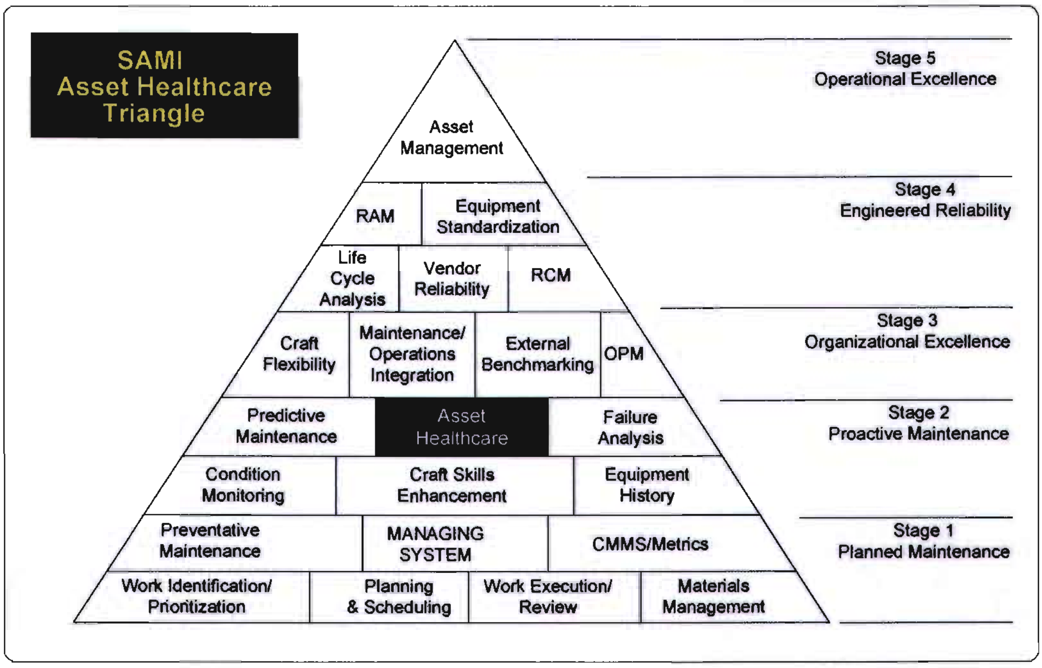

Figure 32: Asset healthcare

5.1 Introduction

The biggest problem in industry today is that asset management systems only access or manage one type of equipment or system, as marketed by companies such as Honeywell, Emerson, ABB, Metso and Endress + Hauser. An example is a solution like AMS that only addresses HART-enabled field devices and smart positioners. All these systems are stand-alone systems and to enable maintenance staff to see all assets on a plant which means that a variety of stand alone systems must be purchased and time and effort must be put in, to monitor the health of the assets (Joubert 2005).

Figure 33 shows, a group of different asset management systems in blocks. These are used in the Solvent site to access the HART-enabled field devices (Joubert 2005). The systems represented are the shutoff valve system managed by FieldCare (see 2.12), linked to the FDM (see 2.9) being interfaced to the Experion PKS R201 subsystem (Honeywell 2006). FDM is used to setup, configure and manage HART-enabled field devices (Honeywell 2006a).

Emerson's asset management system, AMS Ver 7.2 (Emerson 2006) is used to access the HART-enabled field devices and a software snap-on named Valvelink is used to access the HART-enabled smart positioners. This software allows the user to do on-line calibrations and configuration of the positioners, as well as valve signatures to determine the physical status of the valves. These valves are part of the loop management system discussed in the previous chapter.

When the research started, AMS Ver. 5.2 was the first version of the asset management system used on the Solvents site. The software was later upgraded to versions 6.0, 6.2, 6.8, 7.0 and 7.2. Only version 6.0 and 7.0 were used in the research.

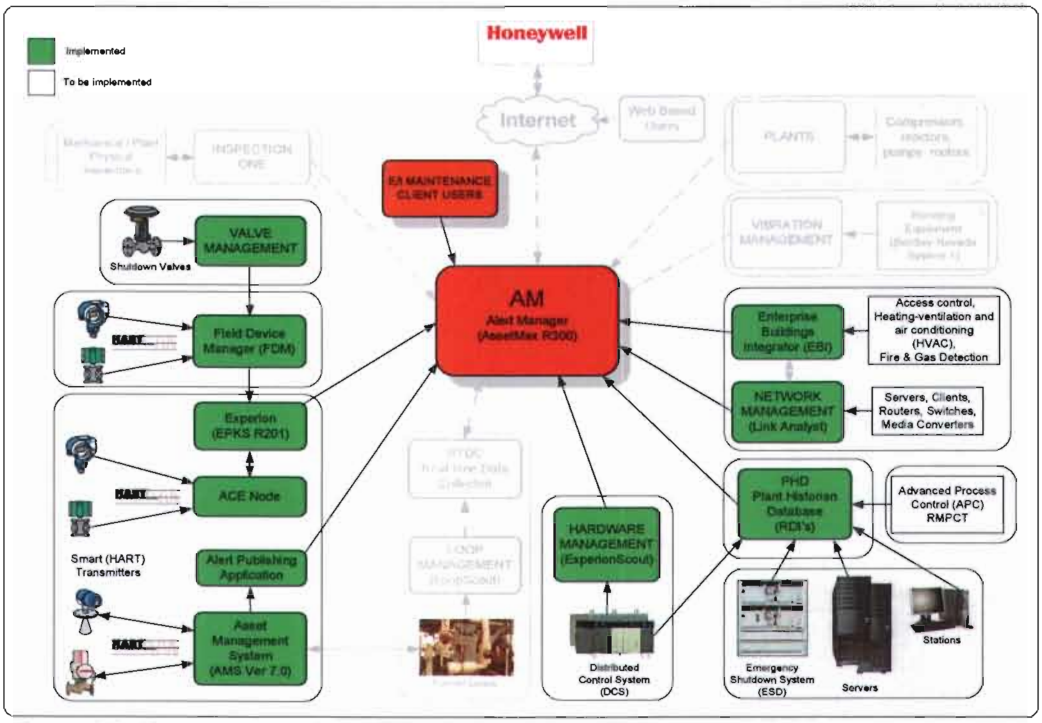

Figure 33: Integration of HART-enabled field devices to AlertManager

5.2 Asset Management Systems Integration

Integration of the diagnostic information from HART-enabled assets is achieved in two ways. The two integration strategies used are:

- Integration of existing Emerson AMS system via a custom developed interface to report symptoms and alerts to the AlertManager.
- Deployment of an Experion™ PKS R201subsystem consisting of the Experion™ PKS R201 DCS and an Application Control Environment (ACE) server is used as software multiplexer, using its native HART asset monitoring capabilities. The systems are integrated to the AlertManager.

Both integrated solutions are implemented on the three plants on the Solvents site.

The two asset management systems, AMS and FDM are connected to a Pepperl+Fuchs (P&F) multiplexer network (see 2.7.1). The network is split up into four multiplexer networks, each for a specific plant. Figure 34 shows the NBA, SCU and AAA System 1 plants connected to the AMS system. The AAA System 2 plant is connected to FDM and Experion™ PKS R201 systems.

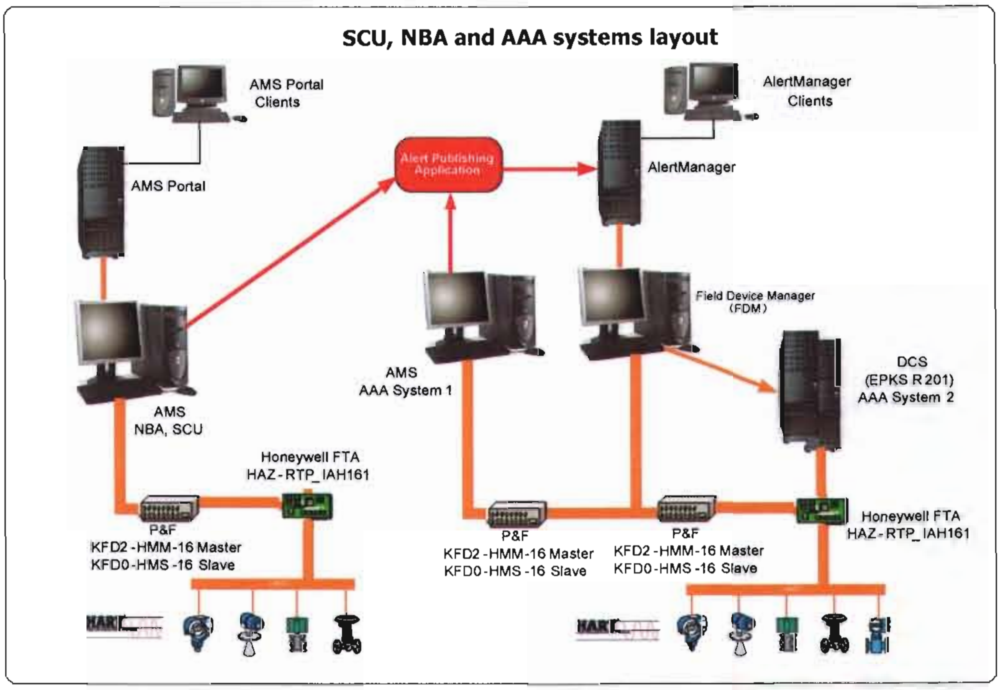

Figure 34: Multiplexer network accessed by AMS and FDM systems

5.3 Asset Management System (AMS)

Only a limited set of diagnostic information is available through the existing AMS interface. This set of information is determined by the elements that the AlertMonitor component is configured to scan for. In order to import the diagnostic information into the AlertManager, a custom interface was developed, utilising the AMS Web Services (Emerson 2005a). This interface will act as a parsing mechanism for the information detected by the AlertMonitor in AMS. Performance of this interface is largely determined by the turn around time of fault diagnostics in the AlertMonitor.

5.3.1 AMS Web Services Alert Publishing Interface

AMS provides extensible markup language (XML) web services that may be used to load HART and FF data into business applications as well as office applications such as Microsoft Excel. The AMS Web Services make various parameter data available that can be used in a typical application retrieving this data. Client applications may be developed on any platform that supports XML web services.

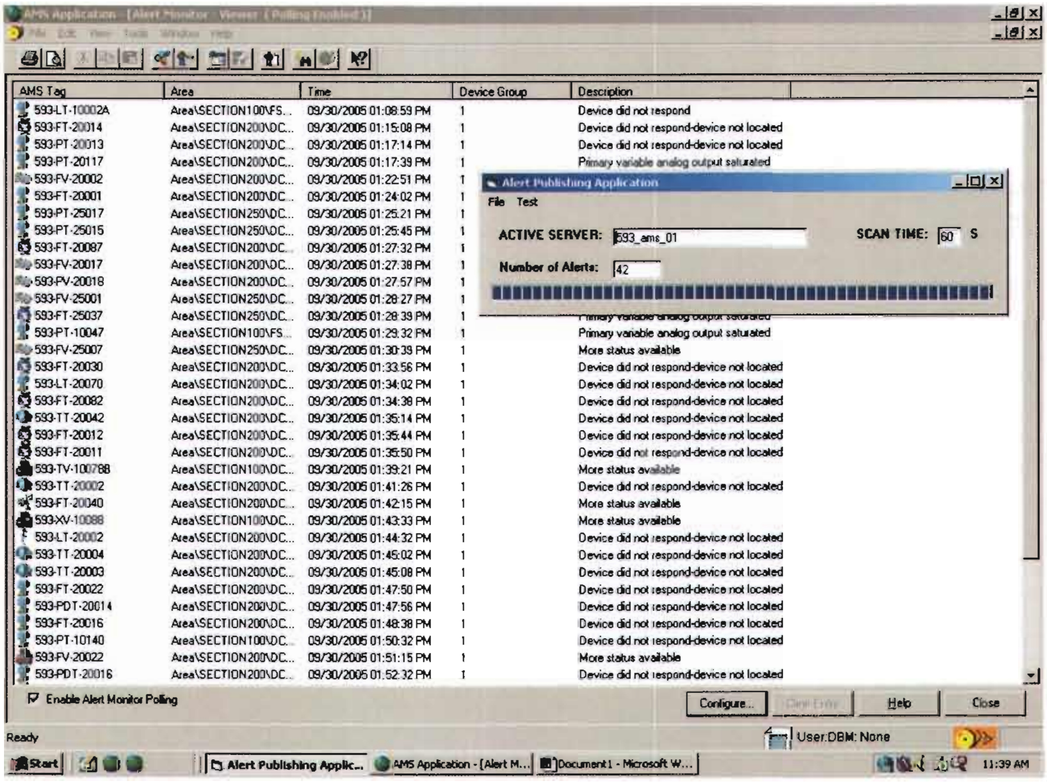

Figure 35: Alert publication application parching alerts from AlertMonitor

The alert application is developed using the AlertMonitor – alerts and poll list. This list produces the alerts from the AMS database. In the background of the running application in figure 35, the alerts that are generated by the field equipment are shown in the AlertMonitor. This is the same data that is made provided by the AMS web services. The developed application/interface uses the alerts from the AMS server which is scanned every 60 seconds, to retrieve the alerts from the database and then transfers the data to the AlertManager.

Figure 35 indicates these connections from the different AMS systems (NBA, SCU and AAA System 1) to the alert publication application and the connection to the AlertManager server which enables the AlertManager clients to access the data retrieved from the AMS systems. The alert publishing application is not used on the AAA System 2 - AMS based system. It also shows the application scanning the AMS database where it retrieved forty-two alerts from the AlertMonitor application running in AMS.

A data flow diagram is developed to ensure that all the correct systems are interfaced with the correct protocols. Performance and PlantScape RDI's is developed for PHD accessing the PlantScape DCS's and the PlantScape/Experion scouts transferring the symptoms and faults to the AlertManager. PHD uses an OPC connection to transfer the symptoms data to the AlertManager. From the FSC systems the scada points were created and linked to the PlantScape DCS. The two solutions are interfaced to the AlertManager via HTTP and API protocols. The Link Analyst application will transfer the network equipment alerts via the MkSymptoms executable. Figure 36 indicates the flow of data and the different interfaces used.

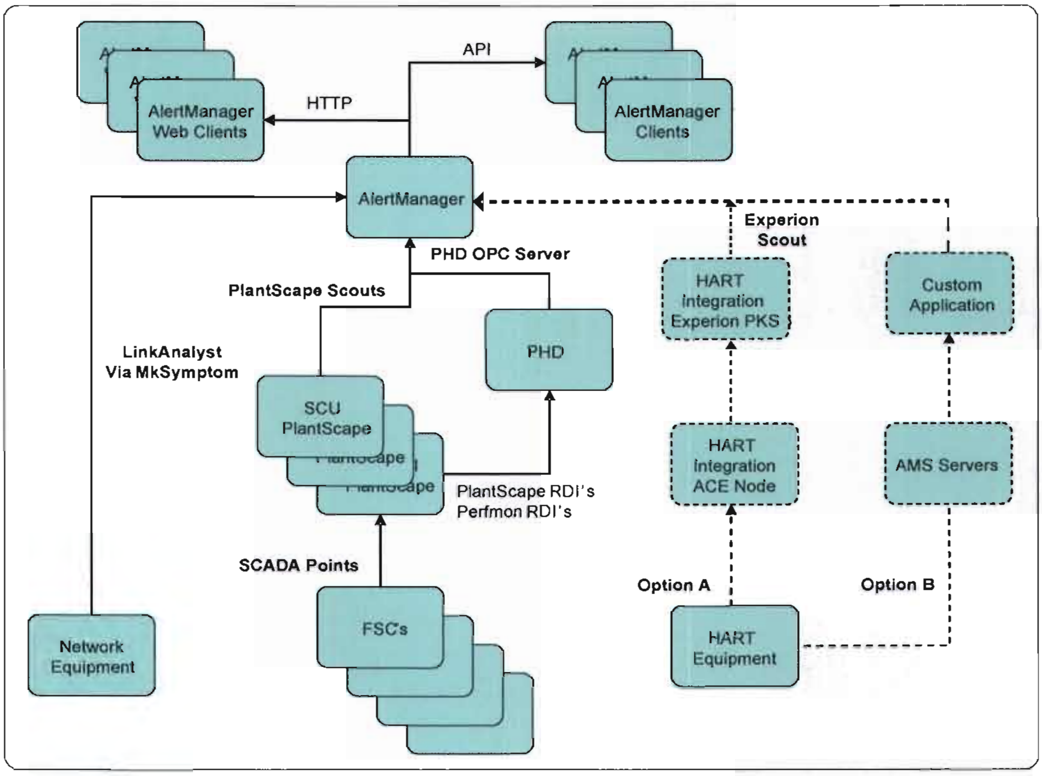

Figure 36: Data flow diagram for the two interfaces

5.4 Experion™ PKS R201

With the Experion™ PKS R201interface all the diagnostic information included in the device description (DD) files would be parsed transparently to the AlertManager infrastructure. All device specific HART Command 48 information provided in the DD files (Pratt 2002:24), will be reported in the AlertManager. This additional information facilitates troubleshooting, monitoring, maintenance and logging of device errors.

With the Experion™ PKS R201 solution a double system check is built-in, to ensure that the data retrieved from the field devices is valid and could be validated. The Experion™ PKS R201 server is connected to the ACE server (see 5.2) which retrieves the HART diagnostic information directly from the multiplexer network.

It serves as software multiplexer, converting the information from the diagnostic information to the required format to be used on the Experion™ PKS R201 software. The ACE uses its own software to detect and view the relevant command 48 data from the devices (Joubert 2005).

The FDM is connected to the multiplexer network stripping the data as previously discussed. This setup is shown in figure 14. The data retrieved from the FDM is fed back to the Experion™ PKS R201 server for validation. By validating the diagnostic data it is possible to ensure that both systems retrieve the correct data from the HART-enabled field devices. From this setup it can also be determined that the FDM reads more diagnostic information from the HART-enable field devices than the AMS system. The AMS system can only show the first seven alert bits whereas the FDM showed 128 bits of data (Honeywell 2006a). This means that more diagnostic information is available that can be used for effective and earlier warning of equipment failure, which would activate typical predictive maintenance actions.

5.4.1 FieldCare (Metso) ValveGuard interface to FDM

FieldCare software (Metso Automation 2006) is used to access and configure VG800 shutoff valves used in emergency shutdown systems as discussed in chapter two. The FieldCare package uses its own HART server and client configuration but has no open platform connections to any AMS or other asset management systems. With the introduction of FDM it is possible to design an interface that will have access to the FieldCare HART server. It is possible to retrieve the diagnostic information from the shutoff valves and make it available for transfer to the AlertManager. Figure 34 shows the FDM connection to the valve management block. The physical connection is done via a RS232 null modem connection. Figure 37 shows the FieldCare software actively monitoring the VG800 shutoff valves connected to the emergency shutdown system (FSC system).

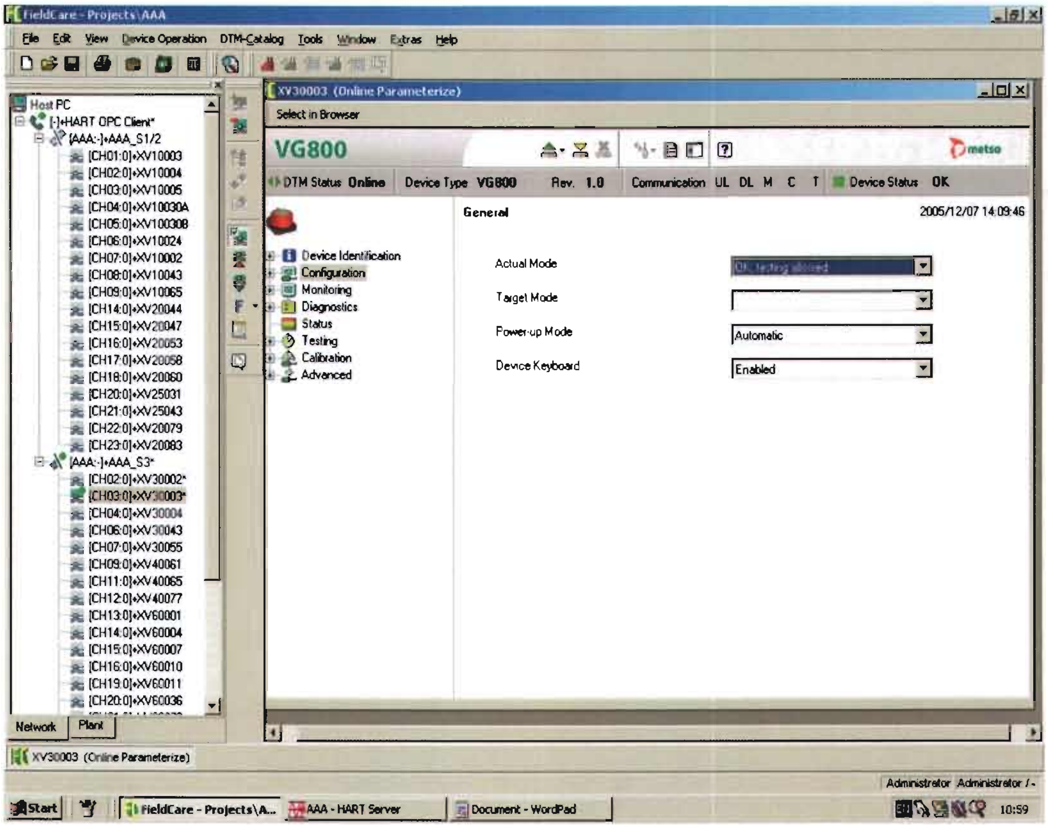

Figure 37: FieldCare monitoring shutoff valves

5.5 Link Analyst Network Alarm Detection

Link Analyst software is an intuitive solution for monitoring critical networks and the routes that connects them (Network Instruments 2006). This stand alone package is used to detect network abnormalities, device and route failures. In the Solvents environment this system is used to monitor the control network as well as the links to the business information network. The network architecture for the total solution is shown in figure 3, on page 14. The software has the functionality of creating maps of the location of servers and stations, situated on the control network. Figure 38 show an example of a typical process plant.

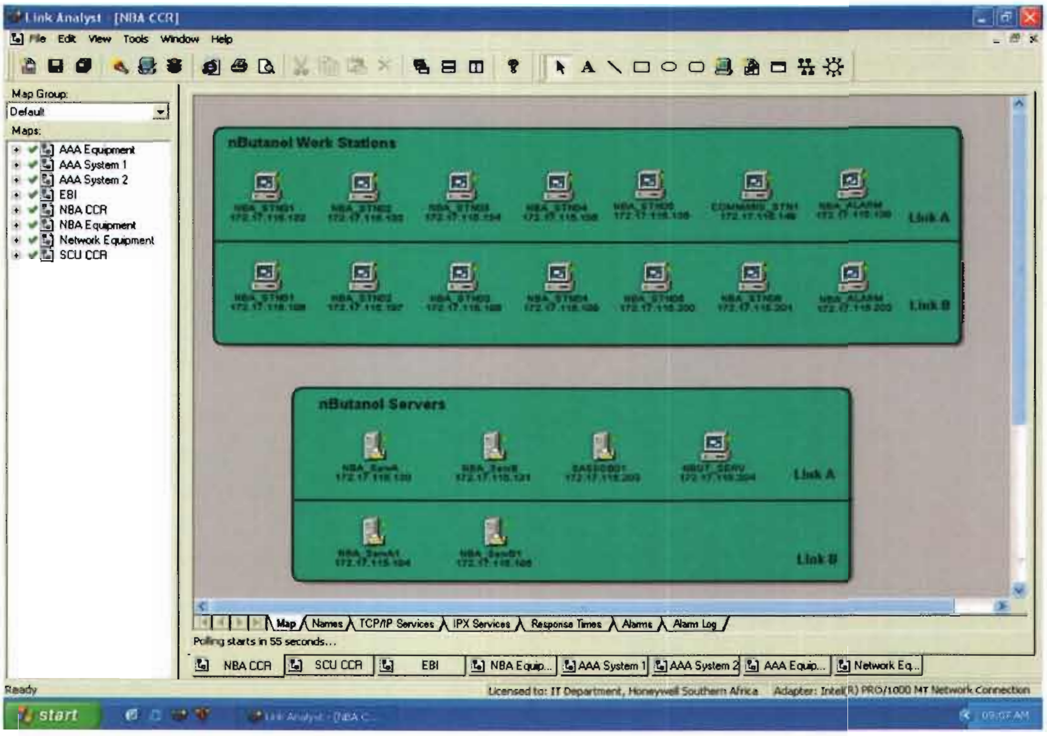

Figure 38: Link Analyst control network layout map

The different maps are created to indicate the specific plant areas and the equipment is also represented in those specific areas. In figure 38 the areas can be seen from the tree display in the maps field, on the left side of the main display. The different maps are shown as tabs at the bottom of the active map. The Plant areas defined are NBA CCR, meaning the presence of the nButanol plant in the area of the central control room, Network equipment and NBA Equipment meaning it is the equipment room in the nButanol plant area.

The need for frequent manual checks of the system led to the decision to have it re-evaluated and to possibly have it re designed. Scripting is written to enable the package to send the alerts to the AlertManager using the MkSymptoms.exe executable. When a network error occurs, the program executes the scripting that activates the MkSymtoms.exe program that parses the symptoms to the AlertManager.

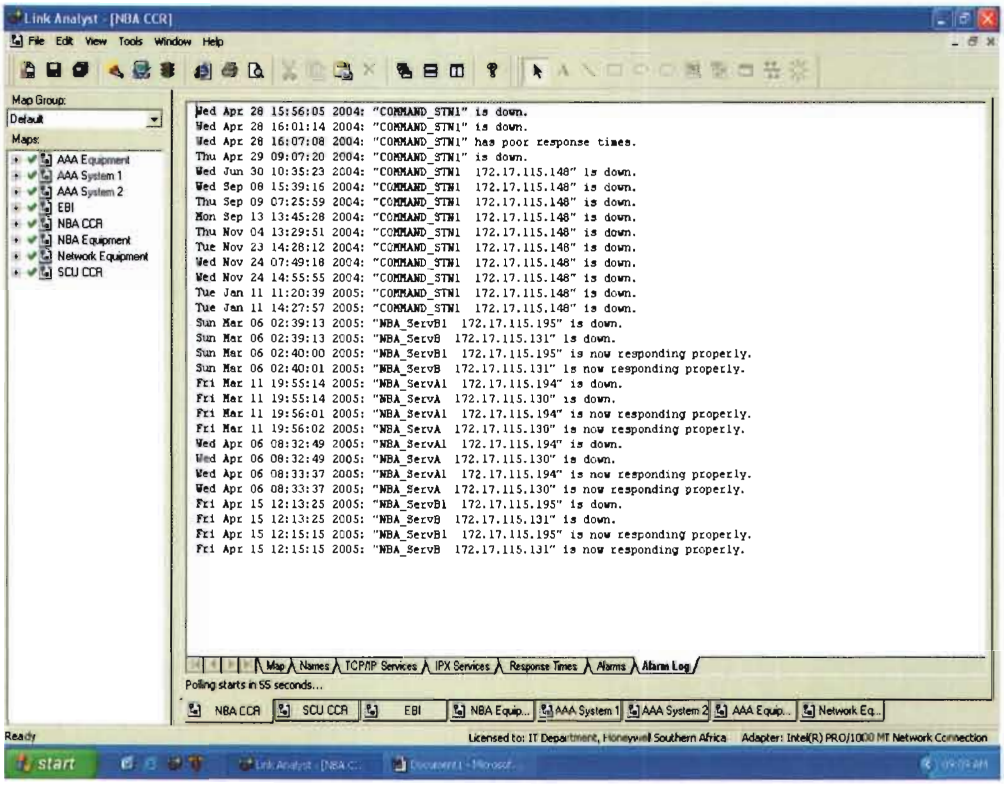

Figure 39: Alarm log

In the Link Analyst software package a log of all the network or device errors and alarms that are generated, is kept. It shows the time when the errors occurred and the time when the situation normalized. Refer to figure 39 for the different errors in the alarm log file.

Using the example in figure 39 it was observed that there was an error on the NBA_ServB1 server. This server NBA_ServB1 is rebooted for maintenance purposes and the error indicated that the server is "down". After the reboot it returned to normal again and the log indicated that the server "is now responding properly". This information is also used in a RCFA process and also forms part of the daily maintenance strategy and checks that need to be done to ensure that all network assets are behaving normally.

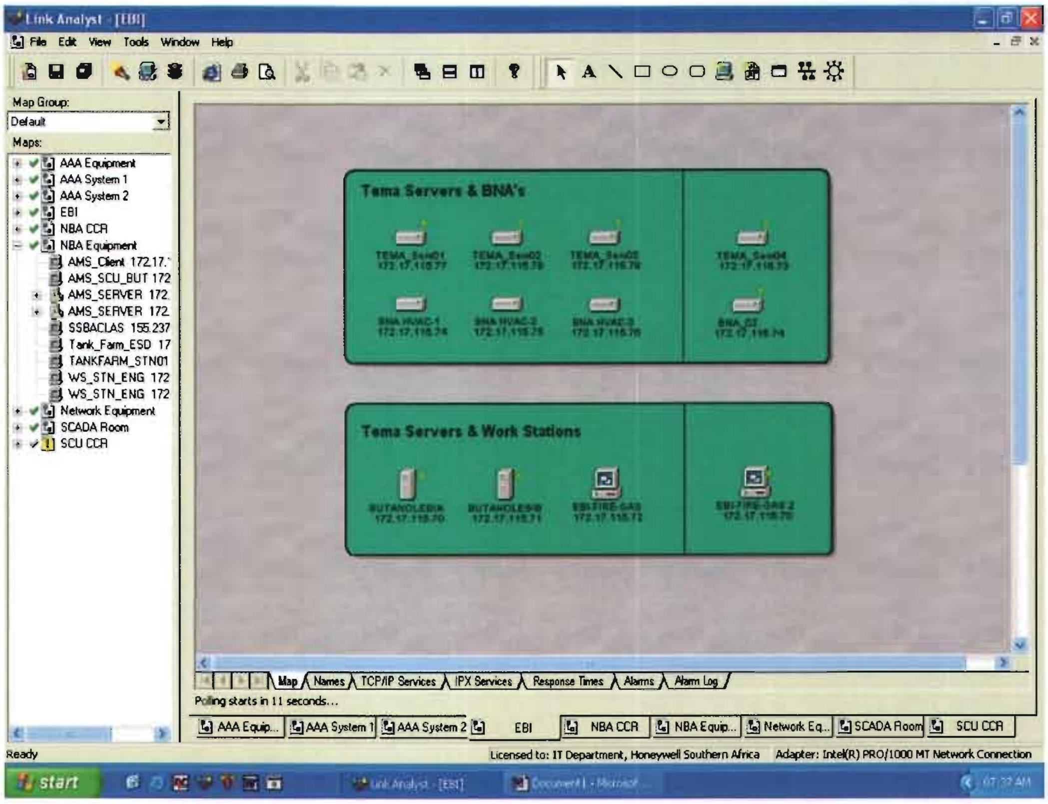

Figure 40: EBI equipment monitoring

The Enterprise Building Integrator (EBI) system (Honeywell 2004) is also monitored by the Link Analyst software. The Tema servers and building network adapters (BNA) that control the Plant Emergency Activation Plan (PEAP) system are also monitored for availability and possible network errors as they occur. The two EBI servers and their clients are monitored as a group since they are situated in the central control room. Tema servers and their associated building network adapters are each monitored in their own group since they are in the different locations on the plant. Note the IP addresses at the bottom of the devices.

This is configured to give faster access to these devices when fault finding needs to be done. The IP addresses would be used for pinging and checks through the different network switches and routers. See figure 40. It is crucially important to monitor this system since it controls such sensitive issues as, fire and gas alarms, and the deluge water system on the different plants; things that pertain to People's safety.

