Development of an information management solution to ensure the sustainability of DSM projects

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1. Abstract

Title:	Development of an information management solution to ensure the sustainability of DSM projects
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The efficient use of energy resources has become a major challenge for the sustainable development of countries around the world. South Africa has not escaped the challenge for sustainable energy. The economic prosperity in South Africa after 1994 brought about an increase in the demand for electricity. By 2007 the increased demand for electricity exceeded the existing electricity supply capacity, especially during peak-time hours. The increase in the peak-time electricity demand made the entire power system vulnerable to power outages.

South Africa experienced severe power outages during December 2007 and January 2008 as a direct result of supply capacity constraints and an increase in electricity demand. Eskom was forced to apply load shedding. Eskom intensified its Demand-side Management (DSM) program in an effort to restore stability to the electrical supply network.

Electricity saving performance of DSM projects tends to deteriorate over time in the absence of proper and frequent monitoring of projects and information feedback. The problem of the performance decline is addressed by analysing how and why an information management approach to DSM can enhance the sustainability of DSM projects.

This study motivates the need for an information management solution to support the information needs of DSM projects and thereby ensure the sustainability of the DSM projects. A database-driven web application is developed and implemented to show how the ESCOs existing information management approach can further be enhanced through the use of a web-based application. The study was conducted at a South African ESCO, namely, HVAC International (Pty) Ltd.

2. Samevatting

Titel: Ontwikkeling van ‘n inligtingbestuursoplossing ten einde die volhoudbaarheid van aanvraagkant energiebestuur (AEB) projekte te verseker

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Die effektiewe gebruik van energiebronne het 'n aansienlike uitdaging geword vir die volhoudbare ontwikkeling van lande wêreldwyd. Suid-Afrika het nie die uitdaging vir volhoudbare energie vrygespring nie. Die ekonomiese welvaart in Suid-Afrika na 1994 het gepaard gegaan met 'n toename in die aanvraag na elektrisiteit. Teen 2007 is die bestaande elektrisiteitsvoorsieningskapasiteit oorskry deur die toename in die aanvraag na elektrisiteit, veral gedurende piektye. Die toename in die piektyd aanvraag na elektrisiteit het die kragstelsel kwesbaar gemaak vir kragonderbrekings.

Suid-Afrika het gebuk gegaan onder ernstige kragonderbrekings gedurende Desember 2007 en Januarie 2008 as 'n direkte gevolg van elektrisiteitsvoorsieningstekorte en 'n toename in die aanvraag na elektrisiteit. Eskom was geforseer om lasskuif toe te pas. Eskom het sy Aanvraag-kant Energiebestuur (AEB) program verskerp in 'n poging om stabiliteit in die elektristeitsnetwerk te herstel.

Die elektrisiteitsbesparingsvermoë van AEB projekte neem geleidelik af in die afwesigheid van voldoende en gereelde monitering van projekte en terugvoer van informasie. Hierdie probleem word aangespreek deur die analise van hoe en waarom 'n inligtingbestuursbenadering tot AEB die volhoudbaarheid van AEB projekte kan verbeter.Hierdie studie motiveer die behoefte vir 'n inligtingsbestuursoplossing om die inligtingsbehoeftes van AEB projekte te ondersteun en hulle volhoudbaarheid te verseker. 'n Databasis-gedrewe webtoepassing word ontwikkel en ge-implementeer om te toon hoe die ESCO se huidige inligtingbestuursbenadering tot AEB verbeter kan word deur die gebruik van 'n web-gebaseerde inligtingsbestuursoplossing. Hierdie studie was onderneem by 'n Suid-Afrikaanse ESCO, naamlik, HVAC International (Edms) Bpk.

3. Acknowledgments

I would like to thank God for showing me once again that nothing is impossible and bringing me onto this path.

I would like to express my appreciation to Prof E.H. Matthews and Prof M. Kleingeld for granting me the opportunity to complete my studies under their guidance and support.

I would like to express special thanks to Dr. R. Pelzer for his patience and motivation during the course of this study.

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7. Nomenclature

CFL	Compact fluorescent lamp
CSV	Comma-Separated Value
DSM	Demand Side Management
Entity	An entity in the context of data modelling represents any person, place, thing or event about which data are to be collected and stored
ESCO	Energy services company
FTP	File Transfer Protocol
GPRS	Global Packet Radio Service
GSM	Global System for Mobile Communication
IPP	Independent Power Producers
KPI	Key Performance Indicator
M & V	Measurement and Verification
Marvin	Monitor Analyse Report Verify Inform Notify
MW	Mega watt
NAESCO	National Association of Energy Services Companies
NERSA	National Energy Regulator of South Africa
PLC	Programmable Logic Controller
PPM	Project Portfolio Management
Rc	Rand-cent
REMS	Real-time Energy Management System
SCADA	Supervisory Control and Data Acquisition
SQL	Structured Query Language

Chapter 1: Introduction to the study

Source: Electricity supply industry of South Africa – general information for potential investors

1.1 A global challenge for sustainable energy

The efficient use of energy resources has become a major challenge for sustainable development around the world [1]. Energy demand is projected to grow in line with the future world population growth [1, 2].

The present global demand for energy resources and energy consumption trends are not sustainable [2]. It is estimated that more than 80% of the global energy demand is based on fossil fuels such as coal, oil and natural gas [1].

According to the Key World Energy Statistics 2009 Report, oil accounted for 34% of the world total primary energy supply by the end of 2007, followed by coal at 26.5% and gas at 20.9% as shown in Figure 1 [3].

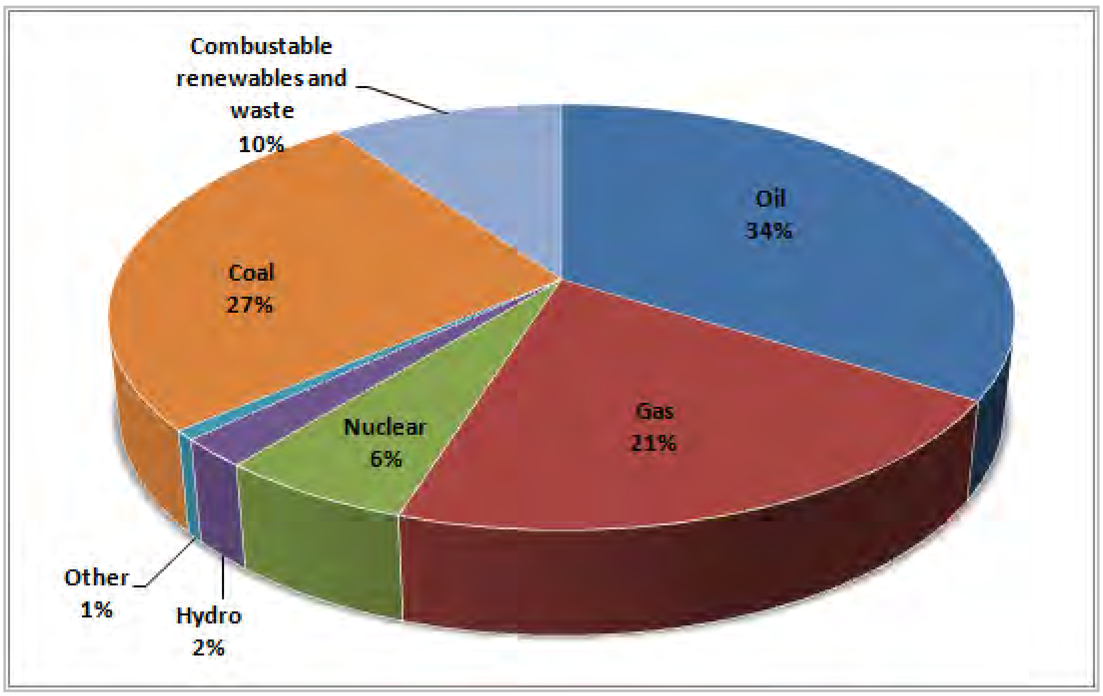


Figure 1 - World total primary energy supply [3]

The Energy Information Administration (EIA) forecasts that the increase in the combined world energy consumption will increase from 138,343,200 GWh in 2006 to 161,791,200 GWh in 2015 and 198,721,800 GWh in 2030 as shown in Figure 2. This will result in a total projected increase of 44% for the period from 2006 and 2030 [4].

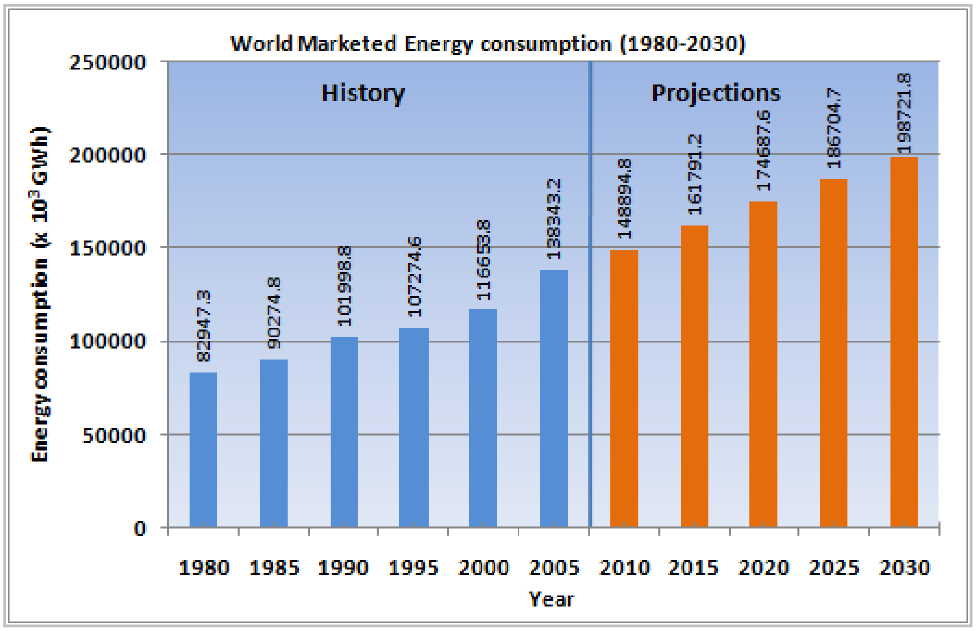


Figure 2 - World marketed energy consumption (1980-2030) [4]

Environmental impact

The intensive use of energy resources is detrimental to the environment. The combustion of fossil fuels has resulted in the emission of harmful greenhouse gasses (CO_2 emissions) into the atmosphere. Greenhouse gases have been identified as the major contributor to global climate changes [2]. The combustion of fossil fuels accounts for more than 50% of the total greenhouse gas emissions worldwide [2]. CO_2 emissions worldwide have been on the increase since 1971 as shown in Figure 3. The largest contribution of CO_2 emissions originate from developing countries [3].

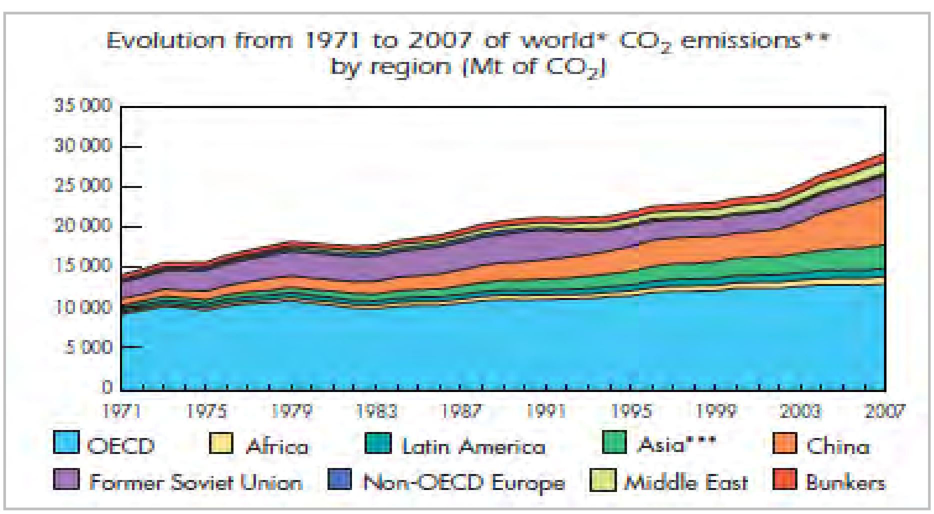


Figure 3 - Global CO_2 emissions by region (Mt of CO_2) [3]

1.2 Electricity supply challenge in South Africa

South Africa is heavily dependent on its energy-intensive mining industry [5]. The country's energy industry itself contributes about 15% to the national Gross Domestic Product [6]. South Africa has been fortunate to have substantial deposits of coal and smaller deposits of oil and natural gas available for energy generation [7].

The South African energy industry is dominated by the use of coal as the primary source of energy. Coal is provided at a cheaper cost to the South African consumer in relation to international standards [8]. By the end of 2007 the use of coal as an input to energy generation accounted for 72.1% of the country's total primary energy supply [5]. Oil contributed 12.6% and gas 2.8% of the total energy supply as shown in Figure 4.

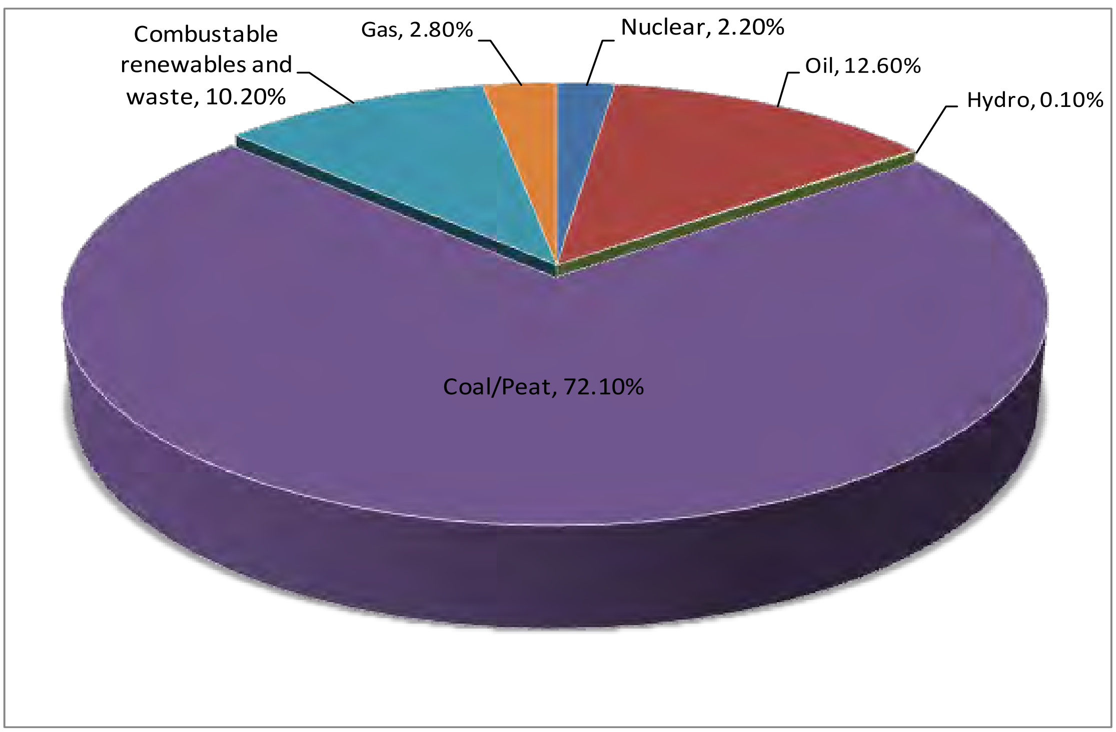


Figure 4 - South African total primary energy supply by type (2007) [5]

Electricity supply chain

The electricity supply industry in South Africa is made up of the following entities, namely, the state-owned enterprise Eskom, municipalities, private generators of electricity and imported electricity [9]. Eskom is the dominant supplier of electricity and generates about 92% of the South Africa's electricity [9]. Eskom exports 5% of the generated electricity to Botswana, Lesotho, Mozambique, Namibia, Swaziland and Zimbabwe [9]. Figure 5 shows the South African electricity supply chain.

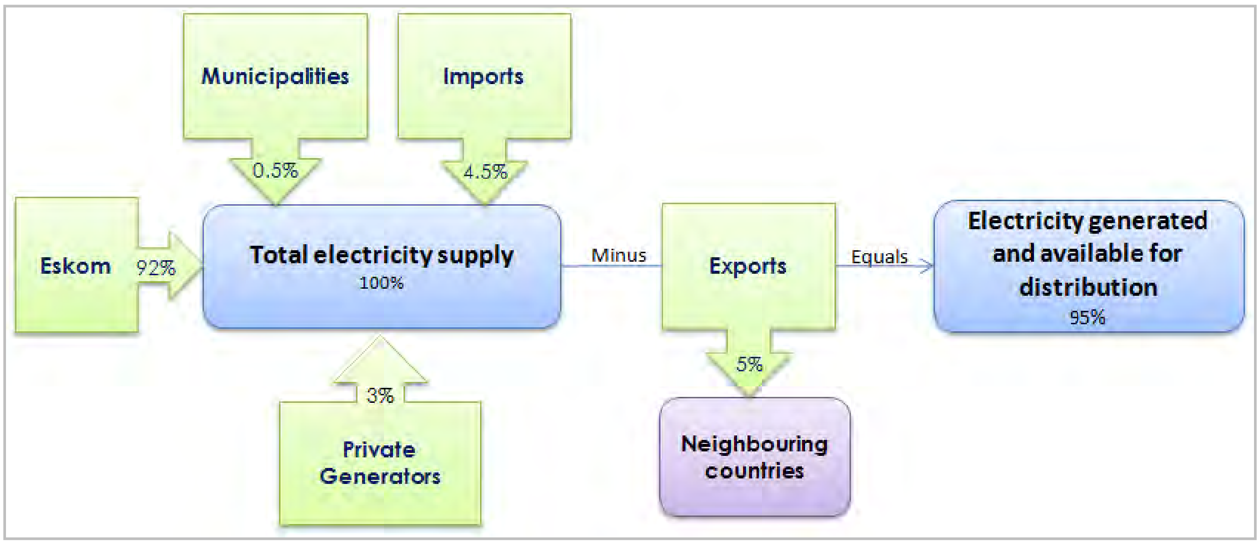


Figure 5 - The South African energy supply chain

Electricity infrastructure cost

It was relatively economical to build a power station prior to the 1990's. The 3600 MW coal-fired Duvha power station, constructed in 1975, cost only R1.6 million [10, 11]. In 2009 the cost of building the new coal-fired 4788 MW Medupi power station in Lephalale was estimated at R124 billion [12]. This is an expensive investment considering the fact that the initial approved budget for building the power station was R26 billion in 2006 [12].

Economic growth and increase in electricity demand

During 1984 to 1994 the South African average economic growth rate was less than 1% per annum [13]. However, from 1994 to 2007 the economy grew at an average annual rate of over 4% [13]. South Africa's Gross Domestic Product (GDP) showed 33 quarters of uninterrupted expansion since September 1999, as shown in Figure 6 [13].

Figure 6 - South African GDP figures from 1999-2007 [13]

Economic prosperity in South Africa after 1994 brought about an increase in the demand for electricity. The annual electricity consumption of South Africa increased from 165,310 GWh in 1994 to 241,170 GWh in 2007, an increase of 45.9%, as shown in Figure 7 [14].

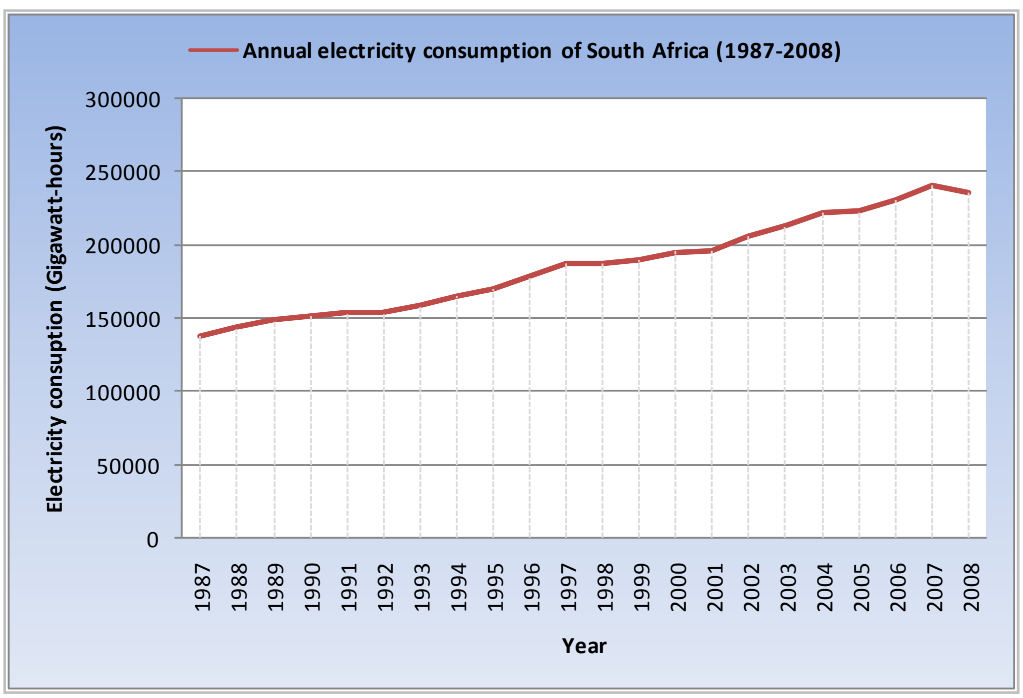


Figure 7 - Annual electricity consumption of South Africa (1987-2008) [14]

Increase in electricity demand was also driven by an accelerated national electrification programme. National household electrification levels increased from 36% in 1996 to 71% in 2004 [15]. The Integrated National Electrification Program (INEP) was introduced after 2004, which provided up to 50 kilowatt-hours (kWh) of free electricity per month to poorer households [16]. An estimated 4.9 million households were connected to the national power grid from 1994 to 2009 [17]. By the end of 2009 a total of 9, 245,357 or 75% of all households had access to electricity [17]. A total of 163 clinics and 4957 schools in South Africa were electrified by the end of 2008 [17].

Peak-time (7:00-10:00 and 18:00-20:00) electricity consumption increased by 4.90% or 1706 MW from 2006 to 2007 [18]. The increase in the peak-time electricity demand resulted in significantly reduced electrical supply reserve margins. By late 2007 and beginning 2008 consumers were subjected to numerous electricity supply failures and electrical load shedding [9].

Reduced reserve margin

A reserve supply margin is required to ensure that sufficient capacity is available to allow for scheduled and unscheduled maintenance operations on the power system [19]. The required reserve margin is calculated as a percentage of the maximum generating capacity [19]. Internationally accepted standards require a reserve margin of 15% [20]. In South Africa, the electricity generation reserve capacity, as shown in Figure 8, declined from 25% in 2002 to 16% in 2006 [9].

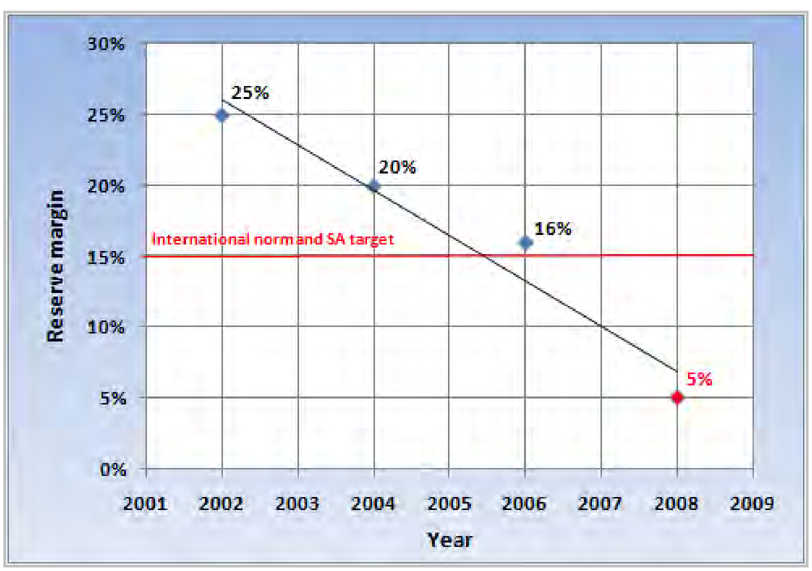


Figure 8 - Reserve margin (2004-2008) [18]

Between December 2005 and May 2006 the electricity demand started to exceed the supply of electricity [21]. The electricity supply problem moved into crisis mode when the nuclear power station at Koeberg in Western Cape started to experience maintenance problems during December 2005 [21]. The Western Cape was hit by power outages, which deteriorated during 2006 and spread to the rest of the country [21, 22]. In January 2008 the reserve capacity margin was only 5% [19].

The electricity supply problem culminated with power outages throughout South Africa during December 2007 and January 2008 [9, 22]. These outages were caused mainly by supply capacity constraints and an increase in demand for electricity [18]. On 24 January 2008 Eskom declared that it could no longer guarantee the supply of electricity [18]. Eskom was forced to apply load shedding, which severely impacted on the operations of the mining industry [20, 22]. On 24 January 2008, the major mining groups suspended their operations due to safety considerations [20, 22].

1.3 Responding to the electricity supply challenge

There are two strategies that can be employed to address the electricity supply challenge in South Africa. One obvious strategy is the construction of new power stations which will only be able to alleviate the supply-side problem in the long term. Another strategy is to apply demand-side management, (DSM), which can be implemented in a relatively short timeframe.

DSM is defined as a set of systematic activities that are used by government and utilities to influence the amount and or timing of the customer's use of electricity for the collective benefit of the utility, the customer and society in general [23]. This is a relatively short-term solution, which will result in a reduction in energy consumption through energy efficient methods or by shifting the use of electricity out of the peak periods. A typical implementation of DSM takes a few months, whilst a new power station can take up to 8 years to construct [24].

Supply-side management

In January 2008 the national government announced an extensive power generation capacity program to address the country's electricity supply constraints [18].

This recovery plan included the return-to-service of three coal-fired power stations (Camden, Grootvlei and Komati) as well as two gas turbines (Ankerlig and Gourikwa) [18]. The Arnot power station was upgraded to an additional 60 MW of generating capacity [18]. Supply capacity was also to be supplemented with electricity generation by private sector partners (co-generation) and was projected to supply an additional 500 MW starting from 2009 [18]. Table 1 lists the details of the medium term expansion program, which is expected to be completed by the end of 2009 [18].

Table 1 - Medium term capacity expansion plan (MW) (2008-2009) [18, 25]

Supply capacity expansion plan	Additional supply capacity (MW)	
Return-to-service (coal-fired power stations)	**2008**	**2009**
Camden (capacity: 1600 MW)	390	
Grootvlei (capacity: 1200 MW)	585	585
Komati (capacity: 1000 MW)	120	240
Upgrade		
Arnot	60	60
Return-to-service (open cycle gas turbines)		
Ankerlig		740
Gourikwa		296
Other		
Co-generation		500
Total	**1155**	**2421**

This recovery program would provide for a maintenance capacity of about 3000 MW needed for planned maintenance operations [18]. The power stations would be brought back into operation at a cost of R16 billion [26]. Grootvlei power station was fully operational by 2009 and Komati power station is expected to be completed by 2010 [26]. Camden power station was already in full operation by June 2008 the [26] .

In 2009 the net maximum supply capacity of Eskom was 40,503 MW [19]. An additional 40,000 MW of electricity generating capacity is required by 2025 to sustain economic growth and satisfy the corresponding increase in demand for electricity [19]. Eskom plans to spend about R385 billion between 2009 and 2013 on medium to long term expansion programs [19]. Table 2 provides a summary of the electricity supply capacity expansion schedule from 2007 to 2015.

Table 2 - Planned electricity supply capacity expansion (MW) [18]

Supply Capacity Expansion Plan		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
		MW	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	**MW**	
Return-to-service	Camden	390	390								**780**
	Grootvlei		585	585							**1170**
	Komati		120	240	320	285					**965**
	Arnot	75	60	60	30						**1329**
	Ankerlig	589		740							**735**
	Gourikwa	439		296							**225**
New	Medupi						798	1596	798	1596	**4788**
	Ingula						666	666			**1332**
	Bravo							803	1606	803	**3212**
Other	Wind farm				100						**100**
	Co-generation			500	1000	1000	1000				**3500**
	IPP				1000						**1000**
	Annual Total	**1493**	**1155**	**2421**	**2450**	**1285**	**2464**	**3065**	**2404**	**2399**	**19136**

By January 2009, the recovery plan outlined in Table 1 managed to increase the reserve margin to 14% [19]. This was mainly due to the technical recovery of the power system and a reduction in the electricity demand brought on by the global recession [19]. Government and Eskom warned that although no load shedding and blackouts occurred by May 2009, the country was still in a grip of a power crisis [27]. Of major concern was the reserve margin which remained below 15% [27]. The national energy minister noted that a healthier reserve margin of 17% to 20% would be preferable [27]. This would ensure that sudden changes in demand and maintenance operations would not cause blackouts [27].

The supply-side expansion program outlined in Table 2 is a long-term perspective and is very costly. In order to respond to present shortages in electricity supply, the option of DSM should be applied. Eskom has therefore accelerated its DSM program in response to the electricity supply challenge in South Africa. The DSM program aims to reduce the national energy demand by 3000 MW by 2011 and another 5000 MW by 2026 [19].

1.4 Rationale for DSM in South Africa

South Africa's immediate electricity supply problem can be addressed by applying DSM initiatives in the various sectors of the economy. In South Africa, the DSM strategy has a dual focus. The first focus area is to reduce the electricity demand during peak periods, which occur from 07:00 to 10:00 and from 18:00 to 20:00 [28]. The second focus area is to reduce the overall electricity demand through the installation of energy efficient equipment and designing more energy efficient industrial processes [28].

Eskom does not expect the constraints of the electricity supply chain to be completely resolved until at least 2012 [19]. This is when the first of the new power stations (Medupi), presently under construction, is expected to come into operation [19]. In the meantime, DSM interventions can be implemented to influence the electricity consumption patterns of consumers. This is of considerable significance during the peak time periods.

DSM Performance overview

Figure 9 shows the cumulative performance of all DSM projects for period from 2005 to 2009.

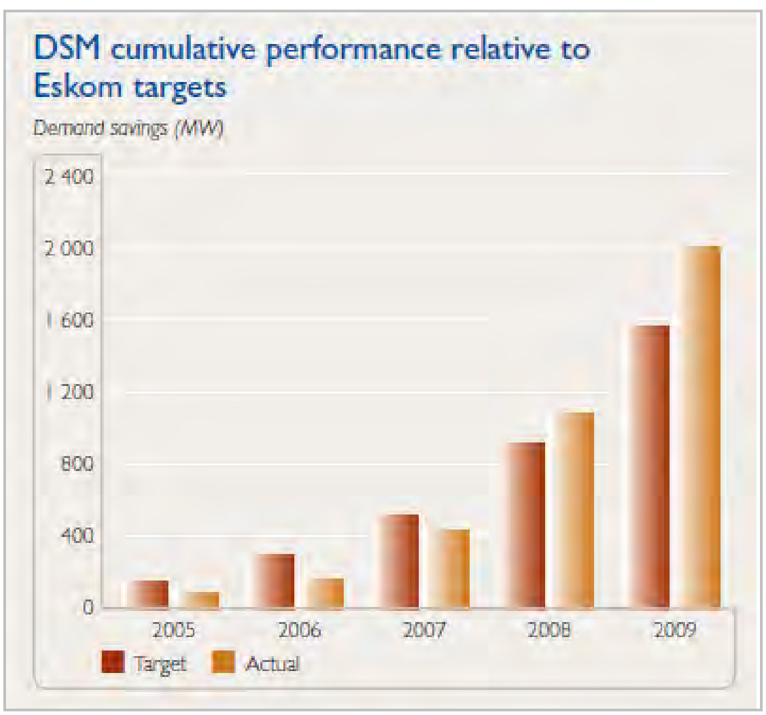


Figure 9 - DSM cumulative performance (2005-2009) [19]

The savings for 2005 includes savings made since the start of the DSM program in 2003 [19]. Savings for 2007 include 100 MW of verifiable savings made directly after the Western Cape DSM intervention [19]. Savings for 2008 includes a 67 MW attributed to Demand Market Participation (DMP) [19]. Figure 10 shows the annual savings achieved from 2005 to 2008 during evening peak hours only [24].

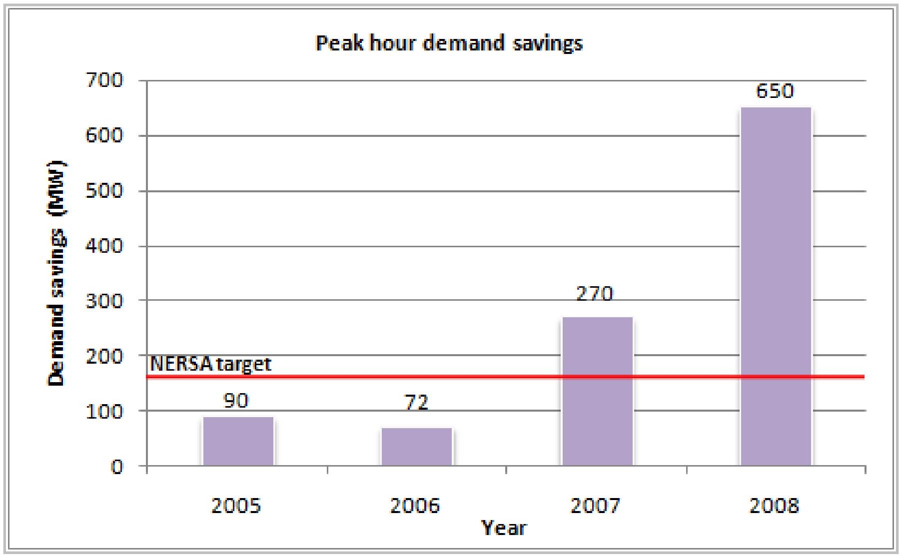


Figure 10 - Annual evening peak savings achieved (2005-2008) [24]

DSM Targets

The Department of Minerals and Energy Affairs (DME), has set a goal to achieve a saving of 4255 MW by 2025 through DSM [28, 29]. An overall reduction of 12% in energy demand is required by 2015 [28, 29]. The National Energy Strategy Review document of 2008 does not set an explicit target for DSM interventions as was the case in the first strategy document of 2005 [30, 31]. However, a 15% reduction in non-essential consumption, such as energy savings in administrative buildings of power plants and depots, is required [31].

Eskom, in support of the national energy targets and in response to electricity supply challenge, established DSM targets to reduce the national electricity consumption. The aim is to reduce the electricity consumption with 3000 MW during the evening peak (18:00 to 20:00) by March 2011, while a further reduction of 5000 MW is envisaged by 2026 [13, 29]. In 2007 Eskom launched the Accelerated DSM program, which increased the annual DSM targets in order to intensify DSM. The initial annual DSM target was increased from 152 MW to 400 MW for 2007 to 2008 and to 645 MW for 2008 to 2009 [28, 30].

DSM Sector focus

The electricity demand distribution for the main economic sectors is shown in Figure 11. The industrial sector is the largest consumer of electricity in South Africa. On its own the mining industry consumes 15% of the total electricity consumption in the country [9]. Other large consumers of electricity include the residential sector which consumes 17% of the total consumption, followed by the commercial sector at 13% [9]. These three sectors pose the opportunity for substantial load savings. DSM therefore includes sector programs that target load reduction and energy efficiency in these sectors.

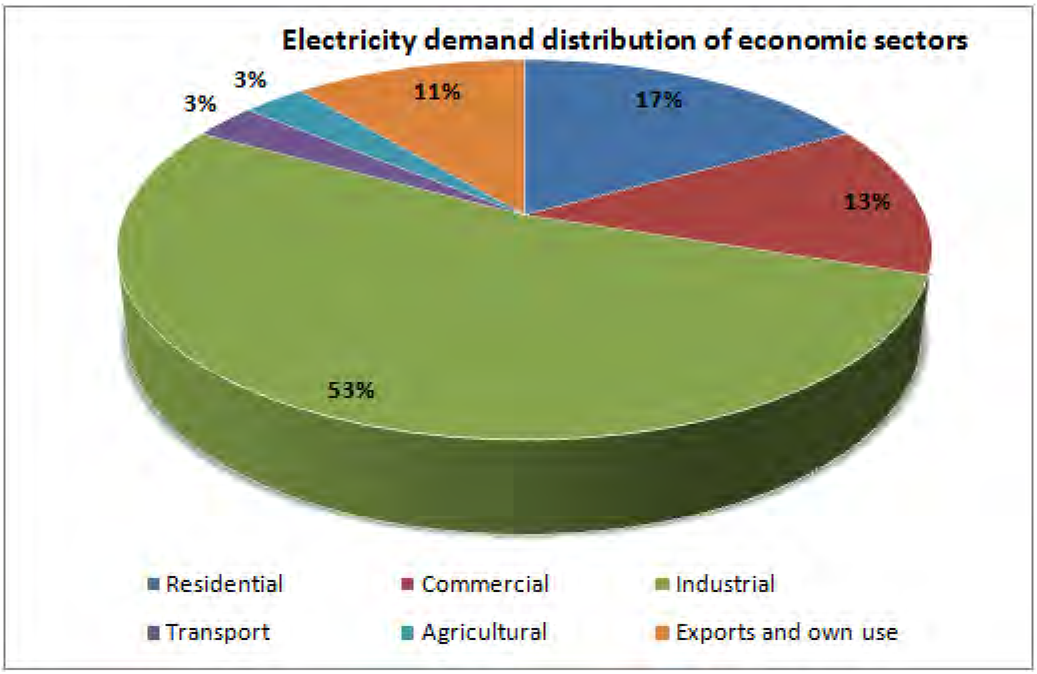


Figure 11 - South African electricity demand distribution (2007) [9]

Benefits of DSM

The DSM program has, since its inception in 2003, proven to be a valuable strategy to alleviate the longer term supply side initiatives. Long term initiatives require the construction of new electrical power stations to ensure a reliable and sustainable power supply. This is not immediately realisable and cannot provide a secure electricity supply in the short term. DSM on other hand has immediate benefits, as seen from the perspective of its economical, social, environmental impact on society and lead time to implementation.

1. Economical benefits of DSM

The DSM program benefits Eskom by deferring the capital intensive investments in electricity infrastructure such as building additional generation, transmission and distribution networks [34, 35]. The reduction on the overall electricity load during peak hours increases the electrical network reliability and therefore improves the efficiency of electrical system operation [34].

A stable and reliable electricity supply means that business will not be subjected to power outages and resultant lost revenues. The consumer benefits from the DSM initiative as a decrease in electricity consumption leads to a reduction in electricity costs [33].

2. Social benefits of DSM

The DSM approach has lead to the development and expansion of the ESCO industry in the South Africa, which resulted in the creation of jobs and thus supports the macro-economic development of the country [28]. Eskom has embarked on an intensive electricity supply expansion program which is very costly. NERSA approved an electricity price increase application by Eskom and announced the new electricity tariffs on 24 February 2010 [35]. The approved price increases for the period 1 April 2010 to 31 March 2013 are listed in Table 3.

Table 3 - NERSA approved electricity price increases [35]

Description	2010/2011	2011/2012	2012/2013
Standard average price (c/kWh)	41.57	52.30	65.85
Percentage price increase	24.8%	25.8%	25.9%

DSM provides the opportunity and benefit to industries and the general consumer by reducing electricity consumption. This is particularly important in the energy intensive industries such as the mining industry.

3. Environmental benefits of DSM

The reduction in the consumption of electricity as a result of the DSM program will also reduce the emission of harmful gasses. Furthermore, less water will be used in the generation of electricity [29, 35].

4. Lead time to implementation of DSM

Large power stations, such as the 4200 MW Medupi power station, can take up to 8 years to build [24, 25]. In sharp contrast, a DSM project usually requires about 3 months to implement. Examples of short-term energy efficiency initiatives include the mass roll-out of energy efficiency technologies, such as the compact fluorescent lamps (CFLs), solar water heating systems and smart meter load limiting equipment. Eskom launched this energy efficiency project in the Western Cape in 2006 through which 5.3 million CFLs were exchanged for incandescent lamps free of charge to consumers in residential areas of the Western Cape. The CFL project saved an average of 215 MW during June 2006 [28].

1.5 Motivation for sustainable DSM projects

The concept of 'sustainability' is generally understood as 'the capacity for continuance into the long term' [36]. However, there is no universal definition for sustainability. The consensus is that the concept 'sustainability' originated from the idea of 'sustainable development'. This description was first introduced at the United Nations Conference on Environment and Development held in Rio de Janeiro in 1992 [37]. In this context, sustainability refers to the 'achievement of continued economic and social development without detriment to the environment and natural resources' [37]. The Rio conference also established the idea of sustainability comprising of three interrelated dimensions or pillars, namely, economical, environmental and social sustainability as shown in Figure 12 [39, 40].

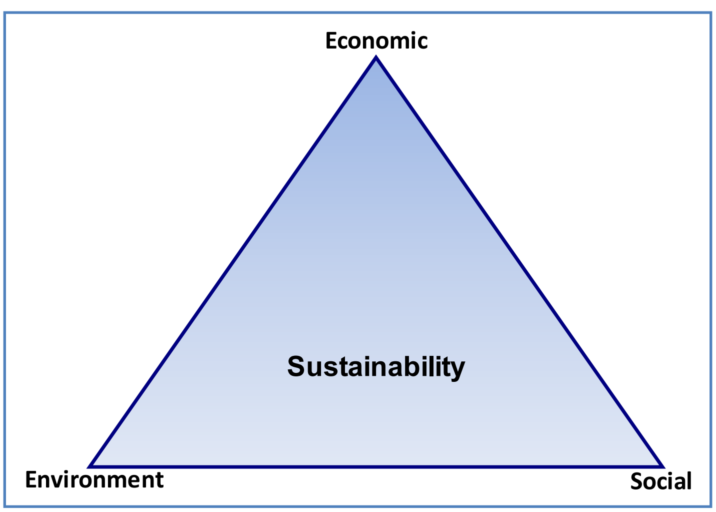


Figure 12 - A representation of sustainability [39]

The concept of sustainability can be applied in various contexts. In a business context, the term sustainability is often associated with a business' 'triple bottom line' [36]. It means that the company's continued existence is not only based on its financial performance, but on its collective financial, environmental and social returns [36]. The general definition of sustainability can also be applied within the context of DSM projects.

Economic sustainability of DSM

Each DSM project must be a profitable venture for all the stakeholders concerned. The financiers of DSM projects will want to ensure that the project returns the maximum energy savings results over the life of the project. It does not make sense for either Eskom or the client to continue investing time, money, resources and effort into a DSM project that is no longer profitable.

The ESCO, who implements the DSM project, will want to ensure that the contractual energy savings are achieved or exceeded in order to gain maximum profit. The ESCO normally commits itself through a performance-based contract with the client. If the performance of the project should decline over time, the ESCO will make less profit on the project and eventually the financiers may withdraw their funding for the project. Furthermore, without a proven track record, the ESCO may find it difficult to convince financiers to sponsor any new DSM projects. It is therefore critical for the ESCO to ensure the economical sustainability of its DSM projects.

DSM clients derive benefits from reduced energy costs. The client normally pays the ESCO a maintenance service fee to take responsibility for the ongoing performance of the project. If the performance of the DSM project deteriorates over time, the client's energy costs will not be reduced. It will therefore become unprofitable for the client to pay a maintenance fee to the ESCO.

Environmental sustainability of DSM

Each DSM project must be implemented in due consideration of the environment. A sustainable DSM project will reduce the emission of greenhouse gasses into the atmosphere and lesson the negative impact it has on the environment such as global warming.

Social sustainability of DSM

Each DSM project must be implemented in due consideration of its impact on society. Even if a DSM project is considered to be economically justifiable and is environmentally friendly, but its implementation is detrimental to society, then it will not sustainable. This is of critical importance in industries such as the mining industry that is both energy and labour-intensive. If the employees view the DSM project as a possible threat to their employment, then the DSM project will not be sustainable. These employees should be properly informed of the benefits of the DSM project [40].

Another important note is that the DSM project should maintain the level of service or standard of living for the energy user prior to the DSM intervention. As a simple example, the maximum saving on the electricity bill can be achieved by simply switching off all electrical equipment. However, this will not provide the energy user with the same level of service or comfort that comes through the use of electricity.

On the macro scale, the collective sustainable savings achieved through each implemented DSM project contributes towards the success of the South African DSM program as a whole. A successful DSM program means that the need for implementing capital-intensive supply-side expansion programs such as the building of the new power stations can be prolonged.

Furthermore, a successful and sustainable DSM program can reduce the electrical consumption during peak hours resulting in a more reliable and stable electrical supply network. A reliable electricity supply network creates an operating environment that is conducive for businesses to operate in.

The implementation of DSM projects in South Africa has resulted in the creation of jobs throughout the ESCO industry. If the DSM program as a whole cannot achieve the expected energy savings, then this and other industries face the threat of possible job losses.

Sustainability of DSM projects

Electricity saving performance of DSM projects tends to decline over time [40]. The deterioration of DSM project performances occurs in the absence of proper and frequent monitoring and information feedback to stakeholders.

This study addresses the problem of the performance decline of DSM projects by investigating how and why an information management approach to DSM promotes the sustainability of DSM projects. A web-based information management application is then developed and implemented. This will extend the ESCO’s existing information management solution and further enhance the sustainability of the DSM projects.

1.6 Objectives of this study

This study will be conducted at a South African ESCO, namely, HVAC International (Pty) Limited (HVACI), which is presently the largest ESCO in the country [41]. At the time of writing this dissertation, HVACI was operating 39 DSM implemented projects and in the development stage of 20 new projects.

The first objective is to document the importance of the sustainability of DSM projects. This is done in the context of the global energy challenge, the South African electricity supply challenge and the Eskom DSM program as a response to the electricity supply crisis.

The second objective is to understand and document the importance of proper and frequent information management and feedback on the progress of implemented DSM projects. This objective aims to emphasize the need for an information management solution to support the information management needs of DSM projects.

The third objective is to design, develop and implement a database driven web application to enhance the information management support needed to sustain DSM projects. This web application will interface with existing information management tools to form part of an integrated information management solution that includes web-based technologies. Extended information management solutions will be presented as an integrated information management approach to ensure the sustainability of the DSM projects over the long term.

1.7 Synopsis

Chapter 1 starts with an overview of the worldwide energy challenge. The focus is then shifted to the electricity supply crisis in South Africa. The application of DSM as a means to address the electricity supply crisis is described. The importance of the sustainability of DSM project implementations is emphasised.

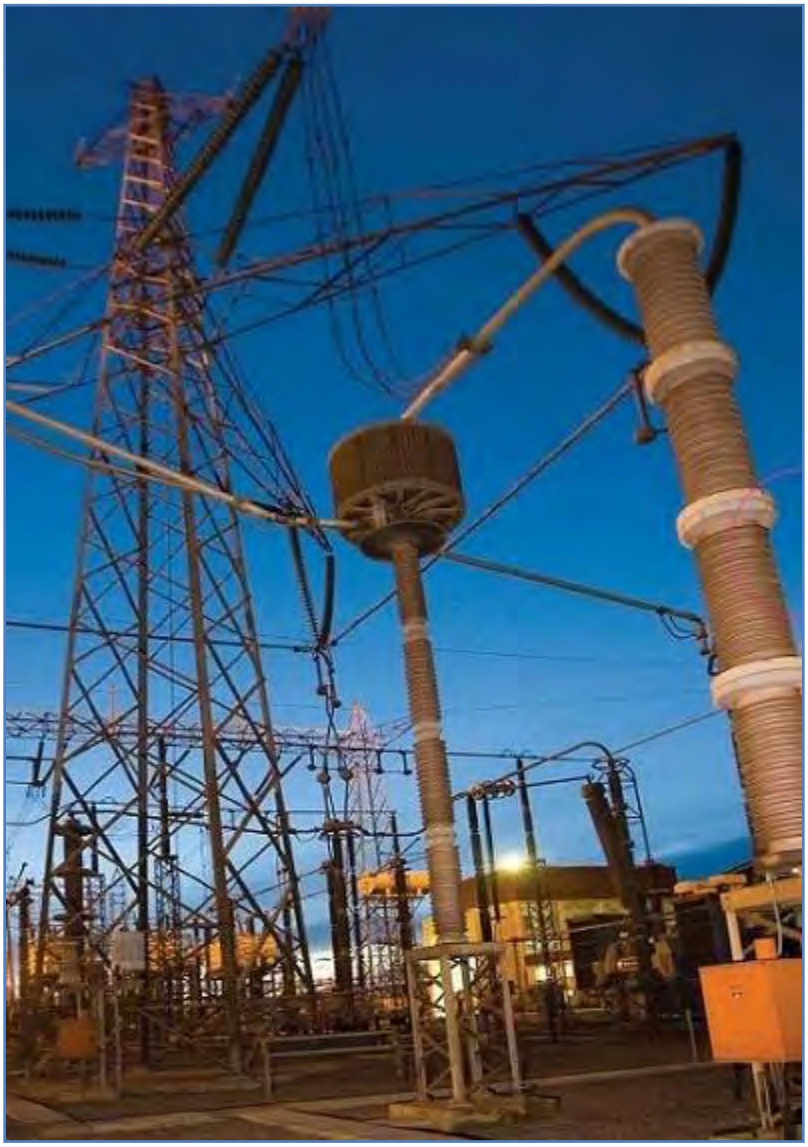
Chapter 2 introduces the different role players in the DSM project framework. The problem statement is described in detail. A description is given of how a technology-driven information management solution can ensure the sustainability of DSM projects. The shortcomings of the existing information model are described. Benefits of a database-driven application as an enhancement to the existing solution is emphasised. A case study is described on how another ESCO has integrated a web-interface into their existing information management approach. The chapter is concluded with the requirements specification for the proposed web-based application to be developed and implemented.

Chapter 3 describes the web application development process of the proposed web-based application that is to be built from the planning and design phases to the implementation, maintenance and testing phases.

Chapter 4 describes case studies of the information flow in a DSM compressed air project and a fridge plant project. A third case study emphasises the measurement and verification process. The last case study analyses the results of user survey conducted to make a qualitative assessment of the implemented web application.

Chapter 5 concludes the study with a summary of the contributions made and recommendations for further work on the subject matter of this study.

Chapter 2: An information management approach to DSM



Source: Eskom Annual Report 2009

2.1 Introduction

The electricity supply crisis in South Africa has placed a renewed focus on the role of ESCOs in reducing the electricity consumption levels in energy-intensive industries. The National Association of Energy Services Companies (NAESCO) defines an ESCO as a business that 'develops, installs, and arranges financing for projects designed to improve the energy efficiency and maintenance costs for facilities over a seven to twenty year time period' [42]. NAESCO defines the main services of an ESCO as that of acquiring project finance, installing and maintaining energy efficient equipment at project sites, measuring, monitoring and verifying project savings and taking on the risk of achieving for the proposed energy savings [42].

There are also other stakeholders involved in the DSM project implementation process and is discussed in Section 2.2. However, the emphasis will be placed on the crucial role of the ESCO and its responsibility to ensure the long term sustainability of DSM projects. The ESCO provides specialised expertise that is critical in supporting the sustainability of the implemented project. There are presently 333 ESCOs listed on the Eskom DSM website [43]. These ESCOs implement and maintain DSM projects across all energy sectors of the South African economy.

This study will investigate how one specific South African ESCO, HVAC International (Pty) Limited, uses an information management approach to ensure the long term sustainability of DSM projects.

2.2 DSM project framework in South Africa

DSM project role players

The South African DSM project environment is made up of four principal stakeholders, namely Eskom, ESCOs, Measurement and Verification (M & V) teams, and the client. These stakeholders are directly involved in the actual implementation process. There are also other stakeholders, such as the Department and Mineral and Energy Affairs (DME) and the National Energy Regulator of South Africa (NERSA), who play an indirect but crucial role in the DSM implementation process. The relations between the various stakeholders are depicted in Figure 13.

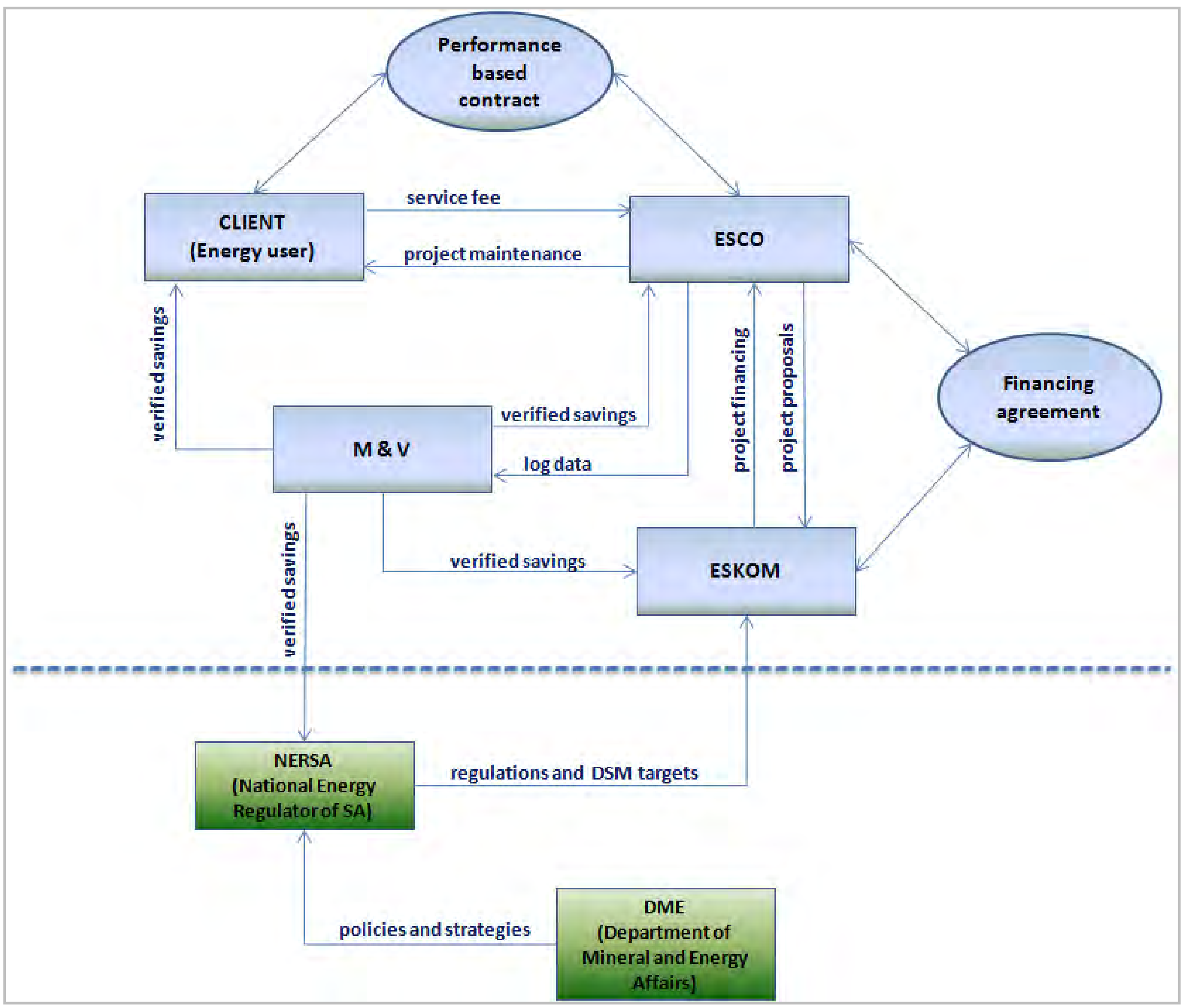


Figure 13 - DSM project implementation stakeholders (adjusted from [44])

The role played by each of the stakeholders will be outlined in the next sections. It is important to understand the relation and flow of information between each participant as it impacts, directly or indirectly, on the sustainability of DSM projects.

Department of Mineral and Energy Affairs (DME)

The DME is responsible for establishing the annual DSM targets for peak time electricity demand reduction [30]. It also develops policies and strategies that has an influence in matters such as DSM funding, administration of DSM funds, development of DSM programs by the energy utility (Eskom), implementation of DSM projects through ESCOs as well as providing a model for the DSM implementation process [45].

National Energy Regulator of South Africa (NERSA)

NERSA advises Eskom on the DSM electricity targets that must be achieved based on the approved policies set by the DME [46]. NERSA also provides regulatory guidance for DSM project implementations and ensures that the monitoring and verification processes of implemented DSM projects are adhered to [45].

Eskom

Eskom implements the national DSM program on behalf of NERSA. The DSM program is undertaken under the guidelines set out in the National Energy Efficiency Strategy [31, 32] and enforced through NERSA. Eskom is responsible for the DSM project fund administration and facilitates the implementation of DSM projects through ESCOs [45]. Eskom also initiates the measurement and verification process of implemented project results [45].

Measurement and Verification (M & V) teams

The M & V teams are specialists from seven South African universities. They are contracted to independently measure and verify the actual project savings achieved against an energy usage baseline established prior to the DSM intervention [46].

The M & V teams will make further measurements of the electricity consumption after the DSM intervention through data recording of electrical systems [46]. After verification is completed, the electrical and monetary savings calculations are made for a specific project.

Energy user

The energy user or client will sign a performance-based maintenance contract with the ESCO for implementing the DSM project on its behalf and ensure the sustainability of the project [33]. In return, the client will pay the ESCO a maintenance service fee for the maintenance of the project based on the reduction of electricity consumption achieved through the intervention of the DSM project [33]. The client will benefit from the agreement through the cost savings achieved with reduced electricity usage and thus a reduced electricity bill [33].

Energy Services Companies (ESCOs)

The role of the ESCO is to conduct feasibility studies of possible electricity savings opportunities in the operations and electrical equipment of the client. Once the feasibility of the DSM project has been established, a project proposal is developed and submitted to Eskom for approval by the ESCO [45]. On approval of a DSM project, the ESCO takes on the responsibility to maintain the DSM project. The ESCO must ensure that the anticipated reduction in electricity consumption and corresponding reduction in electricity cost are sustained over the life of the DSM project.

2.3 Performance decline of DSM projects

The problem

There is an international trend for the performance of DSM projects to decline over a period of time [40]. Figure 14 shows the trend line of the declining performance of a typical DSM initiative.

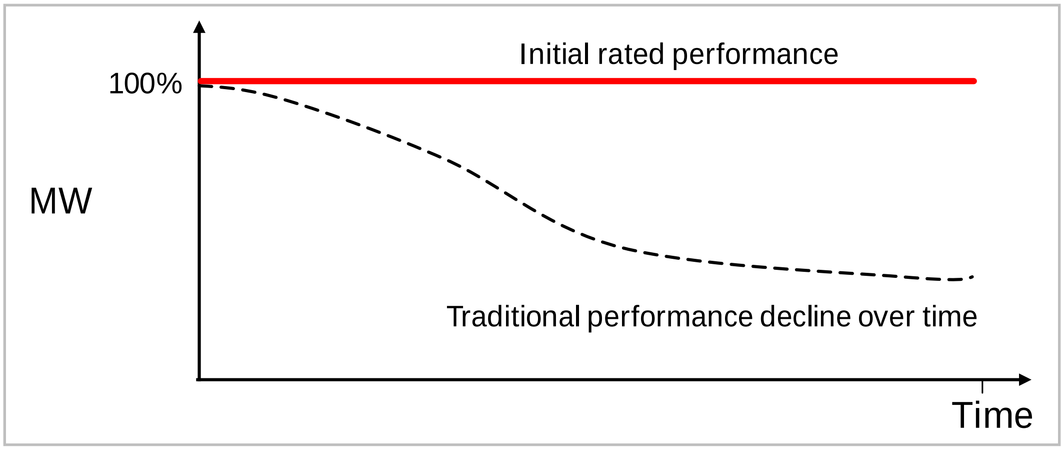


Figure 14 - Performance decline trend line of typical DSM initiative [40]

The DSM project initially delivers the required savings, but with time the performance drops to substantially lower levels. An example of this declining trend manifested itself in the performance results of a DSM initiative in the Western Cape [40]. A series of power outages was caused by maintenance problems at the Koeberg nuclear power station. Eskom launched the DSM initiative as part of a recovery plan to stabilise the Western Cape power supply. This DSM initiative aimed to reduce the peak-time electricity demand in the province. A saving of 400 MW was realised during the winter months of 2007. However, one year after implementation the DSM performance had decreased to 31% of the initial target [40]. The performance decline trendline for this project is shown in Figure 15.

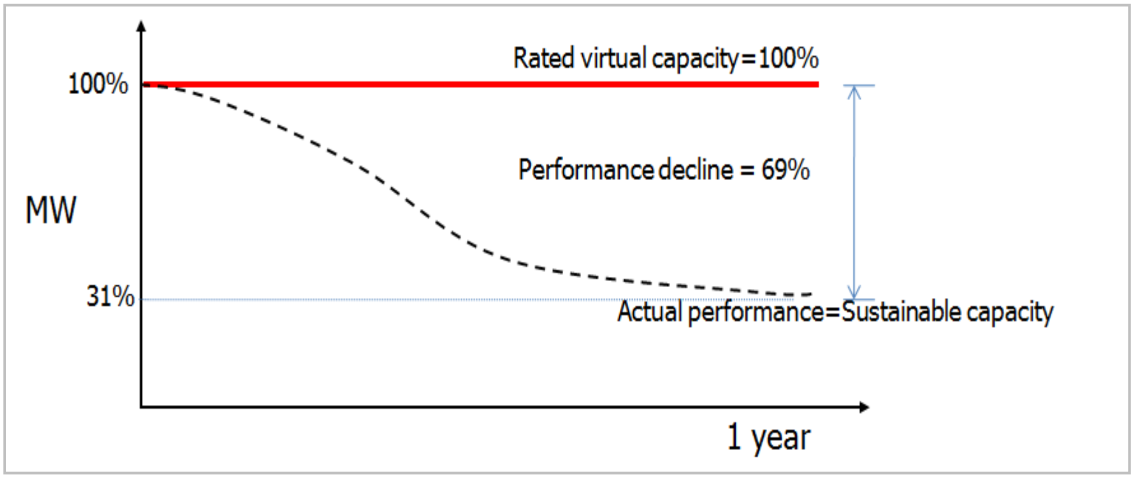


Figure 15 - Performance decline of Eskom Cape Focus DSM initiative [40]

Virtual power station

The concept of a virtual power station (VPS) can be used to represent the units of electricity not consumed by existing users of electricity [47]. This concept was used by the CEO of Iskhus Power, Otto Hager, to create a visual understanding of the terms 'energy savings' or 'energy efficiency'. Hager noted that 'savings' is an intangible concept, because 'it represents something that is not used up' [47]. Hager further defined energy savings as 'the art to produce the same or better levels of production output, comfort levels and service, while consuming less energy' [47]. An analogy can be drawn between a real world power station and the virtual power station. Each DSM project can be modelled as a virtual power station.

The real world power station

In the real world scenario, an electricity utility such as Eskom reserves at least 15% of the maximum capacity of the power station for planned and unplanned maintenance or servicing unplanned technical faults [40]. A real world power station has a maximum capacity of 100%, but this is only its rated capacity and includes a reserve generating capacity of 15%. The real world power station therefore only has 85% of its maximum rated capacity continually available to satisfy the demand for electricity from the consumer. This is the sustainable capacity or availability of the power station as shown in Figure 16. At these levels the utility is able to deliver a reliable and secure energy supply.

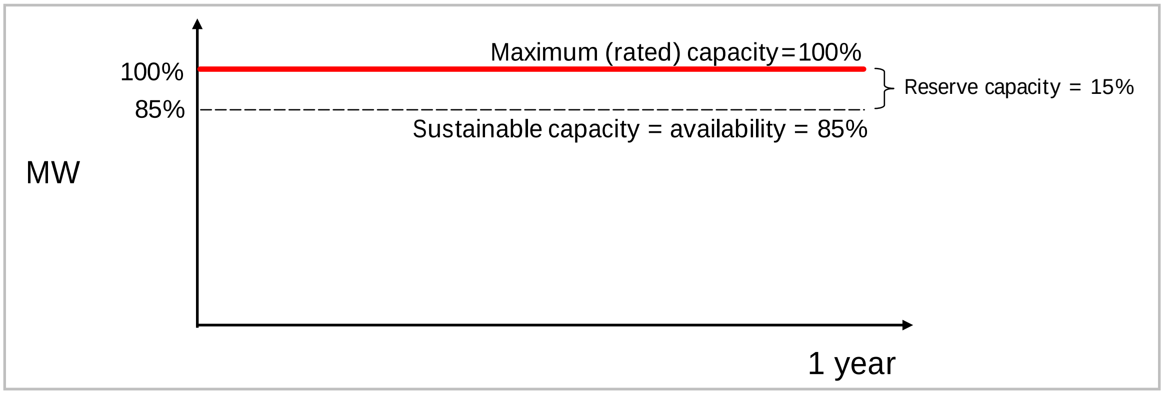


Figure 16 - International definitions of a power station [40]

The DSM project power station

The virtual power station or DSM project power station is based on the similar principles. The DSM project has an initial rated savings potential or rated virtual capacity of 100%. This is the maximum potential savings in electricity consumption that can be achieved by the project over its life cycle. If we apply a reserve margin of 15% to allow for any deviations in the project implementation, then the sustainable capacity of the DSM project should also be 85%. However, ESCOs should aim to achieve a sustainable capacity of over 85% for the DSM project [40].

The performance decline of the Cape Focus project can be related in terms of the virtual power station concept. The project was expected to deliver a saving of 400 MW. Therefore, it had a rated virtual capacity of 400 MW, which was the project's maximum savings potential. However, as Figure 15 shows, one year after implementation, the project's performance declined to only 31% of its initial savings potential. Thus, the sustainable capacity of the project or availability was only 31% or 124 MW. The actual sustainable savings that the project can deliver over the long term is therefore more likely to be around 124 MW and not 400 MW.

Sustainable capacity

The example of the Cape Focus project shows that the sustainable capacity component or availability of the DSM project is often not taken into account. Project stakeholders often make the assumption that the DSM projects will continue to deliver their maximum savings potential or rated virtual capacity [40]. This is one of the main causes for the performance decline of DSM projects over the long term.

An information-management solution for DSM

There is the tendency to focus only on the efficiency of operational equipment to achieve the initial rated capacity [40]. Information management technologies that are essential in ensuring the long term DSM sustainability are often overlooked [40]. These technologies can provide the necessary feedback to indicate whether the project is delivering the contractual savings [40].

A DSM project needs to be continually measured, monitored and verified in real time in order to respond to problems and take corrective actions when required. This will ensure that the maximum sustainable capacity of the DSM project can be sustained. The real time data of all the elements in the DSM project must be collected, processed and transformed into information and communicated to the relevant stakeholders [39]. Decision makers will be able to make informed decisions based on the insights acquired through the feedback of information [39].

2.4 Investigating information-management solutions for DSM

Critical success factors for a sustainable DSM project

HVACI identified a number of factors that are critical to the long term sustainability of DSM projects [40]. These factors are summarised and listed in Figure 17.

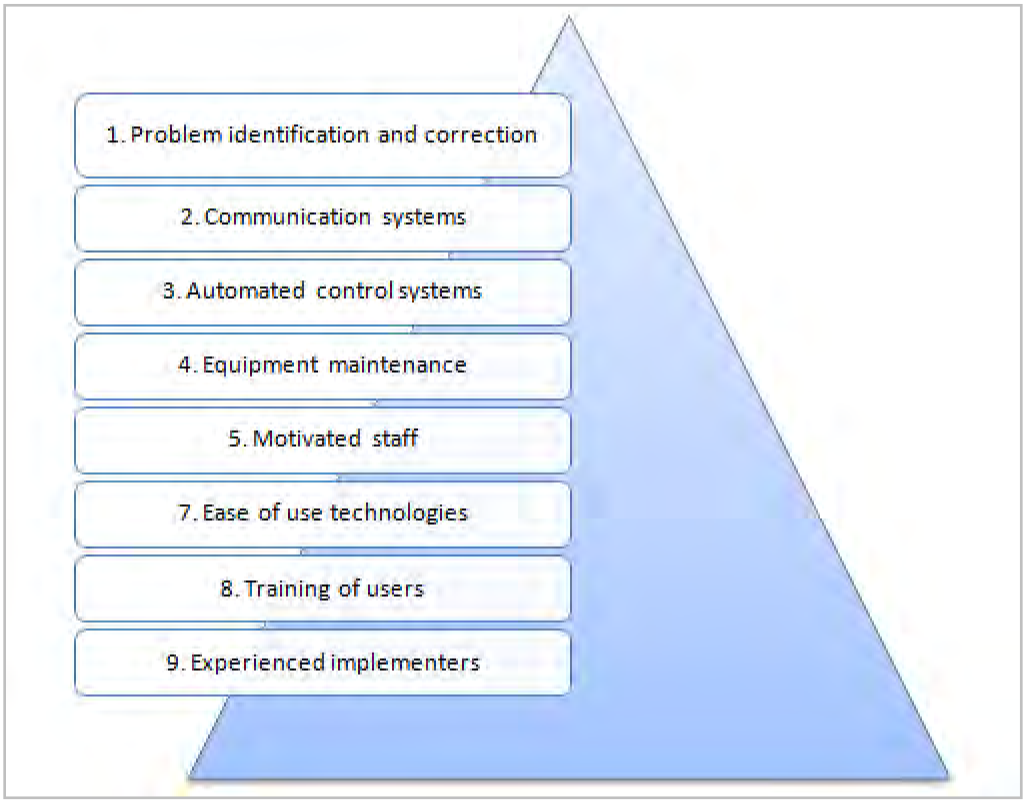


Figure 17 - Factors promoting the sustainability of DSM projects [40]

1. Problem identification and correction

Any problems that are detected must be rectified as soon as possible in order to reduce the risk of damage to equipment [40]. The increased availability of equipment will increase the electricity savings potential of the DSM project [40]. As an example, if the SCADA systems are not operational, the REMS system will be unable to execute an automated DSM scheduling routine, which will result in a loss in electricity savings.

2. Communication systems

The communication system must be adaptable and respond in accordance to the environmental conditions at the different implementation sites, such as signal reception. The communication system must be able to allow connections to remote sites from a central location [40].

3. Automated control systems

The control system must be automated and be able to operate at its rated capacity [40].

4. Equipment maintenance

Equipment should be maintained on a regular basis in order to maximise equipment availability [40]. The scheduled DSM control actions are able to be executed if all equipment is in a working condition [40].

5. Motivated staff

The benefits of the DSM intervention to should be explained to client staff members in order for them to understand the importance of the DSM project [40]. This is particularly important in the unionised mining environment where equipment control workers may see automated DSM scheduling operations as a risk to their employment. It should be communicated to staff members that the automated DSM scheduling improves the efficiency of the mining operation and promotes safety in the mining environment [40].

6. Easy to use technologies

The technologies that are implemented and used as part of the DSM project should be easy to understand and apply [40].

7. Training of users

Users should be provided with the necessary training in the use of the new technologies that are used as part of the DSM project implementation process [40].

8. Experienced implementers

The ESCO should have the necessary expertise, technologies and processes in place to maintain the DSM project [40].

9. Reporting

There should be communication and reporting procedures in place to report on the progress of DSM project implementations. The feedback to the stakeholders will motivate financiers to sponsor additional projects if they are convinced that existing projects deliver the contractual savings.

A real-time information management model

HVACI developed a set of technologies that aims to support the critical success factors that promote the sustainability of DSM projects as shown in Figure 18.

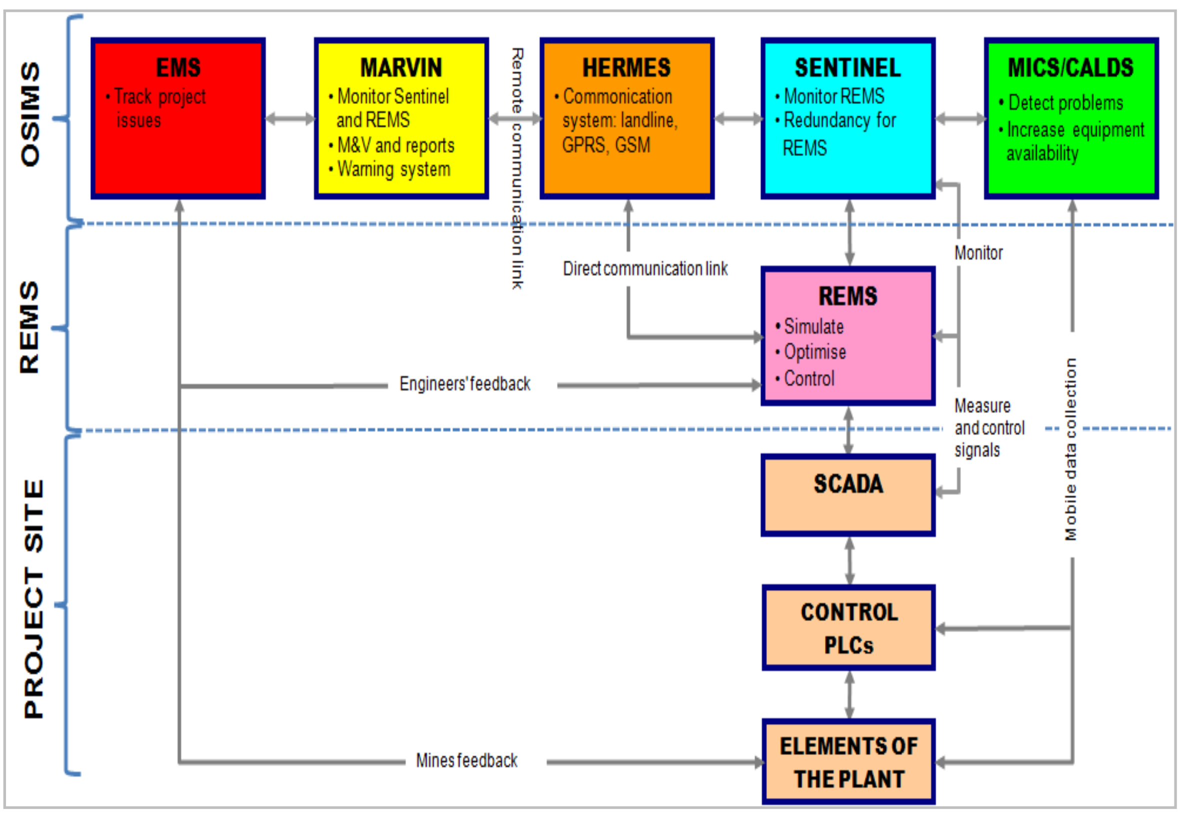


Figure 18 - OSIMS and REMS suite of applications [40]

Hardware technologies are represented by HVACI's Real-time Energy Monitoring System (REMS). Softer technologies are collectively represented by the On-site Information Management System (OSIMS). REMS interfaces with the Supervisory Control and Data Acquisition (SCADA) system and (Programmable Logic Control) PLC controls on the project site. The following paragraphs provide a brief description of each module in the OSIMS suite.

Sentinel

The main function of the Sentinel system is to monitor the operation of REMS and to replace the need for manual system control. If the Sentinel application detects a problem, it will take over control of the REMS system. At the same time it will attempt to restore REMS back to a stable and functioning state. Sentinel will communicate the detected problems to the Marvin application based at the head office in Pretoria. Backups of logged data will be made. These data files will be transmitted using the HERMES communication application. The Sentinel graphical user interface is shown in Figure 19.