5.6 ProfitController

The ProfitController is used as an advanced process control (APC) engine. It is very important to monitor this system to ensure that if something went wrong in the process or controller, it would be reflected in the diagnostics. Figure 41 shows the configured system in the AlertManager. The different inputs and multivariable variables are monitored by the APCScout.

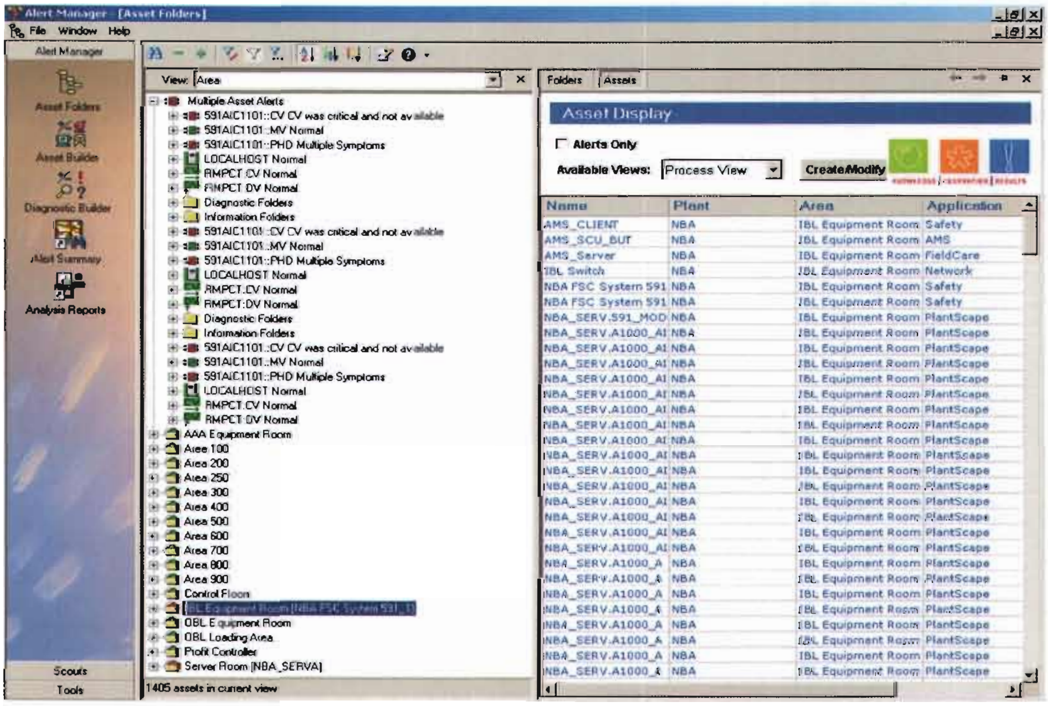

Figure 41: RMPCT assets in AlertManager

From figure 41 it can be seen that there is a problem with the RMPCT controller. The symptoms generating the faults are indicated in red. By using this view it is easier to fault find on the specific system or interface. In this case the analyzer input was indicated, and after analysis it was found that the analyzer in the field had failed. Because the fault report in the AlertManager was so specific, it was easier to take specific corrective action in a very short time.

5.7 AlertManager plant asset views

For all the different systems that were discussed in the previous chapters, the AlertManager asset views will be viewed and the different configurations for the different types of assets will be shown.

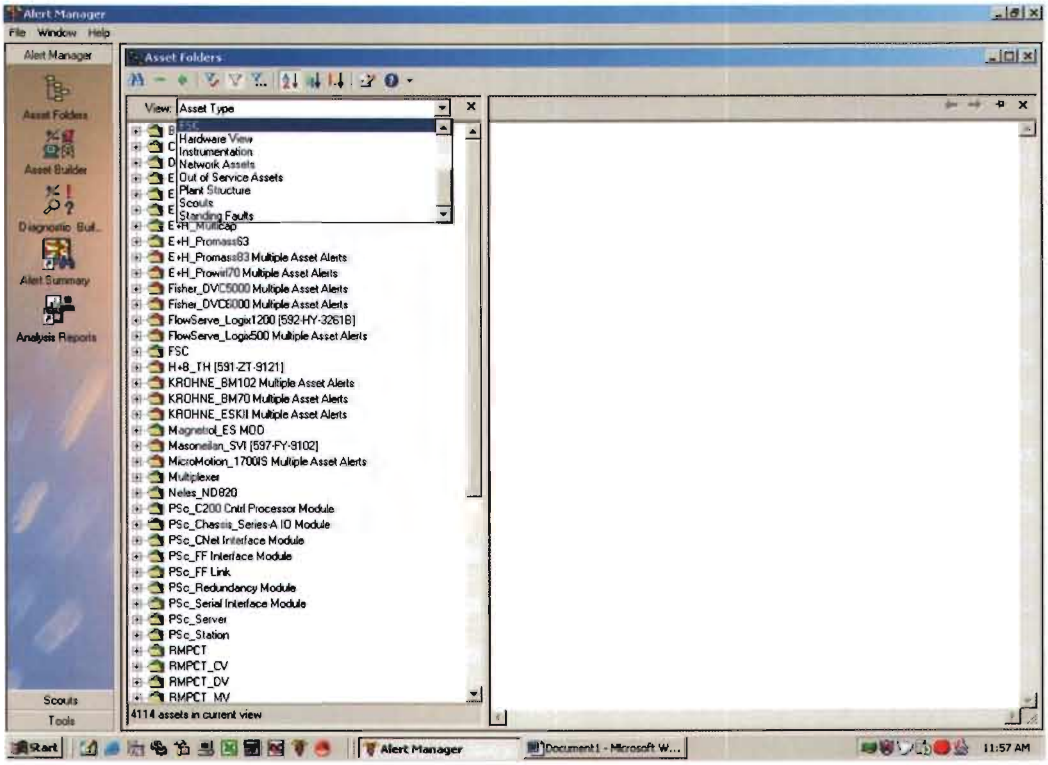

Figure 42: AlertManager view of the different types of asset groups

Figure 42 shows the different asset types that were configured using the Asset Builder. Each system with its related equipment is grouped under a particular view e.g. FSC, where all the FSC systems are monitored. By selecting the specific group view, one can see the configured devices and systems related to this type of equipment.

The plant related views that were configured are as follows:

- Asset Type
- FSC
- Hardware View
- Instrumentation (All HART-enable field devices and positioners)
- Network Assets
- Out of Service Assets (Devices taken out of service for maintenance)
- Plant Structure
- Experion areas (Process areas in a plant configured on the DCS)
- Scouts
- Standing faults (Faults that haven't been resolved)
- DataScouts
- Areas

5.7.1 Asset Type view

The requirements for the configuration of the different plant related views were dictated by process staff and the Electrical/Instrumentation (E/I) maintenance groups as defined in the asset maintenance blueprint and FDS. By configuring the different views one can isolate specific plant areas or equipment within a specified group of equipment. Figure 43 shows all the different assets that are configured for the three different plants on the Solvents site in Sasolburg.

The assets that is built, configured and setup are as follows:

- B+R_ES
- Control loops

- Data sources
- E+H MicroPilotM
- E+H_Promass83
- E+H_Prowirl70
- Fisher_DVC6000
- FSC
- KROHNE_BM70
- KROHNE_ESKII
- Magnetrol_ES MOD
- Masoneilan_SVI
- MicroMotion_1700S
- Multiplexers
- PSc_C200 Cntrl Processor Module
- PSc_Chassis_Series-A IO Module
- PSc_CNet Interface Module
- PSc_FF Interface Module
- PSc_FF Link
- PSc_Redundancy Module
- PSc_Serial Interface Module
- PSc_Server
- PSc_Station
- RMPCT
- RMPCT_CV
- RMPCT_DV
- RMPCT_MV
- Rosemount 3051
- Rosemount 8031Con
- Rosemount 8031pH
- Rosemount 3095MV
- Rosemount 3144

- Rosemount 5081CT
- Rosemount 5081pH
- Rosemount 644
- Rosemount 8800
- Saab Level
- Scouts
- Servers
- Switch
- Workstation
- Yokogawa sc202
- Yokogawa J10
- Yokogawa pH202

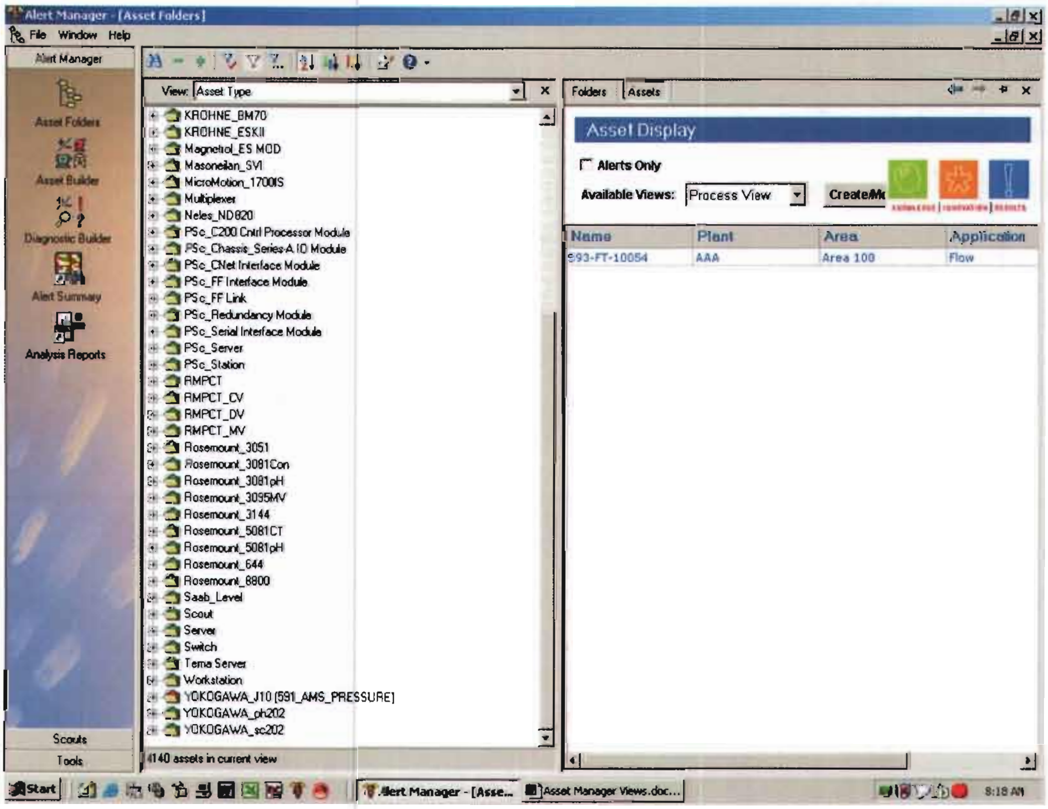

Figure 43: AlertManager view of configured asset per type

5.7.2 Faults by Asset Type

In figure 44, the AlertManager indicates all the possible faults that are currently active for the shown assets. If the folder is red, it indicates a fault that is activated by the configured symptoms for the specific device.

Note the following example; The PSc_Serial Interface Module (Modbus) on the SCU DCS has lost communication. This is the symptom that activated the fault in the AlertManager as shown in figure 44 as example. The DataScout on the AlertManager server failed and its condition is critical as shown in the right hand display. Note the information associated with the specific asset. The plant, the area where it is located and the system on which it is configured, as well as the status, are shown. This information is extracted from six thousand different assets on the three plants, on the Solvents site. This type of view is very crucial in the maintenance process to detect and capture the failure history to enable correcting the problem on the plant where the failure occurred.

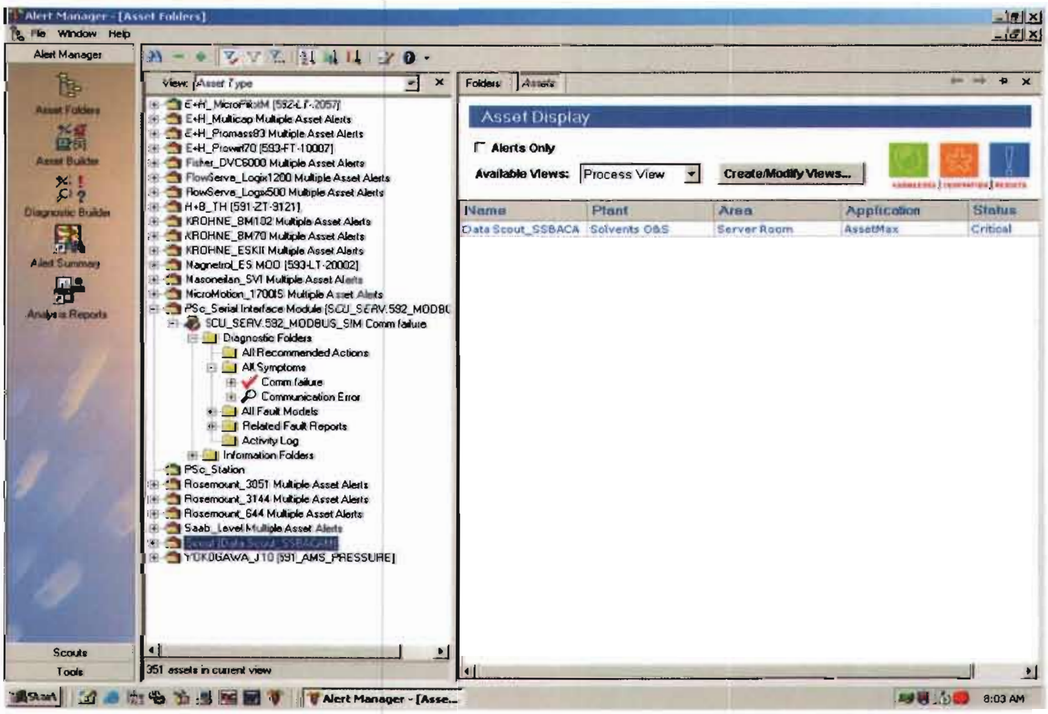

Figure 44: AlertManager view of failed equipment or systems

From the display also shows how many assets are in alarm status. In this case it is three hundred and fifty one assets. This is valuable information that is used in the RCFA process assisting engineers and field technicians to determine where, when and what went wrong with what equipment.

5.7.3 E-mail Message Notification

For each configured asset on the AlertManager, there is an e-mail maintenance message notification configured to send alerts to specific responsible maintenance personnel who will respond as soon as they get the email. A typical mail will be received in configured email program such as Outlook, as shown in figure 45. A typical alert email message is shown in figure 46. In this example the DataScout produced an error.

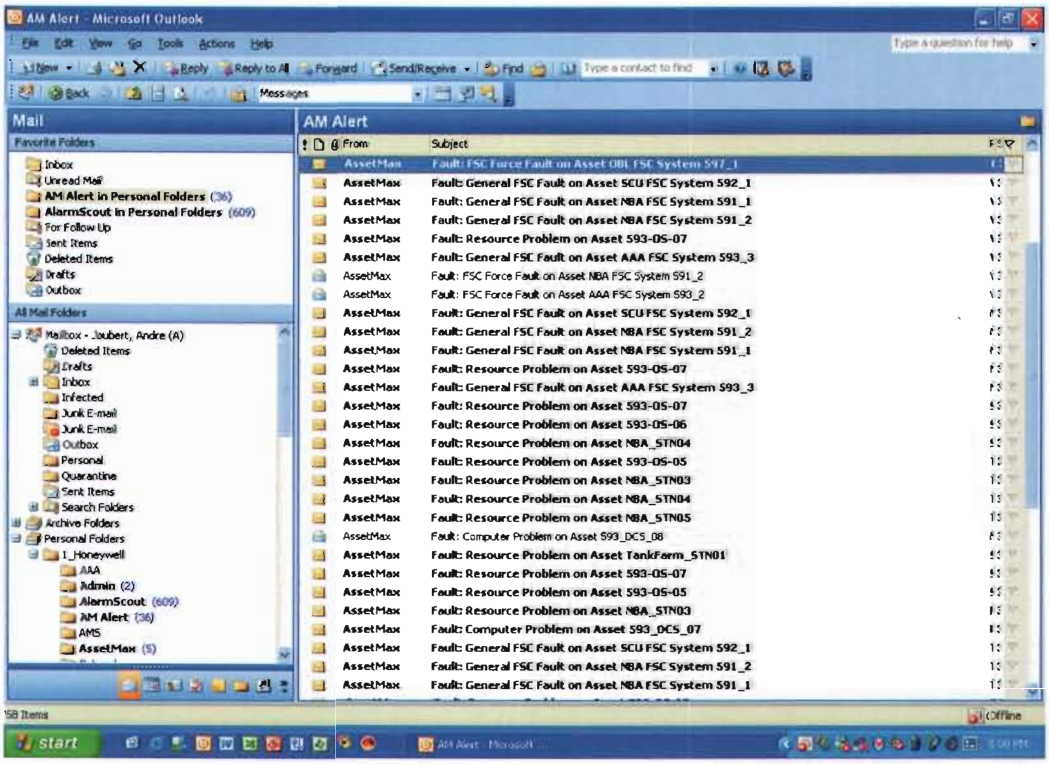

Figure 45: Mail messages in Outlook from the AlertManager

When the maintenance personnel check the AlertManager web clients for the specific faults, the recommended action for fault finding or repairing the system/field instrument will be shown in the asset infrastructure. These actions are part of the adapted work processes as discussed in chapter 3.

As part of the FSC asset configuration, a mail notification is generated if the DataScout detects a process-override condition that is active for longer than 24 hours. By law a process override may only be on for a period of 24 hours. The maintenance manager will be notified by this mail of this condition and this will then be investigated to determine why the process override was allowed for the maximum time.

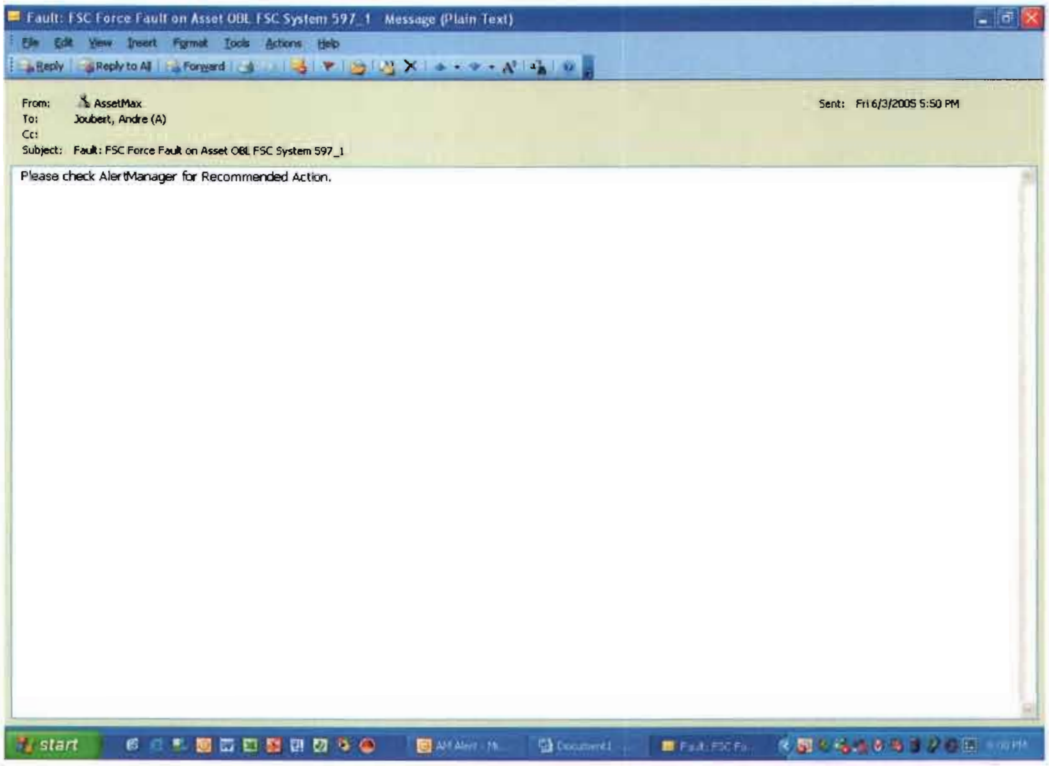

Figure 46: Mail messages contents

The total integration solution is configured and setup in such a way to adhere to all the legal regulations and compliance stipulated by Sasol procedures and the OHSA (Pruger 2005). All the configured assets are fully compliant with these regulations.

5.7.4 FSC Assets

FSC (fail safe control) assets are configured for the seven systems that are part of the overall emergency shutdown system. Figure 47 shows the FSC systems in alert. Three of the configured symptoms indicate active alerts. A closer investigation reveals that the force override key is activated for the A and B central parts (CPU), meaning that overrides can be put on from the FSC navigator work station. The third symptom means that external diagnostic information (A) is available on the FSC's Central Part_A system. This central part must be interrogated to determine where the diagnostic information points. Typically this would be an input that is disconnected from the field and the central part not being reset to clear the alert.

By having this symptom activated in the AlertManager it is then possible to detect problems on these systems without physically inspecting them daily. On the symptom history tag it is possible to see how the different symptoms is activated and returned to normal after maintenance is done. Typical times at which symptoms were active can also be monitored. This is crucial information determining the availability of the equipment and will be addressed in a later chapter.

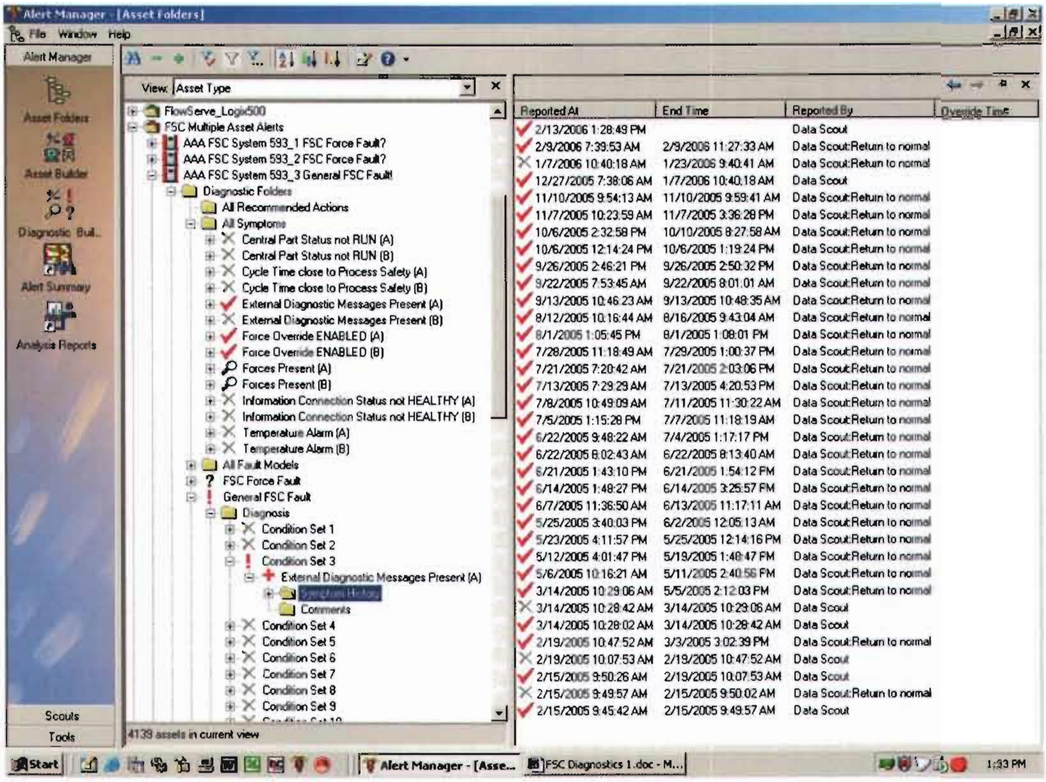

Figure 47: FSC asset information

5.7.5 Plant Structure View

In this view the layout of the different plant areas are shown and the plants have certain areas associated with them. The equipment located in these areas is configured for that specific area. This makes it easy to trace faults on equipment by concentrating on the device which monitors the area in which the equipment is located and a quicker and more effective manner.

The areas shown in the view represent the three plants, NBA, SCU and AAA. Other areas include the central control room, equipment rooms, inside battery limit (IBL) area, outside battery limit (OBL) loading area, compressors (KC101 and KC301) and specific designated areas.

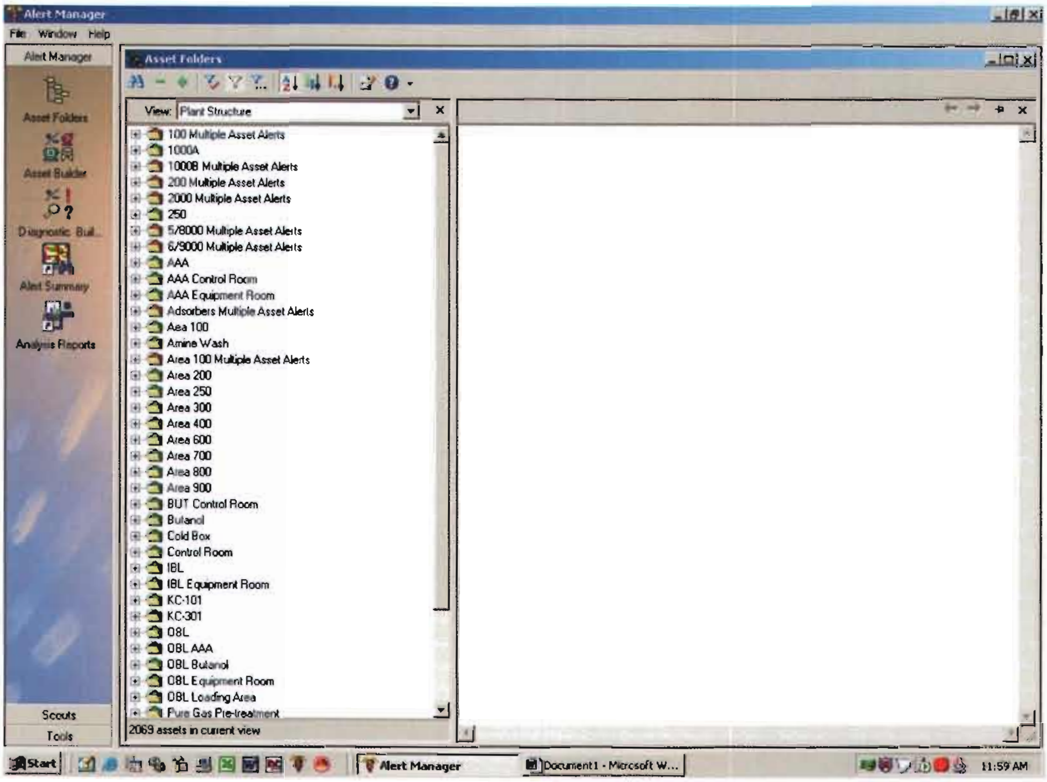

Figure 48: Plant structure view

5.7.6 Hardware View

The hardware view shows all the PlantScape equipment that are being monitored by the ExperionScout as previously discussed. All the IO cards are shown, as well as the C200 controllers and their related redundancy equipment. The PSc_Servers and PSc_Stations are also configured under this view since they are part of the control-net network. In figure 49 shows the different control net interface cards. All of these devices are shown in green, indicating no active symptoms or faults. The information folder per device will indicate the equipment that is configured in that specific group of equipment.

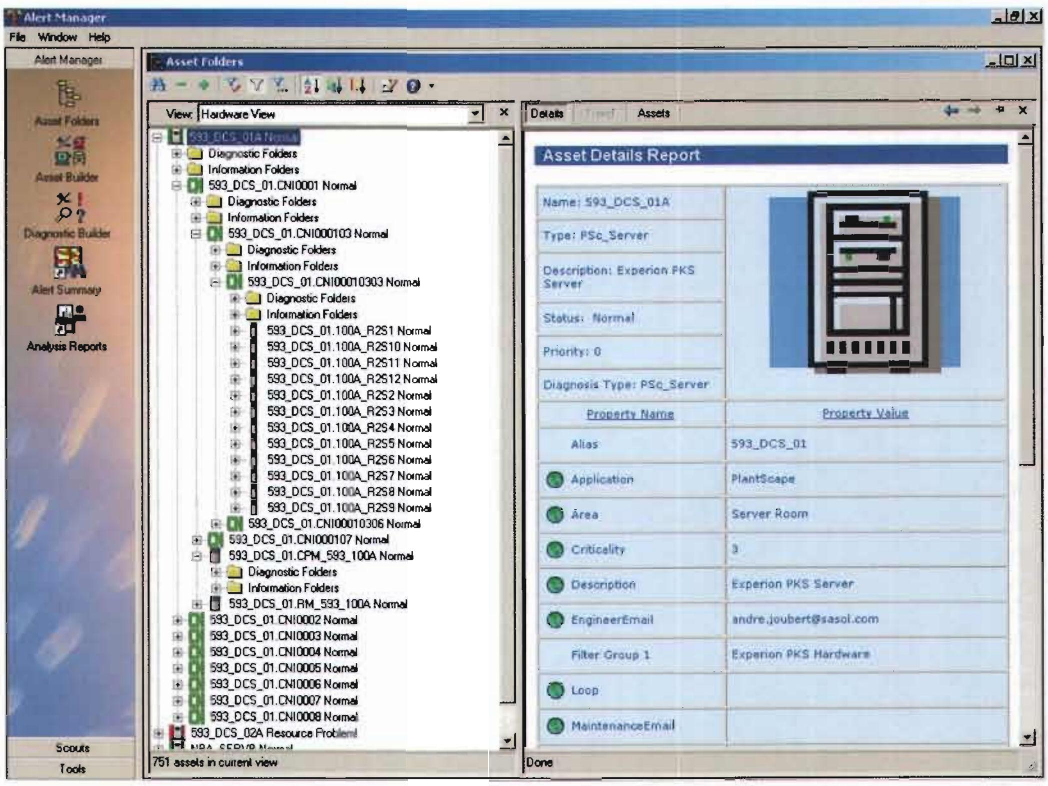

Figure 49: Hardware view

The highlighted asset details are displayed on the asset detail report side (right side of the display page). In this example the 593_DCS_01A PSc_Server details are displayed. The details indicate the area where the server is located, what is the status of the device, who will receive the maintenance or engineering e-mail, the group that the server belongs to and what the status is of the server. In this case it is normal, i.e. there are no symptoms. If it became active, the priority will be activated to indicate the seriousness of the failure.

5.7.7 Network Assets

All the PSc_Servers, servers like PHD and the NW_MON server monitoring the network, PSc_Stations, Tema servers, building network adapters, network switches and work stations (FSC Navigator) that are connected to the control network are part of this view.