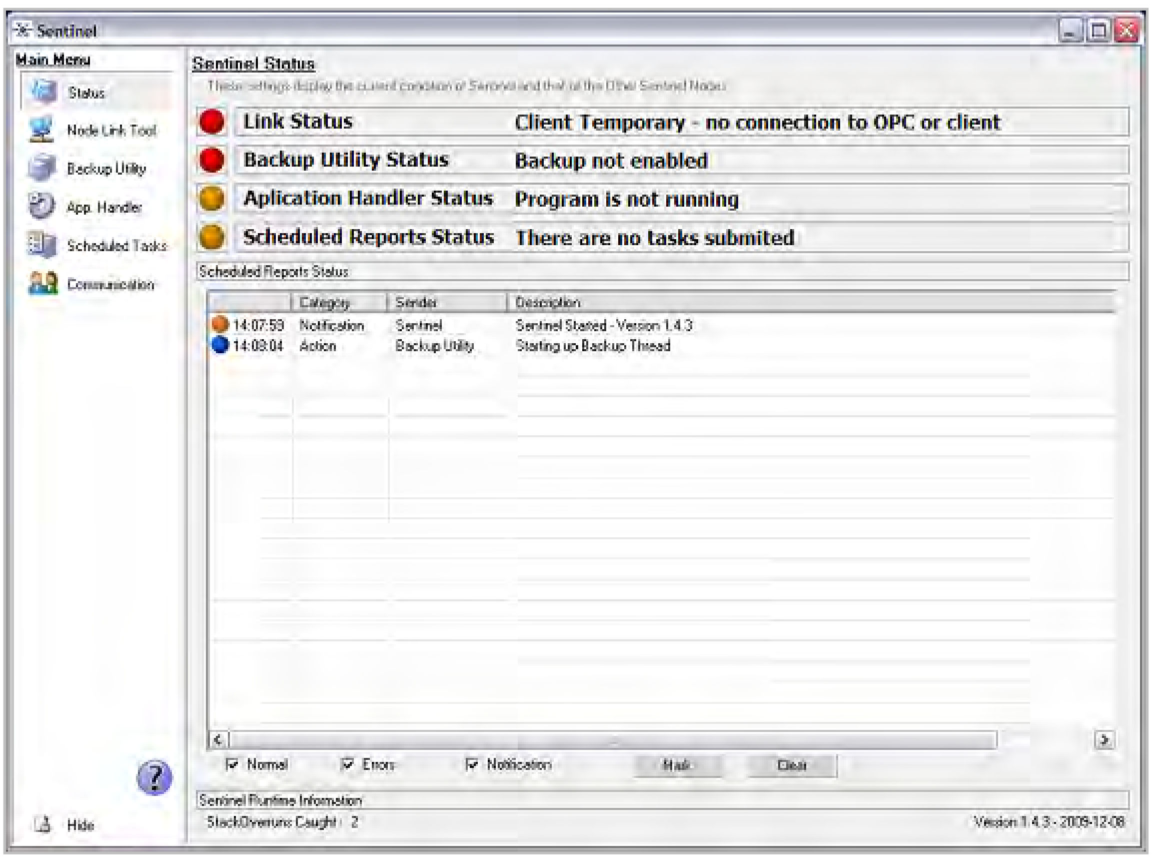


Figure 19 - Sentinel graphical user interface

Hermes

The Hermes application is the communication interface between the off-site data processing and reporting system, Marvin, and the communication module (Sentinel) at the DSM project site. The main function of Hermes is to provide a bidirectional communication between the HVACI head office and the DSM project site. It provides communication through fixed line telephone, Global Pocket Radio Services (GPRS) and GDM (Global System for Mobile Communication) technologies [40]. Most of the DSM project sites are located in remote locations. It is therefore essential that different communication media is available to ensure the best possible line of communication. The Hermes graphical user interface is shown in Figure 20.

Figure 20 - Hermes graphical user interface

Mobile Information Collection System (MICS)/ Compressed Air Leakage Documentation System (CALDS)

The Mobile Information Collection System (MICS) and Compressed Air Leakage Documentation System (CALDS) are applications written for mobile hand-held devices. MICS and CALDS are used to collect and record information of equipment faults on mobile hand-held devices. The hand-held device application is adapted for each DSM project site. The regular recording of equipment faults promotes regular equipment monitoring and maintenance [40].

Enterprise Management System (EMS)

The EMS system is a project management software tool that is used to keep record of project installations. Issues encountered during project installations, project resources and budgets are monitored and recorded by this system.

Real-time Energy Management System (REMS)

REMS is a fully automated control system that directly interfaces with the SCADA system of the DSM project site. This system controls equipment usage using PLC's through an optimised DSM schedule. The REMS scheduler module is supplied with operational constraints for equipment, safety, health and maintenance as well as the time-of-use electrical costs for the mine [48]. These constraints are taken into account when dynamic optimisation DSM scheduler of the REMS system generates a DSM project schedule. An optimised schedule is recalculated every two minutes and automatically executed [48]. The graphical user interface of REMS is shown in Figure 21.

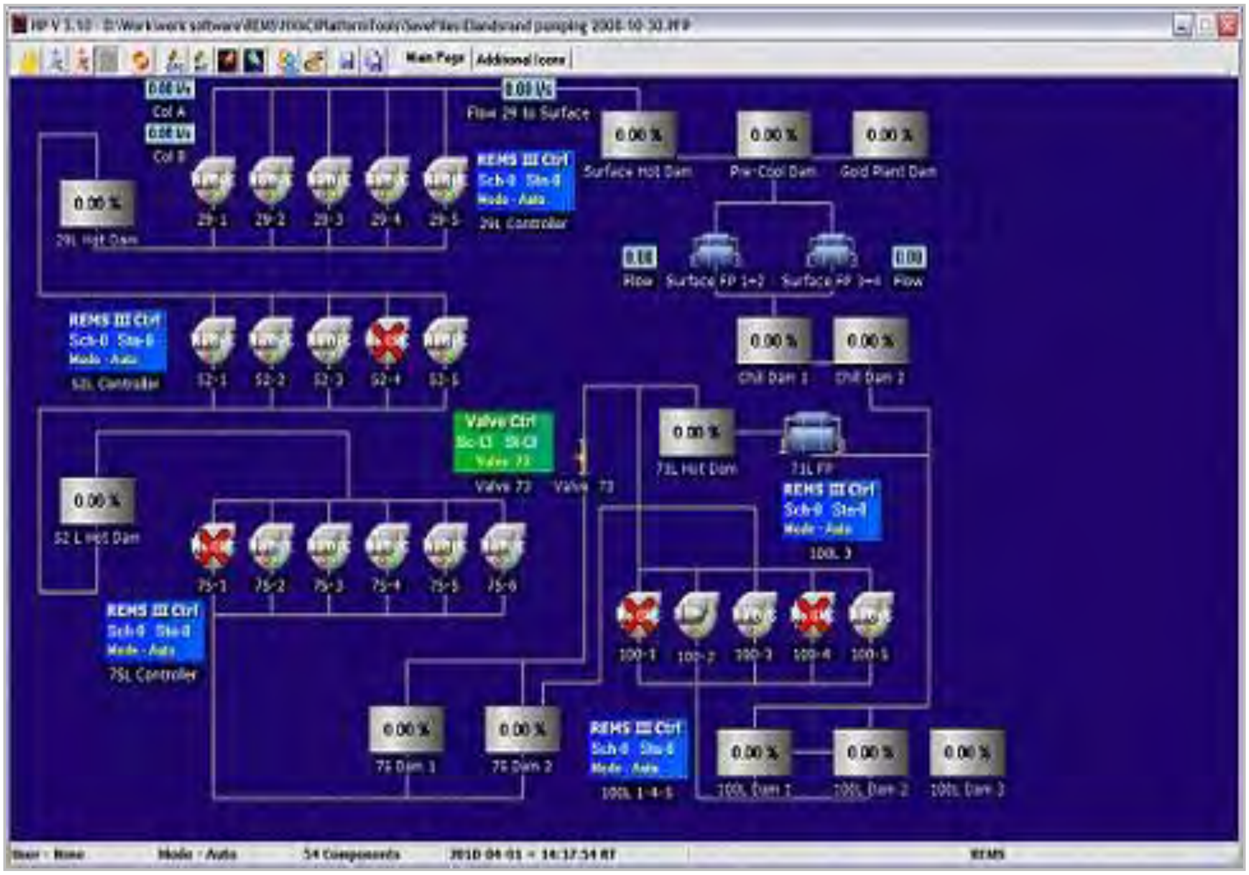


Figure 21 - REMS graphical user interface

Marvin

Marvin is responsible for monitoring all on-site DSM projects. It retrieves, unpacks and processes all incoming log files for the various DSM projects. Each project may have more than one Excel-based log file that needs to be incorporated into the calculation of the daily electricity savings. Processing algorithms evaluate the processed data and will alert via e-mail the relevant project engineers of any deviations [41, 44]. This automated procedure saves the project engineer time and provides an opportunity to proactively respond to problems.

Marvin will also automatically generate relevant reports and distribute them via e-mail to the appropriate clients, including Eskom, and other stakeholders. These include daily, weekly and monthly reports for the DSM projects of each mine as well as Eskom reports, mine and mine group reports, site reports, exception, and summary reports. Each report is designed to address a specific aspect of the DSM project. The Marvin graphical user interface is shown in Figure 22.

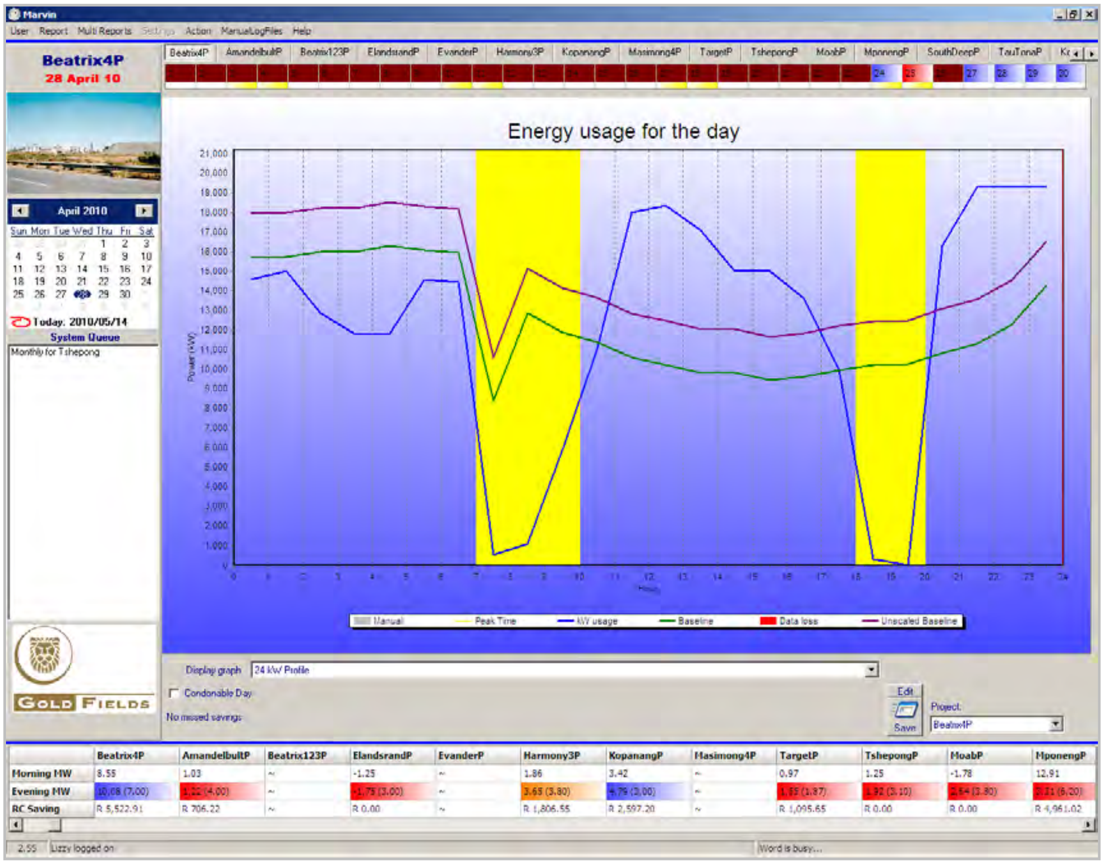


Figure 22 - Marvin graphical user interface

Contribution and impact made

The automatic generation of reports resulted in considerable time savings for project engineers. These engineers are now able to spend more time in the analysis of the reports and problem-solving activities than actually spending time by manually drafting reports. It has been noted by some of the experienced engineers that up to one week were spent on drafting reports and in the end each engineer would have a different format of the report. All reports and presentations are now automatically generated in standard company format.

This information management approach applied by HVACI had a significant impact in ensuring the sustainability of the implemented projects. In January 2008 HVACI reported that a total of 16 DSM projects were completed at various sites and 75.13 MW was shifted during the evening peak periods against a targeted saving of 68.44 MW [50]. Figure 23 shows that since the start of 2004 to January 2008 implemented projects achieved the targeted savings. In some months greater than target savings were obtained.

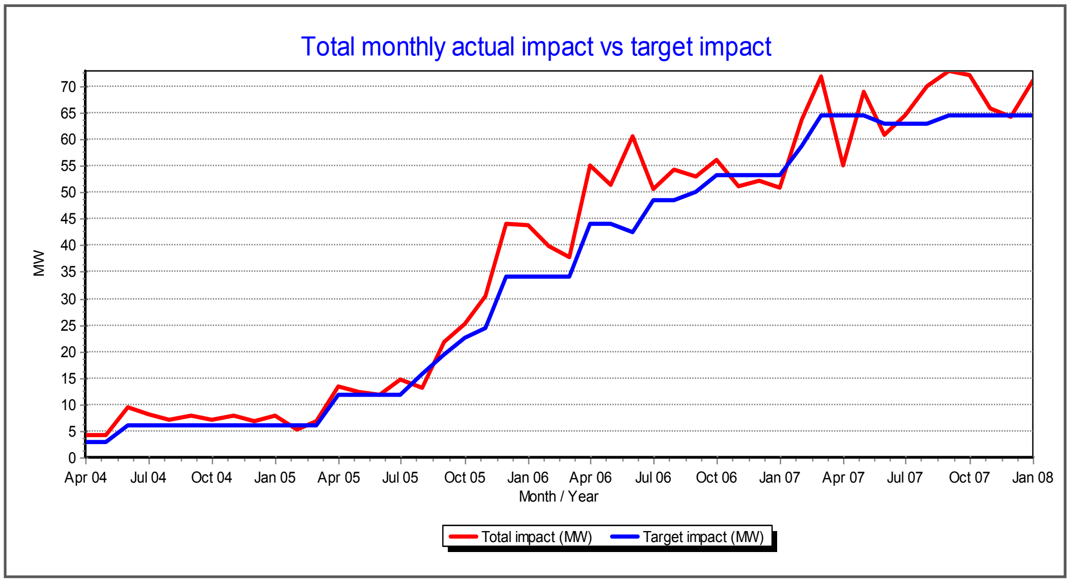


Figure 23 - Total impact for DSM projects (2004- 2008) [50]

Figure 24 shows that the cumulative actual impact increased consistently above the targeted savings. This shows that the information management approach that has been applied to DSM projects through the use OSIMS have been able to ensure the sustainability of these projects.

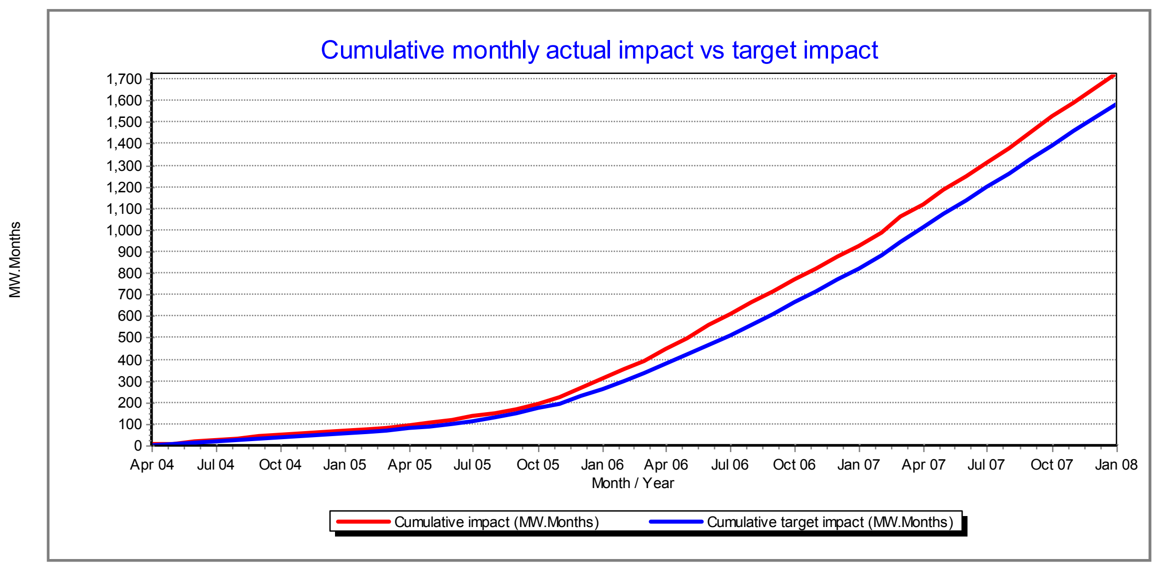


Figure 24 - Cumulative impact for DSM projects since (2004-2008) [50]

HVACI reported that a total of 39 projects were completed by the end of February 2010 with a total of 139.28 MW shifted during the evening peak periods against a targeted saving of 170.86 MW [51].

Figure 25 shows that, since October 2007 to August 2009, the targeted savings were not exceeded. After August 2009 the monthly actual savings approaches the target savings. This shows that the ESCO was able to recover from previous problems or deficiencies and either complied with or exceeded the targets of the contractual electricity savings.

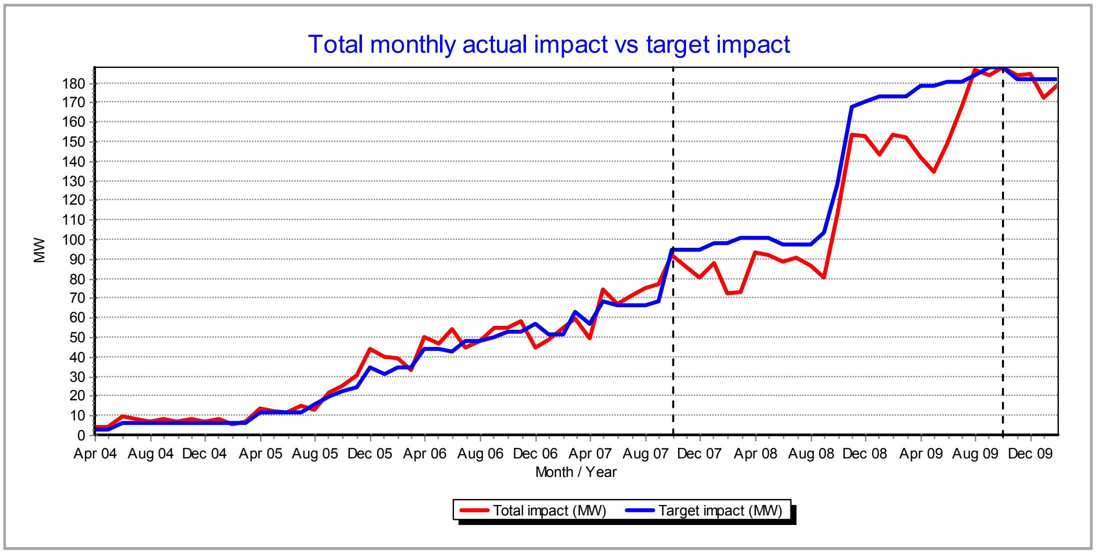


Figure 25 - Cumulative impact of DSM projects (2004-2009) [51]

Figure 26 shows that the cumulative monthly actual impact matches very closely or exceeds the targeted impact until February 2008. After February 2008 the actual cumulative impact started to fall below the targeted savings.

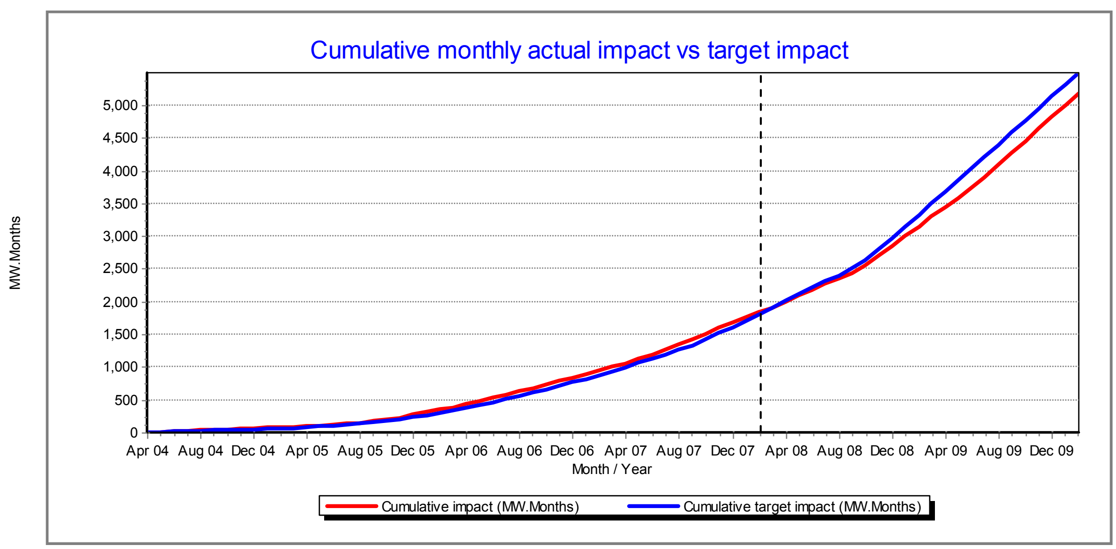


Figure 26 - Cumulative impact for DSM projects (2004-2010) [51]

2.5 Shortcomings of the existing information management solution

An analysis has been performed on the existing information management solution with specific emphasis on the Marvin data processing and reporting application. The focus was placed on those aspects of the system that could negatively impact the flow of information. The results of this analysis identified a number of deficiencies in the existing information model.

- **Lack of a structured database**

Marvin uses a file-based data management system, which was adequate when there were only 3 or 4 projects to maintain. However, as the number and type of projects grew, this data management system became laborious, tedious and time consuming.

Marvin processes a large number of Excel-based log files, but does not save the contents of these files into a structured database. Interim processing results are also not saved into any database tables. Final processing results for each project's daily performance are saved as individual Excel-based files. The main project list, user list, Eskom electricity pricing tables and data processing and system related information are saved into Excel files.

- **Lack of accessibility**

Marvin is a desktop application and its user interface is only accessible to one user at a time. This is inconvenient for users such as project engineers whom may only want to view the performance results of a specific project, but have to wait for an existing user to complete his session.

- **Lack of availability**

Presently project engineers have to contact head office by telephone to query the performance results of a specific project or wait until they return to office. Immediate access to information is often required to evaluate the performance of a DSM project. Eskom, M & V, or the mining clients, may also require the DSM project information to be available and accessible to them at any time and from any location.

2.6 Deriving the requirements specification for a web-based application

Motivation for a web-based solution

The advent of the Internet and World Wide Web has made significant transformations in how businesses operate and communicate with their customers. These transformations have also reached the energy sector. It was a logical transition to use the medium of the web as a tool to facilitate information management within DSM project implementations given its widespread use as a communication medium.

A web-based application will provide convenient access to DSM projects at any time and from any location with Internet connectivity. Access to information will allow problems to be proactively identified and rectified. Historical data can be accessed from a central database and allow all the stakeholders to conduct further analysis. DSM project data will be saved in a structured, standardised format versus the present file-based system. Transparency will be promoted as each stakeholder will be able to view the performance of the project on a daily basis. A wider audience will have access to information in comparison to the existing information management process.

Decision makers will have instant access to project performance. The benefits of a web-based interface will further enhance the sustainability of DSM by ensuring that information is shared, problems proactively identified and escalated to the relevant stakeholders as soon as possible.

Case studies of similar projects

A web research was conducted to find companies, if any, within the energy sector that specifically uses web-based solutions to monitor their DSM projects. The goal was to gain insight into the experience of other companies and how they have benefited from using such web-based tools. Valuable information can be gained of how such web-based applications are integrated with other systems and business processes. The results can then be used as a benchmark for the development of the proposed web application.

Case study 1: 4tell™ Solutions, LLC

4tell™ Solutions LLC prides itself in 'enabling sustainability through knowledge creation' [52]. 4tell™ Solutions has developed an integrated software solution called iPlan™ with a web-based interface. One of the modules of the software is the iPlan™ Demand-side Management Solution. The iPlan™ DSM graphical user interface (GUI) is shown in Figure 27 and Figure 28.

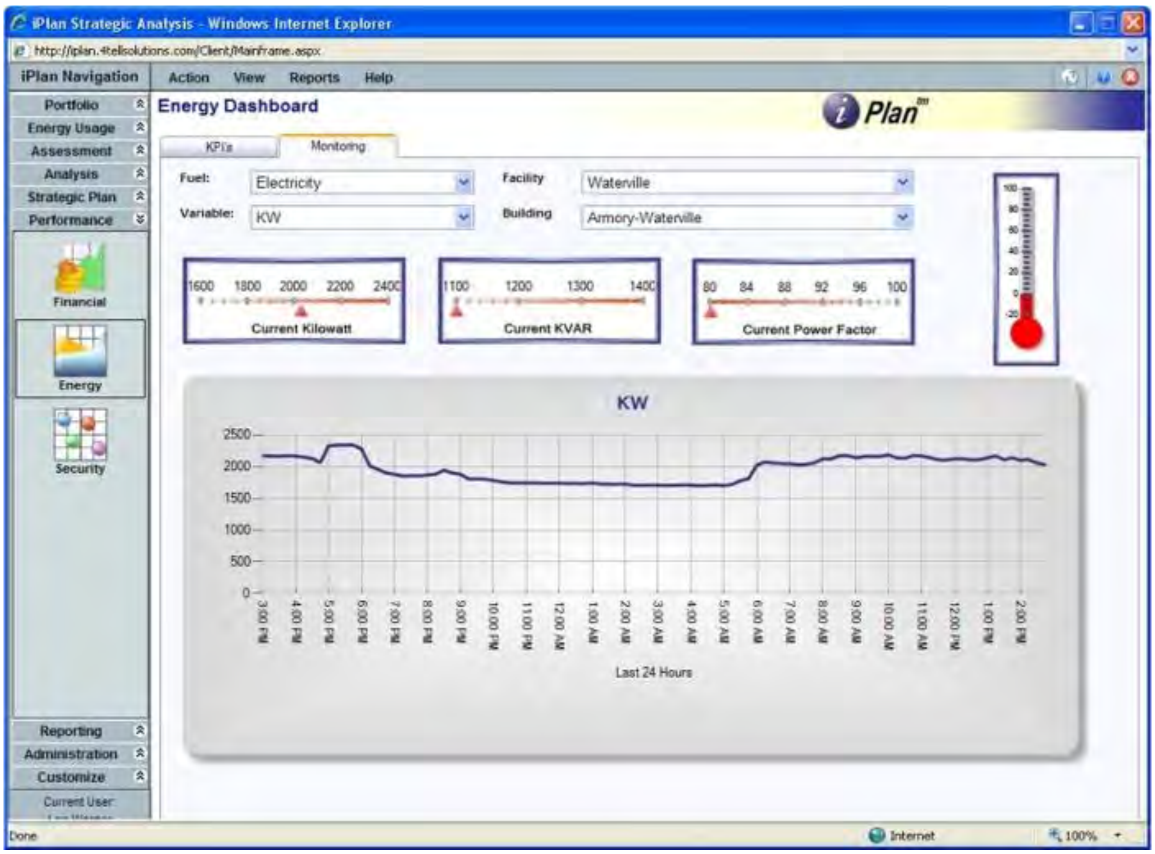


Figure 27 - The iPlan™ Demand-side Management interface [52]

It is useful to compare the GUI of iPlan™ with the Marvin GUI in Figure 22. The software is used for DSM projects in the building environment to reduce the energy and carbon emissions in buildings. The system also provides remote access to project sites, supports unidirectional and bidirectional data transfer to and from external systems through its iPlan-web, iPlan-connect, iPlan-remote and iPlan-configure modules [52].

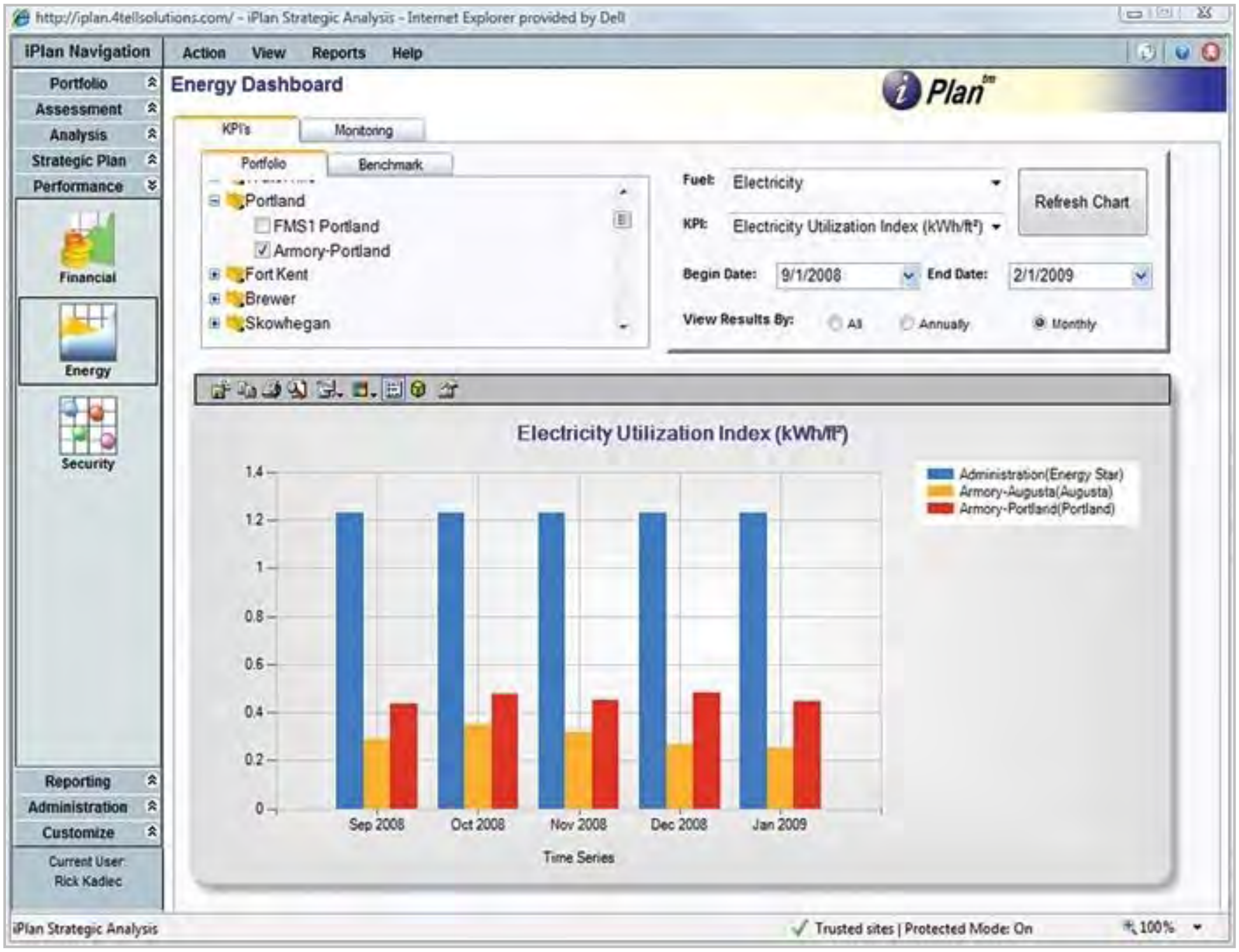


Figure 28 - The iPlan™ Demand-side Management interface (KPIs) [52]

Benchmarking

The aim of the benchmarking is to find the best practices in other systems that can be incorporated or considered when developing the proposed web application. These comparisons will be made based on the functionalities or services that the systems provide and not on the details of each system's architecture. Functional similarities and differences between iPlan™ and OSIMS are listed in Table 4 and Table 5.

Table 4 - Functional similarities between iPlan™ and OSIMS

iPlan™	OSIMS
Supports unidirectional and bidirectional data transfer to and from enterprise systems.	Supports uni- and bidirectional data transfer through Sentinel and Hermes from REMS to Marvin.
Data capture is centred on building assets.	Data capture is centred on mining equipment (pumps, compressors, winders, fans, etc).
Remote access through its iPlan remote module.	Remote access through its Hermes application.
Provides graphical energy performance reporting with Key Performance Indictors (KPIs) (Electricity Utilization Index) (kWh/ft^2).	Provides graphical daily electricity savings performance reporting with KPIs (morning MW savings, evening MW savings, and Rand-cent savings).
Online stakeholder reporting.	Provides automatically generated daily, weekly and monthly reports in Word and Excel formats.

Table 5 - Functional differences between iPlan™ and OSIMS

iPlan™	OSIMS
Adapted for and operating mainly in the building environment.	Adapted for and operates mainly in the mining environment.
Integrates with the financial, ERP and project-based systems.	REMS interfaces directly with the SCADA systems of mines.
XML data transfer.	CSV data transfer.
Centralised relational database architecture.	Presently uses a file-based database structure. Lacks a centralised database.
Provides secure web-enabled interface through its **iPlan**™-web module.	Does not presently provide a web-interface. This study aims to develop and implement a workable production model web application.

Case study 2: Western Power Daptiv PPM

Western Power, an Australian-based utility, which manages over 100 projects, is responsible for transporting electricity to cities, homes and businesses through a large electrical distribution network [53]. An MS Excel-based method of managing projects is used where each project had to be provided with a separate Excel sheet [53]. At the end of each month a consolidated report had to be generated. The format of this consolidated report was designed by an employee of Western Power who had since left the company [53]. Problems arose as the number of projects increased, becoming increasingly cumbersome to update the Excel sheets containing complex formulae [53].

Western Power opted to implement the Daptiv Project Portfolio Management (PPM) software tool. DSM projects can now be securely tracked and monitored. Since using Daptiv PPM, Western Power has been able to gather, update and present information more quickly [53]. This allowed them to move the focus from 'managing system-related issues to the process of managing the work' [53]. The Daptiv PPM graphical user interface is shown in Figure 29.

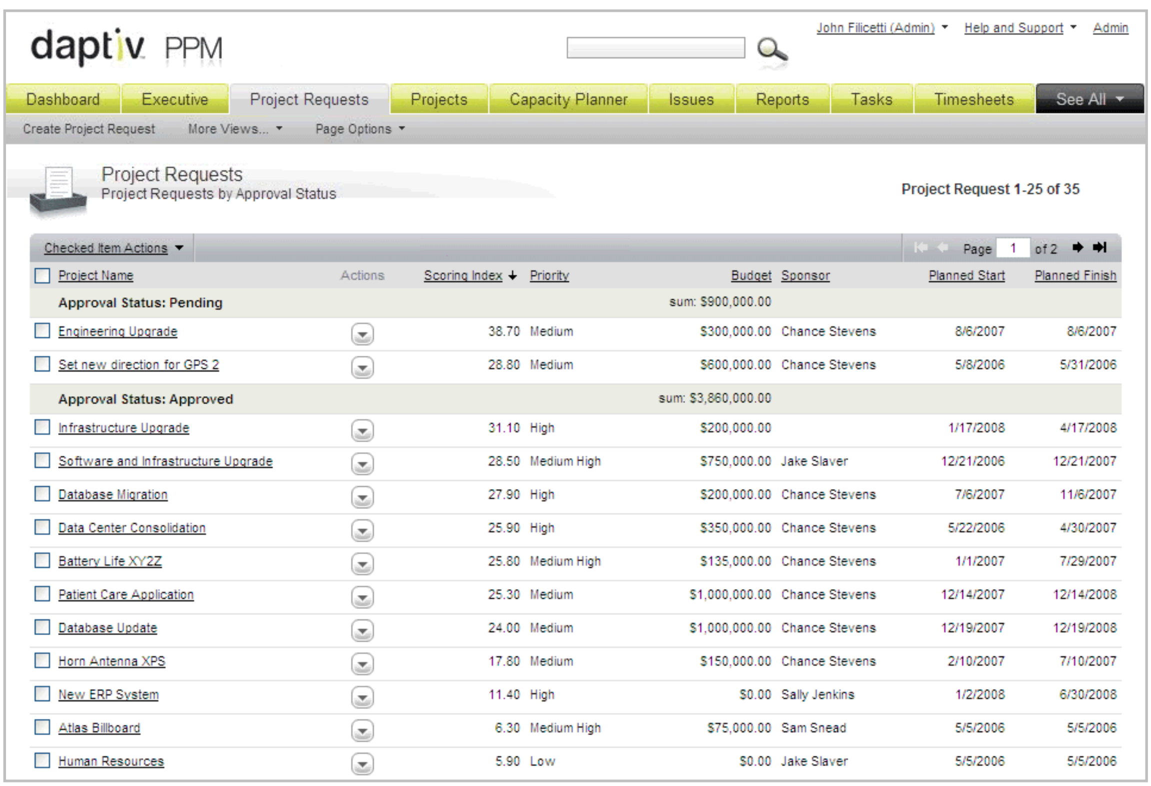


Figure 29 - Daptiv PPM graphical user interface [53]

The Western Power scenario is similar to that of HVACI, where each project has a separate Excel sheet that is used in the calculation of daily DSM project performances. In the case of HVACI the calculation and generation of reports has been automated with minimum human intervention. However, with an increase in the number of projects, it becomes tedious to maintain the Excel based files. Over 700 companies use the Daptiv PPM web-based project portfolio management solution [53]. This is a clear indication that a web-based application can also provide HVACI with the benefit of ensuring the sustainability of the DSM projects.

Requirements specification and implementation plan

A requirement specification table has been documented in collaboration with HVACI management. These specifications are listed in Table 6.

Table 6 - Requirements specification for web application

Key item	Requirement
Database	The web application must be database driven.
Data	The historic processed data from the Marvin system must be converted and uploaded into the newly built web-database.
Users	The web application must account for 5 user groups or roles. The user groups comprise an Eskom user, a mine user, a mine group user, an engineer user and an administrator user.
Security	Users must not be able to register themselves. The addition of new users will be administered from the HVACI office. Each user group must be able to securely access the web application through a user name and password.
Accessibility	The web application must be accessible via high-end web-accessible cellular phones.

2.7 Conclusion

This chapter introduced the key role players in the South African DSM environment. The role of the ESCO, to ensure sustainability, has been emphasised. Information management was shown to be essential to ensure the sustainability of DSM projects. Benefits of a database-driven web application were investigated and shown that it could further enhance the information management solution. Two case studies were presented to illustrate how other companies have benefited from introducing an integrated a web-based interface. The requirements specification was presented for the proposed web application to be built. This will serve as input to web application development process. The design and implementation of this web application will be presented in Chapter 3.

Chapter 3: Developing a web-based information management solution

Source: Electricity supply industry of South Africa – general information for potential investors

3.1 Introduction

Development process of the web application

The web application development process that will be followed in this study is an evolutionary approach, because web applications in themselves are evolutionary and change continually [54]. The generic web application development process that will be followed is shown in Figure 30.

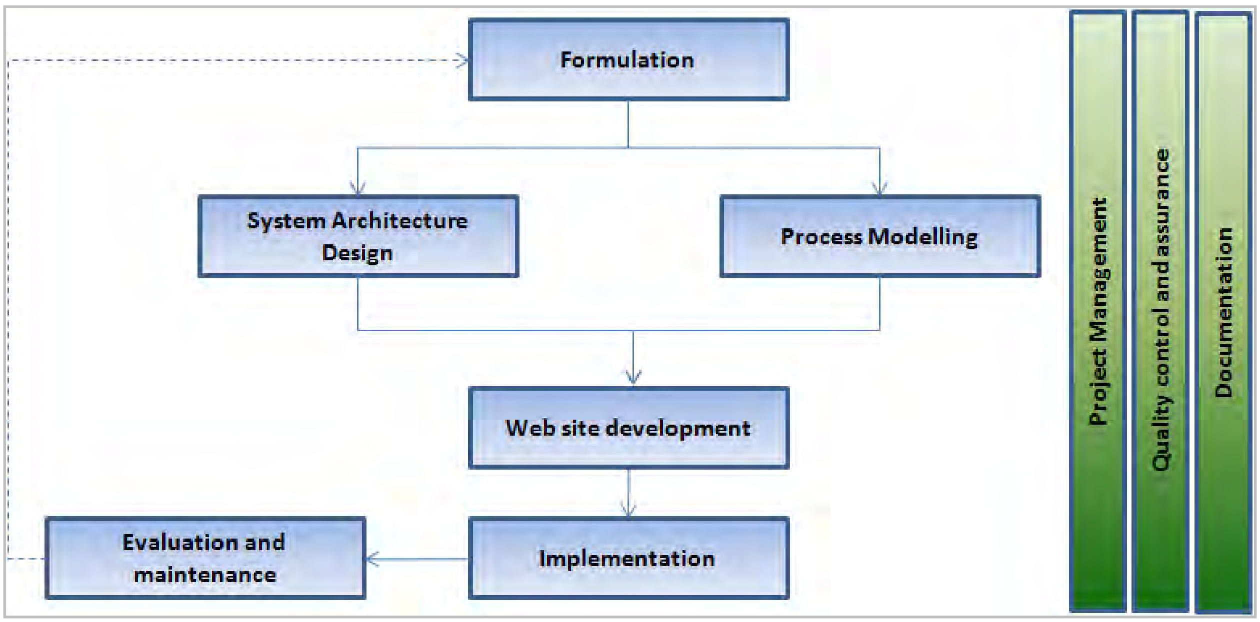


Figure 30 - Web application development process (adapted from [54])

3.2 Formulation of the web application

Formulation has a dual purpose. Firstly, it allows the developer and the customer to establish a common set of goals and objectives with regards to the development of the web application. Secondly, it identifies the scope of the development effort. These goals, objectives and scope can then be used later on to measure the success of the development effort. The process steps of the formulation activity have been adapted from Brandon and Pressman and presented in Figure 31 [54, 55].

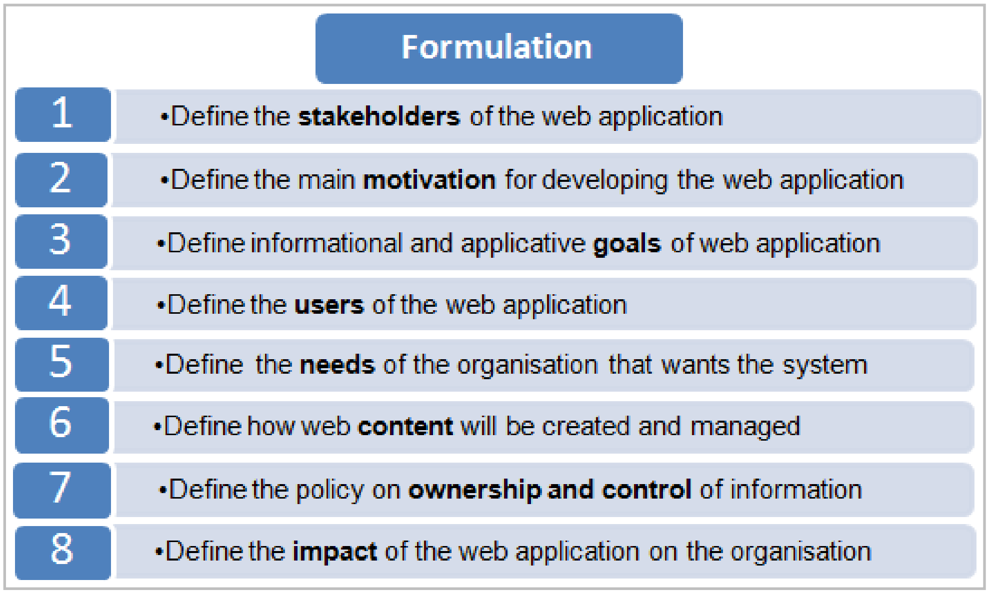


Figure 31 - Process steps of the formulation activity [54, 55]

An expanded explanation of formulation numbers 3, 4 and 8 are required. Formulation 3 describes the applicative tasks that the user will be able to perform through the web application [55]. The different applicative goals for this web application are listed in Table 7.

Table 7 - Applicative goals of the web application

Application goals	Description
Access control	Login and logout.
Presentation	Display electricity savings results for a specific project and selected date. Display project data for a specific project and selected date. Display the average MW savings from a start date to an end date for a specific project. Display a summary of MW savings given a start date and an end date. Display downloadable reports.
Project management	View, add, update and delete a project.
User management	View, add, update and delete a user. Update a user access profile.

The users of the web application noted in Formulation 4 comprise of 5 different user groups. A user group has an access profile that determines the list of projects the user may access. The different user groups and corresponding access profiles are listed in Table 8.

Table 8 - Different user groups of the web application

User group	Access profile (Default scenarios)
Mine group user	Access to all projects across mines and project types (e.g. compressors, pumps, winders) belonging to a specific mine group.
Mine user	Access to all projects across project types belonging to a specific mine.
Engineer user	Access to all projects that may belong to more than one mine group or mine.
ESCO user	Access to all projects across mine groups and mines.
Administrator user	Access to administrative modules within the web application.

The last formulation activity noted in Figure 31 deals with the impact of the web application on the organisation and can further be described as:

- A web administrator is required to maintain the web application on a daily basis. The web application will interface with Marvin. Marvin will continue to perform all data processing tasks.
- A data integration module converts the CSV-files into batch SQL-files. The SQL-files contains the project data and is imported into the local database.
- The web administrator must verify the integrity of the conversion process and upload the data and graphical images from the local database to the web database.
- Figure 32 shows the integration of the web application within the context of the OSIMS information model (compare with Figure 18).

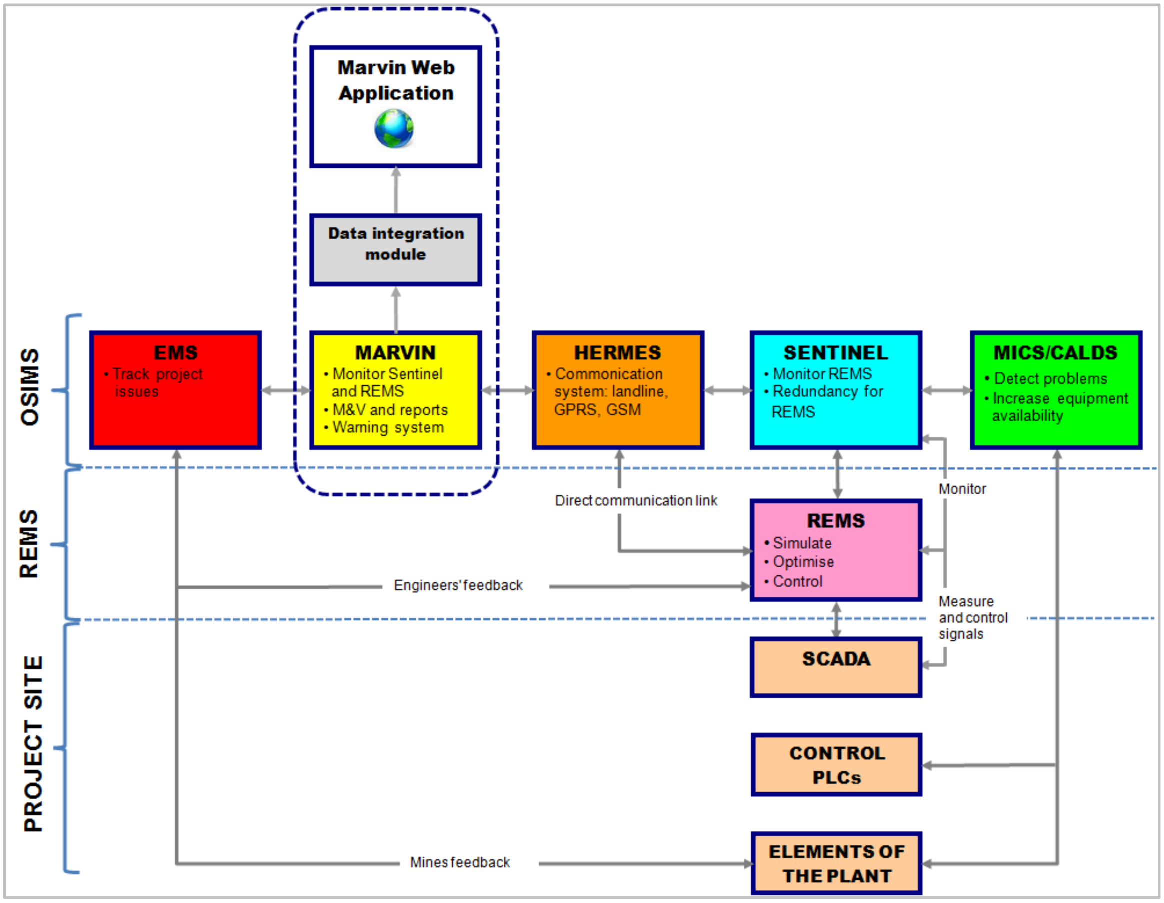


Figure 32 - Integrating the web application into OSIMS

3.3 Database design and implementation

Identification and description of entities

Data entities are those aspects of the DSM process about which information must be gathered and stored in the database. Entities have been grouped into 4 groups: project management, user and security management, navigational and project information entities.

1. Project management entities

Table 9 lists the project management entities. Project management entities relate directly to the data model of the DSM project implementation process.

Table 9 - Project management entities

Entity	Description
Project	A DSM project.
Mining group	A group of mines that belongs to the same mining company.
Mine	A project site where a project is being implemented.
Project status	A progress indicator of a project within the implementation process.
Project type	Defined by type of the equipment for which a DSM initiative is undertaken (example, compressors and pumps).
Energy type	The DSM energy reduction mechanism that will be used for the project (example, load shifting and peak clipping).
Eskom phase	An associated phase that links the project's progress within the overall Eskom DSM project implementation process.

2. User and security management entities

There are also entities that relate to web application itself. These entities have been grouped into user and security-related entities and navigational entities. The user and security-related entities are listed in Table 10.

Table 10 - User and security-related entities

Entity	Description
User	People who will use the web application.
User group	A group of users that are grouped together based on what access they have within the web application.
Access homepage	The first webpage to which the user will be directed to upon successful login to the web application. As an example, a mine user will be directed to a specific mine's homepage in the web application, while an Administrator user will be directed to the Administrator's homepage.
User access rule	Defined as the project with project type that belongs to a mine and mine group to which a user has access to.
Access code	Defines a unique code for a group of access rules. Each user entity is associated with a unique access code and each unique access code is associated with 1 or more user access rules.
Project homepage	Each project will have a webpage within the web application.
Project redirect pages	A webpage that handles validation errors in the web application.

3. Navigational entities

Navigational entities are listed and described in Table 11. These entities are used to controls the navigation from one webpage to the next in the web application.

Table 11 - Navigational and download entities

Entity	Description
Navigation heading	Navigation menu item of a webpage.
Navigation subheading	Navigation sub menu items of a webpage.
Site page	Defines a unique identify number for a webpage within the web application.
Download directory	A designated folder for downloadable project files.

4. Project information entities

There are also entities that relate to DSM project information. These entities model the data for calculated DSM savings results. The project information entities are listed in Table 12.

Table 12 - Project information entities

Entity	Description
Record file	Output log file of a project.
Actual kW usage	Actual 24-hour actual kW usage profile data.
Scaled baseline	Calculated 24-hour kW usage scaled baseline data.
Unscaled baseline	Calculated 24-hour kW usage unscaled baseline data.
MW savings	Daily calculated MW electricity savings for the project.
R-c savings	Daily calculated Rand-cent (R-c) savings.
Data loss	Periods where no data was recorded during a specific day.
Manual operation	Periods where mine operations did not follow the REMS generated automated DSM schedule.
Missed opportunity	Difference between the actual savings and the targeted savings.
Missed opportunity report	Reason(s) for the missed opportunity.
Condonable report	Reason why a specific day has been declared as a condonable day.

Business rules and relationships between projects and its related entities

A project entity represents the central entity about which information is stored in the web database. The business rules and data relationship between the project entity and other entities are described in the next section.

1. Projects and mines

- A project is commissioned by a mine.
- A project can be implemented at 1 and only 1 mine. However, there can be none or many projects that are implemented at a specific mine.

2. Projects and mine groups

- A project belongs to a certain mining group.
- A project can belong to only 1 mining group. Once again, a mining group can have none or many projects that are implemented at its mine.

3. Projects and project types

- A project has a specific type which is determined by the type of electrical equipment for which the electricity usage must be undertaken.
- A project can have 1 and only 1 project type, but there can be none or many projects of a certain project type.

4. Project and energy types

- A project has a specific energy type that is determined by the energy reduction mechanism to be implemented by the project.
- Each project can have 1 and only 1 energy type, but can vary from none to many projects of a certain energy type.

5. Projects and Eskom DSM project phases

- A project is assigned to a specific Eskom DSM project phase during the course of its implementation. Each project can be assigned to only 1 Eskom DSM project phase. There can be none to many projects mapped to an Eskom DSM phase.

6. Projects and Project homepages

- Each project is assigned to a physical webpage within the web application.
- Each project can have 1 and only 1 project homepage and each project homepage is assigned to 1 and only 1 project.

7. Projects and Project statuses

- Each project has a specific status.
- A project can have 1 and only 1 status at any given time, but there can be none to many projects mapped to a project status.

The Entity Relationship Diagram (ERD) between the projects entity and its related entities is shown in Figure 67 (Appendix A).

Business rules and relationships between site pages and its navigation headings

1. Site page and navigation headings

- Each physical webpage is represented as a site page entity in the database. Each site page has a navigation menu that consists of 1 or more navigation headings.
- A navigation heading uniquely maps to one and only one site page.

2. Navigation heading and sub-heading

- Each navigation heading can consist of none or more sub-headings.
- A sub-heading is uniquely mapped to one and only one heading. The ERD between the site pages and its related entities in included in Figure 68 (Appendix A).

Business rules and relationships between users and its related entities

The user entity represents another main entity about which information is stored in the web database.

1. Users and user groups

- Each user of the web application is assigned to a specific user group.
- A user can belong to 1 and only 1 user group. A user group can have none to many users.

2. Users and access codes

- Each user of the web application is assigned an access code.
- A user can be assigned one and only one access code. An access code is therefore unique to a specific user.

3. Users and user access rules

- Each user can be assigned with more than one access rule.
- Each access rule maps to a specific user through the user id of the user.

4. Users and access codes

- Each user's access code links to an access homepage.
- More than one access code can be associated to the same access homepage.

5. Users and user access rules

- Each user can be assigned with more than one access rule.
- Each access rule maps to a specific user through the user id of the user.

6. Access codes and access homepage

- Each user's access code links to an access homepage.
- More than one access code can be associated to the same access homepage.

The ERDs between access homepages and its related entities are shown in Figure 69 (Appendix A). Figure 70 (Appendix A) shows the ERD for the download directory page and its related entities. Figure 71 (Appendix A) depicts the detailed ERD between the Users entity and its related entities.

Business rules and relationships between record files and its related entities

- Marvin presently processes the input log files received from the various projects sites and produces a daily Excel CSV output file for each project. This output file is modelled as the record file entity. Information contained within the output file is modelled as entities that relate to the record file entity.

- The detailed ERD between the Record file entity and its related entities is shown in Figure 72 (Appendix A).

Database implementation

In the implementation of the database design, a separate main database has been created to hold the tables for users, projects, clients and other general website information.

1. Main database architecture

The database architecture for the implementation of the main database is shown in Figure 33.

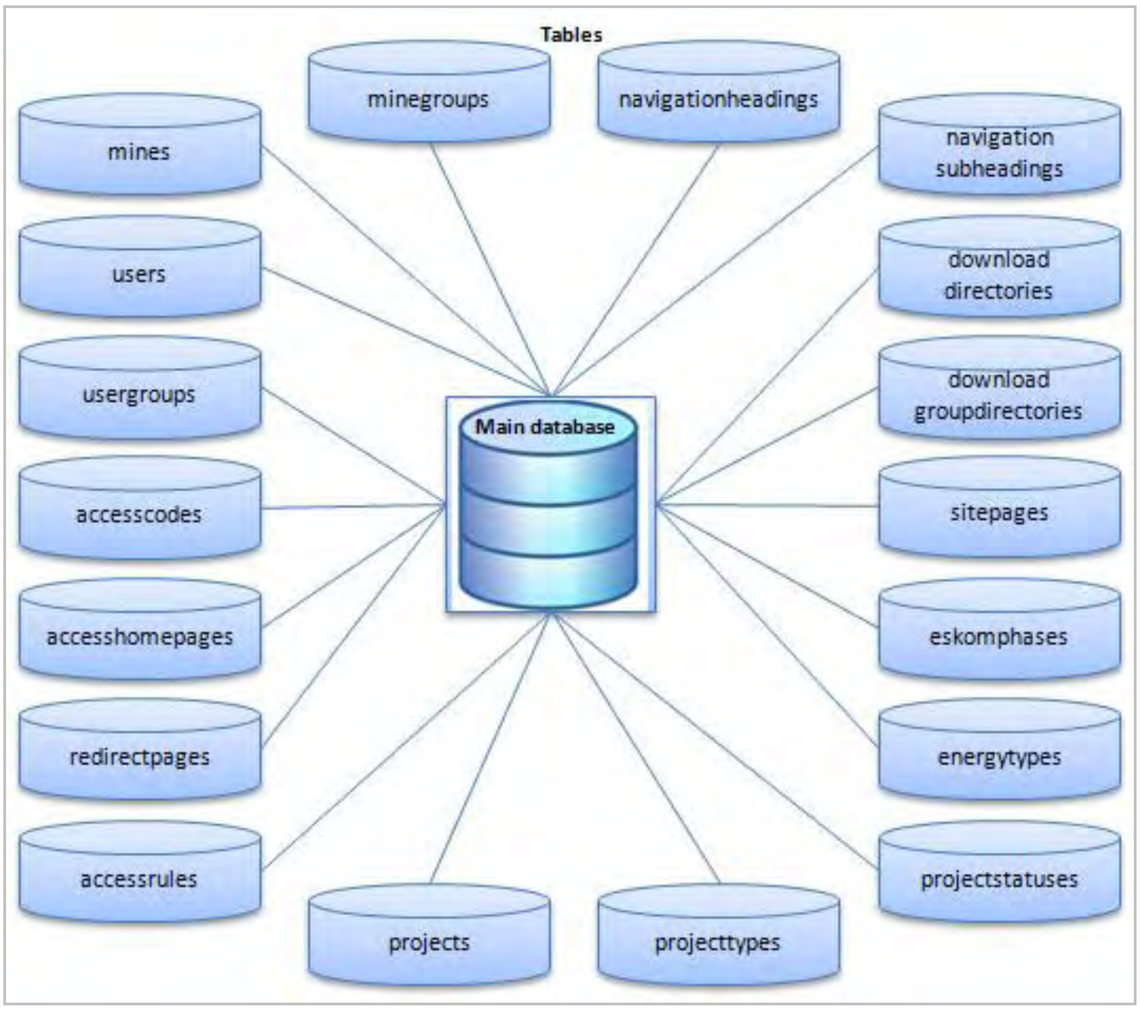


Figure 33 - Architecture for main database

2. Project database architecture

- The database architecture for the implementation of a generic project database is shown in Figure 34.
- A separate database will be created for each project to hold project-related tables that are specific to the project.

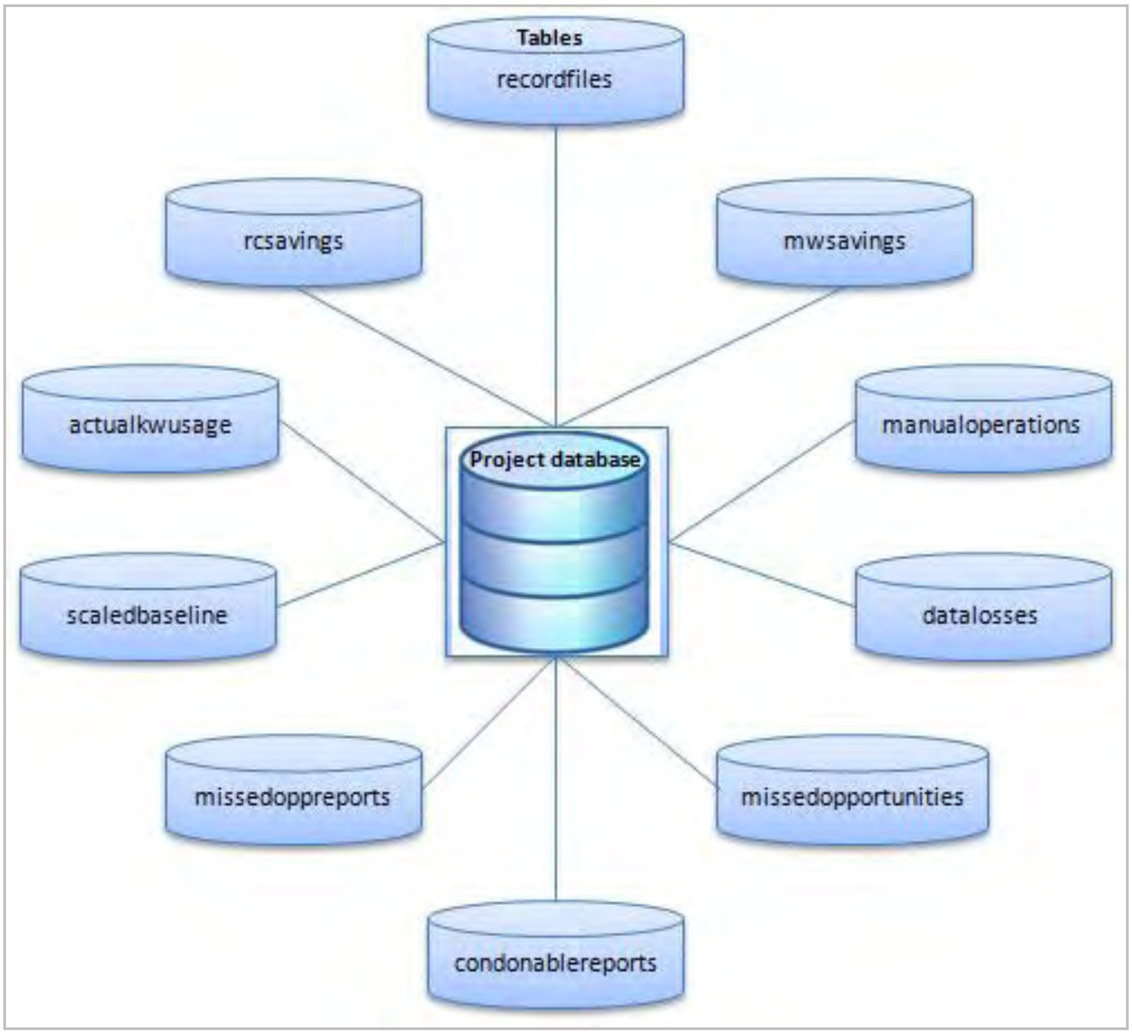


Figure 34 - Architecture for a generic project database

3.4 Analysis and design of the web application

System architecture

The architecture of the web application is shown in Figure 35. It is a three-tiered architecture consisting of a web client, web application and the database server applications. The user interacts with the web application through a desktop web browser application such as Internet Explorer or through the mobile browser of a web-enabled cellphone. The web application interacts with database server applications, which communicates with databases.

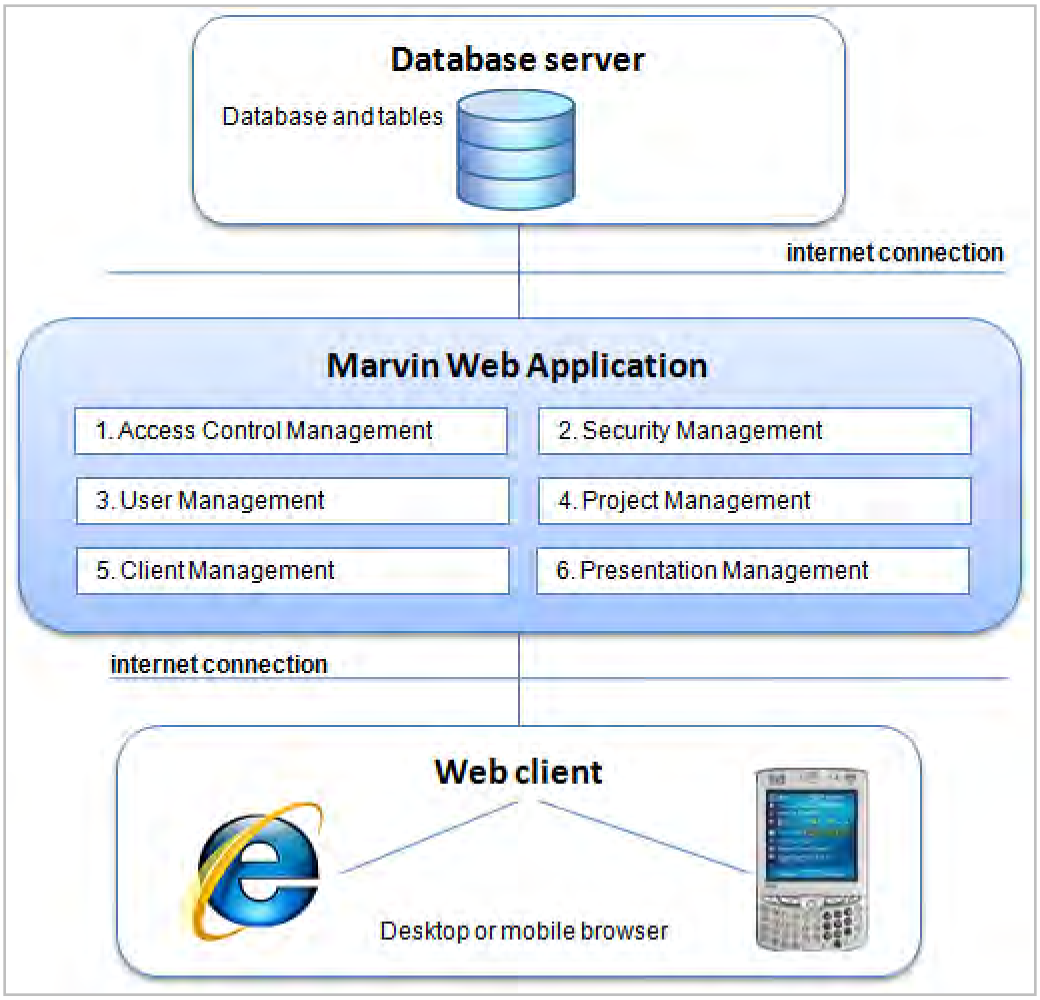


Figure 35 - Marvin Web Application architecture

1. Access control management

Access control determines how users will gain access to the web application. It also controls the access to project data. The access control activity diagram is shown in Figure 73 (Appendix A).

2. Security management

Security management establishes the user's access control profile, which determines the projects the user will be able to gain access to and the default homepage. The process uses a valid username and password to determine which projects the user has access to. The process is shown in Figure 78 (Appendix A).

3. User management

User management handles the addition of new users and the updating, deletion and viewing of existing users. This process also handles the creation of an access profile when a new user is created and updating of an access profile. Detailed activity diagrams are shown from Figure 74 to Figure 77 in Appendix A for the user management tasks.

4. Project management

Project management handles the addition of new projects, updating, viewing and deletion of existing projects and its related entities such as project types, energy types, project statuses and Eskom DSM project phases. An administrative user is also responsible for the project management process. Detailed activity diagrams are shown from Figure 79 to Figure 82 in Appendix A for the project management tasks.

5. Client management

Client management handles the addition of new mines and mine groups as well as the updating of existing mines and mine groups, viewing and deletion of mine and mine group. An administrative user is also responsible for the client management process. An activity diagram is shown for adding a mine in Figure 83 (Appendix A).

6. Presentation management

Presentation management is responsible for the visual presentation of the data. Data is presented in a generic web design template shown in Figure 84 (Appendix A). Each dynamic area of the template is populated with data relevant to the user access profile.

After a user has been directed a specific webpage, the security process determines whether the user should be granted access to the specific webpage. This is accomplished by determining whether all access parameters have been initialised. A database connection is established with the relevant database and tables. Query commands are executed by the database server. Query results are returned to the web application, and the data presentation model is applied to the webpage and returned results. The webpage building process is shown in the activity diagram in Figure 85 (Appendix A).

The user can navigate to different sections of the webpage or filter information via a navigation menu selection. Each webpage also provides a link to return to a previous webpage (through the Back menu) or to exit the web application through the Logout menu link. The navigation logic is shown in Figure 86 (Appendix A).

3.5 Implementation and testing of the web application

This section will demonstrate and test selective scenarios of the implemented web application. The remainder of the scenarios are described in detail in Appendix B.

Scenario 1: A mine user logs into the web application

Figure 36 shows the login screen after a mine user has entered his login details.

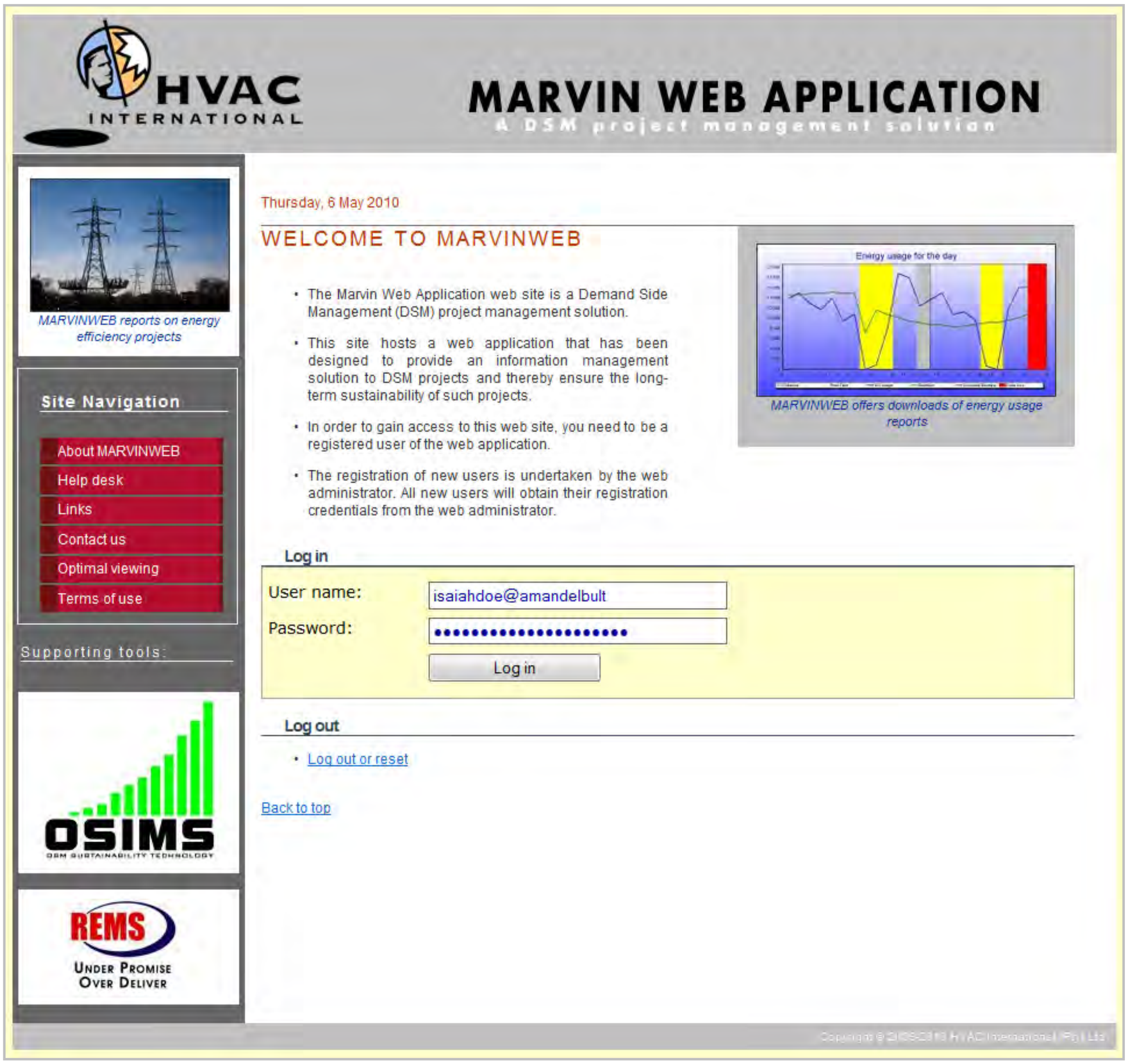


Figure 36 - Login screen

Redirection to the mine page

- The user clicks on the Login button and is directed to Amandelbult mine homepage. The prerequisite for a successful login is a valid username and password. Figure 37 shows the Amandelbult mine homepage.
- Navigational menus are dynamically created depending on the type of projects being implemented at the mine. The project list is dependent on the user's access profile.

Figure 37 - Amandelbult mine homepage

Scenario 2: Navigating to the project page

- The user clicks on the Amandelbult compressor manager project and is redirected to the Amandelbult compressor project homepage as shown in Figure 38.

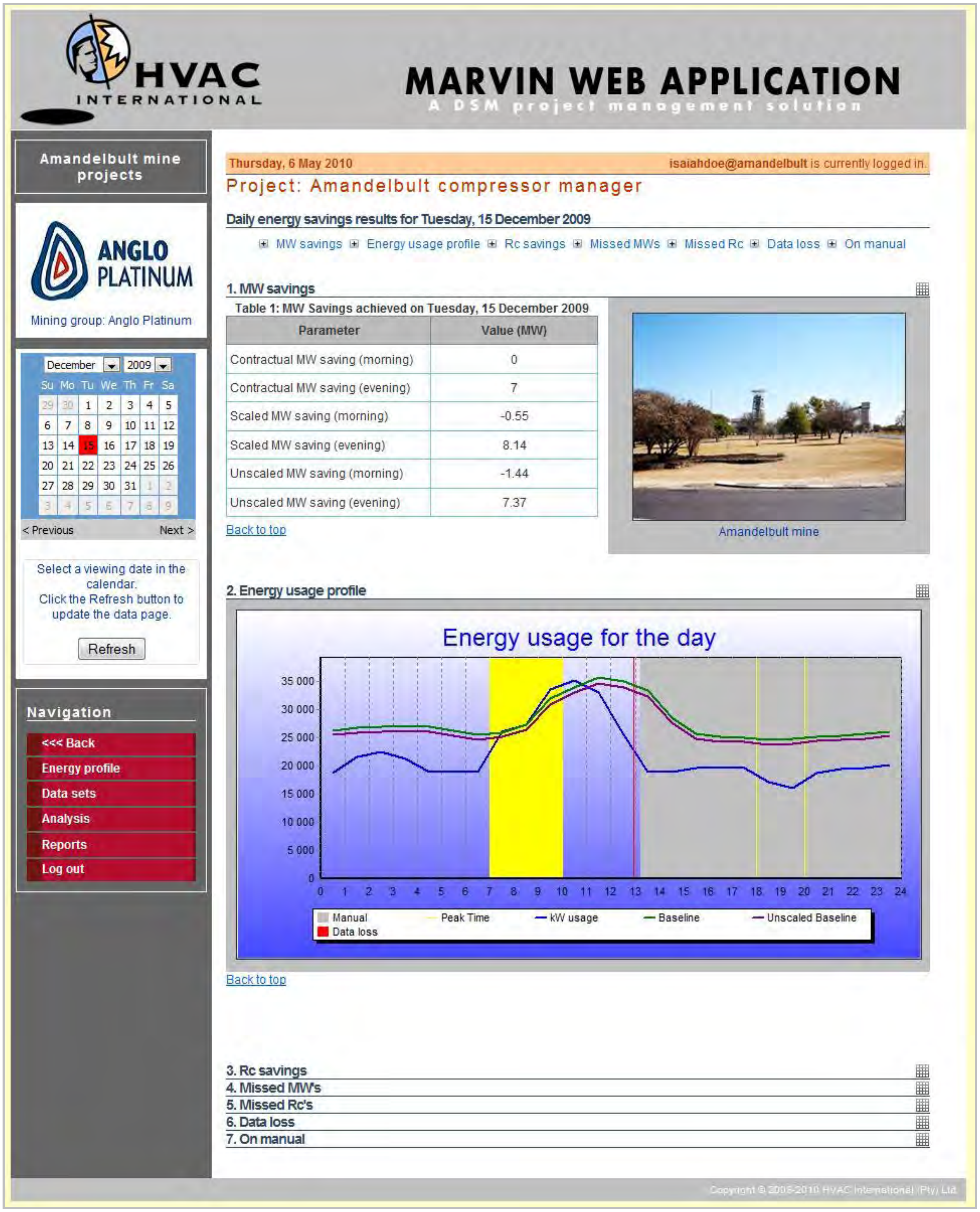


Figure 38 - Amandelbult compressor manager project homepage

- The project homepage shown in Figure 38 is displayed after the user selects a date (e.g. 15 December 2009) from the calendar component and clicks on the **Refresh** button.
- The selected date had data available in the database to display and displays the MW savings as well as the 24-hour graphical energy profile.
- Figure 39 shows the project performance and control data for the selected date when Sections 3-7 are made viewable. The user can navigate to another section of the web application by clicking on the menu links in the navigational bar on the left.