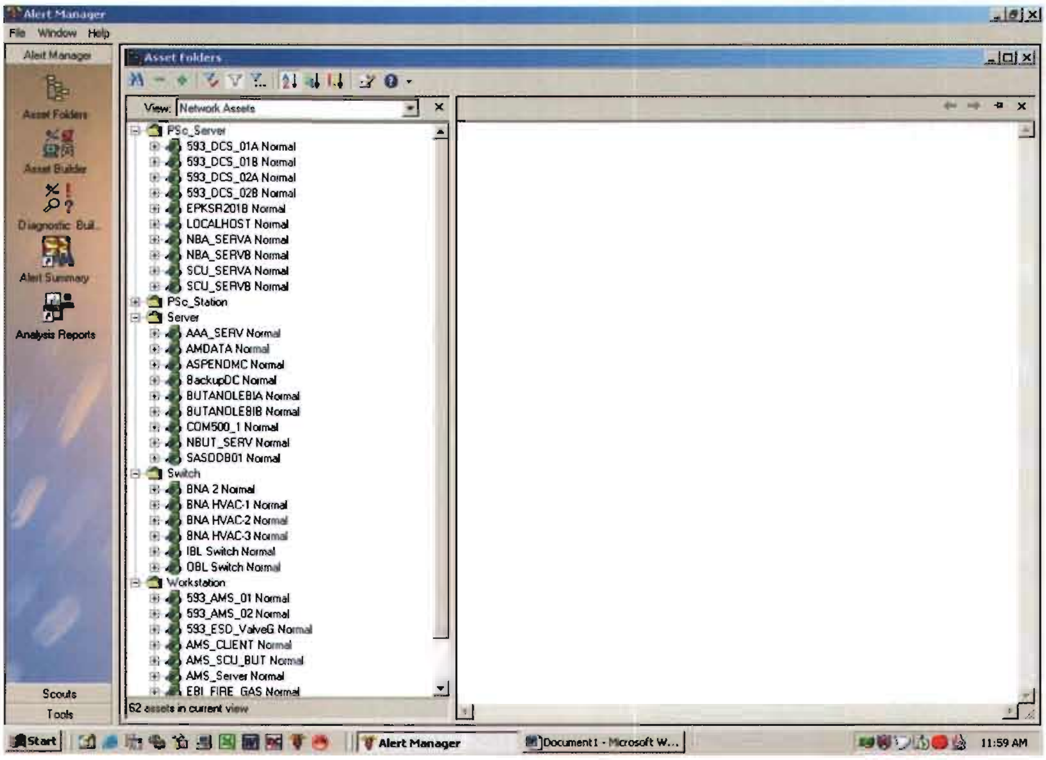

Figure 50: Network view

Link Analysis is used to monitor this group of assets as previously discussed. It is also possible to monitor the hardware resources discussed in chapter four from this view. From the server group it is possible to view the different servers that are not part of the PlantScape servers connected to the control network.

These servers that are part of the control network are as follows:

- AAA_SERV – AAA PHD buffer for the PHD shadow server
- NBUT_SERV – NBA and SCU PHD buffers for the PHD shadow server
- SASDDB01 - PHD shadow server
- ASPENDMC – APC server
- AMDATA - Real time data collector server used for LoopScout
- BUTANOLEBIA – A server for the EBI system
- BUTANOLEBIB – B server for the EBI system
- BackupDC – Domain controller server
- COM500_1 – MCC server that controls and manage the electrical motors

The different AMS systems, the FieldCare (ValveGuard) station, the EBI stations, the NW_Mon station monitoring the control network and the FSC navigator stations are grouped into the workstation group.

5.7.8 Instrumentation View

The instrument view in Figure 51 is configured to show the areas and its associated instruments types that are installed in the particular plant area.

Area 200 in the view example, show the group of instruments grouped as follows:

- Control valves
- Flow
- Level
- Multiplexer
- Pressure
- Temperature

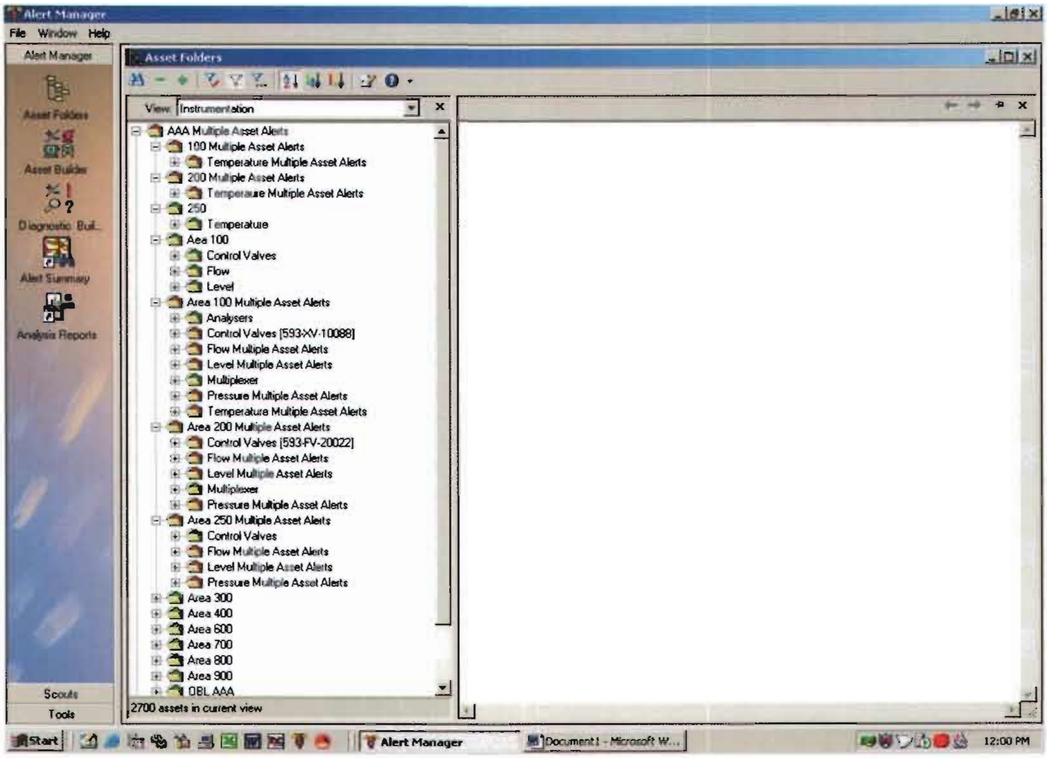

Figure 51: Instrumentation view

Some areas may have analysers also added to the list. For each of these groups like the control valves, the different field equipment in the group is displayed. In the example shown, the 593_FV-20022 flow valve is part of this group and is currently in alert. The asset that is in alert is shown in red and in brackets. If there is more than one asset in the group in alert, it would be shown as multiple asset alerts.

5.7.9 Faults in the last week

All the asset faults that were generated over a period of a week are displayed as shown in figure 52. These faults show both the active and none active alerts. If the asset is opened the history in the log file can be viewed for more detail. This will be addressed in the next chapter.

From the example in figure 52 it is seen that there was thirty one faults during that week. This information will be used in the preventative maintenance strategy and maintenance plans where the faults per week and per month are checked against the key performance indicators (KPI). The KPI's were designed to be a measurement of the plant equipment status and health and this data is linked back to the SAMI model to determine the type of maintenance that must be done. The KPI's will be discussed in the next chapters as part of the asset maintenance process.

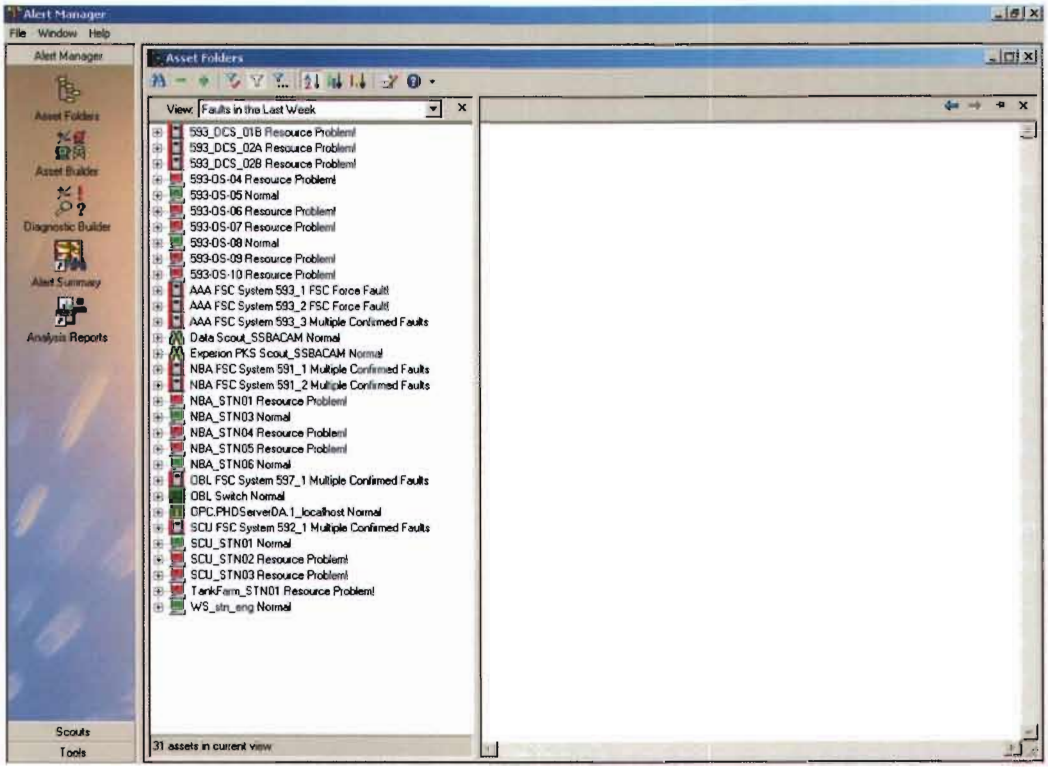

Figure 52: Faults in the last week view

The maintenance staff uses this view to verify that faults generated by the equipment are captured and that defects are generated in SAP which is Sasol's computer managed maintenance system (CMMS). This is an action to ensure that all faults are resolved.

5.7.10 Control Loops

As discussed in the previous chapter, LoopScout is used to monitor the control loops on the different plants. The uploaded and processed data that is received from Honeywell in Thousand Oaks, USA will be fed back into the AlertManager by an interface that is developed to retrieve the diagnostic information for the control loops. The diagnostic symptoms were discussed in chapter 4.

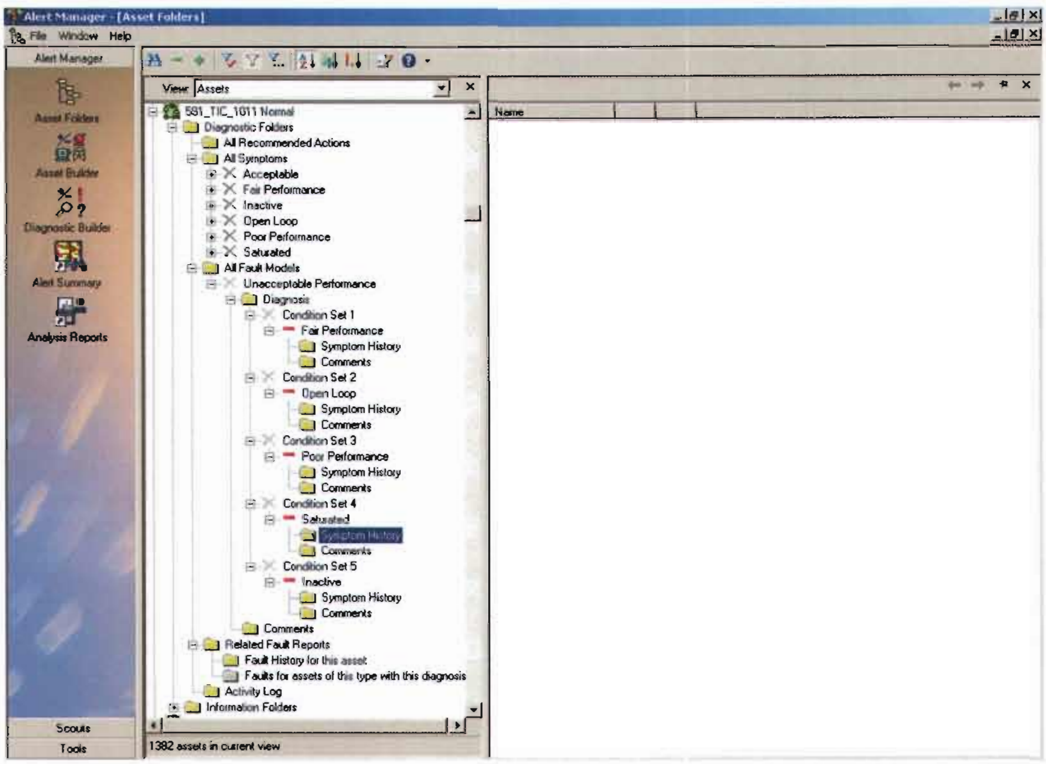

Figure 53: Asset view showing control loops

Honeywell produces a flat file for all the configured control loops and a separate diagnostic report per loop. The different reports will be discussed in a later chapter. The flat file interface strips the data from the flat file, and parses it into the AlertManager to produce the mentioned symptoms and faults that were generated from the report. An example of this is where the loop report produced a typical "Poor Performance" symptom. This would then activate the symptom in

AlertManager. Figure 53 show a temperature control loop with its symptoms and fault tree.

5.7.11 Scouts

For the total solution interfacing the different systems shown in figure 54, two scouts are used to ensure that all the required diagnostic information from these systems is received into the AlertManager. The two scouts, DataScout and ExperionScout are also monitored to ensure that they are active to retrieve the required diagnostic information from the interfaced systems. In the asset details report page the scout details are displayed. The status of the DataScout shown is normal but if it were to fail, the severeness of it would be shown in the sense that no data would be retrieved through the scout. Both scouts are configured on the SSBACAM server. This server is used as the main asset management server for the total asset management solution for the Solvents site.

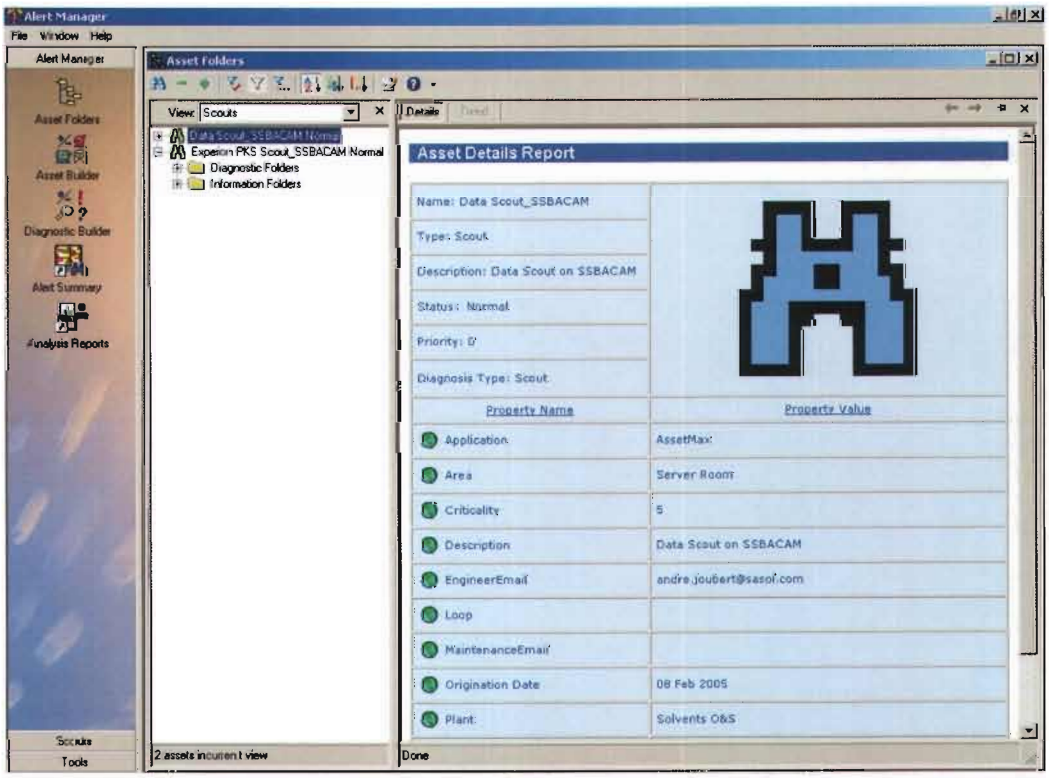

Figure 54: Scouts view

5.7.12 Data Sources

The data sources are the different OPC interfaces to the different OPC servers. Figure 55 shows the different data sources connected to the four Honeywell OPC servers and the PHD OPC server. The OPC servers used on the Honeywell DCS are the HWHsc.OPCServer. When third party software needs to retrieve or access data from these DCS systems, the OPC client from the third party software must interface to this HWHsc.OPCServer on the DCS.

These OPC interfaces are monitored to ensure that all the data needed from these systems is functional. Symptoms and fault trees are configured for these interfaces. All the associated asset information for the data sources is configured. This can be seen in figure 55.

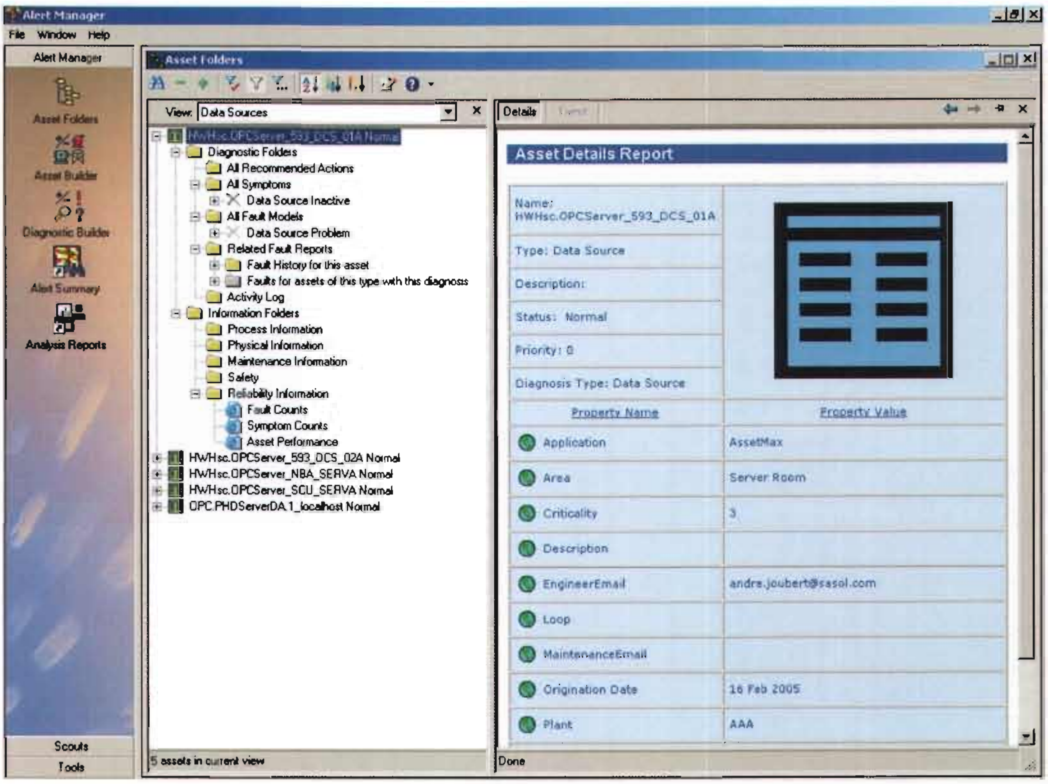

Figure 55: Data sources view

5.7.13 Experion Areas

Within the PlantScape DCS, certain processes, equipment or plants are configured according to specified areas. These areas are not linked to a specific plant area as previously discussed. Experion areas address certain alarms philosophies such as what alarms must be activated for what process or equipment such as a compressor, different views to operators and views to other plants using distributed system architecture (DSA) configurations.

Figure 56 shows the equipment in the Experion areas and non-Experion areas. PlantScape hardware associated with the Experion area is configured in such a way that the equipment generating alarms can be viewed to ensure that they are on line and healthy. In figure 56, Area D41 shows the three C200 controllers that controls that specific area of the process. The non-Experion areas are the areas that are not associated with PlantScape hardware.

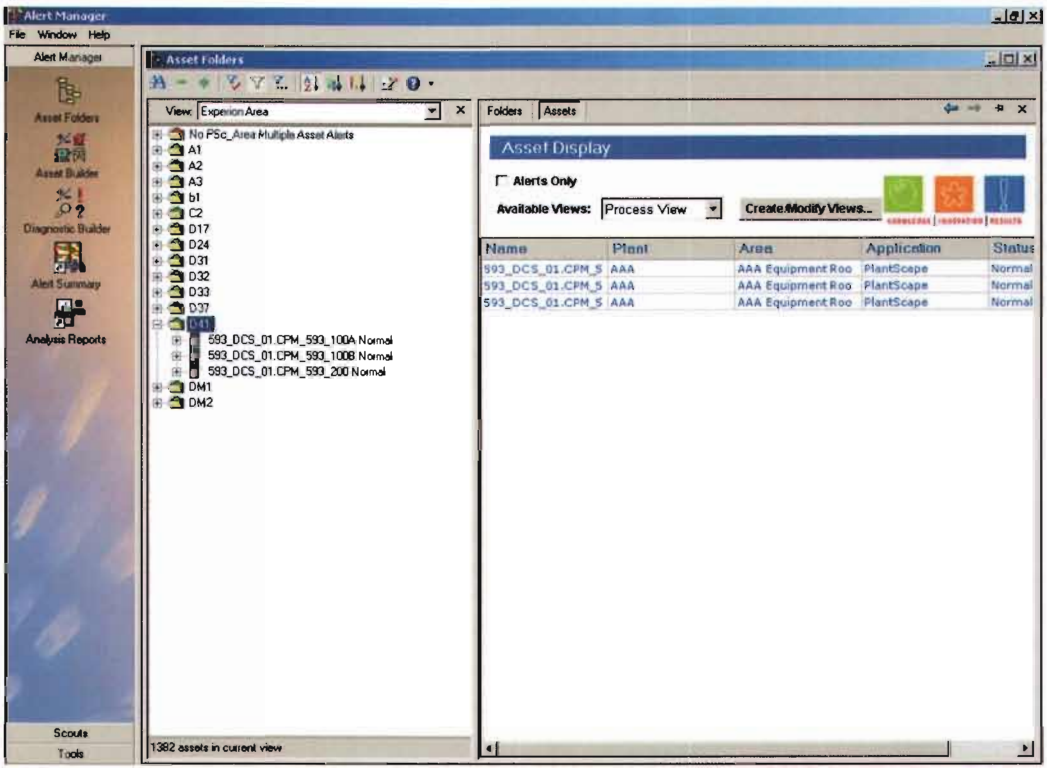

Figure 56: Experion area view

5.7.14 Out of Service View

During shutdown periods it is required to do certain maintenance actions on field devices. When this device is removed from the plant to be cleaned or fixed it is necessary to take this device out of service on the AlertManager. If the device is removed the scouts would pick up that the device is not present in the system and it will start reporting alerts for this device. This would then influence the history data and activity logs. Taking the device out of service before disconnecting it ensures that no false alarms are reported for this device. It is also part of the maintenance process to check that all removed equipment is placed back in the plant and put back into service once the maintenance of such is complete. This view shows what devices are still not put back into service. This example shows a pressure transmitter that is still out of service. At the bottom of the view it indicates how many assets are out of service.

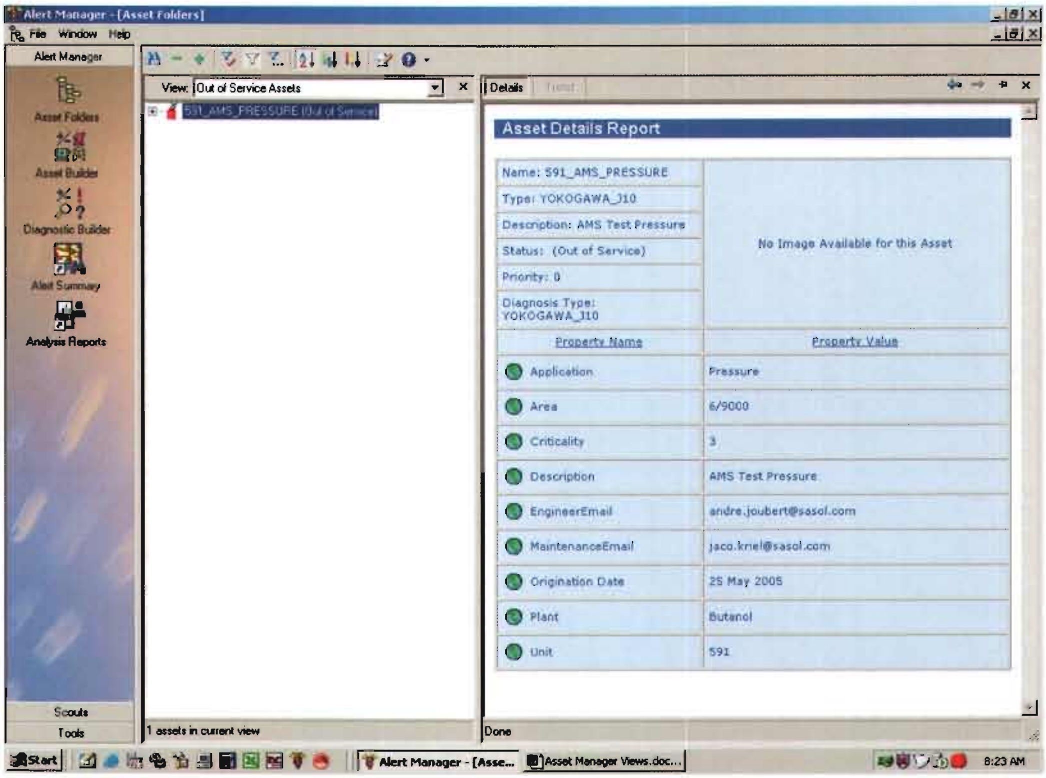

Figure 57: Out of service asset view

5.8 Conclusion

In this chapter asset healthcare of the different field devices and systems were discussed. The developed interfaces and the way they interface to the different systems were reviewed and the views of the configured equipment and systems in the AlertManager were shown and discussed. Asset healthcare information from the different systems discussed in the chapter will be used in the maintenance strategies that is developed and rolled out. In chapter 6 the equipment history block from the SAMI model in stage two will be shown and discussed. The way history is presented and how it will be used in the maintenance strategies will also be discussed.

CHAPTER 7 SKILLS ENHANCEMENT

As the asset strategies become increasingly sophisticated, maintenance and process personnel need to get additional training or have access to data sheets or information bulletins in order to make them aware of new technologies being implemented at modern plants. Improved maintenance strategies demand better maintenance procedures that are supported by up to date maintenance plans (Emerson 2005b).

This chapter will consider the different information available on the asset management solution to address the problem of introducing new technologies and processes as been discussed in the previous chapters. The system must help maintenance and process personnel become more effective and efficient, optimising operations and reduces costs (Honeywell 2004:1).

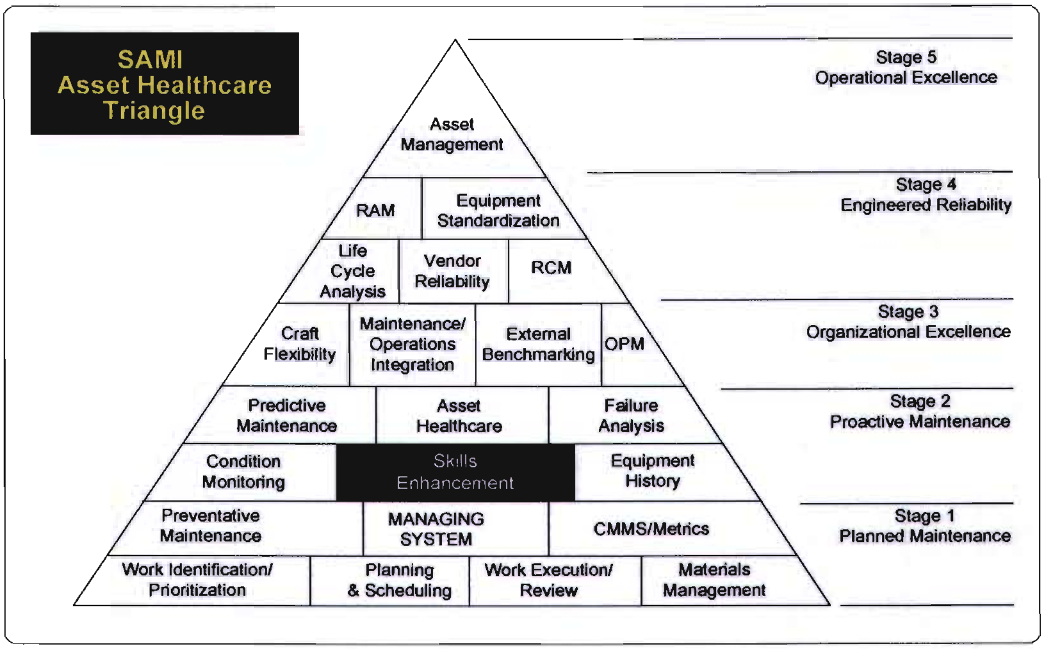

Figure 76: Skills enhancement

7.1 Maintenance Information

Maintenance procedures address the safety aspects and the actual work that must be done on the plant by maintenance staff such as the artisans. Each maintenance procedure is captured in a general procedure that addresses competencies of people working with instrumentation on specific areas of the plants. It is a reference document that will assist artisans and process staff to do a specific task or tasks in a specific way.

Making a maintenance procedure or plan effective requires that it be available at a central point, where it will be used for training purposes for new staff or to refresh existing staff on new field equipment, or what the need may be. This is achieved in the AlertManager. Besides the fact that the maintenance staff can use the software to see what assets are in alert, it is also the central point to access relevant data associated with the asset.

Maintenance procedures were developed for access by maintenance staff from the AlertManager. The procedures were designed as web pages so that it is accessible using any web-based interface software. This would allow any of the maintenance staff to have access to these procedures from the different equipment rooms or central control room.

Figure 77 shows an example of a procedure that is embedded in the AlertManager. It is located in the maintenance folder under the asset folders. If the user double clicks on the procedure, it would open in the right pane. The procedure shown in the example is the one for replacing a FSC module. If the technician is in the equipment room and needs to replace an interface card, he/she can open AlertManager from any one of the web clients to access the required maintenance procedure. The technician can then refer to the procedure to make sure the correct replacement steps are followed.

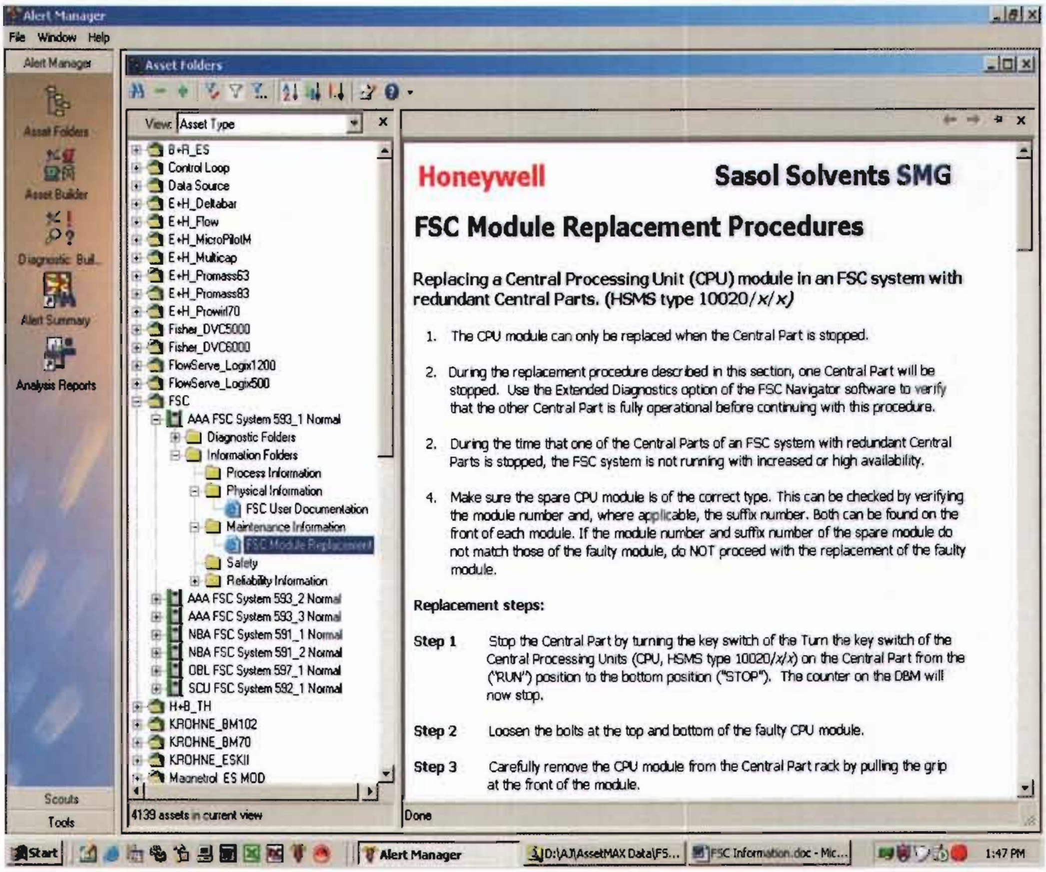

Figure 77: FSC Module replacement procedure

For all the assets configured in the AlertManager, a maintenance procedure was developed. Figure 78 shows the web path to the specific web page based maintenance procedures. The right pane in the example indicates the name of the maintenance procedure and the web path to access its web page.