3. Rc savings

Table 2: Rc Savings achieved on Tuesday, 15 December 2009

Parameter	Value (R)
Scaled Rc saving	25479
Unscaled Rc saving	21258
Scaled proposed Rc saving	6579

Back to top

4. Missed MW's

Table 3: Missed MW's on Tuesday, 15 December 2009

Parameter	Value (MW)
Scaled missed opportunity MW saving (morning)	0
Scaled missed opportunity MW saving (evening)	2.08
Unscaled missed opportunity MW saving (morning)	0
Unscaled missed opportunity MW saving (evening)	2.53

Back to top

5. Missed Rc's

Table 4: Missed Rc's on Tuesday, 15 December 2009

Parameter	Value (R)
Scaled missed opportunity Rc saving	0
Unscaled missed opportunity Rc saving	0

Back to top

6. Data loss

Table 5: Data loss periods on Tuesday, 15 December 2009

Start time	Stop time
12:00:00	12:00:00
12:56:00	12:56:59
11:59:00	11:59:59

Back to top

7. On manual

Table 6: System on manual periods on Tuesday, 15 December 2009

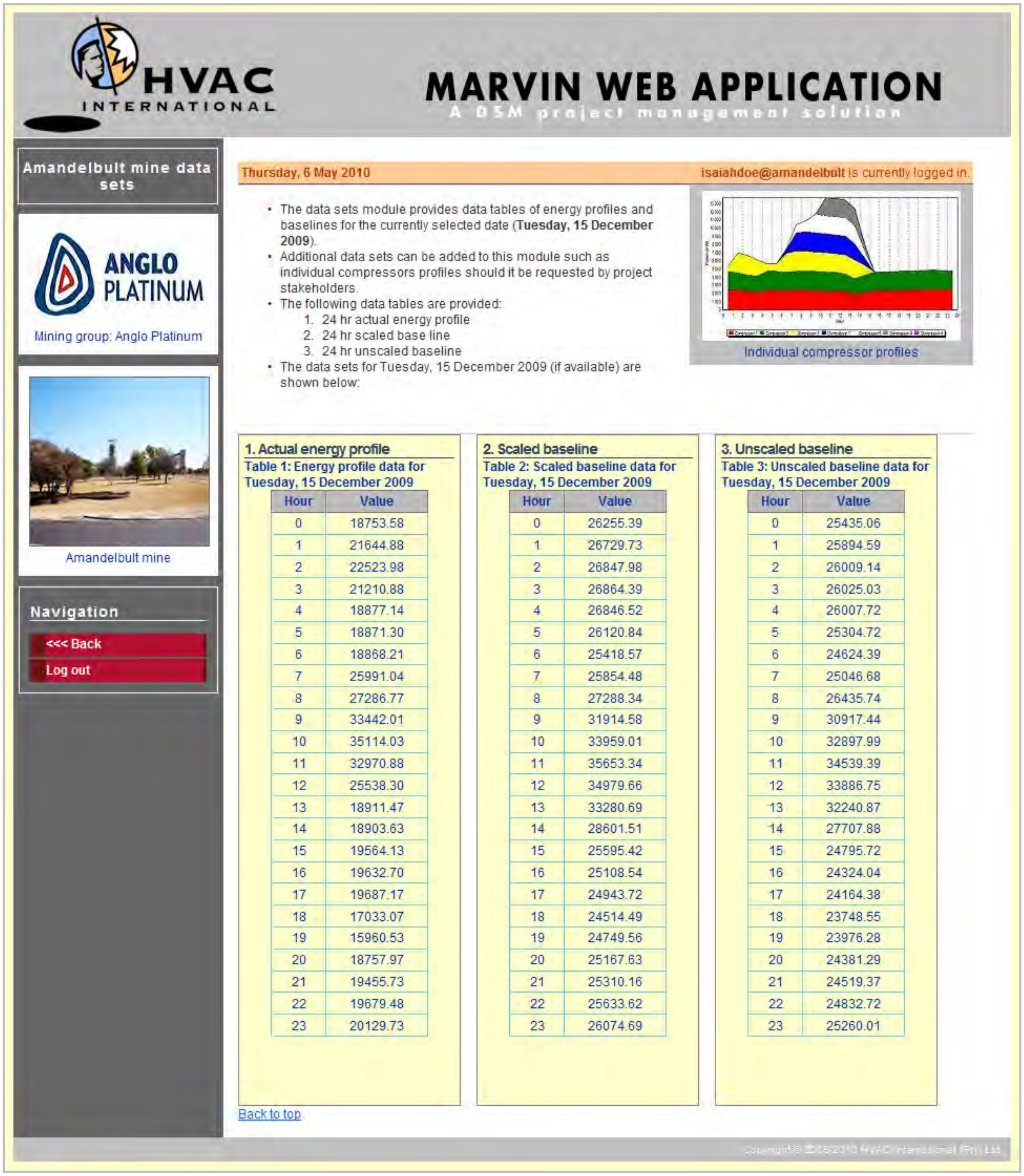
Start time	Stop time
01:12:59	11:59:00

Back to top

Figure 39 - Project performance data

Scenario 3: Navigating to the data sets page

- The user clicks on the **Data sets** menu link and is redirected to the **Data sets** page as shown in Figure 40.



Hour	Value (Table 1)	Value (Table 2)	Value (Table 3)
0	18753.58	26255.39	25435.06
1	21644.88	26729.73	25894.59
2	22523.98	26847.98	26009.14
3	21210.88	26864.39	26025.03
4	18877.14	26846.52	26007.72
5	18871.30	26120.84	25304.72
6	18868.21	25418.57	24624.39
7	25991.04	25854.48	25046.68
8	27286.77	27288.34	26435.74
9	33442.01	31914.58	30917.44
10	35114.03	33959.01	32897.99
11	32970.88	35653.34	34539.39
12	25538.30	34979.66	33886.75
13	18911.47	33280.69	32240.87
14	18903.63	28601.51	27707.88
15	19564.13	25595.42	24795.72
16	19632.70	25108.54	24324.04
17	19687.17	24943.72	24164.38
18	17033.07	24514.49	23748.55
19	15960.53	24749.56	23976.28
20	18757.97	25167.63	24381.29
21	19455.73	25310.16	24519.37
22	19679.48	25633.62	24832.72
23	20129.73	26074.69	25260.01

Figure 40 - The data sets page

- The data sets page in Figure 40 displays the numerical values of the actual 24-hour energy usage profile together with the scaled and unscaled baseline data for the date initially selected by the user on the project page.
- Data sets represent the numerical values for the graphs shown in the energy usage profile as shown of Figure 38.

Scenario 4: Navigating to the analysis page

- The user clicks on the Analysis menu link and is redirected to the **Analysis** webpage as shown in Figure 41.
- This webpage allows the user to execute two requests. The first request calculates the average MW statistics for a given period while the second generates a summary table of evening load shifts and monetary savings for each day over a given period.

Figure 41 - Analysis web page for Amandelbult compressor manager

Execute query 1: Calculate the average MW statistics for a given period

- The user enters a **start date** (e.g. 2010-01-01) and **end date** (e.g. 2010-01-15) on the pop-up calendars and clicks on the **Calculate** button.
- The web application then calculates and displays the contractual evening MW saving, average evening scaled MW savings and average evening unscaled MW saving for the selected period as shown in Figure 42.

Figure 42 - Analysis webpage with average MW statistics results

- The results of the calculation are dependent on the available data in the web database for the specific project.

Execute query 2: Generate a summary of mine report for a given period

- The user enters a **start date** (e.g. 2010-01-01) and **end date** (e.g. 2010-01-15) and clicks the **Generate** button.
- A summary report is generated that displays the scaled and unscaled evening MW load shift and the scaled and unscaled monetary savings as shown in Figure 43.

Figure 43 - Analysis webpage with summary report results

- Note that no data was available for the period 1 January 2010 to 5 January 2010.

Scenario 5: Navigating to the reports page

- The user clicks on the **Reports** menu link and is directed to the Reports webpage as shown in Figure 44.
- In this scenario the user clicks on the **Day reports** menu link.
- The web application searches for available daily reports in the reports download directories of, in this particular scenario, the Amandelbult compressor project.

Figure 44 - Reports web page

- In this scenario a single report for the Amandelbult compressor project and two reports for the Amandelbult #2 pump project were found and listed as shown in Figure 45.
- No daily reports were found for the Amandelbult 1# and Amandelbult 2# air networks projects and the Amandelbult 1# pump and Amandelbult fridge plant projects. These were new projects at the time and therefore no reports were available to download.

Project name: Amandelbult compressor manager

Project type	Report name and link
Compressors	AmandelbultCM 2010-02-19.doc

Project name: Amandelbult 1# pumping system

There are currently no reports available in the Marvin Web Application database to download. Please contact the relevant project engineer.

Project name: Amandelbult 2# pumping system

Project type	Report name and link
Pumps	AmandelbultP 2009-08-12.doc
Pumps	AmandelbultP 2009-08-13.doc

Project name: Amandelbult 1# optimisation of air networks

There are currently no reports available in the Marvin Web Application database to download. Please contact the relevant project engineer.

Project name: Amandelbult 2# optimisation of air networks

There are currently no reports available in the Marvin Web Application database to download. Please contact the relevant project engineer.

Project name: Amandelbult fridge plant

There are currently no reports available in the Marvin Web Application database to download. Please contact the relevant project engineer.

Figure 45 - Daily reports archive webpage

Scenario 6: A mine group user logs into the web application

- In this scenario the user has logged in as an Anglo Platinum mine group user.
- The web application redirects to the homepage of the Anglo Platinum mining group as shown in Figure 46.

Figure 46 - Mine group user homepage

- The Anglo Platinum mine group homepage shows all the mines that belong to this mining group.
- The project list is displayed depending on the project type.
- In this scenario the mine group user filters the projects for the **Lebowa** mine by clicking in **Lebowa** mine menu link under the navigation menu. The webpage is refreshed and a project list containing only the Lebowa mine projects is displayed as shown in Figure 47.

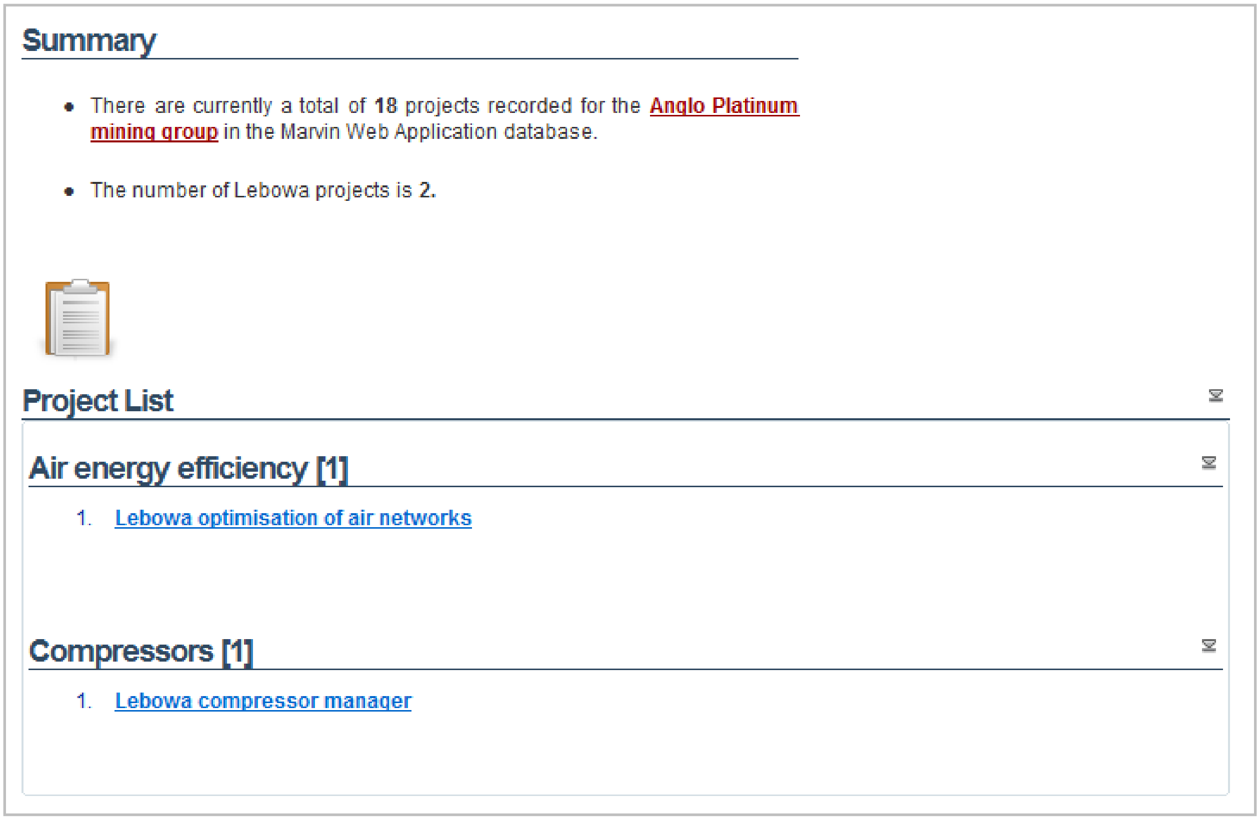


Figure 47 - Mine group project list filtered

- The mine group user can now navigate to the project data pages of any one of the projects listed and follow the same navigational paths as described in previous scenarios.

Scenario 7: An Engineer user logs into the web application

- The web application redirects to the Engineering homepage as shown in Figure 48.

Figure 48 - Engineering user homepage

- The user has only been granted access to the projects of the Amandelbult and RPM mines.
- The user can navigate to the project pages of any of the projects listed and described previous scenarios.

Scenario 8: An Eskom user logs into the web application

- The web application redirects to the Eskom homepage as shown in Figure 49.

Figure 49 - Eskom homepage

- The Eskom homepage provides a list of all the mining groups listed on the navigational bar.
- The user selected the Anglo Platinum mining group. All mines of the selected mining group are displayed in the data section of the webpage.
- The user can again navigate to the project data of any project listed and follow the same navigational paths as described in the mine user scenario.

Scenario 9: An Administrator logs in and adds a new user

- The web application redirects to the administrative homepage as shown in Figure 50.

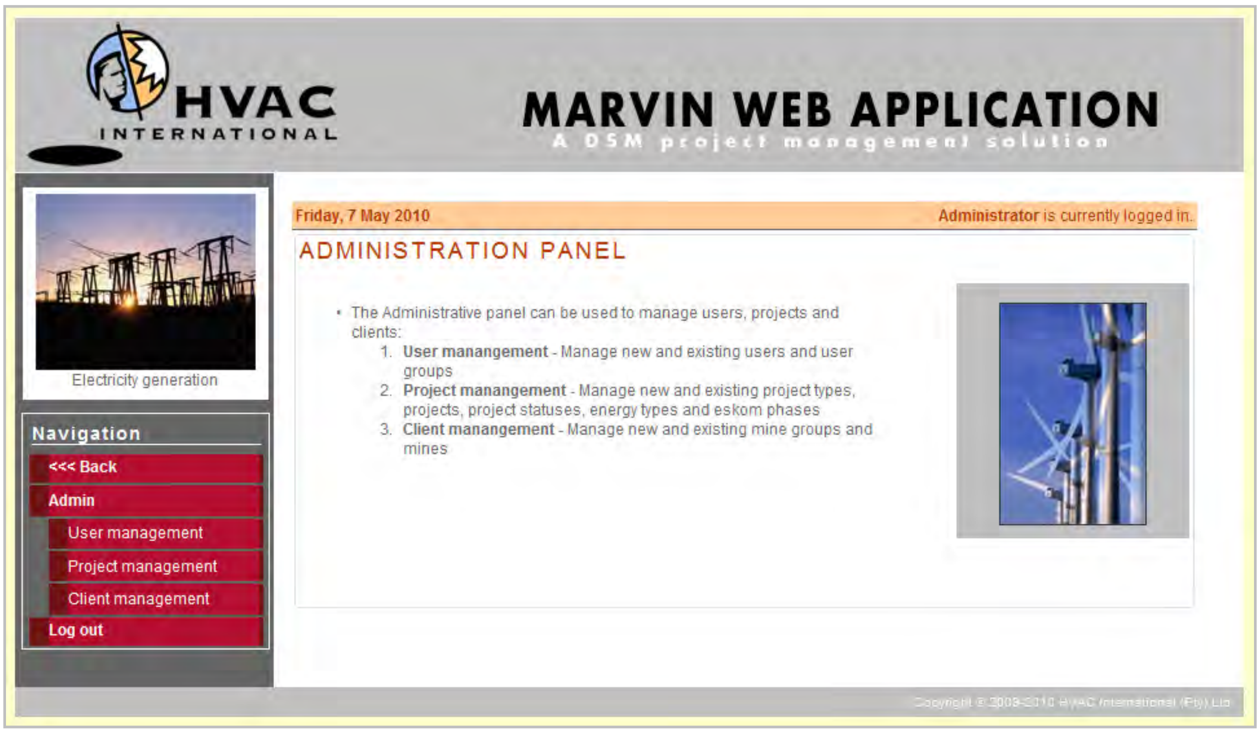


Figure 50 - Administrative homepage

- The user followed the navigation path: **User Management** > **Maintain users** > **Add user**.
- In this case a new mine user will be added to web database.

Step 1: adding a new user's personal details

- The administrator adds the new user's personal details and also assigns the new user to a user group as shown in Figure 51. The user clicks on the **Next** button.

Step 1: adding a new user's personal details

- The administrator adds the new user's personal details.
- The new user is added to the '**Mines'** user group as shown in Figure 51.
- The user clicks on the **Next** button.

Figure 51 - Adding a new user's personal details

Step 2: Selecting a mine

- The administrator selects the mine associated with the new mine user.
- The new mine user is linked to the Amandelbult mine as shown in Figure 52.
- The user clicks on the **Next** button.

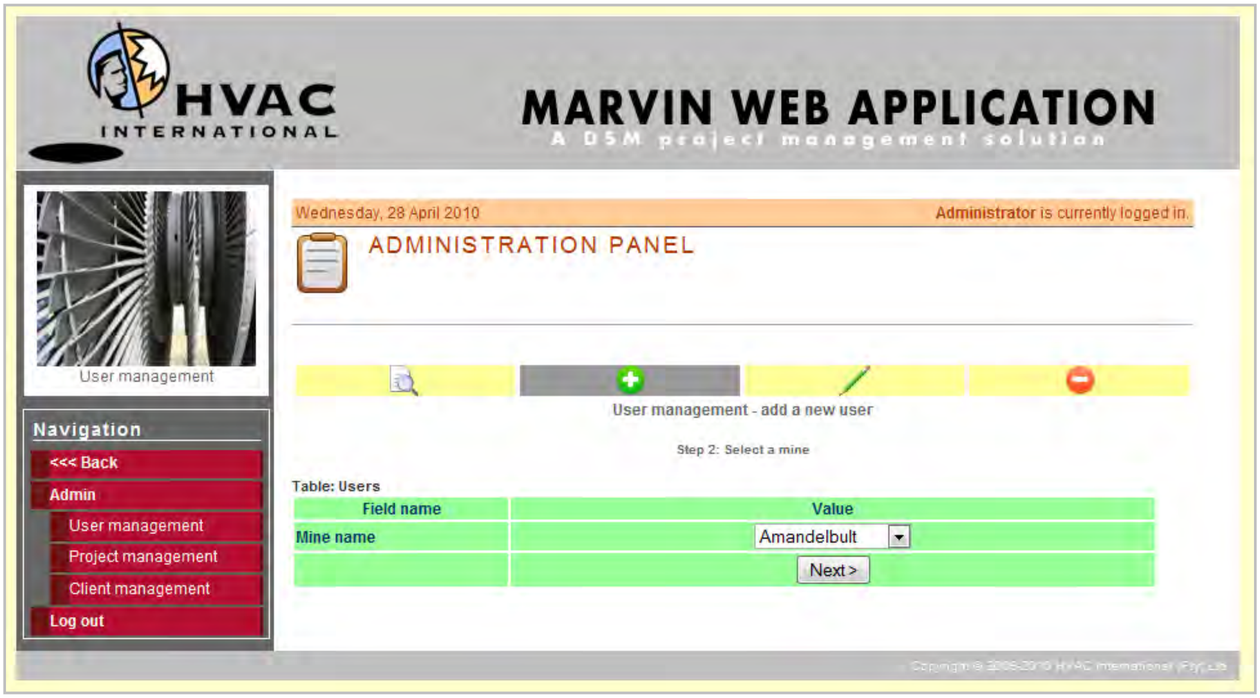


Figure 52 - Selecting a mine

Step 3: Define the user access profile

- A list of projects is displayed based on the user group selection in step 2. Since the Amandelbult mine was selected, all available projects of the Amandelbult mine will be displayed.
- The administrator defines the new user's access profile by selecting the projects the user can access.
- In this scenario, the Administrator grants the new user access to only two projects, namely the Amandelbult 2# pumping project and the Amandelbult #2 compressor project as shown in Figure 53.
- A unique name is entered by which the access profile can be easily remembered. The user clicks the **Next** button.

Step 4: Confirmation

- A confirmation page confirms the addition of a new user as shown in Figure 54.

Figure 53 - Defining the user's access profile

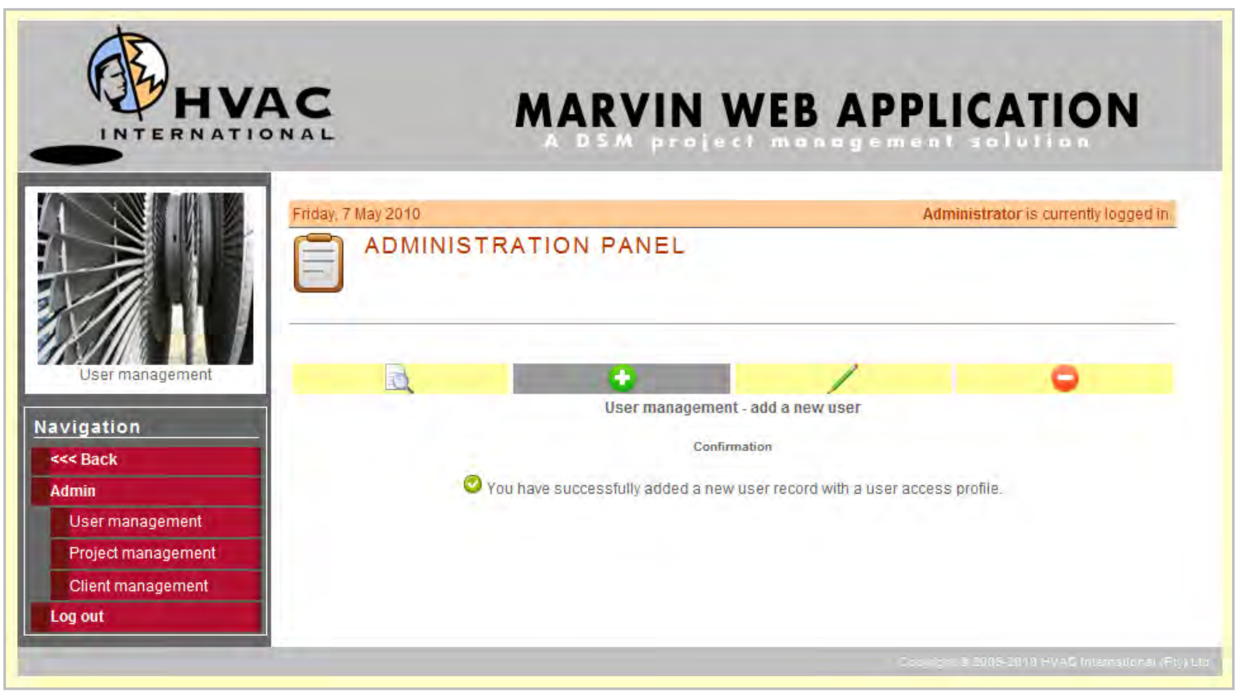


Figure 54 - Confirmation page

Scenario 10: Testing the addition of new user

- When a new user has been added, the new user must be able to login in the web application.
- The new user should only have access to projects defined in his access profile as shown in Figure 53.
- The new user is logged into web application with its user name and password as defined in Figure 51.
- The user is directed to the Amandelbult mine homepage with access available to only the 2 projects as shown in Figure 55.

Figure 55 - Testing a new user's access

3.6 Maintaining the web application

Marvin processes the input log files received from the various projects sites and produces a daily Excel CSV output file for each project. Each output file contains the daily performance results of the specific project. A data integration module converts the Marvin-produced CSV files into a singular batch SQL-file for each project. This SQL-file contains the daily performance results of the project in SQL-format. Each SQL-file is imported into a local database situated at the HVACI head office. The local database will be an exact copy of the remote web database and also serve as an additional backup database. The integration module will also produce the necessary graphical images of each project's daily electricity usage profile. After verification has been completed by the web administrator, the data and graphic images can be imported directly from local database to the web database.

The maintenance of the web application can be summarised as follows:

1. Ensure the successful conversion of Marvin data and import the converted data into the local web database through the execution of the data integration module.
2. Import local data and graphical profile images to the remote data base for each project.
3. Execute daily maintenance of the web application and ensure the synchronisation of data between the local database and the remote database.

3.7 Conclusion

The web application has been successfully implemented and uploaded to a production web-server. This web application is available at: www.osims.co.za. A designated web administrator has been trained in the maintenance of the web-application and a user created for each user group profile. Stakeholders have signed off the project as successfully completed according to the requirements specifications in Table 6 of Chapter 2.

Chapter 4: Case studies - applying the information management solution

Source: Eskom Annual Report 2009

4.1 Introduction

The web application described in Chapter 3 will not operate in isolation, but will form part of an integrated information management solution to address the sustainability of DSM projects. The web application is therefore not a solution on its own, but it enhances and extends the existing information management approach followed by HVACI.

In this chapter, four case studies are presented. The first three case studies present a quantitative analysis of the results of this study. The last case study presents the results of a user survey that was conducted to make a qualitative assessment of the implemented web application.

4.2 Case study 1: Amandelbult 2# compressor manager project

The selected case date chosen was Tuesday, 15 December 2009.

1. Building a simulation model

Project engineers build a simulation model of the DSM project using the REMS simulation interface as shown Figure 21. Data collection points are set that determine where data will be logged and then recorded into log files. These log files are then distributed to the Marvin system situated at the HVACI head office via the Hermes system as described in Section 2.4.

2. Establishing a baseline

Each project has an M & V verified baseline that establishes the electricity usage profile prior to the DSM Intervention. The verified baseline profiles (weekdays, Saturdays and Sundays) that have been established for this project are shown in Figure 56.

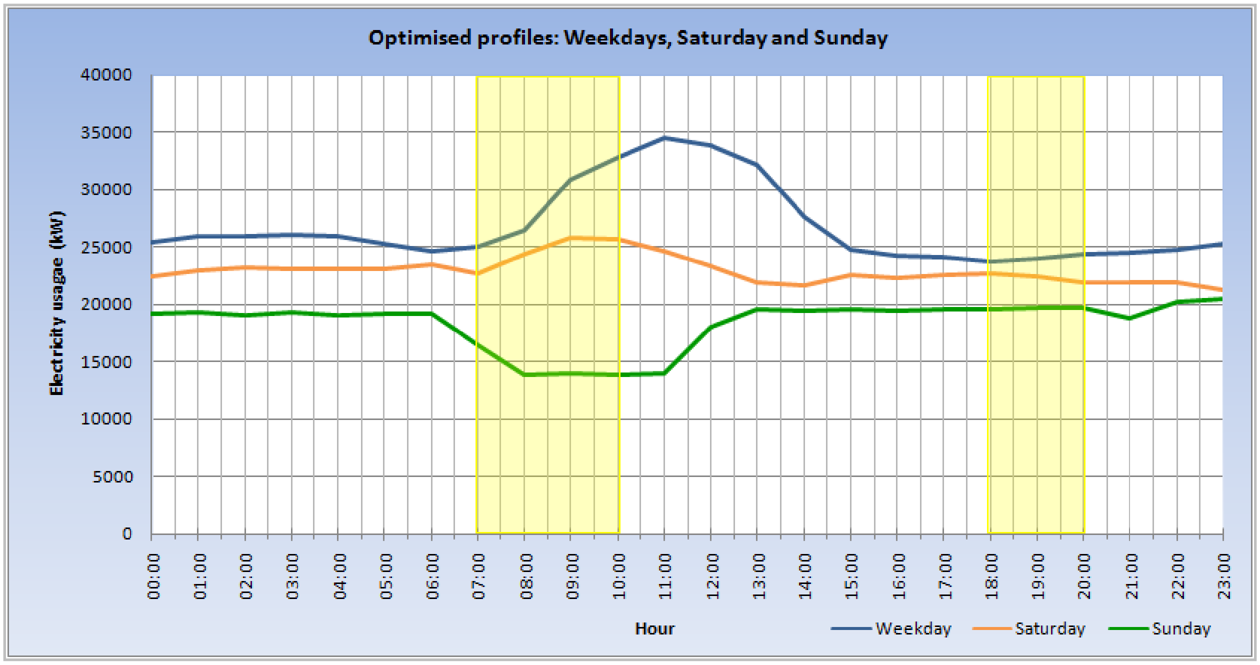


Figure 56 - Optimised profiles for the Amandelbult compressor manager project

3. Establishing an average pressure baseline

An optimised pressure profile is also established prior to the implementation process. The average optimised profile is shown in Figure 57.

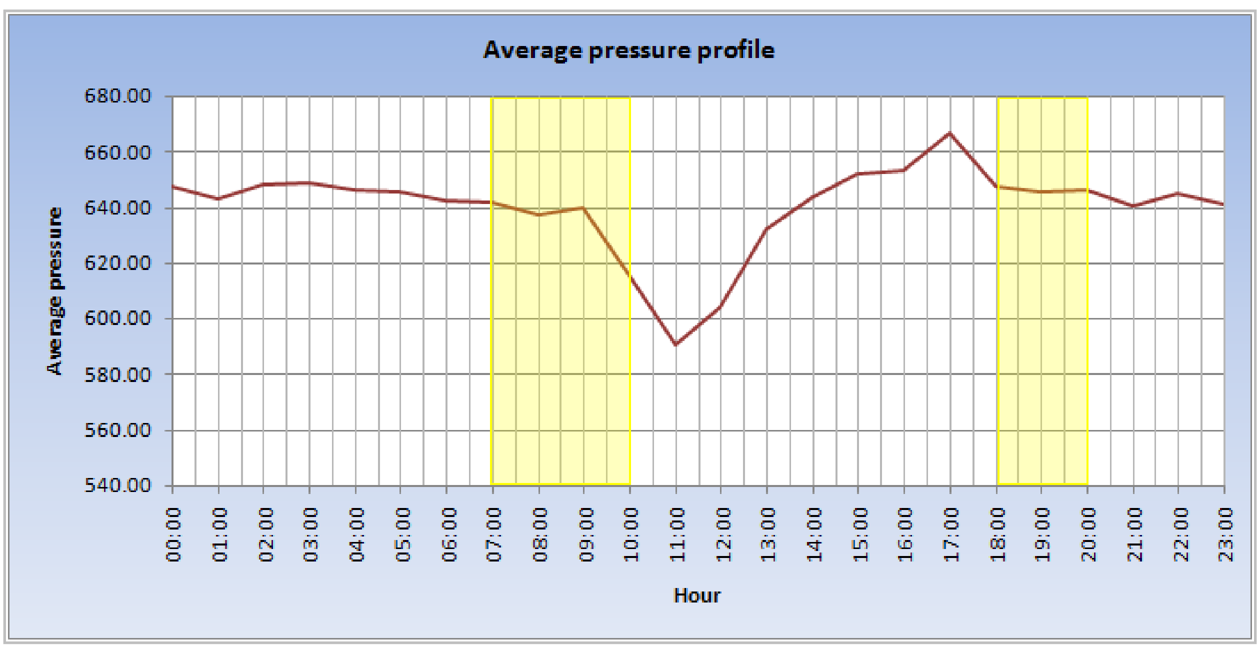


Figure 57 - Average daily pressure profile

4. Establish a proposed optimised profile

The proposed optimised profile is a function of the day of the week. The proposed baseline is therefore calculated on a weekday profile as shown in Figure 58, because 15 December 2009 is a weekday.

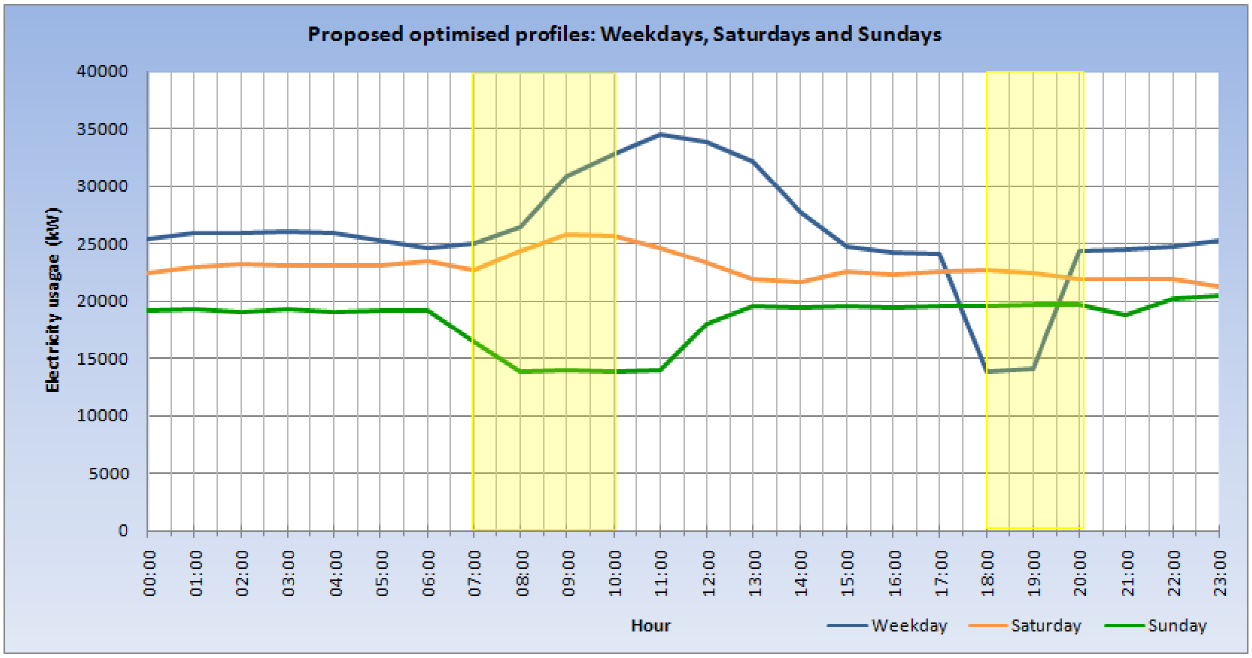


Figure 58 - Proposed optimised profiles (Weekdays, Saturdays and Sundays)

In this specific project, the project engineers, together with the client agreed on a contractual evening electricity saving of 9.90 MW. Hence the energy reduction between 18:00 and 20:00 is reduced by 9900 kW.

5. Input processing

The status and operational parameters of each compressor are logged at predetermined data collection points every two minutes and the results are recorded into log files. These log files are e-mailed via the Hermes system to the Marvin system located at the HVACI head office. Marvin will then automatically detect the log files in the incoming folder for the Amandelbult compressor project. The relevant log file will then be extracted and processed by the Marvin compressor module. A snapshot of the log file used in this case study is shown in Figure 87 (Appendix A).

Processing of log files

Marvin will identify the incoming log file as a compressor project and the compressor module will process this log file. The main processing steps are outlined in the next sections.

(i) Calculate the running status profile of each compressor

Marvin will automatically calculate the average 24-hour running status profile of each compressor as well as the average hourly running status profile of each compressor.

(ii) Calculate the data availability

The availability status of a compressor is logged as a ‘1’ when the compressor is in an operational mode and data has been logged. A ‘0’ is logged if the compressor is unavailable to carry any load, for example, due to faults, maintenance or some other malfunction. In this case a 100% data loss will result. A status logged in the log file as a ‘1’ indicates that no data loss occurred. Marvin calculates an average 24-hour availability status profile of all the compressors.

(iii) Determine the kWh costs

Eskom has different electricity cost structures depending on the day of week, time of the day, industry type and public holidays. The electricity cost profile is automatically extracted from an electricity cost database that reflects Eskom’s latest electricity costs. The electricity cost profile for the case date is shown in Figure 59.