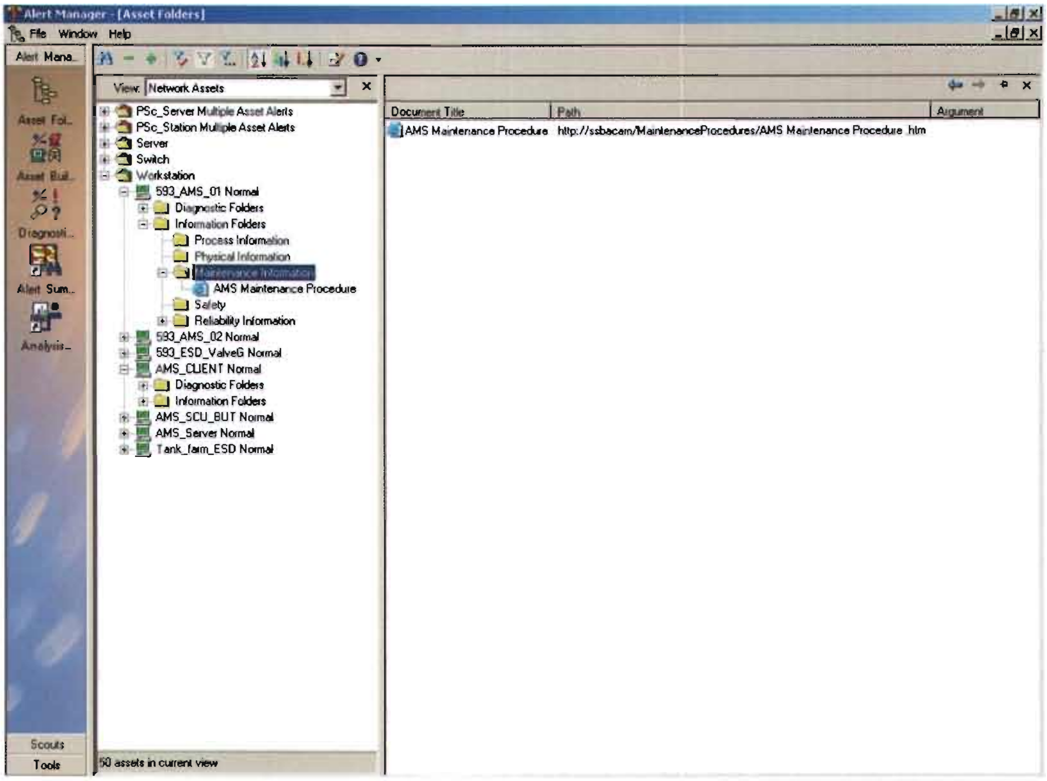

Figure 78: Web path for maintenance procedures

In the maintenance folder, the document name can be seen and this was created in this specific procedure format so that the maintenance staff will identify the procedure with the specific asset. Certain assets are linked to more than one document.

7.2 Physical Information

This folder contains the physical details that are available for the specific assets. Figure 79 shows FSC user documentation which is associated with a specific revision of software which in this case is all equipment related to R60x. The document is in Acrobat Reader format and is activated by double clicking on the "FSC User Documentation" name; the document is opened and displayed in the right pane. This information will assist maintenance staff to use asset related documentation and to learn from the contents thereof.

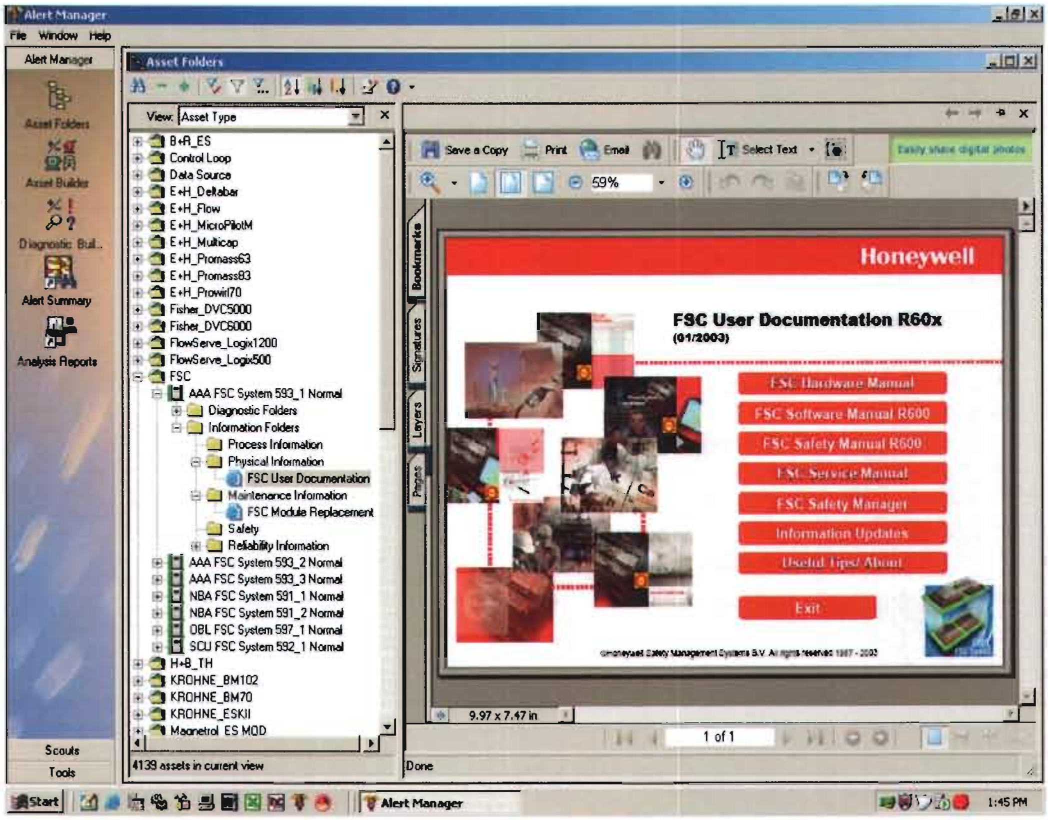

Figure 79: FSC user documentation

In the example shown in Figure 80, the Knowledge Builder software that is supplied with the Honeywell PlantScape DCS is activated to access relevant information for the hardware modules that are installed on the plant. The example shows the redundancy module details. The user can browse within the Knowledge Builder software without interfering with the AlertManager. Additional information can also be accessed from this software as shown in the example, where the user can access specific application notes for the piece of hardware asset.

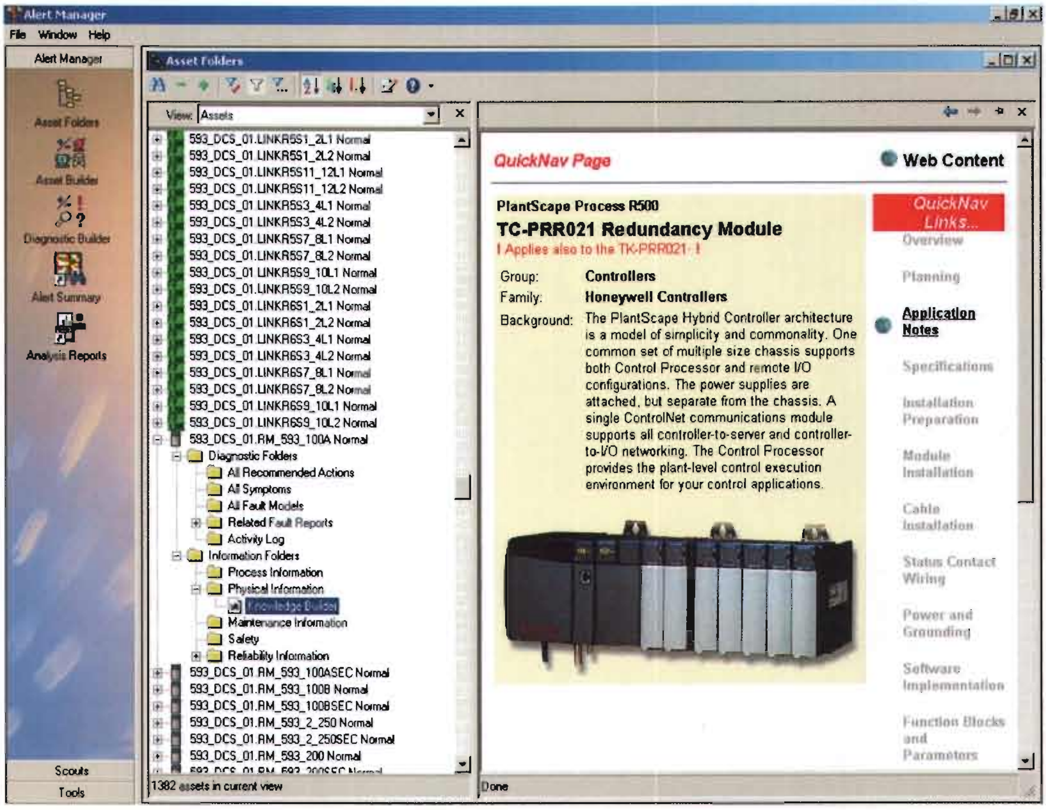

Figure 80: Knowledge Builder software

The example in Figure 81 shows a reference manual that is part of the Rosemount 3051 pressure transmitter asset. This reference manual is accessible via Acrobat reader. All reference manuals for all the HART-enabled field devices were scanned and converted to the .pdf format. These manuals are linked to their referenced assets in AlertManager. Incorporating these manuals into the AlertManager ensures that all manuals and data sheets are at a central point of access.

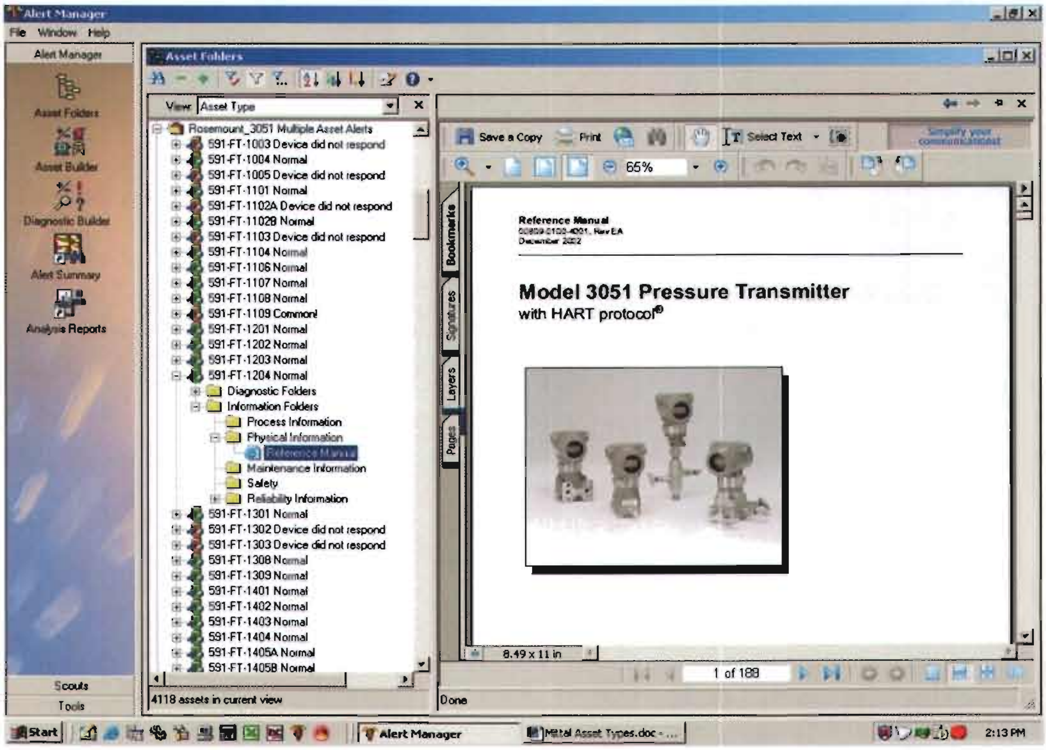

Figure 81: Instrument reference manual

7.3 Process Information

The PHD software suite that is used to allow users to access data may be constrained by License limitation. The Uniformance TotalPlant Process Trend for PHD for example has a limited number of licenses available for access to certain plant trends and views. This software is used to configure certain process trends that may be used to monitor asset tags behavior in a particular process.

The PHD process trend is configured under the process information folder. Double clicking on the name will start the TotalPlant application, and the configured trend for the specific asset will be shown. This can be seen in Figures 83 and 84. These trends were configured in the TotalPlant software and interfaced to the AlertManager. Instead of using four or five licenses to access the software, only one license is used and can be accesses from more that one web-based client using the AlertManager with integrated software produces a major cost saving.

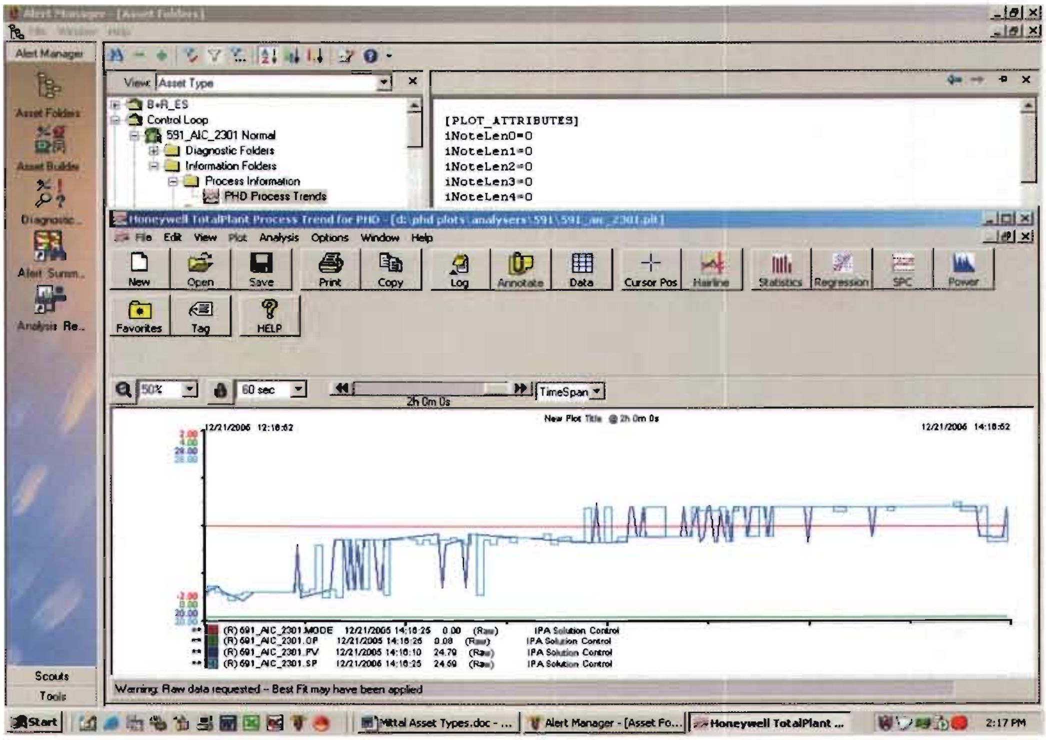

Figure 82: Process trend for an analyzer control loop

The trend data shown in the right pane is in real-time and the asset tags can be monitored especially when doing maintenance on these assets to see whether, for example, an overhauled valve makes a difference to the process. The trend data within the TotalPlant software can still be manipulated as though the user was working on a PHD client.

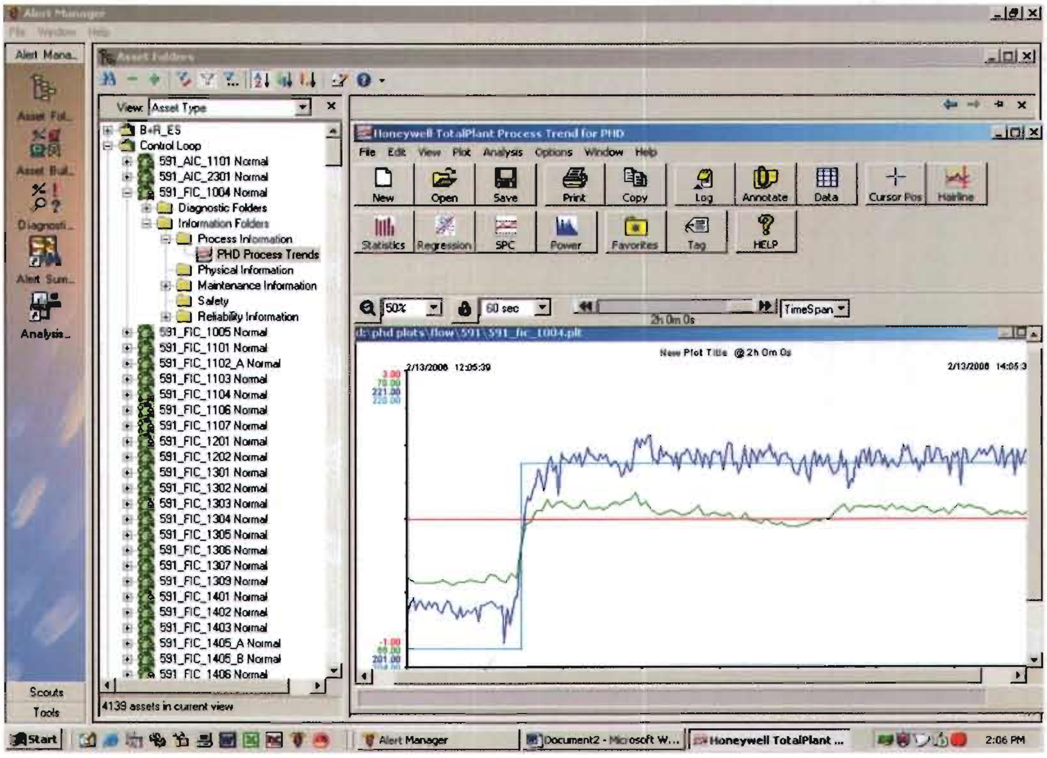

Figure 83: Process trend for a flow control loop

7.4 Recommended Actions

The maintenance information folder includes recommended actions/procedures that have been developed for some of the assets to assist in maintenance actions. These recommended actions/procedures are part of the asset maintenance blueprint and the devices that form part of these actions are typical network assets, specialized FSC assets, PlantScape hardware, control-net equipment and all the different servers used on the control network.

As shown in chapter 5 with figure 46, an e-mail is generated when an asset produces a fault. The e-mail informs to "Please check AlertManager for Recommended Action." This recommended action needs to be checked to assist maintenance staff to try and solve the fault or problem on the specific asset. This may also be accessed from any web-based client. In Figure 84, the recommended action for a network switch is shown. These steps are used as a reference for the maintenance staff.

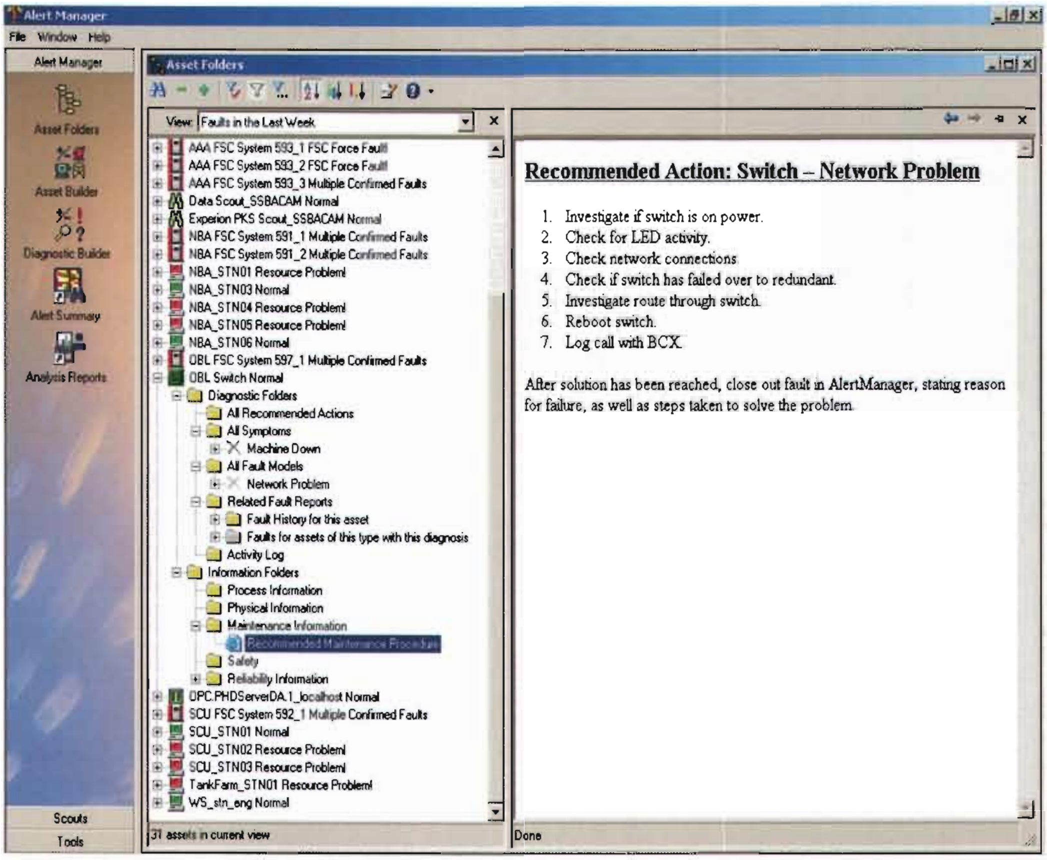

Figure 84: Recommended action for a network switch

7.5 LoopScout Detail Performance Assessment

In previous chapters the LoopScout interface and feedback data from 1000 Oaks in the USA were discussed. The received detail performance assessment is interfaced to the AlertManager in two ways. The first method, namely the flat file process was discussed in chapter four. The second is the assessment report as shown in Figure 86. For each of the control loops configured in AlertManager, this assessment report is available. The report is received every month and the assessments are stored in the maintenance information folder. It also forms part of the history that is made available to maintenance and process staff. From the example shown, it can be seen that the feedback reports are web-based and accessible via a web-based client. When the assessment is double clicked, the detailed information of the specific point on the assessment will be displayed as shown in the example.

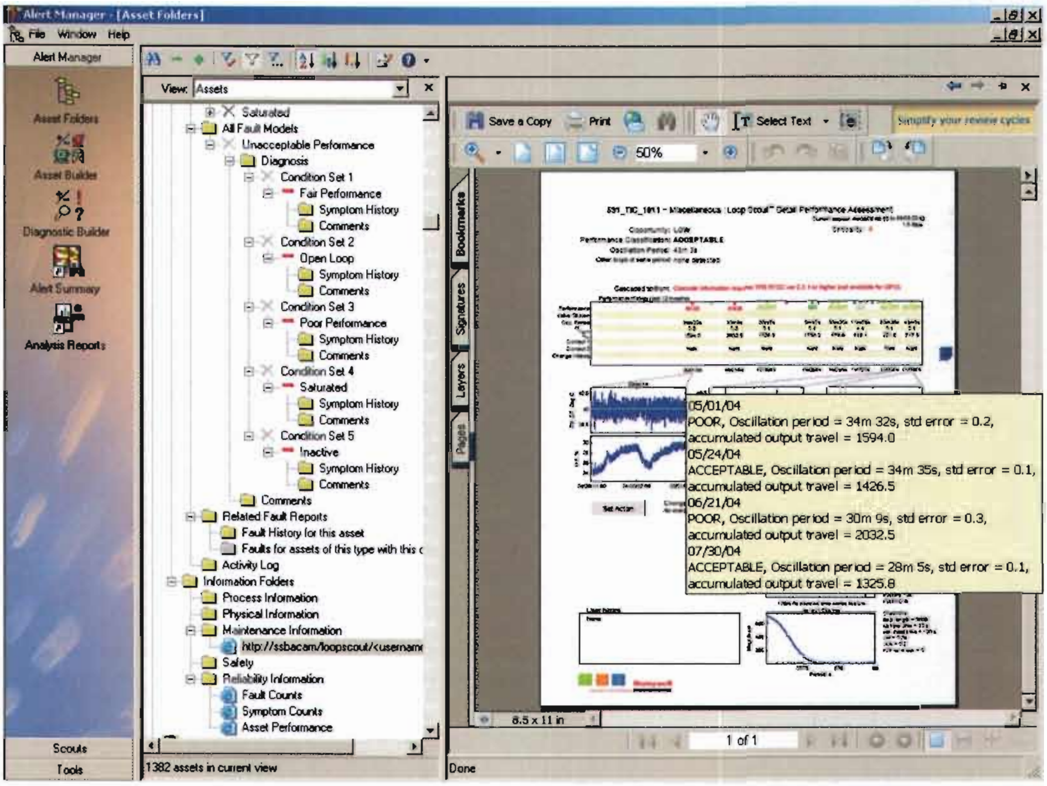

Figure 85: LoopScout performance assessment

More detail is available from the assessment as shown in figure 86. This report will assist the process and maintenance technicians to see where there are problems on the specific control loops. This example shows certain parameters for the control loop. This particular loop is not a critical loop in the process and its probability for stiction is very low. There is a good opportunity to tune this for better performance, which will change its performance classification. From this type of assessment, process people and maintenance staff can be taught how to use the information from this report and to optimize the control loops so as to get a more tuned and optimized plant producing at design specifications. Further particulars on the assessment are not discussed in this thesis.

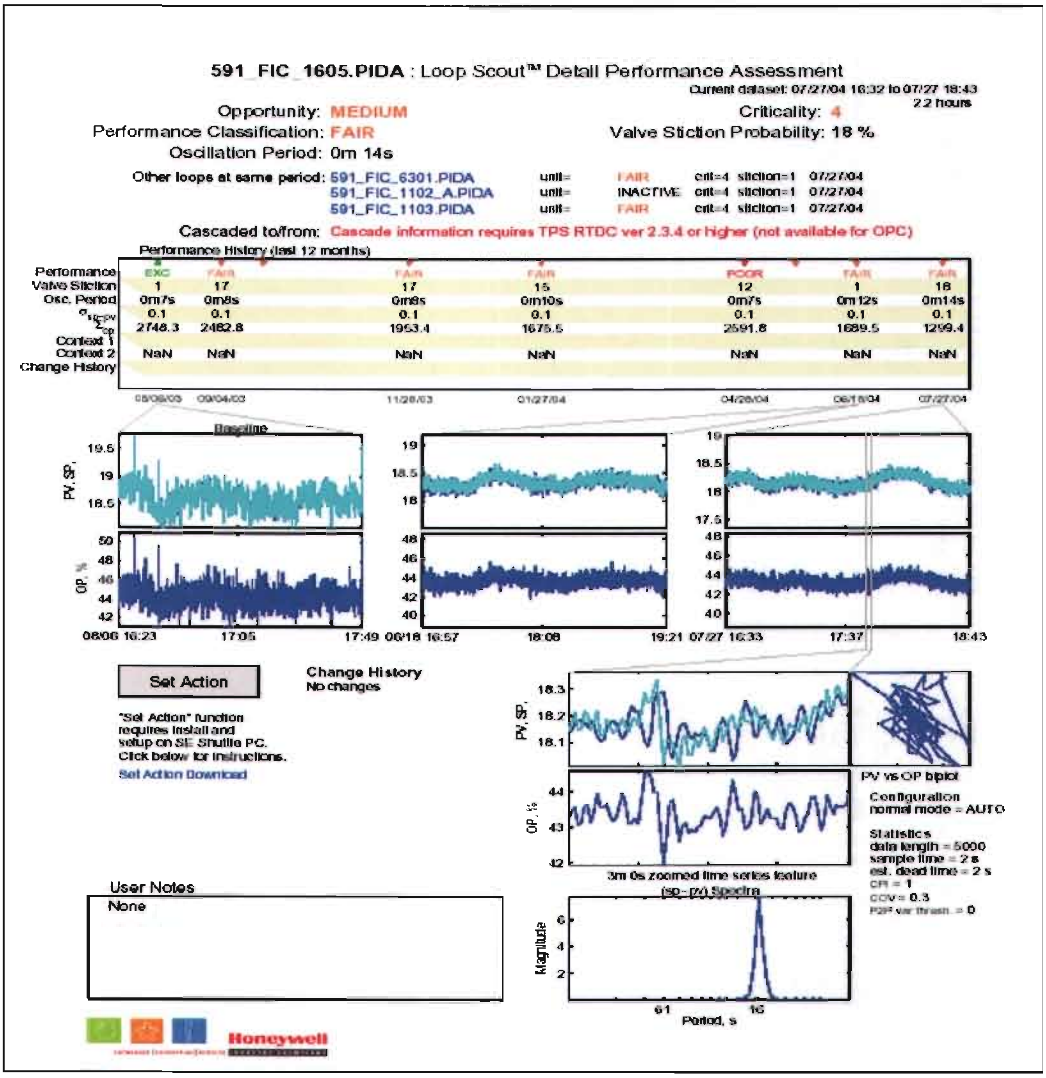

Figure 86: Detail performance assessment

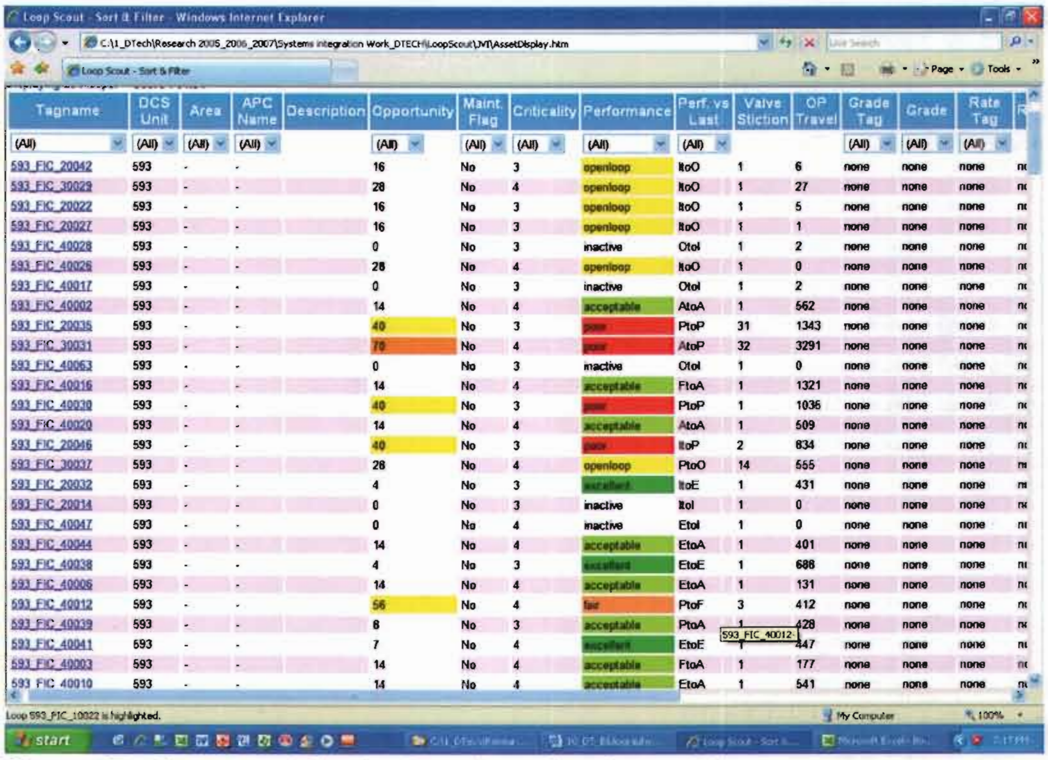

Figure 87a: Loop asset display from LoopScout – part 1

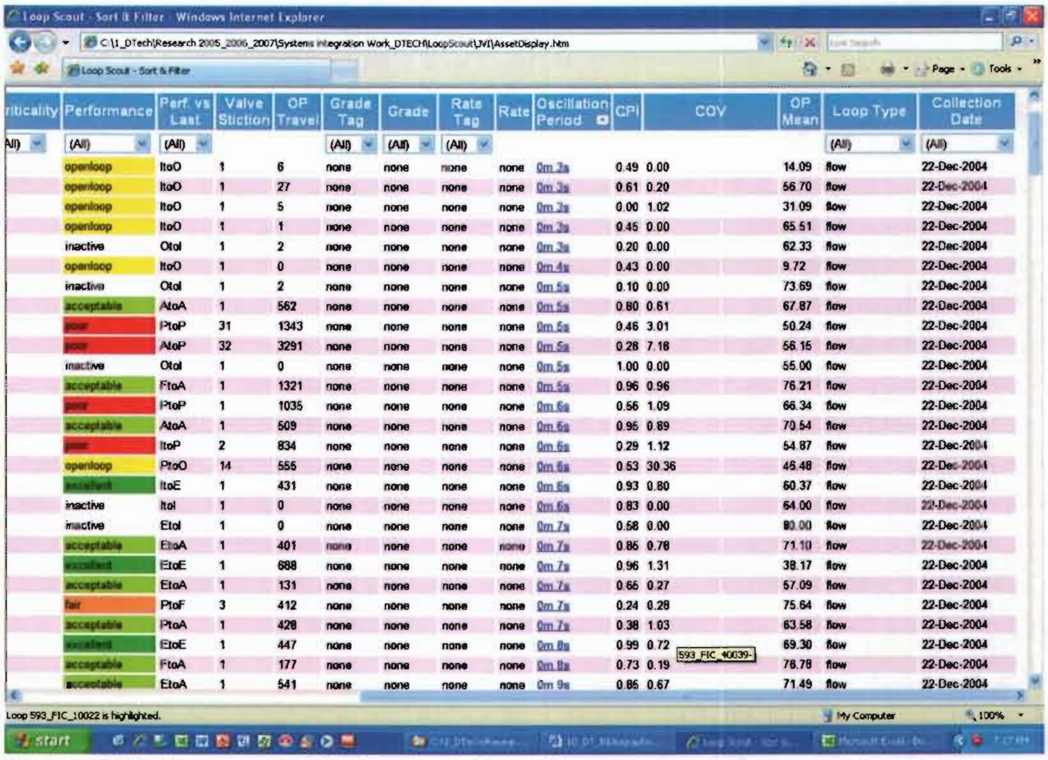

Figure 87b: Loop asset display from LoopScout – part 2

Additional information is provided for different plants where the data collection occurred for LoopScout. Figures 87a and 87b show another type of display, given for the different control loops used on the different plants. This information is also very useful in determining where problems are on the plant with control loops.

Examining this data can determine possible faults with control valve not properly maintained. Again, no detail from the reports will be discussed.

7.6 Shutdown Valve Signatures

With every shutdown the E/I maintenance group goes through a process where all the valves are checked with Valvelink and Valvue snap-on software, to verify the condition of the valves before they are removed for repair or overhauling.

The potential cost of valve failure is fairly high and the standard practice is to remove a valve during a shutdown period for repair. This could mean repairs before service may be necessary. By performing valve signatures it has been proven that less than one-third of the valves actually required removal from the process. Sixty four percent (64%) of the valves could be adjusted or repaired on-line, significantly reducing the total cost of repairs (Lenz 1996).

Based on the diagnostic information available, the next step is to view this information within the asset management system. Valve signature information as shown in Figure 88 is made part of the history information in the maintenance information folder in the AlertManager. This information is used for reference purposes before a shutdown takes place to ensure that the reference signatures are used to note any deviations after the signatures were done. The maintenance shutdown plan will then be updated depending on what valves required to be taken out for servicing and repairs.

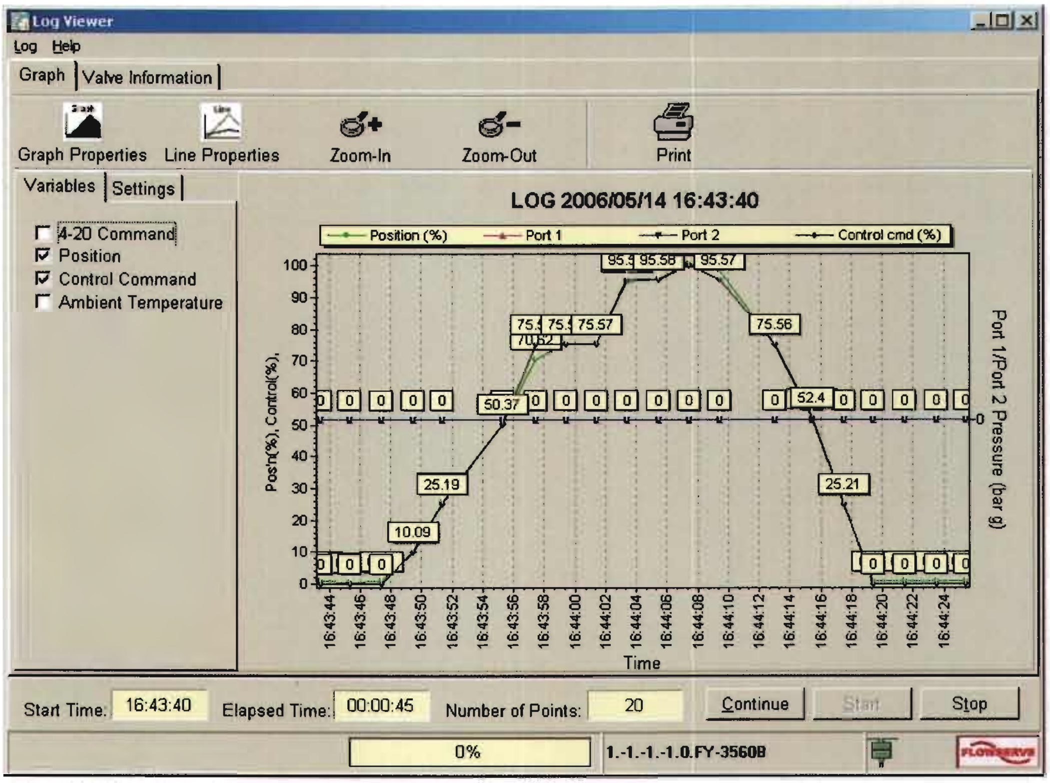

Figure 88: Stroke calibration

7.7 Conclusion

Making maintenance and process data available from one central point ensures that maintenance and process staff have access to this data from a unified platform. Using the AlertManager makes interfacing to web-based applications possible, in order to retrieve the required data for the configured assets. Data sheets and other relevant asset data are more accessible from the different equipment rooms to assist technicians and artisans to do more effective and faster maintenance. Knowledge and plant related information is freely available from the AlertManager including the shutdown valve signature information which is available for reference purposes.

CHAPTER 8 PREDICTIVE MAINTENANCE

8.1. Chapter Overview

This chapter presents the facilitation of preventative and predictive maintenance strategies by considering the integrated asset management system that provides access to monitoring and diagnostic information. Predictive maintenance, based on the asset management system that provides accurate monitoring and diagnostic information is the focal point of Electrical/Instrumentation maintenance activities.

This chapter describes the predictive maintenance that is conducted by means of the integrated asset management solution as discussed in preceding chapters. This is the last block in the second stage of the SAMI asset health triangle, presented below in Figure 89.

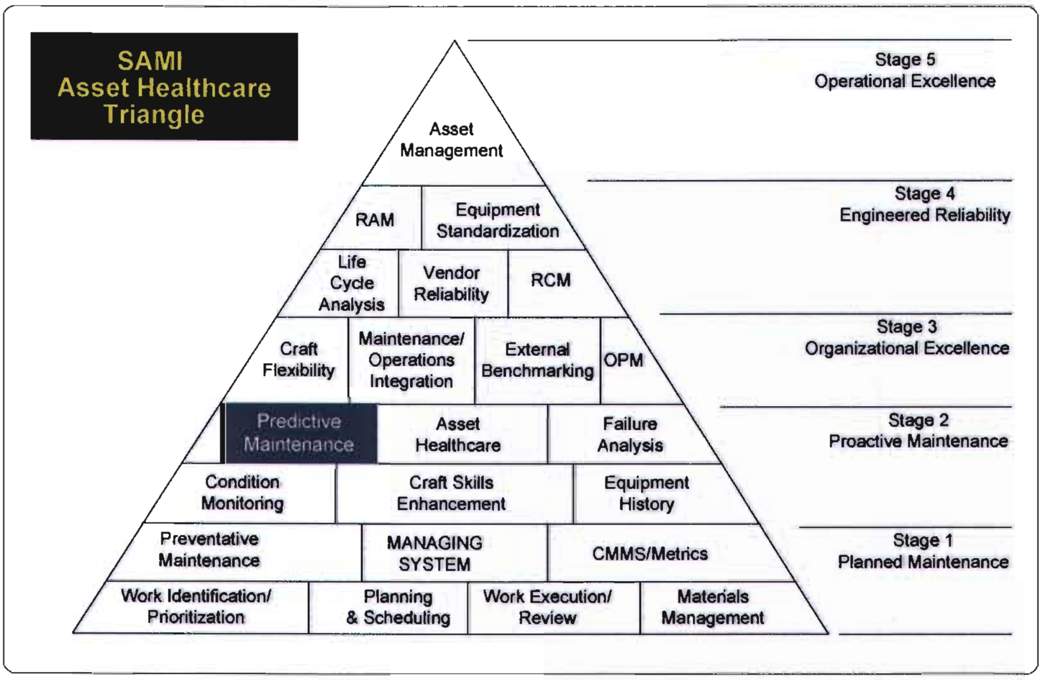

Figure 89: Predictive maintenance

8.2 The Context of Predictive Maintenance

In modern process industry plants, management continually strives to reduce production costs, an estimated one-third of maintenance expenditures are wasted. Maintenance averages fourteen percent of the cost of goods sold in many industries (Mobley 2002), making it a prime target for cost-reduction efforts. According to a DuPont report, "The largest single controllable expenditure in a plant today is maintenance, and in many plants the maintenance budget exceeds annual net profit". Optimizing the return on maintenance is now a key strategy for most process plants.

8.3 Maintenance Approaches

The lack of a considered maintenance strategy, results in evidence of the following patterns in plant operations and maintenance (Moubray 2003):

- Equipment failures that result in lost production and expensive repairs.
- The equipment failures occur repeatedly.
- Maintenance schedules are identical for similar equipment, regardless of application or economic impact.
- No maintenance standards or best practices exist.

A good maintenance strategy can address the above-mentioned symptoms and can improve process operations and maintenance actions whilst simultaneously reducing costs. An effective maintenance strategy can in fact be as important to the business results as the quality program.

The majority of maintenance strategies are based on one or more of four basic maintenance approaches namely (Moubray 2003):

- Reactive Maintenance
- Preventive Maintenance

- Predictive Maintenance
- Proactive Maintenance

The requirements or function of the control systems maintenance group in Solvents must be reviewed before the different approaches to maintenance can be discussed. The main function of the control systems maintenance group within the Sasol Solvent environment is to maintain the integrity, reliability and safe operation of all instrumentation, control systems and emergency shutdown systems on the three plants. This complex operational environment requires a specific approach for every different equipment category.

Ideally the plant management process must move away from reactive maintenance and towards proactive maintenance. By moving from one strategy to the next must be managed so that plant up-time is close to or 100 percent, safety is adhered to at all times and that environmental problems are kept to a minimum. Figure 90 below presents a graphics depiction of the requirements for the approaches namely Reactive, Preventative, Predictive and Proactive Strategies as discussed in Joubert (2006). The four approaches are discussed individually

The approaches to maintenance strategy, as presented above indicates that failures need to be properly managed in order to prevent serious production losses, and optimize production, reduce maintenance costs and ensure compliance to safety, health and environmental requirements (Sasol 2005).

Figure 90 shows that when a plant uses reactive maintenance failures and production losses are at the extreme left of a continuum where improved maintenance strategies start with time based maintenance. One of the most important aspects of such a managed process is that of maintenance strategy setting – deciding what maintenance to do, when and how often. Various strategies are combined to set up the maintenance plans for the maintenance of the Sasol Solvents facility.

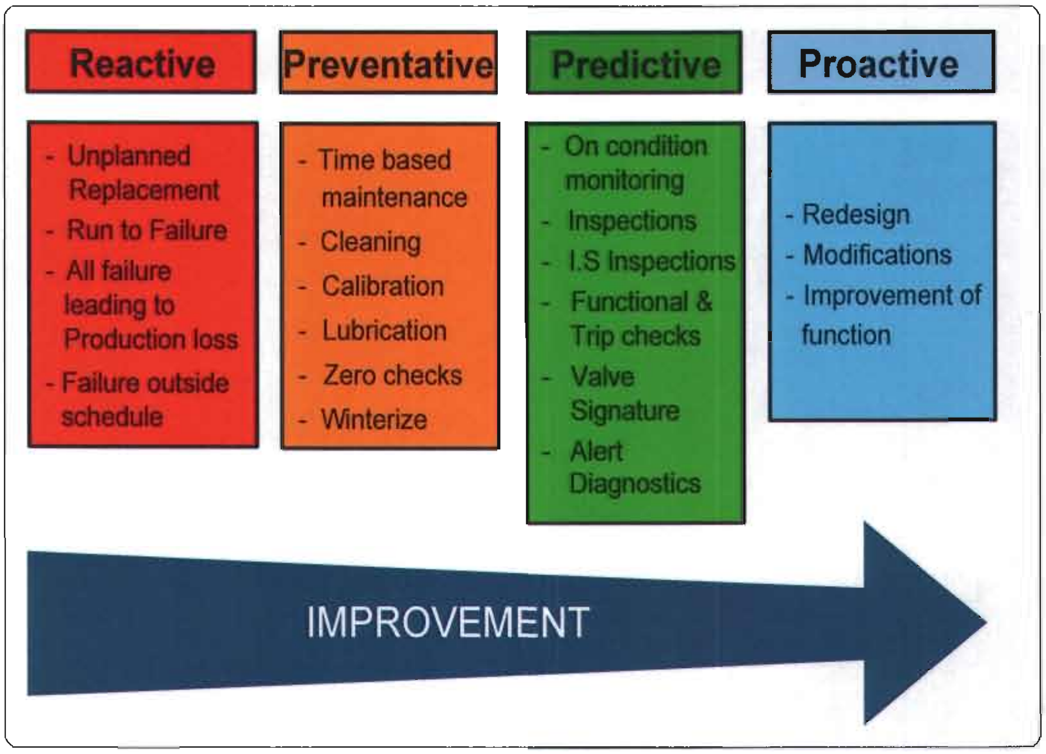

Figure 90: Maintenance strategy approaches

Predictive maintenance requires that on-condition monitoring and alert diagnostics are put into place. The technology that allows field devices to provide real-time systems diagnostics that can interface with a user friendly platform for diverse equipment data obtained from valve signatures and alert conditions. The interface designed and implemented at the Sasol Solvents Site required a considerable effort during this project and allowed plant personnel to move from preventative to predictive maintenance.

Plant operations managers need to make the required investment so that state-of-the-art technology and skilled human resources can enable maintenance strategies to become predictive in nature. Once predictive maintenance strategies are in place the shift to pro-active strategies is an easily obtainable business objective.

8.4 Maintenance Strategies

8.4.1 Reactive Maintenance

The oldest maintenance approach is **reactive**, or "run-to-failure". Equipment is used until it breaks and on failure the equipment is inspected and repaired or replaced as required (Moubray 2003).

Companies that rely on reactive maintenance strategies alone, find that they are faced by the following consequences:

- **Costly downtime.** Equipment fails with little or no warning; the production process therefore could com to a complete halt until replacement parts arrive, resulting in lost revenue.
- **Higher maintenance costs.** Unexpected failures can increase overtime labor costs, as well as expedited delivery of replacement parts.
- **Safety hazards.** Failure with no warning could create a safety issue with the failing equipment or other units that might be affected.

Reactive maintenance can be appropriate under certain conditions for a limited number of non-critical and low cost equipment that is considered to hold little or no risk of collateral damage and will not result in lost production. It's important, to make sure that downtime as a result of non-critical equipment failure will not have a ripple effect and negatively influence more critical equipment and processes.

It is alarming to consider that currently, the majority of maintenance strategies (refer to table 11) remain reactive in nature (Emerson 2005). The implications of a reactive approach include unplanned replacement of equipment and unscheduled failures that disrupt profitable plant operations. Failures due to a reactive maintenance approach often result in loss of production. In addition, unscheduled failures can lead to an even greater number of failures on control systems and equipment.

Table 11: Maintenance strategies comparison

	1988	2004	Best Cost
Reactive	55%	55%	10%
Preventative	30%	31%	25-35%
Predictive	10%	12%	45-55%
Proactive	5%	2%	5-15%

The reactive approach to maintenance requires that personnel must be equipped to deal with breakdowns on a daily basis, by means of effective planning and work execution system. In terms of the reactive approach, some equipment will be run to failure. Failure data will be captured on SAP, and analyzed to determine the effectiveness of preventative and condition based maintenance (Sasol 2006).

8.4.2 Preventative Maintenance

The **preventive** maintenance philosophy is also known as **time-based** or **planned** maintenance. The goal of preventative maintenance approach is to maintain equipment in a healthy condition. Selected service and part replacements are scheduled based on a time interval for each device - whether it needs it or not.

Preventative maintenance is also typically used on non critical equipment, although there are some situations where reactive maintenance may be satisfactory, especially when there is no history of performance problems and the equipment is not associated with a critical loop (Honeywell 2005).

As part of a typical preventative approach, transmitter calibrations may be performed every six months in critical areas. Although this approach may uncover possible problems, the majority of preventative check-ups are unnecessary because the tests are performed on healthy instrumentation.

Figure 91, presented overleaf indicates how preventive maintenance is related to the equipment-failure cycle.

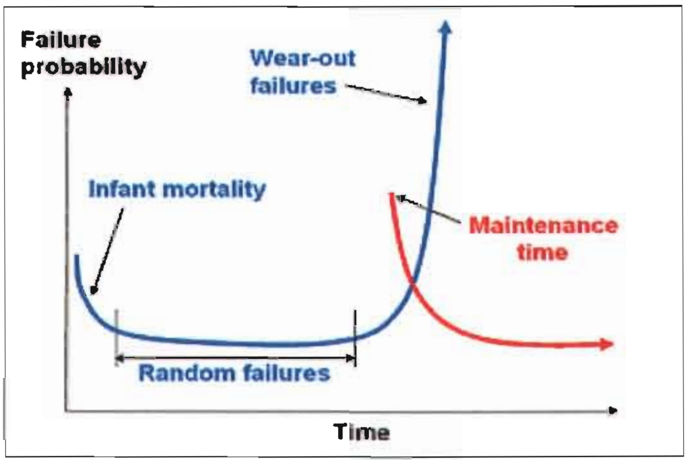

Figure 91: Equipment-failure cycle

The equipment failure cycle starts with a high probability of premature (infant) failures that result from manufacturing or installation errors. The probability of failures remains constantly low until the equipment begins to wear out. Preventive maintenance is scheduled to take place before the probability of failure increases significantly due the equipment run-time exceeding the estimated healthy life-time of equipment (Sasol 2006).

In reality, the maintenance schedule is rarely optimal. Time-based preventative maintenance is typically carried out too soon, which increases costs and decreases reliability (because the failure cycle again begins with a higher rate because of maintenance errors). Or the preventive maintenance comes too late, increasing the risk of wear-out failures. To time the maintenance correctly, you need to know the actual equipment condition and be able to predict the failure point (Sasol 2006).

Disadvantages of depending solely on the preventive approach include (Sasol 2006):

- **Wasteful** - Equipment or components may be replaced prematurely, while they still have plenty of useful life left.
- **Inventory costs** - A larger inventory is typically needed to support a preventive maintenance program.
- **Application-dependent wear often ignored** - In light wear applications, equipment may receive excessive and unneeded maintenance. In severe wear applications, equipment may receive insufficient maintenance. In addition, identical equipment in different applications may require different maintenance intervals.
- **No complete prevention of failures** - A misalignment could be causing bearing wear, creating a possible failure before the next scheduled maintenance.

While preventive practices can be an important part of your maintenance strategy, there's a growing need to include predictive and proactive maintenance as well. Scheduled maintenance will be carried out on specific equipment, and will be scheduled on SAP. These inspections will be carried out on a daily, monthly, yearly, and three yearly periods, depending on the criticality of the piece of equipment or system, the safety integrity level (SIL rated) of the control loops; government inspection requirements and Sasol standards based on experience and historical data from the asset management system (Sasol 2006).

Calibration, cleaning, lubrication and zero checks of equipment forms part of the scheduled maintenance. Winterization is also an action to prevent changes to process. Opportunity maintenance may also be done in this type of maintenance. All the maintenance is based on time / schedules activated by SAP.

8.4.3 Predictive Maintenance

In predictive maintenance, equipment condition rather than time intervals determine the need for service. Online condition monitoring helps identify when wear-out risk begins to increase and predict when failure is likely to occur. This approach can save time and money because it enables maintenance staff to correct the problem before the equipment actually fails. Downtime and repair costs caused by unexpected failure are avoided as well as the costs and lost production caused by unnecessary preventive maintenance (Sasol 2005).

Advanced predictive maintenance programs frequently modify the definition of a failure. Traditionally, a failure is defined as the point where the equipment breaks down and is no longer available for production. A more appropriate definition is that the equipment is no longer able to produce the right quality at the right production rate and the right cost. At this point, the plant is losing profitability and maintenance should be considered (Sasol 2005). .

Predictive maintenance techniques can be applied to all critical pieces of equipment capable of broadcasting information about their condition (i.e., intelligent devices). Critical equipment not having smart instrumentation can be covered by preventive maintenance-applying historical performance data to extend the intervals between scheduled maintenance periods.

There are two focus areas namely Condition based monitoring and Inspections. Condition monitoring will be used where applicable. Typical vibration monitoring on compressors will be done as well as on-line monitoring of the data from the different pieces of equipment. The inspections will include scheduled inspections, Intrinsic Safe (IS) inspections, functional and trip and alarm checks and daily plant inspections done by artisans. Valve signatures and alert diagnostics will be used on the more modern plants with the asset optimization solutions being planned and implemented.

8.4.4 Proactive maintenance

While predictive maintenance uses online condition monitoring to help predict when a failure will occur, it doesn't always identify the **root cause** of the failure. That's where **proactive maintenance** comes in. Proactive maintenance relies on information provided by predictive methods to identify problems and isolate the source of the failure (Sasol 2006).

Take the case of a pump that has periodic bearing failures. A condition-monitoring program may apply vibration sensors to the bearings, monitor the bearing temperature, and perform periodic analysis of the lube oil. These steps will tell when but not why the bearings are failing.

Proactive maintenance might add laser alignment and equipment balancing during installation to reduce bearing stress, lowering failure rates and extending bearing life. But it will also take the next step to find the sources of failures — for example, looking at cleaning procedures before tear-down to see if contamination during rebuild is a root cause for early bearing failures (Sasol 2006).

By determining these root causes and acting to eliminate them, it can not only prolong the life of the equipment. Many seemingly random failures will be eliminated and avoid repairing the same equipment for the same problem again and again. Whenever a failure occurs too often on any type of equipment, it is assumed that there is a need to modify the process or equipment. These problems can be modified working through the change management process (MOC).

If the modification is not working, engineering out the problem must then be considered. The relevant process and engineering staff will be called for a meeting to discuss the problem and give solutions that will be implemented as soon as possible.

8.4.5 Choosing a strategy

For most plants, the best maintenance strategy combines several or all of these approaches. The combination that will be chosen will both affect and be affected by work processes, expertise, technology and management.

The right mix will differ from plant to plant, as well as for different types of equipment. Generally, the more critical the process, the more expensive the equipment, the higher the potential for collateral damage, the more the maintenance practices move toward predictive and proactive strategies (Sasol 2006).

8.5 Maintenance Plans

Based on the above strategies, maintenance plans is developed for the equipment and control systems at the three different plants on the Solvents site. Maintenance plans developed will be worked into work orders, which will be available on SAP. SAP is utilized for planning and scheduling of maintenance actions. All work must be initiated by means of notifications (defects obtained from fault alerts generated by the integrated asset management system) and this work goes through a planning process.

8.6 Maintenance Procedures

Maintenance procedures address the safety aspects and the actual work that must be done. Each maintenance procedure is captured in a general procedure that addresses competencies of people working with instrumentation, responsibilities and authorities. The procedure is worked through by all artisans and signs that he /she understands the contents of the procedure. The legal appointed personnel also familiarised themselves with each procedure and the contents thereof. These procedures are made available electronically on the Asset Manager as discussed in chapter seven.

8.7 Change Management

Moving from a reactive to a more predictive maintenance strategy does not come easy if this was the mode being operated in for a few years. One of the aspects covered in the action research steps is the resistance to change from management and maintenance staff. Managers look at budgets and costs and are very sceptical about the integrated solution since it hasn't been implement elsewhere in a plant similar to the plants in the Solvents environment. Would the integrated solution bring the benefits as predicted at what cost from Sasol's side?

Maintenance staff looks at additional work and the unfamiliar field of equipment and systems. The following issues were raised by maintenance staff:

- New technologies being installed and used differently from old 4-20mA technology.
- Different plant control systems – training takes too long and complicated to operate.
- New asset management systems like AMS and Asset Manager software running on a PC – new learning curve and used to work with HART hand held device – different work methodology.
- Use of valve diagnostics to determine valve status – additional work during shutdown.
- Don't understand the different bus topologies and technologies.

How are heads turned and attitudes changed? The change management model from the book 'Culture change for leaders' was used to address the issue of change. The book stated the following: "Leaders are the catalyst for change in any organisation".

The following model in figure 92 is used to explain the change management process that was followed.

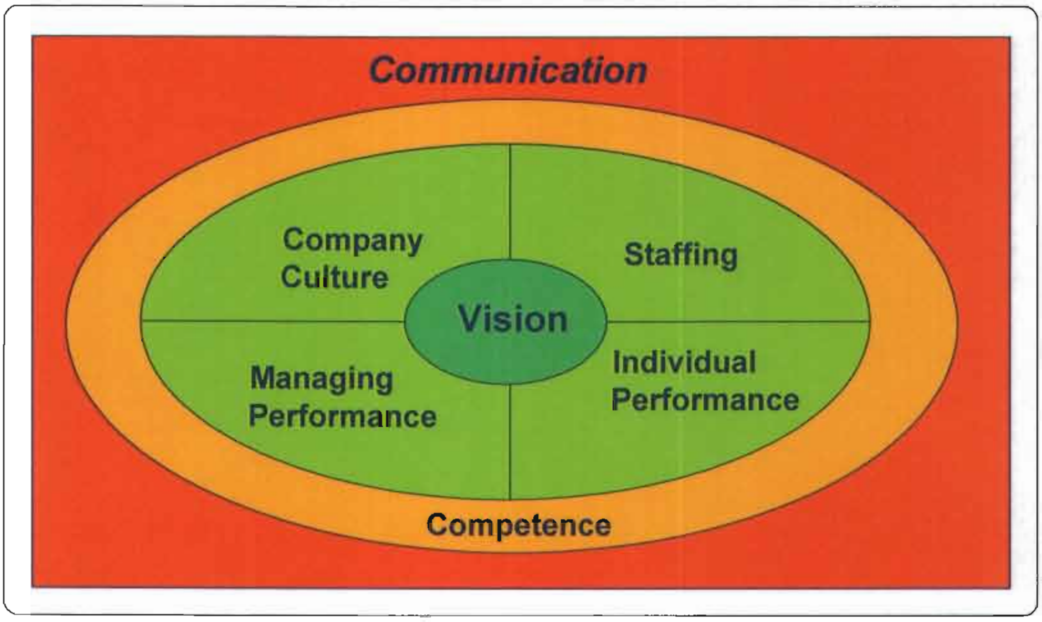

Figure 92: Change management model

A common vision was determined (Joubert 2005):

> "***We set the world benchmark, by responsibly managing & optimizing E&I assets, by balancing people skills with a development program.***"

Referring to the model it was necessary to use the vision to address the four quadrants.

8.7.1 Company culture

Addressing the company culture was crucial for top management to buy into the proposed solution and convince them of the possible benefits. This was achieved with lots of discussions and using the virtual machines (see 2.13) to demonstrate the functionality and the proposed integrated solution (Claassen 2005). The preliminary tests that were done, was used to show some benefits using some of the technology proposed in the final solution.

8.7.2 Correct staffing

The next step was to produce the correct staff for operating the new systems. The artisans and specialist artisans were already in a two year training process that was driven by me and the maintenance manager to achieve the correct staff with the correct experience and knowledge of the different systems.

8.7.3 Individual performance

With a skills development training program that consisted of external training from vendors and suppliers being implemented, it was possible to monitor individual performance on the different areas of the plant where the new technology was used. Training was also given on Wednesdays to enhance communication about the technologies and work processes.

8.7.4 Performance management

Managing the performance of all the maintenance staff and the flow of the proposed project execution for implementing the integrated solution was another crucial aspect that needed to be solved. Some of the implementation was going faster than other parts and this was crucial to manage the different time lines. Certain parts of the program such as the roll-out of the software was faster executed that the training to use the systems. Part of the changes was to implement small changes and not the normal conventional way of doing a full cycle project. This would have a major impact on the implementation of the integrated asset management solution on the live plants effecting production and logistics (Claassen 2005).

All of the above steps were done to ensure that the core competencies were developed and maintained. These competencies would be used to achieve the stated vision. Communication was the most crucial aspect of the model implementation. Everybody was kept informed of the implementation and the progress. One point to mention was that it was very important to the team of maintenance staff assisting in the project to give the smallest acknowledgement and to communicate the small wins to everybody.

Lao Tzu said: " *the best change is what the people think they did themselves.* "

Claassen (2005) made the following statement:

> *"To change culture in an organization you have to re-program employees. Your leaders are the computer programmers and your computer analyst is your HR officer. Programming can only take place with good communication between the programmer and the computer (employees). The computer analyst must measure the effectiveness of the change."*

8.8 Benefits

Implementing the proposed integrated asset management solution on the Solvents plants it was necessary to evaluate the benefits achieved. These benefits are as follows:

- Superior return on assets.
- Significant reduction of maintenance and operating costs.
- Reduction of unplanned downtime.
- Abnormal situation avoidance according to the ASM Consortium.
- Creation of higher level knowledge in workforce.
- Empowering maintenance work force.
- Prevented five plant trips, ± R12 million (USD 2.35 mil).

- In shutdowns valve diagnostic capabilities on control valves was used to determine which valves should be removed from the plant. Only 40 valves out of 350 were removed and saved R1.2 million (USD 0.13m). Valve signatures of all installed control valves, when they left the suppliers factories are in the history folders in the Asset Manager package. The current valve signatures are compared with the blue prints from the factory for each shutdown (Joubert 2005).
- Detected faulty or poorly optimised valve positioners (Saved R2.1 million (USD 0.32m).
- Audit trail on instruments (changes captured). Important for Management of Change – SAFETY.
- Quick download of settings when changing transmitters – Save artisan time.
- More effective, focussed maintenance – Less break down maintenance and more planned maintenance = Reduced maintenance cost.