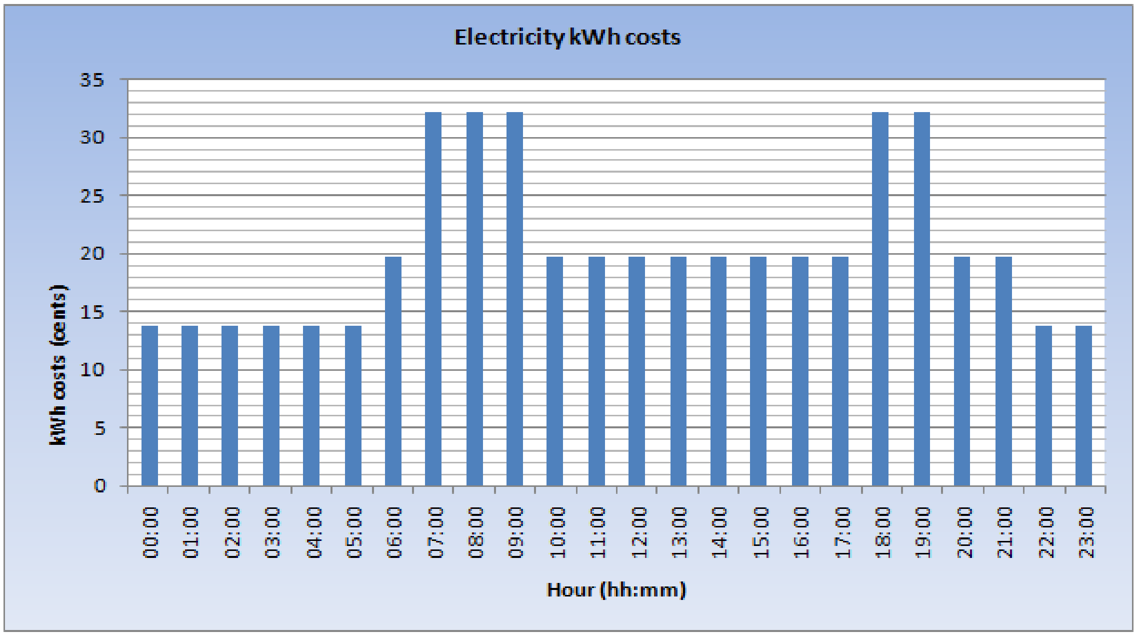


Figure 59 - Electricity cost profile

(iv) Calculate the actual electricity profile

The electricity usage of each compressor is logged every 2 minutes. Marvin extracts this information from the log file and calculates the average 24-hour actual electricity profile of each compressor as shown in Figure 60.

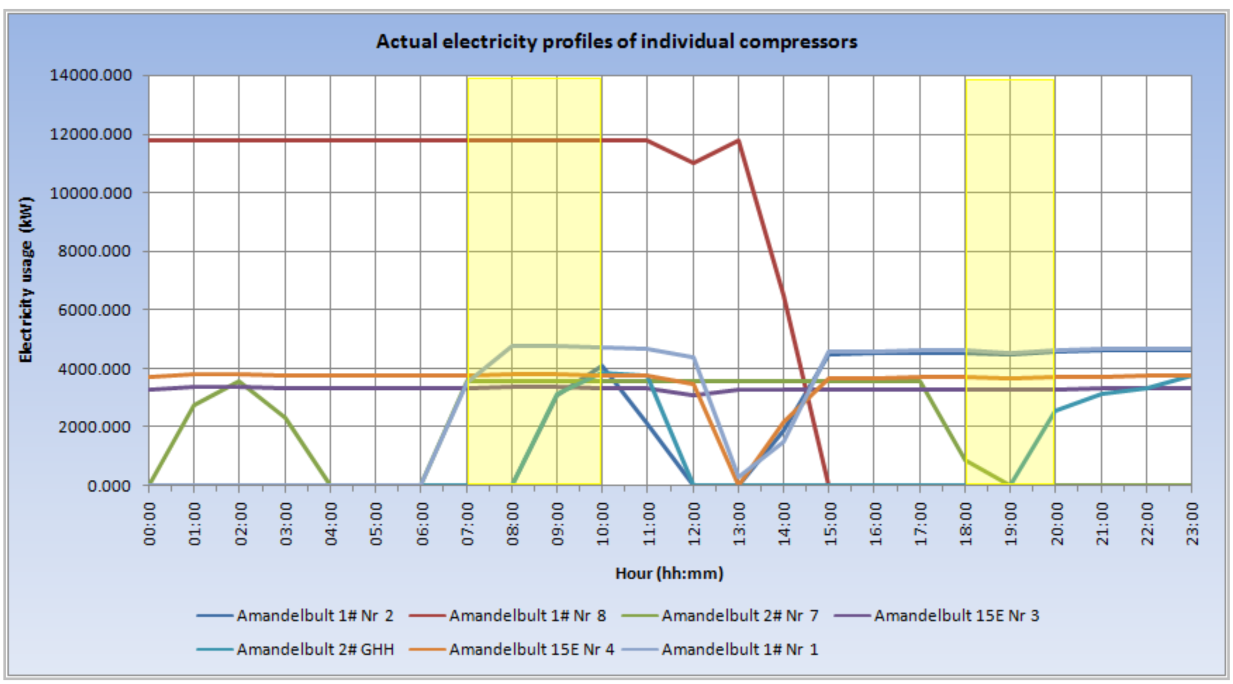


Figure 60 - Actual electricity profiles of individual compressors

6. Calculating the output

(i) Calculating the daily electricity usage profile

The total hourly electricity usage of all the compressors is calculated by summation of the hourly electricity usage for each compressor as expressed in Equation 1.

$$Total\ Actual\ \ kW[h] = \sum_{1}^{7} Actual\ \ kW\ per\ compressor\ [h] \qquad [1]$$

$$where\ \ h = hour$$

The electricity usage profile of all compressors is shown in Figure 61.

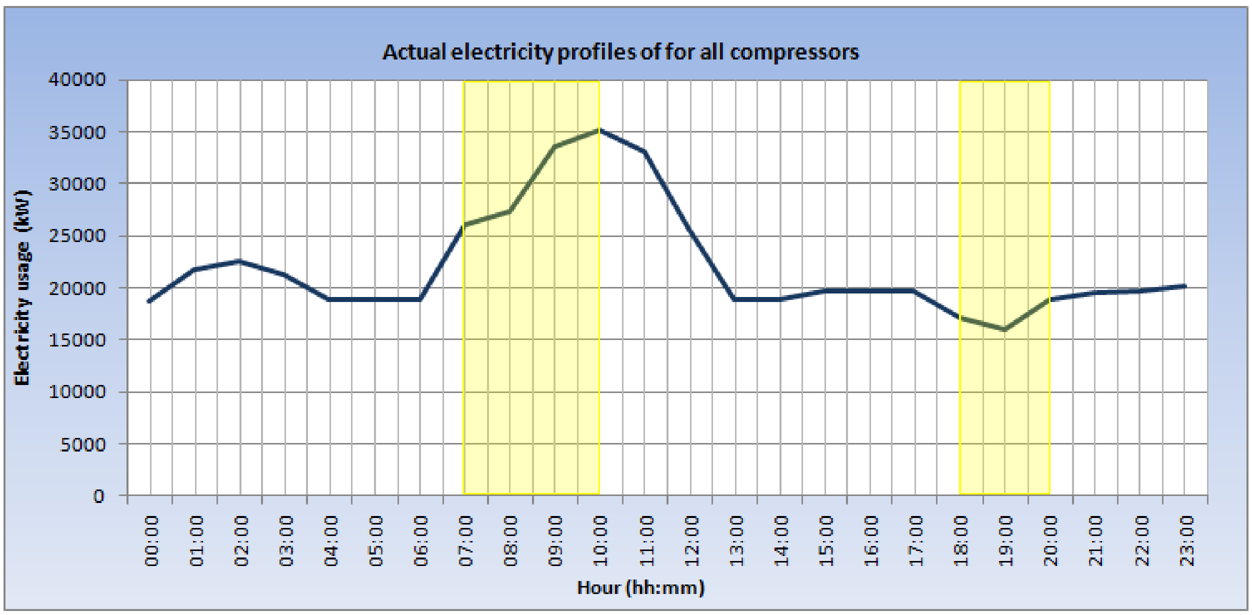


Figure 61 - Actual electricity profiles across all compressors

(ii) Calculate the scaled baseline

a. *Determination of a scaling factor*

A scaling factor, as shown in Equation 2, is calculated by dividing the average hourly total kW usage from hour 9 to hour 11 by the average hourly baseline value from hour 9 to hour 11.

$$Scaling\ \ factor = \frac{\sum_{h=9}^{h=11} Total\ \ Actual\ \ kW[h]}{\sum_{h=9}^{11} Baseline\ [h]} \qquad [2]$$

$$where\ h = hour$$

The scaling factor is used to account for changes in the working environment, such as changes in production levels.

b. *Determination of the scaled baseline profile*

The scaled baseline value, as shown in Equation 3, is calculated as the baseline value as a function of the **day (d)** and **hour (h)** multiplied by the scaling factor value as expressed in Equation 2. The scaled baseline profile is shown in Figure 62.

$$Scaled\ \ baseline\ \ [d,h]\ = Baseline\ \ [d\ ,h]\ \times Scaling\ \ factor \qquad [3]$$

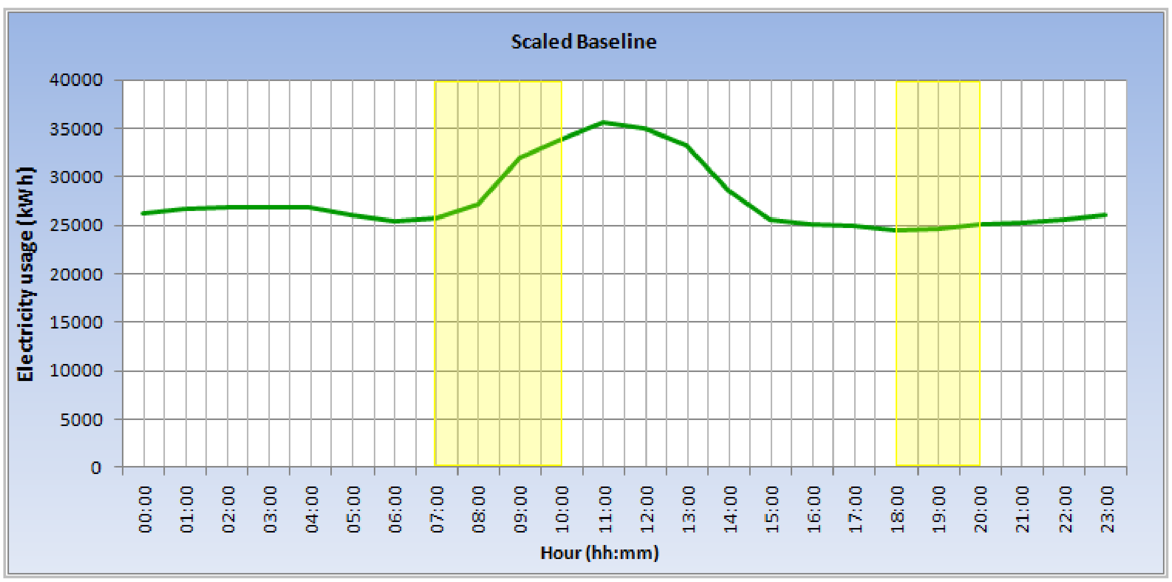


Figure 62 - Scaled baseline

(iii) Determination of the daily R-c savings profile

The daily electricity savings profile is calculated using two scenarios. One is based on the scaled baseline and the other based on the unscaled baseline. Only the scaled baseline procedure will be shown, because the calculations for the unscaled baseline scenario are similar. In Equations [4] to [11] all equation operands are a function of the **hour (h)** of the day.

Calculating the scaled R-c savings

a. *Determining the scaled load shift*

$$Scaled\ \ loadshift\ \ [h] = Scaled\ \ baseline\ \ [h] - Total\ \ Actual\ \ kW\,[h]$$

[4]

b. *Determining the R-c savings*

$$Scaled\ \ Rc\ \ saving\ \ [h] = Sacled\ \ loadshift\ \ [h] \times Electricit\,y\ cost\,[h]$$ [5]

(iv) Determination of missed opportunities

The missed savings opportunities are calculated using two procedures also based on the scaled baseline and the other based on the unscaled baseline. Only the scaled baseline calculation is shown for same reason given in (iii).

Calculating the scaled missed opportunities

a. *Determining the scaled proposed profile*

$$Scaled\ \ proposed\ \ profile\,[h] = Unscaled\ \ proposed\ \ baseline\,[h]\ \times\ Scalings\ \ factor$$ [6]

b. *Determining proposed kW saving*

$$Scaled\ \ proposed\ \ loadshift\ \ [h] = Scaled\ baseline\ \ [h]\ -\ Scaled\ \ proposed\ profile\ \ [h]$$ [7]

c. Determining the scaled proposed R-c saving

$$Scaled\ \ proposed\ R\text{–}c\ saving\ \ [h] = Scaled\ \ \ proposed\ \ loadshift\ \ [h]\ \times \left(\frac{Electricity\ cost\ \ [h]}{100} \right) \quad [8]$$

(v) Calculating the summarised performance results

Only the calculations based on the unscaled example will be shown.

a. Calculate the unscaled morning load shift

$$Morning\ unscaled\ loadshift = \frac{\sum_{h=7}^{h=9} Unscaled\ \ loadshift\ \ [h]}{3000} \quad [9]$$

b. Calculate the unscaled evening load shift

$$Evening\ unscaled\ loadshift\ = \frac{\sum_{h=18}^{h=19} Unscaled\ \ loadshift\ \ [h]}{2000} \quad [10]$$

c. Calculate the unscaled proposed evening load shift

$$Unscaled\ \ proposed\ \ evening\ \ loadshift\ = \frac{\sum_{h=18}^{h=19} Unscaled\ \ proposed\ \ evening\ \ loadshift\ \ [h]}{2000} \quad [11]$$

d. Calculate the unscaled missed evening MW saving

$$Unscaled\ \ missed\ \ evening\ \ MW\ saving\ = (Equation\ \ [10]) - (Equation\ \ [11]) \quad [12]$$

e. *Calculating the Rand-cent (Rc) savings*

i. *Calculate the scaled Rc-saving*

$$Scaled \quad Rc\text{–}saving = \sum_{h=0}^{h=23} Scaled \quad Rc \ saving\,[h] \qquad [13]$$

ii. *Calculate the scaled proposed Rc-saving*

$$Scaled \quad proposed \quad Rc\text{–}saving = \sum_{h=0}^{h=23} Scaled \ \ proposed \quad Rc - saving\,[h] \qquad [14]$$

iii. *Calculate the scaled missed Rc-saving*

$$Scaled \quad missed \quad evening \quad MW \ saving \ = (Equation \ \ [14] - Equation \ \ [13]) \qquad [15]$$

Output

Marvin uses the mathematical model presented in the previous section to calculate the performance results of each project. Processing is completed when a CSV-based output file is generated that contains the summarised performance results. A copy of the Marvin-generated CSV output file is shown in Figure 88 (Appendix A). A graphic output on the Marvin interface displays the 24-hour electricity usage profile and baseline for a particular date.

Marvin uses colour to communicate certain information to the user. As an example, a blue background indicates that the targeted MW saving was either achieved or exceeded for a particular date. An orange background indicates that at least 90% of the targeted MW saving has been achieved. A red background indicates that the targeted MW saving has not been achieved. A grey block is used to communicate periods where the REMS system was in a manual operational mode. A red block indicates a period where data loss was incurred. A yellow block indicates the peak-hour periods. Figure 63 shows the output for this case study on the Marvin interface.

Figure 63 - Marvin screen output for 15 December 2009

Web processing

This generated CSV file, of the processed Marvin results, is used as input source for the conversion of the processed Marvin results from CSV format to SQL format.

Conversion

An external conversion module converts the CSV-file to an SQL-file. The SQL-file is then uploaded to a local database. The generated SQL-file contains the required queries that will write the output results into the relevant database tables. In this scenario the data records will be written to the project database and tables specific to the Amandelbult compressor project.

The conversion process will also generate a profile image of the project performance for that particular date.

Verification and Uploading

The web administrator ensures that the data has been correctly recorded in the local database and that an image file has been generated by the conversion program. When verification has been confirmed, the administrator can upload the image file and import the database data from the local database to the remote database and web server via an FTP tool.

Testing

This step ensures that data has been uploaded to the correct remote database and tables and that the graphic image display correctly. The administrator logs into the web application as an Amandelbult mine user and clicks on the Amandelbult compressor project. The web application redirects to the Amandelbult compressor project page. The administrator selects, for example, 15 December 2009, as the view date and refreshes the web page. The project data page for 15 December 2009 is displayed as shown Figure 64 and Figure 65. After testing has been completed, all valid users will be able to gain access to project's performance results.

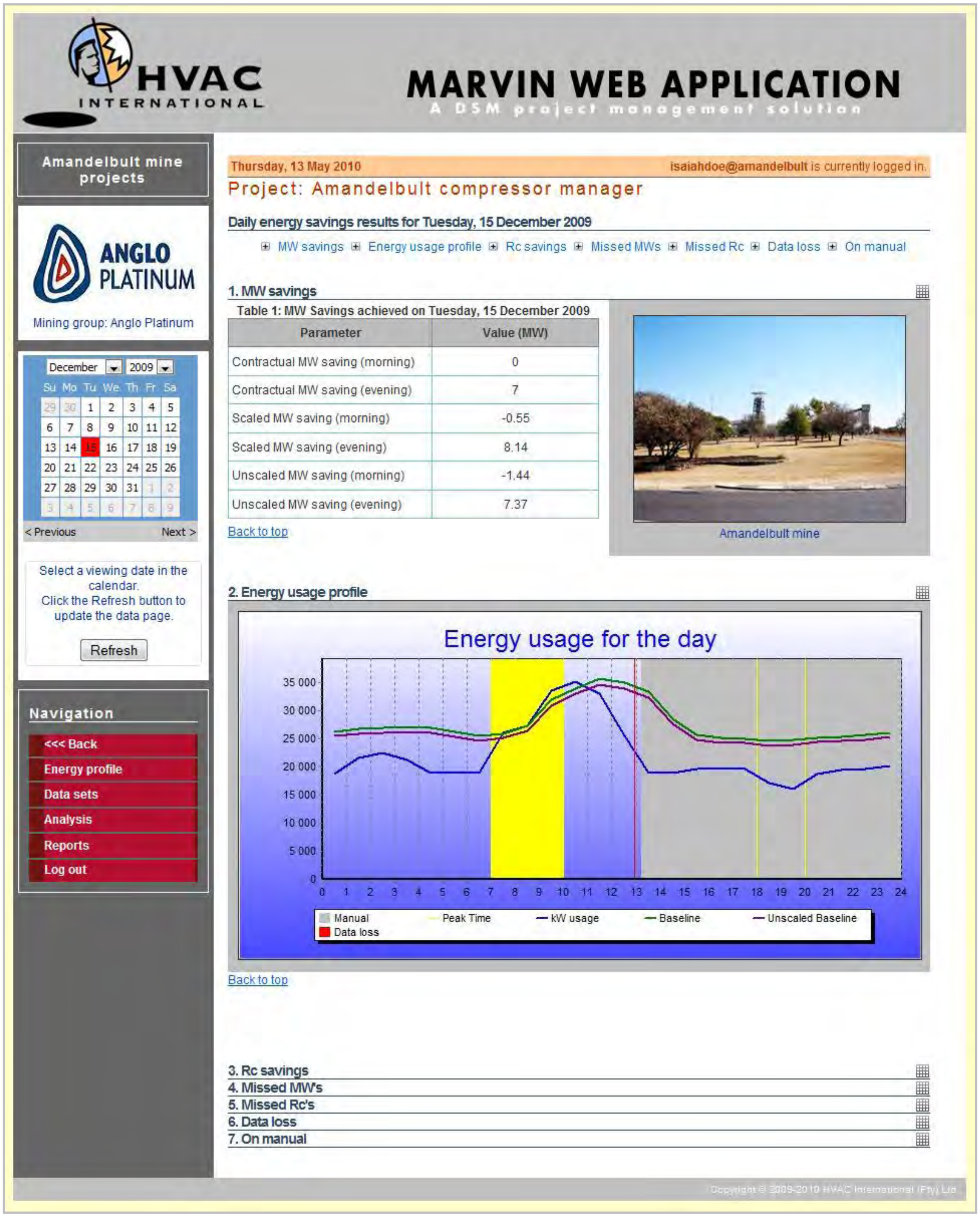


Figure 64 - Amandelbult compressor manager - 15 December 2009

3. Rc savings

Table 2: Rc Savings achieved on Tuesday, 15 December 2009

Parameter	Value (R)
Scaled Rc saving	25479
Unscaled Rc saving	21258
Scaled proposed Rc saving	6579

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4. Missed MW's

Table 3: Missed MW's on Tuesday, 15 December 2009

Parameter	Value (MW)
Scaled missed opportunity MW saving (morning)	0
Scaled missed opportunity MW saving (evening)	2.08
Unscaled missed opportunity MW saving (morning)	0
Unscaled missed opportunity MW saving (evening)	2.53

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5. Missed Rc's

Table 4: Missed Rc's on Tuesday, 15 December 2009

Parameter	Value (R)
Scaled missed opportunity Rc saving	0
Unscaled missed opportunity Rc saving	0

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6. Data loss

Table 5: Data loss periods on Tuesday, 15 December 2009

Start time	Stop time
12:00:00	12:00:00
12:56:00	12:56:59
11:59:00	11:59:59

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7. On manual

Table 6: System on manual periods on Tuesday, 15 December 2009

Start time	Stop time
01:12:59	11:59:00

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Figure 65 - Amandelbult compressor project page expanded

External M & V

HVACI provides M & V with project data on a monthly basis or on request. The data is then verified by M & V for correctness. M & V provides a data validation report to the ESCO. A case study presented in Section 4.4 will describe the M & V process in more detail.

4.3 Case study 2: South Deep fridge plant system

This case study examines an example of a DSM project that initially exceeded the contractual targeted MW savings, but then experienced a performance decline. However, through the application of the information management approach to this project, the project was able to recover from this setback and deliver the contractual MW savings. Frequent monitoring of the project and the provision of daily, weekly and monthly reports to the various stakeholders alerted project engineers to the problem. Early detection of the problem made it possible for project engineers to take the necessary corrective measures taken to ensure the sustainability of the project. A short description is provided of how the project performance was reinstated and made sustainable.

Figure 66 shows the historical performance analysis of the South Deep fridge plant system. The project initially exceeded its targeted MW savings between January 2009 and March 2009. However, by April 2009, the project's performance declined to below the contractual MW target.

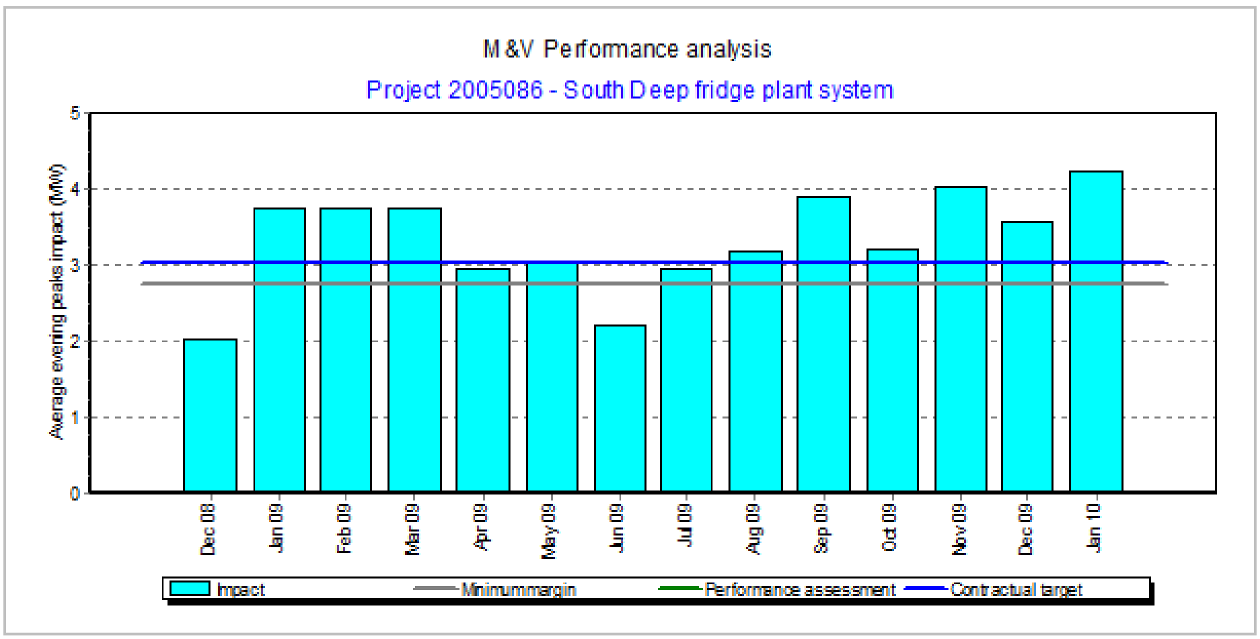

Figure 66 - Historic performance analysis for South Deep fridge plant system [51]

After the implementation of the corrective actions, the project began to show an improvement. By August 2009 the project exceeded the contractual MW savings.

Figure 66 shows that after August 2009 and up to January 2010 the MW savings exceeded the contractual target.

This case study emphasises the benefits of frequent monitoring of DSM project performance. The web-based application presented in Chapter 3 will further enhance the information feedback chain. Project engineers and other project stakeholders will be able to track the performance of projects on a daily basis as described in case study 1.

4.4 Case study 3: M & V data verification

The data of each DSM project must be verified for integrity and correctness by an independent Measurement and Verification (M&V) team. Daily data collected for each project by the ESCO is submitted to an M & V team on a monthly basis. M & V will conduct their own analysis on the data and verify the MW savings for the project as stated by the ESCO. The M & V team then submits a validation report to the ESCO, which is calculated on a monthly scale. This case study examines the comparison of the results from M & V with the results obtained from the ESCO in-house processing. Verification has been conducted for the Masimong #4 Pumps project for September 2009. Verification results from M & V matches very closely the results obtained from the ESCO internal calculation processes as shown in Table 13.

Table 13 - M & V and ESCO data verification [56, 57]

	M & V results	HVACI results
Intended impact	3.90	3.90
Actual impact	4.030	4.04
Financial impact	R52,512	R 54,719

4.5 Case study 4: Analysing user survey results

A user survey was conducted to make a qualitative assessment of the web application. Questionnaires were compiled and distributed among project engineers and managers of the ESCO. The questionnaire, composed of two sections, is given in Appendix C. Section 1 addresses the respondent's computer, Internet and cellphone usage. This section establishes how often the respondent accesses the Internet, either using a PC or cellphone and what type of cellphone is used. The summarised results of the Section 1 of the questionnaire are outlined in Table 14.

Table 14 - General IT and cellphone skills responses

Section 1: Respondent's general IT and cell phone skills								
	Web usage			Cellphone usage			Cellphone type	
	Monthly	Weekly	Daily	Monthly	Weekly	Daily	Lower end	Higher end
Respondent 1			1			1		1
Respondent 2			1			1		1
Respondent 3			1			1		1
Respondent 4			1		1			1
Respondent 5			1	1				1
Respondent 6			1			1		1
Respondent 7			1	1				1
Respondent 8			1	1				1
Total	0	0	8	3	1	4	0	8

Analysis of Section 1: PC and cellphone skills

- All respondents access the web on a daily basis and use advanced technology cellphones.
- Individual respondent cellphone usage to access the Internet is as follows: 57.14% access the Internet via mobile on a daily basis, 14.29% on a weekly basis and 28.57% on a monthly basis.

Analysis of Section 2: Rating of the web application

Respondents were requested to evaluate each statement according to a rating scale that ranged from total disagreement to total agreement. The summarised results of all returned questionnaires are outlined in Table 15.

Table 15 - Results of questionnaire responses

	Respondent's assessment of each question (%)						
	Question numbers						
	1	2	3	4	5	6	7
Respondent 1	82.61	69.57	91.30	83.70	70.65	90.21	84.78
Respondent 2	78.26	96.74	64.13	63.04	84.78	84.78	61.96
Respondent 3	94.57	93.48	100.00	100.00	92.39	96.74	94.57
Respondent 4	80.43	100.00	100.00	98.91	66.30	100.00	85.87
Respondent 5	74.13	70.65	91.30	76.09	58.70	92.39	82.61
Respondent 6	96.74	95.65	93.48	79.35	82.61	95.65	94.57
Respondent 7	76.09	75.00	80.43	100.00	77.17	100.00	93.48
Respondent 8	70.65	71.74	70.65	81.52	100.00	100.00	100.00
Respondent 9	82.61	76.09	82.61	80.43	50.00	40.21	75.00
Average	**81.79**	**83.21**	**85.99**	**84.78**	**75.84**	**88.88**	**85.87**
Score	**83.77**						

Analysis of user survey results

Statement 1: The Marvin Web Application is easy to use

- Respondents found the web application easy to use given the high average rating.

Statement 2: The layout of web-application is well-organised and clear

- Respondents were in favour of the structure of the web. This is to be expected because the design is based on the structure of the Marvin application that is frequently used by respondents.

Statement 3: The language used is easy to understand

- Respondents found the language usage understandable given the high average rating.

Statement 4: The text size used in the web-application is easy to read

- Respondents found the textual presentation of the web application to be acceptable.

Statement 5: The web application contains the information that I need

- Respondents found the information that they were looking for. The high rating is to be expected as the web application was designed in collaboration with project engineers and managers.

Statement 7: This web application compares favourably to similar websites you have visited

- Respondents found the web application to be on a par with other web-based applications they have used.

Open question: How the web-application can be further improved?

Summarised comments and suggestions included:

- The web page should auto-refresh after the selection of a date
- The user must be able to resize the date selector window.
- Weekdays and weekends should be made identifiable in the date selector window.
- Use of dynamic generated charts was suggested.
- The rand-cent values in the tables should be comma-separated.

4.6 Conclusion

Case Study 1 presented the steps in the daily processing of log file data and the calculation of the performance parameters of a DSM project. This process is automatically executed by Marvin. Processed results are populated into the remote databases of the web application. The case study showed how information that was previously only accessible by the ESCO is now also available to other stakeholders of the DSM project.

Case Study 2 showed the inherent problem of performance deterioration of a DSM project. However, because reports were available to track the performance of the project, the problem could be detected and managed. After the problem had been eliminated, the results were also made available in written reports. In this manner, the sustainability of the project could be ensured.

Case Study 3 emphasised the importance of data verification. The verified M & V performance results of the DSM project are compared against the calculated results of the ESCO. The results obtained by the ESCO correlates very closely to those obtained by M & V.

In the last case study the results of a user survey conducted for the web application is presented. Results showed that the web application scored high ratings in the categories of functionality, design and content. This was expected as the development was made in collaboration with the respondents, who will become users of the web application.

Chapter 5: Conclusion

5.1 Summary of contributions

This dissertation contributed towards the understanding of the importance of sustainable DSM projects. It highlighted the economical, social and environmental impact of a sustainable DSM program. On the economical level, capital intensive investments can be deferred only if DSM projects remain sustainable in the long term. Viewed from the social front, electricity consumers benefit directly from reduced electricity costs if the DSM initiatives remain sustainable. Taking environmental issues into account, the reduction in the use of electricity reduces the emission of harmful greenhouse gasses into the atmosphere.

This dissertation also contributed towards the understanding of proper information management within the DSM project environment. It highlighted the value of frequent project monitoring and information feedback to stakeholders. Problems that are detected early can be managed and resolved. Project information is shared with stakeholders and this availability and easy access to information makes it possible to detect and respond to problems as soon as they become evident.

Furthermore, this dissertation also contributes towards the development and implementation of a web application to enhance further access to information of DSM projects. Information that was previously only accessible to the ESCO is now directly accessible to other stakeholders. Project stakeholders can access the status of a project from any location with Internet access. The web application will assist in the enhancement of information management and therefore promote the sustainability of DSM projects.

5.2 Recommendations for further study

It is recommended that the development of the web application be continued. Additional content should be presented that is not presently available on the web application. These include:

- Pressure and flow graphs for compressors
- Dam levels for pumps.
- A simulation tool for project engineers

- Query tools for mine users
- Downloadable data in various formats, based on future users' requirements.

It is also recommended that a further study be made on the use of the cellphones for communicating important DSM performance results to stakeholders. A mobile web application site that presents only limited content can be developed to facilitate easier web browsing from a mobile device.

It is also recommended that the study be expanded to include the data of other ESCOs. This can be valuable for data format standardisation.

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Appendix A: General

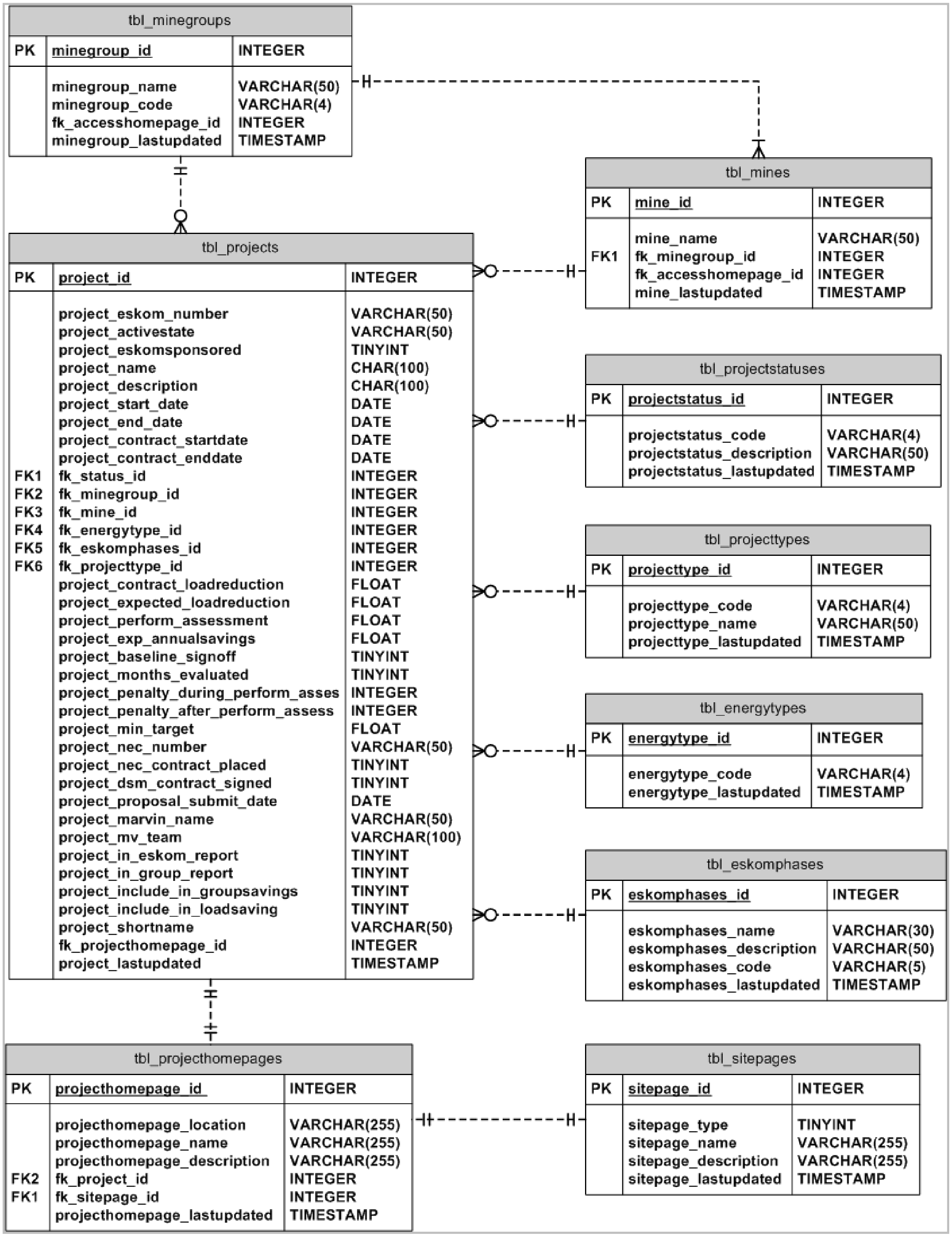

Figure 67 - ERD for Projects and its related entities

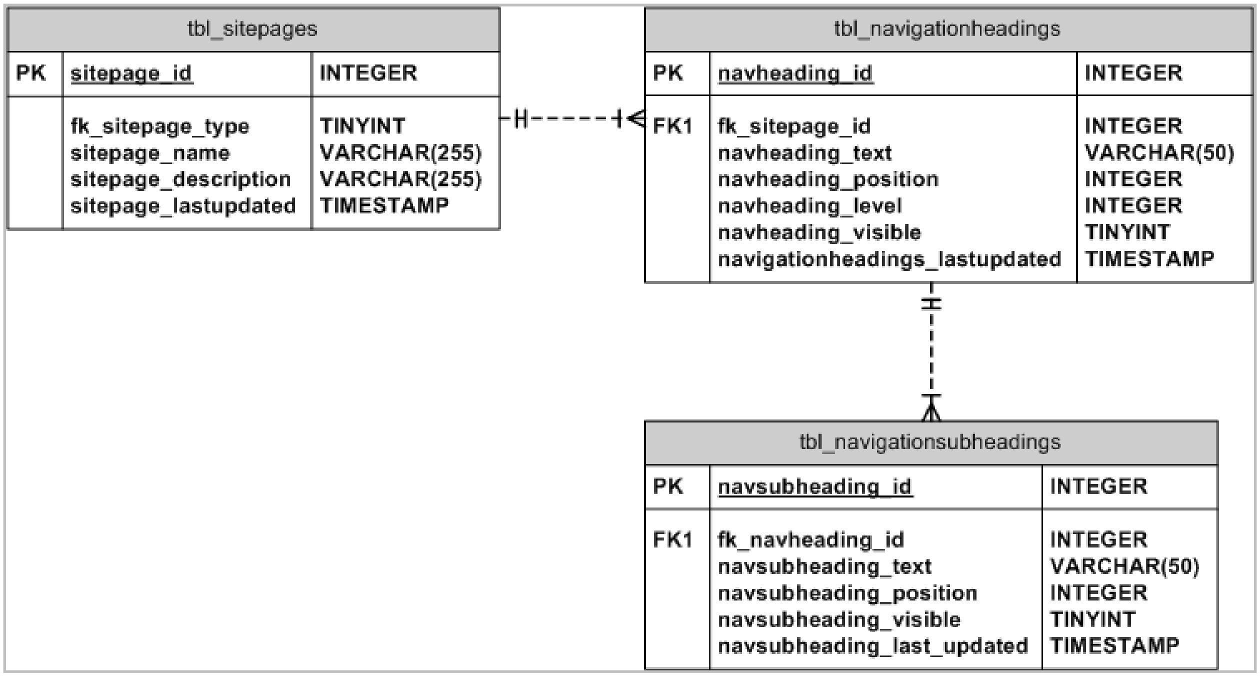

Figure 68 - ERD for Site pages and its related entities

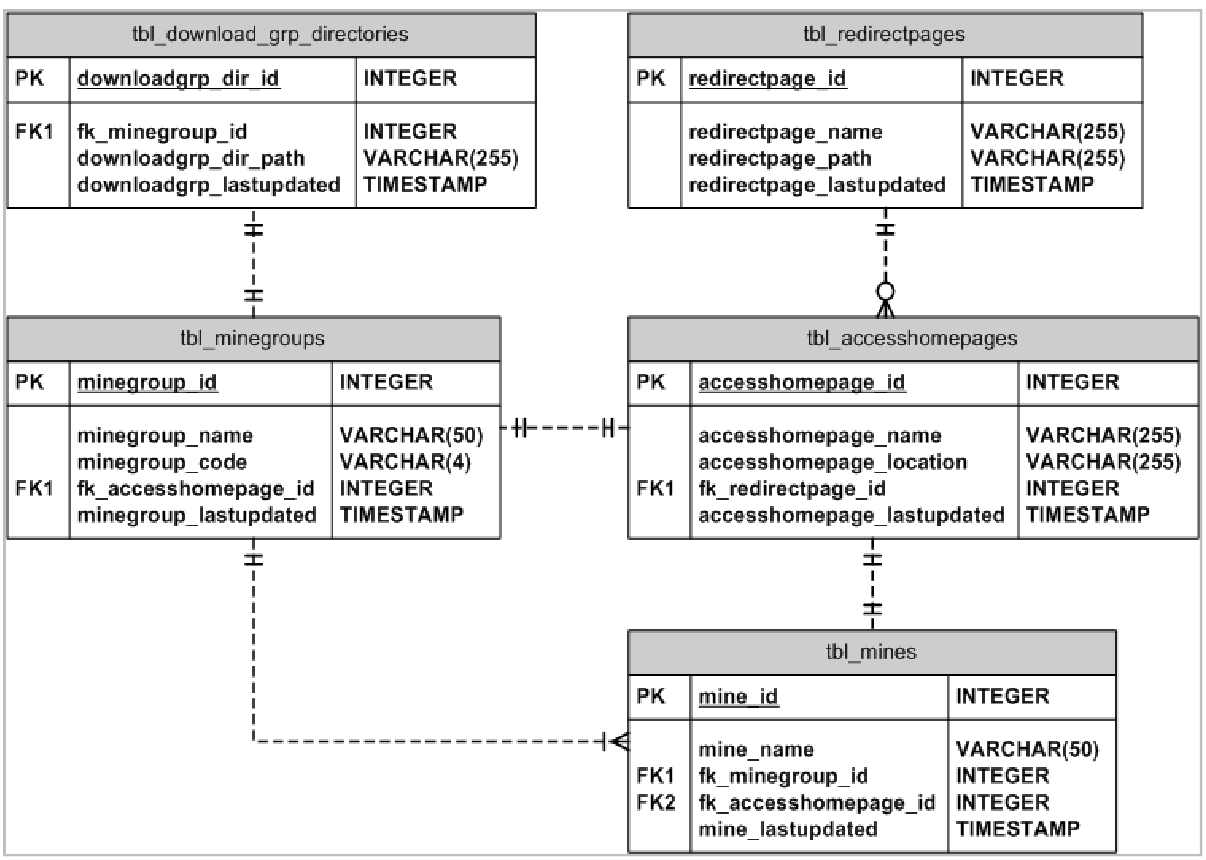

Figure 69 - ERD for Access homepages and its related entities

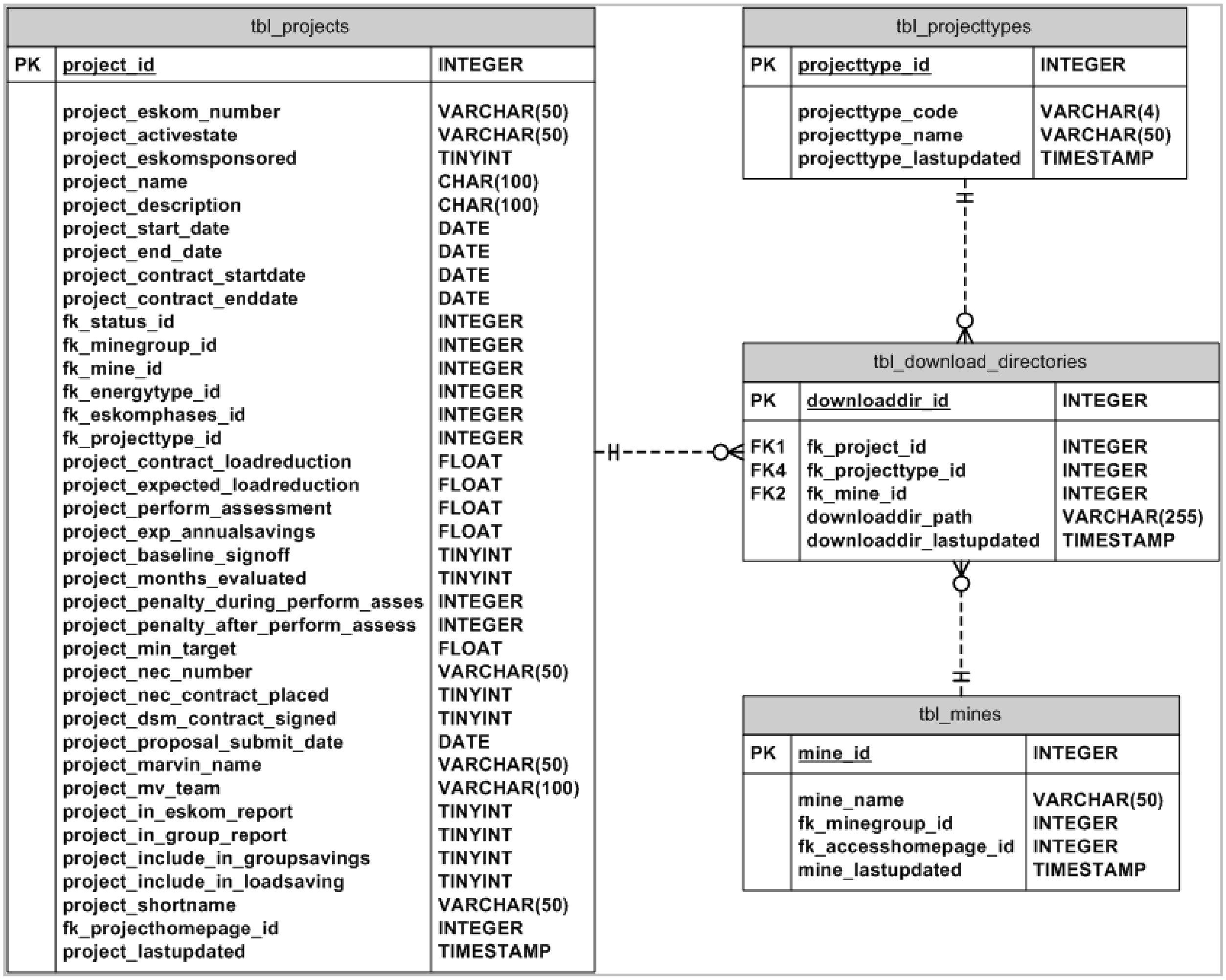

Figure 70 - ERD for Download directory pages and its related entities

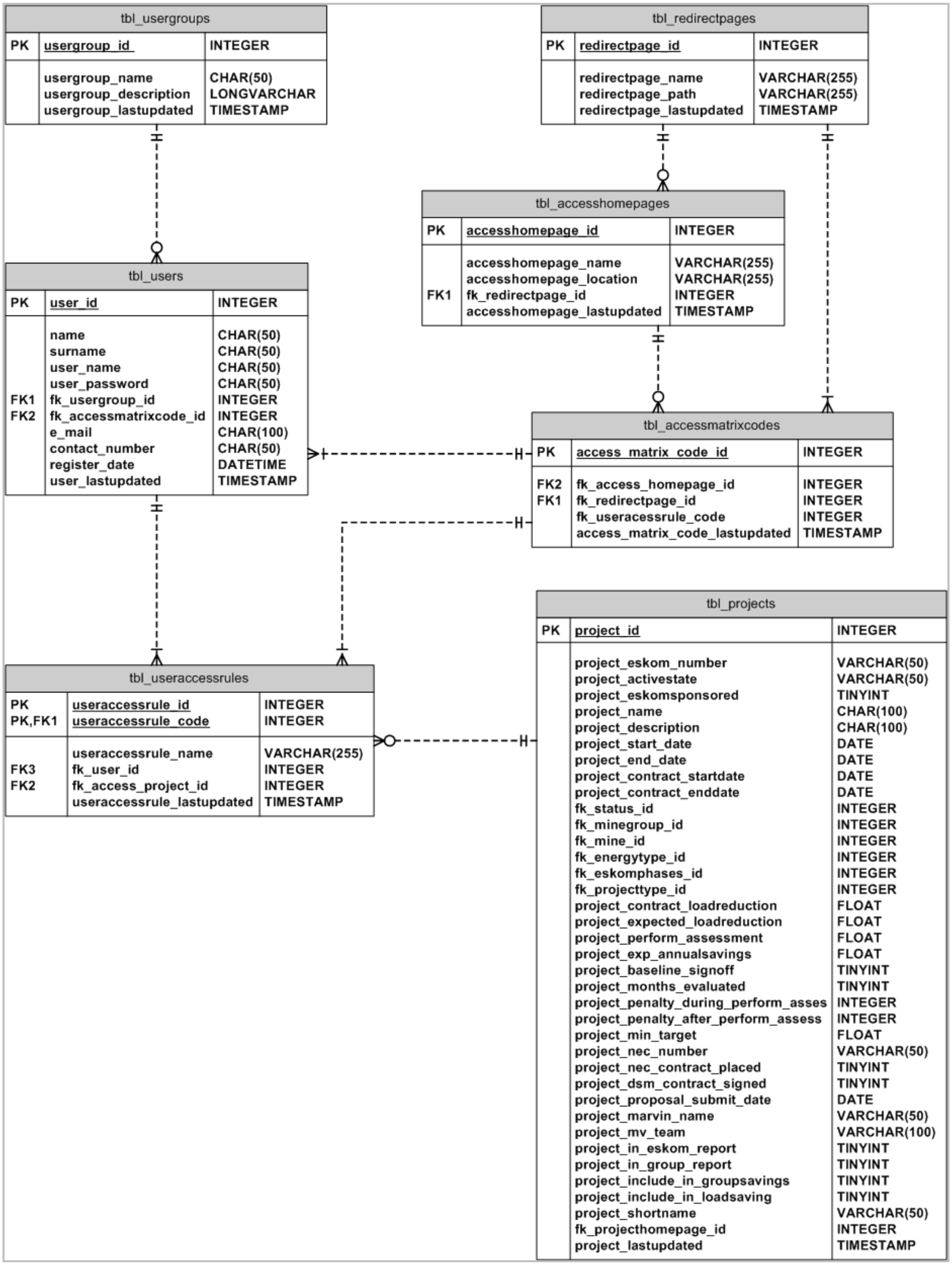

Figure 71 - ERD for Users and its related entities

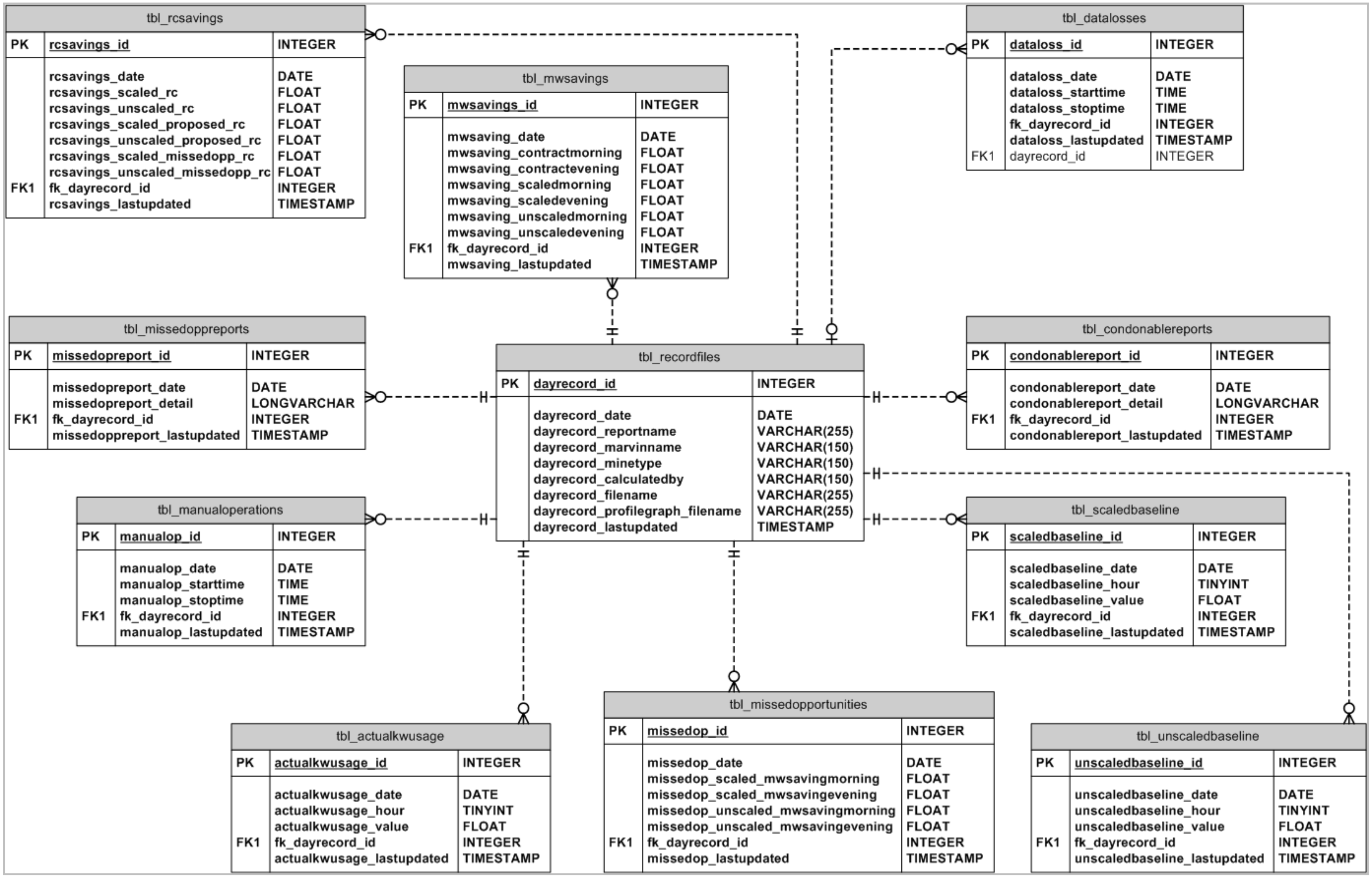

Figure 72 - ERD for a Record file and its related entities

Process: access control

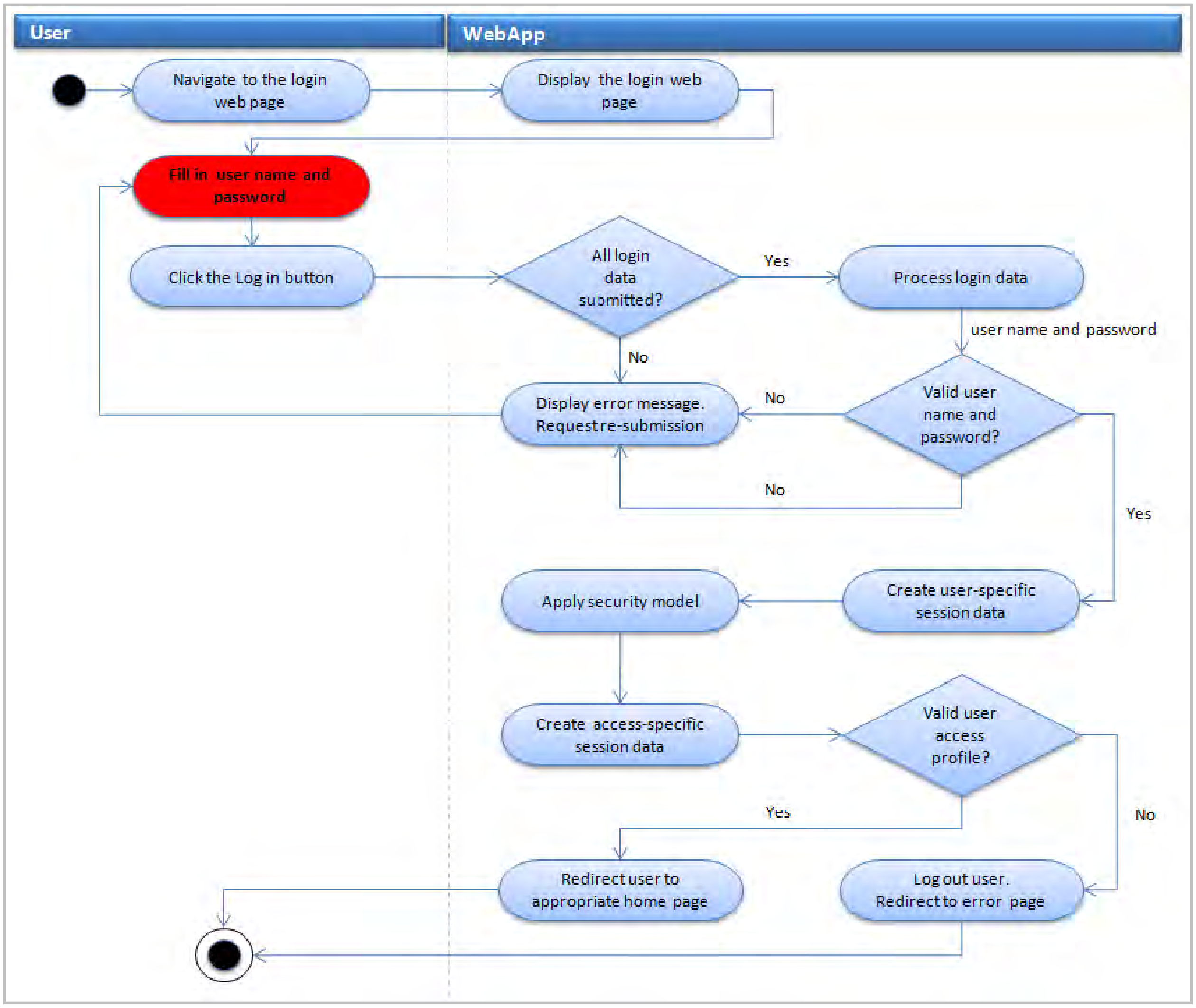

Figure 73 - Activity diagram for the access control process

Process: adding a new user

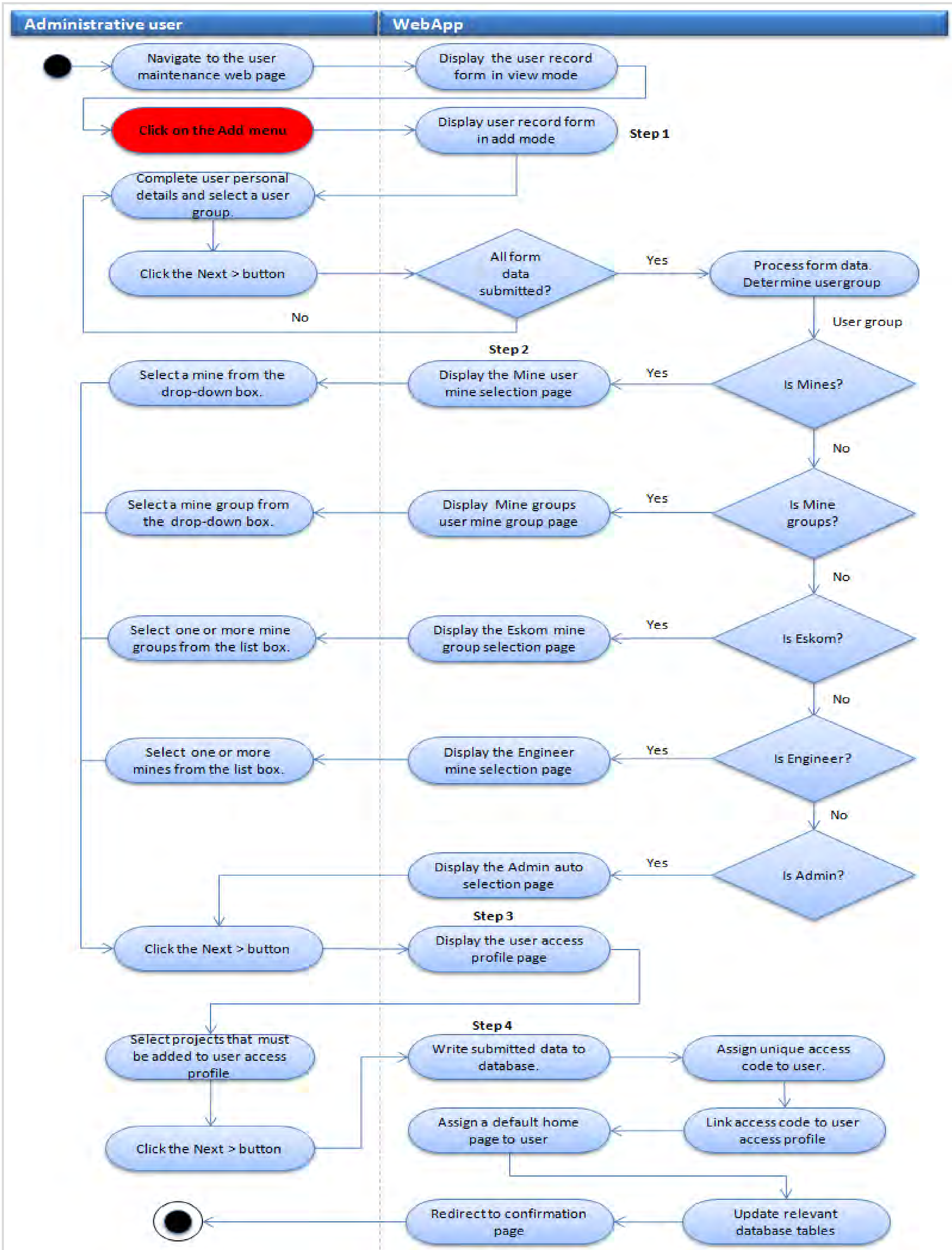

Figure 74 - Activity diagram for adding a new user with access profile

Process: updating an existing user's details and access profile

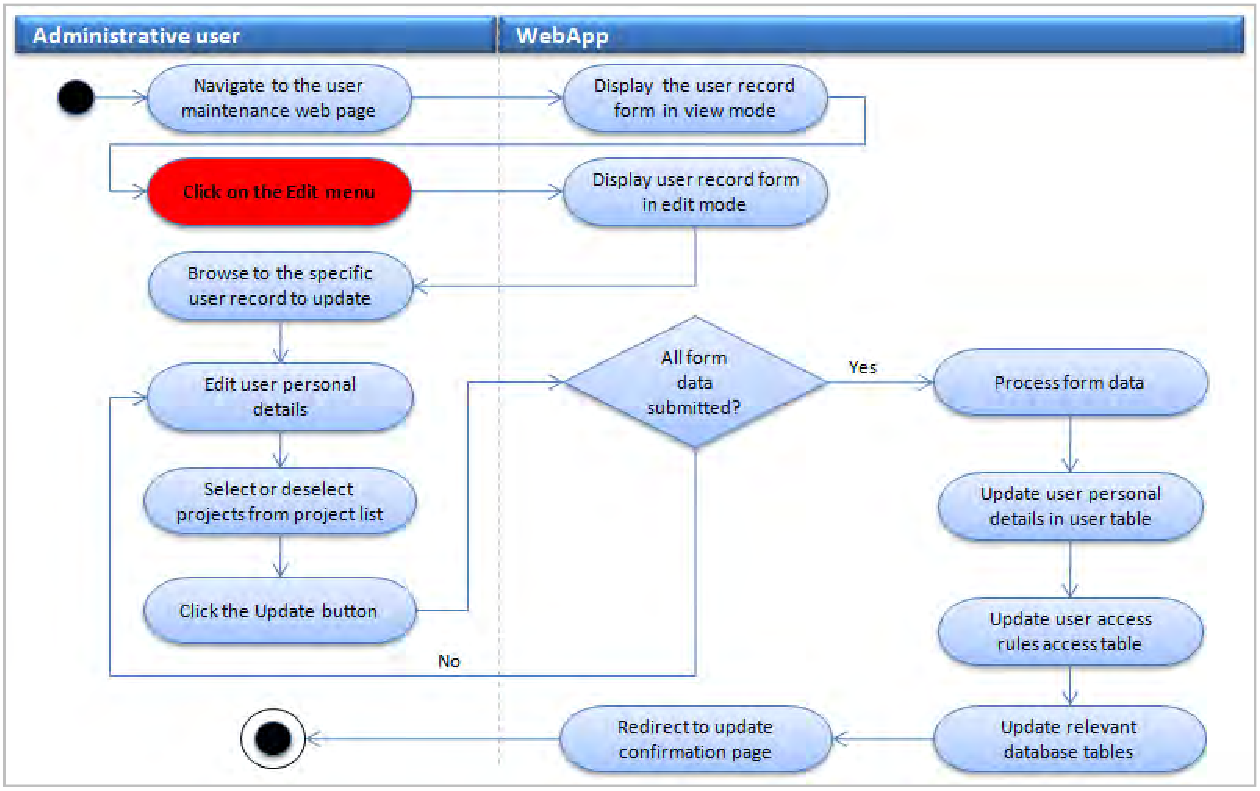

Figure 75 - Activity diagram for updating a user's details and access profile

Process: viewing an existing user's details

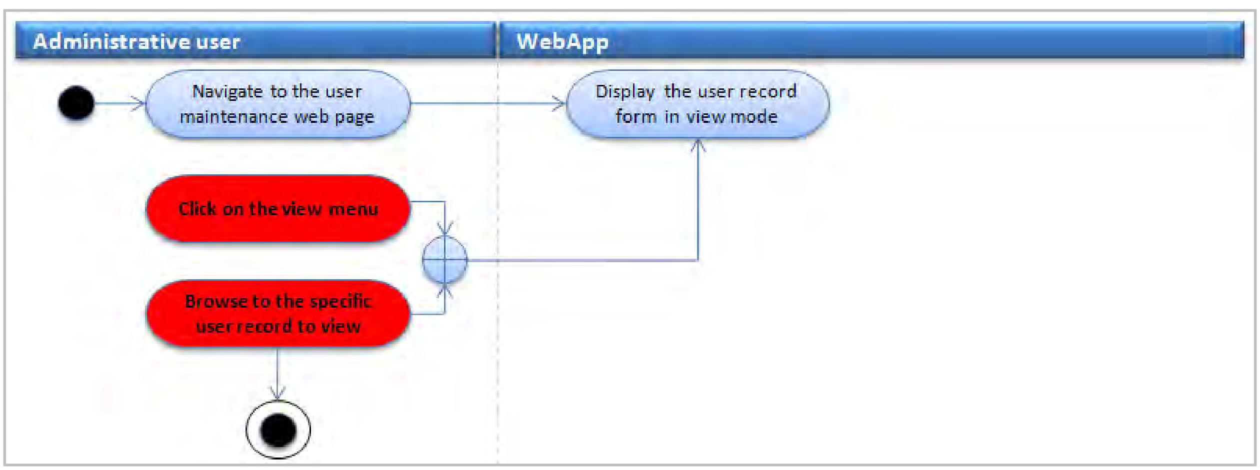

Figure 76 - Activity diagram to view user details

Process: deleting a user

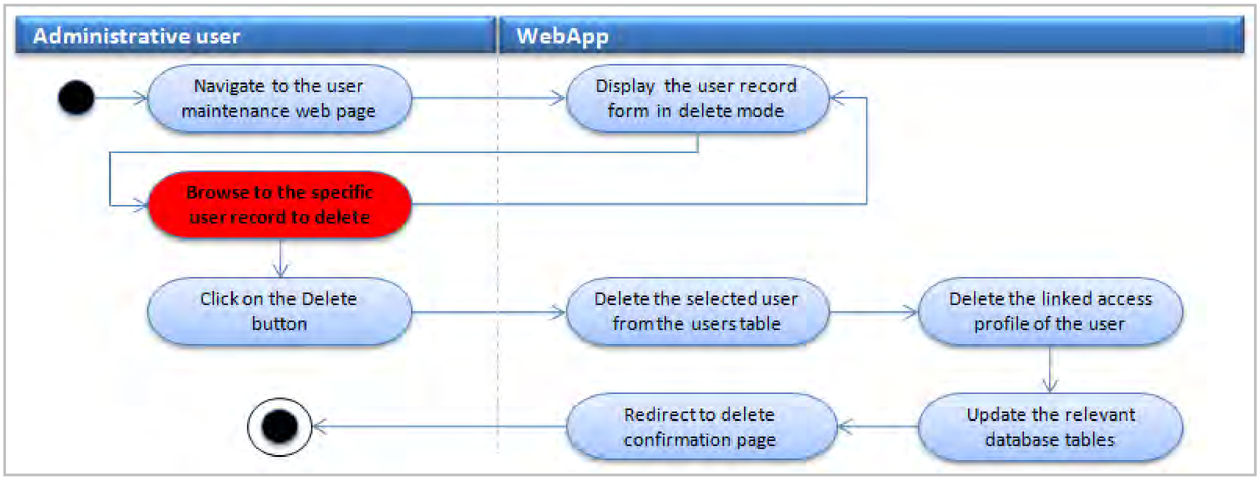

Figure 77 - Activity diagram for deleting a user

Process: security model

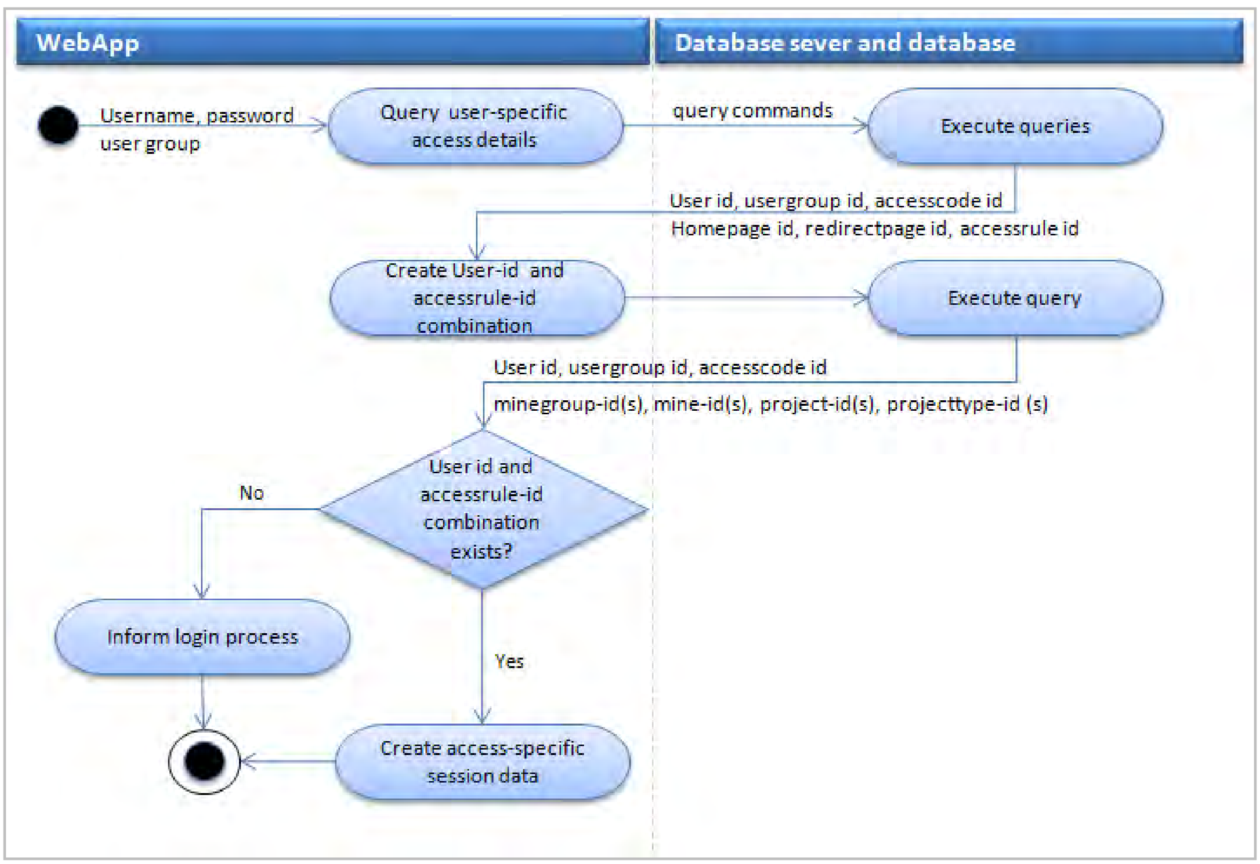

Figure 78 - Activity diagram for the security model process

Process: adding a project

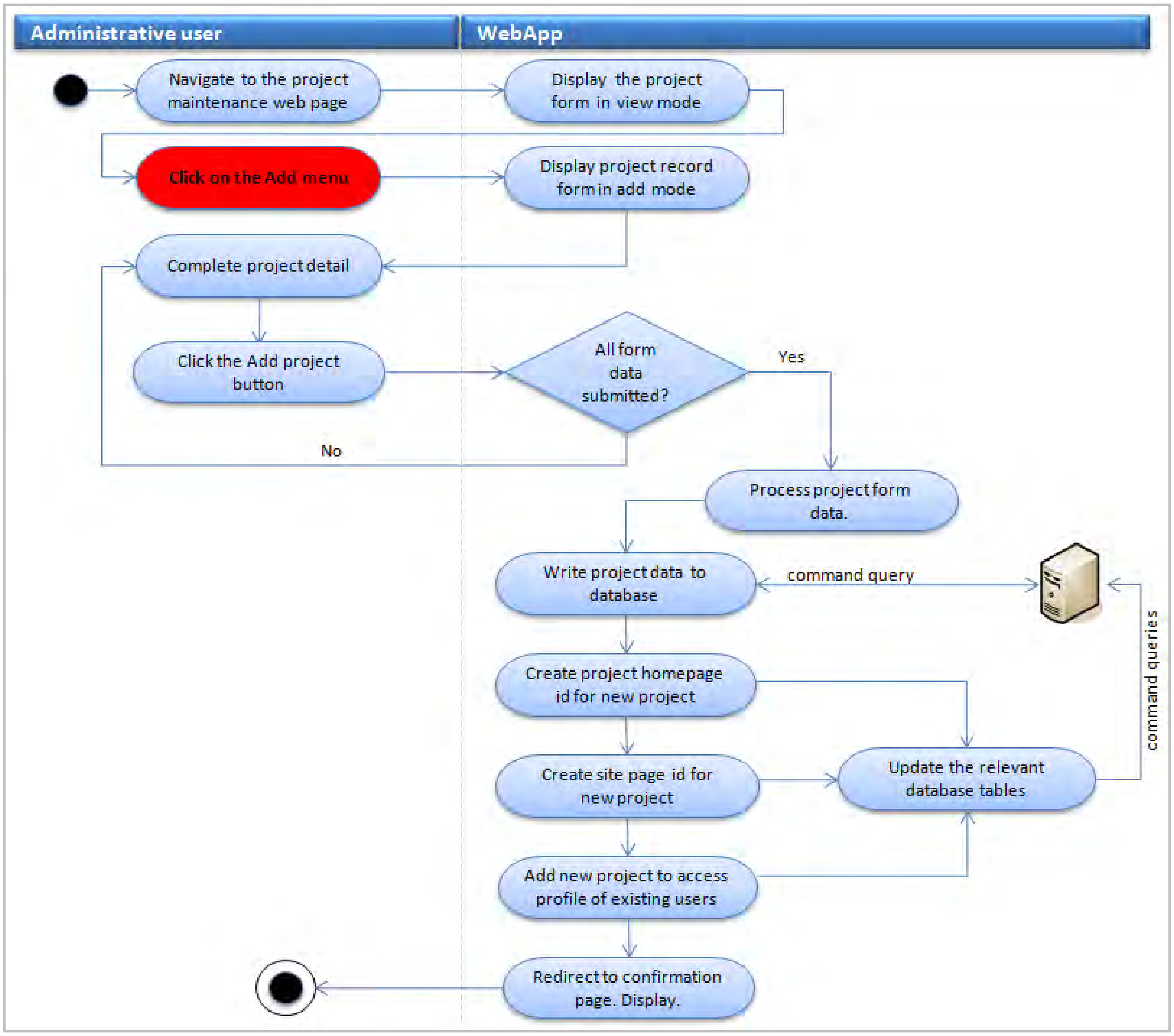

Figure 79 - Activity diagram for adding a new project

Process: updating a project

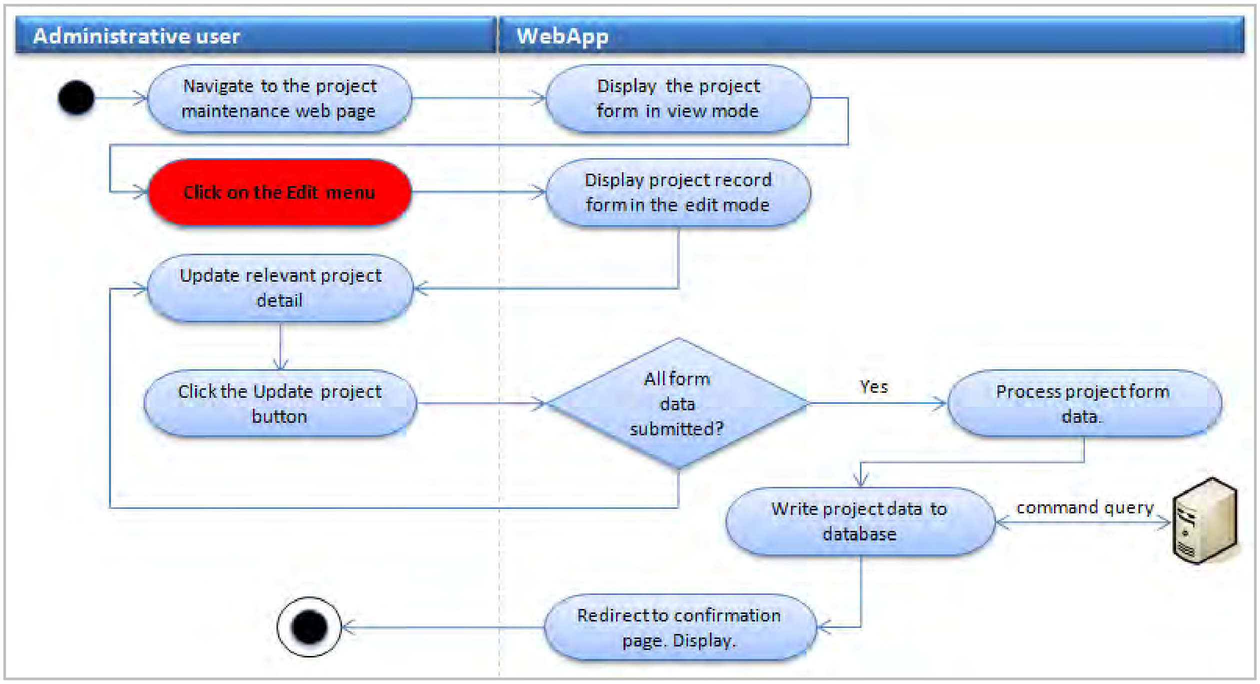

Figure 80 - Activity diagram for updating a project

Process: deleting a project

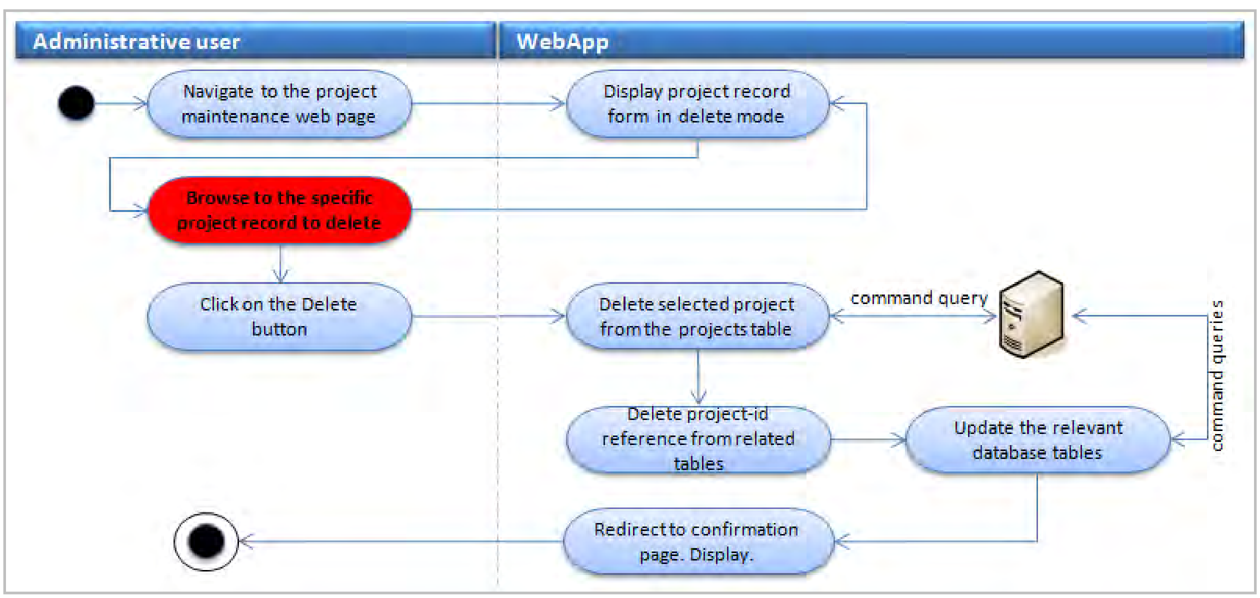

Figure 81 - Activity diagram for deleting a project

Process: viewing a project

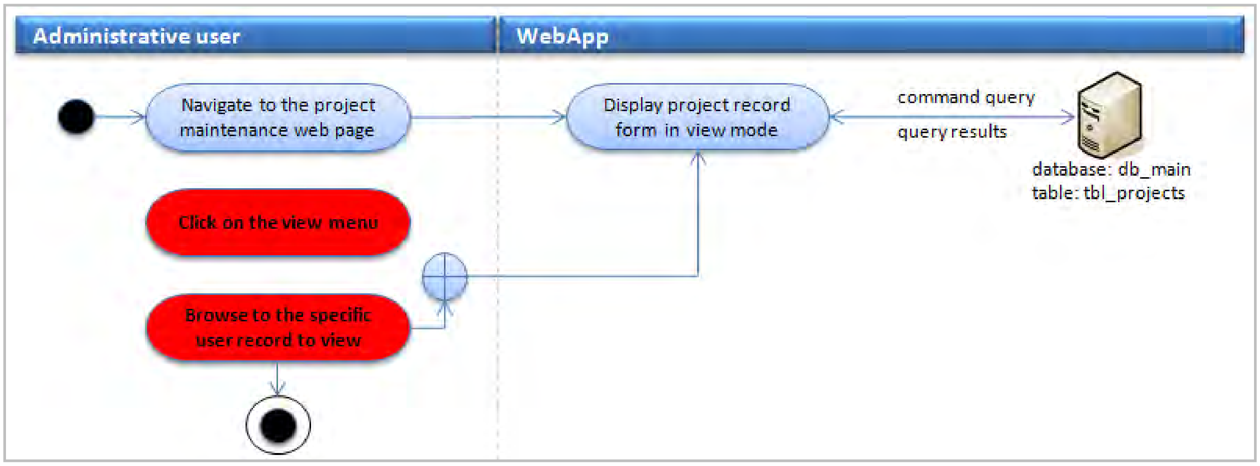

Figure 82 - Activity diagram for viewing a project

Process: adding a mine

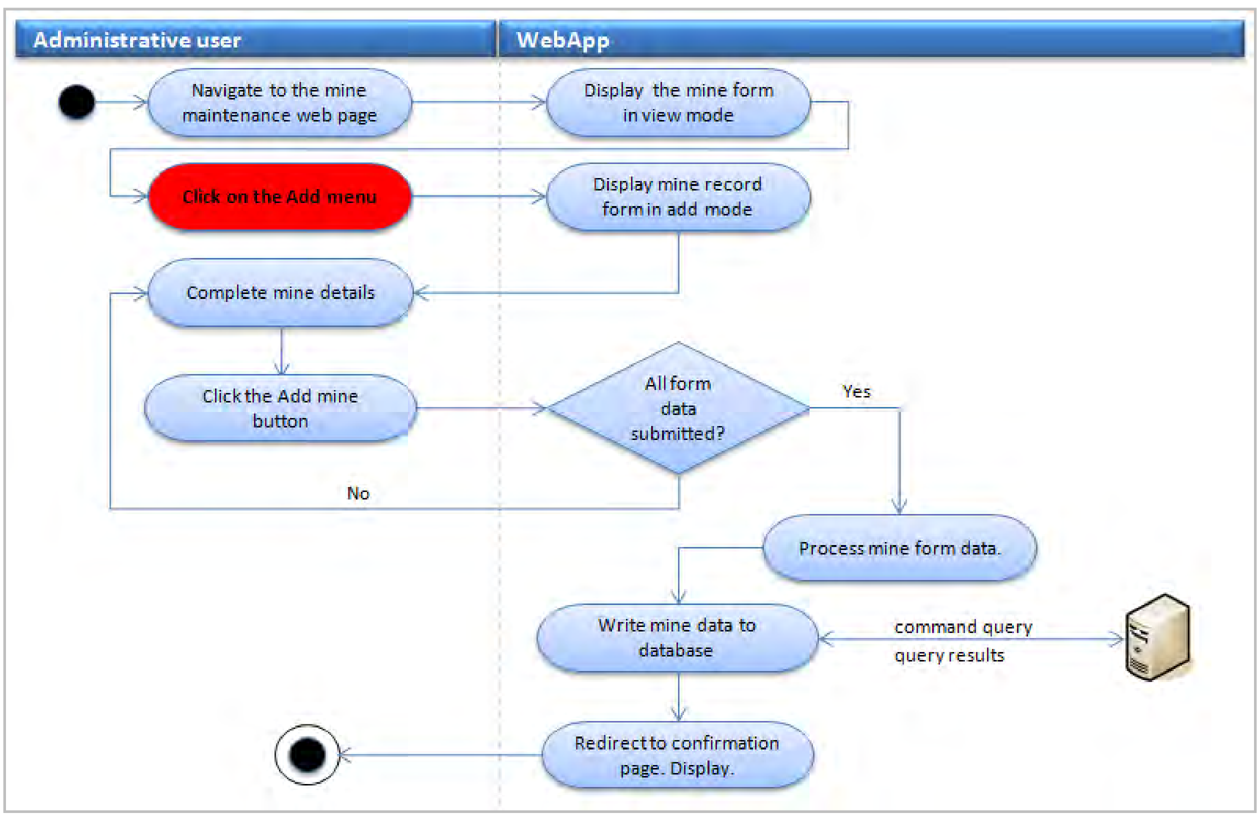

Figure 83 - Activity diagram for adding a mine

Web page design template

- The generic web page consists of header and footer areas, a navigational area and a data area.

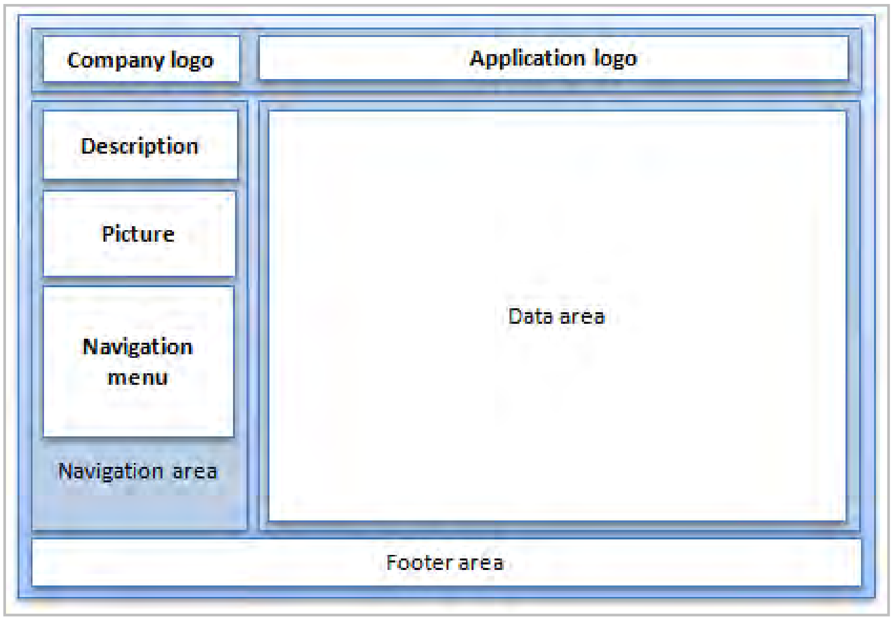

Figure 84 - Generic web page design

Header area

- Consists of a static company logo and application logo that is displayed on every web page.

Navigation area

- Consists of a dynamically created navigation menu and optional description and picture divisions.

Data area

- Displays extracted data from the database specific to a user group and dependent on the navigational menu selection.

Footer area

- The footer area is used to display typical copyright information.

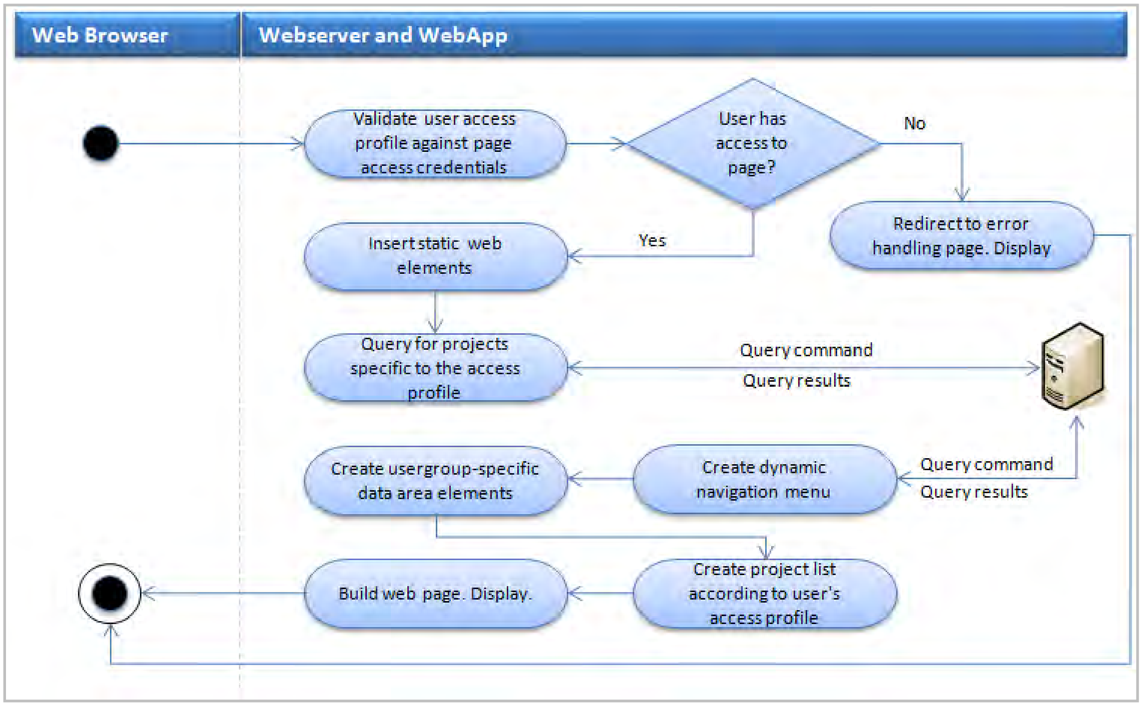

Figure 85 - Activity diagram for building a web page

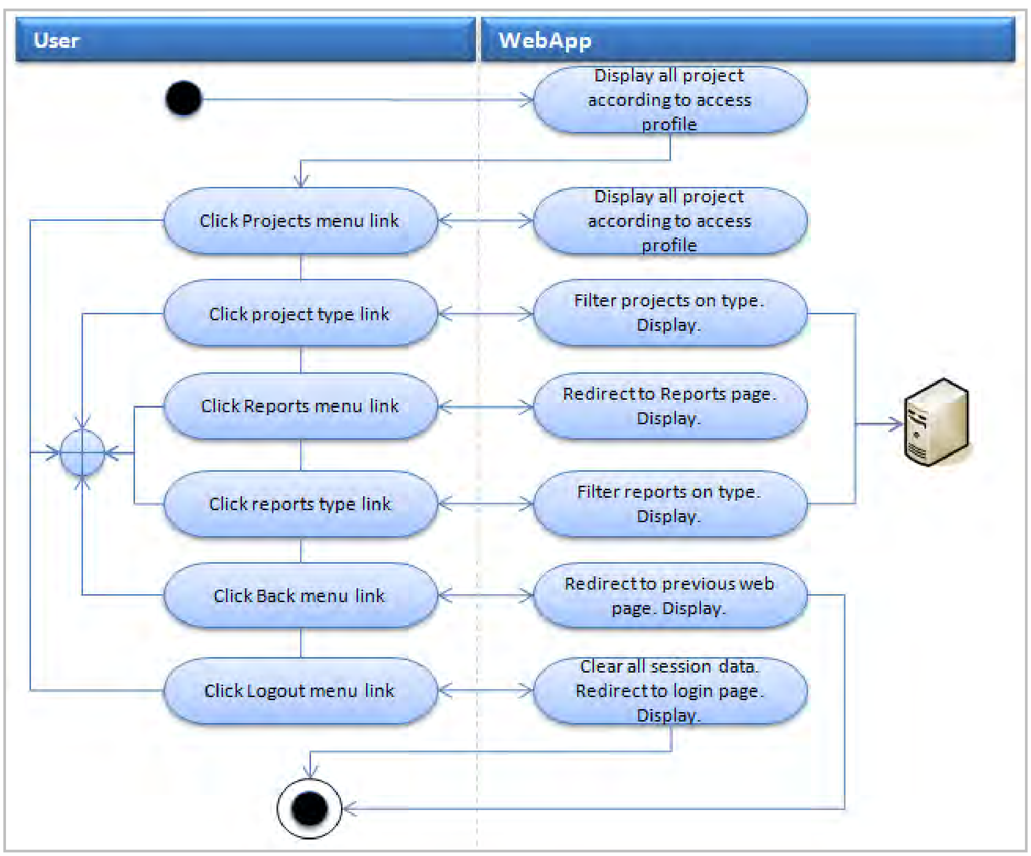

Figure 86 - Activity diagram for navigating a web page

Compressor	Status Running	Status Loaded	Delivery SetPoint	Delivery Presure	Delivery Volume	kW Power Usage	Available	ControlPermission	Max Vain Pos	Min Vain Pos	Vain Pos
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3658.28	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3710.3	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3658.28	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3692.96	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3710.3	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3658.28	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3658.28	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3692.96	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3692.96	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3710.3	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3692.96	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3675.62	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3692.96	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3727.63	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3710.3	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3727.63	1	1	100	0	100
Amandelbult 15E Nr 4	1	1	0	0	0	3727.63	1	1	100	0	100

Figure 87 - Snapshot of a compressor input log file

	A	B	C	D	E
1	Date:	2009/12/15		Ver. 12	
2	Report name:	Amandelbult			
3	Marvin name:	AmandelbultCM			
4	Mine Type:	Compressed Air			
5					
6	Contractual MW Saving Morning:	0			
7	Contractual MW Saving Evening:	7			
8	Target MW Saving Morning:	0			
9	Target MW Saving Evening:	7			
10					
11	Scaled MW Saving Morning:	-0.55			
12	Scaled MW Saving Evening:	8.14			
13					
14	Unscaled MW Saving Morning:	-1.44			
15	Unscaled MW SavingEvening:	7.37			
16	Scaled RC Saving:	R 25 479			
17	Unscaled RC Saving:	R 21 258			
18	Scaled Proposed Rc Savings:	R 6 579			
19	Unscaled Proposed Rc Savings:	R 6 374			
20					
21	Scaled Missed Oppertunity MW Saving Morning:	0			
22	Scaled Missed Oppertunity MW Saving Evening:	2.08			
23	Scaled Missed Oppertunity RC Saving:	R 0			
24					
25	Unscaled Missed Oppertunity MW Saving Morning:	0			
26	Unscaled Missed Oppertunity MW Saving Evening:	2.53			
27	Unscaled Missed Oppertunity RC Saving:	R 0			
28					
29		kWUsage	ScaledBaseline	UnscaledBaseline	
30	0	18753.57733	26255.38673	25435.06029	
31	1	21644.877	26729.7341	25894.58709	
32	2	22523.97667	26847.98446	26009.14282	
33	3	21210.88414	26864.38821	26025.03405	
34	4	18877.14433	26846.51835	26007.72252	
35	5	18871.30033	26120.8403	25304.71764	