From figures 93 and 94 the benefits achieved using the integrated solution are shown. This info is retrieved from SAP to monitor the trends in the different maintenance strategies.

From the graph it indicates the decline in reactive maintenance after the installation and implementation of the integrated solution. Preventative maintenance is going done and the predictive maintenance is increasing. The estimated cost saving in the reactive maintenance component is in the region of R77 000 (USD $11000) per year (Joubert 2005).

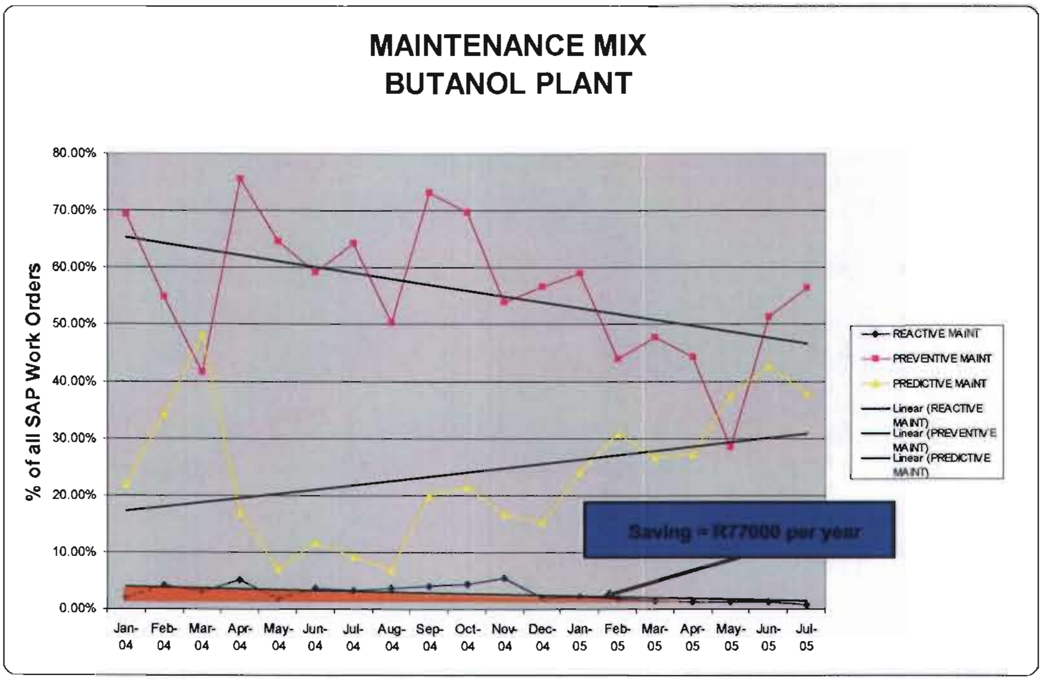

Figure 93: Maintenance mix on the Butanol plant

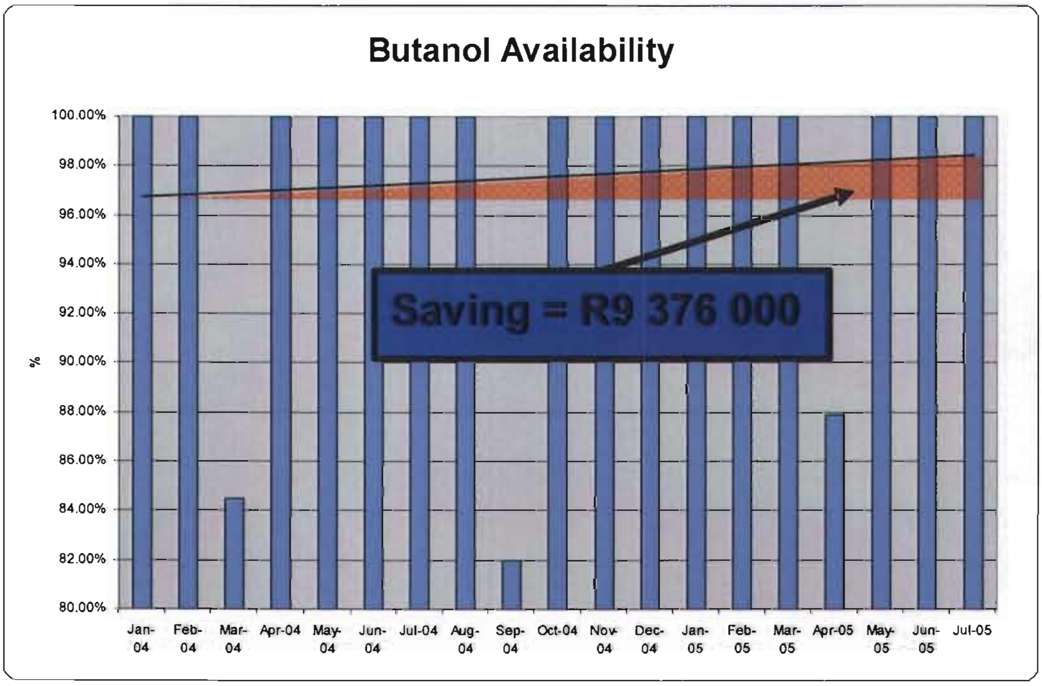

Figure 94: Plant availability on the Butanol plant

After the installation of the integrated asset management solution, the plant availability started increasing. This produced longer plant uptimes, higher production figures and better optimized plant operations. From figure 94 the plant availability for the Butanol plant is shown. Over a period of a year an estimated saving of R9.376 mil (USD $568 000) was achieved (Joubert 2005).

8.9 Conclusion

By implementing a total integrated asset management solution and managing the change control to get maintenance and process personnel competent, it is possible to move from reactive maintenance to predictive maintenance. The integrated solution will increase reliability by combining embedded diagnostics from all plant systems and smart field devices. It will dramatically reduce the time required, in the region of 40 to 60 percent, to identify and resolve system and device faults and abnormal conditions. Optimizing all the control loops on the plant will add to the reliability and produce more consistent production rates and ensuring longer periods of plant availability. It also increase user performance (safety and effectiveness) while reducing the annual training budget.

CHAPTER 9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Introduction – Chapter Overview

This thesis has presented a complete and integrated solution for plant control and asset management systems. The objectives of this study were stated in the first chapter of thesis to include the design, development and implementation of an integrated asset management solution for different plant control and asset management systems (see 1.1) using the SAMI model as reference. The goal of the project further included the design of an interface that would enable plant managers to effectively identify problems pertaining to plant-based assets and react appropriately so that plant uptime and profitability is optimised.

This chapter provides an overview of the completed research and the most important research results and findings are highlighted. Recommendations are thereafter being presented and limitations are considered. Suggestions for further research are discussed and in closing, the benefits of the findings of this thesis are emphasised.

9.2 Overview of thesis

The purpose and aims of the study were presented in the first chapter of this thesis. Contextual information was provided in order to describe the plant maintenance problems that were identified and resulted in this research project.

The aims of the study and research methodology were outlined in Chapter 1. In addition the actuality of the research was emphasised and the need for an applicable solutions and outcomes was stated.

As part of the introductory chapter, the SAMI operational reliability maturity model which was used as a point of departure for the research was discussed. The SAMI

Model is shown below, overleaf. The focus of the research was identified to be the second stage of the SAMI Model, namely proactive maintenance.

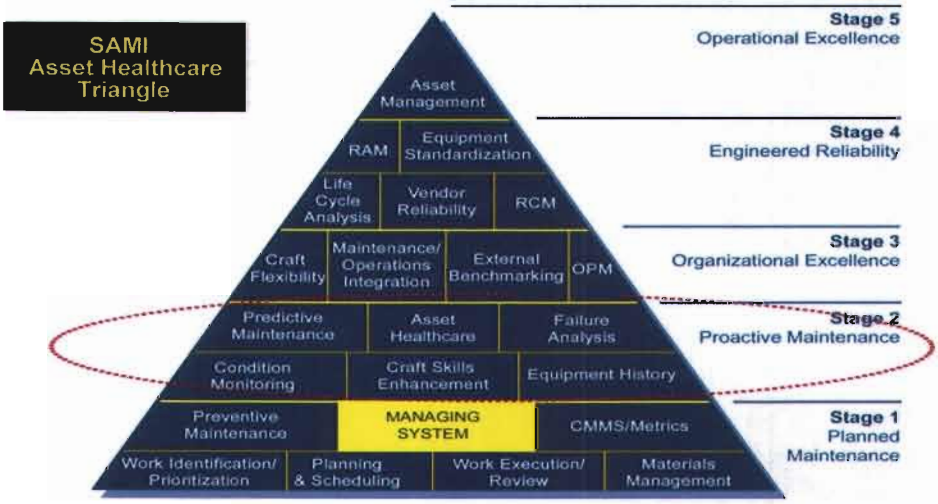

Figure 95: SAMI Asset Healthcare Triangle: Focussing on Stage 2

The literature study was presented in Chapter 2 of this thesis. The different plant control and asset management systems that were installed at the Sasol Solvents site were discussed. The concept of virtualisation was introduced to show how the different systems were linked by means of virtual machines in order to test the different interface functionalities off line (see 2.13). The integrated solution that was developed to communicate with diverse software interfaces was discussed in the second chapter of this dissertation.

The research methodology used to address the objectives of thesis was presented in Chapter 3. The benefits of the action research methodology were discussed. The action research steps taken (figure 96) were outlined in this chapter.

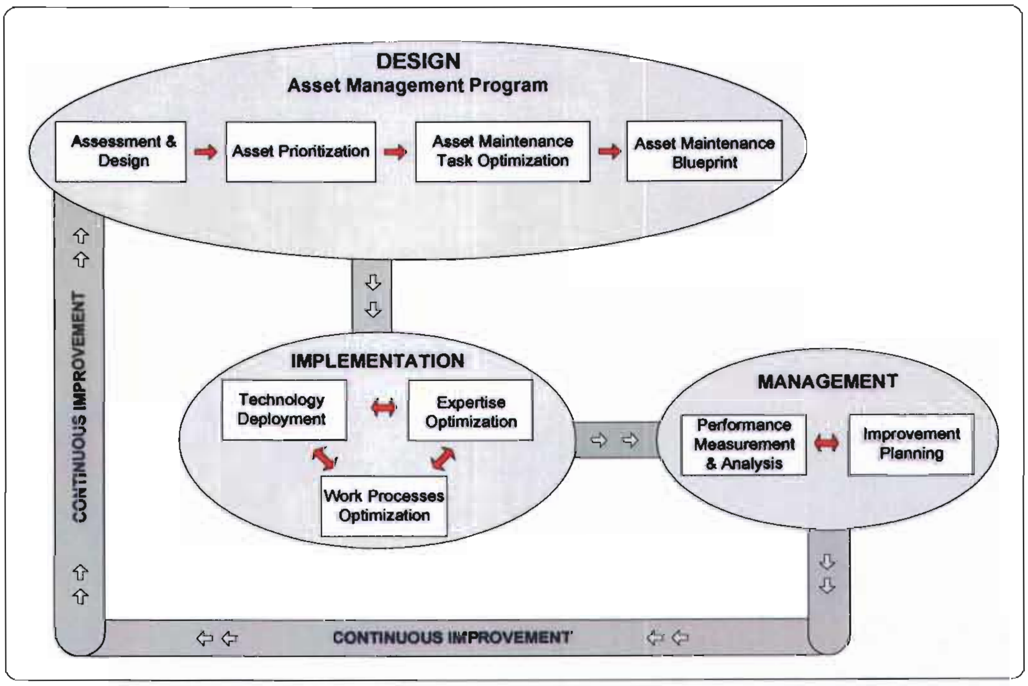

Figure 96: Action research cycle

Chapter 4 provided an in-depth discussion of the symptom and fault models for different assets (see figures 19a and 19b). The failure analysis processes were shown in the Sasol work process for maintenance. The DataScout configurations were explained to illustrate the setup and configurations and how they are used in the AlertManager to produce active alerts when equipment or systems are busy failing or have failed.

Chapter 5 discussed asset healthcare for the different field devices and systems. The interfaces that were developed were discussed. The manner in which these interfaces communicate with different systems was discussed in the fifth chapter. The graphic user interface of the AlertManager application was shown. Views of the configured equipment and systems in the AlertManager were displayed and described. The Asset Healthcare information obtained from the various systems presented in this chapter was used in the maintenance strategies that were developed and rolled out.

Chapter 6 considered the historic information captured by the asset management system. Historic information is an important part of asset management and is used in maintenance plans, maintenance scheduling and data processing. The Plant Historian Database (PHD) provides information that is used to identify and locate typical process problems. The PHD data is an important outcome and this would assist the process engineers to redesign the process, building on the history information referring to the problems that was experienced and captured in the asset management system.

Chapter 7 presented a discussion of the skills enhancement of maintenance personnel using the integrated solution. It is argued that by making maintenance and process data available from one central point, it is possible for maintenance and process staff to access to this data from one a single platform. Using the AlertManager it is possible to interface to web-based applications to retrieve the required data for the configured assets.

Chapter 8 discussed the various maintenance strategies available, with particular emphasis on predictive maintenance. The change management strategy followed was explained. Methods to move from reactive to proactive maintenance strategies were discussed and consideration was given to how the integrated solution was used to achieve objectives of the project.

9.3 Findings

9.3.1 Findings for Aim 1 - To develop a failure analysis model consisting of a symptoms and fault model that will be used for all plant assets. The model will be used to configure all the symptoms and faults via the software interfaces using configuration tools allowing different interfaces to communicate to a central software interface called AlertManager within the AssetMax software application.

In terms of Aim 1, the following deductions can be made:

- The use of the symptoms and fault model make it is possible to determine the diagnostic information needed for any piece of equipment or system to link to the AlertManager (see 4.2).
- Using Device Descriptor (DD) files from the different HART-based equipment vendors, it is possible to configure and update symptoms and fault models to be used in the AlertManager.
- Non-intelligent systems can be interfaced to the AlertManager using the DataScout interface (see 4.3) and real time data interface RDI's configured in PHD (see 4.4).
- The symptoms and fault model enables use of information pertaining to specific failure analysis for equipment or systems to assist RCFA and FMEA processes when needed (see 4.15).
- Failure analysis enables the use the information in maintenance strategies to determine corrective actions to sustain 100 percent plant uptime.

9.3.2 Findings for Aim 2 - To develop software interfaces between the different plant control systems and field devices to retrieve diagnostic information to determine the status conditions of these assets and their availability

In terms of the second aim of this thesis, the following deductions can be made:

- As the volume of diagnostic information that can be retrieved from integrated systems increases, the accuracy of the plant status also increases.
- The availability of on-line diagnostic information will assist maintenance staff to detect failures earlier and faster, thereby contributing to the transition from reactive to maintenance actions (see 8.3.3).
- Different types of plant-based assets and systems may be monitored and the diagnostic information will enable a more accurate view of plant-based assets and systems availability (see 5.7.1).
- Different views of specific types of equipment or systems would allow the maintenance staff to focus faster and more accurately on problems or faults indicated for specific equipment or systems (see 5.7.9).

9.3.3 Findings for Aim 3 - To develop and configure an interface retrieving history from the different configured plant assets and using the data in root cause failure analysis (RCFA) processes

In terms of the third aim of this thesis, the following deductions can be made:

- Improved accuracy of historic data will allow maintenance staff to isolate particular equipment or system faults trends (see 6.2.1)
- The asset management solution contains a detailed history of faults and problems that will improve preventative and predictive maintenance actions (see 6.2.7).

- Historic data will assist process engineers to determine possible problems in the operation of a particular section of a plant by referring to equipment malfunctions or erratic equipment behaviour under certain process conditions (see 6.2).
- Symptom and fault counts over a period (see 6.2.4 and 6.2.6) may be used as a measure of the effectiveness of equipment, the effectiveness of maintenance actions and maintenance services (KPI's) from contractors (see 6.4).
- Reports retrieved from the available history may be applied to a variety of purposes such as manager's report to see faults for a specific instrument or groups of equipment over a period of two months (see 6.3).

9.3.4 Findings for Aim 4 - To develop and configure an interface to have access to maintenance procedures, user manuals, data sheets and relevant process information to enhance the technical skills of the maintenance and process personnel

In terms of the fourth aim of this thesis, the following deductions can be made:

- By using the integrated solution that was developed in this study, all relevant maintenance and process related information to plant and maintenance personnel will be available from any web based computer (see 7.3).
- As a result of the integrated solution, plant personnel have faster access to reference manuals and data sheets. In addition, maintenance procedures can be implemented from a single platform, negating the need to look at different places to find equipment related information required for maintenance (see 7.2).
- The use of loop performance assessment will assist maintenance and process staff to optimize control loops for maximum plant performance and process control (see 7.5).
- Valve signatures will assist maintenance staff to establish which valves are producing problems and must be removed during a shutdown period for

repairs; maintenance and calibration (see 7.6). The base signatures may be used as reference to determine the differences between the signatures before and after a certain period of time. This would result in a shutdown cost saving of close to a R1 million, on valves alone (Joubert 2005).

9.3.5 Findings of Aim 5 - To use the results from the developed interfaces and use them in different type of maintenance strategies to ensure maximum asset availability and plant up time

In terms of the fifth aim of this thesis, the following deductions can be made:

- The integrated solution that was developed during this study will enable plants to effect the transition from a run-to-failure mode to a preventative and finally predictive mode of maintenance (see 8.2).
- The historic information available in the AlertManager can be used to optimise maintenance plans and procedures as well as being used in RCFA and FMEA processes (see 8.4 and 8.5).
- Maintenance procedures (see appendix D) and maintenance plans will form the maintenance strategy that must be implemented at particular plants (see 8.3).
- In order to successfully implement a maintenance strategy, it is important to follow a well formulated change management process and work process (see 8.6).
- By using the correct maintenance strategy it would contribute to a decrease of maintenance cost by sustaining plant availability of 100 percent over longer periods of time and it would move away from reactive to more predictive maintenance modes (see 8.3).

9.4 Recommendations

9.4.1 Recommendation 1

By using the integrated asset management solution presented in this thesis it is possible to address particular problems that have been identified by means of the second stage of the SAMI operational reliability continuity model.

9.4.2 Motivation

By referring to each problem in the second stage of the SAMI triangle it is possible to solve the specific problems associated with maintenance in modern plants. Each block should be used as reference to address the proper type of system or integrated solutions to ensure effective predictive/proactive maintenance.

9.4.3 Recommendation 2

An integrated asset management solution interfaced to different asset management systems and equipment should be used for proper management of plant-based assets to eliminate the use of various stand alone systems.

9.4.4 Motivation

The review of literature revealed that many industrial plants have stand-alone systems that make it difficult to monitor the status of various equipment and systems installed on these plants (see 1.1).

By interfacing the different systems it is possible to centralize asset management and allow maintenance staff to monitor the status of all equipment and systems installed on a plant.

Vendors that supply asset management systems generally only focus on vendor-specific equipment which makes it very difficult for maintenance staff to monitor a variety of systems and equipment. As a result certain systems may be overlooked during monitoring, which may lead to crucial diagnostic information that could prevent a possible plant trip being overlooked.

9.4.5 Recommendation 3

The use of a centralised solution will make it possible for maintenance staff to use different views to monitor particular field equipment and systems and have access to symptoms and faults for these systems (see 1.2.1).

9.4.6 Motivation

The literature review revealed the importance of having access to plant-based asset information in order to ensure maximum plant uptime and availability. The availability of current and accurate diagnostic information will improve performance and enable more effective maintenance actions.

9.4.7 Recommendation 4

Increasingly complex integrated asset management systems are required to ensure that equipment without diagnostic capabilities can be interfaced, monitored and used for highly efficient maintenance.

9.4.8 Motivation

Condition-based monitoring of compressors, pumps, reactors and electrical motors that lack specific diagnostic information (such as HART-based field instrumentation) need to be interfaced to an asset management solution as described in the study (see 1.6.1).

A large portion of equipment installed at older plants lacks onboard diagnostic information; this is a shortcoming that must be addressed to ensure that all equipment is optimally utilised in the total asset management plant solution. This should further assist the maintenance staff and managers to see the status of the complete plant.

9.5 Recommendations for further research

9.5.1 Recommendation 1- Integration of total Solution to SAP

Based on the experience gained from interfacing various systems and how to use the diagnostic information in various maintenance strategies, it should also be possible to integrate the total solution to SAP as shown in figure 97.

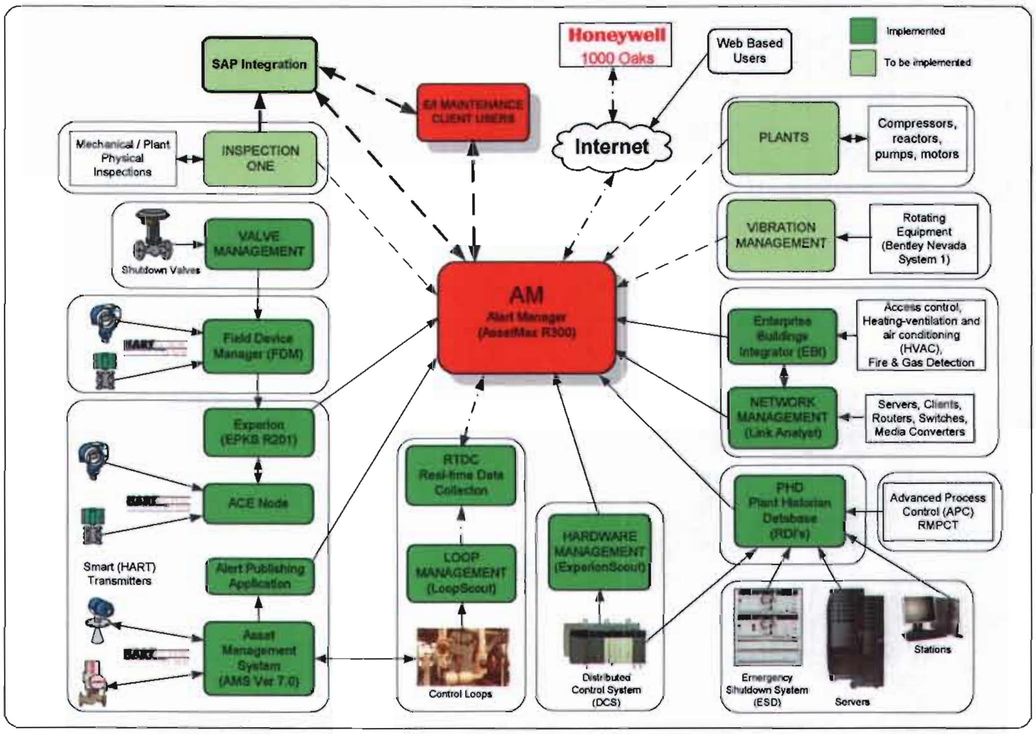

Figure 97: SAP integration

When a fault is flagged in the AlertManager, an electronic defect must be generated by SAP and the planners should then notify the instrumentation artisans and technicians to attend to the flagged problem. After the flagged defect is resolved, the artisan must close out the fault on AlertManager and this must in turn close out the defect in SAP.

This effect will be to close the maintenance loop and trends will subsequently be more readily obtained from SAP to establish whether the maintenance strategies and actions followed has been effective

9.5.2 Recommendation 2- Integration of Vibration Management

The vibration management for conditioning monitoring of mechanical equipment should be interfaced to the different data scouts and to AlertManager.

9.5.3 Recommendation 3- Interface to Inspection One System

The Inspection One system (bar coded system reading tags for preventative maintenance) should be interfaced to the global asset management solution to ensure all equipment on the plant is checked on a scheduled basis and that the recorded information is also used to detect symptoms or faults from non-intelligent devices.

9.5.4 Recommendation 4 - Integration of Process Monitoring

The different sections of the plant such as reactors, distillation columns, furnaces, coolers and heat exchangers as examples can also be interfaced to the total integrated solution to monitor the process side of the plant. Specific section of a plant may be monitored to show deviations to ensure that the mentioned section of the plant do not go in a premature trip condition. All the specific plant variables must be monitored and this will generate the faults if they are controlled wrongly.

9.6 Conclusion

In this chapter a summary of the completed research process were presented, by means of an overview of each chapter. A number of findings from the literature were presented, followed by recommendations and motivations.

In closing a final deduction can be made from the results of this study and is summarized as follows:

Extending asset management to field equipment and systems will empower employees and managers to affect changes in operations and maintenance, including:

- Commissioning efficiency.
- Increased plant uptime by quickly resolving process issues.
- Improved routine maintenance efficiencies.
- Enhanced communication between the control room operators, field operators and maintenance personnel.
- Integration of interfaced field and system data with the Asset Manager decreases the time needed for problem identification and improves decision-making accuracy.

The integrated asset management solution presented in this thesis provides a "best-in-class" infrastructure that allows plant personnel to make key decisions that increase uptime and improve production quality.

The integrated asset management solution functions as a significant productivity tool to release hidden plant profitability; the solution can improve business performance and profitability, decrease incidents, and increase plant availability. The integrated solution connects the right people across the supply chain with the right knowledge when it is needed, improving operational effectiveness and reducing maintenance costs.

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ANNEXURE A KPI TREES

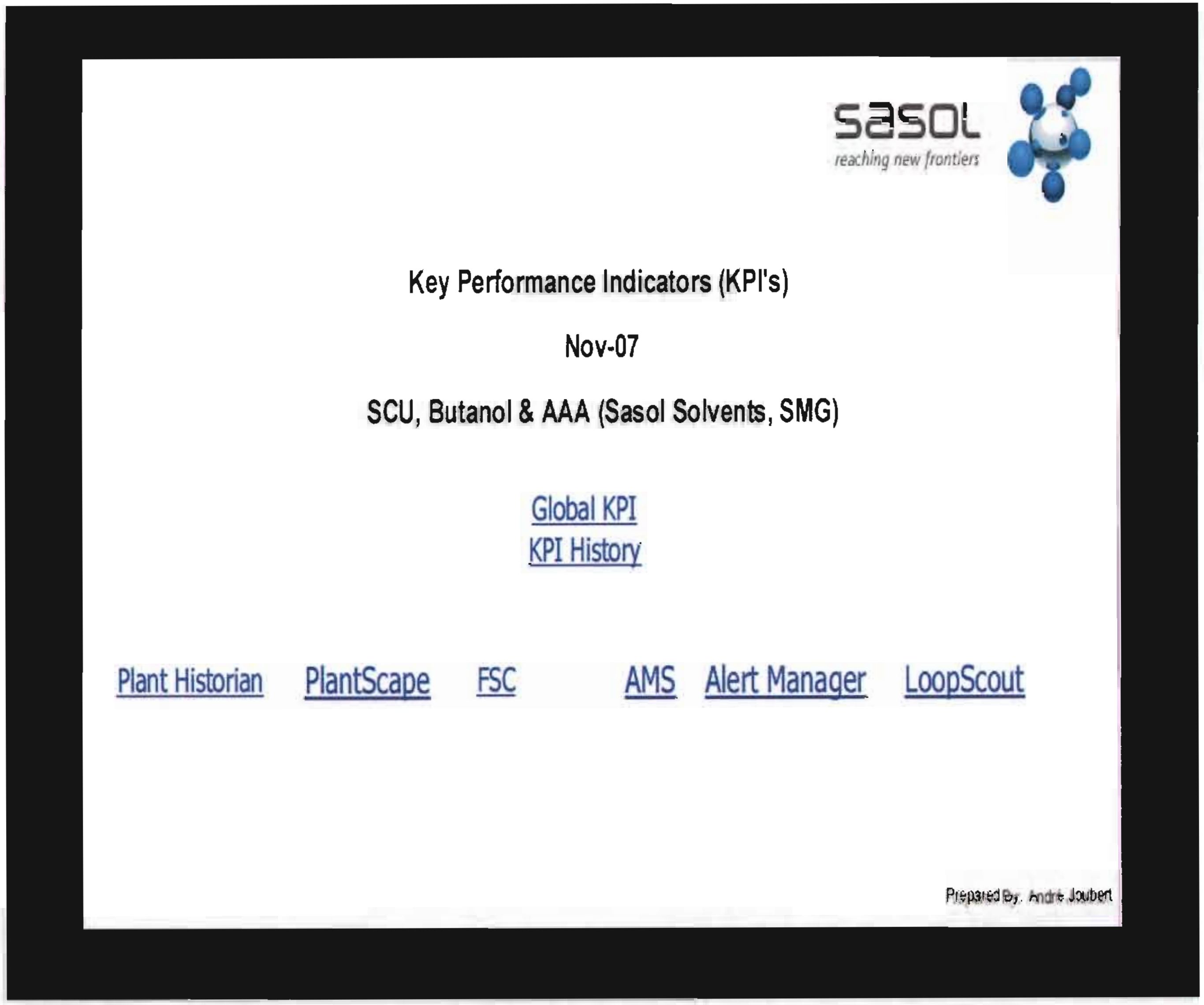
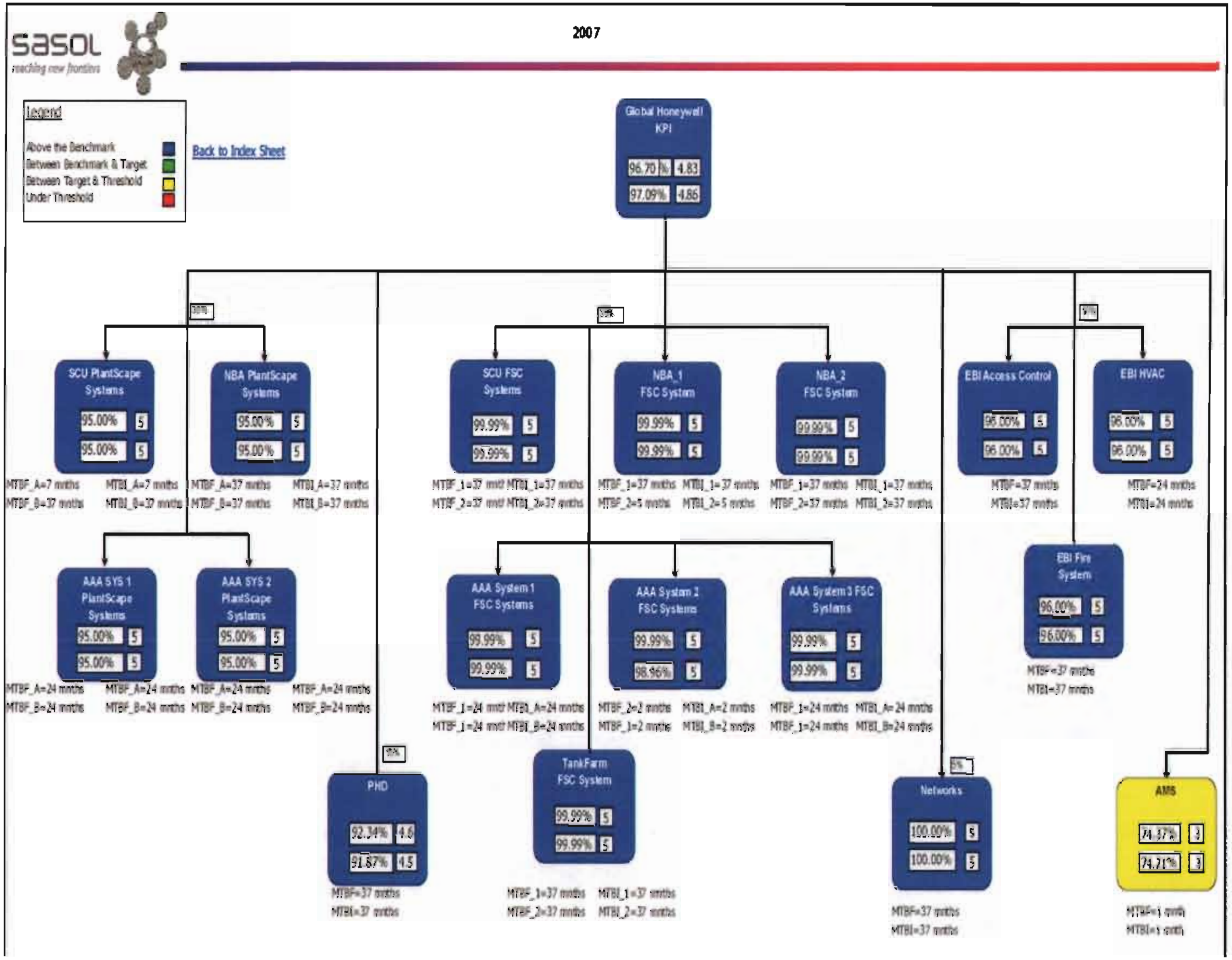


Figure A1: KPI Tree index

Figure A2: Global KPI tree



Back to Index Sheet

KPI History

sasol
reaching new frontiers

	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06	Jan-07	Feb-07	Mar-07	Apr-07	May-07	Jun-07	Jul-07	Aug-07	Sep-07	Oct-07
PHD	87.45	87.45	87.45	89.85	89.85	89.85	89.85	92.5	92.5	92.5	92.34	92.34	92.08	92.08	92.34
Plantscape: SCU	91.5	91.42	91.42	94.50	94.50	94.50	94.50	95.50	95.50	95.50	95.00	95.00	95.00	95.00	95.00
BUT	91.5	91.5	91.5	94.50	94.50	94.50	94.50	95.50	95.50	95.50	95.00	95.00	95.00	95.00	95.00
AAA Sys 1	91.5	91.5	91.5	94.50	94.50	94.50	94.50	95.50	95.50	95.50	95.00	95.00	95.00	95.00	95.00
AAA Sys 2	91.5	91.5	91.5	94.50	94.50	94.50	94.50	95.50	95.50	95.50	95.00	95.00	95.00	95.00	95.00
FSC: SCU	98.98	98.98	98.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
NBA	98.98	98.98	98.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
TF	98.98	98.98	98.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
AAA Sys 1	98.98	98.98	98.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
AAA Sys 2	98.98	98.98	98.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	97.96	99.99
AAA Sys 3	98.98	98.98	98.98	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99	99.99
EBI: Access Control	97.5	97.5	97.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	96	96	96	96	96
HVAC	97.5	97.5	97.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	96	96	96	96	96
Fire	97.5	97.5	97.5	98.5	98.5	98.5	98.5	98.5	98.5	98.5	96	96	96	96	96
Global KPI (Honeywell)	94.20%	94.18%	94.18%	96.40%	96.40%	96.40%	96.40%	97.20%	97.20%	97.09%	96.70%	96.70%	96.66%	96.56%	96.70%

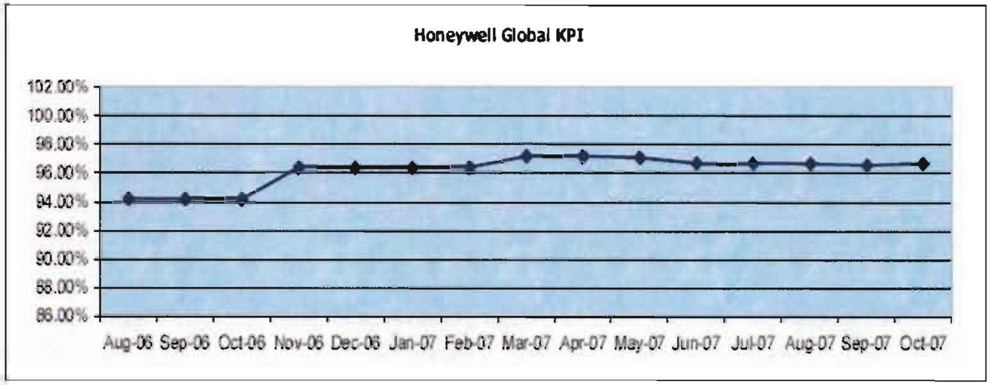


Figure A3: KPI history

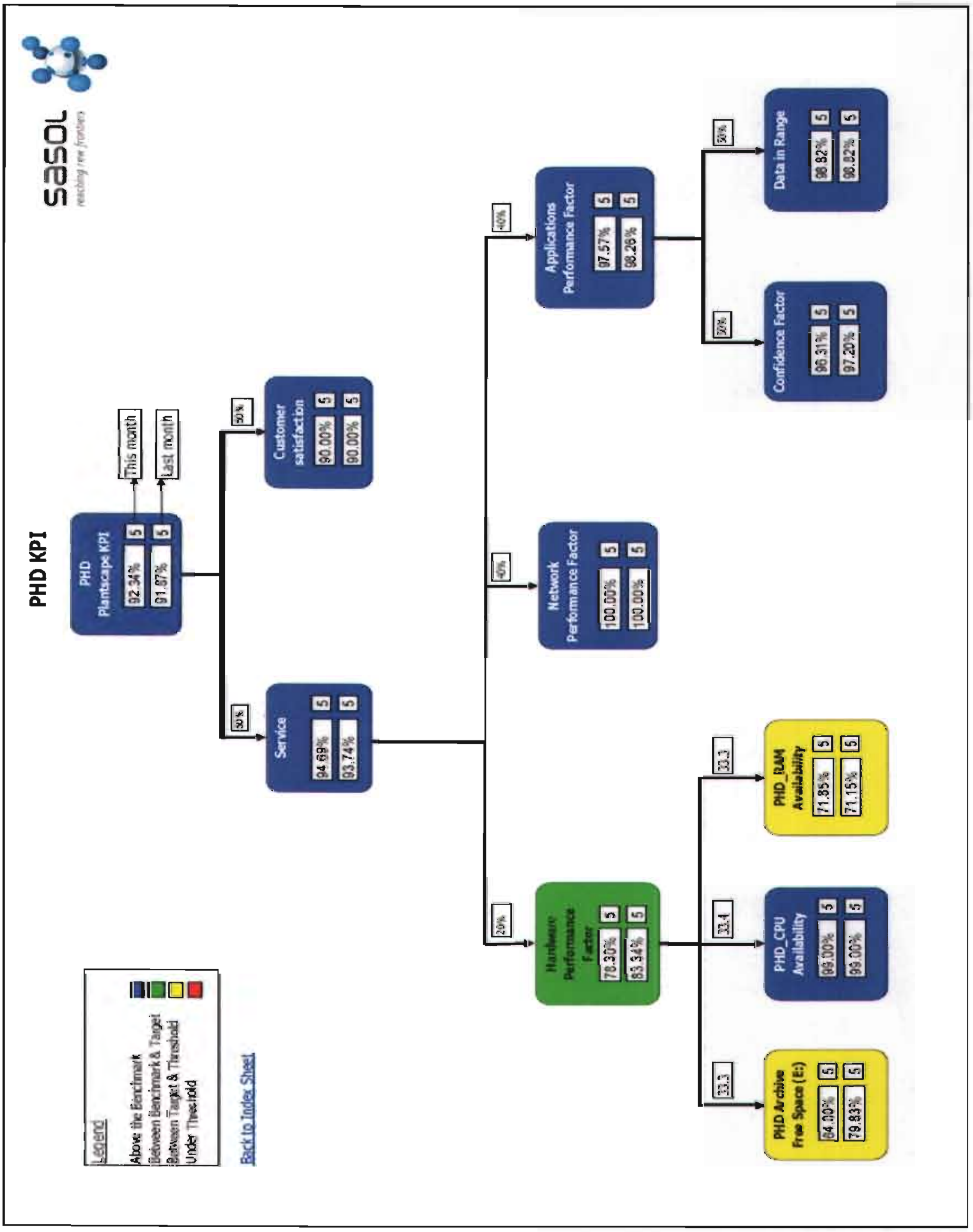


Figure A4: PHD KPI tree

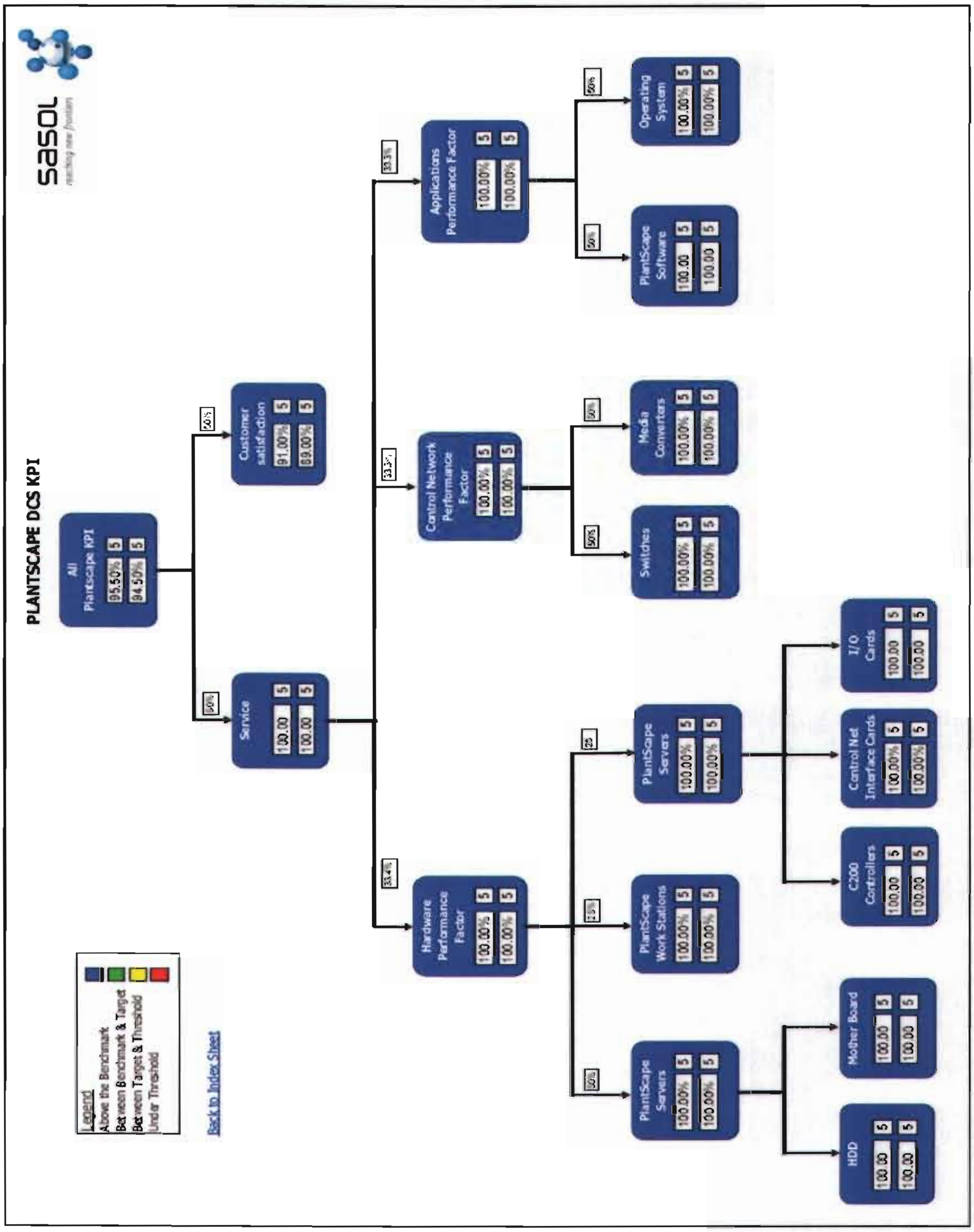


Figure A5: PlantScape KPI tree

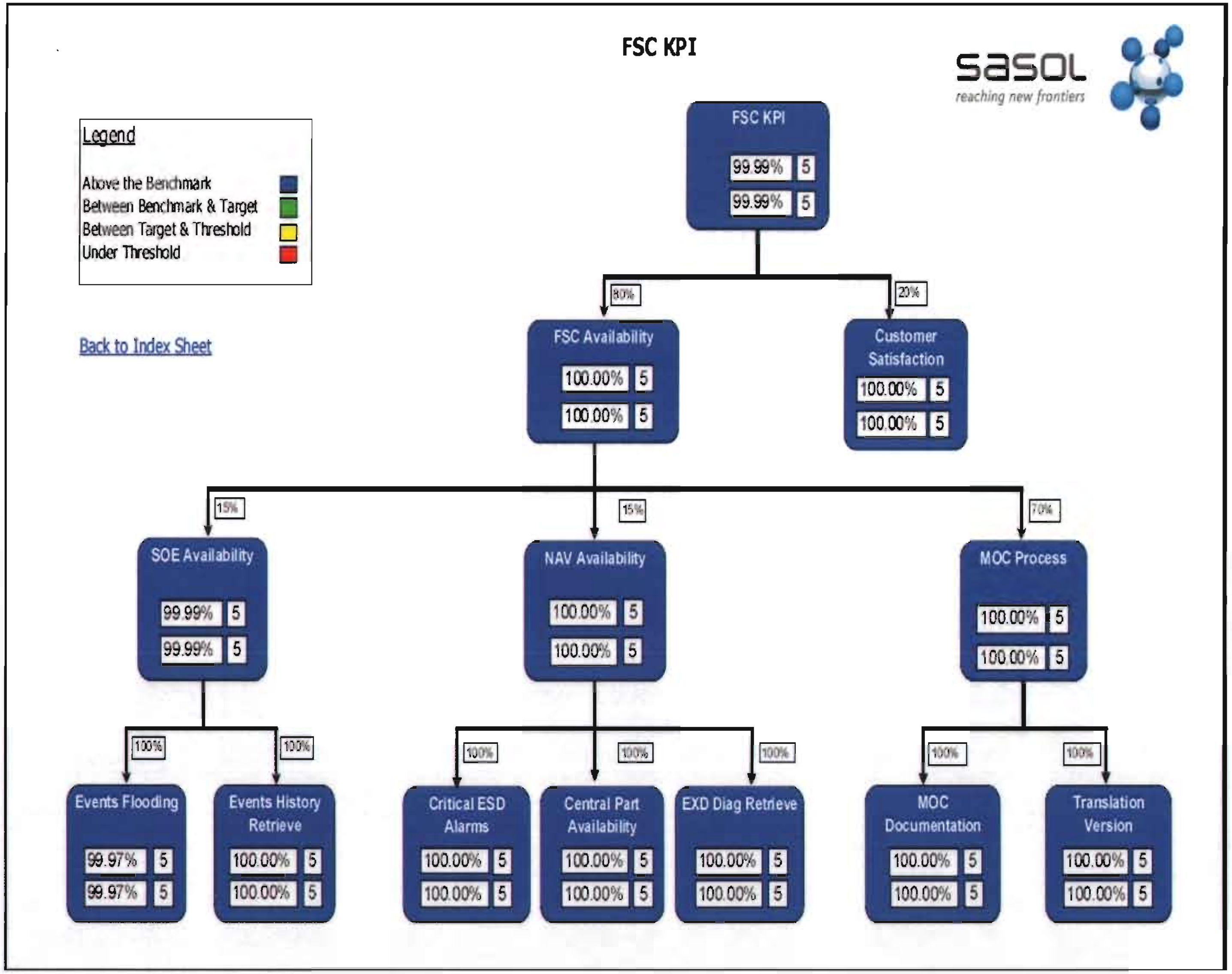


Figure A6: FSC KPI tree

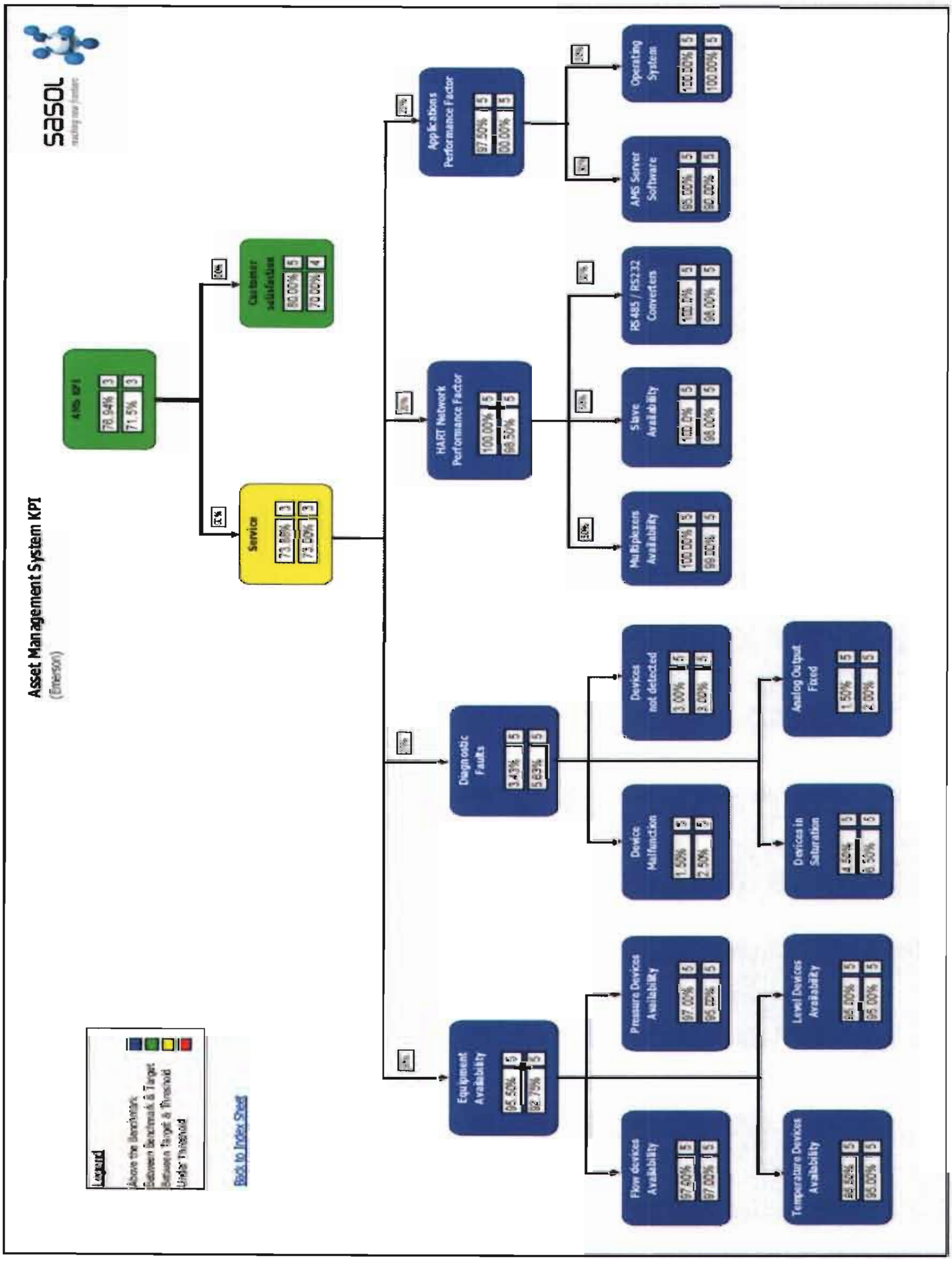


Figure A7: AMS KPI tree

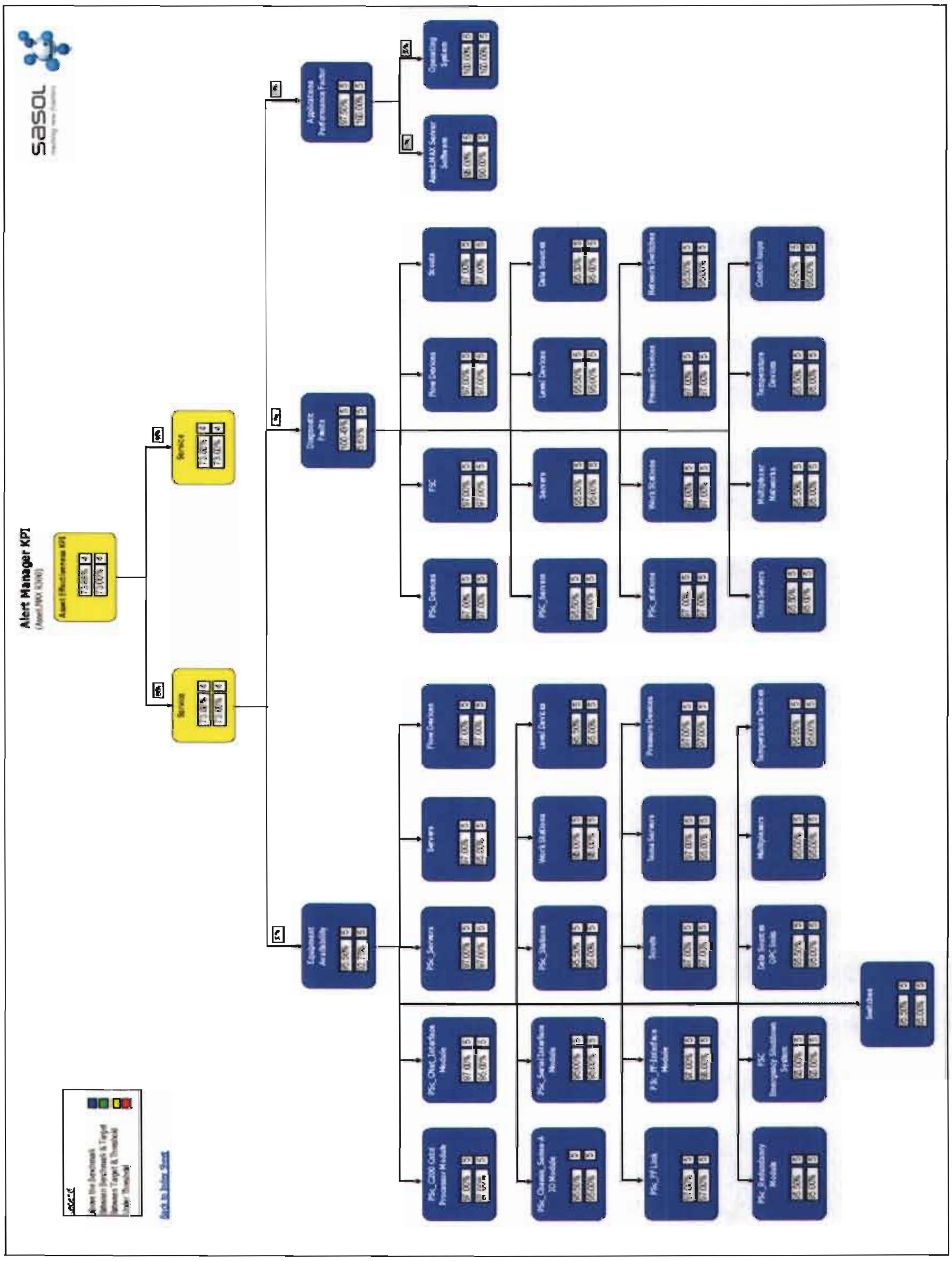


Figure A8: AlertManager KPI tree

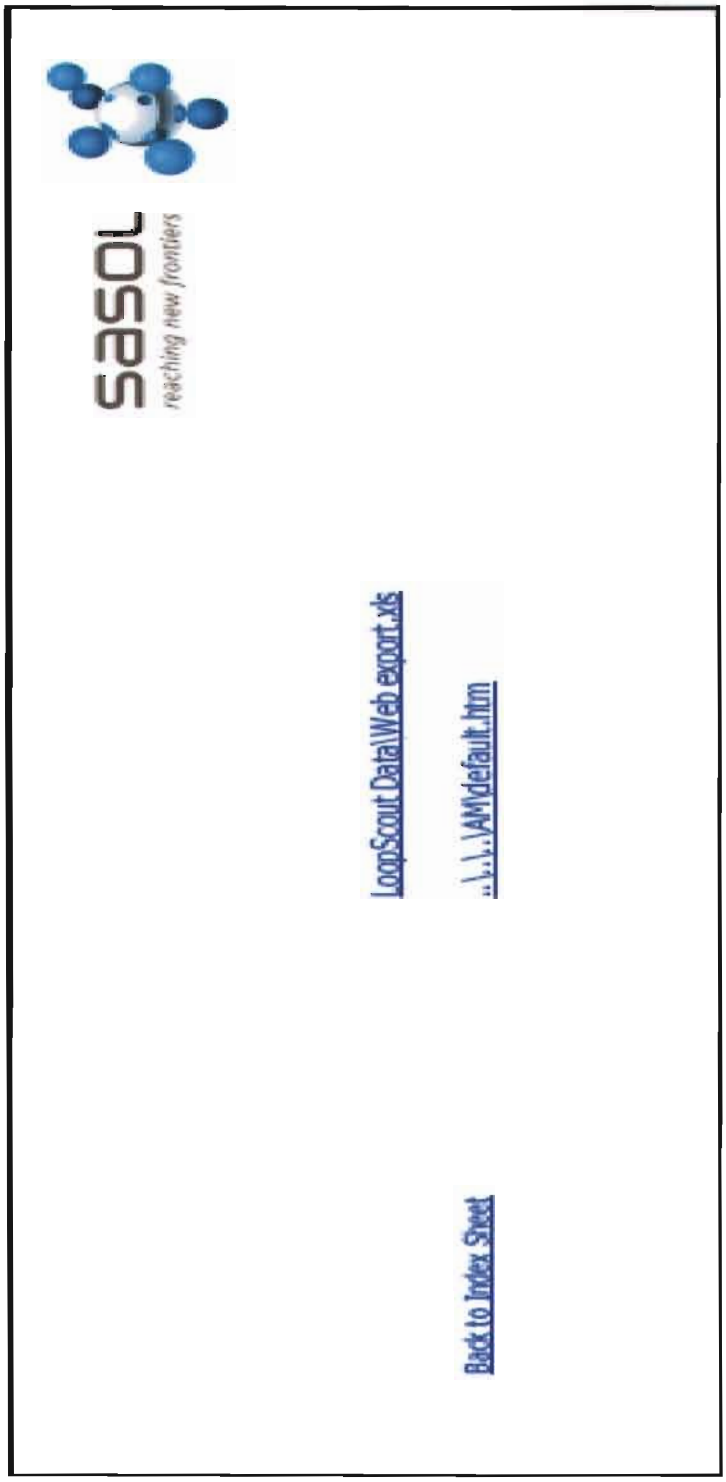


Figure A9: LoopScout KPI tree

ANNEXURE B DVC6000 VALVE SIGNATURE

ValveLink QuickReport
June 14, 2005
14:36:37

admin
ValveLink SNAP-ON
ValveLink SNAP-ON
ValveLink SNAP-ON

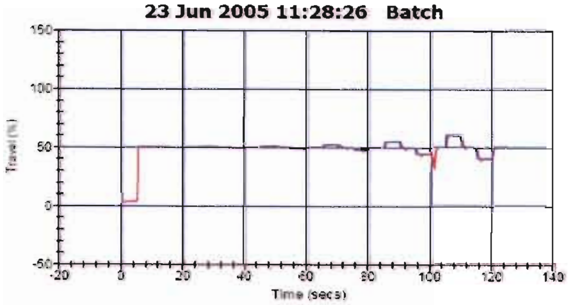
593-FV-30026	HART Tag Name: FV.30026
	Valve Style: SLIDING STEM
	Actuator Style: Spring and Diaphragm
DVC6000 PD	Instrument S/N: 0016407145
	Valve S/N: IA.17500.
	Firmware Revision: -
	Hardware Revision: -

Master Spec Sheet [593-FV-30026]

Valve		Trim		Actuator	
Manufacturer:	Fisher	Seat Type:	Metal	Manufacturer:	Fisher
Type:	EZ	Leakage Class:	IV	Type:	667
Size:	1 in	Port Diameter:		Size:	34
Class:	300	Port Type:	Unbalanced	Effective Area:	69.0 in2
Rated Travel:	75.0 in	Flow Direction:	Up	Air:	Opens
Actual Travel:	0.75 in	Push Down To:	Close	Lower Bench Set:	117.0 kPa
Stem Diameter:	0.375 in	Flow Tends To:	Open	Upper Bench Set:	207.0 kPa
Packing Type:	TFE / Single	Unbalanced Area:		Nominal Supply Pressure:	215.0 kPa
Inlet Pressure:				Spring Rate:	
Outlet Pressure:					

Step Response [593-FV-30026]

23 Jun 2005 11:28:26 Batch



Analyzed Data

Deadband 0.25
Tuning Set
Tuning Set: F
Standard Gain: 6.20
Standard Travel Rate: 3.10
High Perf. Gain:
High Perf. Tvl Rate:
High Perf. Press Rate:
Notes

Analyzed Data (all times in seconds)

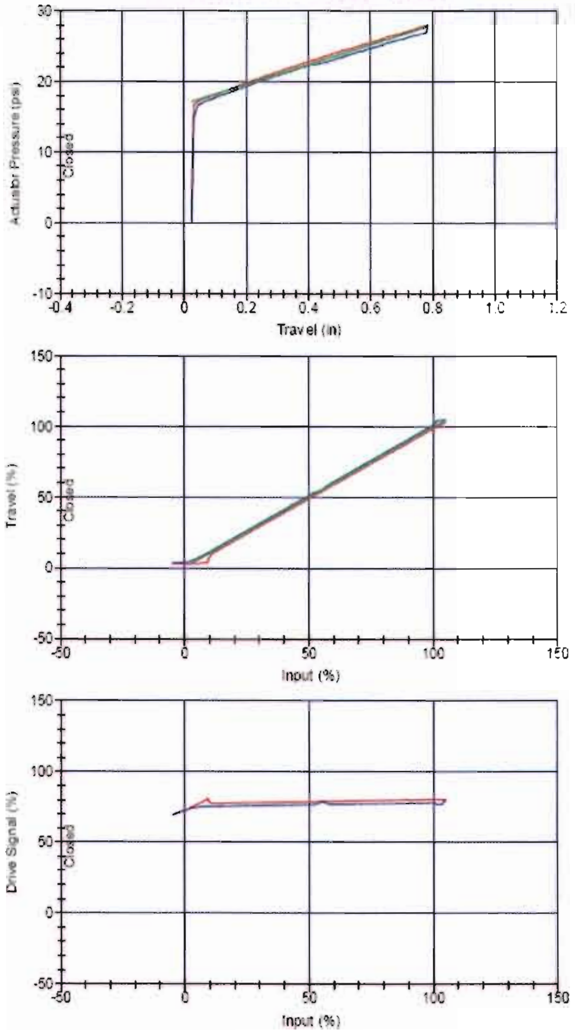
Step	End Point (%):	Ramp Time	Collection Time	Dead Time	Time63	Time86	Stroke Time	OverShoot (%)	Error (%)	Gain
1	50	0	5	-	-	-	-	-	-	0.08
2	50.25	0	5	-	-	-	-	-	-	175.68
3	50	0	5	-	-	-	-	-	-	1.22
4	49.75	0	5	-	-	-	-	-	-	1.51
5	50	0	5	-	-	-	-	-	-	1.46
6	50.5	0	5	-	-	-	-	-	-	0.83
7	50	0	5	-	-	-	-	-	-	0.9
8	49.5	0	5	-	-	-	-	-	-	1.44
9	50	0	5	-	-	-	-	-	-	1.17
10	51	0	5	-	-	-	-	-	-	1.2
11	50	0	5	-	-	-	-	-	-	1.82
12	49	0	5	-	-	-	-	-	-	0.73
13	50	0	5	-	-	-	-	-	-	1.28
14	52	0	5	0.12	0.36	0.36	0.84	0.58	0.33	1.06
15	50	0	5	0.72	1.16	1.16	2.05	36.22	0.1	1.2
16	48	0	5	0.66	1.48	1.48	1.97	-	0.05	1.01
17	50	0	5	0.12	0.37	0.37	0.89	1.63	0.21	1.12
18	55	0	5	0.13	0.38	0.38	0.87	0.0	0.15	0.98
19	50	0	5	0.26	0.57	0.57	1.19	26.61	0.35	1.1
20	45	0	5	0.36	0.66	0.66	1.27	28.47	0.46	1.02
21	50	0	5	1.62	1.86	1.86	2.35	0.9	0.02	1.08
22	60	0	5	0.11	0.37	0.37	0.91	0.24	0.03	1.01
23	50	0	5	0.17	0.45	0.45	1.01	15.29	0.16	1.02
24	40	0	5	0.14	0.45	0.45	1.08	15.87	0.31	1.02
25	50	0	5	0.1	0.35	0.35	0.85	0.0	0.02	1.03

ValveLink QuickReport
June 14, 2005
14:36:37

admin
ValveLink SNAP-ON
ValveLink SNAP-ON
ValveLink SNAP-ON

Total Scan [593-FV-30026]

23 Jun 2005 17:15:56 Batch



Inputs

Input Start:	-5.0 %
Input End:	105.0 %
Scan Time:	50.0 sec
Collection Interval:	150.0 msec.