36	6	18868.211	25418.57444	24624.39346	
37	7	25991.03897	25854.48253	25046.68198	
38	8	27286.77233	27288.33913	26435.739	
39	9	33442.011	31914.5784	30917.4355	
40	10	35114.03333	33959.00706	32897.98778	
41	11	32970.88483	35653.3437	34539.38637	
42	12	25538.29967	34979.65731	33886.74871	
43	13	18911.466	33280.69295	32240.867	
44	14	18903.62517	28601.50575	27707.87688	
45	15	19564.13333	25595.42194	24795.71552	
46	16	19632.7	25108.53761	24324.04346	
47	17	19687.16667	24943.72456	24164.37985	
48	18	17033.06897	24514.48722	23748.55365	
49	19	15960.53333	24749.5603	23976.28208	
50	20	18757.96667	25167.63159	24381.2911	
51	21	19455.73333	25310.16255	24519.36881	
52	22	19679.48276	25633.62233	24832.72237	
53	23	20129.73333	26074.68675	25260.00612	
54					
55	Data loss:	Start	Stop		
56		12:00:00 AM	12:00:00 AM		
57		12:56:00 PM	12:56:59 PM		
58		11:59:00 PM	11:59:59 PM		
59					
60					
61	Manual:	Start	Stop		
62		01:12:59 PM	11:59:00 PM		
63					
64					
65	Calculated by:		0		
66					
67					
68					
69					
70					

DayRecord 2009-12-15

Figure 88 - Marvin generated CSV file

Appendix B: User manual

1. Add new users

The administrator can add a new user to the administrators, engineers, Eskom, mine groups or mines user groups.

Adding a mine group user

- Select a specific mine group as shown in Figure 89.
- Access will be limited to all the projects of selected mine group.

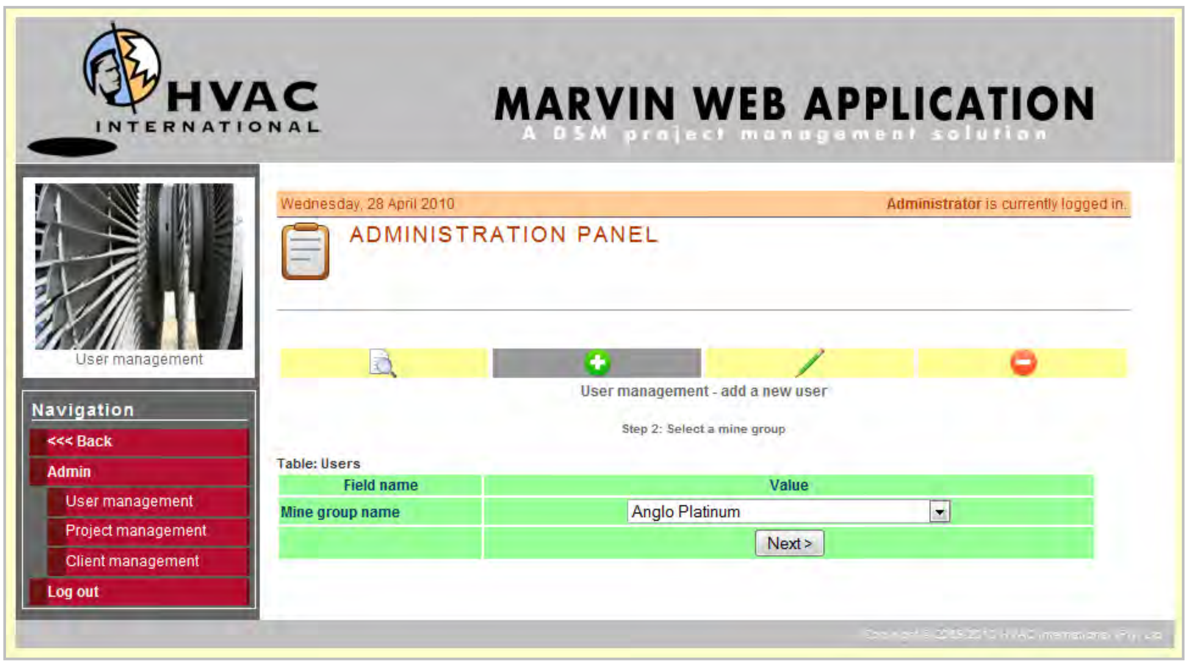

Figure 89 - Selecting a mine group

Add an access profile to a mine group user

- Select the projects to be added to the user's access as shown in Figure 90.
- Provide a descriptive name for easy reference.

Figure 90 - Defining a user access profile for a mine group user

Adding an Eskom user

- Select one or more mine groups as shown in Figure 89.
- Access will be limited to projects of the selected mine group(s).

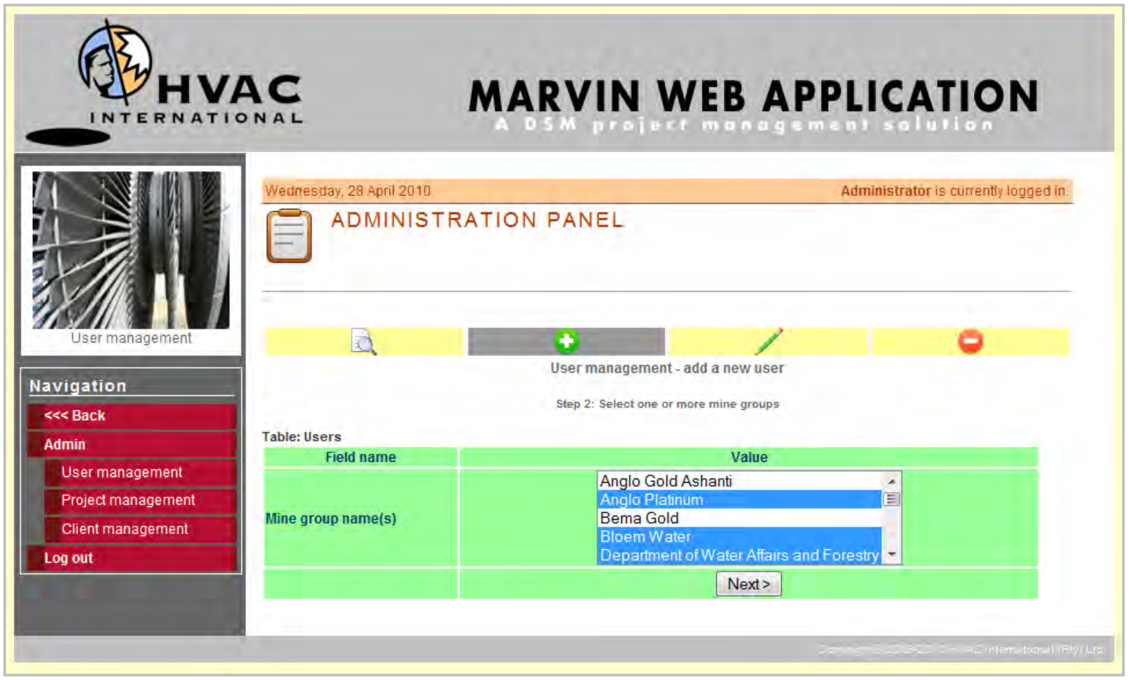

Figure 91 - Select one or more mine groups

Adding an Engineer user

- Select one or more mines as shown in Figure 91.
- Access is limited to the projects of the selected mine(s).

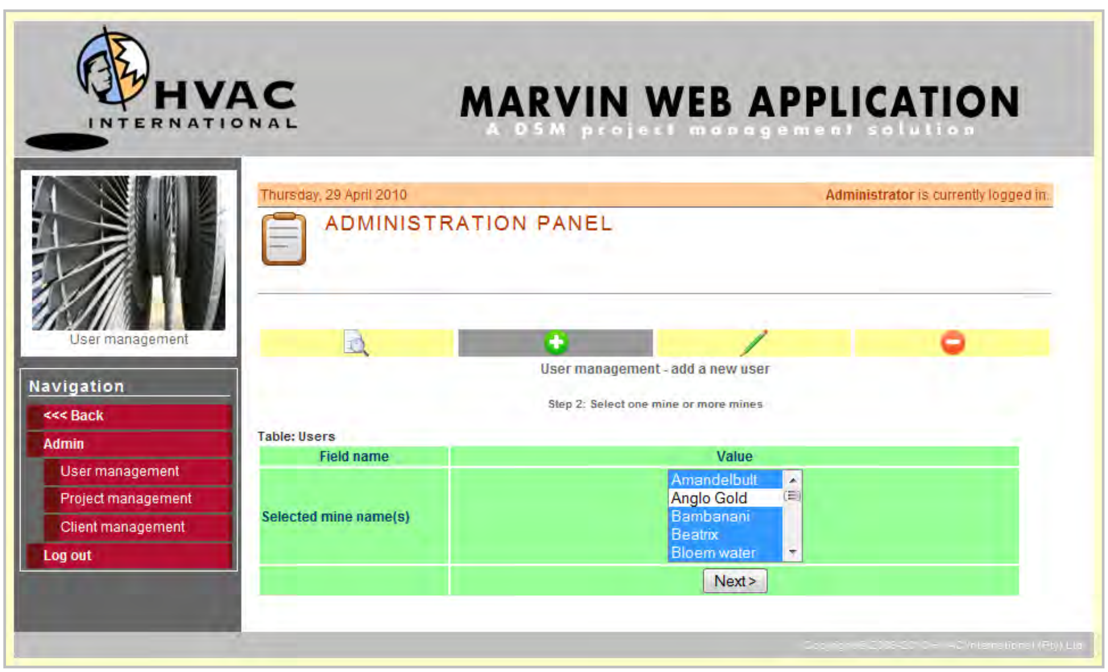

Figure 92 - Select one or more mines

Adding an Administrator

- All projects recorded in the database are automatically added to the access profile of an administrative user.

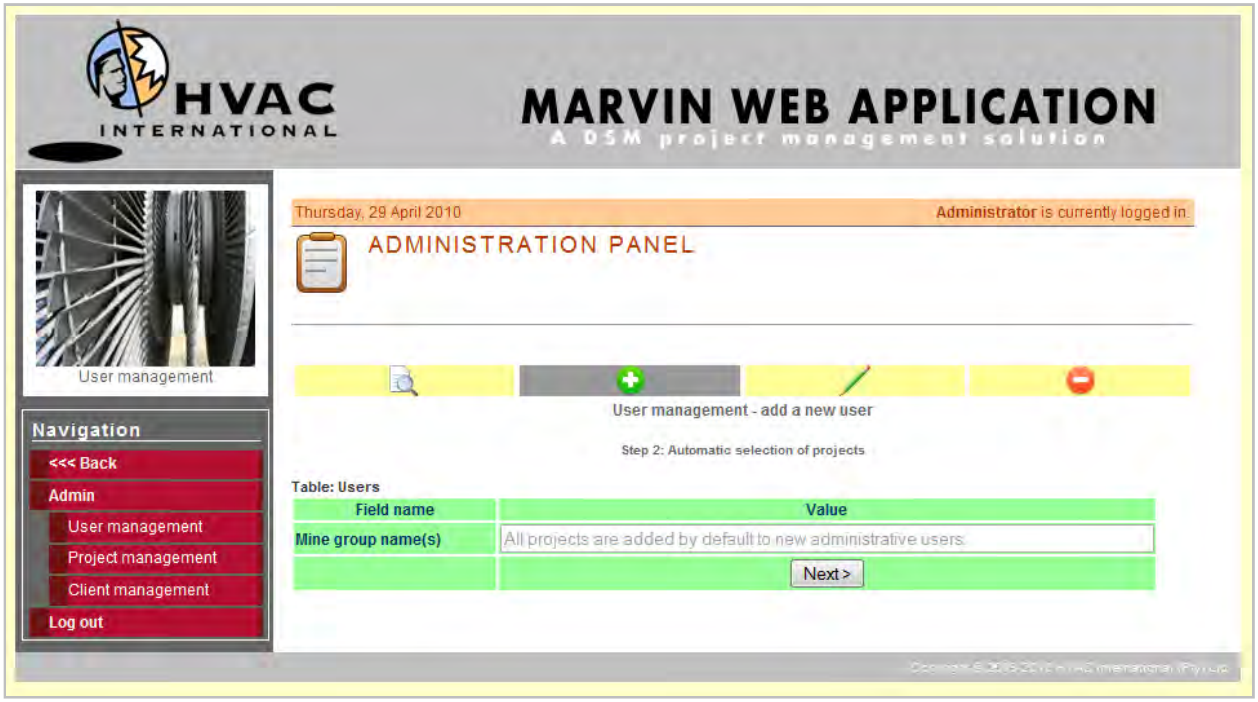

Figure 93 - Automatic selection of projects

Update an existing user

- Select the user whose details need to be modified as shown in Figure 94.
- Select or deselect a project and update other details where necessary.
- Click the **Update** button.

Figure 94 - Edit a user details and access profile

Add a project

- Enter project details in the project from as shown in Figure 95.
- Click the **Add project** button.

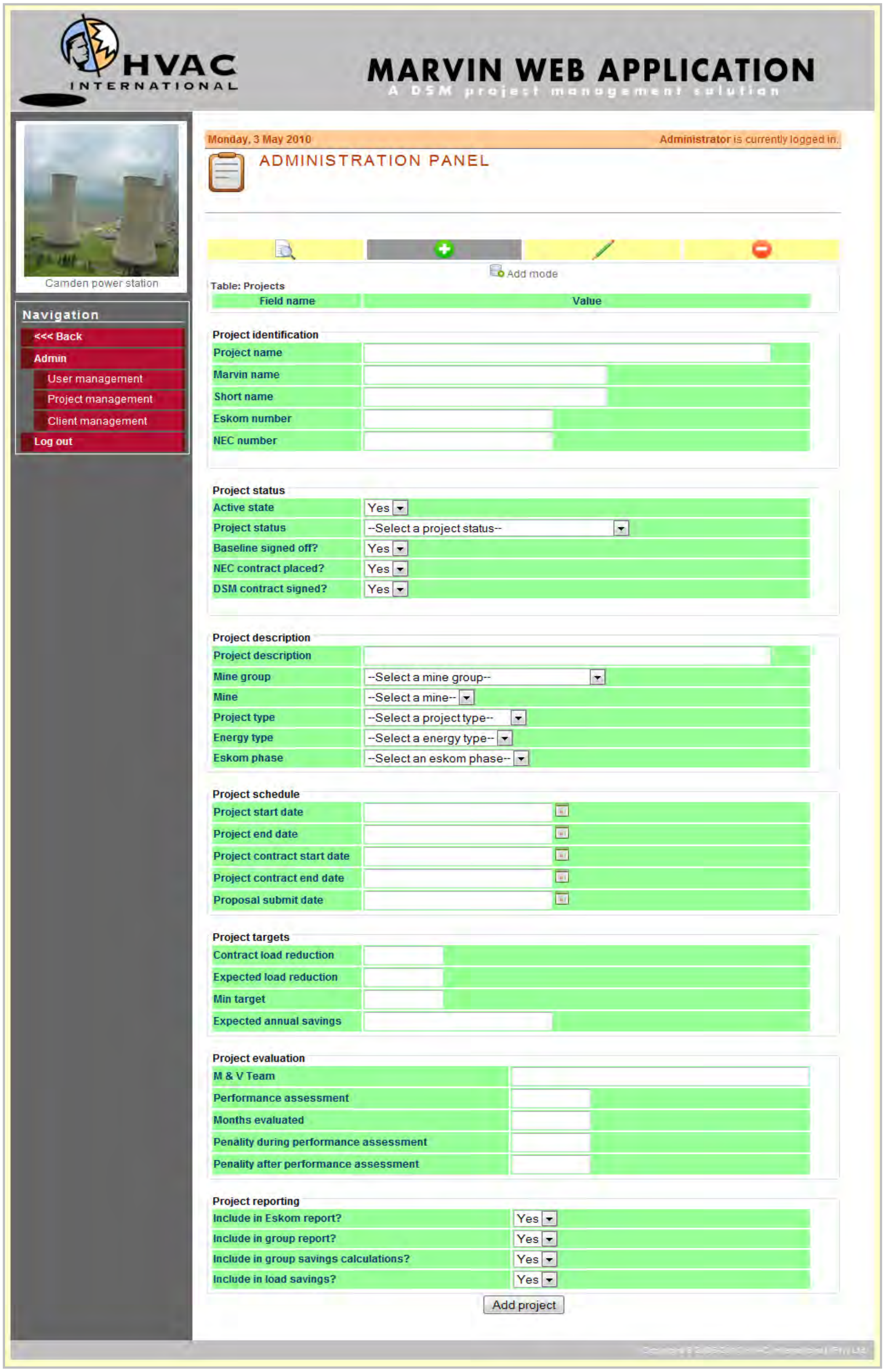

Figure 95 - Add a project

Appendix C: Questionnaire

POST IMPLEMENTATION QUESTIONNAIRE- MARVIN WEB APPLICATION

Please complete the following questionnaire. Your time and effort is highly appreciated.

Date:		**Questionnaire ID Number: MWAQID___**

PLEASE EXECUTE THE FOLLOWING ACTIVITIES:

Note: Please use Internet Explorer for the following activities.

1. Navigate to: http://www.osims.co.za
2. Login with the following credentials:
   Username: testuser@amandelbult
   Password: testuser@amandelbult
3. Click the **Login** button.
4. Click on **5. Amandelbult compressor manager** link under the **Project List** heading.
   Note: Please ensure that Javascript is enabled in your web browser.
5. Select **5 April 2009** from the calendar and click on the **Refresh** button.
6. Examine the updated page.
7. Click on the **Analysis** menu link.
8. In the **'1. Calculate the average MW statistics for a given period'** query box: Enter the **2009-04-01** as the start date and **2004-04-30** as the end date.
9. Click on the **Calculate** button.
10. Examine the results.
11. In the **'2. Generate a summary of mine report for a given period'** query box: Enter the **2009-04-01** as the start date and **2004-04-30** as the end date.
12. Click on the **Generate** button.
13. Examine the results.
14. Click on the **Logout** menu link.
15. Answer all the questions that follow.

GENERAL IT AND CELLPHONE SKILLS

How often do you access the web through a pc?

☐ Once a month
☐ Once a week
☐ On a daily basis

How often do you access the web through your cellphone?
☐ On a monthly basis
☐ On a weekly basis
☐ On a daily basis

What type of cellphone do you use?
☐ Cellphone with limited or no Internet access (lower end)
☐ Cellphone advanced Internet access capabilities (higher end)

MARVIN WEB APPLICATION

Please rate the following statements the Marvin Web Application.

1. THE MARVIN WEB APPLICATION IS EASY TO USE

Strongly disagree Undecided Strongly agree

2. THE LAYOUT OF THE WEB APPLICATION IS WELL-ORGANISED AND CLEAR

Strongly disagree Undecided Strongly agree

3. THE LANGUAGE USED IN THE WEB APPLICATION IS EASY TO UNDERSTAND

Strongly disagree Undecided Strongly agree

4. THE TEXT SIZE USED IN THE WEB APPLICATION IS EASY TO READ

Strongly disagree Undecided Strongly agree

5. IT IS EASY TO NAVIGATE AROUND THE WEB APPLICATION

Strongly disagree Undecided Strongly agree

6. THE WEB APPLICATION CONTAINS THE INFORMATION I NEED

Strongly disagree Undecided Strongly agree

7. MARVIN WEB COMPARES WELL TO OTHER WEB APPLICATION I HAVE USED

Strongly disagree Undecided Strongly agree

8. PLEASE STATE ANY COMMENTS OR SUGGESTIONS ON HOW THE WEB APPLICATION CAN BE IMPROVED?