Analyzed Data

Ave. Dynamic Error:	2.05%
Min. Dynamic Error:	0.79%
Max. Dynamic Error:	2.47%
Dyn. Linearity (Ind.):	0.64%
Zero Ranged Travel at:	3.94 mA
Full Ranged Travel at:	20.06 mA
Average Friction:	23 lbf
Minimum Friction:	10 lbf
Maximum Friction:	34.66 lbf
Spring Rate:	965.46 lbf/in
Bench Set:	-1022.14 - 27.28 psi
Seat Load As Tested:	1080.26 lbf
Service Seat Load:	NA
Required Seat Load:	NA
Expected Packing Friction:	38 lbf
Expected Total Friction:	38 lbf

Tuning Set

Tuning Set:	F
Gains	
Proportional:	6.20
Velocity:	3.10
MLF:	35.00
Integral Control:	Disabled
Integral Gain:	9.4

Notes

Valve

Manufacturer:	Fisher
Type:	EZ
Size:	1 in
Class:	300
Rated Travel:	75.0 in
Actual Travel:	0.75 in
Stem Diameter:	0.375 in
Packing Type:	TFE / Single
Inlet Pressure:	
Outlet Pressure:	

Trim

Seat Type:	Metal
Leakage Class:	IV
Port Diameter:	
Port Type:	Unbalanced
Flow Direction:	Up
Push Down To:	Close
Flow Tends To:	Open
Unbalanced Area:	

Actuator

Manufacturer:	Fisher
Type:	667
Size:	34
Effective Area:	69.0 in2
Air:	Opens
Lower Bench Set:	117.0 kPa
Upper Bench Set:	207.0 kPa
Nominal Supply Pressure:	
Spring Rate:	

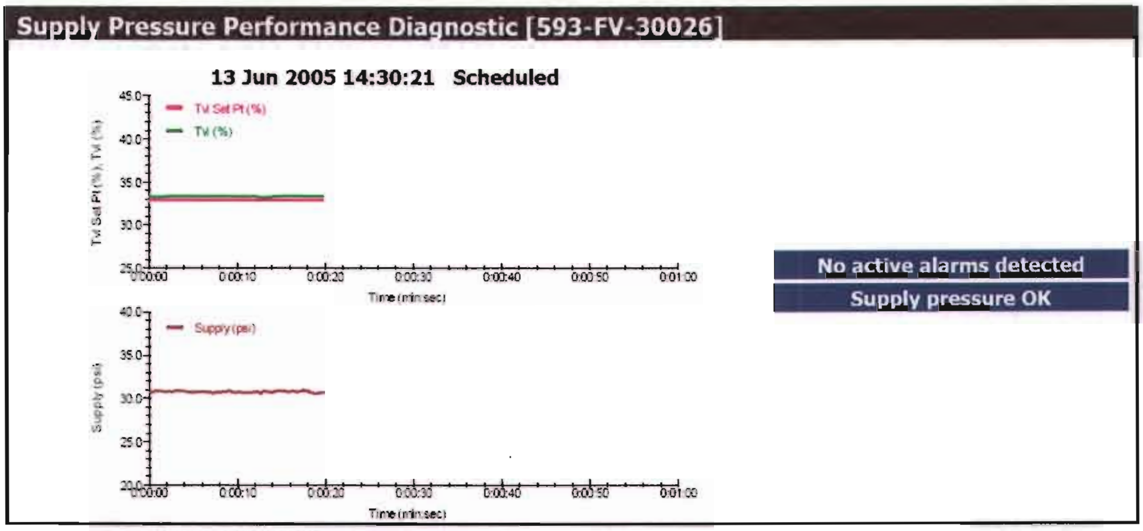


Figure B1: DVC6000 valve signature

ANNEXURE C ASSET MAINTENANCE BLUEPRINT

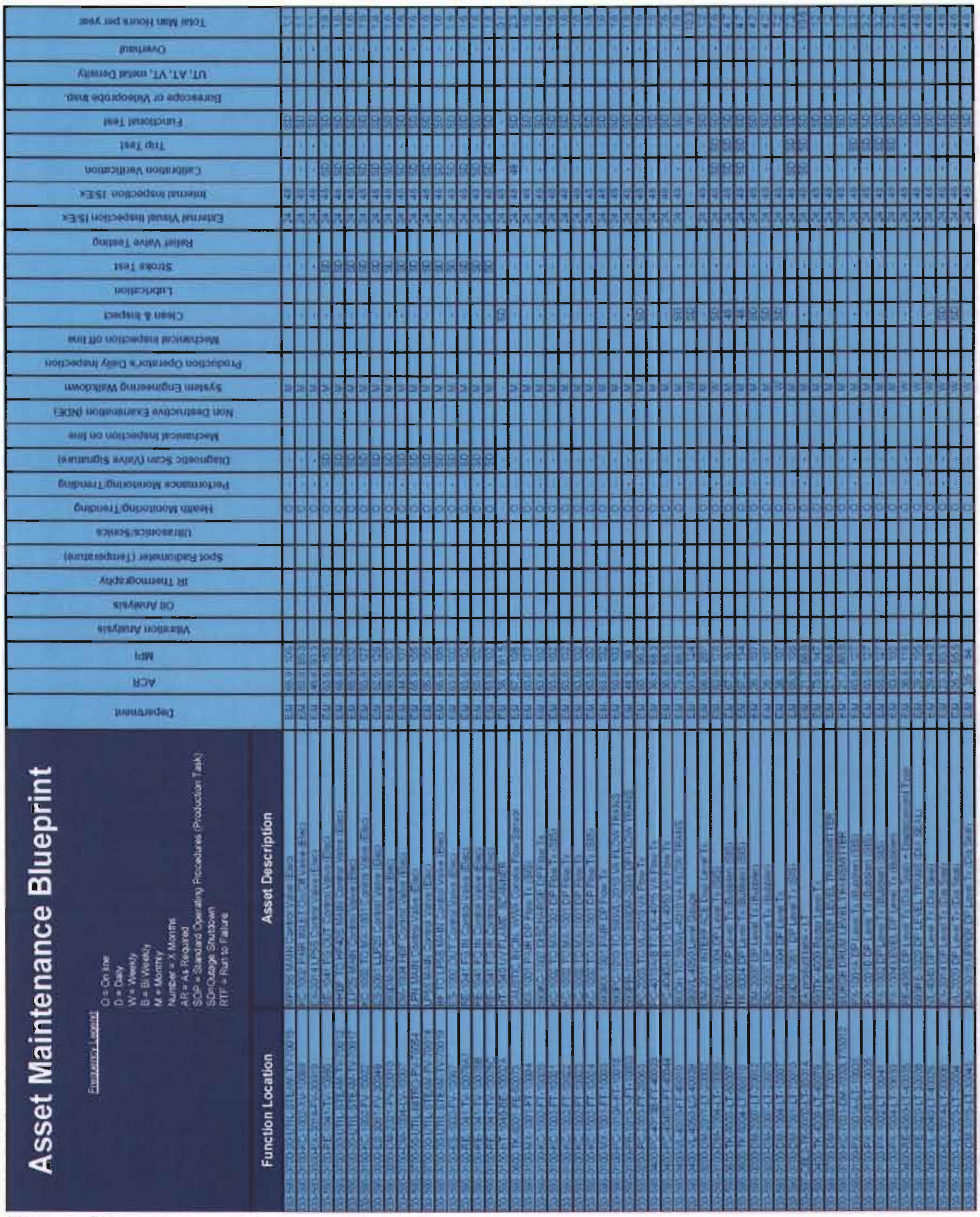


Figure C1: Asset maintenance blueprint

ANNEXURE D MAINTENANCE PROCEDURE

PHD Maintenance Procedure

Introduction

This document provides the system administrator with a standard work procedure to determine whether PHD is functioning correctly on the local machine where PHD is installed.

Purpose

This document is to be used as a quick reference. It defines the various maintenance tasks that need to be performed on a Historian PHD system. This procedure will set a standard on the tasks to be executed for preventative maintenance on all Historian PHD systems.

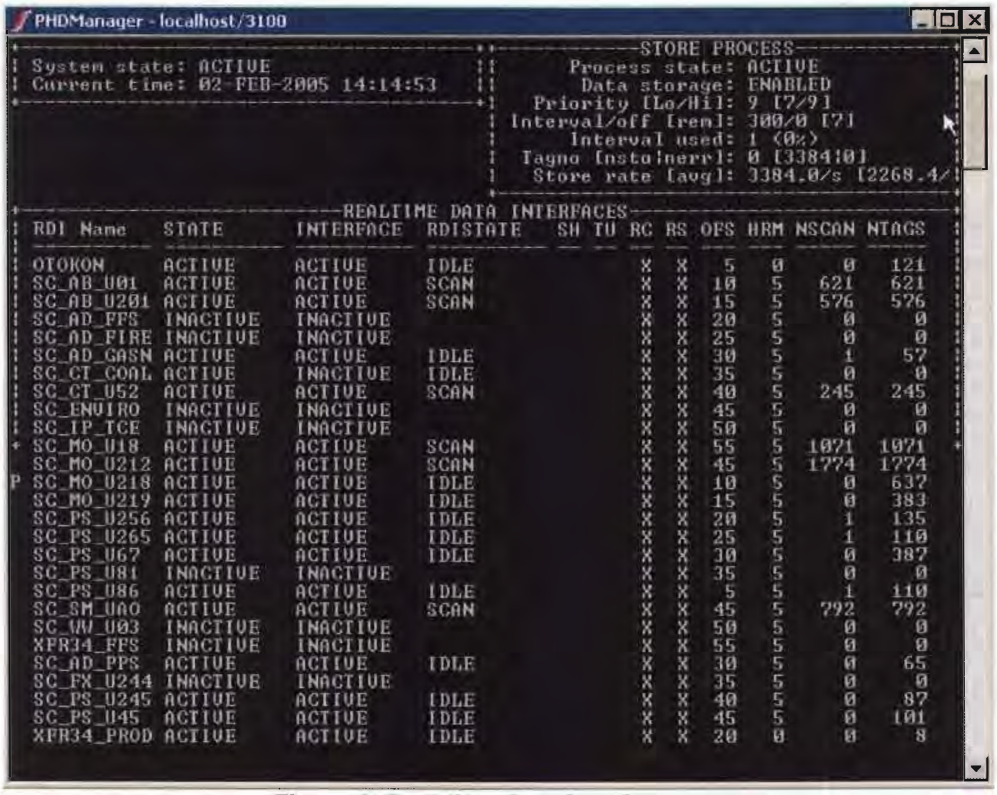
Scope

This document is intended for the use of the Honeywell support personnel, both locally at the SASOL site as well as where offsite work is to be performed, it can also be distributed to offsite customers where Honeywell support personnel delivered services as part of ongoing support.

System maintenance Procedure

PHDMAN command window

- Log on to the PHD server locally or with a remote access tool.
- Open a command window and type "**phdman**" to open the PHD Management console.
- To change from the current window back to the phdman prompt you need to press '**ctrl c**' on the keyboard or open a new window and type in **"phdman".**
- Type in ***"mon sys".*** A window will open with all the RDI's that are configured on PHD for that specified server.
- The RDI's must be in an active, active state for the *state* and *interface* heading. The rdistate must change between scan and idle mode, an indication that the interface is working correctly. In the same window in the top left corner the system state must be active. In the top right hand corner is the store process. Process state must be active and data store must be enabled if history needs to be stored in the archives.



PHDManager - localhost/3100

System state: ACTIVE
Current time: 02-FEB-2005 14:14:53

STORE PROCESS
Process state: ACTIVE
Data storage: ENABLED
Priority [Lo/Hi]: 9 [7/9]
Interval/off [rem]: 300/0 [7]
Interval used: 1 (0%)
Tagno [insto|nerr]: 0 [3384|0]
Store rate [avg]: 3384.0/s [2268.4/

REALTIME DATA INTERFACES

RDI Name	STATE	INTERFACE	RDISTATE	SH	TU	RC	RS	OFS	HRM	NSCAN	NTAGS
OTOKON	ACTIVE	ACTIVE	IDLE			X	X	5	0	0	121
SC_AB_U01	ACTIVE	ACTIVE	SCAN			X	X	10	5	621	621
SC_AB_U201	ACTIVE	ACTIVE	SCAN			X	X	15	5	576	576
SC_AD_FFS	INACTIVE	INACTIVE				X	X	20	5	0	0
SC_AD_FIRE	INACTIVE	INACTIVE				X	X	25	5	0	0
SC_AD_GASN	ACTIVE	ACTIVE	IDLE			X	X	30	5	1	57
SC_CT_COAL	ACTIVE	INACTIVE	IDLE			X	X	35	5	0	0
SC_CT_U52	ACTIVE	ACTIVE	SCAN			X	X	40	5	245	245
SC_ENVIRO	INACTIVE	INACTIVE				X	X	45	5	0	0
SC_IP_TCE	INACTIVE	INACTIVE				X	X	50	5	0	0
SC_MO_U18	ACTIVE	ACTIVE	SCAN			X	X	55	5	1071	1071
SC_MO_U212	ACTIVE	ACTIVE	SCAN			X	X	45	5	1774	1774
P SC_MO_U218	ACTIVE	ACTIVE	IDLE			X	X	10	5	0	637
SC_MO_U219	ACTIVE	ACTIVE	IDLE			X	X	15	5	0	383
SC_PS_U256	ACTIVE	ACTIVE	IDLE			X	X	20	5	1	135
SC_PS_U265	ACTIVE	ACTIVE	IDLE			X	X	25	5	1	110
SC_PS_U67	ACTIVE	ACTIVE	IDLE			X	X	30	5	0	387
SC_PS_U81	INACTIVE	INACTIVE				X	X	35	5	0	0
SC_PS_U86	ACTIVE	ACTIVE	IDLE			X	X	5	5	1	110
SC_SM_UAO	ACTIVE	ACTIVE	SCAN			X	X	45	5	792	792
SC_WW_U03	INACTIVE	INACTIVE				X	X	50	5	0	0
XFR34_FFS	INACTIVE	INACTIVE				X	X	55	5	0	0
SC_AD_PPS	ACTIVE	ACTIVE	IDLE			X	X	30	5	0	65
SC_FX_U244	INACTIVE	INACTIVE				X	X	35	5	0	0
SC_PS_U245	ACTIVE	ACTIVE	IDLE			X	X	40	5	0	87
SC_PS_U45	ACTIVE	ACTIVE	IDLE			X	X	45	5	0	101
XFR34_PROD	ACTIVE	ACTIVE	IDLE			X	X	20	0	0	8

Figure 1 Real-time Data Interface

In a PHD Management console window type in ***"mon sec"*** you can find information in this window:

- When PHD was last restarted.
- Tags currently defined in the system.
- Pool used.
- If the pool used is 100%, the tag no is all used and PHD will not work correctly
  No new tags will be built into the PHD.

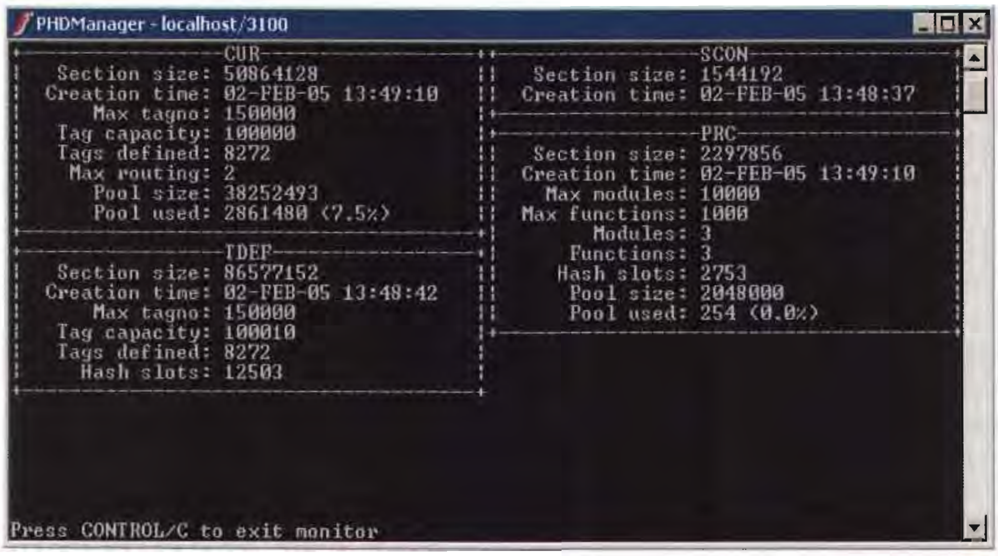


Figure 2 Sections

Reports

In a PHD Management console window type in: ***"rep sum".*** A system summary will be given of the system state.

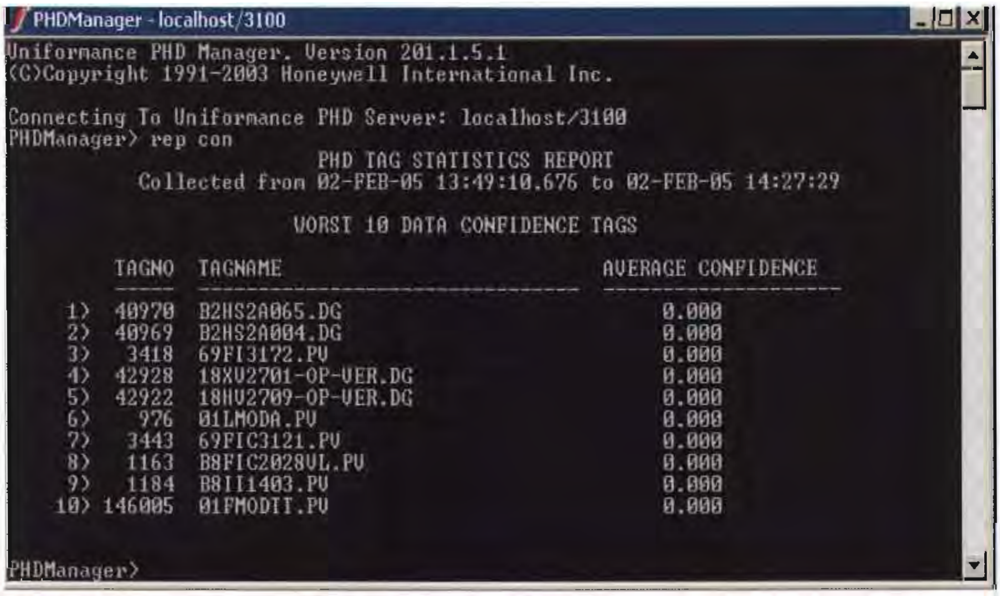
- Number of collecting tags.
- Total range errors.
- Data confidence.

```
PHDManager - localhost/3100
Uniformance PHD Manager. Version 201.1.5.1
(C)Copyright 1991-2003 Honeywell International Inc.

Connecting To Uniformance PHD Server: localhost/3100
PHDManager> rep sum
                    PHD TAG STATISTICS REPORT
         Collected from 02-FEB-05 13:49:10.676 to 02-FEB-05 14:17:20

                         SYSTEM SUMMARY

           Number of tags sampled:       7151
         Total queue overwrite tags:        4
           Total range error tags:         14

                         AVERAGE        MIN          MAX
                         -------      -------      -------
    Analog data compression:     2.908        1.000      205.875
  Discrete data compression:     3.934        1.000        9.667
            Data confidence:    89.180        0.000      100.000
   Percentage gross errors:      0.000%       0.000%       0.000%

PHDManager> _
```

Figure 3 System Summary

In a PHD Management console window type in: ***"rep con xxx c:\Logs.txt"***

- A window will open with the tags with the lowest confidence.
- The xxx specify the number of worst confidence tags to return.
- Export the data to text file using the optional last parameter to specify the path.



```
PHDManager - localhost/3100
Uniformance PHD Manager. Version 201.1.5.1
(C)Copyright 1991-2003 Honeywell International Inc.

Connecting To Uniformance PHD Server: localhost/3100
PHDManager> rep con
                    PHD TAG STATISTICS REPORT
         Collected from 02-FEB-05 13:49:10.676 to 02-FEB-05 14:27:29

                  WORST 10 DATA CONFIDENCE TAGS

        TAGNO   TAGNAME                          AVERAGE CONFIDENCE
        -----   -------------------------------  ------------------
    1)  40970   B2HS2A065.DG                          0.000
    2)  40969   B2HS2A004.DG                          0.000
    3)   3418   69FI3172.PV                           0.000
    4)  42928   18XV2701-OP-VER.DG                    0.000
    5)  42922   18HV2709-OP-VER.DG                    0.000
    6)    976   01LMODA.PV                            0.000
    7)   3443   69FIC3121.PV                          0.000
    8)   1163   B8FIC2028VL.PV                        0.000
    9)   1184   B8II1403.PV                           0.000
   10) 146005   01FMODIT.PV                           0.000

PHDManager>
```

Figure 4 Statistical Report

Archives

In a PHD Management console window type in: ***"sho a"***

- A list of the archives including the current archive will be listed.

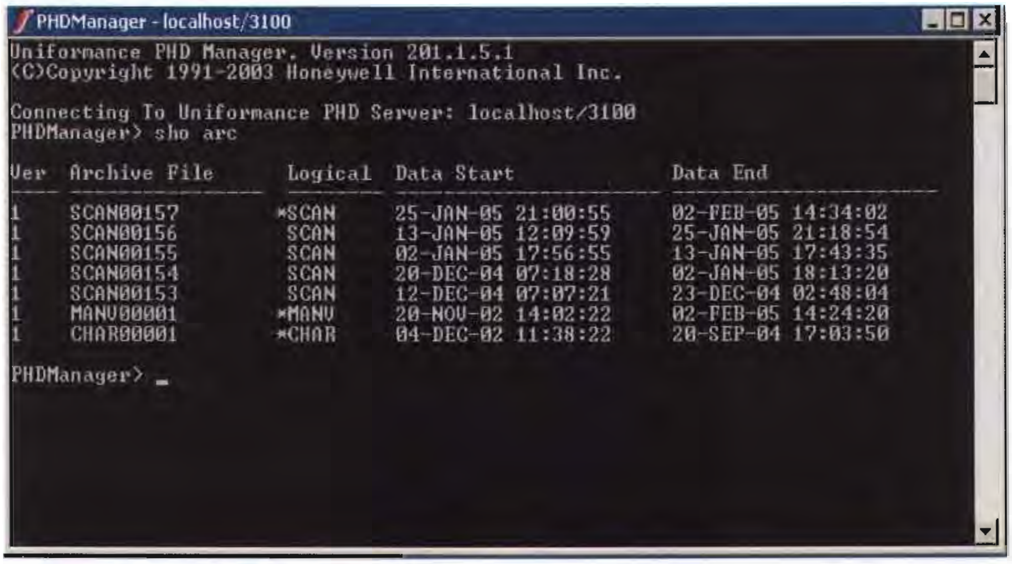


Figure 5 Archive Report

More Help

If more information is needed, the ***"help"*** command can be typed in the PHD window and a list of topics will be given.

Server maintenance procedure

PHD is installed under the following tree:

<Install path> uniformance \ phdserver.

The log files and archive files may be on the same drive but most of the time it is on a separate drive.

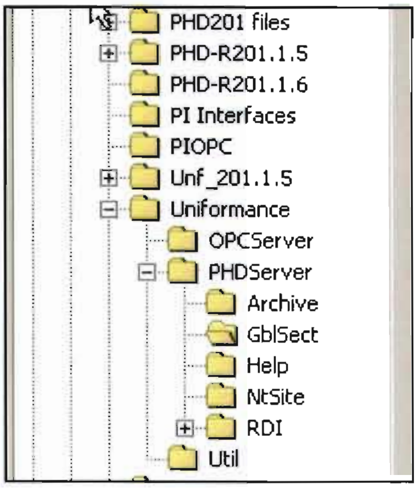


Figure 6 Uniformance Dir

Hard Drive

The hard drive must be checked for space availability. If the drive is full, PHD will not save the tags information and data can be corrupted.

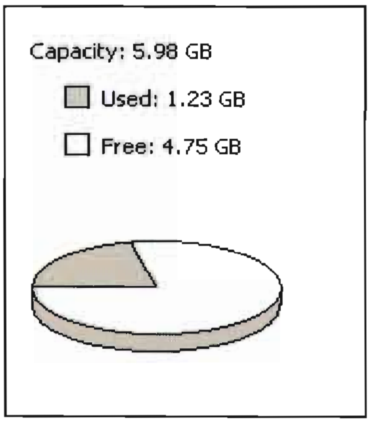


Figure 7 Hard Drive Availability

Log Files

The log files must be checked for size. A good indication can be obtained from them e.g. what is wrong with a RDI that is not collecting data and tags that are not working. A new event log file can be created by typing in **"create logfile"** in the phdman window. If a log file of a RDI needs to be deleted, the RDI should be stopped before the log will be deleted.

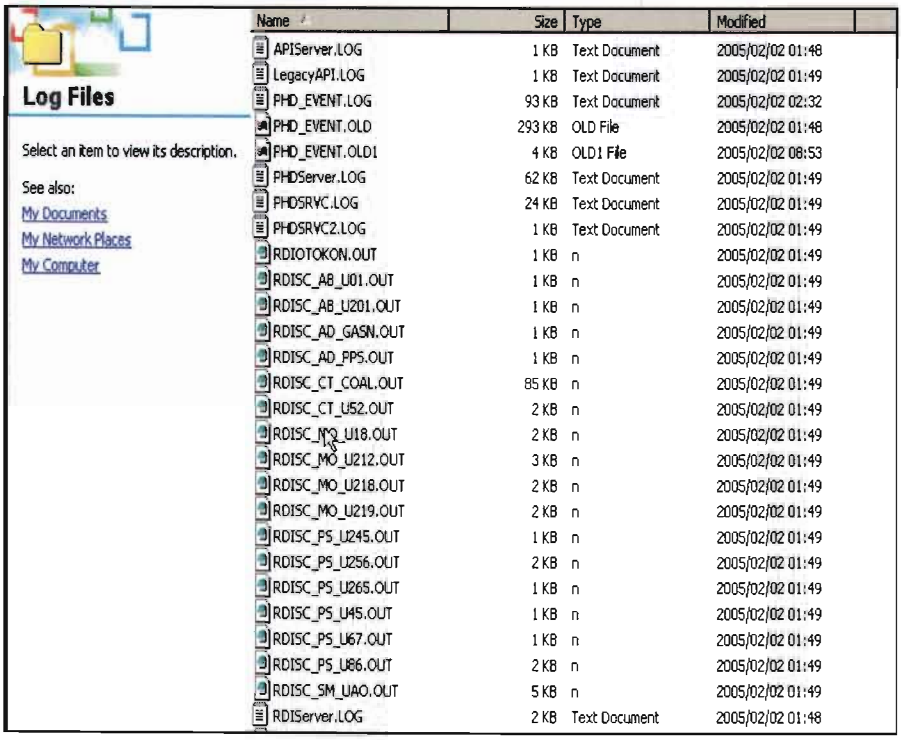


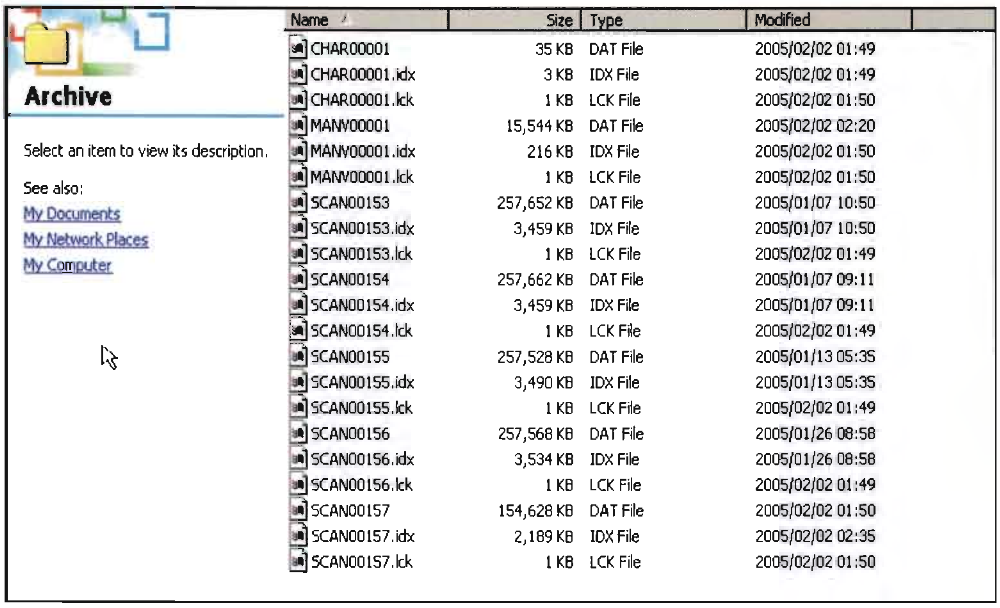
Figure 8 Log Files

Archives

The archives also need to be checked. They are set to a specific size and if there are problems with them, they will grow in size.

Steps to create a new archive

- In a PHD Management console window type **"sho arc"** (this will show the archive that is currently active and the other archives available).
- Set store: enable 0.
- Disconnect scanxxx.
- Create arc scanxx.
- Connect scanxxx scan active.
- Set store: enable 1.



Name	Size	Type	Modified
CHAR00001	35 KB	DAT File	2005/02/02 01:49
CHAR00001.idx	3 KB	IDX File	2005/02/02 01:49
CHAR00001.lck	1 KB	LCK File	2005/02/02 01:50
MANV00001	15,544 KB	DAT File	2005/02/02 02:20
MANV00001.idx	216 KB	IDX File	2005/02/02 01:50
MANV00001.lck	1 KB	LCK File	2005/02/02 01:50
SCAN00153	257,652 KB	DAT File	2005/01/07 10:50
SCAN00153.idx	3,459 KB	IDX File	2005/01/07 10:50
SCAN00153.lck	1 KB	LCK File	2005/02/02 01:49
SCAN00154	257,662 KB	DAT File	2005/01/07 09:11
SCAN00154.idx	3,459 KB	IDX File	2005/01/07 09:11
SCAN00154.lck	1 KB	LCK File	2005/02/02 01:49
SCAN00155	257,528 KB	DAT File	2005/01/13 05:35
SCAN00155.idx	3,490 KB	IDX File	2005/01/13 05:35
SCAN00155.lck	1 KB	LCK File	2005/02/02 01:49
SCAN00156	257,568 KB	DAT File	2005/01/26 08:58
SCAN00156.idx	3,534 KB	IDX File	2005/01/26 08:58
SCAN00156.lck	1 KB	LCK File	2005/02/02 01:49
SCAN00157	154,628 KB	DAT File	2005/02/02 01:50
SCAN00157.idx	2,189 KB	IDX File	2005/02/02 02:35
SCAN00157.lck	1 KB	LCK File	2005/02/02 01:50

Figure 9 Archives

This maintenance must be done on a weekly basis using the procedure and if problems are detected that can not be resolved, please contact the Honeywell support group at the contact numbers that you have been given.